US Navy Coupled System Research and Development under the Earth System Prediction Capability

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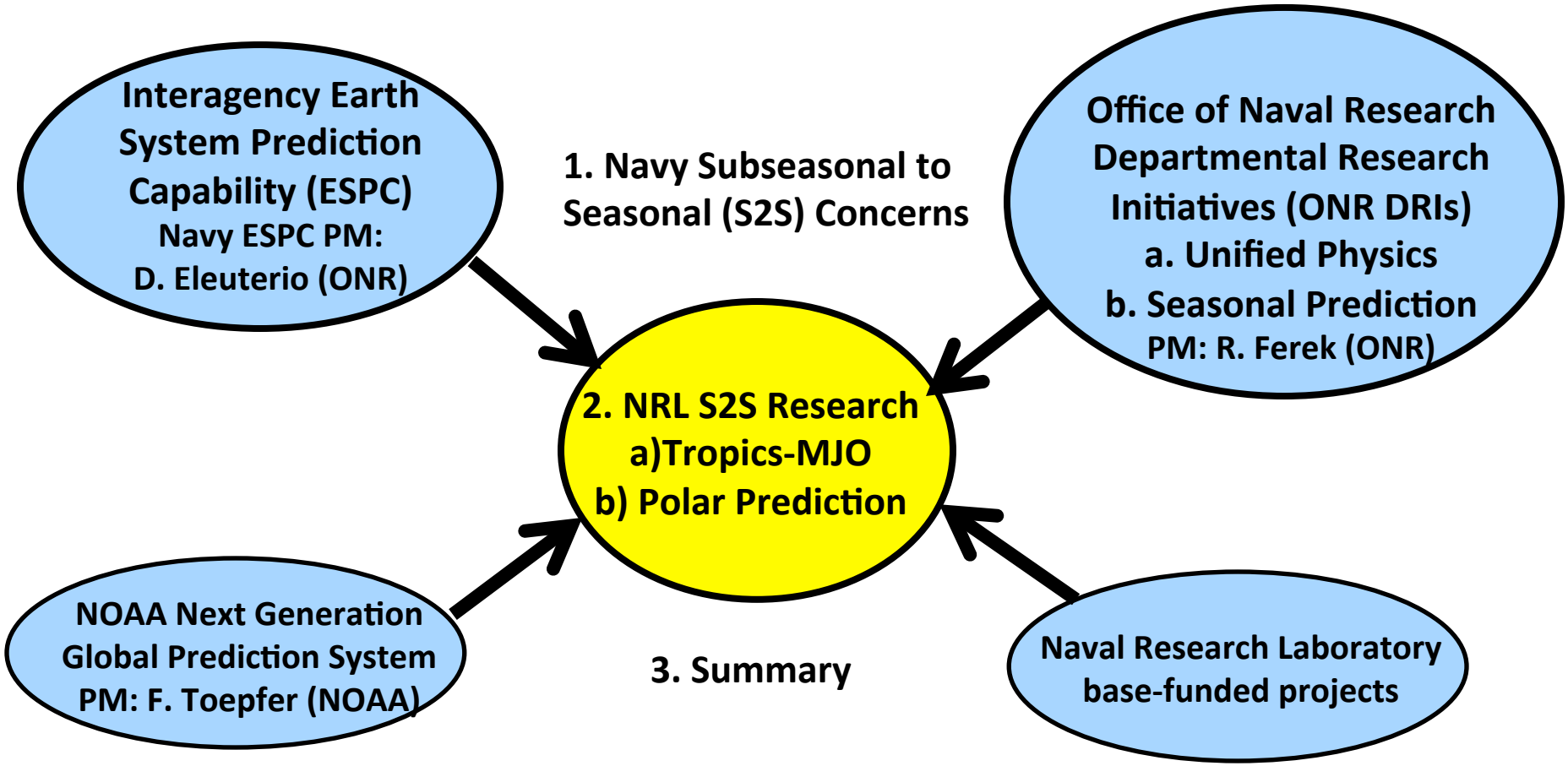
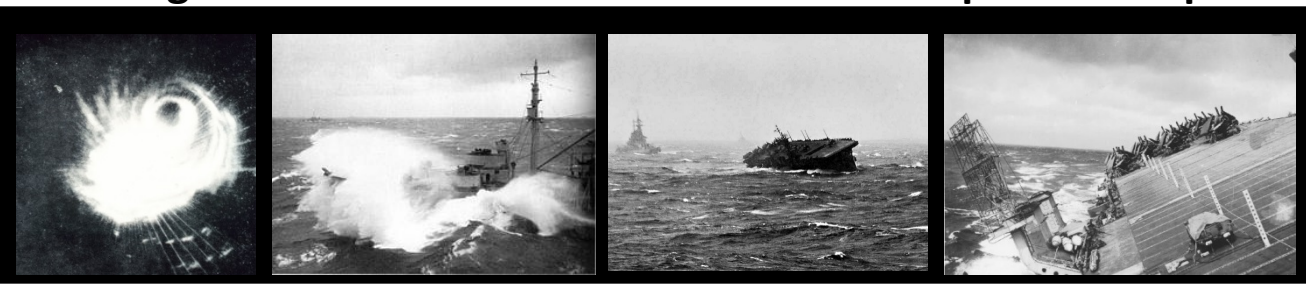


Extended-range Prediction Plays a Critical Role in DoD/Navy Planning and Policy

Navy Operational Planning

- Mission planning (e.g., typhoon risk assessment, ship routing)
- Long-term infrastructure installation and replacement planning



Typhoon Cobra, or Halsey's Typhoon, DEC1944. Three destroyers and 790 lives lost.

US Navy Arctic Roadmap: 2014-2030
Navy Climate Change Task Force

NRL supports US Icebreaker Healy on Geotraces mission to the North Pole.

- US Navy has a long history of Arctic Ocean operations and explorations
- Reduced summer sea ice will make Arctic Ocean viable for international shipping and resource explorations, and critical for national security concerns
- Estimates for economic potential of hydrocarbon resources exceed $1 trillion in U.S. Arctic
- Hazardous environmental conditions make exploration and operations challenging

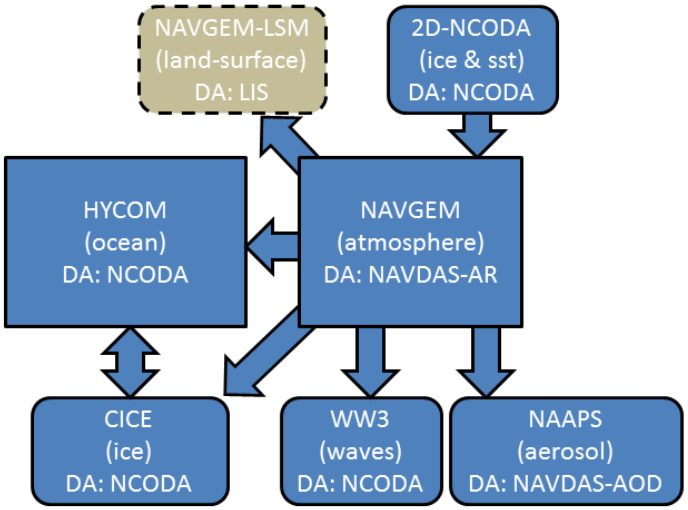
Navy S&T Strategic Plan

Match environmental predictive capabilities to tactical planning requirements: Fully coupled (ocean-atmosphere-wave-ice) global, regional and local modeling and prediction capabilities for operational planning at tactical, strategic, and climate scales

