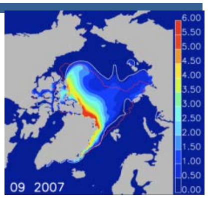
National Earth System Prediction Capability (National ESPC)

Jessie Carman – NOAA/OAR

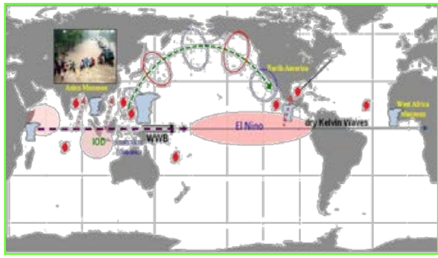
Arctic-Ice Themed Projects

National ESPC:
respond to community calls to action*



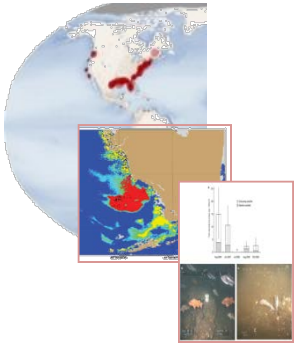
Interagency collaboration to coordinate research to operations for a National earth system analysis and prediction capability; merge NUOPC and ESPC projects

Research to Operations: to expand operational capability leveraging existing inter-agency ensembles, collaboration projects across NOAA:



- Hurricane Forecast Improvement Program (NWS/OAR HFIP: 1-7 days)
- Next Generation Global Prediction System (NWS NGGPS: 1-16 days)
- National Unified Operational Prediction Capability(NAEFS/NUOPC: 5 -16 days, soon 30)
- NOAA 3-4 week Forecast Project (NWS/OAR 16-30 days)
- National Multi-model Ensemble (CPO/CPC NMME: 3-9 months)

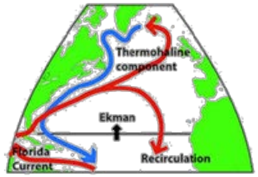
Research: Predictability Focus (various projects)



- **Extreme Weather Events**: Blocking Events and Related High Impact Weather, 1-6 Weeks
- **Seasonal Tropical Cyclone Threat**: Tropical Cyclone Likelihood, Track, Intensity; Weekly to Seasonal
- **Arctic:** Sea Ice Extent and Seasonal Ice Free Dates, Weekly to Seasonal Timescales
- **Coastal Seas**: Coastal Circulation, Hypoxia, and Harmful Algal Blooms,1-6 Weeks
- **Open Ocean**: Atlantic Meridional Overturning Circulation (AMOC), Monthly to Decadal

Common Infrastructure: ESMF

- Component-based framework for building, coupling models
- NUOPC layer: interoperability conventions and tools
- NEMS: ESMF implementation for NWS operational run
- Also CESM, DVSv3, NASA ModelE, GEOS-5



*BAMS articles, NRC reports, etc.

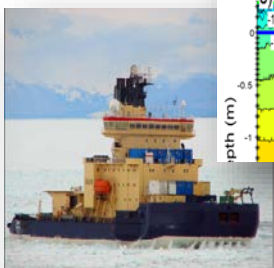
Processes Impacting Sea-Ice Movement and Autumn Freeze-up

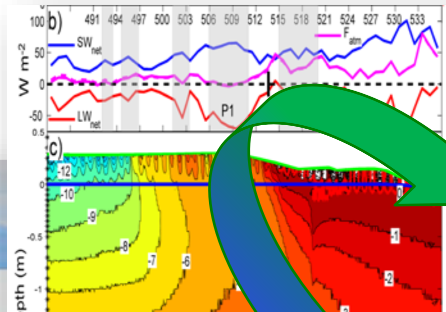
Intrieri et al. (ESRL/PSD)

- Use obs from previous, imminent field programs to study:
  - Atm forcing
    - Sea ice movement (stress, deformation)
    - Sea ice melt/formation (energy fluxes)
    - Ice-free ocn (waves, solar radiation, mixing
  - Ocn forcing
    - Sea ice (bottom heat flux, wave penetration)
    - Atm (seasonal/regional heat release)
- Focus:
  - 0-20 day ice floe movement
  - Autumn freeze up processes (near ice, MIZ)
  - Ocn waves' role in summer retreat, autumn advance
  - Storms' role in above processes
- Routine daily forecast output via coupled ice-ocn-atm (RASM-ESRL) model

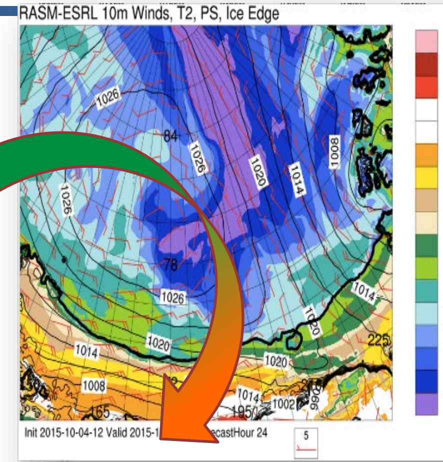
PSD's Earth System Prediction Capability (ESPC) Project Strategy

Our "classic" Goal: Improve understanding of the physical processes that impact sea ice formation
Our "new" Approach: Improved understanding through delivery of an experimental sea ice forecast
Our PSD Sea Ice Forecasting Team: Amy Solomon, Ola Persson, Mimi Hughes, Chris Cox, Andrey Grachev, Janet Intrieri





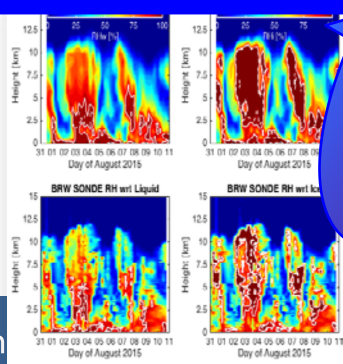
Utilize previously obtained obs of the Arctic atmosphere, BL, & ice-ocean interface as a basis of initial hypothesis testing



Post-deployment analysis of atmospheric process influences on sea ice, model performance, & comparisons to operational forecasts, etc.

