Global Warming, Tropical Expansion and ENSO in OLR – A QC Benchmark Exercise

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Background

- **UMD/NCDC Daily OLR CDR v01r02, 1°x1°, 1979-2014**:
  - **HIRS** instruments onboard NOAA and ESA operational polar-orbiting satellites
  - **Imager** instruments onboard multi-national geostationary satellites (via Gridsat CDR and GSIP products)
- **QC/QA activities:**
  - Direct comparisons with reference OLR products (CERES EBAF Ed2.6r, SYN1deg Ed3A, SSF1deg Ed3A, ERBS Ed3r1)
  - Direct comparisons with other OLR products (Reanalysis products, ISCCP-FD, GEWEX-SRB, AVHRR)
  - Indirect comparisons through applications (MJO, Tropical expansion, etc.)

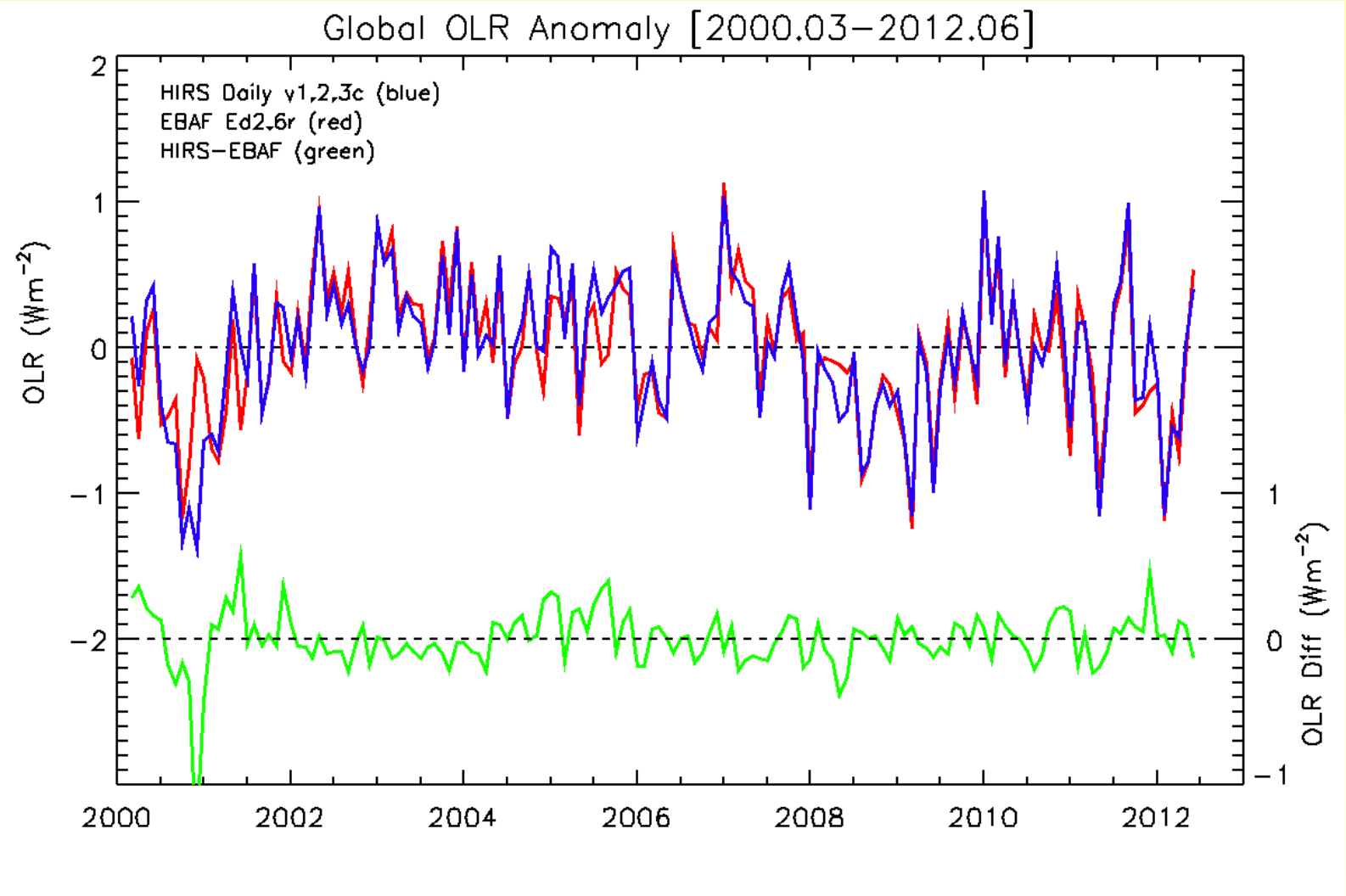
Daily OLR Data

- **Daily OLR CDR v01r02**
  - 1°x1°, Daily
