1) Forecasting North Pacific Blocking and Atmospheric River Probabilities: Sensitivity to Model Physics and the MJO

Lead PI: Elizabeth A. Barnes, Ph.D.
Co-PI: Eric D. Maloney, Ph.D.
Colorado State University

ABSTRACT

Atmospheric rivers (ARs) are intense synoptic-scale plumes of tropospheric water vapor that can lead to extreme precipitation and flooding when they make landfall. These features cause extreme flooding events not only along the west coast of the contiguous United States (CONUS), but also in Canada and Alaska. The ability to forecast ARs would provide society with advanced knowledge of their extreme impacts. Recent work by the our team demonstrates an inverse relationship between winter-time ARs hitting Alaska and CONUS, driven by the presence of a blocking anticyclone over the east Pacific that acts to divert the ARs away from CONUS and into the Gulf of Alaska. The potential exists to forecast the probabilities of North Pacific blocking and AR occurrence through knowledge of the Madden-Julian oscillation (MJO). Specifically, additional recent work by our team demonstrates that the pattern of blocking leading to an increase in Alaskan ARs (and subsequent decrease in CONUS ARs) is driven, at least in part, by phase 8 of the MJO – a phenomenon that is potentially predictable on timescales of 4 weeks or longer. Thus, while ARs are synoptic features unlikely to be forecast explicitly for lead times beyond 10 days, great promise exists for forecasting their probabilities based on knowledge of the MJO. However, many climate models and numerical weather prediction models cannot simulate the MJO with fidelity. The overarching goal of the proposed work is to quantify the extent to which east Pacific blocking and AR probabilities can be skillfully forecast at lead times of multiple weeks through their dynamical link with the MJO, including an explicit investigation of how AR prediction skill varies with a model's ability to forecast the MJO.

To achieve this goal, the tasks outlined in this proposal address two main objectives:

Objective I: Quantification of the predictability and prediction skill of North Pacific blocking and atmospheric river probabilities through knowledge of the MJO.

Objective II: Assessment of the sensitivity of forecast skill to MJO skill and model setup.

To address Objective I, the proposed work will develop statistical forecast models to predict blocking and AR probabilities using knowledge of the MJO and other predictors. Then, we will quantify the ability of operational models to forecast AR and blocking probabilities by analyzing data from two hindcast data sets: the S2S and ISVHE databases. The second objective of the proposed work will address the extent to which AR forecast skill is sensitive to the prediction system setup by further analyzing the S2S and ISVHE databases and performing a series of

simulations with two GCMs. Specifically, we will address the extent to which the forecast skill of blocking and AR probabilities are sensitive to: the model's MJO forecast skill, physics (i.e. cloud parameterization), resolution and forecast lead time.

Relevance to NOAA and Task Force Contributions: This proposal directly addresses the FFO "MAPP – Research to Advance Prediction of Subseasonal to Seasonal Phenomena" by improving the understanding of how formulation of the prediction system, including physics and resolution, impacts the forecast skill of extreme events (i.e. atmospheric rivers and blocking) and what physical processes lead to their predictability. We will aid NOAA's NGSP by improving process-level understanding and prediction skill of persistent flow regimes associated with blocking, and extreme rainfall associated with atmospheric rivers, to provide more accurate "assessments of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decisions." The proposed efforts will contribute to the new MAPP S2S Task Force by (1) providing scientific leadership of the Task Force (2) linking international efforts on advancing S2S prediction, (3) contributing new understanding of the influence of prediction system setup on forecasts of extreme events (4) delivering a database of extreme events, blocking and atmospheric river occurrence and statistical forecast models.

2) The relationship of tropical cyclones to MJO and ENSO in the S2S database

PIs: Suzana J. Camargo[1] (PI), Adam H. Sobel[1,2] (co-PI),
Chia-Ying Lee[3] (co-PI), Fréderic Vitart[4] (collaborator)

1 Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY
2 Department of Earth and Environmental Sciences, Department of Applied Physics and Applied Mathematics, Columbia University, New York, NY
3 International Research Institute for Climate and Society, Palisades, NY
4 European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom

ABSTRACT

It is very well established that tropical cyclones (TCs) are modulated globally by the Madden-Julian Oscillation (MJO) and the El Niño-Southern Oscillation (ENSO). Due to these relationships, TC activity is to some extent predictable on both intraseasonal and seasonal time scales. Given the recent effort to develop TC forecasts on intraseasonal time scales a comprehensive analysis of the skill of various models in simulating and predicting TC activity at these time scales is warranted. The S2S dataset includes many high-resolution global weather and climate models that have capability to simulate tropical cyclone activity well. It is the ideal dataset to explore in depth the skill of TC forecast models.

First, we will detect and track tropical cyclones (TCs) in the S2S model output to generate TC tracks for this dataset. We will then analyze various aspects of the TC climatology in the S2S models, e.g., genesis, tracks, seasonality, intensity. Given that TC seasonal forecasts still have limited skill, as was apparent in the Atlantic as recently as 2013, it is important to analyze how well the models in the S2S database simulate the ENSO-TC teleconnection. We propose to examine the relationship of ENSO to TCs globally within the S2S dataset. Our focus will be on the response to ENSO of the environmental variables that are relevant for TCs, as well as modulation of the models' TCs by ENSO. We will also examine the predictability of the S2S models for TC seasonal forecasts on regional scales. The project will also address how well the models in the S2S database simulate the relationship between the MJO and TCs. First, we will examine how well the different models reproduce the observed modulation of TCs in the active phase of the MJO. Second, we will explore various aspects of this modulation in the models, for instance, if the models modulation by the MJO is dependent on the MJO strength or on the MJO Phase.

In all three aspects of this project - TC climatology, ENSO-TC relationship, and MJO-TC relationship - we will focus on the models' skill in forecasting TC activity on subseasonal to seasonal time scales. Furthermore, we will examine how the individual models' ability to

simulate TC characteristics is dependent on each model's configuration. Our contribution to the MAPP task force activities will focus on the skill of S2S TC forecasts.

