Forced and internal variability of tropical cyclone track density in the western North Pacific

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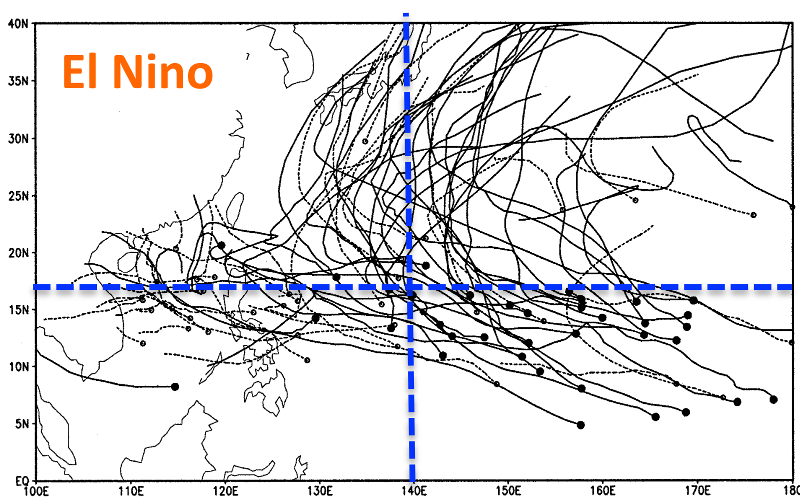
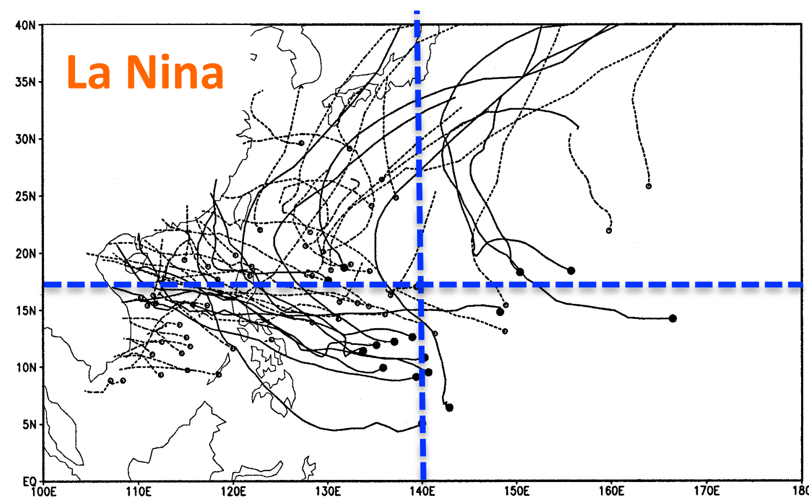
Introduction

- **Western North Pacific (WNP) is the basin where tropical cyclones (TCs) are most active.**
- **The genesis (including both location and frequency) and tracks of WNP TCs are modulated by various climate modes (e.g., ENSO).**





(Wang & Chan 2002)

Introduction

- The variability in TC track density integrates variations in TC genesis and tracks, and thus is expected to be influenced by climate variability as well.
- We use high-resolution AGCM ensemble simulations to isolate SST-forced variability and understand internal variability.
- The results have important implications for predictability of local TC occurrence.

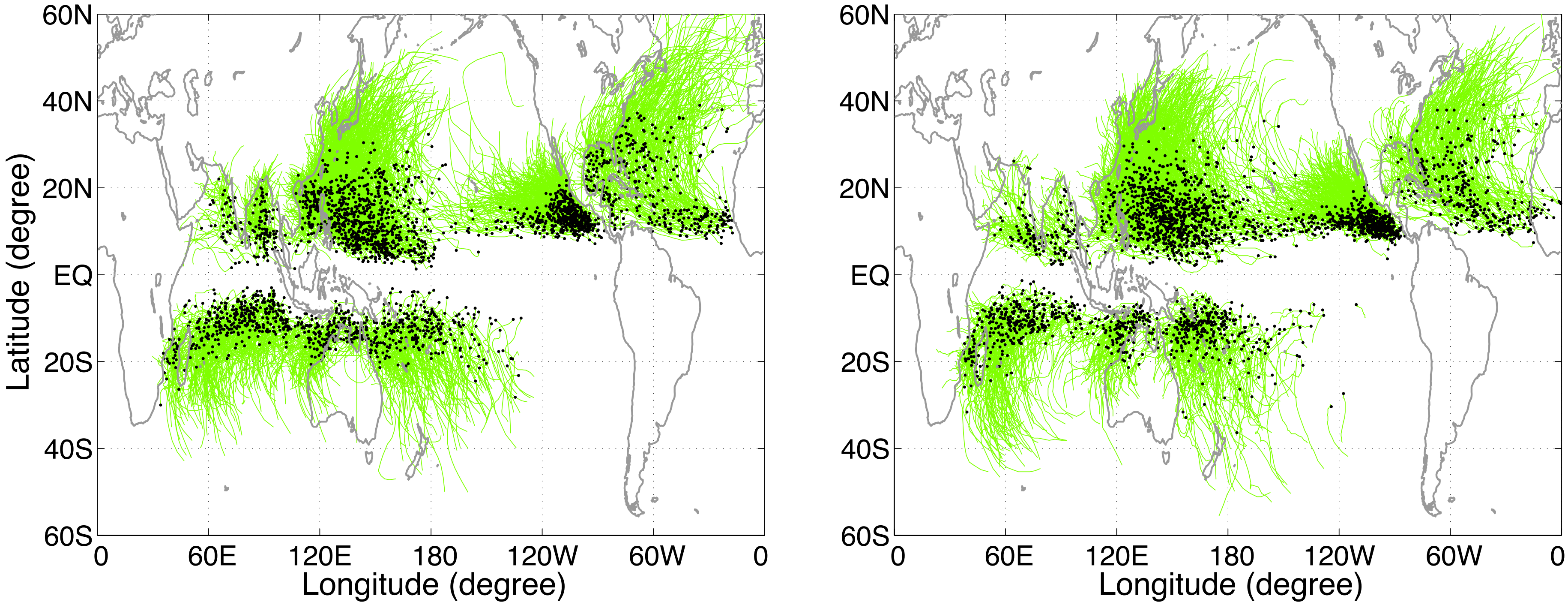
Data and Methods

- Observed and simulated TC tracks
  - Observed TC best-track data
  - GFDL High-Resolution Atmospheric Model (HiRAM):
    - 25 km horizontal resolution;
    - forced by observed SSTs;
    - 3 members that differ only in initial conditions;
    - ensemble mean = SST-forced variability; and
      the deviation from the ensemble mean = internal variability.
  - Study period: 1979-2008
- Calculation of track density

  Calculated as TC days within each 8°x8° grid box on a yearly basis.

