VERIFICATION OF NUMERICAL WEATHER PREDICTION MARINE METEOROLOGY USING MOORINGS: AN OceanSITES APPLICATION

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1. INTRODUCTION

There has been an increased emphasis on coupled ocean-atmosphere modelling at the Australian Bureau of Meteorology with the development of operational seasonal forecasting and short-range ocean prediction capabilities. The ocean models are forced with fluxes or atmospheric state variables from Numerical Weather Prediction (NWP) Models. The surface forcing is critical to the skill of the ocean model forecast. The quality of the surface forcing can be evaluated by comparison with in situ observations over the open ocean. Here we exploit moored buoy observations collected under the OceanSITES flux reference stations program to routinely verify the forecasted NWP marine fluxes at the Australian Bureau of Meteorology. This activity parallels the formal OceanSITES-NWP interactions occurring under the SURFA (Surface Flux Analysis) project.

2. VALIDATION SYSTEM

NWP flux validation requires high quality in situ observations to compute the total heat, mass and momentum fluxes. Wind validation is better achieved using satellite based observations, hence the system described here is primarily concerned with heat and mass fluxes. We note that the observations may have been placed on the Global Telecommunications System and assimilated into NWP systems. In this case NWP analysis cannot be independently validated by the observations. It is expected that the observations will be sufficiently independent to validate forecasts longer than 24 hours due to the diminishing impact of assimilated observations on forecasts at this range, and the short (<24 hour) decorrelation time-scales of the observations. These assumptions need further testing. The observations necessary for computing the fluxes are: wind speed, air temperature, humidity and pressure, SST, precipitation, long- and short-wave radiation, and the surface current. The observations must be of sufficient accuracy to keep flux calculations within acceptable levels of uncertainty. For this application the observation averaging period is required to be daily or shorter. The observations need to be timely - delivered within one day of collection, to enable useful monitoring of the operational NWP forecasts.

The observations are stored in the OceanSITES NetCDF format, which greatly simplifies the ingestion of data streams from multiple providers. Observations are downloaded daily from the data providers (managed by Pacific Marine Environmental laboratory (PMEL), Woods Hole Oceanographic Institution (WHOI) and the National Oceanography Centre, Southampton (NOCS)). NWP forecasts are extracted at the grid point closest to each observation site. In the case of the WHOI observations, no data is placed in real time on the GTS (Global Telecommunication System) so that the NWP fields are independent of these buoy data. No spatial interpolation is performed as the uncertainties associated with point to cell, and flux comparisons are expected to be larger that the variability due to differences in location. Observations and NWP forecasts are all averaged to daily values.

3. THE NWP FORCING FIELDS

Here we focus on the new Australian Community Climate and Earth-System Simulator – Global model (ACCESS-G) that runs twice daily and provides forecasts out to 10 days. Grid resolution is 1.25 degree in longitude and 0.83 degree in latitude, with forecasts available at 3-hourly intervals. The relevant surface forecast fields are: meridional and zonal 10m wind speed and stress, air temperature and mixing ratio at 2m, precipitation and evaporation, mean sea level pressure, Sea Surface Temperature (SST), net and downwards long- and short-wave radiation. Most of the fields are 3-hourly averages.

4. THE OceanSITES IN SITU OBSERVATIONS

Long-term flux reference stations are maintained as part of a number of mooring arrays in the tropics and at a few individual sites in the extra-tropical northern hemisphere. Only those sites that measure the full set of required observations are included in the validation system (Figure 1). This limits the observations to a total of 17 sites: TAO (4), PIRATA (4), RAMA (3), WHOI (3), PMEL (2), and NOCS (1). Sampling resolution varies from 15-minute (NOCS), to hourly (WHOI) to daily. The flux reference stations have been occupied for various lengths of time with the longest maintained since 2000 by WHOI at the Stratus site in the eastern tropical Pacific. Considerable effort is devoted to ensuring the quality of the surface meteorological and air-sea flux observations, including comparisons of shipboard sensors with those on the buoys at deployment and at recovery and also ongoing efforts at sensor calibration and sensor improvement. Where possible, redundant sensors are deployed, supporting elimination of poor quality data from real time telemetry and selection of the best data for preparation of delayed mode time series.