3) Understanding the Sources of Subseasonal Predictability of Extratropical Cyclone Activity and Improving Their Representation in Forecast Systems

Lead PI: Edmund Kar-Man Chang
Co PIs: Minghua Zhang, and Hyemi Kim, Stony Brook University
Wanqiu Wang, NOAA/NCEP Climate Prediction Center

ABSTRACT

Extratropical cyclones cause much of the high impact and extreme weather conditions over the mid-latitudes, including heavy precipitation, high winds, coastal storm surges, and extreme cold events. On the other hand, lack of extratropical cyclone activity (ECA) in summer is linked to extreme heat. Hence skillful predictions of future cyclone activity will provide policy makers, emergency management, and stakeholders advanced warnings to prepare for mitigation measures. Unfortunately at present the National Weather Service does not provide any such forecast products in the subseasonal to seasonal time range.
The goal of this project is to improve the subseasonal prediction of ECA and its associated weather extremes. It has three specific objectives: i) Improve the understanding of the physical drivers that give rise to ECA predictability; ii) Improve the prediction of ECA and its drivers by focusing on the forecasting system set-up and model convection parameterizations; iii) Improve the forecasting of weather extremes associated with ECA variability.
To achieve these objectives, the following tasks will be conducted: 1) Subseasonal prediction of ECA derived from multi-model ensemble hindcasts will be evaluated, and diagnostic and mechanistic model experiments will be conducted, to test the following hypothesis on ECA predictability: ECA predictability depends on the specific combinations of different drivers, such as the combination of the different phases of the Madden-Julian Oscillation and ENSO; 2) The choices of ensemble members, improved convection parameterizations that control diabatic heating and moisture sink profiles, as well as model resolutions will be investigated to improve the set-up of the forecasting system; 3) The impact of model biases and improvements in ECA prediction on the prediction of weather extremes will be quantified.

This project seeks to advance the subseasonal prediction of ECA and its associated weather extremes, thus contributing to NOAA's goals to develop the capability to bridge weather and seasonal predictions, and to extend the lead times at which extreme events are skillfully predicted, thereby allowing emergency managers, water resource managers, and other stakeholders more time to prepare, hence this project is highly relevant to NOAA's long term goals. This project seeks to understand the physical basis behind the subseasonal predictability of ECA, explore how the set-up of the prediction system and model convection parameterization impact system skill in predicting ECA and its drivers, and assess ECA predictability in the

context of its impacts on weather extremes, thus this project is highly relevant to this competition.

4) Collaborative Research: Assessing Oceanic Predictability Sources for MJO Propagation

Lead PI: Charlotte DeMott, Colorado State University
Co-PI: Nicholas Klingaman, University of Reading, UK

ABSTRACT

The body of evidence from decades of work suggests a paradigm of the Madden Julian Oscillation (MJO) as a primarily atmospheric disturbance whose initiation, maintenance, and propagation characteristics may be flavored by surface turbulent fluxes that are modulated by sea surface temperature (SST) variations. The longer-than-synoptic timescale of the MJO and its impact on a variety of high-impact global weather phenomena implies an opportunity to increase global weather prediction skill if the MJO can be reliably predicted. Impediments to MJO predictions include 1) poor predictions of whether a given convective event will propagate from the Indian Ocean to the West Pacific Ocean, where the global teleconnection response is strongest; and 2) a lack of understanding of the processes that initiate MJO convection. The onset of MJO convection can be preceded by a variety of atmospheric precursor signals whose individual expressions can vary from event to event, and can influence prediction skill. Once the MJO initiates, forecast skill tends to be highest for high amplitude events. Both climate and forecast simulations of the MJO are improved in coupled atmosphere–ocean models, suggesting a source of predictability from ocean feedbacks. Leveraging these potential sources of predictability for MJO forecasts remains challenging in light of low amplitude or decaying MJO events, and the variable influence of ocean feedbacks on MJO development. These prediction challenges are rooted in our limited understanding of key underlying physical processes involving MJO evolution and ocean–atmosphere interactions.

To improve our understanding, we propose a multi-pronged approach based on separating observed MJO events into three classes: strong, weak, and “eastward-decaying” (i.e., those that terminate before crossing the Maritime Continent). Factors that differentiate these classes of MJO events and their predictability will be explored as follows:
1. The Subseasonal-to-Seasonal (S2S) database will be used to analyze the predictability of and prediction skill for the three MJO classes, focusing on atmospheric and oceanic precursor signals. Ocean reanalysis data will provide additional context.
2. Specific ocean feedback processes will be tested in hindcast simulations using coupled models with a demonstrated ability to simulate the MJO. Particular attention will be given to MJO events associated with high-impact weather.

3. An ad hoc set of air-sea interaction diagnostics currently being developed in conjunction with WCRP S2S and WGNE MJO Task Force members (and others) for climate simulations will be expanded for application to hindcast simulations.

The proposed work is relevant to MAPP Competition 2 because:
1) it will improve the understanding of MJO predictability,
2) it has the potential to advance predictions of subseasonal and seasonal phenomena,
3) it uses existing (S2S database) and new model experiments to explore how the MJO is influenced by coupling between Earth system components (ocean–atmosphere),
4) it addresses predictability in the context of key underlying physical processes,
5) it actively seeks collaborative activities with WCRP S2S and WGNE MJO Task Force scientists to deliver a set of MJO air–sea interaction diagnostics.

This research will advance core capabilities in 1) understanding and modeling and 2) predictions and projections. It addresses NOAA's long-term climate goals for "improved scientific understanding of the changing climate system" and "assessment of current and future states of the climate system that identify potential impacts and inform science."

5) North American Heat Wave Predictability: Assessing the Role of Land Surface Initialization on S2S and NMME Model Forecasts

PI: Trent W. Ford, Southern Illinois University
Co-PI: Paul A. Dirmeyer, COLA/George Mason University

ABSTRACT

This research addresses the critical need to improve our understanding of how land surface initialization and land-atmosphere interactions influence subseasonal to seasonal (S2S) predictability of extreme heat and heat waves over North America. Accurate forecasting of extreme heat events, particularly on S2S timescales, is important for public health preparation as vulnerability to extreme heat has increased over time. Soil moisture anomalies, through their control on the partitioning of sensible and latent heat fluxes, are linked to temperature extremes. Dry soils limit evapotranspiration and can establish and perpetuate extreme heat events through atmospheric heat accumulation (e.g., Miralles *et al.* 2014). Therefore it is not surprising antecedent soil moisture deficits are found to correspond strongly with extreme temperatures in most regions of the world. Recent studies have demonstrated large spread in model forecasts and simulation of heat wave events over Europe and North America. Significant inter-model variability is purported to be a potential consequence of different boundary layer and convective parameterizations, land surface treatments, and coupled land-atmosphere model sensitivity. To date, few studies have explicitly evaluated the influence of the land surface and its initialization on model predictions of heat waves at S2S time scales.

