Beyond ENSO:
new signals of seasonal to interannual predictability

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Climate Forecast Applications Network

Climate Forecast Applications Network (CFAN)

- Spin-out company from Georgia Tech, led by atmospheric scientists Dr. Judith Curry and Dr. Peter Webster
- Research-driven firm:
  - ➢ understanding complex weather and climate phenomena
  - ➢ Improving forecasts and assessing their predictability
- Helping businesses manage weather & climate risk

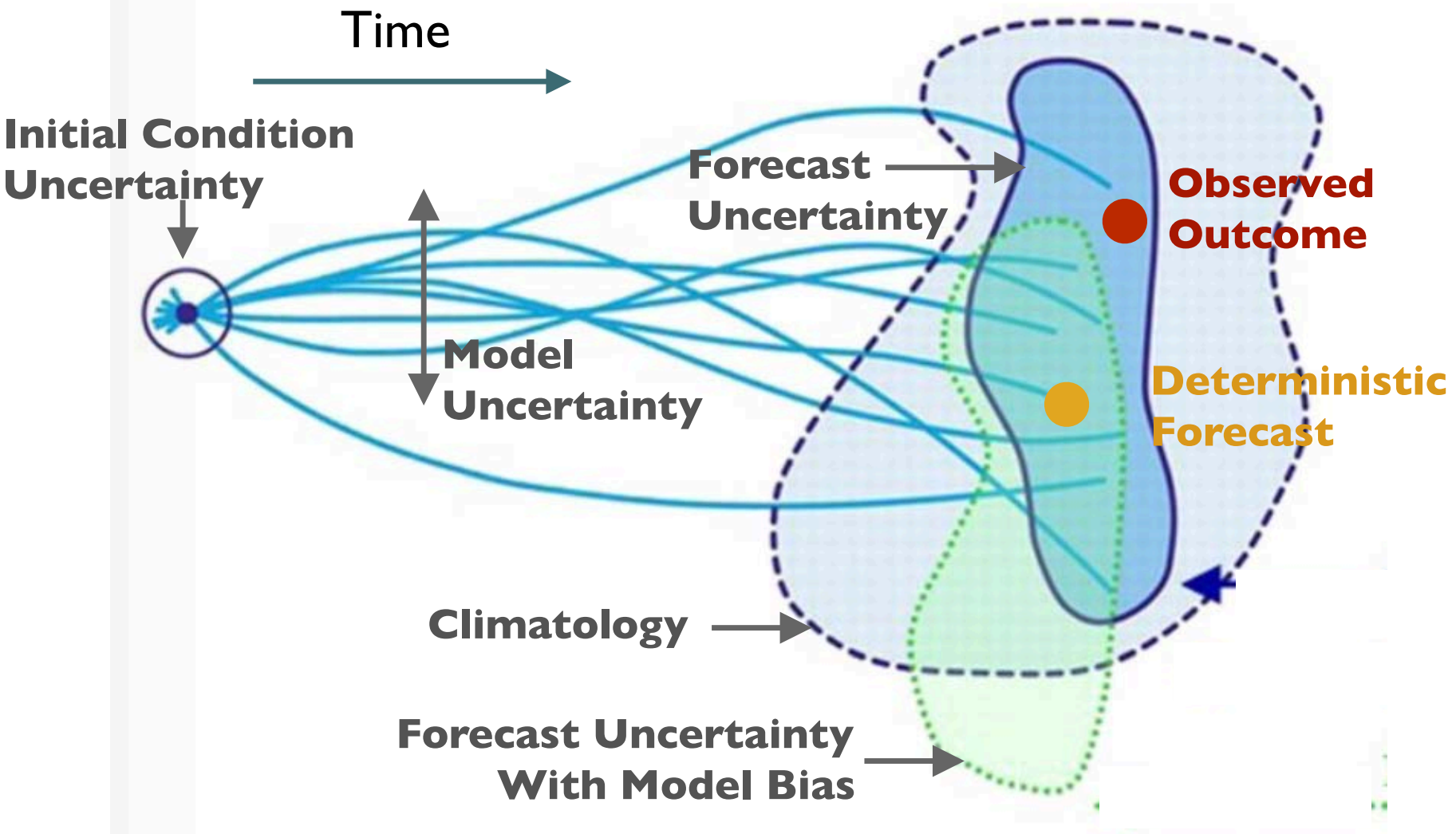
Pushing the frontiers of weather & climate prediction from days to decades

Utility of climate forecasts for risk management

Are the following forecasts ‘useful’?

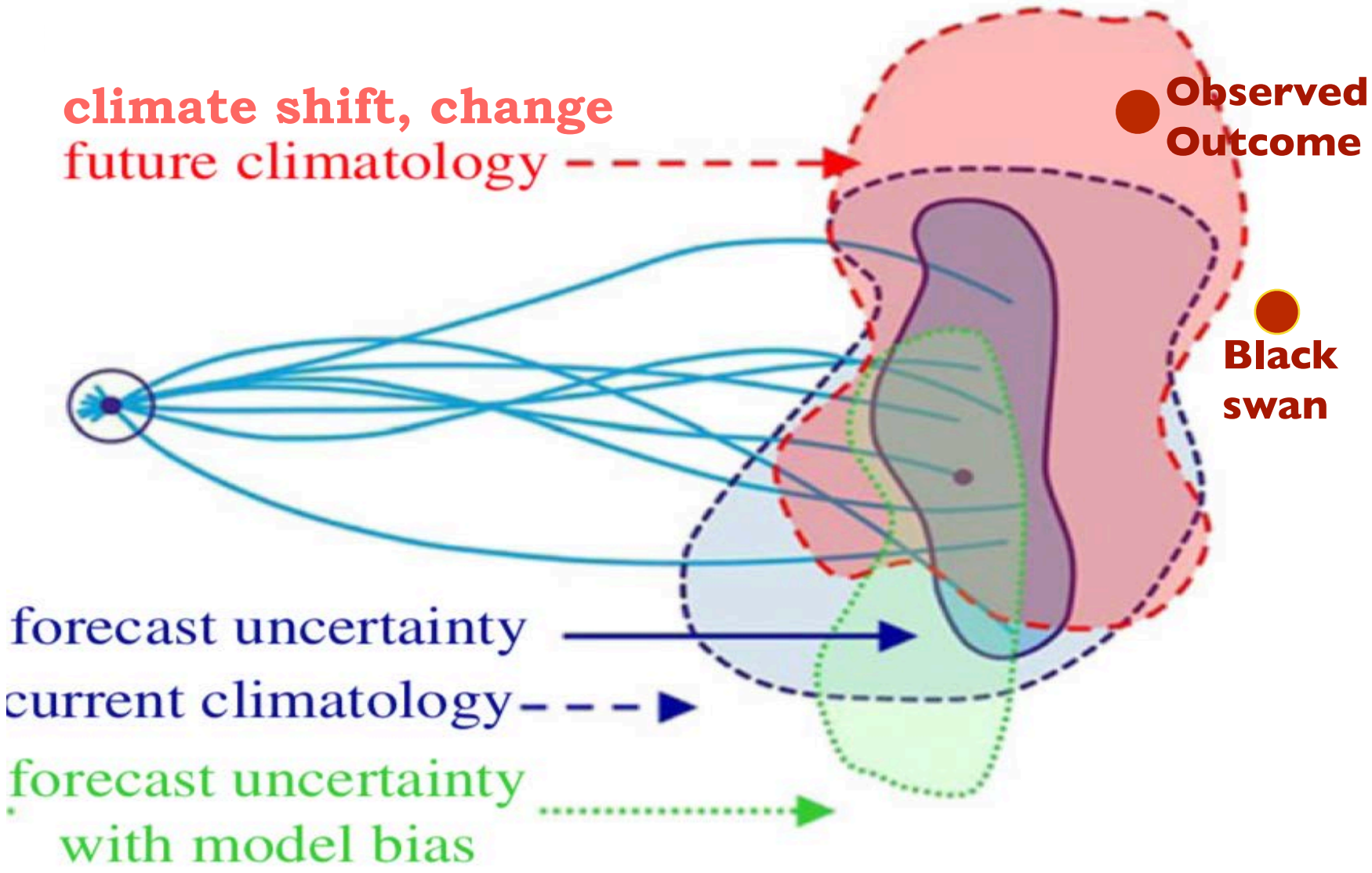
- High precision deterministic forecast:
  Seasonal Atlantic ACE forecast of 167
- Categorical probability forecasts:
  40% probability of El Nino,
  30% neutral, 30% LaNina
- Trend forecast:
  Temperatures in the SE U.S. will increase by 0.2^{o}C by 2030
- **Extreme event scenarios:**
  Heat waves, droughts, tropical cyclones
- **Forecast confidence:**
  Current forecast has little chance of beating climatology

