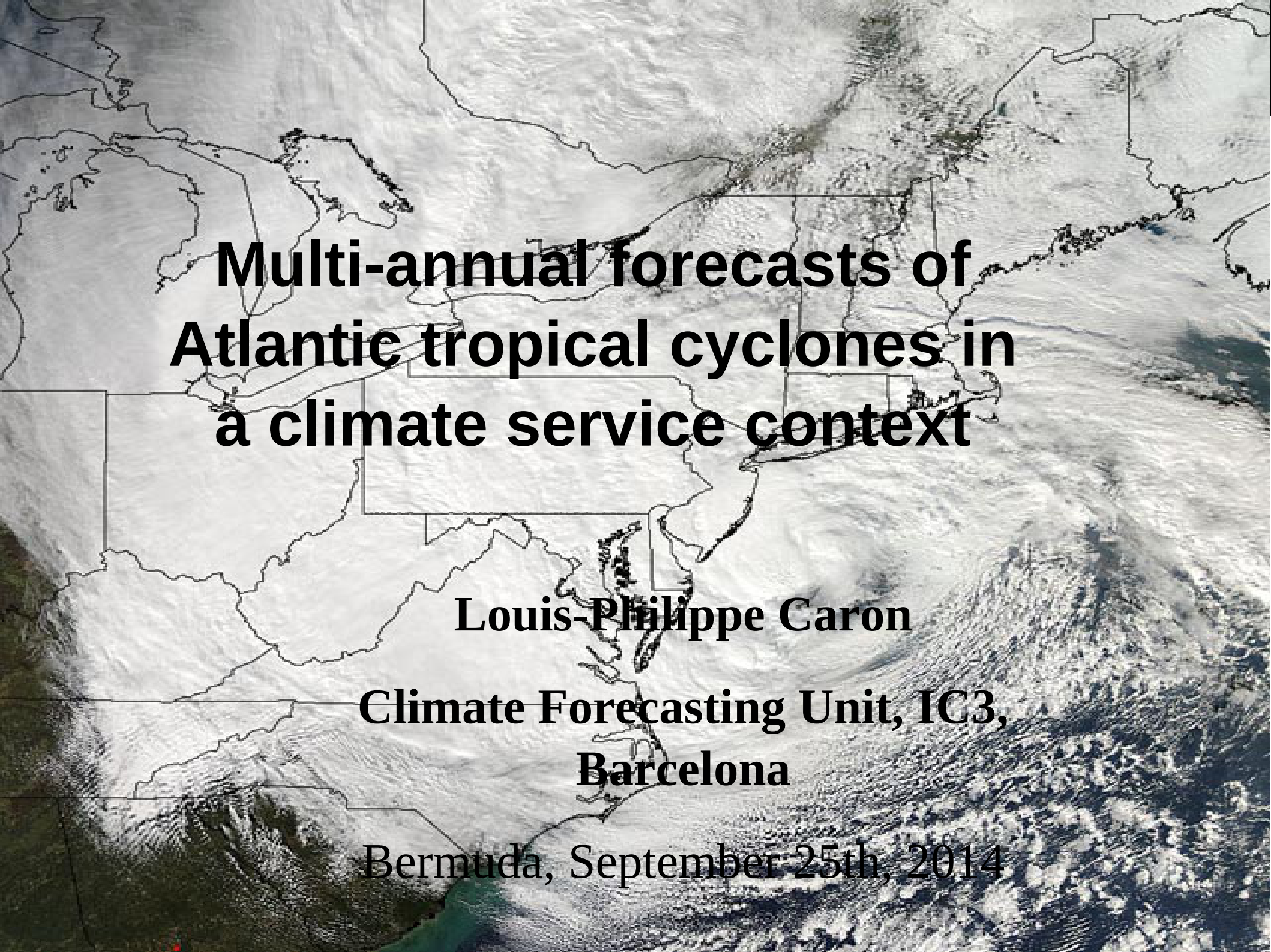


Multi-annual forecasts of Atlantic tropical cyclones in a climate service context

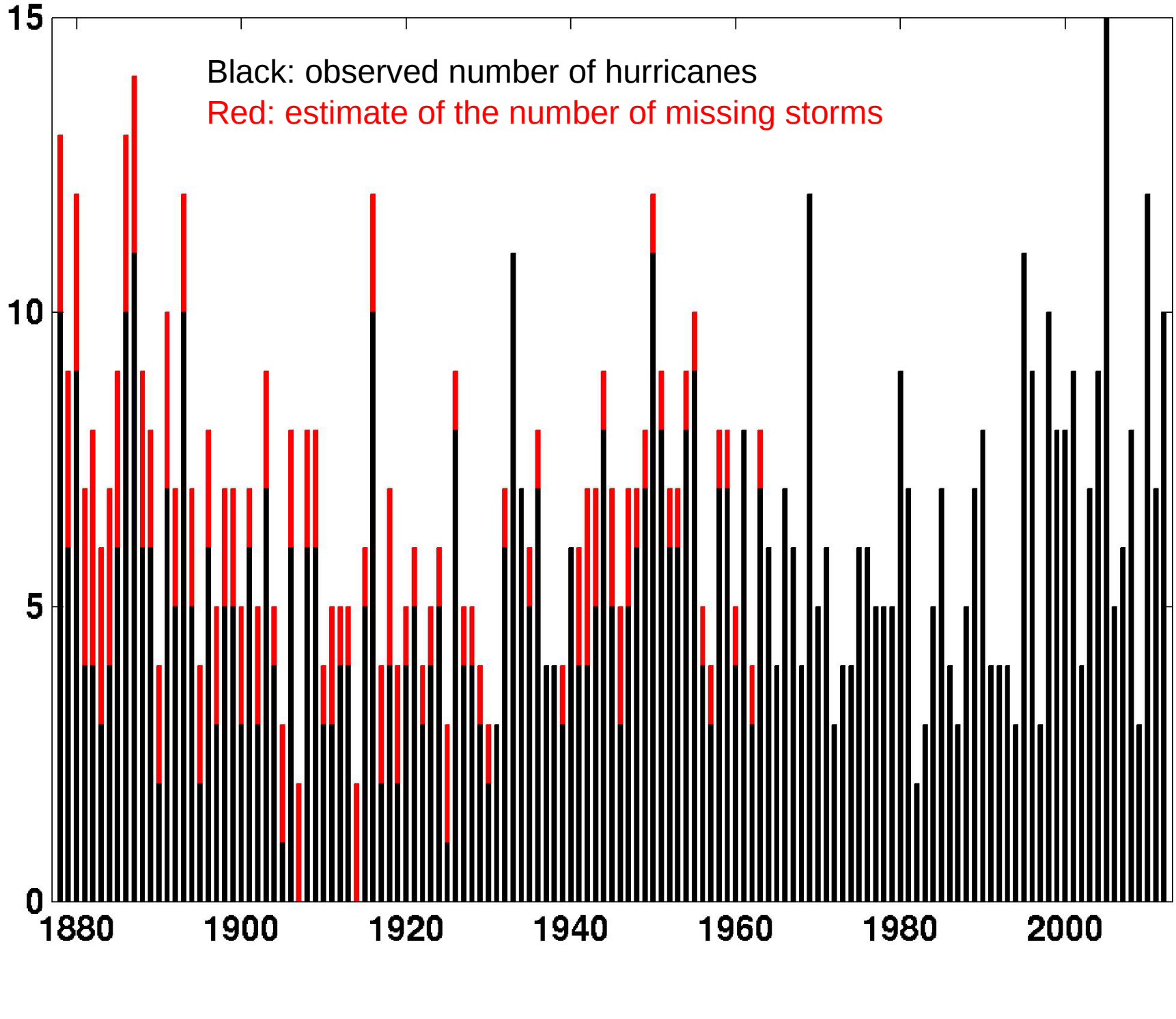
Louis-Philippe Caron

Climate Forecasting Unit, IC3, Barcelona

Bermuda, September 25th, 2014

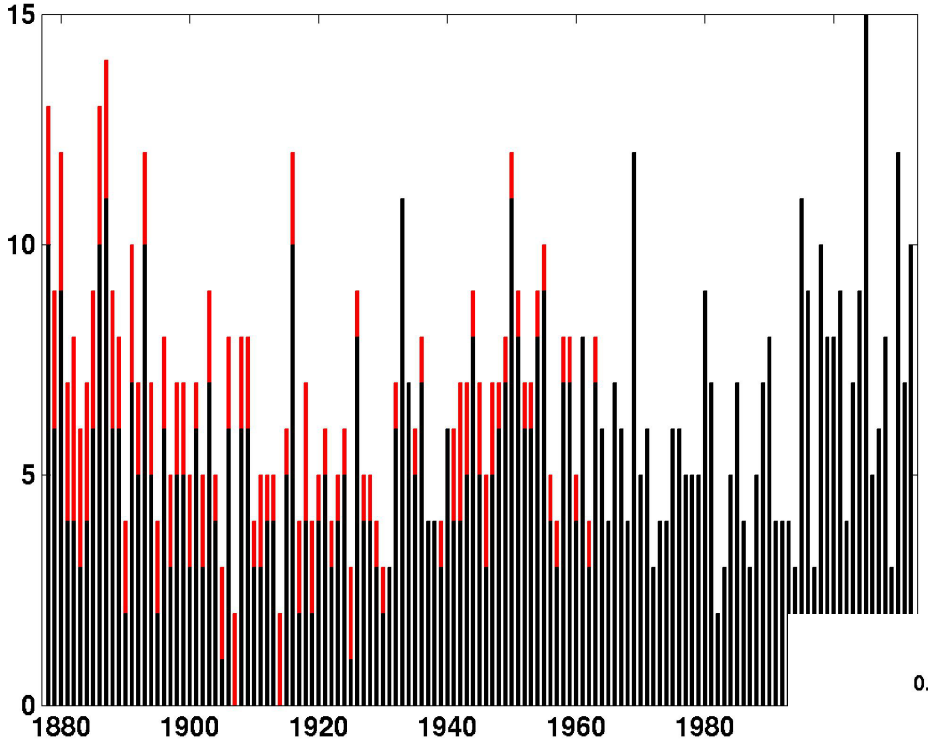
Objectives

- Evaluating the capability of initialized GCMs at predicting Atlantic Tropical Cyclone activity over a 5-year horizon
- Evaluating whether skill comes from persisting anomaly introduced in the systems or if models show true predicting skill
  - Can we predict the climate shifts from active to inactive regime (and vice-versa)?


Black: observed number of hurricanes
Red: estimate of the number of missing storms
15
10
5
0
1880
1900
1920
1940
1960
1980
2000

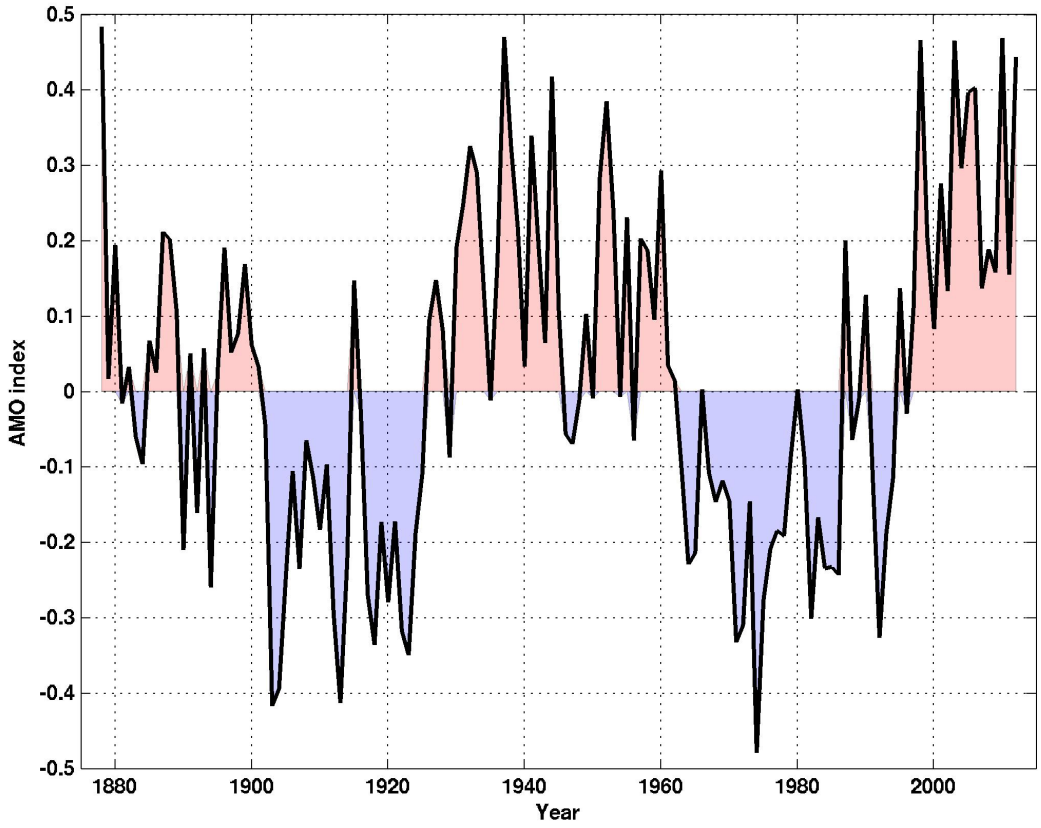
Climate factors influencing Atlantic hurricane activity

Climate factor	Description	Timescale
Atlantic Multidecadal Oscillation (AMO or AMV)	Oscillation in North Atlantic Ocean Temp.	Decadal
El Niño Southern Oscillation	Oscillation in Tropical Pacific Ocean Temp.	Annual (~3-5 yr cycle)
West African Monsoon	Rainfall over Sahel region	Annual
North Atlantic Oscillation (NAO)	Seesaw pattern in sea level pressures b/w Iceland and the Azores	Annual
Solar activity		11-year cycle
Ozone concentration in upper atmosphere		Annual
Dust/aerosols over the Atlantic	Dust originating from Sahara desert	Annual
Maidden-Julian Oscillation	Eastward propagating disturbances in the tropics	Intra-seasonal



