NMME/SubX Science Meeting Abstracts

WEDNESDAY

Morning Oral Presentations

Who cares about S2S research to improve forecasts?
Alison Stevens, NOAA, Annarita Mariotti (NOAA), Dan Barrie (NOAA), Heather Archambault (NOAA)

For many industries, the weather and climate play a significant role in determining revenue. Although weather forecasts are crucial, many critical decisions affecting profits or losses must be made several weeks or months in advance. For example, before the start of the summer season, utility companies need to plan for how much power to produce in order to meet demand for air conditioning. Water resource managers face decisions about managing reservoir levels in the upcoming weeks and months ahead of water use and consumption. Farmers need to understand what crops to plant and when to irrigate to prevent decreased amounts and quality of produce, and ultimately profits, when unprepared for droughts.

Given the current limitations in subseasonal to seasonal forecasts, research to develop and improve them is key to those businesses in many different sectors who aim to improve planning and decision making. This talk will present case studies of companies that use operational or experimental seasonal forecasts such as the CFS and the NMME, based on results from previous NOAA research, for their decision making. Examples of how businesses could benefit from new predictions from projects such as SubX will also be presented.

Morning Poster Presentations

Assessment of sub-seasonal predictability and probabilistic prediction skill over the U.S.
Andrew Robertson, IRI, Columbia University, Nicolas Vigaud, IRI Columbia University, Lei Wang, LDEO Columbia University, and Michael Tippett, APAM Columbia University

The subseasonal predictability of surface temperature and precipitation is examined for two global ensemble prediction systems (ECMWF VarEPS and NCEP CFSv2), with an emphasis on the week 3&4 forecast skill over the United States. The results are interpreted in terms of ENSO, PNA, and AO/NAO teleconnection patterns, the models ability forecast these indices, and in terms of the sub-seasonal and seasonal timescale contributions to the hindcast skill. We then apply extended logistic regression to construct calibrated sub-seasonal forecasts (weeks 1-4, and weeks 3+4) of precipitation, and average these calibrated forecasts from 3 models to obtain a multi-model combination. A clear benefit of multi-model ensembling is to largely remove negative skill scores present in individual forecasts. The forecast skill of weekly averages is higher in winter than summer and decreases with lead time, with steep decreases after one and two weeks. Week 3+4 forecasts have more skill along the US east coast and the southwest US in winter, as well as over west/central US regions and the Intra-American Seas/east Pacific during summer.

Towards version 2 of the University of Maryland / NOAA Subseasonal Excessive Heat Outlook System (SEHOSv2)

Augustin Vintzileos, University of Maryland – ESSIC

The subseasonal excessive heat outlook system version 1 (SEHOSv1) developed by the author provides skillful, real-time, quasi-operational forecast of excessive heat events (EHE) in forecast Week-2 and has some residual skill in forecast Week-3; multi-model forecasts were shown to enhance this skill. Quantities forecast by the SEHOSv1 are (a) categorical forecast of an EHE within a given week, (b) probability of occurrence of the EHE within this given week, (c) mean start date within the week and (d) mean duration in days. The definition of EHE in SEHOSv1 is based on the percentile criterion of maximum heat index of the day only. A new definition of EHE that enhances the SEHOSv1 suite of prediction products was developed. This allows the introduction of multiple criteria e.g., maximum and minimum heat index, max and min dry temperature and wind speed. In this paper I discuss the utility of the new definition by showing evidence of its relation to abnormal mortality over the contiguous United States. Further I discuss qualitative/quantitative differences between different EHE e.g. Chicago July 1995 versus July 2012. Finally, the new definition in used to describe heat events over selected cities worldwide. A discussion of the skill of some initial retrospective forecasts based on the new definition conclude the paper.

Advances in Real-time Probabilistic Seasonal forecasting at The International Research Institute for Climate and Society (IRI)

Nachiketa Acharya, International Research Institute for Climate and Society, Earth Institute at Columbia University, Palisades, New York, USA

The International Research Institute for Climate and Society (IRI), Columbia University, began routinely providing calibrated user-oriented seasonal climate forecasts since the late 1990s based on a two-tiered multi-model ensemble dynamical prediction system. The forecasts are probabilistic with respect to the occurrence of three categories of seasonal total precipitation and mean temperature below, near, and above normal as defined by the 30 year base period in use at the time. The IRI has recently updated this system using coupled ocean-atmosphere models from the NOAA North American Multi-Model Ensemble (NMME) project. It is well established thatåÊcalibration ofåÊmodel probabilities is needed to account for GCM forecast deficiencies and produce reliable probabilistic forecasts. In developing the new NMME-based system, Extended Logistic Regression (ELR) has been applied to obtain calibrated tercile probabilities from each NMME model separately at each grid point; these forecast probabilities are then averaged together with equal weighting to obtain the final multi-model ensemble forecast. This calibration approach is grid point based, thus forecast probabilities tend to be noisy spatially, in particular for precipitation, therefore the final forecast probabilities are then smoothed spatially. While ELR has been successfully applied in the past to ensemble weather forecasts, this is the first time to our knowledge that it has been used to produce seasonal climate forecasts. With the advantage of ELR methodology for making mutually consistent individual threshold probabilities, in addition to 3-category probability forecast, the proposed calibration method also developed a more flexible forecast format that enables users to extract information for those parts of the forecast distribution of greatest interest to them, especially the probability of extremely dry/wet conditions. The skill of ELR-based forecasts is evaluated over 1982-2010 following a leave-one-year-out cross-validation and are found to be more skillful than the more familiar approach of estimating the forecast probabilities by counting how many members exceed a certain threshold. As of April 2017, this new NMME-based system using the ELR method is now is use in real-time at IRI for seasonal prediction.

Application of the NMME for the Intraseasonal Prediction of Tropical Cyclones over the Atlantic and North Pacific Basins

Hui Wang, Christina Finan, Jae-Kyung Schemm, NOAA Climate Prediction Center

This study is to develop a suite of dynamical-statistical forecast models for intraseasonal forecasts of Atlantic and North Pacific basin tropical cyclone (TC) activities using the data from the NMME products. Empirical relationships between observed monthly mean TC activity and the NMME system predicted monthly mean ocean/atmosphere conditions are established for each ocean basin throughout the hurricane season. Sea surface temperature and sea level pressure, as well as vertical wind shear, are identified as potential predictors for the sub-seasonal TC forecasts. The dynamical-statistical model for the intraseasonal TC forecasts is developed based on these empirical relationships and using multiple linear regression method. Cross-validations over the 1982-2010 NMME hindcast period shows that the hybrid forecast system has significant forecast skills for the sub-seasonal TC activity. The forecast skills with a combination of different predictors for each ocean basin are also assessed. The system is being tested for real-time intraseasonal forecasts for the 2017 hurricane season and will be implemented into operations at NCEP Climate Prediction Center.

Subseasonal Skill Sensitivity in the Global FIM-iHYCOM Coupled Model

Shan Sun, NOAA Earth System Research Laboratory, R. Bleck, S. Benjamin, B. Green and G. Grell

A coupled atmosphere (FIM) and ocean (HYCOM) modeling system FIM-HYCOM is being developed for subseasonal to seasonal prediction. Both component models are 3-dimensional grid point models, operating on a common icosahedral horizontal grid, and using an adaptive near-isentropic vertical coordinates. FIM uses the 2015 Global Forecast System (GFS) physics package, with an option of switching its Simplified Arakawa-Schubert shallow and deep convective cloud parameterization to a variant of the Grell and Freitas (2014) scheme (SAS and GF hereafter). Once-per-week subseasonal hindcasts with 4 time-lagged ensemble members over a 16-year period have been carried out with both SAS and GF at 60 km horizontal resolution. Preliminary results from this multi-year hindcast indicate that the forecast skill of FIM-HYCOM is comparable to that of the operational model CFSv2 used by NCEP. We will discuss in details the model sensitivity to different grid resolutions (60km vs. 30km) as well as to physics parameterizations.

Short-Term Climate Extremes in the NMME

Emily Becker NOAA/NCEP/CPC & Innovim

The development of an NMME-based outlook for extreme monthly and seasonal mean 2 m temperature (t2m) and precipitation is discussed. Earlier studies have established the potential for skillful model forecasts of short term climate extremes; here, both deterministic and probabilistic forecasts for extremes are considered. Forecast skill assessments find that skill scores are equal to or greater for extremes than for non-extreme cases. Results are assessed for the real-time (2011-present) and hindcast (1982-2010) periods, and for varying combinations of models in the multi-model ensemble. Seven models from the NMME contribute to this study: NCEP-CFSv2, Environment Canada's CanCM3 and CanCM4, GFDL's CM2.1 and FLOR, NASA-GEOS5, and NCAR-CCSM4.