Obtain in situ observations from the 2015 freeze-up season for model initialization fields & real time verification & validation sea ice evoluti

Produce experimental coupled model forecasts for delivery to ship for operations and to the Arctic Testbed for operational needs & usage information

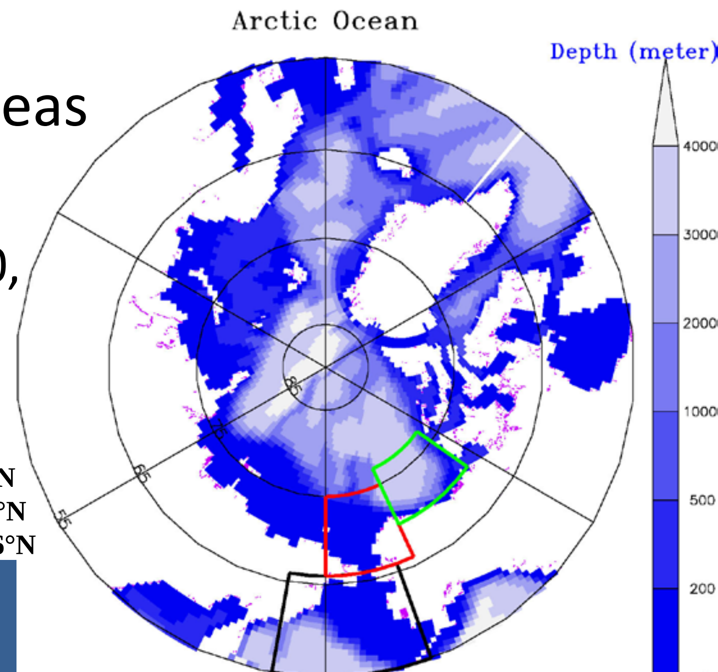


http://www.esrl.noaa.gov/psd/forecasts/seaice/

Assessing Regional Sea-Ice Predictability in the U.S. Arctic: A Multi-Model Approach

Ladd et al. (PMEL)

- US Arctic: Bering, Chukchi, Beaufort Seas
- Models:
  - NCAR CESM Large Ensemble simulations (30 members)
  - NOAA CFSv2 reforecasts
  - Regional Ocean Modeling System (ROMS) pan-Arctic grid, CFSv2 forcing
- Diagnostic and prognostic sea-ice predictability: pan-Arctic and regional seas
  - RMSE, ACC, PPP
  - Three time regimes: 1920-1954, 2005-2040, 2041-2075 to assess increasing/decreasing predictability



pan-Arctic: 55°N-90°N
Beaufort (green box): 155°W-125°W, 70°N-77°N
Chukchi Sea (red box): 180°E-155°W, 66°N-75°N
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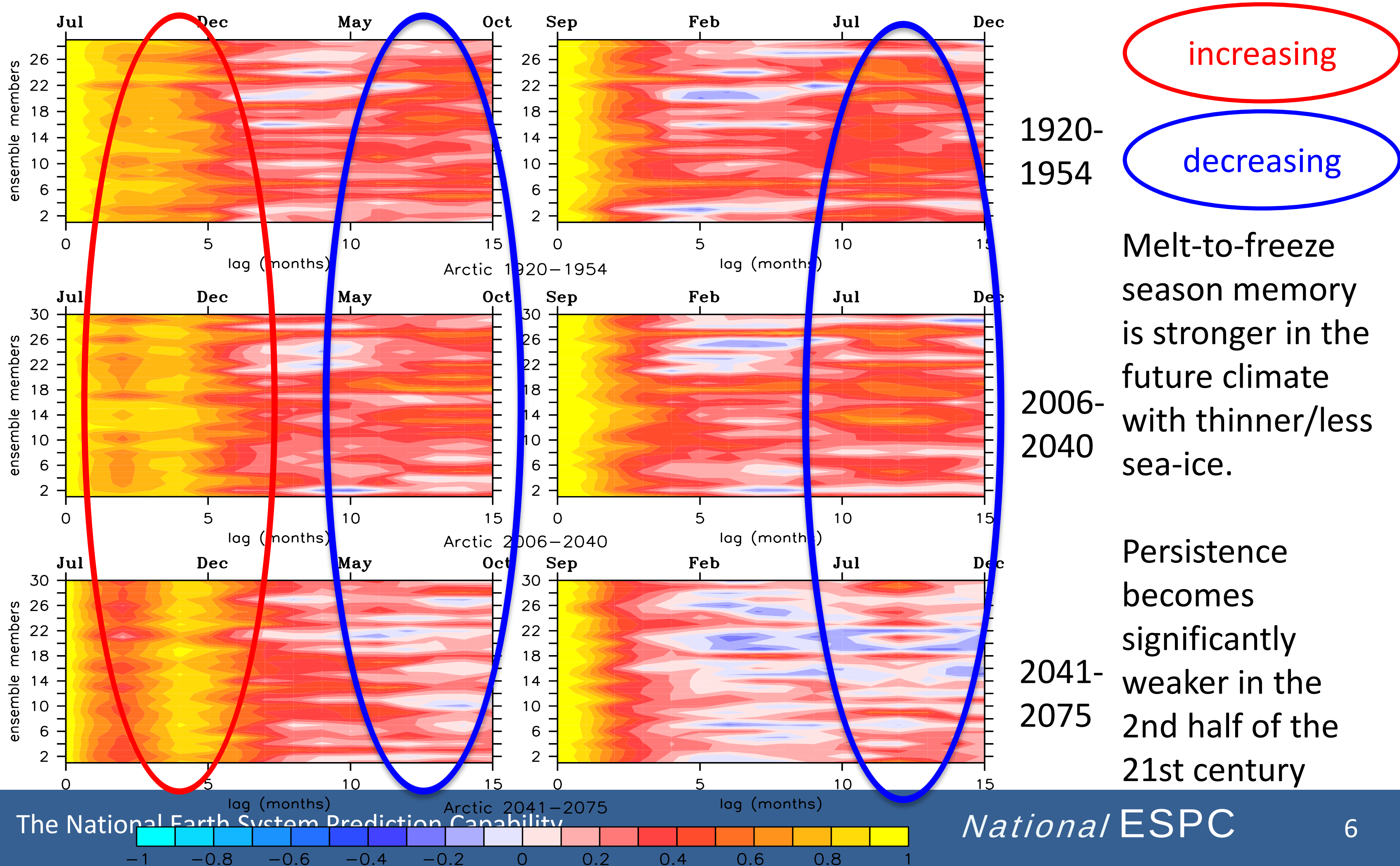
Ice Cover Anomalies: Individual CESM members, pan-Arctic Lagged Correlation



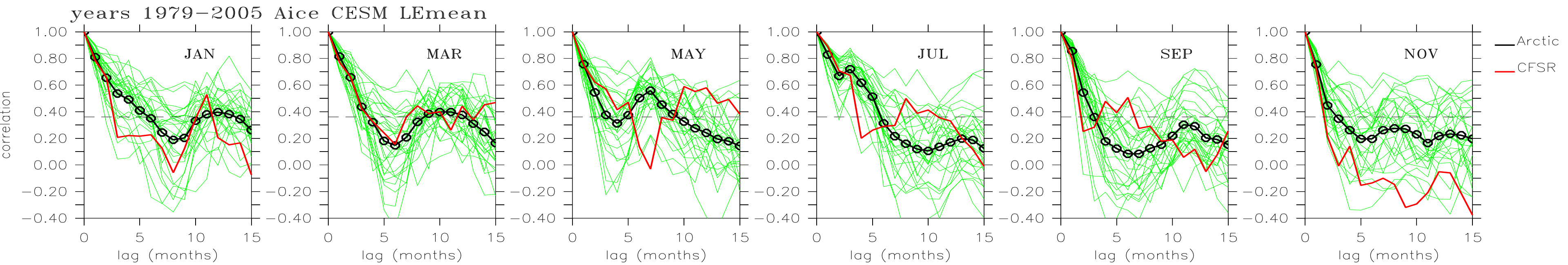
Melt-to-freeze season memory is stronger in the future climate with thinner/less sea-ice.

