

# **Impacts of External Forcing on the Decadal Climate Variability in CMIP5 Simulations**

**Yongqiang Yu and Yi Song**

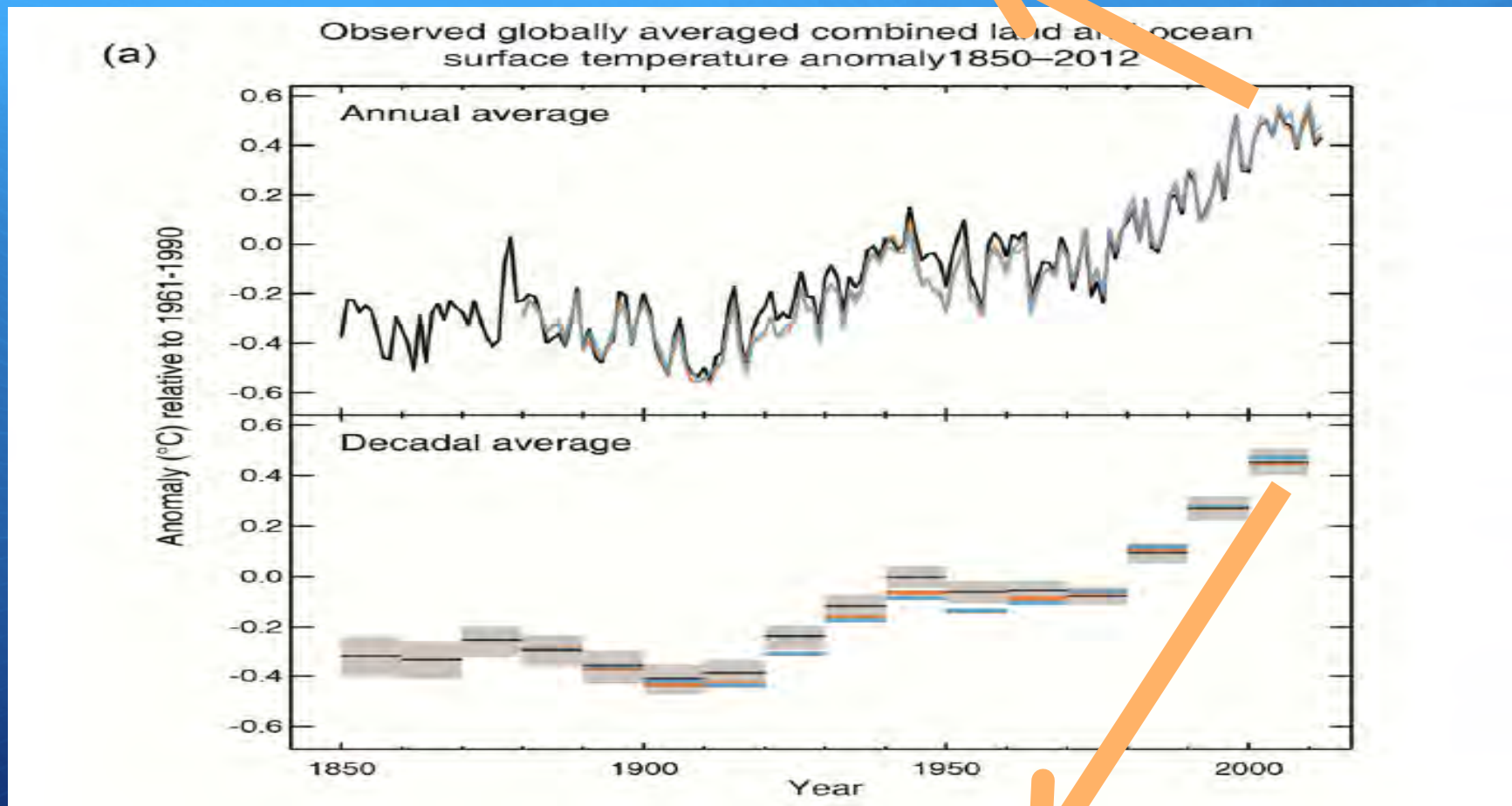
**LASG, Institute of Atmospheric Physics,  
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**PICES, Qingdao, October 22, 2015**

# Outline

- **Introduction**
- **Hiatus and Accelerated Warming in Historical Simulations**
- **Comparison between CMIP5 simulations with and without external forcing**
- **Impact of Volcanic Eruption in CMIP5 Simulations**
- **Summary**

# Global Mean Temp. Rising Slowdown since 1998 (Hia



The recent decade is also the warmest decade

# Possible Causes for Hiatus during the Past 15 years

Heat uptake in the ocean

Purkey and Johnson, 2010  
Katsman and van Oldenborgh 2011  
Kouketsu et al., 2011  
Meehl et al., 2011, 2013  
Palmer et al.2011  
Trenberth and Fasullo, 2011  
Balmaseda el al., 2013

natural variability

Meehl et al., 2011, 2013  
Balmaseda el al., 2013  
Kosaka and Xie 2013  
Li et al., 2013  
Tung and Zhou, 2013  
England et al. 2014

External forcing

Kaufmann et al., 2011  
Solomon et al. (2010)  
Estrada et al., 2013 ;  
Pretis and Allen, 2013  
Frolich, 2012  
Schmidt et al. (2014)

Does the external forcing impact decadal climate variability?

# Model and Data

1. CMIP5 Simulations: Pi Control run, Historical, His Nat, His GHG
2. Observation (HADiSST, ISCCP, Reanalysis data etc.)

Model	PiControl	Historical	HisNat	HisGHG
ACCESS1-0	Y			
ACCESS1-3	Y			
BCC-CSM1-1	Y	Y	Y	Y
BCC-CSM1-1-M	Y			
BNU-ESM	Y		Y	Y
CANESM2	Y	Y	Y	Y
CCSM4	Y	Y	Y	Y
CESM1-BGC	Y			
CESM1-CAM5	Y			
CESM1-FASTCHEM	Y			
CESM1-WACCM	Y			
CMCC-CM	Y			
CNRM-CM5	Y	Y	Y	Y
CNRM-CM5-2	Y			
CSIRO-Mk3-6-0	Y	Y	Y	Y
FGOALS-s2	Y	Y		
FIO-ESM	Y			
GFDL-CM3	Y	Y	Y	Y
GFDL-ESM2G	Y	Y		
GFDL-ESM2M	Y	Y	Y	Y

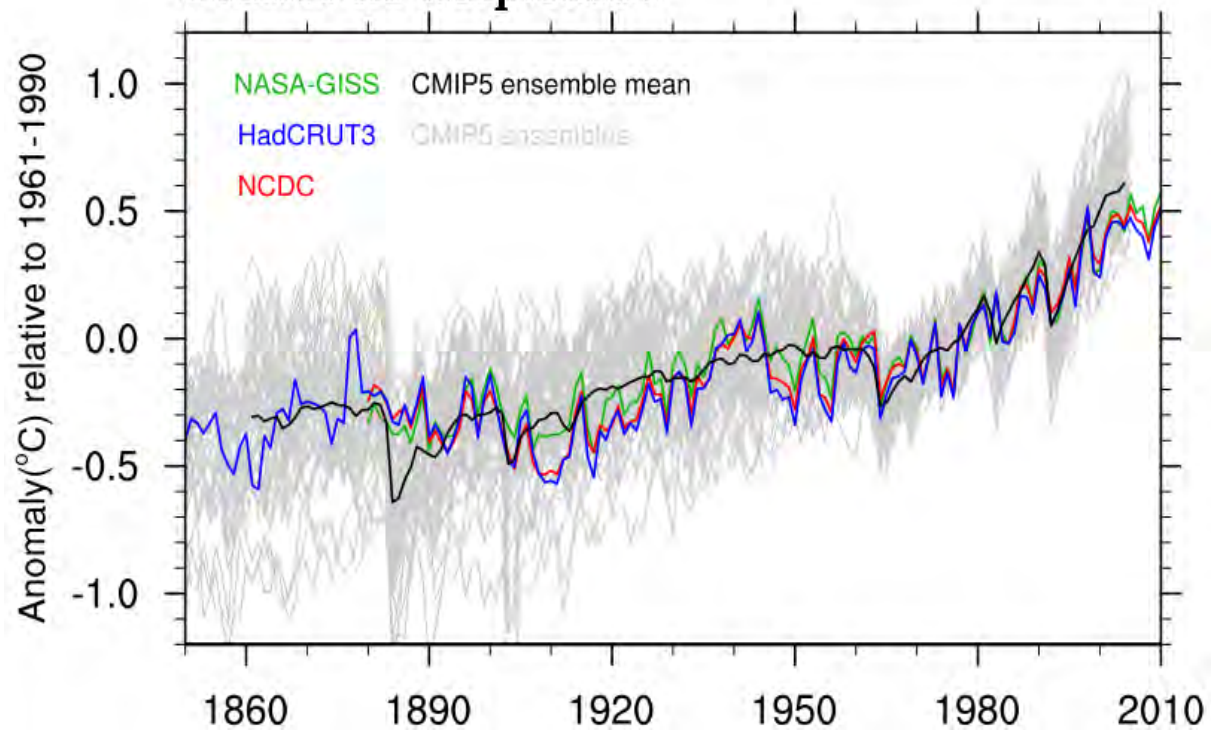
Model	PiControl	Historical	HisNat	HisGHG
GISS-E2-H	Y	Y	Y	Y
GISS-E2-H-CC	Y			
GISS-E2-R	Y	Y	Y	Y
GISS-E2-R-CC	Y			
HadCM3		Y		
HadGEM2-CC	Y	Y		
HadGEM2-ES	Y	Y	Y	Y
INMCM4	Y			
IPSL-CM5A-LR	Y	Y	Y	Y
IPSL-CM5A-MR	Y			
IPSL-CM5B-LR	Y			
MIROC-ESM	Y	Y	Y	Y
MIROC-ESM-CHEM	Y		Y	Y
MIROC5	Y			
MPI-ESM-LR	Y	Y		
MPI-ESM-MR	Y			
MPI-ESM-P	Y			
MRI-CGCM3	Y	Y	Y	Y
NorESM1-M	Y	Y	Y	Y
NorESM1-ME	Y			
Total	39	19	16	16

