Top-of-Atmosphere Earth Radiation Budget Variability During and After the 2014-2016 El Niño Event

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Climate Variability During CERES Record (2000-Onwards)

- Launch of Terra in 1999 occurred during prolonged La Niña conditions, which followed the major 1997/1998 El Niño event.

- 2000 and 2013:

- Relatively quiet period: no major ENSO or volcanic events (in contrast with 1990s).

- So-called "Hiatus" period with lower rate of increase in surface temperature compared to latter half of 20th century.

- Late 2013: Emergence of a persistent "warm blob" over NE Pacific.

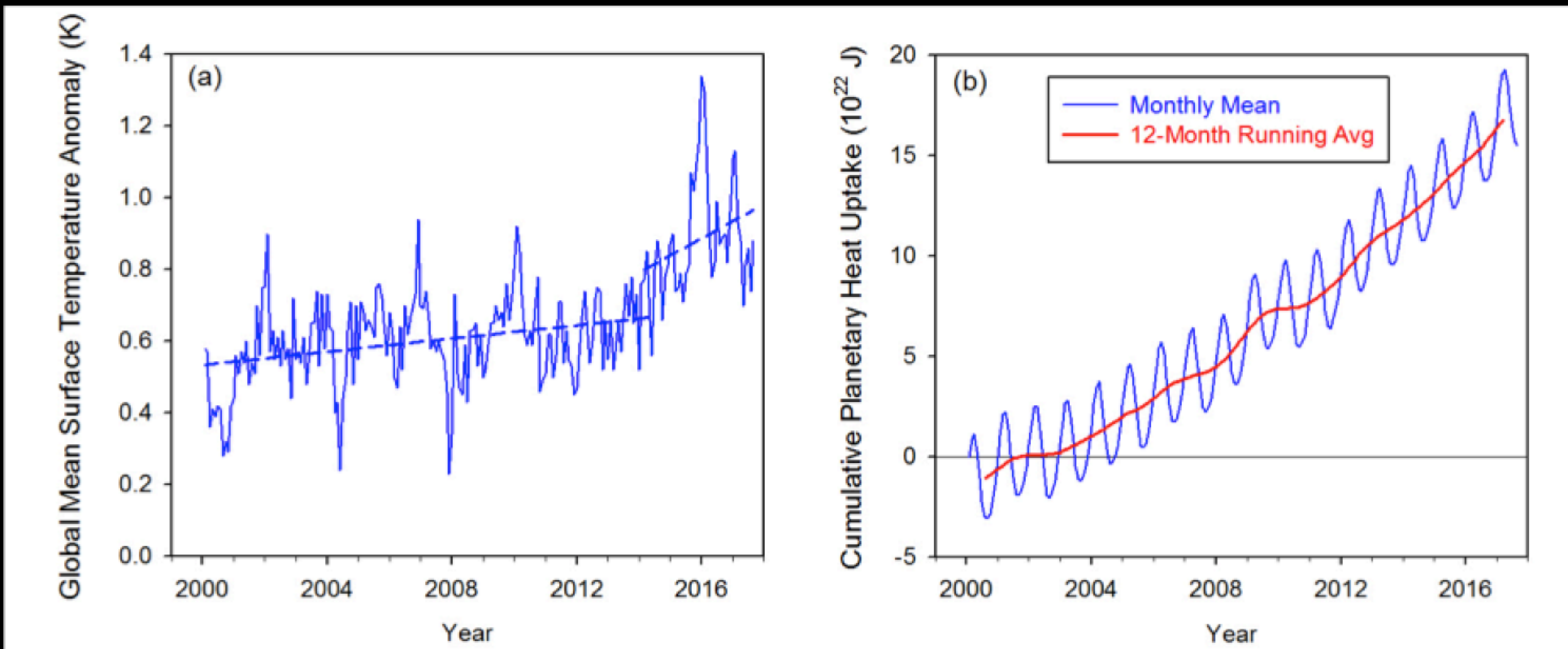
- Spring 2014: Shift in sign of PDO from negative to positive.

- Winter 2015/16: Major El Niño (comparable to 1997/98 event). End of "Hiatus" period.

