Investigating the Influence of Anthropogenic Forcing and Natural Variability on the 2014 Hawaiian Hurricane Season

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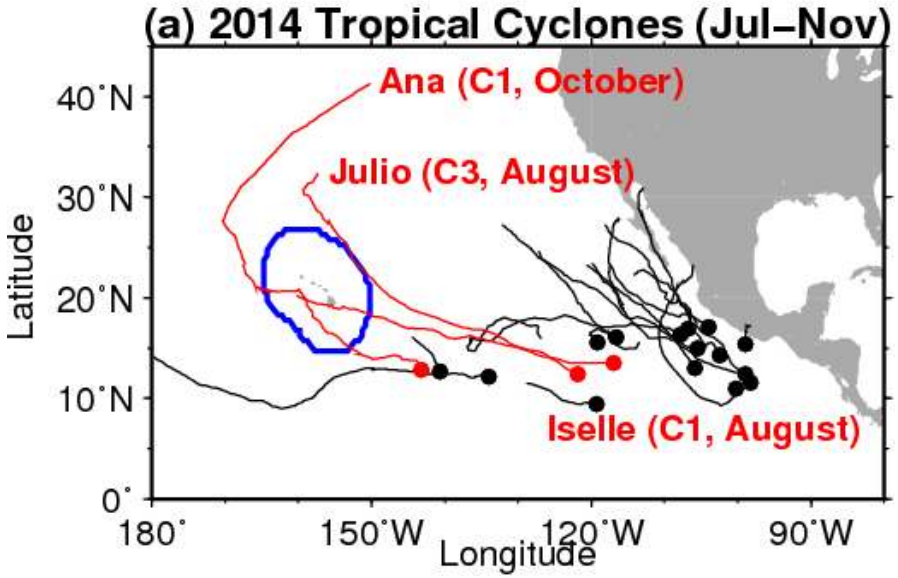
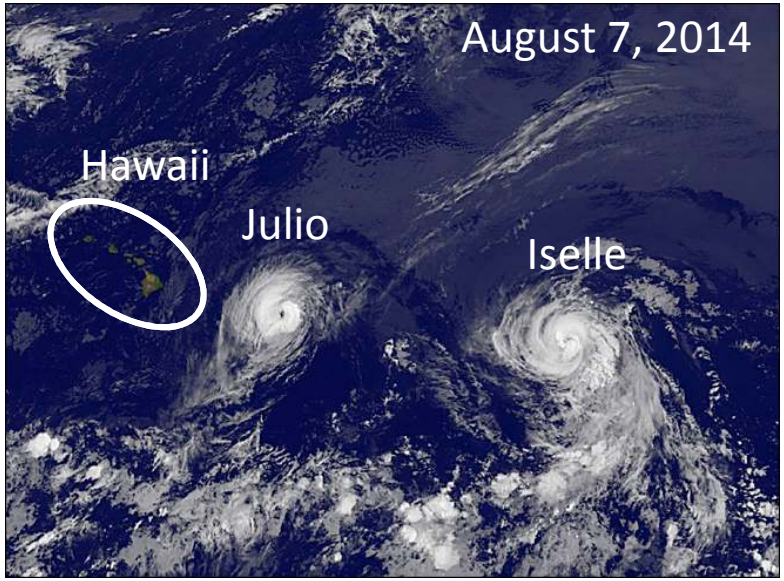
GFDL/Princeton AOS

In press in the 2014 BAMS Explaining Extreme Events report

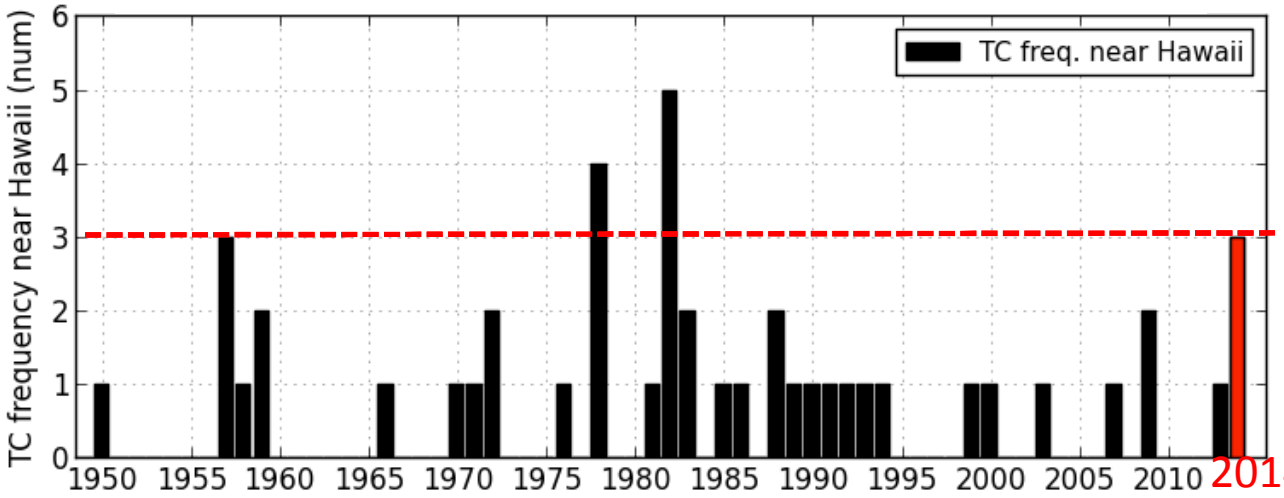
2014 Hurricane Season in the Eastern Pacific





Three hurricanes approached near Hawaii in 2014.

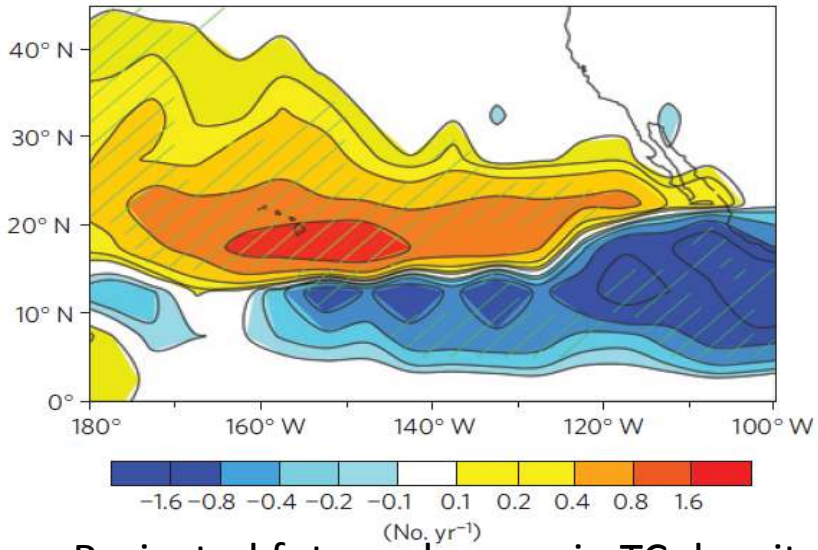
Time series of the observed TC frequency near Hawaii



The third largest number since 1949.

Why? Global warming or Natural variability?

