Seamless Predictions and Projections of Earth's Climate System

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Outline

- SPEAR modeling system
- SPEAR subseasonal to seasonal to decadal predictions
- SPEAR Large Ensemble

Goal

Improve ability to predict and project climate from subseasonal to multidecadal.

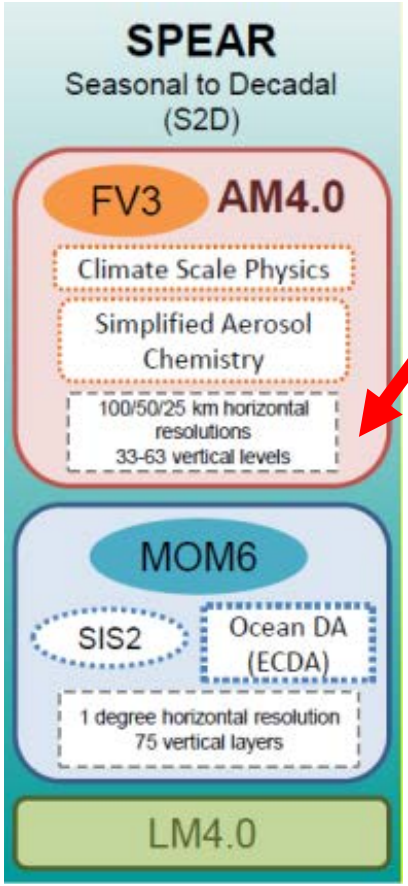
Why seamless?

Similar phenomena across time scales, interactions across time scales; may build confidence in longer term projections with verified short-term predictions

References
Delworth et al., 2020, JAMES - Model description and description of ensembles
Lu et al., 2020, JAMES – Description of SPEAR seasonal prediction system
Yang et al., 2021, JAMES – Description of SPEAR decadal prediction system
Also, see https://www.gfdl.noaa.gov/spear/

SPEAR: One part of a unified suite of models

(**S**eamless system for **P**rediction and **EA**rth system **R**esearch)



Versions of SPEAR w/ different resolutions

SPEAR_LO: 100 km atmosphere, 100 km ocean
SPEAR_MED: 50 km atmosphere, 100 km ocean
SPEAR_HI: 25 km atmosphere, 100 km ocean
SPEAR_HI_25: 25 km atmosphere, 10-25 km ocean

Uses of SPEAR system

Subseasonal prediction (Xiang et al, 2021)
Seasonal prediction (Lu et al, 2021)
Decadal prediction (Yang et al, 2021)
Large ensembles (Delworth et al, 2020)

Closely related GFDL models:
SHiELD – *hi res weather prediction*
CM4 – *higher resolution ocean*
ESM4 – *earth system model*

SPEAR: Initialization systems

Subseasonal: Atmosphere - restore atmosphere to MERRA-2
Ocean – restore SST to NOAA OISST (v2)

Seasonal: Atmosphere – restore to CFSR reanalysis with SST restored to daily OISST v2
Ocean – assimilation with XBT, Argo, CDT, moorings (1991-present)
Use of OTA (Ocean tendency adjustment to reduce bias/drift)

