ESPC Integrated Skill Diagnostics

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LONG-TERM GOALS

The long-goal of this project is to define, develop and implement consistent quantitative skill metrics to assess the advancements in the Earth System Prediction Capability (ESPC). This work will also implement automated monitoring systems for gauging performance of the ESPC. This is an integral part of the overall ESPC goal of developing a global coupled system between the presently separate atmosphere, ocean, surface wave, ice and land forecast systems for the battlespace environment.

OBJECTIVES

Evaluation and validation of the ESPC coupled model system on the subseasonal to seasonal time scales. Development of metrics and process oriented diagnostics for these time scales and the formulation and implementation of the new score card for the coupled system.

APPROACH

The focus of this component of ESPC is on development and testing of the new score card for the coupled system and a "library" of the appropriate process diagnostics that would allow us to examine and improve the coupled system and its component. The existing metrics and diagnostics for various timescales, for deterministic and probabilistic forecasts are gathered and tested using coupled and uncoupled system experiments. Using this pool of metrics, we will define and iterate on a score card. The new score card will be proposed at the end of the first quarter of FY16 and it will be applied to the model hindcasts as they becoming available. The components of diagnostic software are also transferred to other work units such that they can be tested using the ensemble forecasts from international projects such as S2S, YOTC/MJO and others.

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WORK COMPLETED FOR FY15

Work completed this year focused on intraseasonal time scale metrics and diagnostics for the atmosphere and the ocean.

1) We completed the first draft of the white paper on intraseasonal diagnostics.
2) We researched metrics and process oriented diagnostics used by various operational centers for intraseasonal forecasts.
3) We evaluated metrics used for longer time scale for example in CMIP experiments to understand which of these metrics can be used for intraseasonal forecasts.
4) We wrote the diagnostic software for a number of these metrics and applied to the coupled system experiments.
5) We developed and tested the first version of an ocean score card.

RESULTS

Tropical atmospheric metrics

The intraseasonal tropical metrics are usually used to measure the forecast's performance of MJO, monsoons and tropical cyclones. The most widely accepted metric for MJO is the RMM index (Wheeler and Hendon 2004) based on multivariable EOF of meridionally averaged zonal wind and OLR. The biggest challenge in applying this metric to the model forecast is defining the climatology and averages used to filter out interannual variability, especially for OLR which strongly depends on model formulation. For the models used in the YOTC/MJO project all climatologies and monthly averages used to calculate anomalies were based on NCEP reanalysis. At present the same approach is used in evaluation of RMMI for NRL coupled system, but in the future using the model climatology will be more beneficial.

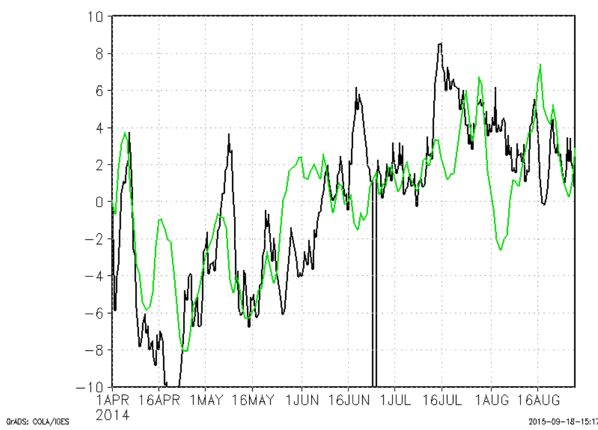

Figure 1. Monsoon MH index, which measures the strength of local Hadley circulation (Flatau et al, 2001) for NAVGEM analysis (black) and coupled model experimental 5 month forecast. MH>0 indicates the monsoon onset. In the observations the development of convective events in the Bay of Bengal in May causes the increase of the index and likely leads to delay of the "proper" monsoon as described in Flatau et al (2001). In the coupled model the early May MH index increase is underestimated and monsoon onset can be observed in late May –a few days ahead of climatological onset.

Monsoon variability can be evaluated using the indices involving all India precipitation, zonal shear of the zonal wind, vertical shear of the meridional wind (Fig. 1), kinetic energy (Flatau at al., 2001) and EOF pattern of wind and OLR anomalies of BSISO (Boreal Summer Intraseasonal Oscillation) (Lee at al 2013).