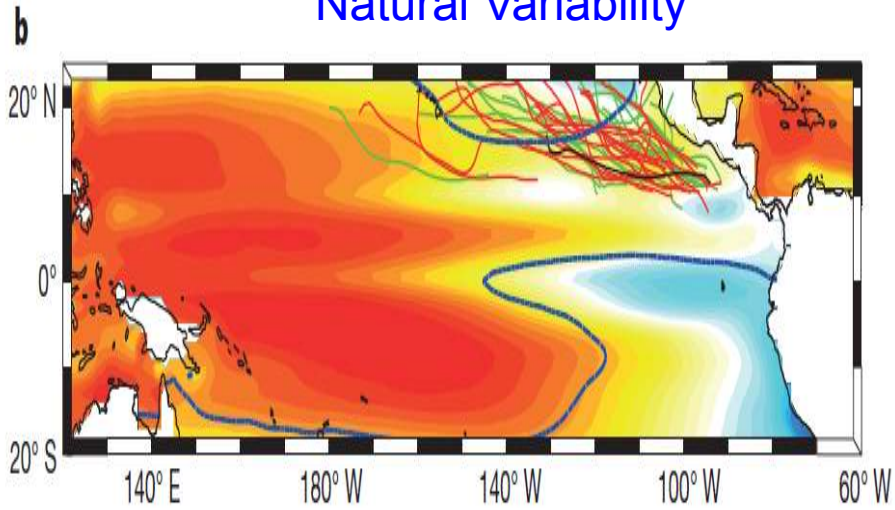
Global Warming



Projected future changes in TC density.

Murakami et al. (2013, *Nature Climate Change*)

Natural Variability



TCs are more active during El Niño years

Jin et al. (2014, *Nature*)

Main goal of this study

We explore whether the unusually large number of Hawaiian TCs in 2014 was made more likely by anthropogenic forcing or natural variability using a suite of climate simulations made using GFDL FLOR.

Simulations used in this study

Dynamical Model : GFDL FLOR (Atmos : 50km mesh; Ocean: 100km mesh)

1. **Retrospective Seasonal Forecasts**

   Period : 1980–2014

   Forecasts : 12 members initialized for each month

   purpose : Evaluation of the model to predict Hawaiian TCs

2. **Control Simulations**

   1860 cntl : 2000-yr run prescribed by radiative forcing fixed at the 1860 level

   1990 cntl : 500-yr run prescribed by radiative forcing fixed at the 1990 level

   purpose : Effect of anthropogenic forcing on Hawaiian TCs

3. **Large Ensemble Simulations**

   Period : 1941–2050 (35 member)

   1941–2005: Observed CO2 + Aerosol + historical volcanic forcing,

   2005–2050: Radiative foricing by RCP4.5

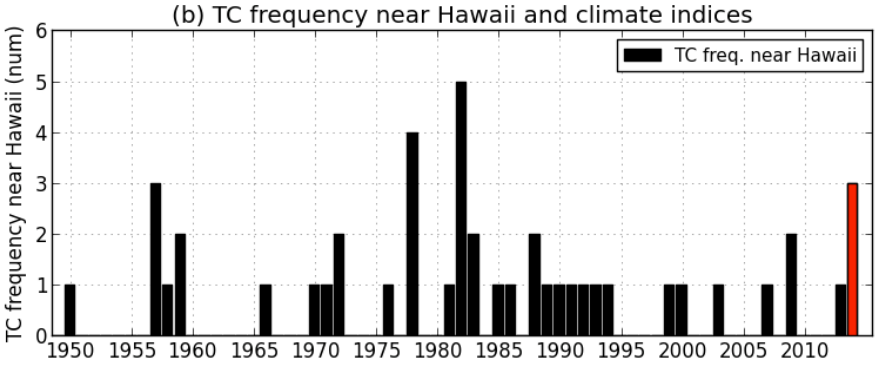
   purpose : Effect of natural variability and anthropogenic forcing on Hawaiian TCs

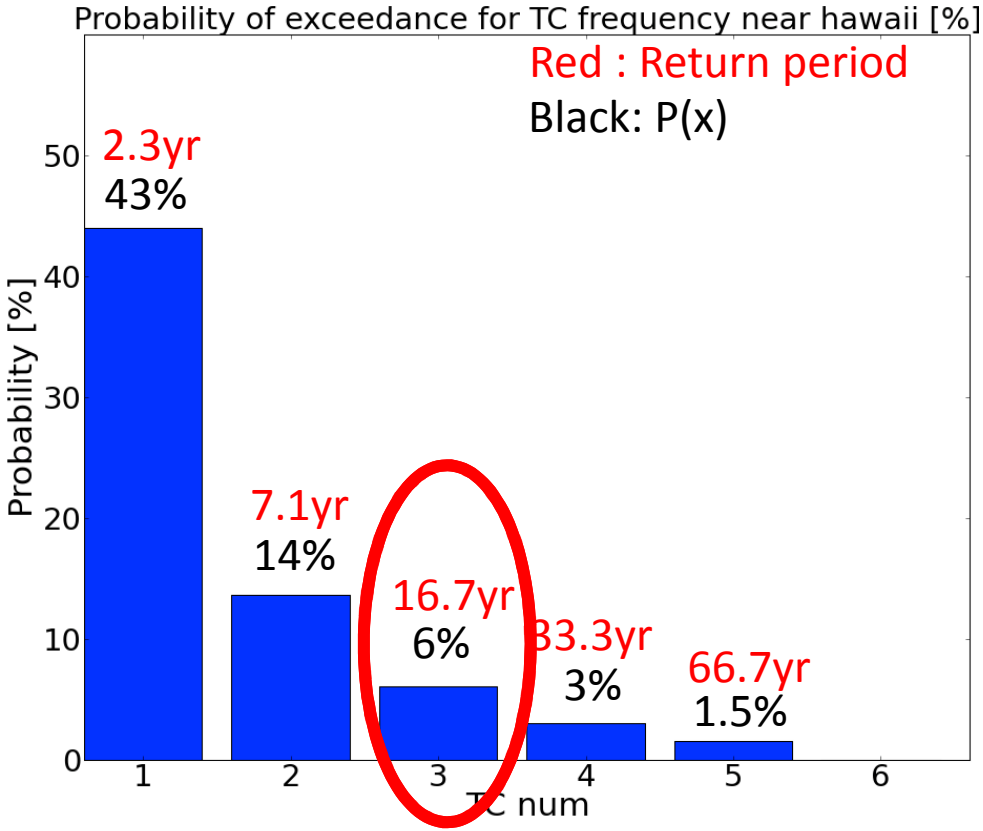
Total simulation years = 10,000

Probability of Exceedance

$$P(x) = \frac{\text{Number of years with TC number more than or equal to } x \text{ near Hawaii}}{\text{Total number of years}}$$

