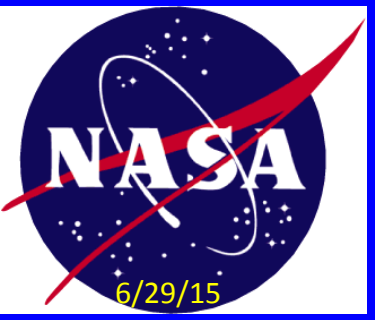
The ENSO Effects on Tropical Clouds and Top-of-Atmosphere Cloud Radiative Effects in CMIP5 Models

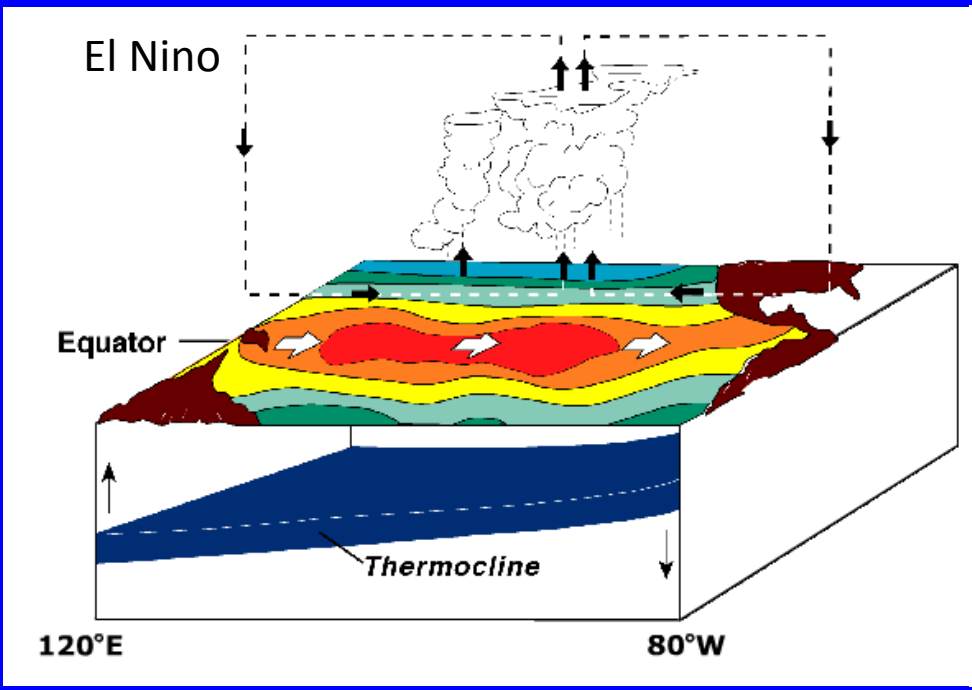
Wenying Su
NASA Langley Research Center, Hampton VA

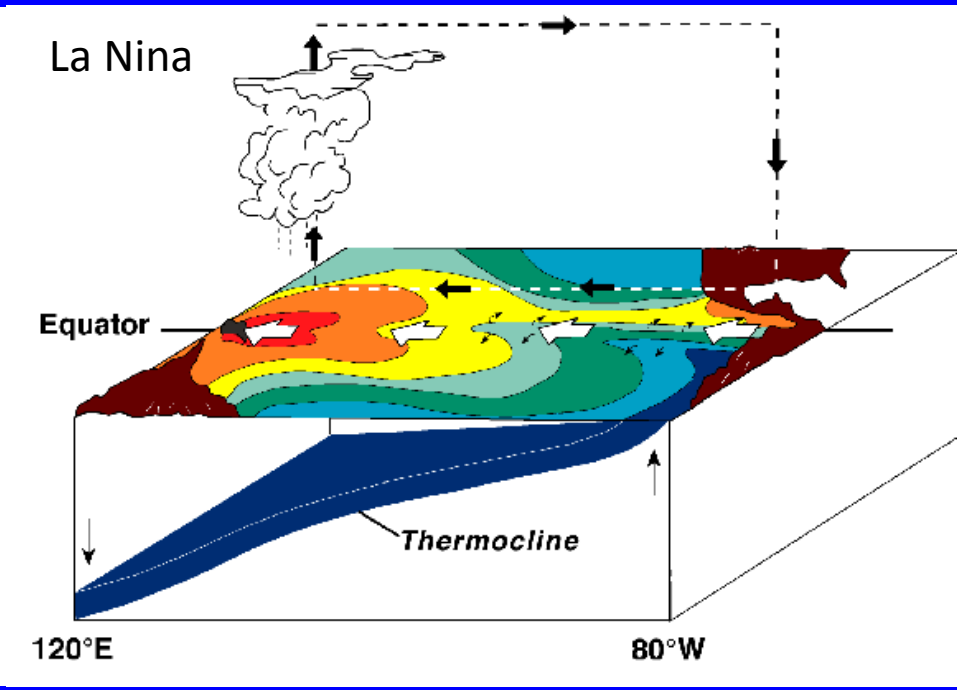
Hailan Wang
SSAI/NASA Langley Research Center, Hampton VA