The BSISO index is somewhat analogical to RMMI index for MJO, but the BSISO EOFS are based on two dimensional patterns of zonal wind and OLR anomalies for the monsoon region. The projection of forecasted or analyzed anomalies on these EOFs can be used to create phase diagrams similar to these used for RMMI (Fig.2). We are presently working on developing this methodology for use in the NRL system.

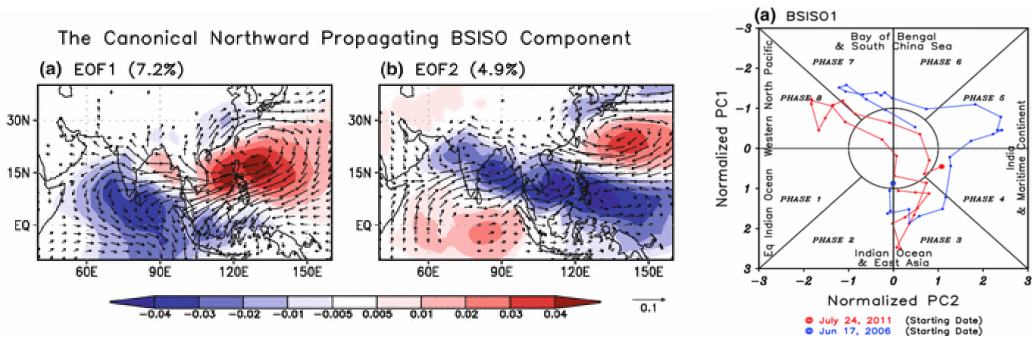

Figure 2. EOFs and a phase diagram for BSISO 1 from Lee at al. (2013). The EOFs are based on OLR and 850mb zonal wind with the meridional wind component obtained from regression. The phase diagram describes the northeastward and then westward propagation of monsoon convectively active phase.

Extratropical metrics

The metrics for the annular modes for the northern and southern hemisphere were developed and applied to NAVGEM analyses and forecasts. The AO and AAO indices are based on projection of 1000mb (for AO) and 700mb (for AAO) geopotential anomalies on the normal modes calculated from the monthly averaged fields of 100mb and 700mb geopotential height. Figure 3 shows the annular modes for November 2011, thirty day forecast with the coupled system. The figure indicates that while AO index is reasonably simulated, the Antarctic index remains much lower than its value based on either NCEP or NAVGEM analysis. That means that the southern hemisphere westerlies which strongly influence the atmosphere ocean interaction may be underestimated. The problems with southern hemisphere winds in climate simulations were recently highlighted by the CLIVAR Southern Ocean Working group that suggested using the strength and position of the southern hemispheric westerlies as one of the important metrics. We plan to include this metric for the NRL system.

Fig. 3c shows the AO indices for various versions of the system physics. The large spread beyond 14 days is consistent with the CPC analyses of GFS AO which indicates the lack of skilled forecasts beyond 10 days. Lin et al. (2005, 2009) indicates that the skill of polar mode forecasts depends on MJO amplitude – further analysis with the coupled system forecasts and ensemble forecasts from ESPC WU 8 should determine if this is true for our system as well. Interestingly the uncoupled version of the model produces the worst AO representation in Fig. 3c.