  - 1979.01.01-2014.10.19
  - http://olr.umd.edu
  - http://www.ncdc.noaa.gov/cdr/operationalcdrs.html
- **CERES SYN1deg Ed3A**
  - 1°x1°, 3-hrly
  - 2000.03.01-2013.03.31
  - http://ceres.larc.nasa.gov
- **CERES EBAF Ed2.6r**
  - 1°x1°, Monthly
  - 2000.03-2012.06

- **ERA-Interim**
  - 1°x1°, 3-hrly fcst
  - 1979.01.01-2014.07.31
  - http://apps.ecmwf.int/datasets/data/interim_full_daily/
- **CFSR**
  - 1°x1°, 1-hrly fcst
  - 1979.01.01-2014.09.29
  - http://cfs.ncep.noaa.gov/cfsr
  - http://rda.ucar.edu/pub/cfsr.html
- **MERRA v5.2.0**
  - 1/3°x1/2°, 3-hrly fcst
  - 1979.01.01-2014.12.31
  - http://gmao.gsfc.nasa.gov/merra
  - ftp://goldsmr2.sci.gsfc.nasa.gov/data/s4pa/MERRA/MAT1NXRAD.5.2.0
- **JRA-55**
  - T319, 6-hrly init, 3-hrly fcst
  - 1979.01.01-2014.12.31
  - ftp://ds.data.jma.go.jp