Persistence becomes significantly weaker in the 2nd half of the 21st century

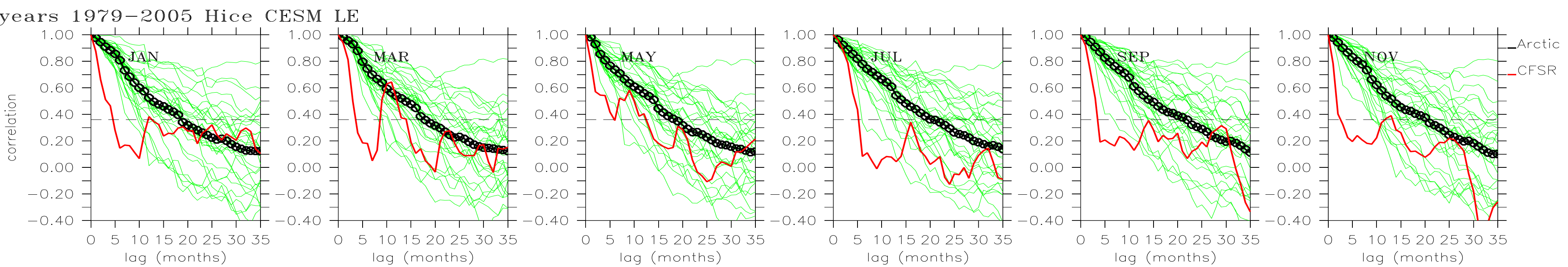
CESM and CFSR Lagged Correlation Comparison
Years 1979-2005

Ice cover

CESM CFSR



Ice thickness



Ice cover: CFSR exhibits similar persistence to any individual CESM ensemble member
Ice thickness: CFSR exhibits consistently less persistence than CESM ensemble members.

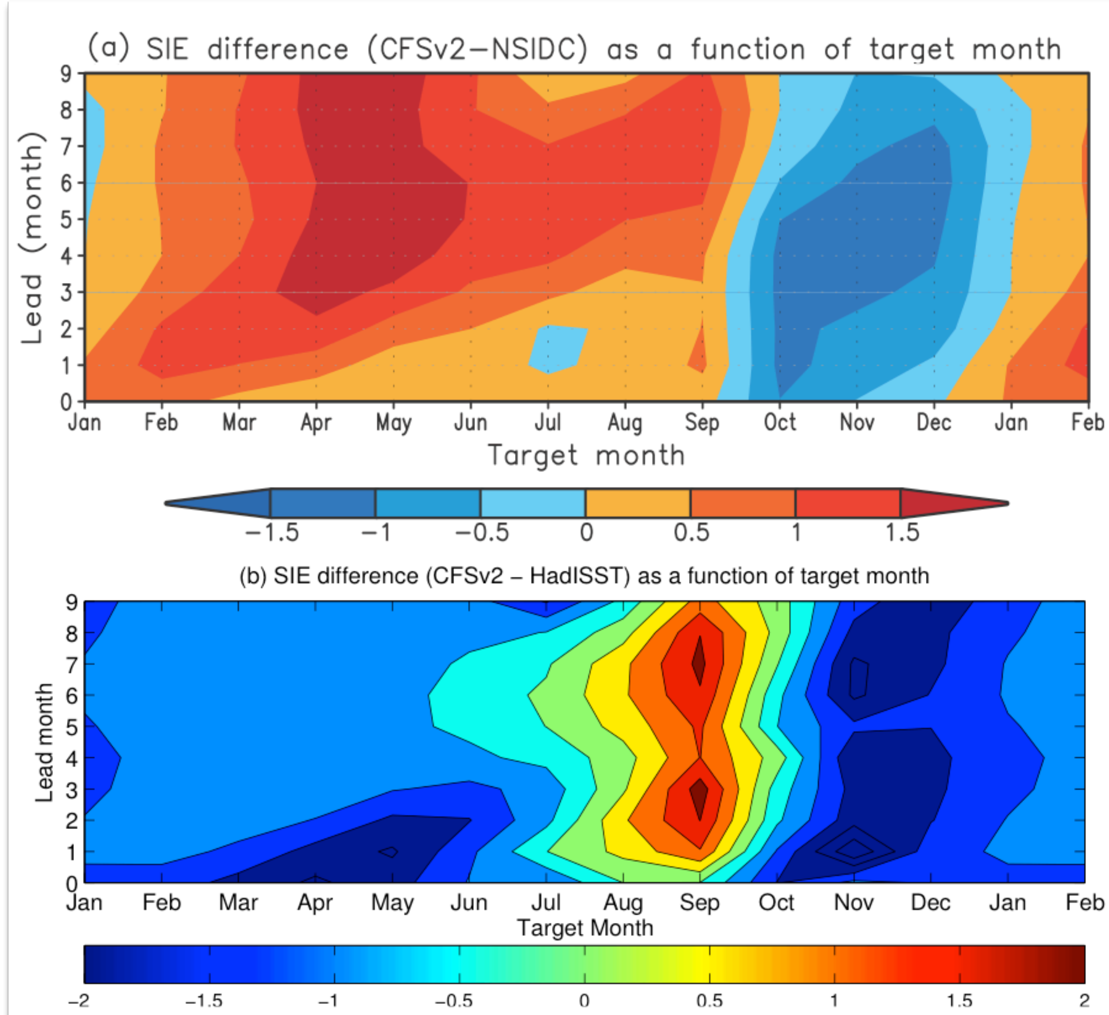
Improving Sea Ice Predictability through Understanding the Role of Atmospheric Forcing and Ice Thickness Contributions