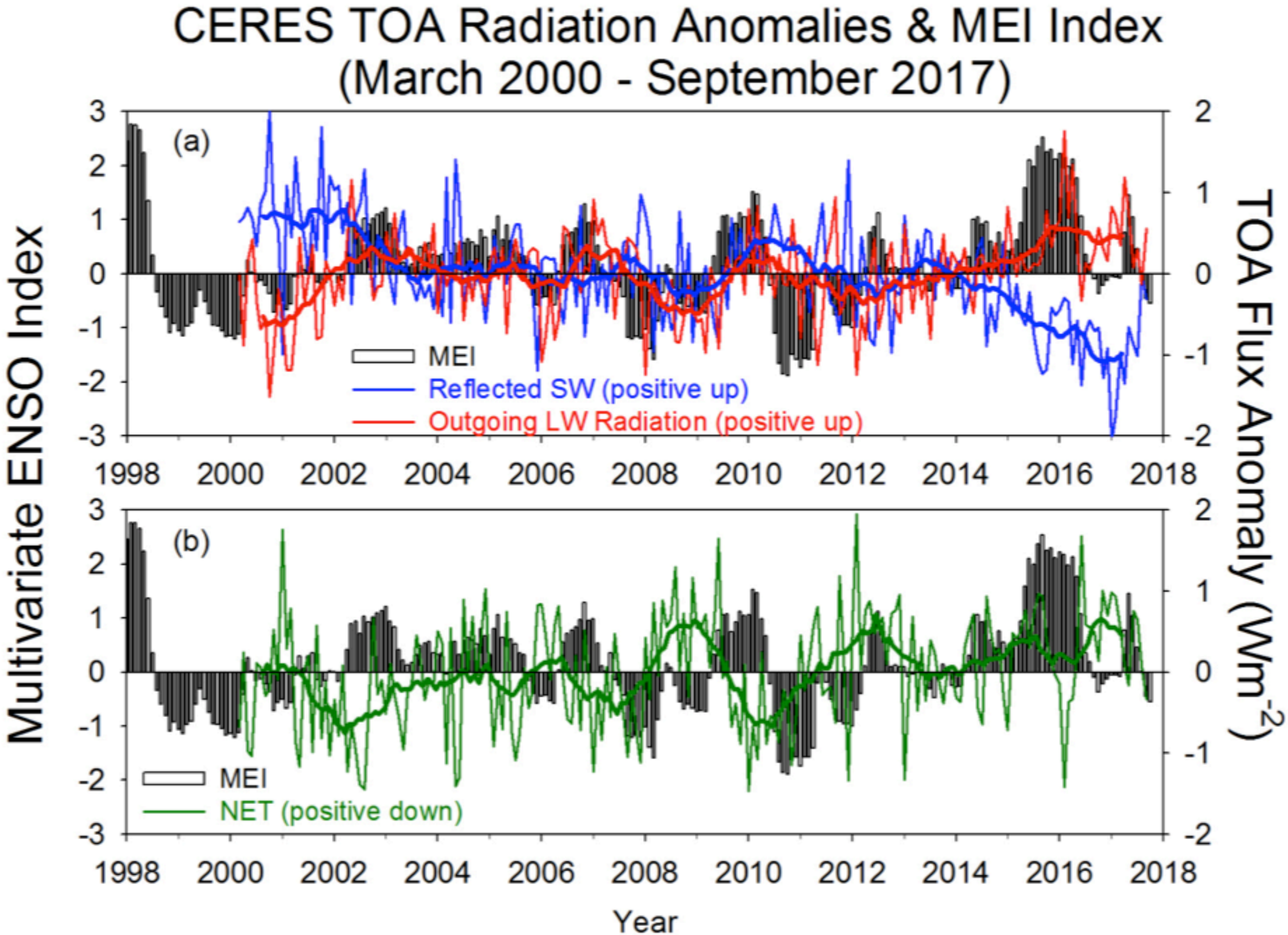
Global Mean Temperature and Planetary Heat Uptake During CERES Period

Global Mean Surface Air Temperature Anomaly Relative to 1951-1980 climatology

Cumulative Planetary Heat Uptake During CERES Period



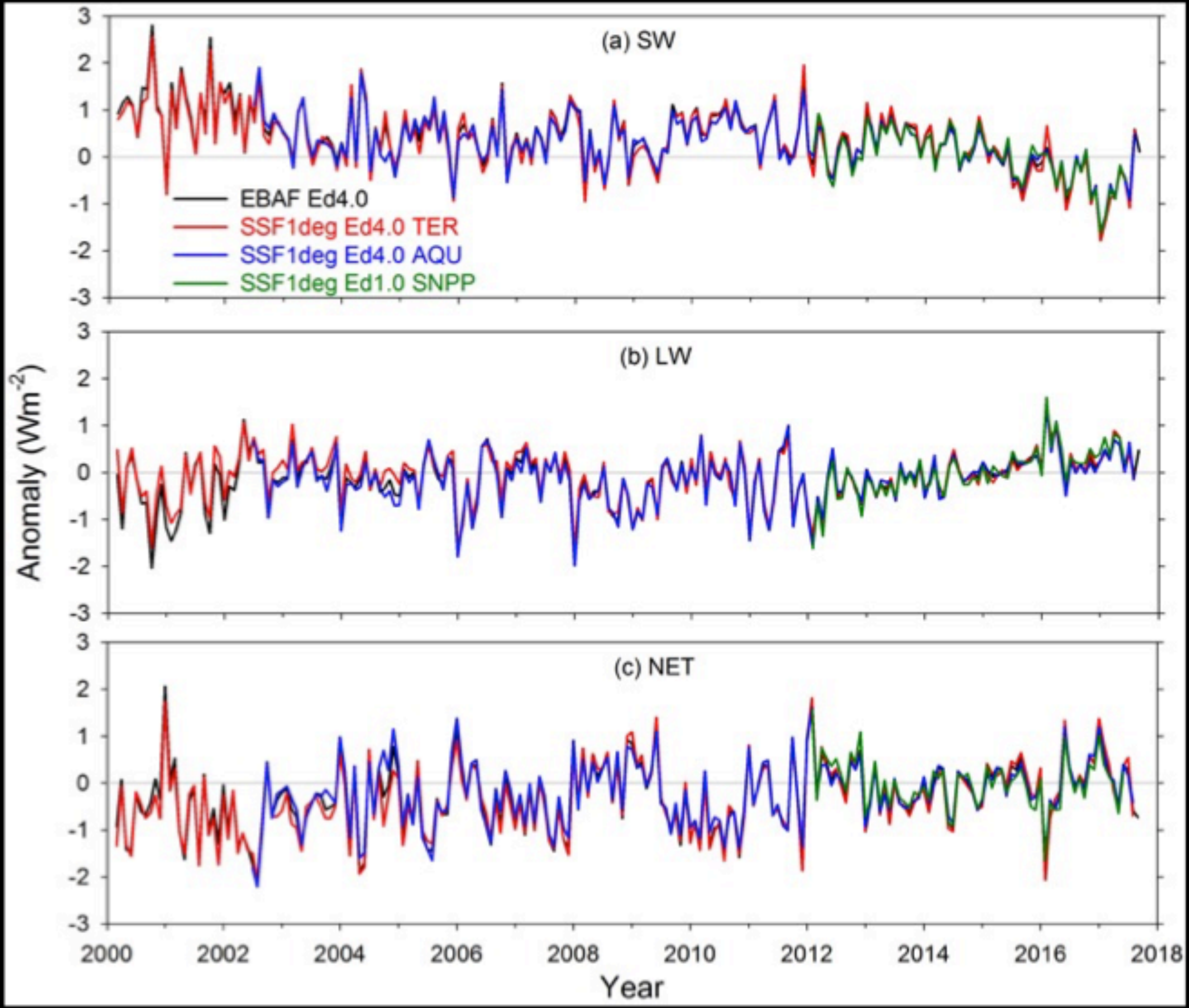
- Rate of increase in global mean temperature is a factor of 5 larger following 2015/2016 El Nino compared to prior ("hiatus") period.
- In contrast, planetary heat uptake steadily increased throughout the entire period.