Observed & simulated TC genesis and tracks

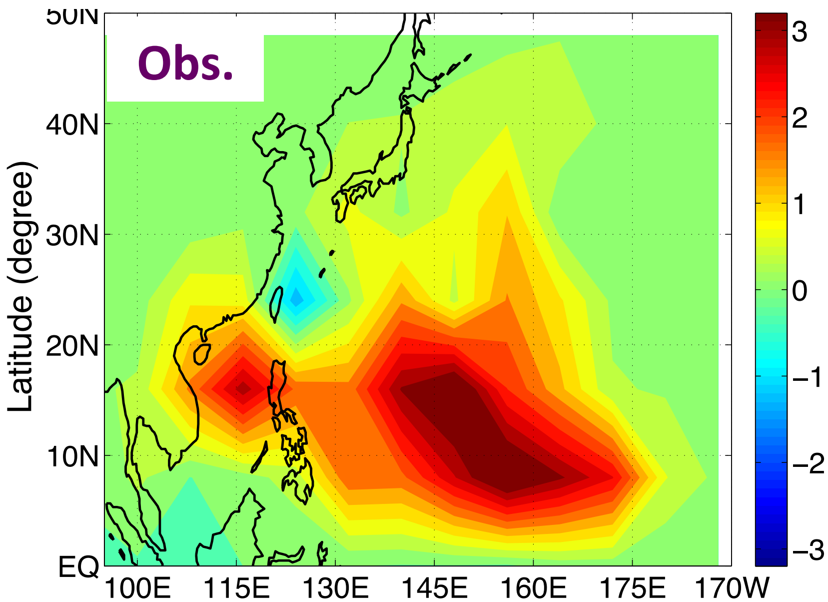
Observations **HiRAM run 1**

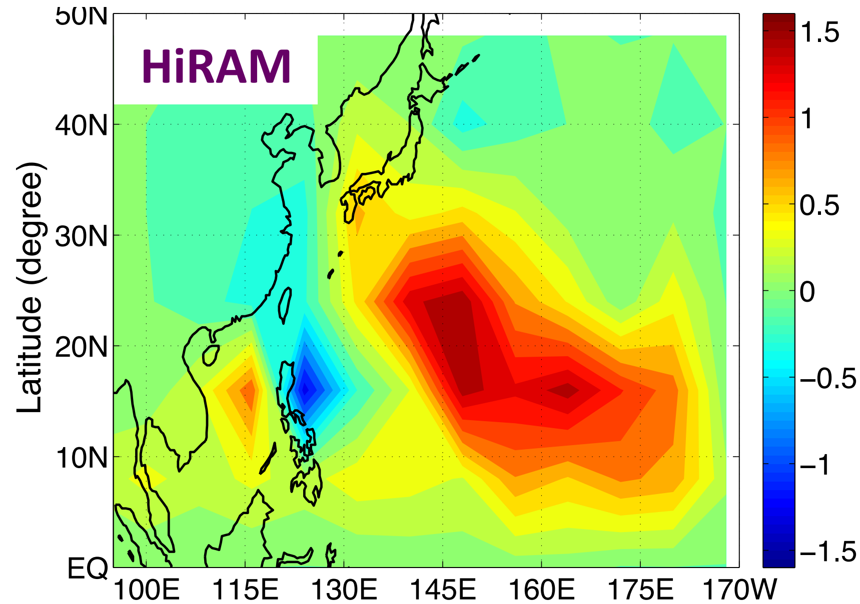


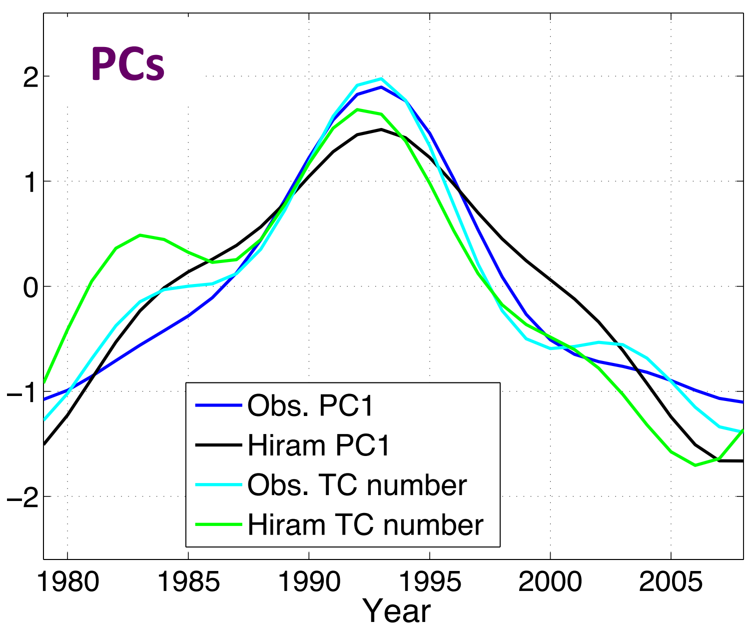
Zhao et al. (2009)

Forced variability:
low-frequency (≥ 10 years)

