Technical report; TR-218

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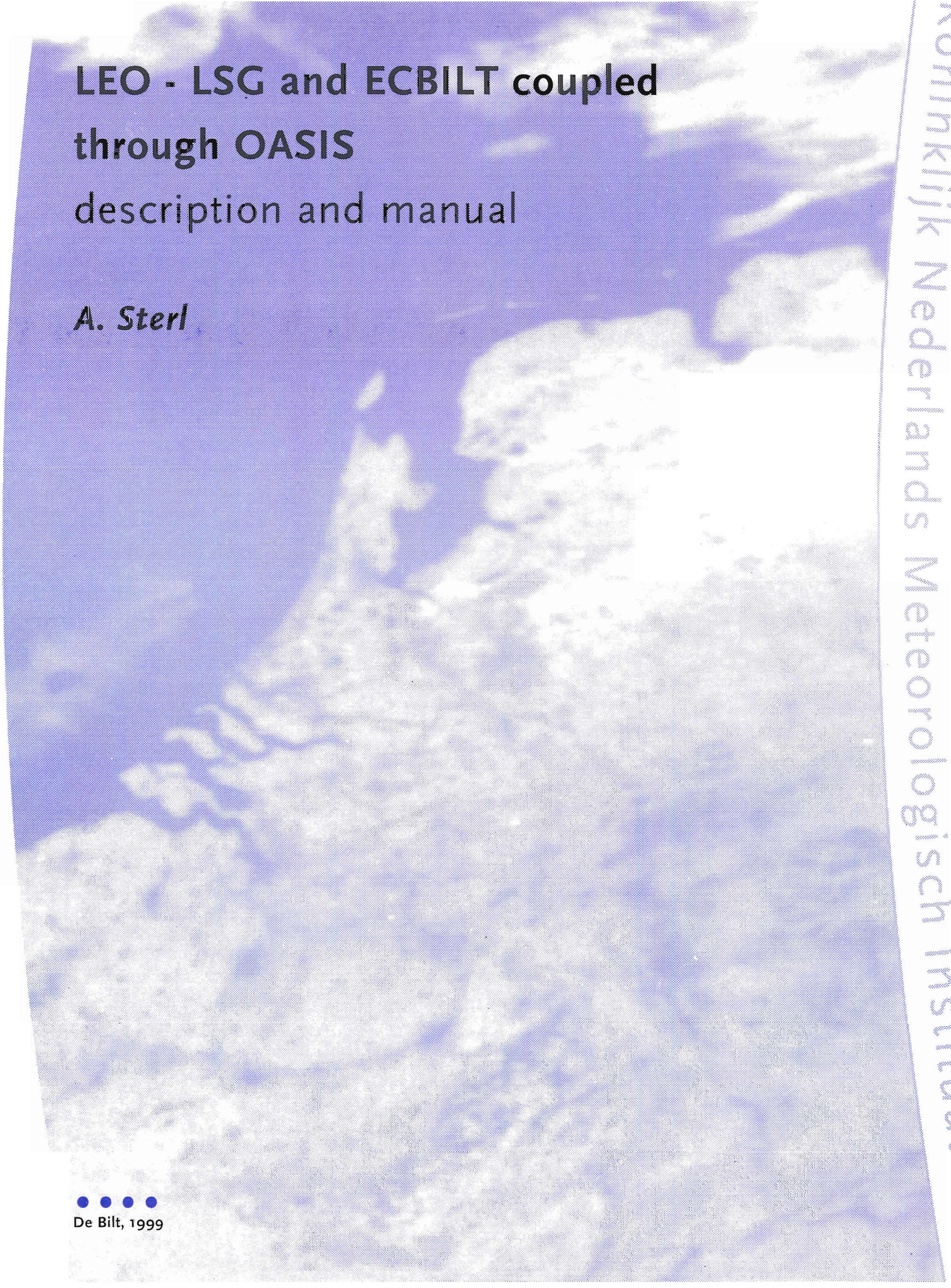

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LEO - LSG and ECBILT coupled through OASIS

Description and Manual

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Abstract

LEO is the coupled climate model formed by coupling the Hamburg Large Scale Geostrophic (LSG) ocean general circulation model to KNMI's ECBILT atmosphere model through the OASIS coupler developed at CERFACS. This note describes the implementation of the coupled system on KNMI's machines and explaines how to use it. Furthermore, some results from a 300 yr integration of the coupled system are presented.

Contents

1 Introduction

1.1 Overview

The Hamburg Large Scale Geostrophic (LSG) ocean general circulation model [1,2] has been coupled to KNMI's ECBILT atmosphere model [3,4] through the OASIS coupler developed at CERFACS [5a,b]. The coupler provides for the synchronization of the two component models and the exchange of fields (e.g., SST and heat flux) between them, including interpolation and, if necessary, manipulation (e.g., changing temperatures from Celsius to Kelvin).

This note gives a short introduction to OASIS and describes its use for the coupling of LSG and ECBILT. This description is *not* self-contained; the reader should read the OASIS description [5a,b] in parallel. Furthermore, the component models LSG and ECBILT are not described here at all.

1.2 Technical Remarks

1.2.1 Conventions

In this note sans serif font is used to denote directories, files, and variables. Program or model names are in ordinary font. Thus "OASIS" stands for the whole coupling software, while "OASIS" denotes the directory containing that software.

1.2.2 Directory structure and contents

In this subsection only a short overview of the directory structure of the model is given. The Appendix contains a step-by-step description of how to get the model running.

The whole coupled model is contained in a *tar* file, KOPPEL.tar. Upon un-tarring, a directory KOPPEL is created that contains in subdirectory

ECBILT0 the atmosphere model,

LSG the ocean model,

OASIS version 2.0 of OASIS,

OASIS_2.2 version 2.2 of OASIS,

REST.SAV start-up files for the coupled model.

In LSG/SUPPORT a compressed postscript version of [1] is found, together with a script to run LSG in stand-alone mode (lsg.run.job). Directory ECBILT0 (a little inconsistently) contains the script to run the coupled model (cprun.job), together with the input file for OASIS, namcouple (see sec. 4). Note that due to some changes necessary within ECBILT (see sec. 3) the version contained in here is not suited to be run in stand-alone mode.

Both LSG and ECBILT0 contain a subdirectory POSTPRO that contains postprocessing software. That software constists of a program to transfer the LSG output into EXTRA-Format files and some plotting routines based on the PV-WAVE package.

1.2.3 OASIS versions

[5a] is contained as a postscript file in subdirectory doc of OASIS. It is, however, sometimes not very clear and contains errors. It is better to use the description of OASIS version 2.2 [5b] (instead of that of 2.0, the version which is actually used here) and refer to that of version 2.0 [5a] only to find out what has been changed between the two versions. The description of version 2.2 can be found in OASIS_2.2/doc.

2 OASIS

2.1 General description

OASIS is a tool to couple independent models to each other. The user has to define - among others - the grids of the models used and the frequency with which they exchange information. The component models (in our case LSG and ECBILT) are executed as independent processes. Communitcation between them and the coupler is done via files. OASIS takes care of transferring the contents of these files at the proper times to the other model (synchronization), thereby interpolating and, if necessary, manipulating the fields to be exchanged.

Let us look at the coupling of LSG and ECBILT as an example. The ocean model LSG has a timestep of one month and uses an E-grid with 72 × 72 points. The atmosphere model ECBILT has a timestep of six hours and a Gaussian grid of 64 × 32 points (for convenience, the Gaussian grid is treated as a regular lat/lon grid). Exchange of information between the models is done every oceanic timestep, i.e., every month.

At the end of one timestep LSG writes its SST to a file and sends a signal to the coupler. The coupler then reads the SST from the file, interpolates it to the atmosphere grid and changes the units from Celsius to Kelvin. Then it writes the modified SST to another file and sends a signal to ECBILT. If ECBILT needs new SSTs it waits until it receives the respective signal from the coupler. It then reads the SST from file and proceeds for another month, at the end of which it writes the averaged fluxes (heat, freshwater, momentum) to a file, sends a message to the coupler and waits for new SSTs. The coupler reads the fluxes, interpolates them to the oceanic grid, writes them to a file and sends a signal to LSG, which now can proceed with the following time step. All three processes (OASIS, LSG, ECBILT) are running independently and in parallel.

