

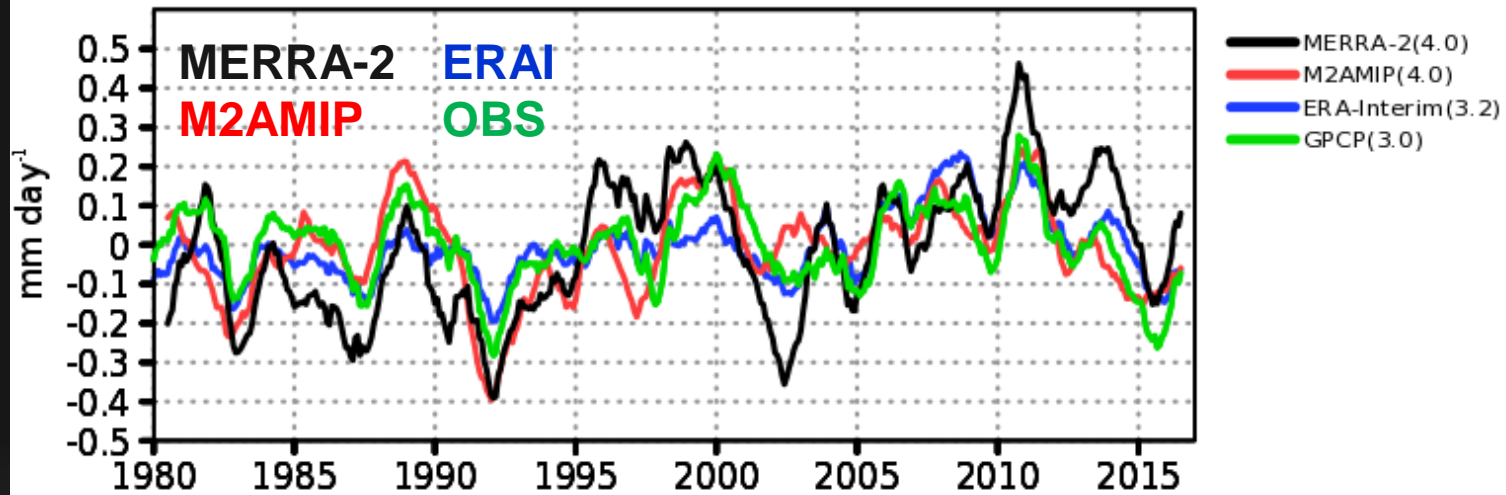


# El Niño Coupled Tropical Land Surface Hydrologic Response

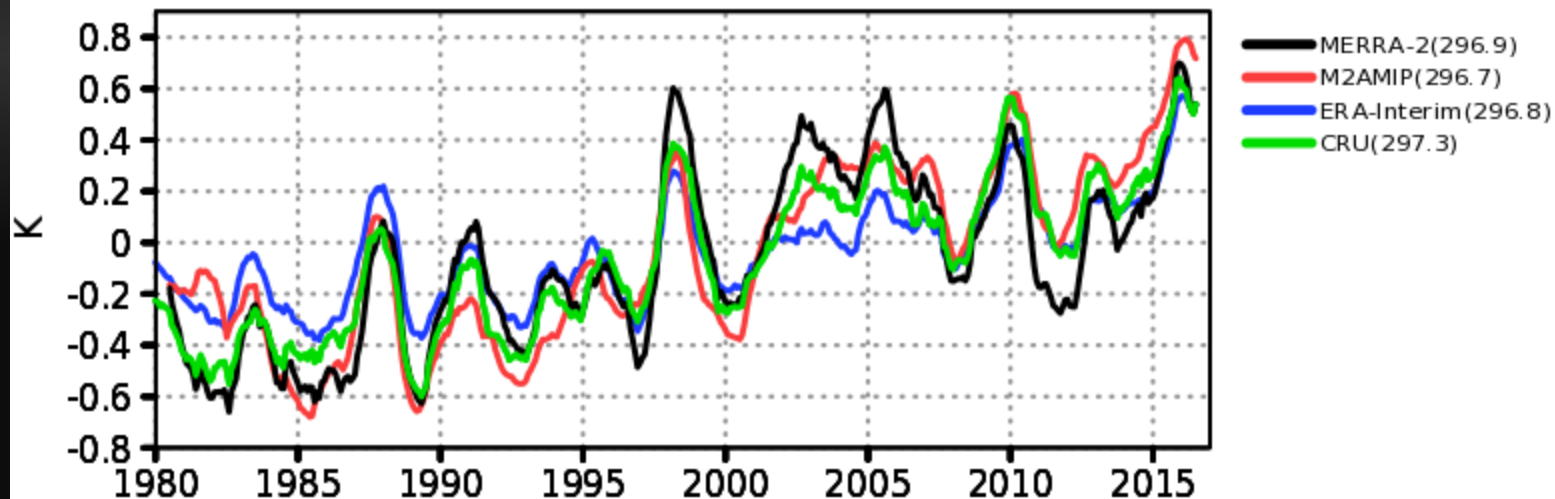
Michael G. Bosilovich (NASA GSFC), Franklin R. Robertson  
(NASA MSFC) and Paul Stackhouse (NASA LaRC)

# Tropical Land Precipitation and Temperature

Land(30) Monthly Anomaly Precipitation ( $\text{mm day}^{-1}$ )

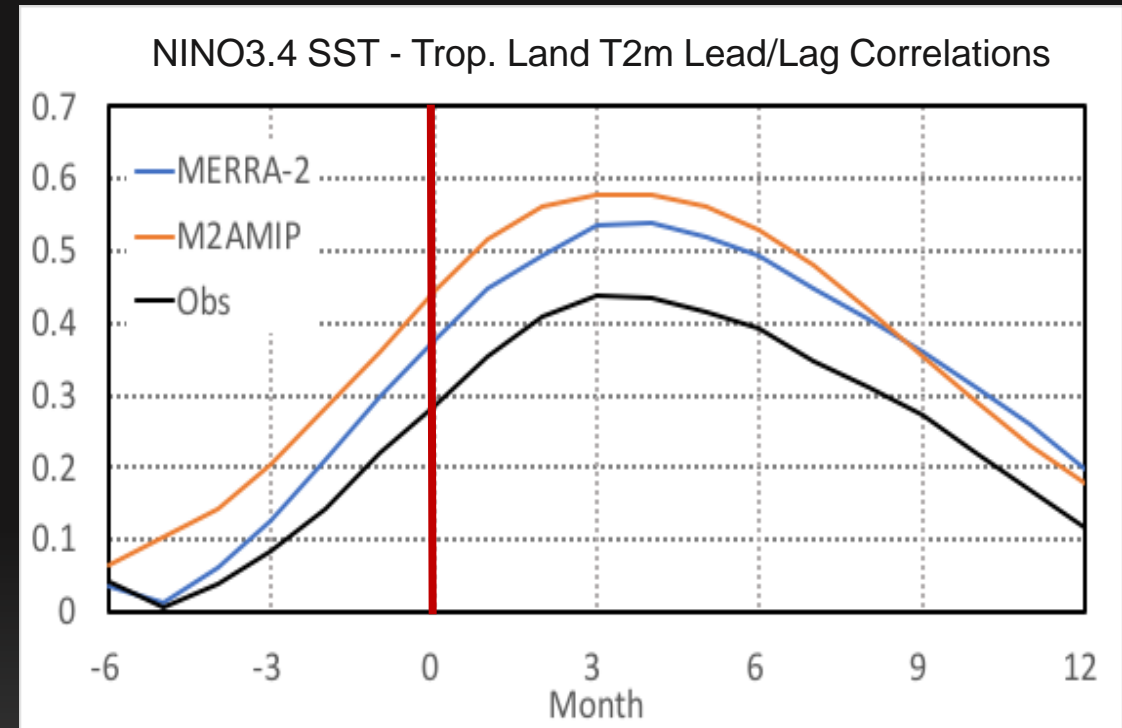
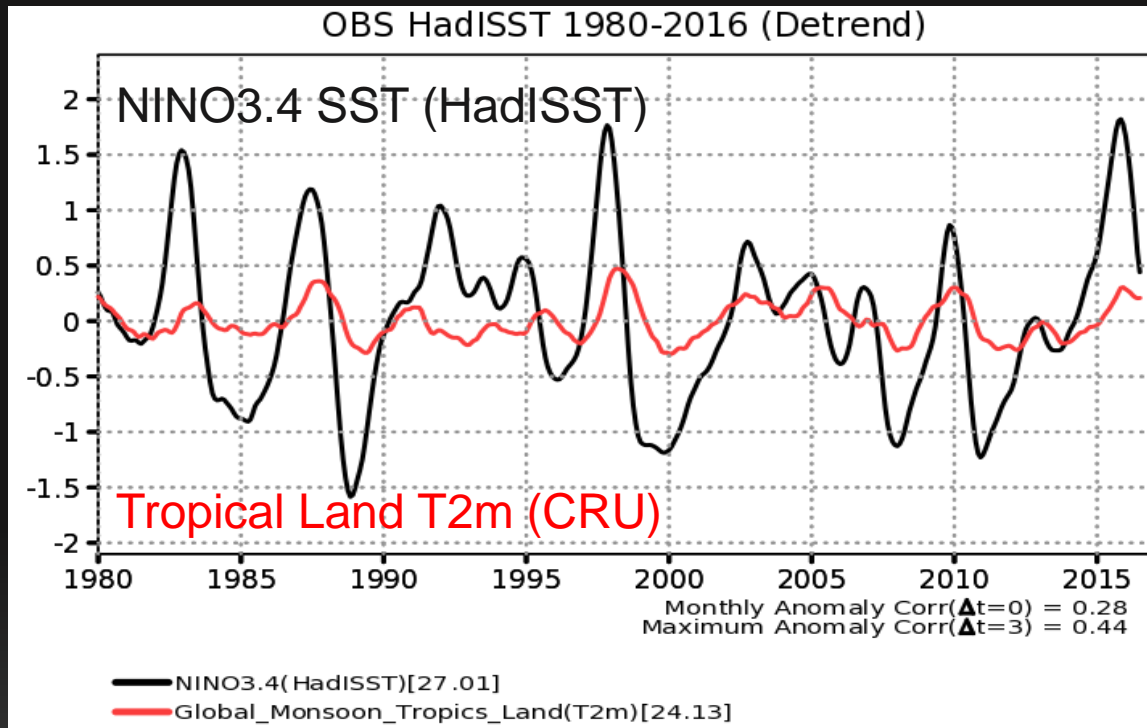


Land(30) Monthly Anomaly 2m Temp (K)



- Many regions around the world, especially in the tropics, show drought modes related to ENSO or SST in general (Schubert et al. 2016)
- El Niño leads to troposphere warming around the tropical belt (Chiang and Sobel, 2002)
- Warming oceans lead to warmer land owing to downwelling LW radiation in present day coupled models (Compo and Shardeshmukh 2009)
- AMIP Ensemble isolates the signal from SST forcing
- **Reanalyses assimilate obs** and so, should provide realistic large scale environment

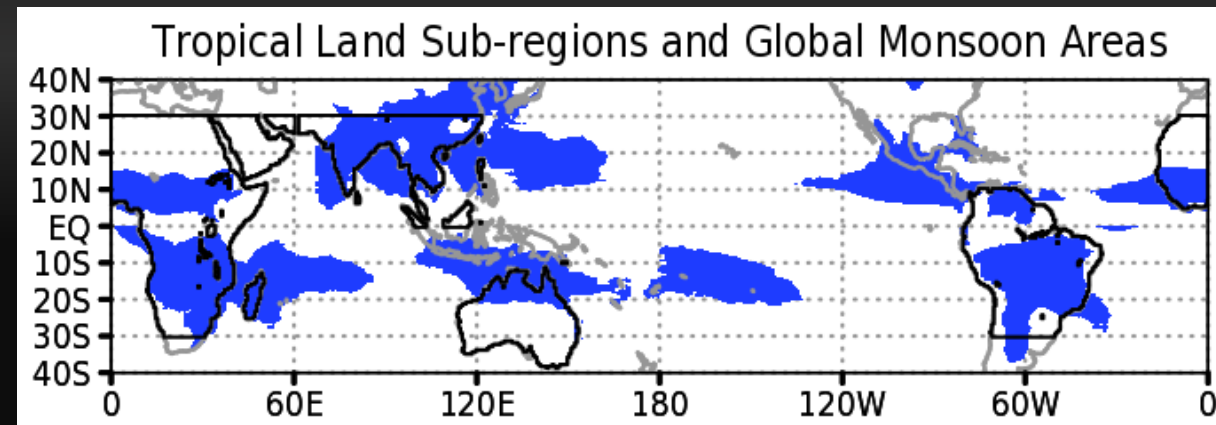
# Motivation: Tropical Land Warming/Drought following El Niño



- The continental tropics warming/drought following El Niño is well observed (Chiang and Lintner 2005; Schubert et al. 2016)
- MERRA-2 and M2AMIP (ensemble) produce similar, but stronger, lead/lag correlations of the tropical land temperatures