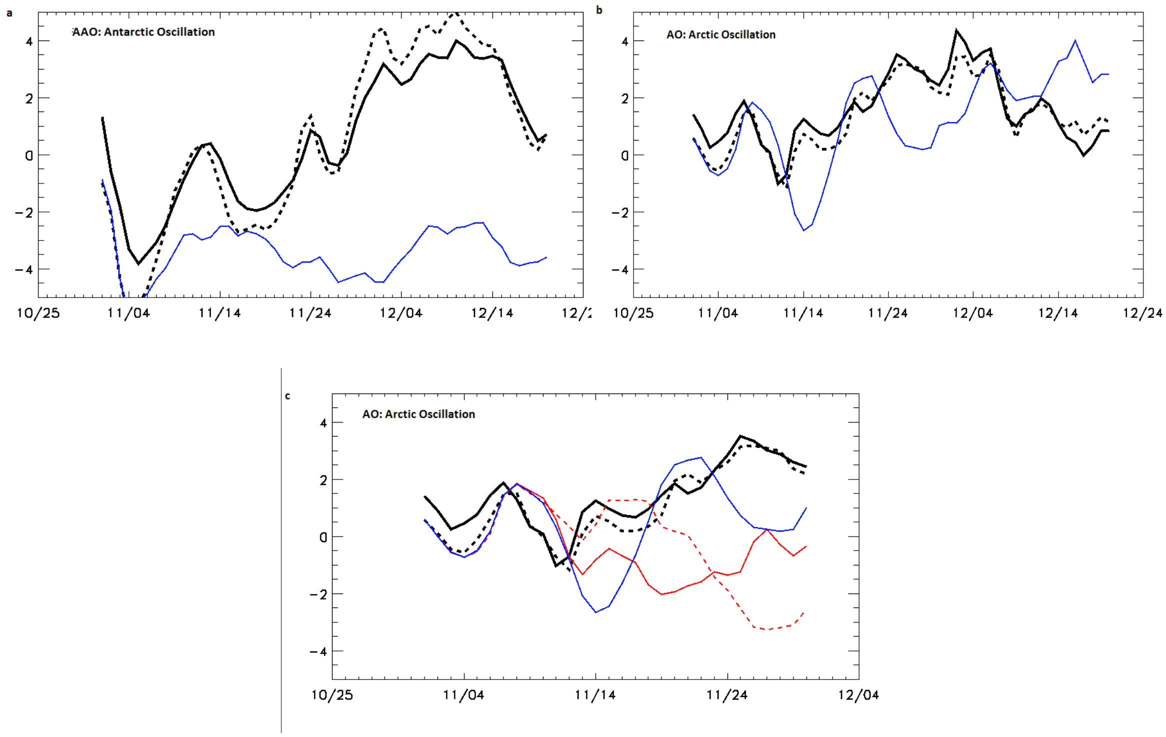

Figure 3. AAO (a) and AO (b and c) indices from NCEP (solid black lines), NAVEM analysis (dashed black lines), and various 50(a, b) and 30 (c) day forecasts. The red dashed line in Fig 3c indicates the uncoupled version of the experiment shown in the red solid line.

Another index used frequently in evaluation of the extratropical forecast is North Atlantic Oscillation index (NAO). The NAO index is strongly correlated with AO, suggesting that the NAO is not an independent mode of variability (Jia, 2013). Unlike the AO index, the NAO index does not have a unique definition. It can be defined either based on the pressure difference between Lisbon, Portugal, and Stykkisholmur, Iceland (Hurrell 1995), by global patterns of surface pressure in the North Atlantic region or by 500mb geopotential patterns in northern hemisphere For example, in Hurrell(2003) the NAO index is defined as the first EOF of the SLP over the North Atlantic(20-80N 90W 40E); Lin (2009) defines the AO loading pattern as a second rotated EOF of the monthly means of the 500mb heights for 20N-90N, with all seasons included. The CDC procedure uses the method described in Barnston and Livzey (1987) in which rotated EOFs of 500mb height are calculated for each month to account for seasonality. Figure 4 shows the NAO index from CPC (based on an EOF procedure) and Lisbon/ Stykkisholmur pressure difference from NAGEM analysis. It can be seen that the indices calculated by this two methods are strongly correlated and the variability in the NAO is similar to the variability of the AO shown in Fig. 3.

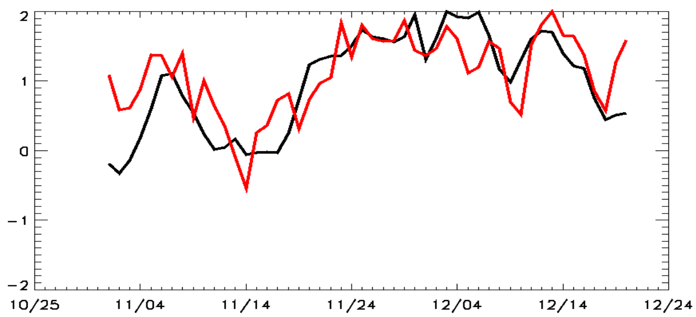

Figure 4. The NAO index for the same time period as the AO and AAO shown in Fig. 3 a and b. The black line indicates the index from CPC while the red line indicates the normalized NAO 2 point index from NAVGEM pressure analyses.