Overland et al., PMEL

- Goal:
  - Improve sea ice predictions in the Arctic by re-initializing the NCEP Coupled Climate Forecast System version 2 (CFSv2) with more realistic ice thickness distribution: Pan-arctic Ice-Ocean Modeling and Assimilation System (PIOMAS)
  - Evaluate contributions from atmospheric forcing and internal sea ice dynamics.
  - Test physics modifications (low-level stratus clouds, ice-ocn heat flux)

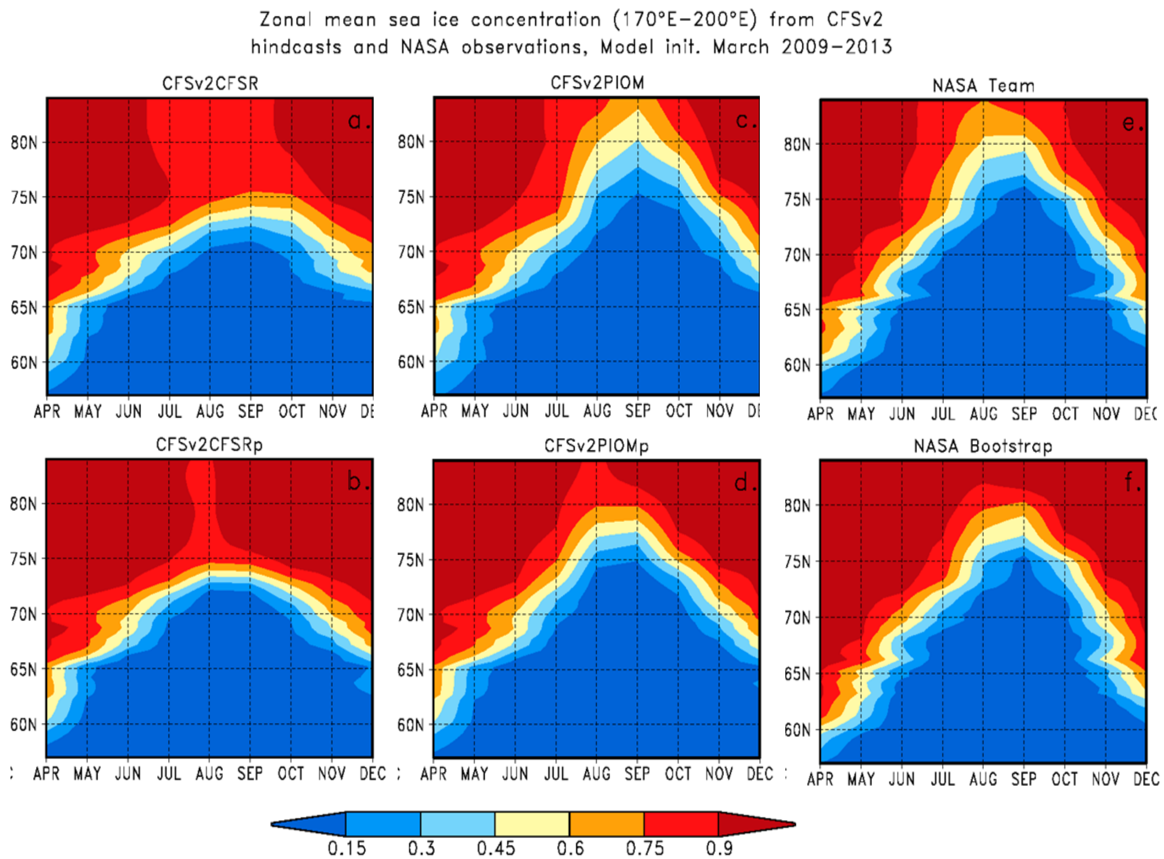
CFSv2 errors

- Ice retreats/grows too slowly compared with obs
  - Positive bias in summer months
  - Negative bias in fall months
- Errors differ between retrospective forecasts (top), operational forecasts (bottom)
  - Attributed to biases in atm forcing fields



Comparisons CFSv2 (CFSR and PIOMAS initial ice thickness)

- March 2009-2013 initialization, 9-month runs
- 5 ensembles each year
- PIOMAS interpolated to CFSR's Arctic grid, ice thickness categories converted from 12-category configuration to CFSR 5 categories
- Seasonal cycle (zonal mean) improvements



Comparisons CFSv2 (CFSR and PIOMAS initial ice thickness)

- Regional improvements
- 6 months following March initialization
- Nearly $5x10^6$ km^2 area improvement late summer/early fall