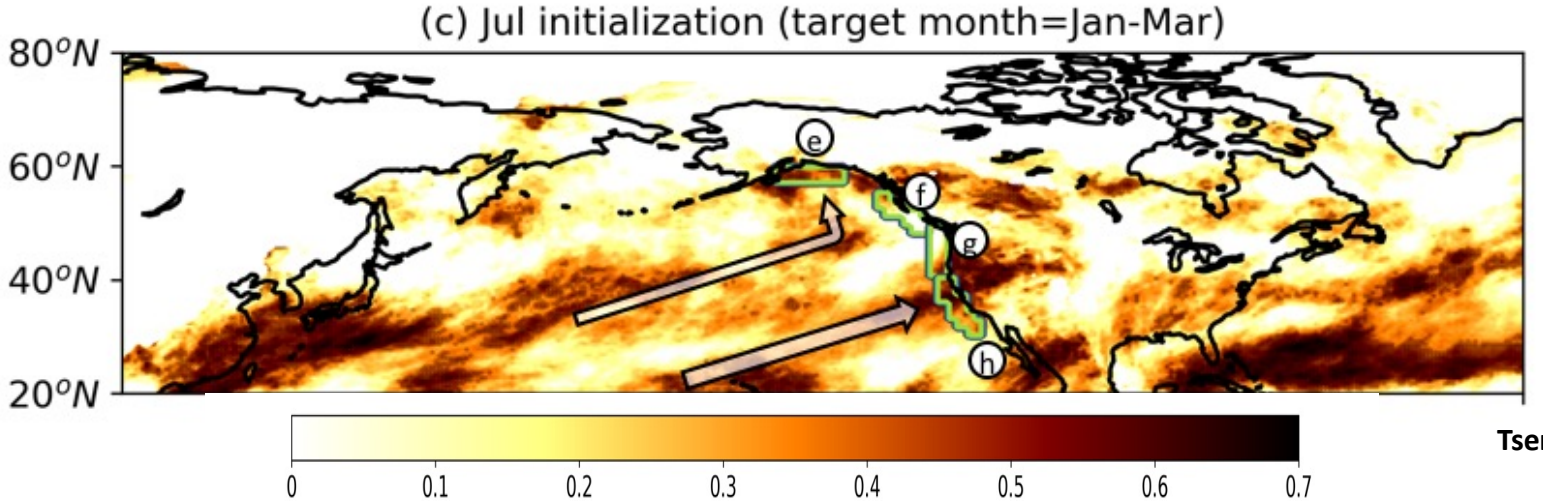
Decadal: Atmosphere – restore to JRA-55 atmospheric reanalysis
Ocean - restore to ERSSTv5 ; no subsurface ocean data incorporated

Seasonal Prediction in SPEAR

- Much reduced RMS error for SST (relative to previous FLOR system)
- Improved predictions for ENSO, sea ice
- Participate in real-time North American Multi-Model Ensemble (NMME)

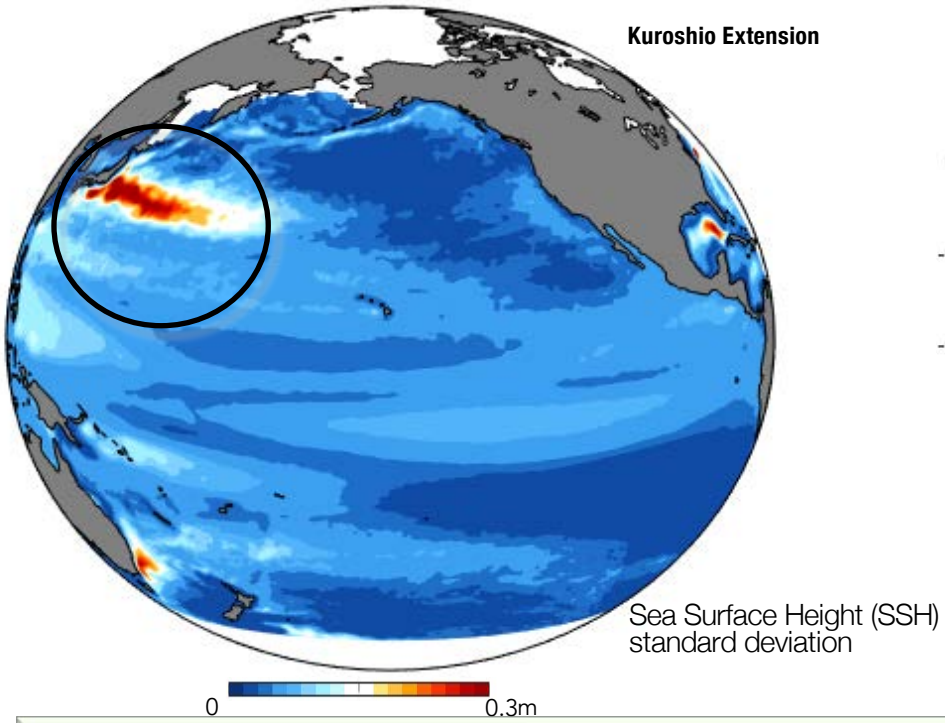
Some new findings:

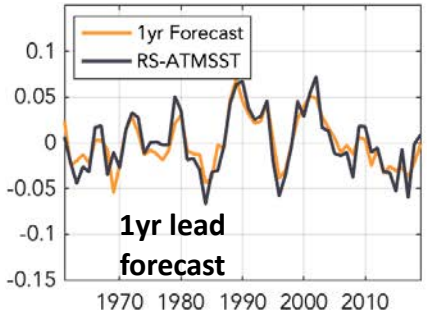
- Potential seasonal predictability of conditions for extreme heat events (Jia et al., 2022)
- Predictability and predictive skill for atmospheric rivers 8-10 months in advance (Tseng et al., 2021)

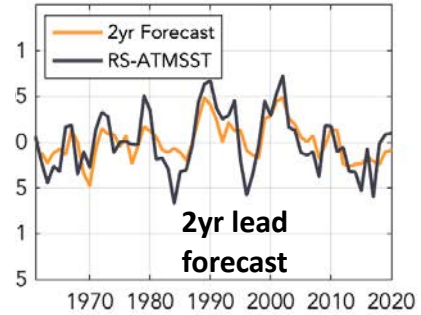


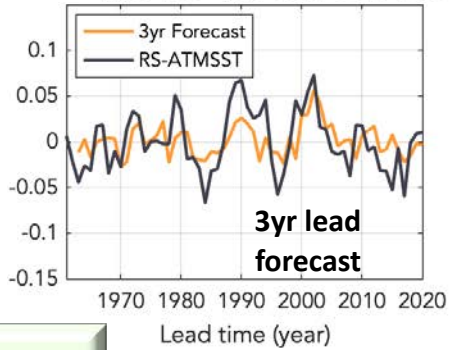
Tseng et al, 2021

Multiannual prediction of Kuroshio Extension (talk by Youngji Joh)