Preliminary Results of Evaluation of Week 3/4 Reforecast for Canadian GEPS

Qin Zhang, NOAA/NCEP/CPC

Since September 2015, the realtime week3/4 forecast for U.S. temperature and precipitation have been made on every Friday in CPC. In order to make bias correction for improving week3/4 forecast skill, reforecasts of the dynamic models are examined the prospects for extension of the products to the week 3-4 time range for both temperature and precipitation over U.S., as well as 500hPa height of the Northern hemisphere . We evaluated reforecast of Global Ensemble prediction system (GEPS) of Environment Canada from the extent 32-day forecast initialized once a week on Thursday with 4 members for period 1995-2014. Verification diagnostic of GESP seasonal prediction skills of week3/4 are conducted in both temporal and spatial scores. The anomaly correlations (AC) are calculated after the mean biases are removed. Comparing with the observation, the model biases are cold over the western Northern America and wet over the eastern Northern America. The GESP reforecast skills of week3/4 are relatively low on average over U.S. and similar to models of ECMWF and JMA. However, forecast opportunities exist in some regions and seasons.

Influence of Convectively Coupled Equatorial Waves, the MJO, and ENSO on the Environment of Tropical Cyclones in Coupled Atmosphere-Ocean Subseasonal Prediction Systems

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Tropical convection is modulated by convectively coupled equatorial waves (CCEWs), the Madden Julian Oscillation (MJO), and the El Nino Southern Oscillation (ENSO). Coupled atmosphere-ocean subseasonal prediction systems such as the Navy Earth System Model (NESM) have demonstrated an ability to produce intraseasonal convective variability consistent with the MJO. However, less is known about the ability of subseasonal prediction systems to simulate the interannual variability of the MJO and the modulation of higher-frequency modes of variability such as easterly waves and Kelvin waves by the MJO. These various modes of convective variability are also known to modulate environmental conditions relevant to tropical cyclones.

In this study, the ability of the NESM and models in the Subseasonal to Seasonal (S2S) database to predict convective variability across a range of spatiotemporal scales and its connection to variability in environmental conditions relevant to TC formation and intensity (e.g. humidity, shear, relative vorticity, and maximum potential intensity) are evaluated using 1999-2015 boreal summer hindcasts. Implications for tropical cyclone prediction on subseasonal time scales are also discussed.

An assessment of predictability for week 3&4 through extended Global Ensemble Forecast System (GEFS)

Yuejian Zhu, NOAA/NWS/NCEP/EMC, Yuejian Zhu, Xiaqiong Zhou, Wei Li, Dingchen Hou, Hong Guan, Eric Sinsky and Christopher Melhauser

In order to provide ensemble based week 3&4 forecasts to support NCEP Climate Prediction Center (CPC)'s operational mission, experiments have been designed through the SubX project to investigate potential predictability in both the tropical and ex-tropical regions. The benchmark (or control) experiment is the current operational Global Ensemble Forecast System (GEFS) version 11 (v11) whose model integration is extended from 16 days to 35 days with a 52km horizontal resolution. Three parallel experiments and a control have been run for the period of 25 months (May 2014 - May 2016; 21 ensemble members; every other 5 days; 00UTC initials only) to focus on three areas; i.e. 1). Improving forecast uncertainty for tropical area through stochastic physical perturbations; 2). Considering the ocean's impact by using 2-tiered SST approach; 3). Testing new scale aware convection scheme to improve tropical convection and MJO propagation.

In the tropical area, in addition to improving probabilistic forecast, the MJO skills have been enhanced from an average 12.5 days (control) to nearly 22 days through applying all three new methodologies. For best MJO skill experiment, RMM2 skills could be extended to 27+ days. In the ex-tropical area, pattern anomaly correlation (PAC) of 500hPa geopotential height of ensemble mean has been used to demonstrate potential predictability of large scale pattern. From this 25 months average, PAC score is improved from 0.31 (control) to 0.41 (experiment 3). In contrast of tropical MJO and ex-tropical PAC of 500hPa height, A CRPS of the Northern Hemisphere raw surface temperature (land only) is improved as well, but not as large as MJO skills and 500hPa ACs. A similar result has been found for CONUS precipitation. In conclusion, the calibration may be important to surface temperature and precipitation due to large model systematic error (or bias).

Evaluating the performance of numerical ENSO forecasts for the June-August time period relative to a statistical/analog approach

Isaac Hankes and Thomas Walsh (Thomson Reuters)

The development of an El Nino event was forecasted by a suite of numerical models during the Northern Hemisphere summer when the lead time was greater than one month. However, as the season approached, most of the same models flipped the forecast trajectory into one that included a neutral ENSO state through August and eventual La Niña conditions by early 2018. This study examines the skill of the numerical ENSO forecasts that were made during March-May for the June-August time period as compared to the skill demonstrated by other methods, including statistical and analog approaches. Any systematic/seasonal bias that may exist amongst these methods is also illuminated in order to help improve the skill of forecasts in future seasons.

Afternoon Oral Presentations

Seasonal Climate Predictions in CCSM4: Influences of ocean-atmosphere coupling and SST biases on skill and predictability

Johnna M. Infanti, University of Miami Rosenstiel School of Marine and Atmospheric Science, Ben P. Kirtman - University of Miami Rosenstiel School of Marine and Atmospheric Science

Seasonal climate predictions are predominantly influenced by slowly evolving surface boundary conditions, including (but not limited to) sea surface temperatures (SSTs). The ocean plays an important role in the skill and predictability of precipitation and temperature, including over remote regions due to teleconnections. Recent efforts in seasonal climate prediction include coupled general circulation model (CGCM) ensemble predictions, but other efforts have included atmospheric general circulation model (AGCM) ensemble predictions that are forced by time-varying sea SSTs. We perform a series of prediction experiments comparing coupled and uncoupled Community Climate System Model version 4.0 (CCSM4) predictions, and forecasted versus observed SSTs to determine which is the leading cause for differences in skill and predictability. Overall, prediction skill and predictability are only weakly influenced by ocean-atmosphere coupling, with the exception of the western Pacific, while errors in forecasted SSTs significantly impact skill and predictability. Comparatively, SST errors lead to more significant and robust differences in prediction skill and predictability versus inconsistencies in ocean-atmosphere coupling.

Subseasonal Prediction Skill from SubX

Timothy DelSole, George Mason University, Laurie Trenary (GMU), Michael K. Tippett (Columbia), Kathy Pegion (GMU), Abhishekh Srivastava (GMU)

In this talk, I discuss recent work in quantifying the skill of predictions on subseasonal time scales. First, I will show that CFSv2 skillfully predicts week 3-4 temperature and precipitation over the contiguous U.S. This work involves a new significance test that rigorously accounts for serial correlation between forecasts, and the use of Predictable Component Analysis to isolate predictable structures. Next, I discuss challenging, technical issues that arise in quantifying the skill of forecasts from the SubX project, especially the problem of estimating the model climatology. This problem is challenging because, during the first year of the project, a complete annual cycle of re-forecast data will not be available for all models. Moreover, different models will have different levels of data availability, with some models having initial starts only at seven day increments. Our goal is to develop a method for computing model climatologies that is accurate, rigorous, and can adapt to the inhomogeneous nature of the SubX data. The skill of SubX forecasts available at the time of the conference will be presented.

Afternoon Poster Presentations

On the Potential Forecast of Extremes by a Multi-Model Ensemble (MME)

Dan C. Collins, NOAA Climate Prediction Center

Probabilistic forecasts from a multi-model ensemble (MME) are calibrated and consolidated using a regression methodology. The primary impacts of calibration are to smooth the forecast probability density function, improve the reliability of probabilities, and weight individual models according to their skill. Models with little skill regress to near zero anomalies or may be removed entirely from anomaly forecasts. Extreme forecasts are identified when the forecast probability exceeding about one standard deviation above or below normal exceeds the climatological probability of approximately 15%. The calibration technique is compared to forecasts made by estimating the probability from the count of ensemble members exceeding the threshold for an extreme forecast. Forecasts are verified using the Heidke and Brier skill scores, as well as assessed for reliability of probabilities, and regions and seasons when the MME is found to have skill in forecasting extremes are found.

Seasonal and Regional NMME Investigation and Visual Updates

Andrew Huang, University of Illinois at Urbana-Champaign, Emily Becker - NCEP Climate Prediction Center

The North American Multi-Model Ensemble (NMME) is an ensemble of model ensembles, presently used in operations to assist in real-time, seasonal-to-interannual predictions at the NOAA Climate Prediction Center (CPC) as well as other forecasting centers around the world. Because the historical forecast archive of the NMME now contains data from more than five years ago, potential to glean new insight from fresh analyses arise. Here, past skill scores are aggregated and analyzed to gain a sense of how the NMME is performing thus far. Objective measures of skill are also applied to subset regions and seasons of the NMME to investigate whether there is some possibility to exploit regional or seasonal differences of individual models to improve overall skill. Visualizations, such as heatmaps and side-by-side bar charts, are generated to clearly and efficiently convey these analyses. Earlier visuals of the NMME forecasts are also in the process of being updated to not only utilize more up-to-date climate data, but also adopt a modern, cleaner graphical style, while retaining familiar aspects of the former figures, to offer forecasters a version that more effectively expresses the forecasts in a non-distracting, accustomed manner.

