Multi-model Analysis For CEOP (MAC): A model data product supporting CEOP science objectives and the GEWEX Roadmap

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DRAFT June 9, 2008

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All model contributors and any contributors to the plan will be added with concurrence, including reviews/contributions from GRP and GMPP

A plan to synthesize the gridded model contributions to the CEOP data archives to facilitate their use in GEWEX science and operational objectives and research the uncertainty of models.

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1. Background

Early in the formulation of the Coordinated Enhanced Observing Period (CEOP), the need for model data to support science objectives became apparent. Additionally, the observations being developed for CEOP would be very useful to the validation of model analyses and forecasts. Invitations were sent to the major international Numerical Weather Prediction and data assimilation Centers (NWPCs). Ten centers responded favorably, and by the end of 2007, seven centers provided 27 months’ worth of data for the CEOP EOP-3 and -4 (Oct 2002 – Dec 2004). Two separate model contributions from ECPC gave a total of 8 (eight) analyses. NASA/GSFC GMAO’s GEOS-5 reanalysis data is currently under development, and is not included within these 8 analyses. The EOP-3/4 period is an excellent timeframe for testing the model data, as tremendous amounts of global remotely-sensed data are also available for verification.

Comparing the analyses from the NWPCs has primarily been through the single-point Model Output Location Time Series (MOLTS) co-located with CEOP reference sites (Yang et al. 2007; Chou et al. 2007; Rikus 2007 and Bosilovich et al. 2007). To get at the comparison of global grids, an ensemble of the analyses is proposed. This ensemble serves several purposes. First, the variance of the analyses can provide a measure of uncertainty in analyses. It also provides a range of the state-of-the-art analyses. Second, this ensemble may make a better benchmark for comparing individual analyses than simply differencing one against another. The veracity of the ensemble can be tested against global independent observations (e.g., GPCP, ISCCP, SRB, etc.). Lastly, it is hoped that these datasets will demonstrate the benefit of such a multi-model analysis for global atmospheric data assimilation systems, for future longer-term studies. The GSWP-2 multi-model analysis provides encouraging results showing that the ensemble average can be a high-quality data product (Dirmeyer et al, 2006).

The purpose of this paper is to outline the methods and procedure for developing a Multi-model Analysis for CEOP (MAC). Input from the GEWEX community (GMPP, GRP, and others) is crucial to develop a dataset useful beyond the interest of the modeling groups. This paper will contain descriptions of the regridding method, common grid, variables to be ensembled, and any special considerations. An accompanying spreadsheet (see Appendix) will provide additional details of the CEOP MAC data. This document contains the description of the first version of the MAC. Subsequent versions may include different variables, methods or new data.

2. Data

The data contributed to CEOP consists of analysis and forecast cycles. Few requirements were placed on the contributing NWPCs; thus, the length of the forecasts, frequency of output, variables and units were left to the individual center (see Tables 1 and 2 in the Appendix). While the archive of data is perfectly useable, these issues need careful consideration for users intending on applying these data to a validation exercise or scientific evaluation.

The CEOP MAC data will synthesize a subset of high-priority variables (see Appendix), ensure that units are consistent, and grids are made common. Each NWPC’s system has its own topography and land/water mask. All centers did not provide a mask and topography for their system, so these will not factor into this initial pilot study of ensembling analyses. Also, the dataset does not synthesize data beyond the first 6-hourly forecast period available past the analysis time. Most of the centers do not provide data beyond the 6-hour forecast, and thus the number of members drops at longer forecast times. However, CPTEC data is only available daily beyond a 12-hour forecast; thus, the daily CPTEC data is...
from a 12-hour to 36-hour forecast. Also, MSC data is only provided from a single daily run at 12Z; thus, the daily data is from 0-hour to 24-hour forecast. The 6-hourly analysis and forecast cycles will be averaged into monthly and daily averages, as these will be well-posed frequencies in the individual time series.

The centers that have provided global gridded analyses to the project are:

- Bureau of Meteorology Research Centre (BMRC)
- Centro de Previsão de Tempo e Estudos Climáticos (CPTEC, The Center for Weather Forecasts and Climate Studies)
- Experimental Climate Prediction Center (ECPC)
- Japan Meteorological Agency (JMA)
- Meteorological Services of Canada (MSC)
- National Centers for Environmental Prediction (NCEP)
- United Kingdom Meteorological Office (UKMO)

The raw model data from the NWPCs participating in CEOP is stored (in Grib1 format) and archived by the Model & Data group at the Max Planck Institute (MPI) for Meteorology in Hamburg, Germany. Only those data files containing the subset of high-priority variables and the minimum-available forecast times described above were downloaded to a workstation at NASA/GSFC GMAO. Because these files typically contained additional variables and forecasts beyond what was desired, often at very high resolution, the amount of data downloaded to data has to date exceeded 1.13 Tb. A significant portion of this data was transferred over a high-speed optical network that was configured during the development of the CEOP MAC. This optical path used end-to-end communication over the University of Illinois-Chicago's TeraFlow Testbed network, which included support from NASA/GSFC's Software Integration and Visualization Office.

