ON IMPROVED MESOSCALE FORCING

Ad Stoffelen*[1]
[1]*KNMI, Royal Netherlands Meteorological Institute, de Bilt, the Netherlands*
* Corresponding author, email: Ad.Stoffelen@knmi.nl

Abstract
Analyses and forecasts generated in Numerical Weather Prediction, NWP, do generally not contain mesoscale wind information over the oceans due to the lack of surface forcing and the sparsity of 3D weather observations. The Advanced scatterometer, ASCAT, was launched on 19 October 2006 as the third wind scatterometer currently in space joining up with the ERS-2 and the SeaWinds scatterometers. Scatterometers measure the radar backscatter from wind-generated cm-size gravity-capillary waves and provide high-resolution wind vector fields over the sea with high quality. In this paper we illustrate and discuss the lack of mesoscale information in NWP models and the improved surface forcing fields brought by scatterometers.

Keywords:
MyOcean, wind forcing, mesoscale

1. Introduction
Surface wind stress is the primary forcing of upper-ocean circulation. To obtain this stress, all non-satellite ocean wind observations have inadequate coverage and representation. Furthermore, while satellites measure the wind stress, conventional wind measurements require additional information on surface ocean currents and atmospheric stratification in order to obtain local estimates of surface forcing. Lacking global in situ observations, oceanographers and climate researchers have long relied on estimates of surface wind forcing based on global atmospheric general circulation models used for NWP. Chelton et al. (2003), for example, use the 6.5-year time series of the near-all-weather QuikSCAT measurements to highlight the inadequacies of these model-based surface vector wind estimates. One of the remarkable discoveries from the scatterometer data is the existence of systematic large- amplitude, small-scale features in the wind field that are found ubiquitously in the vicinity of strong Sea Surface Temperature, SST, fronts. In these regions, SST modifies the surface wind field in such a way as to produce

Table 1. Buoy verification of the Ocean and Sea Ice SAF 25-km ASCAT, SeaWinds 25-km and SeaWinds 100-km product. Both tropical and extratropical moored buoys are used for three months of data.

ASCAT 25		SeaWinds 25		SeaWinds 100	
SD u [m/s]	SD v [m/s]	SD u [m/s]	SD v [m/s]	SD u [m/s]	SD v [m/s]
1.76	1.79	1.84	1.83	2.19	2.00

order one or larger perturbations in the wind stress curl field on scales of a few hundred kilometers. These intense small-scale perturbations of the wind stress curl field, which drive open-ocean upwelling/downwelling, have significant feedback effects on ocean, ecosystem, and local atmospheric dynamics (which are important for Climate Variability and Change, Weather, Ecosystem Dynamics and Biodiversity), but are at best poorly resolved in the wind fields from NWP models. The high-resolution, broad-swath measurements initiated by SeaWinds are continued by ASCAT, among others, in order to better represent these features in ocean general circulation models through assimilation of the satellite wind observations.

2. Scatterometer and NWP wind field characteristics

The standard Ocean and Sea Ice (OSI) Satellite Application Facility (SAF) 100-km SeaWinds product has been developed for NWP assimilation and it is verified to compare better with independent European Centre for Medium-range Weather Forecasts (ECMWF) NWP winds than both the National Oceanographic and Atmospheric Administration (NOAA) SeaWinds product and the OSI SAF 25-km product, and is thus indeed suitable for NWP assimilation. From Vogelzang (2006) we estimate that the ECMWF winds miss 1,2 m/s variance w.r.t. the scatterometer product on scales between 1000 and 25 km, with a 50% wind variance reduction at the 300 km scale.

