Diagnosing CFS2 forecast skill using empirical models of climate prediction and predictability from sub-seasonal to multi-decadal scales

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Abstract

We propose to employ a seamless empirical dynamical modeling approach to construct a state-of-the-art benchmark probabilistic forecast system and to evaluate factors impacting predictability at forecast lead times ranging from weeks to decades in the CFS2 forecast system, including climate drift. The model used, a linear inverse model (LIM) derived from observed simultaneous and time-lag correlation statistics of oceanic and atmospheric variables, can also be used to make forecasts whose skill is competitive with current coupled global forecast GCMs. The geographical and temporal variations of forecast skill are also generally similar for the LIM and CGCMs. This makes the much simpler LIM an attractive tool for assessing and diagnosing climate predictability, including determining factors that contribute to climate prediction skill as well as those that limit it, and also for diagnosing the predictability of climate modes such as the MJO, ENSO, PDO, and AMO. We will use the LIM to diagnose where CGCM improvements should be targeted to yield the most significant gains in forecast skill. The LIM formalism also allows determination of which climate regimes have particularly high or low predictability, and how this affects the predictability of different system variables. This suggests that an important "best practices" aspect of climate forecasts on all time scales should be the issuance of both a forecast and a "forecast of forecast skill", of which the LIM would be an important component.

The proposed work addresses NOAA's long-term goal of climate adaptation and mitigation (see NOAA's Next-Generation Strategic Plan) as well as the goals of MAPP in several ways. It projects strongly on NOAA's fundamental mission responsibilities To understand and predict changes in climate, weather, oceans, and coasts and To share that knowledge and information with others. Its contribution to NOAA science includes discoveries and ever new understanding of the oceans and atmosphere, and the application of this understanding to such issues as the causes and consequences of climate change, the physical dynamics of high-impact weather events, … and the ability to model and predict the future states of these systems. The proposed work will also improve scientific understanding of the changing climate system and its impacts by elucidating the sources of climate predictability and suggesting directions for improvement of their representation in models used in the IPCC assessments. The performance of these tasks will also contribute both directly and indirectly to a climate literate public that makes informed decisions through the direct release of information to the general public by means of web products.

Developing an Optimum Multimodel ENSO Prediction

This work falls under MAPP priority area 1 in the area of achieving an objective comparative evaluation of climate prediction skill from dynamical, statistical, and hybrid or consolidated systems to assess optimal prediction methodologies for specific applications.

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Abstract

The ENSO prediction plume product, issued monthly by the International Research Institute for Climate and Society (IRI), shows a large set of model forecasts for the ENSO state out to 10 months in advance. Although helpful, the product currently has a number of serious deficiencies. First, it shows predicted SST anomalies with respect to differing climatological base periods, because the modeling centers from which the predictions come do not use identical base periods. Secondly, many modeling centers do not correct systematic errors in their predictions, and these errors are perpetuated in the predictions on the plume. Some of the forecast models, while showing skill in their real-time ENSO forecasts, do not have adequate hindcast histories from which to treat such systematic errors. Finally, only a rudimentary method is used to consolidate the predictions into a logically derived multimodel mean prediction, and no attempt is made to develop a forecast probability distribution about the mean prediction. Thus, users gain some idea of the forecast probability distribution solely from visual inspection of the inter-model ensemble mean forecast disagreement-a by-far suboptimum criterion.

The proposed work will substantially improve the calibration as well as the multimodel ensembling inadequacies, leading to a more accurate multimodel deterministic and probabilistic ENSO prediction. Additionally, the product will have a more user-friendly format such that probabilities of the full range of possible values are provided more explicitly. Several methods will be tested to develop the forecast probability density function, including equally and skill based weighting, and including an ensemble regression method that uses the models' individual ensemble members for those models producing ensemble predictions. The forecast probability distributions from the selected methodology mayor may not closely coincide with the spread of the individual model ensemble means; when they do not, the resulting forecast distribution would be the proper indicator of uncertainty that is missing from the current plume product.

The ENSO prediction plume product will have several versions, one of which will be a multimodel ensemble using only the NOAA models participating in the national multimodel ensemble (NMME) experiment, using the same strategy as for the larger set

of models. In examining this smaller model set, the issue of the number of models in a multimodel ensemble will be addressed: How many acceptably skillful models tend to produce the best possible multimodel prediction skill, given the high inter-relatedness of the model ENSO predictions? Experimentation with weighting schemes and number of models wi1llead to new methodological knowledge, and to an optimum version of the all-model and the NOAA NMME model plumes.

