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Tracking Progress on NOAA's MAPP-CTB Projects: Accelerating Transition of Research Advances into Improved Operational Capabilities

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1. Introduction

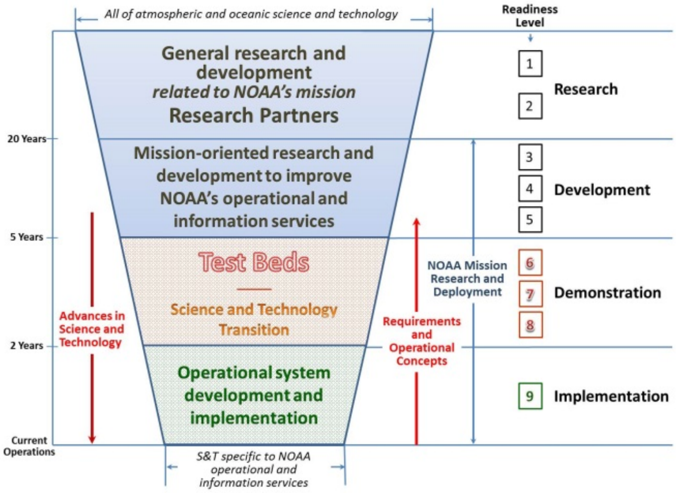

Fig. 1 NOAA research and development funnel. (MacDonald *et al.* 2006)

NOAA's operational climate monitoring and prediction products provide the public with critical information about environmental conditions for better preparedness and improved resiliency. NOAA's Modeling, Analysis, Predictions and Projections - Climate Test Bed (MAPP-CTB) projects support transition of research advances from external community to National Centers for Environmental Prediction (NCEP) to accelerate the improvement of operational climate monitoring and predictions (Fig. 1). Three focus areas are 1) testing the performance of model components and schemes of methodologies, 2) testing experimental prediction methodologies and products, and 3) testing a multi-model subseasonal climate prediction system via model selection, system optimization and products evaluation. By tracking progresses on twenty-three MAPP-CTB projects, this presentation assesses the Transition Readiness Level (TRL) via measurements of benchmarks and deliverables following NOAA Administrative Order 216-105B (NOAA 2016), meanwhile highlights major achievements to date beyond the development phase (TRL > 5).

2. Performance of model components and schemes of methodologies

Targets:

i) Model components critical to subseasonal-to-seasonal (S2S) prediction
ii) Representation of predictability sources
iii) Parameterization of subgrid scale dynamic-thermodynamic processes
iv) Data assimilation

Projects status:

Model Components and Schemes	Research Developer	Operation Beneficiary	TRL
1. Flash lake model	USU	CFS	6
2. Community Noah-MPv2 LSM	NCAR	CFS	7
3. NASA GMAO's physically-based cloud/aerosol packages	SUNY	GFS,CFS	6
4. Cloud and boundary layer processes	UW, JPL	GSF, CFS	7
5. Turbulence and cloud processes	UU	GSF, CFS	6
6. Land Information System	NASA	NLDAS	5

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7. MOM6/SIS2 Hybrid-GODAS (eddy permitting)	UMD	GODAS	5
8. Coupled wave-Ocean System	GFDL	CFS, NGGPS	5
9. LETKF assimilation for sea ice analysis and forecasting	UMD	CFS, NGGPS	5

Progress reports:

Project 1 Flash lake (Flake) model (PI: J. Jin)

- The offline Flake model is improved to better simulate lake ice.
- The lake ice simulations are significantly improved in the coupled CFS-Flake model for the Great Lakes.
- The near-surface air temperature for winter and early spring is better predicted with different forecast leads (Fig. 2).

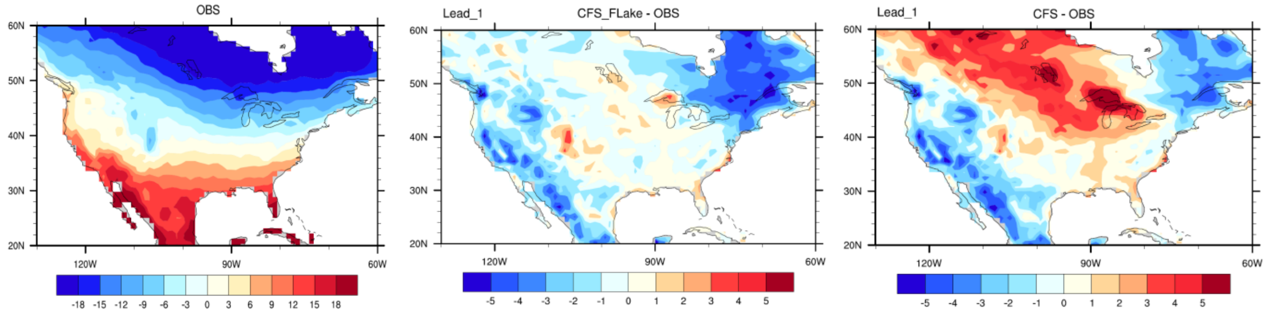


Fig. 2 One-month-lead two meter height temperature ensemble forecasts over North America averaged for JFM 2014. The left panel is for observation. The rest two panels are for the differences of forecast by CFS-Flake (middle) and CFS (right) minus observation, respectively.

