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

Hiroyuki Murakami, Gabriel A. Vecchi, Thomas L. Delworth, Andrew T. Wittenberg, Seth Underwood, Rich Gudgel, Xiaosong Yang, Liwei Jia, Fanrong Zeng, Karen Paffendorf, and Wei Zhang



GFDL/Princeton AOS



TC Frequency in Observations (1966–2015, May–November)



Why were TCs so active in 2015? Big El Niño?

• A strong El Niño developed in 2015.



Nino-3.4 Index was +2.4σ during the 2015 summer season

 Media commonly reported that the extreme frequency of TCs in 2015 was due to the strong El Niño development.



Observed SST Anomaly in the Extreme TC Years

Observed 7 extreme TC years during 1966–2015 Subtropical warming



Tropical warming related to El Niño

Idealized Retrospective Seasonal Forecast (1/2)

• To reveal which of the subtropical or tropical SST anomaly is important for the extreme TC frequency in 2015 in the EPO, we conducted idealized retrospective seasonal forecasts.



Idealized Retrospective Seasonal Forecast (2/2)

SPCLIM





Subtropical SST anomaly is critical for the extreme TC year of 2015.

SPANOM

Pacific Meridional Mode (PMM)



The difference in PMM between 1997 and 2015 may be important for the difference in TC frequency between the two years.

Effect of Anthropogenic Forcing?

Projected Changes (Late 21st century minus present-day)



Murakami et al. (2013, Nature Climate Change)

Models consistently project an increase in TC frequency of occurrence in the CPO in the future associated with more warming over the region.

It is possible that the extreme 2015 event had happened influenced by anthropogenic forcing.

Effect of Natural Variability and Anthropogenic Forcing to Frequency of Extreme TC Year (Large-Ensemble Simulation)

- Large-ensemble Experiments
 - 35-member uninitialized simulations starting from 1940 using FLOR
 - All Forcing (AllForc) Experiment
 - Prescribing historical anthropogenic forcing (e.g., CO₂, aerosols) and volcanic eruptions
 - 1941 Forcing (1941Forc) Experiment
 - Prescribing fixed anthropogenic forcing at the 1941 level and volcanic eruptions



Effect of Anthropogenic Forcing to Mean TC Genesis Change (Large-ensemble Simulation)



Effect of Natural Variability and Anthropogenic Forcing to Frequency of Extreme TC Year (Large-Ensemble Simulation)

Probability of Exceedance

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

x : TC frequency in a year

For each 20-year period, P(x) can be computed using 700 samples (=20 years × 35 members).

$$P(27|AllForc|1980 - 2000) = \frac{N(x \ge 27)}{700}$$



The difference between P(x|AllForc) and P(x|1941Forc) is caused by the effect of the anthropogenic forcing.

Effect of Natural Variability and Anthropogenic Forcing to Frequency of Extreme TC Year (Large-Ensemble Simulation)

- Large-ensemble Experiments
 - 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).



P(x|PMM⁺), P(x|ENSO⁺), P(x|PDO⁺), P(x|IPO⁺), and P(x|AMO⁻) are Evaluated for the AllForc experiments.

Effect of Anthropogenic Forcing and Natural Variability to Frequency of Extreme TC Year (Large-Ensemble Simulation)



Continued increase of probability is expected in the following decades.

The projected increase in the probability depends on the phase of natural variability.

Summary (1/2)

- The 2015 summer was an extreme year in terms of TC frequency in the Eastern Pacific Ocean (EPO), especially over the Central Pacific Ocean (CPO).
- It is likely that the tropical SST anomaly induced by an El Niño development is not a major factor for the extreme TC event, but the subtropical SST anomaly related to positive PMM is a key.

Summary (2/2)

 It is likely that global warming has increased the odds of the extremely large number of TCs in EPO, Central Pacific Ocean.

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

Thank You!



The most destructive force brought by Hurricane Patricia (NASA)