3. Methods and Plan

The procedure for generating the Multi-model Analysis for CEOP (MAC) is as follows:

1. Generate a 6-hourly dataset for all centers, using consistent units and time-frames
2. Regrid the 6-hourly data from each center to a common grid (1.25 deg. by 1.25 deg.)
3. Create an ensemble mean of the 6-hourly data; also create a 6-hourly standard deviation (Figure 1)
4. Create daily-averages and monthly-averages from the 6-hourly ensemble mean (Figures 2 and 3)
5. Create daily- and monthly-averages of the individual centers (Figures 2 and 3)
6. Create daily and monthly standard deviations between the individual centers averages
7. Write the re-gridded data for all centers, the mean, and the standard deviation at the 6-hourly, daily, and monthly times in the final formats of NetCDF and grib1 with consistent units and variable names.

The steps listed above provide a broad outline of the procedure. Many decisions and problems needed to be overcome along the way, and are discussed in further detail below.
a. **6-hourly dataset (Step 1)**

For each NWPC dataset, a Grib table was used to identify and locate the subset of high-priority variables listed in the Appendix. The minimum forecast time available for each variable of the center was then pulled from the raw model data using “wgrib”. The minimum forecast time available typically was the analysis (0-hour forecast) for the instantaneous variables, and the 0-6 hourly forecast for the average/accumulation (ave/acc) variables. Some major exceptions include the CPTEC data, the MSC data, and some variables from the ECPC data. The CPTEC data at 00Z is a 12-hourly forecast, at 06Z an 18-hr forecast, at 12Z a 24-hr forecast, and at 18Z a 36-hr forecast. Similarly, the ave/acc variables from 00Z to 06Z are a 12-18 hourly forecast, and so on. The MSC instantaneous surface variable data at 12Z is an analysis/0-hr forecast, at 18Z a 6-hr forecast, at 00Z a 12-hr forecast, and at 06Z an 18-hr forecast. The upper air data, however, was not available at 06Z and 18Z; the 12Z data is an analysis/0-hr forecast and the 00Z data is a 12-hr forecast. The MSC ave/acc variables from 12Z to 18Z are a 0-6 hourly forecast, and so on. Several ECPC RII and SFM instantaneous surface variables are a 6-hr forecast rather than an analysis/0-hr forecast. Further details, including descriptions of any missing times and variables, are available in the spreadsheet and the Appendix (see Tables 1 and 2).

b. **Regridding (Step 2)**

In order to produce an ensemble, a common grid must be defined. Since most operational analyses are near or going to ~100km spatial scales, a grid on the order of 1 degrees latitude and longitude was desirable. Also, many data products (GPCP and the reanalyses data) use a regular latitude-longitude coarse grid (2.5 degrees). Thus, a regular latitude-longitude grid that is near the spatial scale of the observational analyses, but also can be related easily to the reanalyses coarse grid, was chosen. The resolution is 1.25º longitude by 1.25º latitude (288×144 gridpoints), with the 1,1 center point located at 179.375W, 89.375S.

The native grid from each of the NWPCs supplied to CEOP was interpolated to the common grid using the OpenGrADS re() command (http://opengrads.org/). In the cases where the native grid is finer than 1.25ºx1.25º, box averaging was used. In the cases where the native grid is coarser than 1.25ºx1.25º, bilinear interpolation was be used. No other filtering or screening of the gridded data was applied (except for some below-ground heights – details in Sections 3c-f). At the end of this step, the data from each NWPC was on the common grid at a 6-hourly timestep, with common variable names and units. A list of the available variables for each center can be found in Table 1.

c. **Ensemble Average (Step 3)**

The ensemble average is the straight average of all of the available variables from each NWPC at each 6-hourly timestep. As all centers did not provide all variables, the ensemble averaging was done with those centers that did provide the given variable. If any data was missing from one or more of the NWPCs at a given time, the ensemble average was the average of the remaining data available. For the upper-air data at 850hPa and 700hPa, a masking to the MAC ensemble was applied for areas where the surface pressure at the given time was less than the pressure of the level (less than 850hPa or than 700hPa). This masking was also performed for the BMRC 6-hourly data, but not for the other individual NWPCs. The flowchart decisions used for each variable during the creation of the MAC ensemble at each of the 3292 6-hourly times is shown in Figure 1.
Figure 1: Flowchart of the creation of the 6-hourly ensemble mean and standard deviation.