Project 2 Community Noah-MP (Multiple Parameterization) version 2 land surface model (LSM) (PI: F. Chen)

- CFS land-surface modeling system is enhanced with new global land-use and land-cover (LULC) and soil texture data. Consistent with recent community efforts to improve the specification of surface characteristics.
- Preliminary CFS reforecast results show encouraging signs of positive impact of using Noah-MP with ground-water and dynamic vegetation parameterizations on CFS prediction skills in precipitation and surface temperature (Fig. 3).

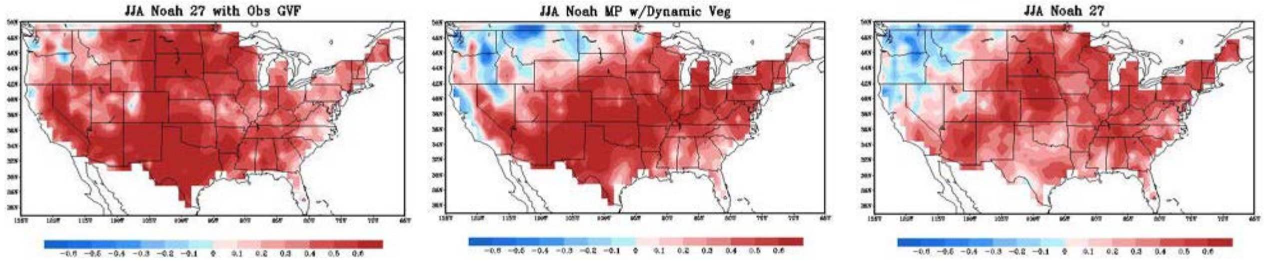


Fig. 3 Anomaly correlation skill of averaged JJA 2-m temperature over CONUS from CFS experiments of using satellite-based GVF in Noah (left) and Noah-MP with dynamic vegetation (middle), comparing with CFS control (right).

Project 3 NASA Global Modeling and Assimilation Office (GMAO)'s physically-based cloud/aerosol packages (PI: S. Lu)

- NOAA Environmental Modeling System (NEMS) Global Forecast System (GFS) physics suite is upgraded. GMAO's physically-based aerosol and cloud microphysics package (Modal Aerosol Model (MAM) aerosol scheme; Morrison-Gettelman (MG) cloud microphysics; and cloud condensation nuclei in cloud (CCN/IN) activation) are implemented, tested and evaluated in NEMS GFS (Fig. 4).

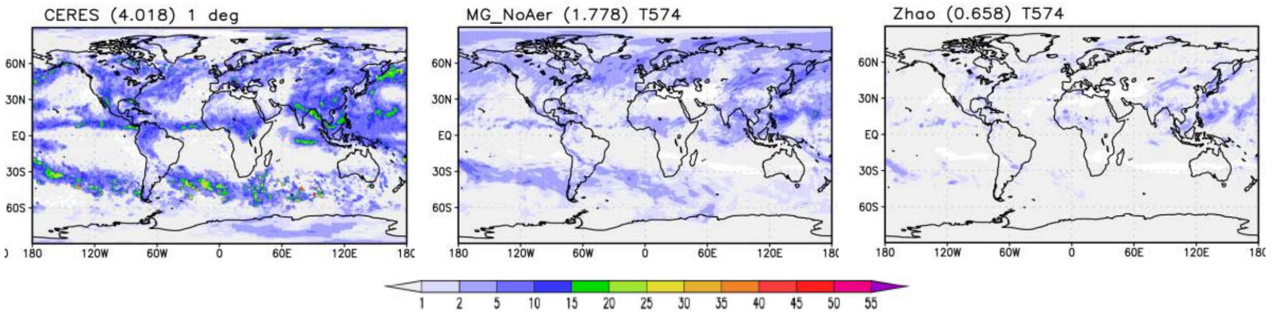


Fig. 4 High-level cloud optical depth from NEMS GFS runs (Clouds and the Earth's Radiant Energy System (CERES) estimates (left), MG_NoAER (middle), and CTRL (right),) averaged for Aug 10-17, 2016.