The influence of antecedent drought conditions is particularly important in North America as past heat wave events may be established and prolonged by both advection of warm, dry air and limitation of local moisture recycling due to dry soils. The strong connection between the land surface and subsequent extreme heat offers promise that realistic soil moisture initialization could improve model forecast skill. Indeed, previous results over the contiguous United States suggest the land surface has a significant impact on extreme heat forecasts, particularly during boreal summer (Ford and Quiring, 2014). However, there is still a lack of consensus about: (1) the role of antecedent drought conditions in forcing heat waves over North America (2) the ability of numerical forecast models to predict extreme heat events at S2S time scales, and (3) the importance of realistic land surface initialization and model fidelity for accurate and timely extreme heat predictions. ***The goal of this project is to enhance our understanding of the connection between droughts and heat waves in the United States, as well as evaluating the ability of a suite of climate forecast models to predict heat wave occurrence.*** This goal will be achieved by addressing three main objectives:

(1) Evaluate the ability of numerical forecast models included in the Sub-seasonal to Seasonal (S2S) Prediction and North American Multi-Model Ensemble (NMME) Phase II projects to predict heat waves following drought events in the United States
(2) Relate model forecast performance to parameterization of land surface variables, coupled land-atmosphere metrics and initialization of land surface conditions

(3) Assess how more realistic land surface initialization in forecast models influences their ability to predict and simulate heat wave events in the United States

This project specifically addresses the **MAPP Competition 2** priority area of addressing the predictability of S2S phenomena in the context of extremes and their key underlying physical processes. We will be using reforecast datasets from the S2S Prediction Project and the North American Multi-Model Ensemble project. Our project goals are closely aligned with the mission of the Climate Prediction Task Force of achieving significant new advances in current capabilities to understand and predict intra-seasonal to inter-annual climate variability. In addition, the objectives of this research addresses the NOAA high priority of the S2S prediction gap (NWS Goal 3, element 1.20 of the Strategic Plan) as well as NOAA's goals for leadership in science and innovation. Finally the contributions of this project to the MAPP S2S Task Force address the important issues of S2S predictability and prediction of extreme heat in the context of land-atmosphere coupling and model land surface initialization.

6) Investigating the Underlying Mechanisms and Predictability of the MJO–NAM Linkage in the NMME Phase-2 Models

PI: Jason C. Furtado, University of Oklahoma
Co-PI: Michelle L'Heureux; Co-I: Adam Allgood, NOAA/NWS/NCEP Climate Prediction Center
Co-PI: Elizabeth A. Barnes, Colorado State University

ABSTRACT

Skillful weather predictions with 10- to 30-day lead times for the Northern Hemisphere (NH) extratropics remain a major challenge for the forecast community. Skillful predictions of extratropical NH subseasonal weather ultimately depend on knowledge of the position and strength of the polar jet stream, commonly represented by the Northern Annular Mode (NAM). Avenues forward to narrowing the subseasonal-to-seasonal (S2S) prediction gap with respect to the NAM seek to exploit interactions of intraseasonal modes of climate variability with the NAM. One such mode is the Madden-Julian Oscillation (MJO), the leading mode of subseasonal variability in the tropics. Another source of extended predictability for the NH extratropics is the polar stratosphere, whereby the state of the polar vortex exerts a downward influence on the tropospheric jet stream and thereby alter weather patterns and the tropospheric waveguide. Whether or not this stratospheric influence can influence MJO-related teleconnections remains unresolved.

The proposed project has three main objectives: (1) Enhance our knowledge about the dynamical links between the MJO and the NAM by considering the modulating influence of the extratropical stratosphere; (2) Evaluate these mechanisms of MJO-NH extratropical atmospheric teleconnections in the North American Multi-Model Ensemble Phase-2 (NMME-2) system; and (3) Connect and apply our findings and evaluations to predictions of atmospheric blocking and extreme weather events. Three synergistic research tasks will accomplish these goals. First, we will use observations to quantify and dynamically understand the MJO-stratosphere modulation effect. We will demonstrate how the strength of the polar vortex can modulate Rossby wave trains associated with the MJO and how this modulation affects NH wintertime blocking frequency. Next we will evaluate the MJO-NAM teleconnections in the NMME-2 models with a focus on blocking episodes and document performance as a function of (a) dynamical stratosphere-troposphere coupling and its relation to jet stream variability, and (b) the stratospheric resolution of the model. The final task will be an assessment of the MJO-stratosphere modulation effect in the NMME-2 models whereby we will quantify its ability to affect forecast skill of MJO-related blocking events.

The proposed work is submitted for consideration for the NOAA Modeling, Analysis, Predictions, and Projections (MAPP) Competition 2: Research to Advance Prediction of Subseasonal to

Seasonal Phenomena. The proposed work satisfies NOAA MAPP's mission "to enhance the Nation's capability to understand and predict natural variability and changes in Earth's climate system". Quantifying the MJO-stratosphere modulation effect offers enhanced "process-level understanding" and an "understanding of predictability and the potential to advance the prediction of phenomena occurring on [subseasonal] timescales." The described tasks collectively "address the predictability and prediction of S2S phenomena in the context of key underlying…dynamical processes (e.g., Rossby wave forcing, wave-mean flow interactions, and troposphere-stratosphere interactions)" and "explore how prediction of S2S phenomena is influenced by various aspects of the prediction system set-up, including: (i) model resolution…(ii) initialization of, and coupling between, Earth system components; [and] (iii) model physics." Finally, narrowing the S2S predictability gap through a process-based understanding and evaluation of the simulation of the MJO-NAM link heightens societal awareness and preparation for potential extreme weather events, which contributes to NOAA's "Weather Ready Nation" goal established in the Next Generation Strategic Plan (NGSP). Findings of this work will be shared with the proposed new NOAA S2S Task Force as well as the World Climate Research Programme (WCRP) S2S Prediction project and Working Group on Numerical Experimentation (WGNE) MJO Task Force via planned presentations, co-organized sessions at international conferences, and direct discussions with the committee members.

7) Improving subseasonal to seasonal forecast skill of North American precipitation and surface air temperature using multi-model strategy

PI: Zhichang Guo, COLA, George Mason University
Co-I: Paul A. Dirmeyer, George Mason University

ABSTRACT

This proposal responds to the 2016 solicitation for CPO's Modeling, Analysis, Prediction and Projection (MAPP) program Competition 2: "Research to Advance Prediction of Subseasonal to Seasonal Phenomena." The proposed project focuses on some of MAPP's primary objectives, namely, "improving methodologies for global to regional-scale analysis, predictions, and projections" and "developing integrated assessment and prediction capabilities relevant to decision makers based on climate analyses, predictions, and projections."