- **Pi Control Run: No anthropogenic and natural radiation forcing**
- **Historical run : realistic anthropogenic and natural radiation forcing 1850-2000**
- **Historical Nat run : only natural radiation forcing 1850-2000**
- **Historic GHG run : only anthropogenic GHG during 1850-2000**

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## Surface air temperature

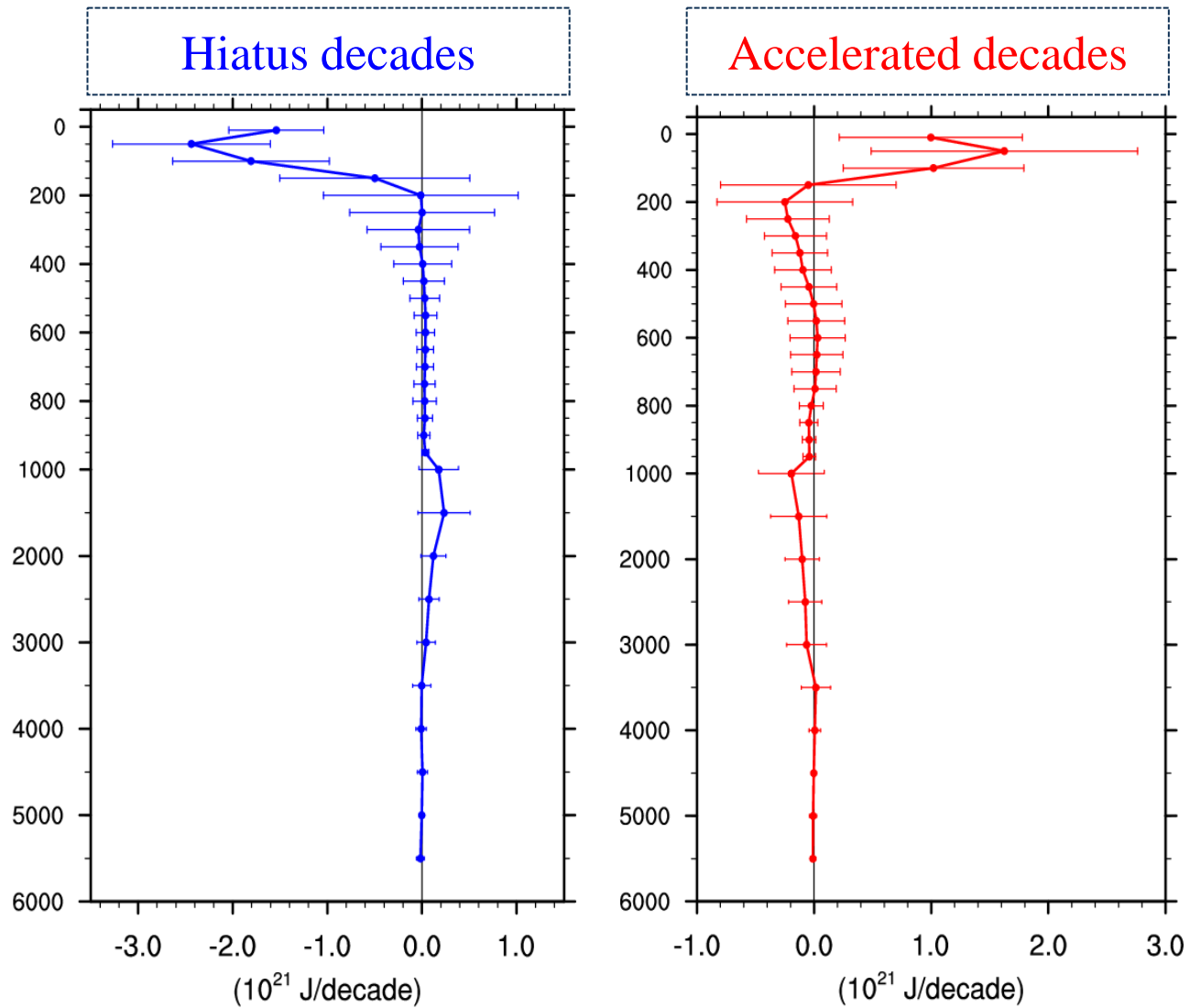


Hiatus Decades: Less than  $-0.15^{\circ}\text{C}/\text{decade}$  (2-3 cases for each simulation);

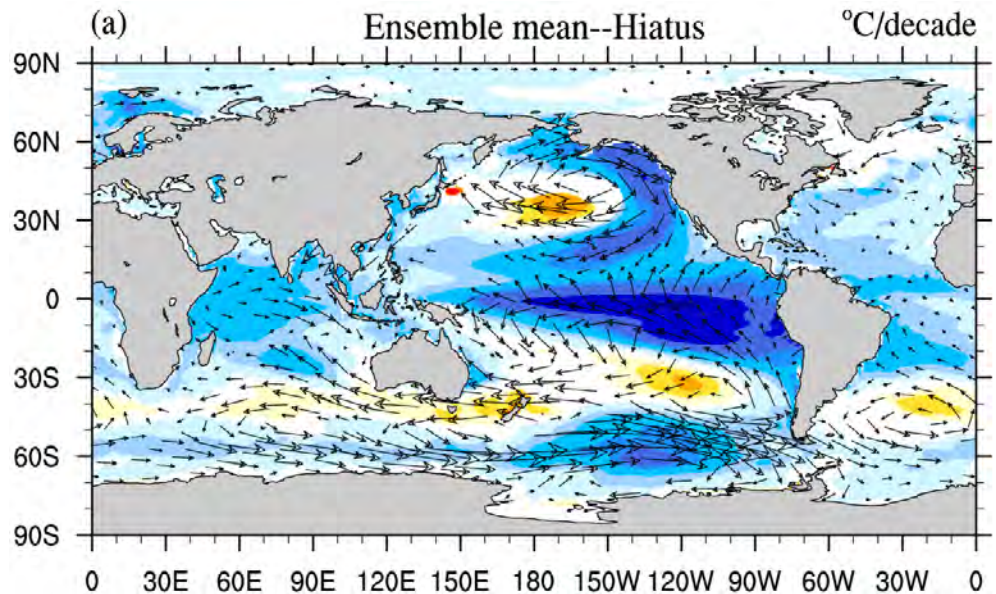
Accelerated Warming Decades: larger than  $0.3^{\circ}\text{C}/\text{decade}$  (2-3 cases for each simulation)



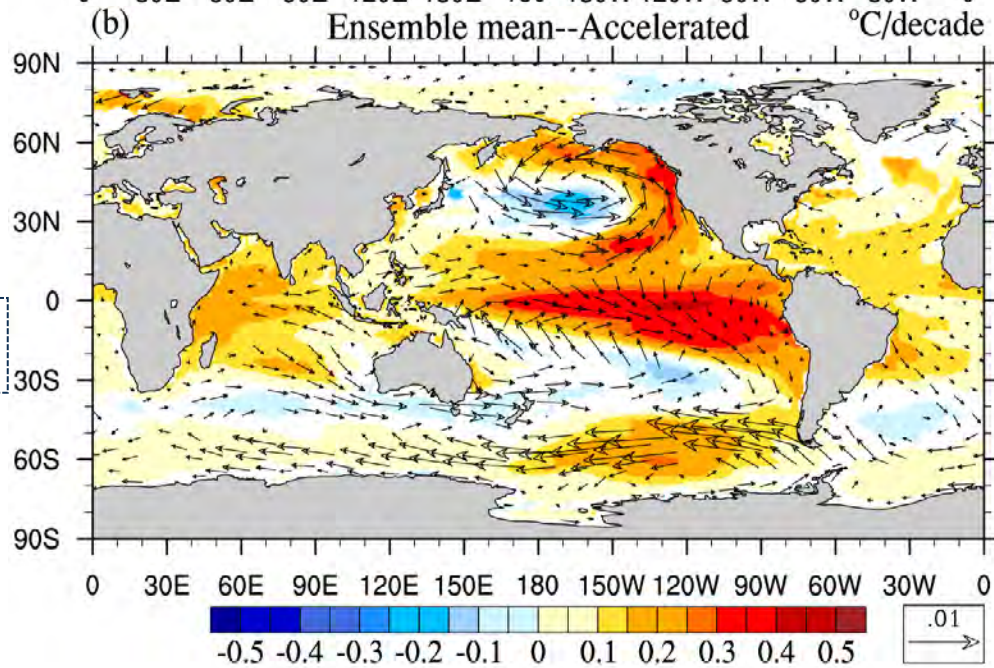
# Linear trend of Global Mean ocean content