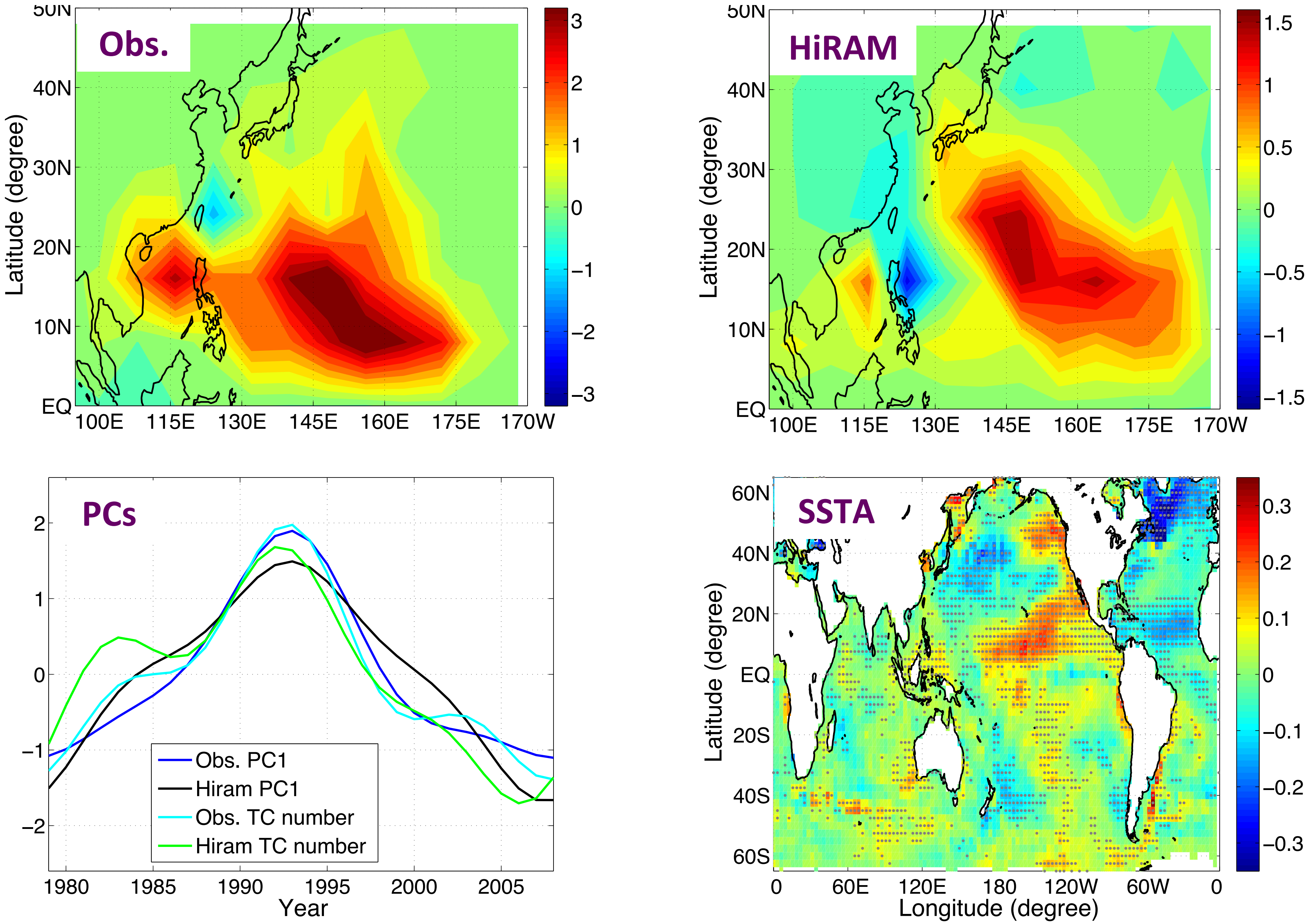
Low-frequency variability: Mode 1



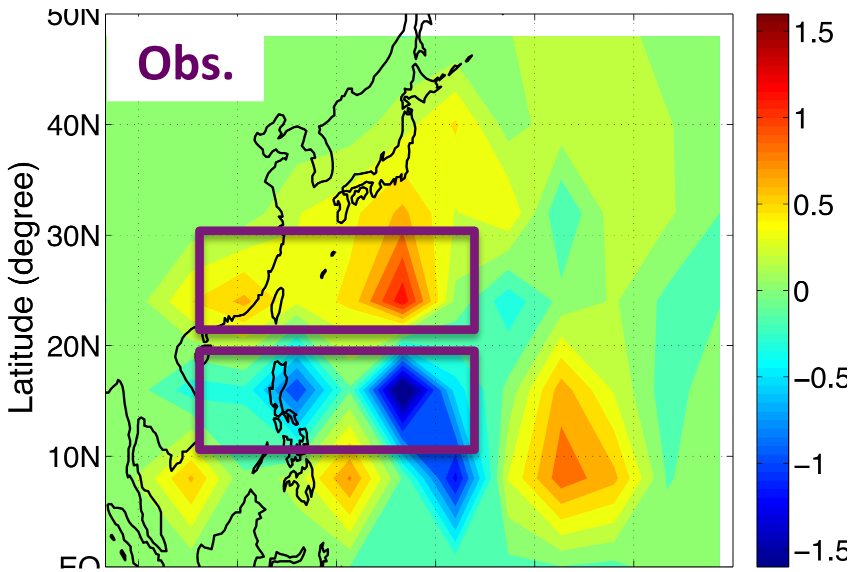


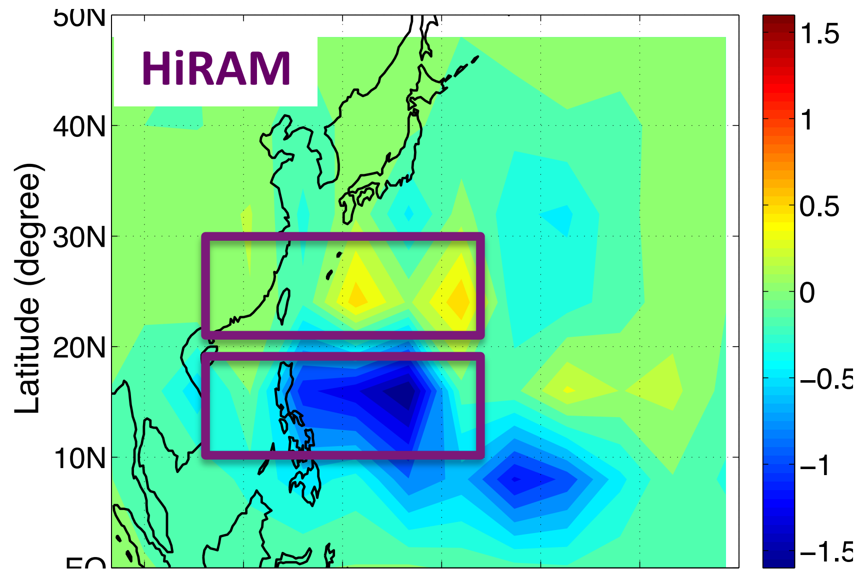