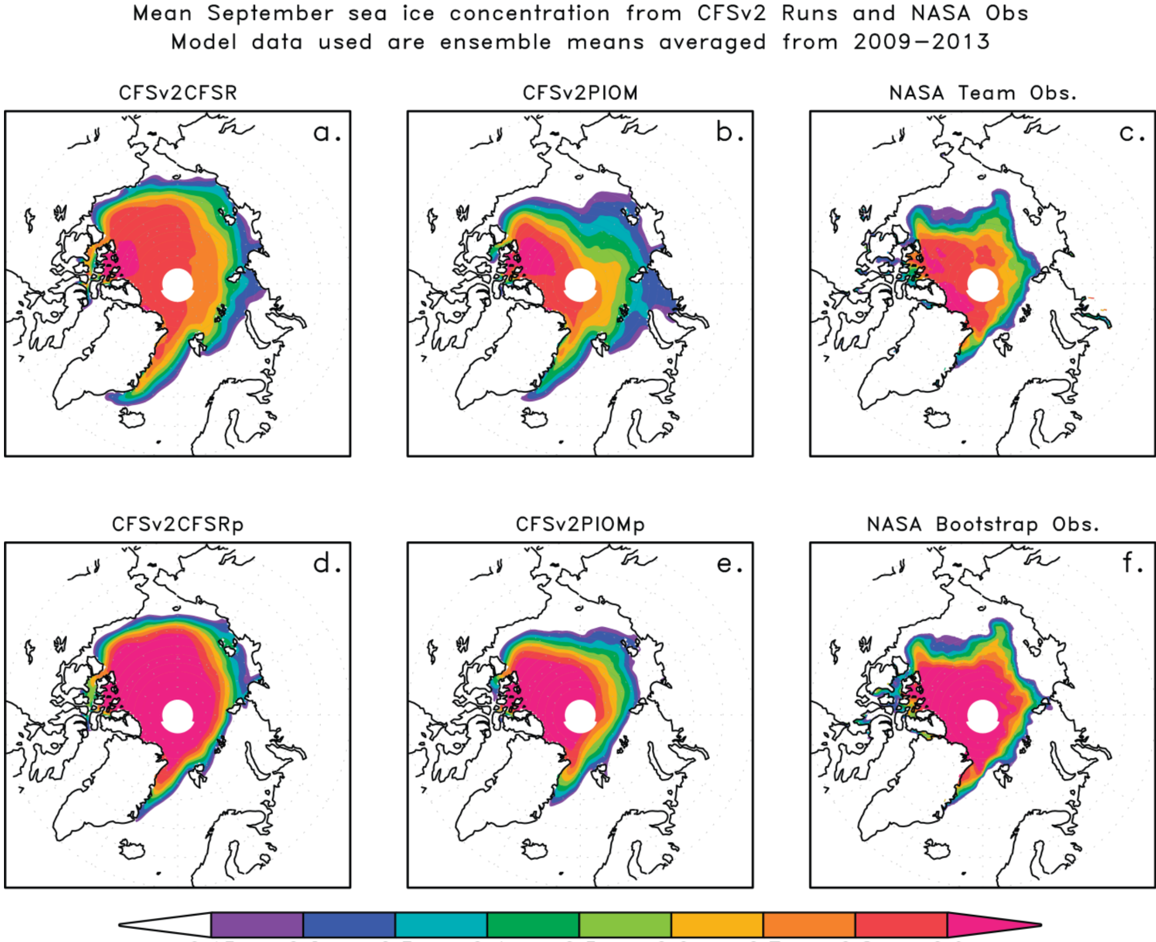
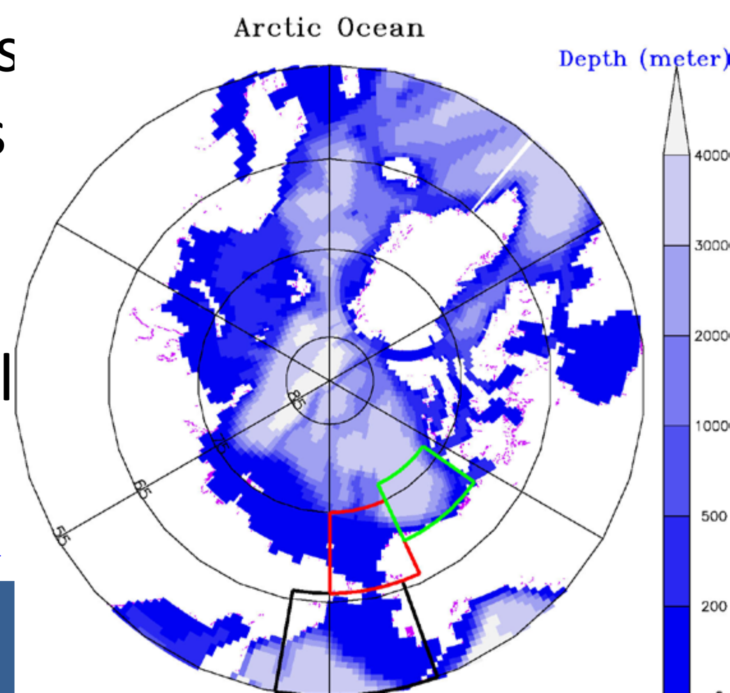


FIG . 2. Mean September sea ice concentration for (a) CFSv2CFSR, (b) CFSv2PIOM, (c) NASA Team observations, (d) CFSv2CFSRp, (e) CFSv2PIOMp, and (f) NASA Bootstrap observations. Only regions with ice concentration values greater than 0.15 are plotted.

Questions?

- NCAR CESM-CAM5 Large Ensemble Experiments
  - ~1 degree version of the CESM-CAM5
  - using historical forcing (1920-2005) and RCP8.5 forcing (2006-2100)
  - ensemble spread generated using small perturbations to the initial atmospheric states
  - 30 members used for this analysis
  - Monthly averages of ice variables
- NOAA CFSR
  - Data downloaded from http://rda.ucar.edu/pub/cfsr.html



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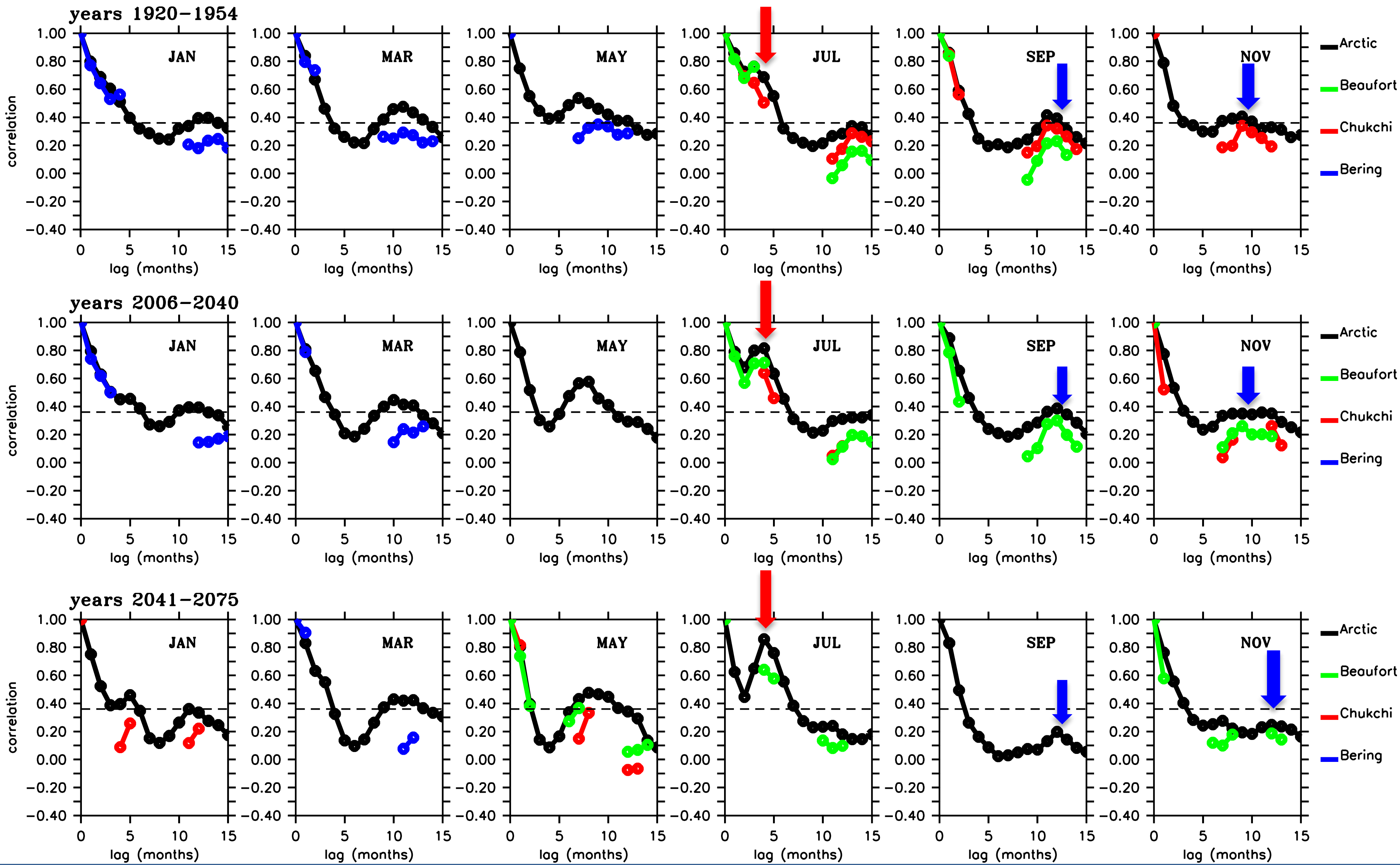
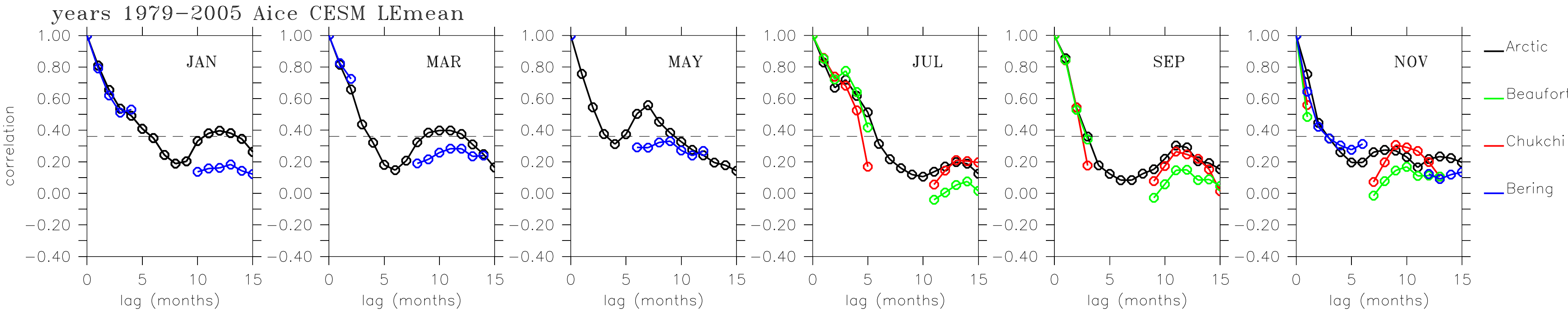
lagged correlation of ice cover anomalies - CESM ensemble mean