A large number of forecasts from a suite of models are routinely provided by the Subseasonal to Seasonal (S2S) Prediction Project and the North American Multi-Model Ensemble (NMME) Project. To develop a reliable and timely climate product from these datasets, we propose a new methodology to assess an individual model's forecast skill, generate statistical weights based on the skill of member model forecasts of slowly-varying surface states, and use aforementioned weights to produce an optimized single forecast. We will compare this methodology to traditional multi-model combination techniques. The new methodology has unique advantages: a) It provides an ideal framework for regional analyses and prediction; b) It allows the combined atmospheric forecast to rely more on models with superior forecast skill of surface anomalies, which are the main drivers of the S2S forecast skill; c) Calculations of forecast skill and weights for each model are highly flexible, and the methodology has many potential applications. The weight of each model member can be calculated from the latest evaluation of the model's forecast performance and may evolve over time.

Preliminary results show that the new methodology outperforms individual models and can increase the one-month lead forecast skill of surface air temperature by 50% over the simple multi-model average across much of the area of focus. Even though the forecast skill improvement of precipitation (P) and surface air temperature (T2m) over North America is our primary target, the effects are expected to reach all forecast variables over the globe. We propose to identify regions where there is significant forecast skill of North American P and T2m and diagnose the dominant factors influencing such skill. We seek to understand how these factors contribute to the forecast skill of P and T2m, especially the role of land surface processes in achieving S2S forecast skill, through crafted numerical experiments with the Climate Forecast System (CFS). The project will also explore the potential to improve S2S forecast skill by improving the quality of land surface initial states in CFS and examine impacts

of land initialization on S2S forecast skill. The overall goal of the proposal is to enhance the Nation's capability to predict variability on S2S time scales. By performing our analysis with the NMME and S2S forecast datasets and adapting it to operational settings, this proposal directly contributes to the NOAA Next-Generation Strategic Plan objectives of "an improved scientific understanding of the changing climate system and its impacts" and "mitigation and adaptation choices supported by sustained, reliable, and timely climate services."

8) Prediction, Sensitivity, and Dynamics of Subseasonal To Seasonal Phenomena Diagnosed Through Linear Inverse Models, Their Adjoints, and Numerical Weather Prediction Models

PI: Dr. Brett Hoover, CIMSS, University of Wisconsin – Madison
Co-PI: Matthew Newman, NOAA/ESRL/PSD
Collaborators: Daniel Vimont and Michael Morgan, University of Wisconsin – Madison

ABSTRACT

Subseasonal to seasonal (S2S) predictability faces a unique set of forecast challenges related to initialization, parameterization, and development of model bias around which the forecast state must evolve. Furthermore, a wide range of phenomena exist on S2S timescales that require realistic evolution of the forecast state over a wide range of geographical regions and physical processes (e.g. tropical intraseasonal variability, low-frequency mid-latitude wave dynamics, and downward propagation from the stratosphere), which presents a major challenge for numerical weather prediction (NWP) models that aim to forecast out to S2S time scales. Additionally, targeted forecasts of different specified extreme events (e.g. blocking, heat waves, cold snaps) may be associated with very different sensitivities to any of these processes. A general framework is needed for analyzing and evaluating the role of initial conditions, model physics, and development of model bias, in S2S predictability of specific extreme events. The project will utilize linear inverse models (LIMs) that are derived to infer the dynamics of the atmosphere and ocean from a set of observed states; these states can come from analyses (which are largely free of model bias) or from forecast model states (which may contain biases around which a NWP model state must evolve). The feasibility of the LIM for studies of low-frequency variability has been demonstrated in previous studies.

This project will advance predictive capacity for S2S forecasting by (i) developing LIMs separately around the analysis state (analysis-LIM) and around NWP forecast states that include the effects of the evolved model bias (forecast-LIM); (ii) analyze the role of initial conditions, model physics, and development of model bias in event-specific subseasonal prediction; (iii) test findings using LIM-informed data-denial initialization experiments in a NWP model; and (iv) blend NWP and LIM strengths to maximize predictive skill on S2S time scales. The combination of tasks in this project compose a general framework that addresses the unique challenges outlined above, and informs priorities for NWP model development related to S2S prediction.

This project is directly relevant to the goals of Competition 2 in the FY16 MAPP funding opportunity, through understanding the predictability and potential to advance prediction of specific phenomena occurring on S2S timescales. The project develops a framework that can be used to investigate how prediction of S2S phenomena is influenced by specific initial states, coupling between different model components and regions, and model physics (and associated

evolution of model bias). The framework will be applied to specific S2S prediction efforts and will be provided in real-time for modeling groups to gain familiarity with the process. Our long-term goal is to develop an operational approach for a priori determination of “state-dependent” subseasonal forecast error. The PIs will also contribute to a MAPP Task Force by providing a product that can be used in real-time to diagnose S2S predictions from a variety of different NWP modeling efforts. Finally, this project is also relevant to NOAA’s Next Generation Strategic Plan for a “Weather-Ready Nation”, through increasing understanding of predictability of potentially hazardous extreme weather, as well as phenomena of importance to the energy sector.

9) Exploring Pathways to improve MJO Predictions

PI: Dr. Arun Kumar; co-PI Dr. Wanqiu Wang; co-I: Dr. Jieshun Zhu
Climate Prediction Center, NCEP/NWS/NOAA

ABSTRACT

The Madden-Julian Oscillation (MJO) is the dominant mode of tropical convection variability on the intraseasonal time scale. The recurrent nature of the MJO with a period of 30-60 days offers an opportunity to bridge the gap between weather forecasting and seasonal prediction. Over the recent years, significant improvements have been made in MJO prediction skill in operational forecasts. However, the MJO prediction performance still differs greatly among the operational systems and efforts are continually underway to seek further improvements. Furthermore, a general guidance on what would be most beneficial developmental pathways to improve MJO simulation and prediction skill remains unclear. Addressing the issues for improving MJO forecasts requires quantifying the sensitivity of MJO predictions to different factors that affect the prediction, and quantifying the relative importance of individual factors. Even though the existing subseasonal to seasonal (S2S) prediction data sets provide an opportunity to evaluate the current capability in predicting atmospheric and oceanic variability at S2S time scale, isolating influences of individual factors based on the existing datasets alone is not sufficient, because various models that were used to produce these databases have different resolutions, initialization procedures and model physics. The objective of this project is to study the influence of different aspects of forecast configurations and their relative importance on the MJO prediction based on a perfect model framework with the CFSv2.

To achieve the objective, the following steps will be taken: 1) A set of long-term control simulations with different model configurations for the atmospheric resolution, convection, and ocean component will first be performed. From them, a control configuration that produces the most realistic MJO simulation will be selected. 2) Potential predictability of the MJO will be assessed for the selected control configuration based on prediction runs with slight perturbations to atmospheric initial conditions taken from its long-term simulation. 3) A suite of forecast experiments will be done with changes to various aspects to the control configuration to determine (and understand) the sensitivity of the MJO predictions to those changes. Our focus will be on the changes in model resolution, convective parameterization, and representation of air-sea coupling. We will work toward isolating the most important factors governing MJO prediction performance.