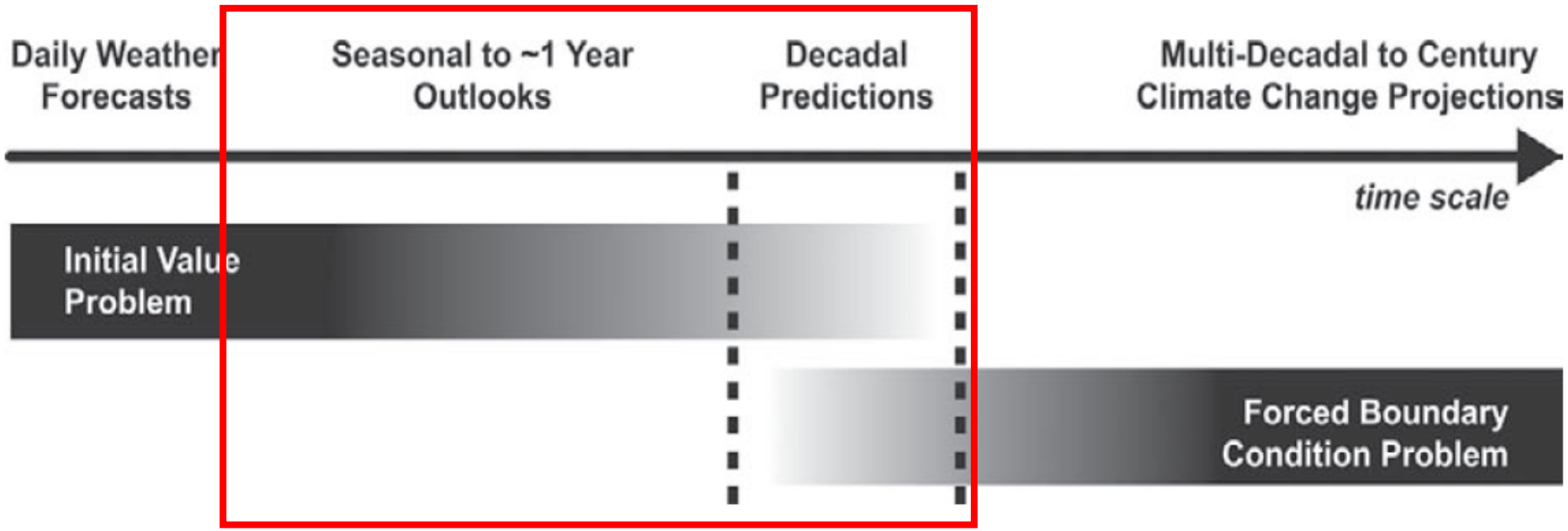
Strong link b/w **AMO** and **hurricane** numbers

AMO:
Oscillation in North Atlantic sea surface temperature



Climate time scales

Progression from initial-value problems with weather forecasting at one end and multi-decadal to century projections as a forced boundary condition problem at the other, with climate prediction (sub-seasonal, seasonal and decadal) in the middle. Prediction involves initialization and systematic comparison with a simultaneous reference.



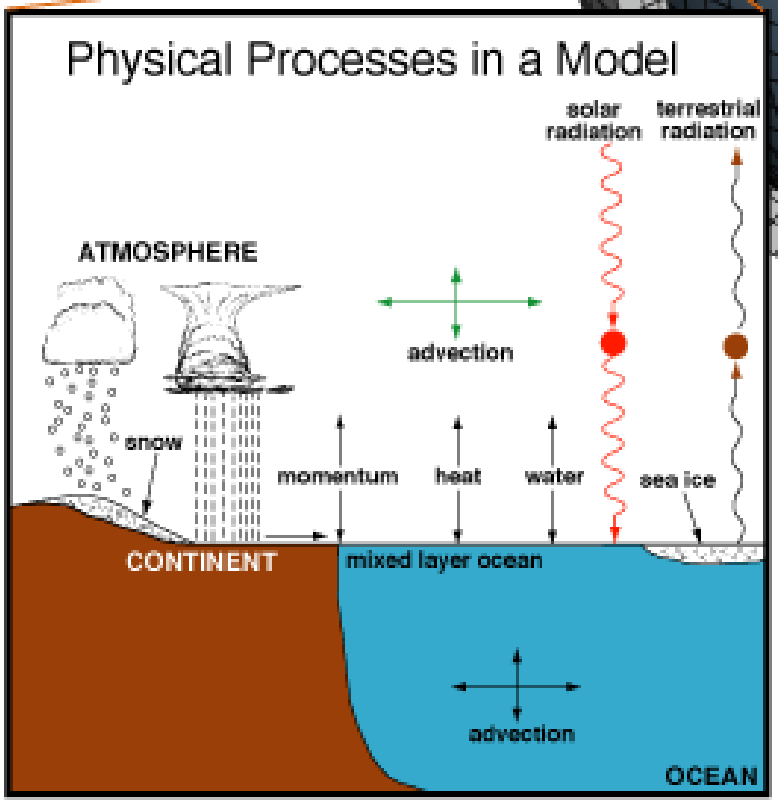
Meehl et al. (2009)

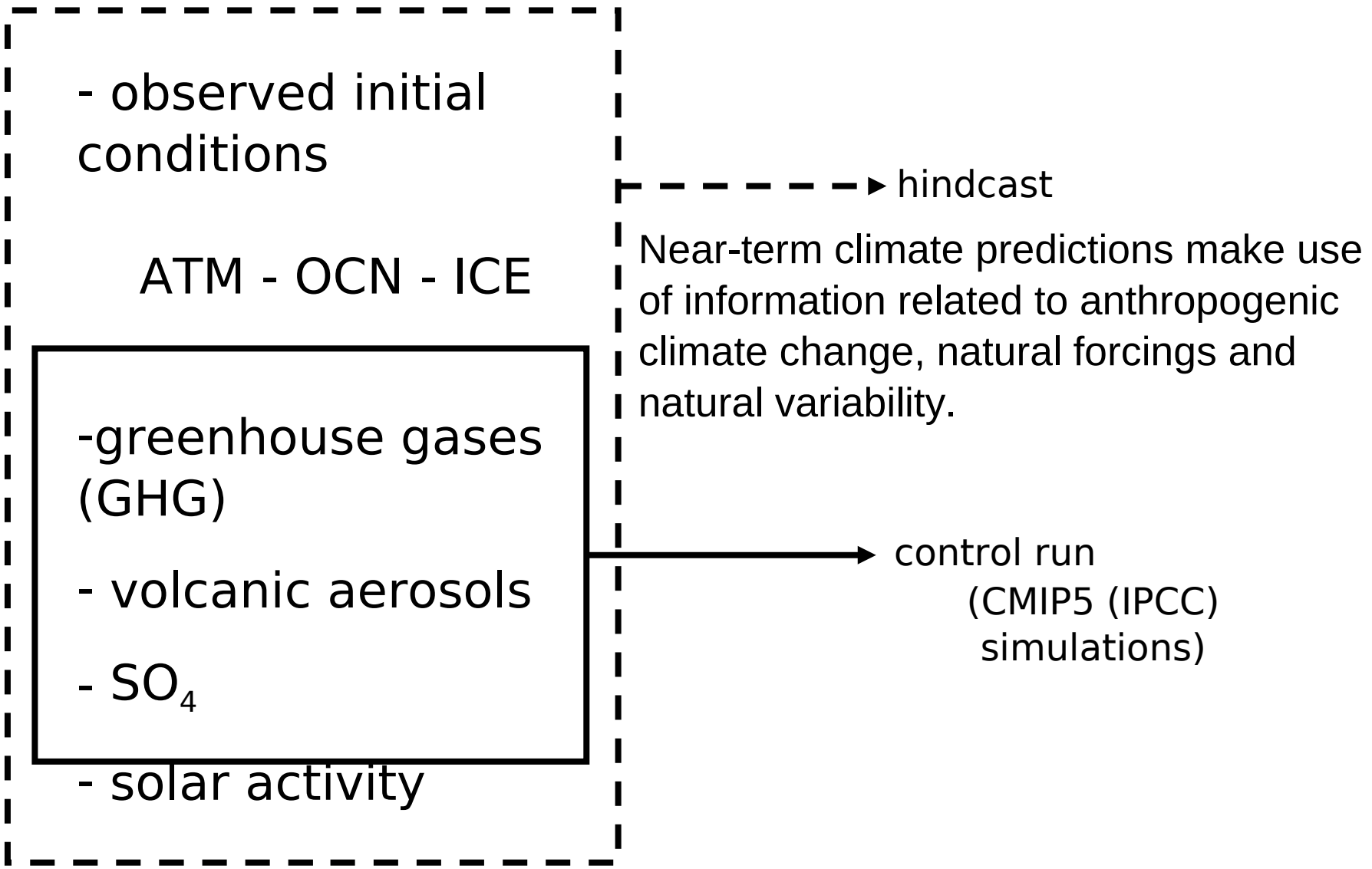
Why do decadal forecasts work?

- Over the near term (a decade or so), uncertainty in climate comes mostly from natural variability
- Portion of the interannual and interdecadal variability is associated with relatively slow ocean changes
- If ocean circulation can be predicted based on knowledge of current state of the ocean, then prediction of temperature, rainfall, etc, correlated with these changes should be possible

Horizontal Grid
(Latitude-Longitude)

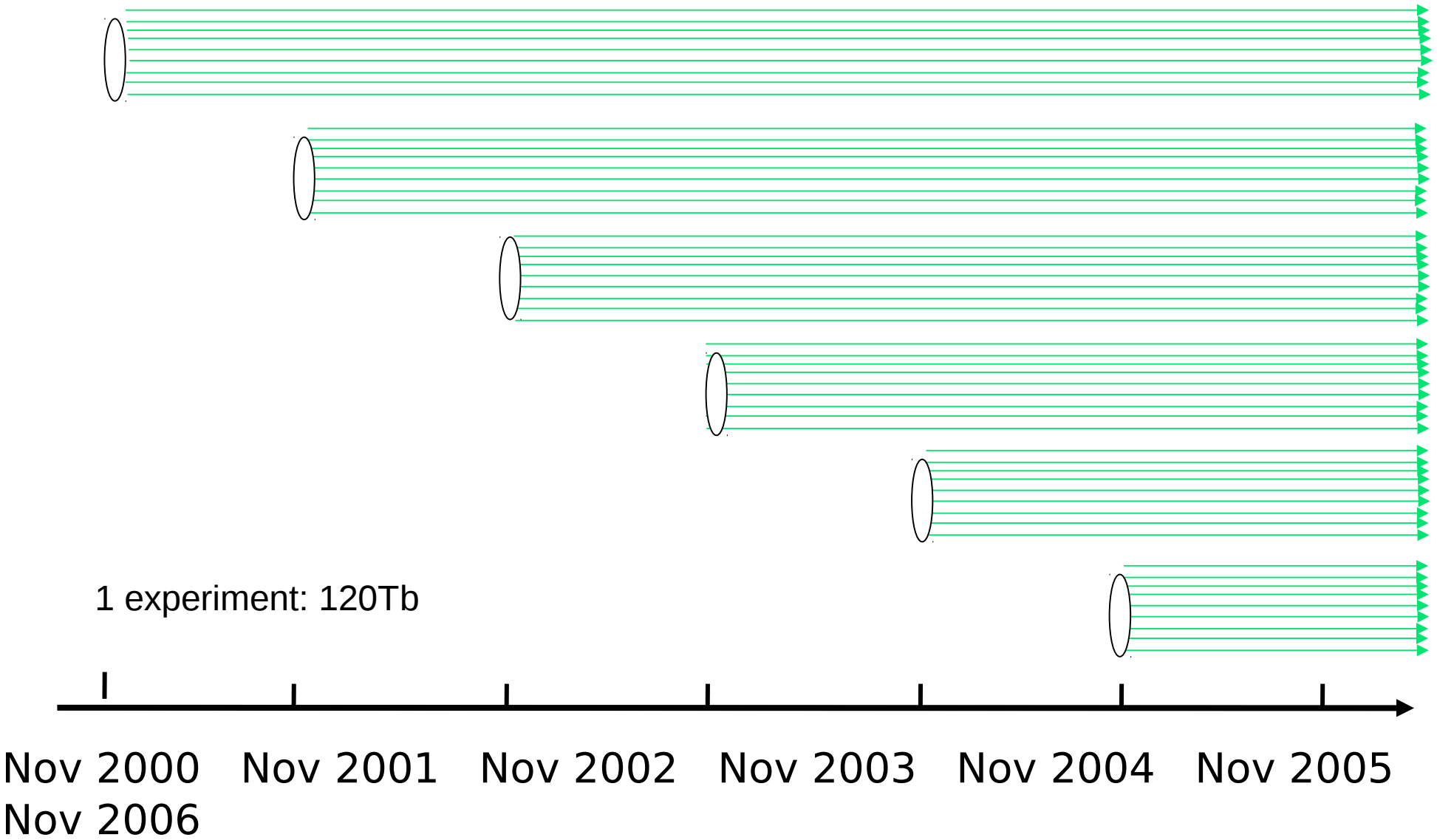
Vertical Grid
(Height or Pressure)




- observed initial conditions
ATM - OCN - ICE
-greenhouse gases (GHG)
- volcanic aerosols
- SO_4
- solar activity
hindcast
Near-term climate predictions make use of information related to anthropogenic climate change, natural forcings and natural variability.
control run
(CMIP5 (IPCC) simulations)