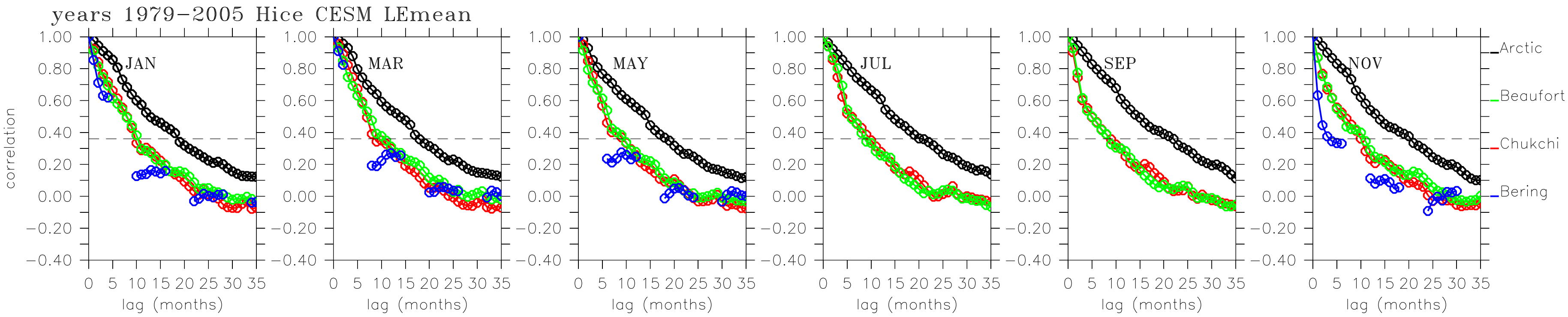


Lagged correlation comparison between **ice cover** and **ice thickness** CESM LE mean, Years 1979-2005

Ice cover



Ice thickness



Summary

Pan-Arctic:

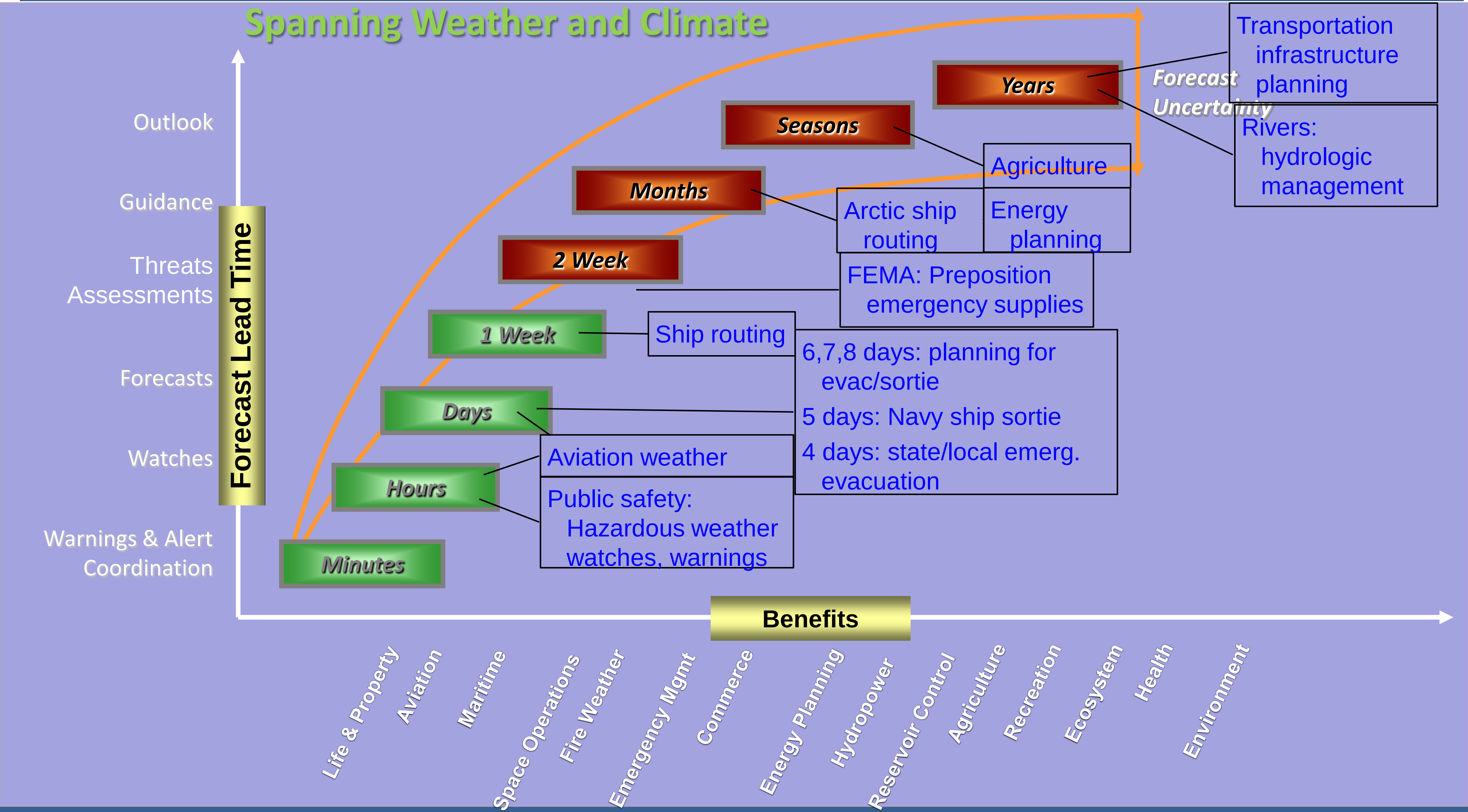
- Lagged correlations of pan-Arctic ice cover summer-to-summer persistency becomes significantly weaker in the 2nd half of the 21st century
  - Forcing strength; consistent with thickness providing summer-to-summer memory. How much thinning is necessary?
- Melt-to-freeze season memory is stronger in the future climate with thinner/less sea-ice. ?!