CERES TOA Radiation Anomalies & MEI Index
(March 2000 - September 2017)
(a)
MEI
Reflected SW (positive up)
Outgoing LW Radiation (positive up)
(b)
MEI
NET (positive down)
Multivariate ENSO Index
TOA Flux Anomaly (Wm-2)
Year
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

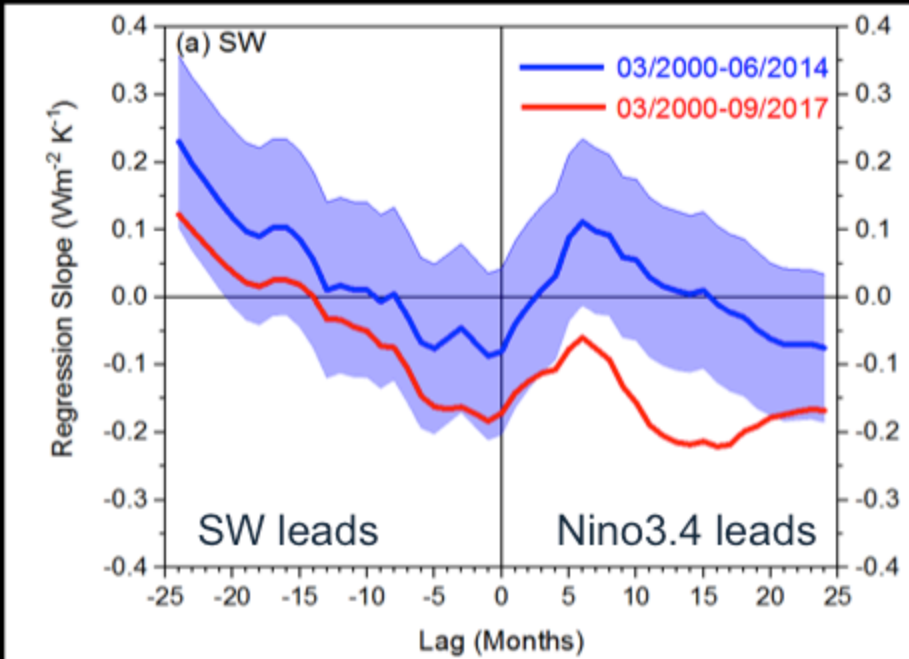
TOA Radiation Consistency Across Different Data Products and Satellites