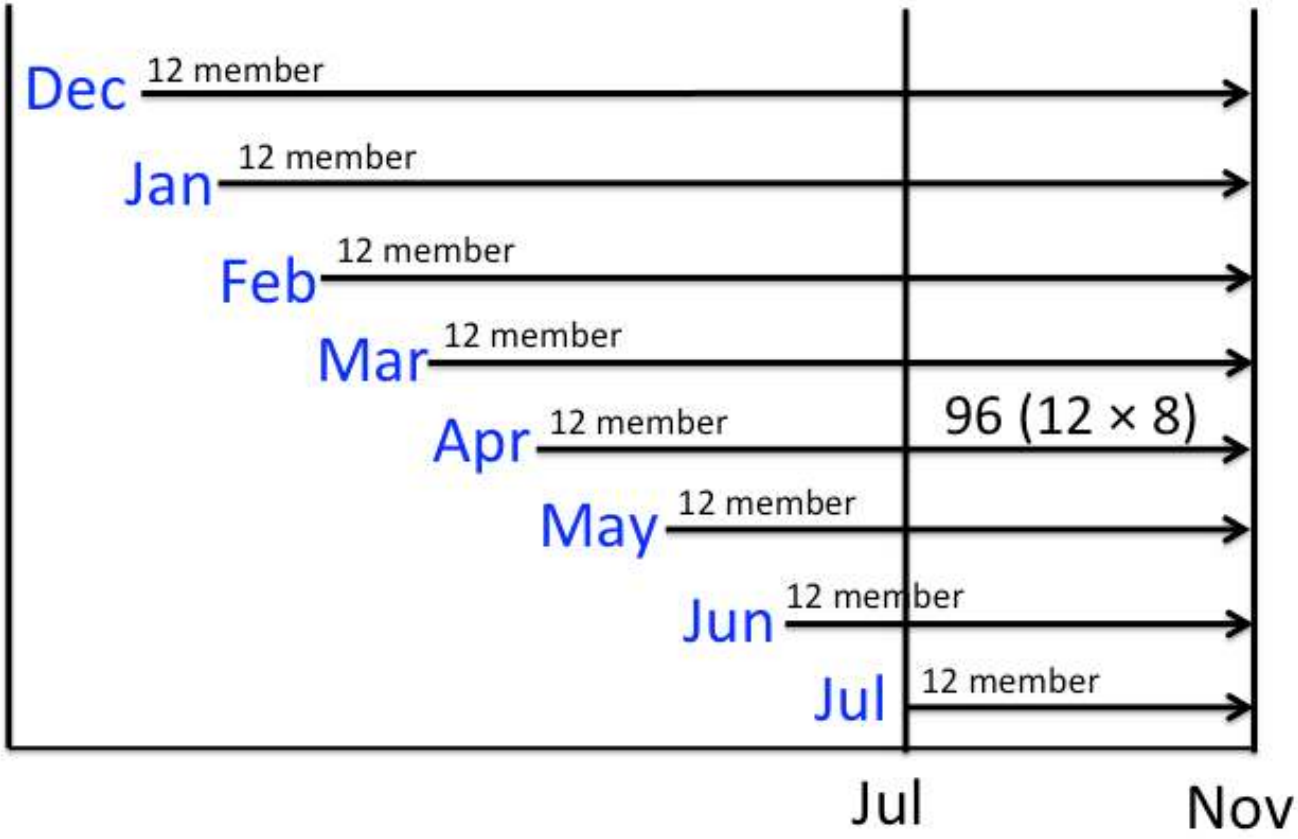
Observations (1949-2014, 66yr)



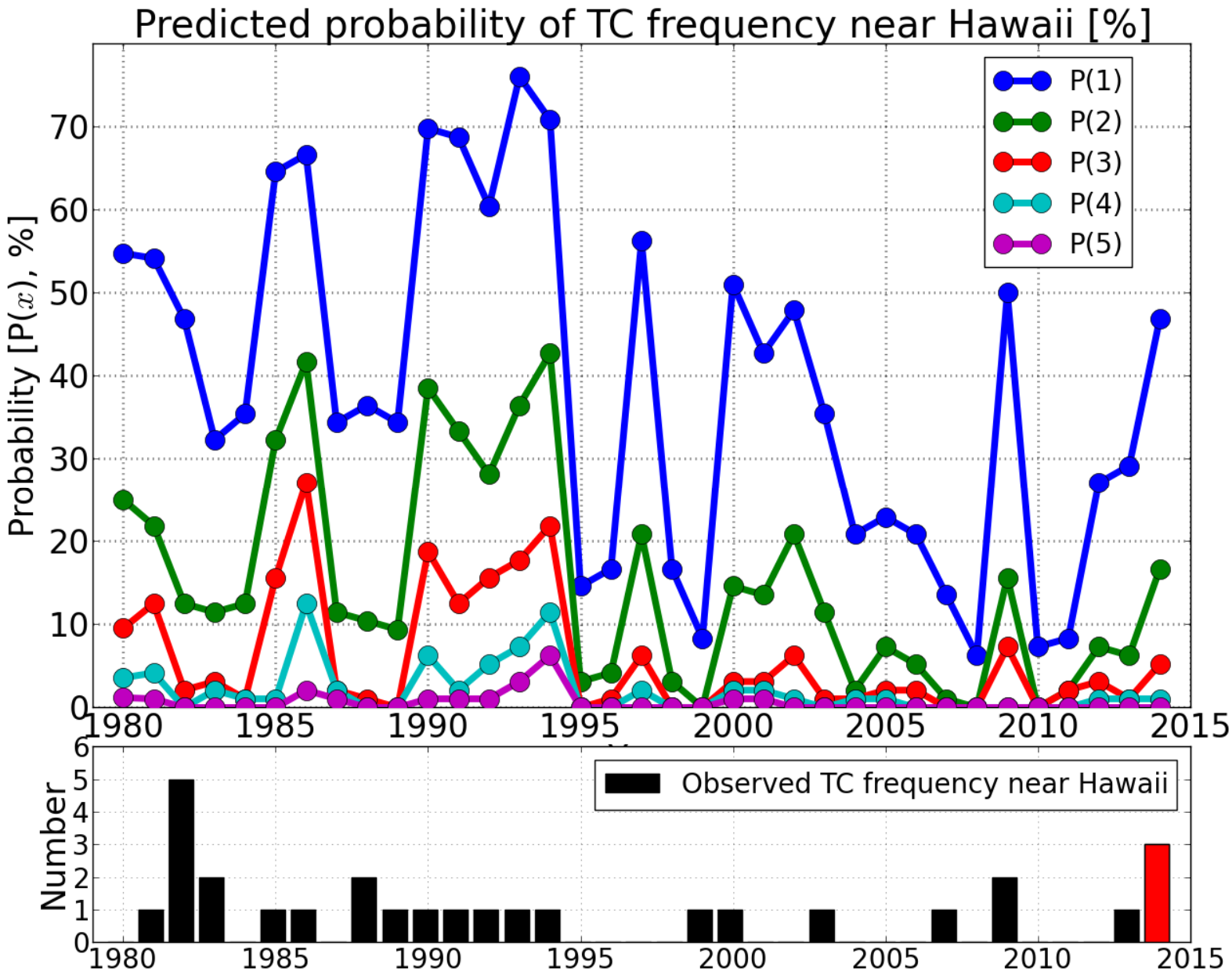


Retrospective Seasonal Forecast

•For each year from 1980 to 2014, 12-member predictions from 8 lead months are used. 96 (= 12 member x 8 months) samples are available for computing P(x).