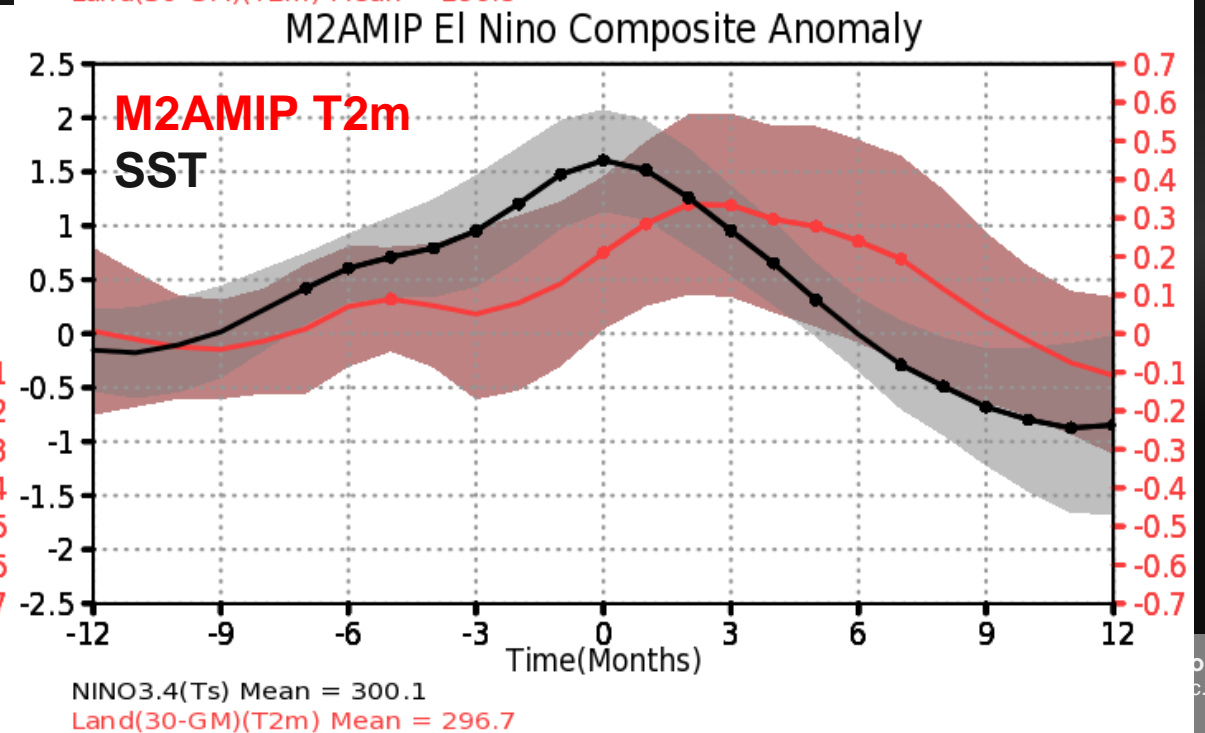
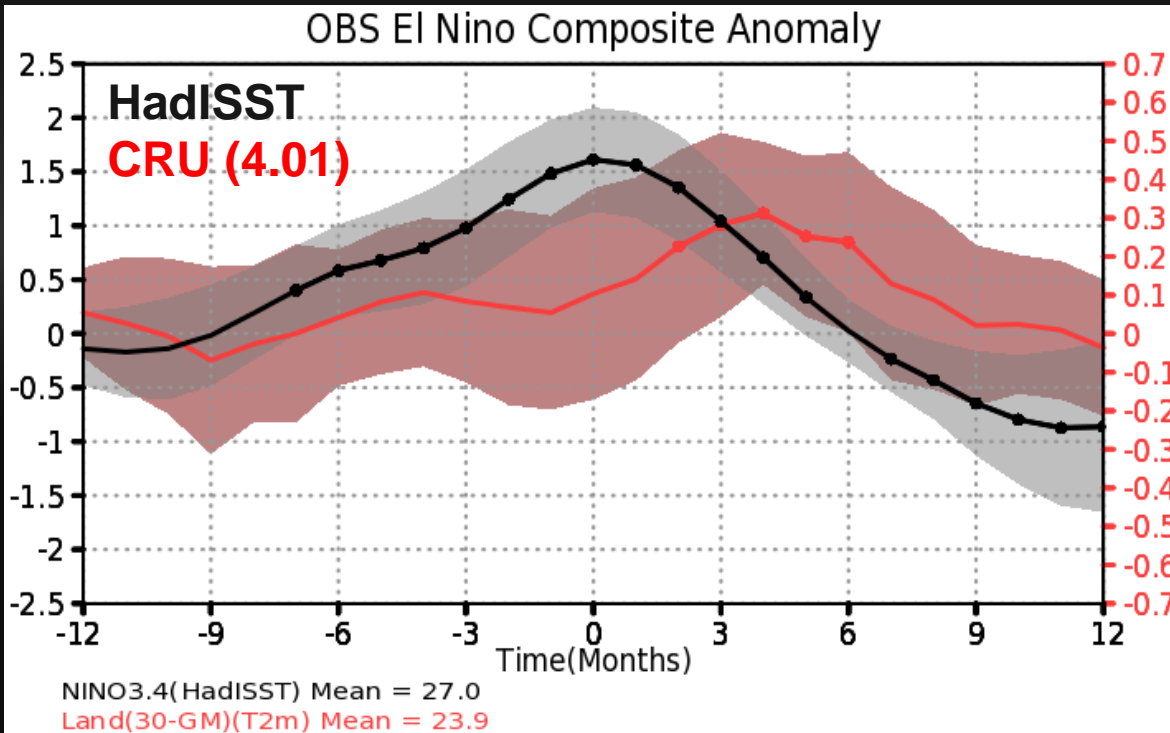
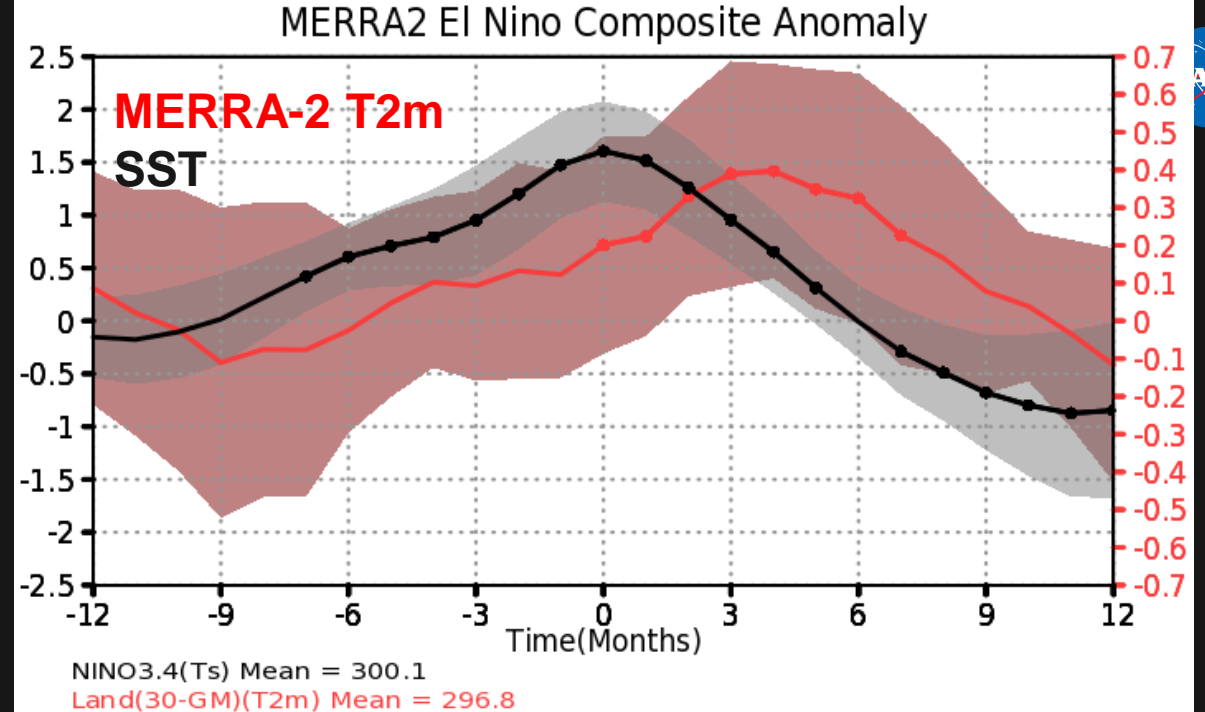
# Data and Methods

- **MERRA-2**: Obs Corr Precip for Land Reichle et al (2017); Gelaro et al. (2017)
- **M2AMIP**: Uses the same model and climate forcing, including SST as MERRA-2. **10-member** ensemble mean. Collon et al. (2017)
- **Observations**: CRU (4.01 Harris et al. 2014), GPCP (v2.3), GEWEX Surface Radiation Budget (3.0 Zhang et al. 2009)
- **Composite El Niño**
  - **Deseasonalize and detrend** the anomaly time series
  - Find the peak surface temperature in the Niño34 region
  - Collect data for each of **8 peak NINO3.4** (+- 12 months) computing mean and st. dev.
- **Global Monsoon Region**: (e.g. Wang et al. 2012)



# Tropics Temperature Composite El Niño

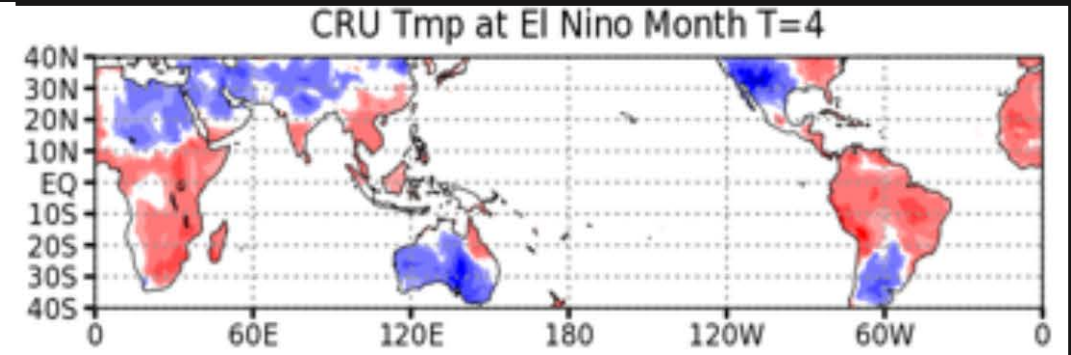
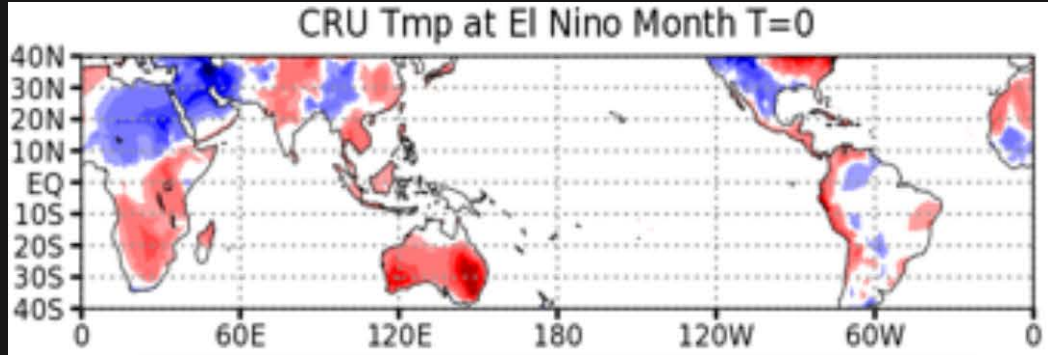
- MERRA-2: warms more than observed, a little earlier
- M2AMIP: Smoother; has early warming, but not as warm as M2
- Warm temps may persist longer



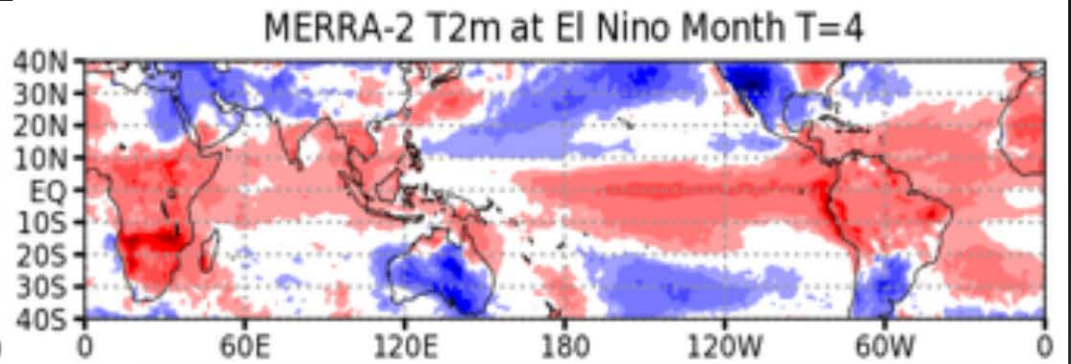
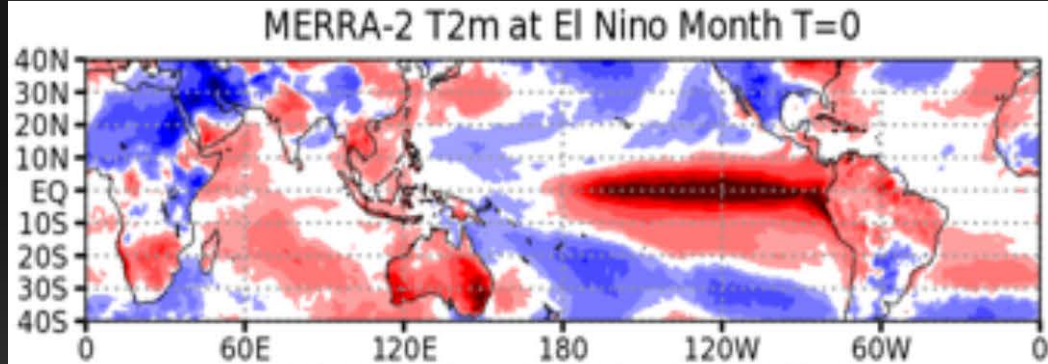


# Composite of 2m Air Temperature

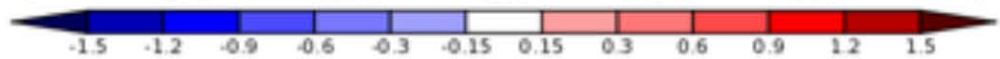
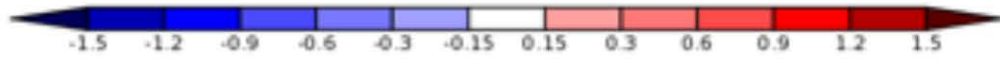
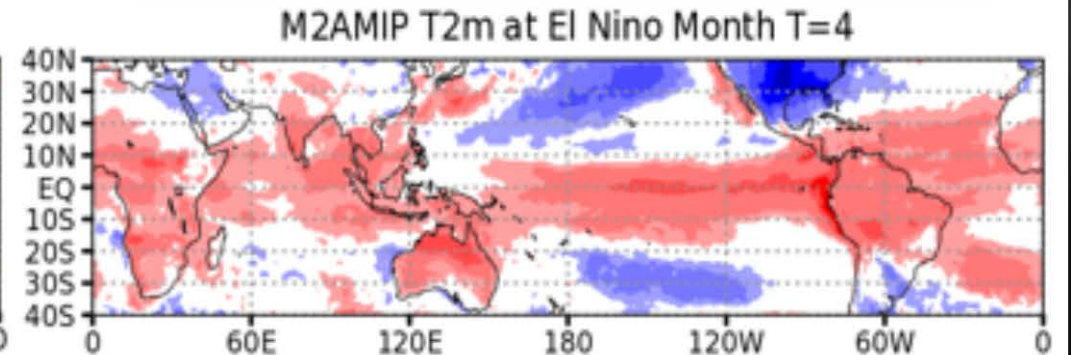
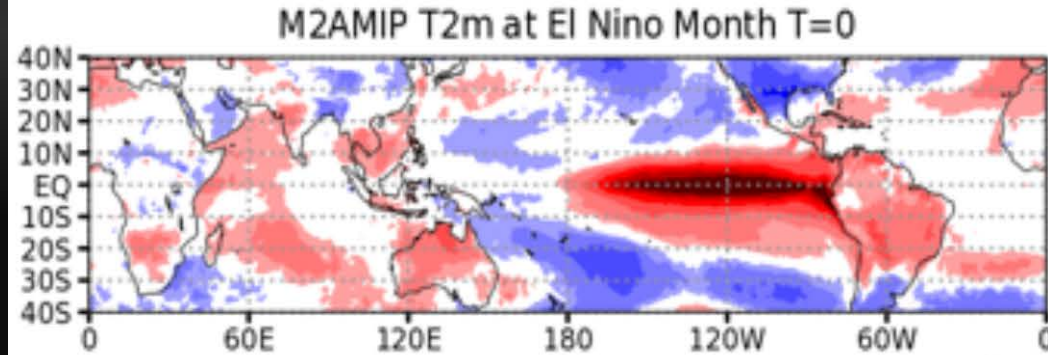
CRU



