K O N I N K L I J K   N E D E R L A N D S
M E T E O R O L O G I S C H   I N S T I T U U T

D e   B i l t

Verslagen

V - 234

J. Wieringa

Verslag van de
"Second Canadian Conference on Micrometeorology.
Ste Anne de Bellevue, P.Q. 10-12 mei 1971"

en van een

"Werkbezoek aan het Bedford Institute of Oceano-
graphy, Dartmouth, N.S., op 13 en 14 mei 1971".

VERSLAG VAN DE

"SECOND CANADIAN CONFERENCE ON MICROMETEOROLOGY"

te Ste.Anne de Bellevue (nabij Montreal),
10 t/m 12 mei 1971

en van een werkbezoek op 13 en 14 mei aan het
BEDFORD INSTITUTE OF OCEANOGRAPHY, Dartmouth, N.S.

J. Wieringa

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1. Inleiding.

De Eerste Canadese Micrometeorologie-conferentie werd in 1965 te Toronto
gehouden, "to introduce to one another the Canadian scientists from various
disciplines who are confronted with common problems at the earth-atmosphere
interface." In 1967 werden de Proceedings gepubliceerd in twee delen (KNMI-
bibl.nº II.u.129). Destijds waren slechts drie niet-Canadezen aanwezig, op
invitatie: G.C.Gill, H.A.Panofsky en F.Pasquill.

Dit jaar werd opnieuw een micrometeorologie-conferentie georganiseerd,
voorafgaand aan het 5th Annual Congress van de Canadian Meteorological Socie-
ty (12 t/m 14 mei) ter zelfder plaats. 12 mei werd als gezamenlijke dag van de
twee bijeenkomsten beschouwd, waarop tevens aan het einde van de dag een
nieuw gebouw in McGill University (centrum van Montreal) werd geopend, met
daarop aansluitend een avondvergadering van de Canadian Meteorological Socie-
ty. Uit een en ander volgt, dat het aantal deelnemers van de Micrometeoro-
logieconferentie slechts ruw geschat kan worden, omdat in de loop van 11 en
12 mei het aantal aanwezigen geleidelijk vermeerderd werd met deelnemers van
het 5th Annual Congress. Op de avond van 11 mei waren circa 120 Canadezen
aanwezig, 13 deelnemers uit de U.S.A. (L.H.Allen, A.L.Friend, J.W.Deardorff,
P.Frenzen, G.C.Gill, H.E.Landsberg, H.H.Lettau, H.A.Panofsky, E.Ryznar, T.R.
Sinclair, W.C.Swinbank, C.B.Tanner en N.K.Wagner), U.Högström uit Uppsala
(met zijn echtgenote, eveneens micrometeorologe) en ondergetekende.

Beide conferenties werden gehouden in Macdonald College, een onderafde-
ling van McGill University te Montreal, met een eigen campus in Ste.Anne de
Bellevue op circa 30 km afstand van het centrum van Montreal. Alle deelnemers
sliepen en aten op de campus, hetgeen het onderling contact zeer bevorderde.
Voertaal ter plaatse is het Engels, hoewel ± 75% der plaatselijke bevolking
van huis uit Franssprekend is — een situatie die vergeleken kan worden met
de Universiteit van Leuven omstreeks 1960. De organisatie der twee congressen
interfereerde enigszins; de organieke leiding berustte bij Prof.R.H.Douglas
(Macdonald College), terwijl de wetenschappelijke organisatie van de Microme-
teorologische conferentie in handen van Prof.R.E.Munn (Toronto) en diens staf
was. Er was bv.geen naam- en adreslijst van aanwezigen beschikbaar.

Door alle aanwezigen werd het als een groot bezwaar gevoeld, dat het
merendeel der voordrachten in twee parallelzittingen werd gehouden: van de
55 micrometeorologische voordrachten werden slechts 20 in enkelvoudige zitting
gepresenteerd. Bij de overigen moest men noodgedwongen de helft missen. Er was
bovendien geen gelegenheid om de gemiste voordrachten alsnog schriftelijk
door te nemen, omdat nog geen 10% in uitgeschreven vorm beschikbaar was. Het
enige wat aan verdere informatie restte was een extra nummer van Atmosphere
(het blad van de Canadian Meteorological Society, qua opzet met Weather te
vergelijken), waarin van vrijwel alle voordrachten een vrij uitgebreid abstract
was opgenomen. Tenslotte zullen er géén Proceedings worden gepubliceerd, omdat
Prof.Munn geen gelegenheid hiervoor heeft naast zijn editorship van Boundary-
Layer Meteorology, en er blijkbaar ook geen ander is die de uitgave van Procee-
dings kan organiseren. Getracht zal worden om zo veel mogelijk de voordrachten
op te nemen in de komende jaargang van Boundary-Layer Meteorology.

Op de ochtend van 13 mei reisde ondergetekende verder naar Halifax, 600 km ten Oosten van Montreal. Op het Atlantic Oceanographic Laboratory van het Bedford Institute te Datmouth, een voorstad van Halifax, werd gedurende anderhalve dag een werkbezoek gebracht aan de Air-Sea-Interaction afdeling aldaar, welke geleid wordt door Dr.Stuart D.Smith. Op de middag van 14 mei werd daar door ondergetekende tevens een voordracht van ruim een uur gehouden over de Flevo-trivaanmetingen voor twee dozijn belangstellenên (titel voordracht: "Turbulence measurements over a lake.").

Er bleek op het Bedford Institute veel instrumenteel en experimenteel werk van hoog gehalte te worden gedaan, o.a. anemometrie, drukfluctuatiemetingen, telemetrie en bouw van stabiele meetopstellingen in zee. Hierop zal in hoofdstuk 5 van dit verslag nog nader worden ingegaan. Tevens bleek echter dat ze op het gebied van theoretische en fysische interpretatie niet veel verder waren dan het KNMI. Aangezien bovendien op de Micrometeorologische Conferentie reeds veel was geleerd, o.a. in persoonlijke gesprekken met R.W. Stewart, Frenzen, Swinbank en anderen, leek het weinig waarschijnlijk dat nog meer kon worden bereikt door met de medewerkers van het Bedford Institute gedurende een periode van niet meer dan een of twee dagen te discussiëren over het Flevo-materiaal (waarin zij bovendien in 't geheel niet waren ingewerkt). Mede om reisfinanciële redenen werd daarom besloten om terug te reizen op de avond van 14 mei.

In verband met het ontbreken van verdere schriftelijke informatie over de inhoud der voordrachten (om de reeds hierboven genoemde redenen) zal getracht worden een zo uitgebreid mogelijk verslag van e.e.a. te geven. In hoofdstuk 2 van dit verslag zal een overzicht gegeven worden van de voordrachten die ik kon bijwonen, terwijl in hoofdstuk 3 de abstracts van de overige voordrachten volgen. In beide hoofdstukken zullen de voordrachten niet gerangschikt worden in tijdsvolgorde, maar volgens onderwerp worden genummerd:

M = micro- en mesometeorologie;   F = fysische meteorologie;
I = instrumentatie;   P = air pollution + stadsklimaat;
N = numerieke methoden en forecasting;   R = resterende onderwerpen.

In hoofdstuk 4 zal verslag worden gedaan over een op de avond van 10 mei bijgewoonde working session inzake het in 1972 rondom Lake Ontario te organiseren internationale meetprogramma (enigermate te vergelijken met BOMEX). In hoofdstuk 5 zijn de ervaringen op het Bedford Institute verwerkt. Tenslotte wordt in hoofdstuk 6 een overzicht gegeven van de betrekkelijk schaarse hoeveelheid schriftelijk materiaal, welke is meegenomen, alsmede van datgene wat naderhand nog is ontvangen naar aanleiding van verzoeken mijnerzijds tijdens de conferentie. Datgene wat van algemeen belang lijkt zal in de bibliotheek worden opgenomen; van de zéér specialistische rapporten zal worden vermeld bij welke KNMI-onderzoeker ze kunnen worden ingezien. In de hoofdstukken 3 en 4 wordt met een omcirkeld cijfer 6 in de kantlijn aangegeven, dat van de betreffende voordracht vóór de verschijningsdatum van dit verslag (8 juli)nog een rapport is ontvangen.

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2. Bijgewoonde voordrachten.

Allereerst dient vermeld te worden, dat geen van de N- of F-voordrachten werd bijgewoond, daar deze aller gehouden werden op 13 en 14 mei, tijdens het 5th Annual Congress. De abstracts van deze voordrachten, die niet binnen mijn eigen werkterrein vallen, zijn ten behoeve van anderen tóch opgenomen in hoofdstuk 3 (blz.19 t/m 29), omdat er immers geen Proceedings zullen verschijnen.

Voor de goede orde volgt hier de chronologische volgorde der voordrachten, waarbij de bijgewoonde voordrachten zijn onderstreept:

10 mei: M 1, M 2, M 3, M 4, M 5, M 6, R 1; P 9, P 10, P 11, P 12, M 21.
M 11, M 12, M 13, M 14, M 15.
11 mei: I 1, I 2, I 3, I 4, I 5, I 6, I 7; M 17; M 26, M 27, M 28, M 29, I 8.
M 18, M 19, M 20, M 23, M 24, M 25, M 22; I 9, I 10, I 11, I 12, I 13.
12 mei: P 1, P 2, P 3, P 4, P 5, P 6, P 7; R 2, R 3, R 4, R 5; P 13, P 14, P 8.
Op 13 en 14 mei nog: I 14, I 15, M 7, M 8, M 9, M 10, I 16, M 16, P 5, R 6, R 7, alsmede alle N- en F-voordrachten.

M 1:   CONVECTIVE HEAT TRANSFER MEASUREMENTS OF PLANTS IN A
WIND TUNNEL
A. Kumar and N. Barthaku-
(Macdonald College)

Heat transfer was studied between intact leaves of various sizes and shapes in vivo under free and forced air condictions. Use of a wind tunnel and a microwave transmitter to heat the leaves facilitated measurements of convective, along with radiative and evaporative, heat losses from plant leaves. Knowledge of input energy, analysis of cooling curves, and established formulae, respectively, formed the basis of the steady-state, unsteady-state, and analytical methods for the determination of heat transfer coefficients.

Typical values of steady-state free convection coefficients for Peperomia Obtusifolia varied from 1.5×10^{-4} to 1.9×10^{-4} cal cm^{-2} sec^{-1} C^{-1} as the temperature difference was increased from 5.9 to 9.6C, while the forced convection coefficient was found to be 4.2×10^{-4} cal cm^{-2} sec^{-1} C^{-1} at 122 cm sec^{-1} wind velocity. For egg-plant, this value was about 9×10^{-4} cal cm^{-2} sec^{-1} C^{-1} at 488 cm sec^{-1} wind velocity. Convection coefficients, as determined under steady-state conditiors, are compared with those for the unsteady-state and analytical values for a single leaf and leaves of three different plants. In general, experimertal values were found to be higher than the analytical ones.

M 2 :   MODEL EXPERIMENTS ON FORCED CONVECTION, HEAT AND MASS
TRANSFER OF LEAVES:
THE EFFECT OF FLUTTER AND LEAF SHAPE
P. Schuepp '(Macdonald College)

The convective mass transfer - and by analogy, heat transfer - of various nickel-plated leaves and of cedar foliage was examined with an electrochemical method for Reynolds numbers $3 \times 10^3 < Re < 4 \times 10^4$. The leaves were mounted both rigidly and also flexibly on stems. Similar measurements were made on flat plates of various two-dimensional shapes, also mounted rigidly and flexibly in the flow, and the results are compared in order to test the validity of the commonly-used analytical expressions which represent the leaf by a flat plate and which assume the effect of flutter to be negligible.

The results, extrapolated for the transfer in air, show good agreement between calculated and measured results only for the rigidly-mounted flat plates. The flutter of plates on flexible stems causes increases in transfer of the order of 20 to 30%. Actual leaf shapes mounted flexibly in the flow show typical increases between 25 and 50%; in some cases, higher. This strongly indicates that heat transfer coefficients calculated for flat plates do not adequately represent the actual convective heat and mass transfer of leaves. The (very high) transfer coefficients measured for cedar foliage are also discussed.

Onderwerp enigszins onbekend voor ondergetekende. In 't algemeen schijnen bladeren ± 85 % der opvallende straling te absorberen. Prof.Tanner's bezwaar tegen Kumar's proeven was, dat de temperatuurverdeling op een blad niet in overeenstemming gebracht kan worden met een uniforme-warmteflux-model. Schuepp stelde dat de bladvorm de mate van turbulent transport rondom het blad bepaalt: maximaal voor dennenaalden,minimaal voor vlakke bladen. De omgeving is doorgaans turbulent genoeg om bladtrillingseffecten te elimineren.

M 3 :   HORIZONTAL FLUX DIVERGENCE OF HEAT, WATER VAPOR, AND
CO_2 IN A CORN FIELD: CASE STUDIES
L. H. Allen, Jr.   (US Dept.Agr.,Ithaca, New York)

Four anemometer masts were placed 15 m apart along a straight line in a field of corn. Temperature, water vapor concentration, and CO_2 concentration were measured at two of these sites, 30 m apart, at 10 levels up to a height of 6 m. Horizontal flux divergences of heat, water vapor, and CO_2 were calculated from data averaged over 30 minutes.

The energy (or mass-diffusion) equation for a fluid volume was simplified to include only two-dimensional flux terms (horizontal and vertical). Experimental data showed that the turbulent flux terms were negligible compared with the mean flux terms. Horizontal flux divergences of heat, water vapor, and CO_2 were found to be caused mainly by variations in measured wind speed from one mast to the other. Except in the case of a line source CO_2 release, horizontal flux divergences due to horizontal changes in temperature, water vapor concentration, or CO_2 concentration were negligible. Theoretical predictions based on our estimates of the errors in determining wind speed, temperature, water vapor concentration, and CO_2 concentration gave the same conclusion.

Total mass flux divergence (horizontal variations in wind speed) can be caused by slight variations in the ground level between the masts and to variations in canopy density. Accuracy and placement of anemometers (heated-thermocouple type) in the crop can influence the flux divergence calculations. Both theory and experimental data show that accurate horizontal wind speed measurements are essential in computing the horizontal flux divergence of heat, water vapor, or CO_2. This wind speed accuracy requirement, plus the need for many sensors, makes it difficult to evaluate flux divergences in such studies as the heating of orchards for frost protection or releasing CO_2 from a line source.

Voordracht behandelde voornamelijk instrumentatie, gaf geen resultaten.

M 4 :   AVERAGE BOWEN-RATIO METHODS OF CALCULATING
EVAPOTRANSPIRATION APPLIED TO A DOUGLAS FIR FOREST
T.A. Black and K.G. McNaughton (Univ.Br.Columbia)

Forest hydrologists speculate about the influence of the surface organic soil layer of the forest on the amount and timing of water yield, especially where this layer may be several inches thick, as in the cool, humid forests of the west coast of British Columbia. To determine the water balance components of the forest floor, a reliable estimate of evaporation is required.

The energy balance/Bowen ratio technique was chosen because the net radiation flux and soil heat flux can be measured relatively accurately, thereby putting some limits on the magnitude of the evaporative flux. As an independent check, the evaporative flux was measured with a simple lysimeter having a resolution of 0.003 mm of water.

The study site was located within an 11-year old Douglas fir plantation having no understory vegetation. A linear net radiometer and 4 heat flux plates connected in series measured net radiation flux and soil heat flux, respectively. The Bowen ratio apparatus measured wet and dry bulb temperature differences over 90 cm with shielded and aspirated thermocouples.

The preliminary results showed that 3 to 5% of the net radiation flux above the canopy reached the forest floor. The dry bulb gradient 50 cm above the forest floor ranged from 0.02C cm^{-1} at night to 1.2C cm^{-1} during the day. The daily vapour pressure gradient was between -0.05 and -2.2 mb m^{-1}. The Richardson number was estimated to be larger than 0.5, indicating extremely stable conditions. On the other hand, smoke studies showed that there was some turbulence. The possibility of advection is not discarded but calculations indicate that it was small compared to vertical energy fluxes.

The energy budget/Bowen ratio estimates of evaporation for 24 hours were approximately 70% higher than lysimeter measurements, while the latter were 20% higher than the evaporation calculated from net radiation flux minus soil heat flux. This indicates that, under prevalent conditions, the similarity assumption used in the Bowen ratio method was not valid.

It is concluded that the energy budget/Bowen ratio approach has serious limitations for use under the canopy. The eddy correlation measurement of the sensible heat flux component of the energy budget is suggested as an alternative to the Bowen ratio method.

(Volledig rapport ter inzage bij J.Q.Keijman).
Discussie: (a) canopy storage is bij balansberekening een probleem, omdat de takken en bladeren enige minuten responsietijd hebben (Tanner). (b) volgens Webb is $\beta = \gamma H/LE$ een fout uitgangspunt, aangezien er tussen H en LE een zekere correlatie bestaat. (c) in een bos kan men beter niet met cupanemometers werken, omdat zelfs Casella's de golflengten korter dan 6 à 7 m niet meer meenemen.

M 5 :   COMPARISON OF PINE FOREST EVAPOTRANSPIRATION
ESTIMATED BY ENERGY BUDGET, AERODYNAMIC AND
PRIESTLEY METHODS
E.I. Mukammal   (Can.Met.Serv., Toronto)

Evapotranspiration of a uniform heterogeneous pine forest was estimated using the energy budget, aerodynamic and Priestley methods. The latter two techniques, although quite different in approach, gave similar results, the Priestley method yielding values about 7% higher than the aerodynamic

method. The energy budget estimate derived from net radiation and temperature and humidity gradients above the canopy (Eb 1) gave values greater than the aerodynamic and Priestley methods by about 22% and 15%, respectively. When separate energy budgets were obtained for the canopy and below the canopy their sum was about 17% greater than Eb 1. This difference is attributed to horizontal advection below the canopy.

The Bowen ratio was found to vary with intensity of net radiation, being about 0.9 when the net energy was about 50 cal/cm^{2}hr, and decreasing to an average of about 0.3 when it was about 15 cal/cm^{2}hr. There was also evidence that the Bowen ratio varied with wind speed when net energy was relatively low, being lower with relatively strong and higher with relatively weak wind speeds. Zero displacements ranged from 16.7 m to 15.2 m, and the roughness parameter from 1.5 m to 1.9 m. The former varied with upwind homogeneity of topographical features and of the forest, but not with wind speed. On the average, conditions at night were found to favour the continuation of evapotranspiration. The accuracy of measurement, method of measurement, and handling of data are also discussed.

