Dominant Role of Subtropical Pacific Warming on the Extreme 2015 Eastern Pacific Hurricane Season

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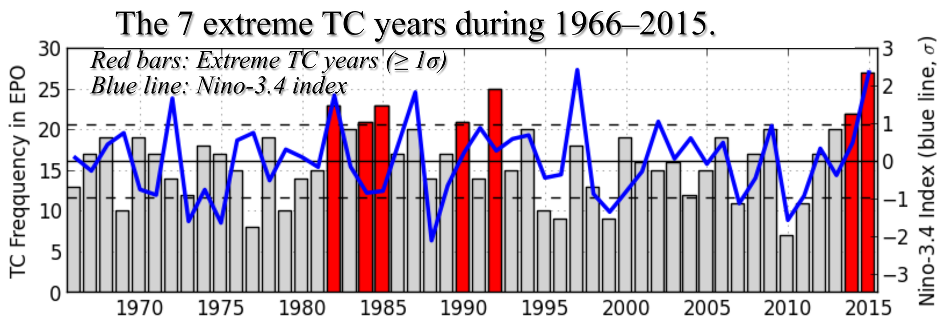
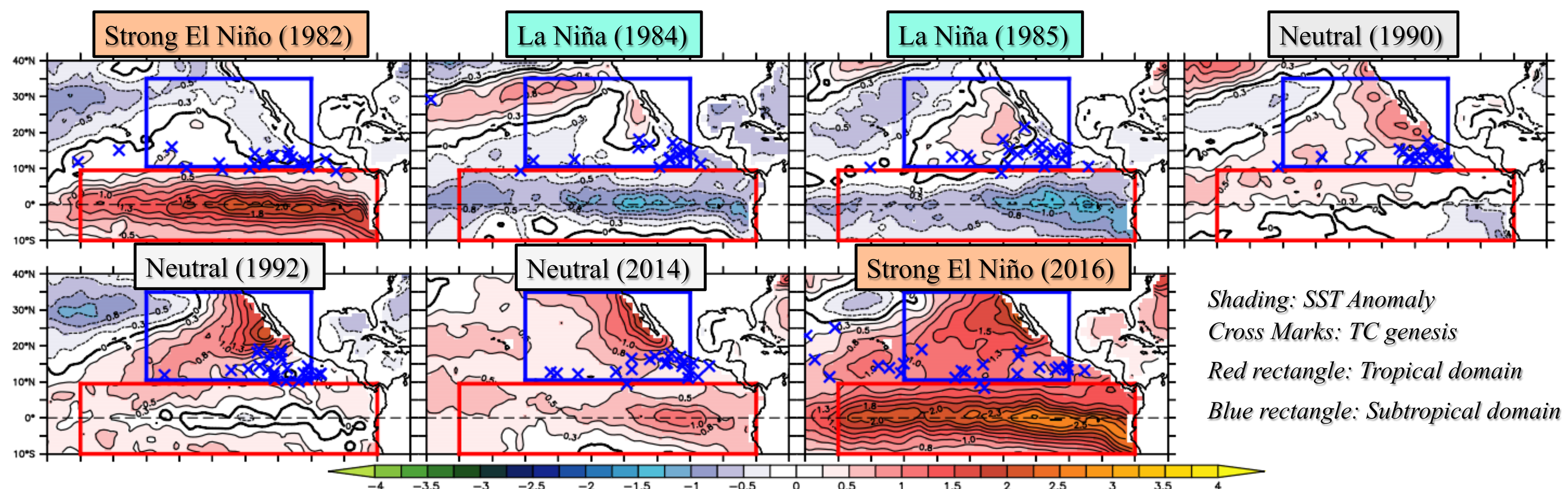
1. Motivation

What caused the hurricane season so active in the Eastern Pacific in 2015?
Did it happen just because of a strong El Niño development?