GEM-NEMO Coupled Model for Seasonal Forecasts

Hai Lin and Ryan Muncaster, Environment and Climate Change Canada

The ECCC numerical weather prediction model, GEM, is coupled with the NEMO ocean model. The objective is to develop a global atmosphere-ocean-sea ice coupled model for climate study and subseasonal and seasonal predictions. A set of hindcast experiments are performed starting from the first of each month for the 30 years of 1981-2010, with 10 members of 12-month integrations. Seasonal forecast skill is assessed for surface air temperature and precipitation, as well as for the Pacific-North American Pattern (PNA) and the North Atlantic Oscillation (NAO). The forecast skill of the Madden-Julian Oscillation (MJO) is also calculated to evaluate its performance on the subseasonal time scale. Comparison is made with the operational Canadian Seasonal and Interannual Prediction System (CanSIPS). It is found that the GEM-NEMO coupled model outperforms the two CanSIPS coupled models in many aspects.

Hybrid dynamical-statistical seasonal forecasts with weather types

Angel G Munoz, Princeton University

Dynamical forecast models provide a foundation for seasonal forecast systems, but systematic errors may arise for various reasons, including insufficient spatial resolution, insufficient ensemble size, and errors in physical parameterizations. Despite these flaws, the ability of dynamical models to simulate the sources of prediction skill (e.g., ENSO) and their large-scale circulation responses allows us to draw from empirical predictor/large-scale circulation relationships to compensate for these shortcomings. In this study we use the framework known as weather types (WTs) to act as the mediator for a hybrid dynamical-statistical seasonal forecast system. WTs are large-scale circulation patterns that, in this application, are determined by k-means clustering of geopotential height. We generate seasonal forecasts for December-February over eastern North America by taking dynamical model forecasts of WTs and then using empirical relationships to translate these WT forecasts into probabilistic temperature and precipitation forecasts. We use hindcasts from both a lower resolution (CM2.1) and higher resolution (FLOR) dynamical forecast model from the Geophysical Fluid Dynamics Laboratory (GFDL), considering different initialization strategies. This application of WTs essentially serves as a pattern-dependent bias correction and downscaling approach. We evaluate the performance of the hybrid dynamical-statistical forecasts in the context of more conventional post-processing methods.

NMME model predictions of El Nino in the far-eastern Pacific: The 2015-16 and 2017 cases

Ken Takahashi, Instituto Geofísico del Perú, Lima, Peru

El Niño was originally identified as anomalous warming along the western coast of South America. However, the far-eastern Pacific (FEP) is one of the most problematic regions for ocean-atmosphere general circulation models, both in the mean climate (warm coastal bias and excessive strength of the southern hemisphere ITCZ) and inter-annual variability (westward shifted variance). Model seasonal prediction skill of sea surface temperature (SST) in the FEP region is relatively low, and bias-corrected hindcasts severely underestimated the anomalous FEP warming during the extreme 1982-1983 and 1997-1998 events. Here we present an analysis of the NMME model predictions during the recent 2015-2016 and 2017 El Niño events defined in terms of the FEP warming, with a focus on the representation of the basin-scale and regional El NiÌ±o feedback mechanisms, and the potential effects of the mean climate biases on the feedbacks.

Probabilistic prediction of extreme temperatures using NMME

Nir Krakauer, City College of New York

I evaluate the ability of the North American Multi-Model Ensemble (NMME) to predict monthly mean temperatures at lead times of 1-12 months, concentrating on skill in predicting extreme values, which can potentially have high impact. This presentation will compare skill metrics by location, season, and lead time for probabilistic prediction methods that differ in bias correction process, equal/differential model weighting, and whether to explicitly include the warming trend. The resulting probabilistic predictions could supplement the existing operational ones, which focus on per-tercile probabilities and generally do not provide direct information on the likelihood of extreme values.

CPC Subseasonal Experiment

Emerson LaJoie, CPC & Innovim

This work will show the efforts to date on the Subseasonal Experiment on week 3-4 timescales (SubX), including model comparisons, methods for computing climatologies, and early week 3-4 experimental outlooks.

Diagnosing the sources of systematic SST biases in CESM using ensemble seasonal hindcasts

Angela Cheska Siongco, Lawrence Livermore National Laboratory, Hsi-Yen Ma, Shaocheng Xie, Steve Klein (Lawrence Livermore National Laboratory)

Simulating the observed magnitude and patterns of sea surface temperature (SST) remains a challenge for coupled general circulation models, mostly due to the complex air-sea coupled processes and feedbacks involved. Here, we investigate the emergence and growth of SST biases using ensemble seasonal hindcast simulations performed with the Community Earth System Model (CESM) version 1, with a focus on the period 2001-2005. Results show that the equatorial Pacific and northern subtropical Pacific and Atlantic oceans develop a cold bias after two to three months, reaching comparable magnitudes to climatological biases within six months of lead-time. Further analysis of the equatorial Pacific cold bias reveals that hindcasts with start dates during the upwelling period (boreal summer to fall) exhibit a strong drift from the reanalyses and observations as well as a large ensemble spread. In contrast, those with start dates outside of the upwelling period show minimal drift and spread. This implies that the cold bias develops quickly during the upwelling period, but takes longer than six months to emerge outside the upwelling period. An upper ocean heat budget analysis indicates that the anomalous cooling comes from biases in vertical advection in the ocean, rather than from surface fluxes.

[This study is funded by the Regional and Global Climate Modeling and Atmospheric System Research Programs of the U.S. Department of Energy as part of the Cloud-Associated Parameterizations Testbed. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-734118]

Bias Correction to Improve the Skill of Summer Precipitation Forecasts as Produced by NMME System over CONUS

Bala, Narapusetty INNOVIM/NOAA-CPC, Dan C. Collins

Improvements in the skill of precipitation forecast in summer as produced by North American Multi-Model Ensemble (NMME) system over Contiguous United States (CONUS) are examined by applying a new bias correction method. The uncorrected precipitation produced by NMME hindcasts exhibits good prediction skill in fall and winter while the spring and summer forecasts are marked with extremely poor skill. The correction method deployed in this study decreases the forecasted precipitation distribution error by utilizing skillfully predicted 2-m air temperature (T2m) forecast. This method averts the low skills of precipitation forecast in summer by exploiting the strong co-variability that exists between precipitation and T2m in nature, and take advantage of the enhanced recycled precipitation occurrence over CONUS in summer to provide an ideal situation to horn the precipitation forecast skills using the T2m forecasts. The proposed bias correction is shown to successfully reduce the root mean square error in precipitation hindcasts in summer and can easily be extended to real-time forecasts as well as providing a framework to dynamically link precipitation with other predictors besides T2m.

Seasonal forecast skill of the Indian monsoon in GFDL high-resolution forecast system

Lakshmi Krishnamurthy, Princeton University / GFDL, Xiaosong Yang, Hiroyuki Murakami, Rich Gudgel, Thomas L. Delworth, Anthony Rosati, Seth Underwood

Accurate prediction of the Indian summer monsoon is of utmost importance considering its socio-economic impacts over the subcontinent. Thus, we analyze seasonal forecast skill of the Indian monsoon rainfall during JJAS season based on June initialized forecasts and its relation to the Pacific and Indian Oceans in GFDL high-resolution forecast system. GFDL models have prediction skill in ENSO-monsoon relationship as they have accurate prediction of floods and droughts when accompanied with La Niña and El Niño, respectively. GFDL models also tend to predict droughts during non-ENSO years. However, the models fail to forecast floods in the absence of La Niña in the tropical Pacific Ocean. We also determine other sources of predictability for the Indian monsoon.

THURSDAY

Morning Oral Presentations

Process-based evaluation of MJO prediction

Hyemi Kim, Stony Brook University

The Madden-Julian Oscillation (MJO) is a special type of organized tropical convection which is distinct from other forms by its vast horizontal scale, subseasonal variability, and propagation over the Indo-Pacific basin. Enhanced or suppressed convection associated with the MJO affects global weather and climate, thereby providing a source of subseasonal predictability. In the most recent decade, MJO prediction has benefitted from the significant strides in the ability of models to represent the MJO. Various operational forecast centers are now releasing MJO forecasts and are continuously upgrading their systems. Current operational forecasting systems now show useful MJO prediction skill up to 3-4 weeks. However, this achievement is still below the theoretical estimate of predictability, which may be 6-7 weeks. Thus, there would seem to be room for further enhancing MJO prediction by improving various aspects of the prediction system based on a better understanding the MJO phenomena. In this talk, the current status and the future challenges of MJO prediction will be discussed. Although many recent studies have investigated the MJO prediction in multi-models, analyses have been limited to simple performance-oriented metrics than process-oriented diagnostics which can provide insights for model success or failure at predicting the MJO. A new diagnostic applied to hindcasts will be introduced. Also, detailed analysis of the propagating mechanism related to the mean biases in the ECMWF ensemble prediction system will be presented.

Skill in the NMME Nino-3.4 Forecasts following the 2015-16 El Nino

Michelle L'Heureux, NOAA Climate Prediction Center

After the strong 2015-16 El Nino, the tropical Pacific returned briefly to ENSO-neutral conditions en route to a weak La Nina during the Northern Hemisphere winter 2016-17. Starting in the spring of 2017, many dynamical models predicted the onset of El Nino in the last half of 2017. Despite these predictions, the tropical Pacific has remained in ENSO-neutral conditions. An evaluation of the NMME forecasts will be presented, with care given to putting aspects of the recent evolution in greater historical context.