Repeat these steps for all 48 MAC variables over each of the 3292 6-hourly times during EOP-3/4.
The individual center’s regridded variable is also provided with the MAC, so that it will be apparent when data is included in the ensemble average or not. Also, a separate dataset is provided that enumerates the number of ensemble members for each variable for each time. Similarly, the standard deviation at each 6-hourly timestep was computed from the available data that made up the ensemble average. The ensemble mean and standard deviation are provided as separate datasets on the same grid and same format as the individual NWPCs described at the end of Section 3b (Step 2).

d-f. Daily- and Monthly-Averages (Steps 4, 5, and 6)

The daily average of the ensemble mean was the simple average of the 00Z, 06Z, 12Z, and 18Z data on the given date. For the individual NWPCs, the daily average was the same, except that if an individual variable was missing or unavailable for at least one time during the date, that variable was considered to be undefined for that center on that day. The one exception to this is the MSC upper-air data, which was only available at 00Z and 12Z, and the daily average is just the average of these two times. Also, for each dataset, if at least one of the four times of the day had a point masked out because the surface pressure was less than the pressure of the upper-air level, then that point was also masked out for the entire day. The flowchart for the daily averages is shown in Figure 2. The daily standard deviation was then calculated between the centers that had valid daily averages for each variable. Note that the daily ensemble mean may include more data/centers than the daily ensemble standard deviation. An example of this is to suppose the 500 hPa heights was missing for 12Z only for one center. The 6-hourly ensemble means will include the 00Z, 06Z, and 18Z times for this center, and thus the daily ensemble mean will proportionally include this data. However, the daily mean for this center/variable will be considered undefined, and will not be included in the daily ensemble mean.

The monthly average of the ensemble mean was the simple average of all times in the month. For the individual NWPCs, the monthly average was calculated differently. First, all the 00Z times during the month were averaged, then the 06Z times, the 12Z times, and then the 18Z times. Next, these four times were summed and divided by four (4). This method was done to minimize the effect of an individual missing time on the monthly average. For example, if a 06Z time was missing for a variable such as downward surface radiation on a single date, this missing time would have a noticeable effect on the monthly average. If the similar times were averaged first, this problem is reduced, but does give a little extra weight to the other dates where the variable was available. No more than 6 times during the month were allowed to be undefined (out of a typical 120 or 124 6-hourly periods). If more than 6 times were undefined, the variable for that month was undefined. Similarly, if a given point had more than 6 times masked because the surface pressure was less than the pressure of the upper-air level, the point was also masked. The exceptions to this were for the UKMO data (numerous missing times, see Appendix), for the CPTEC data (only for May 2003, due to missing data), and for the MSC data (only 00Z and 12Z data available). The flowchart for the monthly averages is shown in Figure 3. The monthly-average standard deviation was then calculated between the individual centers’ monthly averages. Again, because of the different methods of the monthly-average calculations, the monthly-average standard deviation will not be exactly centered about the ensemble mean monthly-average.
Figure 2: Flowchart of the creation of the daily average for ensemble mean and individual models.

Repeat these steps for all 48 MAC variables over each of the 823 daily times during EOP-3/4.

Figure 2: Flowchart of the creation of the daily average for ensemble mean and individual models.
Figure 3: Flowchart of the creation of the monthly average for ensemble mean and individual models.

1. Create MAC monthly average
2. Read variable for all models
3. Variable defined?
   - NO: Entire field undefined
   - YES: Calculate monthly average of 6-hourly (00Z/06Z/12Z/18Z)
4. 850/700hPa or UKMO/UKMO/UKMO/UKMO?
   - NO: Average the 4 times to a monthly average
   - YES: Mask out if >6 times during month with undefined data or Psfc < Plevel
5. Write output; Repeat for all

Repeat these steps for all 48 MAC variables over each of the 27 monthly times during EOP-3/4.
Data were written to binary output, then were converted to the NetCDF and Grib1 formats (using the public GrADS script LATS4d) for release to the contributors and community. The resulting binary (or NetCDF) output size is roughly 284Gb (about 134Gb in Grib1). Each file contains each variable listed in Table 1 (with the common naming convention). Common utilities, ncdump and wgrid, can be used to identify the vital information needed to access the data. A grib table common to all processed centers and the MAC is also provided. The data will be sent to the NASA Goddard Data Information Services Center (DISC) and the MPI Model and Data Center (others can be included if interested).

4. Summary and next steps

The global gridded analyses contributed to CEOP have been modified to fit a common framework to facilitate comparisons among the analyses and make the access to the data easier for science efforts. The eventual goal is to quantify the uncertainty among operational analyses. Preliminary results and evaluation of the MAC ensemble have been favorable, so the data should be returned to the contributing centers, and made available to the scientific community. These results were presented at the AMS annual meeting (http://ams.confex.com/ams/88Annual/techprogram/paper_131182.htm) and the WCRP 3rd International Reanalysis Conference (http://jra.kishou.go.jp/3rac_en.html).

Two major tasks are nearing completion. First, make the data accessible to the contributing centers and CEOP science efforts. Possibly, some review of the data and results could be available by the annual CEOP meeting in September 2008. Second, we would like to invite the data contributors to collaborate on an overview paper of the data set. The eventual manuscript would go to peer review, but perhaps a more broad distribution, for example, Bulletin of the AMS. Lastly, the documentation on each of the system is quite variable. It would be useful to researchers/users to have some basic information and citations for the systems’ model and data assimilation methods.

