Unravel causes for the changing behavior of tropical Indian Ocean in the past few decades

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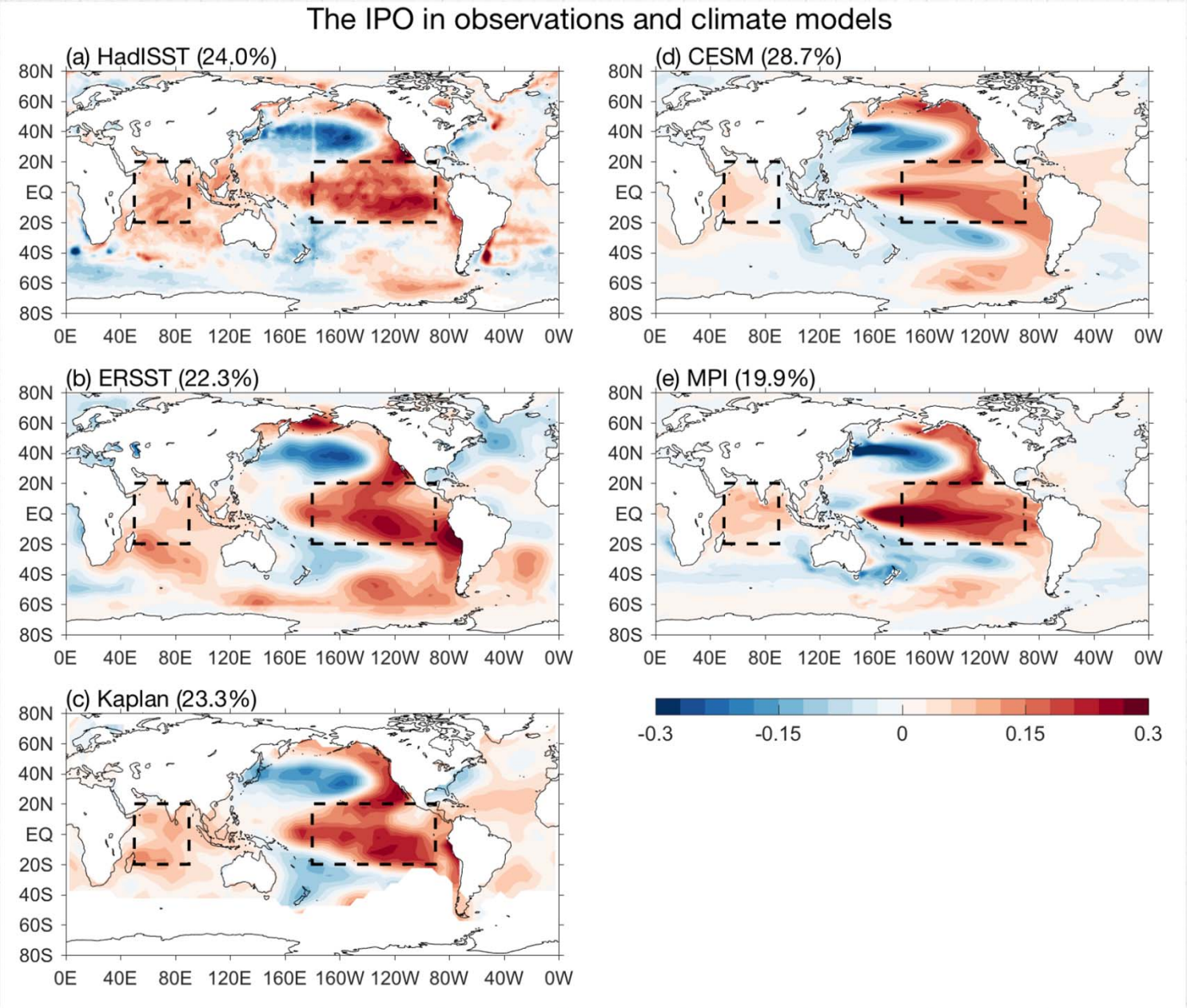
Data and models