Morning Poster Presentations

Subseasonal Forecast Skill over Extratropical Northern Hemisphere in Three Operational S2S Systems

Hai Lin, Environment and Climate Change Canada

Pentad forecast skill over extratropical Northern Hemisphere in winter is evaluated for the subseasonal to seasonal prediction (S2S) systems from three operational centers: ECMWF, NCEP and ECCC. The former two systems are running with air-sea coupled models, whereas the latter with an atmospheric-only model. One objective of this study is to assess the impact of air-sea coupling on subseasonal forecast skill. Previous studies have reported that the ECMWF system has a far better Madden-Julian Oscillation (MJO) forecast skill than the other systems. Whether the MJO skill translates to extratropical forecast skill is of great interest.

The results indicate that the three systems have comparable forecast skill in surface air temperature over the land area of Northern Hemisphere, although the air-sea coupled systems perform slightly better than the atmospheric-only system in pentads 3-6. Pentad skill of the North Atlantic Oscillation (NAO) is also evaluated. In all three systems, the NAO skill is found dependent on the MJO phase of the initial condition. Forecasts initialized from MJO phases (2,3,6 and 7) which have an east-west dipole diabatic heating structure in the equatorial Indian Ocean and western Pacific region are more skillful than those starting from other MJO phases (1,4,5 and 8).

The fact that the two coupled systems have a very close forecast skill in the extratropics indicates that the ECMWF system has not taken advantage of its high MJO forecast skill. This is likely due to systematic errors in the middle latitude mean flow after about 10 days of forecast, which has important impact on the MJO induced Rossby wave propagation beyond week two.

The FIM-iHYCOM Model in SubX: Evaluation of Subseasonal Drift

Benjamin W. Green, CIRES/CU and NOAA/ESRL/GSD, Shan Sun, Stanley G. Benjamin, Georg A. Grell, Haiqin Li, and Rainer Bleck

NOAA/ESRL/GSD has produced both real-time and retrospective forecasts for SubX using the FIM-iHYCOM model. FIM-iHYCOM couples the atmospheric Flow-following finite volume Icosahedral Model (FIM) to an icosahedral-grid version of the Hybrid Coordinate Ocean Model (HYCOM). This coupled model is unique in terms of its grid structure: in the horizontal, the icosahedral meshes are perfectly matched for FIM and iHYCOM, eliminating the need for a flux interpolator; in the vertical, both models use adaptive arbitrary Lagrangian-Eulerian hybrid coordinates. For SubX, FIM-iHYCOM initializes four time-lagged ensemble members around each Wednesday, which are integrated forward to provide 32-day forecasts.

While it has already been shown that this model has similar predictive skill as CFSv2 in terms of the RMM index, FIM-iHYCOM is still fairly new and thus its overall performance needs to be thoroughly evaluated. To that end, this study examines model errors as a function of forecast lead week (1-4) (i.e., model drift) for key variables including SST, 2-m temperature, precipitation, and 850 hPa zonal wind. Errors are evaluated against two analysis products: CFSR, from which FIM-iHYCOM initial conditions are derived, and the quasi-independent ERA-Interim. In general, errors are fairly consistent for weeks 2-4, suggesting that on subseasonal timescales FIM-iHYCOM rapidly adjusts to a fairly stable model state. The errors (and drift) for CFSv2 will be shown for comparison. The impact of hindcast frequency (4 times per week, once per week, or once per day) on the model climatology is also examined to determine the implications for systematic error correction in FIM-iHYCOM.

Combination of Multimodel Probabilistic Forecasts Using Objectively Determined Weights

Gwen Chen, NOAA/NWS/NCEP/CPC & CICS-MD

In this study, we develop an objective weighting system to combine multiple seasonal probabilistic forecasts in the North American Multi-Model Ensemble (NMME). The system is applied to predict temperature and precipitation over the North American continent, and the analysis is conducted using the 1982-2010 hindcasts from eight NMME models, including the CFSv2, CanCM3, CanCM4, CM2.1, FLOR, GEOS5, CCSM4, and CESM models, with weights determined by minimizing Brier Score using ridge regression. Strategies to improve the performance of ridge regression are explored, such as eliminating a-priori models with negative skill and increasing the effective sample size by pooling information from neighboring grids. A set of constraints is placed to confine the weights within a reasonable range or restrict the weights departing wildly from equal weights, which is the fall-back. So when the predictor-predictand relationship is weak, the multimodel ensemble forecast returns to equal-weight combination. The new weighting scheme improves predictive skill from baseline, equally weighted forecasts. All models contribute to the weighted forecasts differently based upon location and forecast start and lead time. The amount of improvement varies across space and corresponds to average model elimination percentage. Area with higher elimination rate tends to have larger improvement in cross-validated verification scores. Some local improvements can be as large as 0.6 in temporal probability anomaly correlation (TPAC). On average, about 0.02-0.05 in TPAC for temperature probabilistic forecasts and 0.03-0.05 for precipitation probabilistic forecasts over North American continent. Skill improvement is generally greater for precipitation than temperature probabilistic forecasts.

Prediction of Stratospheric Sudden Warming Events

Rainer Bleck, NOAA Earth System Res.Lab, Boulder, CO, Shan Sun, Stan Benjamin (both NOAA-ESRL)

Two- to four-week predictions of stratospheric sudden warming events during the boreal winter seasons of 1999-2014, carried out with a high-resolution icosahedral NWP model using potential temperature as vertical coordinate, are inspected for commonalities in the evolution of both minor and major warmings. Emphasis is on the evolution of the potential vorticity field at different levels in the stratosphere, as well as on the sign and magnitude of the vertical component of the EP flux indicative of either upward or downward wave forcing. Material is presented shedding light on the skill of the model (FIM, developed at NOAA/ESRL) in predicting stratospheric warmings generally 2 weeks in advance. With an icosahedral grid ideally suited for studying polar processes and a vertical coordinate faithfully reproducing the evolution of the PV field, FIM is found to be a good tool for investigating the SSW mechanism.

Prediction of Atmospheric Blocking

Rainer Bleck, NOAA Earth System Res.Lab, Boulder, CO, Shan Sun, Stan Benjamin (both NOAA-ESRL)

A data set consisting of once-per-week, 4-ensemble-member, 32-day retrospective forecasts during 1999-2014 is inspected for the occurrence of tropospheric multi-day blocking episodes. Forecasts were generated with an icosahedral coupled ocean-atmosphere model using an adaptive, near-isentropic vertical coordinate in both model components. To lessen the dependence on one particular blocking indicator, results from two popular blocking indices -- Tibaldi-Molteni and Pelly-Hoskins -- are compared. Both the frequency of blocking patterns as a function of lead time and the skill in predicting observed blocking events are investigated. The model's ability to reproduce details of the Rossby wave breaking process, generally considered a necessary (though not sufficient) precursor to blocking, is studied. A low eddy viscosity coefficient is found to be important for maintaining the integrity of vorticity filaments whose rollup is a central ingredient of wave breaking.

Assessing potential predictability of North American Drought in NMME Hindcasts

Robert Burgman, Florida International University, Ben Kirtman , UM/RSMAS

The research utilizes short lead hindcasts to identify mechanisms and periods of enhanced predictability of extreme hydroclimate events in North America.

Is there much room for forecast skill improvement of global sea surface temperature anomalies?

Sang-Ik Shin, CIRES, University of Colorado and Physical Science Division, NOAA/Earth System Research Laboratory, Boulder, CO, Matthew Newman and Prashant D. Sardeshmukh

The hindcast skill of the coupled models included in the North American Multimodel Ensemble (NMME) prediction system is assessed and benchmarked with that of low-order empirical Linear Inverse Models (LIMs). The LIMs are constructed for near-global (60oS-65oN) and tropical (24oS-24oN) domains, and are derived using the observed covariances of monthly sea surface temperature (SST) and sea surface height (SSH) anomalies in the 1961-2010 period. Both LIMs produce SST and SSH forecasts at leads ranging from 1 month to 1 year.

The tropical LIM clearly captures the essence of the predictable tropical SST dynamics. The skills of the LIM and NMME ensemble-mean forecasts closely track one another spatially as well as temporally, and both are only slightly lower than the potential skill estimated using the LIM's forecast signal-to-noise ratios. This suggests that the scope for further NMME skill improvement is small in most of the Tropics, except in the western equatorial Pacific where the NMME skill is currently much lower than the LIM skill.

The near-global LIM, whose domain includes highly productive coastal zones, also has very comparable skill to that of the NMME ensemble mean. In particular, the LIM has significant skill in the Large Marine Ecosystems (LMEs) around the US, and also in predicting extratropical climate indices such as PDO, AMO, and NPGO. Indeed in many of these areas the LIM skill is notably higher than the NMME mean-skill. This suggests a substantial room for NMME skill improvement in the extratropics.