Acknowledgments

We would like to express sincerest appreciation for the numerical prediction centers contributing time and model data to the CEOP archives, without which this study could not have been easily accomplished. In addition, MPI Model and Data center’s effort in hosting and serving the data provided a critical resource. The NASA/GSFC SIVO branch is thanked for the development of a high-speed optical path for quicker downloads between GSFC and MPI. The effort to compile the CEOP model data was funded by the NASA Model, Analysis and Prediction program.
## 5. Appendix 1: Summary of available model data used in the MAC

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**Table 2**: Location in the forecast cycle of each NWPC’s variables included in the MAC.
## CEOP GRID 6-hourly Datasets

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<th>Dimensions</th>
<th>Experiment: Dataset</th>
<th>Key Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>JMA</td>
<td>No times missing</td>
<td>X by Y: 288 by 145</td>
<td>CEOP_JMA_GRID_RAW: CEOP_JMA_GRID_1</td>
<td>T, U/V, ω, Φ (22 levels) Cloud liquid water (12 levels) Total cloud cover % (column) 2-m T, 10-m U/V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lon/Lat: 1.25 by 1.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Levels: 22 pressure levels</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>X by Y: 640 by 320</td>
<td>CEOP_JMA_GRID_RAW: CEOP_JMA_GRID_2</td>
<td>TOA/surface LW/SW ↑/↓ radiation Sensible/Latent heat flux Precip/Pressure/Roughness/TKE Momentum &amp; Water Vapor flux</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lon/Lat: 0.5625 by ∼0.5625</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Levels: 1 surface level</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>X by Y: 320 by 160</td>
<td>CEOP_JMA_GRID_RAW: CEOP_JMA_GRID_3</td>
<td>T, U/V, P, q (40 levels) Local time tendency of T (40 levels)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lon/Lat: 1.125 by ∼1.125</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Levels: 40 eta levels</td>
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<td></td>
</tr>
<tr>
<td>UKMO</td>
<td>278 times missing: (by month)</td>
<td>X by Y: 288 by 145</td>
<td>CEOP_UKMO_GRID_RAW: CEOP_UKMO_GRID_DA_all_2D</td>
<td>TOA/surface LW/SW ↑/↓ radiation Sensible/Latent heat flux Precip w/ Convective/Large-scale Pressure/Roughness/PBL height Total/High/Mid/Low cloud cover % Convective cloud base/top Snow fall/depth/melt Runoff/Soil moisture 2-m T/q, 10-m U/V</td>
</tr>
<tr>
<td></td>
<td>2002: 4, 3, 70</td>
<td>Lon/Lat: 1.25 by 1.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2003: 27, 5, 4, 2, 10, 26, 4, 24, 8, 9, 11, 1</td>
<td>Levels: 1 surface level</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2004: 5, 5, 5, 0, 4, 9, 5, 9, 4, 9, 8</td>
<td>X by Y: 288 by 145</td>
<td>CEOP_UKMO_GRID_RAW: CEOP_UKMO_GRID_DA_all_3D</td>
<td>T, U/V, RH, Φ (18 levels) KE/Enthalpy (18 levels)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lon/Lat: 1.25 by 1.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Levels: 18 pressure levels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMRC</td>
<td>2 times missing:</td>
<td>X by Y: 288 by 145</td>
<td>CEOP_BMRC_GRID with corrections in: CEOP_BMRC_GRID_18Z</td>
<td>T, U/V, ω, Φ (15 levels) Surface LW/SW ↑/↓ radiation Sensible/Latent heat flux Precip/Pressure Precipitable water Snow depth Surface albedo Soil moisture &amp; temp 2-m T/q, 10-m U/V</td>
</tr>
<tr>
<td></td>
<td>12Z2003Dec12 18Z2003Dec12</td>
<td>Lon/Lat: 0.75 by ∼0.75</td>
<td>CEOP_BMRC_GRID_NEWSFC CEOP_BMRC_GRID_SPHUM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Levels: 15 pressure levels</td>
<td>(data obtained direct from BMRC)</td>
<td></td>
</tr>
</tbody>
</table>