(Volledig rapport over metingen zomer 1968 ter inzage bij J.Q.Keijman). In een bos met boomhoogte 18m à 20m waren twee 70m-masten geplaatst, met meetinstrumenten aan een staaldraad tussen de masten t.b.v.betere ruimtelijke integratie. Voor temperatuurmeting was 0.01° precisie vereist, omdat vanwege de ruwheid de gradienten boven de boomtoppen zeer klein zijn. $z_0 \approx 1.5 - 1.8$ m; $C_d \approx 0.07$. Data geklassificeerd volgens nettostraling; per stralingsklasse circa 1000 runs, geeft vertrouwen in precisie van gemiddelden. 25m-niveau sluit no it aan bij het bovenliggend profiel.

M 6 : AN EXTENDED BOWEN-RATIO PROFILE METHOD FOR THE
CALCULATION OF ENERGY FLUX DENSITIES ABOVE VEGETATION
T.R. Sinclair, L.H. Allen, Jr., and E.R. Lemon (Cornell Univ.)

An extended Bowen-ratio profile method for calculating total carbon dioxide, latent heat, and sensible heat flux densities above vegetation is proposed. Temperature, water vapor, and CO_2 concentrations were measured at several heights in the aerodynamic boundary layer above a corn crop. The ratio of sensible heat flux density to carbon dioxide flux density (α) as well as the Bowen ratio (β), were used in our computations. The height variable was eliminated by plotting temperature vs. CO_2 concentration and temperature vs. water vapor concentration. The two ratios, α and β, were determined graphically from the slopes of the two plots. Each of the energy flux densities were computed as a function of the two ratios and net radiation minus soil heat flux density.

An error analysis was performed on this extended Bowen-ratio profile method to evaluate the accuracy of the flux density estimates. Less than 10% error was found for latent heat flux density and less than 15% for carbon dioxide flux density under normal midday conditions for the instrumentation used. However, the carbon dioxide flux density error increased substantially (up to 40%) when the sensible heat flux was small. Nevertheless, the extended Bowen-ratio profile method was found to be inherently more accurate than the standard energy balance method for calculating total crop flux densities.

Instrumentatie: Van de voor temperatuurmeting aangezogen lucht werd een gedeelte via verwarmde leidingen naar een opslagfles (apart voor iedere hoogte) geleid. Per half uur werd de flesinhoud geanalyseerd op CO_2- en watergehalte. Discussiërenden (w.o.Tanner) dachten dat de CO_2-absorptie in het meekomende water in de leidingen geen probleem was, indien de doorgestroomde hoeveelheden voldoende waren. — Similariteit-plots (T-e) toonden rechte lijnen boven 2 gewashoogten, dáár dus ratiobepaling zinvol.

M 11 : AN INTRODUCTION TO THE PERCH LAKE STUDY
P.J. Barry (AECL, Chalk River)

Abstract not available.

Zie: Progress Report on meteorological instrumentation and measurements at Perch Lake 1967 (H.L.Ferguson, K.A.Devine), KNMI-bibl.no II.e.522. Voornaamste voordeel project is aanwezigheid tritium in meer.

M 12 : A COMPARISON OF EVAPORATION ESTIMATE METHODS AT PERCH LAKE

H. L. Ferguson (Can.Met.Serv. , Toronto)

Among the methods being used to estimate evaporation from Perch Lake are the Penman Method, various mass-transfer equations and Class A Pan measurements. A correlation analysis has been carried out using three years of data, on a time-scale ranging from a day to a month. The Penman Method was found to have a relatively high correlation with lake evaporation estimated from par measurements on the downwind side of the lake, the daily correlation coefficient being 0.87. This high value is attributed in part to the fact that net radiation, used in the Penman Equation, is measured over the water surface rather than a standard grass surface. Analysis and intercomparison of wind and pan evaporation data between upwind and downwind sides of the lake reveal large differences. For example daily lake evaporation estimated from pan measurements on the downwind side averages 14% higher than that obtained on the upwind side, about 3000 ft away.

Behalve de **tritium-flux** (Selander, M 13) en de energiebalans (Polavarapu, M 14) werden toegepast:

(3): **waterbalans**; nog steeds niet bevredigend, i.h.b.in najaar 1969. Seepage effecten van kleine beekjes e.d.onvoldoende bemonsterd. Bovendien problemen met waterbalans-activiteiten van bevers. Tot nu toe is niveau van meer (slechts 700m doorsnede, boomhoogte $\approx$ 12 m) slechts op één punt gemeten, maar dit zal worden uitgebreid.

(4) **aerodynamische profielmethoden**; geen resultaten.

(5) **verdampingspannen**. Eén aan de bovenwindse, één aan de benedenwindse kant van het meer — er zijn nl.twee tegengestelde hoofdwindrichtingen, omdat het meer in een dal ligt. Benedenwindse pan correleert het best.

(6) **Horton-formule**: $E = C_1 \left\{ \left[C_2 - \exp(-C_3 u) \right] e_s - e_a \right\}$

(7) **Meyer-Rohwer-Fitzgerald-formule**: $E = (C_4 + C_5 u)(e_s - e_a)$

De **Horton-formule** voldoet beter dan de Meyer-formule.

(8) **Penman**. Voldoet beter met stralingsmeting boven water dan met stralingsmeting boven land.

M 13 : THEORETICAL ASPECTS OF THE EVAPORATION OF TRITIATED WATER FROM PERCH LAKE

W.N. Selander (AECL, Chalk River, Ontario)

The concentration v of vapour over a lake satisfies approximately a mass transfer equation of the form

$$u(z) \, \partial v / \partial x = \partial / \partial x (K(z) \, \partial v / \partial z)$$

where u (z) and K (z) are, respectively, the wind speed and eddy diffusivity associated with turbulent conditions. The coordinates z and x are measured in the vertical and downwind directions, respectively. Lateral or cross-wind variations as well as diffusion in the x-direction, are ignored. Under appropriate assumptions, K (z) can be expressed in terms of u (z), which can in turn be measured. Under many conditions, the wind profile is proportional to z^{m}, where the exponent m varies from one set of conditions to another.

Perch Lake contains a small concentration of tritiated water (HTO, where T is a radioactive isotope of hydrogen), which evaporates with the lake water. Because it is radioactive its concentration in the air above the lake can be measured accurately. Wind speed and tritium concentration have been measured on the down-wind side of the lake during a variety of wind and weather conditions, as a function of elevation. These observations permit a check on theory.

The agreement between theory and observation depends critically on the model used to describe the wind profile. The simplest assumptions predict concentrations which are consistently too high at low elevations and too low at higher elevations. The agreement between theory and experiment can be improved considerably by varying the wind profile exponent m and by varying the length of fetch which for a small lake is critically dependent on wind direction.

The implications of this analysis for further experimental studies are discussed.

Het afvalwater van de nabije atoomreactor bevat grote hoeveelheden
tritium. Boven water werd het tritiumgehalte op verschillende hoogten
gemonsterd met tellers. Tijdens discussie (Frenzen) werd gesuggereerd,
dat op enige hoogte toch wel tritium-advectie van buitenaf mogelijk was;
boven Lake Michigan bv.is een tritium-profielmethode zinloos gebleken.
Er was ook bv. (aan de benedenwindse kant) geen duidelijke similariteit
t.o.v.het windprofiel; de tritium-machtsexponent varieerde tussen 0.07 en
0.13. Omdat het meeroppervlak vaak vervuild is, werden nu bovendien
laboratoriumproeven voorbereid over het verdampingsverschil van schoon
en vervuild water; voor de verdampingspannen scheelde het destijds weinig.

Selander had een theorie voor de tritiumverdamping opgesteld, geba-
seerd op de 1-dim.Sutton-diffusieformule en op visceuze verdamping in een
laminaire grenslaag boven het water, aangezien het meer vrij beschut is.
De resulterende verdampingsformule verloor zijn geldigheid op enige hoogte
en was zeer afhankelijk van het windprofiel, met een fout evenredig aan
de fout in de profielexponent. Tijdens de discussie werd bovendien gesteld:
(a) de Suttonformule is een constant-stress-formule en dus voor dit geval
niet geldig; (b) zelfs boven vlak water is de stress exchange niet vis-
ceus, maar loopt via golfopwekking; (c) er zijn grote exchange-verschillen
tussen bovenwinds en benedenwinds. Gemiddeld is de uitwisselingslaag in
ieder geval dikker dan Selander aanneemt.

M 14 :

THE DETERMINATION OF THE HEAT CONTENT OF PERCH LAKE
R.J. Polavarapu (Can.Met.Serv., Toronto)

Lake temperatures from June to September 1969 were measured hourly
at 12 levels right from the air-water interface down to a depth of 8 ft
including 2 ft within the soil of the lake bed. From these measurements
the hourly changes in heat content of the lake were determined in order
to estimate the evaporative flux from the measurements of net radiation
and Bowen ratio. An attempt was made to estimate the time derivative
of heat content from measurements of the net radiative flux, surface wind
speed and air-water temperature gradient.

The diurnal and seasonal changes in the heat content of the lake are
discussed. The net radiative flux is mostly expended to increase the heat
content of the lake rapidly in the spring and to evaporate the water in the
fall.

The water temperature profile is parabolic during clear nights
when the net radiation at the surface is negative; the temperature is higher
in the middle layers and drops in value toward both the air-water inter-
face and the soil-water interface. During clear days the temperature is
higher at the surface and decreases with depth until very close to the lake
bottom thus forming a stable stratification. The water temperature very
close to the soil-water interface is slightly higher than that for the water
above, indicating that a portion of the visible radiation is still reaching
the lake bottom to heat the soil surface. During cloudy days the temper-
ature profile is either parabolic or nearly isothermal.

O.a.werd bij het gerapporteerde onderzoek de uitwisselingscoefficient
berekend uit het verschil tussen de warmteflux in het meer en de netto-
stralingsmeting.

M 15 :

THE HEAT AND WATER BUDGETS OF A BEAVER POND
E. Vowinckel and Svenn Orvig (McGill University)

Small water bodies create their own characteristic local meteorological
environments. Generally, the heat and water budgets will vary with
surface area and water depth. If a small pond gradually becomes covered
by vegetation, its meteorological conditions will change. On occasion, a
vegetated area may be turned into pond, complete with the established
vegetation in water and extending above the surface. Such are beaver
ponds and other flooded areas.

The paper discusses the main features of the development of
beaver ponds and their heat and water budgets at different stages. The

energy budget procedures used were previously developed by the authors,
but were modified to account for the different phases of the pond devel-
opment. The effects of the various physical changes are evaluated by
comparing the individual heat and water budget terms for the stages from
an open lake surface, through different degrees of progression in the
development of a vegetated pond, to a forest cover.

(Referentie: Arch.Met.Geoph.Biokl.B 17 (1969) 121-174). Het gerappor-
teerde onderzoek is een fascinerende kruising tussen mikroklimatologie,
energiebalansonderzoek en numerieke methoden, waarbij uitgegaan wordt van
o.a.stralingsgegevens van nabijgelegen klimatologische stations, welke
op fysisch-verantwoorde wijze synoptisch worden geïnterpoleerd. Uit de
berekeningen blijkt o.m.dat een meertje van 0.5 m diepte een veel grotere
verdamping heeft dan een van 2 m diepte, daar de heat storage variatie
bij het diepere meertje groter is.

M 17 :   GARP AND SMALL-SCALE METEOROLOGY
           R.W. Stewart   (Univ.of British Columbia)

Abstract not available.

Stewart gaf eerst een overzicht van de huidige stand van zaken in het
Global Atmospheric Research Programme (zie ook het ongeregistreerde confe-
rentieverslag door C.Schuurmans van de GARP conferentie in Brussel, Maart
1970). Zowel de voordracht als de discussie ging daarna voornamelijk over de
wisselwerking tussen macro- en micrometeorologie, waarbij het microgebied
werd gedefinieerd als liggende beneden 500 m hoogte en aan de hoogfrequente
kant van de zg.spectral gap. Stewart merkte over de spectral gap op, dat
het nog dubieus is of deze gedefinieerd moet worden in golflengte dan
wel in frequentie om een universeel resultaat te bereiken.
    Voorlopig is de microschael beschouwd als ruis, te superponeren op
de macrofluctuaties. In de eerste experimenten (t/m 1976) is ook geen
micro-onderzoek van enig belang betrokken. Intussen zouden de microme-
teorologen moeten werken aan de parametrizering van de microprocessen in
macro-terminologie. Ondergetekende merkte hierover op, dat van de zijde
der macrometeorologen nauwelijks de moeite is genomen om te specificeren
wélke macroparameters hunnerzijds geschikt werden geacht om te dienen als
aanknopingspunt voor de parametrizering van bv.microschaal-flux. Stewart
had dezelfde ervaring, en kon ook tijdens deze discussie van de zijde der
aanwezige macrometeorologen geen duidelijke stellingname verkrijgen.
    Het algemene bezwaar van de tot nu toe uitgevoerde micrmeteorologische
experimenten is, dat ze beperkt zijn gebleven tot zeer vlakke gebieden en
stationnaire situaties, zodat ze niet representatief zijn. Bij modelbe-
rekeningen is hier dan ook nauwelijks gebruik van gemaakt: in de gangbare
modellen zijn de grensvoorwaarden voor de onderste modellaag gekozen op
grond van hanteerbaarheid en een minimum aan fysische geloofwaardigheid.
Smagorinsky bv.heeft een natte ondergrens zonder warmtecapaciteit, d.i.
een waterlaagje van 1 mm; verder mengt hij tijdens onstabiliteit in de on-
derste laag wél de warmteflux, maar niet de momentflux. Frenzen sprak
zijn verbazing uit over het feit, dat bij modelberekening de momentflux
wordt gespecificeerd via het snelheidsprofiel, terwijl in de grenslaag
bv.de dragcoëfficiënt C_d een veel beter bekende grootheid is (en boven-
dien constanter). Panofsky stelde dat slechts de helft van de energiedis-
sipatie plaats vindt aan het aardoppervlak, en vroeg of er aandacht
werd geschonken aan de parametrizering van CAT en andere processen in
de vrije atmosfeer: overal waar mechanische energieabsorptie plaats vindt
is momentflux te verwachten. Voor de parametrizatie van de oppervlakteflux
leek de geowind een optimaal uitgangspunt, met de oppervlaktewind als
bruikbaar alternatief.

Verdere discussie betrof voornamelijk anomaal gedrag van fluxen. Uit de experimenten van Miyake (M 24) bleken o.a.onvolkomenheden in de correlatie van warmteflux en waterdampflux. De eerste kan redelijk worden gemodelleerd via de Dalton-benadering u.dq , maar modellering van warmteflux door u.dT blijkt irreëel, i.h.b.bij geringe flux; m.a.w. het werken met gradient en eddydiffusivity kan tot ernstige fouten leiden. Uit BOMEX bleek o.a. dat de herkomst van het laagfrequente deel van het warmteflux-spectrum kan afwijken van die van het hoogfrequente deel: terwijl het laatste bv.warme en vochtige oppervlaktelucht was, bestond het eerste uit lucht van hogere lagen welke warm en droog was. Ook kon de similariteit van de warmteflux ontbreken t.g.v. vertikale variatie in de uitwisseling van latente warmte. Inzake oppervlakte-effecten merkte Allen op, dat boven gewas een grote vertraging van warmte- en temperatuurvariaties te verwachten viel. Inzake aanpassing van flux aan oppervlakte-inhomogeniteit stelde Stewart, dat een redelijke aanpassing te verwachten was na een windweg van $\pm$.1000 meethoogten.

M 22 :   ON THE VERTICAL STRUCTURE OF EDDIES
          O. Johnson, K. Kembry and J.A. McCallum (Suffield Exp.Station)

To determine the slopes of eddies producing atmospheric turbulence, the relationships between the three components of turbulence for three vertically separated points on a 92-metre tower were studied by cross-spectral analysis. The analysis can be completed by utilizing the mean wind speed and the lag of maximum power, or by taking the ratio of the quadrature-spectrum and the co-spectrum - both methods are used in the present paper and the results compared. The analysis is given for nine trials performed in a variety of stability conditions. It is found that the slopes of longitudinal eddies are less than half the slopes of the lateral eddies for all stabilities. In near neutral conditions the slope is found to be a function of mean wind shear. The coherence as a function of the normalized frequency is also investigated.

Een groot gedeelte van dit verhaal bleek al behandeld te zijn in voordracht M 21 (niet bijgewoond wegens parallelzitting Perch Lake). Met zijn toevoeging inzake 9 meetruns met u $\sim$ 5 m/s was de spreker in 2 minuten klaar.

M 23 :   LABORATORY SIMULATION OF NATURAL CONVECTION INTO A
          LAYER OF NEUTRAL STABILITY
          D.R. Hay   (Univ.of Western Ontario)

A laboratory simulation of convection within the lowest kilometer of the troposphere has been developed at the University of Western Ontario and was described earlier by Fanaki. The present work is an extension of the earlier work towards larger surface heat fluxes flowing upwards into a region of neutral stability, in the absence of general horizontal flow. As the surface flux increases to about 8 mW cm^{-2} the observed convective plumes increase in number and in vertical penetration while each maintains constant diameter. These plumes may migrate over the lower boundary while maintaining their identity. At larger surface fluxes, the individual plumes lose their identities as the plume field degenerates. These observations are related to Telford's recently published theory of the convective plume field in the lower atmosphere.

(Referentie:
Proeven in watertank met homogeen vertikaal warmteprofiel tot een hoogte equivalent aan 2 à 3 x Obukhovlengte; dit kan ook als "vrije bovengrens" worden gezien. Geen horizontale stroming; Reynolds- en Prandtl-similariteit aangehouden. Uit schaduw-foto's over een oppervlak equivalent aan 300m x 300m blijkt, dat bij toename der warmteflux het aantal pluimen toeneemt. In tegenstelling met Telford's voorspelling blijven per pluim de doorsnede en kernsnelheid ruwweg constant. Specifieke pluimen kunnen ruim 8 minuten gevolgd worden, maar bewegen wel in horizontale richting.

M 24 :   AIRCRAFT MEASUREMENTS OF TURBULENT FLUXES
                M. Miyake   (Univ.of British Columbia)

By combining the information of fast response sensors of atmospheric
turbulence and the motion of an aircraft, it is possible to determine the
fluxes of momentum heat and moisture from the ocean surface by use of
an aircraft. A Beechcraft Queen-Air has been used off the west coast of
Vancouver Island and over the tropical ocean off Barbados. The results
of the flux measurements as compared to measurements from FLIP and
the inferred structure of the planetary boundary layer will be discussed.

(Referentie inzake vliegtuig-instrumentatie: Journ.Geoph.Res.$\underline{75}$(1970)4506).
BOMEX-vliegtuigmetingen uitgevoerd op 4 à 5 vastgestelde vlieghoogten
tussen 10m en 200m. Vergelijking met FLIP-metingen toonde grote piek in
de FLIP-spectra bij freq.nz/u = 1 tot 0.1 (zeegolven). Bij uitwerking alle
spectra genormaliseerd met flux op 10m hoogte, een zeer interessante
presentatie; de spreker zei zelf nog niet te weten hoe hij de gebleken
hoogtevariaties van spectraalvorm en -ligging moest verklaren. De be-
trouwbaarheid der variaties zelf stond volgens hem zonder meer vast,
aangezien de resultaten consistent waren voor alle metingen, uitgevoerd
gedurende een periode van vier weken.

