Changes in ENSO patterns revealed from TRMM/TMPA, MERRA-2, and AIRS data

A. Savtchenko[1,3], G. Huffman[2], B. Vollmer[1], D. Meyer[1] NASA/GSFC: [1]Code 610.2/GES DISC, [2]Code 612; [3]ADNET

Contact: andrey.savtchenko@nasa.gov

209

INTRODUCTION

- Changes in the El Niño Southern Oscillation (**ENSO**) patterns in recent decades have been identified in numerous publications. In particular, shift to a more Central-Pacific mode has been noted (McPhaden, 2012), and even qualified as new type of ENSO, "Modoki", (Ashok et al. , 2007).
- We explore the information content of a sliver of data, archived at the NASA Goddard Data and Information Services Center, for its potential to reveal these changes.

DATA

❑ MERRA-2
- ✓ M2TMNXSLV (tavgM_2d_slv_Nx): T2M
- ✓ M2TMNXRAD (tavgM_2d_rad_Nx): LWTUP, LWTUPCLR
- ✓ M2TMNXFLX (tavgM_2d_flx_Nx): PRECTOT
- ✓ Access: https://disc.gsfc.nasa.gov/daac-bin/FTPSubset2.pl

❑ AIRS
- ✓ AIRS3STM (IR-only): SurfAirTemp, OLR, ClrOLR
- ✓ Ascending+Descending
- ✓ Access: https://acdisc.gesdisc.eosdis.nasa.gov/data/Aqua_AIRS_Level3/AIRS3STM.006/

❑ TMPA
- ✓ TRMM_3B43: precipitation
- ✓ Access: https://disc2.gesdisc.eosdisc.nasa.gov/data/TRMM_L3/TRMM_3B43.7/

❑ MEI (Multivariate ENSO Index)
- ✓ Access: http://www.esrl.noaa.gov/psd/enso/mei/table.html

METHOD

• Singular Value Decomposition into Normalized Principal Components (PC) , and Empirical Orthogonal Functions (EOF).

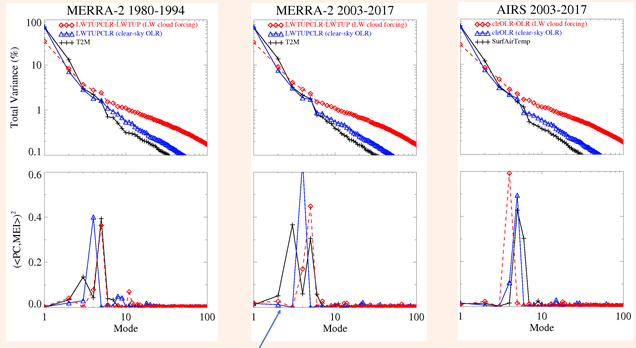
If **F** is monthly time series of precipitation in S-mode [time,position], then:

$\mathbf{C}^T\mathbf{F}^T\mathbf{F}\mathbf{C} = \Lambda$	**C** = EOF, Λ = Eigen Values
$\mathbf{C}^T\mathbf{C} = \mathbf{I}$	**I** = Identity matrix
$\mathbf{A} = \mathbf{F}\,\mathbf{C}$	**A** = principal components
$\mathbf{A} = \Phi\,\mathbf{D}$	Φ = normalized principal components
	D = diagonal matrix with elements $\sqrt{\lambda_i}$

Note:

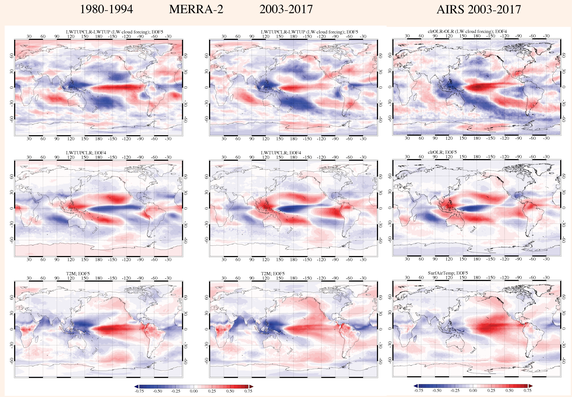
$\mathbf{F} = \Phi\,\mathbf{D}\,\mathbf{C}^T$	Reconstruction of original series
$\mathbf{C}\,\mathbf{D}^T = \mathbf{F}^T\,\Phi$	EOF are actually spatial patterns, representing projections of the original time series onto PC, process known as "homogenous correlation maps" because of the apparent regression. For a particular PC, the corresponding EOF reveals the spatial distribution of this mode of variability.