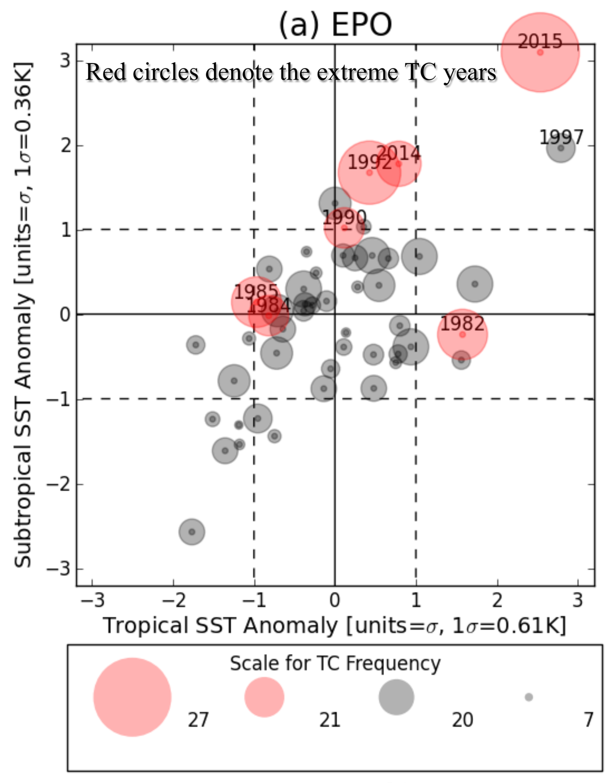
- 27 tropical storms in 2017 (+2.4σ)
- +2.4σ Niño-3.4 index in 2017
- 1997 was also strong El Nino, but was not extreme year
- Correlation (Niño-3.4 index vs TC freq.) = +0.33

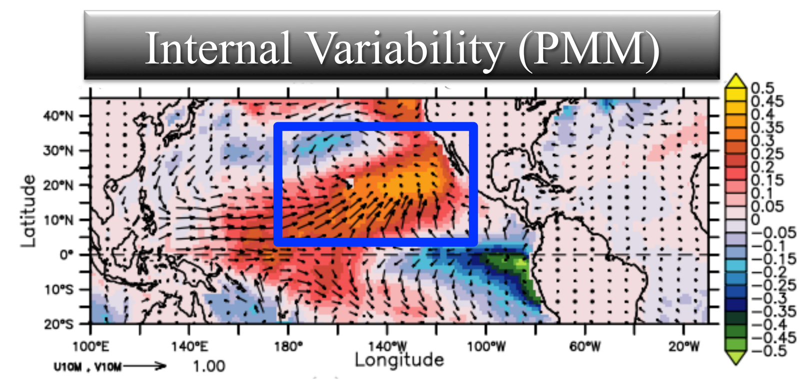


The extreme TC years were not always during El Niño.

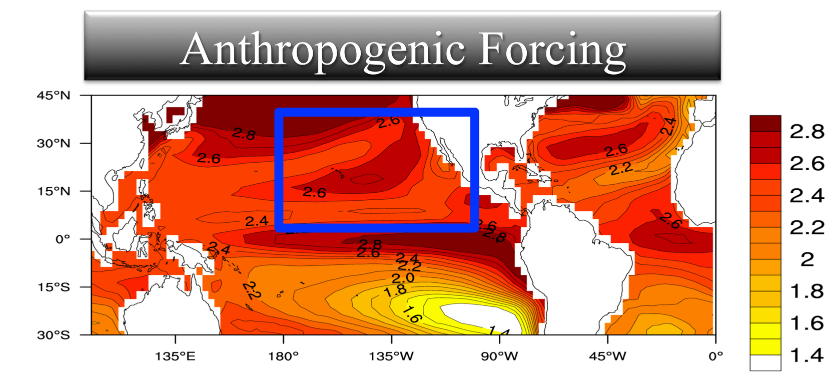
2. Hypothesis

Subtropical Pacific warming plays more important role for extreme TC years for the Eastern Pacific





PMM is the 1st singular decomposition (SVD) mode for the SST and zonal and meridional components of the 10-m wind field (*Chiang and Vimont* 2004).



Projected changes in SST by CMIP5 under the RCP8.5 scenario (2075–2099 minus 1979–2003).

