Comparing model output location time series data with in-situ data

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Introduction

The Coordinated Enhanced Observed Period (CEOP) Project was first proposed at the GEWEX Hydrometeorology Panel in 1997 with an Implementation Plan for what has become designated as Phase I defined in May 2001. This defined a primary focus for the collection of satellite, in situ and numerical weather prediction data for the Enhanced Observing Period 3 (EOP3) to run from 1st October 2002 to 30th September 2003 with the following year designated as EOP4. Planning documents and various reports on the project are available from the CEOP website (http://www.ceop.net/). The basic underlying task of CEOP is to establish a unified collection of large, high quality datasets of satellite, in situ and numerical weather prediction (NWP) data designed to focus on diagnosing the energy and water cycles over continental scale regions at diurnal to annual time scales. As part of that process three main data centres have been established to collect and disseminate data along with data mining studies to improve access and increase the synergy of the data. This aspect of CEOP is progressing well but is beyond the scope of this paper.

Eight NWP centres and two data assimilation centres have contributed a mixture of gridded data and model output location time series (MOLTS) data. The later are time series of model variables at 41 specified locations including GEWEX Continental Scale Experiments, Atmospheric Radiation Measurement (ARM) sites and the Murray-Darling Basin (MDB). These reference sites have hydrological and basic weather data available over the entire EOP with a temporal resolution of a half hour which is stored in four standard ascii formats covering surface meteorological and radiation data (SFC), flux data (FLX), soil temperature and moisture data (SLM) and meteorological tower data (TWR). It is readily available from the data management site at http://www.joss.ucar.edu/ghp/ceopdm/.

BMRC is one of the operational NWP centres contributing to the CEOP dataset. So far only MOLTS data for EOP3 is available. Two basic MOLTS were requested; output from the assimilation cycle and equivalent data from 36-hour forecasts. It was generated by running six hourly forecasts based on the operational analysis files for the entire year of EOP3 with hourly output of the closest model columns to each of the 41 designated reference sites. The individual analysis and forecast files were concatenated together to form two separate contiguous time series for EOP3 in one hour time steps; the forecast series formed from concatenated 12 to 36 hour forecasts. This paper is a preliminary look at comparing the BMRC MOLTS with selected reference site SFC data to identify problems and suggest techniques to extract useful information.

Comparing MOLTS and in situ data

Although it is meant to facilitate the investigation of continental scale cycles MOLTS data is essentially just an isolated single column of the global model and as such presents a number of difficulties when trying to compare it with the reference site data. The most obvious problem is determining the effective resolution of the two datasets. Some reference locations encompass data from a number of sites spanning areas comparable to the model grid scale e.g. the ARM Southern Great Plains (SGP) data includes 23 sites distributed over 143,000 square kilometres. The MDB dataset covers an area spanning several model grid points. Most locations have less than a handful of sites and have effectively much higher resolution than the model for most variables. Most models have contributed only a single model grid point for each reference site although the Japanese Meteorological Agency has provided an additional dataset which includes the four points around each MOLTS site which should facilitate studies of effective resolution as well as provide an interface to single column models. There is some evidence (Yang et al 2005) that the spatial representativeness of in situ observations are different for different variables. Factors such as the scales of surface properties and local weather phenomena or the strength of horizontal advection are important as are the relationship of these factors with specific variables. Precipitation is notoriously grid scale dependent; reference site data at a point is almost certainly not representative of the spatial scales described by the model grid scale. However, given that only single column data is available there is no obvious method to downscale the model to solve this.

The next question is the representativeness of the model grid point and the reference site; do they have the same physical properties such as surface type, vegetation class, topography etc? Some fields e.g. surface pressure, have a strong dependence on surface elevation. In the case of multi-site locations one choice would be to take an average over all the sites but this ignores the non-linearities in the height/pressure dependence of the different fields. Comparison of reference site data with model variables also requires them to be comparable. There can be problems in definition e.g. soil moisture can mean different things in different models and all be different to the in situ data. In addition different reference site locations have different sets of data making a 'global' comparison problematic.

When comparing data certain limitations inherent in the type of data assimilation employed may need to be taken into account. One of these is model physics spin-up; due to local imbalances in the model fields some fields will drift away from the analysis series with time only to be pulled back at the next data insertion cycle. The analysis system itself can also be subject to 'data shock' when particular data types are only available at certain times and their intermittent presence forces the analysis onto a different track at different times. The Bureau's operational assimilation scheme during EOP3 (Seaman et al 1995) was a statistical interpolation scheme in which water vapour is independent of the dynamical variables and particularly susceptible to spin up. Of course modern assimilation systems such as those based on four dimensional variation techniques should minimise these effects but may be subject to problems of their own.

Specific site comparisons

The reference sites chosen for this study represent different challenges for comparison with the MOLTS data. The SGP with its 23 sites with a range of different sensors at different elevations was simply averaged over all the sites to produce a grid-scale average file. The MDB data was treated in a similar fashion even though it covers an area much larger than a model grid square. The Western Pacific Ocean data comes from two sites with disparate data streams; one over the ocean and one on a tropical island. As it is the only ocean reference data site in the CEOP datasets Peleliu was selected and the island site (Aimeliik) was ignored. Lindenberg has two sites; a forest and and an open field site. The bulk of the fields are very similar for the two sites, but the forest data is only available for the last two thirds of the EOP3 period. Thus to avoid possible sampling problems only the field (Falkenberg) site was considered. The remaining reference locations, the ARM Darwin and the Equatorial Island locations have data from single sites only.