Hiatus decades



Accelerated decades

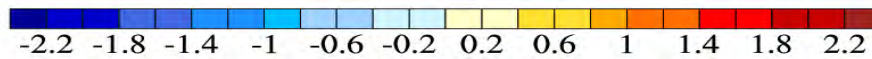
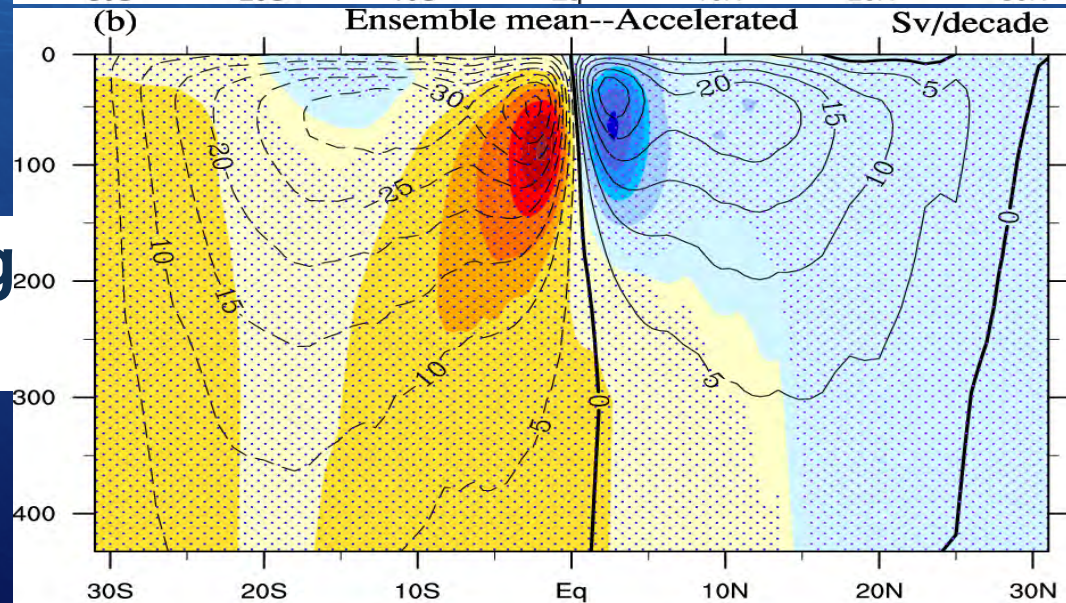
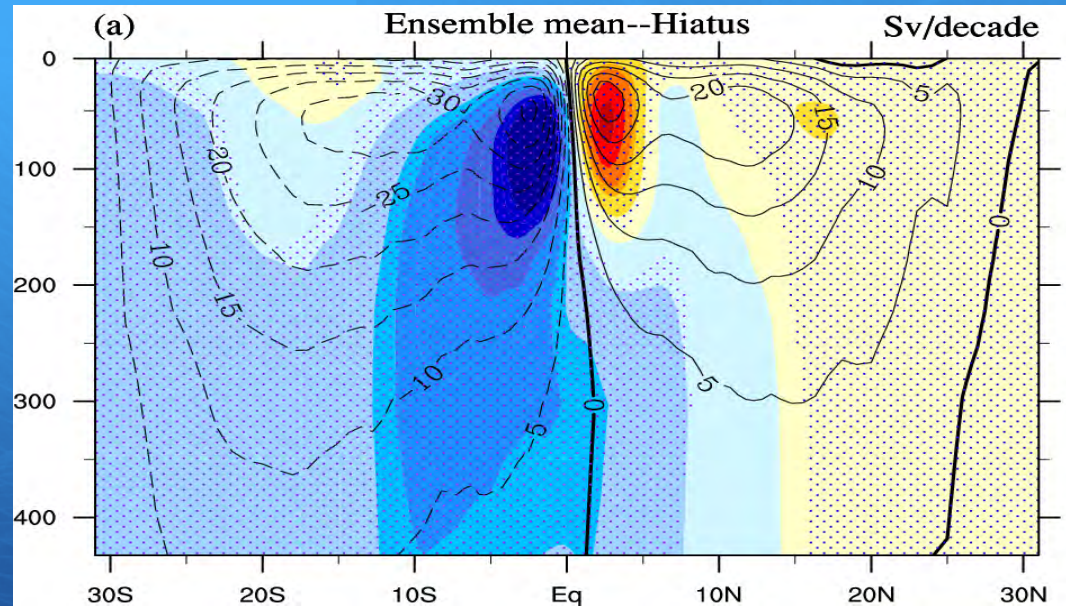


Hiatus decades



Accelerated decades

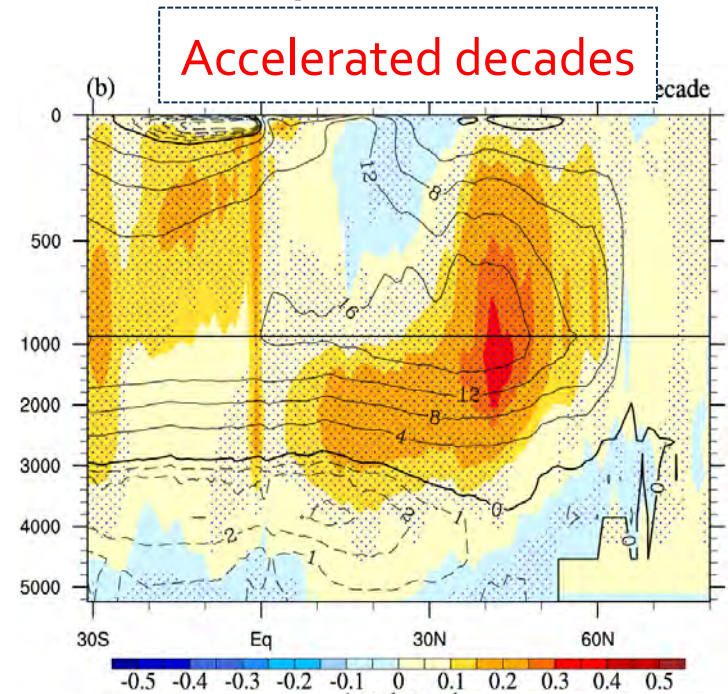
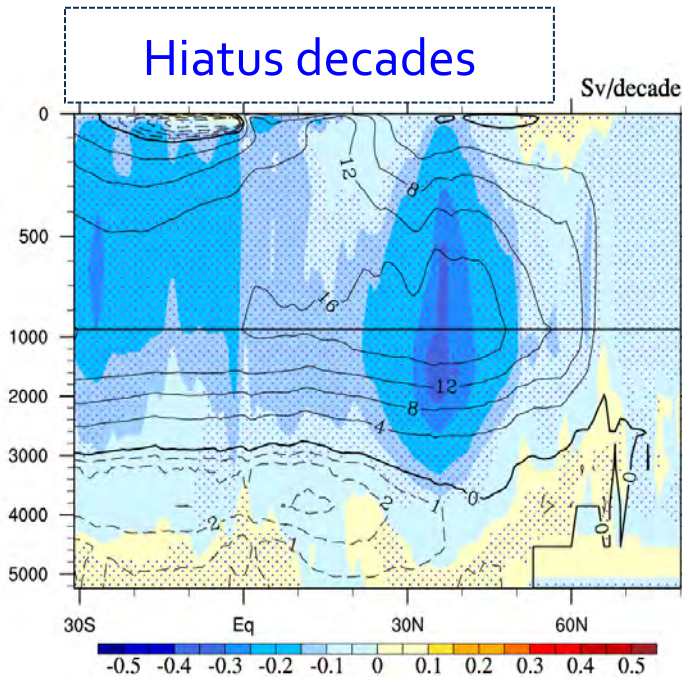
Hiatus Decade:  
STC enhanced



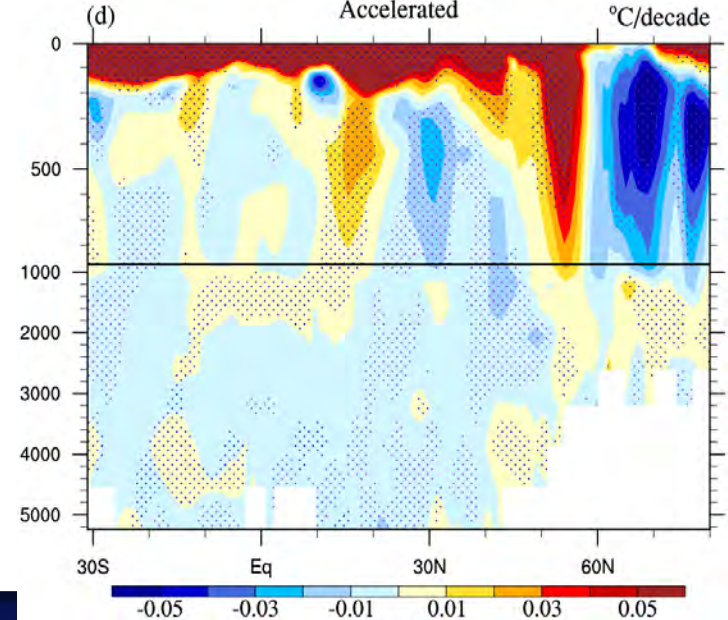
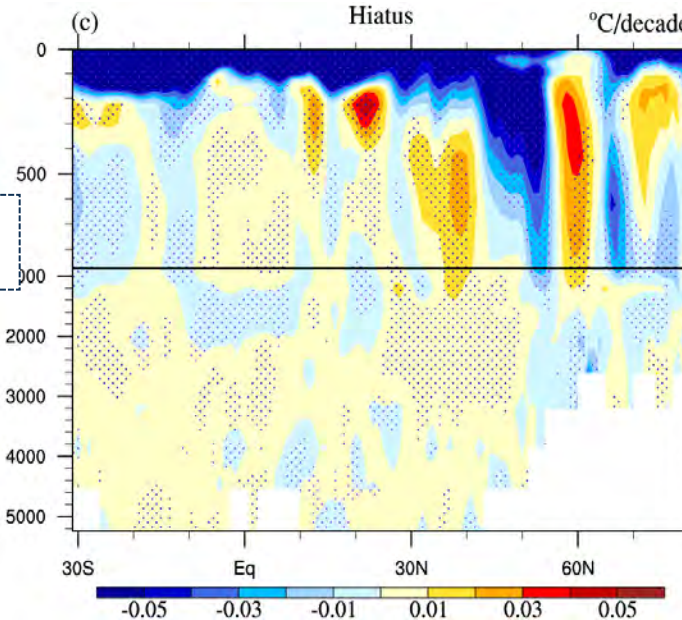
Accelerated warming  
STC weakened