In het bijzonder werden de w-spectra en de cospectra van w met andere
grootheden beschouwd. De piekligging hiervoor variëerde van (nz/u)=10
voor de w-, wT- en wQ-spectra tot (nz/u)=100 voor de uw-spectra; voor
alle w-afhankelijke spectra gold, dat boven een hoogte 100m de piek af-
vlakte of zelfs verdween. Bij hoge frequenties werd de (-5/3)-wet i.h.a.
goed gevolgd. De wT-spectra hadden vaak voor langgolvige variaties een
teken dat tegengesteld was aan dat voor kortgolvige fluctuaties.

M 25 :   THE MICROSTRUCTURE OF DRY COLD FRONTS
                H.C. Martin   (Can.Met.Serv., Toronto)

On seven occasions when dry cold fronts passed over a coastal site, the
fine structures of temperature and horizontal wind speed were measured
at a height of 14 m. On one occasion the fine structure of refractive index
(essentially humidity) was also measured.
     The frontal zone is very narrow and turbulent with the bulk of the
change occurring within a minute. The wind freshens in the few moments
before the temperature starts to drop and reaches a maximum some seconds
after the temperature starts to change.
     The temperature and refractive index are highly correlated over a
wide range of scales. It is suggested that the steep gradients in refractive
index are typical of gradients at greater heights which gave rise to the
band or line echoes observed on five occasions by means of 10-cm radar.
     From the microstructure records the existence of two mesoscale
features was inferred: the friction head which is characteristic of flow
in stratified fluids and the circulation associated with complex fronts.

De gerapporteerde 3 meetseries waren uitgevoerd op een 20m-radartoren,
gelegen tussen een complex van lage hutten op ca.200m van de kust. Met
een refractometer ($\tau \approx 0.05$ s) werden ook vochtigheidsfluctuaties ge-
volgd; een zeer hoge correlatie tussen T en deze vochtigheidsfluctuaties
werd gevonden. Zonder bijbehorende bewolkingsvariatie werden zéér plotse-
linge sprongen waargenomen, tot 4°C/10 s, met soms een gelijktijdige ver-
andering van windsnelheid en richting.

M 26 :   TURBULENT TRANSFER MECHANISMS: A TIME-DOMAIN
           ANALYSIS
                G.A. McBean   (Can.Met.Serv., Toronto)

Direct measurements of the turbulent fluxes of momentum, heat, and
moisture were made in the atmospheric surface layer. These data were
previously examined in the frequency domain by the author in order to
investigate and to compare the turbulent transfer mechanisms of the
three fluxes. In this paper the results of the analyses in the time domain

will be presented. Single and joint probability density distributions of
the turbulent variables were computed for a range of atmospheric stability
conditions. The interpretation of these results, as they apply to the
turbulent transfer mechanisms, will be compared with the earlier results
based on spectral analysis.

(Referentie: Bound.Layer Meteor.$\underline{1}$ (1971) 438-457).

Een vervolgstudie van de in bovenstaande referentie genoemde 91 runs
met een sonische anemometer op 2m hoogte boven vlak grasland. De genor-
maliseerde cospectra van uw, wq en uT bleken geen van allen Gaussisch:
alle skewness-waarden waren > 1, alle kurtosis-waarden ≥ 5. Het grote
aantal runs maakte de bepaling van de relatie tussen
$Q \equiv r_{wT}/r_{uw} \sim K_H/K_M$ en de stabiliteitsparameter z/L
mogelijk, zoals geschetst hiernaast. Verder werden
snel nog enige dia's van scatter diagrams van ver-
schillende parameters getoond, zonder dat er nog tijd
was voor nadere interpretatie. Voor dergelijke onder-
zoeken is een kwartier spreektijd veel te kort.
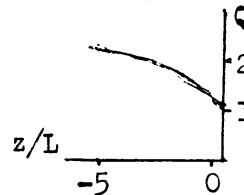
M 27 :   WIND STRESS OVER ICE AND OVER WATER IN THE BEAUFORT SEA
          S.D. Smith (Bedford Inst., Dartmouth, N.S.)

A sonic anemometer-thermometer has been used in a preliminary study
of Reynolds stress, sensible heat flux, and velocity and temperature
spectra over ice (3 runs) and over water (2 runs) in the Beaufort Sea.
The wind drag coefficient C_{10} is 0.0025 over ice (stable conditions) and
0.0014 over water (unstable).

Een vervolgstudie op de in ref [B 6] (Hfdst.6) genoemde metingen, in de
vorm van een soort interim-verhaal over twee spectra, met dia's van
inderhaast handgeschreven tabelletjes. Waarschijnlijk zal e.e.a.in de
uiteindelijke publicatie (die op het Bedford Instituut doorgaans binnen
een jaar na het doen van de metingen verschijnt) beter uit de verf komen.
Er was een korte discussie over eventuele voorkeuren voor definitie van
stabiliteit via z/L dan wel via het flux-Richardsongetal Rf. In stabiele
situaties is er nl.tussen de twee geen eenduidig verband vanwege straling.

M 28 :   MICROSTRUCTURE TURBULENCE AND KOLMOGOROFF CONSTANTS
          R.W. Burling (Univ.of British Columbia)

Abstract not available.

(Referentie: Lumley & Panofsky 1964, 162-167). Voordracht door R.W.Stewart.

Voor golflengten kleiner dan ong.2 maal de meethoogte behoort in
stationnaire gevallen de inertial-subrange-wet te gelden: bij een energie-
dissipatie e neemt de spectraalenergie E_{uu} van de longitudinale windcompo-
nent af met het golfgetal k volgens: $E_{uu} = C_k \, e^{2/3} k^{-5/3}$
waar C_k de bijbehorende Kolmogorov-constante is. Voor de experimentele
k-exponent vinden verschillende onderzoekers 1.67 $\pm$ 0.3, d.i.redelijke
overeenstemming. (N.B. Bij vertikaliteitsfcut tijdens fluxmeting kan te-
vens een fout in deze -5/3 helling ontstaan. J.W.). Verder werd tot nu
toe algemeen geaccepteerd $C_k = 0.47$. Deze waarde was gebaseerd op atmosfe-
rische metingen van Pond (resultaat: 0.48) en op metingen in een water-
tunnel van Grant (resultaat: 0.46).

Allereerst is van Grant's metingen nu gebleken, dat de aanname van neu-
trale stabiliteit tijdens zijn proeven incorrect was. Weliswaar waren de
temperatuurfluctuaties verwaarloosbaar tijdens zijn metingen, maar het bleek
dat bij meting op die schaal nog wél saliniteitsfluctuaties konden optreden,
zodat het geheel tóch onstabiel was. Herrekening der gegevens gaf $C_k = 0.54$.
Dit stemt redelijk overeen met recente atmosferische metingen door Gibson
(resultaat: 0.55 - 0.6) en McBean (resultaat: 0.55). Waarschijnlijk is de
waarde van deze Kolmogorov-constante dus ongeveer 0.55.

M 29 :   CHARACTERISTICS OF TEMPERATURE FLUCTUATIONS AT 1 AND
2 METERS
E. Ryznar and D.J. Portman   (Univ.Michigan)

Temperature fluctuations were measured at 1 and 2 meters over a level
grass field coincidently with temperature and wind profiles up to 4 meters.
Measurements were made at one height for some observation periods and
simultaneously at both heights for others. Intensity and spectral charac-
teristics of the fluctuations are discussed in relation to the Richardson
number for lapse and inversion conditions.

For lapse conditions, average values of the power $p = \dfrac{\ln(^{\sigma}T_2/^{\sigma}T_1)}{\ln(Z_2/Z_1)}$

in the relation $\sigma_T = AZ^P$, where σ_T is the standard deviation of temperature,

A a constant, and Z the height, are shown by the results to: (1) increase
gradually from about -0.15 for $Ri = -0.002$ to -0.05 for $Ri = -0.05$; (2)
increase abruptly to about +0.24 between $Ri = -0.05$ and -0.1; and (3)
gradually level off at about +0.3 for $Ri = -0.2$.

Aspects of the results are not in agreement with either similarity
theory or the results of others. They are discussed in relation to the
heights of the measurements and the formation and structure of micro-
thermals in unstable thermal stratification.

Warrig voorgedragen verhaal, voornamelijk inhoudend dat een herhaling van
thermals was geobserveerd met een golflengte van ong.50m en met een
steilere temperatuursafname dan -toename. Dit laatste verklaarde spreker
uit een beeld van thermal-buizen met de warmste lucht bovenaan en een
helling tgv.wind shear. (Kaimal & Businger, JAM 2, 180, geven een soort-
gelijke verklaring van overeenkomstige waarnemingen, maar doen dit in
termen van convergentie, hetgeen een minder gewrongen constructie lijkt).
Volgens Hay was de theoretische achtergrond van Ryznar's verhaal bij voor-
baat incorrect, omdat zijn model uitging van neutrale stabiliteit.

I 1 :   THE DEVELOPMENT OF ACCURATE WIND-MEASURING
INSTRUMENTS FOR THE RESEARCH METEOROLOGIST
Gerald C. Gill   (Univ.Michigan)

During the past twenty years the writer has employed and developed a
number of mechanical and electrical wind speed and direction sensors
for the accurate measurement of the wind near the ground. He has used
anemometers of the hot-wire, 3-cup and propeller types; wind vanes of
the flat plate, splayed, and aerodynamic shapes; anemometer transducers
of the D.C. tachometer, light-chopper and gear-reducer-potentiometer
types; and, wind vane transducers of the D.C. selsyn, A.C. selsyn and
potentiometer types. He has developed light weight fragile "fair-
weather" bivanes; "all-weather" anemometer bivanes; vertical flow
anemometers and a triaxial U V W anemometer. The merits and limita-
tions of most of these sensors or systems will be briefly discussed or
demonstrated.

For highest fidelity measurement of the three components of wind
speed at a tower location the writer suggests the use of two adjacent
sensors - a "propeller vane" to measure the horizontal component of the
wind speed and the corresponding azimuth angle of the wind; and an ad-
jacent vertical-shaft propeller anemometer to measure the vertical
component of the wind speed. Identical light weight expanded polystyrene
propellers of true helicoidal shape, each driving miniature precision
direct current tachometers, are normally used for the two-speed sensors.
A light-weight expanded polystyrene wind vane of the flat plate style,
appropriately damped, and driving a precision low torque potentiometer
is used for azimuth wind direction measurements. Recording can be on
three channels of a magnetic tape or other suitable recorder. Fidelity
of recording is good for wind speeds in the range 1 - 25 m sec^{-1} and for
gusts of 10 meters or longer in wavelength. The starting speed of the
propeller anemometers is usually 0.2 to 0.3 m sec^{-1}.

(Gill had twee voordrachten geprepareerd, een over moderne instrumenta-
tieontwikkelingen en een historisch overzicht. De congresleiding had de
laatste voordracht geprefereerd.)

Na een korte inleiding, o.a.over de windtunnel van de Universiteit
van Michigan, waar de anemometers op een excentriek werden geplaatst om
via anemometerbeweging sinusvormige windfluctuaties te simuleren, kwam

de door Gill ontwikkelde propeller ter plaatse. Deze helix-propeller heeft in water dezelfde ijking als in 3 mb lucht (dichtheidsfactor 10^5 !). Gebruikt als vertikale propeller, heeft hij geen strikte cosinusresponsie maar kan over een $\pm$ 30° range tot op 2% worden benaderd door een lineaire ijking. Helaas is er loodrecht op de asrichting een "dode hoek" van 2° à 3°; een dunne aluminium-versie is in voorbereiding om deze dode hoek te verkleinen. (Ook Gill heeft met glasvezelmat geen gunstige resultaten). Aangetoond werd, dat de zg. XYZ-opstelling (drie propellers in onderling loodrechte richtingen) ook uit de richting van de propelleras een vrijwel normale responsie had, indien de propellers trapsgewijze boven elkaar werden opgesteld.

I 2 : A PROPELLER-TYPE WIND SENSOR
D. Champ (Can.Met.Serv., Toronto)

A relatively simple flat-bladed propeller was designed for wind profile measurements in the International Field Year on the Great Lakes. At speeds more than double the starting speed, it displays a cosine response within 5% of wind speed, linearity within 0.5%, a sensitivity of 0.95 m per revolution and an incremental distance constant of 2.1 m. Its starting speed is about 0.3 m/sec. The sensor principle could be adapted to special anemometers for micrometeorological use by producing a lighter, less rugged, model.
Since its cosine error is quasi-symmetrical about 45°, simple computer calculations will resolve the wind vector with speed inaccuracies less than 2.5% and angular inaccuracies less than 3° at speeds greater than 2.5 m sec^{-1}.
In the transducer, form A reed switch closures,are fed to C/MOS integrated circuitry for propeller direction determination and wind component accumulation. The C/MOS logic allows operation at low power (microwatts) over a wide temperature range (-40 to 85C).

Twee propellerbladen maken een hoek van 20° met de as, de andere twee een hoek van 65°. Dit was meer een probeersel dan dat het op theoretische voorstudie was gebaseerd. Interessant, maar onvoldoende uitgewerkt.

I 3 : A "DAMPED" WIND DIRECTION DIGITIZER
J.S. Dickson (Can.Met.Serv., Toronto)

A Wind Direction Digitizer that has a voltage controlled slewing rate is described, the voltage being selected to meet the user's requirements. Digital and voltage outputs of the instantaneous difference between the lagged position and the vane position are also available, permitting measurements of the wind direct on variation about a slowly varying mean value to be recorded.

Electronische schakeling; zeer interessant, maar veel te uitgebreid en te detaillistisch voor een voordracht van een kwartier. Nadere gegevens krijg ik hopelijk nog opgestuurd.

I 7 : INSTRUMENTS FOR TURBULENCE MEASUREMENTS NEAR THE WATER SURFACE
F.W. Dobson (Bedford Institute, Dartmouth, N.S.)

Results from field tests of a hydraulic wave-following device designed and constructed at Chesapeake Bay Institute have been analysed using spectral techniques. The analyses show the device to be suitable for maintaining turbulence sensors at small fixed distances above the surface of wind-driven waves. The uses of such a device for air-sea interaction studies are discussed.

Voor metingen met hot-wire anemometers en drukfluctuatiemeters (Elliott, zie hfdst.5) op 2 tot 4 cm boven golven met een maximum amplitude van 30 cm is een "wave follower" ontworpen, analoog aan die van G.M.Davis (M.Sc.thesis UBC 1969: Measurement of air temperature and wind velocity

from 1 to 80 cm above the sea surface. Op KNMI aanwezig bij W.A.Oost.)
Een 15 mm $\emptyset$ roestvrij stalen volgmast van 1 m werklengte wordt servo-
hydraulisch in positie bij het golfoppervlak aangepast; de maximaal
noodzakelijke versnelling is 1.5 g, de maximale snelheid 1.5 m/s. De
volgmast kan met 2.5 kg instrumenten worden belast.

I 8 :   THE USSR INTER-COMPARISON EXPERIMENT
              J. McDonald and M. Miyake (Univ.of Br.Columbia)

During the period 15 June to 20 July 1970 an international inter-
comparison of turbulence equipment was held at Tsimlyansk, U.S.S.R.
Groups from Australia, the United States, Canada and the U.S.S.R.
participated. Synchronized measurements of fluctuations of horizontal
and vertical winds, temperature, and humidity were carried out using
different instruments placed near each other. Some results of this
experiment will be presented and discussed.

(Referenties: BAMS 51, 1150; Izv.AkNaukSSSR Fiz.Atm.Ok.6, 1084/br.650).
    Uit de vergelijking van spectra van de Kayodenki en van de Russische
sonische anemometer bleek weliswaar goede vorm-overeenkomst, maar een
absoluut ijkingsverschil van 20%; ook waren op gelijke hoogte de Russische
kruisspectra anisotroop (constante=4/3 in uw-inertial range) en de Kayo-
denki-kruisspectra isotroop (constante = 1). Sonische weglengte voor
beiden 10 cm, met bij de Russische sensor-opstelling mogelijkheden tot
onderlinge wake-effecten van de transducers. — De zeer lichte cupane-
mometers van Frenzen (L = 0.7 m) bleken aan het laagfrequente spectraal-
einde een 10% overshoot te geven t.o.v.de sonische metingen.

P 1 :   THE URBAN AREA AS TARGET FOR METEOROLOGICAL RESEARCH
              H.E. Landsberg (Univ.of Maryland)

Meteorological research in the recent past has placed most emphasis on
large-scale atmospheric motions, storms and damaging weather patterns,
synoptic scale forecasting, and applications to aviation and agriculture.
With continuing concentration of population in urban areas (in western
countries now 70%) greater attention than heretofore has to be focussed
on the meso- and micrometeorological problems of densely settled areas,
which also coincide with high concentrations of industry and road traffic.
These have, for example, created pollution hazards intimately related to
meteorological conditions. A considerably higher premium has also been
placed on pin-pointed forecasts of snow conditions.

Surface characteristics	T	$\frac{\Delta T}{\Delta z}$	Synoptic situation U	N	Z_0/cm^3	local conditions V	q	precip.
			Parameters under notable influence of					
Total urban area	2	1	2	2	2	1	2	1
Portion vegetated	1		1		1	1	2	1
Albedo	2	2						
Roughness		2	3	1				2
Combustion & other heat products	2	3	1	1	3	2	2	3

1 weak 2 moderate 3 strong interaction
T temperature, $\Delta T/\Delta z$ low-level temperature gradient, U wind speed,
N cloudiness, Z_0/cm^3 nuclei number, V visibility, q specific humidity,
precip. amount and character of precipitation.

        Adequate density of surface observations and low-level vertical
soundings have become essential needs. Model formulation has lagged
because of the great complexity of interaction. Much of the current re-
search is still phenomenological. The problem can be illustrated in the
form of a very simplified and schematized matrix.
        Neither the columns nor the rows are independent of each other, so
that various boxes are more or less highly correlated.
        Some of the implications will be discussed with illustrations drawn
from recent pertinent literature and experiments conducted in an area
undergoing rapid urbanization.