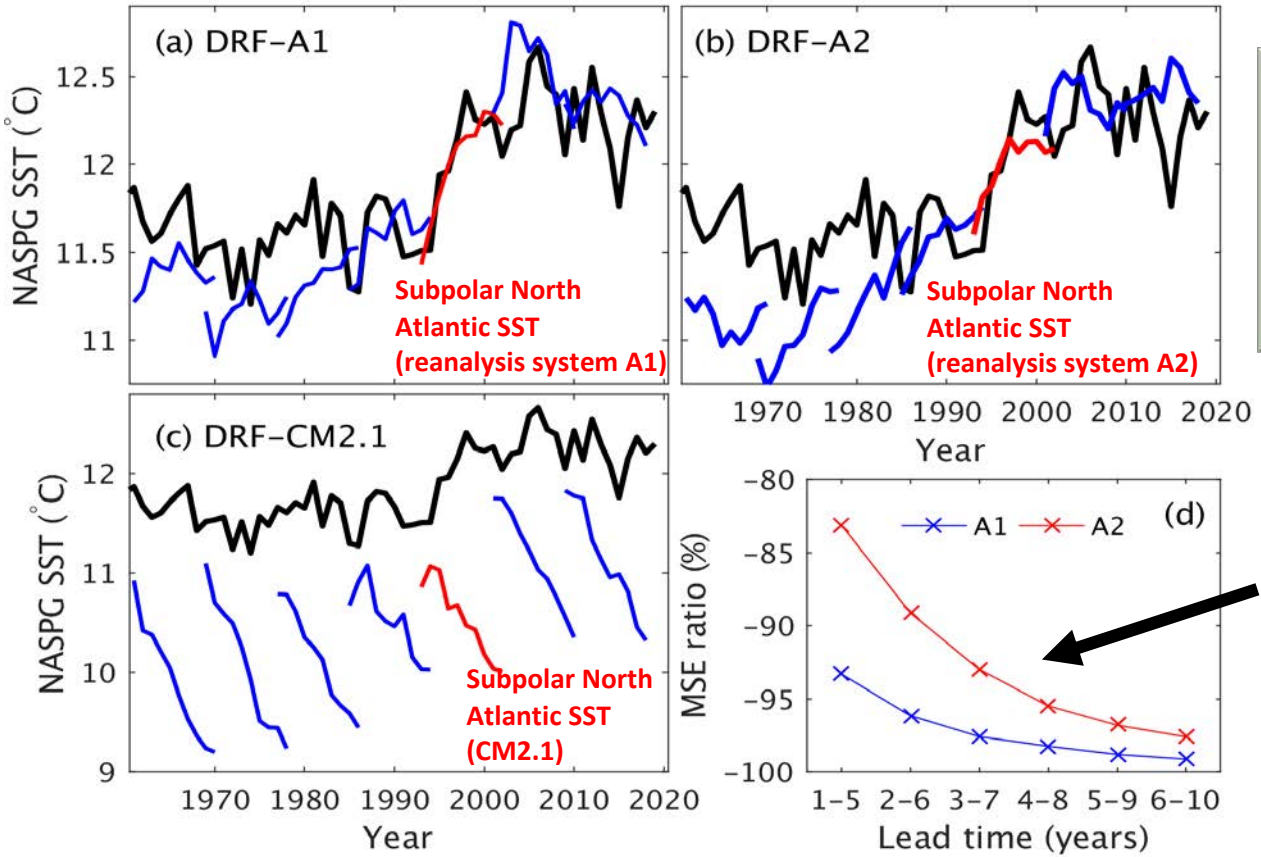






- *Substantial skill in both decadal and seasonal prediction systems.*
- *Higher skill with winter initialization*
- *Extending seasonal prediction system to interannual might reveal more skill*
- *Skill from ocean wave propagation, air-sea interaction*

SPEAR Decadal Predictions



➔ Contributor to WMO Interannual to Decadal Prediction Project

➔ Initialization system does not use subsurface ocean data)

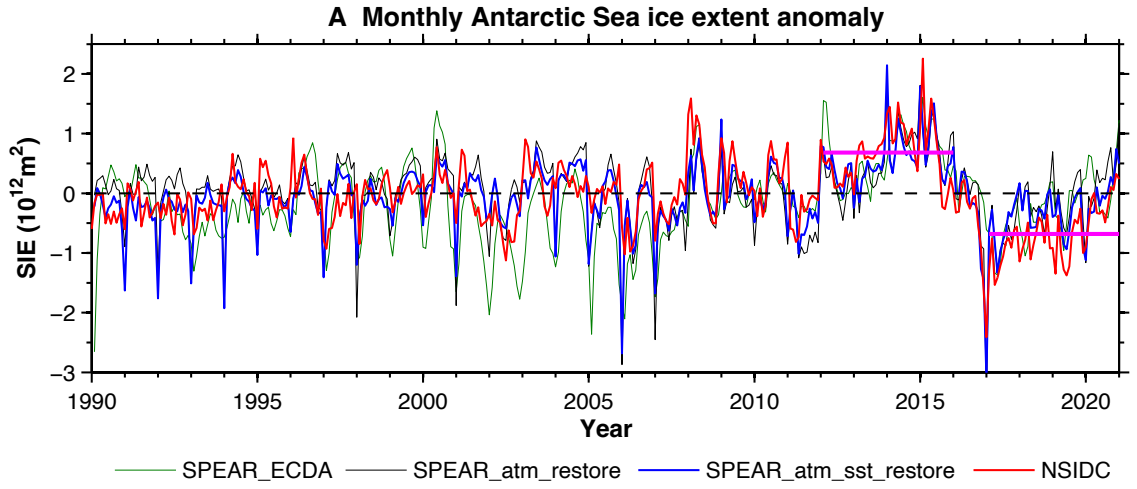
Reduction of error relative to CM2.1 (more negative is better)

Multiannual predictive skill for Sahel precipitation, reconstructed AMOC, regional temperature, etc.