# AMOC (Atlantic Meridional Overturning Circulation)

AMOC



Temperature



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# Two Approaches for Ensemble Mean

## AMEM:

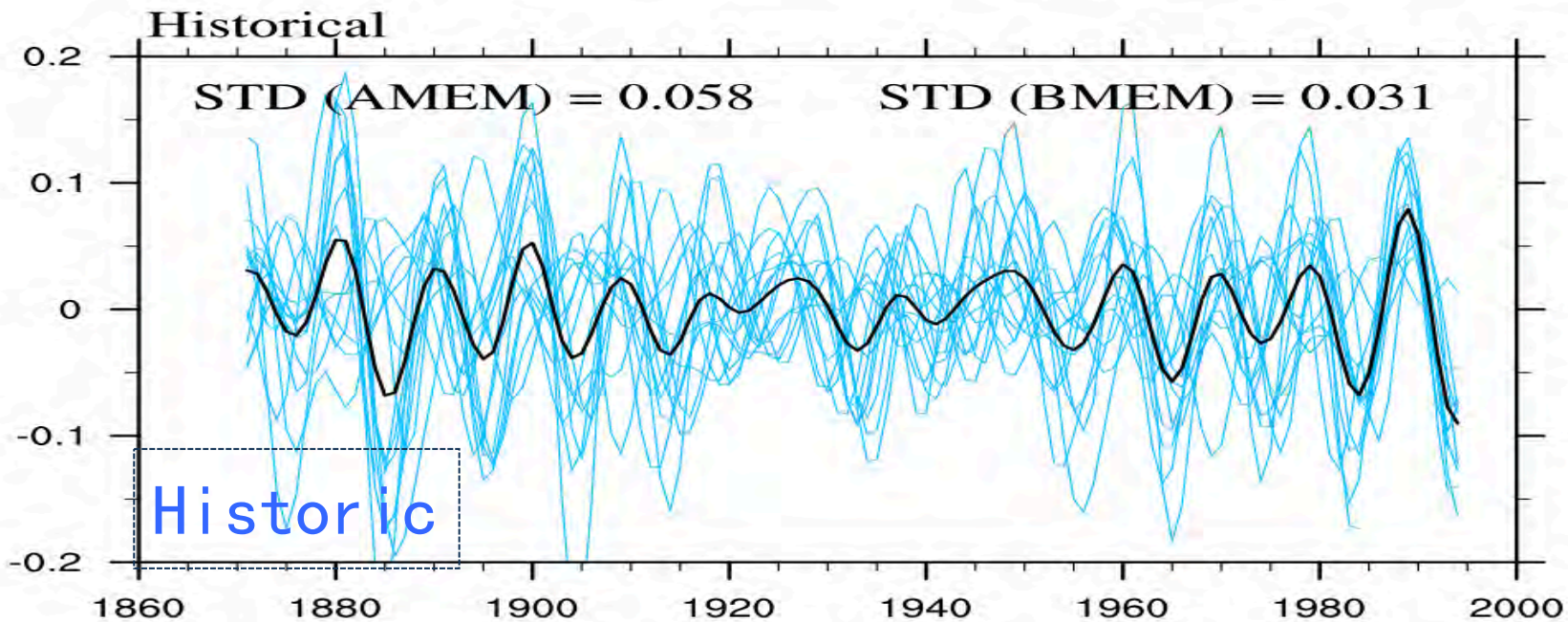
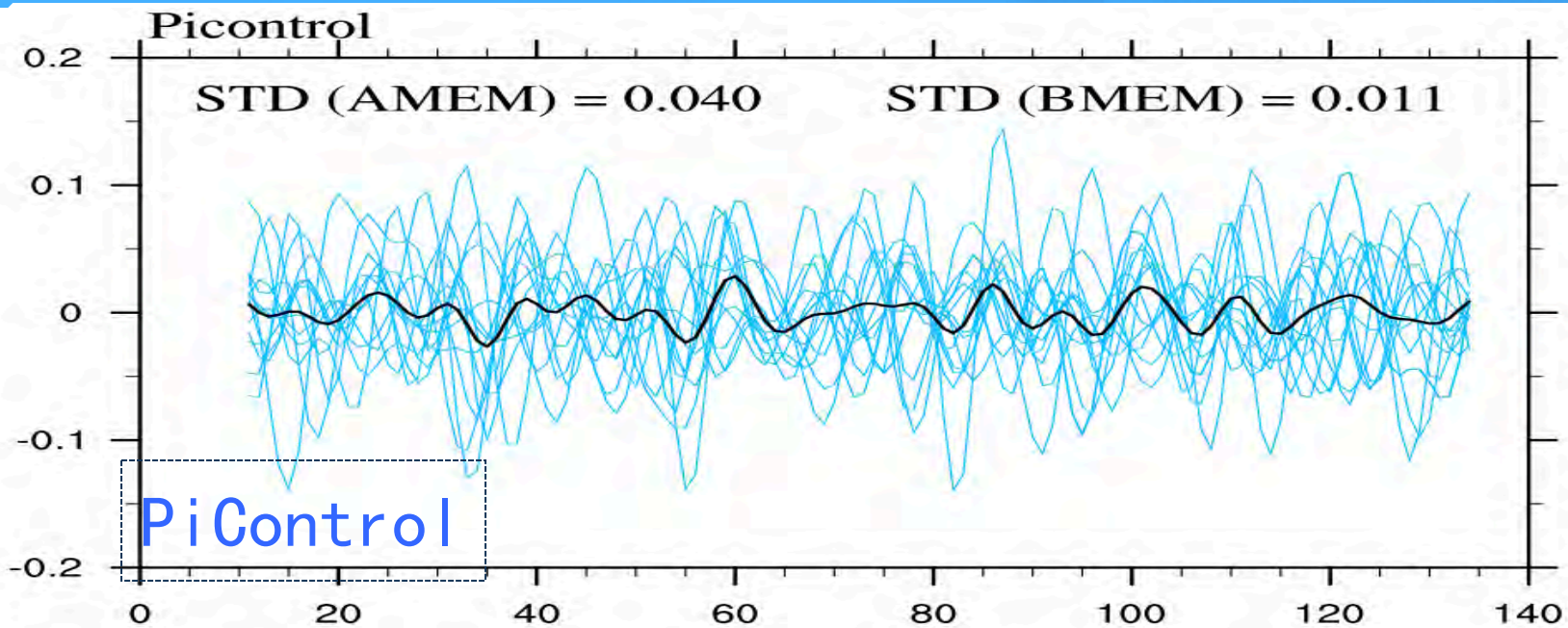
1. Calculate Variance or correlation for each simulation
2. Calculate multi-model ensemble mean of variance or correlation

**Both the internal variability and responses to external forcing are retained.**

## FMEM:

1. Calculate multi-model ensemble mean for any variable
2. Calculate Variance or correlation of multi-model ensemble mean

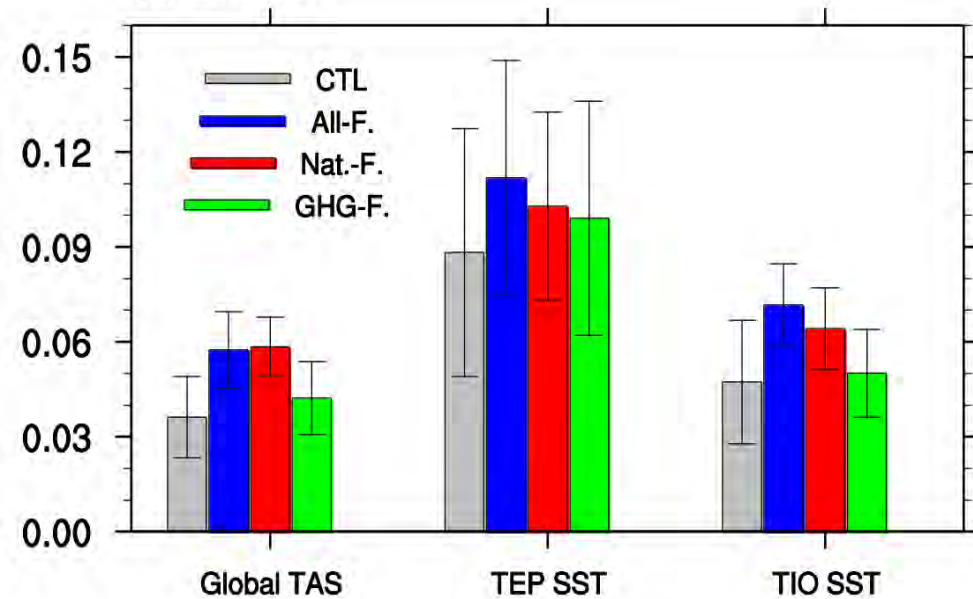
**The internal variability is canceled out, only response to external forcing is retained.**