Ensembles & probabilistic weather prediction



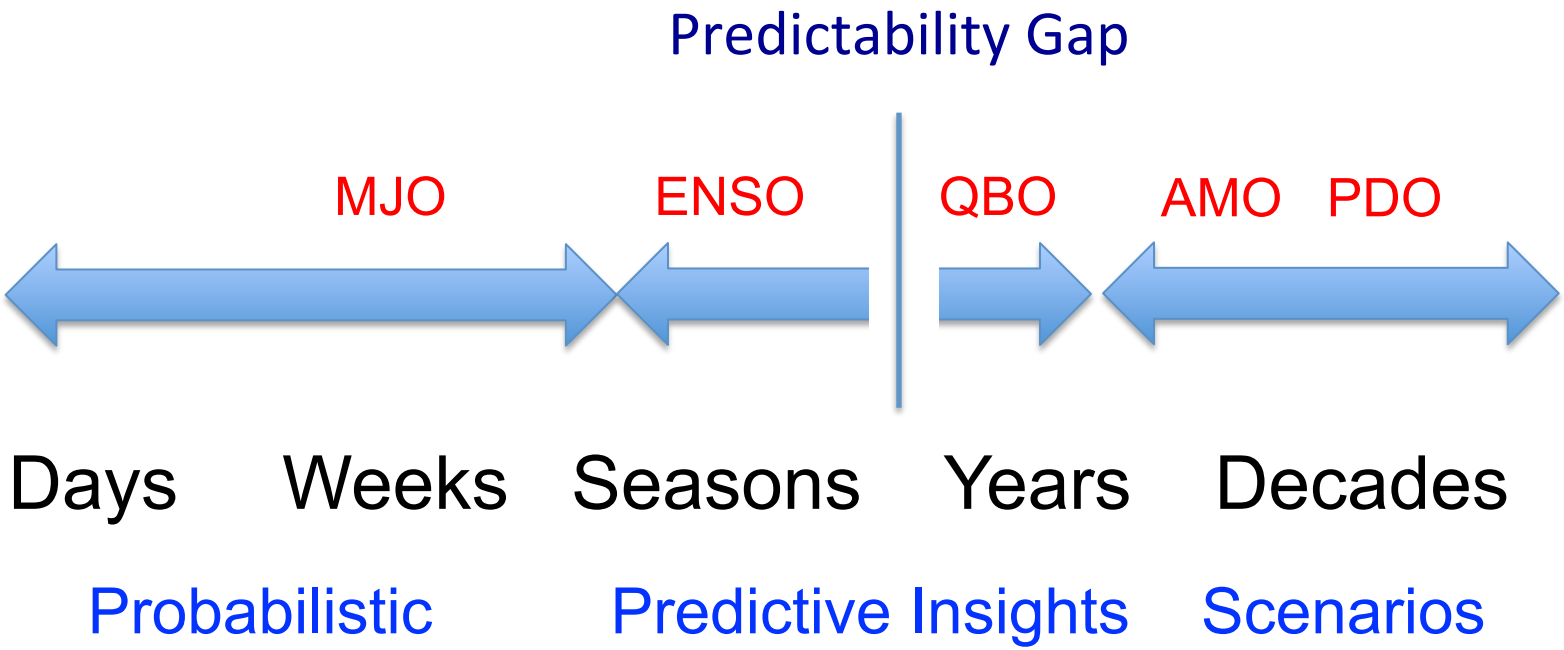
Slingo & Palmer 2011

Ensembles & probabilistic climate prediction



Slingo & Palmer 2011

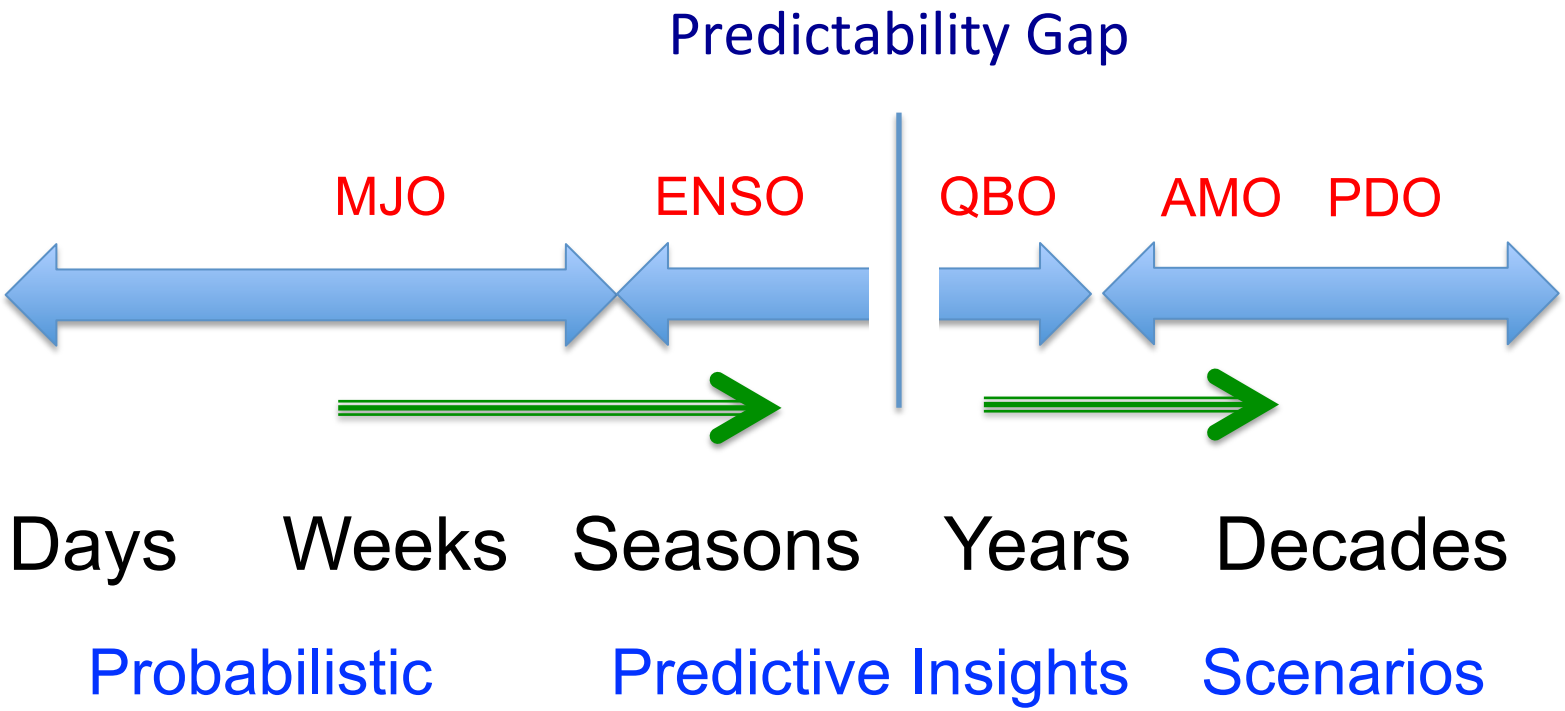
Predictability, prediction and scenarios