Regional:

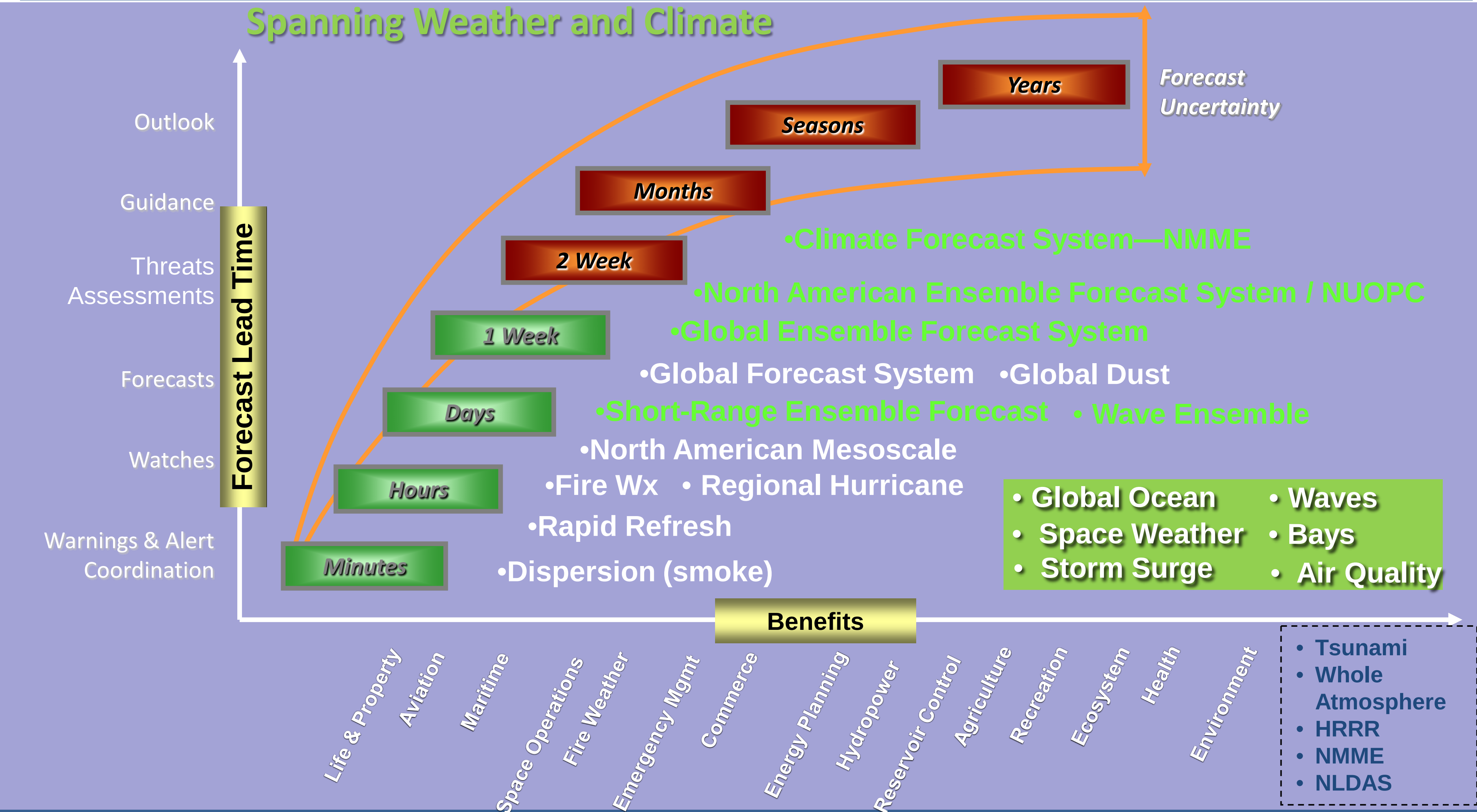
- Ice cover in the pacific regional seas exhibits reemergence of memory in a manner similar to the pan Arctic ice cover
  - Perhaps not surprising, since pan Arctic ice cover variability reflects what happens in the regional seas. However, for ice thickness, regional persistence decays faster than pan Arctic persistence.
- For ice cover, CFSR exhibits similar persistence as any individual CESM ensemble member; for ice thickness, CFSR exhibits consistently less persistence than CESM ensemble member.