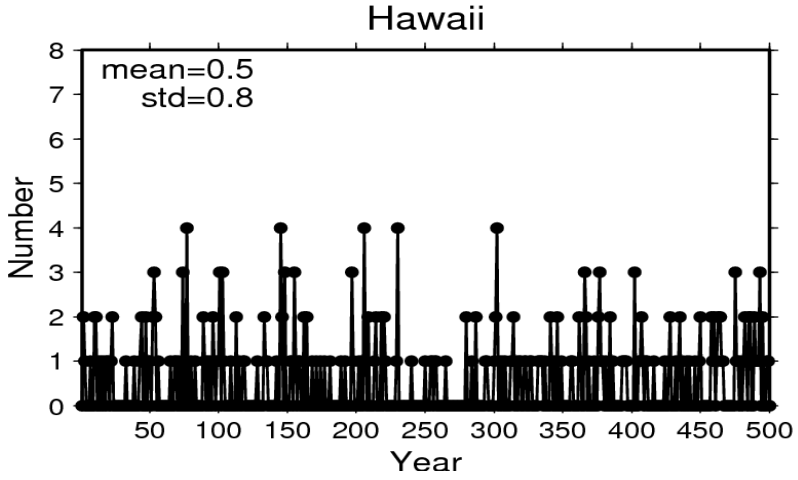


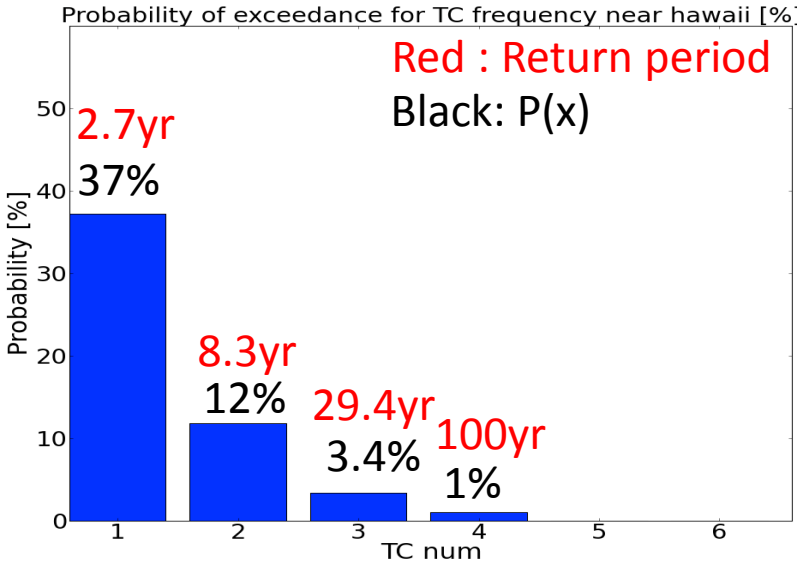
Retrospective Seasonal Forecast



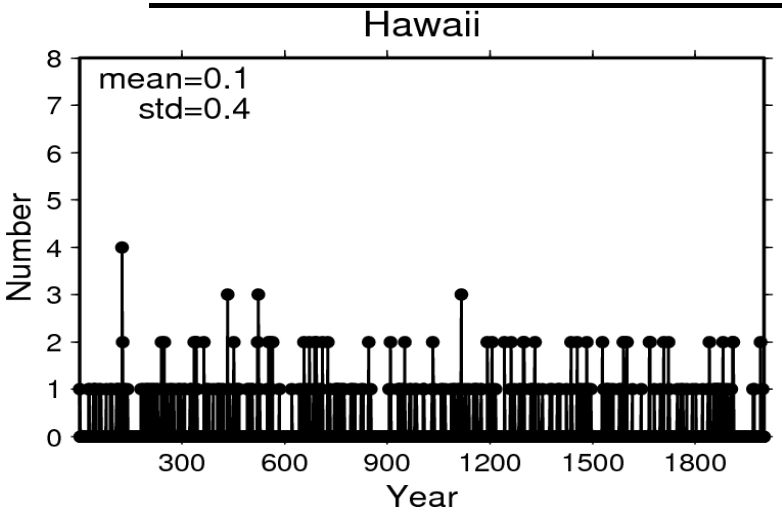
Control Experiments

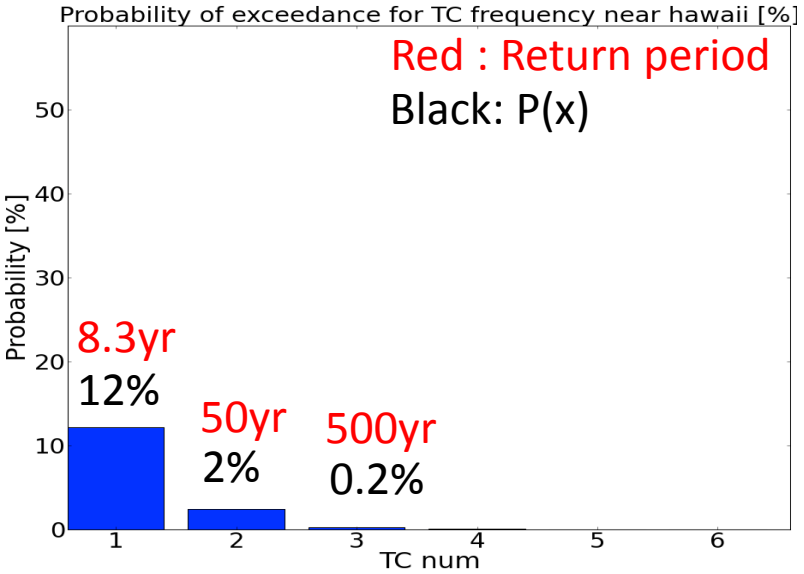
1990-level Radiative Forcing Control Experiment (500 yr)



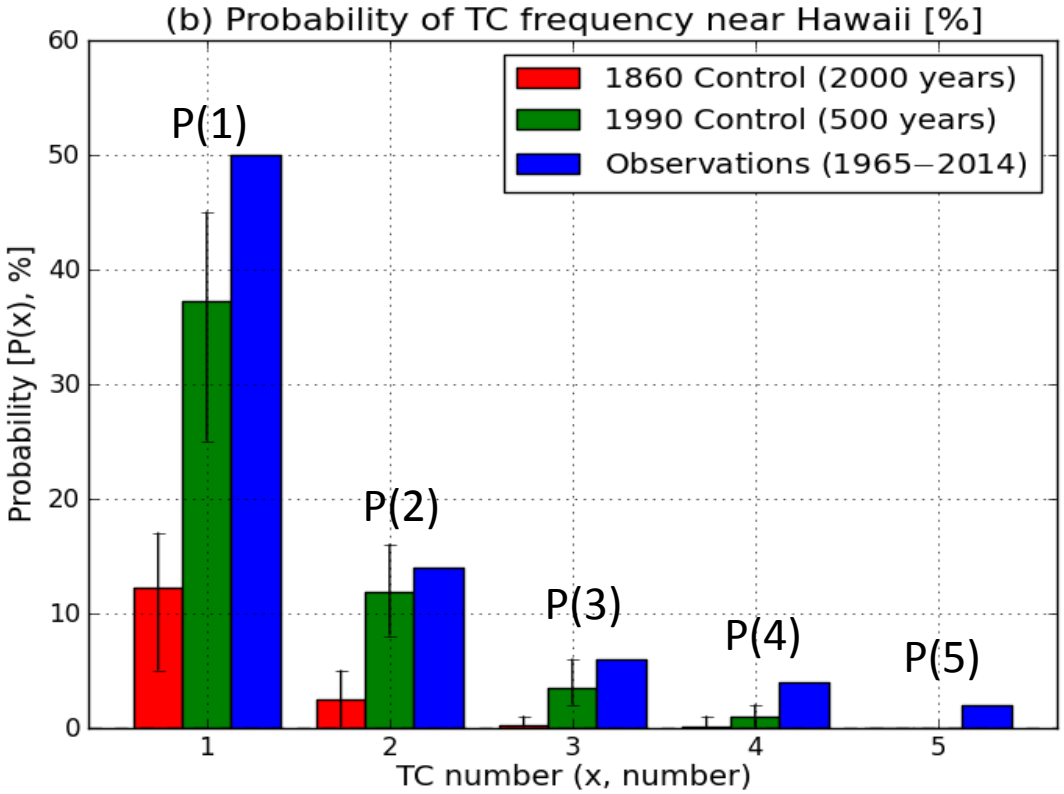


1860-level Radiative Forcing Control Experiment (2000 yr)





Summary of the Control Simulations



P(2) and P(3) are about 5 and 17 times larger in 1990 control than 1860 control.