Statistics of Extreme Events

black swans, surprises, discontinuities, abrupt change

Predictability, prediction and scenarios



Statistics of Extreme Events

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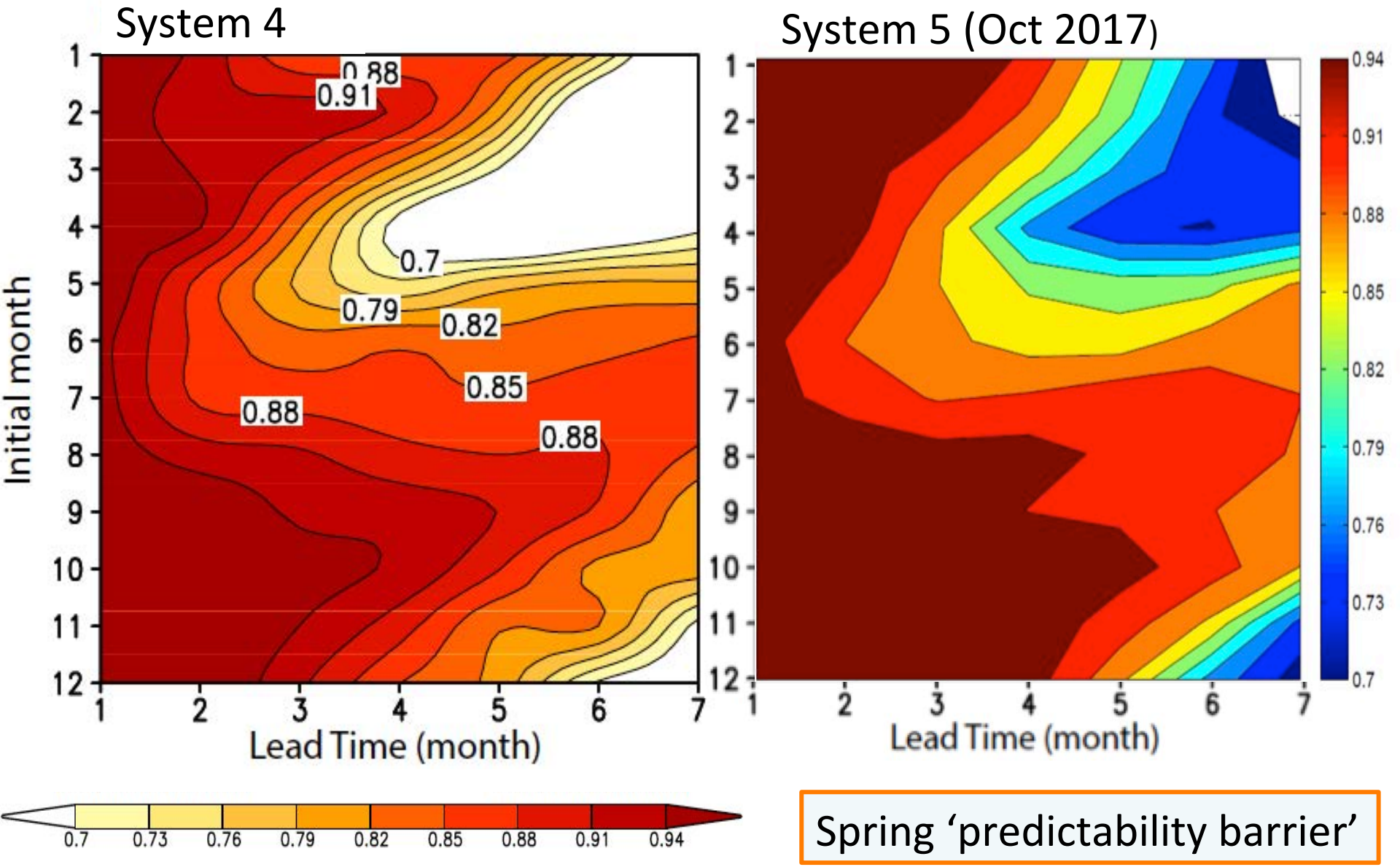
ECMWF ENSO forecast skill



Spring ‘predictability barrier’

Climate prediction: signal – to – noise problem

The signal (predictable components):

- Long-term trend
- Regimes and teleconnection patterns
- Cyclical effects
- Seasonal effects

The noise:

- Unpredictable chaotic components
- Random weather variability
- Model error

Biggest challenge:

- Regime shifts
- Shifts triggered by random weather events

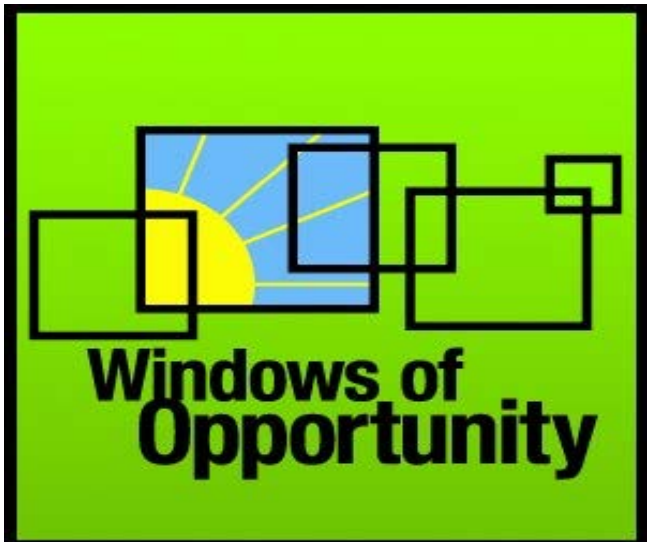
Riding the wave

Weather roulette

Climate prediction: can we beat climatology?