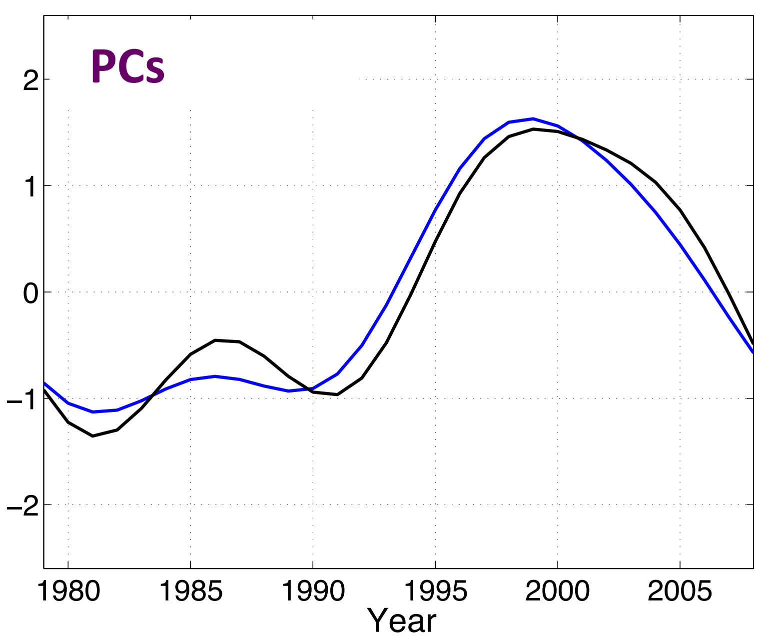
Low-frequency variability: Mode 1



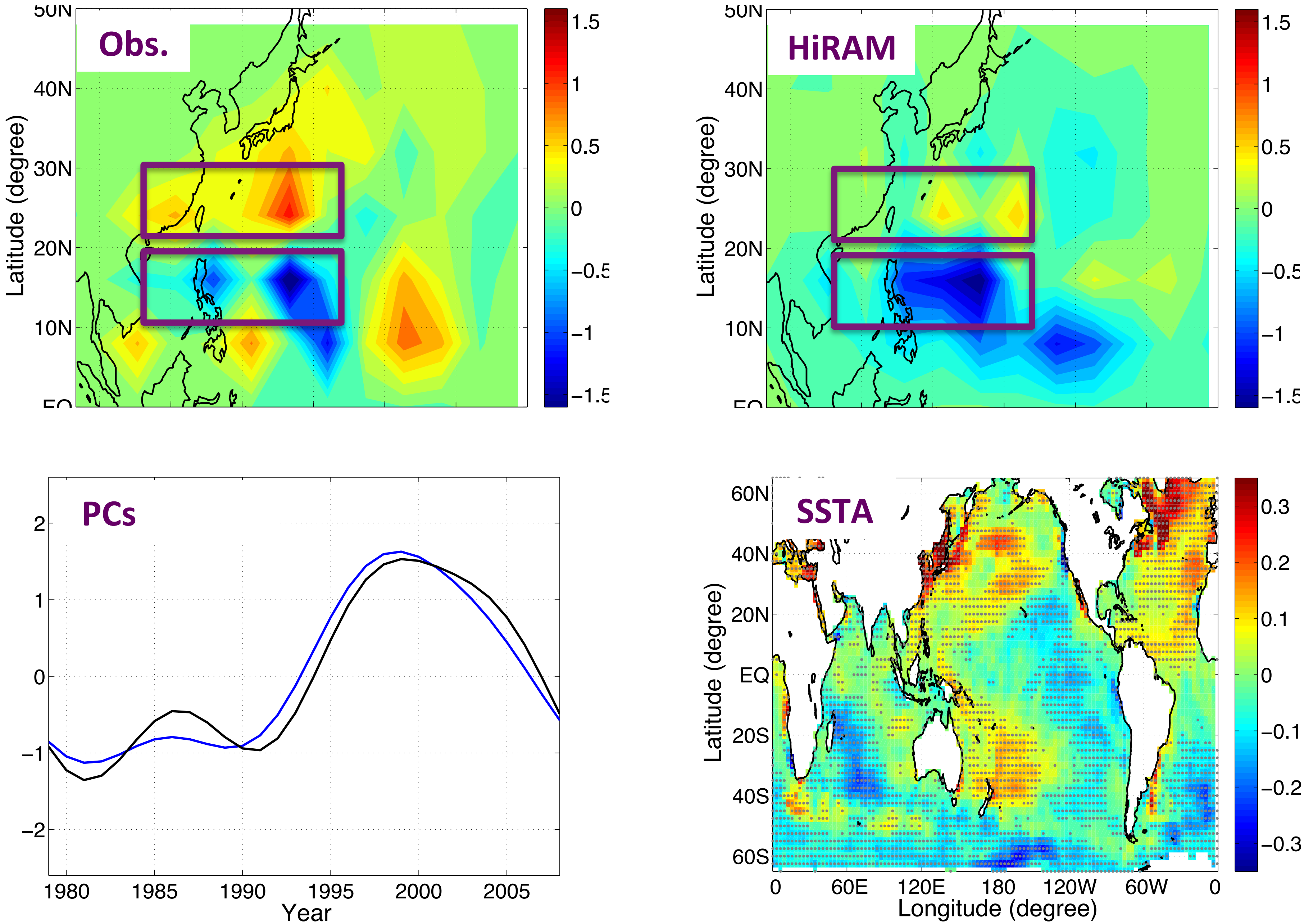
Low-frequency variability: Mode 2