MERRA-2



M2AMIP



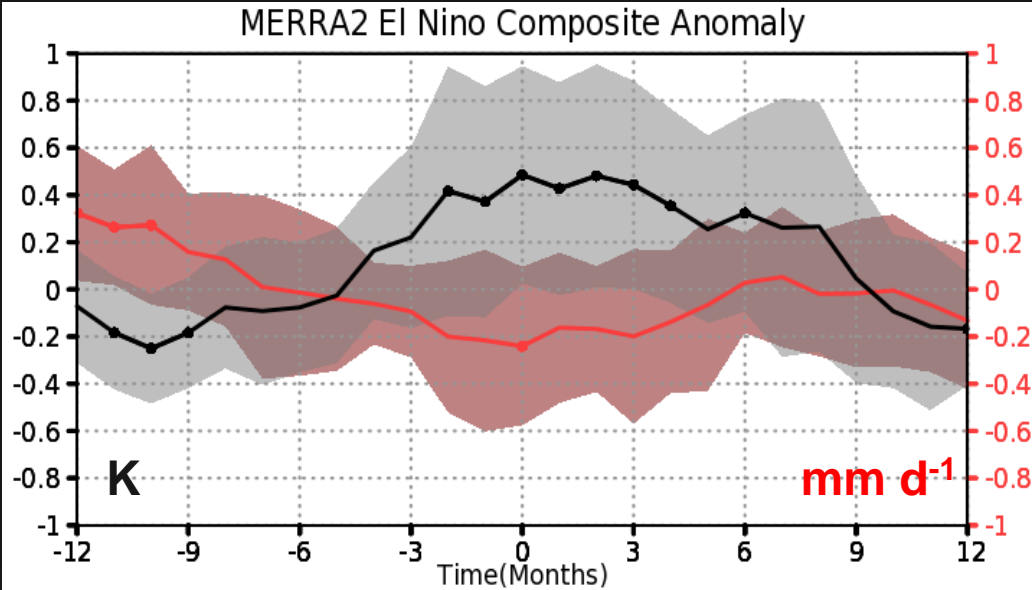
T=0

T=+4

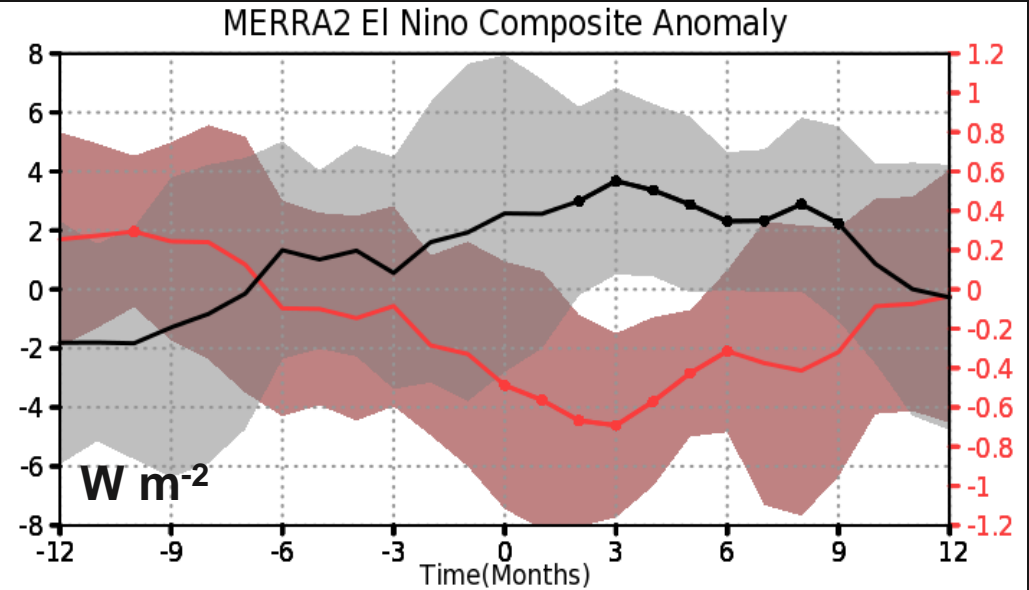
# South America: MERRA-2

T2m  
Prec

SWgCRE  
LWgCRE



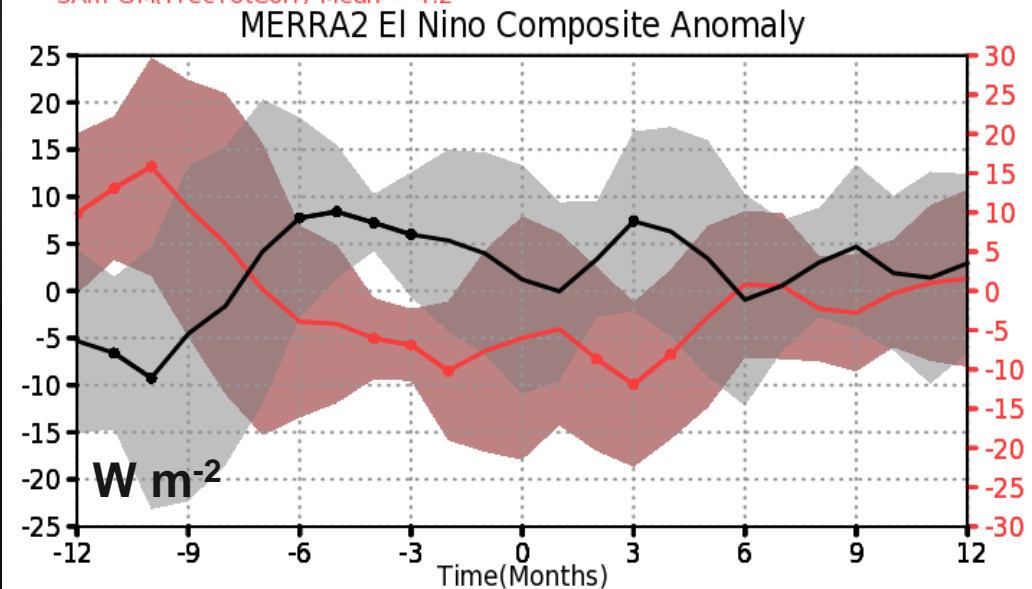
SAm-GM(T2m) Mean = 297.2  
SAm-GM(PrecTotCorr) Mean = 4.2



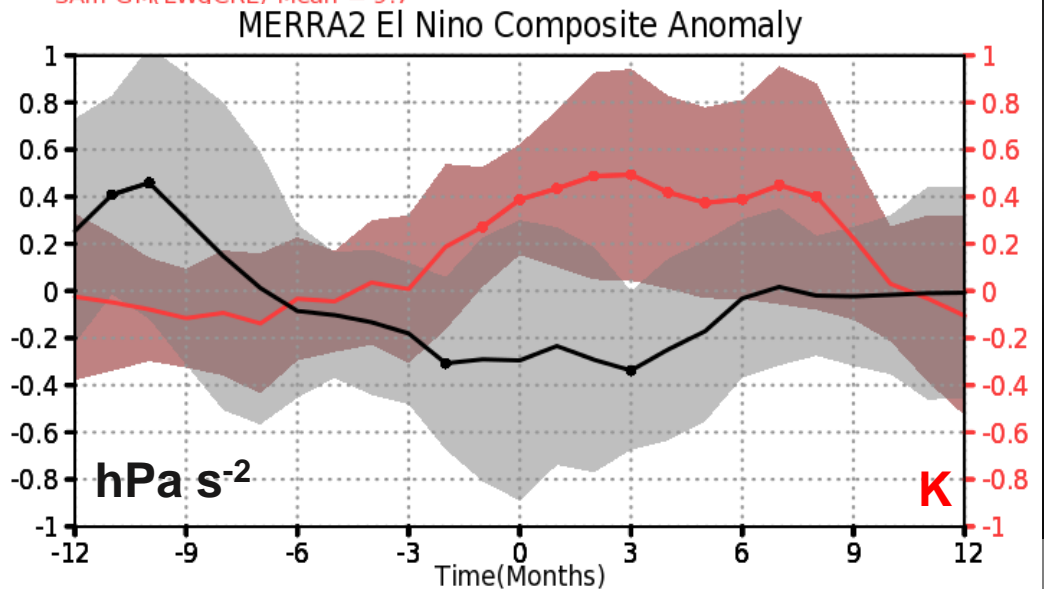
SAm-GM(SWgCRE) Mean = -55.8  
SAm-GM(LWgCRE) Mean = 9.7

Conv.  
CpT+Phi  
Lqv

-Ω (500)  
T(500)



SAm-GM(-(divCpT+divPhi)) Mean = -108.0  
SAm-GM(-2.454e6\*divqv) Mean = 42.2



SAm-GM(-100\*Omega500) Mean = 1.5  
SAm-GM(T500) Mean = 267.3

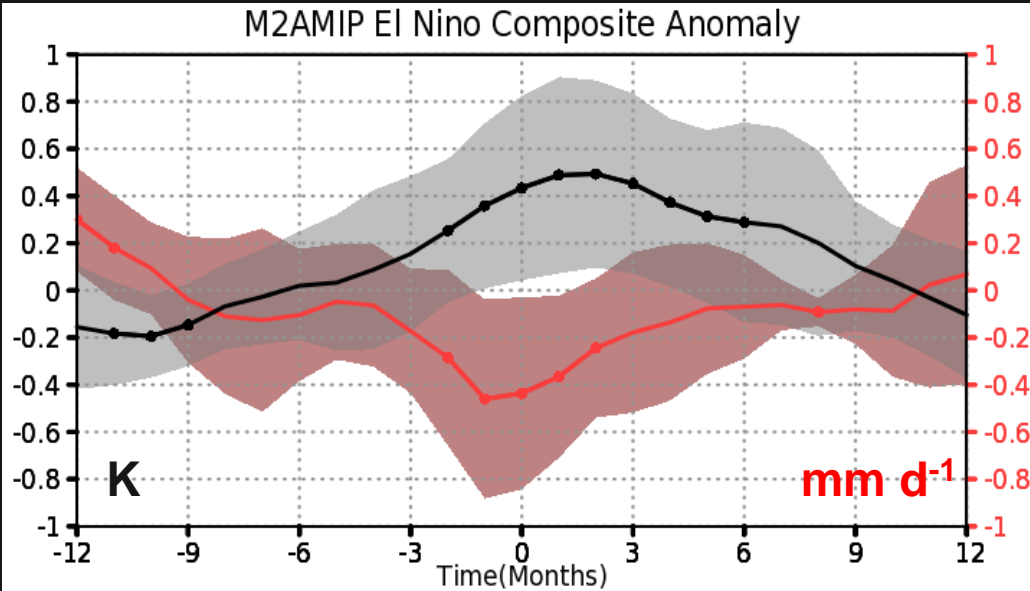




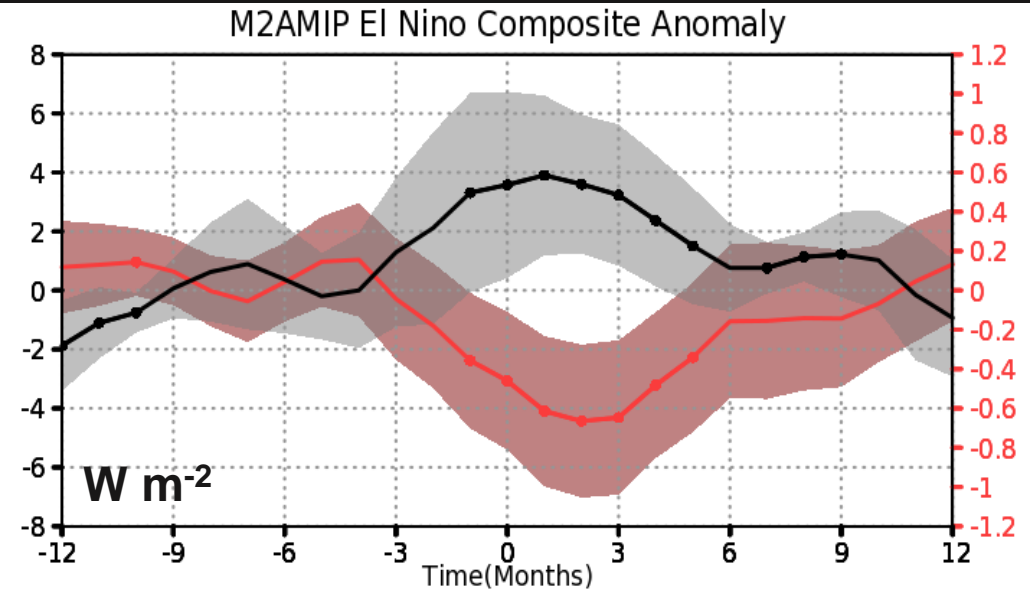
# South America: M2AMIP

T2m  
Prec

SWgCRE  
LWgCRE



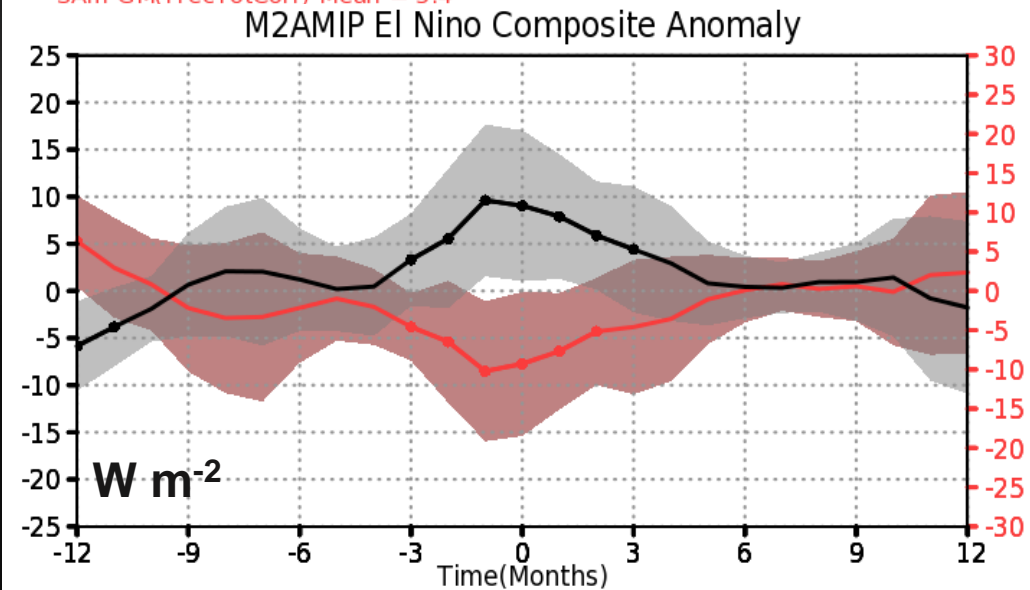
SAm-GM(T2m) Mean = 297.2  
SAm-GM(PrecTotCorr) Mean = 5.4



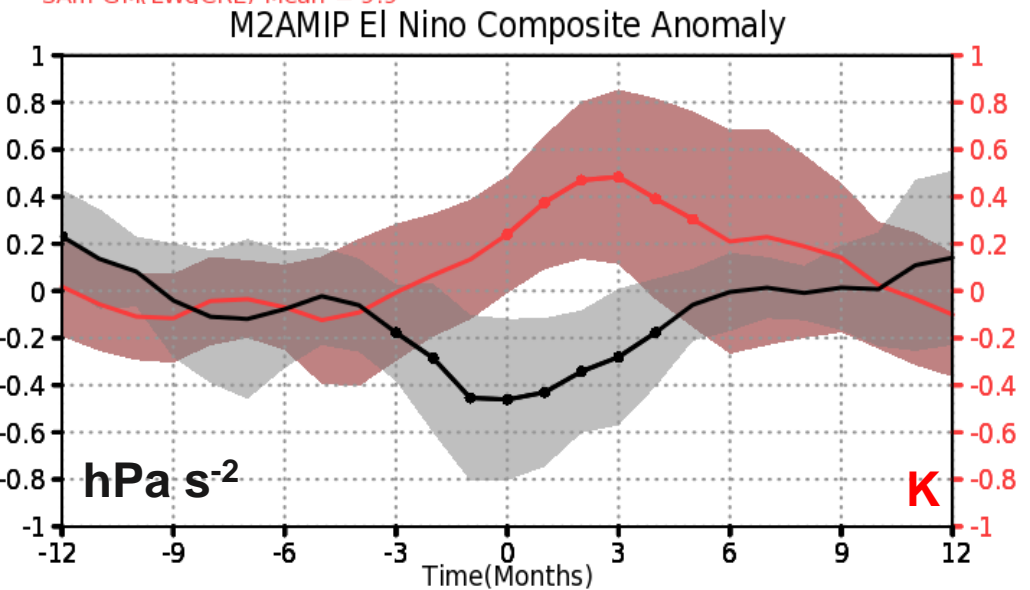
SAm-GM(SWgCRE) Mean = -56.9  
SAm-GM(LWgCRE) Mean = 9.9

Conv.  
DSE  
Lqv

-Ω(500)  
T(500)



SAm-GM(-(divCpT+divPhi)) Mean = -107.6  
SAm-GM(-2.454e6\*divqv) Mean = 56.4



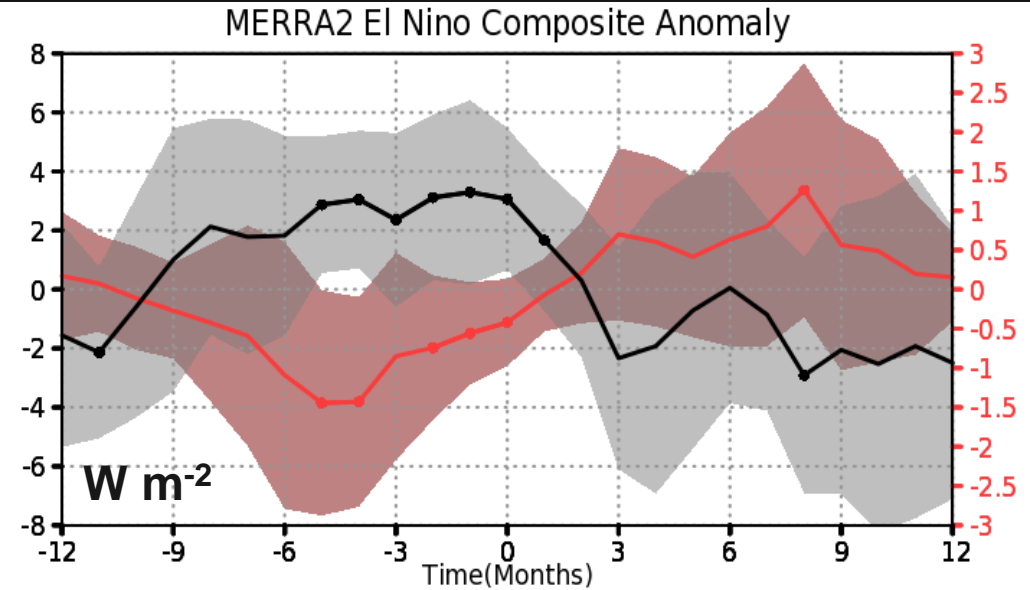
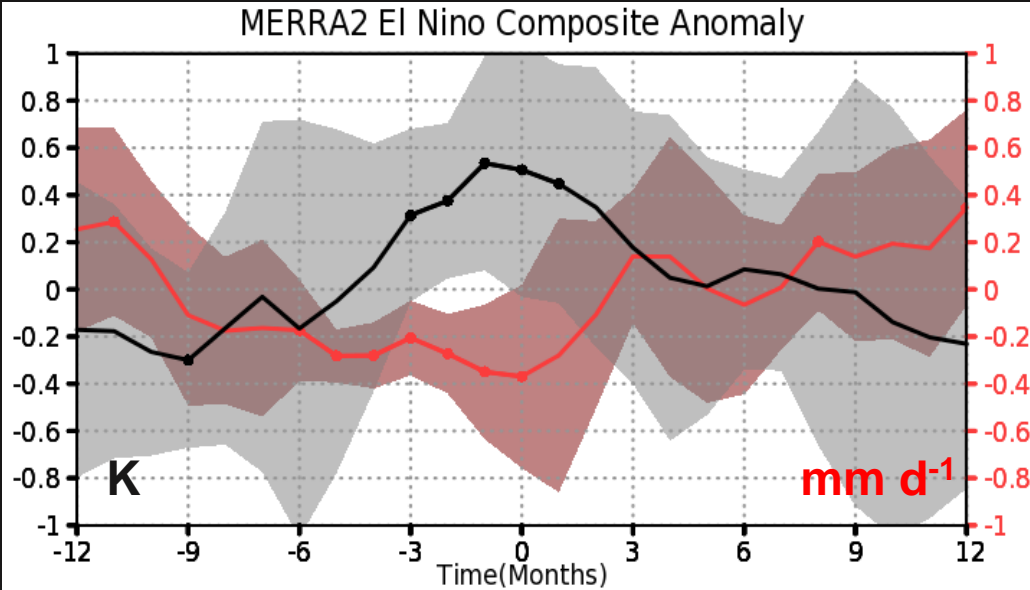
SAm-GM(-100\*Omega500) Mean = 2.1  
SAm-GM(T500) Mean = 267.5