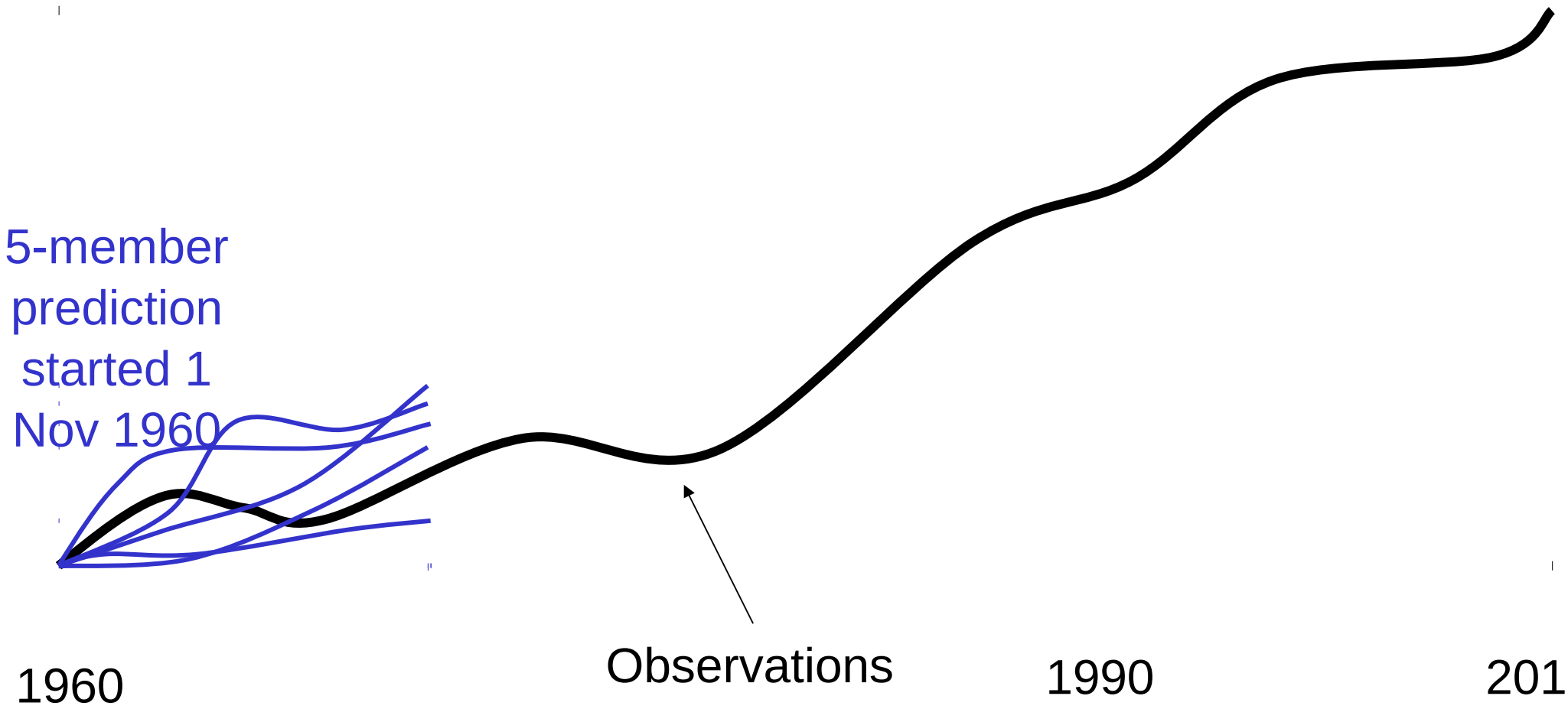
Ensemble initialized near-term predictions