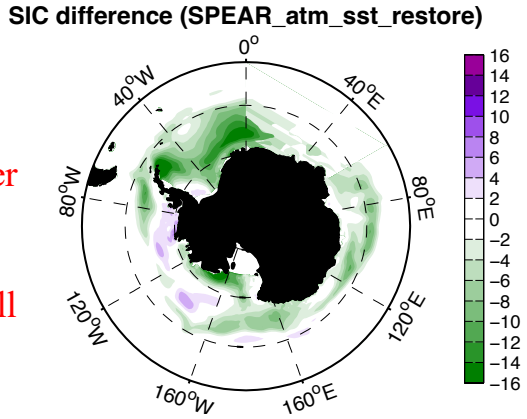
➔ Potential multiannual relevance includes storm tracks, extremes, regional precipitation, etc.

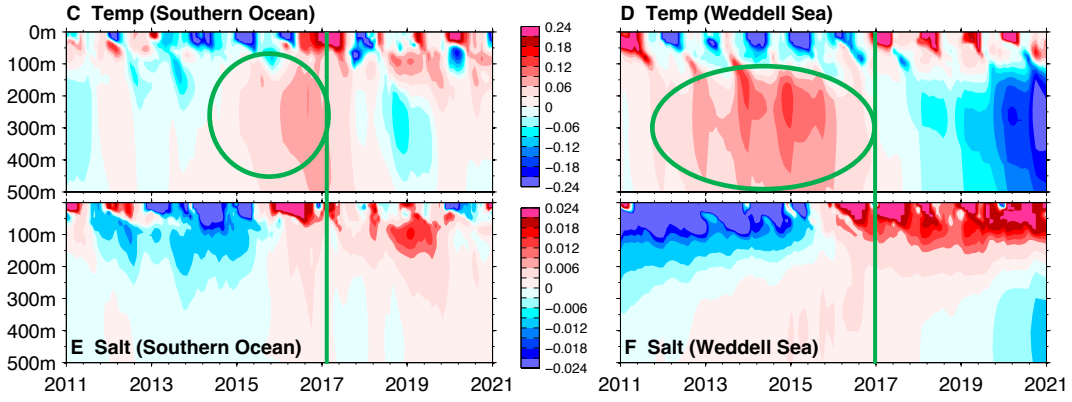
Yang et al., JAMES, 2021

Predictability from the subsurface in the Southern Ocean



Dramatic decline in sea ice after 2015, mainly in the Weddell Sea





Ice decline is preceded by subsurface heat buildup in the upper ocean (decade long enhanced wind indued warm horizontal and vertical temperature advection) and surface salinification

➔ ***Significant skill in SST and sea ice predictions up to leads 3-7 yrs***

Slide courtesy of Liping Zhang (see poster by Liping Zhang)

Climate Change as a Multiannual "Prediction"