OLR, T2M



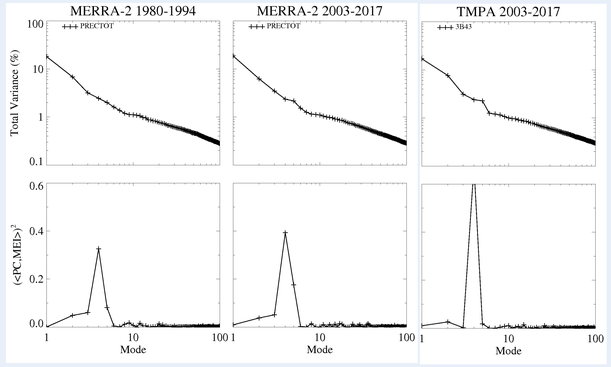
The first (most informative) 100 PCs of the LW Cloud Forcing, clear-sky OLR, and 2-m temperature. Variance explained (top), and regression of PCs onto MEI (bottom).

Note:
- ENSO signal in the semi-seasonal PC3 of MERRA-2 T2M becomes stronger than in the normally major ENSO PC5, in the past 15 years.
- ENSO signal also split in AIRS SurfAirTemp, but in adjacent PC4-5

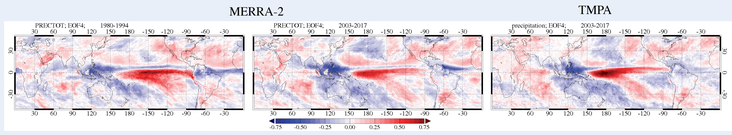


Changes in EOF (spatial patterns) of the major global ENSO modes, 1980-1994 vs 2003-2017

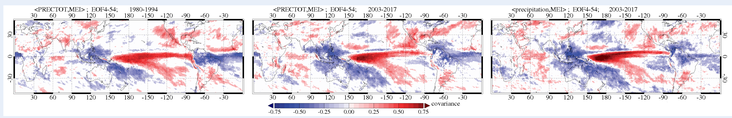
Precipitation



- Explained variance in MERRA-2 and TMPA global precipitation, using the first 100 PC.
- (Regression)² of the first 100 PC on MEI.
- PC4 is the ENSO mode.
- ENSO has been contributing more than 60% to TMPA PC4 variability in the past 15 years.



EOF (spatial patterns) of the major ENSO modes of global precipitation, 1980-1994 vs 2003-2017. (MERRA-2 spatial domain truncated to ±50 latitudes to match TMPA)

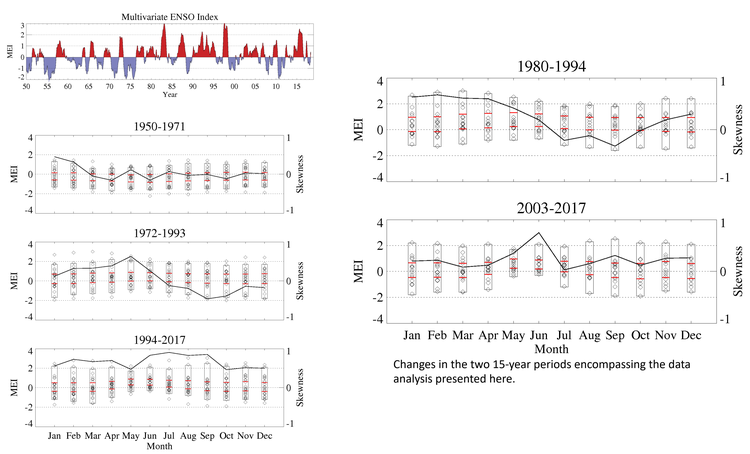


Series of global precipitation reconstructed from ENSO (PC4) and above, regressed on MEI, 1980-1994 vs 2003-2017