More accurate, usable predictions of the ENSO state are the fundamental aims of improving the ENSO prediction plume product. Because the ENSO state is related to seasonal climate, better and more easily understood ENSO predictions are of benefit to users in the U.S. and worldwide. Better ENSO predictions lead to better predictions of seasonal climate in known seasons/locations in the U.S. and the globe. Better seasonal climate prediction, in turn, is relevant to the mission of the MAPP Program, seeking to advance intra-seasonal to decadal climate prediction. This work is also relevant to the Next Generation Strategic Plan, as enhanced climate predictions leads to more valued, relied-upon climate services for the benefit of any climate-sensitive sector (e.g., water management, coastal sustainability). The combination of the effects of climate change and ENSO has potential for the hazard of record-breaking climate extremes.

Application of information theory to measure and increase the skill of long-term forecasting

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Abstract

The research program proposed here aims to systematically apply information theory metrics to post-processing and evaluation of long-range forecasts, with the goal of quantifying and increasing their usefulness to end users. To support climate adaptation, NOAA and other national and international forecast centers are providing long-range forecasts based on increasingly sophisticated ensembles and super-ensembles of dynamical model runs. For such forecasts to be useful to end users, post-processing must be applied to move from often biased model outputs to calibrated probability distributions for quantities of interest that calibrate model output based on the observational record and past forecasts or hindcasts. The concept of information gain (IG) from a baseline probability distribution function (PDF) for the quantity of interest to a refined PDF that incorporates model predictions offers an intuitive measure of the skill of models at long-range forecasting that has a solid theoretical basis and provides an objective function for optimally combining multiple dynamical forecasts with climatology and statistical patterns.

The main components of the proposed work are (1) evaluate IG of current and archived forecast products compared to suitable baseline PDFs based on simple statistical models that incorporate persistence and trends; (2) develop and test generally useful methods for constructing maximally informative PDFs from available single-model or multimodel ensemble forecasts; (3) evaluate the statistical uncertainty of expected IG computed from finite available samples; (4) compare IG to other widely used metrics for the ranking of forecast models and post-processing methods in order to understand the behavior and respective advantages of different methods. We will test and demonstrate our methods with existing sets of archived model forecasts and hindcasts, including NOAA's Climate Prediction Center seasonal forecasting product and the new NCEP Climate Forecast System Version 2, focusing on the seasonal (<1 year) prediction timeframe for which more independent calibration data are available. We will deliver not only publications describing our results but an open-source software tool to apply information metrics for the post-processing and evaluation for any given forecast problem that has available historical calibration data, facilitating the adoption and further development of information metrics by diverse research and applications communities.

Our project goals are closely aligned with the "intra-seasonal to decadal climate prediction" MAPP competition's priority area of achieving "an objective comparative evaluation of climate prediction skill . . . to assess optimal prediction methodologies for specific applications". We believe that the research and software tool proposed here will tangibly advance the MAPP Program objective of "developing integrated assessment and prediction capabilities relevant to decision makers", and through it NOAA's goal of a "Weather-Ready Nation" achieved through delivering relevant environmental information.

Best Practices for Estimating Forecast Uncertainty in Seasonal-to-Decadal Predictions

A research proposal to the NOAA Climate Programs Office (CPO) for FY 2012 Program Element: Modeling, Analysis, Predictions, and Projections (MAPP) Priority Area 1: Advance Intra-Seasonal to Decadal Climate Prediction

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Organization: International Research Institute for Climate and Society
Co PIs: Simon Mason

Partner Institution on this proposal: University of Exeter
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Abstract

Seasonal predictions are increasingly acknowledged by the adaptation community as a valuable resource to inform management of risks and opportunities. There is also growing awareness of the role that decadal variability plays in our experience of climate change. Given that decadal prediction experiments will be part of CMIP5, it is almost certain that the adaptation community will want to add these predictions to their portfolio of climate information. The problem is that predictions across these timescales carry various model biases, including probabilistic unreliability, unless they are recalibrated.

Our proposal offers a systematic framework to recalibrate seasonal-to-decadal predictions to yield estimates of forecast uncertainty that can be used to inform decisions such as planning and risk management across these timescales. A comprehensive sensitivity study will also provide guidance on the optimal design of prediction systems in the face of limited resources often faced by many modeling and forecast centers. This guidance will allow for informed decisions on trade-offs between, amongst other factors, the frequency and number of historical hindcasts, ensemble sizes, and the complexity of the recalibration scheme. Through this study we will assess the appropriate level of complexity of recalibration scheme for a given prediction problem, quality of ensemble predictions, and design of hindcasts: in the face of small hindcast samples or small ensemble sizes, more complex schemes may actually degrade the predictions through the addition of noise. This work will involve the development and use of mathematical models in order to test the full range of design choices associated with seasonal-to-decadal hindcasts and forecasts. The mathematical models synthetically represent the ensemble prediction and observation time series, and the relation between the two. Existing dynamical model data sets of seasonal-to-interannual simulations and hindcasts and seasonal-to-decadal initialized and uninitialized hindcasts will be used both to parameterize the mathematical models and to demonstrate the impact of recalibration on forecast performance.