Subdirectory toy1 of the OASIS library contains a set of "toy" programs that show how this general description is implemented in OASIS. The toy programs are "atmosphere" and "ocean" models that do nothing but exchanging information to show how OASIS works. These toy programs are those that are shipped with the original OASIS software and will not run on KNMI's machines. It is nonetheless instructive do read the source codes. In the form of comments they include valuable information on how OASIS works. Toy programs that run on SGI machines are found in OASIS/TEST. They where developed independently of the respective original OASIS routines and can be run by executing the script oasis.sc.

2.2 Communication strategy

OASIS has three possibilities to communicate with the component models. The first is based on message passing (PVM), the second on named pipes (a UNIX feature), and the third on SVIPC, also a UNIX feature. More details can be found in [5b]. When starting with OASIS, the third option was not yet available, and the amount of work needed for implementing the first was hard to estimate. Therefore, the implementation of OASIS at KNMI is based on named pipes.

A named pipe is a special sort of file. Information is written to and read from that file according to the FIFO (First In, First Out) principle. Information written onto the file is read and deleted in the same order it is written. Suppose OASIS wants to inform LSG that is has produced the wind stress for the tenth month. It will then write the number '10' to the appropriate pipe. Somewhere at the beginning of each timestep in LSG there will be a statement that reads the new wind stress. This statement must be preceeded by a read from the pipe. LSG will stop at this read statement until information appears in the pipe. Once the '10' of our example appears in the pipe, LSG will read it, leaving the pipe empty for the following information. The contents of the message read, '10' in our example, is used to control the timestepping. The field to be exchanged, here wind stress, has been written to an ordinary file from where it can be read.

2.3 Changes for use at KNMI

The original pipe version of OASIS was intended to run on CRAY computers and contains CRAY-specific subroutine calls. To make the coupler run properly on KNMI's machines, some modifications had to be made. They mainly concern the way files and pipes are opened and referenced (subdirectory lib/pipe of the OASIS directory structure), memory allocation in the lib/fscint library, and the signal handling. Files changed contain an entry with "A. Sterl" as the prgrammer in the "history" section contained in all files. The following list gives some details of the modifications performed. To understand them, some familiarity with the principles of OASIS is neccessary.

2.3.1 Pipes and files

- In the original pipe-version, the pipes are set up using the CRAY ASSIGN statement. This is replaced by an OPEN statement, and the option "-u", causing an immediate system call after the file/pipe has been accessed, by the keyword share. The latter is, however, not standard FORTRAN and may cause future problems.

- In the original pipe-version, the pipes are referenced by names in the corresponding WRITE statements ("UNIT = <name>"). As this does not work properly on the SGIs, it has been replaced by unit-numbers.

- These unit-numbers, as well as those referencing the files used to exchange data, have been made three digits long.

- Besides the routines to create the pipes and files to transfer data (subdirectory lib/pipe) also those routines using them (directory src) had to be altered to comply with the modifications described above.

- Two subprograms, oasis_field and oasis_time, have been written to connect the component models (LSG and ECBILT in our case) to the pipes and files. These subroutines have to be called from the component models (see next section). Both subroutines are included in the lib/pipe subdirectory.

2.3.2 Memory allocation

- The original CRAY-version uses system routines HPALLOC/HPDEALLC to allocate/de-allocate memory. Equivalents for the SGI-system would be MALLOC and FREE, together with a pointer statement. However, arrays allocated this way cannot be used in COMMON blocks. Therefore, the arrays originally allocated through subroutine MEMOIRH have been given a fixed size (see include files gaussgd.h and qqqcom1.h), and MEMOIRH has been brought back to emptying these arrays. Furthermore, MEMOIRH has been split into two subroutines, one for REAL and one for INTEGER quantities to avoid problems when using REAL*8 together with INTEGER*4 variables.

  These changes usually have no consequences for the user. Only when the allocated fixed space appears to be insufficient, the corresponding statements in the include files gaussgd.h and qqqcom1.h have to be changed.

- The sizes of the arrays used for interpolation (parameters jpmax, jpmxold, jpmxnew in include-file parameter.h of the include directory of the OASIS directory-tree) have been made smaller.

2.3.3 Signal handling

- The handling of signals (ABORT, ERROR, etc.) has been changed to SGI-routines. This mainly concernes subroutine ferror from directory src.

3 Changes in component models

Two main changes have to be made in the component models in order to make them communicate properly with OASIS.

- In the initialization phase of each model the proper pipes and files for communication have to be opened, and some basic parameters as the length of a time step have to be exchanged. In this phase the above-mentioned subroutines oasis_field and oasis_time are called. In LSG this is done in subroutine circ, and in ECBILT in ecbilt.

- Each model contains a loop over time steps. Within this loop a place has to be identified at which information has to be passed to or received from the other model. In LSG information is passed to OASIS in subroutine circ and received from the coupler in readbou. In ECBILT both exchanges are done in ecbilt.

With these changes the structures of LSG and ECBILT correspond those of the "toy" programs mentioned in sec 2.1.

Both LSG and ECBILT contain a sea ice model. The sea ice model of LSG is driven by the air-sea heat flux and can alter that flux according to the ice cover. It was therefore decided to keep the LSG ice model and abandon that of ECBILT. However, ECBILT needs the ice temperature to calculate the heat flux between atmosphere and ice. This quantity is not provided by the ice model of LSG. As an easy fix to this problem the surface temperature over sea ice is set uniformly to 240 K.

In the original ECBILT version the atmosphere was inherently coupled to an ocean model. This coupling has been replaced by OASIS, and both the atmosphere and the ocean became independent models. To achieve this the initialization of ECBILT had to be altered, and some fields and subroutines were no longer necessary. Among them are the ice model (see above) and the lake model (see [3]). To keep the resulting code as simple as possible, it was decided not to introduce a switch to toggle between the new coupling (OASIS) and the old one. As a consequence, the altered model cannot be run as a stand-alone atmosphere model, as this was achieved in the original version by calling a "fixed" ocean model, i.e., a dummy ocean model that did nothing but provide a fixed SST as the lower boundary condition for the atmosphere. To run the new ECBILT version as a stand-alone atmosphere model one would have to write a corresponding dummy ocean model and couple it through OASIS to the atmosphere model. It is just the strength of the OASIS philisophy that this can be achieved with minor modifications to the model code - just let OASIS call another ocean model!

4 Input to OASIS

As input OASIS needs information about the grids of the component models and the fields to be exchanged.

- The grid definitions have to be created once before the start of the model runs. Subdirectory LSG_GRID contains a program called grid.f that creates the necessary information from the original topography files of the component models. To understand the details the user should consult the descriptions of the component models as well as the OASIS manual [5a,b].
- The specification of the fields to be exchanged and how they have to be manipulated is done in OASIS's input file namcouple. This file is described in [5a,b]. Furthermore, the namcouple file actually used (in KOPPEL/ECBILT0) contains a long description of its features.
- The component models read input through *namelist* files. These files are generated by the scripts to run the models as described in sec. 1.2.2. For the meaning of the input variables see the model descriptions [1] and [3].

5 Performance

On KNMI's SGI PowerChallenge (locally known as "broeikas") the coupled system needs about 5 hours of CPU to complete 25 years of integration on a single processor. About 1% of this time is used by OASIS, 10% by LSG, and the remaining 90% by ECBILT.

6 Typical results

The first tests with the coupled model were done with the same version of ECBILT as was used in [4]. However, the coupled climate rapidly drifted away from the actual climate. The most embarassing features of that climate where a too warm Pacific with nearly no zonal temperature gradient, an Equatorial Current flowing to the east, and a rapid breakdown of the ACC. These erroneous features could be related to deficiencies of ECBILT, which had (nearly) no trade winds and much too weak winds in the ACC-region. In [4] a breakdown of the ACC was prevented by prescribing the streamfunction so as to force a 100 Sv flow through Drake Passage.