On the correspondence between short- and long-time-scale systematic SST biases in the CESM

Hsi-Yen Ma, Lawrence Livermore National Laboratory, Cheska Siongco, Steve Klein, Shaocheng Xie (Lawrence Livermore National Laboratory)

In this study, we systematically examine the short- and long-time-scale sea surface temperature (SST) biases in the Community Earth System Model (CESM), version 1. The short time-scale simulations are from ensemble seasonal hindcasts between 2001 and 2005, and the long time-scale simulations are from the CESM large-ensemble simulations (LENS). Our analysis shows that there is a good SST bias correspondence between short time-scale hindcasts and long-term climate runs over most tropical and subtropical oceans. For example, the equatorial Pacific cold tongue bias, the cold biases over the sub-tropics in the pacific and Atlantic are emerging within a few months. There is also interannual variability in the bias pattern and magnitude. This indicates that many long-term SST errors are the result of relatively fast (a few months) processes and atmospheric and some fast oceanic processes may be the major culprits

(This study is funded by the Regional and Global Climate Modeling and Atmospheric System Research Programs of the U.S. Department of Energy as part of the Cloud-Associated Parameterizations Testbed. This work is performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-733961)

Examining Systematic Biases in the NMME

John Mejia, Desert Research Institute/Division of Atmospheric Sciences,
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Shraddhanand Shukla, University of California, Santa Barbara

The North American Multimodel Ensemble Phase-II (NMME) exhibits some systematic biases, meaning that a subset of the models suffer from similar consistent biases in the same parameters. Particularly well-known systematic biases in coupled Global Climate Models (GCMs), including those participating in the NMME, are the warm sea surface temperature (SST) biases over the N. Pacific basin and the subtropical region over eastern oceanic boundaries, which are more pronounced over the upwelling region of coastal California and the Baja California peninsula. Over the California and Baja California upwelling zones, the NMME SSTs are higher than observations by ~ 3-5°C. This bias fluctuates seasonally, with the warmest biases occurring between April and October, and notably develops within the first month of initialization. In this presentation, we show that theses biases in simulating upper and surface ocean parameters can have a strong local, remote, or even inter-hemispheric influence in GCM predictive skill. Particularly, we show that N. Pacific and Coastal California SST biases in the Regional Climate Models (RCMs) and GCMs (including CMIP3, CMIP5 and NMME models) are related to wet precipitation biases in atmospheric parameters that propagate deep into the Western U.S. Understanding the response of the atmosphere to SST biases is very challenging. We discuss the impacts this error propagation can cause in the forecast skill of extreme weather phenomena involving land-atmospheric feedbacks such as heat waves and droughts.

Assessing the Fidelity of Predictability Estimates

Kathy Pegion, GMU/COLA, Tim DelSole GMU/COLA, Emily Becker, Innovim/CPC, Teresa Cicerone, GMU

Predictability is an intrinsic limit of the climate system due to uncertainty in initial conditions and the chaotic nature of the atmosphere. Estimates of predictability together with calculations of current prediction skill are used to define the gaps in our prediction capabilities, inform future model developments, and indicate to stakeholders the potential for making forecasts that can inform their decisions. The true predictability of the climate system is not known and must be estimated, typically using a perfect model estimate from an ensemble prediction system. However, different prediction systems can give different estimates of predictability. Can we determine which estimate of predictability is most representative of the true predictability of the climate system? We test three metrics as potential indicators of the fidelity of predictability estimates in an idealized framework --- the spread-error relationship, autocorrelation and skill. Using the North American Multi-model Ensemble re-forecast database, we quantify whether these metrics accurately indicate a model's ability to properly estimate predictability. It is found that none of these metrics is a robust measure for determining whether a predictability estimate is realistic for El Nino-Southern Oscillation events. For temperature and precipitation over land, errors in the spread-error ratio are related to errors in estimating predictability at the shortest lead-times, while skill is not related to predictability errors. The relationship between errors in the autocorrelation and errors in estimating predictability varies by lead-time and region.

Afternoon Oral Presentations

Calibration of Monthly and Seasonal Probabilistic Prediction of Extremes in NMME
Huug van den Dool, CPC/Innovim, Emily Becker and Li-Chuan Chen, both at CPC

Using time series of NAO projection coefficients we demonstrate how probability forecasts (based on ~100 ensemble members when all models are used in the mix) can be calibrated by using a fairly new technique called PAC, the probability anomaly correlation. This technique amounts to a regression between predicted and observed probabilities, and it minimizes the Brier Score (BS). Initially (April 2016) this was implemented at CPC/NCEP for terciles and has been used since by the forecasters. We here attempt to apply this technique to any point in the pdf. When we talk about extremes we mean from a practical standpoint the 15 and 85% points in the pdf. While the reliability diagram is useful we present a new visual aid more basic than the reliability diagram to show how the PAC works as one moves the exceedance point in the pdf. We obviously encounter many familiar questions such as -) about the low skill for the categorical Near-Normal forecasts (which for BS translates to small probability anomalies (PA), i.e. not just in the N class), -) the higher skill from a signal to noise ratio standpoint in the extreme classes and the extreme PA, -) whether PAC should be applied to each model separately followed by some combination scheme (ad hoc or by a 2nd formal minimization of BS), -) how the results on dependent data are expected to hold up on independent future data, -) how a regression can actually be an inflation (very rare and very curious), etc.

Stratosphere-Troposphere Coupling and NAM Predictability in the NMME Phase-2 Models
Jason C Furtado, University of Oklahoma

The position and strength of the Northern Hemisphere (NH) polar jet stream, measured by the Northern Annular Mode (NAM) index, remains a key element to successful wintertime subseasonal-to-seasonal (S2S) forecasts in the middle and high latitudes. Changes in the NAM directly alter NH mid-latitude weather regimes and can influence extreme winter weather across the NH, particularly in its negative phase. Among several factors, extratropical stratosphere-troposphere coupling dynamics are strongly linked to extended-range NAM predictions and associated winter weather regimes, with potential lead times weeks to months.

This talk examines the characteristics and predictability of the tropospheric and stratospheric NAM via stratosphere-troposphere coupling as simulated in the North American Multi-Model Ensemble Phase-2 (NMME-2) models. The NMME-2 models present mixed performance in capturing the spatiotemporal characteristics of the near-surface and stratospheric NAM and their associated teleconnections. Significant biases exist in the persistence of positive vs negative NAM regimes, the strength of the Atlantic jet stream, and temperature patterns across Eurasia. For the stratosphere, the models forecast a polar vortex that is less variant and somewhat too strong compared to reanalysis. Next, we examine major sudden stratospheric warming (SSW) events, which represent the distortion / destruction of the NH stratospheric polar vortex and precede significant changes in the tropospheric NAM by 2-6 weeks.

Lifecycles of SSW events are examined for simulated (i.e., those in the models) and actual SSW events (i.e., those identified from reanalysis). Model biases in several key facets of SSW events are quantified, including weaker-than-observed wave forcing for SSW initiation, inconsistent post-SSW teleconnections, and poor (or absent) downward propagation signals and persistence of NAM anomalies in the troposphere, a prevalent issue in many coupled climate models. Forecast errors for actual SSW events illustrate the models' inability to capture particularly the post-SSW changes. Taken together, we also offer potential pathways forward for improving the simulation of SSW lifecycles and associated stratosphere-troposphere coupling dynamics in hopes to improve S2S NH winter weather predictions

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Afternoon Poster Presentations

Prediction and Predictability of Extremes at Different Timescales

Teresa Cicerone, George Mason University

This project extends the work done in Becker et al. (2012) by examining the prediction skill of the National Centers for Environmental Prediction (NCEP) Climate Forecast System Version 2 (CFSv2) model on daily and weekly timescales. The focus for this study is model predicted extreme temperature and precipitation events over the Americas for the months of March, June, September, and December; quantified using the anomaly correlation (AC). These spatial and temporal regions were chosen to capture both the northern and southern hemisphere over a full seasonal cycle. Two time series are then generated for analysis; (1) using the entirety of the data and (2) isolating the (extreme) events in the model data that fall in the 5th and 95th percentile. Coinciding with the results in Becker et al. (2012) it is found that the extreme event time series are more skillful compared to the entire time series. As proven in Becker et al. (2012) it is not an artifact of reduced sample size and as shown in this paper, using a simple first order auto-regressive process or an AR(1) process, it is not a statistical artifact occurring by random chance. An analysis is also done to try and see if a teleconnection is present between the extreme events and ENSO.