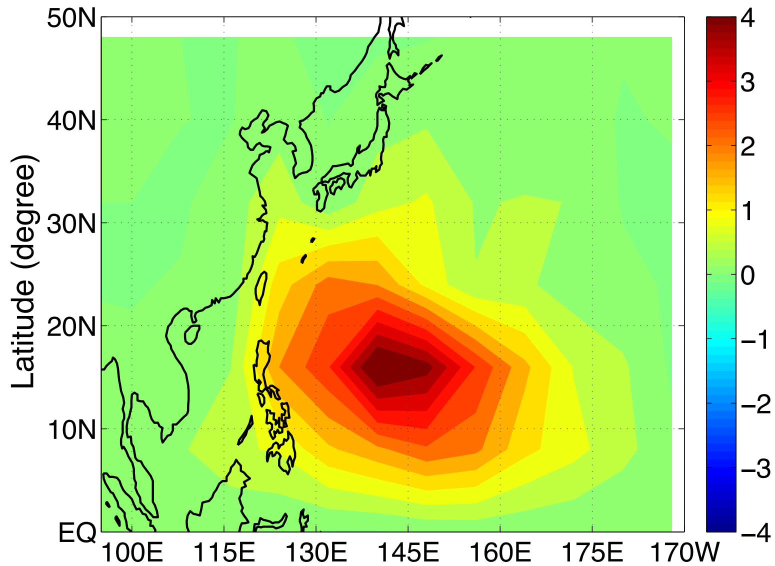
Low-frequency variability: Mode 2

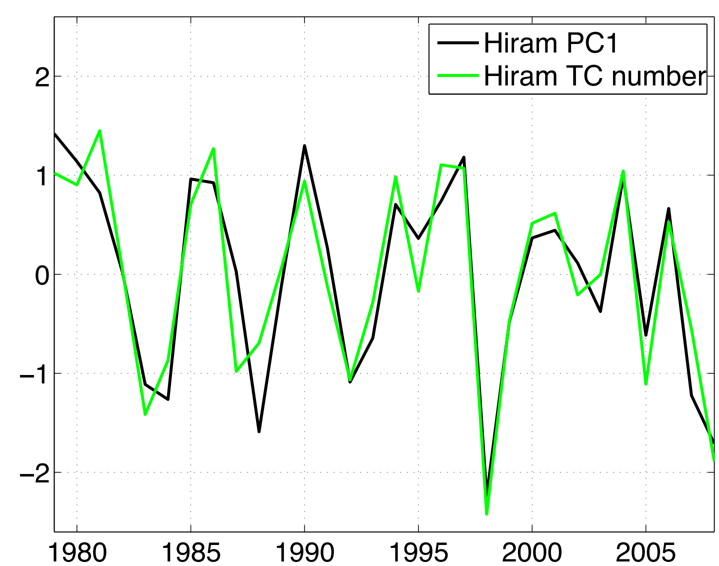


Forced variability:
high-frequency (< 10 years)