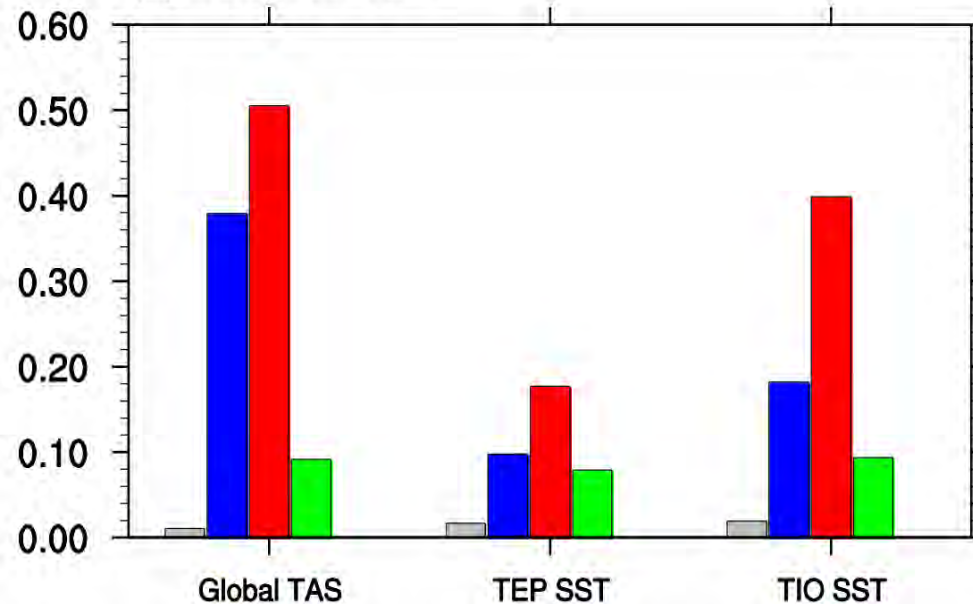
✓ Standard Deviation of TAS using AMEM method

✓ Ratio of TAS standard deviation from FMEM to that from AMEM

(a) St Dev.



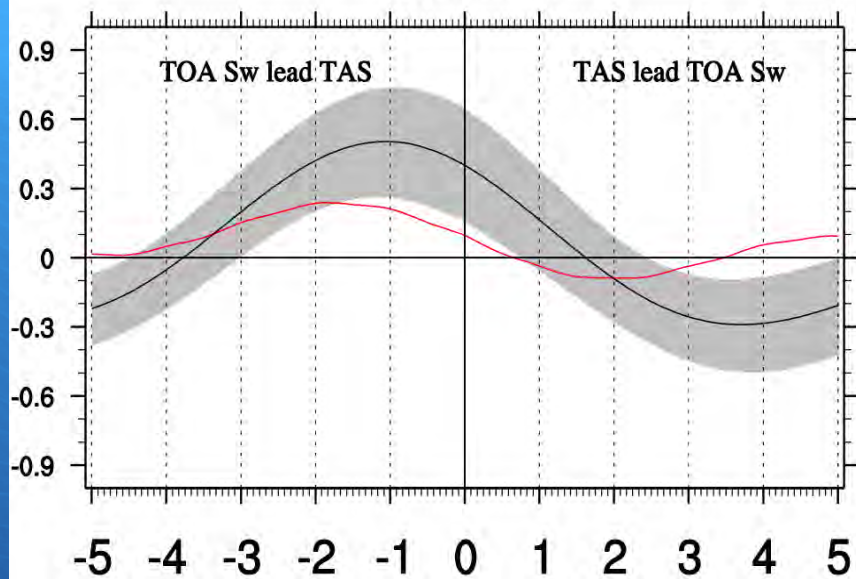
(b) Ratio of Var.