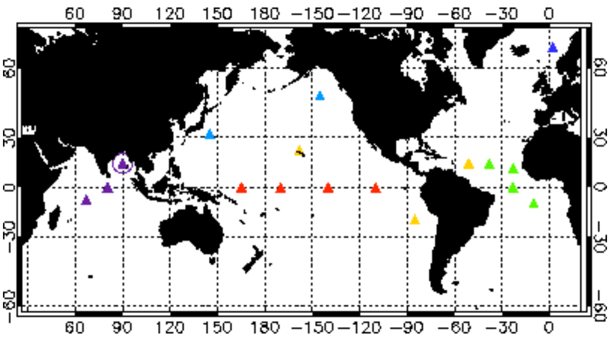

Figure 1 The network of observations used in the NWP verification system. Symbols represent position, colour coded: TAO (red), PIRATA (green), RAMA (purple), PMEL (light blue), WHOI (yellow) and NOCS (dark blue). The circled RAMA mooring is at 15N, 90E.

5. THE VALIDATION

A validation at each mooring location is performed daily, and runs 12 days behind real-time to enable 10-day forecasts to be validated against the observations. Fluxes are calculated and validated from the daily average values using the COAR bulk flux algorithm. In addition, the daily verification is compiled into monthly statistics to yield a more robust result. Statistics are presented as a function of forecast period and compiled across each model run - approximately 30 per month. An example is provided (figure 2) for net heat flux at a RAMA mooring (15N, 90E) in the Bay of Bengal (Indian Ocean).

The contoured histogram (left panel) shows the distribution of the difference between the model forecasts and observations. For each forecast period the mean bias (centre panel) and standard deviation (right panel) is computed from a horizontal slice though the histogram plot. For example, the histogram shows that for forecast day 2 (forecast hours 24-48), the highest occurrence (4 times) of forecast-observation difference is in the range -20 Wm^{-2} to -35 Wm^{-2} (model warms the ocean compared to observations), but with a large secondary grouping around 75 Wm^{-2} (model cools the ocean compared to observations). The mean bias is 10 Wm^{-2}, and the standard deviation is 65 Wm^{-2}. The bias increases to 30 Wm^{-2} for forecast day 4, before decreasing gradually to -10 Wm^{-2} at forecast day 10, but this is not significant given the initially large standard deviation that rapidly increases to 115 Wm^{-2}.

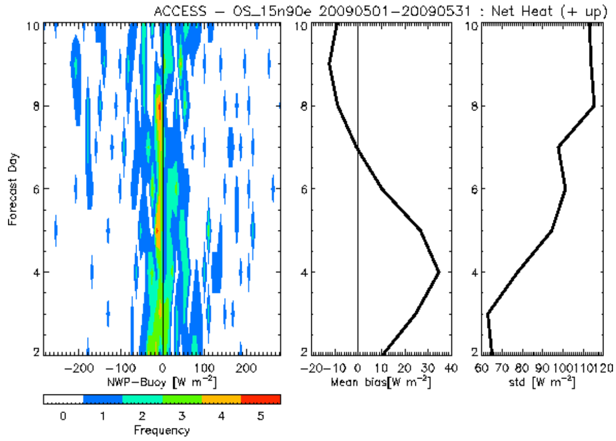

Figure 2 Statistics of daily averaged NWP (ACCESS-G) - observations (RAMA, 15N, 90E), May 2009, net heat flux. See figure above for explanation. Vertical axis is forecast period: day 2 - 10. Contoured histogram (left) (colour = occurrences) is the NWP-observation difference for each forecast and each model run in the month. Mean bias (centre) and standard deviation (right) of the NWP-observations for each forecast period. A positive bias indicates model cools the ocean compared to observations.

6. CONCLUSIONS

An automated NWP marine flux verification system has been developed at the Australian Bureau of Meteorology in parallel to the SURFA project. The system takes advantage of the common specification and formats developed by the OceanSITES program, to retrieve daily observation from a network of open ocean flux reference stations. Here we present an example of the validation for the ACCESS-G NWP model forecast for one variable (net heat flux) at a RAMA mooring site. The current observational array is concentrated in a band along the tropics, and expansion into the extra-tropics is essential if the array is to be considered truly global. The issue of whether or not the model fields are independent of the buoy observations is being addressed. Some buoys do not pass data to the GTS. For the other buoys, methods are being looked at where GTS telemetry can include a flag to exclude data from assimilation while at the same time making data available if needed for forecasters. The impact of assimilated observations on the independence of the validation needs to be resolved, but it is clear that the planned expansion of the OceanSITES array offers great promise as a means of marine flux verification and as resource for ongoing model improvement.