To overcome some of these shortcomings a modified version of ECBILT was developed in which a PV (= potential vorticity) forcing derived from ECMWF analyses is applied (R. Haarsma, personal communication). Like flux correction this extra forcing acts as a to drive the model winds towards observed wind climatology. It results in realistic Trade Winds and much stronger winds over the Southern Ocean.

Two coupled runs each 300 years long where done with this modified version of ECBILT. In the first run (P2) SST and SSS of LSG where relaxed towards climatology with a time constant of 180 days, while in the second run (P3) no additional external forcing was applied. Relaxing SST and SSS may also be regarded as a form of flux correction.

For both runs a couple of plots are shown to assess the state of ocean and atmosphere at the end of the runs (year 295). As can be seen from an intercomparison of these plots the extra relaxation of SST and SSS has a strong influence on the results. For instance, SST is about 1 K lower in P2 with maxima of 27°C in the central Indian and western Pacific Oceans than in P3, where maxima in the same regions exceed 28°C. At first sight the results from P3 seem to be more realistic, but it should be noted that SST here is the temperature of the first model layer, which has a thickness of 50 m. Relaxation in P2 is towards an average of the temperature over these 50 m, so that the resulting model SSTs are lower. To a certain extent it is therefore a question of taste which of the two results is to be regarded as "better". Another example is the flow through Drake Passage, which is much weaker in P3 (about 60 Sv) than in P2 (about 80 Sv). Note that even this last figure is much lower than the 120 Sv obtained from observations.

It is beyond the scope of this technical note to explore the reasons and mechanisms behind the differences noted. The user of LEO should be aware of the shortcomings and is invited to improve them.

A How to get LEO running?

To implement the coupled model and get it running the user has to perform the following steps.

1. Untar KOPPEL.tar.
2. Print out the LSG manual (LSG/SUPPORT/lsg.manual.ps.Z) and the OASIS manual(s) (KOPPEL/OASIS/doc/doc.oasis.ps and KOPPEL/OASIS_2.2/doc/doc.oasis2.2.ps). Order [3] from KNMI's library. Read the manuals to make yourself familiar with the models and with OASIS.
3. Change the paths contained in the various *script* (extensions job or sc) and *make* (extension mk) files. These files are found in subdirectories ECBILT0, LSG/SUPPORT, OASIS, and OASIS/TEST. If appropriate, change also the compiler and/or compiler options in the *make* files.
4. Inspect the "toy"-programs contained in OASIS/toy1.
5. Inspect and run the programs contained in OASIS/TEST by executing the script oasis.sc. Inspect the output files generated. Plot the fields that are output from atmos.f and ocean.f using the PV-WAVE routine mapflux.pro from LSG/POSTPRO and see how well OASIS performs the interpolation between the ocean and the atmosphere grid.

6. Play around with the OASIS input parameters in file namcouple and observe their effect on the performance of the coupled test model.

7. Copy the contents of directory REST.SAV into the directory you want to use as the working directory for.LEO. REST.SAV contains fields for the first time OASIS is called. They are needed because OASIS does not wait for a signal from the component models for the first interpolation to be done.

8. Go to ECBILT0 and execute cprun.job to make your first coupled run wit LEO. Use the PV-WAVE routine mapecb.pro from ECBILT0/POSTPRO to plot fields from the atmosphere model (ECBILT). LSG fields can be plotted by maplsg.pro (scalar variables) and veclsg.pro (velocities) from LSG/POSTPRO.

9. Publish your paper and send a copy to the author of this note.

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5a Terray, L., E. Sevault, E. Guilyardi, O. Thual (1995), OASIS 2.0 Ocean Atmosphere Sea Ice Soil User's Guide and Reference Manual, CERFACS, Toulouse, France.

5b Terray, L., S. Valcke, A. Piacentini (1998), OASIS 2.2 Ocean Atmosphere Sea Ice Soil User's Guide and Reference Manual, CERFACS, Toulouse, France.

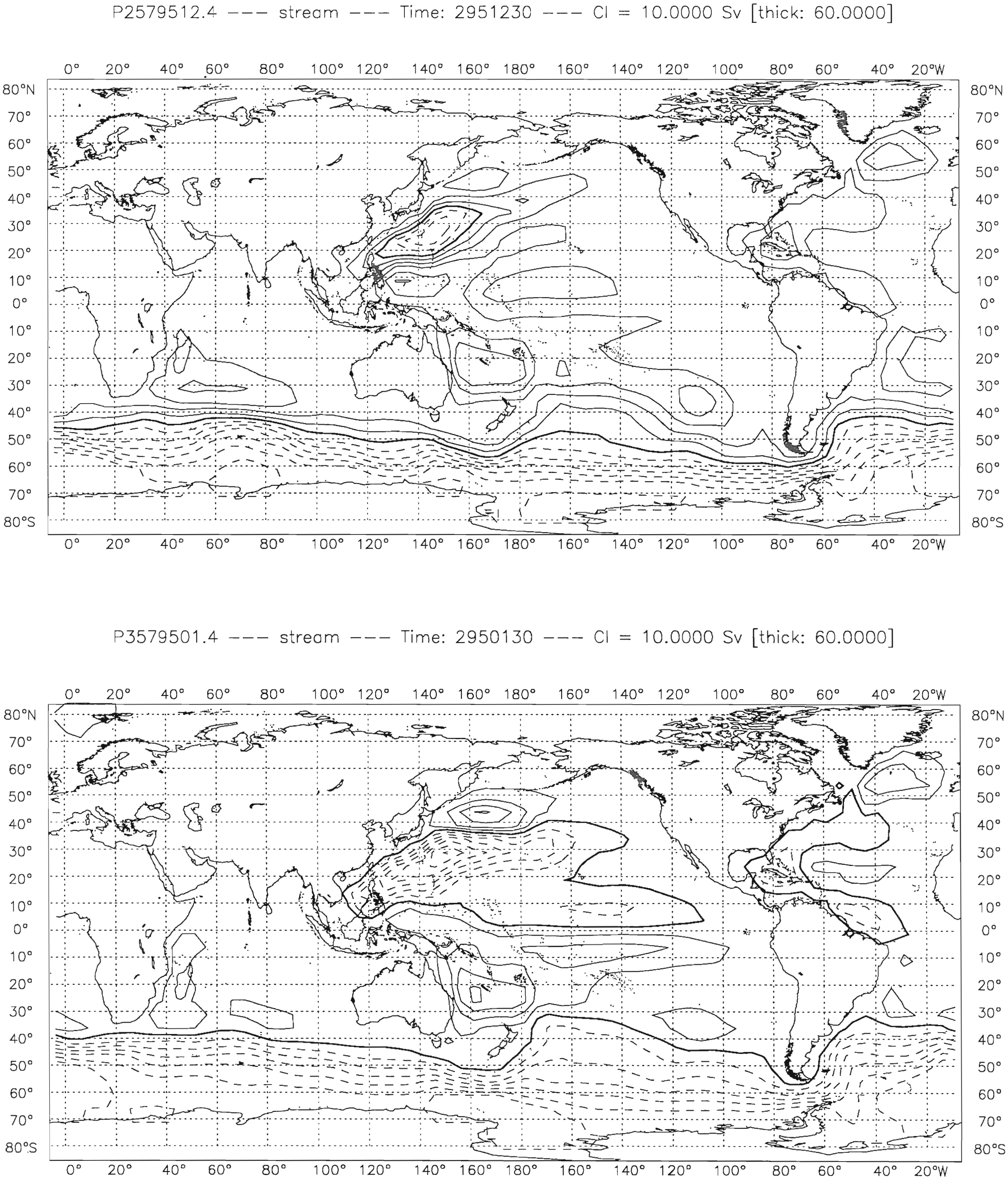


Figure 1: *Barotropic streamfunction of the ocean (top: P2, bottom: P3; CI = 10 Sv with values below 60 Sv dashed).*