**Center**

- **JMA**: Japan Meteorological Agency
- **UKMO**: United Kingdom Met Office
- **BMRC**: British Met Office Research Center
<table>
<thead>
<tr>
<th>Dataset</th>
<th>Missing Times</th>
<th>X by Y:</th>
<th>Lon/Lat:</th>
<th>Levels:</th>
<th>Data Fields:</th>
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</thead>
</table>
| NCEP      | 1 time missing: 12Z2003Aug26 | 360 by 181 | 1.0 by 1.0 | 26 pressure levels | T, U/V, Φ (26 levels) 
Cloud water, RH, ω (21 levels) 
TOA/surface LW/SW ↑/↓ radiation 
(no TOA SW↓, however) 
Sensible/Latent/Ground heat flux 
Precip/Pressure/PBL height 
Total cloud cover % (column) 
Precipitable & Cloud water (column) 
Snow depth 
Surface albedo 
Runoff/Soil moisture & temps 
2-m T/q, 10-m U/V |
| ECPCRII   | No times missing | 192 by 94 | 1.875 by ~1.915 | 1 surface level | TOA/surface LW/SW ↑/↓ radiation 
Sensible/Latent/Ground heat flux 
Precip w/ Convective Pressure/Roughness/PBL height 
Momentum flux/Gravity wave stress 
Total/High/Mid/Low cloud cover % 
Cloud base/top/temperature/CWF 
Snow fall/depth/melt 
Surface albedo 
Runoff/Soil moisture & temps 
2-m T/q, 10-m U/V |
|          |               | 144 by 73 | 2.5 by 2.5 | 17 pressure levels | T, U/V, RH/q, ω, Φ, η (17 levels) 
Precipitable water/RH (column) 
Lifted index 
Max wind level T, U/V, Pressure 
Tropopause T, U/V, Pressure, Shear |
<table>
<thead>
<tr>
<th>Dataset</th>
<th>Times Missing</th>
<th>X by Y</th>
<th>Lon/Lat</th>
<th>Levels</th>
<th>CEOP Grid Raw</th>
<th>TOA/Surface LW/SW Radiation</th>
<th>Sensible/Latent/Ground Heat Flux</th>
<th>Precip w/ Convective Pressure/Roughness/PBL Height</th>
<th>Momentum Flux/Gravity Wave Stress</th>
<th>Total/High/Mid/Low Cloud Cover %</th>
<th>Cloud Base/Top Temperature</th>
<th>Snow Fall/Depth/Melt</th>
<th>Surface Albedo</th>
<th>Runoff/Soil Moisture &amp; Temps</th>
<th>2-m T/RH, 10-m U/V</th>
<th>T, U/V, q, ω, Φ, η (17 Levels)</th>
<th>Precipitable Water (Column)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ECPC SFM</strong></td>
<td>2 times missing: 12Z2003Aug22 12Z2003Aug25</td>
<td>X by Y: 192 by 94</td>
<td>Lon/Lat: 1.875 by ~1.915</td>
<td>Levels: 1 surface level</td>
<td>CEOP_ECPCSFM_GRID_RAW: ECPCSFM6_fix_f00_MUL (analysis)</td>
<td>TOA/surface LW/SW ↑/↓ radiation</td>
<td>Sensible/Latent/Ground heat flux</td>
<td>Precip w/ Convective Pressure/Roughness/PBL Height</td>
<td>Momentum flux/Gravity wave stress</td>
<td>Total/High/Mid/Low cloud cover %</td>
<td>Cloud base/top temperature</td>
<td>Snow fall/depth/melt</td>
<td>Surface albedo</td>
<td>Runoff/Soil moisture &amp; temps</td>
<td>2-m T/q, 10-m U/V</td>
<td>T, U/V, q, Φ, ω, η (17 levels)</td>
<td>Precipitable water (column)</td>
</tr>
<tr>
<td>No times missing</td>
<td>X by Y: 144 by 73</td>
<td>Lon/Lat: 2.5 by 2.5</td>
<td>Levels: 17 pressure levels</td>
<td>CEOP_ECPCSFM_GRID_RAW: ECPCSFM6_pgb_ft00_MUL (analysis)</td>
<td>T, U/V, q, Φ, ω, η (17 levels)</td>
<td>Precipitable water (column)</td>
<td></td>
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<td></td>
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<tr>
<td><strong>MSC</strong></td>
<td>No times missing</td>
<td>X by Y: 800 by 600</td>
<td>Lon/Lat: 0.45 by 0.3</td>
<td>Levels: 1 surface level &amp; 4 upper-air levels (upper-air only 12-hourly)</td>
<td>CEOP_MSC_GRID_RAW: CEOP_MSC_GRID_RAW_xxxx (xxxx = variable name)</td>
<td>T, U/V, q, Φ (4 levels)</td>
<td>TOA/surface LW/SW ↑/↓ radiation</td>
<td>Sensible/Latent/Ground heat flux</td>
<td>Precip/Pressure 1.5-m T/q, 10-m U/V</td>
<td>Total cloud cover % (column)</td>
<td>Precipitable &amp; Cloud water (column)</td>
<td>Snow depth/SWE</td>
<td>Surface albedo</td>
<td>Runoff/Soil moisture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CPTEC</strong></td>
<td>35 times missing: (by month) 2002: 0, 1, 0 2003: 1, 1, 1, 0, 14, 2, 1, 0, 1, 0, 3, 2004: 0, 0, 0, 1, 4, 0, 0, 1, 0, 4, 0</td>
<td>X by Y: 384 by 192</td>
<td>Lon/Lat: 0.9375 by ~0.9375</td>
<td>Levels: 15 pressure levels</td>
<td>CEOP_MSC_GRID_RAW: CPTEC_GR_gposnmc_fct_12_MUL CPTEC_GR_gposnmc_fct_18_MUL CPTEC_GR_gposnmc_fct_24_MUL CPTEC_GR_gposnmc_fct_30_MUL</td>
<td>T, U/V, q, ω, Φ, diverg. (15 levels)</td>
<td>TOA/surface LW/SW ↑/↓ radiation (no TOA SW↓, however)</td>
<td>Sensible/Latent heat flux</td>
<td>Precip/Pressure/Roughness Runoff/Soil moisture 2-m T/RH, 10-m U/V</td>
<td>Total cloud cover % (column)</td>
<td>Precipitable water (column)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### JMA