We anticipate that the proposed research will identify the beneficial development pathways to further improve MJO predictions. It will provide guidance for improving the next generation CFS and other coupled forecast system models in the climate community. Results from this project

will also help improve our understanding of the processes related to the MJO dynamics and how to properly represent them in the coupled climate models.

10) A categorical assessment of forecast skill, uncertainty and biases in extended-range ensemble forecasts of stratospheric regime changes

PI: Andrea Lang, University at Albany – SUNY

Relevance to NOAA's MAPP competition and long-term climate goal: The proposed work is highly relevant to the MAPP completion: Research to Advance Prediction of Subseaonal to Seasonal Phenomena (ID: 2542967) as it examines the ability of operational NWP systems to represent underlying predictability sources, both physical and dynamical, that influence the subseasonal phenomena of stratospheric regime changes. During the winter season troposphere-stratosphere coupling provides a dynamic mechanism for the stratosphere to influence the troposphere on subseasonal timescales. Stratosphere-troposphere coupling can manifest itself as a stratospheric regime change or, in extreme cases, a sudden stratospheric warming (SSW). On subseasonal timescales, SSWs have been linked to extreme weather and climate, such as cold air outbreaks and negative Arctic Oscillation (AO), which can impact the U.S., Europe and Asia.

When troposphere-stratosphere coupling is skillfully resolved in a forecast, it can provide valuable information to public and private sector forecasters and end users in industry. However, there is a gap in our understanding of the skill, uncertainty and biases in forecasts of stratospheric regime changes that is currently a source of confusion for decision makers. In addressing NOAA's long term climate goal (e.g., NGSP section I.A.i), this research aims to close the gap in our understanding such that end-users of subseasonal forecast data will be better informed and have higher confidence in planning and decision-making.

The increase in our understanding of the two-way coupling between the troposphere and stratosphere has led many operational centers to raise the top of their NWP models to more fully resolve the stratosphere. Raising the top in a model was the first step in the goal to improve forecast skill beyond the medium range. The next steps in reaching this goal are to understand when stratospheric forecasts of wave coupling events are skillful and to increase our understanding of the sources of uncertainty in the forecast of troposphere-stratosphere wave coupling events. This research addresses these next steps by conducting research to assess stratospheric forecast skill and assess sources of uncertainty in operational NWP models during wave coupling events that produce a stratospheric regime change.

The proposed work explicitly examines how model physics, model horizontal resolution, model vertical resolution, and model top level impact the forecast skill and uncertainty of the physical (i.e., diabatic processes) and dynamical (i.e., wave activity) forcing for stratospheric regime changes at several forecast lead times. For the analysis, the physical forcing is represented by metrics that quantify the diabatic processes in the mid- and upper troposphere and the

dynamical forcing is represented by metrics that quantify the troposphere-stratosphere wave coupling. Composite forecasts from the ensemble members that produce the top and bottom quartile of metrics in a forecast will serve as a means to investigate forecast biases. The model biases associated with the physical and dynamical metrics will be quantified in terms of their manifestations in important flow features in the troposphere and stratosphere. Biases in the location and amplitude of the tropospheric precursor blocking as well as biases in the location, shape and strength of the stratospheric vortex best-fit ellipse will be calculated for each composite group. The main scientific objective of this work is to evaluate whether a categorical assessment of errors and uncertainty associated with physical forcing mechanisms lead to an improved understanding of sources of biases in the stratospheric forecasts initialized prior to a stratospheric regime changes. The results of the proposed work will be available online for immediate use by the forecasting community as they become available.

11) Role of stratospheric processes in predicting ENSO-NAO connections on subseasonal time scale

PI: Judith Perlwitz, CIRES/University of Colorado and NOAA/ESRL/PSD
Co-PI: Jadwiga H. Richter, Climate and Global Dynamics Division, NCAR
Co-Is: Lantao Sun, CU/CIRES and NOAA/ESRL/PSD and Julio Bacmeister, NCAR/CGD
Collaborator: Joseph Tribbia, NCAR/CGD

ABSTRACT

There is increasing evidence that stratospheric processes and stratospheric-tropospheric coupling contribute to an enhanced predictive skill of tropospheric phenomena, including El Niño/Southern Oscillation-North Atlantic Oscillation (ENSO-NAO) connections on seasonal time scale. The role of the stratosphere on the predictive skill on the subseasonal time scale has not been systematically explored, and the available data and model studies are not conducive to understanding the responsible processes. This joint proposal between CIRES-University of Colorado/NOAA-ESRL-Physical Sciences Division and CGD-NCAR aims to improve our understanding of the role of the stratosphere on the predictability of the NAO and related extremes and to quantify to what extend NAO predictability can be improved by including a well-resolved stratosphere in a subseasonal modeling framework.

This proposed project has three main objectives:
1. To improve our understanding of the role of the stratosphere on the predictability of the NAO and related extremes on subseasonal time scale in the context of ENSO-NAO connections,
2. To quantify changes in predictive skill of a model with and without a well-resolved stratosphere,
3. To provide the scientific community with a thoroughly tested and evaluated stratospheric resolving subseasonal to seasonal (S2S) forecast system and dataset based on the Community Earth System Model (CESM).

We hypothesize that the skill of predicting the NAO phase and related climate extremes on a subseasonal time scale can be advanced during periods of extreme stratospheric vortex events, and the knowledge of the phase of the tropical stratospheric Quasi-biennial Oscillation (QBO) specifically when also taking into account the phase of ENSO. This project will utilize the default 30-level, as well as the newly developed 46-level version of CESM in subseasonal forecasting and reforecasting mode. The detailed comparison of reforecasts performed with two models with the same tropospheric physics and model resolution but a poorly and well-resolved stratosphere, will allow for the examination of the processes responsible for potentially enhanced predictive skill. Predictive skill of the 46-level CESM subseasonal to seasonal forecasting system (46LCESM-S2S) will be compared to the predictive skill of other S2S

systems from the international modeling community participating in the Subseasonal to Seasonal Prediction Project, a joint research program between the World Weather Research Programme (WWRP) and the World Climate Research Programme (WCRP). All datasets generated as part of this project will follow the S2S protocol and will be provided for public use. The proposed project directly addresses MAPP competition 2 on research to advance prediction of phenomena on S2S time scale in the context of troposphere-stratosphere coupling and NAO predictability. This project addresses NOAA's long-term goal: "Weather-Ready Nation Society is prepared for and responds to weather-related events" by carrying out research on and providing tools for the prediction of extreme events on the subseasonal time scale.