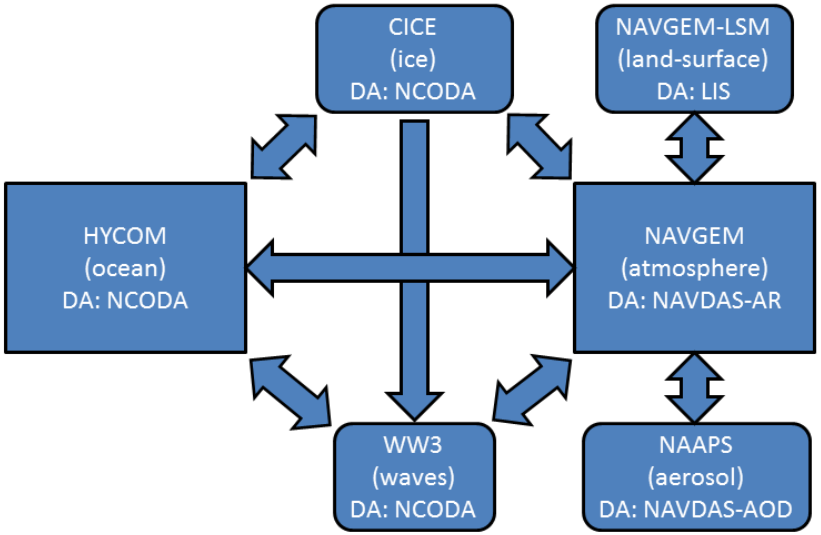
Earth System Prediction Capability

- National, multi-agency collaborative effort to focus resources to develop the next generation earth prediction system
- Navy Earth System Model (NESM): NAVGEM-HYCOM-CICE-WW3-Aerosol using Earth System Modeling Framework Infrastructure

Current Navy Operational Global System



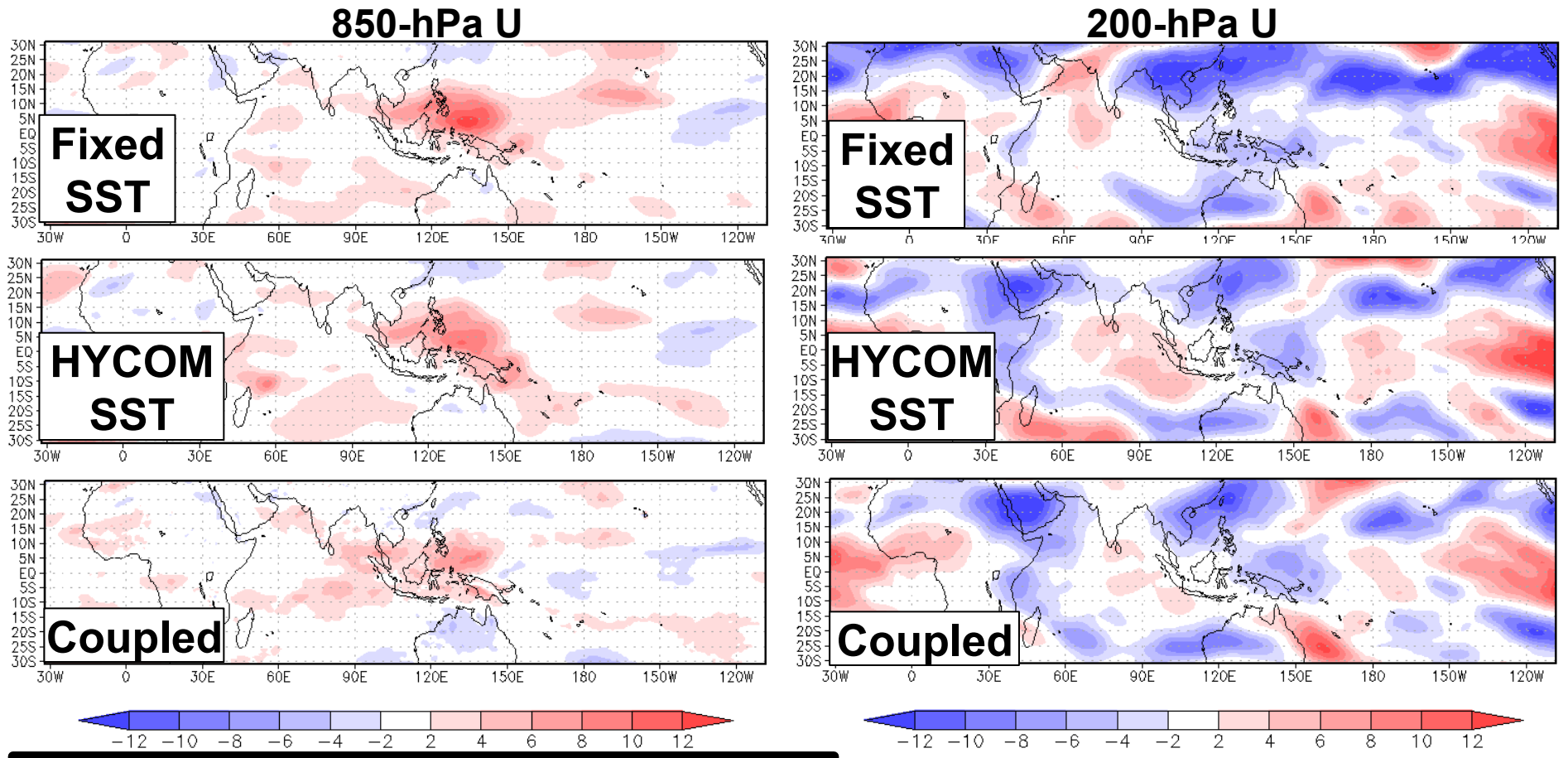
NESM under development



Collaboration between NRL Monterey, NRL Stennis, ESMF (NOAA)

NAVGEM Sensitivity to SST

Zonal Wind Biases (m/s) 1-30 NOV 2011 (DYNAMO)