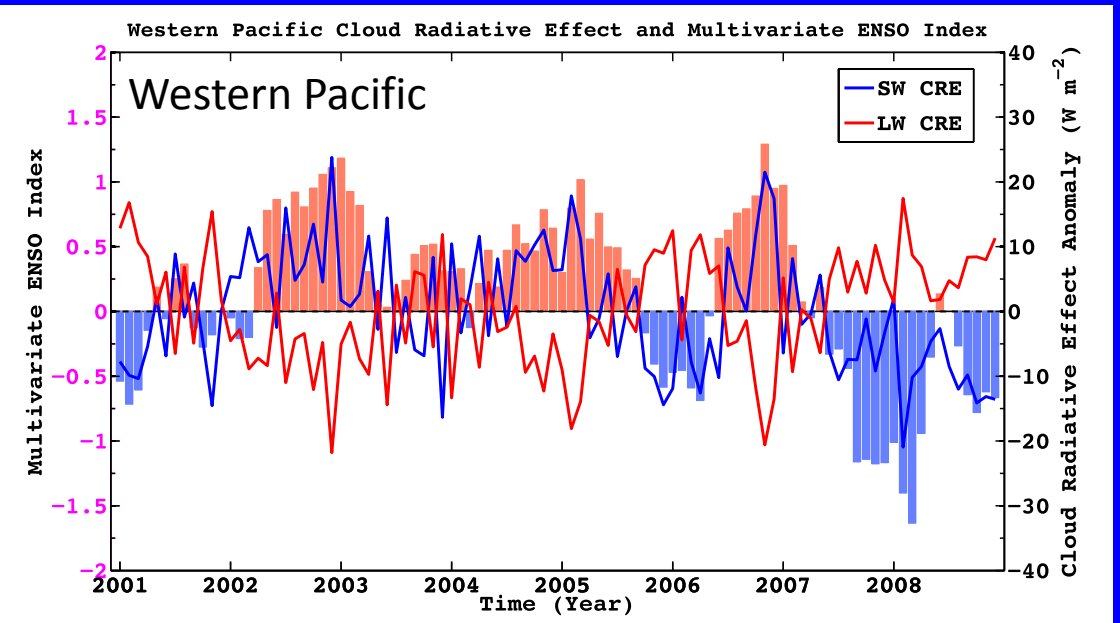
El Niño-Southern Oscillation (ENSO)

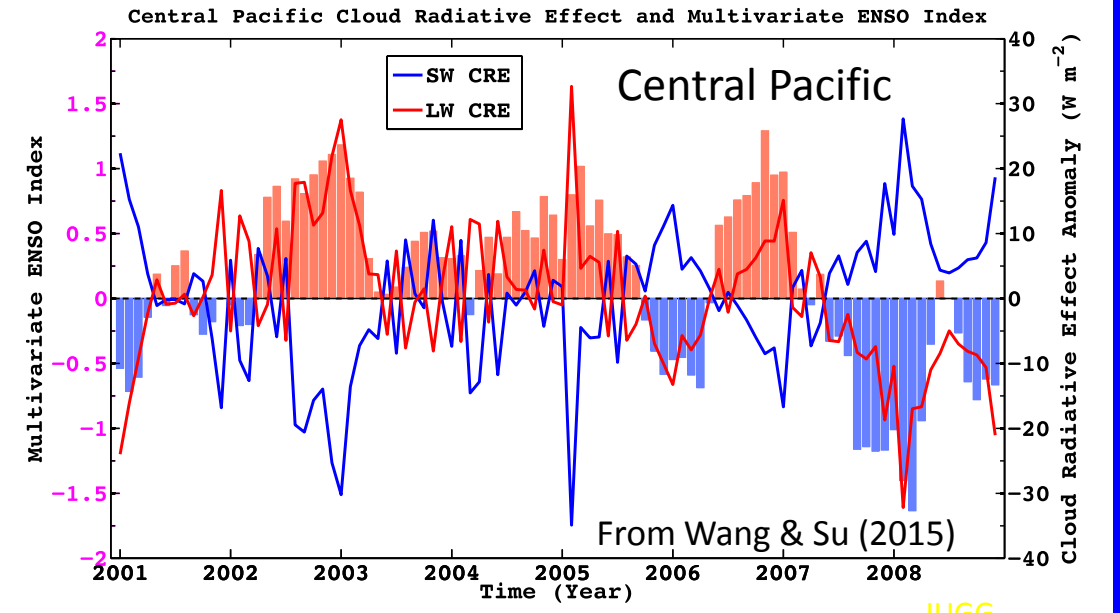
- ENSO is the leading mode of natural interannual climate variability in the tropics; it consists of two phases (El Nino and La Nina)
- During El Nino, warmer Sea Surface Temperature (SST) anomalies in the central and eastern tropical Pacific, but cooler SST anomalies in the western tropical Pacific
- During La Nina, the opposite of the above occurs