This work is highly relevant to NOAA's long-term goal of climate adaptation. This work will assist in the effort to create and sustain enhanced resilience in

communities and economies by creating climate prediction and projection information, and associated methodologies, that enable society to better anticipate and respond to climate and its impacts. Our work directly addresses two of NOAA's five-year climate objectives: "assessments of current and future states of the climate system that identify potential impacts and inform science, service and stewardship decisions"; and, "adaptation choices supported by sustained, reliable, and timely climate services". Of particular relevance to the MAPP program and Priority Area 1 to advance intraseasonal to decadal climate prediction, the proposed work will "assess the optimal choice of ensemble members, forecast times, and model diversity in order to characterize the impact of initial condition and model uncertainties in climate prediction", and also "improve understanding of the impact of climate model biases and their evolution in forecast time on prediction skill, and the 'best practice' for post-processing predictions".

Toward Developing a Seasonal Outlook for the Occurrence of Major U.S. Tornado Outbreaks

Institutions: University of Miami/CIMAS, NOAA/AOML and NOAA/CPC
Principal Investigator: S.-K. Lee (Lead PI), S. J. Weaver, R. M. Atlas, C. Wang and D. B. Enfield

Abstract

The record-breaking U.S. tornado outbreak in the spring of 2011 prompts the need to identify and understand long-term climate signals that may provide seasonal predictability for intense tornado outbreaks. Currently, seasonal forecast skill for intense U.S. tornado outbreaks, such as occurred in 2011, has not been demonstrated. A recent study by Lee et al. [2011] used both observations and modeling experiments to find that a positive phase of the Trans-Niño (TNI), characterized by cooling in the central tropical Pacific and warming in eastern tropical Pacific, is associated with large-scale processes that may contribute to major tornado outbreaks over the U.S. In particular, they found that seven of the ten most active tornado years during 1950 – 2010, including the top three, are characterized by a strongly positive phase of the TNI, suggesting that if we can predict the TNI, we may be able to issue a seasonal warning (or outlook) for extreme tornado outbreaks over the U.S.

The main goals of this proposal are (1) to refine the potential predictive skill provided by the TNI, (2) to explore other long-term climate signals that may provide additional predictability in seasonal and longer time scales, and (3) to evaluate and potentially improve seasonal forecast skill for intense U.S. tornado outbreaks in the NCEP Climate Forecast System version 2 (CFSv2). With these three goals in mind, our work will be comprised of five tasks: (task-1) reanalyzing the severe weather database (SWD); (task-2) establishing meteorological indices for estimating the occurrence of tornadoes; (task-3) exploring long-term climate signals that may provide predictability of U.S. tornado activity; (task-4) analyzing the CFSv2 reforecasts; and (task-5) exploring the potential of an experimental hybrid dynamical-statistical seasonal forecasting system. Completing task-1 and -2 will result in a bias-corrected SWD and reanalysis based proxy tornado datasets, which will be essential for studying the tornado-climate linkage and thus useful for the wider climate and tornado research community. Completing task-3 will identify long-term climate signals that may provide predictability of U.S. tornado activity. Completing task-4 and -5 may potentially result in an experimental hybrid seasonal forecast system for U.S. tornado activity. If the experimental forecast system is shown to provide skillful seasonal predictability of U.S. tornado activity, it will be used to develop a seasonal tornado outlook at NOAA CPC.

The proposed work contributes directly to a high-priority topic for NOAA FY2012 MAPP funding Priority Area-1 Advance Intra-seasonal to Decadal Climate Prediction: "(i) Achieve an objective comparative evaluation of climate prediction skill from dynamical, statistical, and hybrid or consolidated systems to assess optimal prediction methodologies for specific applications." This proposed work will be conducted under the auspices of the Cooperative Institute of Marine and Atmospheric Science program at the University of Miami's Rosenstiel School of Marine and Atmospheric Science, and addresses CIMAS Theme: (Climate Research and Impacts). This work is relevant to the NOAA goals: (Weather-Ready Nation: Society is prepared for and responds to weather-related events, and Climate Adaptation and Mitigation: An informed society anticipating and responding to climate and its impacts) in support of NOAA's Strategic Plan.