- Skill depends on forecast initialization relative to the annual cycle: late winter/early spring forecasts are most difficult
- Regime dependent skill: forecast initialized during a well-established regime are more skillful

Key predictive insight: whether current forecast can beat climatology



Data – driven prediction methods

Statistical forecasts

- Past analogues
- Time series based

Challenges:

- Too simplistic
- Insufficient analogues
- Climate shifts

CLIMATE DYNAMICS

Big data analytics

- Data mining
- Artificial intelligence
- Network-based methods

Good data + **Domain Knowledge** + Data Mining + **Thinking** = Success

Richard DeVeaux

Seasonal to interannual predictions: predictive insights ⟶ probabilistic predictions

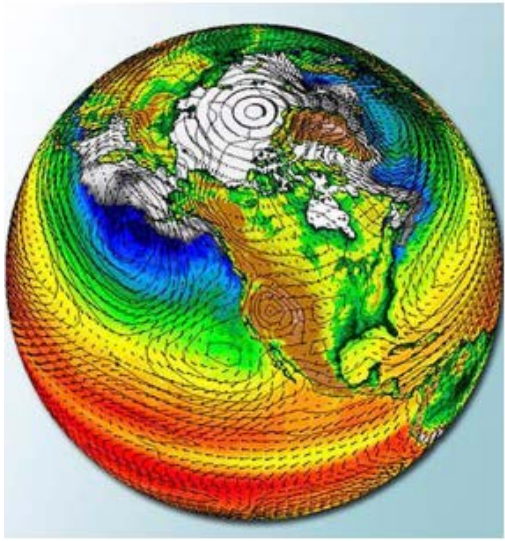
HYBRID PREDICTION SCHEME

Integrate:

- **Climate model ensemble predictions** revert to climatology after few months; ensemble spread too large to be useful
- **Data-driven forecasts** lack space − time resolution
- **Climate dynamics**: regime analysis and shifts

Method:

- '**Clustering**' of ensemble members based on predictors from data-driven forecasts
- **Confidence assessment** based on probability of a regime shift



Data-driven forecasts: climate dynamics analysis

CFAN's analysis of climate dynamics includes consideration of 5 time scales and their associated regimes:

1) **annual cycle:** useful predictors vary over the annual cycle

2) **quasi-biennial** (2-3 years): dominated by stratospheric signals

3) **interannual** (3-7 years): dominated by ENSO

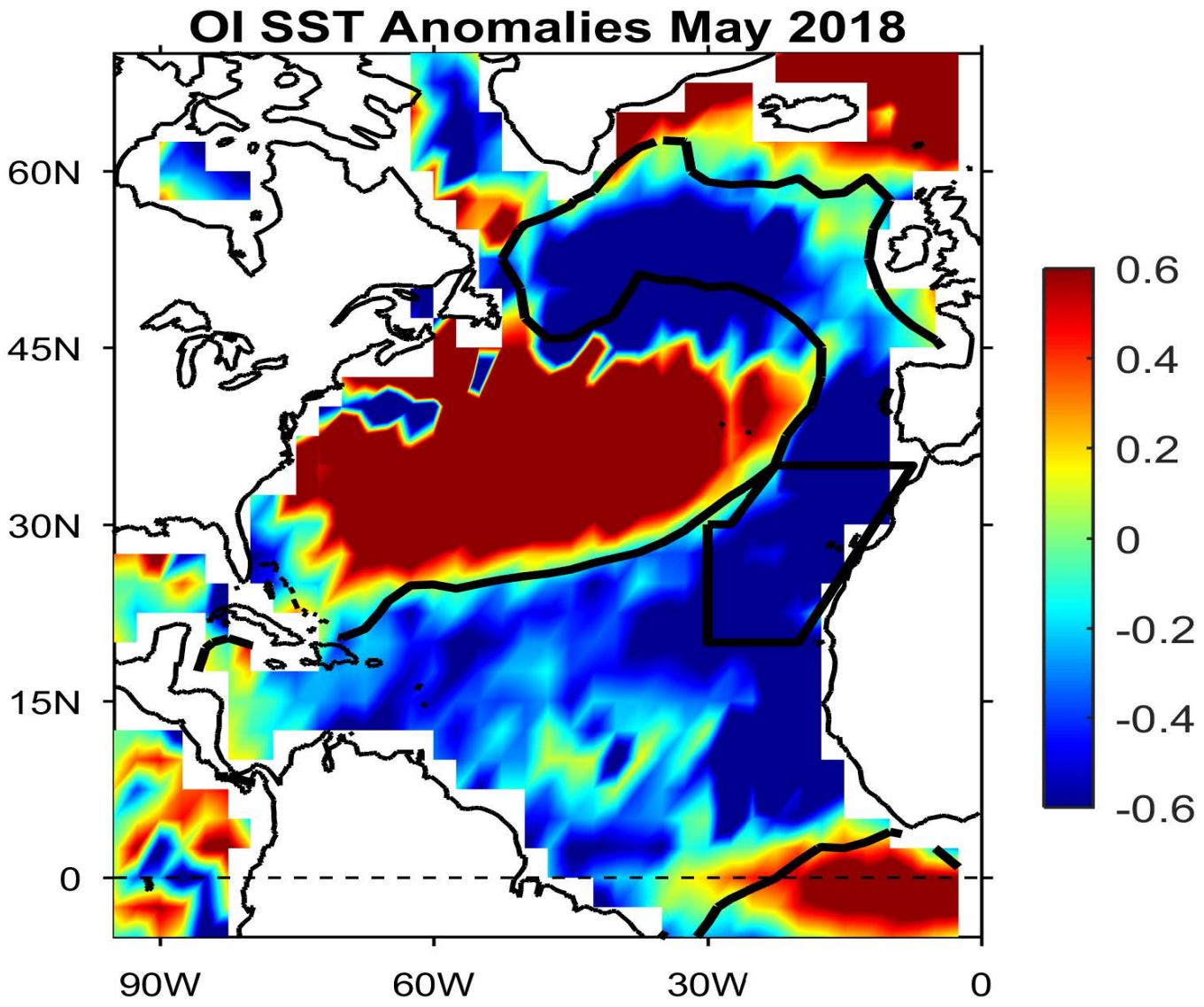
4) **decadal** (7-16 years): dominated by Atlantic/Pacific circulations. Phase-locked ENSO state since 2008

5) **low frequency** (15+ years): warm phase of the AMO since 1995

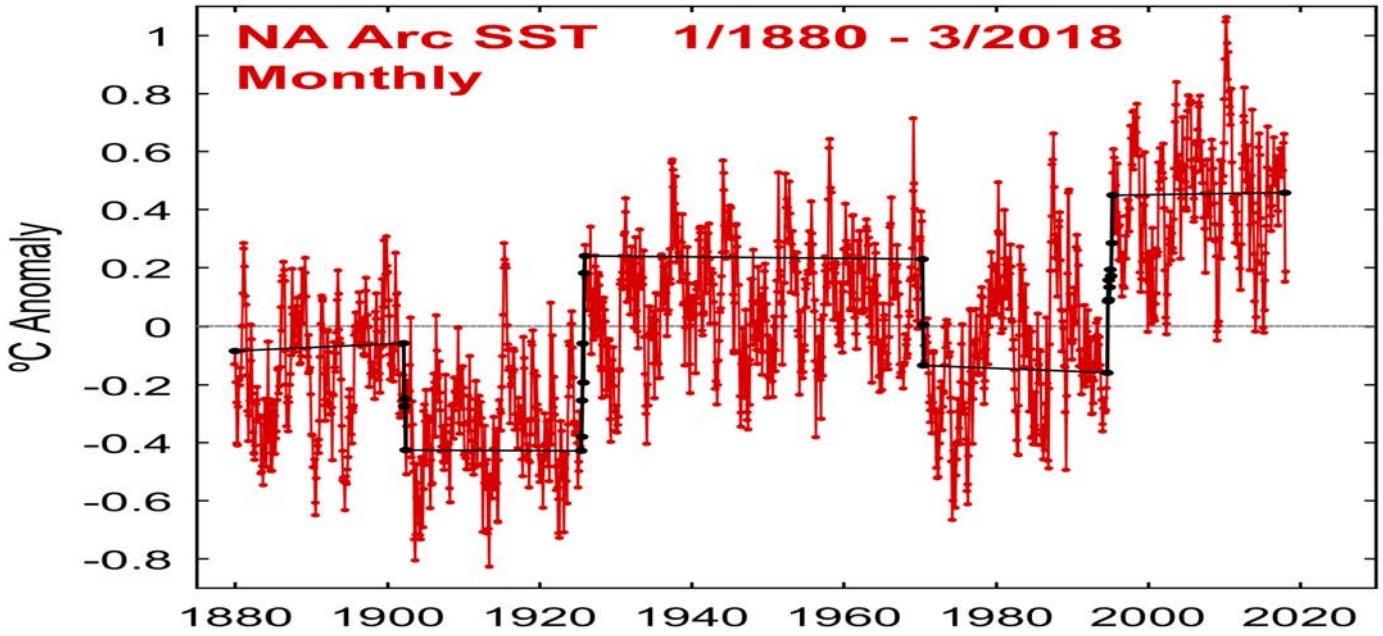
Circulation modes: sources of predictability