Cloud radiative effect anomalies tracks the MEI index very well in the western and central tropical Pacific





- During El Nino reduced deep convection and high clouds in Western Pacific (100° E-140° E, 10° S-10° N) → weakened TOA shortwave cooling and longwave warming of clouds
- During El Nino enhanced deep convection and high clouds in central Pacific (160° E-200° E, 10° S-10° N) → enhanced TOA shortwave cooling and longwave warming of clouds

Data and Methodology

- Observations
  - TOA Radiative fluxes: CERES EBAF 2.7 (2001-2008)
  - Clouds: ISCCP joint CTP-τ histogram of cloud fraction: 1984-2007
- CMIP5 AMIP simulations: 1979-2008

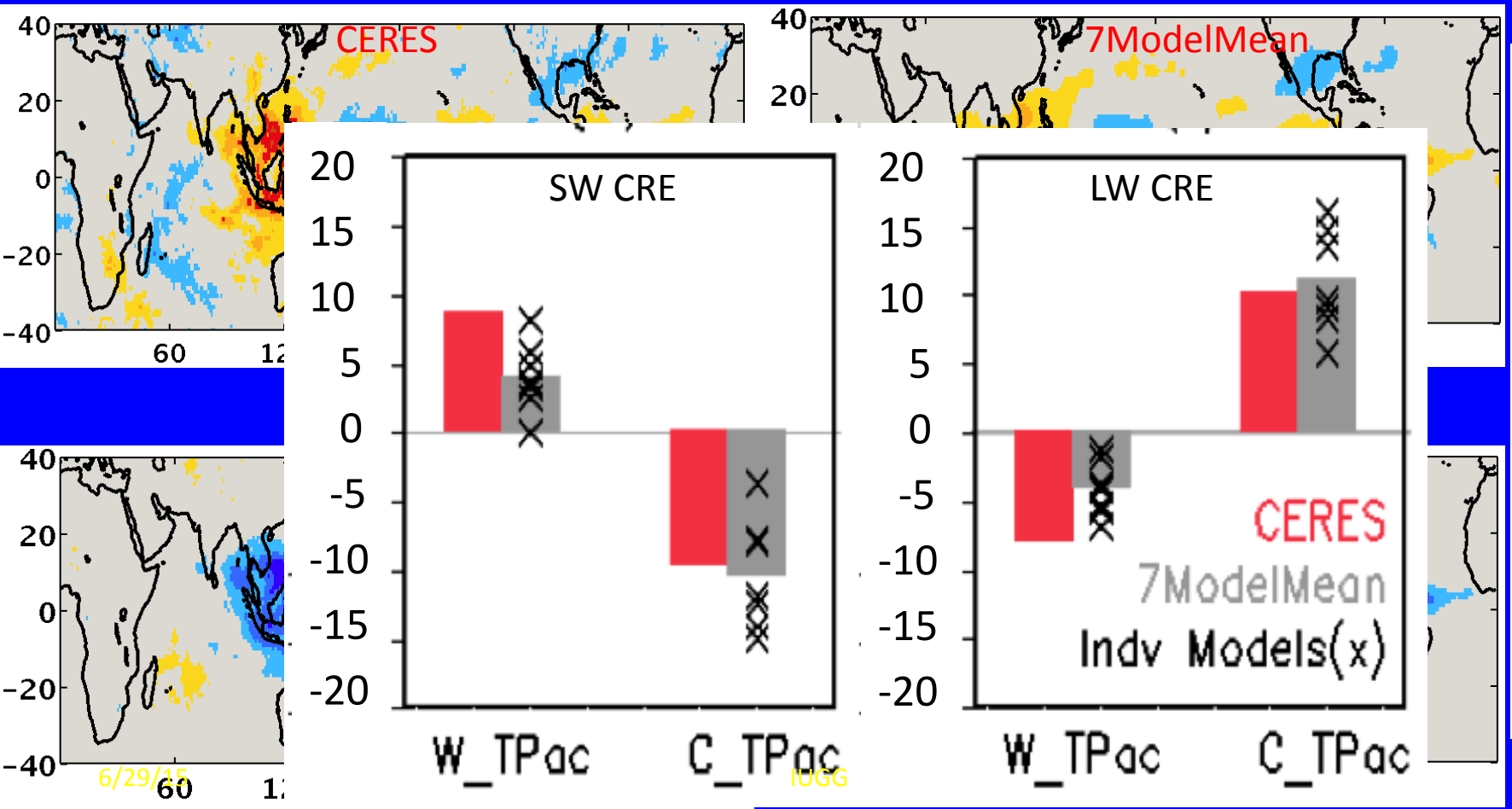
Model ID	Country	Resolution
CanAM4	Canada	2.8°x2.8°
CNRM-CM5	France	1.4°x1.4°
GFDL-CM3	USA	0.3°x0.3°
HadGEM2-A	UK	1.9°x1.3°
MIROC5	Japan	1.4°x1.4°
MPI-ESM-LR	Germany	1.9°x1.9°
MRI-CGCM3	Japan	1.1xx1.1°