Title: A US National Multi-Model Ensemble ISI Prediction System

A collaborative proposal to the NOAA Climate Program Office for FY2012 Modeling, Analysis, Predictions and Projections Program (MAPP) Priority Area 2: Develop and experimental National Multi-Model Ensemble climate prediction system

Principal Investigator: Benjamin Kirtman

Co-PIs: James L. Kinter III[1], Dan Paolino, David DeWitt[2], Michael K. Tippett, Anthony G. Barnston Anthony Rosati[3], Kathy Pegion[4], Siegfried Schubert[5], Michele Reinecker, Max Suarez, Huug van den dool[6], Malaquias Pena Mendez, Jin Huang, Scott Weaver, Joe Tribbia[7], Eric Wood[8]

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Abstract

The proposed research leverages an existing National Multi-Model Ensemble (NMME) team that has already formed and is already producing routine real-time intra-seasonal, seasonal and interannual (ISI) predictions and providing them to the NOAA Climate Prediction Center (CPC) on an experimental basis for evaluation and consolidation as a multi-model ensemble ISI prediction system. The experimental prediction system developed by this NMME team is as an "MME of opportunity" in that the ISI prediction systems are readily available and each team member has independently developed the prediction protocol.

The activity proposed here is to develop a more "purposeful MME" in which the requirements for operational ISI prediction are used to define the parameters of a rigorous reforecast experiment and evaluation regime. The NMME team will design and test an operational NMME protocol (i.e., a purposeful MME) that is to guide the future research, development and implementation of the NMME beyond what can be achieved based on an "MME of opportunity."

The proposed activity will:

i. Build on existing state-of-the-art US climate prediction models and data assimilation systems that are already in use in NMME-1 and ensure interoperability so as to easily incorporate future model developments.
ii. Take into account operational forecast requirements (forecast frequency, lead time, duration, number of ensemble members, etc.) and regional/user specific

needs. A focus of this aspect of the work will be the hydrology of various regions in the US and elsewhere in order to address drought and extreme event prediction.

iii. Utilize the NMME system experimentally in a near-operational mode to demonstrate the feasibility and advantages of running such a system as part of NOAA's operations.

iv. Enable rapid sharing of quality-controlled reforecast data among the NMME team members, and develop procedures for timely and open access to the data, including documentation of models and forecast procedures, by the broader climate research and applications community.

The proposed activity will also include several NMME research themes:

i. The evaluation and optimization of the NMME system in hindcast mode (e.g., assessing the optimal number of ensemble members from each model, how to best combine the multi-model forecasts, sources of complementary prediction skill, etc.),

ii. Ocean and land initial condition sensitivity experiments.

iii. The application of the NMME forecasts for regional downscaling and hydrological prediction.

Understanding climate variations in the Intra-Americas Seas and their influence on climate extremes using global high-resolution coupled models

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Abstract

We propose to use a hierarchy of GFDL high-resolution climate models to improve our understanding of the climate of the Caribbean Sea and Gulf of Mexico ("Intra-Americas Seas", or "IAS"), including its influence on climate-scale variations and changes in Atlantic hurricane activity and North American drought. Because of the complex, mutli-scale oceanographic, atmospheric and coupled air-sea phenomena that characterize the IAS region, we will focus on both atmospheric and oceanic climate, and their interactions. We will explore the sensitivity of the simulation of the mean climate and climate variations in the IAS to changes in resolution and parameterization in the context of the coupled GFDL high-resolution models. The role of remote influences on climate in the IAS will be explored, assessing oceanic and atmospheric teleconnections by performing "data override" and "partial coupling" experiments with the climate models. Analogous perturbations to the coupled model will be used to explore the influence of the IAS on remote climate through atmospheric and oceanic processes. We will focus particularly on the influence of the IAS on North Atlantic hurricanes and on drought over North America. Predictability of the climate variations and teleconnections from the IAS will be explored using initialized prediction experiments using the GFDL high-resolution modeling system.

The principal hypotheses to be tested are i) increased resolution and high-order numerics in global coupled climate models improve simulation of mean climate and variations of the Intra-Americas Seas, ii) remote, large-scale factors (e.g., ENSO and the Atlantic Meridional Overturning Circulation) drive variations and changes in the IAS through atmospheric and oceanic bridges, iii) changes in oceanic circulation and atmospheric convection in the IAS have a detectable influence on remote oceanic and atmospheric conditions, iv) modeled climate variations in the IAS modulate North American drought and North Atlantic tropical cyclone activity in the North Atlantic, v) the improved representation of drivers of IAS variability (e.g., ENSO and AMM) and the mean climate of the IAS in higher resolution models leads to enhanced predictive capacity for regional climate due from initialization and response to radiative forcing. The proposed work should improve our understanding and ability to model a key area of the global climate system, and the model simulations performed in this study and analysis of them will be beneficial to the high-resolution climate model development.

