SEASONAL TO DECADAL VARIABILITY AND PREDICTABILITY

Presented by Thomas L. Delworth

Q2: Concerning NOAA's key mission element of understanding, predicting, and projecting changes in the Earth System, how can GFDL drive further advances in these areas, including extremes and environmental hazards, through scientific innovation based on observations, theory, and modeling? Where are the strengths, gaps, and new frontiers?

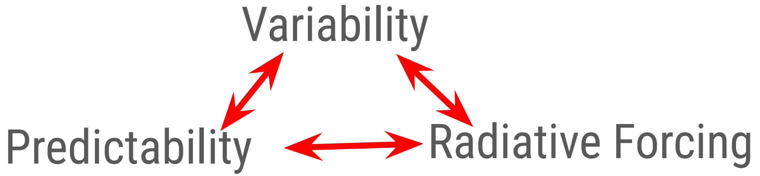
GOAL: Increase understanding leading to predictive capability across timescales

RELEVANCE: NOAA Mission (first 2 of 3 goals):
1. To understand and predict changes in climate, weather, ocean, and coasts
2. To share that knowledge and information with others

Improve understanding of seasonal to multidecadal variability, predictability, and response to changing radiative forcing. Use observations and models.

Development and application of models to <u>translate understanding to predictive capabilities</u> of use to NOAA and society

*References can be found **here**.*



We customize GFDL modeling blocks for seasonal to multidecadal applications

SPEAR: Seamless system for Predictions and EArth System Research

Building blocks:

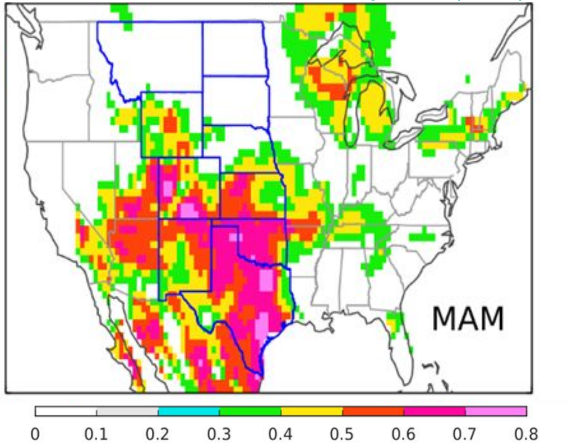
AM4 atmosphere
MOM6 ocean & sea ice
LM4 land model
Initialization Systems

MODEL	Atmos-Land resolution	Ocean-Ice resolution	Applications
SPEAR_LO	100 km	100 km	Decadal prediction
SPEAR_MED	50 km	100 km	Seasonal prediction; Multidecadal projections
SPEAR_HI	25 km	100 km	Projections and Extremes
SPEAR_HI_25	25 km	25 km	Projections and Extremes
SPEAR_HI_8	25 km	8 km	In development

Exploring subseasonal to seasonal predictability & predictions

- Subseasonal and seasonal predictability and prediction research
  ⇒ heat extremes, atmospheric rivers, marine heat waves, seasonal tornado activity, atmospheric blocking (see prerequisite slides)
- Real-time seasonal prediction with SPEAR_MED (NMME, Nat Johnson, Q3 presentation)
- Seasonal prediction input to hi-res regional ocean prediction
- Seasonal hurricane prediction (Hiro Murakami) and role of radiative forcing
- Exploration of initialization and bias reduction
- Analog forecasts and use of ML/AI

SPEAR forecast skill (ACC) of Mar - May wind energy for a 1 Feb initialization. From Yang et al. (2023).

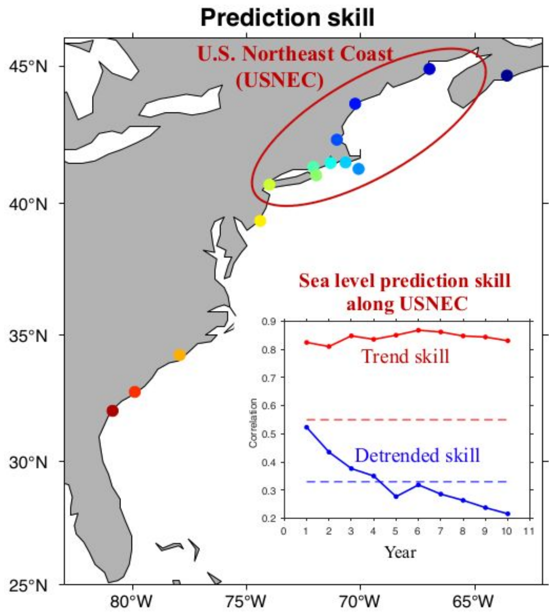


Exploratory research can lead to new products
⇒ High skill for seasonal wind energy production

Exploring decadal variability, predictability & predictions

RELEVANCE: Crucial need to predict and project changes over the next 1-20 years - internal variability + radiatively forced change. Vital information for planning.