# Australia: MERRA-2

T2m  
Prec

SWgCRE  
LWgCRE

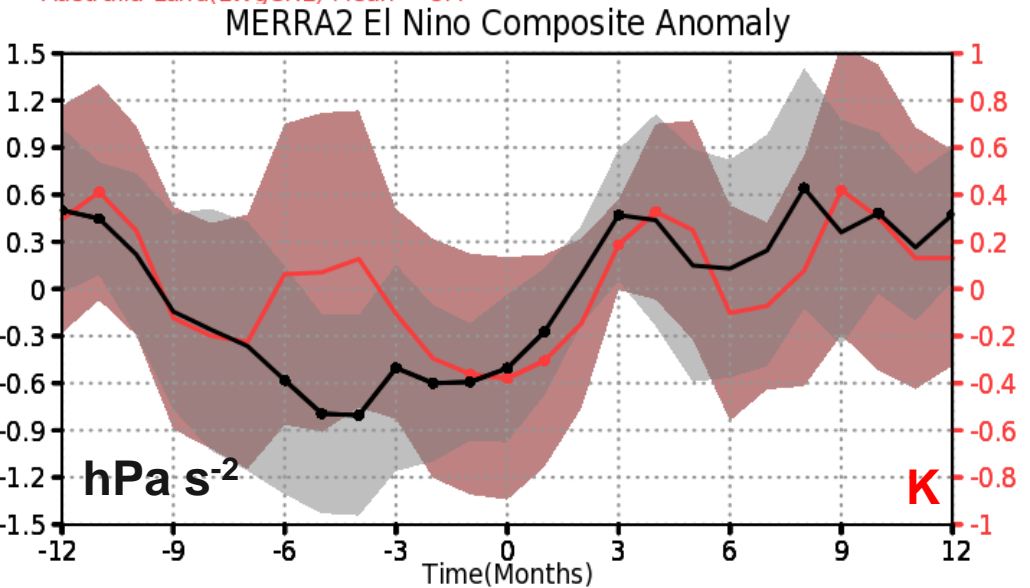
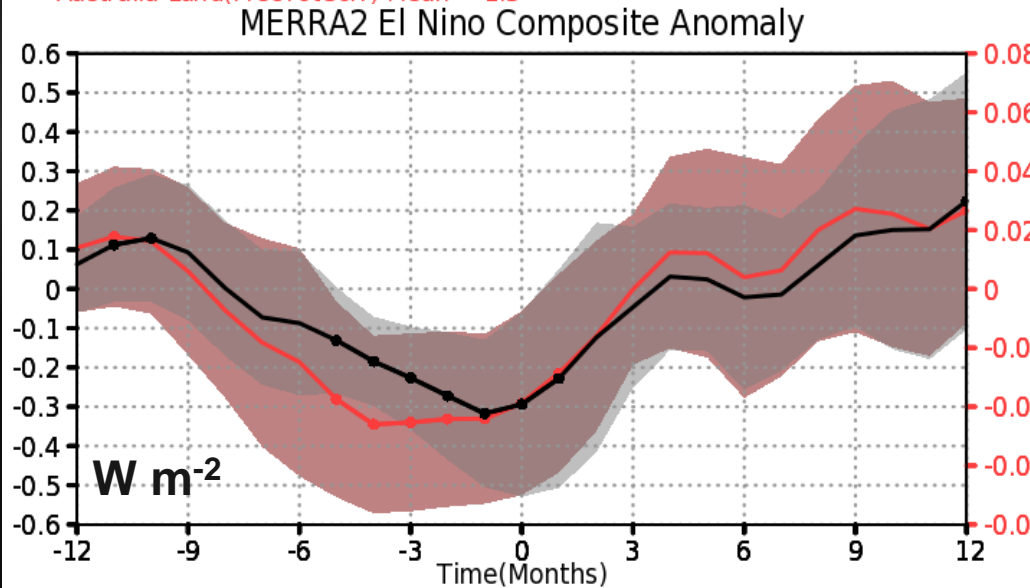


Australia-Land(T2m) Mean = 295.4  
Australia-Land(PrecTotCorr) Mean = 1.3

Australia-Land(SWgCRE) Mean = -24.9  
Australia-Land(LWgCRE) Mean = 8.4

LEvap  
GwTop

$-\Omega(500)$   
T(500)



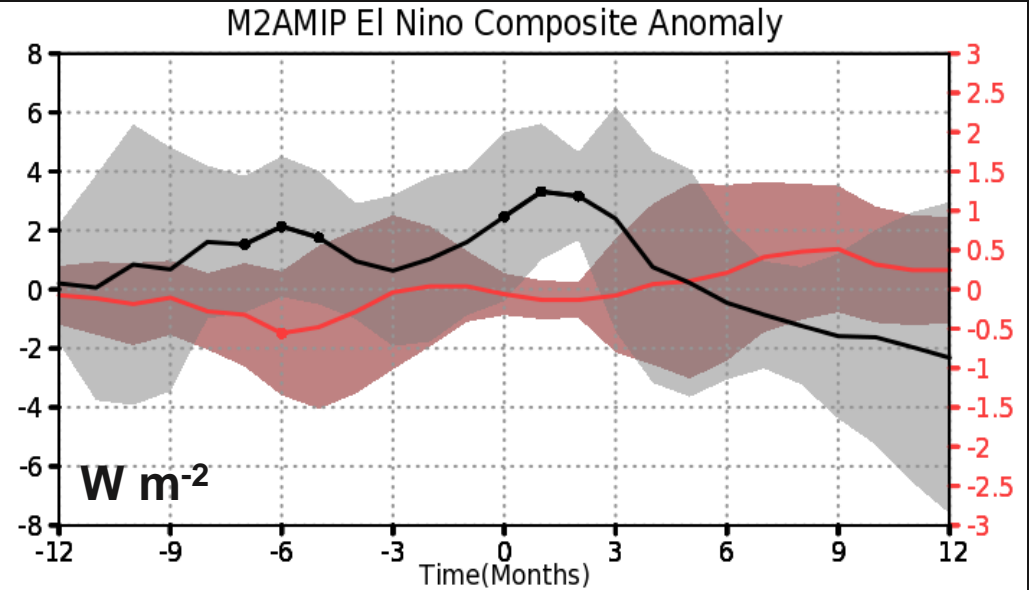
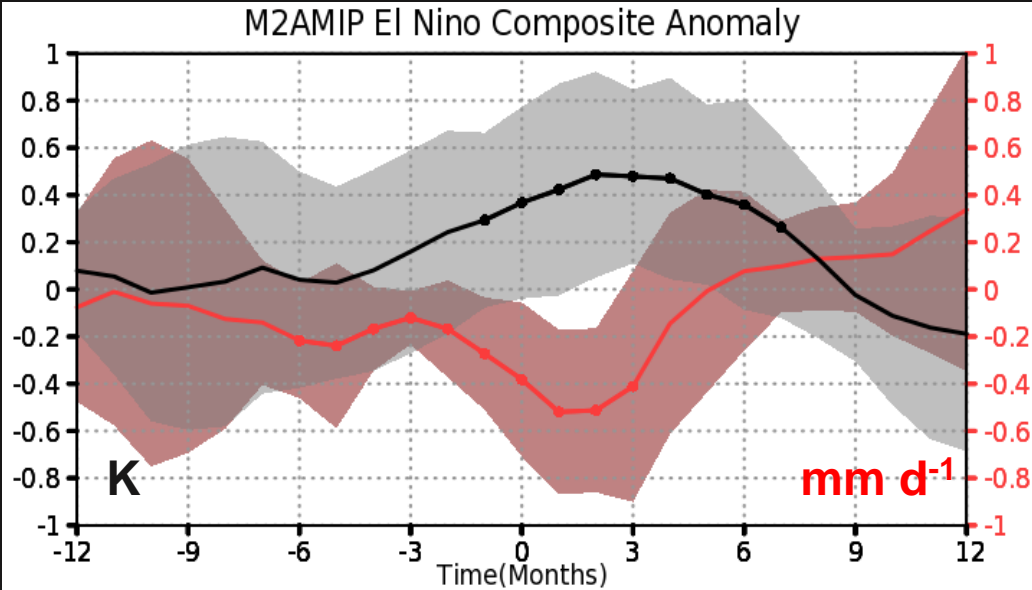
Australia-Land(Evap) Mean = 1.2  
Australia-Land(GwetTop) Mean = 0.3

Australia-Land(-100\*Omega500) Mean = -1.4  
Australia-Land(T500) Mean = 263.3

# Australia: M2AMIP

T2m  
Prec

SWgCRE  
LWgCRE

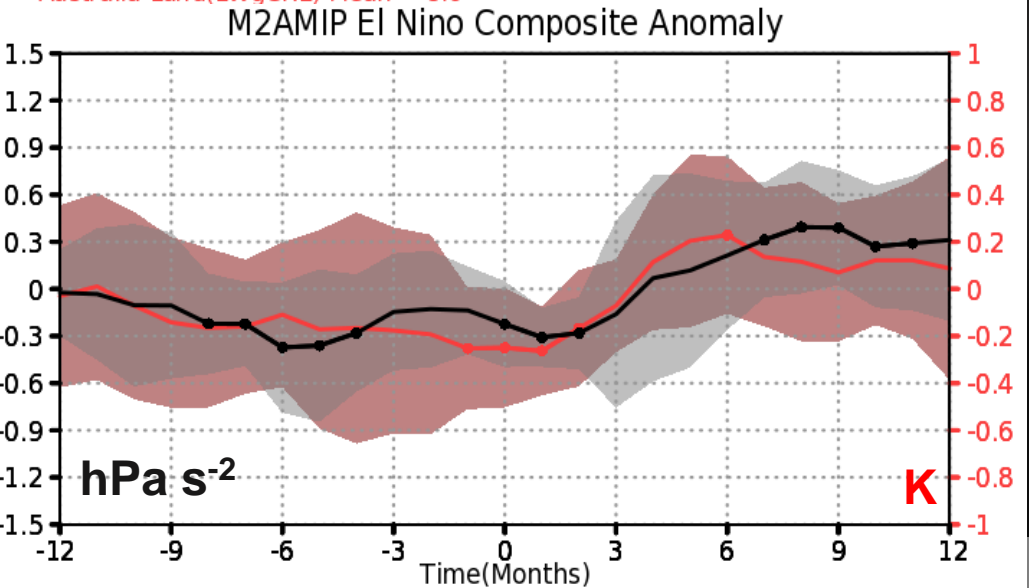
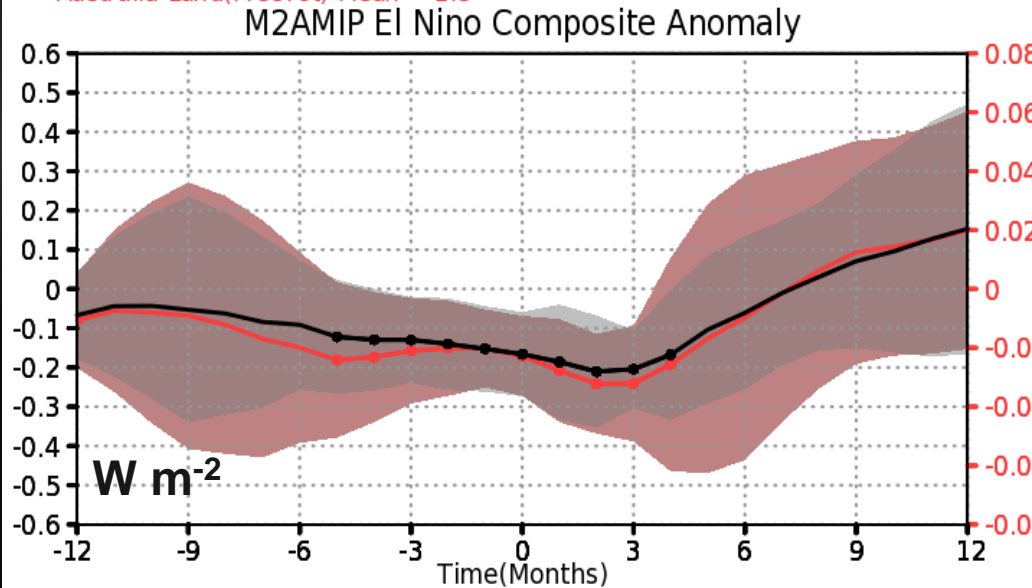


Australia-Land(T2m) Mean = 295.1  
Australia-Land(PrecTot) Mean = 1.8

Australia-Land(SWgCRE) Mean = -26.0  
Australia-Land(LWgCRE) Mean = 8.6

LEvap  
GwTop

$-\Omega(500)$   
T(500)



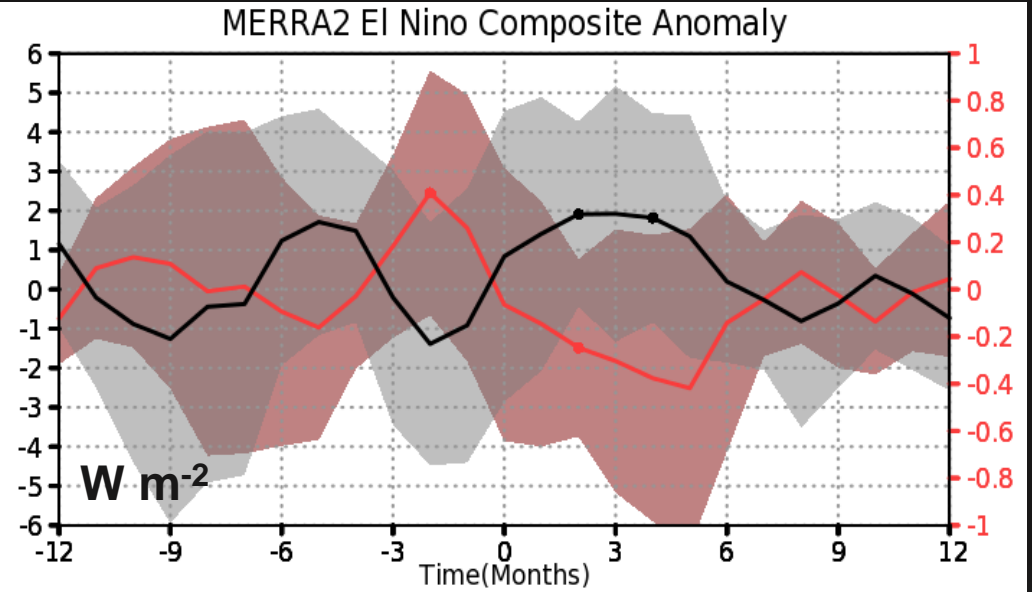
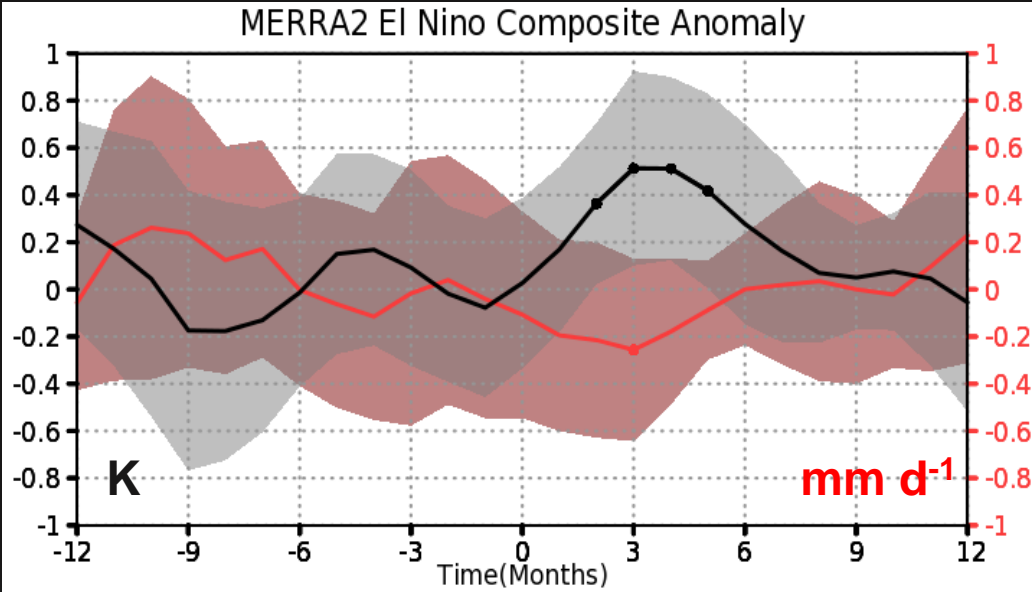
Australia-Land(Evap) Mean = 1.4  
Australia-Land(GwetTop) Mean = 0.4