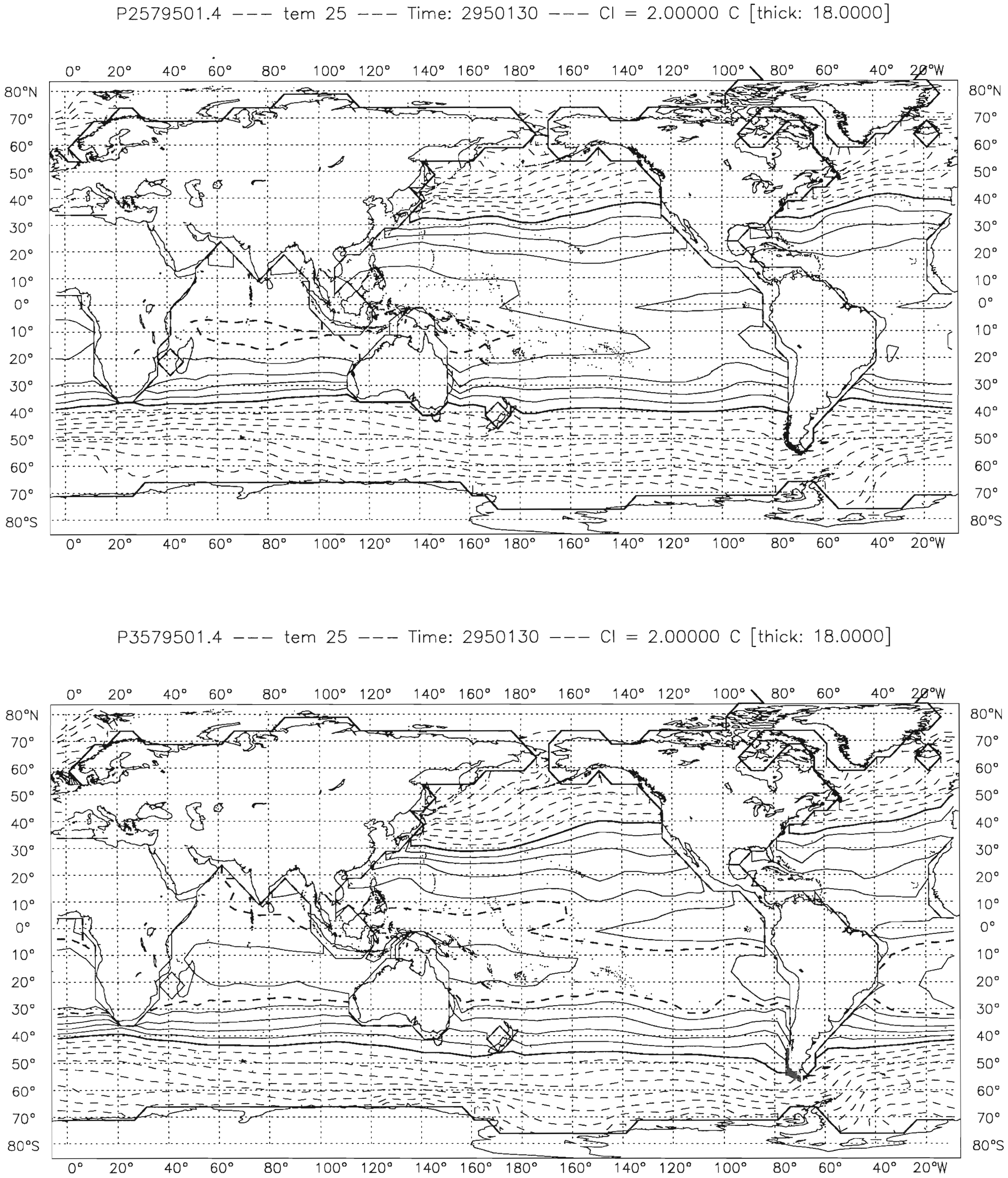


Figure 2: *SST in January (top: P2, bottom: P3; CI = 2 K with values below 18° C dashed).*

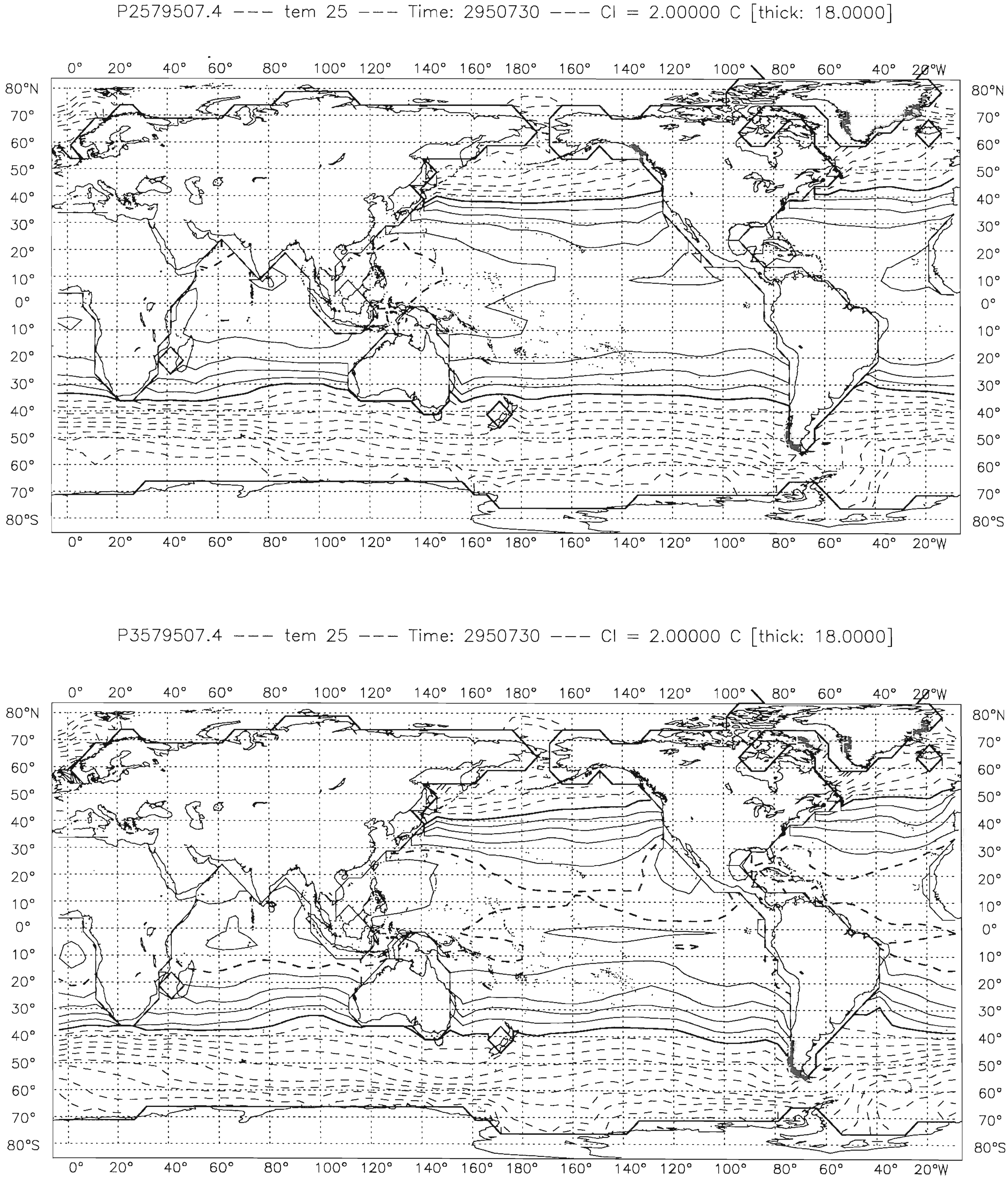


Figure 3: *SST in July (top: P2, bottom: P3; CI = 2 K with values below 18° C dashed).*