Assessment of NMME Skill over Southwest Asia and Horn of Africa

Ryan D Smith, 14th Weather Squadron (14WS), Robb M Randall, 14WS; Raymond B Kiess, 14WS; Jeremy P Anthony, 14WS

The 14th Weather Squadron (14WS) is the Department of Defense (DoD)‰Ûªs organization responsible for delivering climate information and services to DoD entities. One of the most recent efforts at 14WS to deliver relevant decision-grade climate information to DoD mission planners has been to introduce long-range forecast capability based on the North American Multi-Model Ensemble (NMME). The National Centers for Environmental Prediction (NCEP) Climate Prediction Center (CPC) currently uses NMME as one of many inputs into their monthly long-range forecast production process. However, whereas CPC‰Ûªs long-range forecast efforts are focused primarily on the Contiguous United States

(CONUS), the DoD operates in many locations throughout the globe outside of CONUS. Recently, extreme drought in Somalia and exacerbated tensions in Syria have caused the focus of DoD military and humanitarian mission planning to shift to the Horn of Africa (HoA) and further remain in Southwest Asia (SWA). The skill of NMME's temperature and precipitation anomaly forecasts is assessed at all available lead times (1-7 months) and over the area including Afghanistan, Iran, Iraq, Syria, Pakistan, Jordan, the Arabian Peninsula, Djibouti, Somalia, Ethiopia, and Kenya. The operational forecasts from August 2011 ‰ÛÒ June 2017 will be considered. Ranked Probability Skill Score (RPSS) is used to assess the skill of the adjusted probabilistic forecasts, and a skill score based on the root mean squared error (RMSE_SS) is used for the deterministic anomaly forecasts.

Evaluation of GEOS5-S2S-2.1 seasonal forecast

Zhao Li, GSFC-GMAO, Andrea Molod

In recent years, sub seasonal to seasonal (S2S) forecasts are in increasing demand to provide scientific base for various policy making and business decisions. A comprehensive understanding of the strength and the limitations of current S2S forecast capability plays a vital role in forecast application, uncertainty assessment and model improvement. This study analyzes monthly data of the retrospect hindcast from NASA-GMAO's new S2S forecast system GEOS5-S2S-2.1. Statistical metrics such as forecast bias, skill, predictability and reliability of precipitation, surface air and sea-surface temperatures, zonal and meridional wind at 200mb etc are performed and compared with observational/reanalysis data, previous GEOS-Fortuna forecast as well other NMME models as first assessment of the capability of GEOS5-S2S-2.1 in seasonal forecasting

Skillful climate forecasts of the tropical Indo-Pacific using model-analogs

Matthew Newman, University of Colorado/CIRES and NOAA/ESRL/PSD, Hui Ding (University of Colorado/CIRES and NOAA/ESRL/PSD), Michael Alexander (NOAA/ESRL/PSD), and Andrew Wittenberg (NOAA/GFDL)

This presentation explores the idea that seasonal forecasts made by coupled general circulation models (CGCMs), at lead times where skill is significantly impacted by model climate drift, should be initialized directly in the model's phase space rather than in the phase space of nature. Here, a simple analog approach is tested, in which an ensemble of model states closest to each observed initial state is determined from a data library taken from long control simulations of CGCMs corresponding to the forecast CGCMs. The forecast is then just the ensemble mean of the evolution of those model states. This model-analog technique is applied to four of the eight CGCMs comprising the North American Multimodel Ensemble (NMME). Model-analogs are determined over the tropical IndoPacific domain, using monthly SST and SSH anomalies. The resulting perfect-model skill of the model-analogs, including a NiÌ±o3.4 correlation above 0.5 for forecast leads up to 24 months, matches other perfect-model potential predictability studies. The technique is then applied to make hindcasts for the years 1982-2009 for leads of 1-12 months, initializing with observed anomalies over that period. The model-analog hindcast skill is comparable to (even sometimes better than) the corresponding CGCM hindcast skill throughout the tropical Pacific both for the individual model ensemble means and, when the model-analog hindcasts are averaged together, to the grand NMME mean. This suggests that any CGCM with a sufficiently long control run may be used to produce skillful forecasts of monthly tropical IndoPacific SST anomalies, before additional development of its data assimilation system or generation of forecast ensembles.

Evaluating the MJO forecast skill in the NCEP GEFS 35-day Experiments

Wei Li, NOAA EMC and IMSG, Xiaqiong Zhou, Yuejian Zhu, Malaquias PeÌ±a, Dingchen Hou, Hong Guan, Eric Sinsky and Christopher Melhauser

NOAA is accelerating its efforts to improve the numerical guidance and prediction capability for extended range (week3&4) prediction in its seamless forecast system. As a dominant mode of tropical variability and has been found as a source of the sub-seasonal predictability, the Madden-Julian Oscillation (MJO) forecast skill is investigated in this work.

The NCEP Global Ensemble Forecast System (GEFS) based on the Global Forecast System (GFS) model is used to perform the experiments. The configurations of the four experiments include: 1). The operational version of the stochastic perturbations forced with operational SST (STTP); 2) An updated stochastic physics (SKEB+SPPT+SHUM) forced with operational SST (SPs); 3). An updated stochastic physics (same as SPs) forced with bias corrected CFSv2 forecast SST (SPs+CFSBC); and 4). An updated stochastic physics (same as SPs) forced with bias corrected CFSv2 forecast SST using a scale aware-convection scheme (SPs+CFSBC+SA-CNV) in GFS. Each of the four experiments include 21 members and are integrated for 35 days initialized from May 1st, 2014 to May 26, 2016 every 5 days.

We evaluated the Wheeler Hendon MJO forecast skill and examined the performance of the forecast system on the forecast skill of the MJO key components. Compared to the operational version of GEFS, GEFS with the updated stochastic scheme (SPs) improved the MJO forecast skill by ~4 days. Further updating the underlying SST (SPs+CFSBC) and convection scheme (SPs+CFSBC+SA-CNV) led to an improvement of MJO skill by an additional 2 days and 3 day, respectively. Consistent with the performance of the MJO skill, analysis of the three MJO variables (OLR, zonal wind at 850 hPa and 200 hPa) also indicated an evident improvement of the skill in all three SPs experiments, with the best performance in SPs+CFSBC+SA-CNV, especially for lead times beyond two weeks. Future analysis will focus on the MJO skill with bias-correction. GEFS extended forecast will be part of NCEP CPC/CTB's NMME for sub-seasonal prediction.

California Drought and the 2015-2016 El NiÌ±o

Benjamin Cash, GMU/COLA

California winter rainfall is examined in observations and the NMME data, with an emphasis on the 2015-2016 season. We find that the multimodel ensemble mean (MMEM), as well as the ensemble mean for individual models, over-emphasizes the influence of El Niño events on southern California winter rainfall. We show that currently unpredicted variations in geopotential heights off the west coast strongly influence seasonal rainfall totals. Improving prediction of these variations is thus a key target for improving seasonal rainfall predictions for this region.

GEFS tropics to extratropics teleconnections in the Northern Hemisphere

Malaquias Pena, IMSG-EMC/NCEP and U. of Connecticut, Yuejian Zhu and Yan Luo

Numerous studies have shown that tropical heating associated with MJO induces atmospheric circulation anomalies that propagate to the extratropics via Rossby wave trains. Using daily OLR and reanalysis data quantitative assessments of surface temperatures in the Northern Hemisphere have been linked to meridionally propagating waves particularly during the boreal winter. We examine the simulation quality of these features in the GEFS-Legacy and in the GEFS 35-days. Our results indicate that the teleconnection features in the model though different from observations maintain a strong resemblance with realistic tropics to extra tropics relationship strengths.

Assessing the Sources of Subseasonal to Seasonal Predictability in the Climate Forecast System Version 2

Zhuo Wang, University of Illinois at Urbana-Champaign, Doug Miller, University of Illinois at Urbana-Champaign

Low frequency climate modes are a key source of predictability on the subseasonal to seasonal time scales, and such modes may modulate prediction skill of the mid-latitude atmosphere. The 200-hPa geopotential height from the Climate Forecast System Version 2 (CFSv2) reforecasts are used to assess the effects that low frequency climate modes have on the northern hemisphere winter predictability. In addition, the representation of teleconnections between tropics and extratropics in the CFSv2 are evaluated through the analysis of 200-hPa geopotential height, precipitation rate, and sea surface temperature data, with the objective to identify the windows of high predictability and assist in model improvements.

Improving NMME seasonal forecast skill through Calibration, Bridging, and Merging (CBaM)

Sarah Strazzo, CPC, Dan Collins (CPC), Andrew Schepen (CSIRO), Q.J. Wang (U. Melbourne)

Recent research suggests that the observed relationship between the El Nino/Southern Oscillation (ENSO) and North American wintertime 2-m temperature is not consistently reproduced by the members of the North American Multi-Model Ensemble (NMME), particularly across large swaths of the northern United States. This inability to capture an important teleconnection contributes to poor model forecast skill over these regions during the winter season (December-February, DJF). We show that application of statistical post-processing leads to improvements in forecast skill. Specifically, we apply the Calibration, Bridging, and Merging (CBaM) framework described by Schepen et al. (2014) and Schepen et al. (2016) to post-process NMME forecasts of North American temperature. We calibrate the NMME by applying Bayesian joint probability (BJP) modeling to the NMME hindcast and observed North American 2-m temperature data. Also developed within the BJP framework, bridging models use NMME forecasts of relevant climate indices (e.g., ENSO) as predictors of North American temperature. Bridging and calibration models are first developed separately and then merged using Bayesian model averaging to yield an optimal forecast. We implement bridging using NMME forecasts of the NiÌ±o 3.4 index to correct for discrepancies in NMME representations the ENSO-temperature teleconnection over North America. We apply the CBaM method to both NMME hindcast and real-time data. We find that although calibration generally yields more skillful 1-month lead forecasts for most of the overlapping three-month seasons, bridging improves upon calibrated model skill for forecasts of DJF 2-m temperature. The largest improvements occur over portions of the northern United States, where the observed ENSO teleconnection is not well-represented by the NMME models. As expected, merged forecasts achieve the highest skill scores. Overall, the improvements in skill are modest but, for some regions, statistically significant.