CMIP5: ensemble forecast systems using an initialized ESM



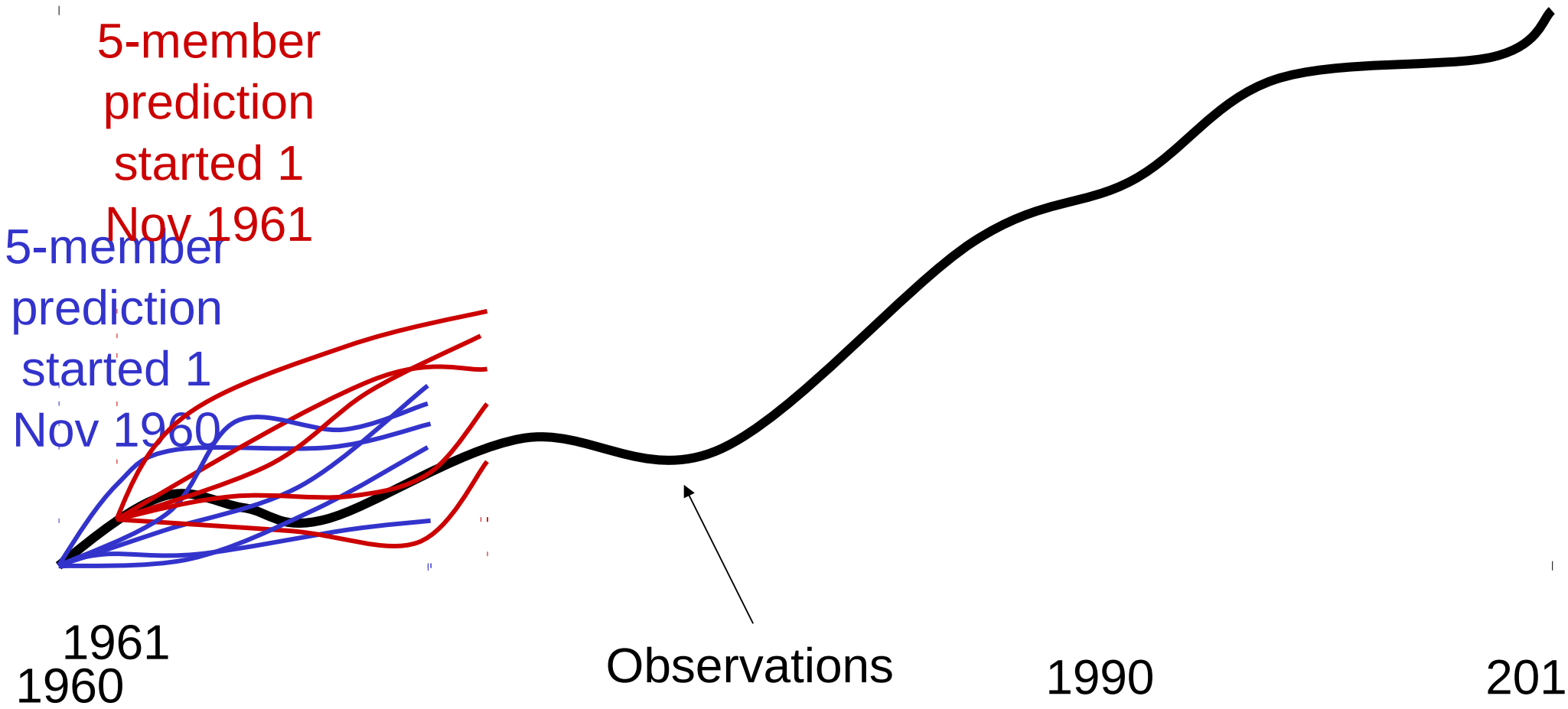
Methodology

Experimental setup



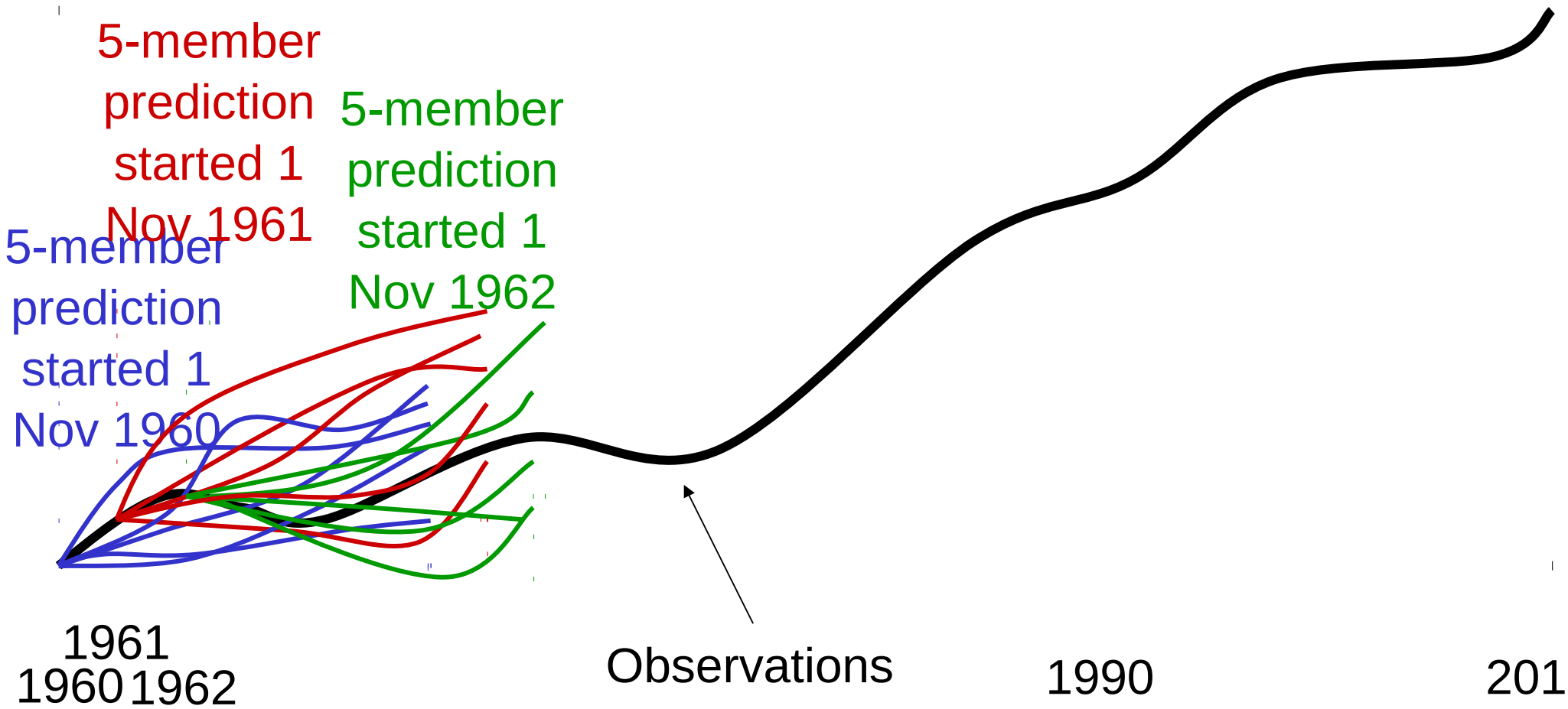
Methodology

Experimental setup



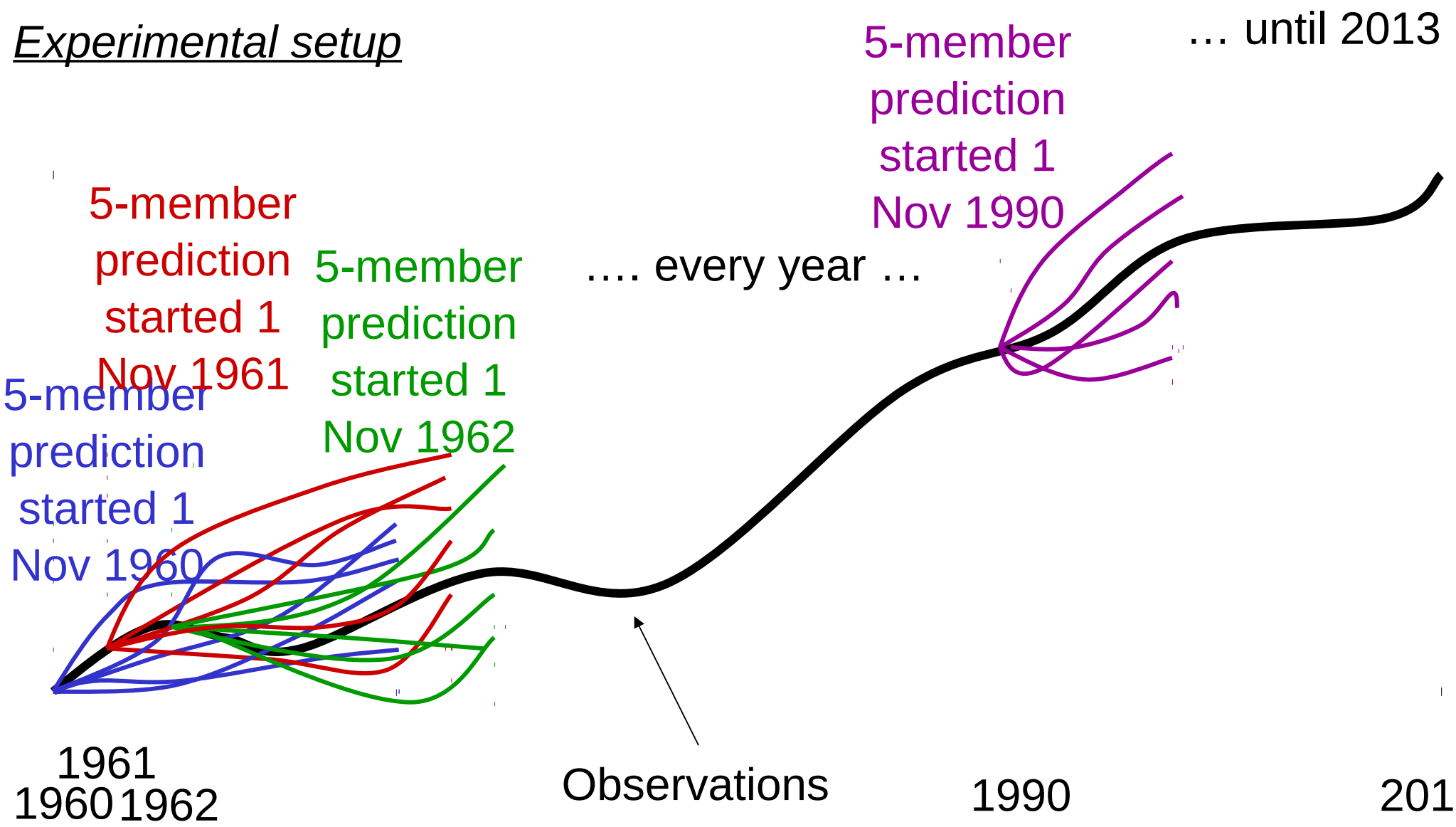
Methodology

Experimental setup



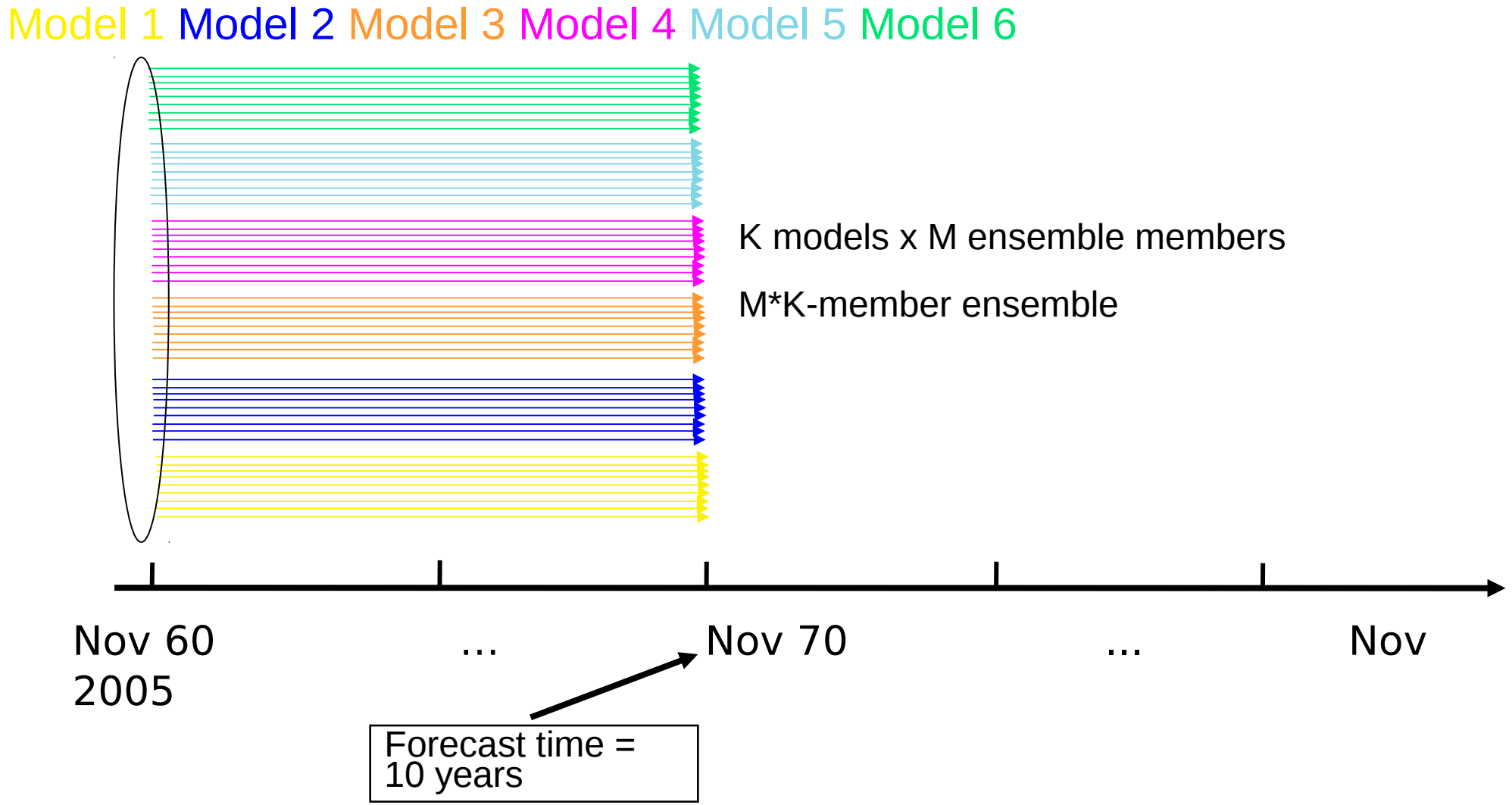
Methodology

Experimental setup



Ensemble climate forecast systems

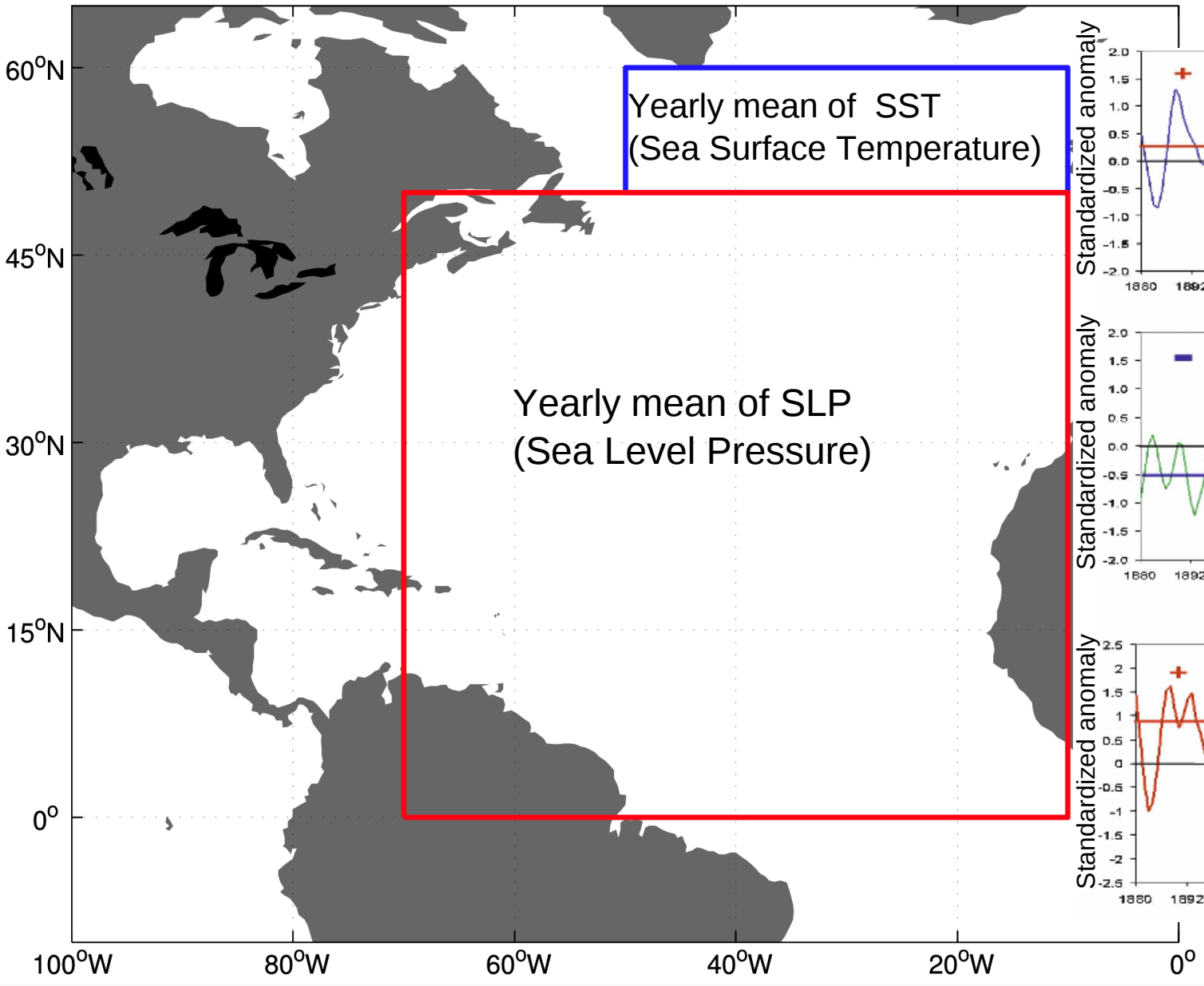
Assume a multi-model ensemble system with coupled initialized GCMs



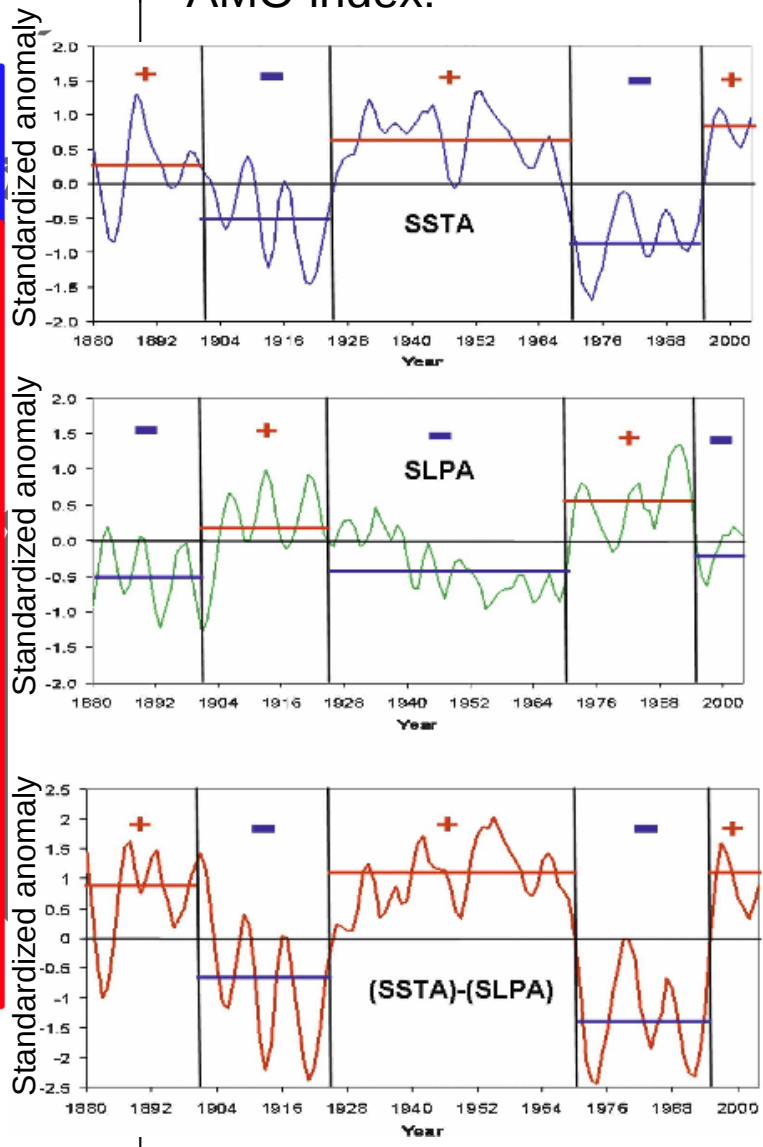
Two techniques are typically used to evaluate TC activity in climate simulations:

1. Direct analysis of tropical cyclones statistics
   - Low-res GCMs are bad at simulating TC activity in the Atlantic
   - Huge amount of data required

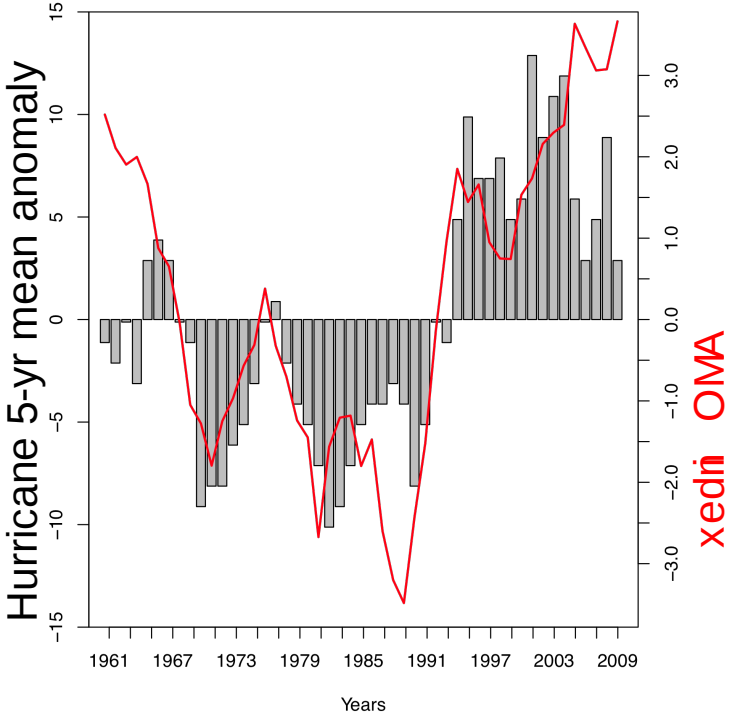
2. Indirectly through changes in large-scale fields that impact TC activity



AMO index:

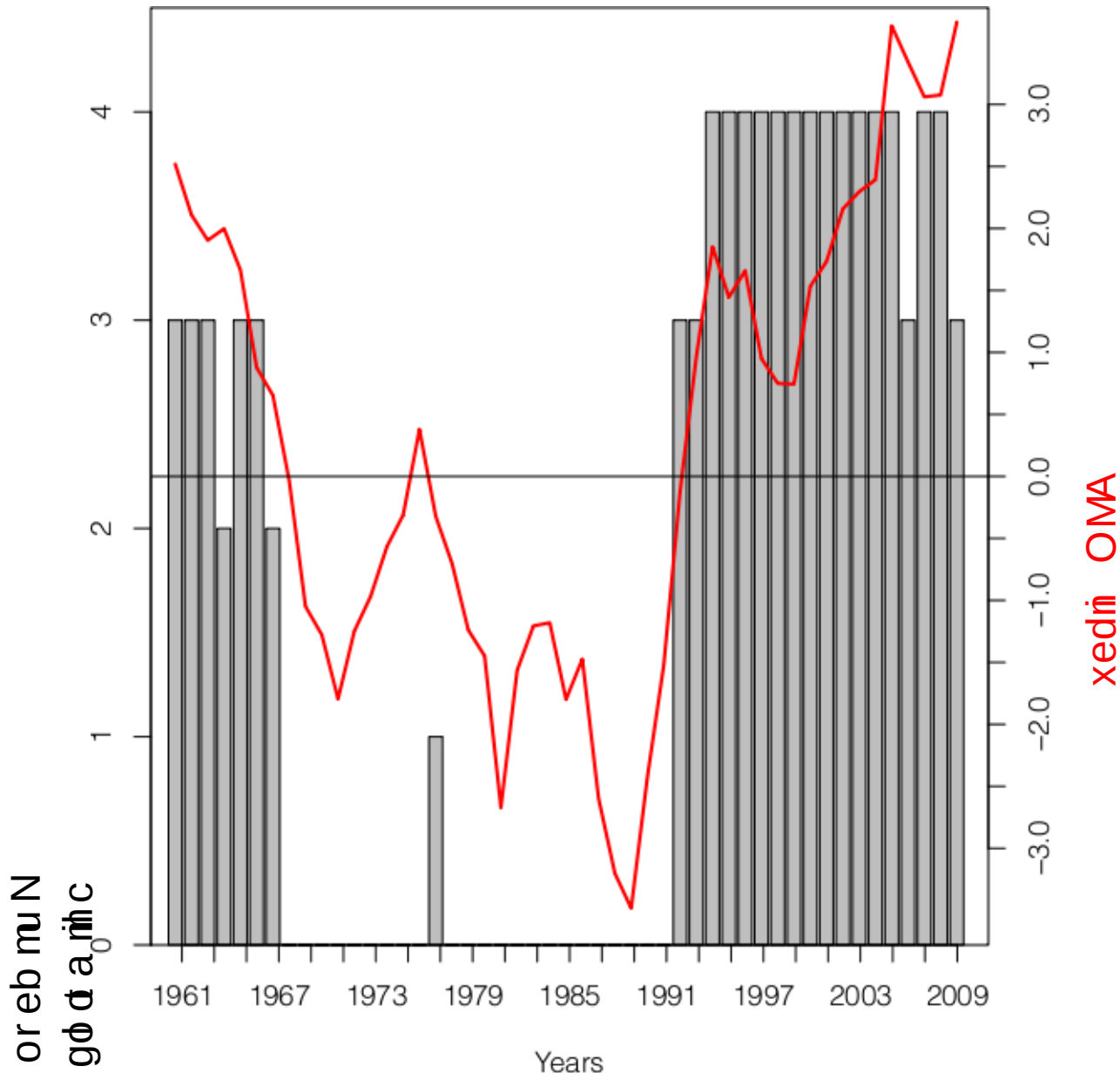


from Klotzbach and Gray (2008)