Fraction of Attributable Risk (FAR)

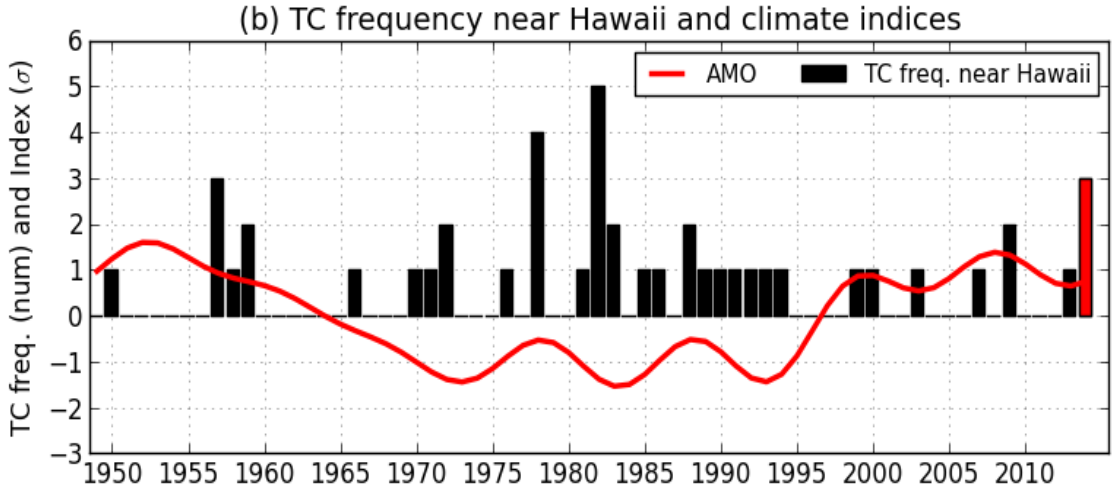
$$FAR(x) = \frac{P(x \mid E_1) - P(x \mid E_0)}{P(x \mid E_1)}$$

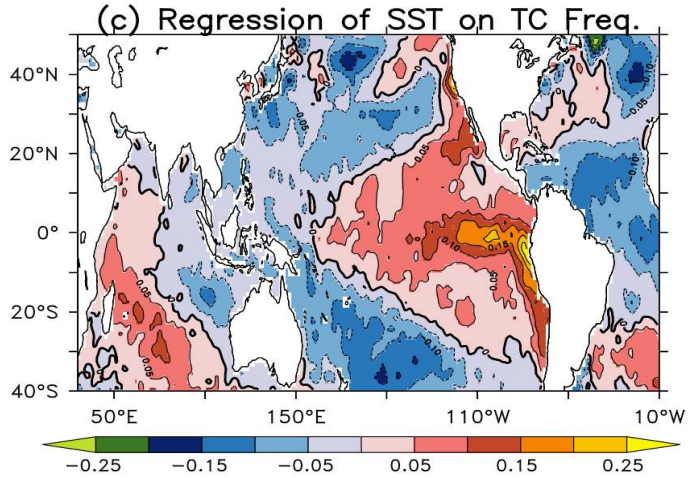
E_1: Anthropogenic Forcing
E_0: Non-anthropogenic Forcing

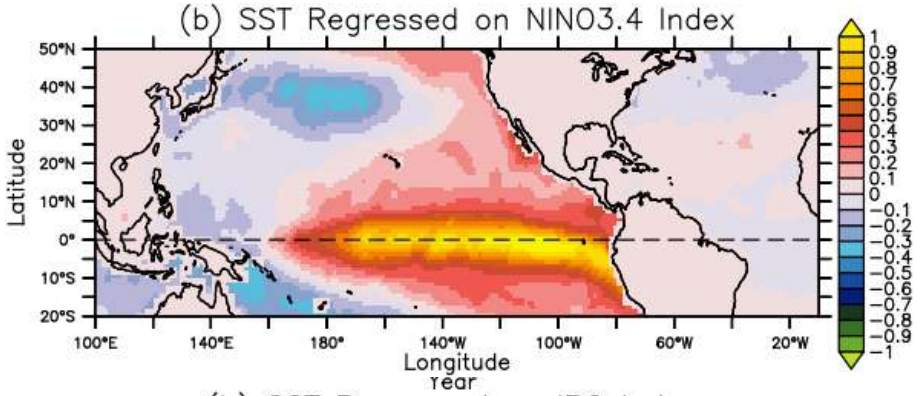
FAR(2) = 0.79
FAR(3) = 0.94

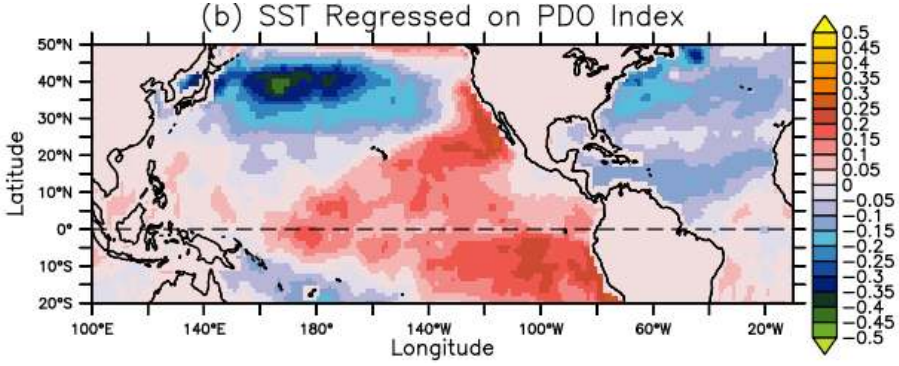
Anthropogenic forcing has substantially changed the odds of TC seasons like 2014 near Hawaii relative to natural variability alone.

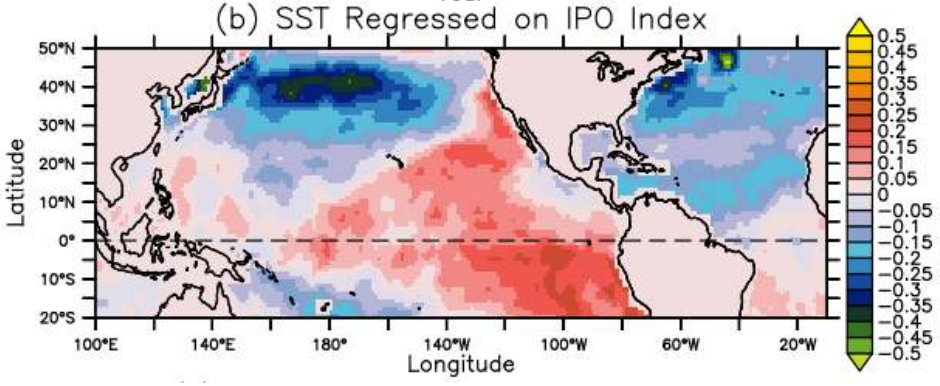
Effect of Natural Variability on TCs near Hawaii