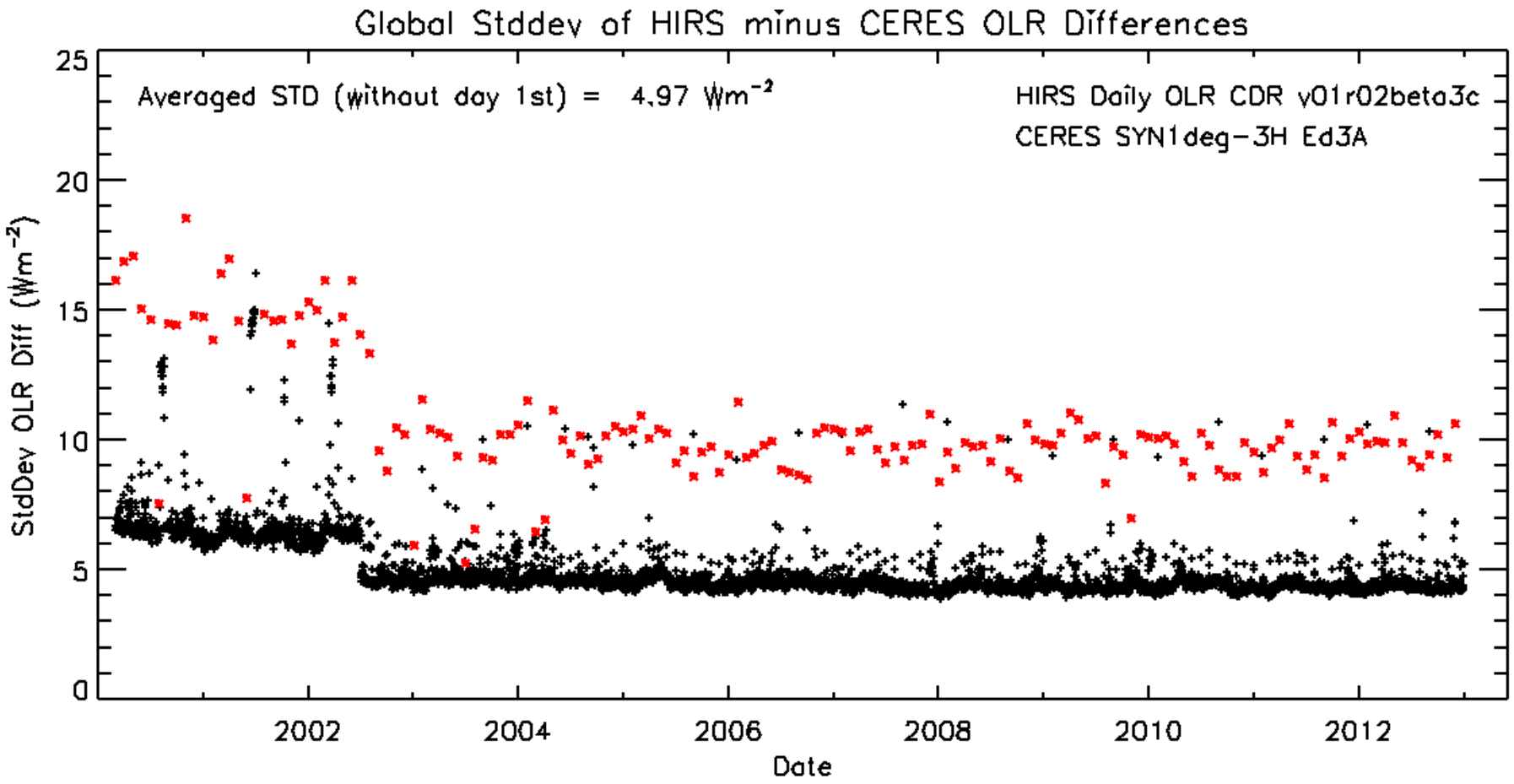
Direct Comparisons

Global OLR Anomalies (2000-2012)



Slope of OLR anomalies diff = 0.03 ± 0.09 Wm^{-2}/decade with 2-sigma

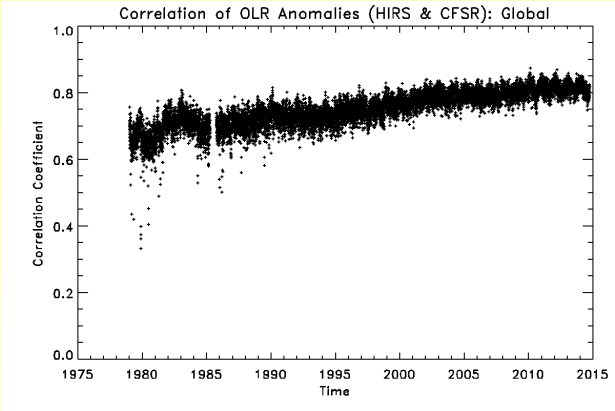
STD of OLR Differences (Daily, Global)



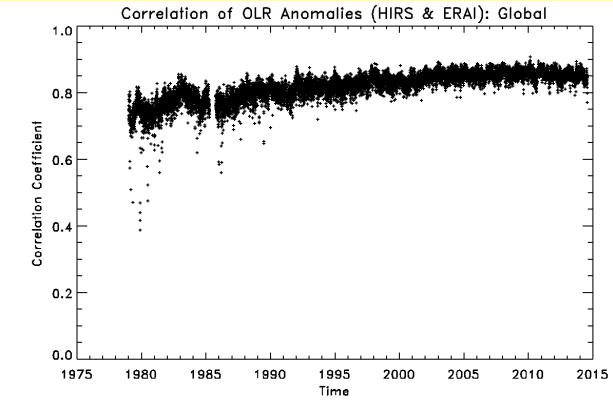
- *CERES SYN1deg-3hr Ed3A has a processing bug on 1st day of each month (red points).*
- *Time series 'shock' due to CERES sampling change when Aqua entered in July 2002.*