HiRAM simulations

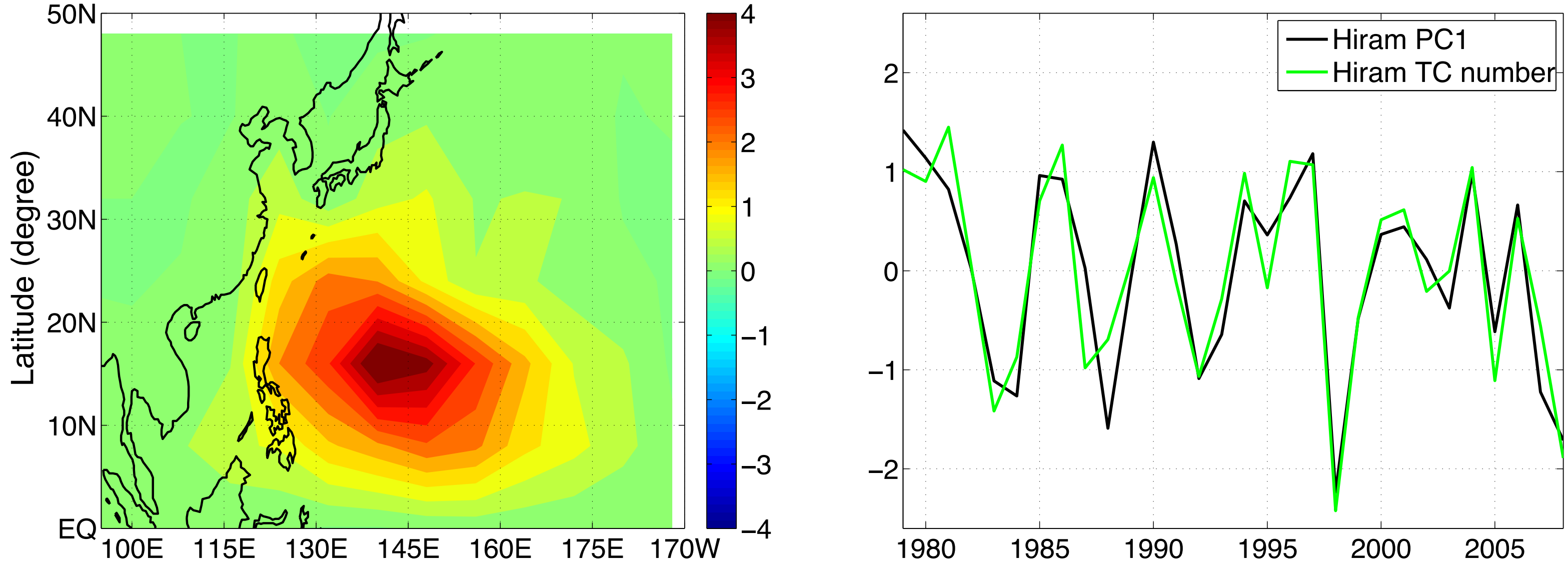
Mode 1



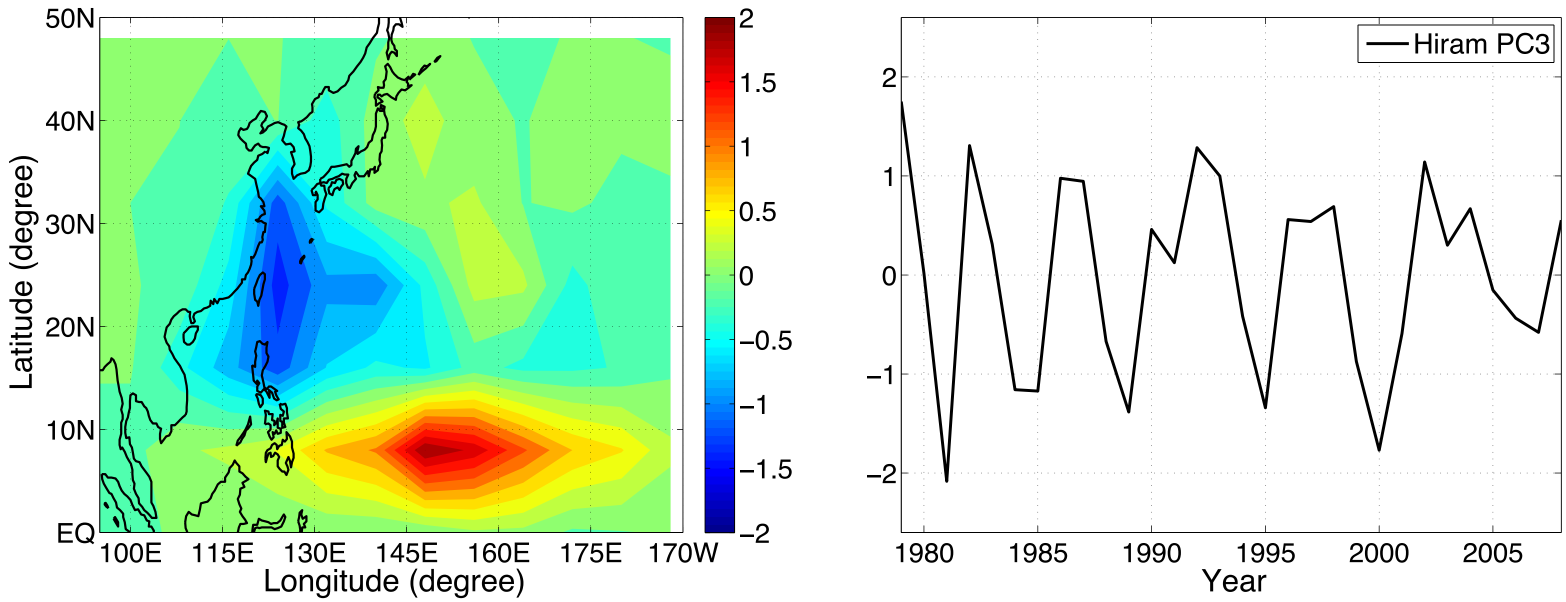


HiRAM simulations

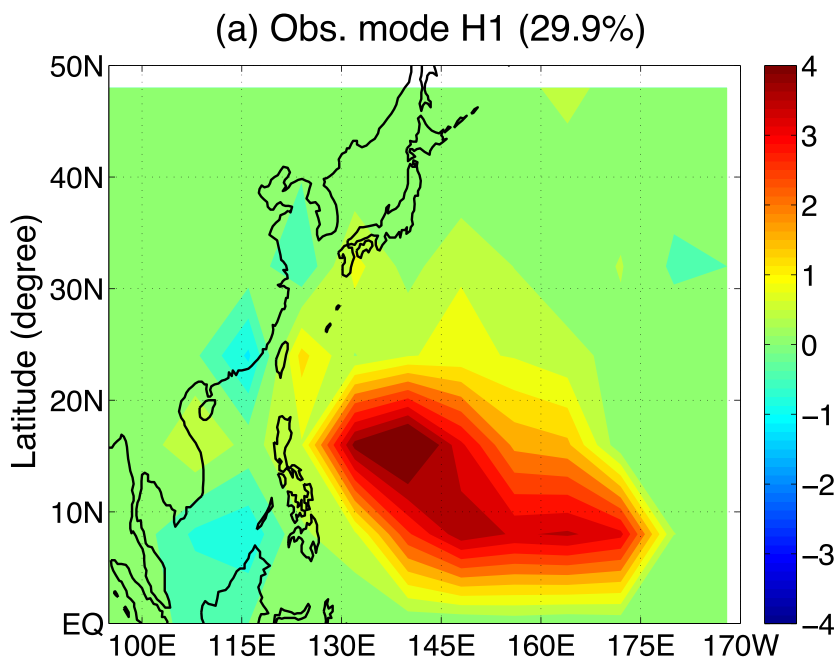
Mode 1

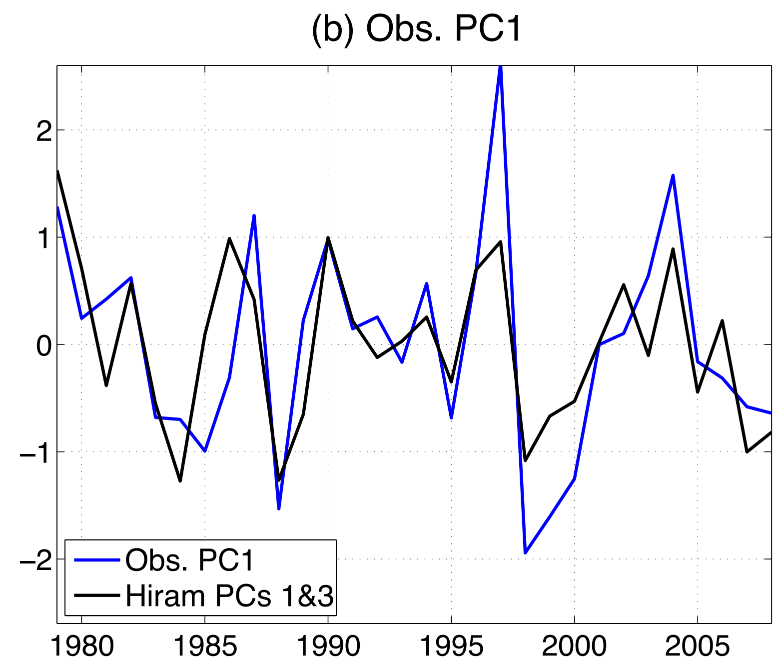


Mode 3



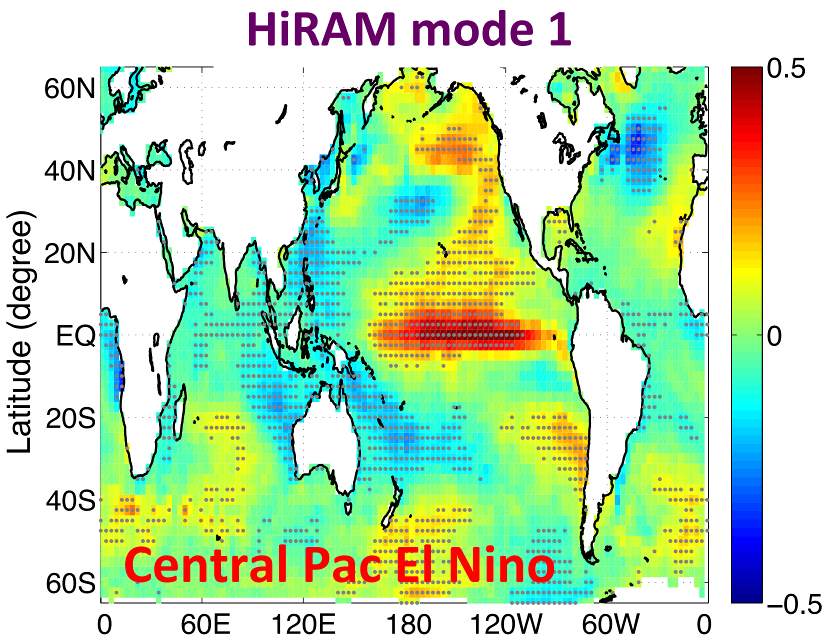