Experiment name at MPI: CEOP_JMA_GRID_RAW

Dataset name at MPI: CEOP_JMA_GRID_1  
Spatial resolution: 288x145 (1.25 lon. X 1.25 lat.)  
Vertical resolution: 22 pressure levels  
Temporal resolution: 6-hourly (3292 total files)  
Missing data: None  
Key variables: T, U/V, ω, Φ (22 levels)  
Cloud liquid water (12 levels)  
Total cloud cover % (column)  
2-m T, 10-m U/V

Dataset name at MPI: CEOP_JMA_GRID_2  
Spatial resolution: 640x320 (0.5625 lon. X ~0.5625 lat.)  
Vertical resolution: 1 surface level  
Temporal resolution: 6-hourly (3292 total files)  
Missing data: None  
Key variables: TOA/surface LW/SW ↑↓ radiation  
Sensible/Latent heat flux  
Precipitation/Pressure/Roughness/TKE  
Momentum & Water Vapor flux  
Land/Sea/Ice Mask, Deep soil T

Dataset name at MPI: CEOP_JMA_GRID_3  
Spatial resolution: 320x160 (1.125 lon. X ~1.125 lat.)  
Vertical resolution: 40 eta model levels  
Temporal resolution: 6-hourly (3292 total files)  
Missing data: None  
Key variables: T, U/V, P, q (40 levels)  
Local time tendency of T (40 levels)

Pull binary data from grib:  
~/CEOP/JMA/pull_grid1.bash  
~/CEOP/JMA/pull_grid2.bash  
~/CEOP/JMA/pull_grid3.bash

Re-grid 6-hourly binary:  
~/CEOP/JMA/mma_regrid.gs

Daily average creation:  
~/CEOP/MAC/daily_average.gs  
Daily average description: “lats4d” average of 00Z, 06Z, 12Z, and 18Z times

Monthly average creation:  
~/CEOP/MAC/monthly_average.gs  
Monthly average description: “lats4d” average of 00Z (day 1) to 18Z (last day of month)

### UKMO

Experiment name at MPI: CEOP_UKMO_GRID_RAW

Dataset name at MPI: CEOP_UKMO_GRID_DA_all_2D
Spatial resolution: 288x145 (1.25 lon. X 1.25 lat.)
Vertical resolution: 1 surface level
Temporal resolution: 6-hourly (3014 total files)
Missing data: 278 times missing (by month):
2002: 4, 3, 70
2003: 27, 5, 4, 2, 10, 26, 4, 24, 8, 9, 11, 1
2004: 5, 5, 0, 4, 9, 5, 9, 9, 4, 9, 8
Key variables:
TOA/surface LW/SW ↑↓ radiation
Sensible/Latent heat flux
Precip w/ Convective/Large-scale
Pressure/Roughness/PBL height
Total/High/Mid/Low cloud cover %
Convective cloud base/top
Snow fall/depth/melt
Runoff/Soil moisture
2-m T/q, 10-m U/V

Dataset name at MPI: CEOP_UKMO_GRID_DA_all_3D
Spatial resolution: 288x145 (1.25 lon. X 1.25 lat.)
Vertical resolution: 18 pressure levels
Temporal resolution: 6-hourly (3014 total files)
Missing data: 278 times missing (by month):
2002: 4, 3, 70
2003: 27, 5, 4, 2, 10, 26, 4, 24, 8, 9, 11, 1
2004: 5, 5, 0, 4, 9, 5, 9, 9, 4, 9, 8
Key variables:
T, U/V, RH, Φ (18 levels)
KE/Enthalpy (18 levels)

Pull binary data from grib:
~/CEOP/UKMO/pull_da2d.bash
~/CEOP/UKMO/pull_da3d.bash
Re-grid 6-hourly binary:
~/CEOP/UKMO/mma_regrid.gs
Daily average creation:
~/CEOP/MAC/daily_average.gs
Daily average description: “lats4d” average of 00Z, 06Z, 12Z, and 18Z times
Monthly average creation:
~/CEOP/MAC/monthly_average.gs
Monthly average description: “lats4d” average of 00Z (day 1) to 18Z (last day of month)

BMRC

Experiment name: CEOP_BMRC_GRID
(obtained directly from BMRC)

Dataset names: N/A
Spatial resolution: 480x240 (0.75 lon. X ~0.75 lat.)
Vertical resolution: 15 pressure levels & 1 surface level
Temporal resolution: 6-hourly (3290 total files)
Missing data: 2 time missing: 12Z2003Dec12 & 18Z2003Dec12
Key variables:
T, U/V, ω, Φ (15 levels)
Surface LW/SW ↑/↓ radiation
Sensible/Latent heat flux
Precip/Pressure
Precipitable water
Snow depth
Surface albedo
Soil moisture & temp
2-m T/q, 10-m U/V