Buoy verification statistics of OSI SAF 25-km ASCAT, SeaWinds 25-km and SeaWinds 100-km product are provided in Table 1. Both tropical and extratropical moored buoys are used for three months of data. It is interesting to note that the ASCAT 25-km product compares best to the ECMWF model fields as it compares best of all products to the buoys as well, providing evidence of the superior quality of the ASCAT scatterometer winds. The ASCAT 25-km winds are effectively at 50 km resolution and it is interesting to note that the SeaWinds 25 km product, while supposedly at higher resolution and containing more mesoscale wind detail, also must contain more wind error than ASCAT in order to provide worse buoy verification. Finally we note that the ECMWF model verification with the buoys is very similar to the SeaWinds 100-km product, as may be expected from the above-presented analysis (not shown here). Scatterometer data thus indeed capture mesoscale detail not resolved by NWP model analyses and forecast fields, but that verifies with buoy merasurements.

Scatterometer winds are routinely provided to the ECMWF analyses, as are other resolving wind measurement systems over the ocean, such as drifting and moored buoy and ship data. Moreover, passive radiometers do resolve wind scales in the ECMWF model spatial deficit regime. One may therefore expect that much of this resolved mesoscale variability will be added to the ECMWF analysis.

However, this is not the case as illustrated in Figure 1, which shows the mean RMS 10m wind analysis increment for an arbitrary day which appears modest with respect to the noted spatial deficit. In terms of wind variance, i.e., the squared RMS values, the analysis increments represent about 0.5 m^2/s^2 or less than 50% of the noted spatial deficit. Moreover, the changes do not only appear on the mesoscale, but also on much larger scales. The mesoscale scatterometer information thus remains largely unexploited, as is the mesoscale information provided by the other wind finding systems.