Observations

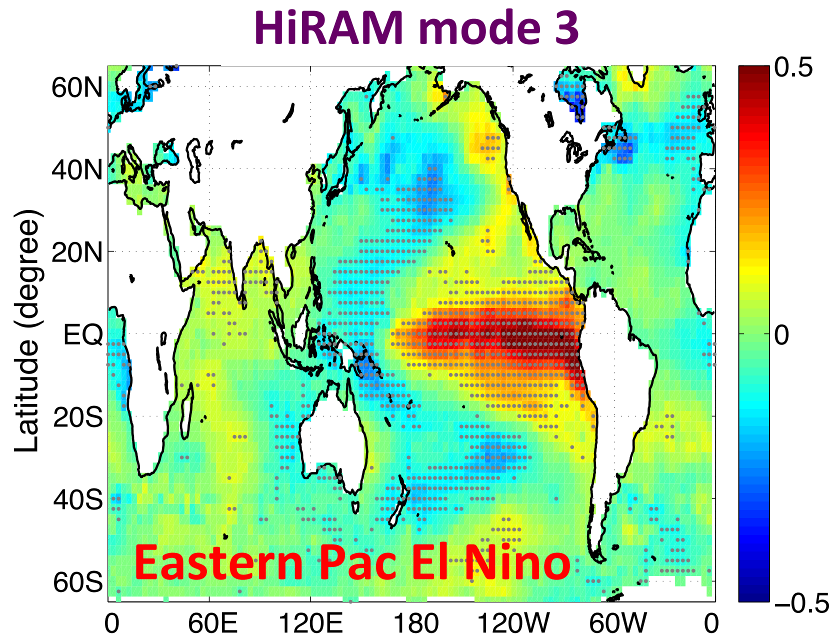


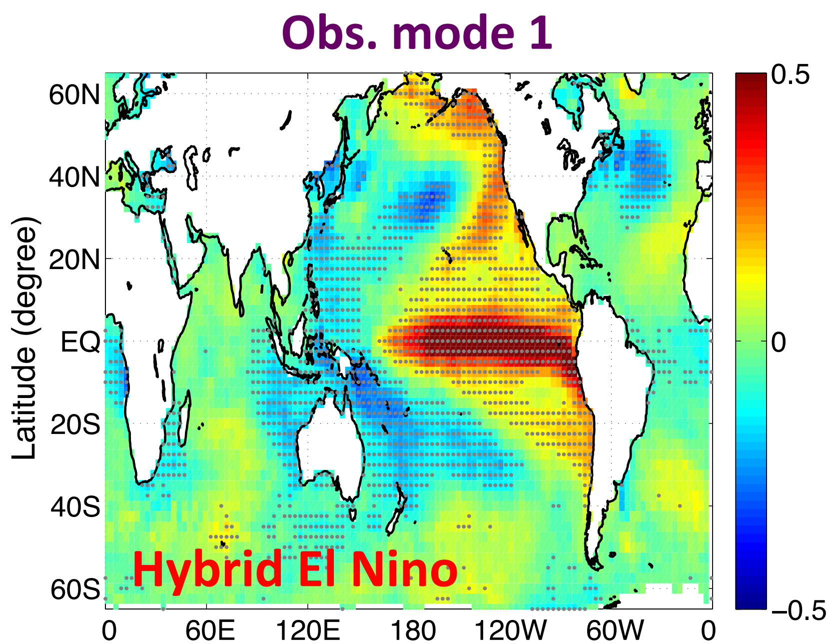


Only one physically meaningful mode exists in observations, and this mode can be considered as a mixture of the two modes of HiRAM simulations.