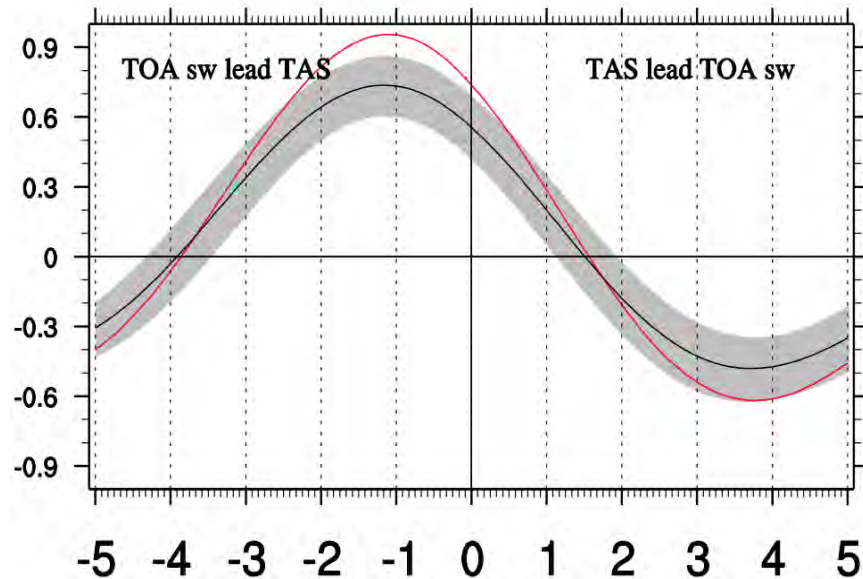


# Lag Correlation between SW and TAS AMEM(black) FMEM (red)

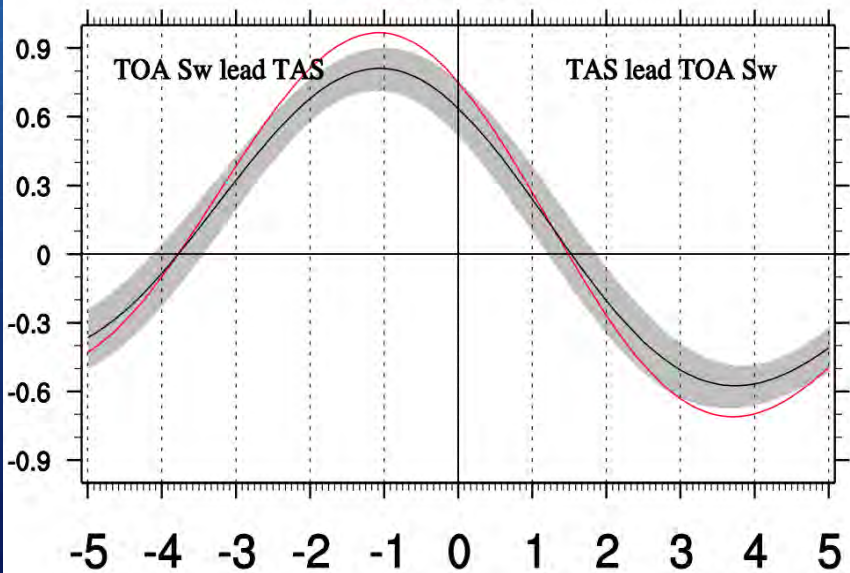
(a) PiControl



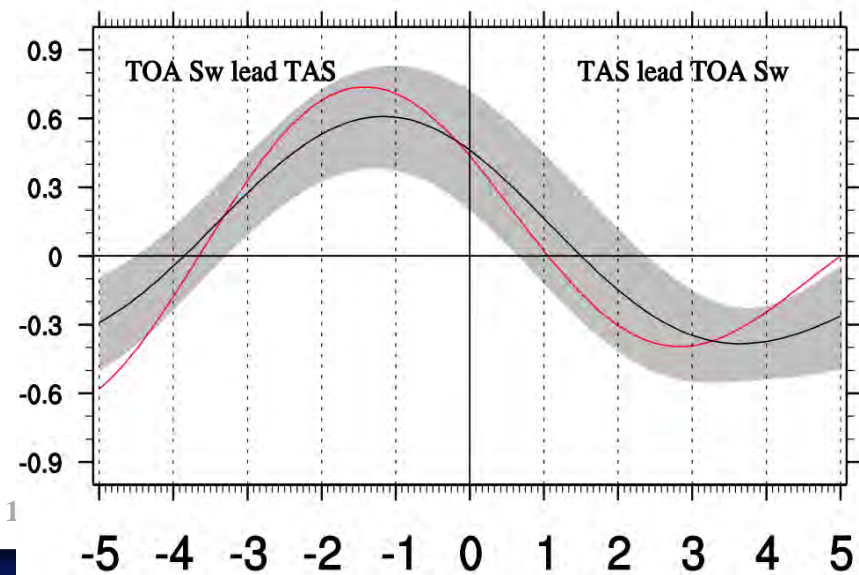
(b) Historical



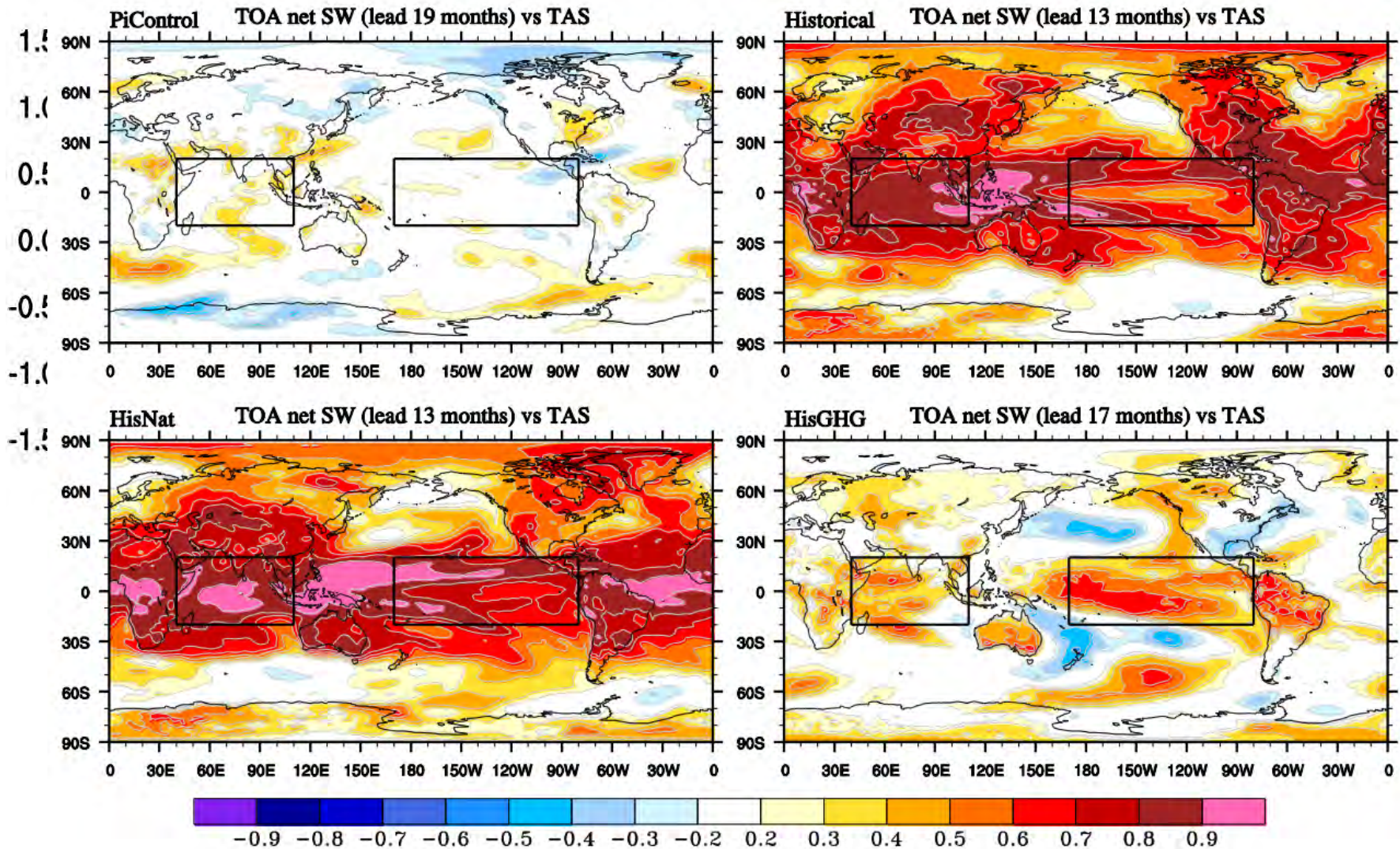
(c) HisNat



(d) HisGHG



# FMEM Regression analysis : Global mean SW vs TAS



# Outline

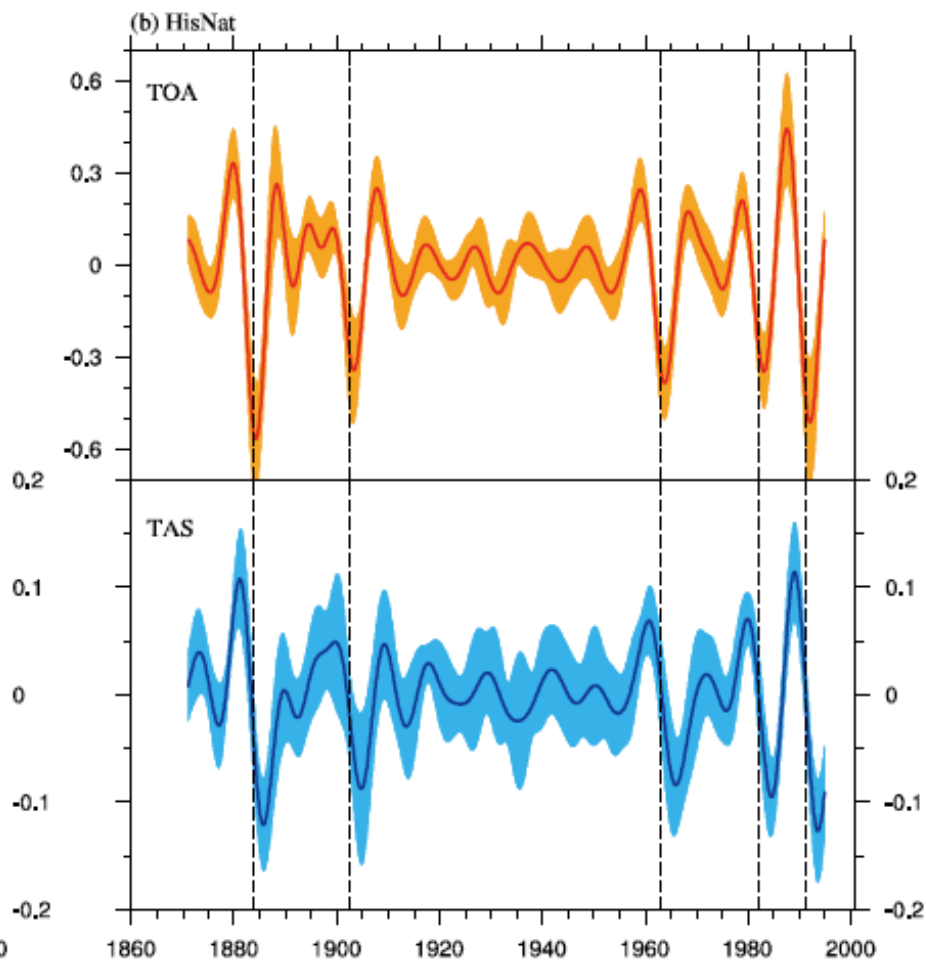
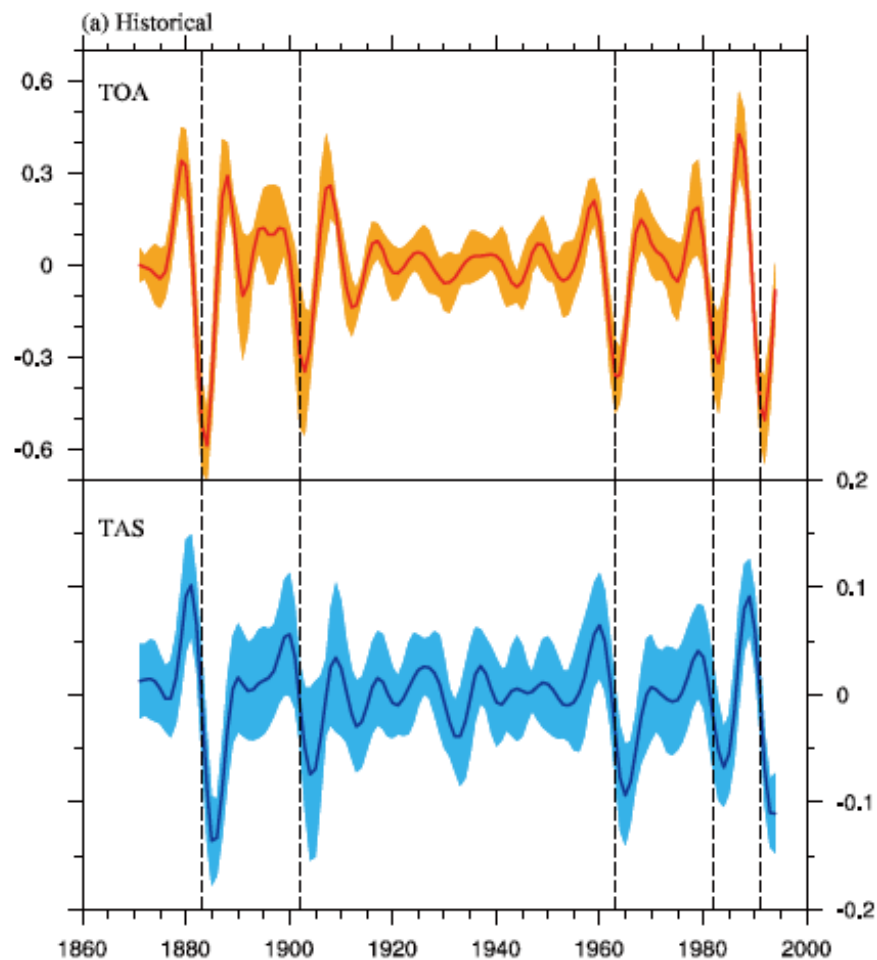
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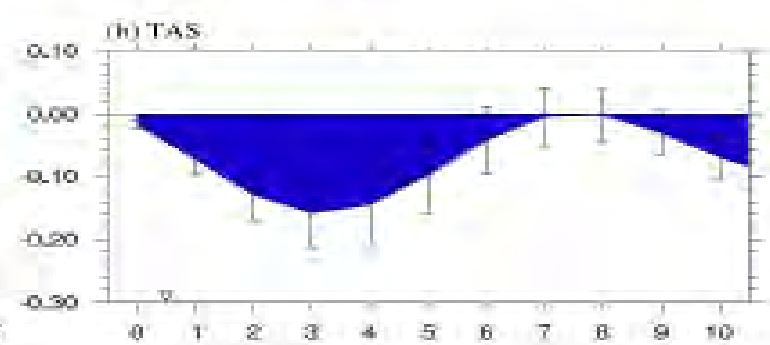
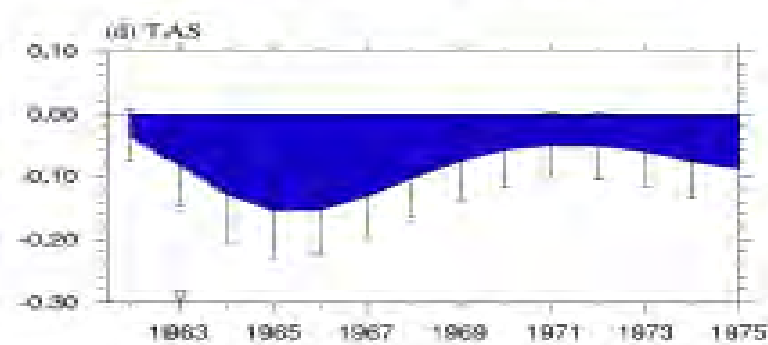
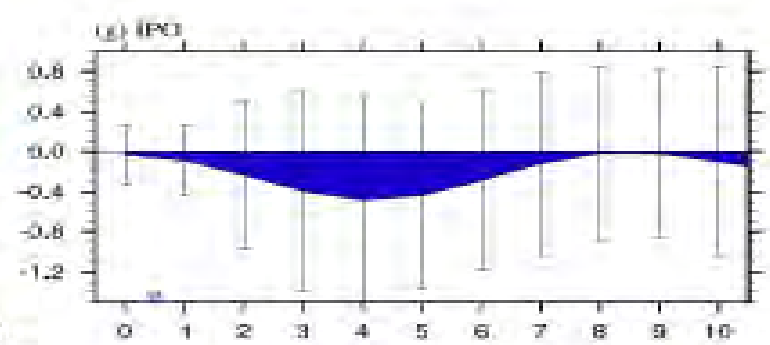
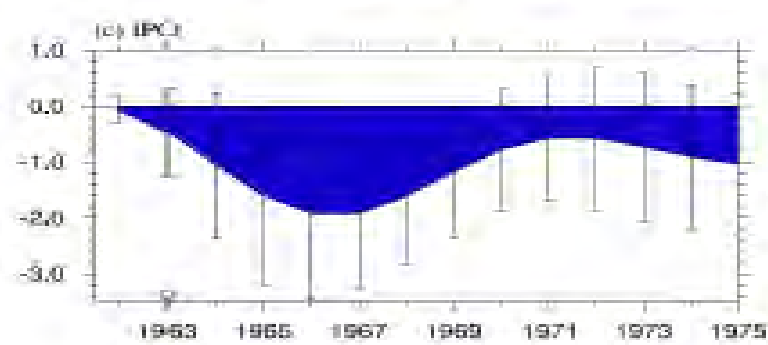
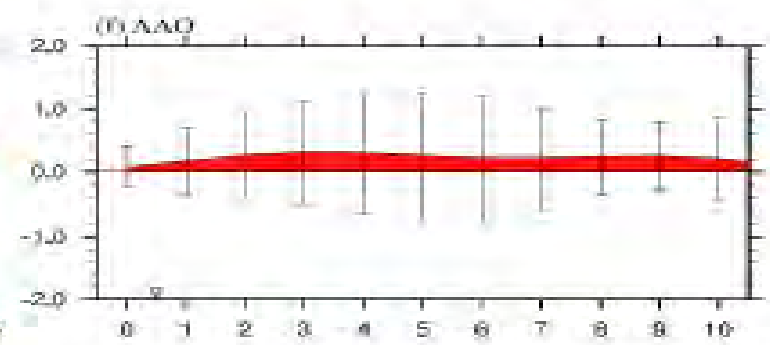
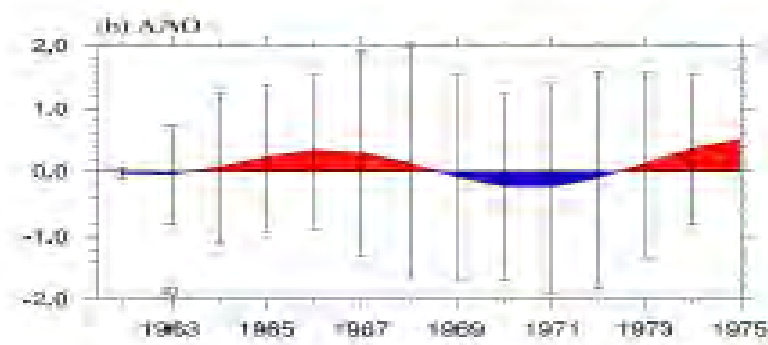
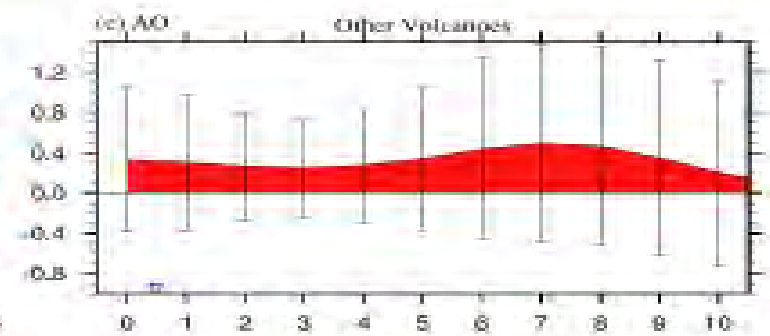
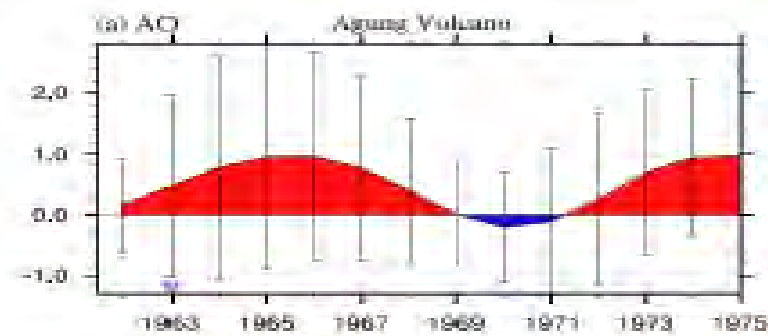
## Volcanic impact on climate: short-range or long term ?