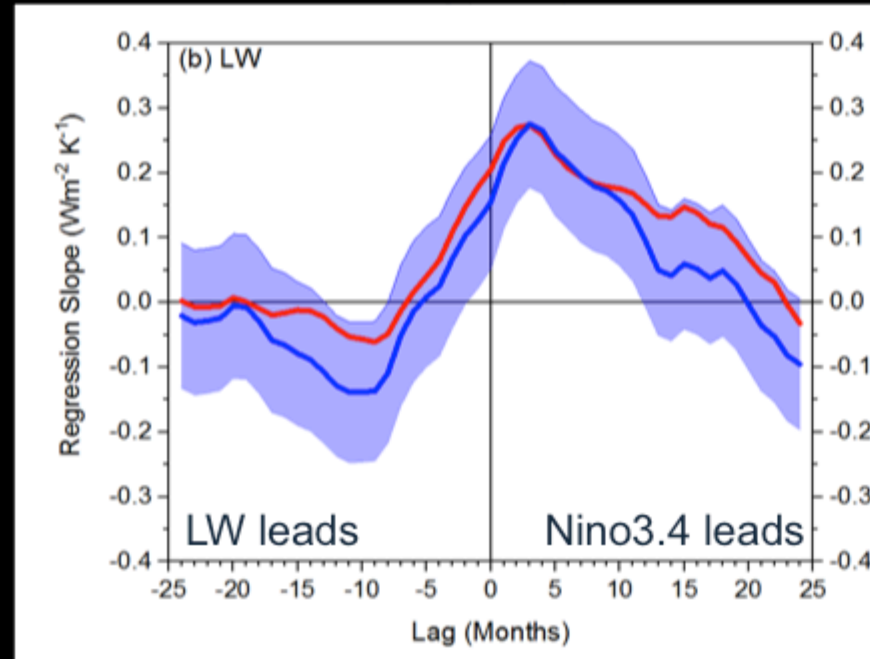
(Anomalies Calculated Using Common Climatology: February 2012-June 2017)

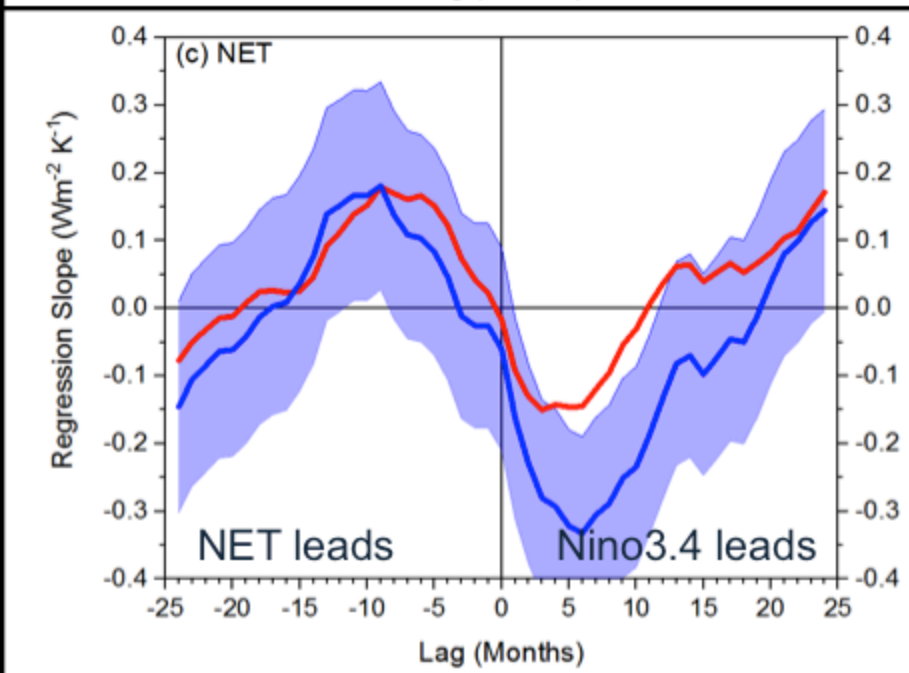


- RMS differences between monthly anomalies are < 0.12 Wm^{-2} for SW, < 0.16 Wm^{-2} for LW and < 0.17 Wm^{-2} for net TOA flux.