- Variability associated with ENSO
  - Linear regression of deseasonalized anomaly against Multivariate ENSO Index (MEI)
- Calculate Cloud radiative kernel (CRK) using Fu-Liou radiative transfer model
  - Derive for each 2.5° lat-lon grid and each calendar month, for both observation and AMIP5 multi-model mean, using the respective monthly climatologies
- TOA cloud radiative effect (CRE) anomaly due to ENSO
  - CRK(CTP, τ, mon)*deseasonalized cloud fraction (CTP, τ, mon, year), then linearly regress against MEI

TOA CRE anomalies associated with El Nino

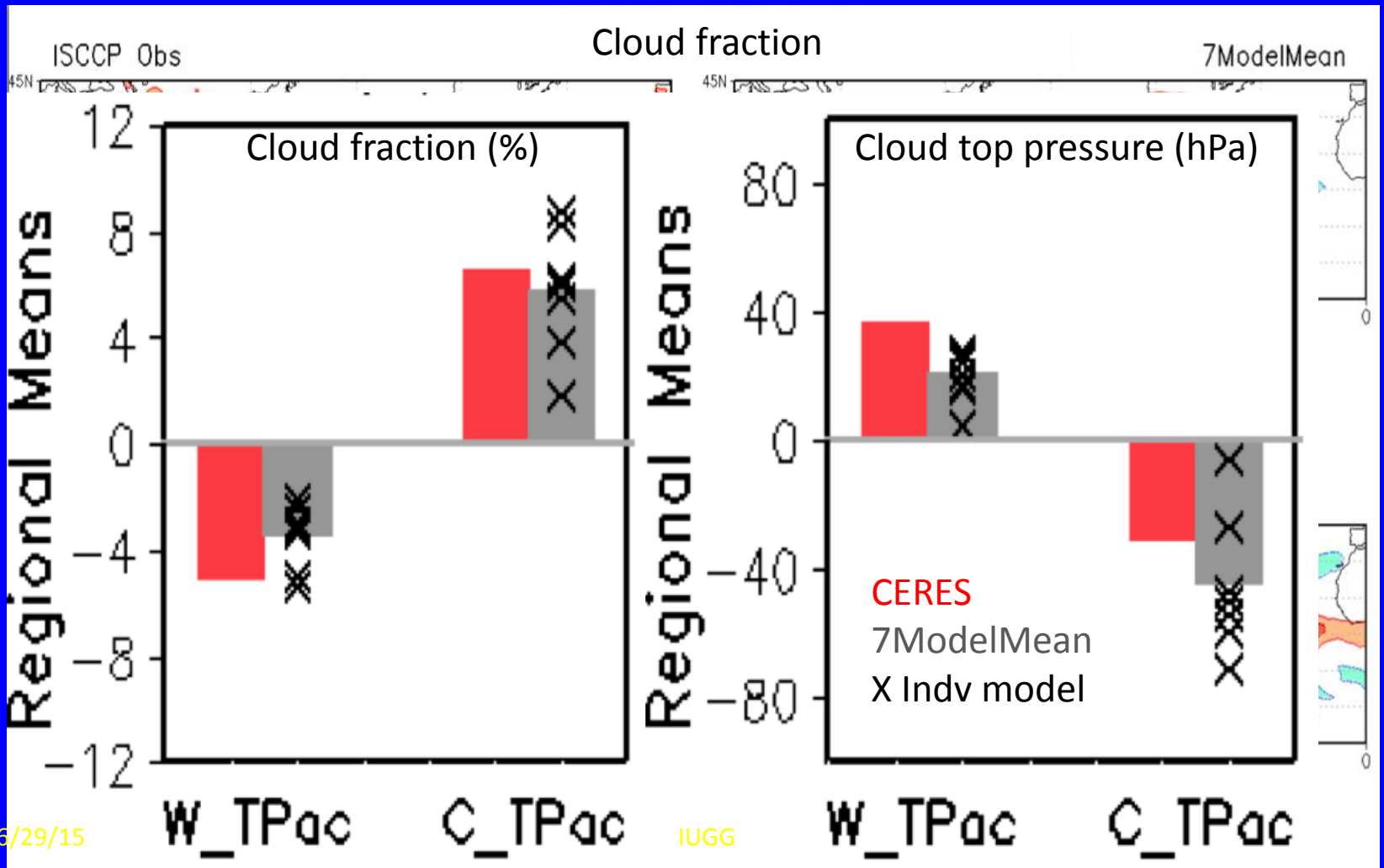
- During El Nino, SW cooling and LW warming are stronger in the central and eastern tropical Pacific, but weaker over the western tropical Pacific.
- CMIP5 multi-model mean shows similar distribution, with a pattern correlation of 0.78 for shortwave CRE and 0.86 for longwave CRE.