Seasonal Prediction of Atmospheric Rivers in the NMME

Yang Zhou, Stony Brook University, Hye-Mi Kim, Stony Brook University

Atmospheric Rivers (ARs) are spatially elongated narrow plumes of tropic-to-midlatitude moisture transport that are closely related with winter storms. The water resources in the coastal regions like the west coast of US and the western Europe are greatly influenced by AR activities, which makes the seasonal prediction of ARs urgent. Prediction skills of the wintertime ARs and moisture flux over the Northeast Pacific and the North Atlantic in response to El NiÌ±o Southern Oscillation (ENSO) forcing are evaluated from the North American Multi-Model Ensemble (NMME) hindcasts (CFSv2, CCSM4, CanCM3, CanCM4, GEOS5, and GFDL CM2.1). The skill is estimated for the active AR season, December-February (DJF) with initial conditions around early November. ENSO predictions are generally good but the asymmetry between El Niño and La Niña is underpredicted. Models underestimate the climatological moisture flux to different extents corresponding with various climatological biases in predictions of sea surface temperature (SST) and large-scale atmospheric circulation fields. The anomalous moisture flux and AR frequency over the Northeast Pacific are predicted in models but in weaker amplitude than the reanalysis. Large bias appears in AR predictions over the North Atlantic. Significant regional biases are shown in the anomalous landfalling AR frequency corresponding with ENSO, underlining the challenge in regional precipitation forecasts.

Assessing subseasonal to seasonal prediction of storm track activity using NMME daily hindcast data

Edmund Chang, Stony Brook University

Extratropical cyclones form an important part of the global circulation. They are responsible for much of the high impact weather in the mid-latitudes, including heavy precipitation, strong winds, and coastal storm surges. They are also the surface manifestation of baroclinic waves that are responsible for much of the transport of momentum, heat, and moisture across the mid-latitudes. Thus accurate prediction of storm track activity is of great importance. Previous efforts have focused on short term prediction out to about 10 days, or long term projection of how storm tracks may change under global climate change. The in-between weeks to months time scale has largely been ignored. With the availability of NMME data, subseasonal to seasonal prediction of storm track activity has become possible. This study makes use of daily hindcast data to assess how well storm track activity is predicted by the NMME system. In this study, the skill of climate prediction model ensembles in predicting storm track activity in the subseasonal to seasonal time scale has been assessed using NMME reforecast data. Direct dynamical model predictions have also been compared to statistical predictions constructed based on model predictions of the sea surface temperature (SST) and monthly/seasonal mean flow. Our results show that significant skill can be found out to 6 months (the longest lead examined) over North America, which appears to be the most predictable region due to influence of the El Nino Southern Oscillation. More details will be discussed in the presentation.

FRIDAY

Morning Oral Presentations

Seasonal Arctic sea ice in the NMME

Kirstin Harnos, NOAA CPC/Innovim LLC, Michelle L'Heureux (NOAA CPC), Qin Zhang (NOAA CPC), Qinghua Ding (UCSB)

Given the potential ecological and socio-economical impacts, prediction of seasonal Arctic sea ice has become a topic of high interest for both research and forecasting applications. Previous studies have extensively highlighted two aspects of sea ice prediction: The majority of skill comes from accurately capturing the long term trends in sea ice extent (SIE) and using a multi-model ensemble provides skillful improvements to prediction. With the NMME already providing operational guidance to forecasts for other variables, it is logical to explore the potential usefulness for future Arctic sea ice prediction. Here five NMME models (CanCM3, CanCM4, CFSv2, FLORB-01, and CCSM4) are utilized to provide analysis on the NMME representation of SIE in terms of the climatology, long term trend, interannual variability, and prediction skill.

Seasonal Forecasts for Fisheries Applications

Desiree Tommasi, NOAA SWFSC

The productivity and distribution of fish populations is strongly influenced by climate variability. The inability of fisheries managers to anticipate such environment-driven fluctuations in fish dynamics can lead to overfishing and stock collapses. Here we demonstrate how recent advances in global dynamical climate prediction systems have allowed for skillful sea surface temperature anomaly predictions at a scale useful to understanding and managing fisheries. Such predictions present opportunities for improved fisheries management and industry operations. Pioneering case studies demonstrating the utility of seasonal climate predictions to inform fisheries decisions will be highlighted. We conclude by offering remarks on priority developments required for the expanded use of climate predictions for fisheries management.

Morning Poster Presentations

Sub-seasonal to seasonal climate forecast products for hydrology and water management

Andy Wood, NCAR, Sarah Baker (U. of Colorado), Balaji Rajagopalan (U. of Colorado), Peitao Peng (NOAA/CPC)

The potential value of operational climate forecast from efforts such as the National Multi-Model Ensemble (NMME) system for sub-seasonal to seasonal (S2S) prediction has not yet been realized by stakeholders in the water management sector. Key hurdles include: (1) products not aligned with users space-time analysis needs (which often follow specific watershed boundaries): (2) products in formats that users cannot easily process into their analysis tools; (3) products based on raw model outputs are biased relative to user climatologies; and (4) product verification is primarily tailored toward forecast producer diagnostic needs. In each of these areas, more can be done to bridge the gap with potential stakeholders and enhance quality, specificity, and accessibility - hence usability - of NMME predictions. In addition to climate-scale variations, water stakeholder impacts often arise from short-range extremes (such as 2-3 day storms or 1-week heat waves) for which few products exist at S2S time-scales. Weather-scale events are inherently uncertain at S2S lead times, but there may be value for stakeholders in probabilistic products describing the potential for short-term extremes to occur at these lead times (an analogy is the seasonal prediction of the number of land-falling hurricanes).

We present interim results of a development effort to address the hurdles to water stakeholder adoption described above and also to explore opportunities for extremes prediction at S2S time scales. The project will use NMME reforecasts to train post-processing approaches to enhance the skill and reliability of the raw real-time forecasts, where possible. A set of prototype S2S water sector climate data products (forecasts and associated skill analyses) are now being operationally generated at NCAR and staged to a public website to facilitate further product development through interactions with water managers and hydrologic prediction centers. Initial demonstration products are based on the CFSv2 45-day ensemble predictions, and include bi-weekly climate forecasts (weeks 1-2, 2-3, and 3-4) for sub-regional scale hydrologic units (204 HUC2s cover the CONUS domain). Raw model mean skill at these time-space resolutions for weeks 3-4 is unusably low, but for weeks 2-3, both temperature and prediction exhibit skill at levels sufficient to benefit the water sector.

Seasonal scale water deficit forecasting in Africa and the Middle East

Dr. Kristi R. Arsenault, SAIC, Inc.; NASA/GSFC, Shraddhanand Shukla (UCSB), Augusto Getirana (UMD/ESSIC), Sujay V. Kumar (NASA/GSFC), Ben F. Zaitchik (JHU), Hamada S. Badr (JHU), Chris Funk (UCSB, USGS), Randal Koster (NASA/GSFC), and Christa Peters-Lidard (NASA/GSFC)

Drought and water scarcity are among the important issues facing several regions within Africa and the Middle East. A seamless and effective monitoring and early warning system is needed by regional/national stakeholders. We present on the ongoing development and validation of a seasonal scale water deficit forecasting system based on seasonal climate forecasts, including those from the NMME forecast modeling systems, and NASA's Land Information System (LIS). This drought forecasting system uses seasonal climate forecasts from NASA's GMAO (the Goddard Earth Observing System Model, version 5) and NCEP's Climate Forecast System, version 2, and it produces forecasts of soil moisture, ET and streamflow out to six months in the future. Forecasts of those variables are formulated in terms of indicators to provide forecasts of drought and water availability in the region.

Seasonal climate forecasts are first bias-corrected and downscaled to 0.25 deg resolution using reanalysis datasets (e.g., MERRA-2) and observation-based data (e.g., CHIRPS v2), and then they are used to drive offline land surface models to derive the hydrological and agricultural drought forecast indicators. Comparison of the individual and ensemble of those drought forecast indicators against independent observations in these regions are presented. Finally, we highlight our ongoing collaboration with end-user partners in the region (e.g., USAID's Famine Early Warning Systems Network, FEWS NET), and on formulating meaningful early warning indicators related to monitoring and forecasting products.