<u>Project 4</u> Cloud and boundary layer processes (Lead PI: C. S. Bretherton)

- Further development of moist eddy diffusion-mass flux (EDMF) scheme implemented in GFS and port to the Finite-Volume on a Cubed-Sphere Dynamical Core (FV3) model almost complete.
- Further tuning of Thompson microphysics scheme implemented in GFS, which now improves CONUS precipitation skill scores compared to the operational model (Fig. 5). Ported to FV3.

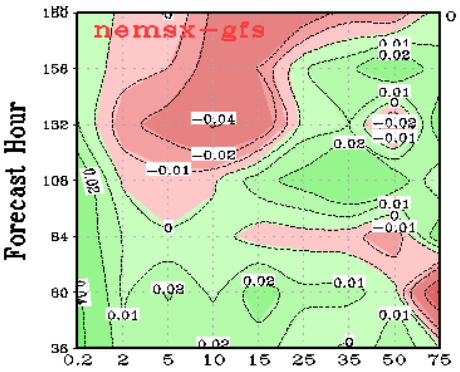


Fig. 5 Modified Thompson cloud microphysics improves GFS precipitation skill over CONUS, as measured by the equitable threat score (ETS). The horizontal axis is precipitation in mm/day. The green regions show improvement. For almost all precipitation intensities at forecast leads up to 72 hours, the ETS is improved by about 5%.

<u>Project 5</u> Turbulence and cloud processes (Lead PI: S.K. Krueger)

- To improve the prediction of the high-level tropical cloud fraction, which is too large in the SHOC (Simplified Higher-Order Closure) test runs with the GFS, SHOC was modified to include two new prognostic equations for variances of total water and static energy; meanwhile the source terms for total water variance were diagnosed from a Giga LES, and a simplified representation of the impact of detrainment of total water on the variance developed.
- Algorithms were developed that efficiently sample the distribution of cloud condensate diagnosed by SHOC for radiative transfer calculations. The algorithms have been tested against a time series of SHOC parameters fit to tropical deep convection (giga-large-eddy simulation (Giga-LES) simulations using high resolution (100-m horizontal grid size) and large domain (200 km by 200 km). (Fig. 6).

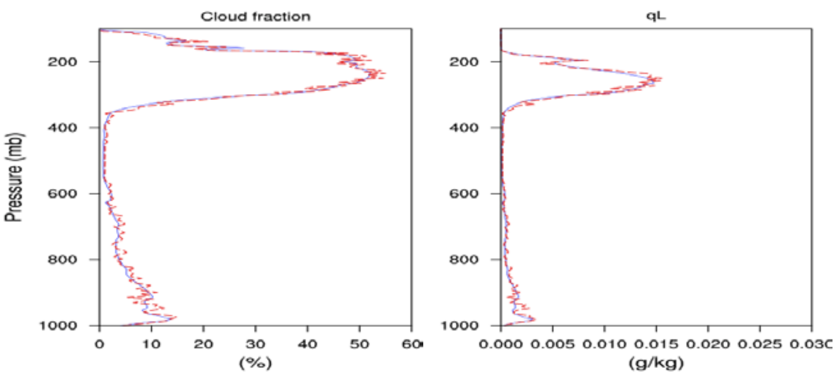


Fig. 6 The figure shows domain-mean profiles of cloud fraction (left panel) and cloud liquid water content (right panel) obtained directly from the simulation (blue), and as reproduced by Monte Carlo methods (red) using 250 samples. The instantaneous errors are a few percent in cloud fraction and a few mg/kg in cloud water content.

- The closure for updraft fraction for multiple updraft types was tested by using a large-eddy simulation of deep convection in a large domain.

3. Experimental prediction methodologies and products

Targets:

i) Prediction of extreme events
ii) New tools and ideas
iii) Products for End-user needs

Projects status:

Monitoring and Prediction Methodologies	**Research Developer**	**Operation Beneficiary**	**TRL**
10. CFS-based severe weather forecast tools	CU	CPC	**7**
11. Week 3 & 4 T and P forecast products	UCSD	CPC	**8**
12. Flash drought monitoring processes	UCLA	CPC in real-time	**7**
13. Subseasonal Excessive Heat Outlook System for global tropics and subtropics	UMD/ESSIC	CPC	**6**
14. Water sector applications of S2S climate products	NCAR	CPC	5
15. Calibration, bridging and merging (CBaM) for S2S prediction	CPC	CPC	5
16. Application of seasonal climate forecast to wildland fire management in Alaska	UAF	CPC, NWS/AR	5

Progress reports:

Project 10 CFS-based severe weather forecast tools (PI: M.K. Tippett)

- Assessment of skill of monthly forecasts for NOAA regions (Fig. 7).
- Case studies examining the relation between forecast consistency for notable events.
- Upward trends in number of tornado reports per outbreak.