Zhang et al., 2024



ACTIVITIES:

⇒ Better understand decadal variability & predictability - focus on ocean

- Atlantic Meridional Overturning Circulation (AMOC) & sea level
- North Pacific (Kuroshio extension, 5-year prediction skill)
- Southern Ocean (Liping Zhang; see prerequisite slides)

⇒ Real-time decadal predictions (with WMO; variability + rad. forcing)

⇒ Input to high resolution regional ocean predictions

⇒ "On-Demand" decadal prediction after volcanic eruption

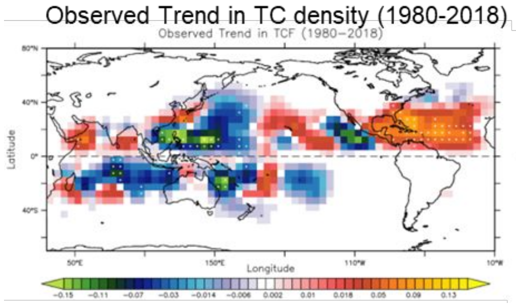
Large ensembles of SPEAR for understanding & risk assessment

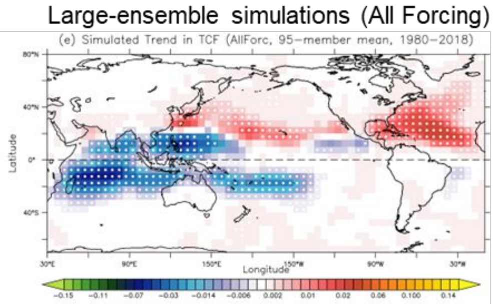
SPEAR_LO, SPEAR_MED,
SPEAR_HI, SPEAR_HI_25
https://www.gfdl.noaa.gov/spear_large_ensembles/

Forcing scenarios used (years 1921-2100):
SSP119, SSP245, SSP585, SSP370, SSP534OS
(30-member ensembles)

RELEVANCE:

- Attribution of real-time seasonal to decadal predictions
- Extreme heat and storms (data contributing to ASCE)
- Regional hydroclimate change
  (extreme precipitation; data contributing to ATLAS-15)
- Ocean circulation and variability changes (AMOC,ENSO,Pacific,SO)
- Risk assessment in support of decision making
- Reversibility of change