Urbanisatie-effecten werden geïllustreerd aan de hand van metingen in de binnen 3 jaar gebouwde "new town" Columbia, Md.,USA. Besproken effecten:
(a) Runoff neemt sterk toe door impermeabiliteit bestrating → droogheid.
(b) Doordat een hard oppervlak 2 à 3 maal de warmteflux van grasland heeft, zowel overdag als 's nachts, zijn er warmte-eiland-effecten, welke zeer goed kunnen worden bestudeerd via IR-luchtfotografie. 's Avonds blijft de stad langer warm dan begroeid land; een bij-effect is, dat bv. in Los Angeles de relletjes beginnen wanneer de temperatuur boven een bepaald punt stijgt.
(c) Bewolking neemt toe boven de stad, zoals bv.blijkt uit vergelijking van de synops van de vliegvelden LaGuardia (in New York) en Kennedy (aan de rand van New York). In onstabiel weer leidt dit tot verhoogde regenval.
(d) Luchtverontreiniging wordt door het warmte-eiland beïnvloed als geschetst, zoals door Bach & Patterson voor Cincinnati is aangetoond: de ontweken pollutie wordt door convergentie in de stad teruggevoerd.

Iedere stad heeft eigenaardigheden, zodat per stad individuele pollutie-forecasts nodig zijn. Het warmte-eiland bv.kan door sterke winden worden verplaatst en verzwakt.
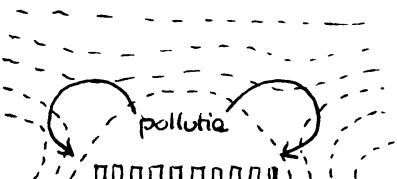
P 2 :   NOCTURNAL TEMPERATURES IN EDMONTON
              K.D. Hage   (Univ.of Alberta)

A network of seven thermographs has been operated continuously within the city of Edmonton since February, 1968 by Geoscience Research Associates Ltd. under contract to the Department of Health of the Government of Alberta. Data from these stations, together with hourly observations from two rural airports, and one urban airport, in the Edmonton area are inadequate for mapping the temperature field, but provide an unusual opportunity for the study of some climatological characteristics of urban temperatures over relatively flat terrain undisturbed by lake and sea influences. All thermographs are calibrated at regular intervals and supplementary calibrations are carried out using airport observations during periods of continuous precipitation. Annual variations in heat island intensity, based on analyses of two years of data, are ill-defined because of large variations in month-to-month frequencies of favourable nights. Stratified monthly samples consisting only of nights with intense heat islands appear to show weak intensity maxima in mid winter and early summer. A well-defined diurnal cycle in heat island intensity is found with a maximum before midnight in the cold season and just after midnight in the warm season. The results are discussed in relation to the development of realistic heat island models.

Dag-analyses zijn voor deze data onmogelijk wegens onvoldoende stralingsafscherming der thermografen.

P 3 :   CHALEUR URBAINE A MONTREAL
              Conrad East   (Université de Montréal)

Grâce à des sondages de température effectués en hélicoptère à 12 sites de l'île de Montréal, on a pu calculer la chaleur générée par la ville en 38 jours assez bien distribués à travers l'année.
      Une relation linéaire inverse entre la chaleur urbaine et la température ambiante a pu être établie. Toutefois, la chaleur artificielle estimée à partir de la consommation des combustibles de l'industrie et du chauffage représente à peine 25 pourcent de la chaleur urbaine totale, telle que mesurée directement dans l'atmosphère. On discute l'hypothèse selon laquelle le reste de la chaleur urbaine devrait être attribuée au rayonnement solaire absorbé, puis réemis par les surfaces et structures de la ville.

(Volledig rapport ter inzage bij C.A.Velds; zie ook Bound.Layer Met.$\underline{1}$ (1971), 411-437). Kwalitatief zeer interessante, maar kwantitatief onverantwoord ver doorgerekende analyse van temperatuurmetingen vanuit een helicopter.

P 4 :   COMPARISON OF URBAN/RURAL ATMOSPHERIC COUNTER
          RADIATION
               T.R. Oke and R.F. Fuggle   (Un.Br.Col., McGill Un.)

The effect of an urban atmosphere upon the incoming longwave radiation
is investigated by direct measurement. Counter radiation and air tem-
peratures were continuously monitored during automobile traverses
across the Island of Montreal at night. Results show that urban counter
radiation values are consistently higher than those for rural locations,
but that the magnitude of the differences is small. Comparison between
the measured radiation and that computed from empirical equations shows
good agreement in rural areas, but important differences in the city.
There is a correspondence between the air temperature and incoming
longwave radiation profiles across the city. However, it is felt that,
contrary to previous opinion, the increased counter radiation is an effect
rather than a cause of the urban heat island. It is concluded that increased
incoming longwave radiation in urban areas is not a major contributor to
urban/rural heat balance differences.

Enige hypothetische oorzaken van het nachtelijk warmte-eiland in de stad
zijn: opslag van warmte in bouwmaterialen, kunstmatige verwarming, ver-
minderde verdamping, en toename van de neerwwaartse atmosferische straling
door verhoogde luchtverontreiniging in het stadscentrum. Tijdens de meet-
ritten nam de counter-radiation zowel in het stadscentrum als nabij de
raffinaderij aan de stadsrand toe in vergelijking met het open veld; uit de
beschikbare data kan nog niet worden afgeleid of dit een gevolg is van
emissiviteitsverandering of van variaties in de luchttemperatuur. In
ieder geval zijn de stralingsverschillen kwantitatief veel te gering om
als uitsluitende verklaring van het warmte-eiland bruikbaar te zijn. Op
een vraag van Landsberg , of de waterdamp-drukverschillen tussen centrum
en stadsrand een rol speelden, werd geantwoord dat dit verschil 10 mb
dampdruk zou moeten bedragen om de stralingsverschillen te verklaren.
Het instrumentatie-verslag maakte een verzorgde indruk; o.a.was de ven-
tilatie der radiometers enigszins onafhankelijk van de autosnelheid.

P 6 :   SIMULATION OF THE NEUTRALLY STRATIFIED URBAN WIND IN
          CONVENTIONAL WIND TUNNELS
               N.M. Stander and R.J. Templin (Nat.Res.Council,Ottawa)

⑥

The Low Speed Aerodynamics Section of the National Aeronautical
Establishment is currently engaged in a programme to produce scale
models of urban winds in conventionally sized wind tunnels. At present,
contoured, two-dimensional "spires", mounted on the tunnel floor at the
entrance to the working section, are being used in the attempt to generate
a shear layer approximately the height of the spires and with a mean
velocity profile and turbulence characteristics similar to a neutrally stable
wind over a city.
       A recent test in the NAE thirty-foot tunnel at Uplands compared the
characteristics of a shear layer generated by four-foot spires with those
of a shear layer generated by a boundary layer growing over 3-inch cube
roughness along the entire working section floor. The effects of these
two shear layers on a 1/400 scale model of downtown Montreal were also
compared. Quantities measured included the mean velocity profile, lon-
gitudinal turbulence intensity, Reynolds stress and longitudinal turbulence
power spectral density.

Deze poging tot het simuleren van een hoge grenslaag in een korte wind-
tunnel komt uiterlijk overeen met die van Counihan (Atm.Env.3,197-214).
De indruk ontstond, dat de auteurs i.h.b.over de vorm van de gesimuleerde
spectra nog niet tevreden waren, maar verder bruikbare resultaten hadden.

P 7 :   WIND STRUCTURE IN CITIES
               A.G. Davenport, M. Hogan, N. Isyumov and T. Jandali
               (Univ.of Western Ontario)
          The paper describes a number of wind climate studies for large cities
          carried out while establishing the wind loading on tall buildings. Mete-
          orological records of both surface and upper level winds are used
          extensively.

In addition the use of topographic models in conjunction with the boundary-layer wind tunnel is described for the purpose of describing general airflow characteristics.
The situation in Toronto will be discussed in detail. Field data on the mean flow and turbulence will also be described and compared with wind tunnel observations.

De abstract hoort m.i.niet bij de voordracht: dit was een review over wind-belasting, voornamelijk historisch getint.

P 13 :   A SIMULATION MODEL FOR AIR POLLUTION OVER TORONTO
N.E. Bowne, D.G. Cooper, L. Shenfeld and A.E. Boyer
(TRC,Hartford,Conn.; Ontario Dept.Energy Man.,Toronto)
The devlopment of a mathematical model to simulate the atmospheric environment over Toronto has provided a means of evaluating the relative importance of pollutant emissions, meteorological factors, and the geographic distribution of pollution sources in determining air quality.
Changes in air quality produced by atmospheric changes must be evaluated side by side with air quality changes resulting from the increased or decreased pollutant emissions.
An extensive emission inventory is described, including a review of major pollution sources.
Toronto Model predictions, based on hour-by-hour measurements of meteorological variables from a network of observation points and pollutant emissions from thousands of sources, are compared with air quality measurements from eight sampling locations. The relative importance of meteorological changes and pollutant emission changes is illustrated.

(Volledig rapport ter inzage bij S.L.Sarin).
Zeer interessant overzicht, allereerst van uitgevoerde emissie-inventari-satie van 250 puntbronnen, 8000 oppervlaktebronnen (combinaties van kleine bronnen) en een aantal lijnbronnen (wegen). Via totaalverbruik en dagelijkse gang van verbruik per bronscort is voor de totale emissie het volgende resultaat gevonden:

	auto's	krachtcentrales	overige bronnen
SO2	<1%	78%	22%
stof	6%	28%	66%
stikstofoxyden, als NO2	19%	53%	28%
koolmonoxyde	98%	<1%	2%
koolwaterstoffen,als CH4	69%	<1%	31%

Voor lange-termijn-planning van industrialisatie e.d.worden de resultaten sociaal-geografisch bestudeerd. De voordracht ging over het korte-termijn gebruik, waarbij de brondiffusie-resultaten worden gesommeerd per 1 km²-blok in een gebied van ong.20 bij 40 km. Een contrôle m.b.v.een 9-punts meetnet gaf bemoedigende resultaten. In het gebied zijn 5 meteo-stations (3 vliegvelden, 2 100m-masten); aangezien Lake Ontario zeewindeffecten geeft, blijkt dit aantal onvoldoende om het windveld te bepalen tot op de modeltechnisch vereiste $10°$ richtingsnauwkeurigheid. Een goed topografisch-mesometeorologisch windmodel lijkt wenselijk.

P 14 :   TIME-LAPSE PHOTOGRAPHY FOR THE STUDY OF AIR POLLUTION KINETICS OVER AN URBAN AREA
J. Havlena and M.F. Mohtadi   (Univ.of Calgary)

A photogrammetric technique using time-lapse cine-photography has been developed for the study of the formation and movement of pollution clouds over an urban area. Qualitative evaluation of results for the City of Calgary obtained during the summer of 1970 shows that this technique provides information on:
1) the formation of pollution clouds,
2) the movement of pollution clouds due to meteorological factors,
3) the extent of the contribution of traffic and industrial sources to pollution, and
4) certain optical properties of the pollution cloud.
The technique appears also suitable for monitoring of polluted air. Densitometric evaluation of results planned for the future will provide a basis for verification of the mathematical model of air pollution above a given area.

Leuke very-slow-motion film vanaf vér buiten de stad.

P 8 :

BLOWIN' IN THE WIND
P.J. Barry   (AECL, Chalk River, Ontario).

More than one way of managing our industrial and residential airborne wastes is open to us. Our options include:
- (i) Meteorological control, whereby the strength of selected sources is reduced during periods of poor atmospheric dispersion,
- (ii) Siting, meaning the horizontal or vertical displacement of sources relative to sensitive receptors,
- (iii) Source strength reduction, achieved by removing to a greater or lesser degree, potential pollutants from effluents.

Which of these alternatives or combination of them we choose will depend on their effectiveness per unit cost. Effectiveness of a control measure is the amount by which the harmful effects of pollution are reduced when the control is applied. To assess the harm done we must know how particular adverse effects are related quantitatively to the time course of exposure of sensitive receptors (e.g., people, buildings, agricultural crops, etc.).

To elucidate these relationships, meteorologists will have to cooperate closely with epidemiologists, toxicologists, plant pathologists and other specialists. In addition, meteorologists will have to predict temporal and spatial distributions of pollution levels for a variety of alternative source conditions and alternative source-receptor configurations so that the amount of harm per unit of release corresponding to each case can be estimated.

Unfortunately, we do not yet know enough about atmospheric dispersion. More research is needed but of a kind different from and having a different emphasis from that which has been popular hitherto. The meteorologist will have to answer questions other than his own and his answers will have to be expressed so that they will contribute to the solution of practical problems.

Humoristisch-serieus sluitingsverhaal. Volgens de laatste telling van de spreker zijn er 22 verschillende formules voor pluimopstijging.

R 1 :

CLIMATONOMY
H.H.Lettau (Jniv.Wisconsin)

It is proposed to use the term "climatonomy" if at specific regions of a planetary surface, the spatial--temporal variations of climatic elements are numerically calculated as response functions that are coupled, by mass and energy budget requirements, to externally prescribed forcing functions. Essential is an approach to this complex design problem similar to modern "systems engineering". The following five system components are considered: input (1) to a defined process (2) generating output (3) which triggers natural feedback (4) and may stimulate control (5) by human reactions. Feedback, as well as control, can be directed towards input, or process, or both.

Applications of the concept will be examplified by climatonomies of (1) insolation attenuation in the air, (2) seasonal soil-moisture variations for watersheds, and (3) temperature variations (annual as well as diurnal, and experimental) at and near the earth/air interface. Important is process-parametrization to the degree that climate changes can be predicted numerically if any single parameter is quantitatively modified by feedback or control. Specific examples to be discussed include climatonomic studies for (1) the desert region of Peru, (2) the hydrologic cycle in various regions including North America, Europe and Asia, and (3) spatial microclimatic differences in Wisconsin. Emphasized will be the relationship between Budyko's dryness ratio and Bowen and run-off ratio's, also the consideration of regional mass and energy input (by precipitation and insolation) as a substitute for Thornthwaite's estimate of "potential evapotranspiration".

Interessante dia's, voordracht onverstaanbaar wegens zachte stem spreker en ontbreken geluidsinstallatie.

3. Overige, niet-bijgewoonde, voordrachten.

M 7

ON THE INTERRELATIONSHIP BETWEEN NET RADIATION, SOIL
MOISTURE AND EVAPORATION
B. Padmanabhamurty (Can.Met.Serv., Toronto)

Diurnal and seasonal variations of evaporation and net radiation along
with the space and time variations of soil moisture over bare soil at
Waltair will be presented and discussed. Variations of evaporation in
relation to soil moisture and net radiation have been examined under
diverse meteorological conditions obtained at Waltair. The results
suggest that the fraction of net incoming energy utilised for evaporation
is linearly proportional to soil moisture at one foot depth.

M 8

EVALUATING AND MAPPING SURFACE VARIATIONS IN GLOBAL
RADIATION
B.J. Garnier (McGill University)

Although micrometeorology has taken considerable heed of the variation
of radiation with slope and aspect, little attention has been given to the
problem of portraying the actual spatial distributions which occur in a
given region under different weather conditions. A method to evaluate
such variations has been developed and perfected over the past three
years (Garnier and Ohmura).
　　　The basic data required consist of observations of global and diffuse
radiation at a site representative of the area to be mapped. Calculation
of surface variations from these data is effected by reference to earth/sun
relationships and the surface geometry, which can be analysed from a
standard topographic map. Tests of the system in tropical latitudes (at
Barbados, 13°N) and in middle latitudes (at Mont St.Hilaire, Quebec,
45°N) show it to be accurate to within ±5%. Results from Barbados
emphasize three features: (a) the range of topographic variation from one
month to another is much greater than the observations taken on a hor-
izontal surface might lead one to suspect; (b) many slopes receive their
maximum radiation during low-sun periods of the day, east slopes in
particular being rapidly warmed during the first hour or two after sun-
rise in the clear air before clouds develop; (c) surface variations are
negligible during the four hours centred on noon. At Mont St. Hilaire,
daily totals of the topographic variations have been found to be greatest
in the six-week period centred on the equinox; at other times the surface
variations in daily totals are minimised, despite different short-period
intensities, because of (a) small radiation values in winter, and (b) long
summer days whereby the lower intersities on northern slopes as com-
pared with southern slopes are compensated for by the duration of
daylight. In general, days of low atmospheric transmissivity (P≤0.45)
in both test areas display an insignificant amount of surface variation
owing to the high component of diffuse sky radiation in the global totals.
Results in general encourage the hope that a rational climatology of
radiation on slopes in relation to characteristic weather conditions can
be developed.

M 9

A METHOD AND EXAMPLE OF ESTIMATING EFFECTIVE NET
RADIATION FOR A MOUNTAINOUS WATERSHED
D. Storr (Can.Met.Serv., Calgary)

There are several methods of calculating the short-wave radiation
received by the terrain in mountainous areas, but none for calculating
net radiation.
　　　After a discussion with some examples of the variability of net
radiation in a mountainous watershed including the effects of topography
and cloudiness, annual curves of measured net and short-wave radiation
under clear skies at one point in the basin are shown.
　　　From these and Ferguson's curve for clear sky effective insolation
for the basin, and from a consideration of the ratio between net and in-
coming short-wave radiation and its relationship to albedo, the annual
curve of effective clear-sky net radiation for the basin is obtained. The
variable ratio between basin effective clear-sky net radiation and mea-
sured point clear-sky net radiation is the numerical factor applied to
measured data in order to obtain the basin average of effective net
radiation for all weather conditions.
　　　Some conclusions are drawn about the representativeness of the
measuring site, while areas of need for further refinement are outlined.

M 10

TOPOGRAPHIC VARIATION OF FOREST CANOPY TEMPERATURE
AS MEASURED BY AN AIRBORNE RADIATION THERMOMETER
R.B.B. Dickson and D.O. Greenbank (Univ.of New Brunswick)

A Barnes PRT-5 radiation thermometer was flown over a section of
northwestern New Brunswick during the period 18-21 June 1970 in an
attempt to determine the topographic variability of canopy-level tem-
perature. The purpose of the project was to develop a local climate map
to overlay a forest cover map in order to identify areas most favourable
for spruce budworm development. Recognition and mapping of such
areas or epicentres would prove valuable in surveying and monitoring
incipient outbreaks and reduce the extent and cost of applying insecticides.
　　　Six flights were carried out during the six-day period under cloud
conditions varying from clear to overcast, and including one night-time
flight under ideal conditions of radiative cooling.
　　　The greatest variations of temperature occurred at noon on a day
of high values of solar radiation, but the influence of topographic slope
and aspect produced temperature differences of only 1 - 2C between
north-facing and south-facing slopes in areas of solid forest cover.
Much greater temperature differences resulted from variations in forest
cover. In some cut-over areas surface temperatures of 55C (131F) or
higher were measured, 25C higher than average canopy-level temperatures
in areas of solid forest cover. Elevation was unimportant during the mid-
day flight but was the dominating factor during the pre-dawn flight.