Australia-Land(-100\*Omega500) Mean = -0.9  
Australia-Land(T500) Mean = 264.0

# Africa: MERRA-2

T2m  
Prec

SWgCRE  
LWgCRE

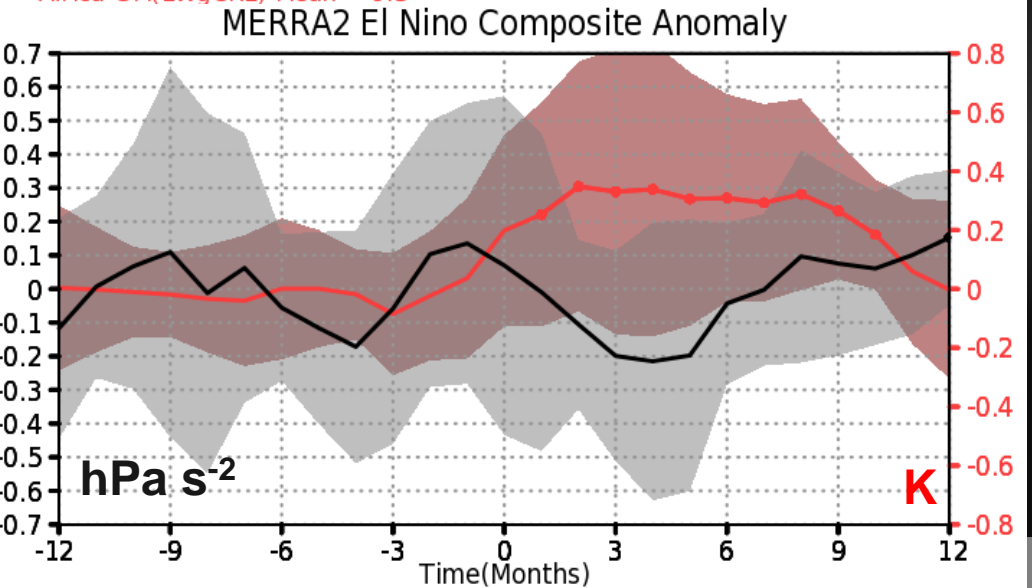
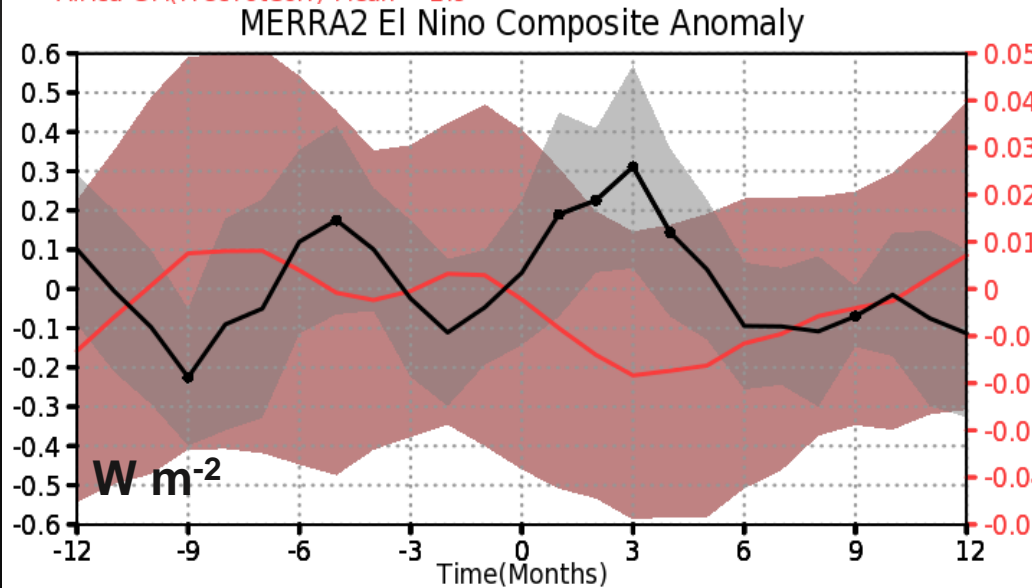


Africa-GM(T2m) Mean = 297.4  
Africa-GM(PrecTotCorr) Mean = 2.9

Africa-GM(SWgCRE) Mean = -45.0  
Africa-GM(LWgCRE) Mean = 9.3

SfcNet  
GwTop

$-\omega(500)$   
T(500)



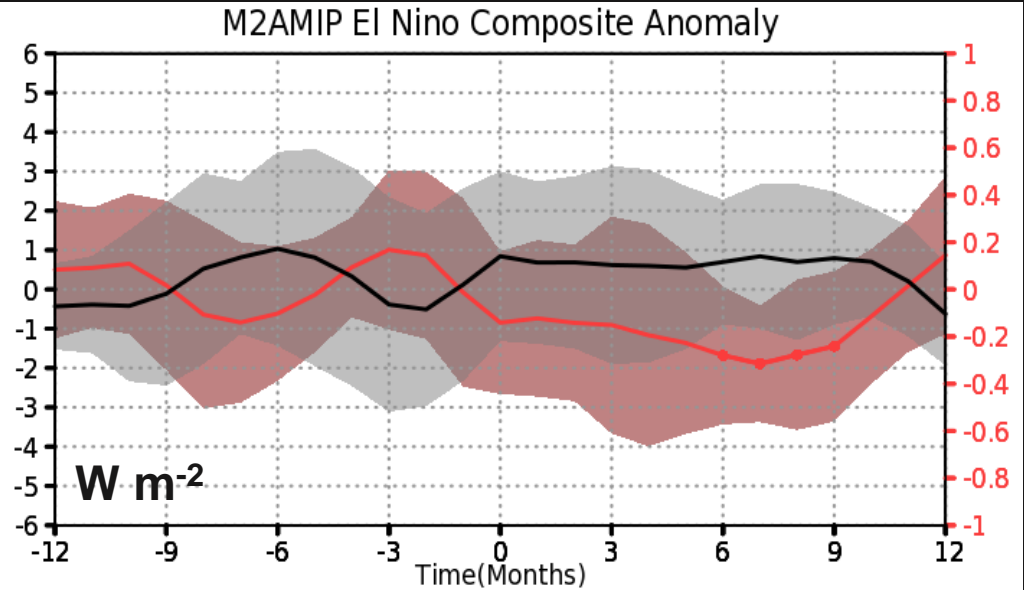
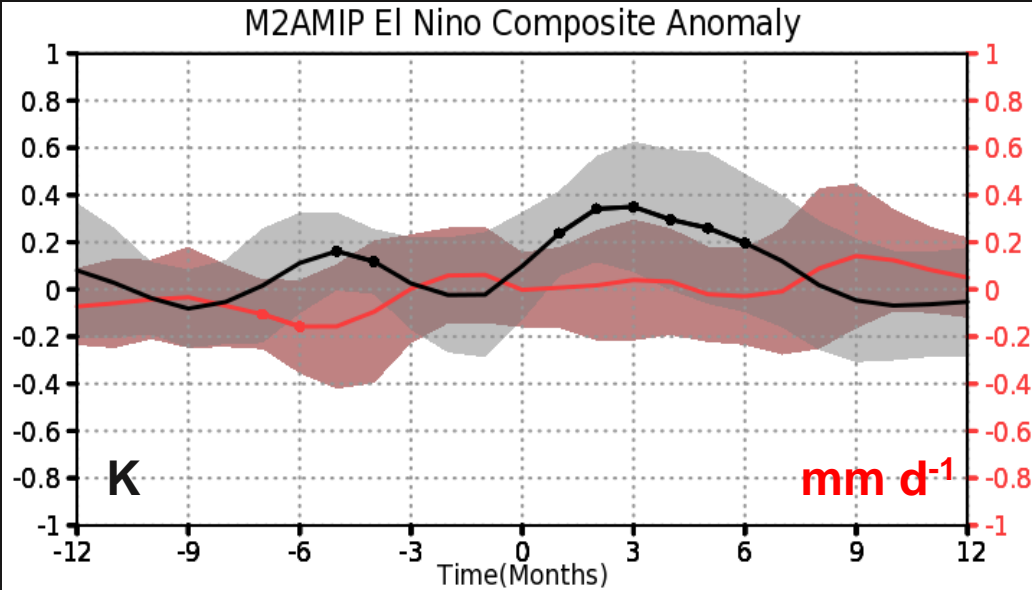
Africa-GM(SfcNet) Mean = 0.2  
Africa-GM(GWetTop) Mean = 0.5

Africa-GM(-100\*omega500) Mean = 0.7  
Africa-GM(T500) Mean = 267.2

# Africa: M2AMIP

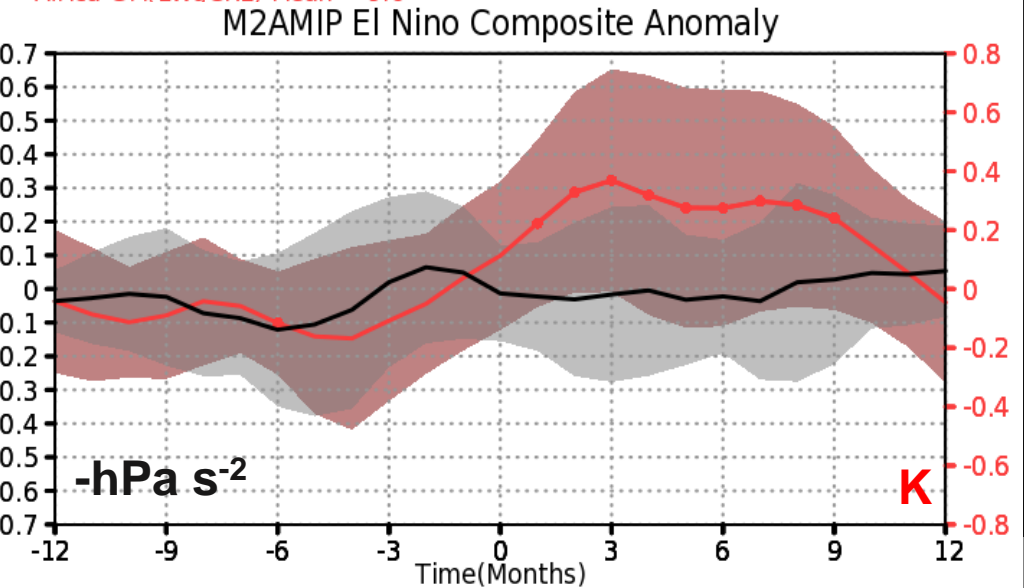
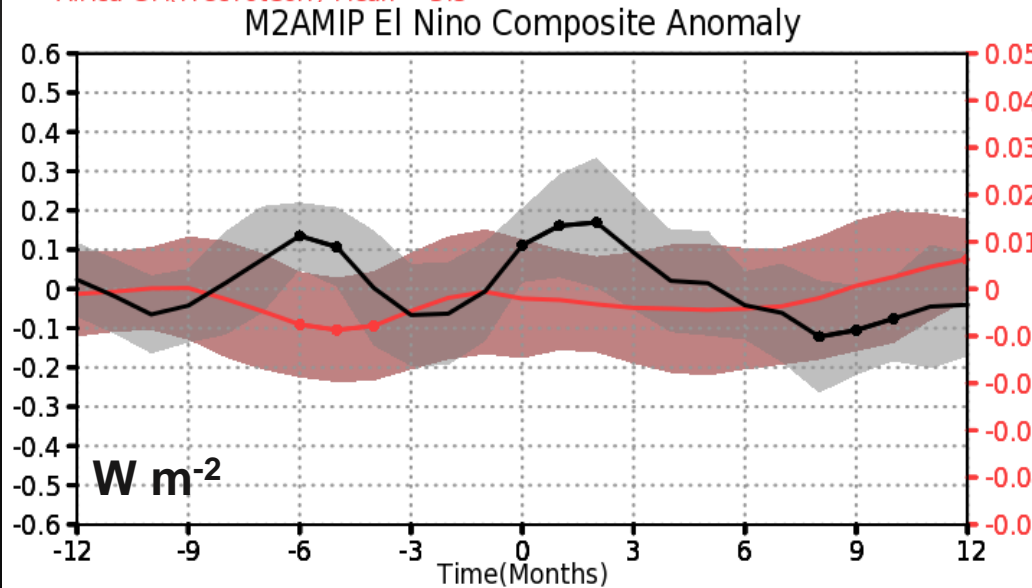
T2m  
Prec

SWgCRE  
LWgCRE



SfcNet  
GwTop

$-\omega(500)$   
T(500)



Africa-GM(T2m) Mean = 297.3  
Africa-GM(PrecTotCorr) Mean = 3.5

Africa-GM(SWgCRE) Mean = -44.7  
Africa-GM(LWgCRE) Mean = 9.6

Africa-GM(SfcNet) Mean = 0.2  
Africa-GM(GWetTop) Mean = 0.5

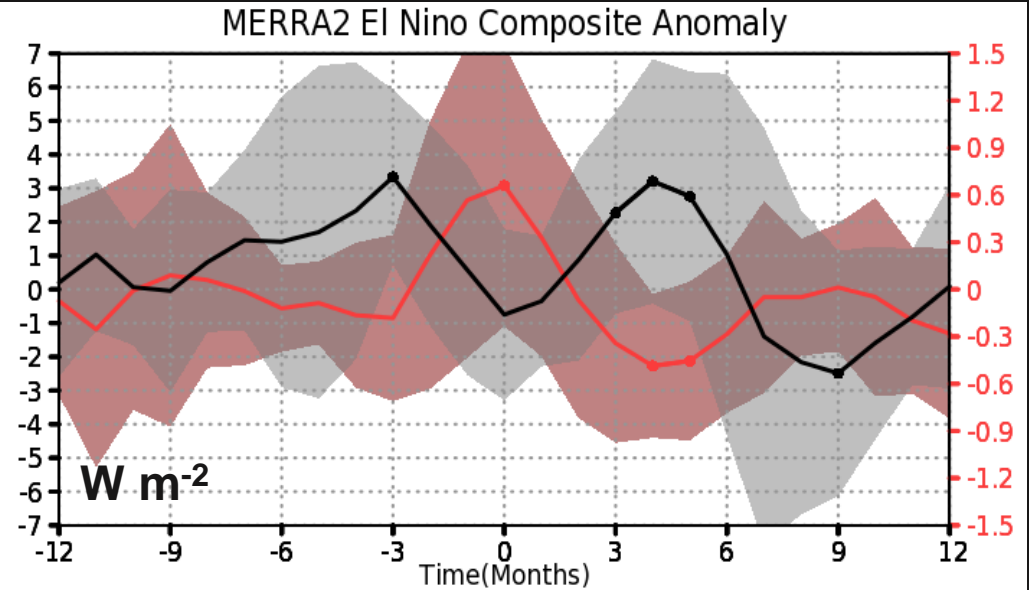
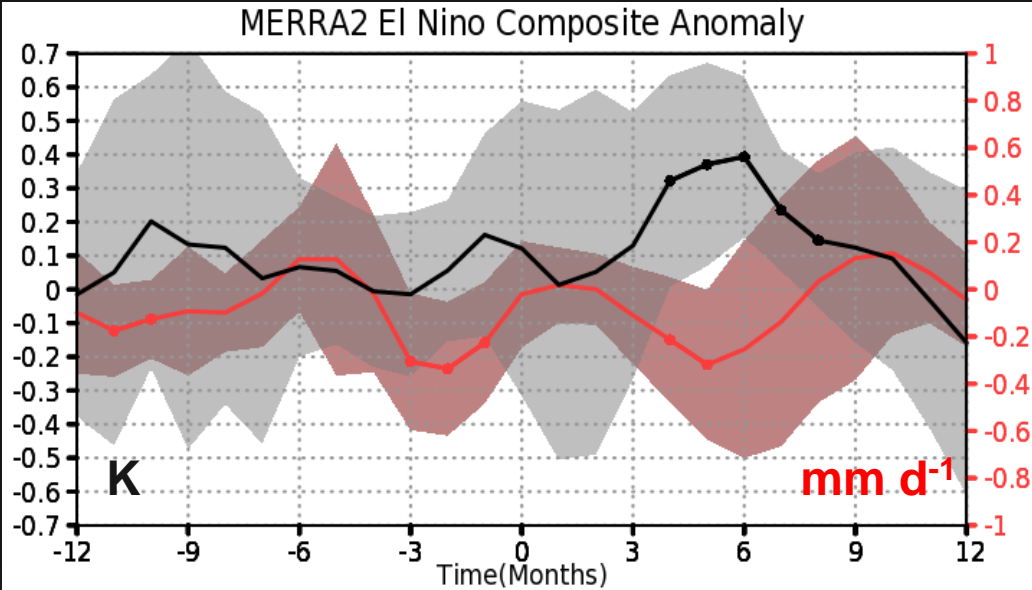
Africa-GM(-100\*omega500) Mean = 1.0  
Africa-GM(T500) Mean = 267.5