The blocking index that reflects the meridional gradient of 500mb height (Tibaldi and Molteni, 1990) calculated for the November 2011 coupled forecast and analysis is shown in Fig. 5. The figure indicates that the forecasts shows development of the Eastern Pacific blocking mid-month while Atlantic blocking appears to be delayed compared to the analysis.

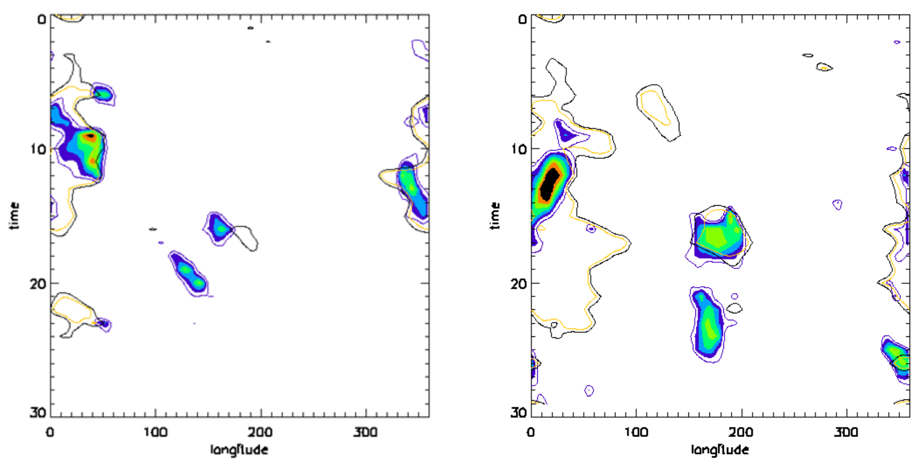

Figure 5. The blocking index for the NAVGEM analyses (right) and 30 day forecast (left) for November 1-30 2011. The shading indicates the northern meridional pressure gradient GHGN<10, while the contours indicate southern meridional pressure gradient GHGS>0 for each longitude. For blocking to occur at a given longitude both conditions need to be satisfied.

An ocean/ice/waves scorecard for ESPC coupled ocean atmosphere forecast performance
This section describes progress in developing a scorecard system to monitor the ice/ocean/wave performance of the HYCOM-NAVGEM coupled Earth System Prediction Capability (ESPC) targeted for a 2018 Initial Operational Capability (IOC) at the Navy DoD Supercomputing Resource Center (DSRC).

Since the ESPC scorecard system will run daily and monitor an operational system, it needs to ingest dependable, regularly available data sources for evaluation. To accomplish this goal it is being designed to ingest data that is available in the operational data streams at NAVO. The data streams currently available are sea surface height, sea surface temperature, profiles of temperature and salinity and ice concentration. There are additional data types that are desirable to add to the data regularly available such as wave direction and period. We will work with NAVO to secure these new data streams.

Matchups

The first and most expensive step of this metrics system is model matchups/data extraction. The archive files from HYCOM are large and an efficient way to matchup the model and observations is crucial. This step will utilize the AutoMetrics system (Dykes, 2011) that is currently operational at NAVO. This set of software modules was developed to produce model-observation or model-model comparison matchups and statistics to help assess ocean model performance. Utilizing this existing infrastructure would avoid the creation of a second matchup system to support/maintain, and it would upgrade a present capability at NAVO. The matchups are currently being processed using the OCNQC (Cummings and Smedstad, 2013) processed observations for temperature and salinity, computing "on the fly" sound speed, sonic layer depth (SLD) and below layer gradient (BLG) based on the matched profiles to produce additional matches. Statistics are computed on location and the matchup files are stored for later access.

The capabilities of AutoMetrics are presently focused on acoustics metrics, and they will need to be upgraded to include wave and ice metrics. Necessary upgrades have been identified and will be completed during FY16.