M 16

THE PASSAGE OF A LAKE-BREEZE FRONT: A COMPARISON
BETWEEN THE CITY AND THE SUBURBS
M.S. Hirt and R.W. Shaw   (Can.Met.Serv.,Toronto)

The penetration and retreat of a lake-breeze front in the urban, lake-
shore environment of Toronto was observed by means of two instrumented
towers, one in the downtown business section and the other in the suburbs.
The effects of the additional city heating upon the front were most evident.
In the city, there was a greater contrast between the inland air and the
lake air, with the result that the advancing front was steeper and more
sharply defined in the city than in the suburbs. Overland heating during
the day modified the air so that in the suburbs, the front was steeper
when it was retreating than when it was advancing. Over the city, the
lake air was even more extensively modified by the additional man-made
heat sources, with the result that the lake-breeze front was hardly
detectable by the ime it retreated.

M 18

THEORY OF THE WIND PROFILE UP TO 100-m HEIGHT
A.K. Blackadar and H.A. Panofsky   (Pennsylvania St.Univ.)

Under the assumption that the turning of the wind with height can be
neglected up to about 100 m height, a log-linear wind profile is derived
for neutral conditions. The vertical variation of stress and mixing
length are obtained from earlier Ekman layer theories.
    The results show that corrections to the logarithmic profile must
be taken into account when stress and roughness length are determined
from winds observed above 15 m. Generalizations to unstable air are
discussed, along with practical methods to determine roughness lengths
and surface stress from tower profiles over homogeneous terrain.

M 19

⑥

THE GEOSTROPHIC DRAG COEFFICIENT OVER HETEROGENEOUS
TERRAIN
F. Fiedler and H.A. Panofsky   (München; Penn.St.Univ.)

The geostrophic drag coefficient and contour wind-angle are functions
of surface Rossby number and a stability parameter. Over heterogeneous
terrain, the Rossby number is expressed in terms of an "effective"
roughness length which gives the correct surface stress under the same
large-scale conditions if the ground were homogeneous. Typical effec-
tive roughness lengths are evaluated from vertical-velocity variances
observed in the Lo-Lo-Cat project.
    In order to allow for stability, an empirical diagram is developed
for geostrophic drag coefficient in terms of both surface Rossby number
and insolation.

M 20

GEOSTROPHIC DRAG, HEAT AND MASS TRANSFER
COEFFICIENTS FOR THE DIABATIC EKMAN LAYER
G.T. Csanady   (Univ.of Waterloo)

The "asymptotic matching" principle has been applied to the equilibrium
Ekman Layer with vertical heat flux. This principle requires that the
properties of the "surface" or "inner" layer overlap asymptotically (at
large z) with those of the "outer" layer, or rather with the asymptotic
behavior of the latter as z → 0. In this manner, it is possible to derive
relationships for the geostrophic drag-, heat and mass transfer
coefficients (i.e., relate surface fluxes to large-scale properties of the
motion) without considering the detailed dynamics of the outer Ekman
layer, by relying on the fairly accurately known surface layer distribu-
tions of non-dimensional velocity, temperature and humidity gradients.
Such bulk transfer coefficients are presented as a function of non-
dimensional parameters involving large-scale measures of the flow only.

M 21

TURBULENCE STATISTICS AT 16, 48 AND 92 METRES AT DEFENCE
RESEARCH ESTABLISHMENT SUFFIELD
O. Johnson and B.R. Larson   (Suffield Exp.Station)

For a number of years, measurements of the three components of tur-
bulence have been made at three levels on the DRES tower in a variety
of stability conditions. Most of these were made during summer and
fall, but a few measurements were made during one winter. Mean values
of the standard deviations of the azimuth and elevation angles are given
for various wind and stability conditions and also as a function of height.
The results are discussed in relation to practical systems which have
been suggested for estimating downwind diffusion.

I 4

A GAS EXCHANGE METER BASED ON THE EDDY CORRELATION
TECHNIQUE
R.L. Desjardins and M. Johnson   (CDA Plant Res.Inst.,
Ottawa, and Cornell University)
A newly developed sampling system for measuring fluxes of gases will
be described. The operation of this system is based on the eddy corre-
lation technique. Air is sucked into special bags at a rate proportional
to the vertical wind speed. This gives integrated values of the flux of
any gas. Water vapor and carbon dioxide fluxes above a corn crop at
Ithaca, New York, during the summer of 1970 will be discussed. The
results will be compared with the Bowen ratio approach for a few
special cases. An extensive discussion of errors will be presented.
    Applications of this system to air pollution studies on a national
scale will also be discussed.

I 5

⑥

MECHANICAL BALANCE - ELECTRICAL READOUT WEIGHING
LYSIMETER
E.I. Mukammal G.H. McKay and V.R. Turner
(Can.Met.Serv., Toronto)
As part of the research programme of the Canadian Meteorological
Service a large, sensitive, weighing lysimeter has been constructed
north of Toronto on the research site of the Canadian Meteorological
Service. Features of the instrument include: measurement of runoff;
free water drainage; drainage for water held by tension; addition of
water from below during dry conditions; equalization of soil temperature
profile inside with that outside the lysimeter; humidity control to elim-
inate condensation; low area of discontinuity at the rim to reduce the edge
effect; and semi-monolith filling. This paper describes the construction
and installation of the lysimeter, problems encountered and some
infrequently considered sources of error.

I 6

THERMISTOR-BASED AVERAGING THERMOMETERS WITH DIGITAL OUTPUTS
A. Bootsma and T.J. Gillespie (Univ of Guelph)

Thermistor-based instruments have been built which produce, for any desired averaging period, a single number representing the average temperature during that period. A small volume of data is thus obtained even for observations over lengthy periods of time.

An inexpensive, battery-operated averaging thermometer was first developed for use in orchards as a guide for scheduling spray programs to control apple scab. For this and many other temperature measurements in the air there is no need for shielding and aspirating because very tiny thermistors can be used. The same simple circuit has also been used to monitor soil temperatures. A more complex thermistor bridge device was later built for an air temperature application requiring greater accuracy. Both circuits produce pulses at a rate proportional to temperature with the more complex device having a linear calibration. Electromechanical or electronic counters were used to log the data in digital form.

I 9

MEASUREMENT OF EVAPOTRANSPIRATION FROM A DOUGLAS FIR FOREST
T.A. Black and K.G. McNaughton (Univ.of Br.Columbia)

Reliable estimates of evapotranspiration from west coast forests are required for the testing of hydrologic models and for management decisions in forested watersheds. The objectives of this study were: (1) to measure evapotranspiration from an 11-year old, 9-meter high Douglas fir forest during the summer months when drought limits forest growth; and (2) to determine the feasibility of measuring evapotranspiration using the energy balance/Bowen ratio method continuously over an extended period of weeks.

The Sargeant-Tanner psychrometric Bowen ratio apparatus design was modified for use on a micrometeorological tower by making a sturdier frame and sensing heads, epoxy mounting the diode-thermometer elements in the sensing heads rigidly, and eliminating the influence of lead resistance in the bridge circuit. The apparatus continuously measured the differences in the wet and dry bulb temperatures over 1 meter to less than 0.01C. The Bowen ratio apparatus and a net radiometer were mounted on a 10-meter tower. Canopy heat storage was calculated from the canopy air and tree temperatures, and canopy air vapour pressures. Soil heat flux density was measured by soil heat flux plates and integrating thermometers.

The contribution of the soil heat flux and canopy heat storage rate to the total evapotranspiration over several days could be neglected. The temperature and vapour pressure gradients did not exceed -0.4C/m and -0.4 mb/m respectively. The Bowen ratio rarely exceeded 2.0 during the daytime hours. The sensible heat flux reached a maximum just prior to noon while the latent heat flux and canopy vapour pressure deficit maxima occured in mid-afternoon on clear days.

The energy balance system operated successfully over a period of six weeks continuously regardless of rain. Evapotranspiration was measured to within 20%. This data will be used in a water balance model at this site.

I 10

A NEW SUNSHINE DETECTOR
John Cook (Can.Met.Serv., Toronto)

The design and performance of a sensor whose output is directly related to the duration of bright sunshine is described. The system was designed to meet W.M.O. recommendations for a sunshine detector, compatible with automatic weather stations.

The new instrument's output is compared to the standard Campbell Stokes' record, and corresponds well with the output from the Eppley sun-tracking pyrheliometer.

The sensor appears to have potential application as a relatively inexpensive quantitative radiation sensor.

I 11

A SOUNDING SYSTEM FOR URBAN PROFILES
J. Markes, H.E. Turner and M.S. Hirt (Can.Met.Serv.,Toronto)

A portable sounding system for obtaining wind and temperature profiles in an urban environment is described. The sonde is an expendable, solid-state, 403 MHz device which can be carried aloft by a standard pilot balloon. The ground receiving system is compact, light-weight and operates from a 12 volt d.c. source. Temperature is read directly from a chart recorder.

I 12

SECOND GENERATION SENSORS FOR REMOTE AUTOMATIC WEATHER STATIONS
J. Whiting (Saskatchewan Res.Council, Saskatoon)

This paper surveys the sensors commercially available for use with remote recording weather stations. Tables are presented for typical models, and give the accuracies and time responses of the sensors: (a) by themselves and, (b) in actual field operation associated with specific analogue and analogue-to-digital recorders. The importance of the choice of the sensors is shown to have dramatic effects on the quality of the data and on the representativeness of the data with respect to the actual micro-climatic history. The conclusion reached stresses the need for further research especially into the question of frequency response: is the response of the sensor to the actual oscillations of the parameter measured, either under-damped, damped, filtered, or over-damped?

I 13

A REVIEW OF CANADIAN METEOROLOGICAL SERVICE INVESTIGATIONS INTO THE MEASUREMENT OF PRECIPITATION
D.J. McKay (Can.Met.Serv., Toronto)

Investigations over the past several years have concentrated mainly on improving the accuracy and reliability of precipitation measurements made by conventional gauges. These include development of a new larger capacity ordinary or standard rain gauge and a replacement metering unit for the tipping-bucket rain gauge.

The Service has also investigated some relatively new methods of measuring winter precipitation, such as those using the heated liquid surface volumetric gauge and the snow pillow.

Some details of these new instruments are given, as well as a discussion of their limitations under operating conditions.

I 14

LIDAR PROBING OF THE ATMOSPHERE
A.I. Carswell, A. K. McQuillan and R. McNeil (York Univ.)

A LIDAR (Laser Radar) system has been constructed at York University to investigate the use of optical scattering for atmospheric diagnostics. The system is capable of previding up to 150 MW peak power at the ruby fundamental (6943 Å) and up to 10 MW at the doubled frequency in the ultraviolet (3472 Å). The transmitter has a Pockel's cell Q-switch to generate 20 ns pulses at a repetition rate of 10/min. An 8-inch Newtonian telescope serves as the receiver. The entire unit is mounted on a mobile and steerable platform to permit field operation.' Details of the LIDAR will be presented along with a discussion of its application to obtain information on atmospheric constituents from measurements of the Rayleigh, Mie and Raman backscattered return. Sample scattering measurements for a variety of atmospheric conditons will be presented.

I 15

LABORATORY MEASUREMENTS OF LIGHT SCATTERING BY
AEROSOLS
R.G. Quiney and A.I. Carswell (York Univ.)

As part of a continuing programme of investigation of the optical properties of the atmosphere, we are presently investigating the scattering properties of aerosols. Using the Stokes vector formulation we have measured the four principal components of the scattering matrix under controlled laboratory conditions, both for atmospheric air as a function of relative humidity and for laboratory generated water droplet clouds. A 50 mW He-Ne laser is used as the light source and a sensitive automated polar nephelometer, which has been developed for these measurements, records the scattering matrix as a function of scattering angle. Data reduction is accomplished rapidly using the IBM 360/50, the final results being drawn with an automatic plotter. Measurements under controlled conditions for a series of parameters will be presented.

I 16

THE DETECTION OF SILVER IODIDE PARTICLES IN HAIL
L.N. Rogers (Res.Council of Alberta)

A technique for the detection of silver iodide particles in situ is described. A thin section of a hailstone is evaporated on a Millipore filter in such a manner that the particles present in the section maintain their original positions relative to one another. The filter is then treated with a super-saturated solution of silver iodide. Any silver iodide particles originally present in the section act as seed crystals for the solution and grow sufficiently large to be easily observed. A study of the positions of the silver iodide particles in conjunction with the structure of the stone can provide information as to whether the particles were effective as nucleating agents or whether they were collected by accretion without having a nucleating effect.
Data from a number of hailstones will be presented.

N 1

THE CURRENT STATUS OF WEATHER FORECASTING BY
NUMERICAL METHODS
André Robert (Can Met.Serv., Montreal)

Records of verification scores for the past 25 years show a drop of the order of 35% in the errors associated with weather forecasts. Experiments dealing with the predictability of the atmosphere indicate that the errors in current short-range forecasts could be reduced by at least a factor of four. The various sources of errors in numerical models are examined with the percentage contribution given in each case. Short-term projections are made of the expected increase in the accuracy of numerical predictions.

N 2

A PROGRESS REPORT ON PRECIPITATION FORECASTING
David Davies (Can.Met.Serv., Montreal)

Numerical forecasts of precipitation amount for transmission over the facsimile circuits have been produced operationally on the Central Analysis Office computer since February 1968. The basic scheme was designed to work in conjunction with a baroclinic model. It features three-layer moisture resolution in the vertical, the gradual onset of large-scale precipitation at some threshold value of dew point depression, and the prediction of small-scale precipitation by means of empirical formulae.
For the last three years further development work has been carried out on experimental versions of the same baroclinic-precipitation package. This has resulted in several successful innovations which have already been incorporated into the operational run. For instance, the eddy diffusion of potential vorticity has replaced smoothing in the baroclinic model, and associated changes have been made in the vertical motion computations. Crude radiation and ccean heating terms have been added to the predictive equations for temperature and dew point depression. Some temperature dependence has been introduced into the maximum total precipitation permitted at a grid point, and also in the threshold criteria for frontal precipitation. And some non-linearity has been introduced into the formula for large-scale precipitation.
Other aspects of the experimental integrations did not have immediate operational application, but appear to have interesting implications. For instance, the release of latent heat appears to affect the large-scale circulation in a manner which is highly dependent on the scale of the precipitating cells. The effective eddy diffusion constants appear to be highly dependent on the baroclinicity. And a highly sensitive model appears to be a disadvantage in no-data areas.
The baroclinic-precipitation package is now being converted to operate over a fine grid mesh with a spacing half the standard size.

N 3

TRUNCATION ERROR IN A SPECTRAL MODEL
P.E. Merilees (McGill University)

A spectral barotropic model of the northern hemisphere is integrated from the same initial condition using various resolutions for a five-day period. The various integrations are compared as a function of time in order to determine the dependance of truncation error on wave number.
The initial data are truncated at longitudinal wave number 6, using 6 degrees of freedom for latitude variations. Subsequent integrations use the same number of degrees of freedom in latitude and truncate successively at longitudinal wave numbers 9, 12, 15, and 18.
Preliminary results indicate that the truncation error falls off with increasing resolution but at a rate which is considerably less than exponential.

N 4

EXPERIMENTS WITH A PRIMITIVE EQUATIONS MODEL
Maurice B. Danard   (Univ.of Waterloo)

An 8-level primitive equations model has been developed including
orography, large-scale release of latent heat, long-wave radiation,
friction, and fluxes of heat and water vapor from water surfaces. The
clouds and moisture patterns used ir the radiation calculations are pre-
dicted (i.e., vary with time). Drag coefficients vary spatially. Thirty-
six hour predictions are performed for an intense mid-latitude winter
cyclone over North America.
    The influences of long-wave radiation, surface friction, and the
Great Lakes have been studied. Truncation error has also been inves-
tigated by halving the grid size from 380 to 190 km. The improvement
in the lower troposphere is quite striking. After 36 hours the Great
Lakes cause a lowering of the 1000-mb heights by about 70 m (i.e.,
surface pressure is dropped about 7 mb). Effects on wind speeds and
precipitation are also noted.

N 5

HORIZONTAL TRUNCATION ERRORS
C. Chouinard   (McGill University)

Spatial auto-correlation functions designed for objective analysis
schemes provide a meaningful method of evaluating truncation errors
associated with the calculations of finite-difference derivatives involved
in the integration of an atmospheric model.
    A simple hemispheric barotropic model was integrated using grid
sizes of 400, 280, 200 and 140 km. A comparison of these results pro-
vides another method of evaluating truncation errors and their behaviour
with time.
    A third method consists of evaluating spectrally, the so called
"exact values" of the vorticity, advection and tendency fields. Comparing
these to grid calculations, also produces reasonable estimates of trun-
cation errors. All three methods show that the usual 381-km grid, still
used operationally, does not provide us with sufficient horizontal resolution.

N 6

QUANTITATIVE EVALUATION OF INITIALIZATION PROCEDURES
Richard Asselin   (Can.Met.Serv., Montreal)

With the help of the Dynamic Prediction Research Unit 5-level P.E.
model (simplified pressure-coordinate version) the consequences of
starting an integration with non-divergent winds, or winds satisfying
the linear or non-linear balance equation, have been evaluated in terms
of differences from a forecast started from "ideal" initial conditions.
Statistics on the height, divergence and vorticity errors for up to
several days will be presented ard interpreted.

SESSION TH2: Numerical Weather Prediction II

N 7

ASSIMILATION OF GEOPOTENTIAL BY A PRIMITIVE EQUATIONS
MODEL
I.D. Rutherford and R. Asselin   (Can.Met.Serv., Montreal)

The so-called assimilation problem involves the periodic updating of
the fields produced by a forecast model with data from the real atmo-
spheric fields. Observations of any of the variables are unevenly
distributed in space or time and must be combined with the predicted
values (containing past observations) in such a way as to best define the
"true" state of the atmosphere. In the past the fields of geopotential
and wind have generally been adjusted according to some constraints
(i.e., the balance equation) at each assimilation cycle.
    The experiments to be described have been conducted using a
(barotropic) P. E. model with the aim of investigating the adjustment
of the wind field to periodic assimilation of only the geopotential during
the integration. The particulars of the adjustment process have been
found to depend upon the assimilation frequency, the dissipation prop-
erties of the model, the spectral distribution of the variables, the type
of motion (rotational or divergent) and other details.

N 8

TIME-DEPENDENT BOUNDARIES IN A BAROCLINIC PREDICTION
MODEL
W.S. Creswick and M.P. Olson (Can.Met.Serv., Montreal)

A four-level baroclinic model is integrated over a limited area with
lateral boundaries prescribed by forecast values from the same model
integrated from earlier data over a hemispheric grid. Radiation and
ocean heating terms are simulated through an error feed-back technique.