SW CRE

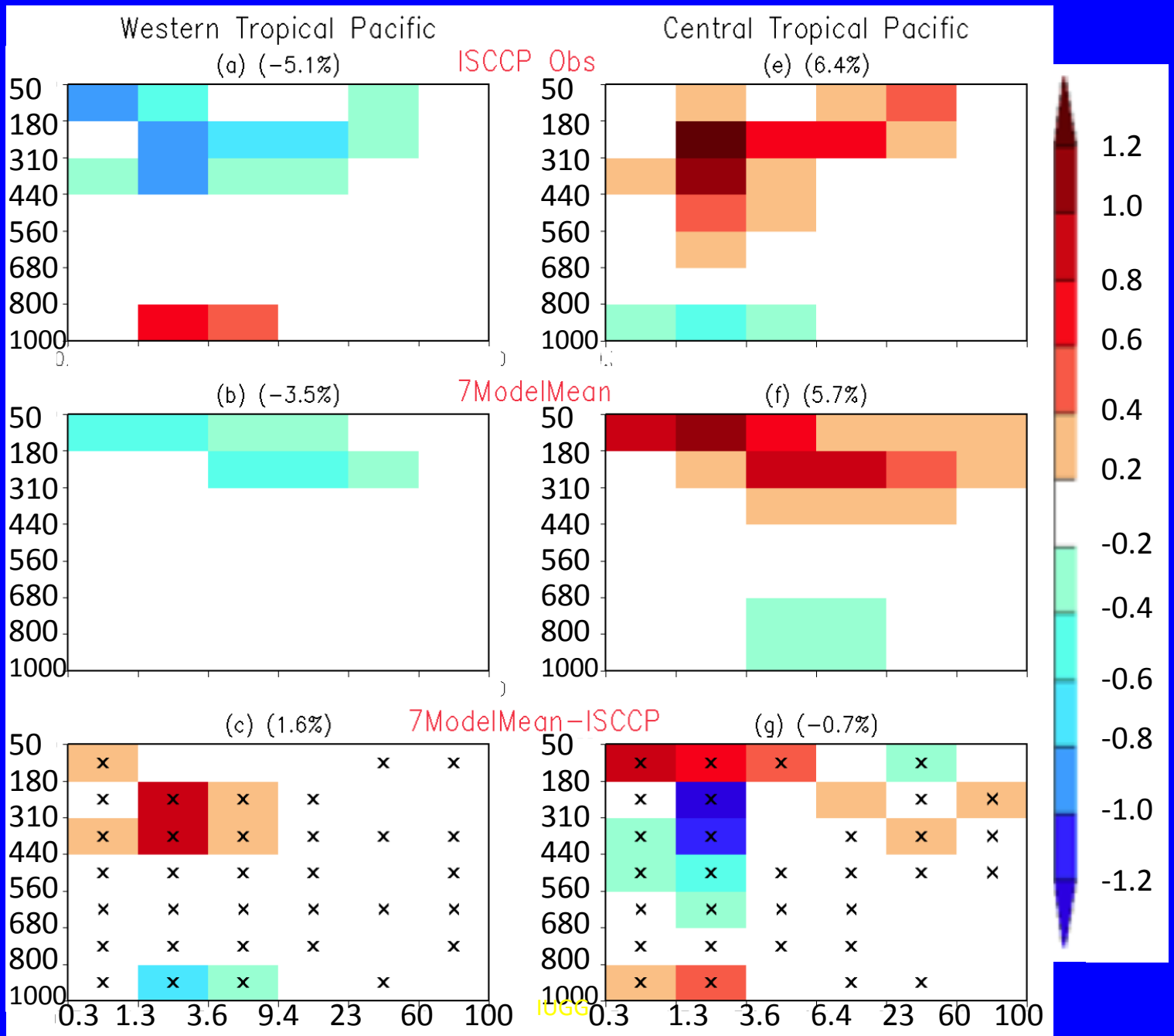


Cloud fraction and cloud top pressure anomalies associated with El Nino

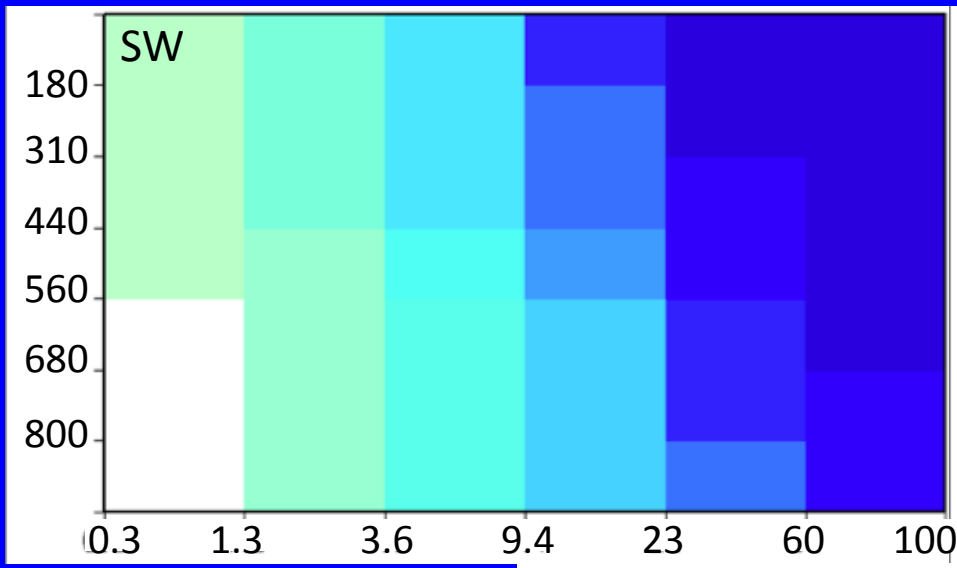
- Enhanced convection and more high clouds over central Pacific
- Weakened convection and less high clouds over western Pacific