# Tropical South Asia: MERRA-2

T2m  
Prec

SWgCRE  
LWgCRE

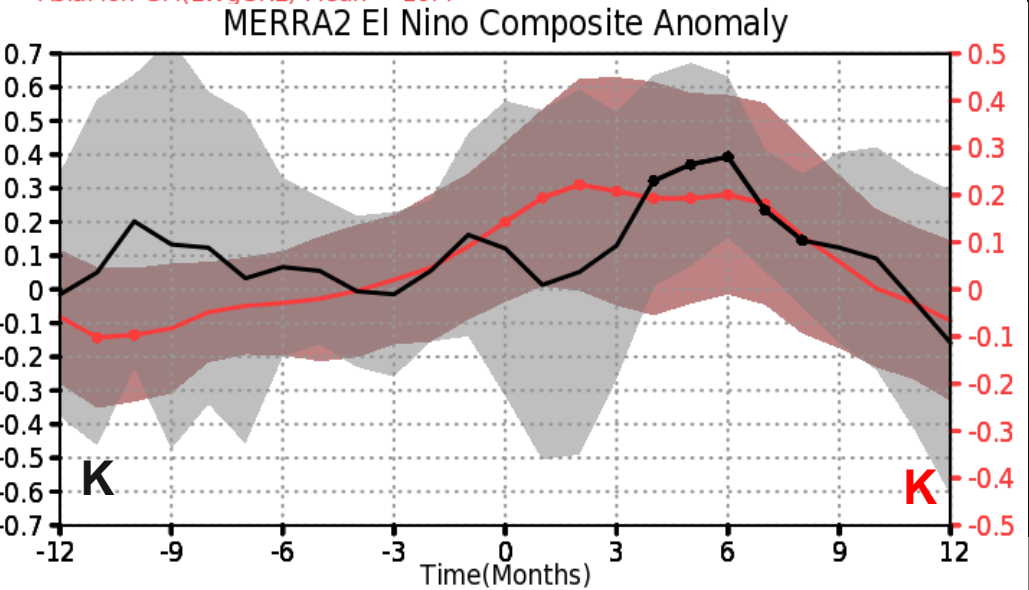
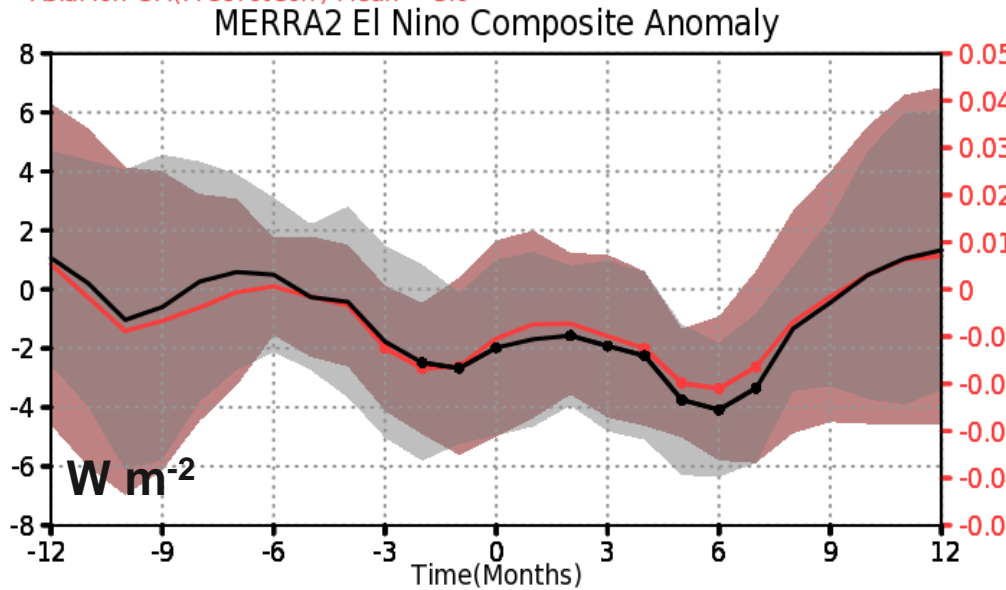


AsiaMon-GM(T2m) Mean = 294.6  
AsiaMon-GM(PrecTotCorr) Mean = 3.0

AsiaMon-GM(SWgCRE) Mean = -47.4  
AsiaMon-GM(LWgCRE) Mean = 10.4

LEvap  
GwTop

T2m  
Indian  
Oc SST



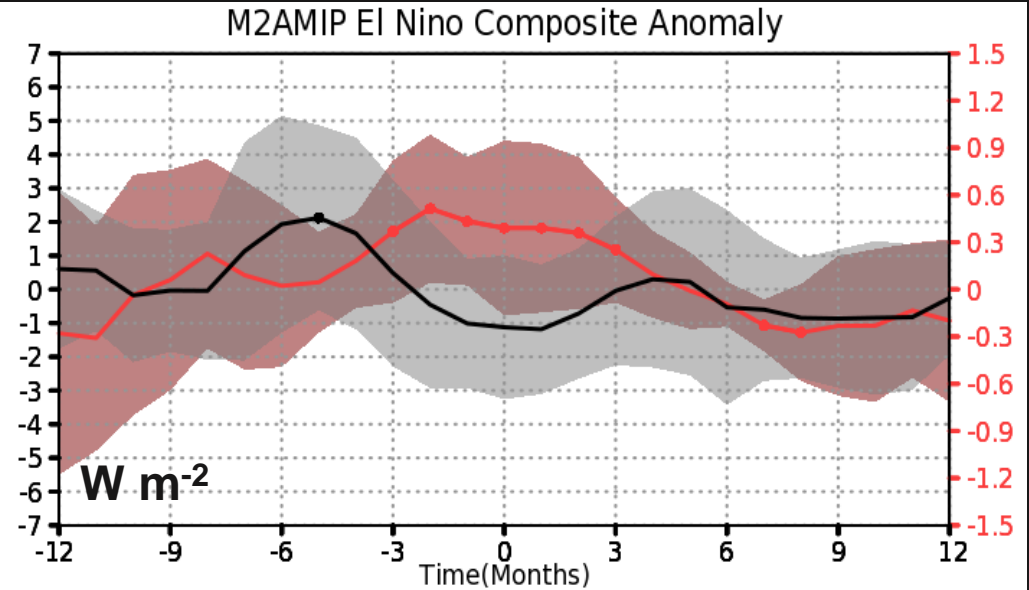
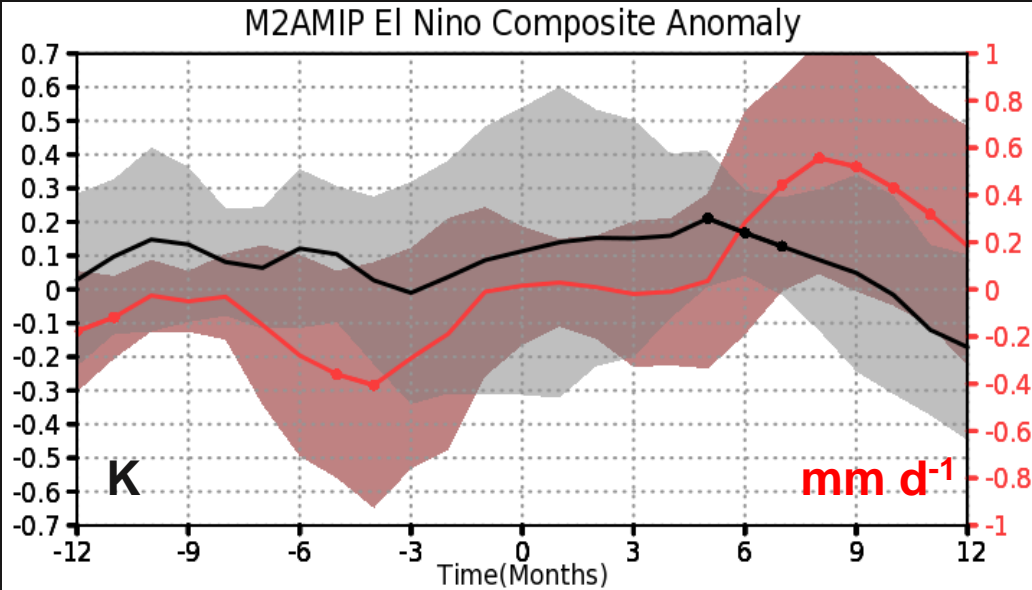
AsiaMon-GM(Eflux) Mean = 68.9  
AsiaMon-GM(GWetTop) Mean = 0.6

AsiaMon-GM(T2m) Mean = 294.6  
Indian Ocean(Ts) Mean = 299.9

# Tropical South Asia: M2AMIP

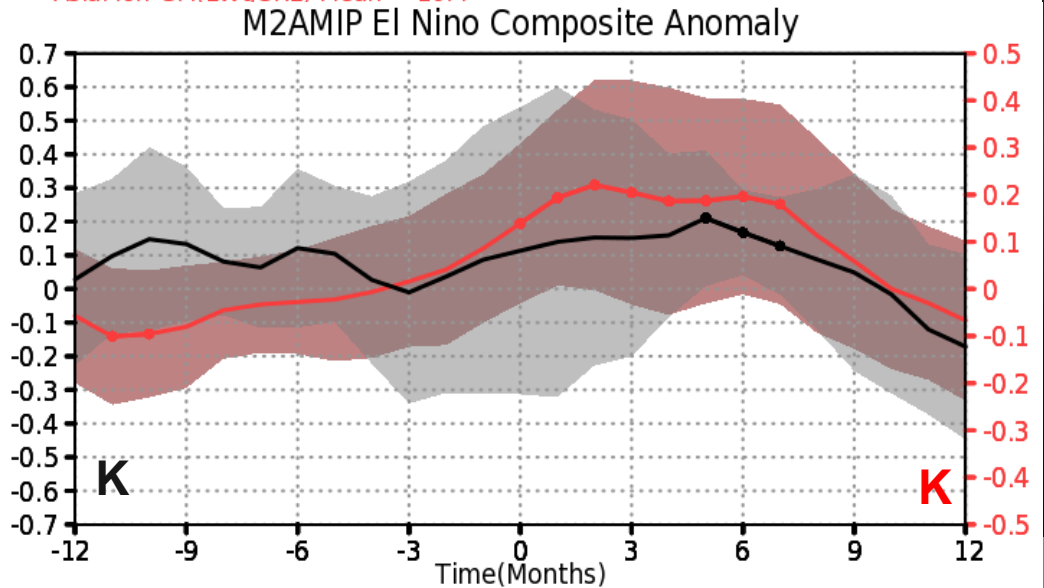
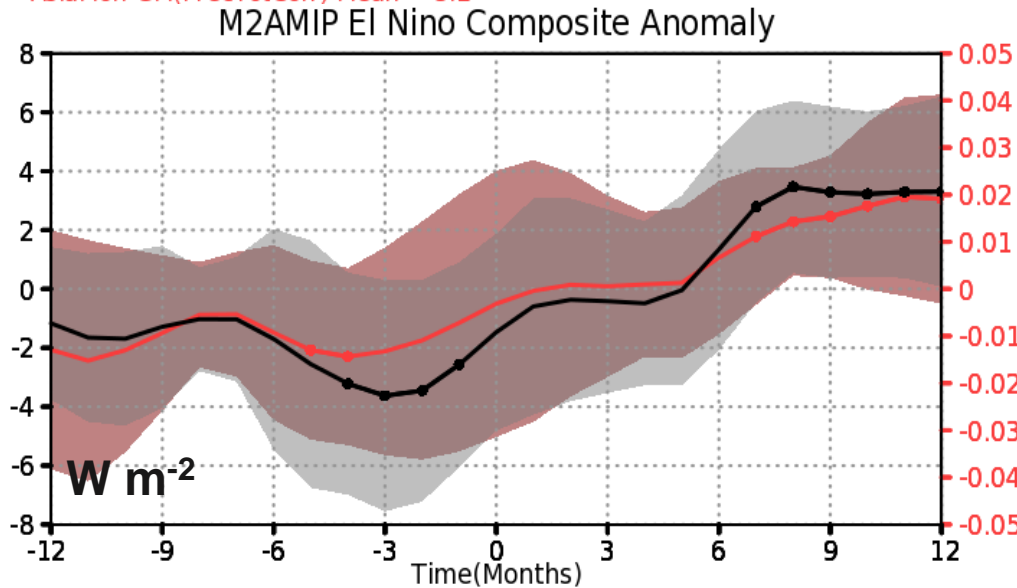
T2m  
Prec

SWgCRE  
LWgCRE



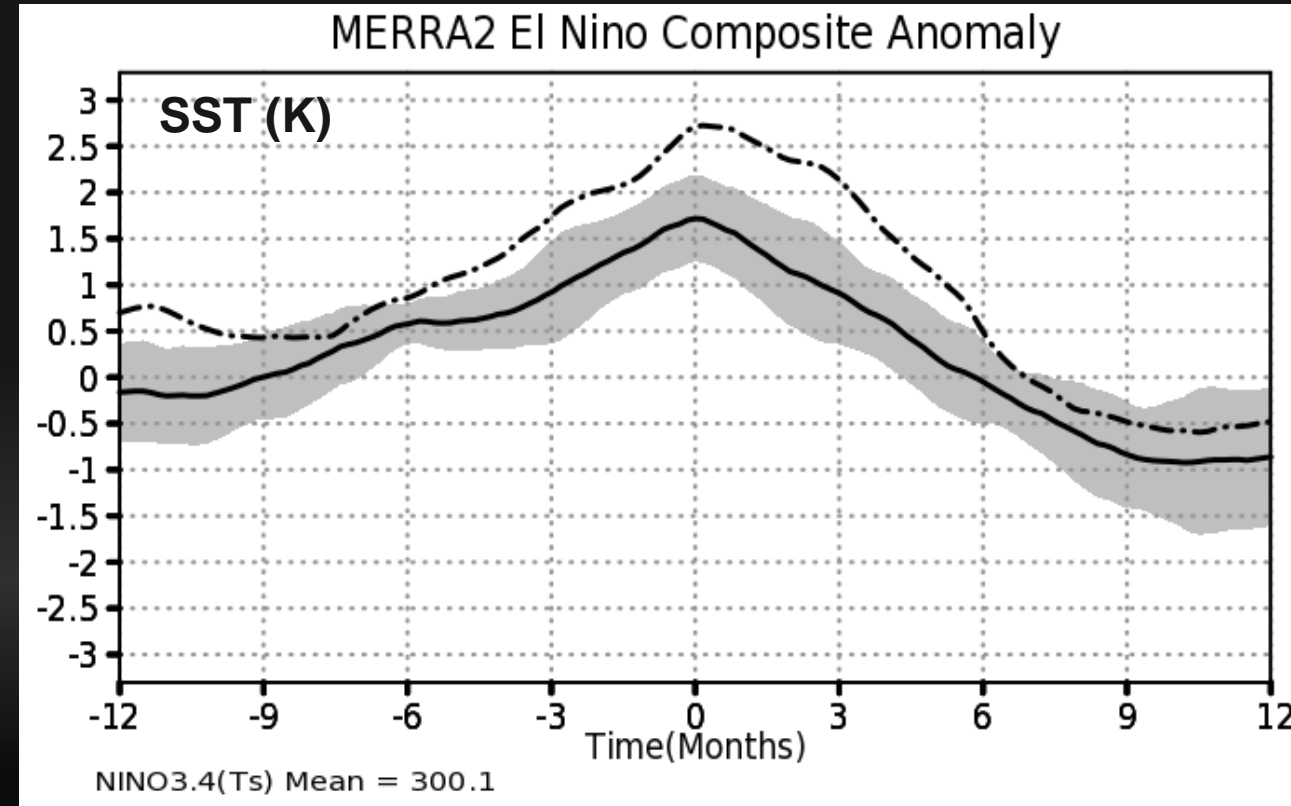
LEvap  
GwTop

T2m  
Indian  
Oc SST



## Examining Variations within the Composite

- Monthly means facilitated the comparison with the AMIP and global observed data
  - MERRA-2 hourly data reduced to **pentads to examine higher frequency variability** in the composite El Niño
- 8 El Niño events were composited over the 36 years of MERRA-2
  - 2015-16 El Niño was not included
  - One of the strongest events, will compare to the Pentad composite