12) Investigation of the Effects of Oceanic Mesoscale Eddies on the Midlatitude Storm Tracks and Their Predictability

PI: Istvan Szunyogh, Texas A&M University

A recent analysis of the THORPEX Interactive Grand Ensemble (TIGGE) showed that while the operational global ensemble forecast systems of the world's leading numerical weather prediction centers were efficient, in general, in capturing the uncertainty dynamics associated with the high-frequency (synoptic scale) transients, they all predicted the slowly varying large-scale component of the flow with a systematic error whose magnitude increased with the forecast time. Such a systematic error poses a major obstacle to extending skillful forecasting into the subseasonal to seasonal (S2S) forecast range. The fact that the different ensemble forecast systems, which use different models and are also generated differently, all fail in the same general fashion, suggests that there may be one or more important dynamical processes that are not accounted for in the current forecast models. Our goal is to investigate the possibility that ocean mesoscale eddy-atmosphere (OME-A) feedback from the ocean to the atmosphere is such a process. This goal is driven by the hypothesis that oceanic mesoscale eddies, which can persist for months in the western boundary current regimes, may play an important role in S2S predictability through modulating the midlatitude storm tracks by inducing mesoscale SST variability.

We will carry out both deterministic and ensemble forecast experiments with a global atmospheric model (the NCAR CAM model at 1/4° resolution) coupled to a simple thermodynamic ocean model. The focus will be on representing the OME-A feedback (and the uncertainty in the OME-A feedback) from oceanic fronts and eddies in the mid-latitude storm track regions. The effect of the parameterization of the OME-A feedback on the synoptic scale waves in the global model simulations will be validated against the results of previous high (9 km atmospheric and 3 km oceanic) resolution process studies with a regional coupled model. We will analyze the results of the forecast experiments by both detailed computations of the energy conversion processes and ensemble-based diagnostics.

The results of the proposed research project are likely to improve the understanding of predictability of phenomena occurring at the S2S time scales. The advances made are expected to lead to improved prediction and better understanding of such S2S process as the transitions between the two phases of NAO and a blocked flow regime.

13) Madden Julian Oscillation - the Maritime Continent barrier and seamless verification

PI: Shuguang Wang, Columbia University
Co-PI: Adam H. Sobel, Lamont–Doherty Earth Observatory, Columbia University
Co-PI: Michael Tippett, Columbia University

ABSTRACT

The Madden Julian Oscillation (MJO) is of central importance in subseasonal to seasonal forecasts but remains difficult to predict. An outstanding problem is that models have difficulty simulating or predicting the propagation of the MJO across the Maritime Continent. This deficiency results in a “prediction barrier.” Overcoming this barrier is a challenge because its precise cause or causes are unknown. Proposed causes include poor representation of th diurnal cycle, biases in mean climate and failure to capture precursor signals. Our project seeks to improve both understanding and prediction of the MJO, focusing on the relation of the MJO to the Maritime Continent. We propose a systematic analysis of forecast and reforecast ensembles from the Seasonal-to-Subseasonal (S2S) prediction project dataset. Success in forecasting MJO propagation across the Maritime Continent varies between different runs in each ensemble as well as across models. Relating forecast success, as well as MJO characteristics, to other variables across the ensembles will identify which variables and processes are most important for determining the success of the forecast and for achieving a good representation of the MJO itself.

Interactions between the diurnal cycle, the MJO, and the mean climatology in structuring deep convection over the Maritime Continent are of particular interest. The moist static energy budget will be adopted to interpret results from a thermodynamic prospective. Dynamic precursors pertinent to the MJO will be extensively explored to evaluate their roles in the MJO forecasts and relation to model biases. All the analysis of these variables will be carried out based on a “seamless” verification approach by which variables are averaged with varying time windows to facilitate smooth transition from daily weather forecast to seasonal climate prediction time scales.

Relevance to NOAA’s goal and to the competition: Our proposal targets Competition 5: Research to Advance Prediction of Subseasonal to Seasonal Phenomena. This competition focuses on the predictability and prediction of S2S phenomena in the context of key underlying physical processes and dynamical processes. Our proposed statistical analysis specifically addresses this issue. Our project is well within the scope of the NOAA’s MAPP program, whose goal is to advance understanding and prediction of variability and changes in Earth's climate system and infuse research advances into NOAA’s service. One particular focus of the MAPP is to improve intraseasonal and interannual climate prediction. Our proposed research is designed to improve understanding of the MJO prediction barrier over the Maritime Continent, and to help

identify ensemble forecast error, and sources of that error, in NOAA's forecast systems. By transforming knowledge learned from the basic research to operational practice, our project will benefit the general public by improving subseasonal to seasonal forecasts and providing better weather service.

14) Variability of Rossby Wave Breaking and its Impacts on the Large-scale Circulation and Extreme Weather: Implications for S2S Prediction and Predictability

Lead PI: Zhuo Wang, University of Illinois at Urbana-Champaign
Co-PI: Melinda Peng, Naval Research Laboratory
Co-PI: Stan Benjamin, NOAA Earth System Research Laboratory, Global Systems Division

ABSTRACT

Rossby wave breaking (RWB) is characterized by large-scale, irreversible overturning of potential vorticity (PV) on isentropic surfaces. The eddy-mean interaction involved in RWB is an important process for the maintenance and variability of the midlatitude jet, and mixing associated with RWB plays an important role in moisture and momentum transport between the tropics and extratropics. In particular, extratropical PV intrusion modulates the moisture distribution in the subtropical dry zone, which affects the infrared energy loss and is an important factor in the global energy budget.

RWB is also closely related to extreme weathers, such as blocking and atmospheric rivers. Our recent study revealed a strong relationship between RWB and Atlantic tropical cyclones (TC). Anomalously frequent RWB enhances the equatorward intrusion of cold, dry extratropical air and leads to a significant reduction in precipitable water over the tropical/subtropical Atlantic and an increase in vertical wind shear, both hindering TC formation and intensification. The correlation of Atlantic hurricane counts with a basinwide RWB frequency index is comparable to the correlation with the Atlantic Main Development Region SST, and stronger than the correlation with the ENSO.

In this project, we propose to i) examine the variability and impacts of RWB on the subseasonal to seasonal (S2S) time scales using reanalysis and observational data; ii) assess the representation of RWB in global prediction systems and investigate model deficiencies using the WWRP/THORPEX/WCRP S2S prediction project database; and iii) investigate the implications of the findings for the S2S prediction and predictability, especially for the prediction and predictability of Atlantic tropical cyclones.