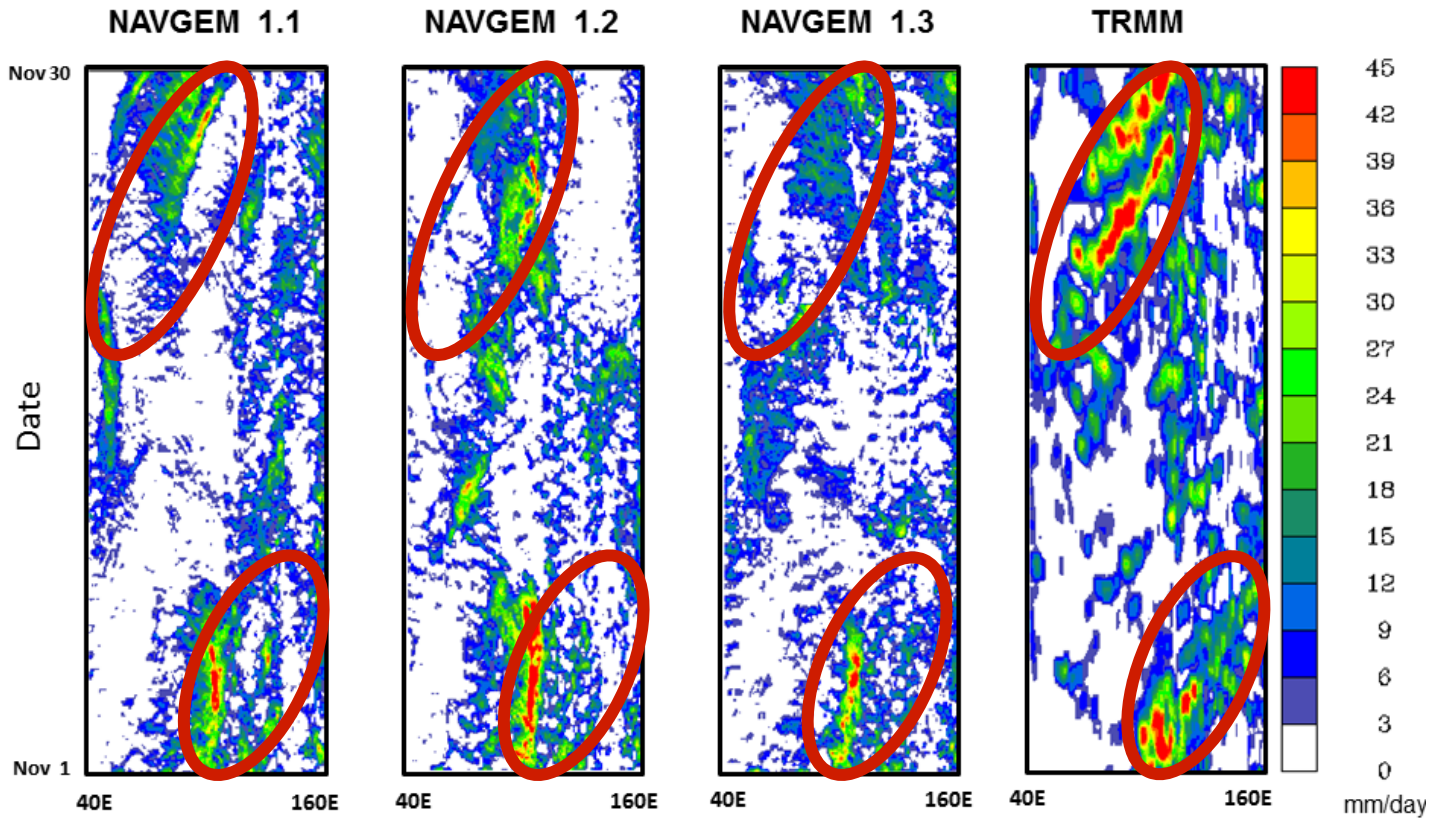


Low-level biases clearly reduced when going to observed SST, reduced further when going to fully coupled system.

Upper level biases are reduced as well, but impact not as pronounced.

NESM Sensitivity to NAVGEM Physics

NESM 30-day reforecasts (5S-5N precip) from 1NOV2011



Insertion of global NWP model into ESPC coupled system not sufficient to resolve difficulties with the MJO

NAVGEM Parameterization Improvements

Convection Scheme Development and Testing (*J. Ridout*)

Modified Kain Fritsch Convection Scheme – Based on treatment of Ridout et al. (2005), but including recent improvements to better simulate the MJO.

Main Points:

1) **Closure relation based on an assumed quasi-balance in updraft parcel buoyancy at cloud base, similar to Emanuel and Živković-Rothman (1999). Also, constraint imposed to ensure that available buoyant energy does not entirely vanish.**

Changes since publication:

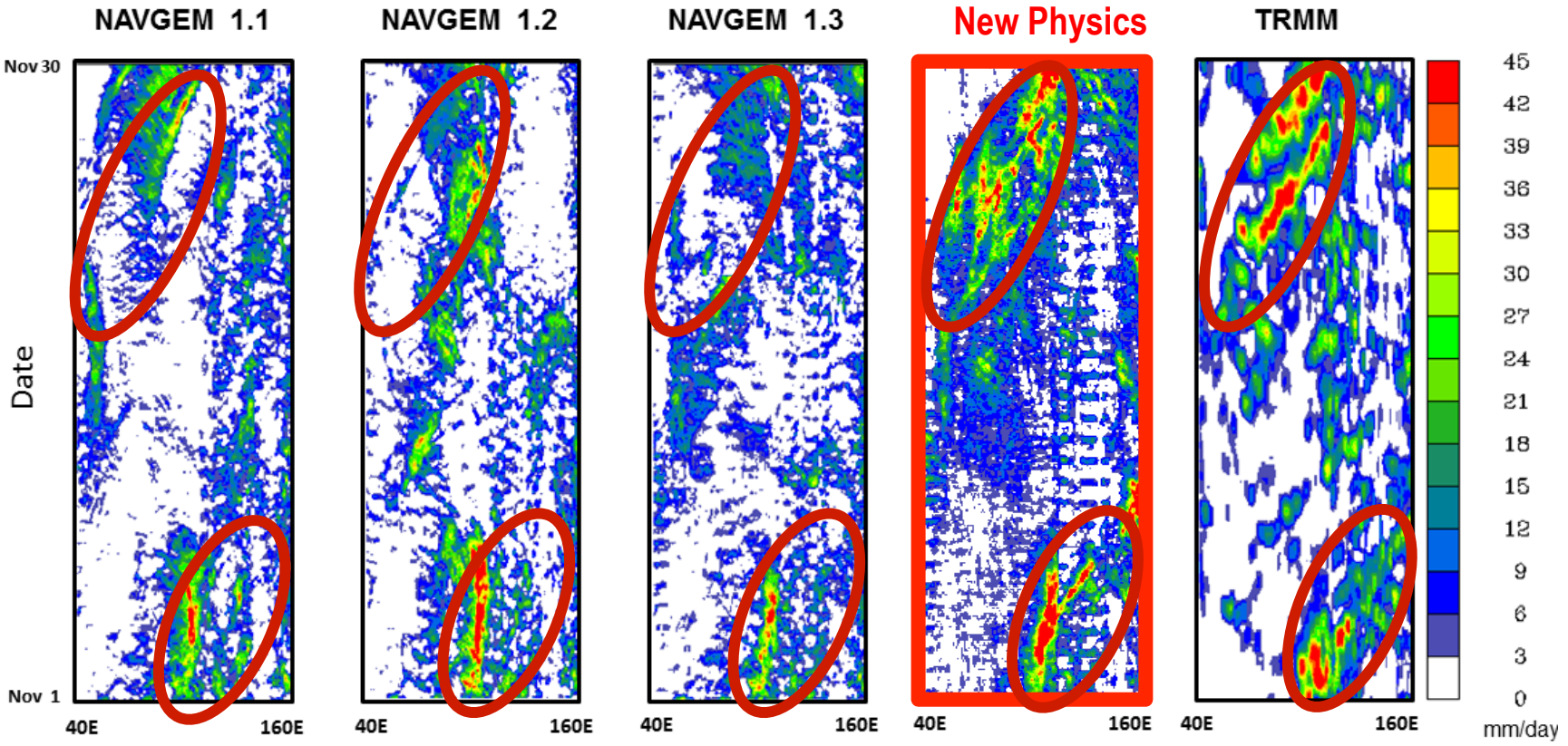
2) **Added convective momentum transport (similar to treatment in the Emanuel convection scheme).**