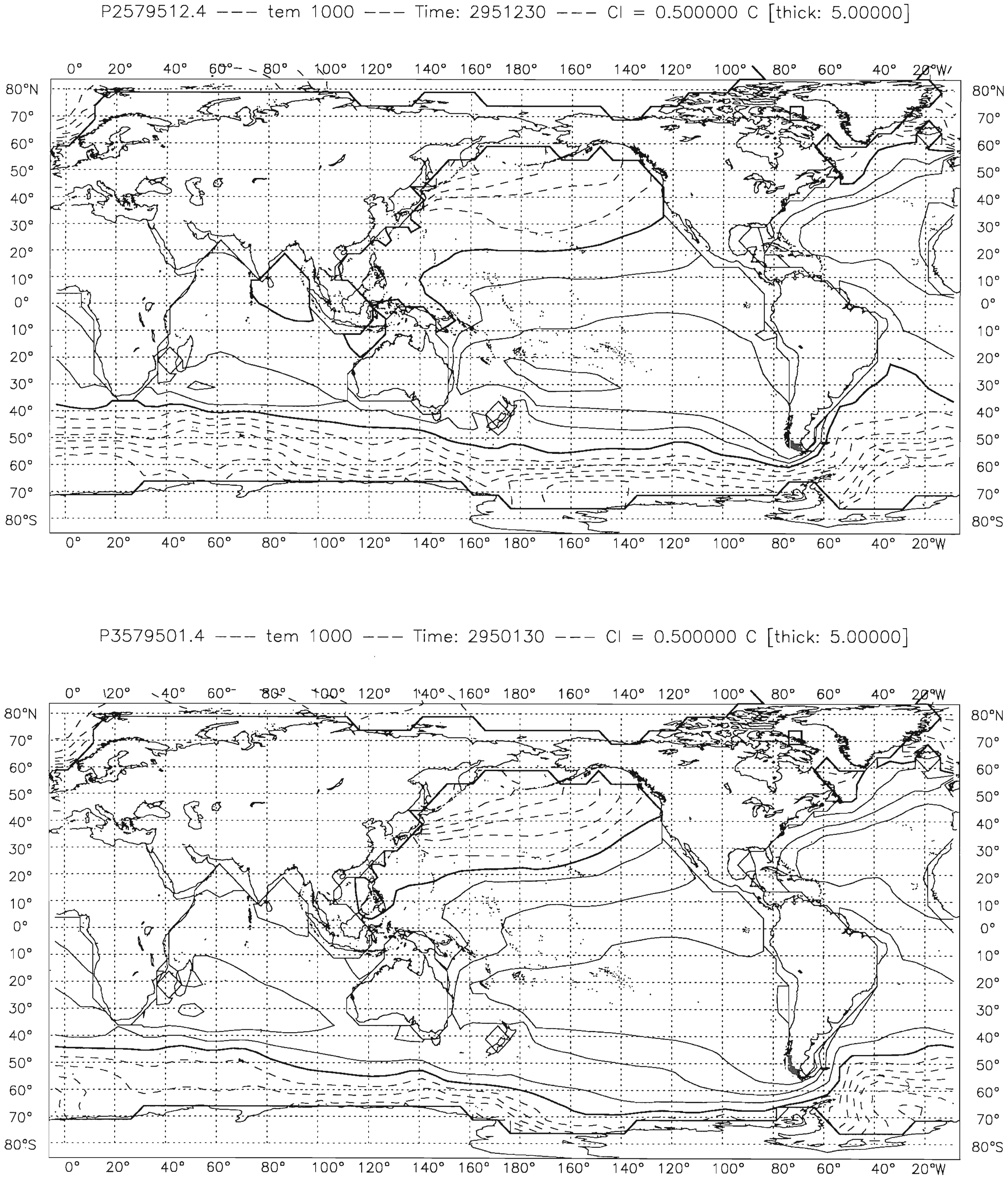
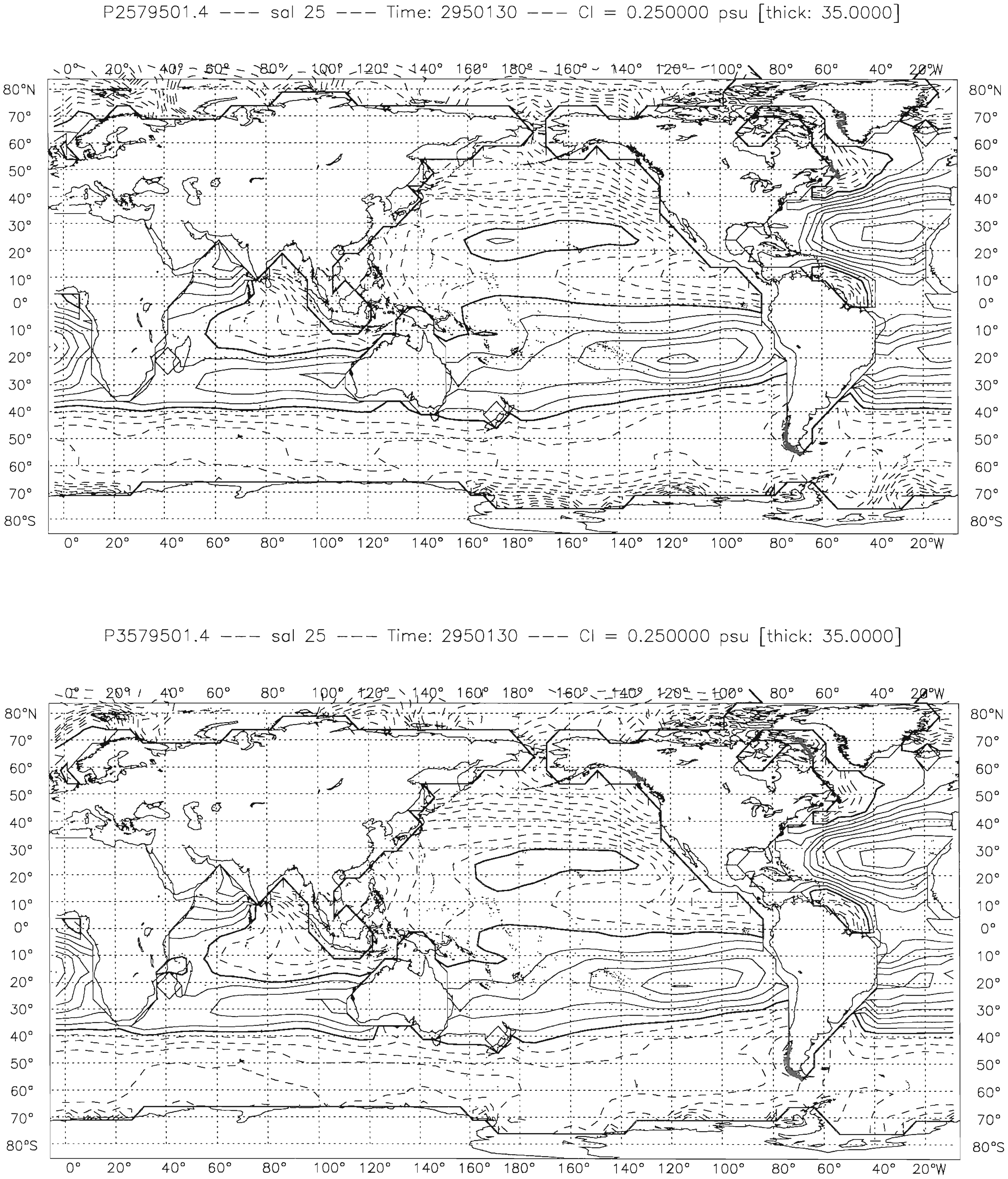


Figure 4: *Temperature at a depth of 1000 m (top: P2, bottom: P3; CI = 0.5 K with values below 5°C dashed).*



P2579501.4 --- sal 25 --- Time: 2950130 --- CI = 0.250000 psu [thick: 35.0000]

P3579501.4 --- sal 25 --- Time: 2950130 --- CI = 0.250000 psu [thick: 35.0000]

Figure 5: *SSS in January (top: P2, bottom: P3; CI = 0.25 psu with values below 35 psu dashed).*