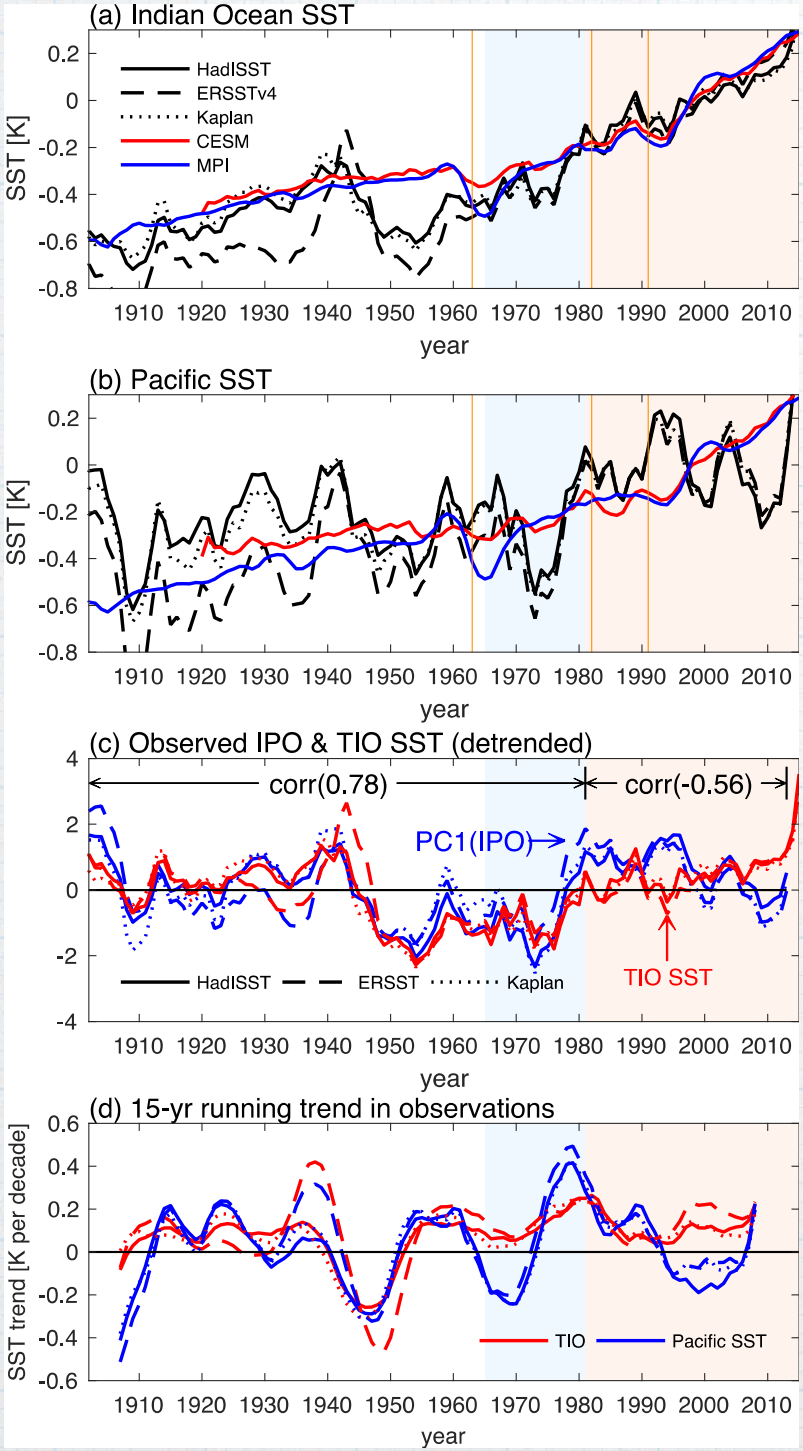
- **Observational data sets (1900-2015):**
  - HadISST (Rayner et al. 2003)
  - ERSSTv4 (Huang et al. 2015)
  - Kaplan SST (Kaplan et al. 1998)

- **Large-ensemble simulations from two climate models:**
  - **CESM** (Kay et al. 2015)
    - 40-member ensemble
    - 1920-2100
    - RCP8.5 forcing scenario
  - **MPI** (Bittner et al. 2016)
    - 100-member ensemble
    - 1850-2099
    - RCP4.5 forcing scenario

The IPO is reasonably simulated in the two climate models



- Tripole-like SST anomalies in the Pacific;
- In-phase relation between Indian Ocean and Pacific;
- Smaller amplitude in IO compared to the Pacific;