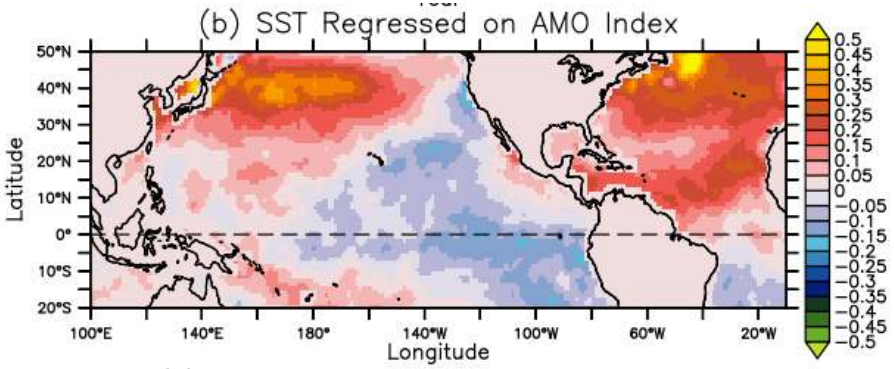






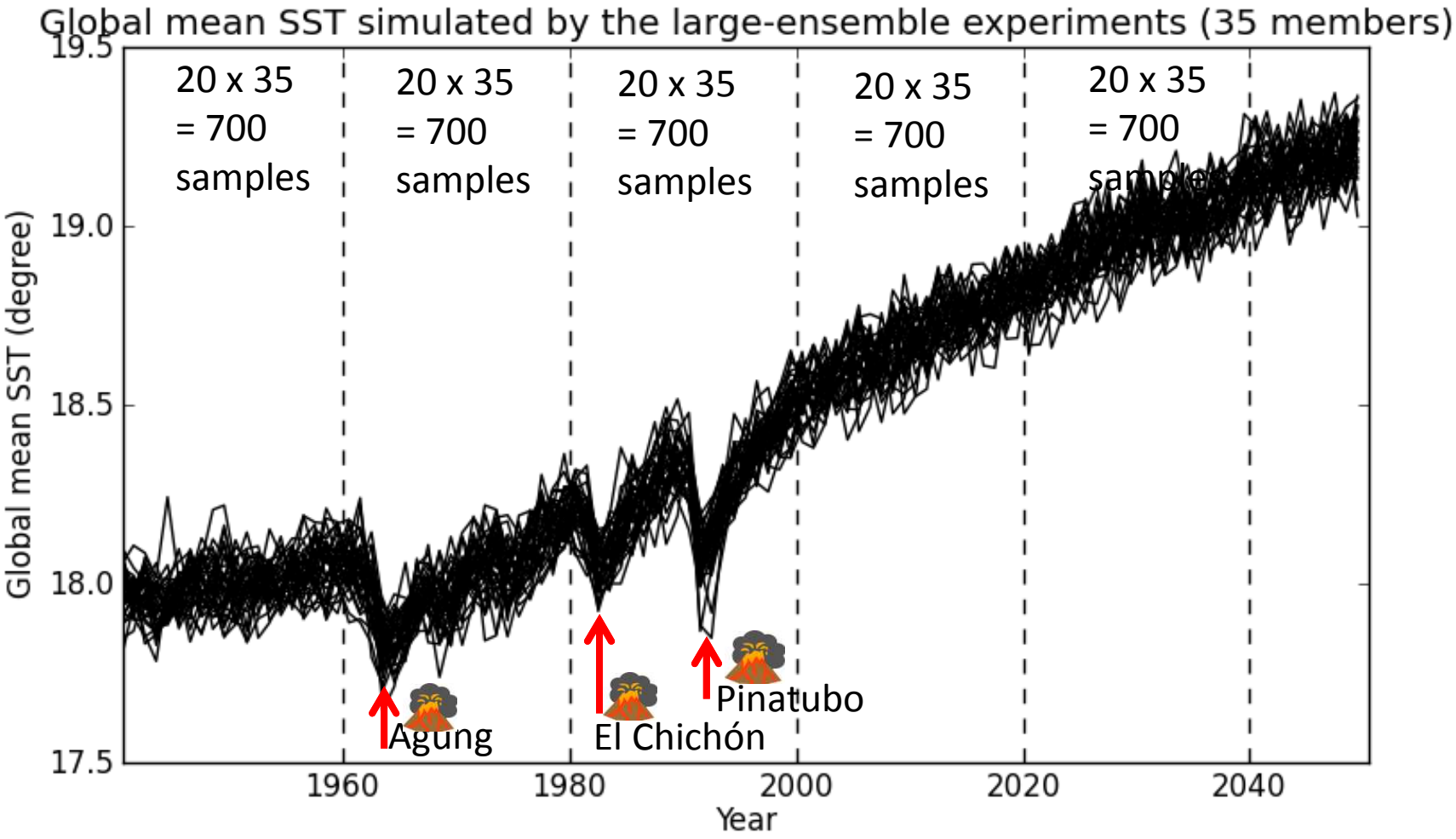






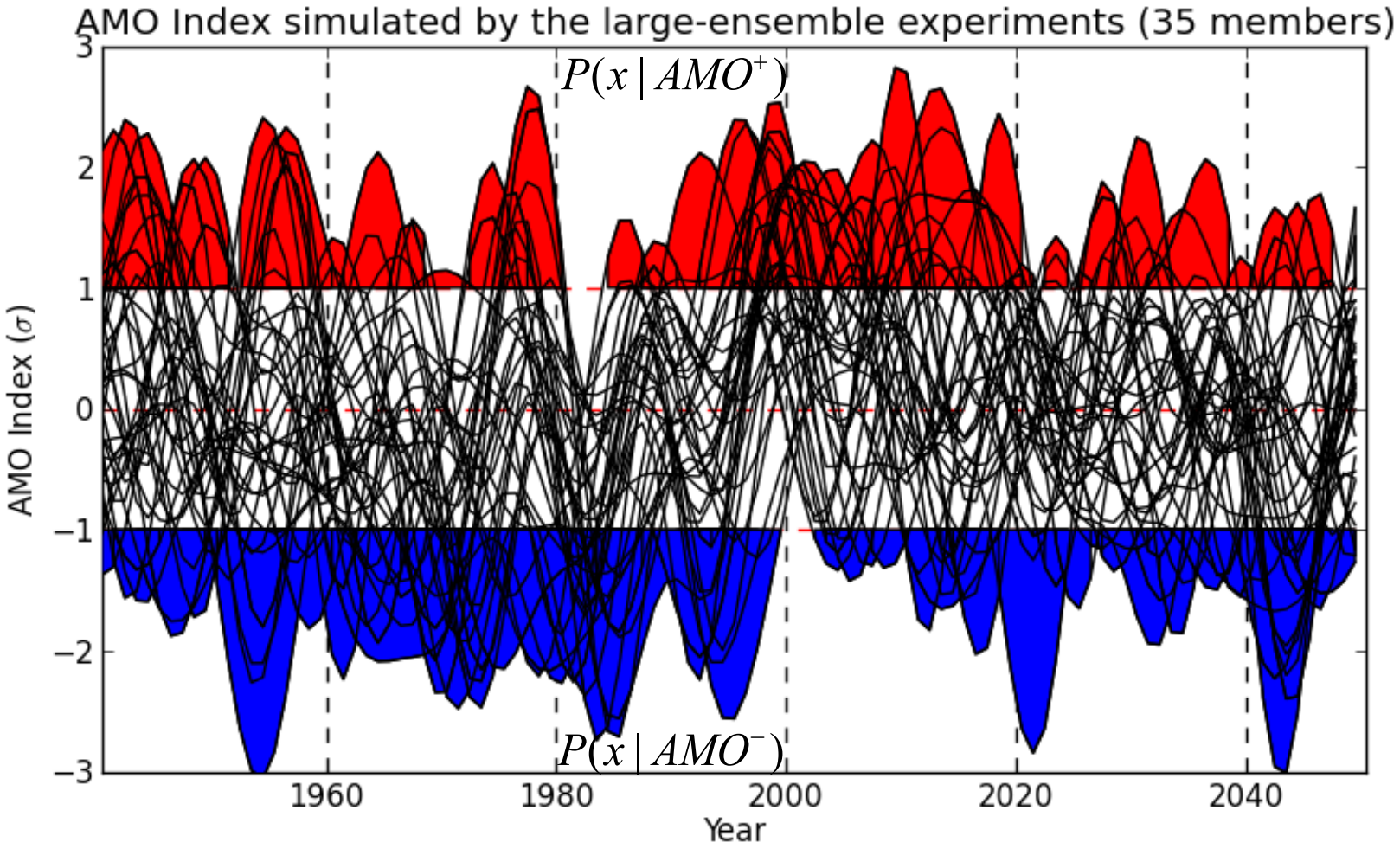
Large-ensemble Experiments

- 35-member large-ensemble simulations for the period 1941–2050.
- Historical volcanic forcing and aerosols are prescribed between 1941–2005. No volcanic event after 2005.
- After 2005, RCP4.5 scenario is assumed for the anthropogenic forcing.
- For each 20-yr period, there are 700 (20 yr × 35 member) samples to compute P(x).