Pull binary data from grib:  ~/CEOP/BMRC/pull_grid.bash
Re-grid 6-hourly binary:  ~/CEOP/BMRC/mma_regrid.gs
Daily average creation:  ~/CEOP/MAC/daily_average.gs
Daily average description:  “lats4d” average of 00Z, 06Z, 12Z, and 18Z times
Monthly average creation:  ~/CEOP/MAC/monthly_average.gs
Monthly average description:  “lats4d” average of 00Z (day 1) to 18Z (last day of month)

NCEP

Experiment name at MPI:  CEOP_NCEP_GRID_RAW

Dataset names at MPI:  
NCEP_GR_FORC_06__00H
NCEP_GR_FORC_06__06H
NCEP_GR_FORC_06__12H
NCEP_GR_FORC_06__18H

Spatial resolution:  360x181 (1.0 lon. X 1.0 lat.)
Vertical resolution:  26 pressure levels & 1 surface level
Temporal resolution:  6-hourly (3291 total files)
Missing data:  1 time missing: 12Z2003Aug26
Key variables:  T, U/V, Φ (26 levels)
Cloud water, RH, ω (21 levels)
TOA/surface LW/SW ↑/↓ radiation (no TOA SW↓, however)
Sensible/Latent/Ground heat flux
Precip/Pressure/PBL height
Total cloud cover % (column)
Precipitable & Cloud water (column)
Snow depth
Surface albedo
Runoff/Soil moisture & temps
2-m T/q, 10-m U/V

Pull binary data from grib:  ~/CEOP/NCEP/pull_grid.bash
Re-grid 6-hourly binary:  ~/CEOP/NCEP/mma_regrid.gs
Daily average creation:  ~/CEOP/MAC/daily_average.gs
Daily average description:  “lats4d” average of 00Z, 06Z, 12Z, and 18Z times
Monthly average creation:  ~/CEOP/MAC/monthly_average.gs
Monthly average description:  “lats4d” average of 00Z (day 1) to 18Z (last day of month)
**ECPC RII**

Experiment name at MPI: CEOP_ECPCRII_GRID_RAW

Dataset names at MPI: ECPCRII6_flx_ft00_MUL (analysis)  
ECPCRII6_flx_ft03_MUL (00-03 hour forecast average)  
ECPCRII6_flx_ft06_MUL (03-06 hour forecast average)  

Spatial resolution: 192x94 (1.875 lon. X ~1.915 lat.)  
Vertical resolution: 1 surface level  
Temporal resolution: 6-hourly, with forecast data 3-hourly (3292 total files)  
Missing data: None  
Key variables: TOA/surface LW/SW ↑↓ radiation  
Sensible/Latent/Ground heat flux  
Precip w/ Convective  
Pressure/Roughness/PBL height  
Momentum flux/Gravity wave stress  
Total/High/Mid/Low cloud cover %  
Cloud base/top/temperature/CWF  
Snow fall/depth/melt  
Surface albedo  
Runoff/Soil moisture & temps  
2-m T/q, 10-m U/V  

Dataset names at MPI: ECPCRII6_pgb_ft00_MUL (analysis)  
Spatial resolution: 144x73 (2.5 lon. X 2.5 lat.)  
Vertical resolution: 17 pressure levels  
Temporal resolution: 6-hourly, with forecast data 3-hourly (3292 total files)  
Missing data: None  
Key variables: T, U/V, RH/q, ω, Φ, h (17 levels)  
Precipitable water/RH (column)  
Lifted index  
Max wind level T, U/V, Pressure  
Tropopause T, U/V, Pressure, Shear  

Pull binary data from grib:  
1) ~/CEOP/ECPC-RII/pull_analysis.bash  
2) ~/CEOP/ECPC-RII/pull_6hourly.bash  
3) ~/CEOP/ECPC-RII/combine_3hourly.gs  

Re-grid 6-hourly binary: ~/CEOP/ECPC-RII/mma_regrid.gs  
Daily average creation: ~/CEOP/MAC/daily_average.gs  
Daily average description: “lats4d” average of 00Z, 06Z, 12Z, and 18Z times  
Monthly average creation: ~/CEOP/MAC/monthly_average.gs  
Monthly average description: “lats4d” average of 00Z (day 1) to 18Z (last day of month)

**ECPC SFM**

Experiment name at MPI: CEOP_ECPCSFM_GRID_RAW
Dataset names at MPI:  
ECPCSFM6_flx_ft00_MUL (analysis)  
ECPCSFM6_flx_ft03_MUL (00-03 hour forecast average)  
ECPCSFM6_flx_ft06_MUL (03-06 hour forecast average)