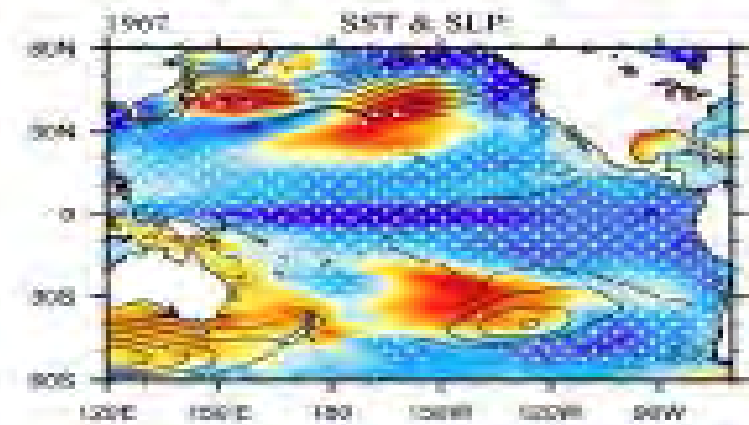
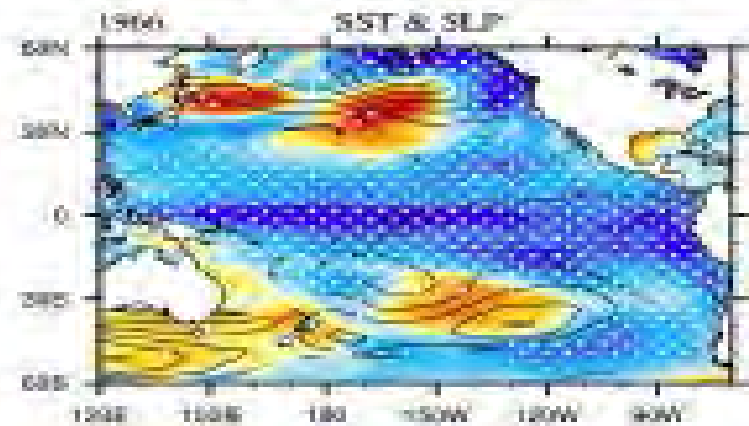
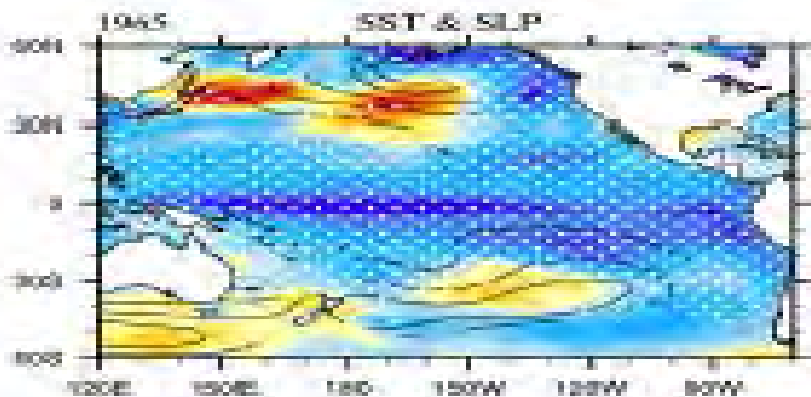
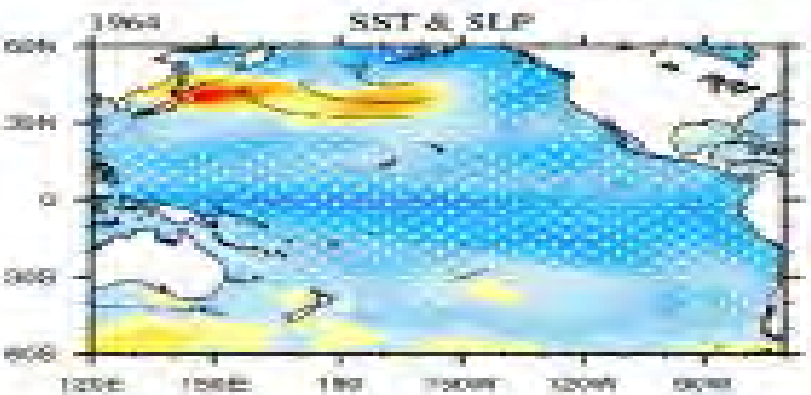
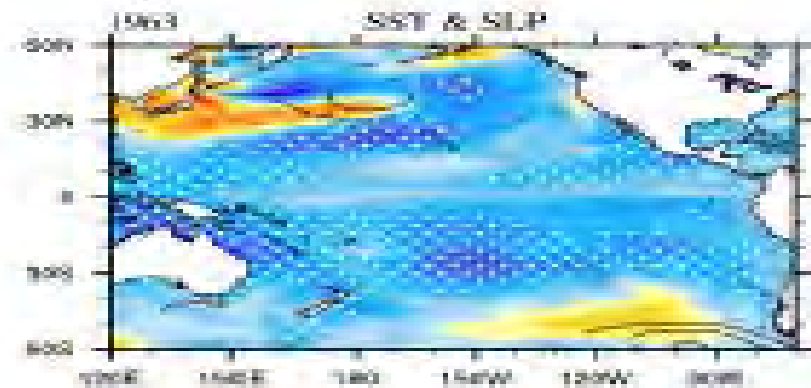
Previous studies suggested Volcanic impact lasted 1-2 years (Gillett et al. 2004; Trenberth and Dai 2007; Shen et al. 2008; Peng et al. 2010) .