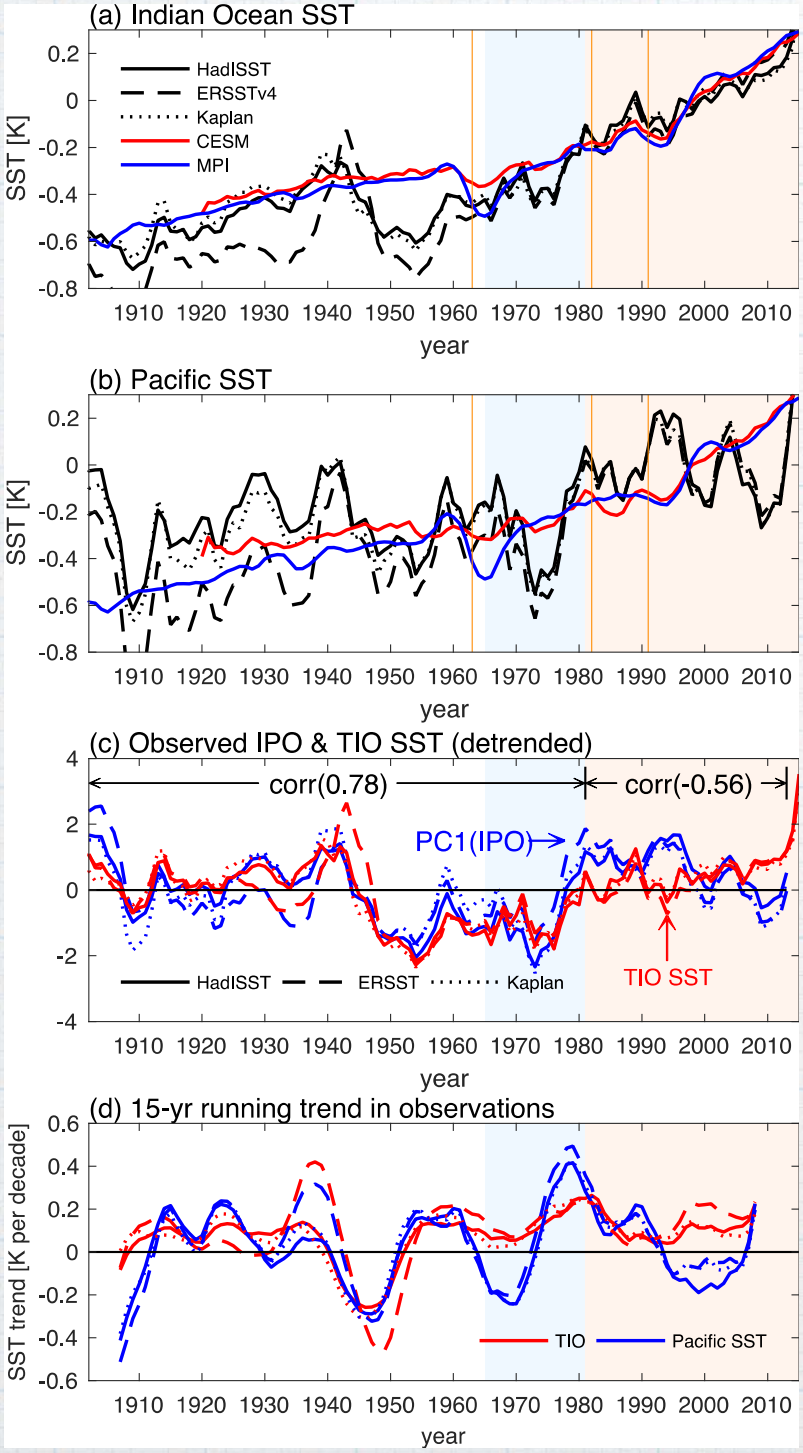


Inter-decadal time scales (>20yrs):

- Indian Ocean: persistent warming trend after 1960s.
- Pacific: large SST fluctuations associated with IPO.

Decadal time scales (10-20yrs):

- Prior to 1980s, in phase (r=0.78);
- After 1980s, out-of-phase (r=-0.56);