N 9

U.S. AIR FORCE GLOBAL WEATHER CENTRAL BOUNDARY-LAYER
MODEL
A.L. Friend (US Air Force, Offutt AFB, Nebraska)

An eight-level physical numerical model has been developed for the
lower tropospheric region (surface-1600 m). This model is an integral
part of the complete AFGWC meso-scale (sub-synoptic) numerical
analysis and prediction system. It provides greater horizontal and
vertical resolution in both the numerical analyses and forecasts by pre-
dicting the more detailed smaller scale atmospheric perturbations.
    Important features include: a completely automated objective nu-
merical analysis of input data; the three-dimensional transport of heat
and moisture; terrain and frictionally induced vertical motion; latent
heat exchange in water substance phase changes; and eddy flux of heat
and moisture.
    Input data are conventional synoptic surface and upper air reports.
Other AFGWC prediction models provide horizontal wind components at
the upper boundary and an estimate of cloudiness above the boundary-
layer region. A case study is used to demonstrate the potential of this
model, despite some approximations which broadly simplify the real
planetary boundary-layer processes, to realistically simulate and accu-
rately predict the actual behaviour of the atmosphere in the boundary-
layer region for up to 24 hours.

N 10

SOME OPERATIONAL DIAGNOSTIC FIELDS FOR THE BOUNDARY LAYER
M.W. Baishaw (Can.Met.Serv., Winnipeg)

Problems in diagnosis and short-range prediction of subsynoptic scale weather patterns, such as low cloud and precipitation isohyets, are discussed and related to vertical motion fields induced in the boundary layer. Three principal kinematic fields are identified: low level divergence, orographic lift and turbulent mixing. An operational method for evaluating these fields from the synoptic surface observations has been developed and programmed on the Prairie Weather Central CDC 6500. A test run was made on 29 days of 1200Z data observed in June 1970 (3113 cases), and a statistical study was made of the usefulness of these fields in the operational diagnosis and short-range prediction of cloud and precipitation. The fields for a few days are presented in detail and these will demonstrate dramatically the ability of the fields to assist in the diagnosis of weather patterns.
   Other operationally useful fields of low-level temperature advection, available moisture, potential temperature, geostrophic wind and wind trend are also included in the operational package of charts available to the meteorologists approximately 45 minutes after time of observation. Finally an approach to evaluating explicitly the vertical motion induced through the boundary layer, using available surface data, is discussed and preliminary results are presented.

N 11

NON-LINEAR INTERACTIONS BETWEEN WAVE FIELDS AND NON-WAVE FIELDS
M. Shabbir (Can.Met.Serv., Toronto)

This contribution focuses on the importance of resonance mechanisms in the atmosphere. The problem studied concerns the longtime behaviour of the planetary motions of the atmosphere. It is demonstated that by adopting an approach based on different time-scales - a short time-scale characterising the period of pertubations and a long time-scale characterising slow secular changes, i.e., period of modulations- the resonant non-linear interaction theory provides a new and suggestive mechanism for the forcing of stratospheric zonal flow by the vertically propagating planetary wave packets.
   The analysis is restricted to a conservative physical system, and a wave package approach is adopted.

N 12

SOME RESULTS OF THE PREDICTIVE DECOMPOSITION OF ATMOSPHERIC TURBULENCE
Bryan R. Kerman (Pennsylvania State Univ.)

Several theoretical attempts have been made recently to expand turbulence in terms of associated stochastic processes. Most have utilized the properties of wide-band "white" noise with a Gaussian probability distribution. The paper outlines how this concept, as well as associated features of systems theory, can be directed towards an empirical expansion of atmospheric turbulence in terms of response functions. The procedure is a consequence of Weld's decomposition theorem and Wiener's functional representation of stochastic processes. In principle, the decomposition is a synthesis of the realizations of a self-excited, non-linear process, such as turbulent fluid flow, without the artifice of explicit external excitation. Some preliminary results concerning the low-order response functions for atmospheric turbulence as measured by an aircraft in the upper planetary boundary layer over a flat plain will be given. Some dynamical interpretations and measures of the approximations of the representation are attempted.

N 13

HAILSTORM FORECASTING FOR PROJECT HAILSTOP
A.J. Chisholm (Can.Met.Serv., Toronto)

Project "Hailstop" is a hail suppression experiment operated by the Alberta Hail Studies (ALHAS) Project under the joint sponsorship of the Research Council of Alberta, the Canadian Meteorological Service, the National Research Council and McGill University. Accurate hailstorm forecasts are highly desirable for the successful operation of this project. The various hailstorm forecast requirements may be outlined as follows:
   (i)   Occurrence
   (ii)   Location and timing
   (iii)   Depth and intensity
   (iv)   Maximum hailstone size
   (v)   Storm type
   (vi)   Direction of motion
   (vii)   Updraft velocity and temperatures for cloud-seeding.
   The basic problems of forecasting hailstorms in central Alberta are outlined and the forecast methodology used during the 1970 summer operation is reviewed including the operation of a computer convection model. A summary of the forecast results is given which yields an overall Hail-No Hail forecast accuracy of 86% and a skill score of 0.71. Based on operational experience from the 1970 season, problem areas are defined and suggestions for their solution outlined.

N 14

AN APPROACH TO THE MAPPING OF GRADIENT-LEVEL WINDS OVER CANADA
A.G. Davenport and C. Baynes (Univ.of Western Ontario)

This work was initiated to try to establish the pattern of gradient-level winds over Canada. This information is relevant to many problems including the wind loading of structures, air pollution and other environmental problems. The advantage of gradient-level winds is their independence of local terrain influences.
   The data from which the preliminary maps were prepared were recorded by twice-daily radiosonde ascents at a network of ten Canadian upper air stations. A most continuous records are available for the decade 1960-1969, and these were used in conjunction with the U.S. Weather Bureau's "Winds Aloft Summaries" for selected points in the northern United States. Existing maps of "Upper Winds over Canada" have also proved useful in establishing the overall pattern.
   Data analysis and subsequent mapping initially centred on certain statistical properties of winds at the 300- and 500-metre levels, corresponding to the approximate gradient heights over very flat terrain and built-up city centres, respectively. These statistical properties include the mean, vector mean and vector standard deviation.
   The obvious relevance of extreme wind conditions in building design prompted investigation of maximum gradient winds using Weibull and "probability of exceedance" models. Some preliminary maps have been prepared for extreme wind occurrences and the parameters of the associated extreme-value distributions.

N 15

AN OPERATIONAL METHOD OF TOTAL INSTABILITY ANALYSIS
AND FORECASTING
  W.S. Harley (Can.Met Serv., Toronto)

A method of determining and combining into a single instability index,
the Potential and Latent Instabilities for the 700-850 mb and for the
500-700 mb layers, based on equivalent potential temperatures, is
outlined. The relation between the instability index patterns for each
layer and thunderstorm occurrence is demonstrated. A method of
determining the region of greatest increase in instability is also
demonstrated.

N 16

AN INTERESTING ARCTIC STORM
  H.P. Wilson   (Can.Met.Serv., Edmonton)

On 15 September 1970 a storm with two major centres developed over
the Beaufort Sea and moved to Cambridge Bay in three days. The first
low was a baroclinic wave. The second deepened because of diabatic
heating but partly also as a result of its amalgamation with two smaller
centres. It caused some loss of life and produced serious erosion to
the peninsula on which Tuk Tuk is located.

F 1

ALBERTA HAIL STUDIES IN THE FIELD AND AT McGILL
UNIVERSITY
  Walter Hitschfeld   (McGill University)

In the late fifties, a cooperative program for studying the hail storms
of Alberta was instituted by the Research Council of Alberta (which took
the first initiatives and undertook to look after the logistics in the field),
the Canadian Meteorological Service (which was to provide a variety of
services, including forecasting, climatology and sondes), and the
National Research Council (responsible for the radar and related instal-
lations). The Stormy Weather Group at McGill was asked to provide
scientific advice, and initially to staff the project in the field.
  Many changes have taken place in the organization, especially in
the division of the responsibilities of sponsors and participants. But
the essential mission of the project has remained the elucidation of the
structure and dynamics of the hail storm, the mechanism of formation
of hail stones within the storm, and the specification of a method of
suppressing hail, or of at least reducing the damage. In line with these
goals, such techniques as detecting the hail by radar, measuring the
freezing characteristics of the precipitation, modelling the storms nu-
merically, forecasting the incidence of hail, and many others were
undertaken. An extensive field program was built up, which at the same
time prompted the development of such techniques, allowed their ver-
ification and led to their refinement. An important success is the high
precision with which many observing techniques can be focussed on a
single storm.
  Though many questions about the physics of the storm remain ·
unresolved, a field experiment in seeding for suppression has been
initiated in 1970, and is being continued in 1971.

F 2

PROJECT HAILSTOP 1970
  Peter W. Summers   (Res.Council of Alberta)

Since 1956 the Alberta Hail Studies Project has been collecting data on
hailstorms in Alberta. Substantial progress has been made in developing
realistic models of hailstorm kinematics and the growth of the hailstones
themselves within the storm. Whilst still far from complete, the under-
standing of hailstorms has now reached the point where worthwhile experi-
ments can begin. The eventual aim of these experiments is to develop
cloud seeding techniques capable of interfering with the natural growth of
hailstones in such a way that the amount and size of the hail reaching the
ground causes less crop and property damage. The economic potential of
such a seeding system is self-evident, since damage to crops alone is
estimated to average $20 to $50 million annually in Alberta.
  A seeding concept applicable to Alberta hailstorms was developed.
The National Aeronautical Establishment in Ottawa supplied a T-33 jet
aircraft and the engineering required to convert it into an experimental
seeding platform. Specifications for droppable pyrotechnic cloud seeding
flares were drawn up to include the unique feature of 10-cm radar chaff
which was released at the end of the burn and could then be used as a
marker of targetting accuracy. The flares were manufactured by Olin
Corporation.
  The seeding system was tested in Alberta during July 1970, and
five cloud seeding experiments were carried out. The operational logis-
tics of this seeding technique turned out to be quite straightforward. By
means of radio communication between the project radar control room
and the seeding aircraft, it was always possible to unambiguously identify
and seed the selected target storm.
  Detailed case studies have been made of the seeded storms of
11 July and 9 July 1970. The analysis includes the behaviour of the radar
reflectivity in three dimensions, hail fallout patterns, visual appearance
of the cloud recorded photographically from the ground and the aircraft,
freezing nuclei spectra and silver content of precipitation. These results
will be presented along with some preliminary conclusions.

F 3

THE LARGE MONTREAL HAILSTORM OF 1 AUGUST 1969
  Marianne English and Charles Warner   (McGill University)

Exceptional hail fell on Montreal on 1 August 1969. Largest dimensions
up to 7.5 cm and masses up to 70 gm were measured.
  Radar and other data provided a simple picture of the storm cir-
culation. Feeding on its left front flank, the storm moved to the left of
all wind directions above cloud base, reached 12 km altitude, and pro-
duced a hail swath about 40 km long and 6 km wide. 115 hailstones were
collected, and for each a mean diameter and minor axis were measured.
The axial ratios calculated from these measurements ranged from 0.24
to 0.95, the mean being 0.6. Calculations based on a simple model
consistent with the observations showed that spherical hailstones can
grow to a mass of 35 gm in 18 min in a single up-and-down trajectory.
With reasonable assumptions as to the effect of shape, aspherical hail-
stones can grow to 75 gm in the same time under the same conditions.
The results of the calculations thus agree with the observations, and
strengthen our confidence in the assumptions made both in the construc-
tion of the model and in the growth calculations.

F 4

THE EDMONTON HAILSTORM OF 4 AUGUST 1969
L.N. Rogers and P.W. Summers (Res.Council of Alberta)

On 4 August 1969 a severe hailstorm passed over Edmonton, Alberta causing several million dollars worth of property damage. The synoptic situation was a classical one for the development of severe persistent-type storms in Alberta. As a result of a radio and TV appeal about 300 residents of the city and the nearby countryside saved hail samples. When these samples were collected detailed information on the storm was solicited. Analysis of these data shows that, although a continuous hail swath was produced by the storm, many pockets of intense hail occurred. Over Edmonton two cells centred about 7 miles apart started to produce hail simultaneously. There were significant differences in the shape of the hail in these two cells. The total amount of hail that fell on Edmonton is estimated to have been about 1.1 million tons.
The radar analysis shows evidence of a large echo-weak vault with strong rotation; also a tornado was reported at least three locations along the storm's path.

F 5

MESOSCALE RAIN AND HAILFALL PATTERNS IN SEVERE CONVECTIVE STORMS
P. W. Summers (Res.Council of Alberta)

With the current telephone survey system, the Alberta Hail Studies Project is able to obtain hundreds of hail reports from farmers within two days of a storm. Most farmers have a simple type of rain gauge and during the last three years an effort has been made to solicit storm-point rainfall data also. For specific storms the reporting density is between 20 and 50 reports per 100 square miles.
Using these data for about 15 well documented severe convective storms in the summers of 1968-1970 detailed hailfall and rainfall patterns are plotted. While the hail and rain swaths are continuous, there is a great variation of intensity. The heaviest hail and rain falls in pockets which are typically 10 miles long and 2 to 5 miles wide. In many cases the heaviest rainfall is displaced a few miles downwind from the heaviest hailfall indicative of a size sorting mechanism due to the different fall velocities of hail and rain and/or the presence of vertical wind shear.
The implications of these findings on the use of climatological statistics in an area such as the Canadian Prairies where most of the summer precipitation comes from convective storms is discussed.

F 6

RADAR MAXIMUM REFLECTIVITY PROFILES OF CELLS IN A PERSISTENT MULTI-CELLULAR ALBERTA HAILSTORM
J. H. Renick (Res.Council of Alberta)

Individual cells in a persistent multi-cellular hailstorm in central Alberta have been tracked by means of the Alberta Hail Studies 10-cm radar. Vertical profiles of the maximum radar reflectivity within these individual cells for each successive three-minute scan sequence of the radar have been prepared for several cells in the storm complex. These "time-height max Z_e" profiles show the beginning and vertical development of the radar echoes within the cells and, as such, are radar histories of the growth of precipitation and its eventual fallout to the ground.
The structure and dynamics of a persistent multi-cellular storm will be illustrated and the significance of the profiles as related to precipitation growth models and hail growth trajectories will be discussed.

F 7

AIR BUBBLES IN HAILSTONES
Roland List, W.A. Murray and Carole L. Dyck (Univ.of Toronto)

One of the first things obvious to any investigator of natural hailstones is their shell structure, i.e., the alternating layers of opaque and more or less clear ice. The opacity is caused by the presence of air bubbles, however, their concentration and size distributions have never been measured, except for the bulk densities of shells (List, Cantin and Ferland, 1970).
A recent attempt to measure cumulative distributions of bubbles and total shell densities of hailstones from an Alberta sample was, surprisingly, very successful. It was possible to show that size versus cumulative occurrence (plotted with lognormal probability) can always be approximated by straight lines, their slope essentially constant and not affected by concentration or opacity. The mean diameter of bubbles of opaque layers turned out to be rather smaller than that of clear shells. Correlations with density or crystallographic features definitely show the different bubble history. Opaque shells seem to consist of "primary" or original bubbles whereas in clear ice those initial bubbles might have had time enough to diffuse and coalesce with others in order to form larger entities.
In summary, it is obvious that air bubble size distributions and concentrations may represent the needed final clue to unravel the life history of hailstones which is imprinted in their structure.

F 8

FREEZING OF WATER DROPS AT TERMINAL VELOCITY
W.A. Murray and R. List (Univ.of Toronto)

An investigation was made of the ice structures and heat exchanges of water drops frozen while they were suspended at terminal velocity in a vertical wind tunnel. The diameter range for the drops was 3 to 8 mm. Air temperatures varied from -1 to -18.5C. Asymmetry of the freezing is evident from thin sections made from partially frozen drops. Despite the asymmetry, the observed freezing times agree reasonably well with the estimates from a symmetric freezing model. A microcalorimeter was used to determine the amount of ice in frozen drops at different stages of freezing. The mass of ice increased linearly with time. Air bubble and crystal sizes, and crystal orientations were determined from replicas and microphotographs of vertical main sections of the frozen drops. Air bubble sizes were corrected for spatial effects, that is, the effects of sampling from a plane rather than a volume. The volume of air in the frozen drops is up to 70% lower than the amount estimated to have been dissolved in the water originally. Both the air bubble and crystal sizes decrease with the increase in rate of freezing at lower air temperatures. Purity of the water affects the crystal size; crystals are smaller in drops of impure water. Histograms of c' axis orientation show a preferred orientation with the axis perpendicular to the radial direction. This relationship weakens as the temperature decreases.

F 9

ELECTRIFICATION ASSOCIATED WITH SPLASHING OF
SUPERCOOLED DROPLETS ON ICE
      H.G. Hengeveld, P.Y.T. Louie and J.V. Iribarne
      (Univ.of Toronto)

The charge separation occurring during the splash of supercooled drop-
lets on rotating ice spheres was investigated. Droplets of 360 and 500
microns were used with varying impact velocities (1 to 9 m/sec) and
temperatures (ice at -2 to -15C); pure water and solutions were tested.
The splashes impart a positive charge (in the order of 10^{-5} e.s.u.) to
the ice, except for the larger droplets and lower temperatures, when
the sign is reversed. Flash photography shows the development of a
crown and droplet ejection during the splash. The results are compared
with previous measurements with larger drops at 0C, and the possible
charge separation mechanisms are discussed.

F 10

INFLUENCE OF INITIAL CHARGES AND EXTERNAL FIELDS ON
SPLASHING ELECTRIFICATION
      J.B. Maxwell and J.V. Iribarne (Univ.of Toronto)

The separation during the splash of large crops on rotating spheres was
studied. The impact velocity, the initial charge of the spheres and of
the drops, and the intensity of an applied vertical field could be varied.
The charges were measured by induction. Saturation curves were
obtained for room temperature and for a cold room using ice-coated
spheres and drops at 0C. The saturation charges are independent of the
impact velocity but vary with the nature of the surface, the liquid com-
position and the field strength. The results are interpreted in terms of
a superposition of electrical double layer shearing and induction effects.

F 11

ON THE SATURATION VAPOUR PRESSURE OF WATER
      J.M. Richards (Univ.of Waterloo)

In theoretical and numerical work on convective processes, as in other
fields, one often desires a simple, yet accurate, expression for the
relation between the saturation vapour pressure of water and the temper-
ature.
     The paper introduces a neat approximation to represent this pres-
sure between -50 and 140C. Over this range the accuracy of the
approximation is about 0.1 percent and over the range between 0 and
100C the accuracy is about 0.02 percent.

F 12

SUMMARY OF THE 1970 FOG DISPERSAL PROGRAM AT
VANCOUVER INTERNATIONAL AIRPORT
      Wm. C. Thompson (CanMet.Serv., Vancouver)

During the three months October to December, 1970, six fog seeding
operations were conducted at Vancouver International Airport under a
program financed by seven airlines. The objective of the program was
to improve runway visibility by the aerial seeding of warm fogs with
hygroscopic particles.
     An analysis of transmissometer traces, visual observations, the
official weather observations and aircrew comments from a few of the
operations indicate differences of opinion regarding the effectiveness of
the program. Some reasons for these disparities are discussed.