TC metrics are:

- **Number of hurricanes**
- **Number of major hurricanes**
- **Number of hurricane days**
- **Number of major hurricane days**

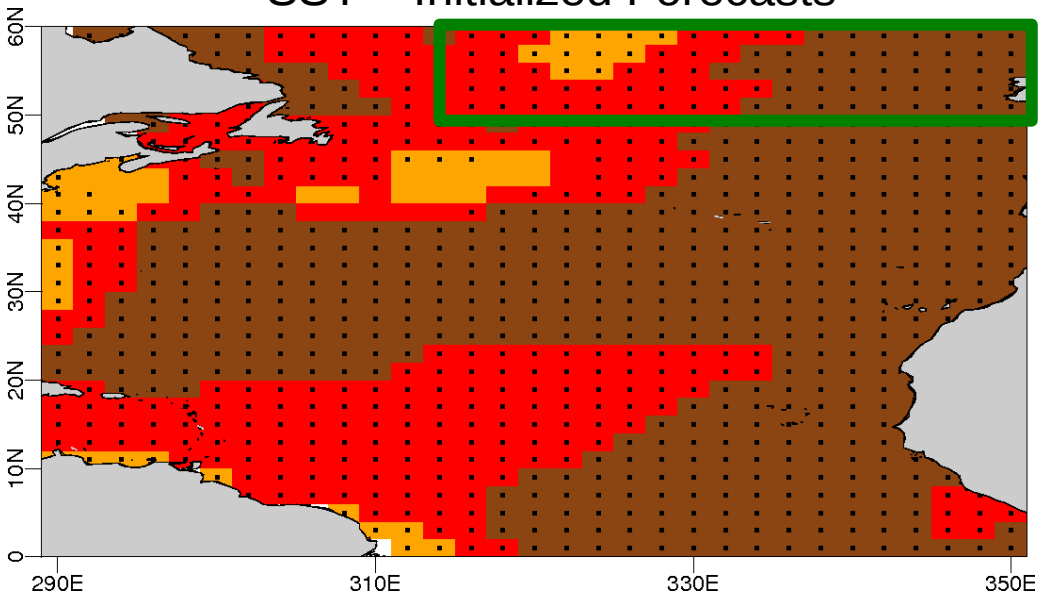


Climate Forecasting Unit

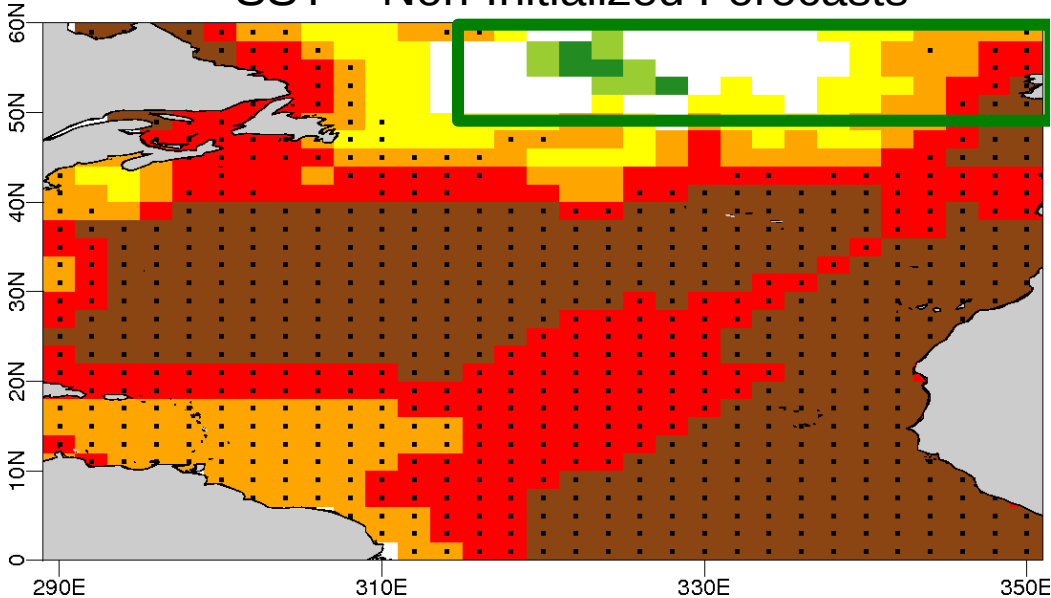
SPECS
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

RPI2.0
Connecting Science and (Re)Insurance

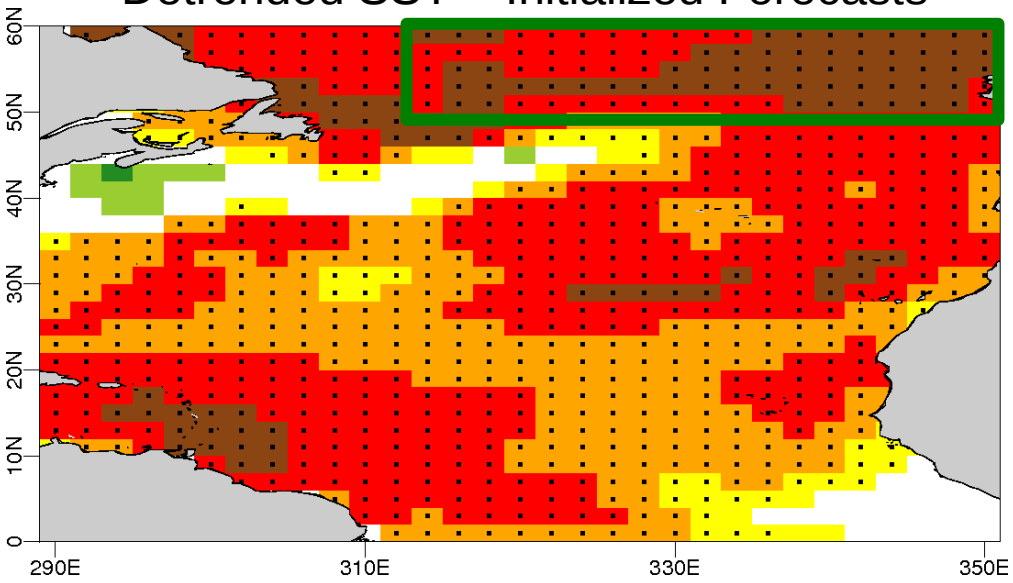
SST – Initialized Forecasts



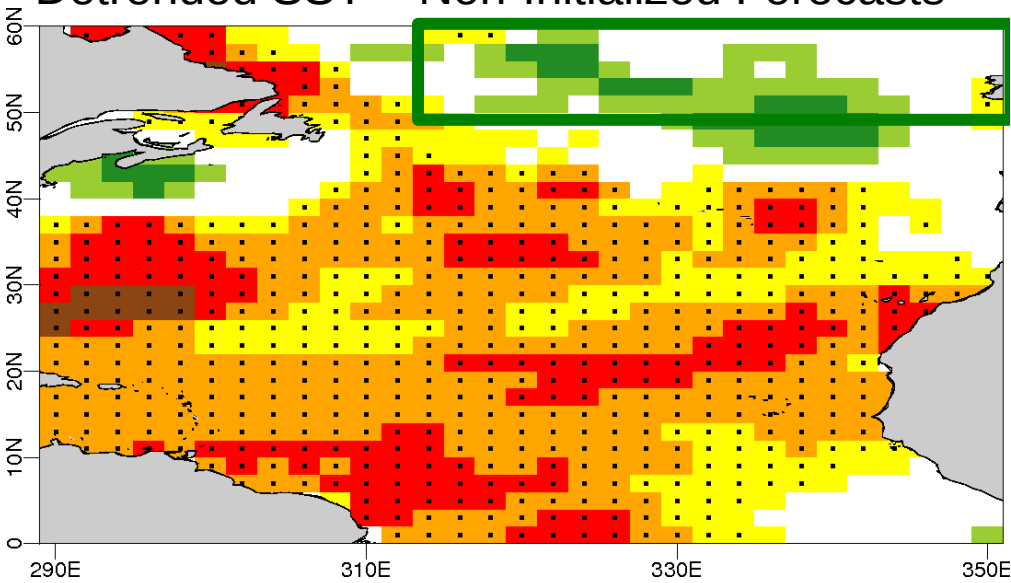
SST – Non-Initialized Forecasts

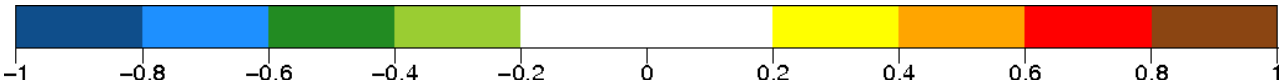


Detrended SST – Initialized Forecasts



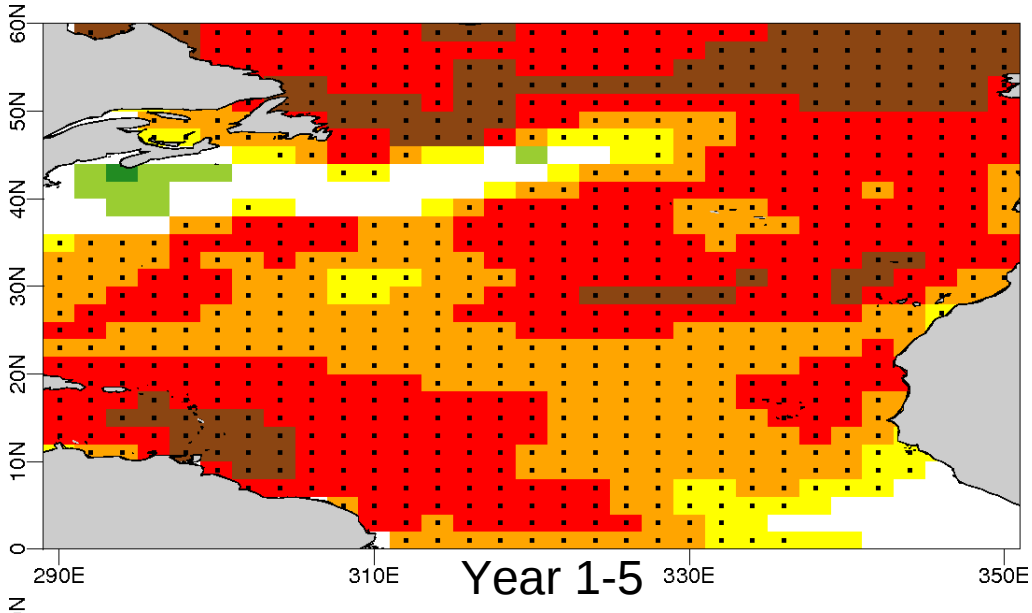
Detrended SST – Non-Initialized Forecasts