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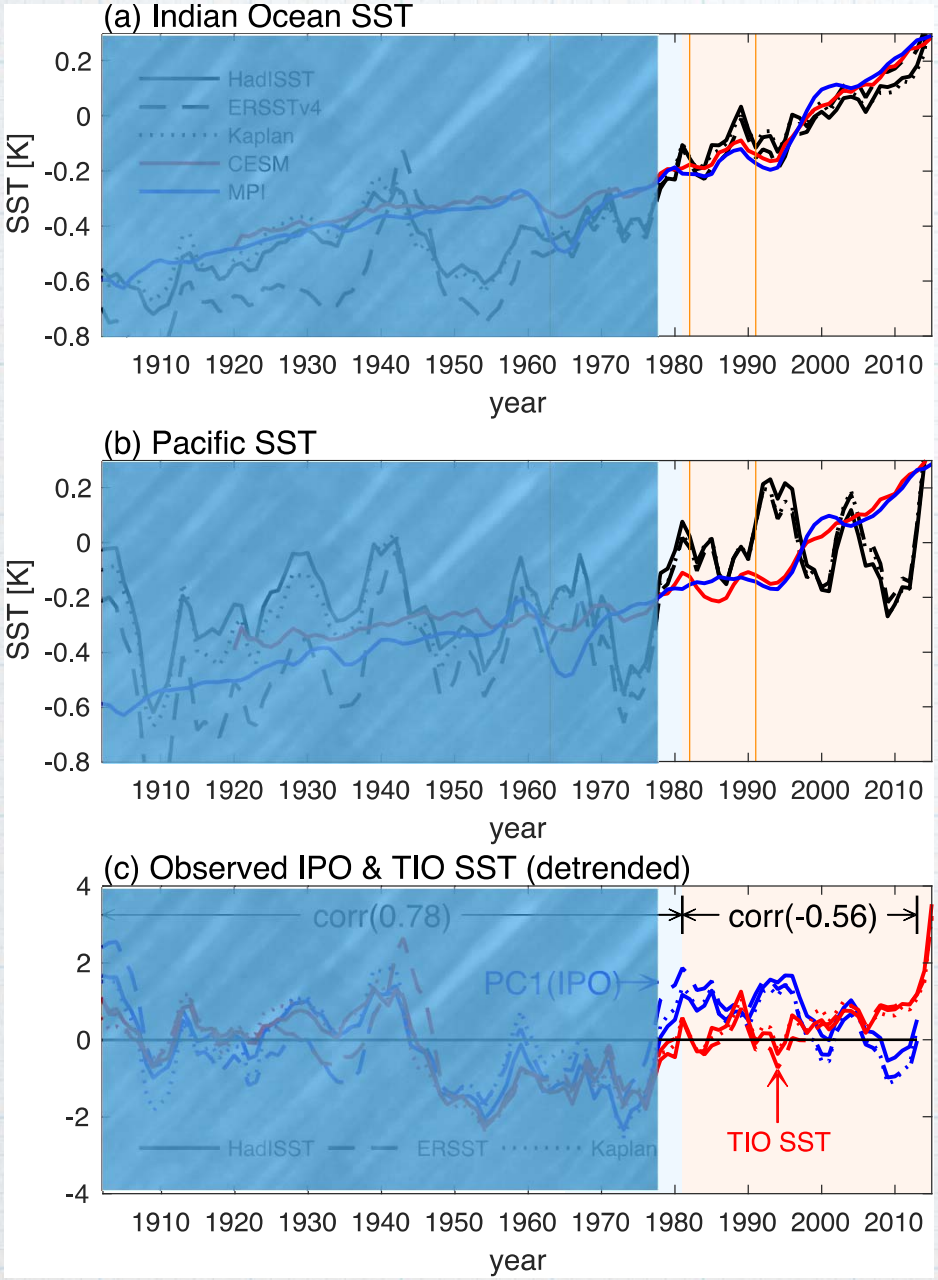
- External forcing controls IO decadal to inter-decadal variability since 1960s.

How does the external forcing affect Indian Ocean SST decadal variability since 1980s?



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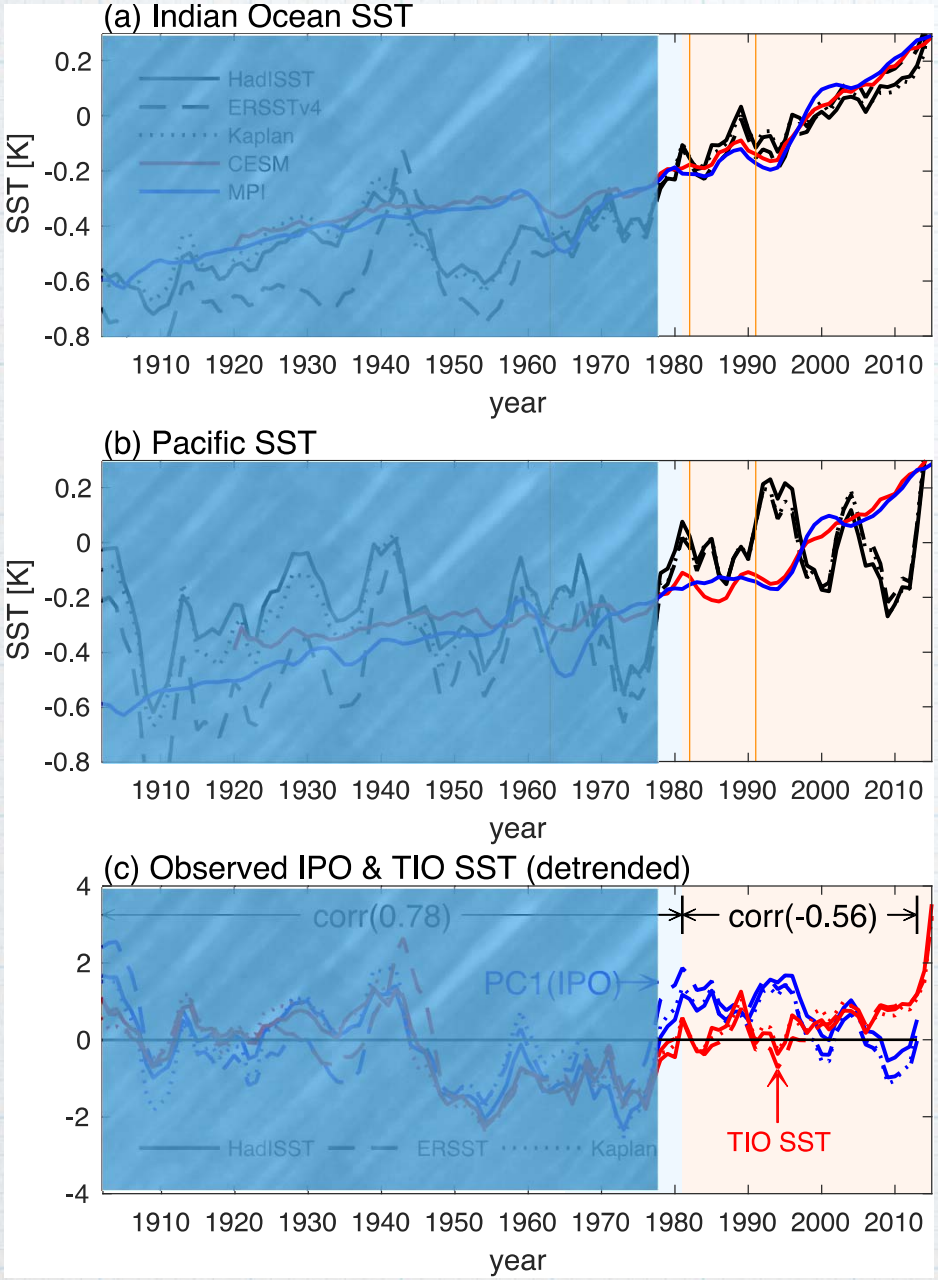