3) **Modified mixing rate based on the updraft mass flux and parcel buoyancy (in part, adopting an approach described by Peng et al. (2004)).**

4) **Enhanced capability to represent turbulence-forced convection, with inputs from plumes modeled in the NAVGEM EDMF scheme (Sušelj et al. 2013).**

NAVGEM Parameterization Improvements

NESM 30-day reforecasts (5S-5N precip) from 1NOV2011

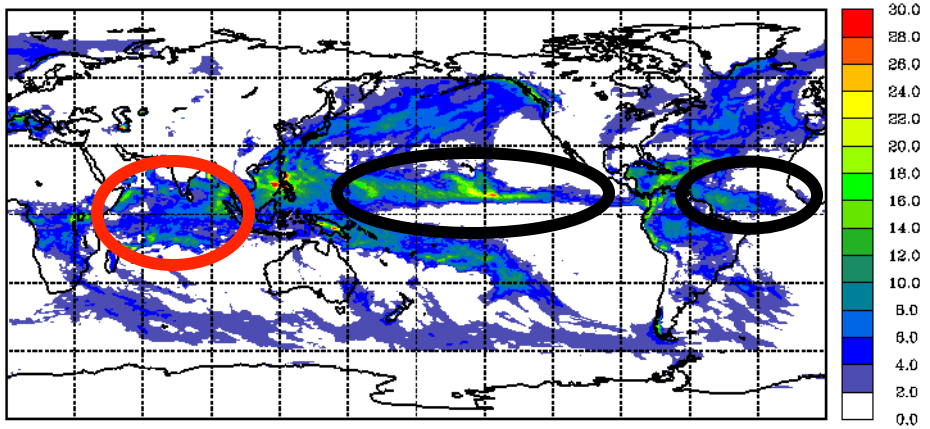


MJO much improved– main factor is change in convection scheme. Also includes implementation of COARE 3.0 air-sea flux scheme in NAVGEM, following the treatment in the ocean model component (HYCOM).

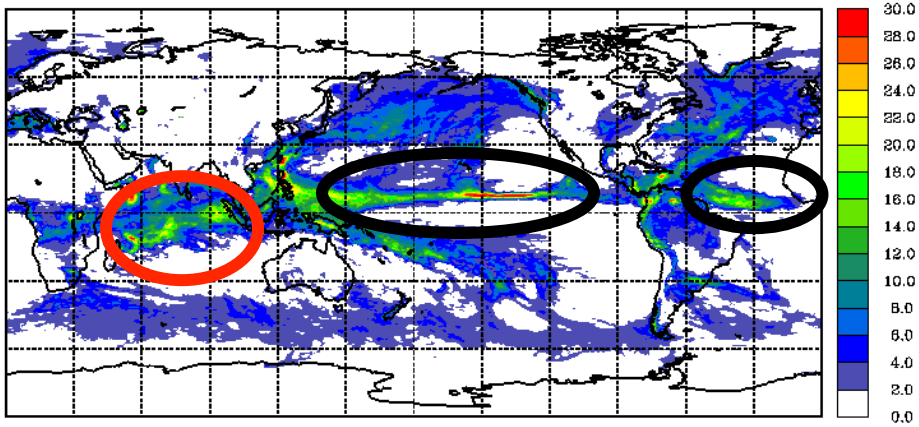
NAVGEM Parameterization Improvements

NESM 30-day reforecast ave. precip. (mm/day) for NOV2011

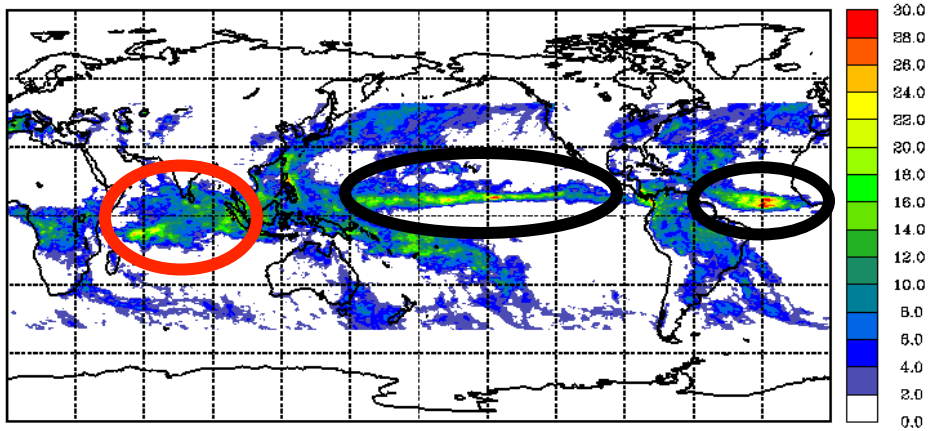
NAVGEM 1.3 (run at t359l50)