Relevance to NOAA's long-term goal and to the competition: This work will contribute to NOAA's long-term goal of climate adaptation and mitigation through improving our ability to model, predict and understand climate extremes over North

America. The IAS is a principal moisture source for rainfall over much of the southeastern and central US, provides a warm water energy source to tropical cyclones and is key in the development of tornadic activity over the US. Therefore improved understanding, modeling and prediction of this key region is necessary to understanding likely changes in droughts, landfalling tropical cyclones and tornadic activity over the US, and help inform adaptation strategies. Though the IAS is influential to climate and extremes, “state-of-the-art global models have very large mean bias and erroneous variability over the [IAS] region,” according to the IAS Climate Processes (IASCliP) Modeling Working Group (Misra et al. 2010). This proposal seeks to use higher resolution models to help remedy this important limitation to our current modeling capability.

Climate Variability of the Tropical Western Atlantic Storms: Is it hinged to Intra-Americas Seas climate processes?

Institutions: Earth, Ocean and Atmospheric Science & Center for Ocean-Atmospheric Prediction Studies, Florida State University

P.I.: Dr. Vasubandhu Misra

Abstract

The proposal seeks to understand the low frequency variability of the Tropical Western Atlantic Storms1 (TWAS) and its relationship with Intra-Americas Seas (IAS) climate processes. Traditionally simulations and predictions beyond the NWP range for tropical Atlantic storms have largely been on their frequency of occurrence throughout the basin over the 6-month period from June through November. This type of forecast or simulation has limited application although they have demonstrated admirable skill on seasonal time scales and on longer time scales in their rendition of the 20th century variability. The success of this study could be a harbinger for attempting predictions of a subset of the tropical Atlantic storms that are geographically more limited in the basin (western Atlantic). Furthermore a majority of TWAS make landfall over continental North America. In addition, the TWAS climatologically has a characteristic dominance of genesis in June and November, which could also be potentially exploited if we understand their causality. Thus this proposal is relevant to NOAA's NGSP mission on climate adaptation and mitigation to the threat of potential land falling tropical storms in North America.

The proposed work will employ high-resolution (~10km) coupled ocean-atmosphere model centered over the IAS in an attempt to resolve the TWAS, the Caribbean Low Level Jet (CLLJ), air-sea fluxes in the IAS, the diurnal variations in the region and capture the associated, intricate sub-surface ocean structure. In addition several sensitivity experiments are also proposed to understand the influence on the genesis and lifecycle of TWAS. This framework of regional coupled ocean-atmosphere modeling is deliberately chosen to afford the high resolution for multi-decadal integrations and limit the model drift by forcing the regional system with credible large-scale reanalysis (NCEP CFSR). The coupled GCM's have shown acute climatological bias in the IAS region with poor depiction of the associated variability in the boreal summer season.

The central objective of the proposal is to understand whether (and followed by how) IAS climate processes like the evolution of the IAS SST and sub-surface ocean evolution from the prior seasons, variability of CLLJ, air-sea fluxes in IAS, overlying atmospheric meridional cell can influence TWAS. The basis for this investigation is buttressed by several related observational evidence, a clear working knowledge of the models to be employed with its demonstration of use over another domain, and availability of computing resources to conduct the proposed integrations.

Variability and Predictability of the Atlantic Warm Pool and Its Impacts on Extreme Events in North America

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Abstract

Our current/previous NOAA/CPO-funded research has pointed out the importance of the Atlantic Warm Pool (AWP) for summer climate and extreme events in the Western Hemisphere. AWP variability occurs on seasonal, interannual, multidecadal, and secular (global warming) timescales, with large AWPs being almost three times larger than small ones. The effect of the AWP is to weaken the North Atlantic subtropical high (NASH) and strengthen the summer continental low over the North American monsoon region. A large AWP also weakens the southerly Great Plains low-level jet, which results in reduced northward moisture transport from the AWP to the central U. S. and thus decreases the summer rainfall over the central United States. A large AWP increases the number of Atlantic hurricanes by reducing vertical wind shear and increasing the moist static instability of the troposphere, and influences the hurricane steering flow changes that become unfavorable for hurricanes to make landfall in the United States. Our research also suggests that the AWP serves as a link between the Atlantic Multidecadal Oscillation (AMO) and climate and hurricane activity. Despite its importance, almost of all state-of-the-art coupled models exhibit serious biases in the AWP region, which limit the seasonal prediction of AWP-related climate and extreme events.