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Tropical volcanic eruptions :

El Chichón (1982) and Pinatubo (1991)

(Santer et al. 2014)

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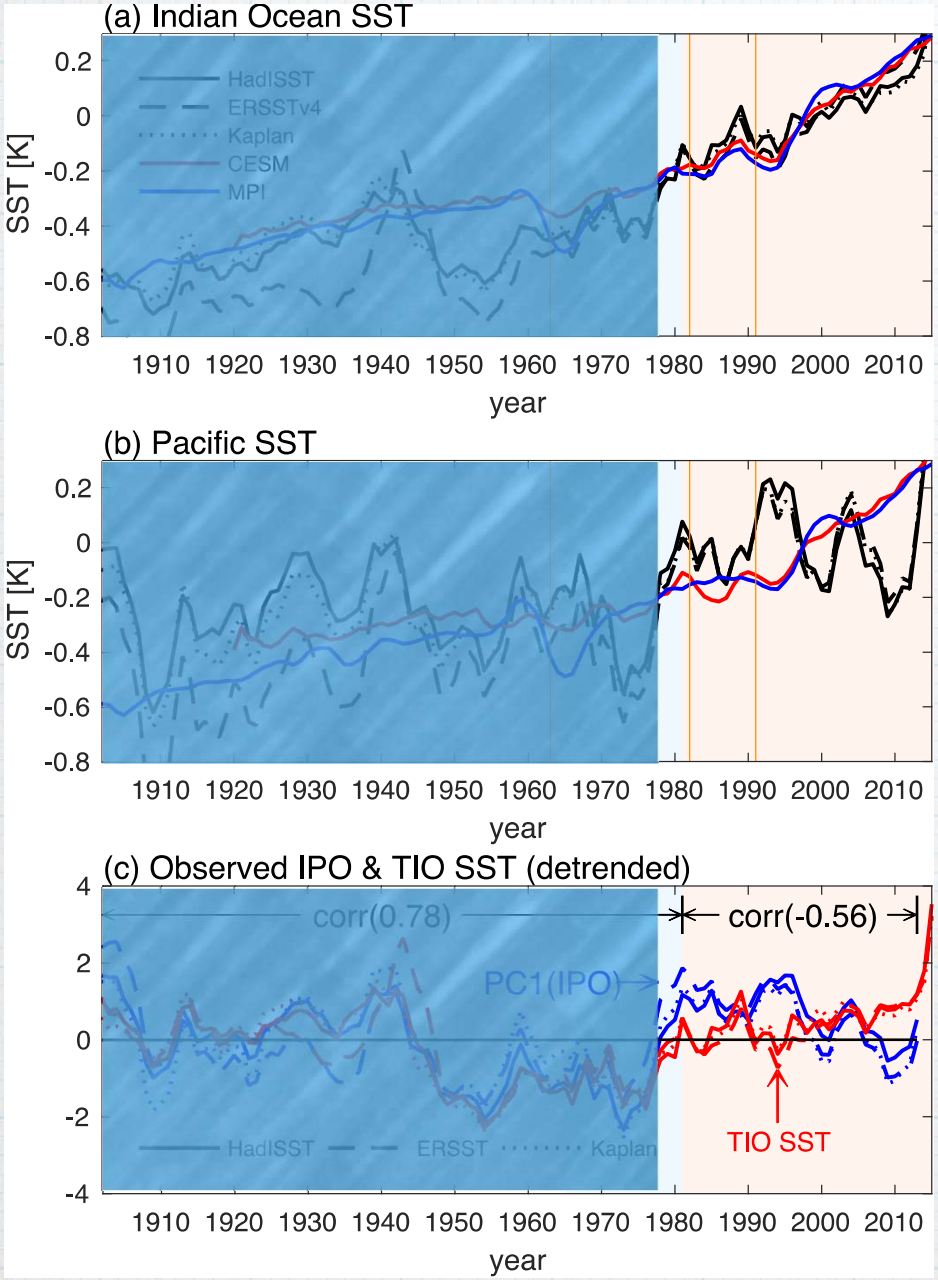