Modified NAVGEM Physics



TRMM

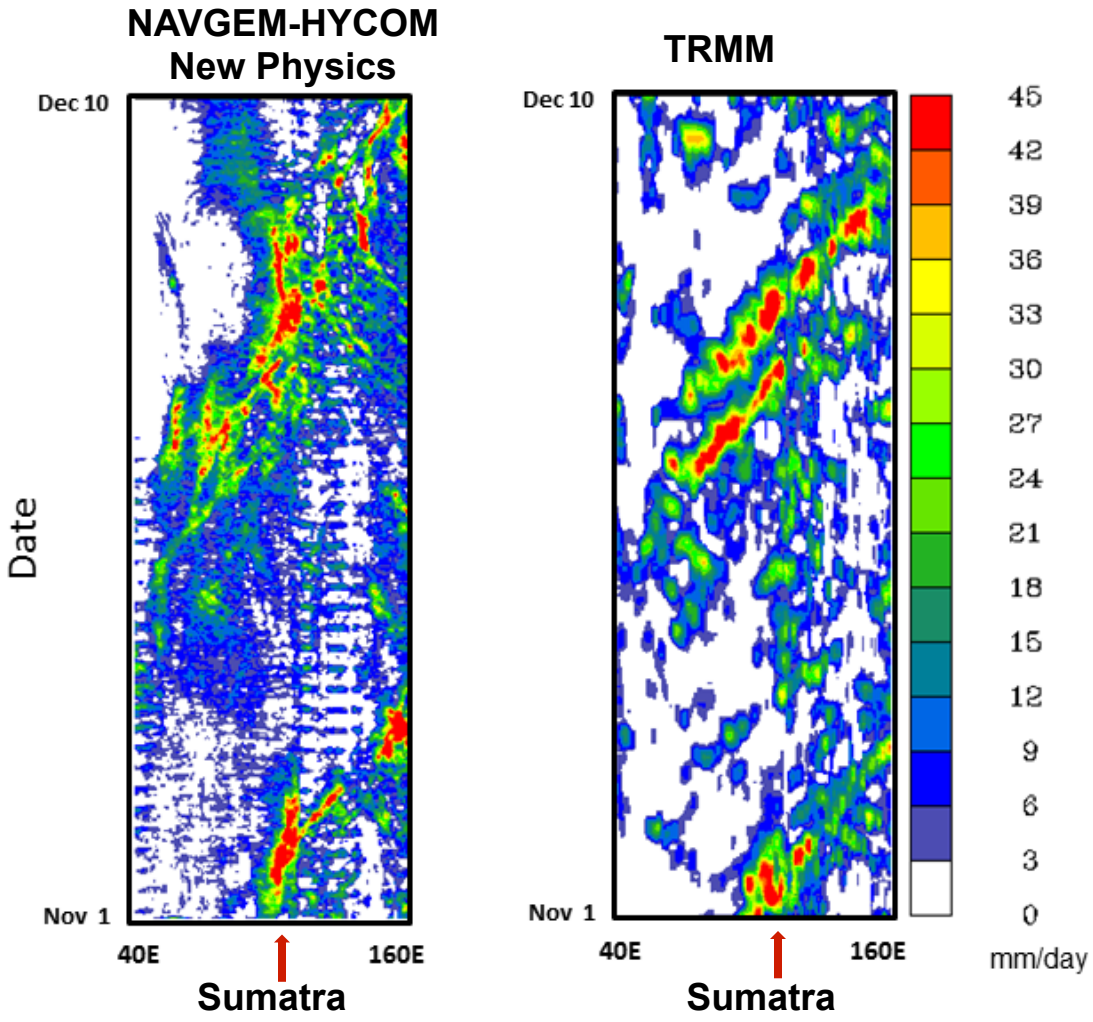


Improved precipitation pattern in Indian Ocean

Improved (narrower, stronger) ITCZ

NAVGEM Parameterization Improvements

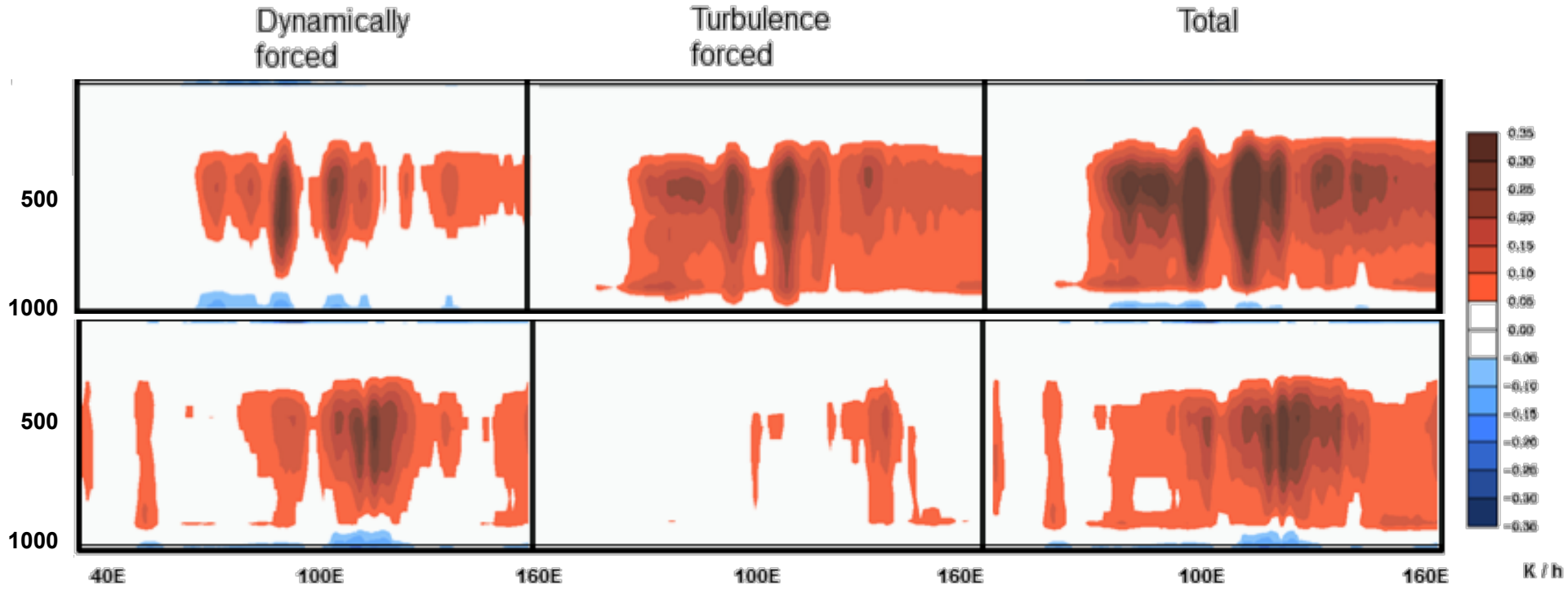
NESM 40-day reforecasts (5S-5N precip) from 1NOV2011



While results suggest some predictability beyond one month, both MJO episodes in the reforecast exhibit excessive slowing in propagation while crossing the Maritime Continent.

NAVGEM Parameterization Improvements

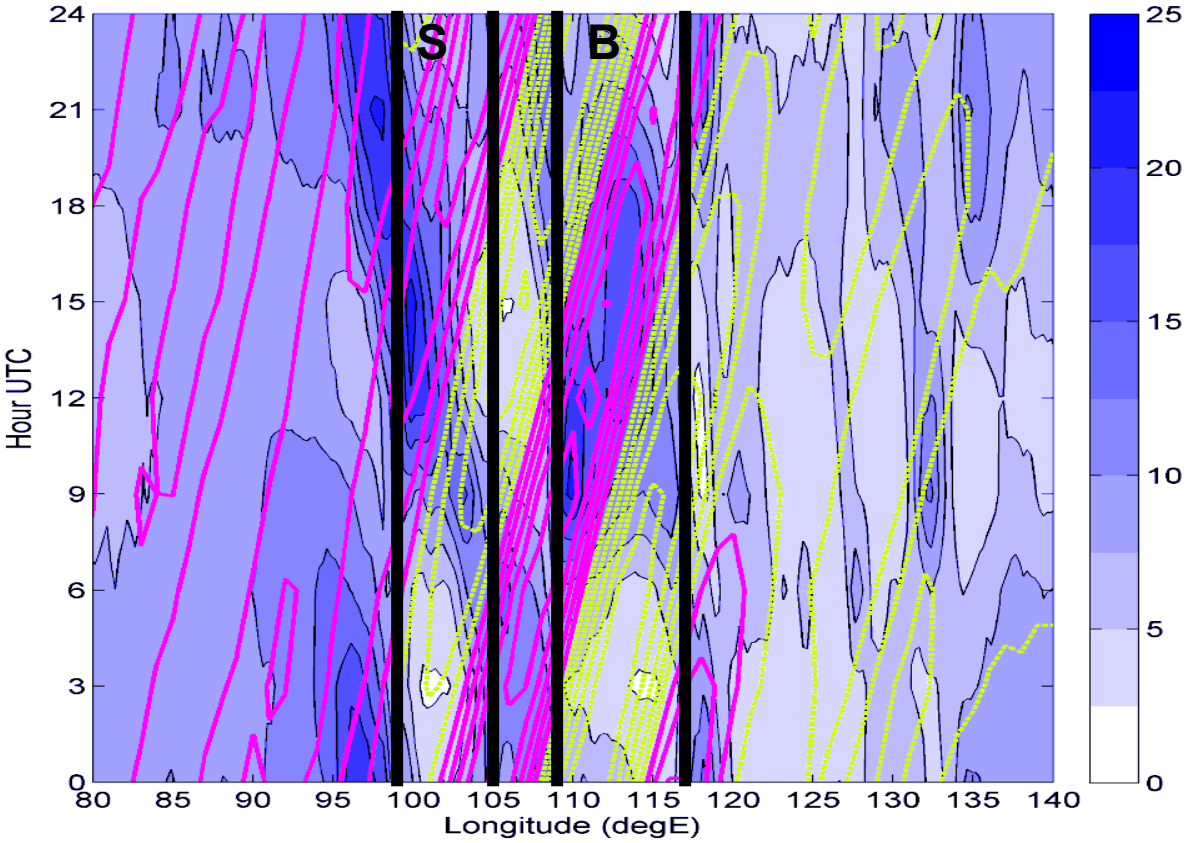
NESM Convective Heating Rates (5S-5N) for 1-4 DEC 2011