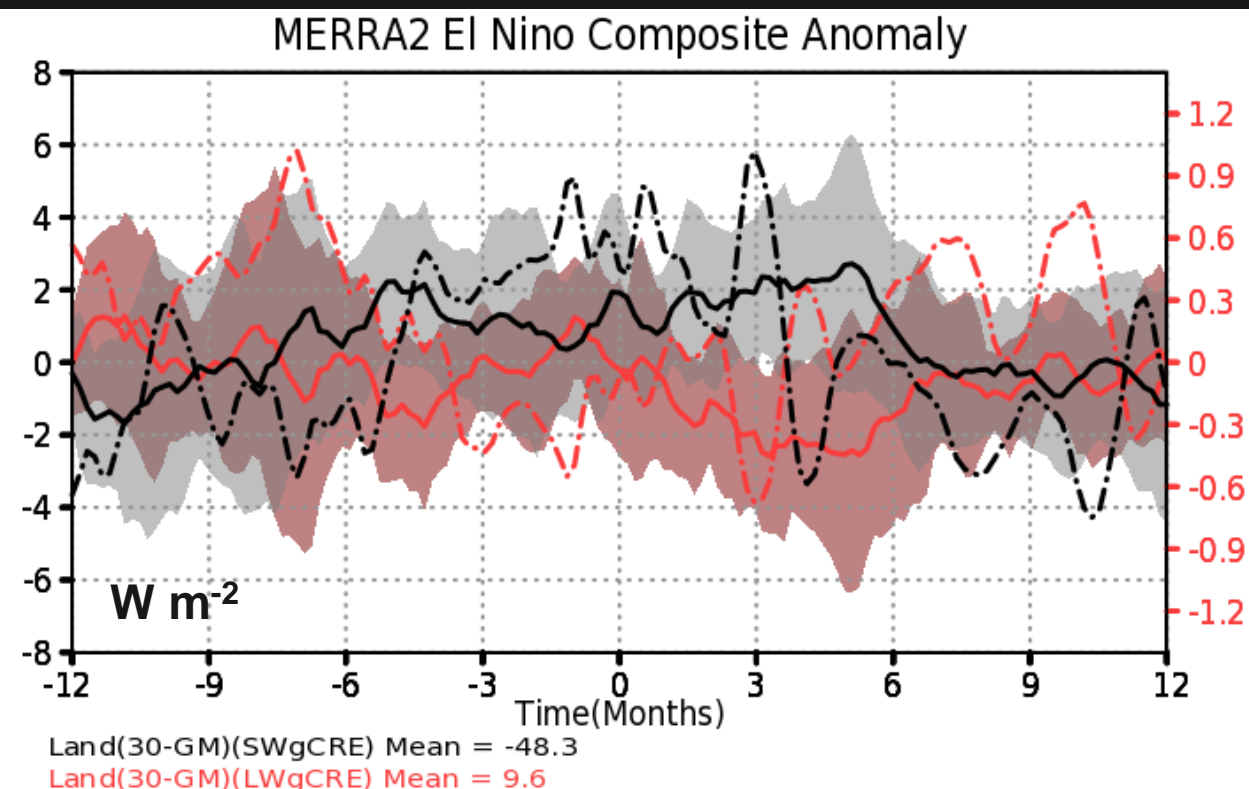
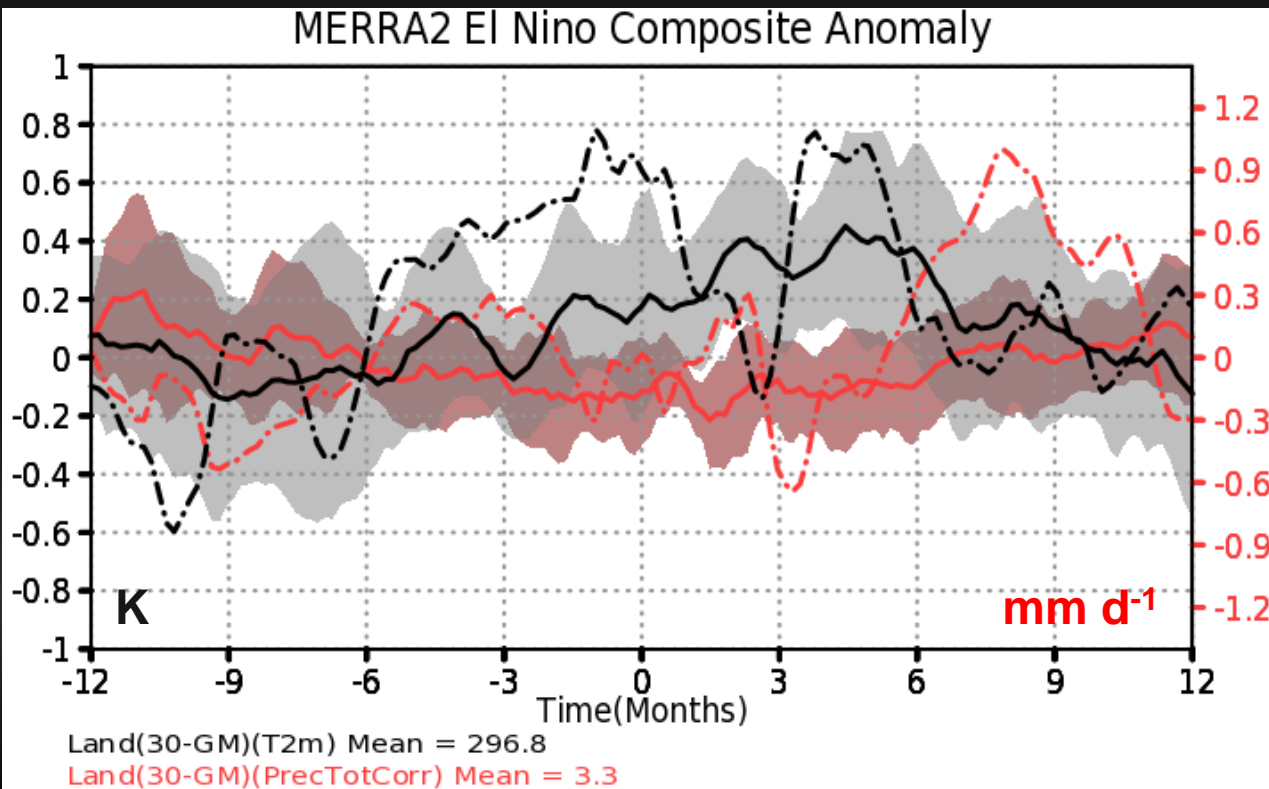
# 2015-16 compared to Composite: Tropics Land

T2m

Prec

SWgCRE

LWgCRE



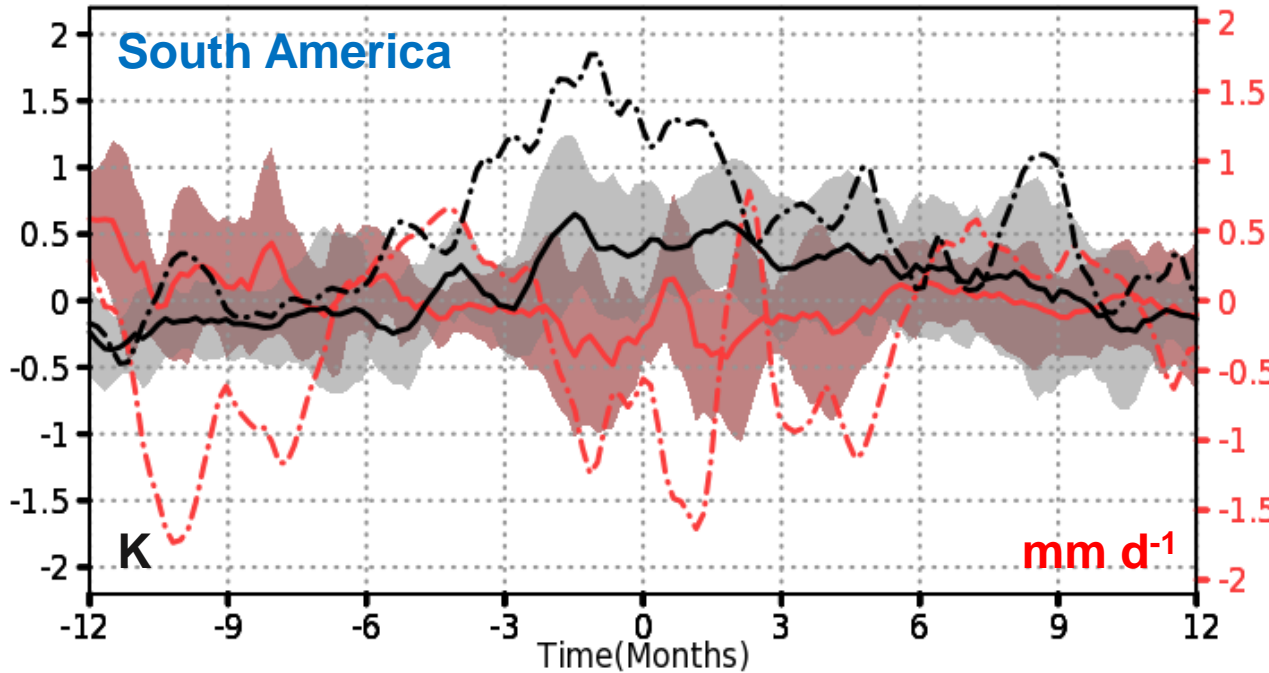
With Precipitation above composite El Niño, 2m temperature is also warm, clouds (and the SWgCRE) appear as a strong driving force, in the first part of the composite



# Regional Pentad Temperature and Precipitation

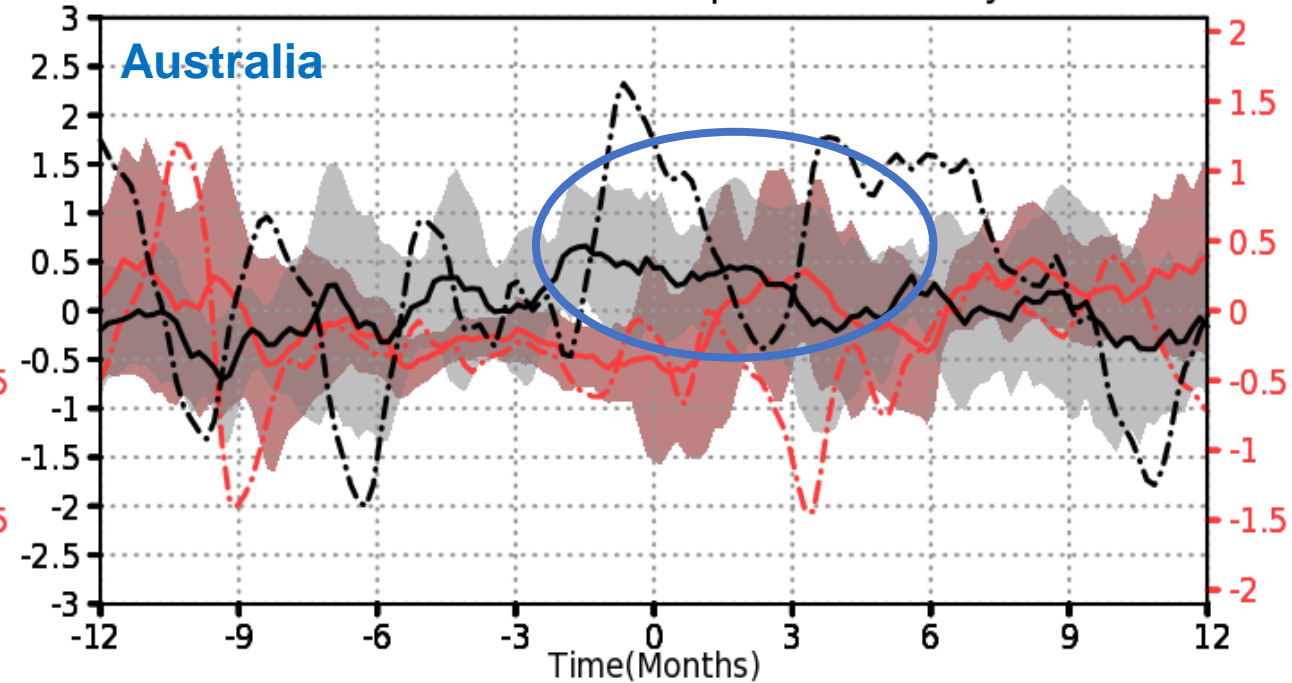
T2m **Prec**

MERRA2 El Nino Composite Anomaly



SAm-GM(T2m) Mean = 297.2  
 SAm-GM(PrecTotCorr) Mean = 4.2

MERRA2 El Nino Composite Anomaly



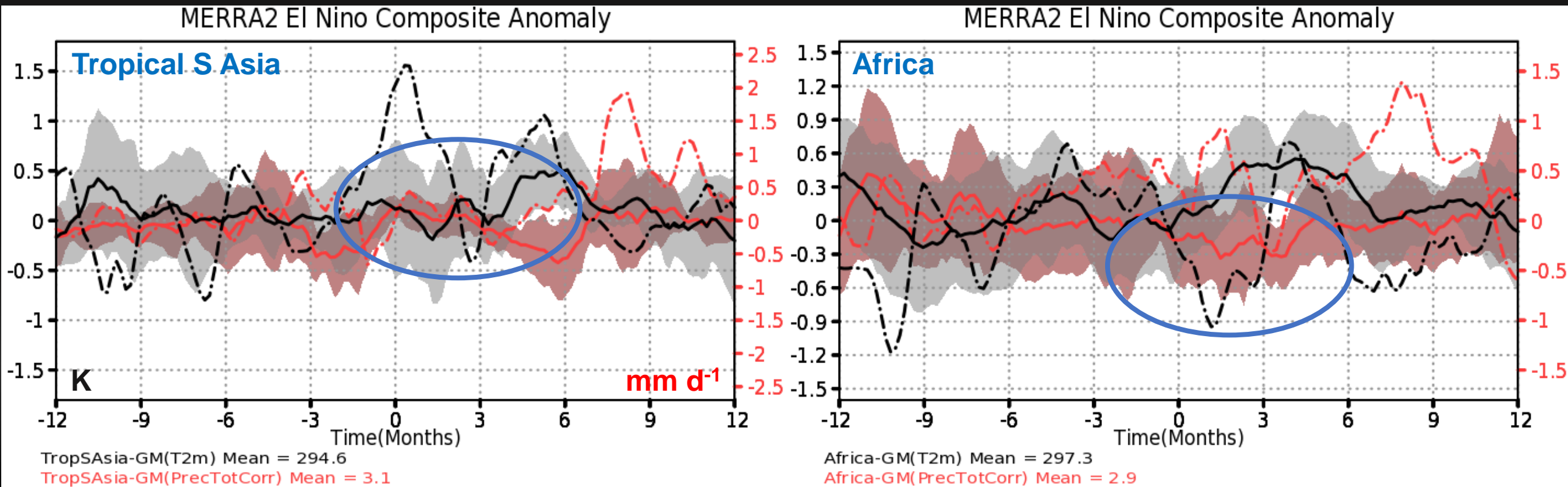
Australia-Land(T2m) Mean = 295.4  
 Australia-Land(PrecTotCorr) Mean = 1.3

South America warm temperatures with precipitation reduction

Australia has reduced precipitation tracking composite, but temperatures much above composite

# Regional Pentad Temperature and Precipitation

T2m    Prec



Tropical South Asia has warm temps after Nino34 peak, precip not affected much  
Africa experiences increased precipitation and decreased temperature