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Why didn't the external (volcanic) forcing control the Pacific SST?

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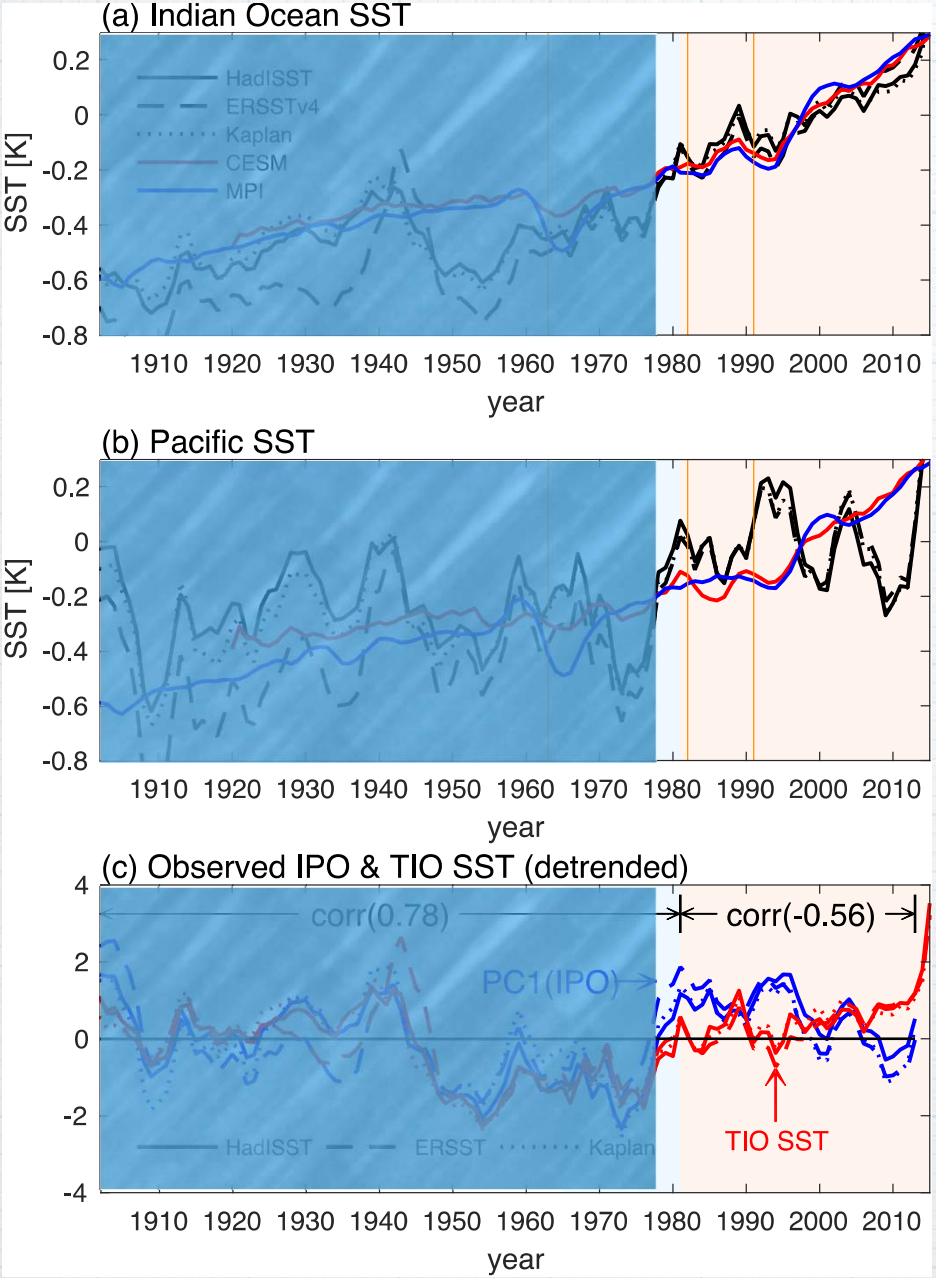