- North Atlantic ARC pattern (SST anomalies)
- Indo-Pacific-Atlantic pattern (SST anomalies)
- NH stratospheric vortex anomalies
- SH stratospheric vortex anomalies
- Bi Polar patterns in the stratosphere
- NAOX: North Atlantic SLP/wind pattern
- Global patterns of North − South winds

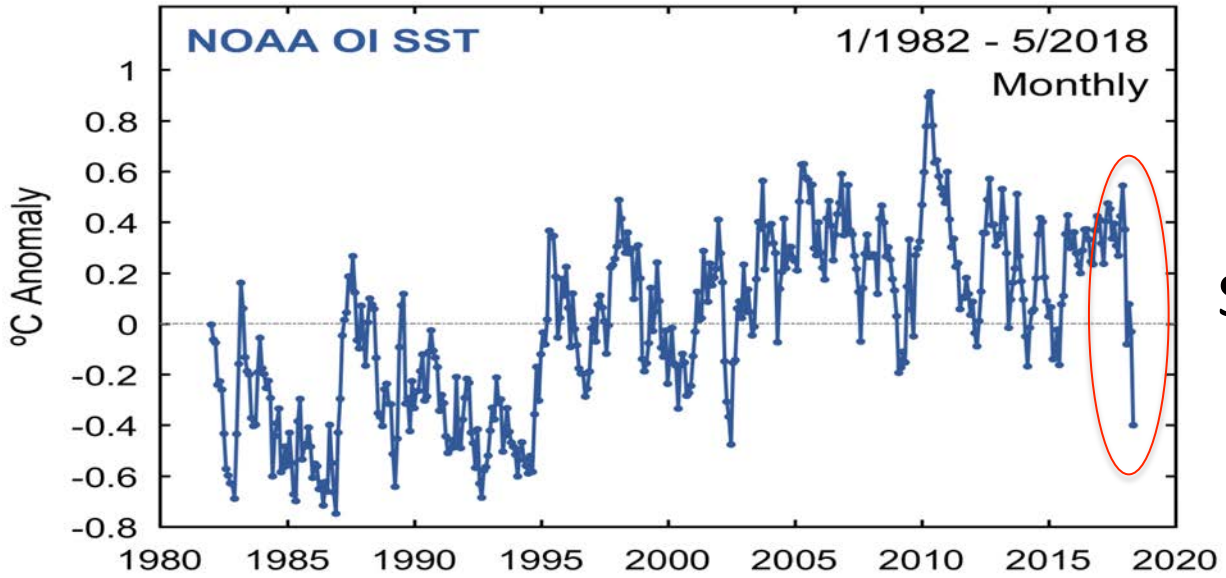
North Atlantic ARC pattern



North Atlantic ARC SST anomalies



Atlantic Multidecadal Oscillation (AMO)



Cool anomaly?