- With current (modified Kain-Fritsch, top) formulation, turbulence-forced mode is dominant, contrary to observations (cf. Mapes 2000).
- Incorporation of a mixed-layer Richardson number constraint on turbulence-forced convection (bottom) results in more realistic dominance of dynamically forced mode.
- Also improves eastward propagation speed (please see Jim Ridout's poster: Bimodal Representation of Convection with a Modified Kain-Fritsch Cumulus Scheme).

Observed Diurnal Variability and Kelvin Waves

Diurnal cycle in precip: 16 years of TRMM data



Blue shading: Mean diurnal cycle of full precipitation (mm/day).

Contours: mean diurnal cycle of filtered precipitation associated w/ Kelvin wave.

Solid magenta: 8.5 to13.5 mm/day

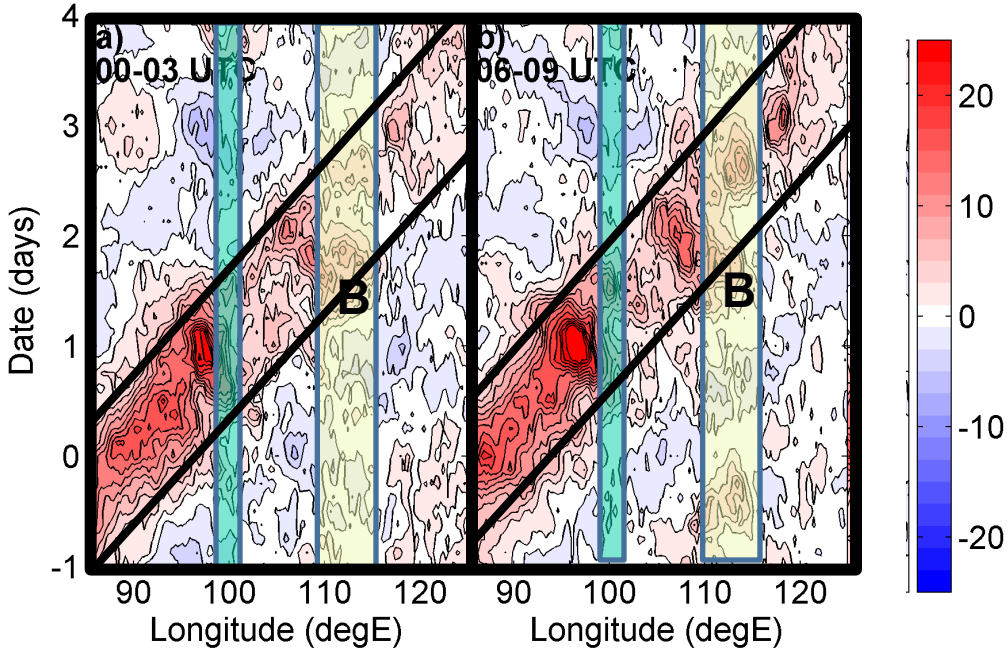
Dashed yellow: -3.5 to -7.5 mm/day

Baranowski D. , M. K. Flatau, P. J. Flatau, A. J. Matthews, 2015: Impact of the atmospheric equatorial convectively coupled Kelvin waves on the precipitation over the Maritime Continent, Science, submitted.

Kelvin waves propagating over Maritime Continent are phase locked with the local diurnal variability. Biases in model diurnal cycle may alter this relationship.

Observed Diurnal Variability and Kelvin Waves

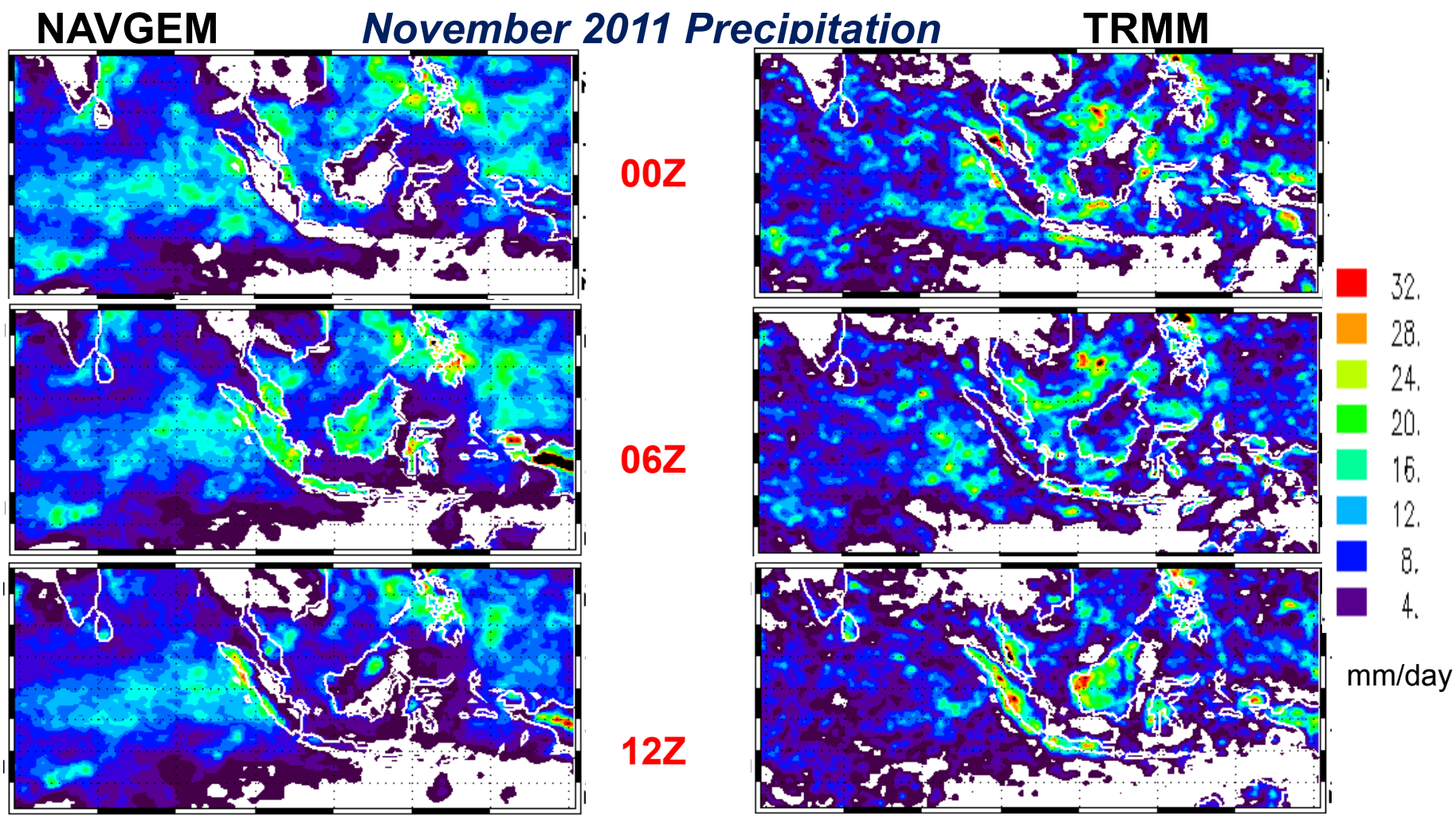
Diurnal variability and MJO/Kelvin wave propagation