An Intercomparison of Arctic Sea-ice predictability based on CanCM3, CanCM4, CFSv2 and GEM-NEMO hindcasts

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Seasonal forecasting of sea-ice concentration is of great importance in the Canadian northern regions and Saint Lawrence Gulf. Many aspects of life such as regional climate and industries driven by transportation depend on correct forecast of sea-ice concentration. In this work we assess historical (1981-2010) sea-ice concentration hindcasts from a suite of climate models in order to compare their respective historical performances over the Arctic region. We assess Environment and Climate Change Canada's models: CanCM3, CanCM4 and GEM-NEMO along with NOAA's CFSv2 and also their combination (MME). Possibilities for the future real time forecasts over the Arctic region using multimodel approach will be discussed in the context of the Polar Regional Climate Center. Monthly mean biases and anomaly correlations against analysis will be shown up to 5-month long lead times.

Description and Initial SubX results from the Navy Earth System Model (NESM)

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The Navy Earth System Model (NESM) developed by the Naval Research Laboratory is currently contributing to the NOAA SubX project. NESM is a global coupled model that includes an atmosphere component - NAVy Global Environmental Model (NAVGEM), an ocean component - HYbrid Coordinate

Ocean Model (HYCOM), and a sea ice component - Community Ice CodE (CICE). NESM is unique compared to other global coupled models in that the ocean model is fully eddy resolving: ~ 9km resolution at the equator, ~7 km in the mid-latitudes. In addition, the atmospheric model is fairly high resolution (about 37 kilometers). For the SubX project, four time-lagged 45 day forecasts are performed once a week and retrospective forecasts are performed from 1999 to 2015. Initialization for the hindcast runs differ slightly depending on year, and results show that skill at 2 days is affected by the changes in initialization while 10-20 day forecast skill is fairly consistent throughout the hindcasting period. In addition to evaluating systematic bias analysis, we will quantify the NESM predictive skill in simulating the Madden Julian Oscillation (MJO) in the sub-seasonal range.

Indian Summer Monsoon Variability Forecasts in the North American Multimodel Ensemble (NMME)

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The representation of seasonal mean and interannual variability of the Indian summer monsoon rainfall (ISMR) in Nine global ocean-atmosphere coupled models participated in the North American Multimodal Ensemble (NMME) phase 1 (NMME:1) and Nine global ocean-atmosphere coupled models participating in the NMME phase 2 (NMME:2) from 1982-2009 is evaluated over the Indo-Pacific domain with May initial conditions. The multi-model ensemble (MME) represents Indian monsoon rainfall with modest skill and systematic biases. There is no significant improvement in the seasonal forecast skill and interannual variability of ISMR in NMME:2 as compared to NMME:1. The NMME skillfully predicts seasonal mean sea surface temperature (SST) and some of the teleconnections with seasonal mean rainfall. However, SST-rainfall teleconnections are stronger in the NMME than observed. The NMME is not able to capture the extremes of seasonal mean rainfall and the simulated Indian Ocean-monsoon teleconnections are opposite to what are observed.

Using NMME temperature forecasts to improve seasonal streamflow forecasts in the Colorado and Rio Grande basins

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Recent studies document an increasing influence of temperature on streamflow across the American West, including snow-melt driven rivers such as the Colorado or Rio Grande. At the same time, some basins are reporting decreasing skill in seasonal streamflow forecasts, termed water supply forecasts (WSFs), over the recent decade. While the skill in seasonal precipitation forecasts from dynamical models remains low, the little skill there is in seasonal temperature forecasts could potentially be harvested for WSFs. Here, we investigate whether WSF skill can be improved by incorporating seasonal temperature forecasts from NMME into traditional statistical streamflow models. We find improved skill relative to traditional WSF approaches in a majority of headwater locations in the Colorado and Rio Grande basins, especially at longer lead times. Incorporation of temperature into WSFs thus provides a promising avenue to increase the robustness of current forecasting techniques in the face of continued warming.

S2S Prediction Skill in a developing Unified Global Coupled System at NCEP

Suranjana Saha, EMC/NCEP, Christopher Melhauser, Malaquias Pena and Huug van den Dool

NCEP's mission for S2S prediction requires developing a successor model to the present operational CFSv2. For several years, a concerted effort has taken place, both internal and external to EMC/NCEP, to create the infrastructure of a multi-component global coupled system in the NEMS framework. The UGCS is currently composed of the atmospheric spectral GSM coupled with the MOM5.1 ocean model and the CICE sea ice model. The land surface model is still internal to the GSM. This configuration will change when the spectral dynamics are replaced by the FV3 dynamic core. The ocean model will also be upgraded to MOM6. A verification module has been developed to validate the UGCS as it evolves and converges to its final configuration. This module consists of generating 144 35-day forecasts from the 1st and the 15th of each month, over a 6-year period from April 2011 to March 2017. Calibration climatologies are prepared for all variables being studied by fitting four harmonics and the mean to the model time series, as well as to the matching observed time series used for verification. The studied variables include z500, SST, T2m and PRATE, as well as U850, U250 and OLR to study MJO prediction. Forecasts of the various configurations and the control operational CFSv2 are compared in terms of RMSE and AC, both with and without systematic error correction (SEC). Special emphasis is given to NH z500, US-land T2m and PRATE verified against CPC daily observations, and SST and PRATE for the Nino3.4 area. Global maps of skill are also made for each variable for week 1, week 2, week 3, week 4 and combined weeks 3&4. Preliminary results show that the new system, without any type of tuning, is equal to or better than the control operational CFSv2 over the last 6 years. In the near future, the final configuration will be fine-tuned for optimal performance, especially with regard to the physics

Statistical-dynamical seasonal forecast of North Atlantic and U.S. landfalling tropical cyclones using the GFDL FLOR coupled model

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Retrospective seasonal forecasts of North Atlantic tropical cyclone (TC) activity over the period 1980-2014 are conducted using a GFDL high-resolution coupled climate model [Forecast-Oriented Low Ocean Resolution (FLOR)]. The focus is on basin-total TC and U.S. landfall frequency. The correlations between observed and model predicted basin-total TC counts range from 0.4 to 0.6 depending on the month of the initial forecast. The correlation values for U.S. landfalling activity based on individual TCs tracked from the model are smaller and between 0.1 and 0.4.

Given the limited skill from the model, statistical hybrid methods are developed to complement the dynamical seasonal TC prediction from the FLOR model. These models use large-scale climate predictors from the FLOR model as predictors for generalized linear models. The hybrid models show considerable improvements in the skill in predicting the basin-total TC frequencies relative to the dynamical model. The new hybrid model shows correlation coefficients as high as 0.75 for basin-wide TC counts from the first two lead months and retains values around 0.50 even at the 6-month lead forecast. The hybrid model also shows comparable or higher skill in forecasting U.S. landfalling TCs relative to the dynamical predictions. The correlation coefficient is about 0.5 for the 2-5-month lead times.

Initialization of dynamic phenology variables in a subseasonal forecast system
Randal Koster, Yehui Chang, Sarith Mahanama, and Greg Walker of GMAO, NASA/GSFC

Past work demonstrated that incorporating a dynamic vegetation phenology module into the GEOS-5 modeling system and initializing the associated carbon reservoirs with observations-based values lends skill, at least in some places, to monthly forecasts of 2-meter air temperature. Here we review this work and describe updated research into this question using the most recent version of the GMAO subseasonal forecast system.

Prediction and predictability of the Madden Julian Oscillation in the NASA GEOS-5 seasonal-to-subseasonal system
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In this study, we examine the prediction skill and predictability of the Madden Julian Oscillation (MJO) in a recent version of the NASA GEOS-5 atmosphere-ocean coupled model run at ~1/2 degree horizontal resolution. The results are based on a suite of hindcasts produced as part of the NOAA SubX project, consisting of seven ensemble members initialized every 5 days for the period 1999-2015. The atmospheric initial conditions were taken from the Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2), and the ocean and the sea ice were taken from a GMAO ocean analysis. The land states were initialized from the MERRA-2 land output, which is based on observation-corrected precipitation fields.

We investigated the MJO prediction skill in terms of the bivariate correlation coefficient for the real-time multivariate MJO (RMM) indices. The correlation coefficient stays at or above 0.5 out to forecast lead times of 26-36 days, with a pronounced increase in skill for forecasts initialized from phase 3, when the MJO convective anomaly is located in the central tropical Indian Ocean. A corresponding estimate of the upper limit of the predictability is calculated by considering a single ensemble member as the truth and verifying the ensemble mean of the remaining members against that. The predictability estimates fall between 35-37 days (taken as forecast lead when the correlation reaches 0.5) and are rather insensitive to the initial MJO phase. The model shows slightly higher skill when the initial conditions contain strong MJO events compared to weak events, although the difference in skill is evident only from lead 1 to 20. Similar to other models, the RMM-index-based skill arises mostly from the circulation components of the index. The skill of the convective component of the index drops to 0.5 by day 20 as opposed to day 30 for circulation fields. The propagation of the MJO anomalies over the Maritime Continent does not appear problematic in the GEOS-5 hindcasts implying that the Maritime Continent predictability barrier may not be a major concern in this model. Finally, the MJO prediction skill in this version of GEOS-5 is superior to that of the current seasonal prediction system at the GMAO; this could be partly attributed to a slightly better representation of the MJO in the free running version of this model and partly to the improved atmospheric initialization from MERRA-2.