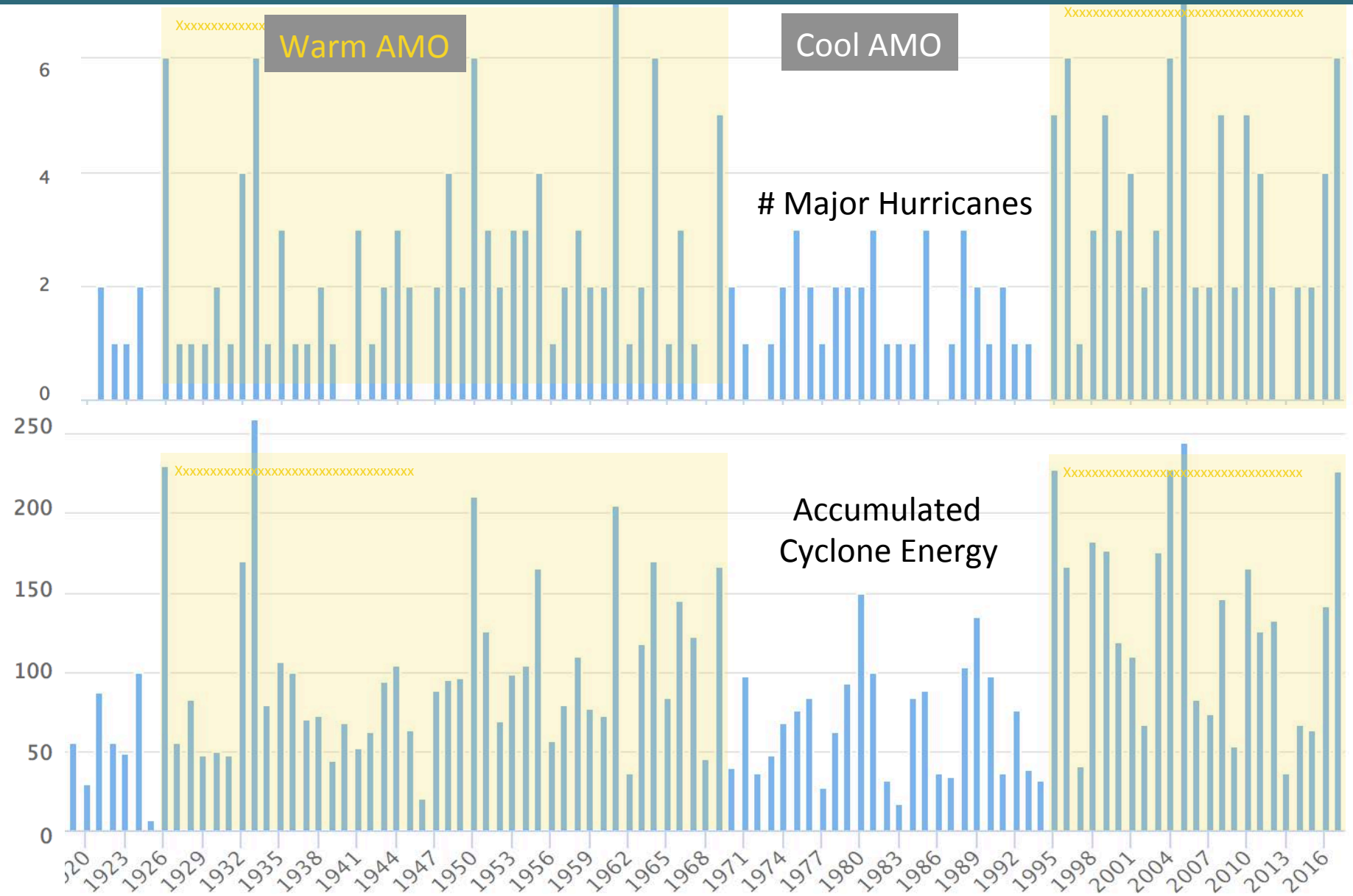
OR

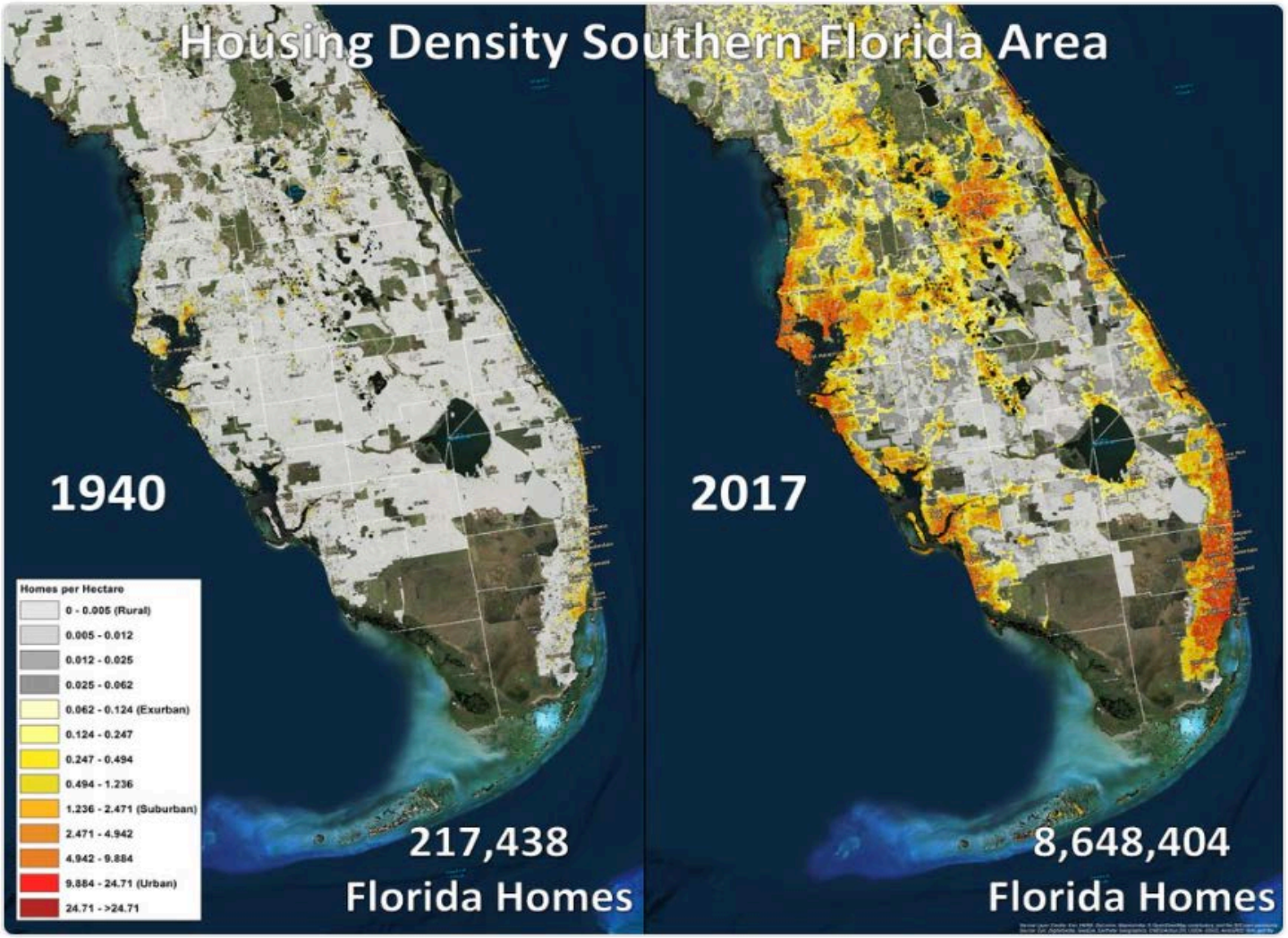
Shift to cold phase?

Atlantic AMO cool phase: impacts

- diminished Atlantic hurricane activity
- increased U.S. rainfall
- decreased rainfall over India and Sahel
- shift in north Atlantic fish stocks
- acceleration of sea level rise on NE U.S. coast

AMO impacts on Atlantic Hurricanes





AMO Impact on FL Hurricanes

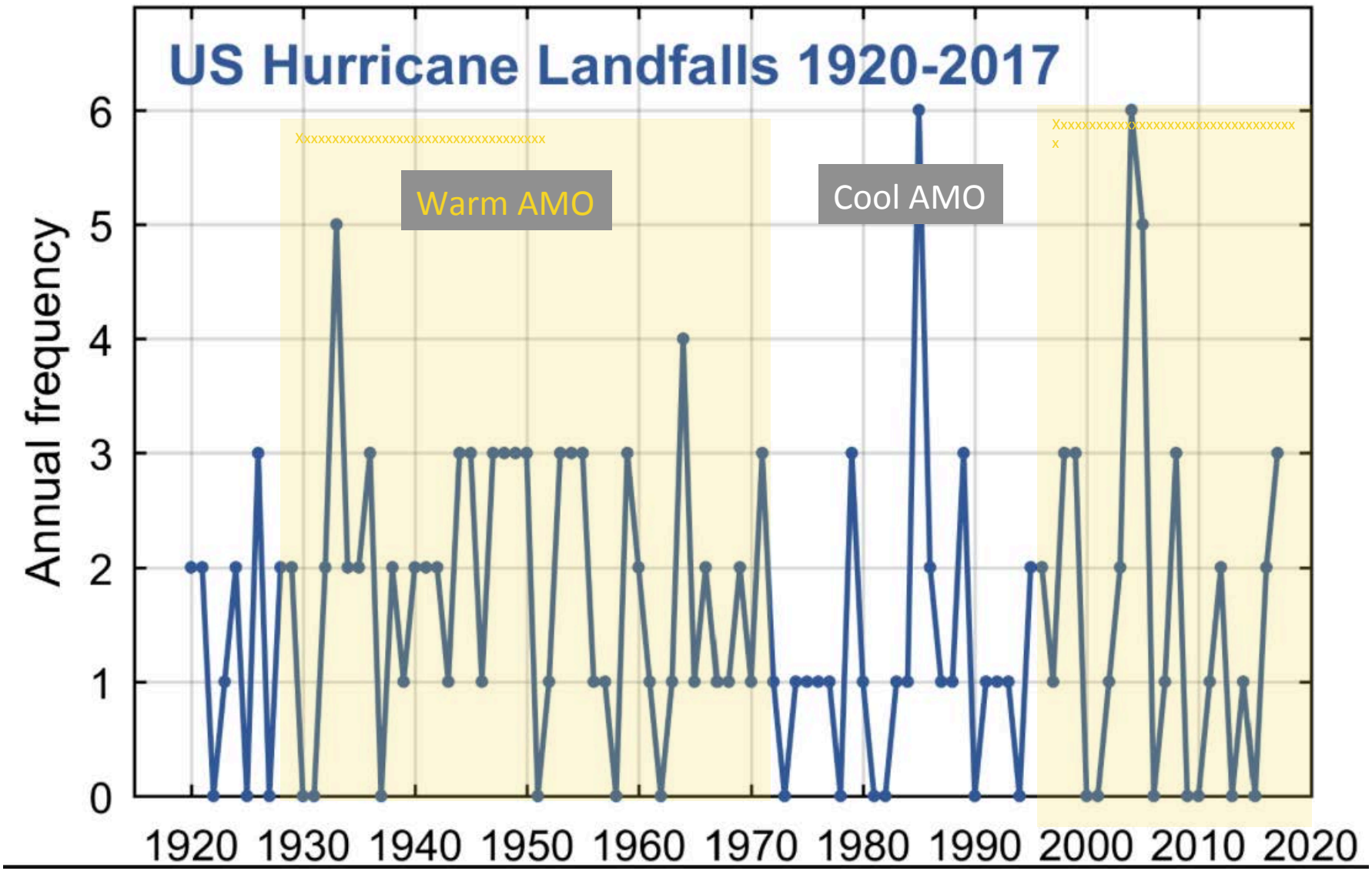
Hurricanes starting in 1926 killed the FL boom that began in 1920