- Pattern correlation coefficients are 0.84 for cloud fraction and 0.89 for cloud top pressure

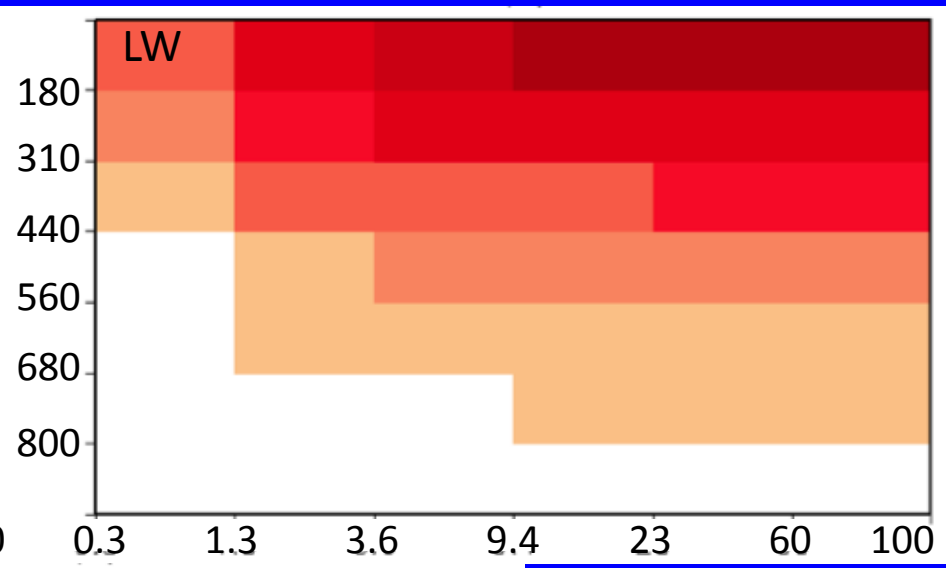


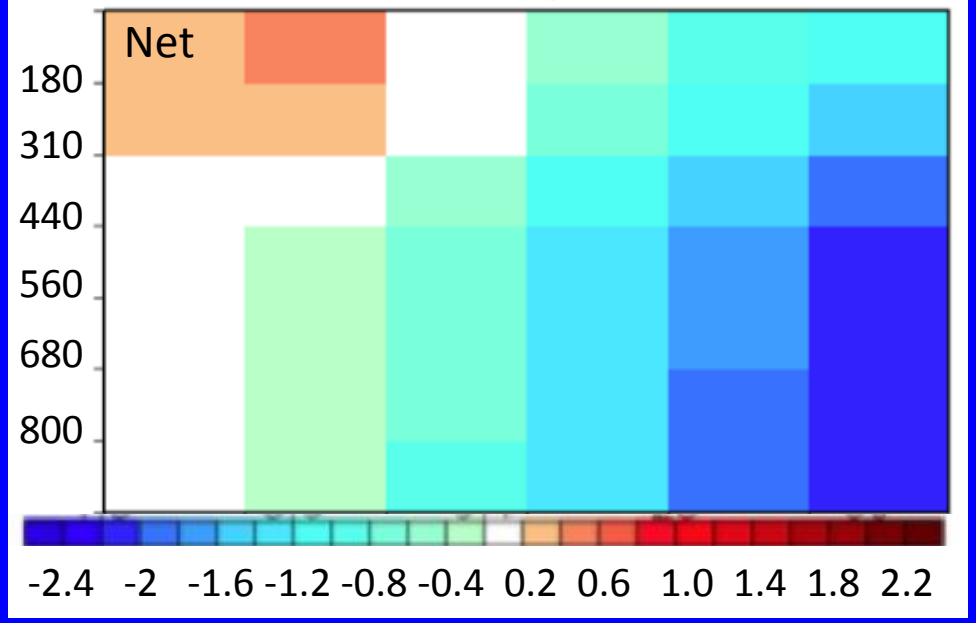
Joint CTP-τ histogram of cloud fraction anomalies associated with El Nino