Decision Time Scales

Need for "Seamless" (Internally Consistent) Forecasts

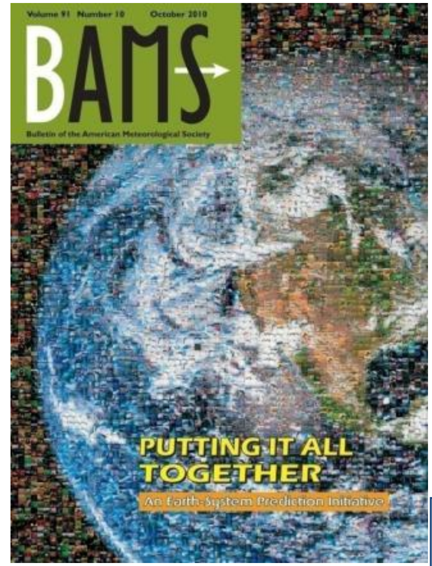


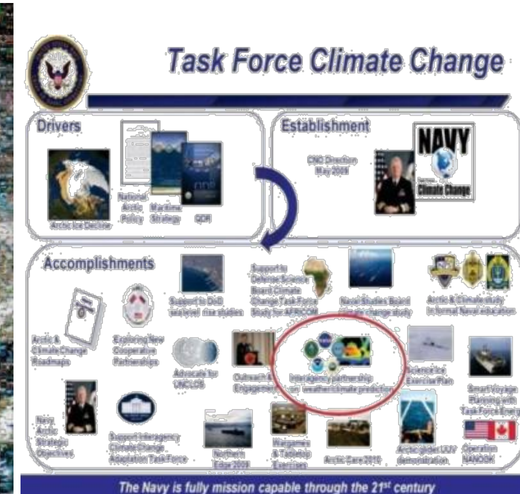
Vision:
Multi-model ensemble system across scales



Interagency Effort: Result of Community and Agency Calls to Action

- An Earth-System Prediction Initiative for the Twenty-First Century (Shapiro et al. 2010)
- Collaboration of the Weather and Climate Communities to Advance Subseasonal-to-Seasonal Prediction (Brunet et al. 2010)
- Assessment of Intraseasonal to Interannual Climate Prediction and Predictability (Weller, 2010)
- A National Strategy for Advancing Climate Modeling (NRC Press, 2012)
- Arctic Security Considerations and the U.S. Navy's Roadmap for the Arctic (Titley and St. John, 2009)
- The Uncoordinated Giant: Why U.S. Weather Research and Prediction are not Achieving their Potential (Mass, 2006)

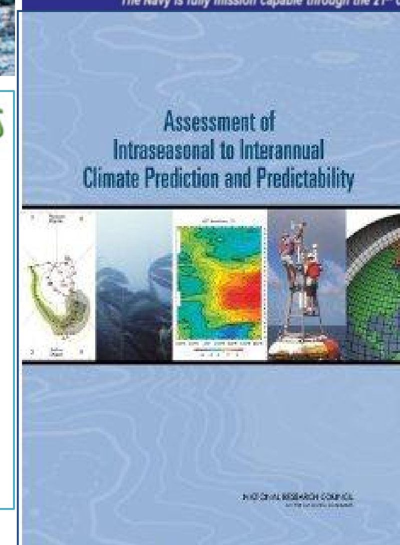





ARTICLES

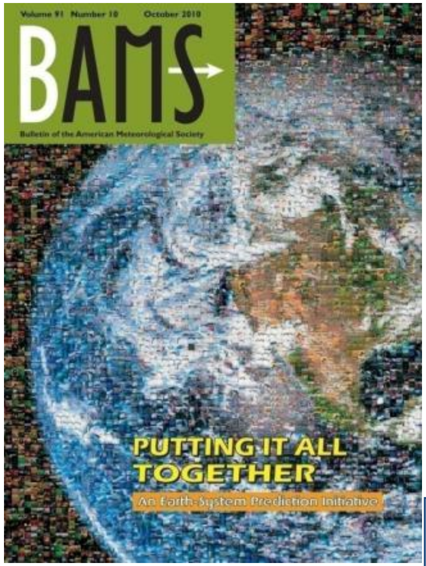
THE UNCOORDINATED GIANT

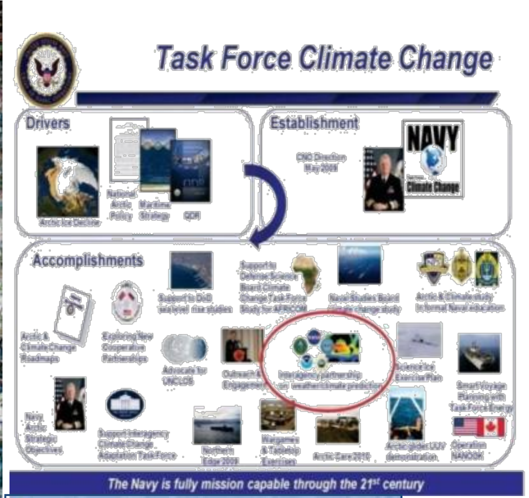
Why U.S. Weather Research and Prediction Are Not Achieving Their Potential

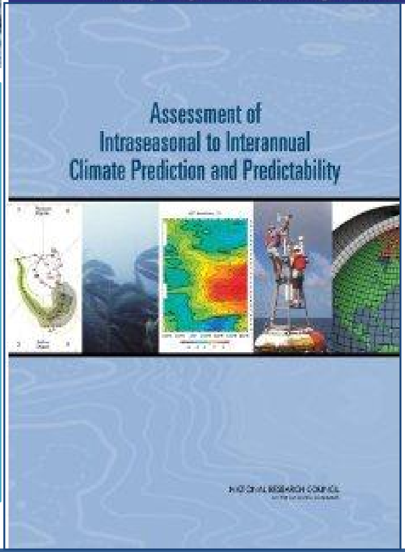


Scientific rationale: same documents call for

- Holistic approach
  - Obs, models, DA, HPC
- Seamless weather-to-climate systems, including uncertainty
- Multi-model ensembles
- Improve representation of processes, esp. convection
- Air-ocean-land-ice coupling
- Exploit sources of predictability in system
  - MJO, ENSO, Arctic ice, monsoon variability
- Common shared software infrastructure







Operational requirement

- Nowcasts (minutes to hours): tornadoes, severe weather, aviation, wind and solar energy
- Short Range Forecasts (hours to days): general public, DoD operations, emergency management, commerce
- Medium Range Forecasts (days to month): agriculture management, energy industry, emergency planning, ice concentration, DoD planning
- Intraseasonal to Interannual Predictions: Tropical cyclone activity, drought, flooding, heat waves, Arctic ice, agriculture planning, water resource management, DoD strategic planning
- Intradecadal and Interdecadal Projections: sea level for coastal infrastructure; precipitation/snow pack changes for agriculture, water, and transportation infrastructure construction; politically destabilizing events; support for national/international climate assessments.