Population increase accelerated in 1970's. Low hurricanes plus changes in federal policies (NFIP, SE HR Disaster Relief Act, FEMA) reduced the risk.

FLORIDA HURRICANE LANDFALLS

	Total # MHR	Max annual # HR
1926 – 1971	13	3
1972 – 1994	3	1
1995 – 2017	7	3

AMO impacts on U.S. hurricane landfalls



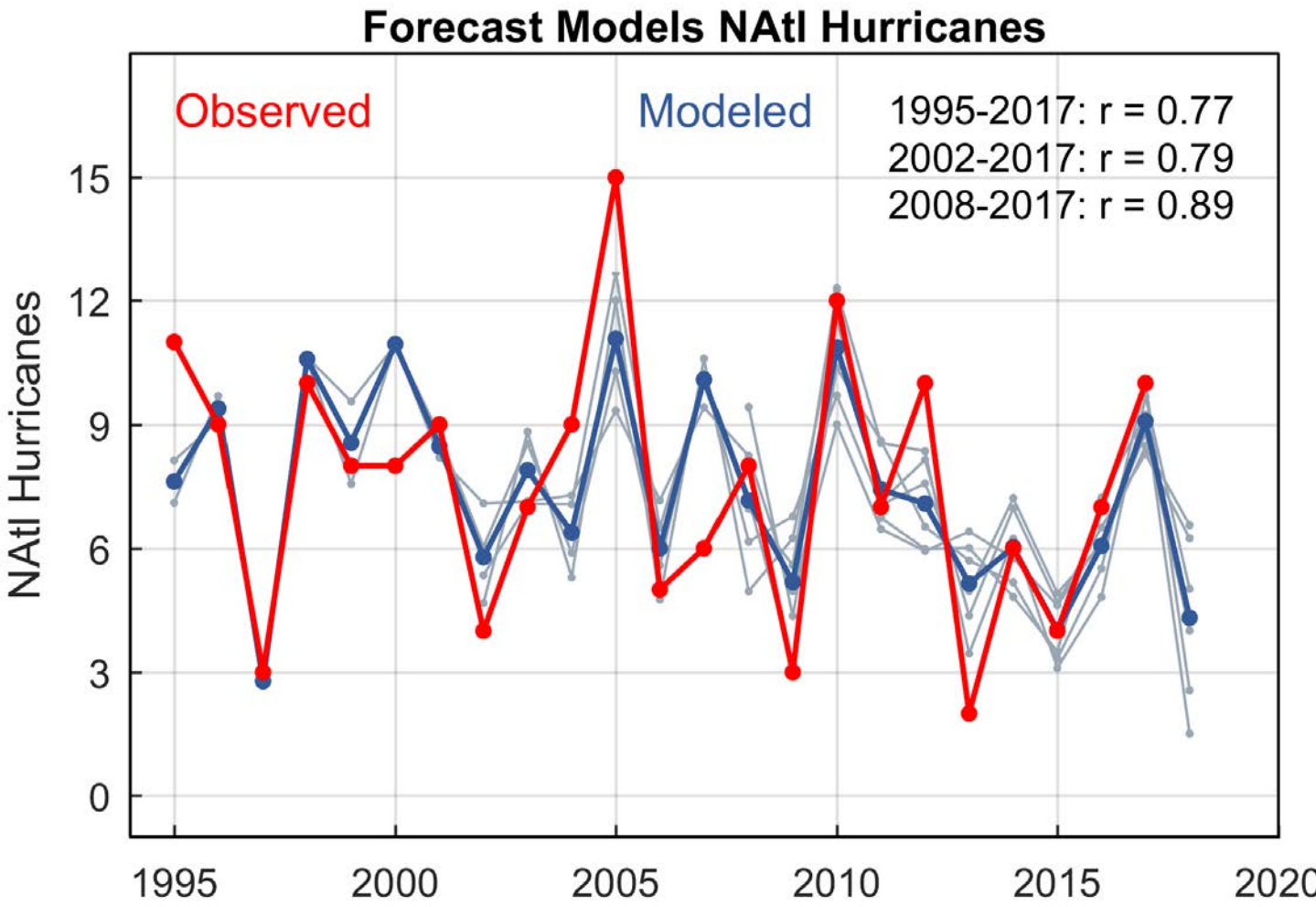
CFAN's seasonal forecasts of North Atlantic hurricanes

- Regime identification ('ride the waves'):
  - 1995 → : warm phase of AMO
  - 2002 → : 2001 shift in North Pacific Ocean
  - 2008 → : phase-locked ENSO state (tropics/stratosphere)
- Potential predictors are identified from circulation patterns in the ocean/ troposphere/stratosphere via data mining.
- Predictors are selected based on climate dynamics analysis and statistical evaluation in hindcast mode.

CFAN's forecast for 2018 Atlantic hurricane season

	fcst	s.d.
# HR	4.3	2.0
# MH	1.6	0.8
# LF	0.4	0.3
ACE	63	21

Below normal activity



TropiCast
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CFAN's predictors for seasonal Atlantic hurricane forecast

August (May • Jun • Jul predictors):

- Global and North Atlantic troposphere circulation patterns

June (Mar • Apr • May predictors):

- Sea level pressure patterns
- Global equatorial wind patterns in troposphere/stratosphere

April (Jan • Feb • Mar predictors):