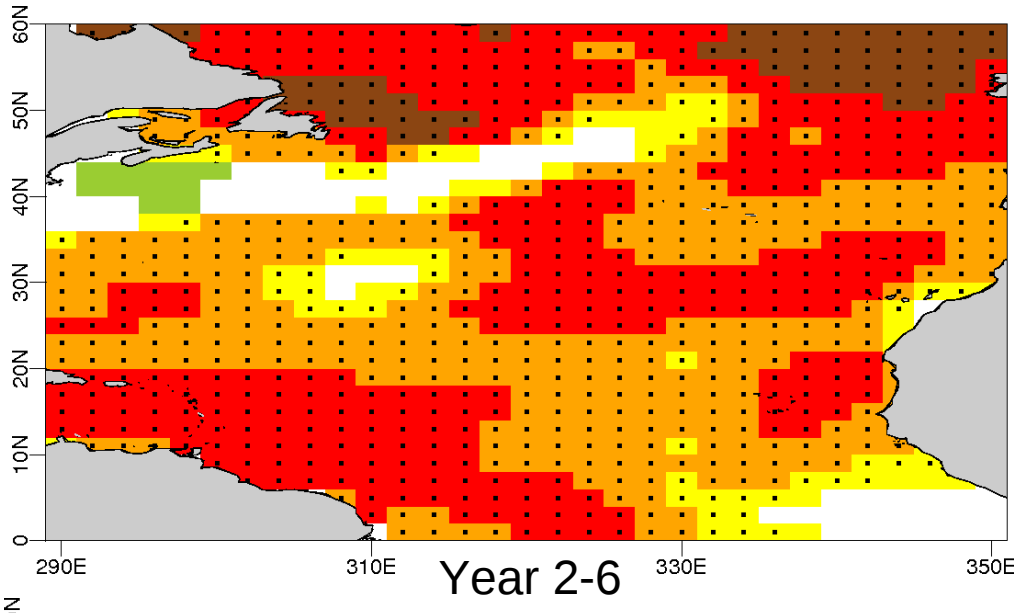


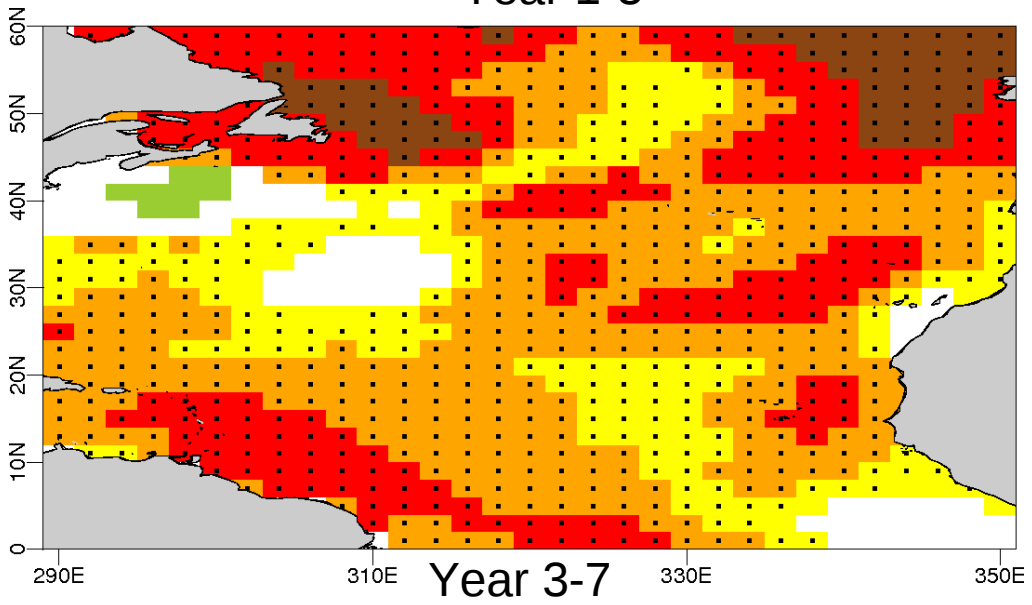


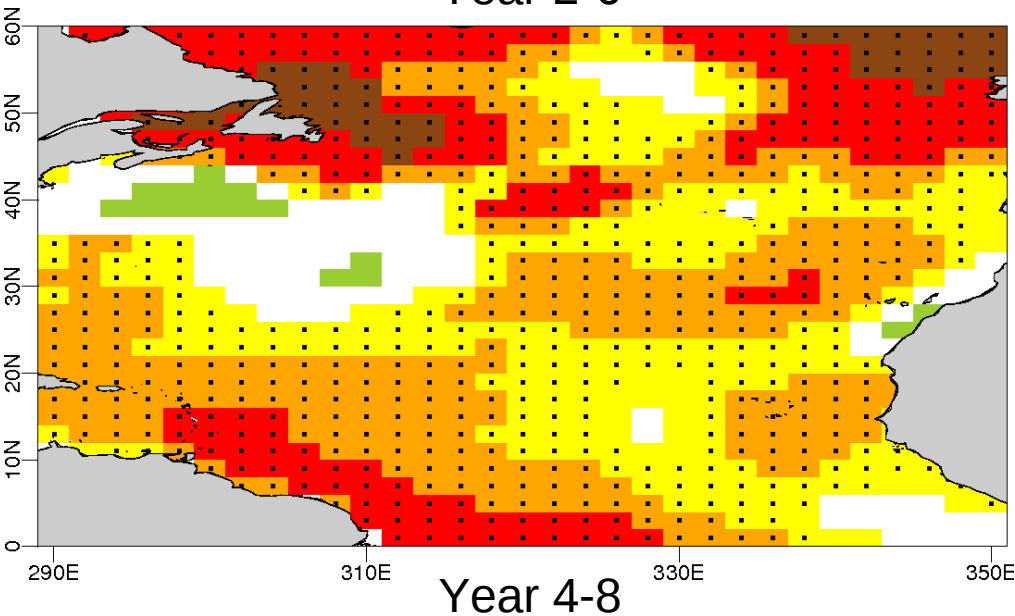
Anomaly Correlation Coefficient (ACC)-Year 1-5

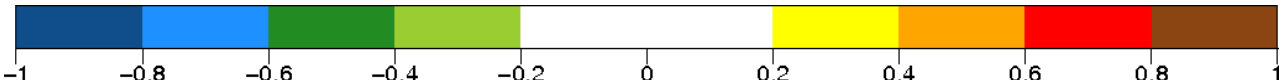
ACC, 5-year mean detrended SST – Initialized Forecasts



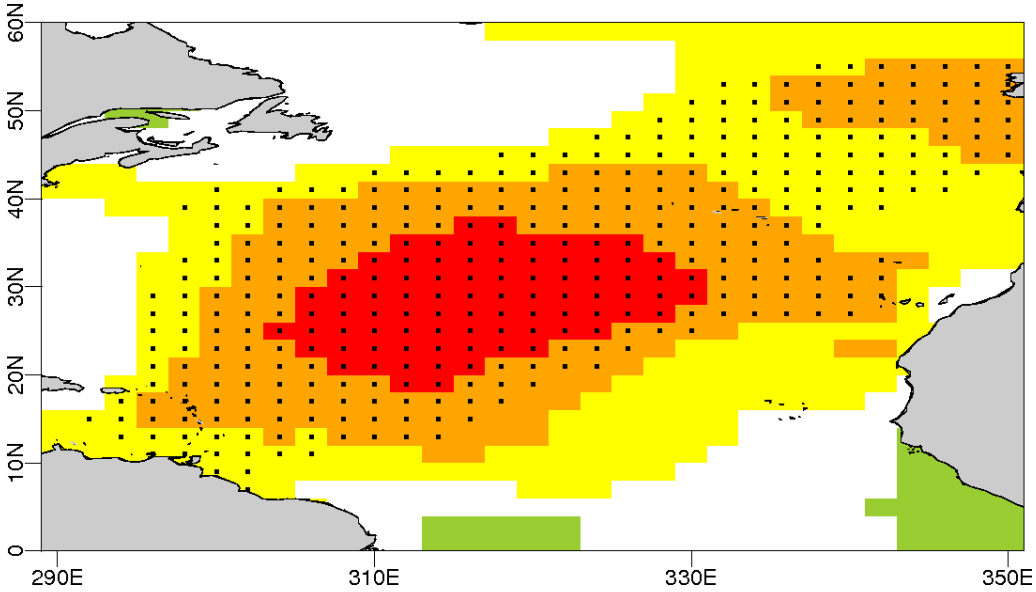




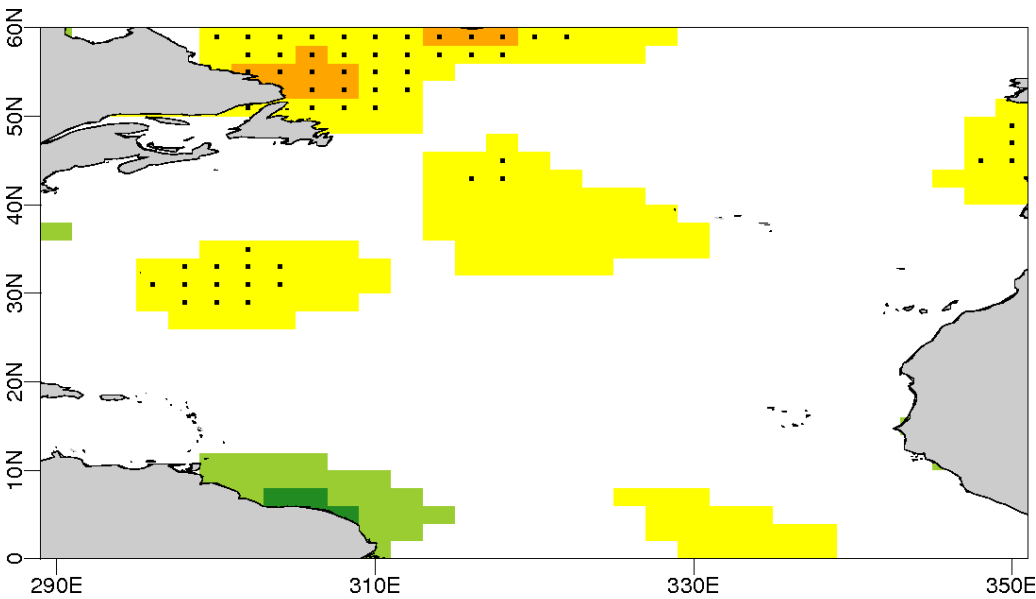


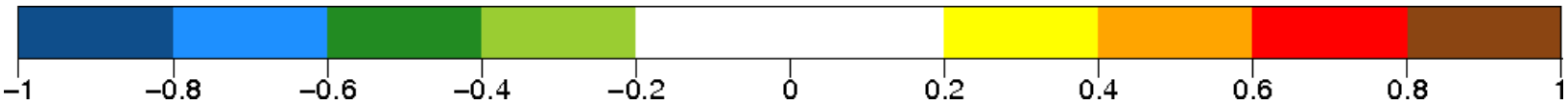


MSLP – Initialized Forecasts



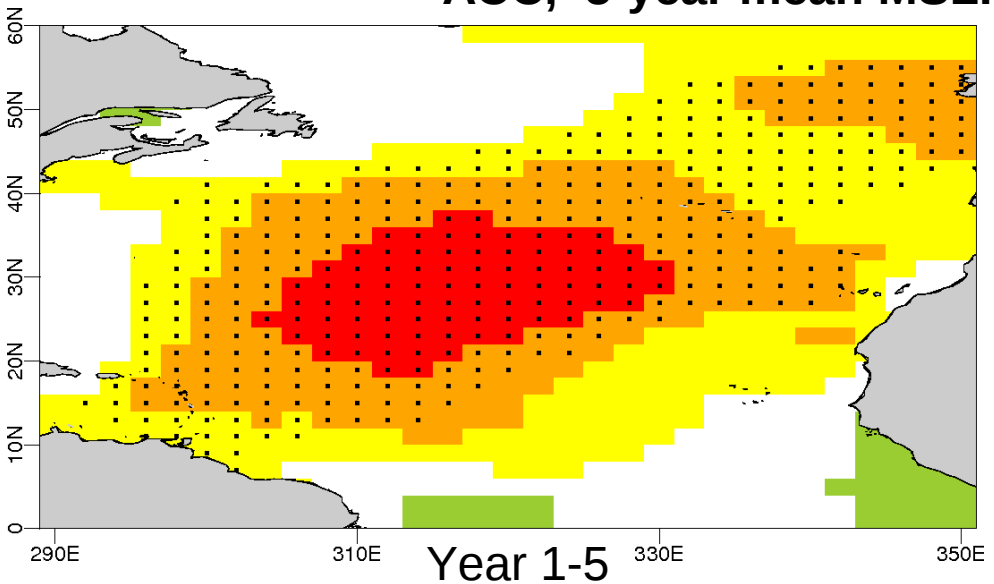
MSLP – Non-Initialized Forecasts



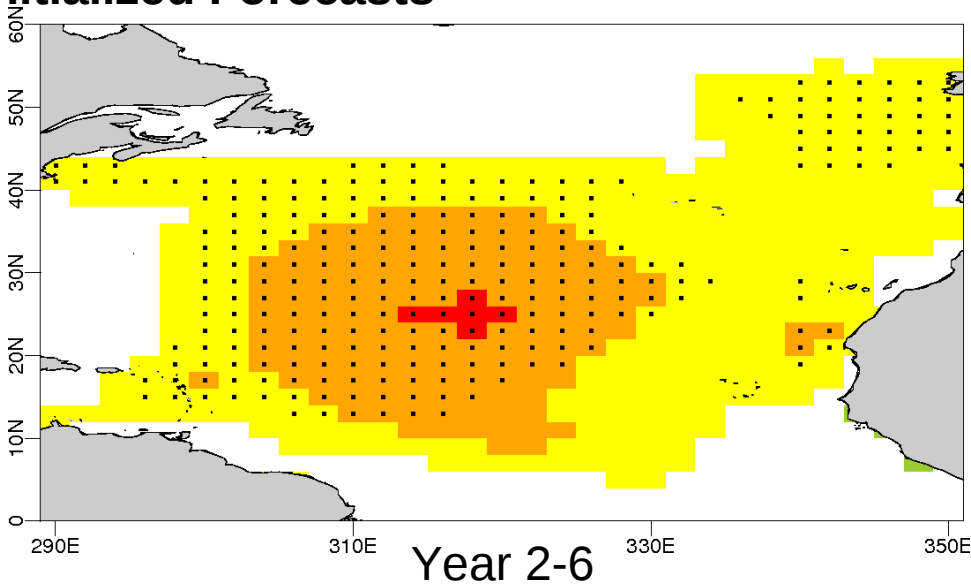


ACC Year 1-5

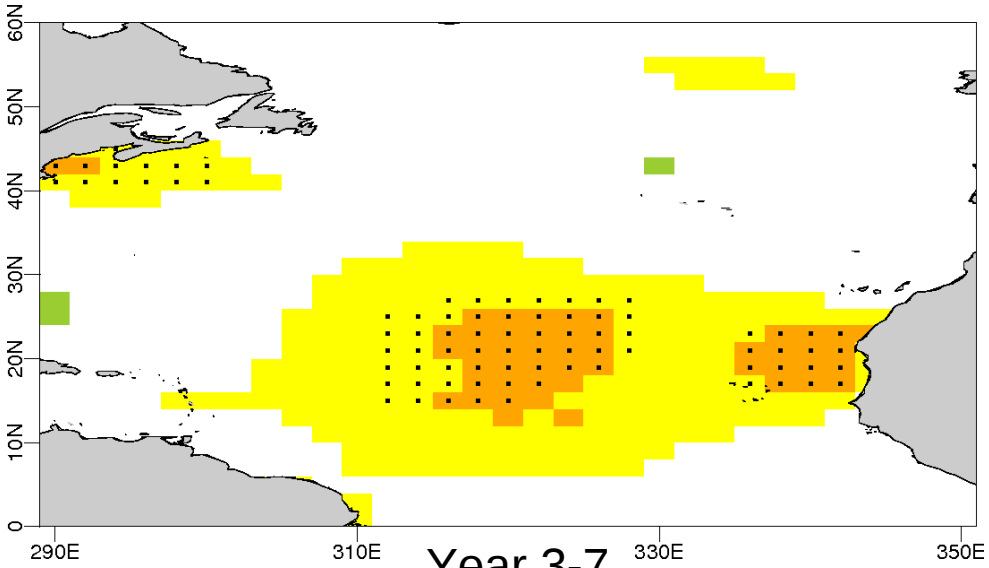
ACC, 5-year mean MSLP – Initialized Forecasts