Spatial Correlation of OLR Anomalies (Daily, Global)

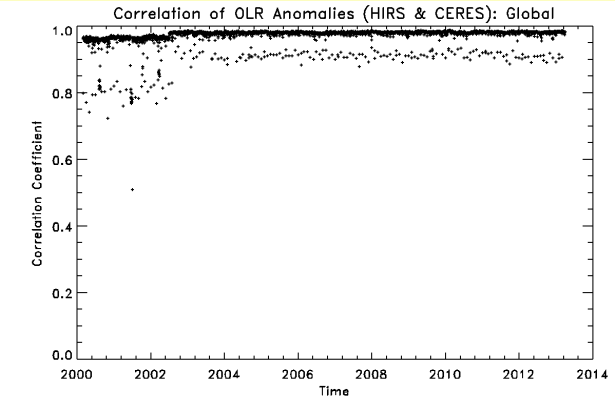
CFSR & HIRS



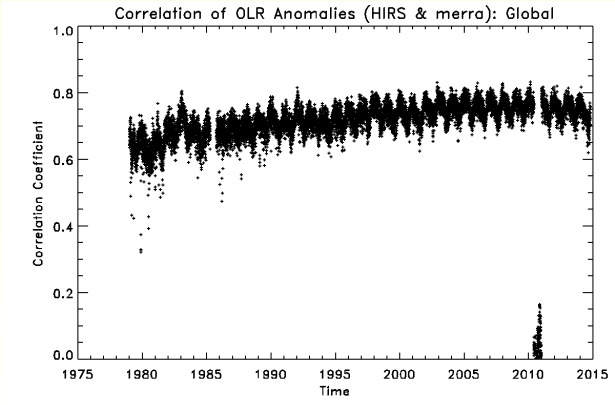
ERAI & HIRS



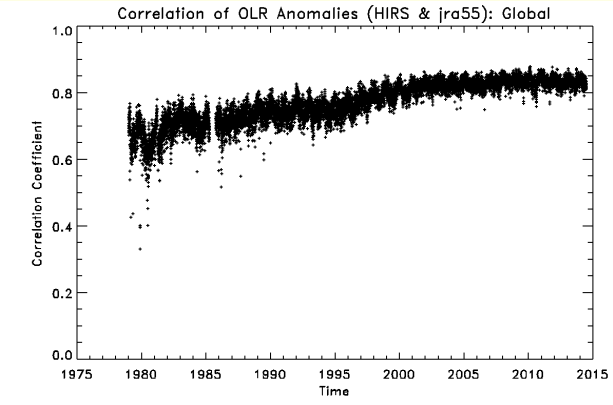
CERES & HIRS



MERRA & HIRS

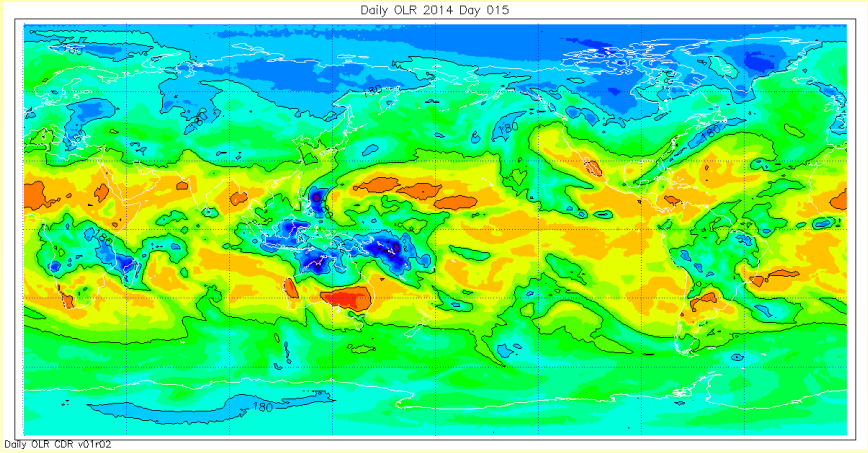