Spatial resolution:  
192x94 (1.875 lon. X ~1.915 lat.)
Vertical resolution:  
1 surface level (with 3 soil moisture/temperature levels)
Temporal resolution:  
6-hourly, with forecast data 3-hourly (3292 total files)
Missing data:  
Key variables:  
TOA/surface LW/SW ↑↓ radiation  
Sensible/Latent/Ground heat flux  
Precip w/ Convective  
Pressure/Roughness/PBL height  
Momentum flux/Gravity wave stress  
Total/High/Mid/Low cloud cover %  
Cloud base/top/temperature/CWF  
Snow fall/depth/melt  
Surface albedo  
Runoff/Soil moisture & temps  
2-m T/q, 10-m U/V

Dataset names at MPI:  
ECPCSFM6_pgb_ft00_MUL (analysis)  
Spatial resolution:  
144x73 (2.5 lon. X 2.5 lat.)
Vertical resolution:  
17 pressure levels
Temporal resolution:  
6-hourly, with forecast data 3-hourly (3292 total files)
Missing data:  
None
Key variables:  
T, U/V, RH/q, ω, Φ, h (17 levels)  
Precipitable water/RH (column)

Pull binary data from grib:  
1) ~/CEOP/ECPC-SFM/pull_analysis.bash
2) ~/CEOP/ECPC-SFM/pull_6hourly.bash
3) ~/CEOP/ECPC-SFM/combine_3hourly.gs
Re-grid 6-hourly binary:  
~/CEOP/ECPC-SFM/mma_regrid.gs
Daily average creation:  
~/CEOP/MAC/daily_average.gs
Daily average description:  
“lats4d” average of 00Z, 06Z, 12Z, and 18Z times
Monthly average creation:  
~/CEOP/MAC/monthly_average.gs
Monthly average description:  
“lats4d” average of 00Z (day 1) to 18Z (last day of month)

MSC

Experiment name at MPI:  
CEOP_MSC_GRID_RAW

Dataset names at MPI:  
CEOP_MSC_GRID_RAW xxxx
(xxxx = variable name)
Spatial resolution:  
800x600 (0.45 lon. X 0.3 lat.)
Vertical resolution:  
1 surface level (with 4 upper-air levels used)
Temporal resolution:  
24-hourly, with forecast data 3-hourly (823 total files)
Upper-air forecast data 12-hourly only
Missing data: 2 times missing: 00Z2002Oct01 & 06Z2002Oct01
Key variables: T, U/V, q, Φ (4 levels)
TOA/surface LW/SW ↑/↓ radiation
Sensible/Latent/Ground heat flux
Precip/Pressure
1.5-m T/q, 10-m U/V
Total cloud cover % (column)
Precipitable & Cloud water (column)
Snow depth/SWE
Surface albedo
Runoff/Soil moisture

Pull binary data from grib: 1) ~/CEOP/MSC/pull_analysis.bash
                                    2) ~/CEOP/MSC/pull_3hourly.bash
Re-grid 6-hourly binary: ~/CEOP/MSC/mma_regrid.gs
Daily average creation: ~/CEOP/MAC/daily_average.gs
Daily average description: “lats4d” average of 00Z, 06Z, 12Z, and 18Z times
Monthly average creation: ~/CEOP/MAC/monthly_average.gs
Monthly average description: “lats4d” average of 00Z (day 1) to 18Z (last day of month)

CPTEC

Experiment name at MPI: CEOP_CPTEC_GRID_RAW

Dataset names at MPI: CPTEC_GR_gposnmc_fct_12_MUL
                                    CPTEC_GR_gposnmc_fct_18_MUL
                                    CPTEC_GR_gposnmc_fct_24_MUL
                                    CPTEC_GR_gposnmc_fct_30_MUL
Spatial resolution: 384x192 (0.9375 lon. X ~0.9375 lat.)
Vertical resolution: 15 pressure levels & 1 surface level
Temporal resolution: 6-hourly, with forecast data from 12- to 30-hourly (3293 total files)
Missing data: 35 times missing (by month):
                                    2002: 0, 1, 0
                                    2003: 1, 1, 1, 0, 14, 2, 1, 0, 1, 0, 0, 3
                                    2004: 0, 0, 0, 1, 4, 0, 0, 0, 1, 0, 4, 0
Key variables: T, U/V, q, ω, Φ, diverg. (15 levels)
TOA/surface LW/SW ↑/↓ radiation
    (no TOA SW↓, however)
Sensible/Latent heat flux
Precip/Pressure/Roughness
Runoff/Soil moisture
2-m T/RH, 10-m U/V
Total cloud cover % (column)
Precipitable water (column)

Pull binary data from grib: ~/CEOP/CPTEC/pull_grid.bash
Re-grid 6-hourly binary: ~/CEOP/CPTEC/mma_regrid.gs
Daily average creation: ~/CEOP/MAC/daily_average.gs
Daily average description: “lats4d” average of 00Z, 06Z, 12Z, and 18Z times
Monthly average creation: ~/CEOP/MAC/monthly_average.gs
Monthly average description: “lats4d” average of 00Z (day 1) to 18Z (last day of month)
6. References


7. Acronyms