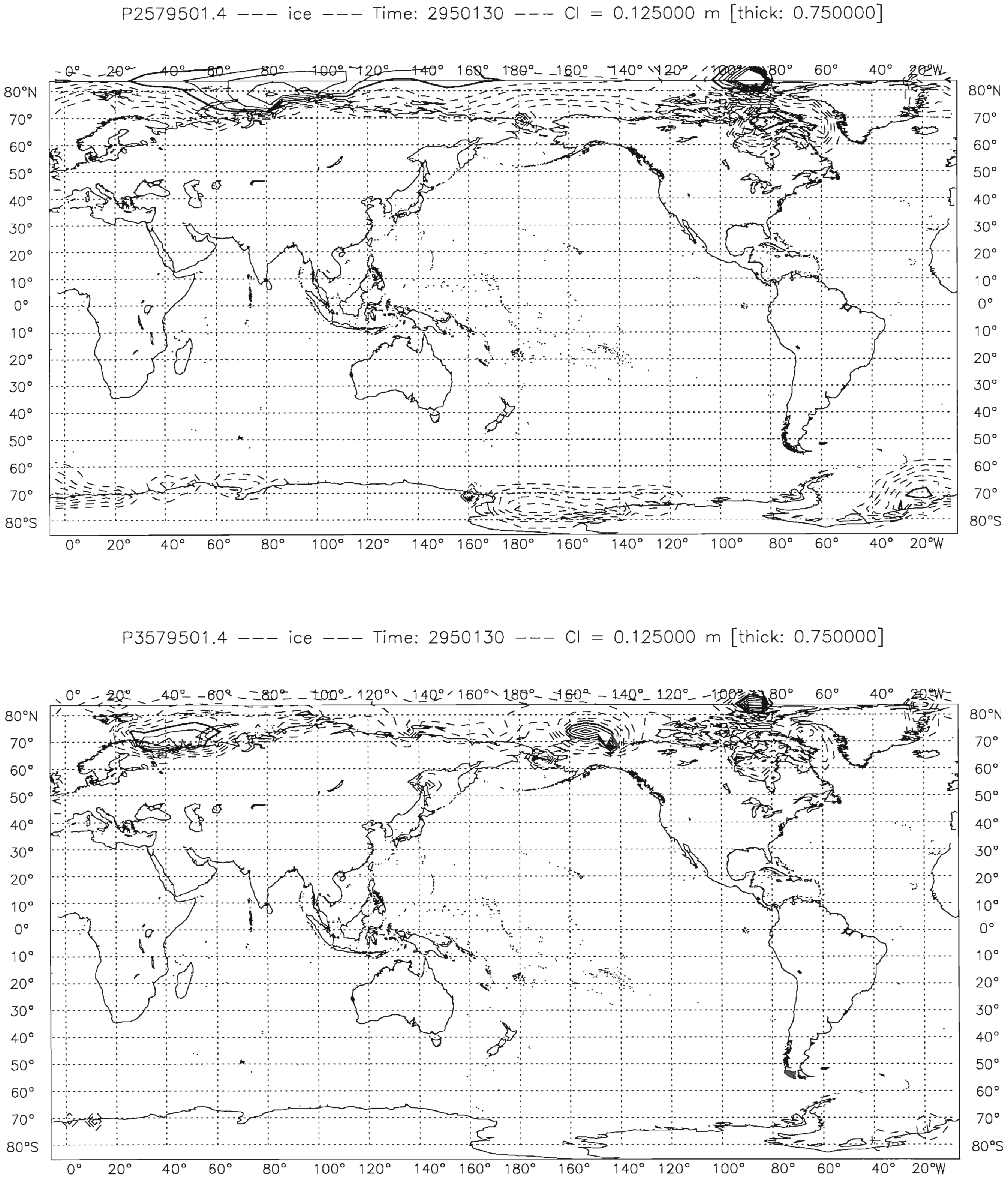


Figure 6: *Sea ice concentration in January (top: P2, bottom: P3; CI = 0.125 m with values below 0.75 m dashed).*

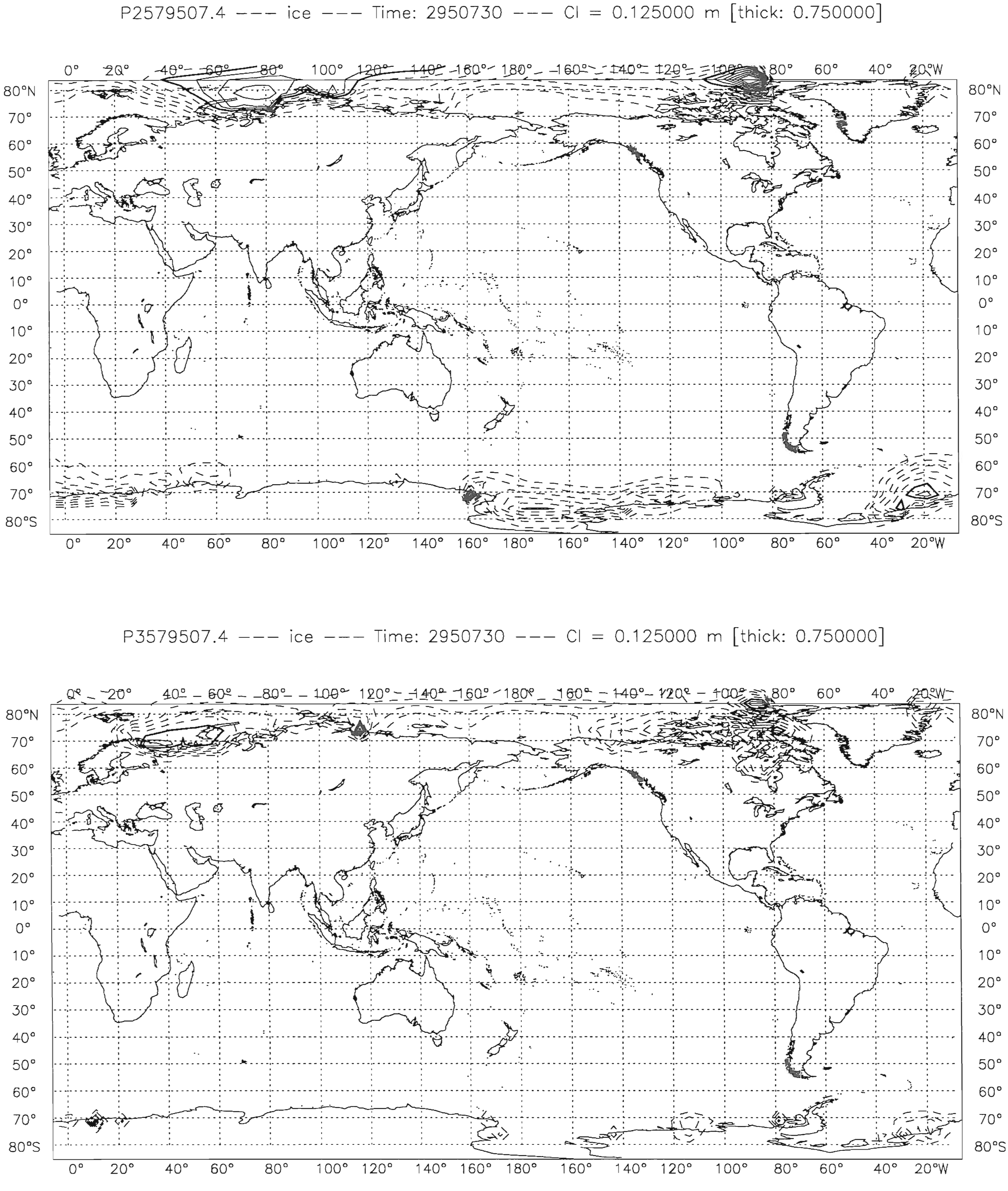
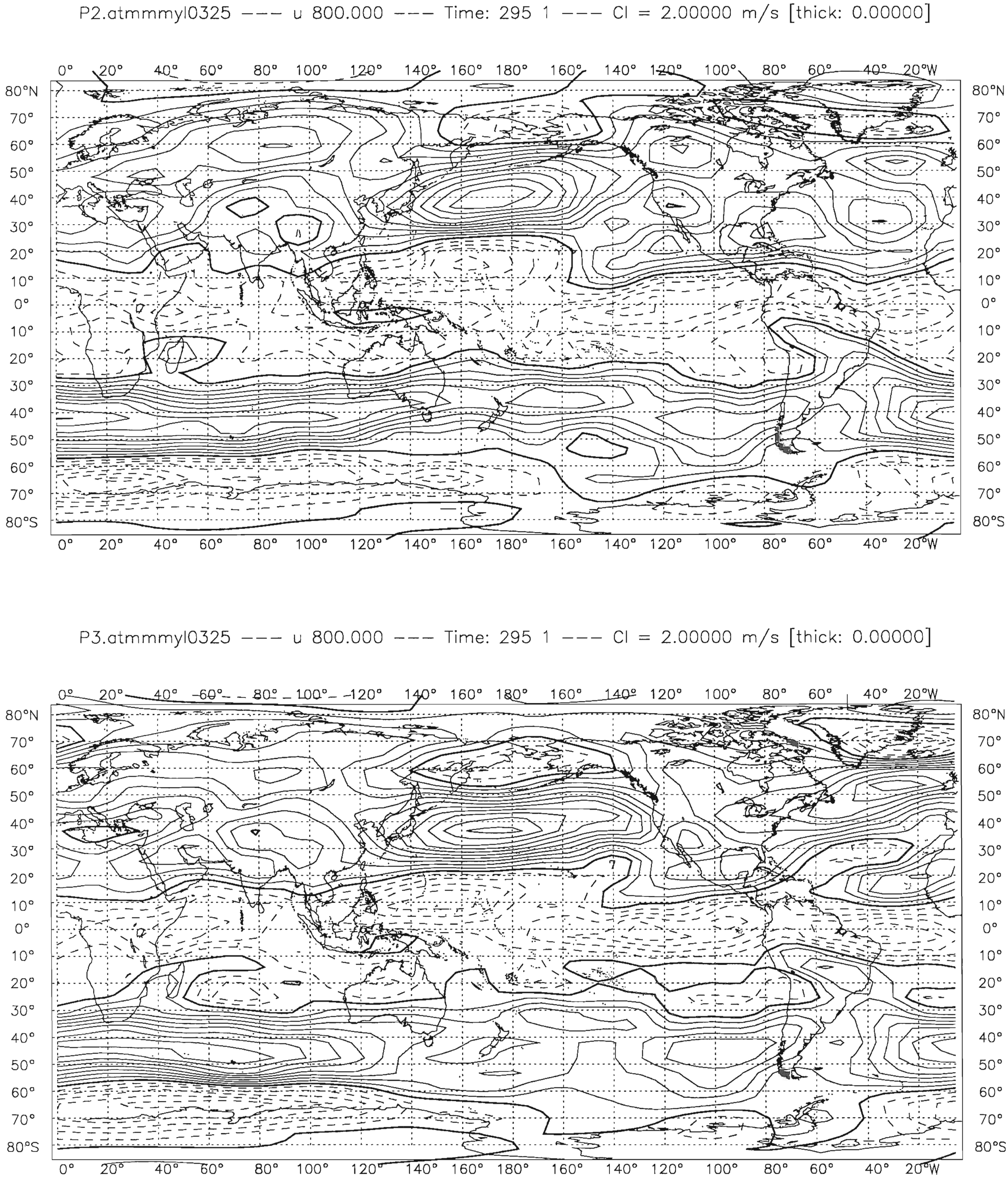