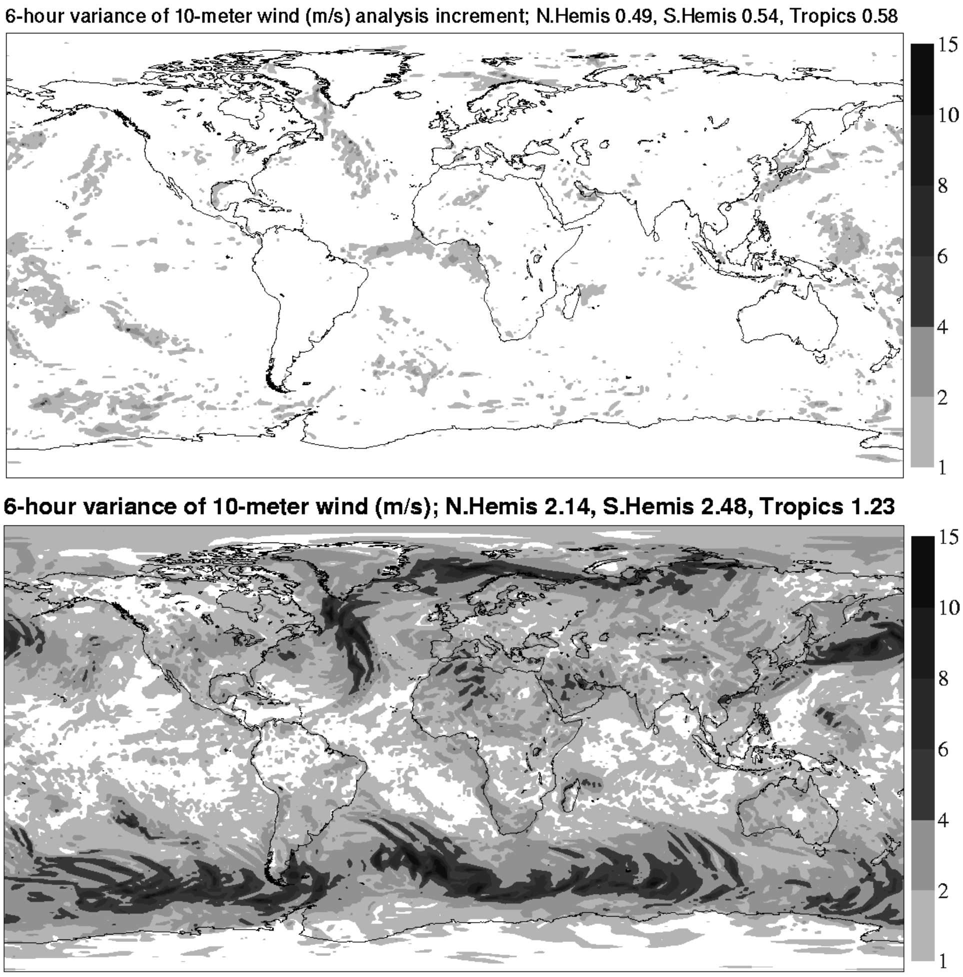

Figure 1: Mean RMS analysis increments of the ECMWF 4D-VAR analysis system (top), and the mean RMS 6-hourly change in the ECMWF model over the same day (bottom) for the 10-m wind vector.

We note that the objective of NWP data assimilation is NWP forecasting. Adding uncertain mesoscale information to the NWP analyses, only near the surface and not in the upper air, may be detrimental for medium-range NWP. NWP analyses thus extract mainly the larger scales (low pass filter). Other applications, such as ocean forcing, and wave or surge modeling may need inputs on scales not provided by NWP analyses.

In the context of the European Global Monitoring and Environmental Services, GMES, Marine Core Services, MCS, the MyOcean consortium proposed, among many other services, a mesoscale gridded wind product. A main question is how often such mesoscale gridded wind product should be provided. Currently, ocean models, and also many surge and wave models are forced by 6-hourly or 3-hourly fields. One may wonder how such temporal frequency matches the spatial scales of interest. Figure 1 (bottom) shows the mean RMS temporal change over 6 hours in terms of the 10-m wind vector over the same day as shown in the top plot. We note that in the storm track regions the temporal wind change over 6 hours in terms of vector variance is much larger than the noted spatial benefit, i.e., 3 to 4 times larger. So, if one would keep the wind field fixed over 6 hours, then one would make an average RMS error in the ocean wind forcing that is much larger than the error due to the lack of mesoscale detail. We suggest that forcing by the smooth ECMWF 10-m wind fields may be carried out reasonably well by using cubic time-interpolated 3-hourly fields. Clearly, using 6-hourly wind forcing without interpolation causes serious additional error on top of the errors caused by the spatial deficit.

3. Way forward

KNMI is involved in the GMES MCS MyOcean consortium with the ambition to provide, together with IFREMER (L'Institut Francais de Recherche pour l'Exploitation de la Mer), gridded mesoscale wind forcing with an hourly frequency. It is clear that ocean forcing is dominated by transient or temporal effects. An important question thus emerges, whether eddy-scale ocean forcing can be provided at the hourly scale ? We show in section 2 scatterometer analyses on the mesoscale that well verify with buoy wind measurements. Another question is whether the scatterometer increments may be advected in time? Evidence from mesoscale analyses and simple evolution models, e.g., shallow water models, show that mesoscale details may be beneficial for the verification scores up to several hours. Anyway, these questions will be addressed in more detail in MyOcean. For the MyOcean wind services, a product will be investigated providing hourly mesoscale winds.

The Indian Space Research Organisation (ISRO) OceanSat-2 scatterometer at 12 LST nicely complements SeaWinds at 6 LST, ERS-2 at 10:30 LST and ASCAT at 9:30 LST, and will be a very useful complement for providing temporally-resolved eddy-scale ocean winds. Global Near-real time backscatter (L2A) products would be greatly appreciated from ISRO to aid in a timely exploitation of the instrument and its data.

Acknowledgements

Gert-Jan Marseille of KNMI is acknowledged for providing figure 1.

References

Chelton, Dudley B., Michael G. Schlax, Michael H. Freilich, Ralph F. Milliff, 2003, Satellite Measurements Reveal Persistent Small-Scale Features in Ocean Winds, Science 303 no. 5660, pp. 978 – 983.

Vogelzang, 2006, On the quality of high resolution wind. fields. NWPSAF-KN-TR-002, www.metoffice.gov.uk/research/interproj/nwpsaf/scatterometer/

OSI SAF Scatterometer site, 2008, www.knmi.nl/scatterometer/