Increasing risk of another Cape Town "Day Zero" drought in the 21st century

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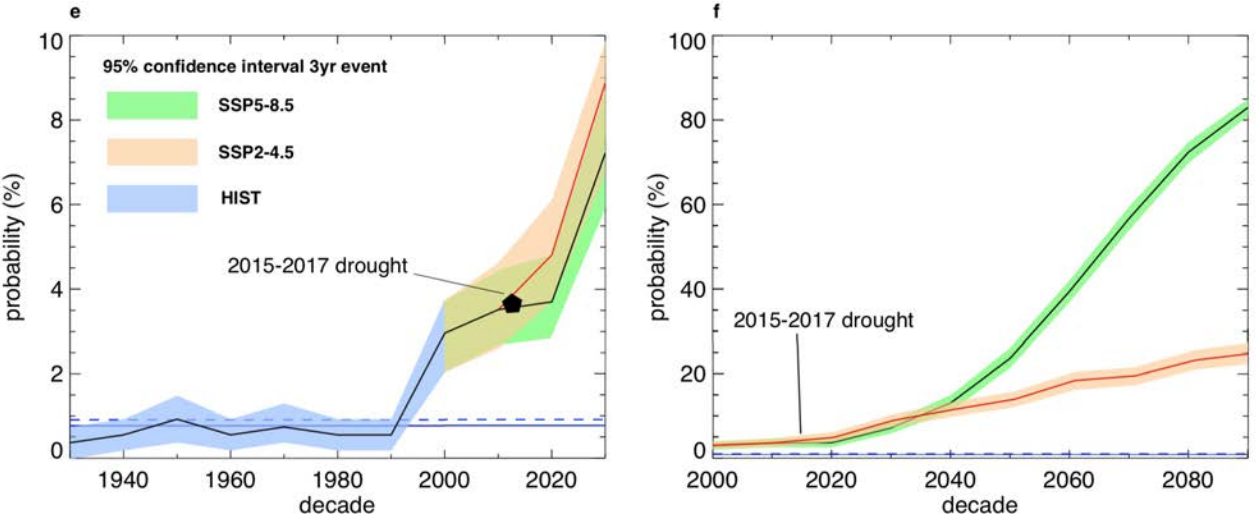
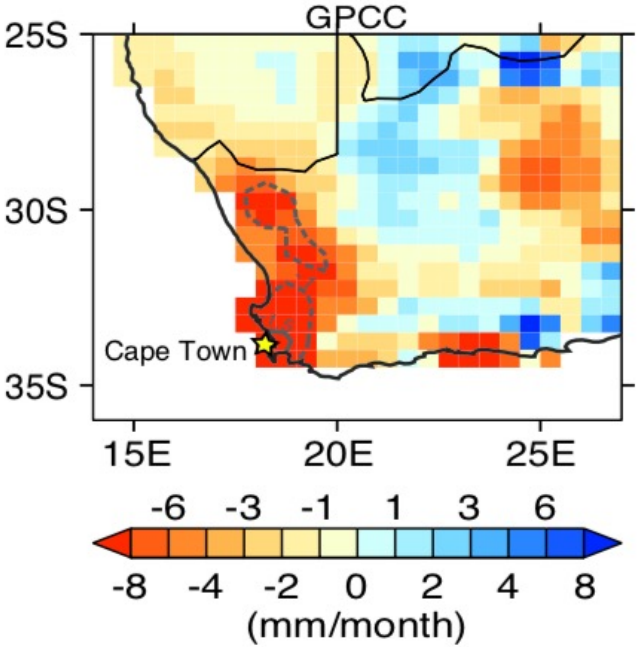
South African multi-year Drought (2015-2017)

- Dams supplying Cape Town ≈ **20% in May 2018**
- If below **13.5%** "**Day Zero**": disconnect much of the municipal water supplies

Use Large Ensemble to evaluate likelihood of such droughts in the future, and the role of changing radiative forcing





Summary and Discussion

SPEAR system in use at GFDL for:

- Real-time seasonal to decadal predictions
- Multidecadal projections including large ensembles

Multiple examples of seasonal to multiannual to decadal skill

- Seasonal to annual (8-10 month lead) atmospheric river activity
- North Pacific seasonal to multiannual variations of the Kuroshio Extension
- Interannual to decadal Atlantic variability (SST, AMOC)
- Interannual to decadal Southern Ocean variability (relevance for climate change)
- Radiatively forced changes (Capetown drought example)

Ongoing work

- Exploring impacts of model resolution and bias on predictability across scales
- Predictability of extremes (temperature, precipitation)
- Tradeoffs of resolution, ensembles, ability to represent extremes

Some considerations for prediction

- What physical processes give rise to the predictability?
- What type of model? (dynamical, statistical)
- Model composition, resolution, initialization system are crucial