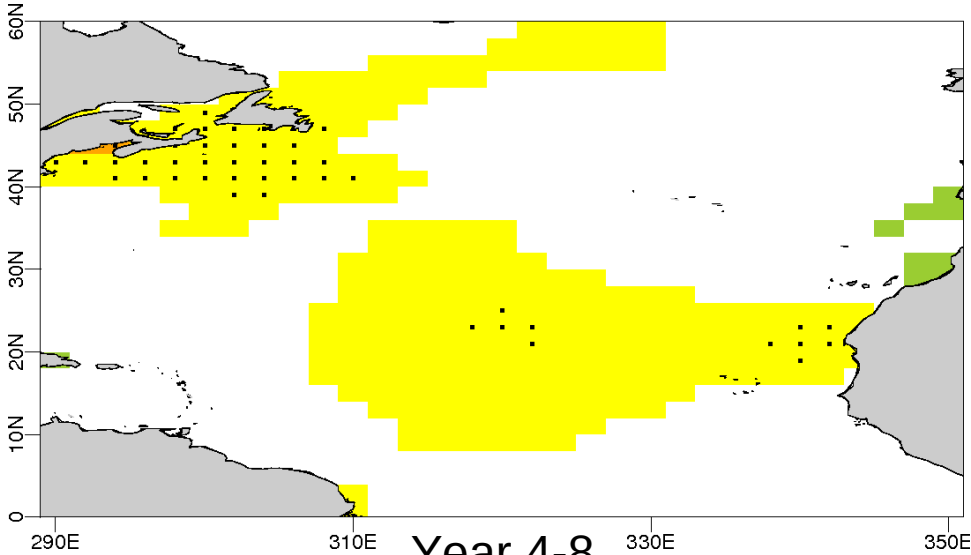
Year 1-5



Year 2-6

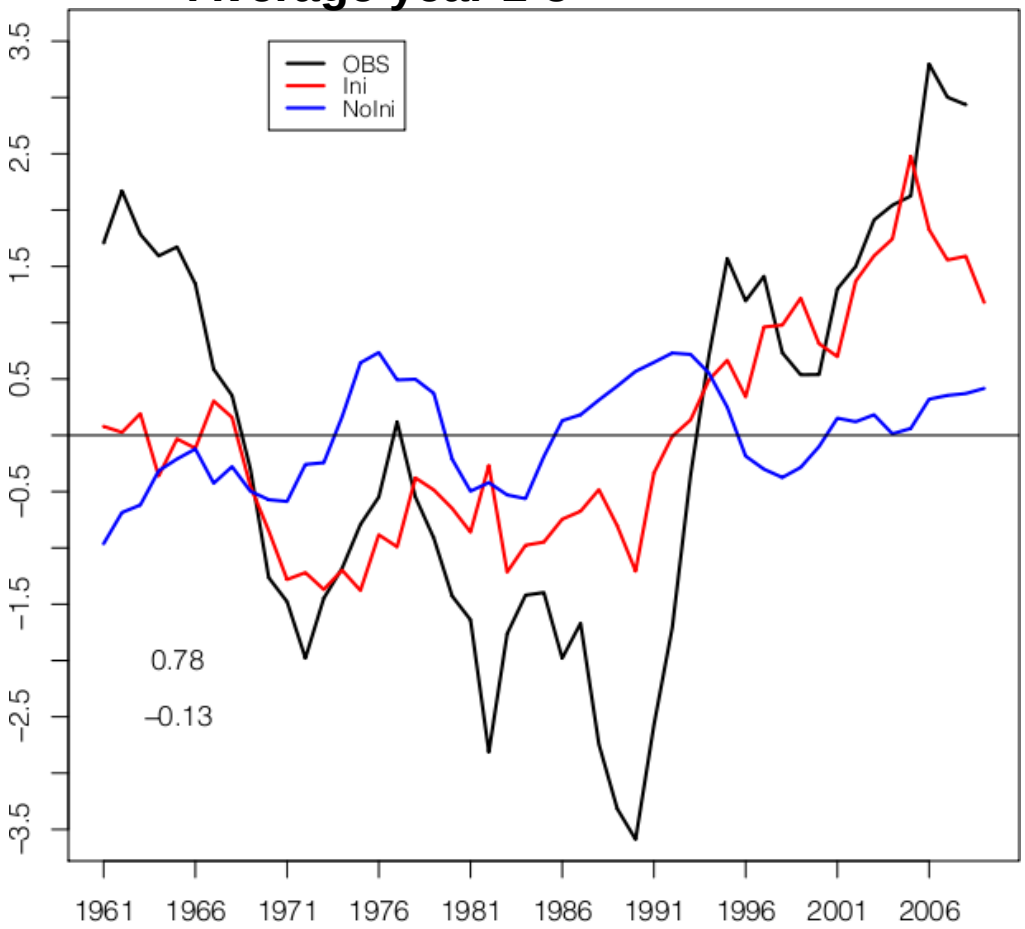


Year 3-7

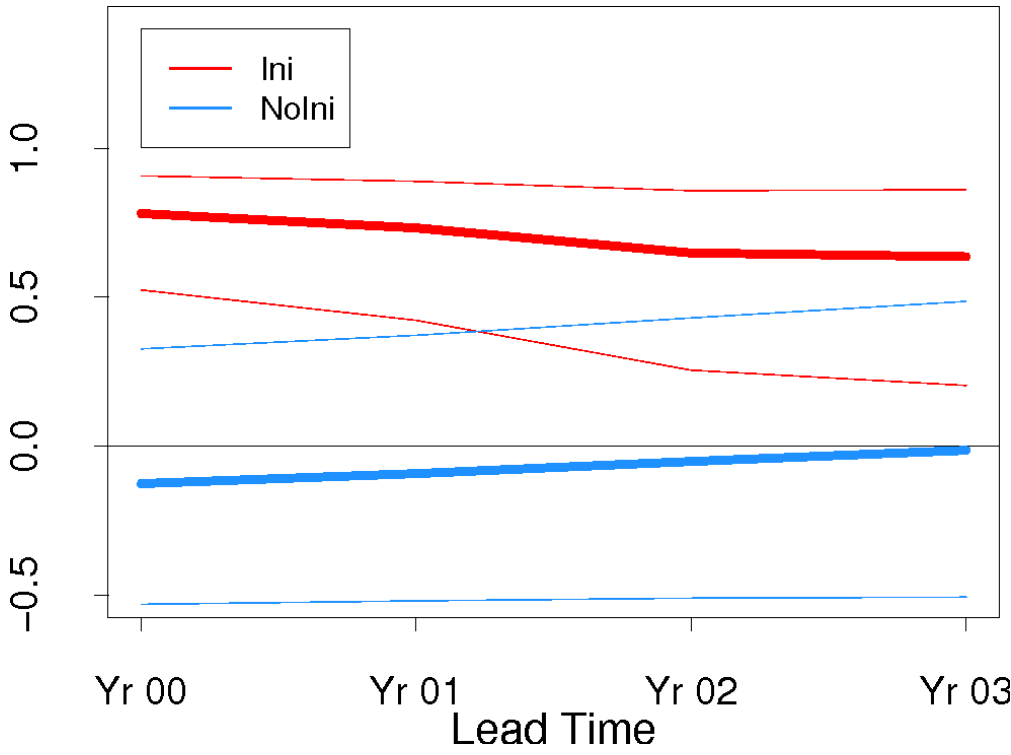


Year 4-8

AMO index
Average year 1-5

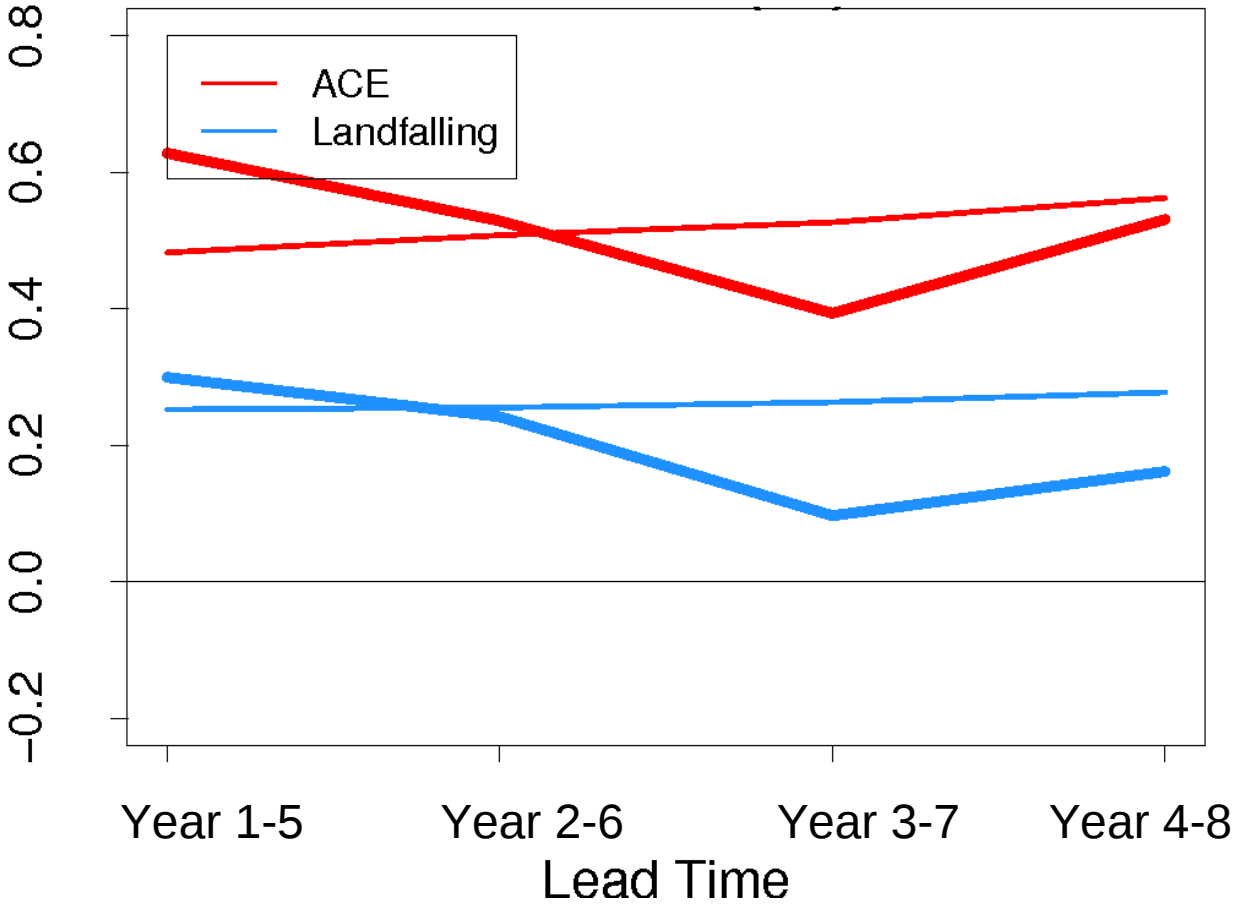


ACC – 5 year mean



How does this skill translate into forecasting cyclone activity?

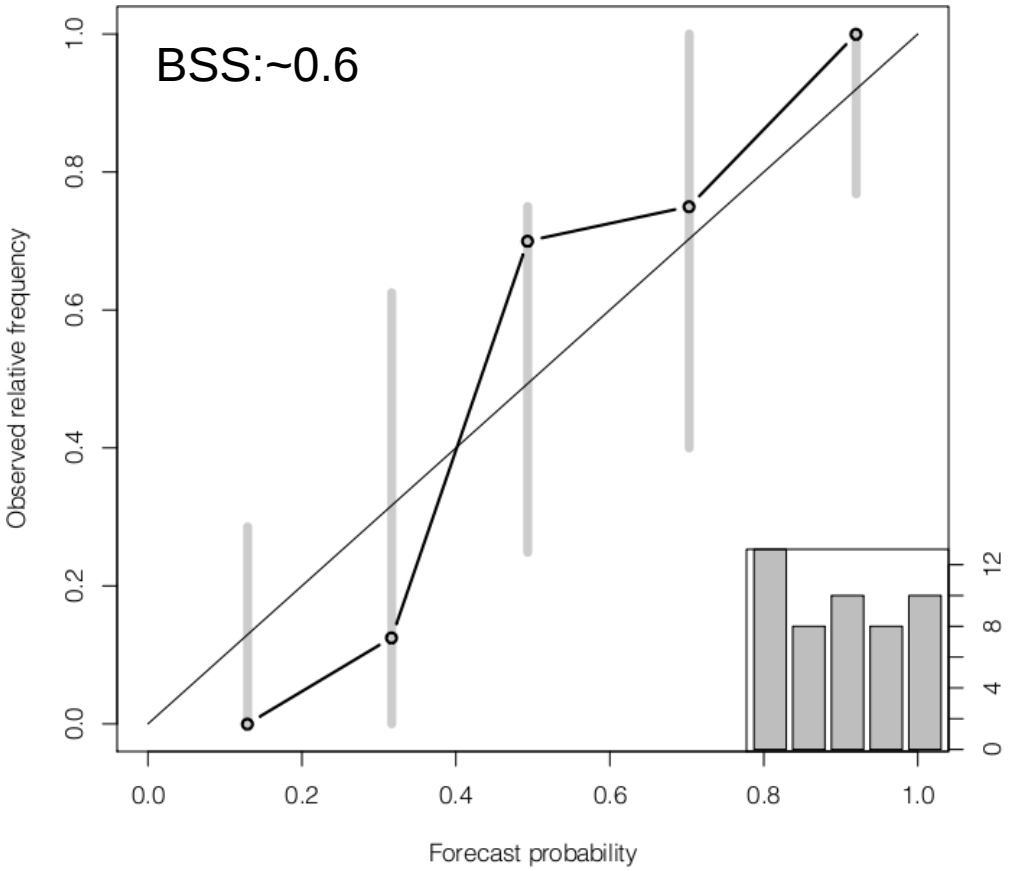
ACC: 5-yr predicted index vs observed activity