Diurnal behaviour

One of the primary foci of the next phase of CEOP is the study of diurnal cycles. The simplest way to analyse the diurnal part of a time series is to simply sort the series into daily time bins representing the diurnal cycle. This assumes that the non-diurnal behaviour is random and that the diurnal behaviour itself is invariant over the total time of the series. This latter assumption is certainly not correct for annual series of variables where seasons play an important role. The binning technique shows sensitivity to the presence of model spin-up. Since the forecasts are explicitly 'tied' to the analysis series every 6 hours a saw tooth pattern can be induced which can add harmonics which confuse the interpretation.

A more sophisticated way to investigate the variation of the diurnal cycle of a time series is to perform a wavelet analysis and filter on diurnal time scales. Using statistical significance tests (Torrence and Compo 1998) the time periods when diurnal power is strong can be isolated and studied in more detail. Fig 1. shows the power spectrum for surface humidity for the model forecast series (left) and the in situ data for the Western Pacific Ocean site. The model shows a much broader peak above the significance level. The in situ data shows a stronger structure but has less statistical significance.
Fig 2 shows the strength of the diurnal power of precipitation for Darwin for the model forecast series (left) and the ARM site data (right) showing the localization to the wet season and that the model tends to have a much stronger and coherent diurnal signal.

Other periodic variations with strengths which vary over seasonal time scales are also amenable to this technique e.g. the MJO (Wheeler and Hendon 2004).

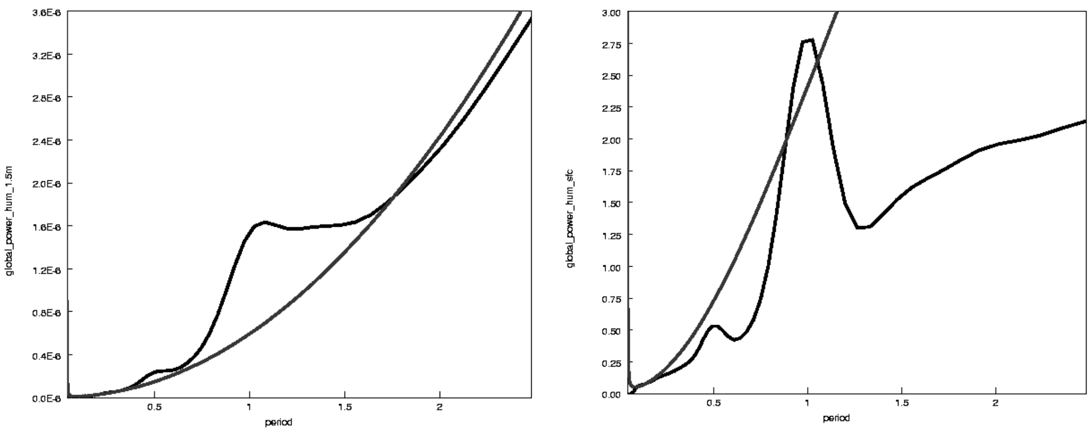

Fig 1: Power spectra for the Peleliu site in the Western Pacific Ocean for the model (left) and the reference site (right). The x-axis is time in days over the EOP3. The black lines are the spectra and the smoothly varying grey lines represent minimum statistical significance levels.

Conclusions

The CEOP EOP3 data set has great potential but it requires some work to determine how useful it will be for model validation purposes. The intercomparison is sensitive to effective resolution issues as well as specific model problems such as data insertion anomalies and model spin up as well as the complication of the representativeness of the site to the model grid square. Some aspects of the problems can be alleviated by using time averages for the comparison but special care is needed for diurnal cycle investigations because averaging will not remove systematic errors inherent in the assimilation process.

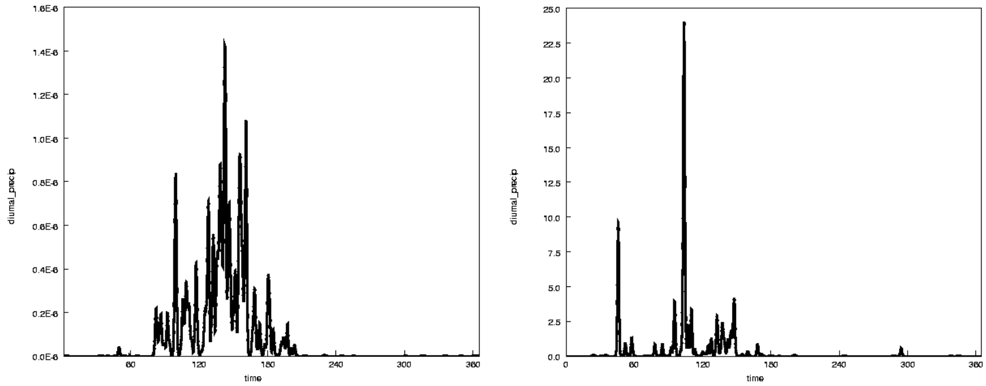

Fig 2: The strength of the diurnal power in precipitation for Darwin over the EOP3. The model forecast result is on the left and the ARM in situ data on the right.

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