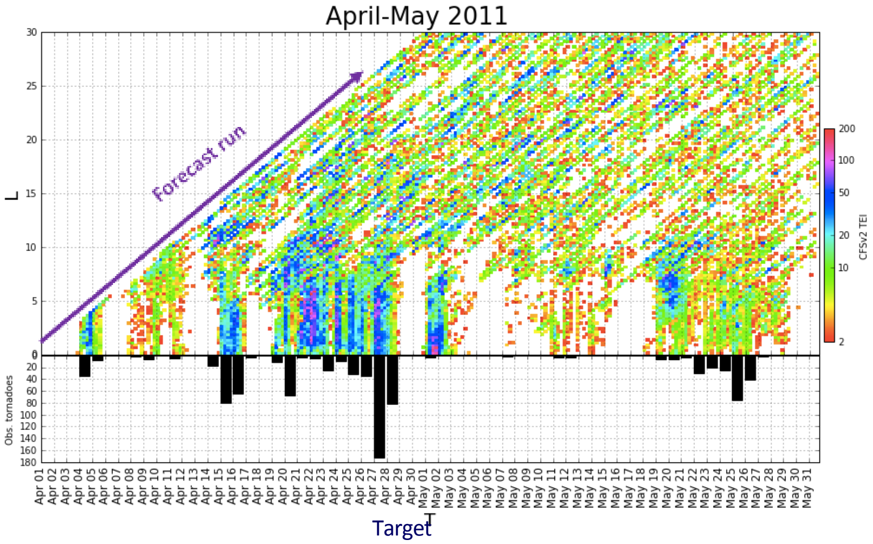


Fig. 7 CFSv2 forecasts (colors) of daily Tornado Environment Index (TEI) summed over the US at varying lead during the period April-May 2011 when historic and deadly tornado outbreaks occurred. Bar plot shows the number of tornadoes reported on the corresponding day. It shows good indications of active/inactive periods at around the 10-day lead and fairly accurate timing around the 5-day lead mark.

Project 11 Week 3 & 4 T and P forecast products (Lead PI: S.-P. Xie)

- Continued monitoring and demonstration of skill of the MJO/ENSO statistical models in CPC's Experimental Week 3-4 temperature and precipitation outlooks (Fig. 8).