Wang et al. (2012) and Santer et al. (2014) indicated Volcanic contribution to decadal changes

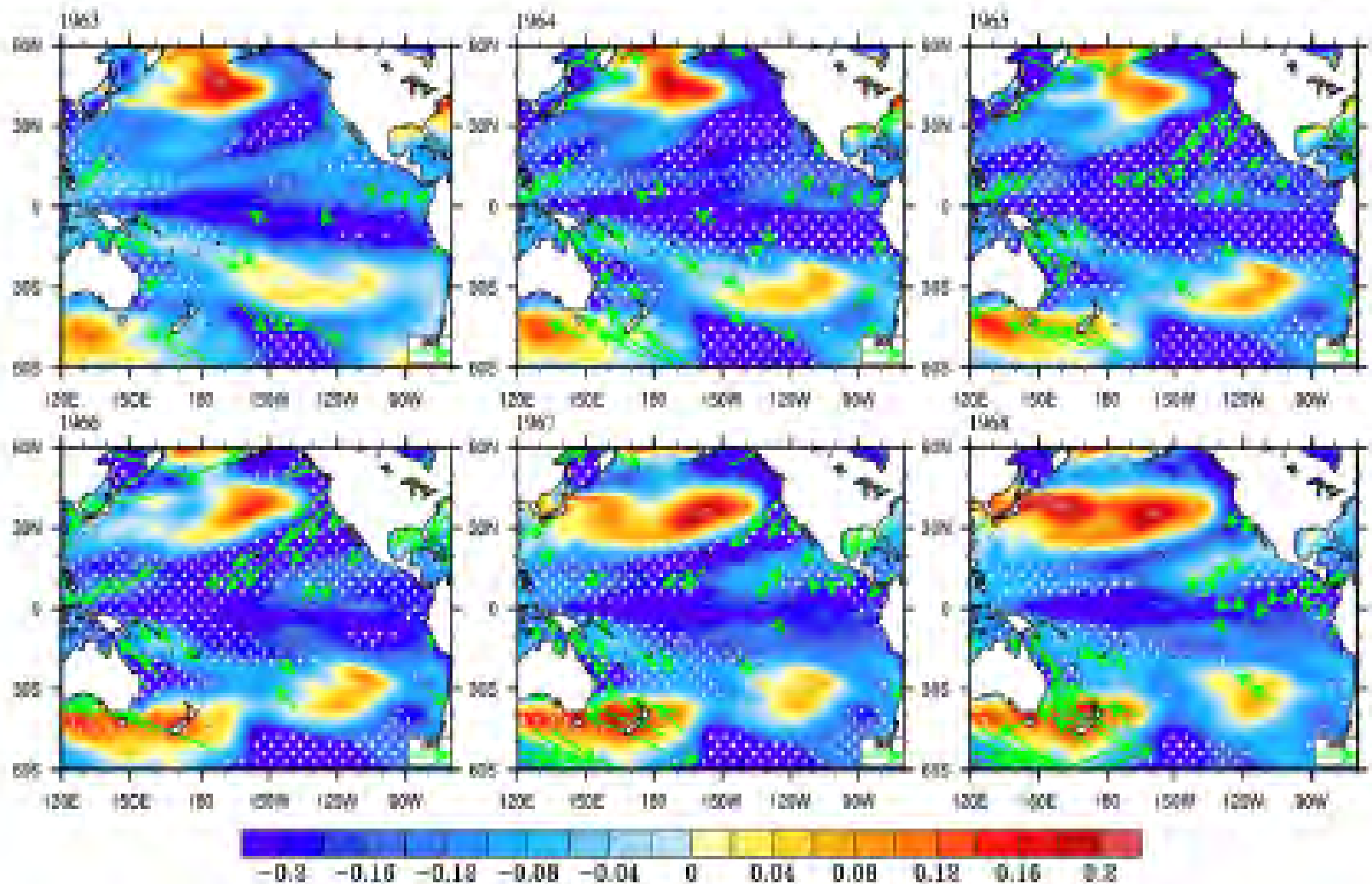
# Global Mean SW at TOA and Surface Air Temperature





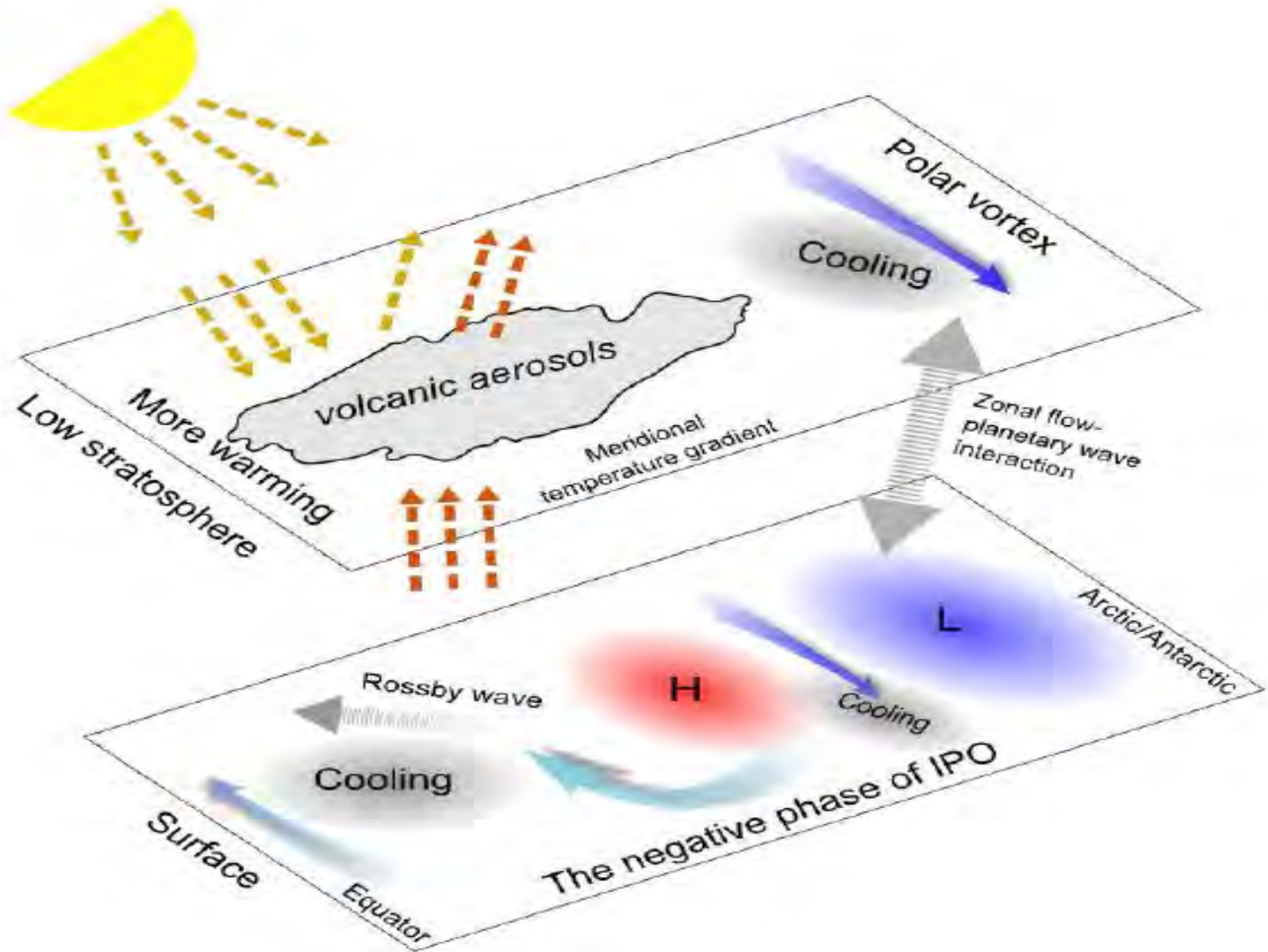


Ensemble mean SST  
and SLP Anomalies



SST and SLP Anomalies for two IPSL Models





# Summary

- The coupled models can reproduce the hiatus and accelerated warming period to some extent
- Hiatus and Accelerated warming exhibit IPO pattern in the Pacific
- The external forcing can enhance or modulate decadal variability, e.g. the IPO.
- The strong volcanic eruption may induce decadal variability such as IPO, AO, and AAO