F 13

URBAN GROWTH EFFECTS ON LOW-TEMPERATURE FOG IN
EDMONTON
      K.D. Hage (Univ.of Alberta, Edmonton)

Visibility observations at rural and urban airports in the Edmonton area
during the severe winter of 1968-69 are compared with similar obser-
vations described in 1955 by G.W. Robertson for the winter of 1949-50.
The new observations tend to confirm Robertson's finding that low-
temperature fog in Edmonton is due mainly to saturation of the air by
water vapour produced in burning natural gas. Visibilities in such fog
are strongly temperature-dependent. The urban population more than
doubled between 1950 and 1969, and new large sources of water vapour
were added to the city. The effects of both changes are apparent in the
visibility data. Estimates of future low-temperature fog frequencies
together with the assumptions needed for such estimates are included
for the city of Edmonton.

P 5

HORIZONTAL TEMPERATURE FIELD - GREATER VANCOUVER, B.C.
      J.H. Emslie (Can.Met.Serv., Vancouver)

Conventionally, a single official temperature reference is provided at
most Canadian cities, and in many cases this temperature is taken at
an airport located in the outskirts. Is this temperature representative
of the city as a whole, and if not, what range of values might be expected
across a city? Further, what local influences produce this temperature
range?
     In view of the current Public Forecast experiment, providing ranges
of maximum and minimum forecast temperatures instead of spot values,
some appreciation of the factors affecting the temperature field across a
city is essential if the forecaster is to issue realistic figures.
     At Vancouver, British Columbia, the official temperature is taken
at Vancouver International Airport, located approximately six miles
south-southwest of the city centre. Additionally, maximum and minimum
temperatures have been recorded at twenty-four Climatological Stations
in the Greater Vancouver area, during various periods, since 1957.
     This study analyses published climatological mean daily maximum
and minimum temperatures at these stations, expressed as seasonal
departures from the temperature reference point, Vancouver International
Airport, and illustrates the effects of elevation, urban heat island, sea
breeze and nocturnal drainage, and points out locations where additional
climatological stations should be established to complete the urban
temperature-range picture.

P 9

ANALYSIS OF DOWNWIND DEPOSITION OF DRIFTING SPRAY-
CLOUD BY NEUTRON ACTIVATION AND GAMMA-RAY SPECTROMETRY
K. Yoshida, J. Maybank, H. Mizuma, and S. Iwamoto
(Saskatchewan Research Council, Saskatoon)

Field trials of spray deposition were conducted under various turbulent
conditions by using flat-fan nozzles and manganese sulphate solution as
a tracer. The nozzle can produce droplets smaller than 200-micron
diameter in at least 8% of the total volume of spray; subsequently these
droplets become a drift potential for herbicide spray operations in the
Prairies.

Spray deposited on targets of low ash-content filter paper was
then irradiated at a thermal neutron flux of $3.5 \times 10^{13} N/cm^2/sec$ at
(Pn -1); and the activity of tracer element in each sample was obtained
by means of a pulse analyser and was converted into the deposition
density by a comparison method.

A 10-m meteorological tower near the source, provided information
for the wind and temperature profiles. Horizontal (X-Y) and vertical (Z)
components of the eddy velocity were obtained by using a set of Gill-type
propeller-anemometers at 1-m height.

The downwind deposition density, which was obtained, ranged from
470 to 0.1 microgram/cm^2/min, and can be empirically expressed as an
exponential function of the downwind distance. The downwind deposition
density increases proportionally with the horizontal component of the
mean eddy velocity $\sqrt{\overline{u'^2} + \overline{v'^2}}$. The deposition density reduction factor,
which is a ratio of deposition density at 10 m to that at 2.5 m, decreased
proportionally with the vertical component of the mean eddy velocity $\sqrt{\overline{w'^2}}$
and with the Richardson number Ri.

The value of $\sqrt{\overline{w'^2}}$, which is related to the eddy diffusivity, appears
to give an orientation to the droplet trajectory in the initial stage of the
transport process and controls the distribution pattern of deposition. On
the other hand the value of $\sqrt{\overline{u'^2} + \overline{v'^2}}$, with respect to the mean windspread,
controls the quantity of deposition downwind. The physical properties of
the spray liquid were found to influence the value of the eddy diffusivity.

The results provide information required for a realistic assessment
of the threshhold level of the deposition from drifting herbicidal spray in
the Prairies.

P 10

CROSS-WIND SHEAR EFFECTS ON ATMOSPHERIC DIFFUSION
G.T. Csanady
(Univ. of Waterloo)

Some experimental data on atmospheric diffusion over a "medium"
distance range (order 30 km) have been analyzed in an attempt to dis-
cover any effects on lateral spread attributable to the skewed wind
profile of the planetary boundary layer. The observations analyzed were
obtained over "natural" terrain (containing woodlots and villages) in
Arkansas. Wind shear effects on diffusion were considered "significant"
when the cloud decisively outgrew the size predicted by the Hay-Pasquill
technique from fixed-point cross-wind velocity fluctuations. Such "sig-
nificant" effects were found only on a few occasions, associated with
quite extreme rates of cross-wind shear, accompanied by strong stability.

P 11

⑥

A TURBULENT DISPERSION COMPUTATION
G.B. France and R.D. Rowe   (Univ. of Calgary)

Turbulent dispersion from single and multiple sources, such as urban
areas and industrial stacks, is currently under investigation at the
Department of Chemical Engineering, University of Calgary. The phe-
nomena of turbulence has been represented by many different mathemat-
ical methods with varying degrees of sophistication. The turbulent field
methods, as summarised by W.C. Reynolds at the recent Amer. Instit.
Chem. Eng. workshop, offer some expectation for modelling the atmo-
spheric boundary layer containing the above-mentioned sources of heat and
pollution. In this paper one such method, developed by Harlow of the Los
Alamos Group and others, known as "Mean Turbulent Energy Closure"
(MTE) is used.

The case of the turbulent jet in an infinite fluid has been studied so
far. Numerical results are presented for various quantities including the
mean velocity distribution. These results indicate that the MTE method
adequately represents the momentum plume and can therefore be used to
predict dispersion from jets.

(The buoyant plume is now being investigated and some preliminary
results for this case may also be available in time for the Conference).

P 12

BUOYANT MOIST BENT-OVER VAPOUR PLUMES AT A PILOT
STACK FACILITY
P.R. Slawson   (Univ. of Waterloo)

Dry buoyant plume-rise theory has been extended to moist plumes for
the prediction of the condensation and reevaporation points. Also, a
simplified formula for predicting condensed plume lengths is developed.
Observations on condensation and condensed plume lengths from a pilot
stack facility compare favourably with those predicted.

R 2

WINTER CLOTHING REQUIREMENTS FOR CANADA
A. Auliciems and F.K. Hare   (Univ. of Toronto)

Amounts of clothing insulation needed to maintain thermal equilibrium
have been calculated from hourly observations of air temperature, wind
velocity and cloud cover over a period of ten years at eighty stations.
This enables the prediction of actual clothing requirements (in clo units)
for a variety of activities, and provides a human classification of the
country for the months of September to April.

R 3 INDICES OF WIND CHILL OF CLOTHED PERSONS
R.G. Steadman (Univ.of Manitoba)

(6)

The concept of wind chill as a measure of the combined effects of low
temperature and wind is reviewed. An analysis is presented of the
effect of these variables on a person dressed for cold climates and takes
account of all important modes of heat loss, including breathing, and
heat transfer through clothing. This analysis leads to two chief indices
of wind chill: the wind-chill equivalent temperature, which is tabulated
and compared with existing tables, and the clothing thickness required
to maintain a person in thermal equilibrium. The distributions of
clothing thickness and of the wind chill of exposed skin at 30°C are
described.

R 4 VARIATION OF THE SKIN TEMPERATURE UNDER THE INFLUENCE
OF FLUCTUATING WIND IN A COLD ENVIRONMENT
F.H. Fanaki (Can.Met.Serv., Toronto)

The loss of heat from a man exposed to a fluctuating wind of short and
long periods is analyzed. In the analysis it is assumed that heat is lost
from the body to the environment by convection, conduction, radiation
and through breathing. The loss of heat by evaporation has been ignored.
With this assumption the governing equation for the transfer of heat is
described and is solved by the application of a Laplace transformation.
The solution is expressed in terms of the amplitude and periodicity of
the wind fluctuations. Numerical results are given. The results obtained
serve as a guide to the degree of refinement required in determining the
chill factor.

R 5 PERCEPTION OF LOCAL CLIMATE IN THE URBAN AREA OF
ABERDEEN, SCOTLAND
G.R. McBoyle (Univ.of Waterloo)

(6)

The most frequented living area today is the urban scene but what is known
of people's perception of climate in the urban environment is very little.
In order to obtain some information on the problem a postal questionnaire
was sent to 600 adults within the urban area of Aberdeen, Scotland during
the summer of 1970.
The respondents' answers indicate that Aberdonians in general dis-
like damp conditions, excessively high and low temperatures, and consider
that their city is colder and windier than the surrounding countryside. The
public's opinions on the warmest and coldest areas of the city by day are
very accurate when compared with scientific observations. The situation
by night, however, is different with Aberdonians appearing to be unaware
of such phenomena as frost hollows and night-time, urban heat islands.
It is surprising that most respondents accurately named the most windy
and least windy parts of the city yet 7 out of every 10 respondents con-
sidered that there was little difference in precipitation within the city even
with a 600-foot amplitude of relief. Since fog is one of the main dislikes
of Aberdonians its predominant areas are well known, namely, near the
sea and along the valleys. At the other end of the spectrum the different
slope aspects have resulted in varying amounts of sunshine in different
parts of the city. This too has been translated accurately into people's
minds.
Aberdonians always tend to open a conversation with a comment on
the weather and it would appear from the study that they are well qualified
to do so with the exception of night-time, intra-urban temperature
differences.
The survey's results should be encouraging to most researchers
because they indicate that the average citizen's knowledgeable, interested
and probably able to assimilate more knowledge about meteorology and
climatology than we give him credit for. A follow-up study would be to
ascertain if the respondents put their weather knowledge to use in every-
day decisions and in weather-sensitive activities.

R 6 ON THE VARIATION OF ANGLES OF INCIDENCE AND PHASE
VELOCITIES OF ANOMALOUS SOUND WAVES
E.R. Reinelt (Univ.of Alberta, Edmonton)

Precise timing of the arrival of individual pulses of sound at arrays of
detectors permits the calculation of angles of incidence and phase veloc-
ities of sound waves propagated anomalously over large distances.
Measurements made some 200-400 km from large test explosions, set
off at Suffield in the past ten years, show 10 to 5 per cent variations in the
phase velocity of sound waves returned to the ground from the mesosphere.
Some of the smaller fluctuations can be accounted for by low-level vari-
ations of wind and temperature, but the larger variations are due to the
sonic fine-structure, e.g., subducts, in the lower mesosphere.
Angles of descent deduced from the observed phase velocities range
from 10 to 30 degrees at most recording sites, indicating that the pulses
of sound energy have travelled along different ray paths.

R 7 THE ECONOMIC EVALUATION OF METEOROLOGICAL INFORMATION
FOR SNOW-CLEARING IN MONTREAL.
A. Dasgupta, M. Inagaki and R. Robinson (Can.Met.Serv.,Montreal)

This paper outlines an attempt to measure the economic benefits resulting
from the use of meteorological information in the snow removal activity
in Montreal.
Among cities of comparable size, Montreal suffers from one of the
highest levels of Winter snow fall in the world, much of which occurs
during snow storms with a paralysing effect on ground transportation.
To aid in the efficiency of snow clearing and snow removal oper-
ations, the Dorval Weather Office has for the past several years provided
a special forecast service to the City Roads Department.
The service includes written messages, transmitted four times
daily, indicating detailed forecasts of important meteorological variables.
These are supplemented when required, by direct telephone consultation.
The benefits accruing from the use of the forecast service consist
primarily of faster snow clearing, leading to improved road conditions,
and hence to reductions in the accident rate and in travel-time.
The paper consists of three parts describing:
(1) the development of a mathematical model relating the use of
the meteorological service to the resulting benefits,
(2) the application of the model to estimate the quantity of benefits
of various types, on the basis of detailed time-series data
relating to storm occurrences, taken in conjunction with data
on observed accident rates, absenteeism and late arrivals, and
(3) the conversion of benefits into monetary terms by the use of
appropriate techniques of cost-benefit analysis.

4. International Field Year for the Great Lakes (IFYGL) 1972.

Op 10 mei werd 's avonds een working session gehouden over bovengenoemd project. Floyd Elder, een van de U.S.coordinatoren van IFYGL, organiseerde dit in verband met de aanwezigheid van vele vertegenwoordigers van meewerkende U.S. en Canadese instituten, en nodigde voor deze bespreking circa twee dozijn mensen uit, waaronder ondergetekende.

Het IFYGL-project wil in het kalenderjaar 1972 (was oorspronkelijk 1971, maar is een jaar uitgesteld vanwege organisatorische en financiële moeilijkheden aan de U.S.zijde) Lake Ontario en de bijbehorende watershed (ca.400 x 400 km) hydrologisch en meteorologisch zo uitgebreid mogelijk onderzoeken. Een samenvatting van de plannen is te vinden in Eos 51 (1970) 500-502,508. De organisatie berust bij vier "panels": (1) hydrologie en water movements; (2) energiebalans; (3) "meteorological panel"= klimatologie; (4) boundary layer studies (tot ca.1 km). De samenwerking der panels blijkt minimaal te zijn. De bespreking ging voornamelijk over de boundary layer studies.

De grenslaagexperimenten kunnen als volgt worden onderverdeeld: (a) fluxmetingen in de oppervlaktelaag; (b) flux handover metingen in vertikale richting door de planetaire grenslaag; (c) numerieke modellen en parametrizatie. Over het laatste ontstond een heftige discussie: de voorbereiding van de modellen, en de theoretische ondersteuning van het project in het algemeen, blijkt geenszins voldoende om de experimentatoren de zekerheid te geven dat alle voor een modelstudie benodigde gegevens inderdaad gemeten zullen worden in 1972. Verder blijken plannen voor mesometeorologische studie tot nu toe te ontbreken. Voorgesteld wordt om te proberen onderzoekers, die modelstudies doen van luchtverontreiniging in stadsgebieden, voor een jaar los te weken t.b.v.IFYGL.

De grenslaagexperimenten zullen allereerst worden geconcentreerd in de ZW-hoek van het meer, waar fluxmetingen zullen worden uitgevoerd op drie vaste masten. Voorts zullen drie windprofielboeien met 20m-masten worden verspreid over het meer, alsmede een zware verankerde meetboei van het Bedford Instituut (zie hfdst.5). Tenslotte zullen op 15 à 20 plaatsen meetboeien worden gestationneerd, voor dit project speciaal ontworpen door Texas Instruments (TI) in contractopdracht van NOAA; contractkosten minstens $ 2 millioen. Aangezien niemand ooit voldoende aandacht besteed schijnt te hebben aan de benodigde specificatie, zal deze boei drukmeting tot max. 1 mb nauwkeurig uitvoeren, en de windsnelheid op één hoogte eens in de 6 minuten momentaan gemonsterd worden. Voor stationnaire gevallen is daardoor het uurgemiddelde slechts op 5% nauwkeurig te bepalen; het schijnt contactueel niet meer mogelijk te zijn om TI nog het ontwerp te laten wijzigen, al was 't maar met een afvlakfilter.

Om alsnog het drukveld tot de grootteorde 0.1 mb te leren kennen (onontbeerlijk indien men wil interpoleren), zullen Dobson & Elliott (Bedford Instituut) worden verzocht om een methode uit te voeren voor goede drukmeting vanaf schepen. Tijdens BOMEX schijnt de drukfout ongeveer 0.1 mb/100 km te zijn geweest; dit had nog beter kunnen zijn als men de schepen aan begin en eind had samengebracht voor onderlinge ijking.

Voor meting op grotere hoogte zal het vliegtuig van UBC (Univ.of British Columbia) worden gebruikt; Miyake hoopt dit tijdig tegen een hoge mast te hebben geijkt. Ook Telford en Lenschow hebben vliegplannen. Een probleem is, dat van geen der vliegtuigexperimenten de financiering al rond is. — Voorts zouden de Engelsen met kabelballons (Cardington) metingen willen doen tot 600m, maar raken daarbij in de knoop met het Amerikaanse voorschrift dat niets dat zwaarder is dan 1 kg meer dan 150m boven het dichtstbijzijnde obstakel mag vliegen. In Cardington schijnen andere regels te bestaan.

Intensieve metingen zoals fluxbepalingen en vluchten zullen bij voorkeur op bepaalde dagen geconcentreerd worden. Speciaal wordt gelet op koude en warme advectie, zeewindeffecten en dergelijke zaken. Stewart drong er i.h.b. op aan dat apparatuur van te voren zou worden uitgeprobeerd. Herhaling van een dergelijk project is voorlopig onwaarschijnlijk in verband met GARP-plannen.

5. Air-sea interaction instrumentatie op het Bedford Institute (B.I.)

Het Bedford Institute te Dartmouth, N.S. is een instituut voor zeeonderzoek. Het beschikt over circa 750 man perscneel en een uitgebreide outillage, o.m. een half dozijn schepen. Visserijonderzcek, fysisch zeeonderzoek e.d. zijn de hoofdactiviteiten; de air-sea-interacticn onderafdeling heeft de grootte van een KNMI-projectgroep, een klein aantal stafleden (in de zomer aangevuld met graduate students) welke projecten uitvoeren, gesteund door een instrumentele afdeling, een computerafdeling enzcvoort. De bibliotheek schijnt niet adequaat op meteorologisch gebied, als ik nag afgaan op de onbekendheid van verscheidene fundamentele artikelen inzake meteorologische instrumentatie, o.a. inzake de op het Bedford Institute ontwikkelde thrust anemometer.

De air-sea interaction groep staat op 't ogenblik onder leiding van Dr.Stuart D.Smith, die zich bezig houdt met het uitvoeren en interpreteren van windturbulentiemetingen. Daarvoor beschikt hij over een thrust anemometer (pingpongbal-anemometer), ontwikkeld door zijn voorganger Dr.L.A.E.Doe, en over twee Kayodenki sonische anemometers. Experimenteel onderzoek vlakbij het wateroppervlak doet Dr.Fred W.Dobson (zie hoofdstuk 2, voordracht I-7). Dr.Jim A.Elliott ontwikkelt methoden voor drukfluctuatiemetingen. Claude Hicks houdt zich bezig met de electronicaproblemen, o.a.van de Kayodenk: . Verder waren tijdelijk op het Instituut werkzaam: Michael R.Thorpe (Nieuw Zeeland) en Les Spearing (UBC undergraduate). Tijdens mijn bezoek waren niet aanwezig de stafleden Dr.R.H.Loucks (theorie, stress-interpretatie) en E.G.Banks. De instrumentele afdeling assisteert bij de ontwikkeling van meetboeien en meetplatforms (John Brooks) en beschikt over een laboratorium voor het doen van uiterst verfijnde druk- en temperatuurijkingen ("metrology"), geleid door een ex-Nederlander waarvan ik helaas de naam niet noteerde.