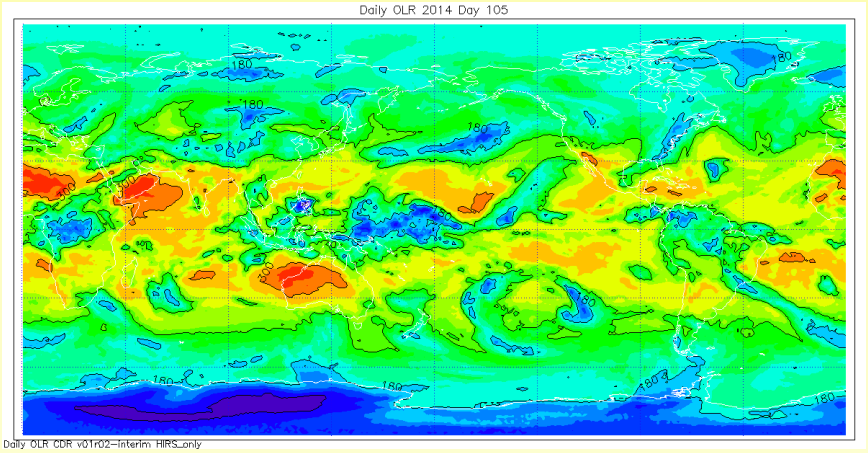
JRA55 & HIRS

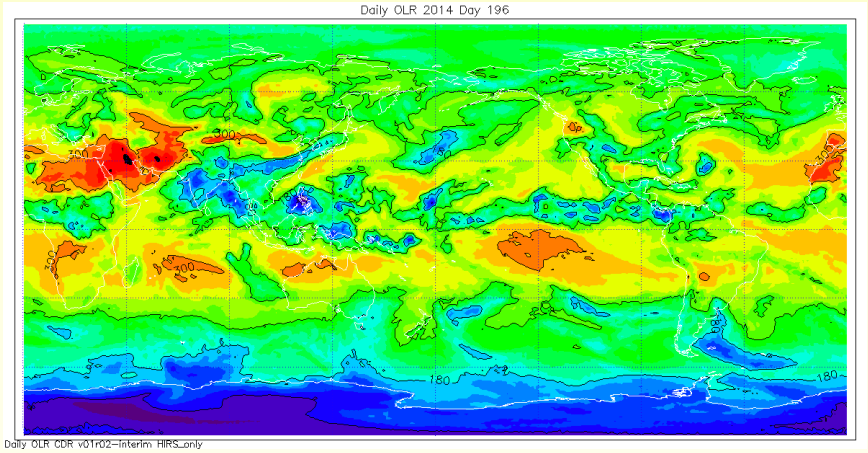


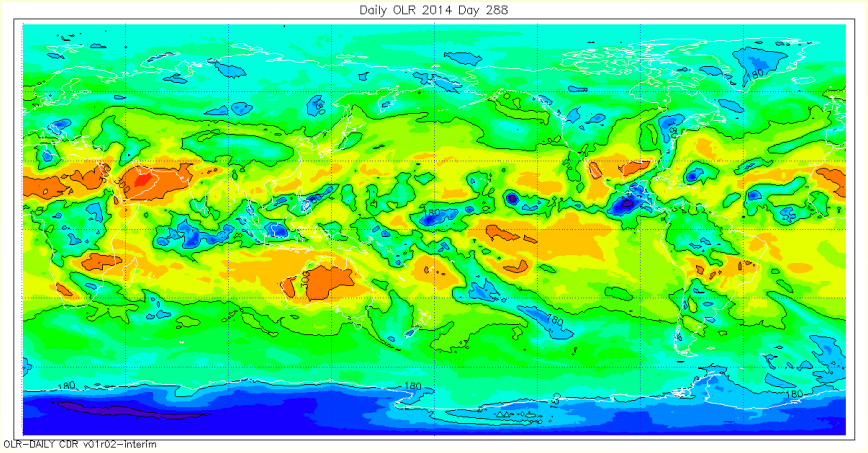
Tropical Expansion

Daily OLR Seasonal Variations



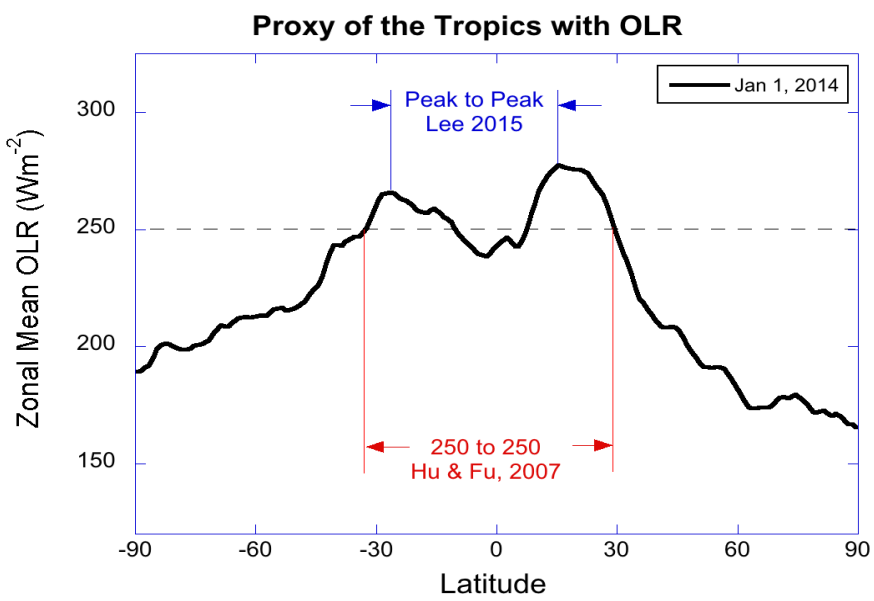


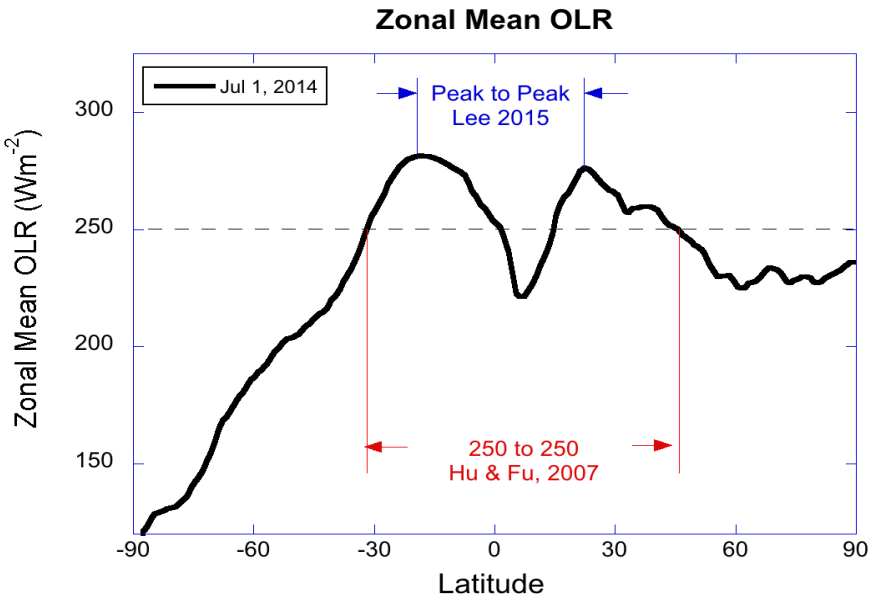




The large OLR values (yellow-orange-red) are most associated with the subtropical zones, with transient convective and advective cloud systems (green/blue) cutting through them. The boundary of the tropics cannot be well defined on a daily mean OLR field due to the disruptions by the transient dynamical features.