- **Extreme TC years are more frequent during subtropical warming years.**
- **Subtropical warming could be attributable to both internal variability (PMM) and anthropogenic forcing.**

3. Relative Importance of Natural Variability and Anthropogenic Forcing on the active TC year like 2015

Control Experiments (Impact of Anthropogenic Forcing)

We analyzed two control experiments of 1860-Control and 1990-Control using FLOR.
FLOR: 50km Atmosphere and Land + 100 km Ocean and Ice global coupled climate model developed at GFDL (Vecchi et al. 2014, *J. Climate*)

1990 Control
Fixed Radiative Forcing (CO_2, Aerosols, Ozone, etc) at 1990 Level , 500-year simulations

1860 Control
Fixed Radiative Forcing at 1860 level, 3500-year simulations

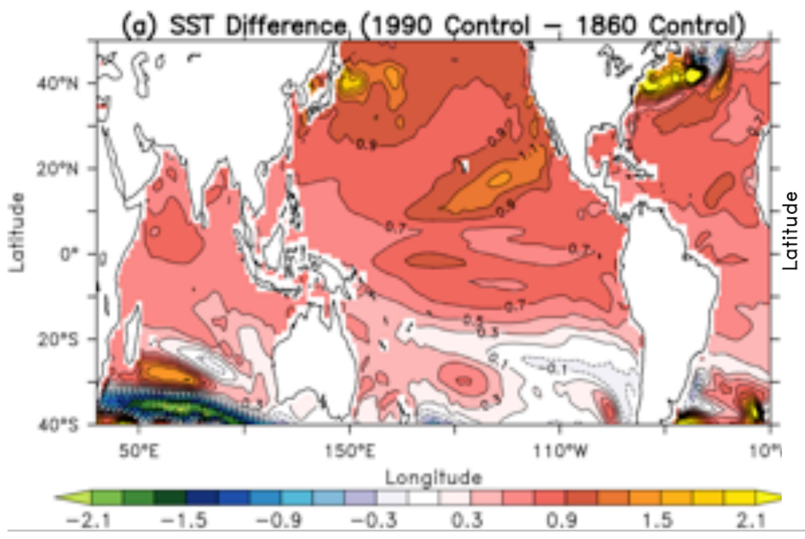


Fig. Difference in mean SST between 1990- and 1860 Controls.

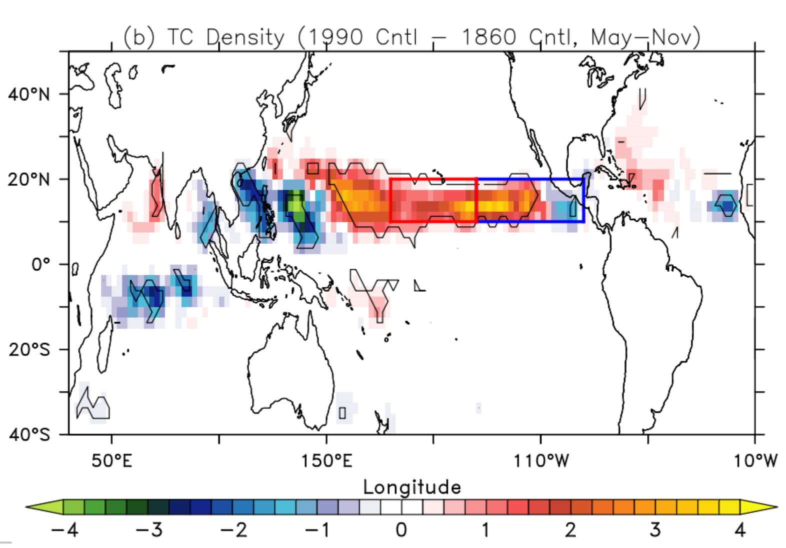
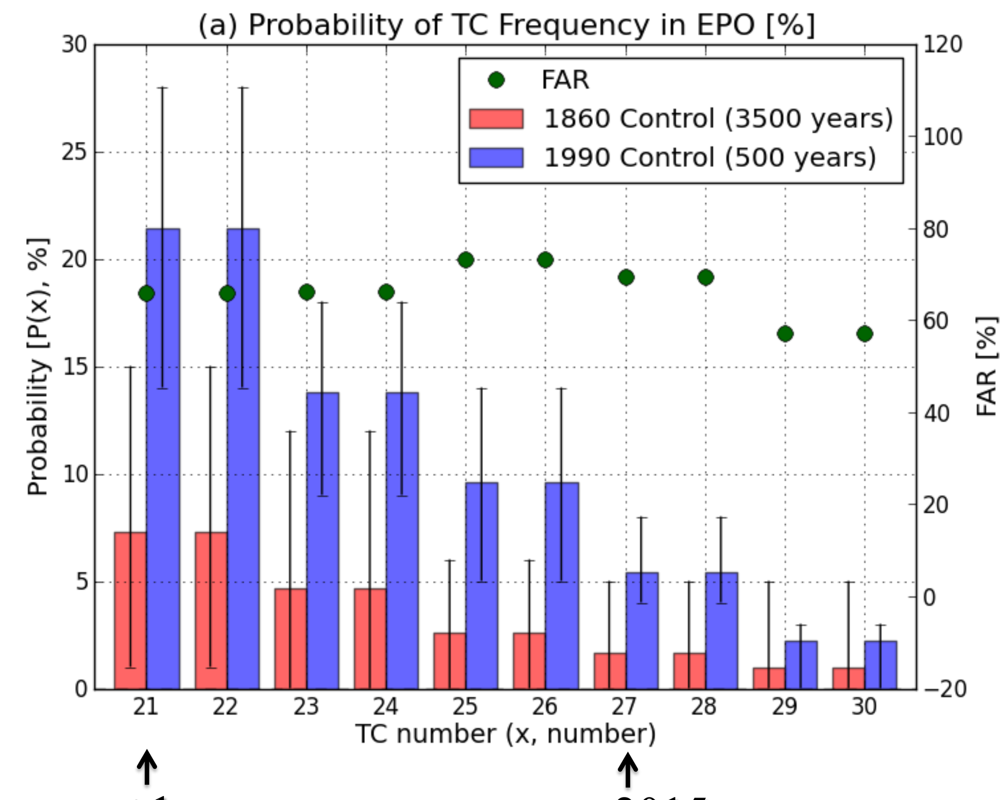