In de loop van het bezoek ontvig ik enige rapporten en overdrukken, in hoofdstuk 6 nader gespecificeerd als [B 1] t/m [B 7]. Hiervan berichten[B 3] t/m [B 6] over de resultaten van meetexpedities in 1969 en 1970, voornamelijk in het ijsgebied van de St.Lawrence Rivier. Uit deze rapporten en uit [B 2] blijkt, dat men de problemen van gegevens-transmissie en -registratie redelijk beheerst. [B 7] beschrijft een general-purpose Fortran programma voor de verwerking van meetresultaten van alle beschikbare sensoren.

Afgezien van de reeds vermelde voordracht over de Flevo-metingen, welke ik op 15 mei hield, heb ik tevens de groep geïnformeerd over de KNMI-werkzaamheden op instrumenteel gebied. Bijzondere interesse bestond voor de Aeolivaan, en waarschijnlijk zal nog een verzoek aan HINSA om nadere informatie volgen, aangezien ze eventueel de trivaan zouden willen nabouwen. Overigens is i.h.a. de instrumentatiepolitiek van het Bedford Institute om zo veel mogelijk te kopen, en seriebouw van zelfontwikkelde instrumenten steeds uit te besteden.

Het werkingsprincipe van de <u>thrust anemometer</u> (TA) is de meting van de winddruk op een geperforeerde pingpongbal, welke zo is gemonteerd dat zijn beweging in drie richtingen door veerkracht is beperkt. De balanspositie in een bepaalde richting tussen windkracht en veerkracht is dan een kwadratische functie van de windsnelheid; dit kwadratisch verband heeft tot gevolg, dat eerst een totale krachtvector moet worden berekend voordat afzonderlijke componenten van de windsnelheid kunnen worden bepaald. Het meten van de TA-balanspositie gebeurt op het B.I. m.b.v.differentiaaltransformatoren [B 2], doch men is commerciële bouw van het instrument aan het voorbereiden en wil daarbij overstappen op straingages, onder meer omdat in de huidige opzet verdere miniaturisering onmogelijk is. Dit zou de opzet meer in lijn brengen met de constructiemethoden van andere onafhankelijke onderzoekers zoals Högström, Morrison en Maidens (de meeste TA-onderzoekers schijnen elkaars artikelen niet te lezen). De B.I.-anemometer wordt in een enigszins gewijzigde versie (Mk.IV) ook gebruikt door Kirwan en McNally (New York University); een rapport over hun resultaten is in hoofdstuk 6 opgenomen als [B 8].

Uit [B 2], [B 8], op het B.I. gevoerde gesprekken en een in 1969 door mij verrichte litteratuurstudie (waarvan i.h.b.relevant is een artikel van Norwood et al.,JAM 5('66)887) blijkt het onderstaande:

(a) Het gebruik van mechanische veersystemen is essentieel voor iedere TA-constructie. Hieruit volgt: (a-1): de output is niet voldoende door de dimensie- en materiaalkeuze bepaald, zodat voor iedere meting en ieder instrument een nieuwe ijking nodig is, zéker wanneer er kruip optreedt door verschil van temperatuur-uitzettingscoëfficiënten;   (a-2):voor een redelijke hoog-frequentresponsie is oliedemping noodzakelijk;   (a-3): met het in veer-constructies opgehangen bolletje kan alleen dán betrouwbare windmeting worden verricht indien de meetbasis volkomen trillingsvrij is opgesteld.

(b) De kwadratische responsie en de mechanische ruis maken meting onmogelijk bij windsnelheden beneden 3 à 4 m/s.

Deze theoretisch-instrumentele feiten leiden in de praktijk tot de volgende praktische konsekwenties:

(c) Aan het begin en het einde van iedere in het veld verrichte meting wordt een ijkrun gedaan. Hiertoe wordt de gehele TA omsloten door een winddicht huis, dat bij voorkeur op afstand geplaatst en weggenomen moet kunnen worden. Op het B.I.wordt daartoe om het bolletje (∅ 4 cm) en het veersysteemhuis een cylinder (∅ 15 cm) naar boven geschoven m.b.v.een wormwiel-constructie. De aerodynamische effecten, die de aanwezigheid van een dergelijk obstakel op relatief korte afstand onder het bolletje zou kunnen veroorzaken, zijn door de onderzoekers onderkend maar niet onderzocht. In ieder geval zou ik een stoor-trilling verwachten t.g.v.vortex street-effecten.

De t.g.v.storing door de cylinderomkapping te verwachten systematische fout in de vertikale windcomponent lijkt me in dit geval van minder betekenis, omdat i.v.m. (a-1) toch steeds operationeel moet worden geijkt. Voor de vertikale komponent w is daarvoor als hypothese w̄ = dw̄/dt = 0 vereist, omdat de drift vrij groot is (equivalent met een verloop in w zelf van 0.8 m/s per uur). Uit de registratie van de ijkrun blijkt tevens de grootte van de ruis t.g.v.mechanische trillingen en verster-kingsinstabiliteit; nadat eerst de frequenties boven 10 Hz waren geëlimineerd, bleek de lagerfrequente ruis in w nog 0.1 m/s te kunnen bedragen, hoofdzakelijk in het frequentiegebied boven 1 Hz.

(d) De dimensies van het geheel en de eigentrilling van het verend opgehangen bolletje leiden tot een hoogfrequente bruikbaarheidsgrens van 0.3 m golflengte en 10 Hz frequentie. Vanwege de kwadratische responsie (b) is alleen de golflengte-grens van praktische betekenis. Voor de Aeolivaan ligt deze grens omstreeks 1.2 m golflengte.

(e) De instabiliteit van het geheel blijkt ook hieruit, dat verschillende onderzoekers in windtunnelproeven een hoek (elevatie of azimuth) zelden binnen 2° kunnen reproduceren. Ook hieruit blijkt de noodzakelijkheid van een ijkrun aan begin en einde van iedere meting. Per meting komt hier t.g.v.ruis nog een on-zekerheid van 0.3° à 0.5° bij.

De algemene indruk van de huidige TA-constructie is matig. De in [B 2] geschetste opzet, met centreerveren, fosforbronsdraden enz., lijkt onnodig ingewikkeld. Dit blijkt ook uit de bouwkosten: $ 500 voor constructie der mechanische componenten, $ 300 voor drie differentiaaltransformatoren, en dan nog $ 200 om e.e.a.in elkaar te zetten; dit laatste bedrag moet bij iedere re-paratie opnieuw worden uitgegeven. Bovendien zou de door Norwood gesuggereerde linearisering van de output aanbeveling verdienen. Zelfs mét een linearise-ringsschakeling is echter de complexiteit van de noodzakelijke outputelectronica gering, hetgeen een voordeel is t.o.v.de sonische anemometer.

Indien de TA commercieel verkrijgbaar zou worden in een door een ervaren constructeur herziene versie, zou hij mijns inziens voor het KNMI uitsluitend bruikbaar zijn voor fluxmeting tussen 1m en 4m hoogte (energiebalans), en dan
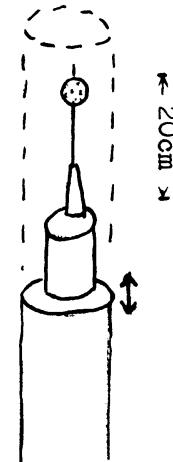
nog alleen indien de operationele problemen van een sonische anemometer met
10 cm geluidsweg of een fluidic anemometer te groot zouden zijn. De responsie
is namelijk beter dan die van een sonische anemometer met 20 cm geluidsweg, en
de kosten zijn belangrijk lager. — Voor gebruik op zee lijkt me de TA echter nu
en in de toekomst niet geschikt, omdat de vereiste trillingsvrijheid van de TA-
opstelling daar te grote problemen schept.

Aangezien S.D.Smith c.s. de TA juist wèl op zee gebruiken, hebben zij res-
pectabele **stabiele meetboeien** ontwikkeld ([B 1],[B 2]). De hieronder geschets-
te 1968-constructie is verticaal schaal 1:1000, terwijl horizontaal de tekening
niet op schaal is; de andere drie schetsen zijn noch horizontaal noch verticaal
op schaal. De 1968-constructie is verankerd aan betonblokken van 2x2x2 m, 13
in getal. Wegens onvoldoende mogelijkheden om de tuispanningen in balans te
brengen was er in "moderately heavy weather conditions" nog altijd een $3°$ tot
$5°$ hellingsfluctuatie, alsmede een periodieke rotatie van het geheel. De 1969-
versie, waarvan de benedenpunt op de grond werd geforceerd,kon eerst niet
worden gebruikt vanwege telemetrie-problemen; juist toen deze waren opgelost,
ging de constructie (mèt twee thrust-anemometers) ten onder in zwaar weer. Een
nieuwe, nog zwaardere constructie zal komend najaar beproefd worden voor IFYGL.
De rechts geschetste DOT-windprofielboei (enigszins vergelijkbaar met de wind-
profielboei van Hasse & Brooks) is te onstabiel en voor fluxmetingen minder
geschikt. Voor corrosiebestrijding worden Mg-anodes aan de boeien gemonteerd.

Het ongeluk met de 1969-boei was niet het gevolg van de impuls van golf-
slag, maar van de amplitude der lange deining, die de bovenbouw overspoelde.
Een overeenkomstig ongeval is kort na BOMEX gebeurd met FLIP: ofschoon deze
niet aan de grond gefixeerd was, is de responsietijd van een goed gestabili-
seerde boei toch met opzet vrij lang gemaakt door de ontwerpers. De bovenbouw
van FLIP schijnt vrijwel geheel vernield te zijn, en ik heb niet te weten kunnen
komen of hij weer in oude staat zal worden hersteld, dan wel zal worden gemodi-
ficeerd. In ieder geval heeft Smith voor de B.I.-1972-boei rekening gehouden
met 18 m golfhoogte, en dus ook een grotere meethoogte.

B.I.1968
(ontworpen voor
12m-golven)

B.I.1969
(ontworpen voor
10m-golven; leed
schipbreuk in
storm)
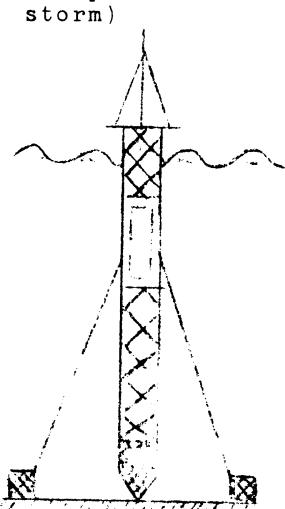
B.I.ontw.1972
(ontworpen voor
18m-golven t.b.v.
IFYGL 1972)

DOT boei voor
profielmetingen
IFYGL 1972 (niet
voor fluxmeting)

25-ton blokken
(15 t bleek te
licht te zijn)
Goed maar duur.
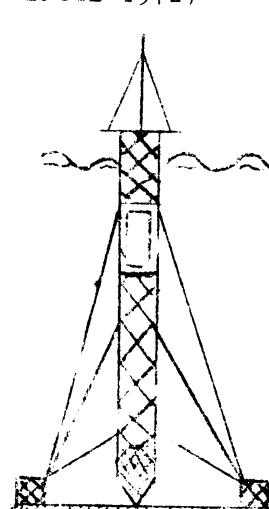
150-ton blokken

150-ton blokken
(plaatsingskosten
$ 50 000.-)
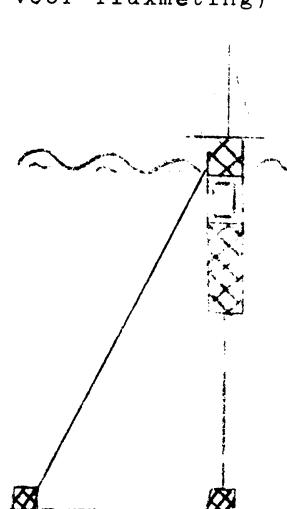
alleen één lich-
te ankertui om
draaiing tegen
te gaan

In afwachting van het herstel van meetboei en thrust anemometer hebben
S.D.Smith c.s. deelgenomen aan een bemonstering van de eigenschappen van het
ijs in de Gulf of St.Lawrence([B 3],[B 4],[B 6]) met een tweetal Kayodenki

sonische anemometers: één gebouwd in januari 1968 (nº 139), en één gebouwd in december 1969 (nº 187), waarbij de laatste duidelijk beter geconstrueerd was. Over de Kayodenki is reeds e.e.a.vermeld in het ongeregistreerde en ongedateerde rapport van J.H.Rietman en W.A.Oost over een bezoek aan Risö in november 1970. Onderstaande opmerkingen sluiten aan bij dit rapport (en veronderstellen dus voorkennis daarvan) en hebben betrekking op nº 187.

— (K-1): Voor goede werking van de Kayodenki moet de electronica in temperatuur volledig geacclimatiseerd zijn aan de ruimte waarin hij opgesteld staat.

— (K-2): Voor de zekerheid werd tijdens veldwerk steeds Si-gel meegepakt in de junction box. Er was geen experimenteel bewijs dat dit veel uitmaakte.

— (K-3): Een operationeel bezwaar was het grote stroomverbruik (100 W AC), dit in tegenstelling tot de betrekkelijk zuinige thrust anemometer-opstelling.

— (K-4): In het frame van de probe liggen dunne coaxiaalkabeltjes; aangezien het frame teveel scherpe hoeken heeft, waren enige gevallen van gedeeltelijke kabelbreuk opgetreden. B.I. had nieuwe kabeltjes (RG-174/U) gemonteerd, welk voor hun arctische werkzaamheden het voordeel hadden ook bij -55° C nog buigbaar te zijn.

— (K-5): Tijdens veldwerk bleek regelmatig bijstelling nodig te zijn van de 10 kOhm instelpotmeters. Aangezien de geleverde exemplaren slechts een garantieperiode van 200 bijstellingen hadden, waren deze vervangen door de (even kleine) Amphenol D-2750-P Res.103, welke voor 500 instellingen gegarandeerd waren.

— (K-6): De kwaliteit van de Japanse elco's was matig, ook deze waren vervangen. De transistoren hadden de merkwaardige eigenschap dat het keramisch omhulsel verging: bij storing plachten de B.I.technici eerst alle transistoren aan te tikken met een potlood, en gewoonlijk viel dan een van hen in poeier. Aangezien vervanging moeilijk bleek, was Japan om herziening gevraagd.

— (K-7): Geluidsreflectie aan de hoeken van de probes bleek mogelijk, i.h.b. bij nº 139, waardoor crosstalk tussen de componenten optrad.

— (K-8): Bij de huidige opstelling van de probe transducers is de geluidsweg 20 cm voor de w-component (die tevens het minst door de overige componenten wordt gestoord), 10 cm voor de u-component en 30 cm voor de v-component, als men de benodigde meetkundige optellingen goed beziet.

Men was op het B.I.van plan het benodigde richten van de probe op de hoofdwindrichting uit te voeren door de probe te plaatsen op een TV-antennerotor welke servo-gestuurd werd door het verschil der twee (symmetrische) horizontale windcomponenten.

De metrology afdeling (ijkingen) inspireerde door de conscientieuze en zorgvuldige opzet tot een rotsvast vertrouwen in de nauwkeurigheid van B.I. meetresultaten van oceanografische temperaturen en drukken, maar was niet van direct belang voor atmosferische metingen. Men was aan het experimenteren met een prototype salinity-temperature depth profiling system, te bouwen door Guildline Instruments, Ontario, waarover men zeer tevreden was.

Eveneens interessant was een nieuwe vochtigheidsmeter, waarover men nog slechts beperkte schriftelijke informatie had (copie bij Drs.Wierda). Het was een halfgeleider welke door electron exchange op waterdamp reageerde; hoe werd niet vermeld. De ongeventileerde responsietijd van dit Brady Array BR-101 zou minder dan 1 seconde zijn, en duurzaamheid in vervuilde omgeving werd als zeer groot opgegeven. Men had in de U.S.A.een exemplaar besteld voor proeven.

Jim A.Elliott was bezig met de afronding van een rapport over een door hem ontwikkelde drukfluctuatiemeter. Als basis-meeteenheid gebruikte hij een differentiaalmanometer die oorspronkelijk aangeschaft was t.b.v. de B.I.windtunnel-pitotbuis. (De windtunnel zag er goed uit: een closed-circuit opzet met een snelheidsbereik van 1-35 m/s en een meetruimte van ca.60x60x120 cm.) Deze Barocel Pressure Sensor 511-10 (with manometer type 1014 A $ 1000.-) had een range van 0-10 mm Hg, een output 0-10 V en resoneerde bij 50 à 60 Hz. Voor uitwendige trillingen was hij in twee richtingen gevoelig. Interessant

was, dat hij als drukinlaat een schotelplaatje ter groote van een rijksdaalder
met aan beide kanten een gaatje van minder dan 1 mm doorsnede gebruikte. De
opzet is in principe gelijk aan de door J.H.Rietman in 1969 onderzochte micro-
barograafopstelling, maar heeft een buffervat voor de gemiddelde atmosferische
druk en gebruikt de Barocel-eenheid ter plaatse van de dubbelbalg-opstelling
van de Rietman-opstelling. (Voor het principe van de Rietman-microbarograaf
zie R.V.Jones & S.T.Forbes, J.Sc.Instr.39 (1962) 420-426). Elliott verwachtte
zijn drukfluctuatiemetingen te kunnen uitvoeren parallel met thrust anemometer
metingen, aangezien beide instrumenten overeenkomstige eisen stelden aan de
trillingsvrijheid van het meetplatform.

6. Beschikbare rapporten en overdrukken.

In onderstaande lijst staat achter iedere titel tussen haakjes het KNMI-
bibliotheeknummer, dan wel de naam van de persoon bij wie een exemplaar kan
worden ingezien.

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B 5 - S.D.Smith: Thrust-anemometer measurements of wind turbulence, Reynolds
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B 6 - S.D.Smith, E.G.Banke, O.M.Johannessen (1970): Wind stress and turbu-
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I 12 - J.Whiting (1971): Second generation sensors for remote automatic
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P 6 - G.S.Campbell, N.M.Standen (1969): Progress Report II on simulation of
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R 5 - Questionnnaire on climate in Aberdeen.   (J.P.M.Woudenberg)

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N 10 - M.W.Balshaw (1971): Operational computer-produced diagnostic fields
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