Lagged Regressions in TOA Radiation Anomalies Against Nino3.4 Anomalies



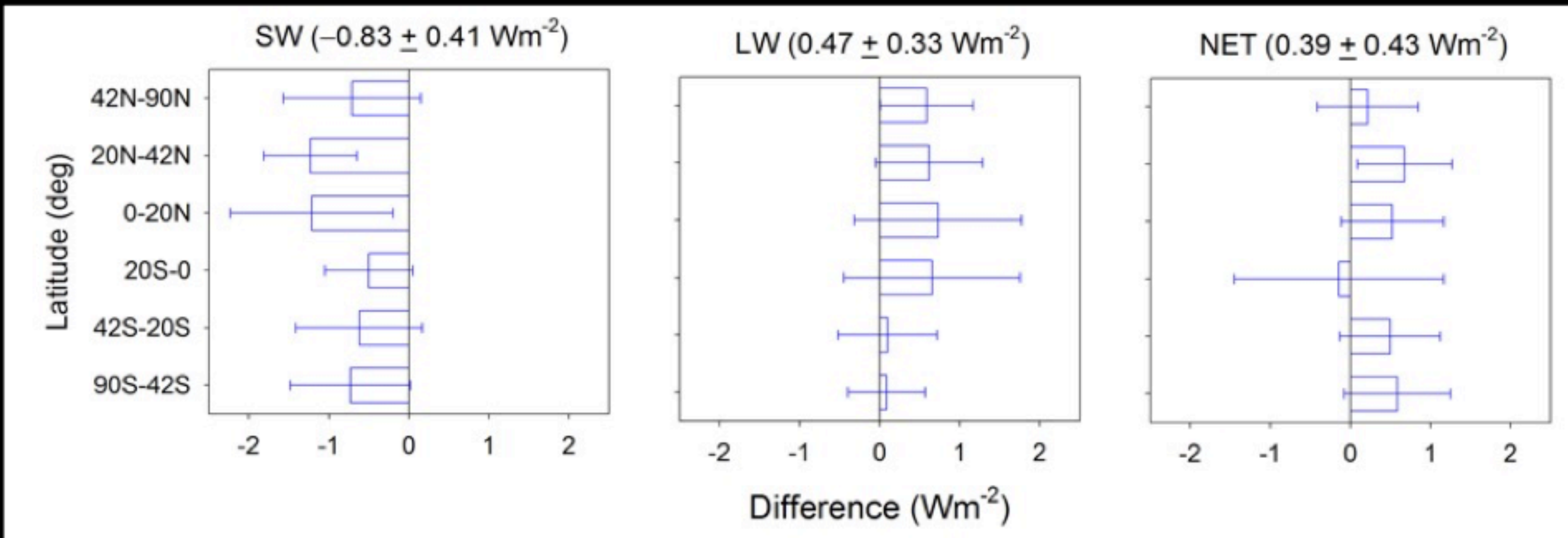




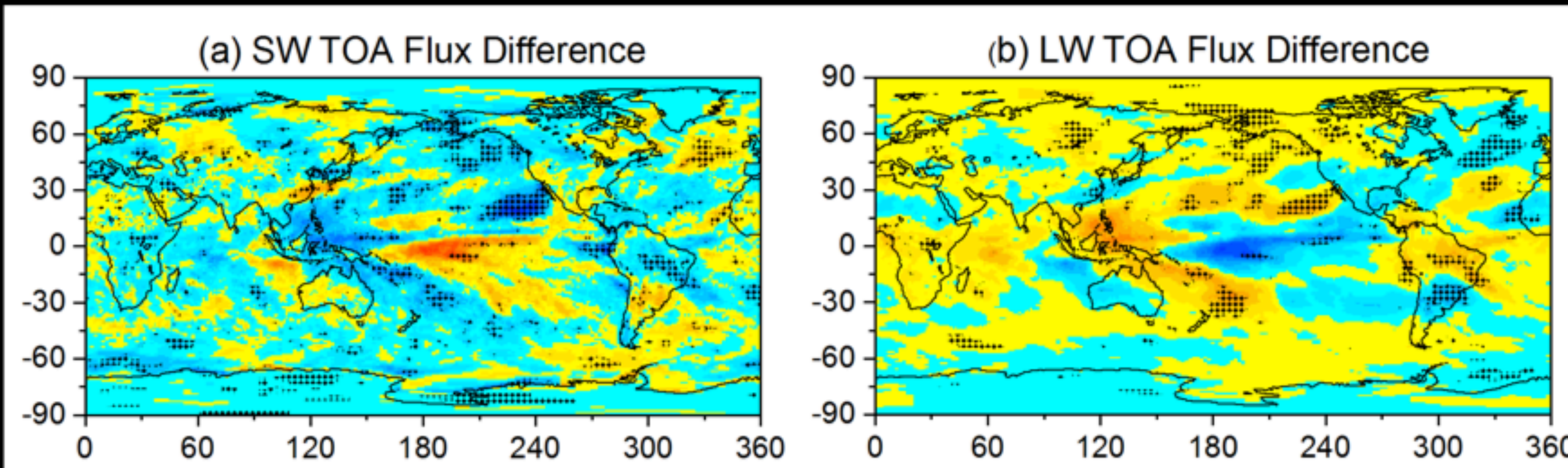
- An El Niño at zero lag is typically preceded by heat uptake into the system and followed by release of heat out of the system.
- This pattern is mainly driven by OLR.
- Unprecedented negative SW anomalies following the 2015-2016 El Niño significantly alter the TOA net radiation response to ENSO (red line).

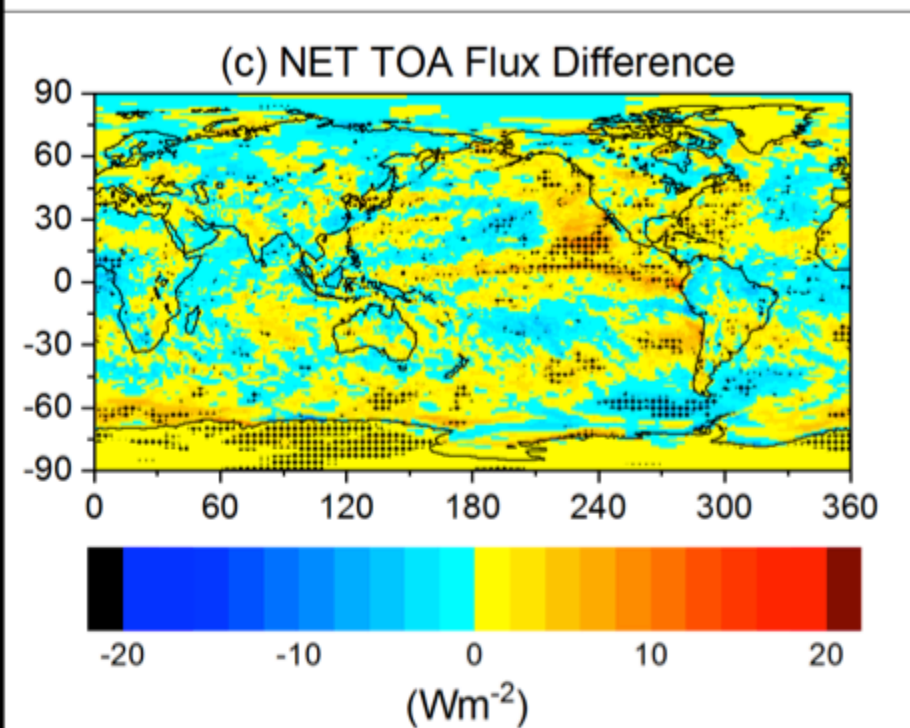
⇒ Less heat release out of the system following El Niño.