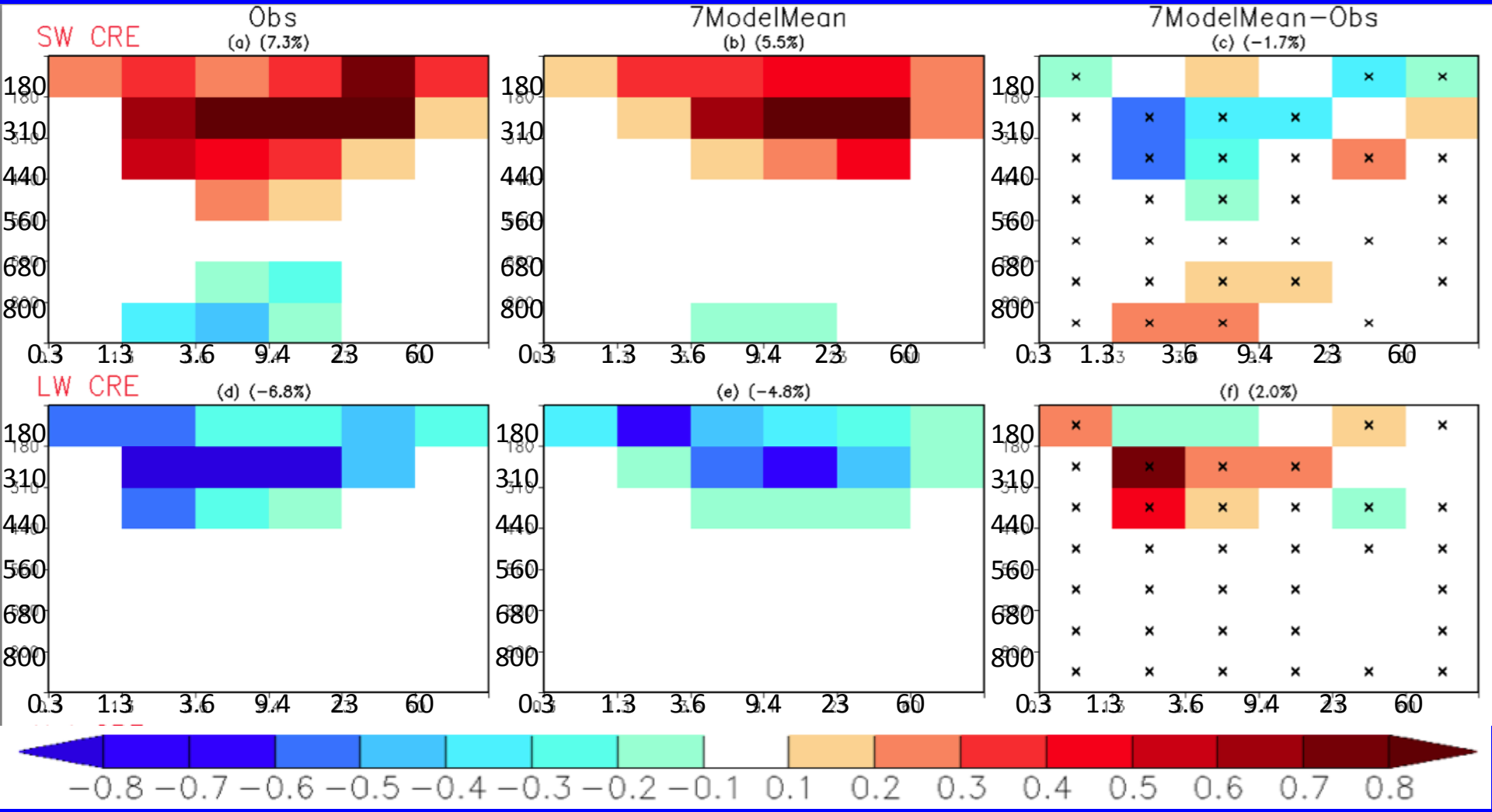
Joint CTP-τ histogram of Cloud radiative kernel (W/m2/%)