Studies on S2S prediction have primarily focused on tropical forcing and processes (such as the MJO and tropical SST) in the past. This project complements those efforts through its unique perspective in emphasizing the extratropical impacts on tropical circulation and extreme weathers and stressing the link between midlatitude transient eddies and the S2S prediction and predictability. The ultimate goal of the project is to improve the prediction skill of global models on the S2S time scales, and it is well aligned with the focus of the NOAA MAPP Competition 2 to “improve the understanding of predictability” and “advance the prediction of

phenomena occurring on S2S time scales”. It is also highly relevant to the NOAA’s long-term climate goal to improve the scientific understanding of the changing climate system and its impacts.

This project team consists of scientists from research institutes and operational centers. Their combined expertise in atmospheric dynamics, global modeling, and operational forecasting together forms the particular strength of this project, and will also facilitate transition from research to operations and help to bridge the gap between numerical weather forecasting and short-term climate prediction.

SubX Projects

1) Developing a Real-Time Multi-Model Sub-Seasonal Predictive Capability

(SubX Core Team Proposal)

PIs: K. Pegion, T. DelSole, George Mason University
A. Robertson, M. Tippett, International Research Institute for Climate and Society, Columbia University
R. Burgman, Florida International University
H. Lin, Environment Canada
J. Gottschalck, D. Collins, National Centers for Environmental Prediction

ABSTRACT

Recent advances in our understanding of sub-seasonal phenomena and improvements in our ability to simulate sub-seasonal variability along with the demand for sub-seasonal forecasts for decision support suggest that now is the time to develop an experimental multi-model subseasonal predictive capability. Indeed, preliminary multi-model sub-seasonal hindcasts conducted by the North American Multi-Model Ensemble (NMME) team indicate that a multimodel prediction system has more overall skill than any single system alone.

The core team proposed here includes the leadership from the seasonal NMME team, and will organize and coordinate the sub-seasonal multi-model experimental reforecasts and real-time predictions that will be tested under separate awards as part of MAPP CTB announcement of opportunity. The coordination efforts will use the lessons learned from the NMME seasonal prediction project to ensure that sub-seasonal hindcasts and real-time forecasts are available to the entire research community in a timely fashion. We will establish robust links with the operational forecasters at the outset of the project so that forecast products developed meet operational needs. We propose to develop rigorous techniques to combine the multi-model predictions into reliable probabilistic forecasts, and to comprehensively evaluate the skill of the forecasts. Particular emphasis will be place on forecast products most relevant for drought prediction. This proposed team is ideal to lead this effort given our leadership the NMME seasonal prediction project and the associated sub-seasonal experiment, and that we led the development of the sub-seasonal prediction protocol that is to be followed in this experiment. The coordination activities proposed here have four basic elements: (i) Collecting and serving data both internally at CPC for use by operational forecasters and for the external community via the IRI data library largely serving research needs; (ii) providing a baseline verification particularly for the weeks 3-4 temperature and precipitation probability forecasts; (iii) multimodel

evaluations and combinations including selecting suitable models, optimizing the design of the system, and evaluation of the prediction products; and (iv) enhancing communications especially between operational forecasts and the forecast producers.

The proposed research will be carried out as part of the CIMAS program, and addresses the CIMAS climate research and impacts theme in that the objective include improved sub-seasonal predictions using multi-model ensembles that directly serve NOAA's goal of understanding climate variability and change.

2) Estimating the Subseasonal Forecast Skill in the NASA GEOS-5 System with a Focus on the Madden Julian Oscillation and the Land Surface Memory Feedback Processes
(SubX Proposal)

Deepthi Achuthavarier (PI), Universities Space Research Association and Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, MD
Randal D. Koster (Co-I), Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, MD
Jelena Marshak (Co-I), Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, MD
NCEP Collaborators:Dan C. Collins, Jon Gottschalck, CPC

ABSTRACT

In this project, we will demonstrate the feasibility of using the NASA GMAO GEOS-5 coupled model forecasting system to conduct real-time subseasonal forecasts for inclusion in the NOAA subseasonal North American Multi-model Ensemble (NMME) project. As the main thrust of this work, we will perform 45-day reforecasts for each week of the period 1981-2015 and corresponding real-time forecasts for 1 year and deliver the forecast data to NCEP in real time as required by the subseasonal NMME protocol.
Prior to performing the forecasts, however, we will examine and potentially improve the subseasonal forecast skill of our system with a focused analysis on the Madden Julian Oscillation (MJO) and land surface memory feedback processes, two phenomena highly relevant to subseasonal prediction. The MJO, a critical link in bridging the gap between weather and climate prediction, is a large-scale spatially coherent quasi-periodic oscillation in convection and circulation that directly affects most of the tropics and indirectly modulates many weather and climate patterns in the midlatitudes. GEOS-5 already successfully forecasts an MJO when initialized with an observed signal; in this project we will adjust various aspects of its MJO simulation (particularly by adjusting the threshold minimum entrainment rate and the model time step) to improve even further, if possible, the realism of the simulated MJO. We will also provide an assessment of the MJO forecast skill as a function of the different stages in its convective initiation as well as longitudinal positioning of the convective anomaly along the equator, usually identified by the phase of the real-time multivariate MJO index. Land-atmosphere feedback in the GEOS-5 system will be addressed by examining land-atmosphere coupling strength and land surface state persistence using established techniques and then adjusting land model parameters to optimize their agreement with observations to the fullest extent possible. The land model being used for the reforecasts and real-time forecasts in this project will include a dynamic phenology component (capturing, for example, variations in the “leafiness” of the vegetation); thus our analysis will include a focus on how vegetation state influences land-atmosphere feedback.

This proposal is submitted in response to the NOAA MAPP Climate Test Bed call, “Accelerating Transition of Research into Operations”, (Competition 3a), as a potential contribution to the NOAA subseasonal NMME project.

3) The Inclusion of Sub-Seasonal to Seasonal Predictions of the Navy’s Earth System Model in the North American Multi-Model Ensemble (NMME) (SubX Proposal)

Lead PI: Neil Barton, Naval Research Laboratory, CA
Co PI: E. Joseph Metzger, Naval Research Laboratory, Stennis Space Center, MS
Dan C. Collins (collaborator), NCEP/CPC
Jon Gottschalck (collaborator), NCEP/CPC

ABSTRACT

An important aspect of NOAA’s core mission is to support and protect American lives and the economy through their operational climate monitoring products and predictions. One avenue to provide subseasonal climate prediction is via multi-model systems that will provide operational 30-45 day forecasts. However, before an individual model system can be included in the suite, it must be tested to be skillful and demonstrate suitability for real-time prediction at these time scales. Here we propose to use the Navy’s Earth System Model (NESM) to support the North American Multi-Model Ensemble intercomparison of subseasonal forecasts. NESM is built upon the NAVy Global Environmental Model (NAVGEM) for the atmosphere, the HYbrid Coordinate Ocean Model (HYCOM) for the ocean and the Community Ice CodE (CICE) for the cryosphere. It is unique in that the atmospheric component will be run at relatively fine resolution (T359) compared to many other models used in NMME and the oceanic mesoscale will truly be resolved with its 9 km equatorial horizontal resolution. In the polar latitudes the horizontal resolution for ice is approximately 3.5 km. NESM has been shown to have predictive skill with regard to the Madden-Julian Oscillation and multi-month forecasts of the Arctic sea ice minimum.
During the first part of the proposed project, NESM will be used to provide weekly reforecasts (with 4 ensemble members) for the time period 1999-2015. Initial conditions (ICs) for the atmosphere will be derived from operational versions of the Navy Operational Global Atmospheric Predictions System or NAVGEM. Ocean and ice ICs will be derived from HYCOM/CICE reanalyses that span this time frame and assimilate all available observations.