Zonal Mean Differences in TOA Radiation (07/2014-06/2017) minus (07/2000-06/2014)



Regional Mean Differences in TOA Radiation (07/2014-06/2017) minus (07/2000-06/2014)





- TOA flux difference pattern in the tropics is dominated by ENSO.
- Substantial decrease in SW TOA flux (increase in net downward flux) over Eastern Pacific (especially off of CA) and N. Pacific Ocean.

CERES-PRP (Partial Radiative Perturbation) Methodology

- Goal is to decompose the total radiative flux anomalies into the contributions from individual variables (e.g., cloud, surface, aerosol, etc., parameters).

$$\partial F^f_{\Delta x} = F(x, y_1, ..., y_N) - F(\overline{x}, y_1, ..., y_N) + O^f(\Delta x) \quad (1)$$

- Flux (F) difference of monthly means (x,y) and climatological monthly means ($\overline{x}$,$\overline{y}$)

Can also compute the same thing relative to a different base state:

$$\partial F^b_{\Delta x} = F(x, \overline{y_1}, ..., \overline{y_N}) - F(\overline{x}, \overline{y_1}, ..., \overline{y_N}) + O^b(\Delta x) \quad (2)$$

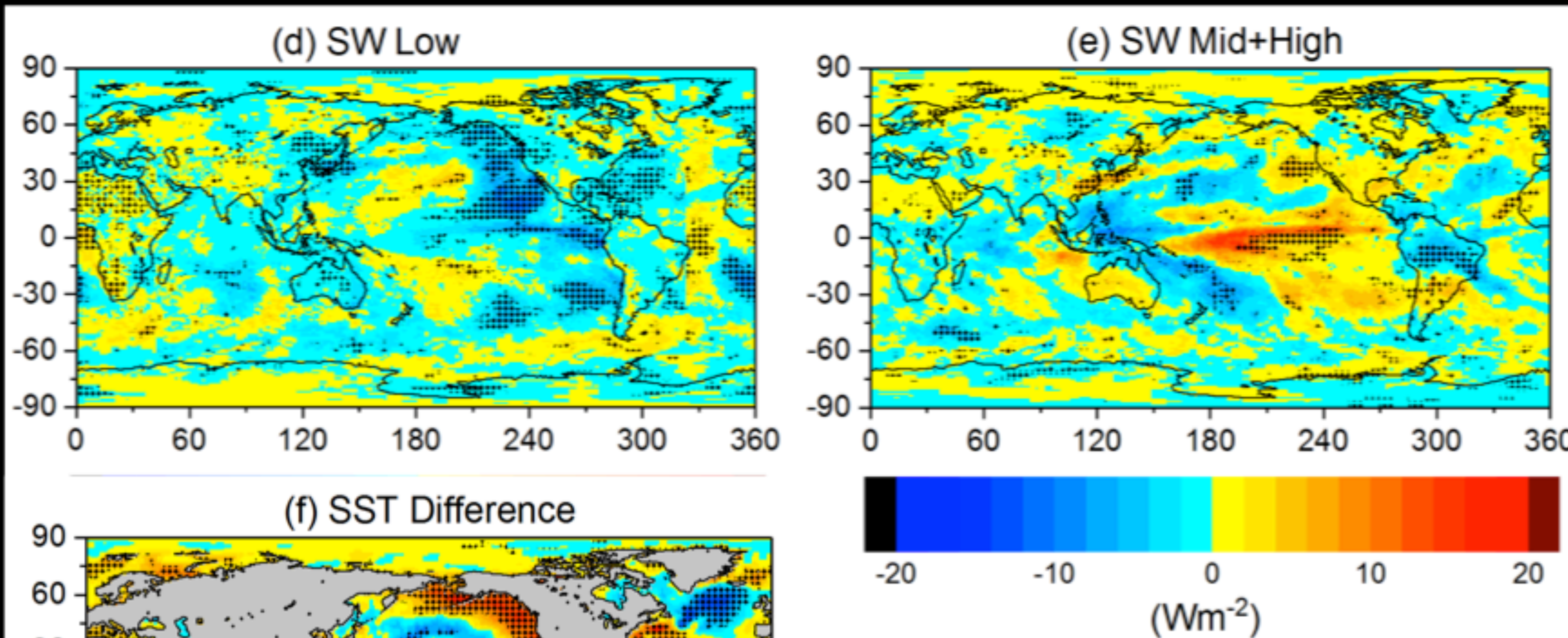
- $O^f(\Delta x)/O^b(\Delta x)$: truncation error