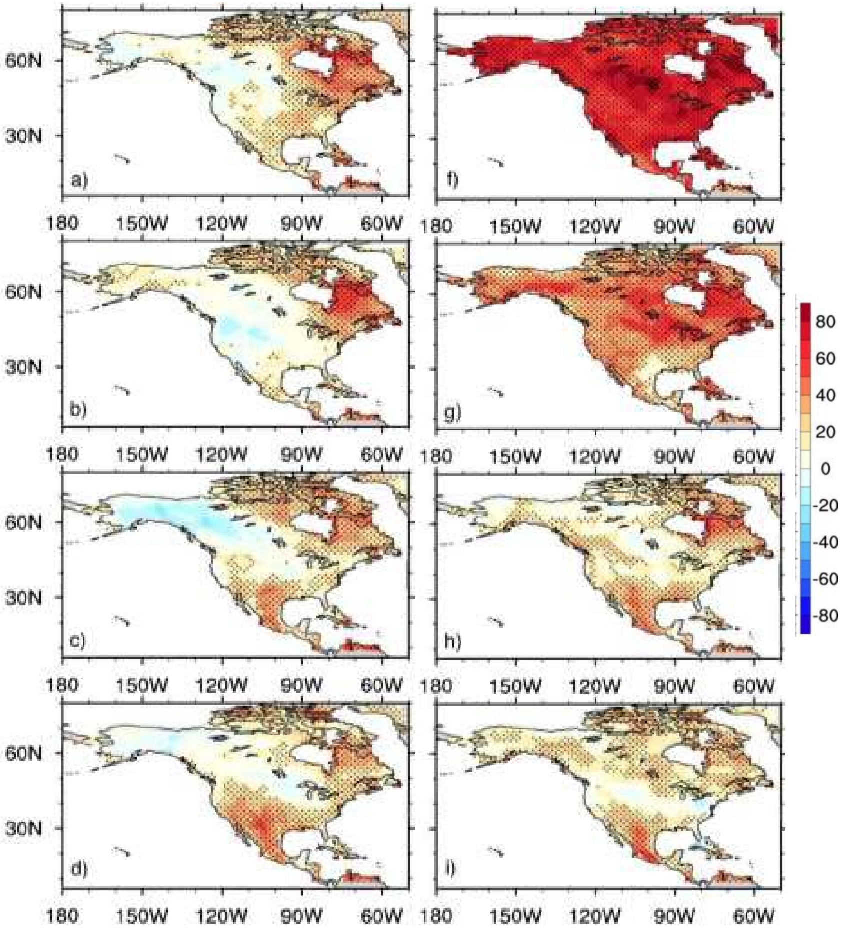
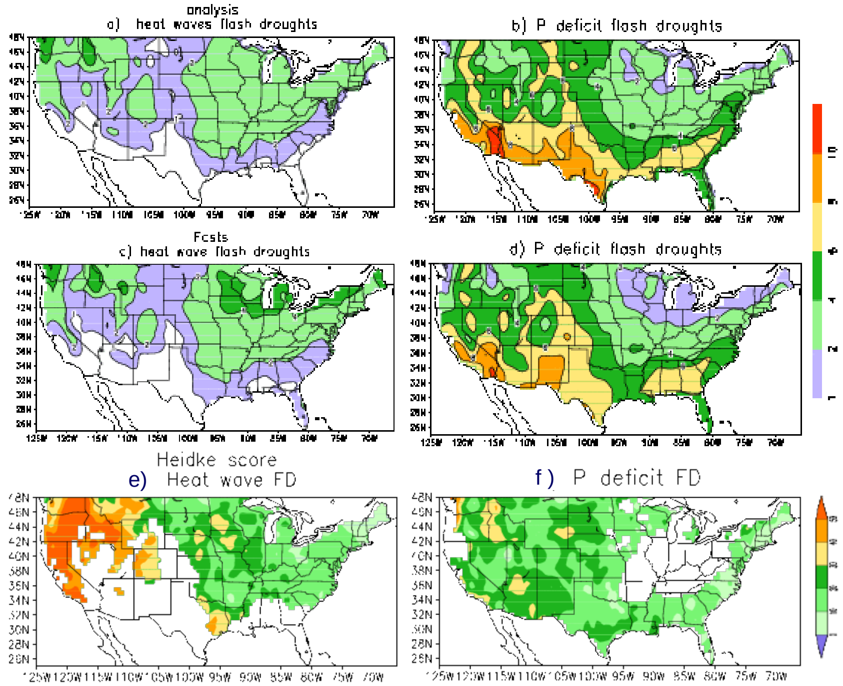


Fig. 8 To examine the role of atmospheric initialization, two versions of initialization are compared using GFDL FLOR model. FLOR-v1 primarily captures the forcing from the ocean surface, whereas FLOR-v2 includes the additional contribution from realistic atmospheric initial conditions (AICs). The figure on left shows Heidke skill scores (HSSs) of wintertime (DJF) weekly ensemble mean T2m hindcasts of 50th percentile exceedance from FLOR-v1 (a-d) and FLOR-v2 (f-i) at lead times of 1 through 4 weeks. It reveals that the forecast skill of T2m increases dramatically for the first two weeks over the majority of North America from FLOR-v1 to FLOR-v2, and FLOR-v2 also performs noticeably better at week 3, indicating that accurate AICs are important for week 3-4 forecasts over North America.

Project 12 Flash drought monitoring processes (PI: D.P. Lettenmaier)

- Evaluated the ability of the CFSv2 seasonal forecasts to capture the number of flash droughts of both types (Fig. 9).

Fig. 9 The ability of the CFSv2 seasonal forecasts to capture the number of flash droughts has been evaluated. The figure shows the frequency of occurrence (%) of pentads under (a) heat wave flash droughts from analysis, (b) P deficit flash drought from analysis, (c) and (d) same as (a) and (b), but from CFSv2 seasonal forecasts, starting from 1 April, 1 May, 5 June and 5 July pooled together for the period from 1982-2010, (e) and (f) are corresponding Heidke skill scores. An experimental real-time flash drought monitor is provided on the CPC website.



- Produced daily ET and total soil moisture fields by forcing the VIC model with CPC precipitation and temperature analyses.
- Now provide an experimental real-time flash drought monitor on the CPC website;

Project 13 Subseasonal Excessive Heat Outlook System for global tropics and subtropics (PI: A. Vintzileos)

- Developed a quasi-operational real-time version of Global Subseasonal Excessive Heat Outlook System (G-SEHOS) and conducted a reforecast, which is diagnosed to show the need for a generalization of the definition of extreme heat events.
- The generalized definition in principle of (1) describing adequately tipping points in human physiology that lead to heat disease, (2) being general enough to be applicable in both extra-tropical, subtropical and tropical areas, (3) having a relation with mortality, and (4) being predictable in subseasonal-to-seasonal lead times was tested (Fig. 10) and refined using direct observations from Meteorological Terminal Aviation Routine Weather Report (METAR).
- Compared excessive heat events (EHE) intensity differences for METAR and Reanalysis data, and calculated quantile mappings between METAR observations and reanalysis products.