Figure 7: *Sea ice concentration in July (top: P2, bottom: P3; CI = 0.125 m with values below 0.75 m dashed).*


P2.atmmmyl0325 --- u 800.000 --- Time: 295 1 --- CI = 2.00000 m/s [thick: 0.00000]

P3.atmmmyl0325 --- u 800.000 --- Time: 295 1 --- CI = 2.00000 m/s [thick: 0.00000]

Figure 8: *Zonal winds at 800 hPa in January (top: P2, bottom: P3; CI = 2 m/s with negative values dashed).*

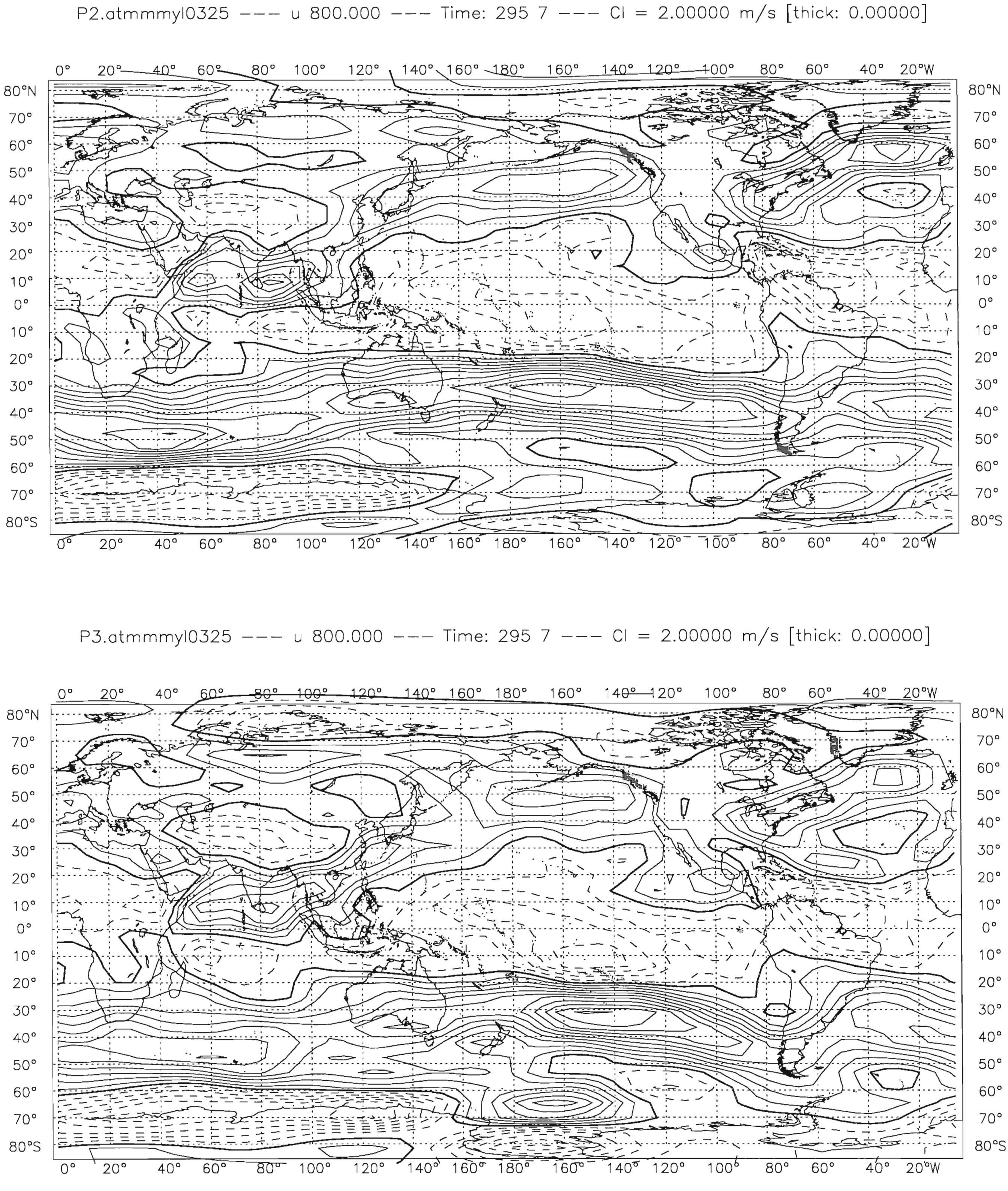


Figure 9: *Zonal winds at 800 hPa in July (top: P2, bottom: P3; CI = 2 m/s with negative values dashed).*