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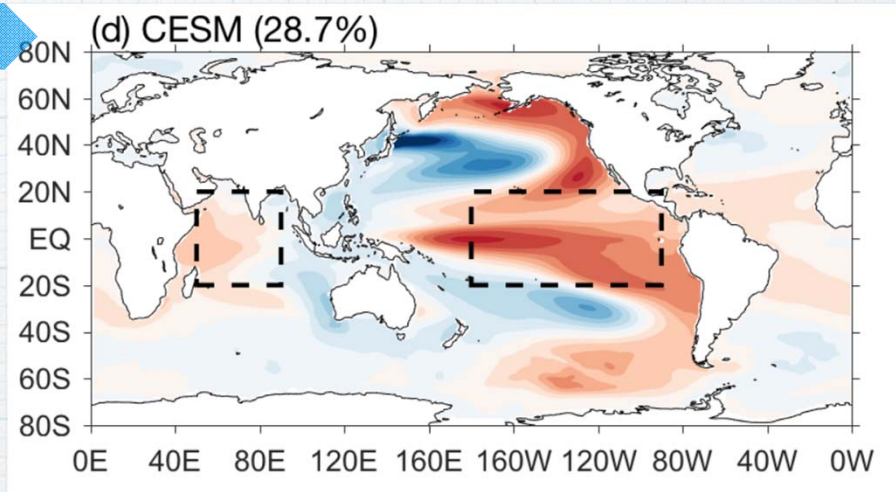


Volcanic forcing

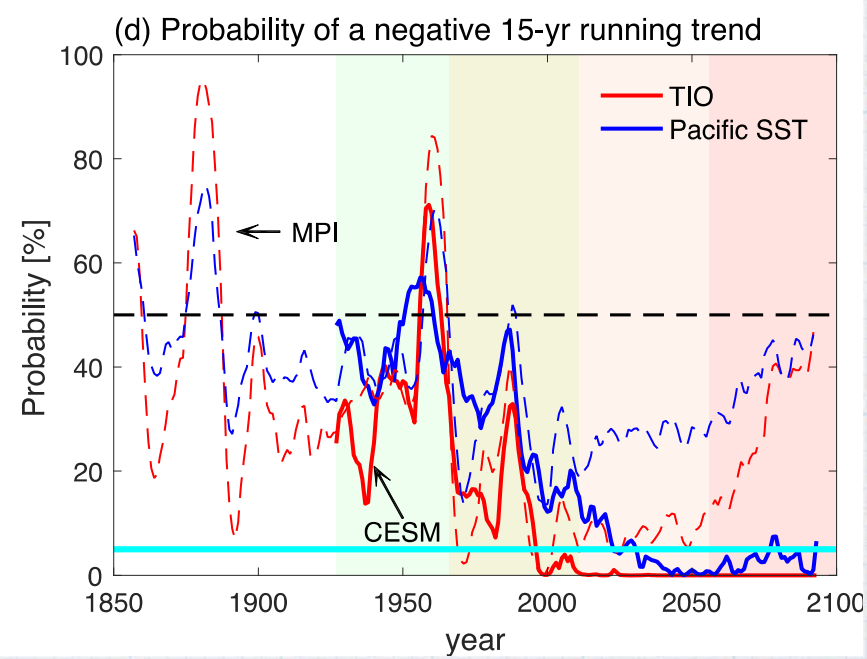
Signal (externally forced) to noise (internal variability) ratio is ~3x greater in Indian Ocean than that in Pacific.

Greater signal (externally forced) to noise (internal variability) ratio in Indian Ocean

Anthropogenic greenhouse gases

Time of emergence:

the time when the anthropogenic warming trend emerges from natural variability



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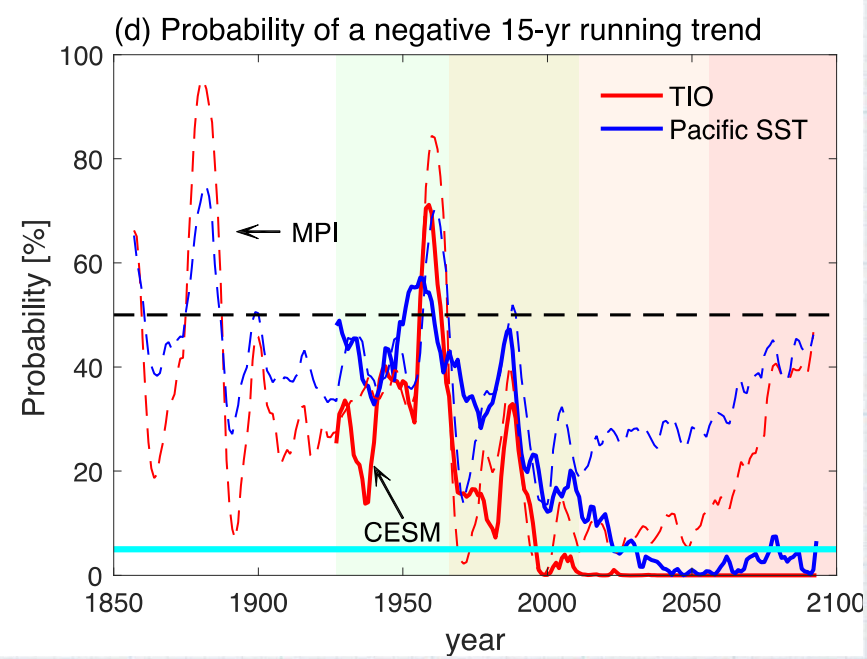
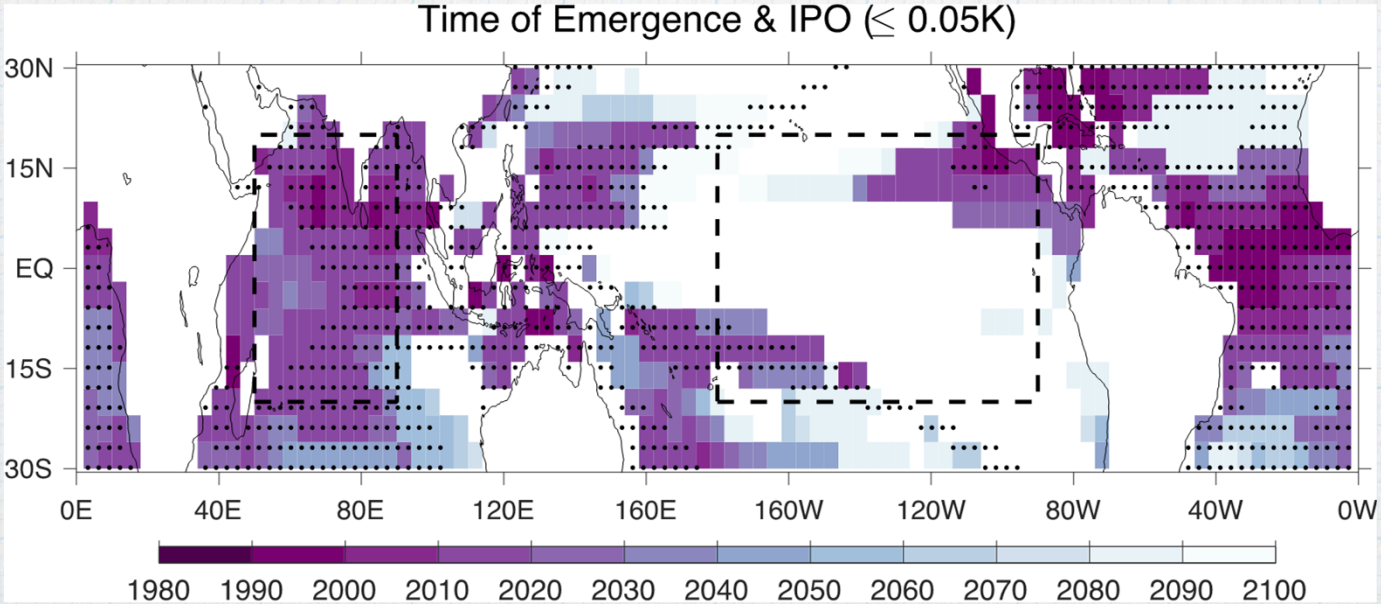


Spatial pattern of time of emergence in CESM



Conclusions

- Observations show that decadal (10-20yrs) to inter-decadal (>20yrs) variability of tropical Indian Ocean SST closely follows that of the Pacific until the 1960s. Since then, IO SST exhibits a persistent warming trend, whereas the Pacific SST shows large-amplitude fluctuations associated with the Inter-decadal Pacific Oscillation (IPO), and decadal variability of IO SST is out-of-phase with that of the Pacific after ~1980.

- By analyzing multiple observational datasets and the recently available large-ensemble simulations from two climate models, we find that on inter-decadal timescales, the IO persistent warming trend is caused by the emergence of anthropogenic warming overcoming internal variability, while the time of emergence occurs much later in the Pacific.

- On decadal timescales, two major tropical volcanic eruptions occurred in the 1980s and 1990s cause decadal SST cooling over the IO, during which the IPO was in warm phase, yielding the out-of-phase relation.

- The more evident fingerprints of external forcing over the IO compared to the Pacific result from the much weaker IO internal decadal to inter-decadal variability, making the IO prone to external forcing.

Thanks, comments?