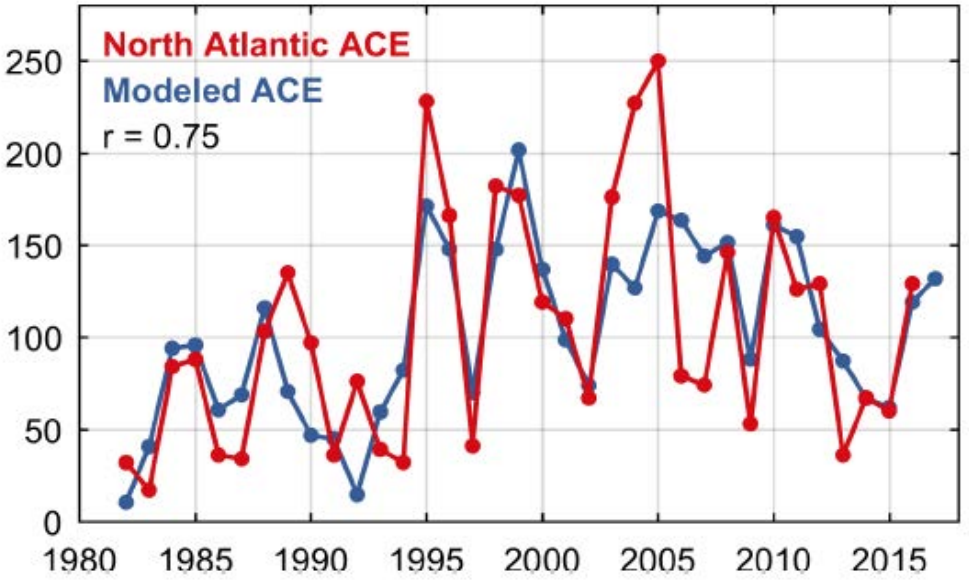
- Global N-S patterns of tropospheric/stratospheric winds
- Tropospheric circulation patterns

December (12 month predictors):

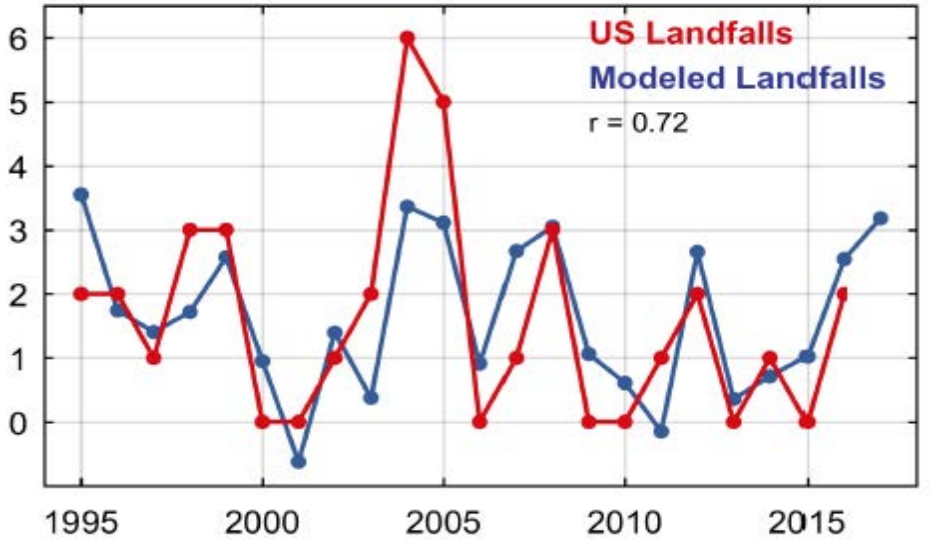
- Upper troposphere/stratosphere circulations

6/1/17 Atlantic hurricane forecast

	forecast	observed
ACE	134	225
# LF	3	3



CFAN predicted above normal ACE, but missed the extreme activity



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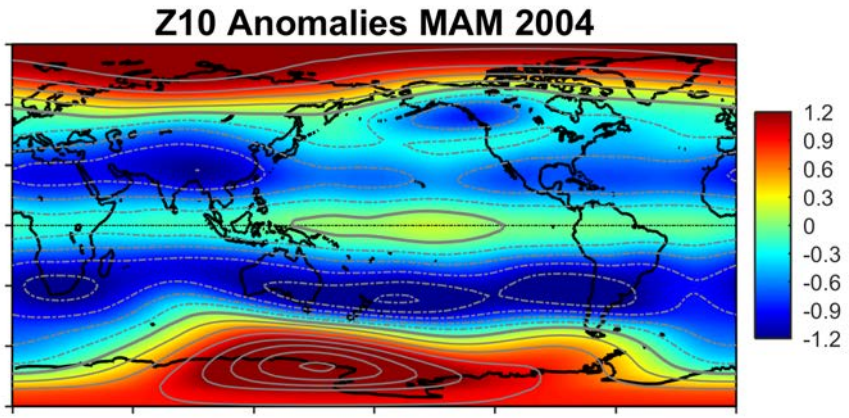
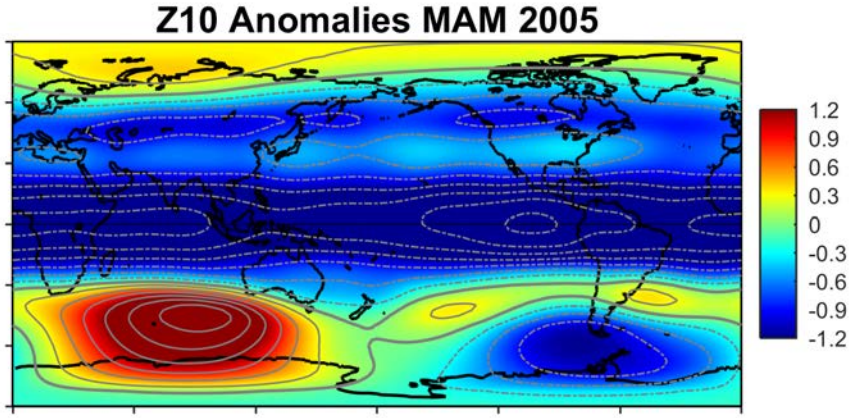
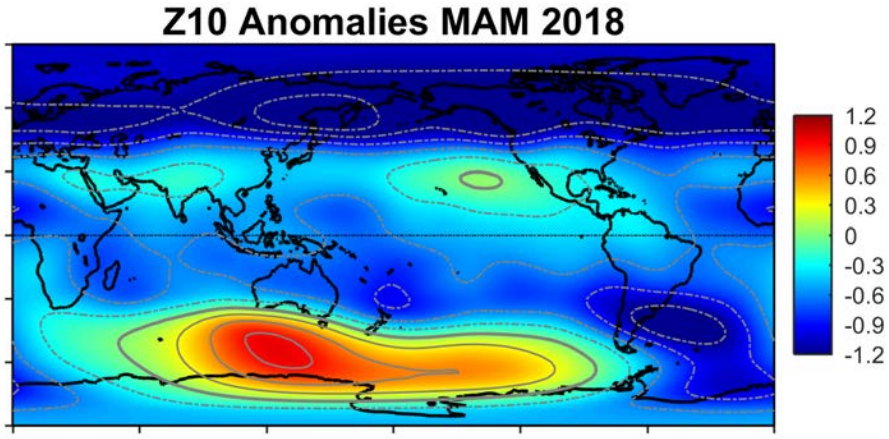
What caused the 2004/2005 NATL activity? Was it predictable?







Data mining unearthed an anomalous 2004/2005 pattern in the stratosphere in the Antarctic Pacific sector. Possible factor for 2018.

Have we unearthed a ‘diamond’ or ‘fools gold’?

CFAN's forecast solutions

Extended-range prediction of high impact **extreme weather** events:

- Temperature and renewables forecasts for the energy sector: **OmniCast**
- Tropical cyclone forecasts: **TropiCast**
- Consulting services

days • weeks • seasons • decades

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