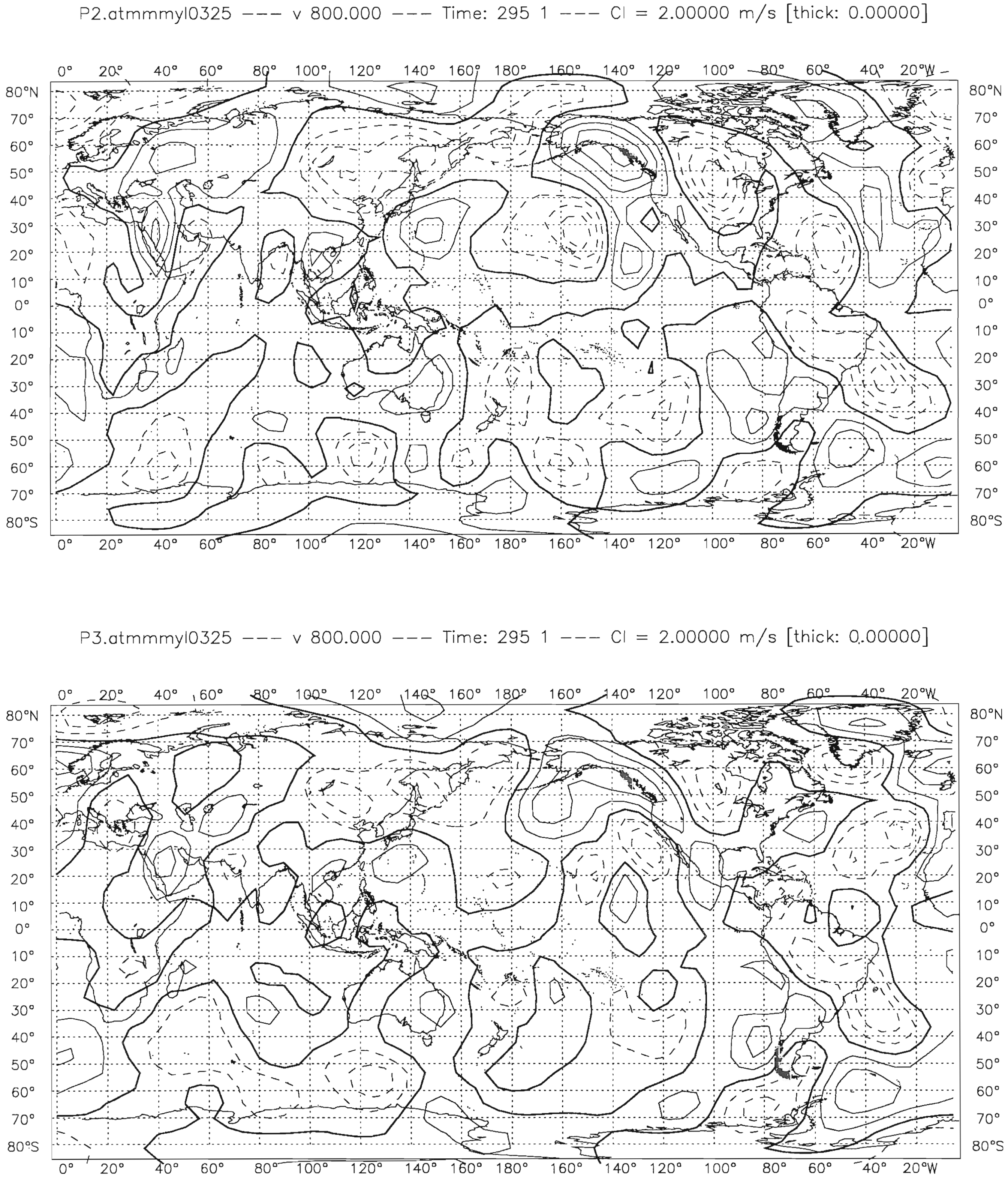
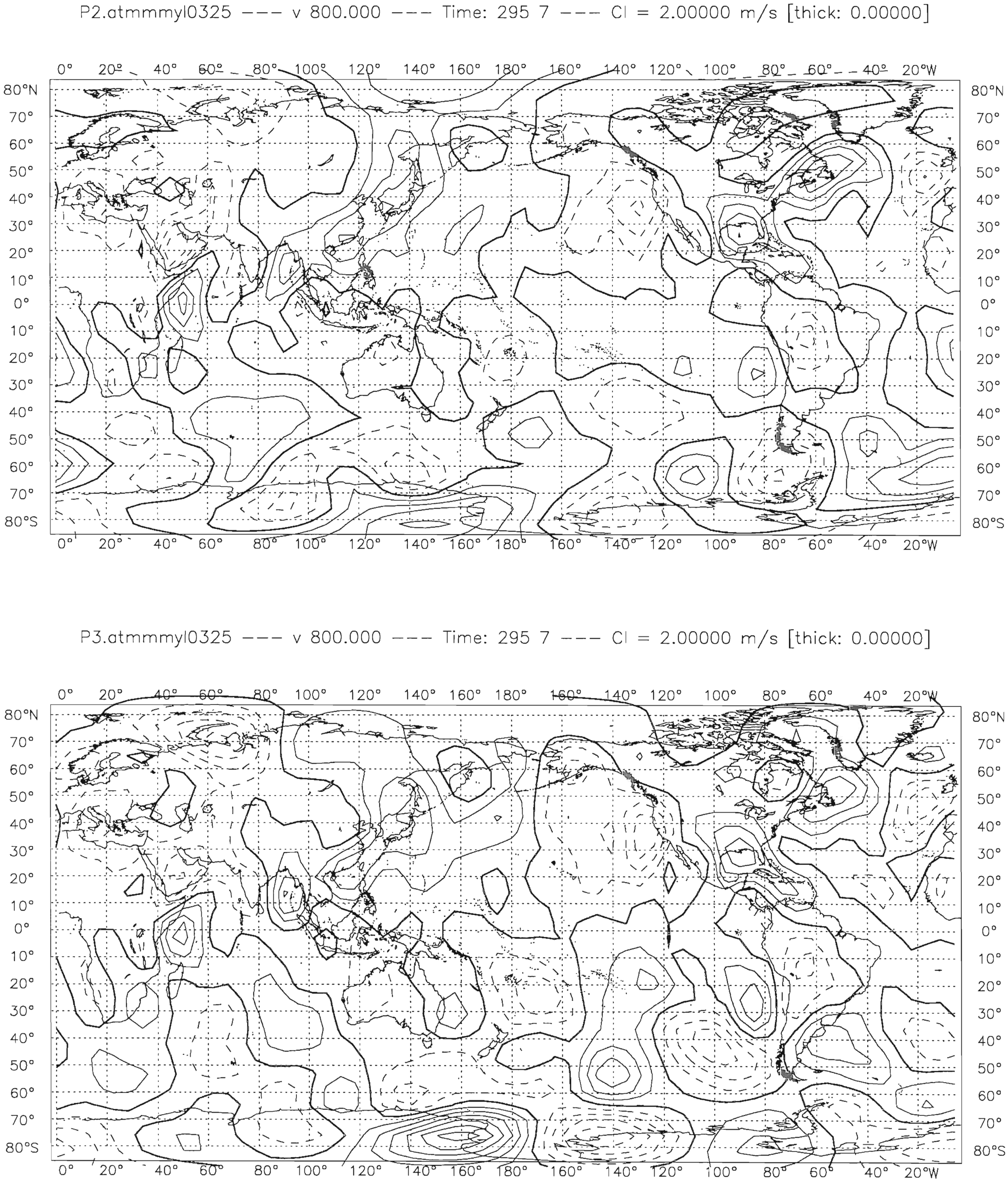


Figure 10: *Meridinonal winds at 800 hPa in January (top: P2, bottom: P3; CI = 2 m/s with negative values dashed).*



P2.atmmmyl0325 --- v 800.000 --- Time: 295 7 --- CI = 2.00000 m/s [thick: 0.00000]

P3.atmmmyl0325 --- v 800.000 --- Time: 295 7 --- CI = 2.00000 m/s [thick: 0.00000]

Figure 11: *Meridinonal winds at 800 hPa in July (top: P2, bottom: P3; CI = 2 m/s with negative values dashed).*

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