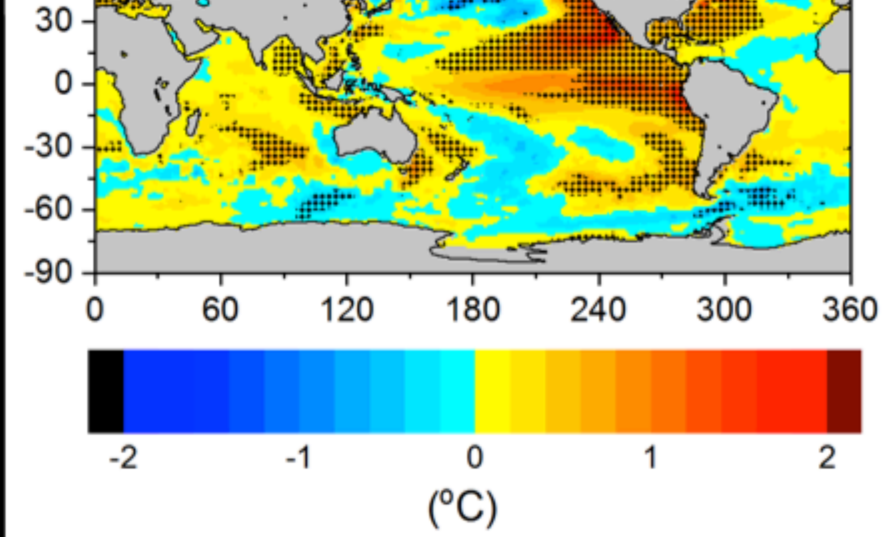
Reduce error by averaging the forwards (f) and backwards (b) difference

$$\partial F_{\Delta x} = \frac{\partial F^f_{\Delta x} + \partial F^b_{\Delta x}}{2} + O(\Delta x^2) \quad (3)$$

- From monthly-mean inputs, climatologies are constructed and the variables combined to make the 4 sets of inputs $\rightarrow$ Fu-Liou radiative model

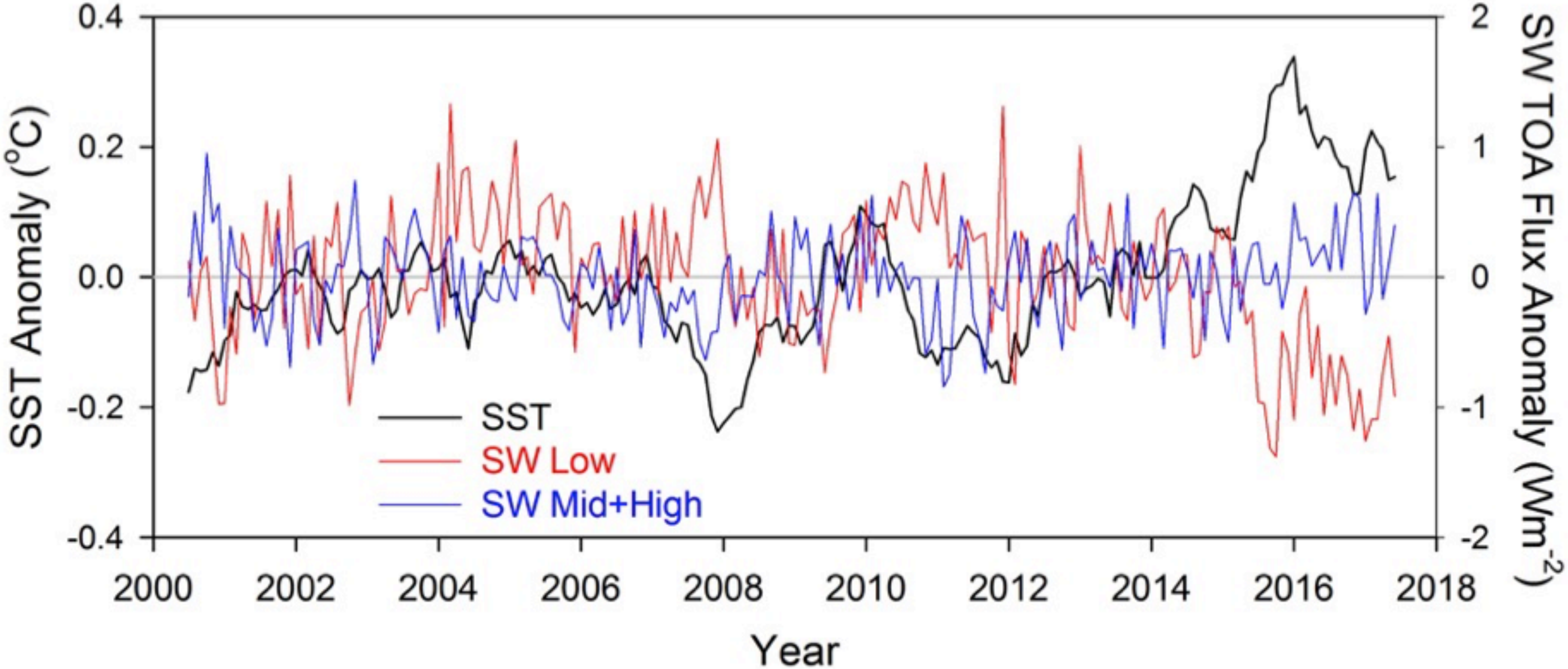
PRP SW TOA Flux & SST Difference Patterns
(07/2014-06/2017) minus (07/2000-06/2014)