Fig. Difference in mean TC density between 1990- and 1860 Controls.



↑ +1σ FAR(21) = **0.66**

↑ 2015 FAR(27) = **0.57**

Anthropogenic forcing substantially changes the odds of extreme TC seasons like 2015 relative to natural variability alone.

Probability of Exceedance for the Frequency

$$P(x) \equiv \frac{\text{Number of years with TC number } \geq x}{\text{Total number of years}}$$

x: TC frequency

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 (1990 Contl)
E_0: Non-anthropogenic Forcing (1860 Contl)

$-\infty$ (not attributable) < FAR ≤ +1.0 (attributable)

Large-ensemble Experiments (Impact of Anthropogenic Forcing and Natural Variability)

AllForc
Historical anthropogenic forcing and aerosols (1941–2005) historical volcanic events, and future levels based on RCP4.5 scenario (2006–2040). 35 ensemble members, not initialized.

NatFor
Anthropogenic forcing and aerosols are fixed at 1941 levels. 35 ensemble members, not initialized.

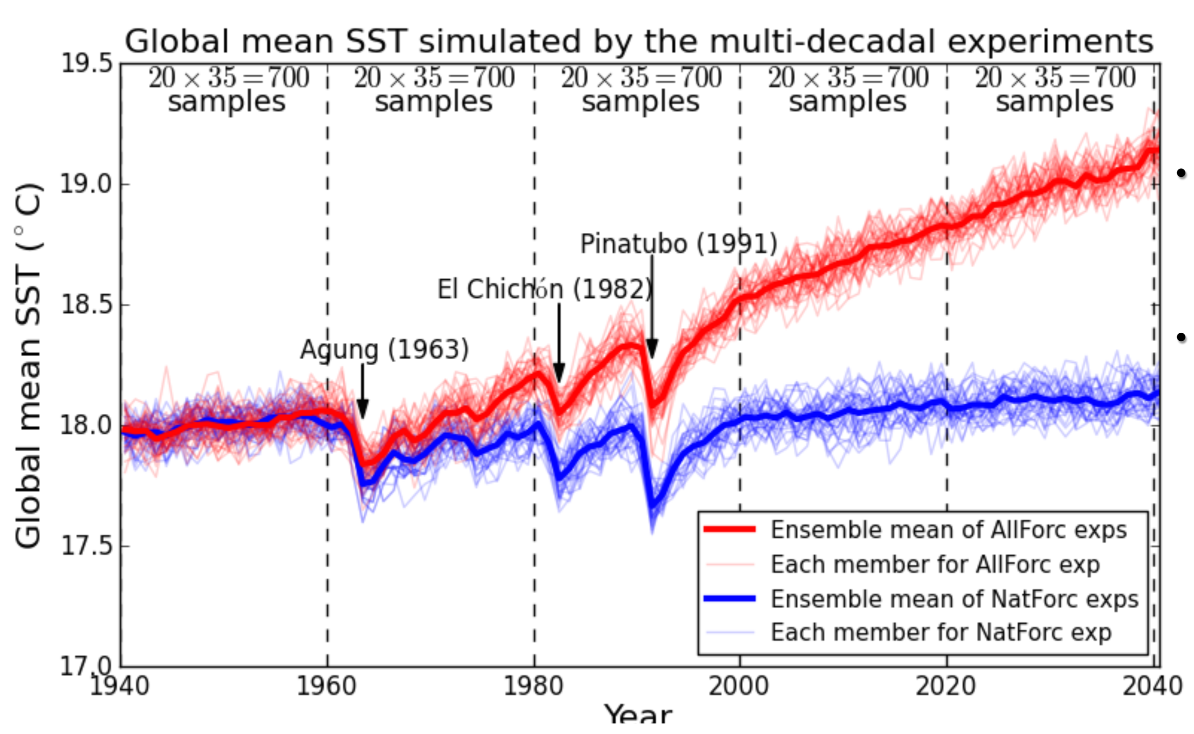


Fig. Global mean SST in AllForc (red) and NatForc (blue).

- The mean difference between AllForc and NatForc is due to anthropogenic forcing.
- For each decade of 20 years, we can compute $P(x)$ using 700 samples (=20 years X 35 members).

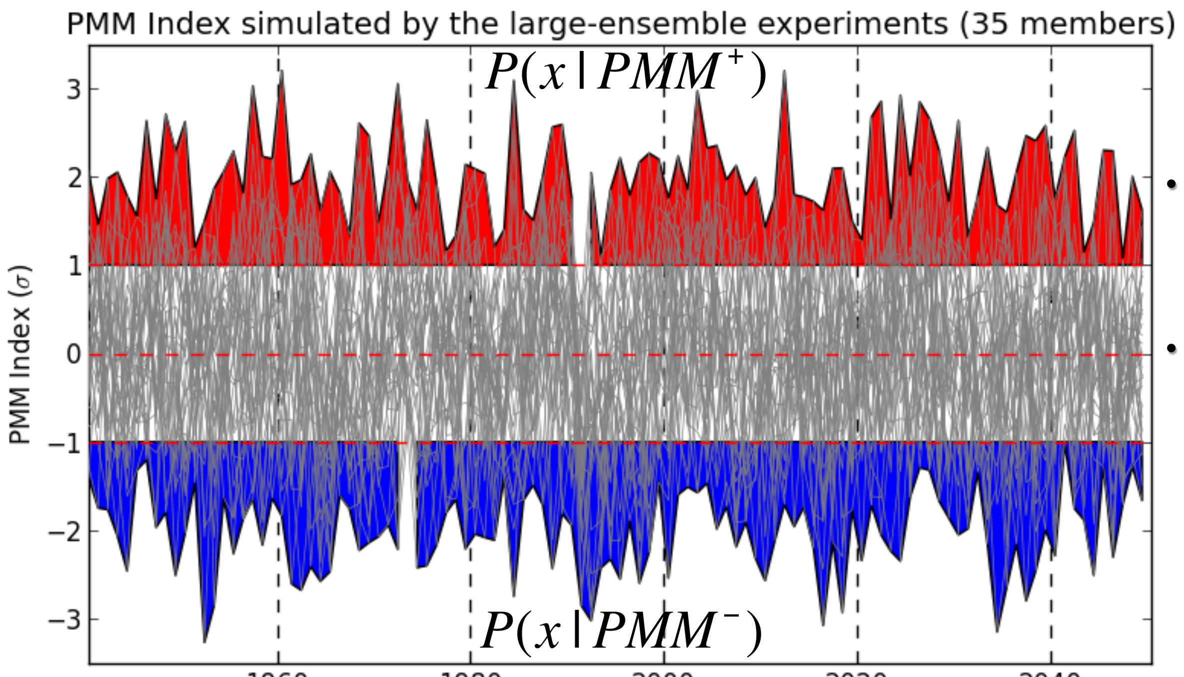


Fig. PMM index simulated by the AllForc experiment.