We propose to continue our investigation of the AWP using fully coupled climate models. Two specific areas of proposed work are (1) diagnosing the CMIP5 outputs to assess model biases near the AWP region and to understand their skill in simulating the mechanisms and climate impacts of AWP variability, and (2) performing coupled model experiments using CESM1 (also called CCSM4) and analyzing the Climate Forecast System version 2 (CFSv2) reforecasts to assess and improve predictability of the AWP and its impacts on climate and extreme events such as hurricanes, flood and drought in North America. The diagnostic analyses will mainly focus on variability of the AWP, and its impacts on the NASH, the Caribbean low level jet and its moisture transport, and the Great Plains low-level jet and its moisture transport. Other areas of the focus in the diagnostic analyses include the relationships of rainfall in the U.S. with the AWP, the external influences (such as ENSO, the AMO, and the NAO) versus local ocean-atmosphere processes on AWP variability, and the relationships among environmental factors contributing to hurricane activity. We will perform CESM1 model simulations with and without realistic initialization of the AWP to explore the impact of AWP initialization on seasonal forecasts. We will also examine the influences of model resolution and deep convective parameterizations in CESM1 on AWP SST and rainfall biases. One of the tasks is to analyze the CFSv2 reforecasts to explore its skill for seasonal predication of the AWP and AWP-related climate and extreme events. The CESM1 experiments and the analysis of CFSv2 reforecasts are designed to identify the sources that contribute to the model biases, thus provide a basis for improving model simulations and predictions. In collaboration with scientists at NOAA/CPC, we will attempt to transition research results to operations at NOAA/CPC. The proposed work directly contributes to all of four topics listed in the NOAA/CPO MAPP FY12 Priority Area 3 of "modeling of IAS climate processes associated with extremes over North America". It is hoped that over a longer time frame, this work will result in the regional implementation of data- and model-based outlooks for flood/drought in the United States, hurricanes and climate variability, when successfully combined with land-based models.

Predictability of Atlantic Hurricane Activity by the NMME Coupled Models

This work pertains to priority area 3 within Modeling, Analysis, Predictions, and Projections (MAPP): Modeling of Intra-Americas Sea climate processes associated with extremes over North America. Within area 3, it falls into the specific area of evaluating how predictions of climate processes in that region impact predictions in the activity of extremes over North America.

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Abstract

We propose to investigate, and then implement into a real-time forecast system, the response of the CFS CGCM to the Madden-Julian Oscillation (MJO) in north Atlantic hurricane activity. The very high resolution (T382) version of CFS will be used, as it has already been found to reproduce the interannual variations of hurricane activity level and individual hurricane tracks quite effectively over a multidecadal hindcast period.

Seasonal Atlantic hurricane activity level is known to vary in response to environmental variables such as the ENSO state, the sea surface temperature (SST) in the Main Development Region (MDR), and the state of the north Atlantic multidecadal oscillation. Relatively recently, dynamical tools have been used to predict hurricane activity with some success, defining individual cyclones and quantifying their seasonal total energy. The MJO phase and strength is also definable, and some statistical and dynamical predictability for the MJO is discernible out to the first 2-3 weeks. The MJO is also found capable of affecting the genesis and strength of tropical cyclones in both the Pacific and Atlantic oceans, and this MJO-cyclone relationship is reproducible in some dynamical models. We plan to capture these relationships in a real-time hurricane prediction system that can distinguish preferred timings and locations of hurricane activity up to 2-3 weeks.

Four main tasks of the project will be to (1) assess the extent and quality of MJO representation in the T382 CFS model; (2) examine the relationship between the model's MJO and its hurricane activity compared with that found in observations, and statistically correct systematic errors; (3) repeat steps (I) and (2) for the standard (T 126) CFS version 2 model and for the other models in the NMME experiment, and test multimodel ensemble prediction; and (4) assuming favorable results from (l), (2) and/or (3), implement a real-time hurricane forecast system using the T382 CFS and/or other models in the NMME.