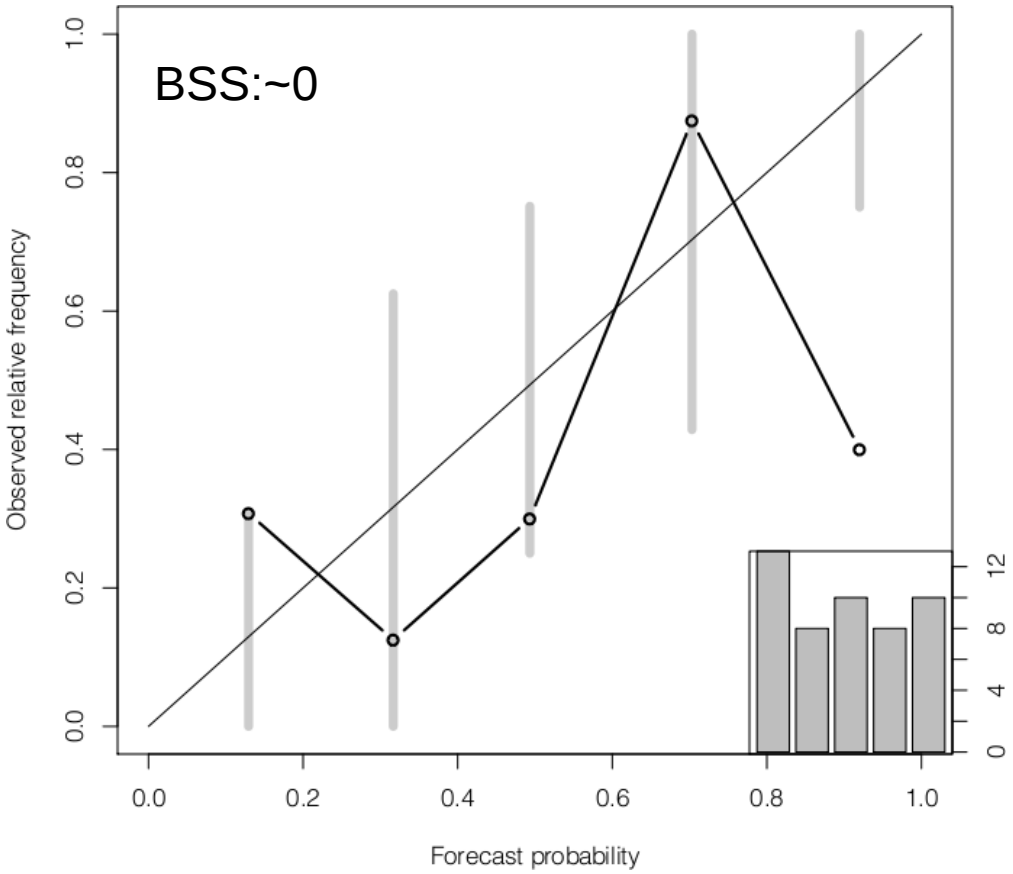
Accumulated Cyclone Energy (ACE): is the square of the max wind speed every 6 hours. The ACE of a season is the sum of the ACE for each storm and takes into account the number, strength, and duration of all the tropical storms in the season.

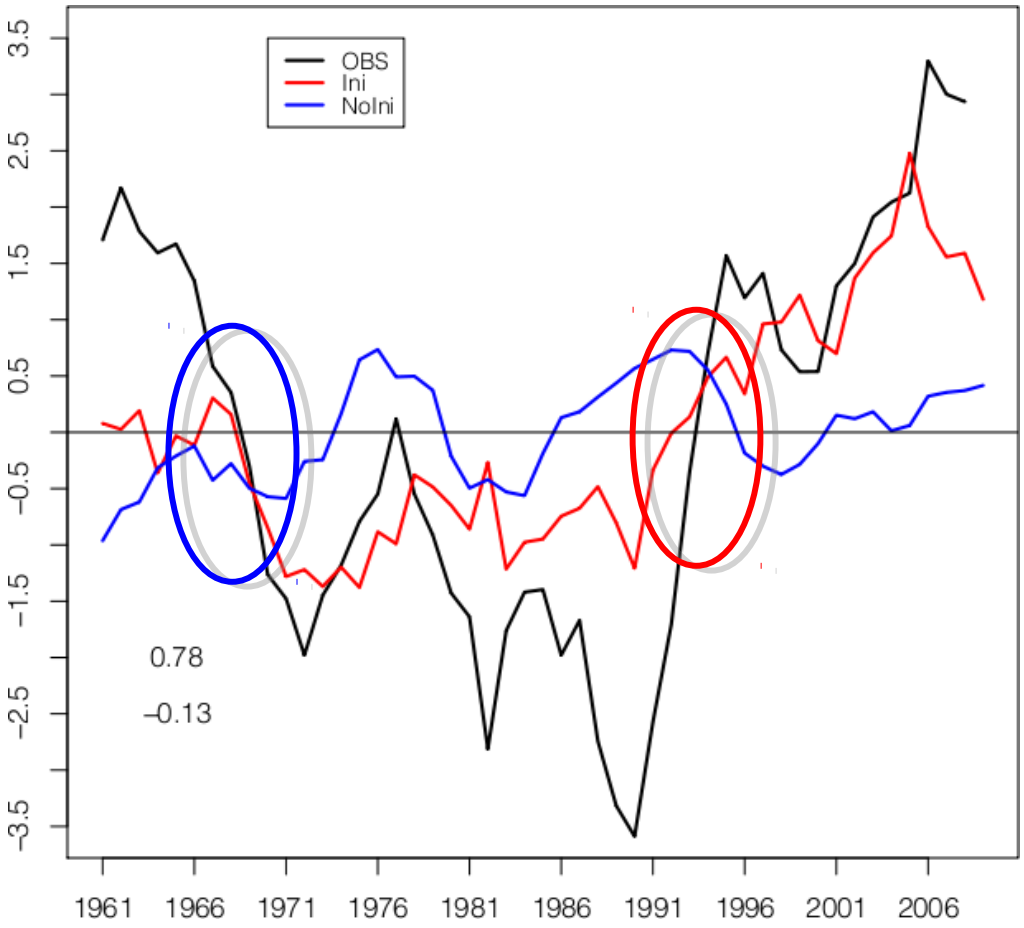
What is the probability that the 5-yr mean activity will be above the climatological mean?

Probabilistic forecast: ACE

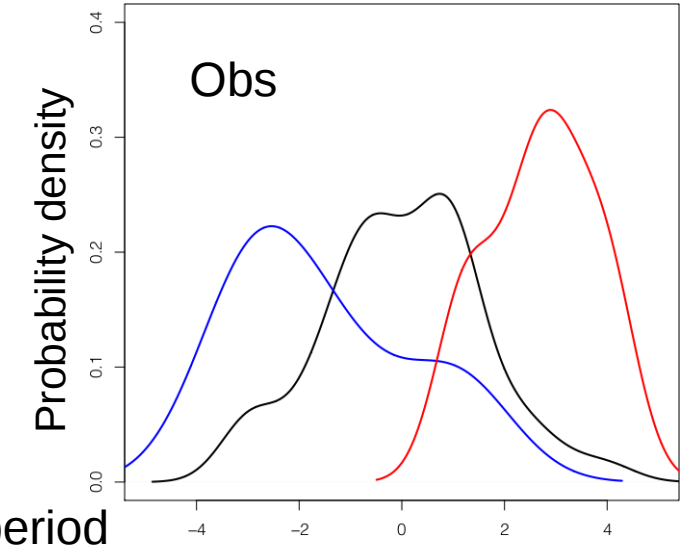


Probabilistic forecast: Landfalling

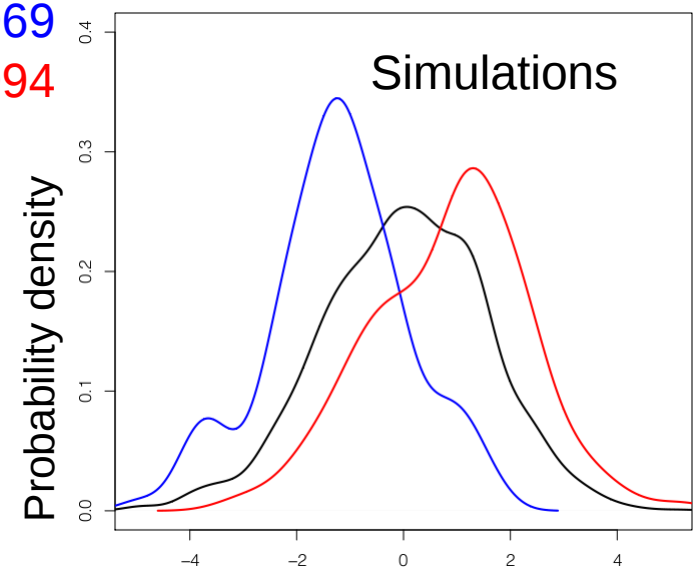




Average AMO index
Years 2-6 minus
AMO index Year 1

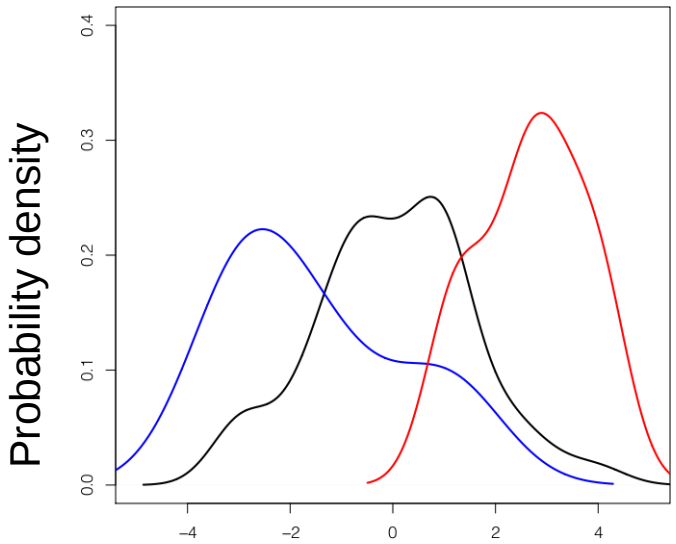


Entire period
1966-1969
1991-1994

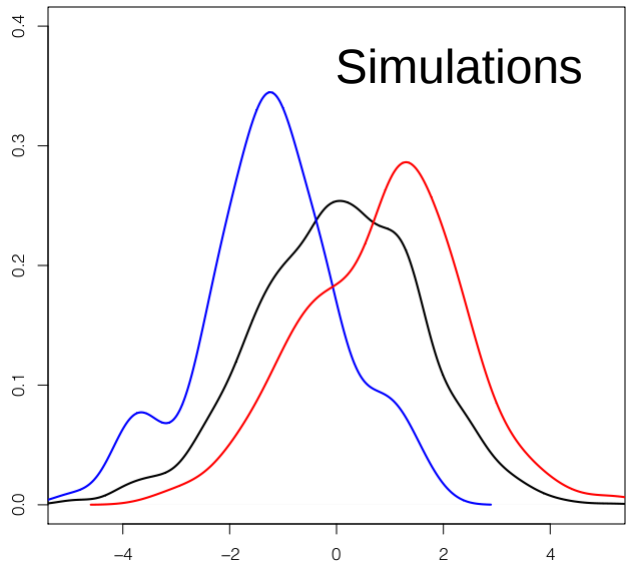


(Average Years 2-6) – (Year 1)

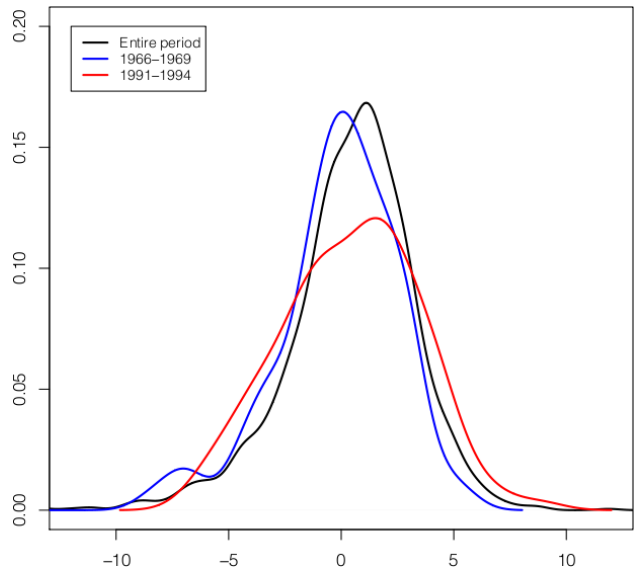
Observed Index



Simulated Index



Simulated ACE



Entire period
1966-1969
1991-1994

$$ACE = e^{1.707 + \beta_1 SST_{MDR} - \beta_2 1.521 SST_{TROP}}$$

from Villarini and Vecchi (2012)

Real-time forecast

- Probability that period 2013-2017 will be above average:
  - HadCM3: 55%
  - HadGEM: 100%

  } Above climatology, but trend is downward

  - GDFL CM2.1: ??
  - MIROC5: ?? (upcoming for 2014-2018)
  - MPI-ESM: ?? (upcoming for 2014-2018)

Summary

- Initialized GCMs do seem capable of predicting AMO index, which is linked to Atlantic TC level, at multi-annual timescale (5yrs)
- Skill doesn’t come only from persistence, i.e. we can predict shift between active and quiet phases

Thank you