- Internal variability is independent among the ensembles.
- We can compute conditional probability under any phases of natural variability in order to estimate impact of natural variability on P(x).

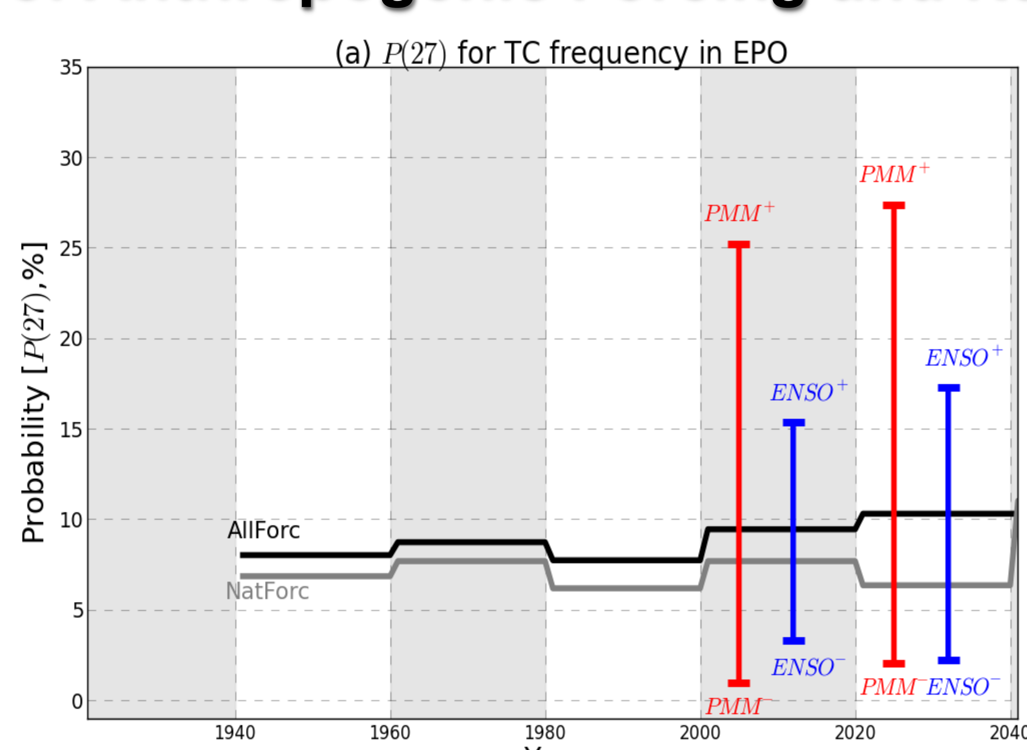


Fig. P(27) and P(27|PMM) and P(27|ENSO) by large-ensembles

P(27|AllForc) > P(27|NatForc)
=> Anthropogenic forcing increases odds of occurrence of extreme TC year

P(27|PMM⁺) >> P(27|ENSO⁺)
=> PMM is the larger influence on variability, following ENSO

P(27|2020–2040) > P(27|2000–2020)
=> Continuing increase in occurrence of extreme TC year, depending on phase of PMM (and ENSO).

4. Summary

(a) The extreme 2015 Eastern Pacific hurricane season was *not* primarily induced by the 2015 El Niño's tropical warming, but by warming in the subtropical Pacific Ocean induced by positive PMM.

(b) Anthropogenic forcing largely contributes to the occurrence of active TC year like 2015.

(c) Future projections show a continuing increase of the probability of occurrence of active TC year like 2015. However, the increase is dependent of phase of natural variability like IPO and PDO.