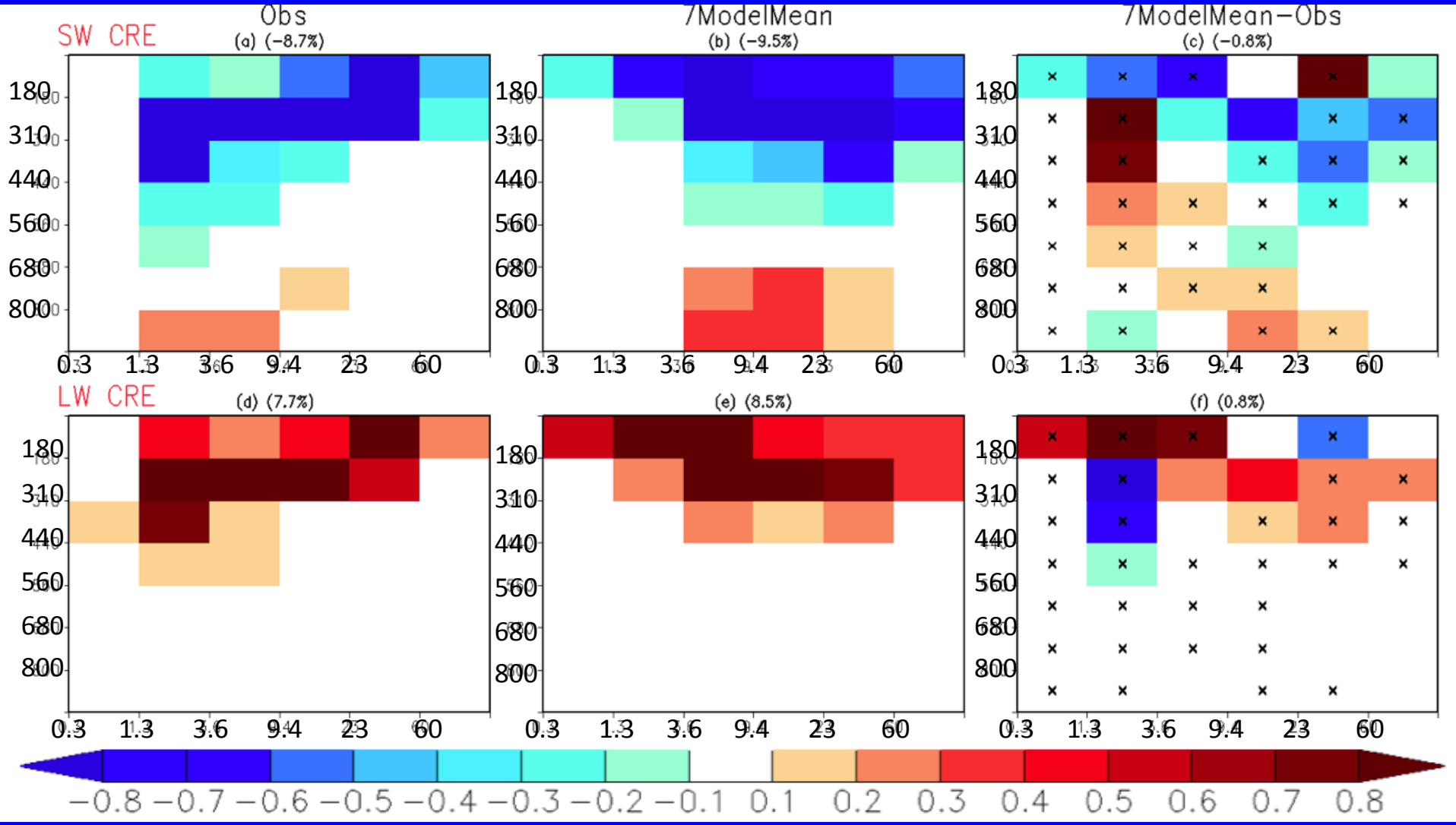




TOA cloud radiative effect anomalies associated with El Nino over the western tropical Pacific



TOA cloud radiative effect anomalies associated with El Nino over the central tropical Pacific



Summary

- Satellite observations are used to evaluate how well CMIP5 models simulate the ENSO events.
- CMIP5 multi-model means agree with the observations fairly well in the spatial pattern of cloud fraction and cloud top pressure anomalies, and the shortwave and longwave TOA CRE anomalies, but with notable differences in magnitudes.
  - Over western tropical Pacific, most CMIP5 models underestimate TOA CRE and cloud changes. The total cloud-induced shortwave and longwave TOA CRE anomalies in the multi-model mean are about 25% and 30% weaker than those derived from the observations.
  - Over central tropical Pacific, while the multi-model mean resembles observations in TOA CRE and cloud amount anomalies, it overestimates cloud top pressure decreases; there are also substantial inter-model variations.