Underlying SST pattern







Internal variability

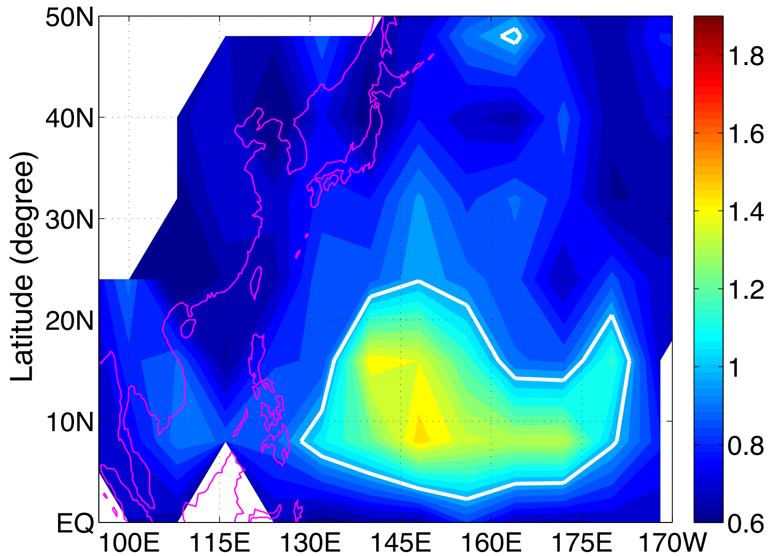
Definition

- **Track density = forced response (ensemble mean) + internal variability (departures from the ensemble mean).**
- **The internal variability is measured as the signal-to-noise ratio:**

$$R = \frac{\sigma_F}{\sigma_I} = \frac{\text{forced response}}{\text{internal variability}}$$

A large value of R indicates that the internal variability is not as important as the forced response, and hence high predictability.

Signal-to-noise ratio of annual TC track density



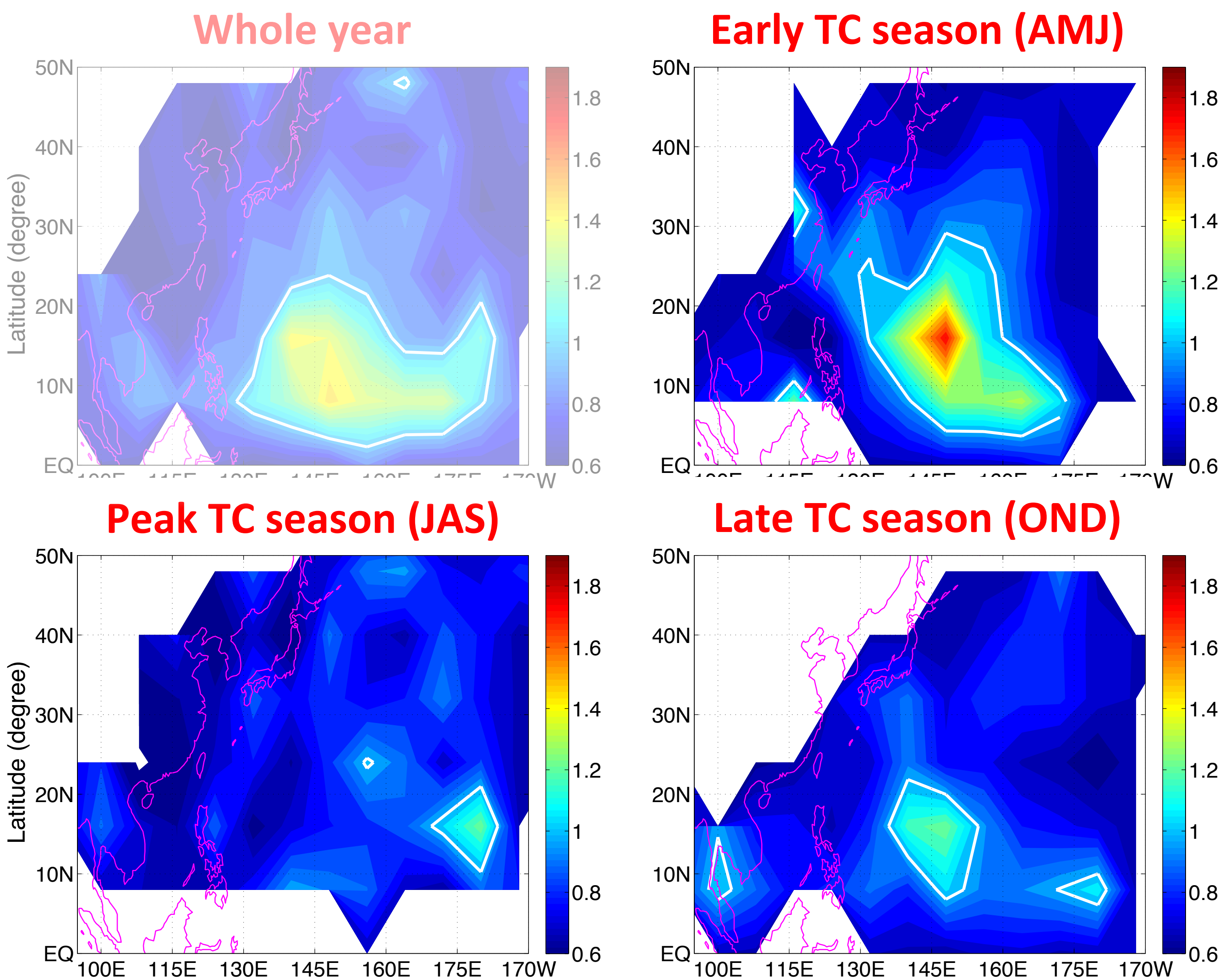
- Large over the ***main development region***, and small over the ***South China Sea*** and along the ***coast of East Asia***.

Landfall is hard to predict.

- The local maximum value is ~1.4.
- In contrast, the signal-to-noise ratio of total TC numbers/days is ~1.7.

Basin-integrated metrics are more predictable.

Signal-to-noise ratio of seasonal TC track density



- **Peak season is high in internal noise.**
- **Landfall is hard to predict.**

Summary

- Modes dominating on decadal timescales:
  - a nearly-*basin-wide* mode, linked to variations in SSTs over the northern off-equatorial tropical central Pacific;
  - a *dipole* mode between the subtropics and lower latitudes, associated with the Atlantic Multidecadal Oscillation.
- Modes dominating on interannual timescales:
  - a *basin-wide* mode, driven by central Pacific ENSO;
  - a southeast-northwest *dipole* mode, connected to eastern Pacific ENSO.
- TC track density is less predictable in peak season and over the South China Sea and along the coast of East Asia. Total TC number/days are more predictable than local TC occurrence, particularly the landfall.

Thank you for your attention!