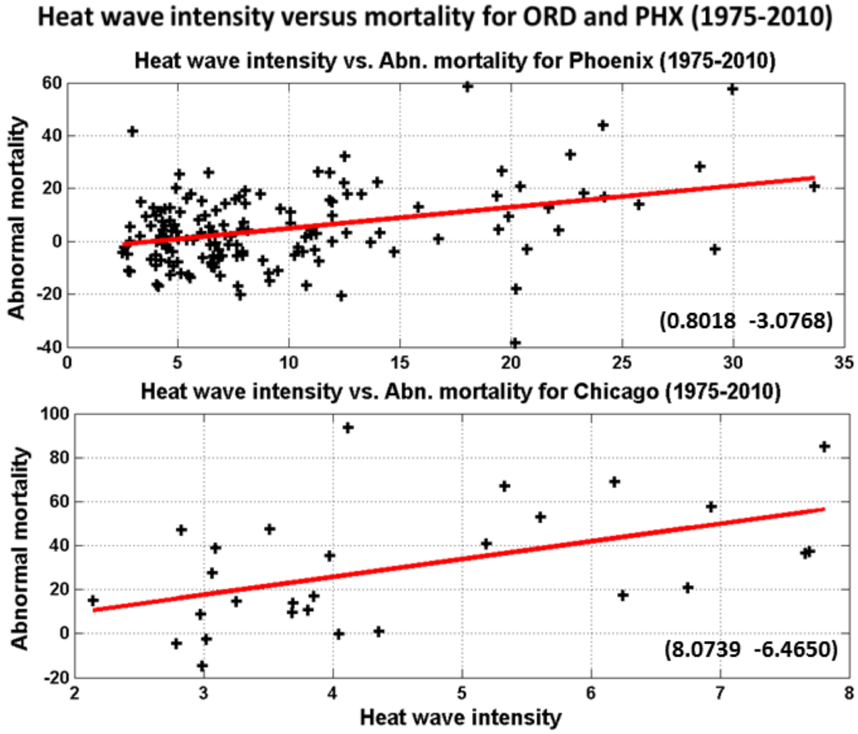


Fig. 10 In order to extend existing operational SEHOS to the entire globe, a new definition of EHE was introduced The functionality of this new definition has been tested against a list of documented EHE. The figure shows scatter plots of the intensity of EHE and abnormal mortality for Phoenix-PHX (humid type) and Chicago-ORD (dry type). Red lines show the linear regression between intensity of EHE and abnormal mortality. For low EHE intensity mortality is not correlated with EHE however as the intensity of the EHE increases there is a clear increase of abnormal mortality.

4. Multi-Model Subseasonal Climate Prediction System

Targets:

i) Optimization of model design
ii) Robust MME forecast system

Projects status:

Multi-Model System	Research Developer	Operation Beneficiary	TRL
17. Diagnosis of subseasonal NMME forecasts on skill, predictability, & multi-model combinations	GMU	CPC	6
18. NCEP GEFS for monthly forecasts	EMC	CPC	6
19. Operational NMME probabilistic seasonal forecast products improvement	IRI	CPC	9

20. Real-time MME subseasonal forecast system	UM-RSMAS	NMME	5
21. NASA GEOS-5 system	NASA, USRA	NMME	5
22. CCSM4 subseasonal prediction	UM-RSMAS	NMME	5
23. Navy's Earth System Model S2S prediction	NRL	NMME	5

Progress reports:

Project 17 Diagnosis of subseasonal NMME forecasts on skill, predictability, & multi-model combinations (PI: T. Delsole)

- Demonstration of forecast skill of temperature and precipitation over the contiguous United States on the 3-4 week timescale (Fig. 11). These results provide a scientific basis for predictability on these timescales.
- Formalization of a rigorous significance test for serially correlated daily data.
- A new method for determining the ensemble size and initialization frequency of the lagged ensemble that minimizes the MSE. The method can identify the optimal lagged ensemble without having to actually run that particular forecast configuration.
- Identification of the optimal lagged ensemble for subseasonal forecasts of the MJO and seasonal forecasts of ENSO in CFSv2.