Composites precipitation in equatorial Kelvin waves (mm/ day) for waves approaching 90E at a) 00-03 UTC and b) 06-09 UTC . Green shading indicates Sumatra, yellow indicates Borneo.

Kelvin waves approaching the Maritime Continent at different times of the day have different propagation characteristics due to interaction with diurnal cycle over Sumatra and Borneo. Biases in model-simulated diurnal cycle will alter this relationship.

Observed Diurnal Variability and Kelvin Waves

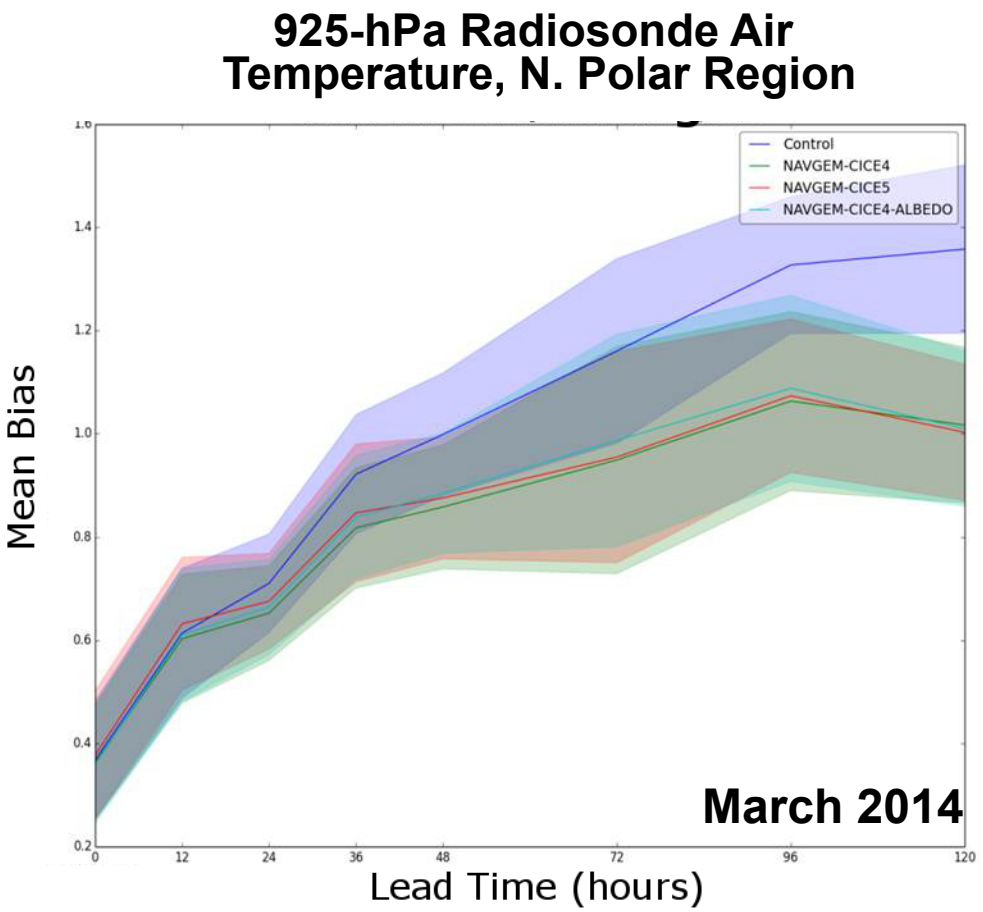


NAVGEM convection over MC land occurs too early. Borneo convection is too weak: this can impact the MJO propagation. Plan to participate in YMC/PISTON.

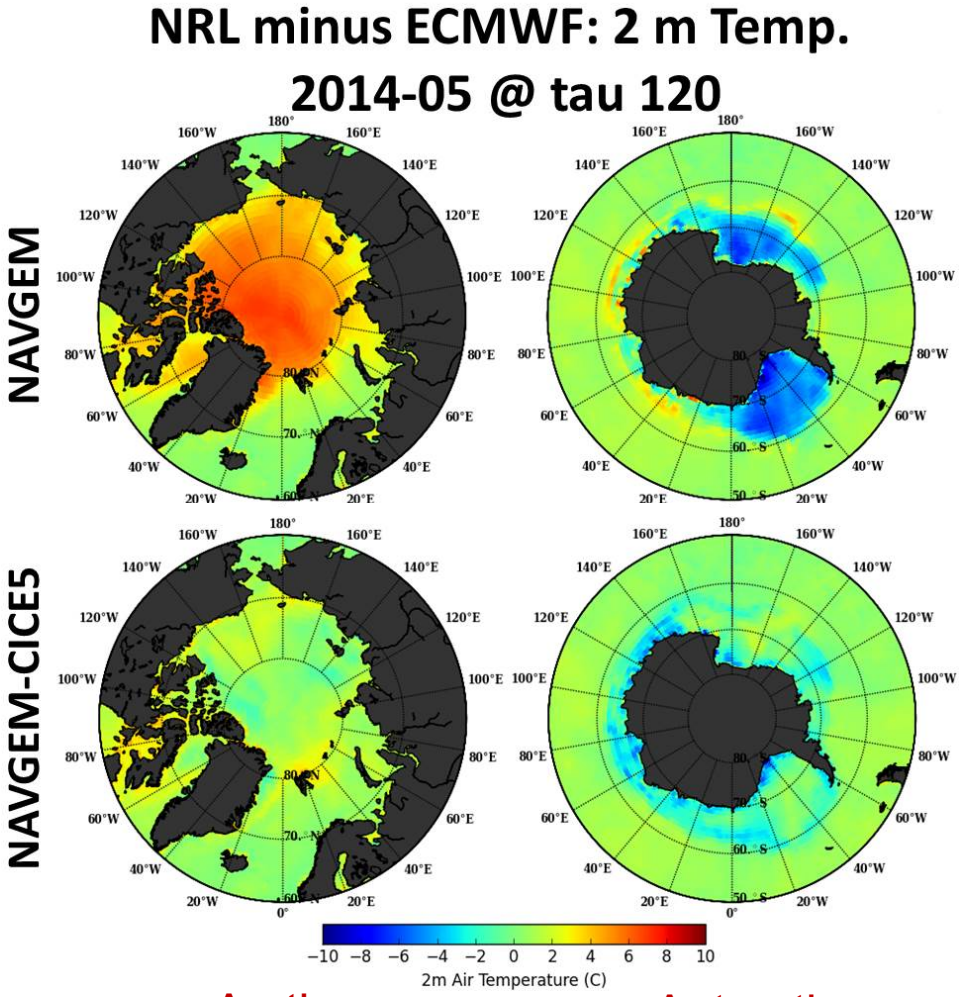
NAVGEM-CICE Coupling

NAVGEM-CICE in NAVGEM Update Cycle (*N. Barton*)

- NAVGEM has a known polar temperature bias in the lower atmosphere during spring months.
- NAVGEM – CICE are coupled and run with NAVGEM-DA to test the effect of implementing a new dynamic sea ice model on the known biases.
- All coupled runs have smaller biases in lower atmospheric temperatures compared with the control run.