Scorecard Metrics

In FY15 we completed the development of ocean scorecard version zero (SVZ) (Zamudio et al. 2015). SVZ has been used to evaluate the performance of the ESPC coupled system and the operational HYCOM nowcast/forecast system. The model evaluations concentrate on the comparison of model output versus observed temperature and salinity profiles, upper ocean currents, and sea surface height. The observed and modeled profiles were used to calculate mean error (bias), root mean square error, mixed layer depth (MLD), and acoustical proxies as SLD, BLG, and cutoff frequency. In addition, the upper ocean currents (which were represented by drifting buoys) were used to calculate distance in km (between the observed and simulated buoys) as a measure of the degree to which the observed and modeled currents differ as a function of time. An example of the statistics produced by SVZ is shown in Figure 6.

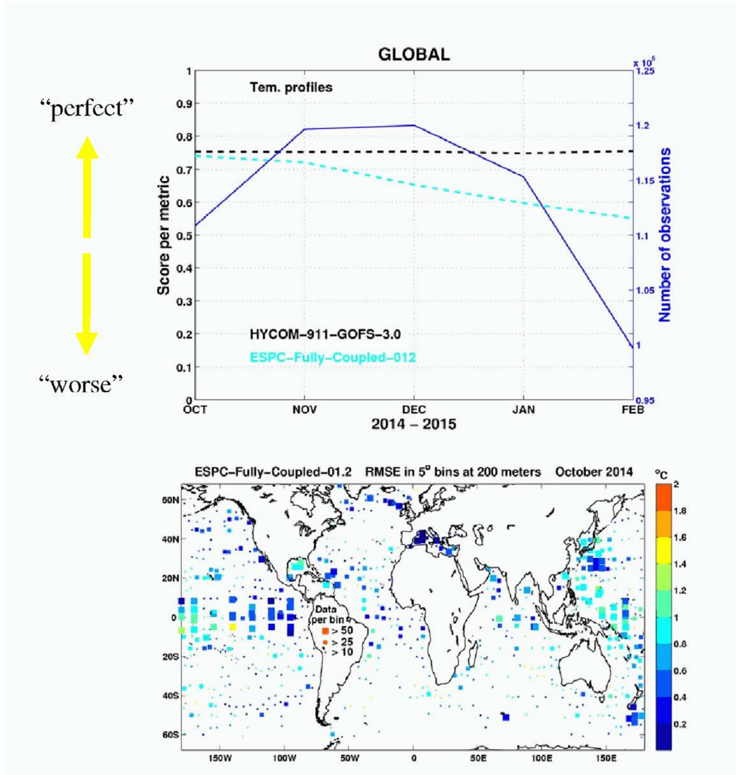

Figure 6. The upper panel tracks the global temperature profile scores from Oct 2014 – Jan 2015 for a coupled HYCOM-NAVGEM forecast and the operational HYCOM nowcast/forecast system (GOFS 3.0). As part of the scorecard calculations RMSE statistics are computed at each observation location, which are used to form error maps (lower panel). The maps add spatial information about the performance of the models and complement the scores produced by the SVZ.

This scorecard framework in FY16 (a) will be expanded to include wave and ice metrics and (b) ported to the NAVO DSRC in preparation for monitoring the coupled system. We are having discussions with other work units to (a) define the ice and wave scorecard constituents and (b) identify the observation data streams needed for these model-data comparisons. Discussions have taken place with NAVO, they are onboard with this scorecard system and we will be working collaboratively with them on its continued development and implementation in FY16. Issues we're discussing with NAVO include implementation of new data streams and refining the constituents of the scorecards to meet their operational needs. We are planning a technical report in FY16 detailing this scorecard package, examples of metrics and real-world examples of its value in revealing system performance issues.

IMPACT/APPLICATIONS

The metrics and diagnostics developed in this project will help to evaluate and result in the ability to routinely monitor the coupled model system assisting in the development of a skillful coupled ensemble forecast system for intraseasonal and seasonal time scales.

TRANSITIONS

Some the tools developed under this project were transitioned to WU-8. The score card that will be proposed in FY16 will be transitioned to other units of the ESPC project.

RELATED PROJECTS

This project is related to other units of the ESPC project through gathering of the diagnostics developed under other units (e.g. ice diagnostics, process oriented atmospheric diagnostics) as well as 6.2 MJO base effort and ONR Seamless Prediction effort. The diagnostics development will depend on availability of hindcasts and reanalysis of the ESPC coupled system. The feedback from other units will impact the refining of the score card and choice of process oriented diagnostics.

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