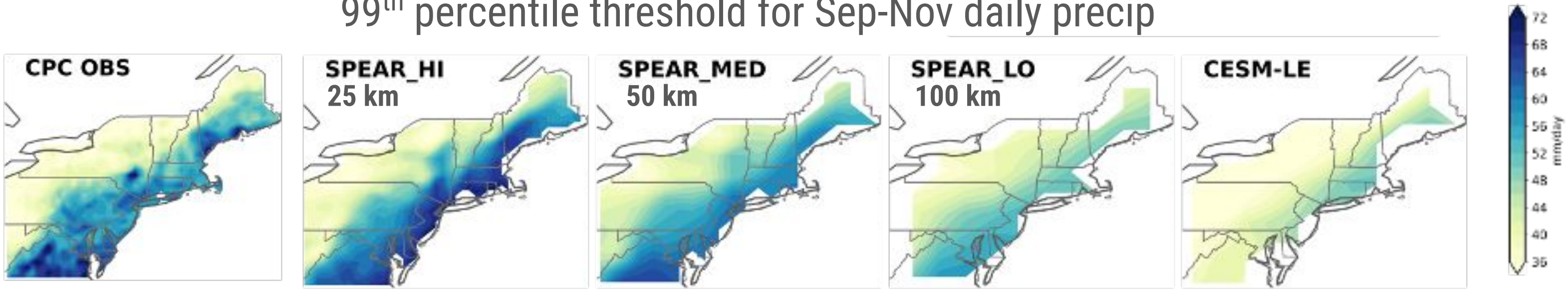




https://www.gfdl.noaa.gov/spear_large_ensembles/

Changing extreme precipitation is well simulated by 25km SPEAR

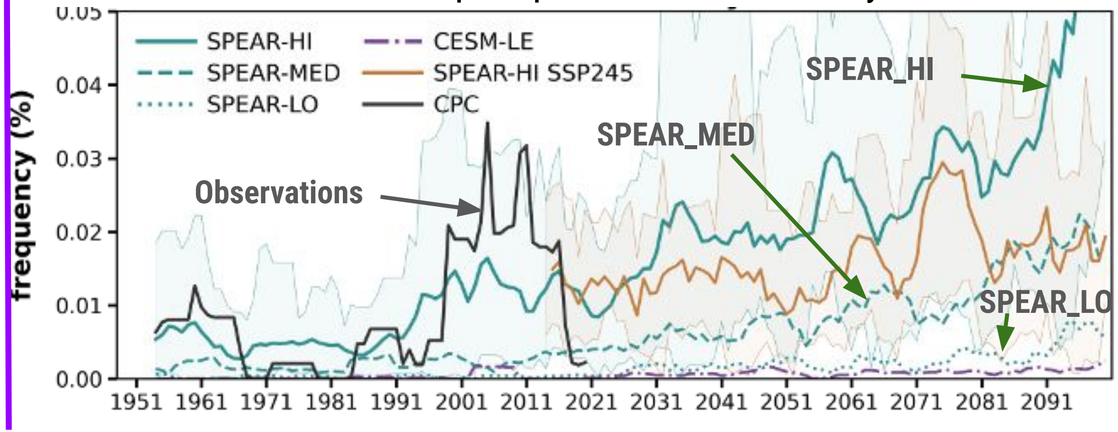
99th percentile threshold for Sep-Nov daily precip



Jong et al., 2023, 2024

Large ensembles of high-resolution models are critical for realistic simulation of **characteristics and mechanisms** of changes in extreme precipitation.

NE US precipitation > 150 mm day^{-1}



Final Points and Future Directions

Predictability of regional extremes using high resolution models

⇒ from atmospheric rivers to heat to coastal sea level

Connecting predictions & projections to societal impacts

⇒ coastal flooding, land falling TCs, Santa Ana Winds

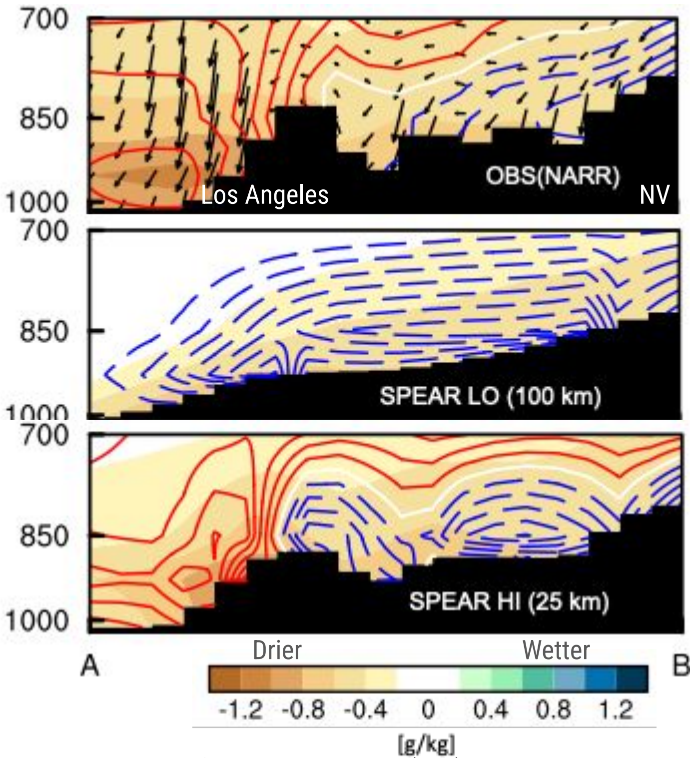
Air-sea interaction at high-resolution

Exploration of high-resolution prediction

AI/ML and climate

⇒ detection, attribution, prediction

Climate Reversibility



Cross section from Los Angeles (left) to Great Basin (Nevada) showing atmospheric temperature (contours) and moisture (shading) during Santa Ana wind events

Figure courtesy Yujia You