Maps show regression coefficients at confidence no less than 95%

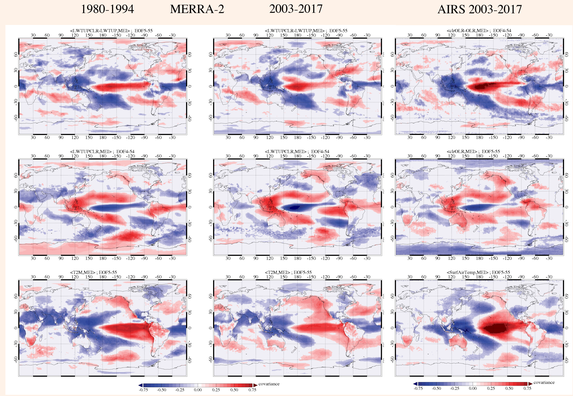
ABBREVIATIONS

AIRS	- Atmospheric Infrared Sounder
ENSO	- El Niño Southern Oscillation
MEI	- Multivariate ENSO Index
MERRA	- Modern-Era Retrospective analysis for Research and Applications
LW	- Longwave
OLR	- Outgoing Longwave Radiation
TRMM	- Tropical Rainfall Measuring Mission
TMPA	- TRMM **M**ulti-satellite **P**recipitation **A**nalysis

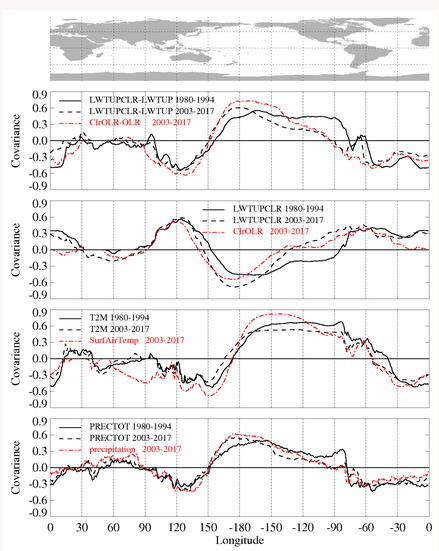


Multivariate **ENSO** Index and its statistics in the past ~70 years.
Black bars enclose 90% of data. Red bars show 95% confidence in the mean.

Changes in the two 15-year periods encompassing the data analysis presented here.



Reconstructed series from ENSO modes and above, regressed on MEI, 2003-2017 vs 1980-1994
Maps show regression coefficients at confidence no less than 95%



Equatorial meridional averages from maps of regressions, within ±7 deg latitudes band along the Equator. Broken lines show the recent 15-years patterns.

SUMMARY

❑On examples of OLR and precipitation data, it is evident that ENSO patterns in the equatorial Pacific have changed substantially in the past 15 years (2003-2017), as compared to 1980-1994. There are noticeable changes in the teleconnections, too.

❑Westward shift toward more central-Pacific ENSO pattern is manifested by longwave cloud forcing, clear-sky OLR and precipitation, and to a lesser degree by the surface atmospheric temperatures.

❑The El Niños (warm phase) of the past 15 years:
- Have stronger warming and weaker precipitation impacts in the East Pacific and the US West Coast;
- Caused wider cooling in the tropical Atlantic, implying stronger descending branch of the Walker cell in the north tropical Atlantic.

❑Implications if these patterns persist:
- El Niño is likely to be less effective in relieving water shortages in California; even reverse conditions, i.e. drier and warmer, will be more probable, contrary to the patterns from decades ago.
- El Niño may have better potential to offset Atlantic hurricane formation and intensity.

References

Ashok K., S. K. Behera, S. A. Rao, H. Weng, T. Yamagata, 2007: El Niño Modoki and its possible teleconnection, *J. Geophys. Res.*, Oceans, **112**, doi:10.1029/2006JC003798

McPhaden, M., J., 2012: A 21st century shift in the relationship between ENSO SST and warm water volume anomalies, *Geophys. Res. Lett.*, **39**, doi:10.1029/2012GL051826