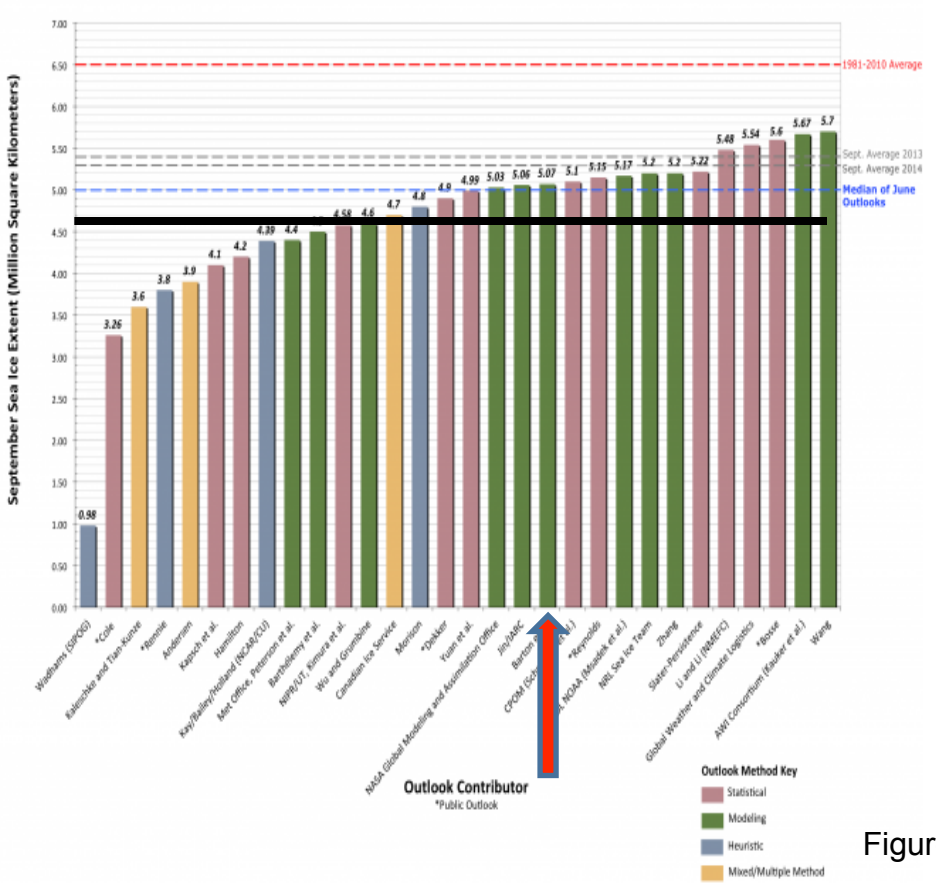
NAVGEM-CICE Coupling

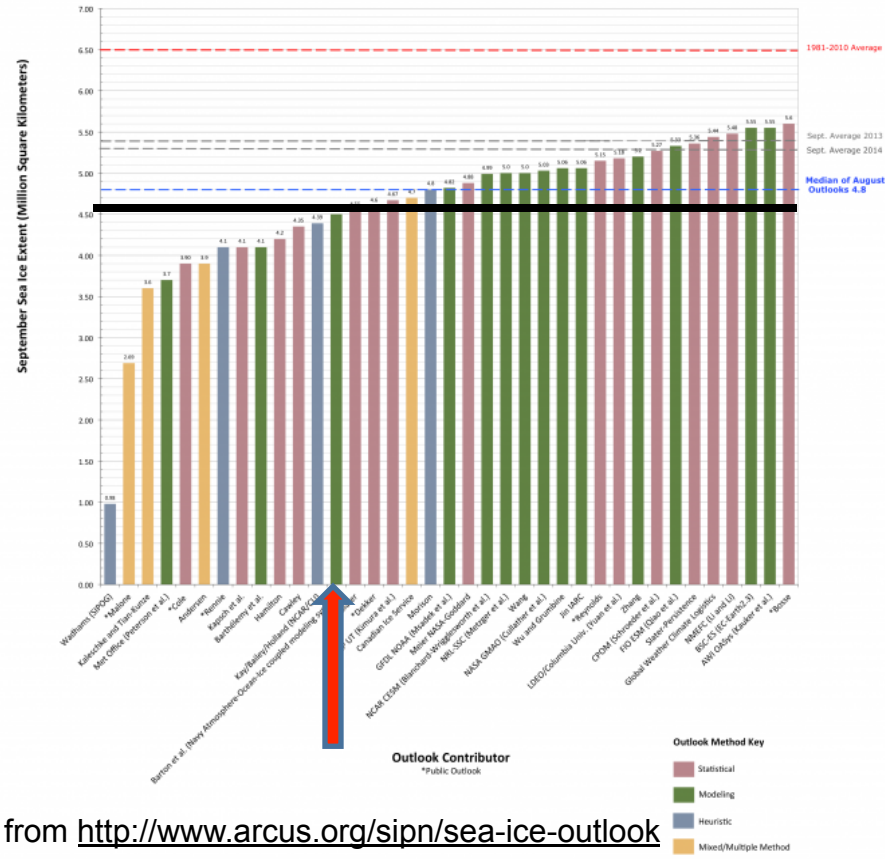


Coupled NAVGEM-CICE5 run reduces biases in Arctic and Antarctic regions.

NESM Sea Ice Minimum Prediction

NH September 2015 Sea Ice Prediction Network June (left) and August (right) Sea Ice Outlooks *(N. Barton, A. Wallcraft, P. Posey, J. Metzger (NRL), J. Chen (SAIC))*





Figures from http://www.arcus.org/sipn/sea-ice-outlook

- **While SIO predictions encouraging, evidence of excessive sea-ice growth in winter, potentially tied to PBL and cloud biases.**
- **Need to improve parameterizations to reduce model biases and improve fidelity of simulations.**

Summary

- NESM shows potential
  - Physics modifications improving MJO simulations
  - Promising start for September sea ice minimum predictions

- Future Challenges/Opportunities:
  - Parameterization Development
    - Consistency across systems (e.g., A-O fluxes)
    - account for uncertainty (probabilistic, stochastic)
  - Scalability, efficiency on new architectures (ESPC AOLI NOPP)
  - Probabilistic system development (how many ensemble members, what resolution, etc.)

- Priorities for improving S2S
  - Continued development of coupled system, including DA
  - Leverage work in wider community (e.g., NGGPS, NMME, CLIVAR MJO working group, YMC (PISTON), YOPP, etc.)