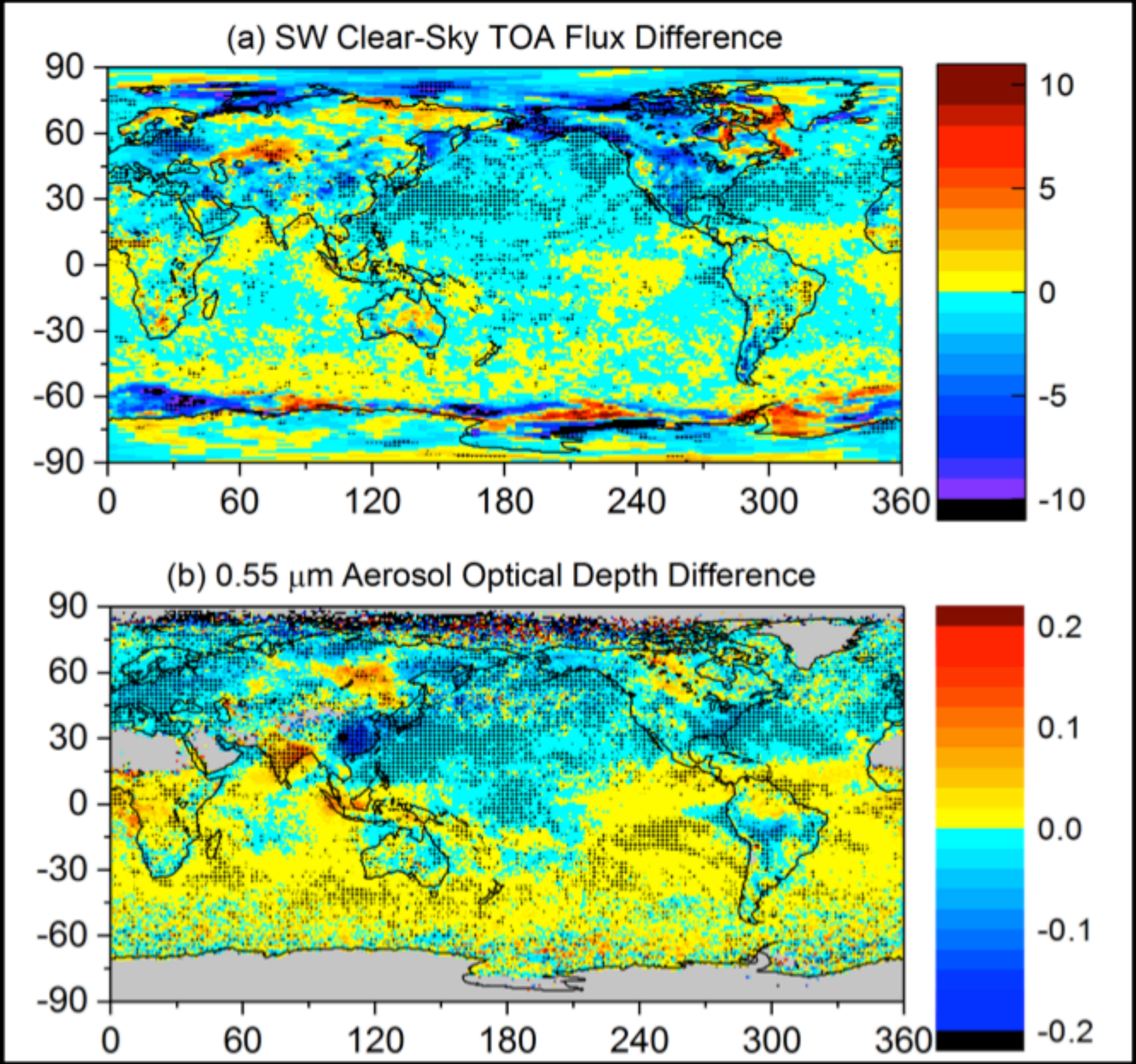


- Reduction in SW TOA flux along Eastern Pacific due to decrease in low cloud cover.
- Low cloud cover decrease occurs in regions of significant SST warming.

PRP SW TOA Flux & SST Anomalies



Regional Mean Differences in SW Clear-Sky TOA Radiation & AOD (07/2014-06/2017) minus (07/2000-06/2014)



Conclusions

- Latter part of CERES record characterized by significant decrease in SW TOA flux due to a decrease in low cloud fraction over the Eastern Pacific.

- These changes coincide with shift in sign of PDO to positive, and anomalous SST pattern over E. Pacific.

- Largest uncertainty in projecting climate response to doubling CO_2 is associated with low cloud feedback.

- Observed low cloud fraction changes provide an unprecedented opportunity for testing climate models (e.g., AMIP simulations vs observations).

Thank You!

NPP Launch Arc, Oct. 28, 2011