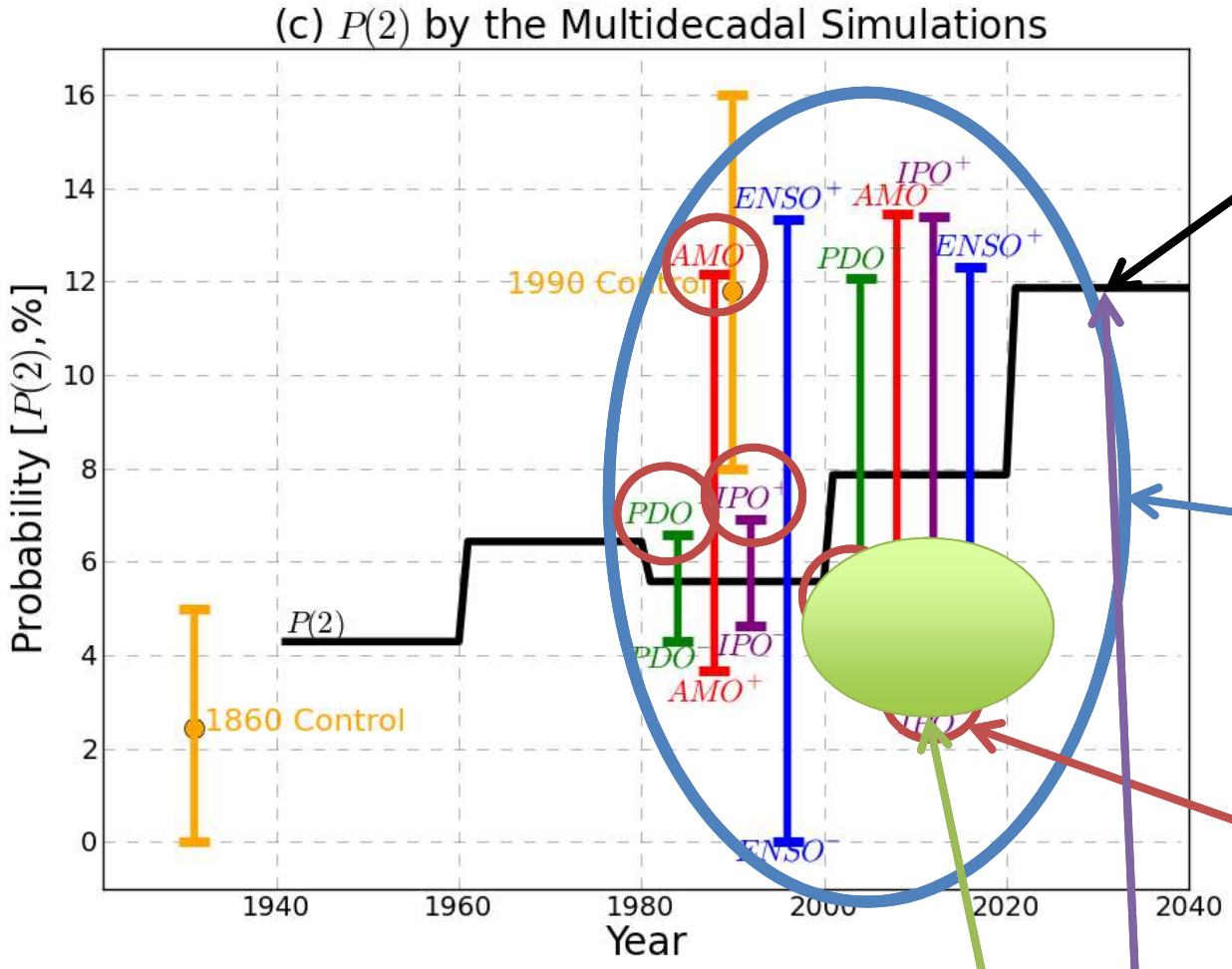


Large-ensemble Experiments

- Internal variability is independent among the ensembles.
- We can compute conditional probability under any phases of natural variability.



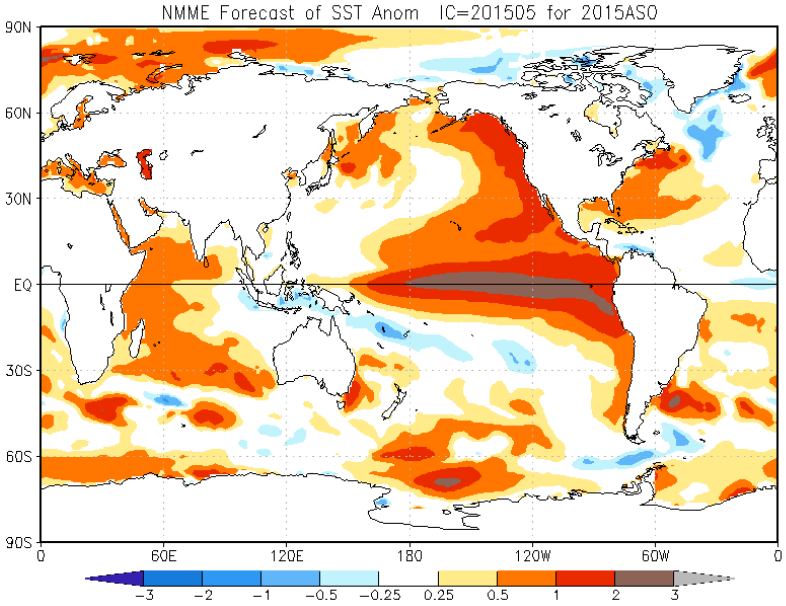
Large-ensemble Experiments

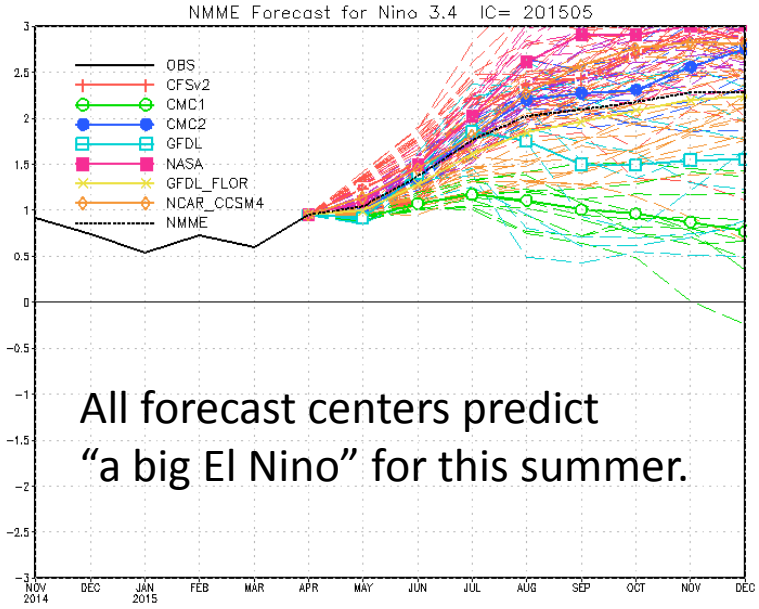


- Black line reveals a gradual increase from 1940 to 2040, indicating global warming generates more TCs near Hawaii.
- Colors bars indicate that natural variability has marked potential to influence the probability.
- Observed multi-decade difference between 1980–2000 and 2000–2020 was mainly due to natural internal variability.
- The extremely large number of TCs during the 2014 summer season occurred despite the unfavourable IPO (–2.0), AMO (+0.6), and PDO (–0.7), and moderate El Niño (+0.6).
- Continued increase of probability is expected in the following decades.

What about seasonal forecast for 2015?

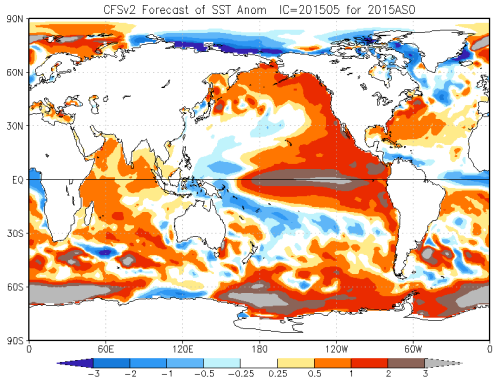
2015 April initial to predict 2015 JAS.