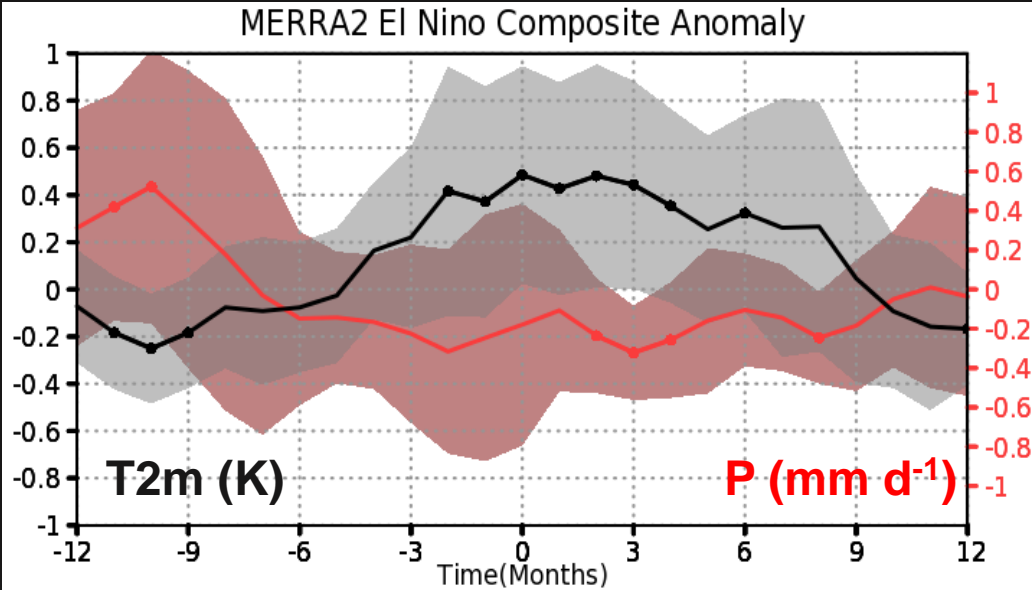
## Summary

- MERRA-2 and M2AMIP **capture broad warming** over land following El Niño
- **Shortwave cloud radiative effect** is a dominant forcing process for the warming
  - More downward motion over the continents, clearer skies
  - Reduced precipitation and evaporation coincides **Needs more analysis**
  - Dynamical convergence (transport) is not a strong or consistent source of warming (Analysis Increments also are not a clear source of heat)
- M2AMIP has some regional issues, reducing its reliability (e.g. Australia)
- Each event is unique, yet some processes appear robust in composite El Niño
- MERRA-2 **simulated precipitation and 2m air temperature composites** reasonably reproduce observations at the regional scale, confidence in studying El Niño in general

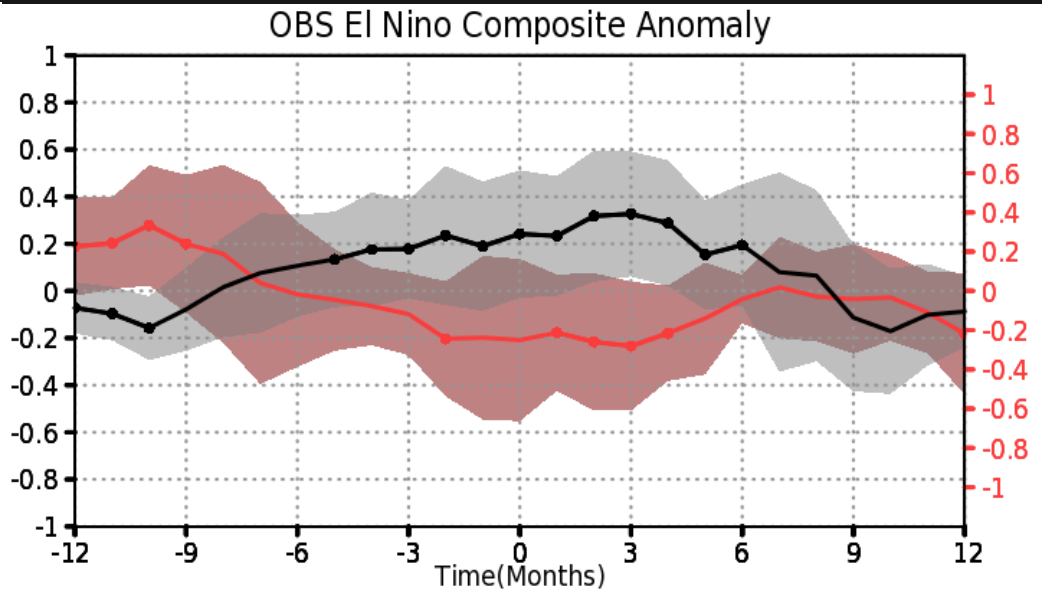
# MERRA-2

# OBS

South America

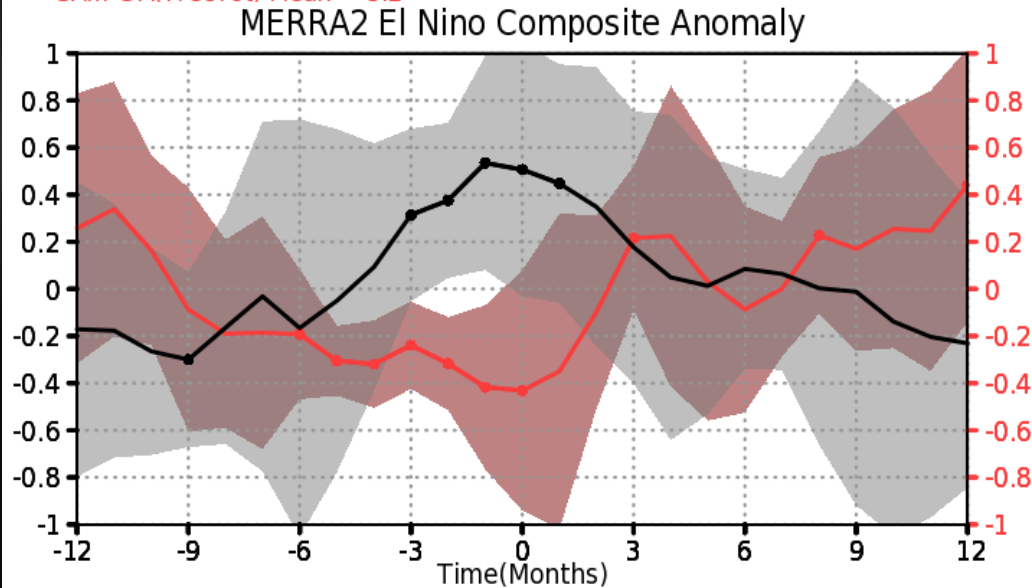


SAm-GM(T2m) Mean = 297.2  
 SAm-GM(PrecTot) Mean = 5.2

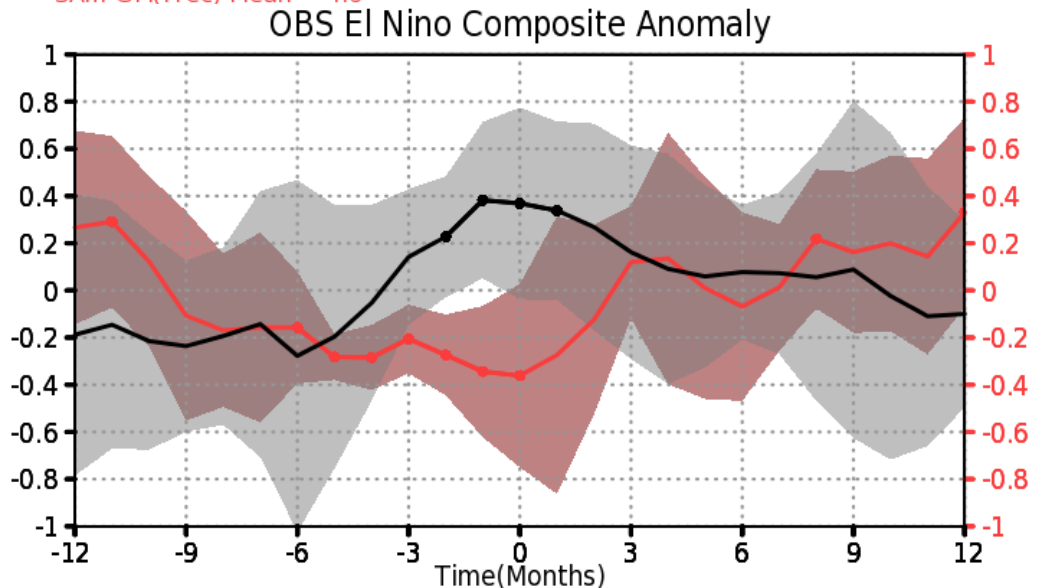


SAm-GM(T2m) Mean = 24.4  
 SAm-GM(Prec) Mean = 4.6

Australia



Australia-Land(T2m) Mean = 295.4  
 Australia-Land(PrecTot) Mean = 1.5



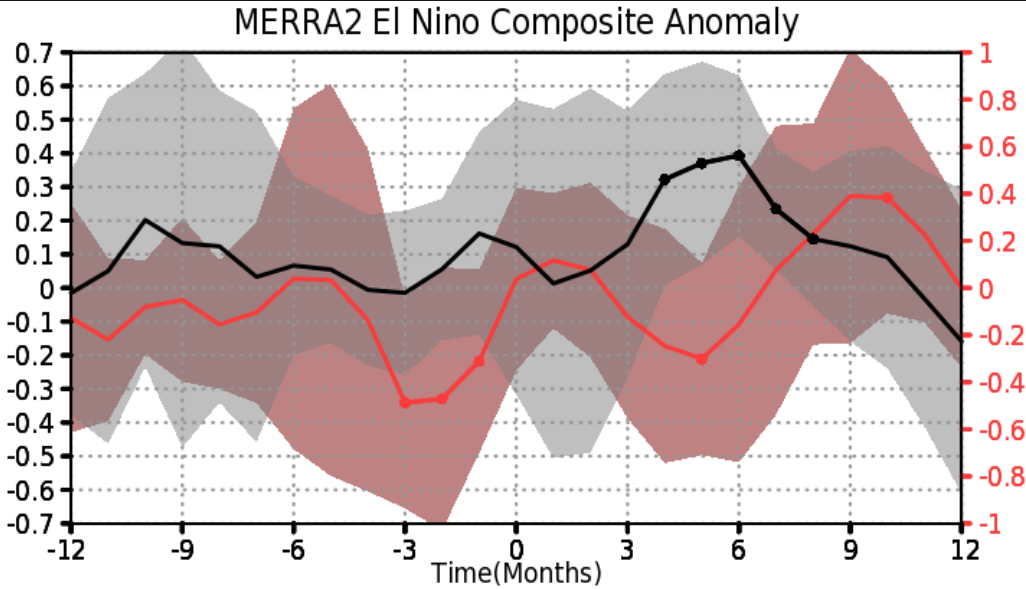
Australia-Land(T2m) Mean = 22.1  
 Australia-Land(Prec) Mean = 1.3



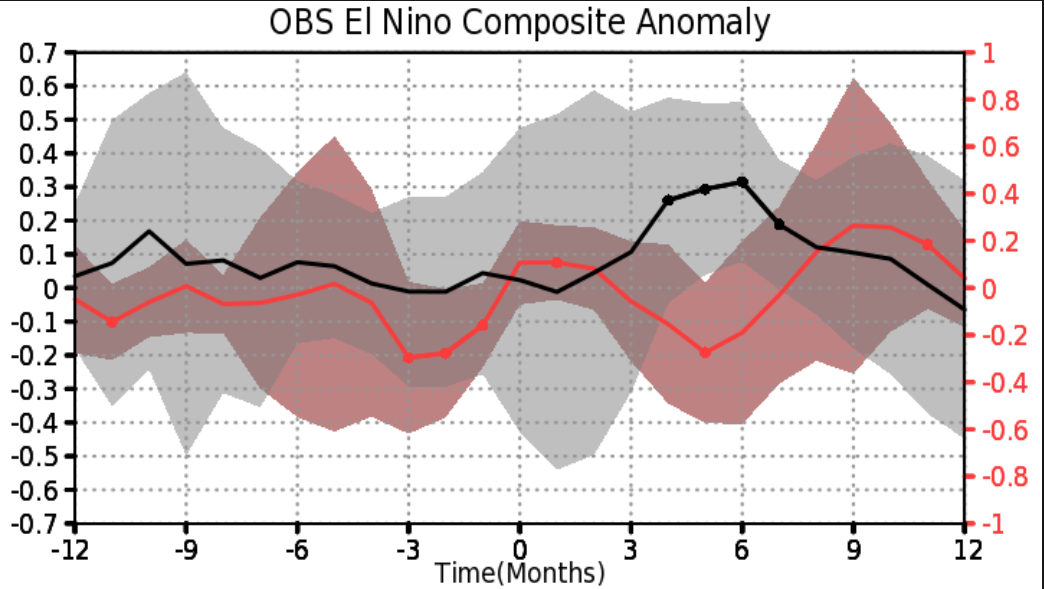
# MERRA-2

# OBS

Tropical South Asia

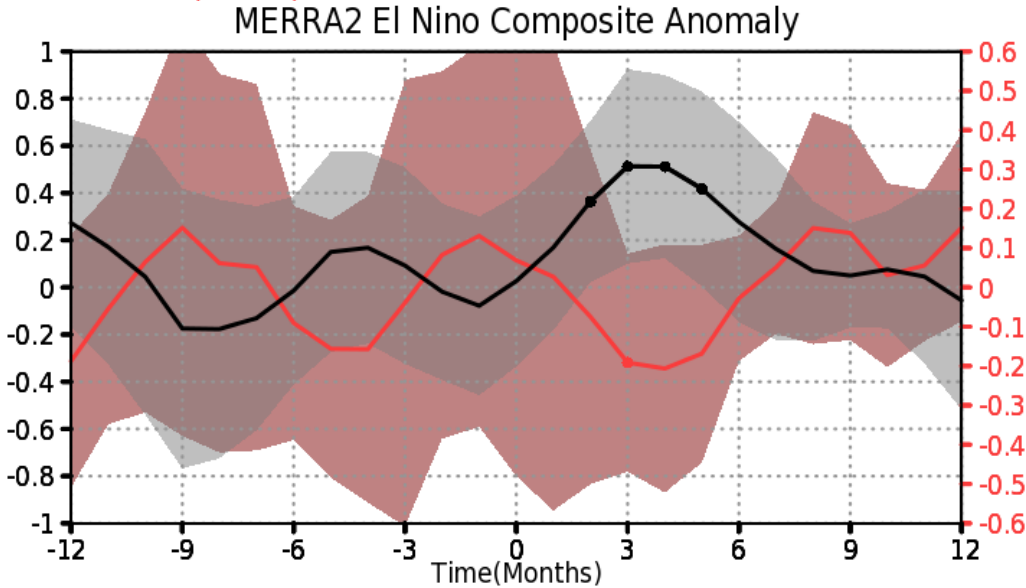


AsiaMon-GM(T2m) Mean = 294.6  
 AsiaMon-GM(PrecTot) Mean = 5.3

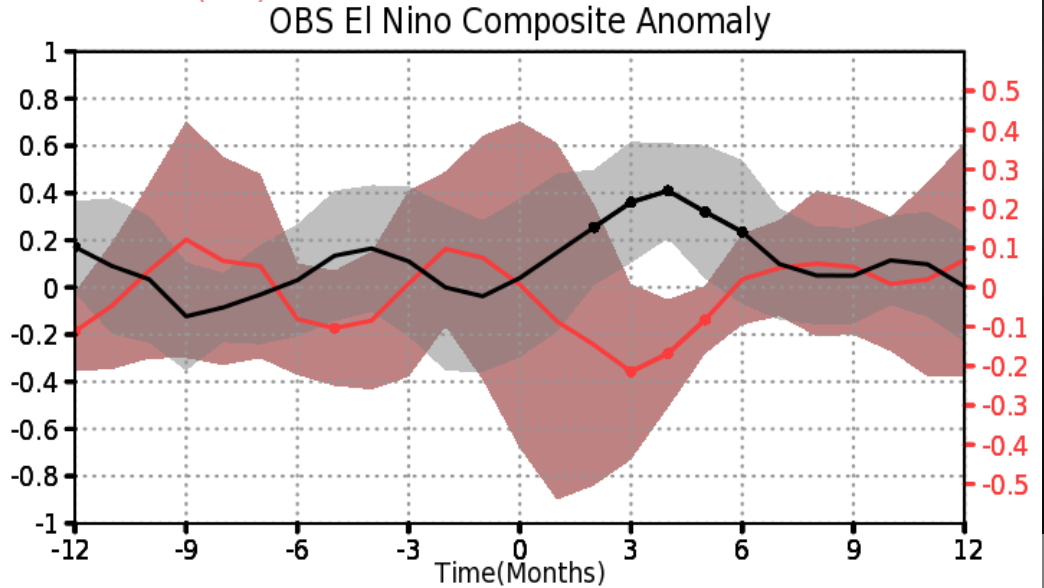


AsiaMon-GM(T2m) Mean = 21.6  
 AsiaMon-GM(Prec) Mean = 3.9

Africa



Africa-GM(T2m) Mean = 297.4  
 Africa-GM(PrecTot) Mean = 3.4



Africa-GM(T2m) Mean = 24.1  
 Africa-GM(Prec) Mean = 2.8