Better prediction of the seasonal Atlantic hurricane activity level, and of preferred sub-regions for hurricane activity in the medium-range timescale (first few weeks) due to the

MJO, is relevant to U.S. economic, safety and national security issues--disaster management, water management, health, and protection of life and property. An example of the level of hurricane forecast detail potentially resulting from the proposed work would be: "During week 1, hurricanes are more likely to emerge in the GulfofMexico or in the vicinity of Cuba than near or north of the Leeward Islands, while during week 2 they are most likely in the subregion south of Haiti, the Dominican Republic, Puerto Rico and Virgin Islands, and relatively unlikely in the western Gulf of Mexico. " Such intraseasonal specificity, still not targeting individual hurricanes, would complement the overall seasonal prediction of hurricane activity to render the suite of time scales more seamless. This work is also more generally relevant to the Next Generation Strategic Plan, as better Atlantic hurricane predictions lead to more valued, relied-upon climate services for the benefit of hurricane-sensitive human activities (e.g., coastal sustainability). The combination of the effects of climate change and the year-to-year variations in hurricane activity has potential for the hazard of record-breaking extremes in coastal region inundation and storm surge.

Modulation of Tropical Cyclone (TC) Activity over the Intra-Americas Sea by Intraseasonal Variability: Implications for Dynamical TC Prediction on Intraseasonal Time Scales

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Summary

Tropical intraseasonal variability (ISV, e.g. Madden-Julian Oscillation) exerts significant influences on global climate and weather systems including tropical cyclones (TCs). This serves as a critical basis of the "Seamless Prediction" concept by bridging the forecasting gap between medium to long-range weather forecast and short-term climate prediction. For extended range forecasts of TC activity on an intraseasonal time scale (10~60 days), most of current approaches are based on statistical models or downscaling techniques. Recently, with the development of high-resolution general circulation models (GCMs) with improved model physics, it has become possible for these GCMs to represent both ISV and hurricanes, leading to a new avenue for intraseasonal TC prediction by using dynamical models.

Our recent analyses (Jiang et al. 2011b; Jiang et al. 2011a) of ISV and TC activity over the eastern North Pacific (ENP) based on simulations by the high resolution NOAA/GFDL HiRAM AGCM illustrate that the observed dominant ISV modes over the ENP are captured well in HiRAM; meanwhile, the observed relationship between ISV and TC activity over the ENP can also be faithfully represented in this model. Motivated by these encouraging results, we propose to use HiRAM, a leading edge model in terms its ISV-TC fidelity, to qualify the predictive skill and estimate the predictability for TCs across the Intra-Americas Sea (IAS) on intraseasonal time scales. The objectives of this proposed study are as follows:

1. Conducting hindcast experiments to fully evaluate the prediction skill of ISV over the IAS by the NOAA/GFDL HiRAM;
2. Analyze the HiRAM hindcast ensembles to estimate the intrinsic predictability of TC activity over the IAS;
3. Evaluate the role of ISV in characterizing the prediction skill of TCs over the IAS on intraseasonal time scales;
4. Explore the physical mechanisms associated with ISV modulation of TC formation over the IAS;
5. Using both HiRAM climate simulations and hindcasts, evaluate how model horizontal resolution and different physical parameterization specifications influence model skill in simulating / predicting ISV and TC activity.

With a focus on the close linkage between TCs, one of the most disastrous extreme events, and ISV, a prominent climate mode with broad impacts over the IAS, this proposal directly addresses MAPP program's FY2012 goals of "modeling of Intra-Americas Sea climate processes associated with extremes over North America". Moreover, this proposed study is in great agreement with recommendations by the

National Academy of Science's 2010 report "Assessment of Intraseasonal to Interannual Climate Prediction and Predictability" that "Many sources of predictability remain to be fully exploited by intraseasonal to interannual (ISI) forecast systems. To better understand key processes that are likely to contribute to improved ISI predictions, …, MJO influences on other important components of the climate system, such as tropical cyclone genesis should continue to be explored and exploited for additional predictability."

TITLE OF PROPOSAL: "Intraseasonal to Interannual Variability in the Intra-Americas Sea in Climate Models"

INSTITUTION: Colorado State University (DUNS: 78-597-9618), Cooperative Institute for Research in the Atmosphere (CIRA)

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Abstract

This study assesses the ability of CMIP models to produce realistic intraseasonal to interannual variability (IAV to ISV) in the Atlantic warm pool (AWP) region and the implications for hurricanes, the ability of parameterization modifications in the GFDL AM3 to improve the simulation of AWP ISV, and how mean state biases in CMIP models develop and the implications for forecast biases in ISV and IAV. The following questions will be answered:

1. **Can IAS-region intraseasonal variability in the GFDL AM3/CM3 be improved through modifications to the treatment of deep convection?**
   The sensitivity of IAS mean state and ISV to modifications in the Donner convection scheme in GFDL AM3/CM3 will be assessed, including different treatments of triggering, rain evaporation, and entrainment. The degree to which IASregion ISV is coherent with that in the Eastern Hemisphere will be assessed, which has consequences for prediction. Variables that impact hurricane genesis potential will be a focus.
2. **How do model errors develop over the Atlantic warm pool?**
   In the AWP, the ensemble mean of CMIP3 models features SST errors of 2$_{o}$C or larger in the annual mean, with considerable variability in rainfall errors among different atmosphere models forced by observed SSTs. A systematic investigation into errors of SST, rainfall, sea level pressure and wind in the AWP based on the CMIP3/5 database will be conducted, including the similarities and differences among models. Initial emphasis will be GFDL models, especially initialized seasonal forecasts, followed by a diagnosis in the broader suite of CMIP5 models.
3. **How well can CMIP5 models simulate the ENSO-Atlantic hurricane teleconnection?**
   Substantial biases in the ENSO-Atlantic hurricane teleconnection occur in all CMIP3 models (Shaman and Maloney 2011). We will assess the ability of CMIP5 models to capture the ENSO teleconnection to the Atlantic and its manifestation in large-scale variables that affect tropical cyclone (TC) genesis, with specific

focus on the GFDL CM3. We will also intercompare CMIP5 model ability to capture other modes of Atlantic IAV including the Atlantic meridional mode and Atlantic Multidecadal Oscillation, and the variables relevant for TCs.

4. **How do IAS-region mean state biases affect forecasts of ISV and IAV and extreme events?**
   The climatology of a coupled prediction model drifts quickly, and the model errors approach the equilibrium in a matter of months. Biases in the mean state, such as those in SST, precipitation, and winds can have profound implications for Atlantic climate variability and how remote forcing from climate variability in other basins is manifest in the Atlantic. The effect of the climate drift on forecast results within the IAS will be assessed. The regional climate model from U. Hawaii will be used to examine how mean state biases affect biases in ISV and IAV and extreme events over the IAS region. ISV to IAV in boundary conditions will be retained while biasing the mean state to that of the GFDL CM and other CMIP models to determine how changes in the climate state and its statistics affect the simulation of extreme events like TCs.

This proposal directly addresses MAPP Priority Area Three. We intend a comprehensive study to document the ability of CMIP5 climate models including GFDL CM/AM to accurately simulate the ISV to IAV of the IAS region and associated TC activity. Parameterization modifications to the GFDL AM3 and their ability to improve ISV in the IAS region will be assessed. A close look into model biases in the IAS to identify their sources is an important step toward improving seasonal forecasts of extremes over the Americas. This proposal also supports NOAA's NGSP by improving understanding of model biases that will allow more accurate predictions of future climate, allowing society to better anticipate and respond to the challenges of climate change. This proposal entails research that advances the nation's core capabilities in understanding and modeling the climate system, which is a primary goal of the CPO.

Towards improving convection parameterization and the MJO in next-generation climate models

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Abstract of Proposal

Tropical biases remain a significant problem in global atmosphere models, even at horizontal resolutions of 20-50 km. In addition to mean state errors, another glaring deficiency is the general absence of the 30-60-day Madden-Julian oscillation (MJO), which modulates the frequency of tropical cyclone genesis over several basins and interacts with the lower-frequency El-Nino Southern-Oscillation. It is thought that such errors stem mainly from deficiencies in convection parameterization, but the precise nature of these deficiencies remains unclear. In order to address such tropical problems, we propose to run and analyze a suite of short-term [O(10-day)], high-resolution weather hindcasts, focusing on a 40-day period of enhanced MJO activity during the Year of Tropical Convection (YoTC) when special observational and assimilated datasets are available. The hindcasts will be performed using 4 different high-resolution atmospheric models (GEOS-5, CAM5, HiRAM, and WRF) as part of a multi-institutional collaborative research effort. The goal is to see how simulations of the MJO and other high-impact weather phenomena, as well as the mean state, are affected by either i) increases in model resolution (going from 50- down to 5-km horizontal grid spacing) or ii) the use of a "superparameterization" of convection at 50-km horizontal grid spacing. Hindcasts will also be generated with each of the models' convection schemes turned off, to see how the various schemes tend to improve (or degrade) their respective model's performance at high resolution. We hypothesize that models with more realistic convective processes will do better at simulating the MJO, so our diagnosis of model output will include both process-level and global-scale aspects, and will compare these in order to test this hypothesis. Improved understanding of this convective process-global performance relationship will serve the overall goal of improved ability to simulate convection variability and the MJO in models used to predict changes in regional-scale climate and high-impact weather for the decades to come.