Model diagnostics, especially those related to subseasonal time scales, will be performed to test model capabilities and all model output in the required formats will be forwarded to NCEP. In the second year, atmosphere/ocean/ice ICs will be provided by the operational centers running the systems. A total of four one day lagged ensembles will be completed each week before the Wednesday deadline and model output will be forwarded to NCEP. The proposed work is submitted for consideration as part of the Modeling, Analysis, Predictions, and Projections Program Competition 1 – NOAA Climate Test Bed – Accelerating Transition of Research into Operations, Topic 3a., and is directly relevant to NOAA’s long-term climate goal of climate

adaption and mitigation by aiding in the scientific understanding of producing predictions than will inform decision making.

4) Sub-Seasonal Prediction with CCSM4 (SubX Proposal)

Lead PI: Benjamin Kirtman, University of Miami – RSMAS
Principal Investigators: K. Pegion, George Mason University, AOES
R. Fu, The University of Texas at Austin
Collaborators: J. Gottschalck, D. Collins, National Centers for Environmental Prediction

ABSTRACT

There is a growing interest in a wide swath of user communities for forecast information on time scales beyond 10 days but less than a season. Moreover, there is compelling evidence that leveraging multiple modeling groups and centers to produce a multi-model ensemble is a practical approach to both increase the overall ensemble size and to represent at least some aspects of the forecast uncertainty due to model uncertainty. This proposal seeks to participate in a coordinated multi-model sub-seasonal effort. Specifically, the proposed work described here leverages the existing seasonal North American Multi-Model (NMME) effort at the University of Miami:
I. To produce retrospective CCSM4 sub-seasonal forecasts following an already agreed upon uniform protocol;
II. To participate in a 1-year experimental multi-model real-time CCSM4 prediction effort including the on-time delivery of real-time forecasts and the retrospective forecasts for calibration;
III. To participate in the coordination of research and rapid data sharing to support both research and real-time prediction needs.

In addition to the production of the retrospective and real-time forecasts, we will demonstrate the skill of CCSM4 in predicting sub-seasonal phenomena as sources of predictability, including MJO, blocking, NAO, sub-seasonal variability of ENSO and their impact on various hazards (e.g. precipitation, tropical cyclones, heat waves/cold spells). We will develop tools for performing quality control checks on CCSM4 forecasts based on the re-forecasts and apply them to the real-time predictions. We will also document the relative contributions of land surface vs. atmospheric initialization in forecast quality, diagnose how well the forecasts capture the interactions of the MJO and NAO, and how this impacts forecast quality of rainfall variability over the US. Moreover, we will examine how strong sub-seasonal drying events during spring along with land surface-cloud-precipitation feedback serve to initiate droughts in the US Great Plains. This later effort will leverage existing collaborations with Texas water managers to improve the use of sub-seasonal forecast information in decision support.

The proposed research will be carried out as part of the CIMAS program, and addresses the CIMAS climate research and impacts theme in that the objective include improved sub-seasonal predictions using multi-model ensembles that directly serve NOAA's goal of understanding climate variability and change.

5) An NCEP Global Ensemble Forecast System for Monthly Forecasts (SubX Proposal)

Principal Investigator: Yuejian Zhu, NOAA/NWS, NCEP, Environmental Modeling Center
Co- PIs: Malaquías Peña, Wei Li, and Xiaqiong Zhou, IMSG at EMC/NCEP/NWS/NOAA
Hong Guan, System Research Group at EMC/NCEP/NWS/NOAA

Collaborators: Dingchen Hou, Richard Wobus, Xu Li, NCEP, Environmental Modeling Center
Qin Zhang, Dan Collins, Jon Gottschalck, NOAA/NWS, NCEP, Climate Prediction Center

ABSTRACT

This project will construct, test and prepare for implementation an ensemble forecast system for the 1-35 days lead-time with the more advance ensemble methods, coupled with realistically evolving SST that outperforms current skill benchmarks, providing routine forecast outputs to CPC forecasters and contributing to the NMME-Phase 2 sub-seasonal project. The motivation of this project is the potential to implement a two-tiered GEFS forecast and hindcast system of "opportunity", which can be setup and run routinely within a year. The two-tiered approach consists in prescribing bias-corrected predicted SSTs from the CFSv2 as the integration of the GEFS moves forward. The approach has been tested in the parallel version of the GEFS in a limited set of experiments resulting in skill gains in predicting the MJO signal and reducing the RMSE of forecasts of upper air circulations for weeks 3 and 4. The hindcast is being completed for the first 16-days forecast segment and an extension to the 35-days can be generated for the last 20 years and be setup to provide real-time updates. In parallel with this activity, a next version of the GEFS will be tested in which surface (SST and land) variables are stochastically perturbed to represent analysis uncertainty at initial time.

The proposal targets Priority 3a of the MAPP-CTB FY16 Competition 1: NOAA Climate Test Bed - Accelerating Transition of Research into Operations. The project will select a prediction system suitable for inclusion in an operational multi-model ensemble system, optimize the design of the system, and evaluate prediction products from the system. A major activity will be to test the skill and demonstrate suitability of the selected prediction system for real- time prediction on subseasonal timescales. The proposed prediction system has a pre-existing,documented capability to simulate some of the phenomena and drivers relevant on subseasonal timescales (e.g., Madden Julian Oscillation and blocking) and produces extended-lead skill from initialization. A baseline 35-days GEFS without enhanced surface forcing (referred to as Control MGEFS) was setup to perform real-time predictions twice per

week to show sustained real-time production as part of NOAA's operational prediction activities. A plan to share real-time data with NOAA Central Operations and the broader multi-model ensemble prediction system research team is included. The project is in line with the NOAA's Next-Generation Strategic Plan, particularly the NWS' Weather Ready Nation by providing high quality numerical guidance to severe weather in the medium to extended range.