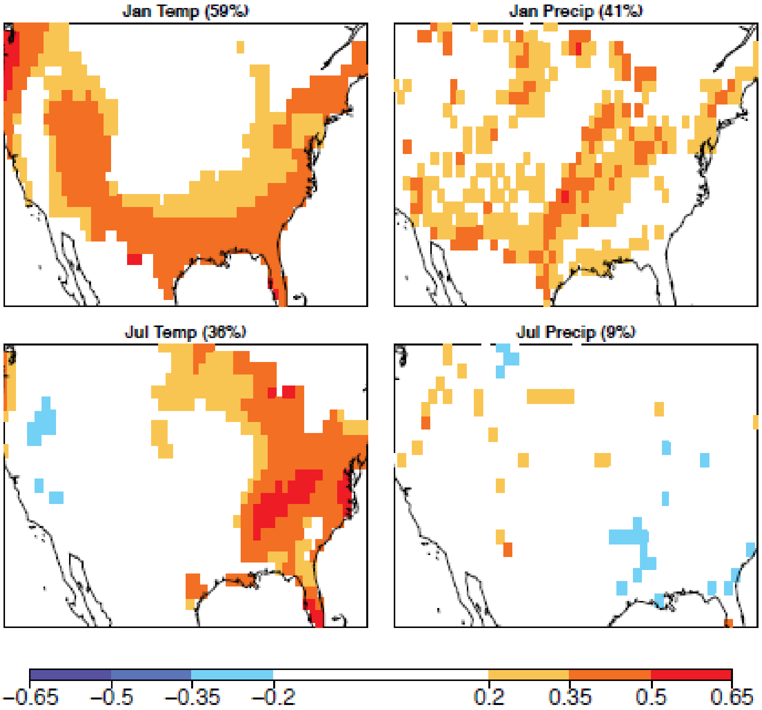


Fig. 11 Correlation skill of week 3-4 temperature (left) and precipitation (right) CFSv2 hindcasts over CONUS during January (top) and July (bottom), 1999-2010 (12 years). The hindcasts are based on a 4-day lagged ensemble (comprising 16 members drawn from 4x daily hindcasts). Values that are statistically insignificant at the 5% level (according to the permutation test) are masked out. The percentage area with significant correlation skill (positive and negative) is indicated in the title of each panel.

Project 18 NCEP GEFS for monthly forecasts (PI: Y. Zhu)

- Investigation of the configuration for MGEFS through 4 suites of experiments during a 2-yr experiment period. (Fig. 12).
- Finished an 18-yr reforecast with a high-resolution (34km for 0-8 days and 52km for 8-35 day) model and 11 member ensemble, every other 7 days.

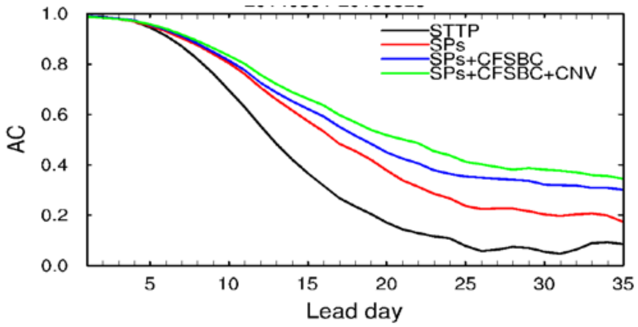


Fig. 12 NCEP MGEFS MJO forecast skills in terms of bi-variant correlation of the Wheeler-Hendon RMM indices for four different experiments during the period of May 2014 to May 2016. A significant improvement in MJO forecast skill (from 12.5 days to 22 days) is carried out after applying the new stochastic physics perturbation (SPs), updated SST (CFSBC) and new convective schemes (CNV).

- Readiness of a real-time MGEFS version with the identical configuration as reforecast but larger ensemble size (21 members).

Project 19 Operational NMME probabilistic seasonal forecast products improvement (PI: A Barnston)

- At IRI, systematic errors in individual coupled model forecast spatial patterns were corrected, resulting in skill improvements in specific regions and seasons. Overall improvements are quite limited, however. On the other hand, improvements at a local (not pattern) level are substantial for both precipitation and temperature. The CCA was therefore found to be useful for an unintended purpose, as local corrections can be done using simpler methods than CCA. Another unexpected finding was that applying the CCA to the entire globe as a single region produced equal or better results (Fig. 13) than applying it to individual regions and merging the corrected forecasts into a global forecast.