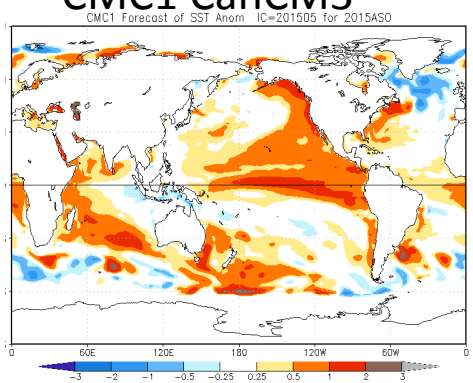


All forecast centers predict
“a big El Nino” for this summer.

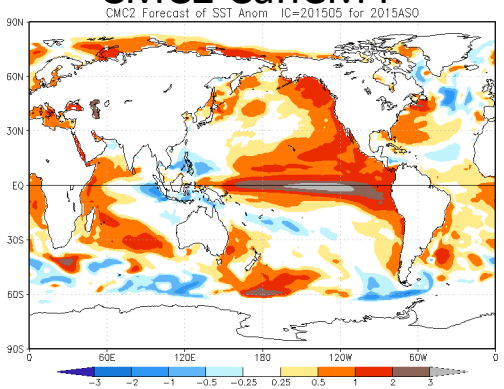
NCEP CFSv2



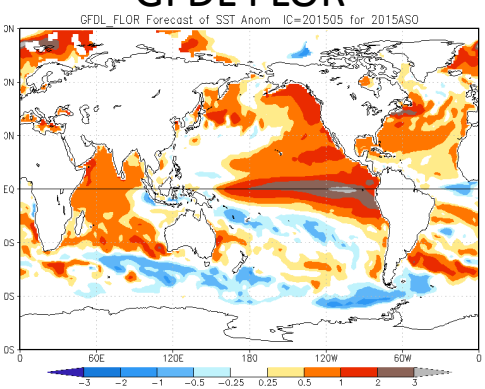
CMC1 CanCM3



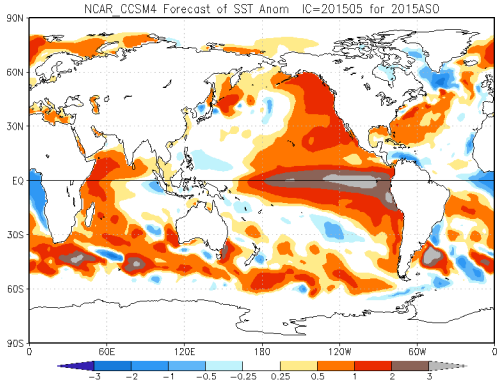
CMC2 CanCM4



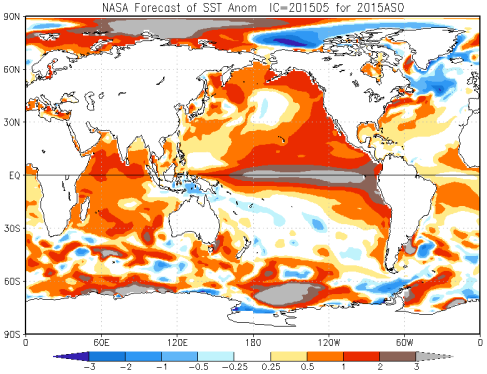
GFDL FLOR



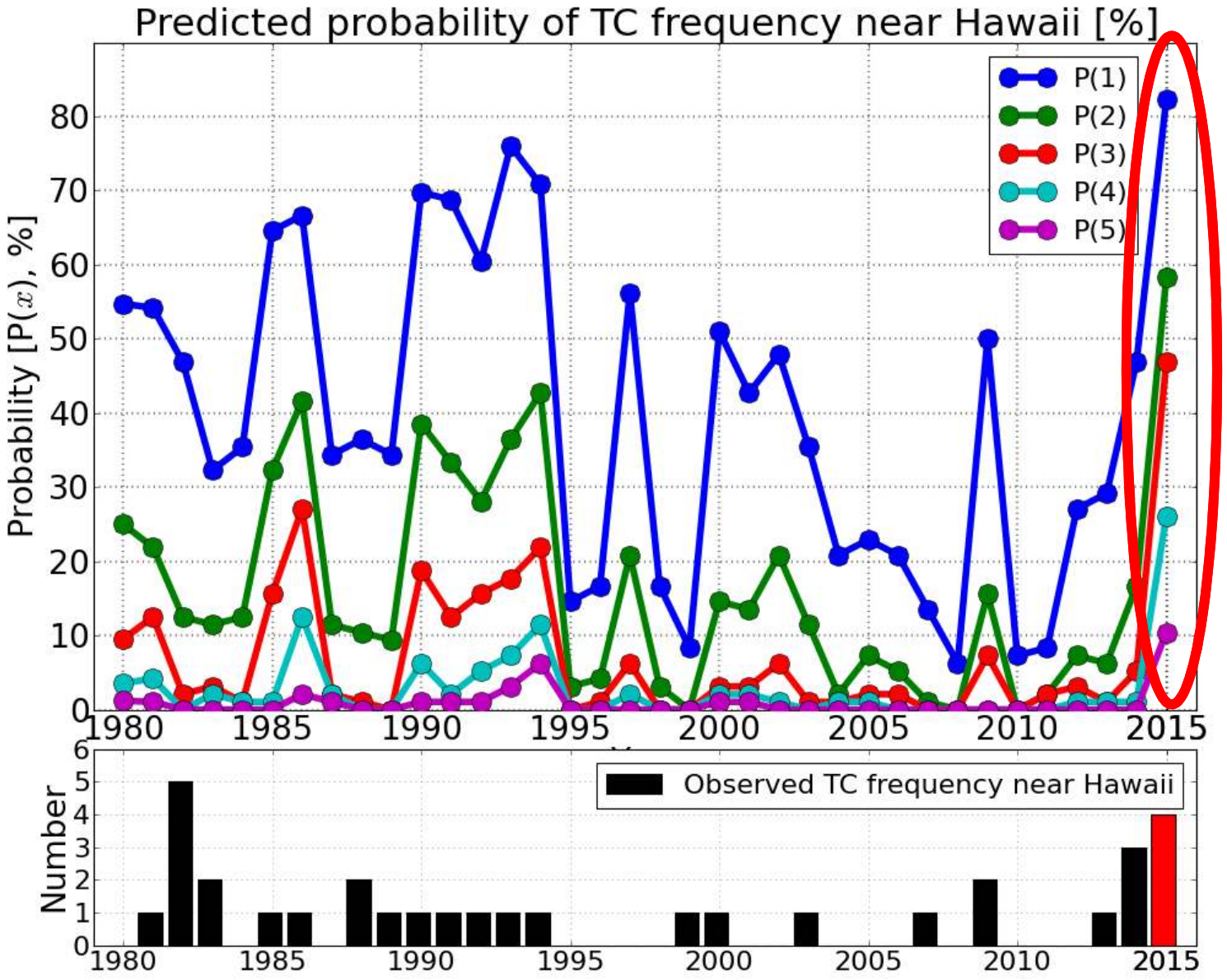
NCAR CCSM4



NASA GEOS5



Seasonal Forecast by FLOR including the 2015 forecasts



FLOR predicts historical record of Hawaiian TCs in 2015.

Summary

- The observed multi-decadal difference in TC frequency near Hawaii between 1980–1994 and 1995–2014 was mainly caused by **natural variability**.

- It is likely that **global warming** has increased the odds of the extremely large number of Hawaiian TCs in 2014, in combination with the moderately favorable condition of El Niño.

- The ensemble future experiments indicate **a continued increasing probability** of active seasons around Hawaii over the next few decades – though there will be substantial modulation on interannual and decadal timescales from internal variability.