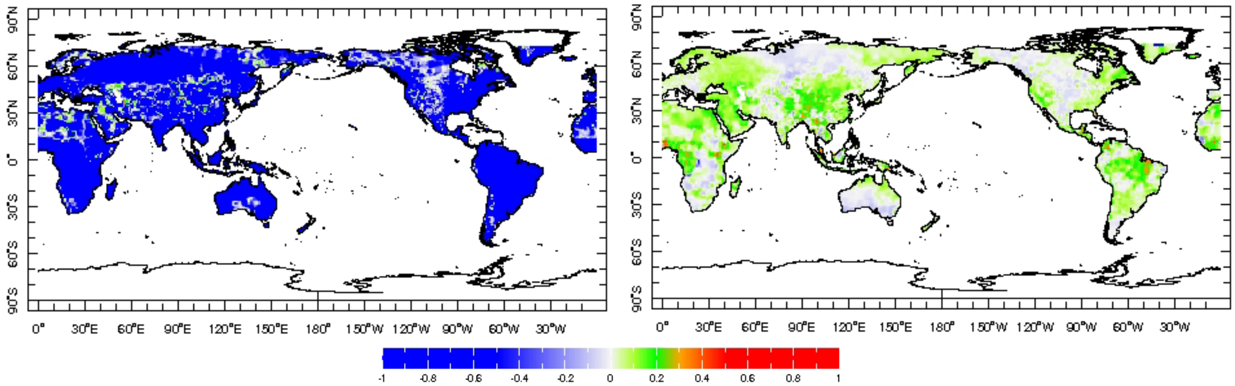
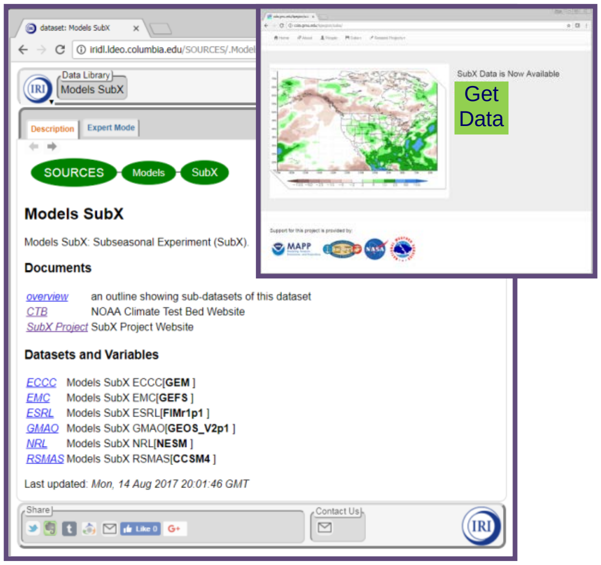


Fig. 13 Geographic distribution of root mean squared error skill score (RMSESS) over the globe as a single region, for temperature forecasts by the NCEP-CFSv2 model for January-March made in early December. The left panel shows the original skill, and the right panel the skill following the CCA correction. The RMSESS is in terms of standardized anomalies with respect to the observed mean and standard deviation.

Project 20 Real-time MME subseasonal forecast system (PI: B. Kirtman)

- Production of re-forecasts by modeling groups
- Re-forecasts being posted at IRI
- Coordination with CPC in preparation for real-time forecasts in July
- Website (Fig. 14)



Models SubX

Models SubX: Subseasonal Experiment (SubX).

Documents

overview an outline showing sub-datasets of this dataset
CTB NOAA Climate Test Bed Website
SubX Project SubX Project Website

Datasets and Variables

ECCC Models SubX ECCC[**GEM**]
EMC Models SubX EMC[**GEFS**]
ESRL Models SubX ESRL[**FIMr1p1**]
GMAO Models SubX GMAO[**GEOS_V2p1**]
NRL Models SubX NRL[**NESM**]
RSMAS Models SubX RSMAS[**CCSM4**]

Last updated: *Mon, 14 Aug 2017 20:01:46 GMT*

Fig. 14 A website has been created to provide public information about the Subseasonal Experiment (SubX) project, datasets, models, and research activities. (http://cola.gmu.edu/kpegion/subx/) Each modeling group is producing re-forecasts following the SubX protocol. The re-forecasts are being made available to the research community on the IRI data server. The IRI continues to update the NMME monthly archive in the IRI Data Library in real time every month as new output files are made available by the contributing forecast centers. It also assists users of the NMME archive who send requests for help in accessing the data.

5. Remarks

The creditability of seasonal-to-subseasonal climate service relies heavily on the prediction skill, which currently is limited in forecast operation, and the researches on the topic present many challenges (as appeared in the Project 19 research). NWS sincerely invites partners in the research community to work together on the strongholds to meet the legislative act for S2S forecasting innovation passed recently (U.S. 115th Congress 2017). As the skill improvement brought about by the advancement of existing dynamical models and statistical tools has been approaching bottleneck, shifting research paradigm in approach to think outside of the box to foster innovation stimulated from rapid developing science areas, such as machine deep learning (Jones 2017), system experimental design (Zhou and DeWitt 2016) *et al.*, needs much attention and encouragement for their potential helpfulness to make breakthrough.

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