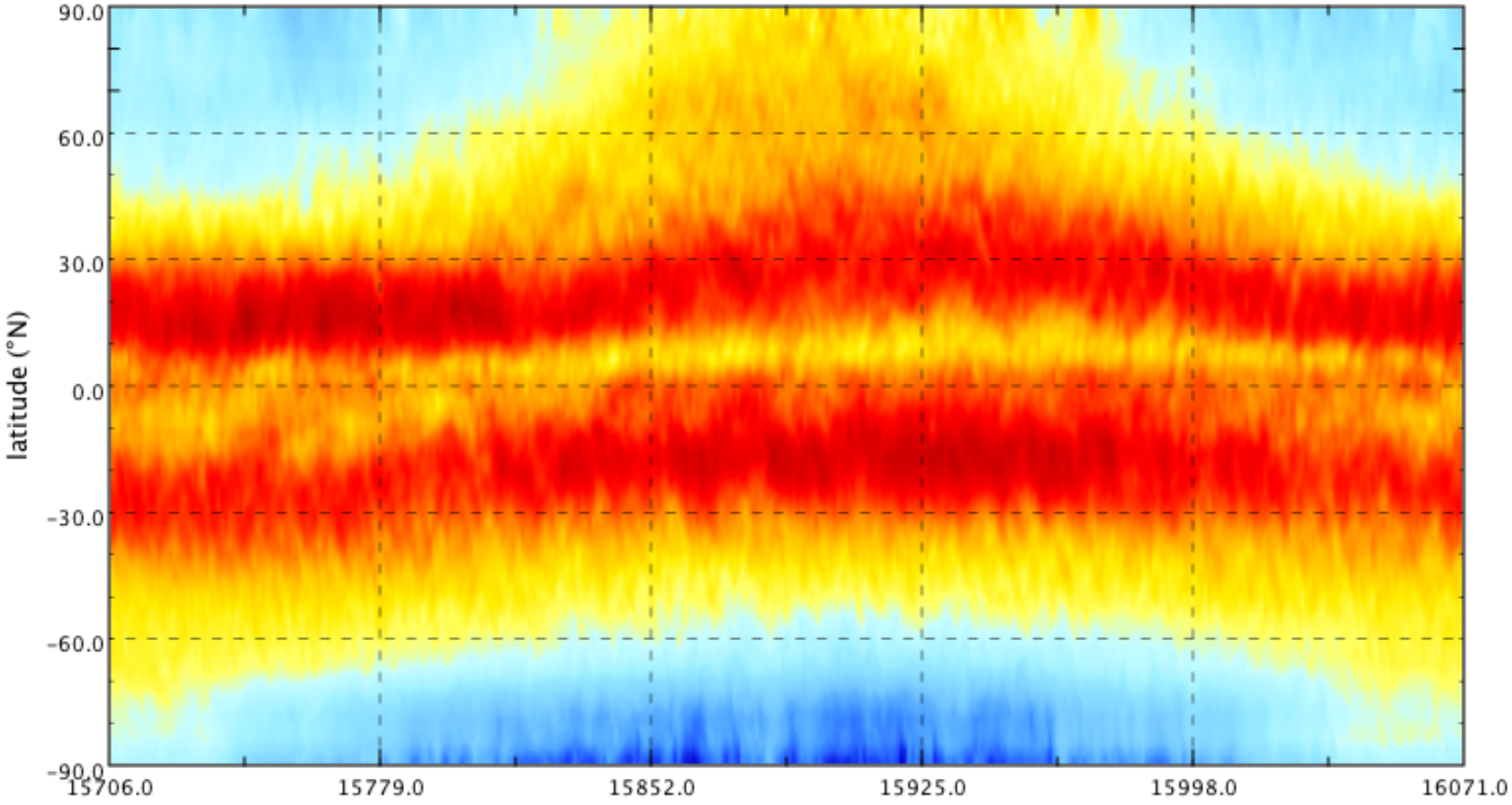
Proxies of Tropical Width by OLR





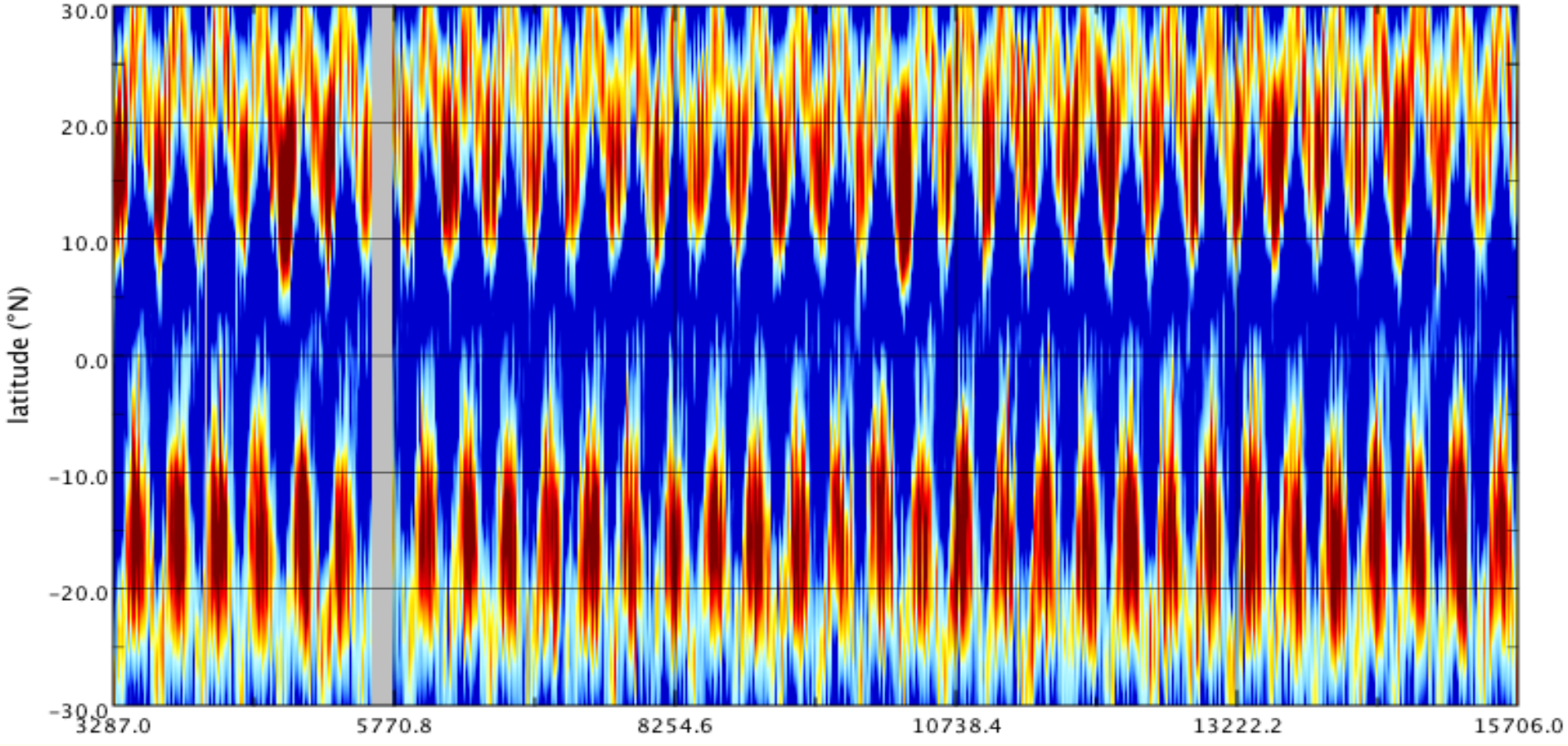
- Hu & Fu (2007) uses poleward-most latitudes of 250 Wm^{-2} zonal mean OLR to define the tropics. We suggest to use the OLR peaking latitudes.
- The peaking latitudes are closely associated with the location of the subtropical subsidence dry zone and the underlying warm emitting surface.
- The advantage lies in its robustness that the determination is tolerant of problems like systematic biases (offset or scaling), drifting, or discontinuities.

Daily Zonal Mean OLR for 2013



Peak OLR values in zonal mean OLR are very well-defined. The two peaking latitudes correspond approximately to the center of the subsidence zone. We use them to describe the variation of the tropical zone.

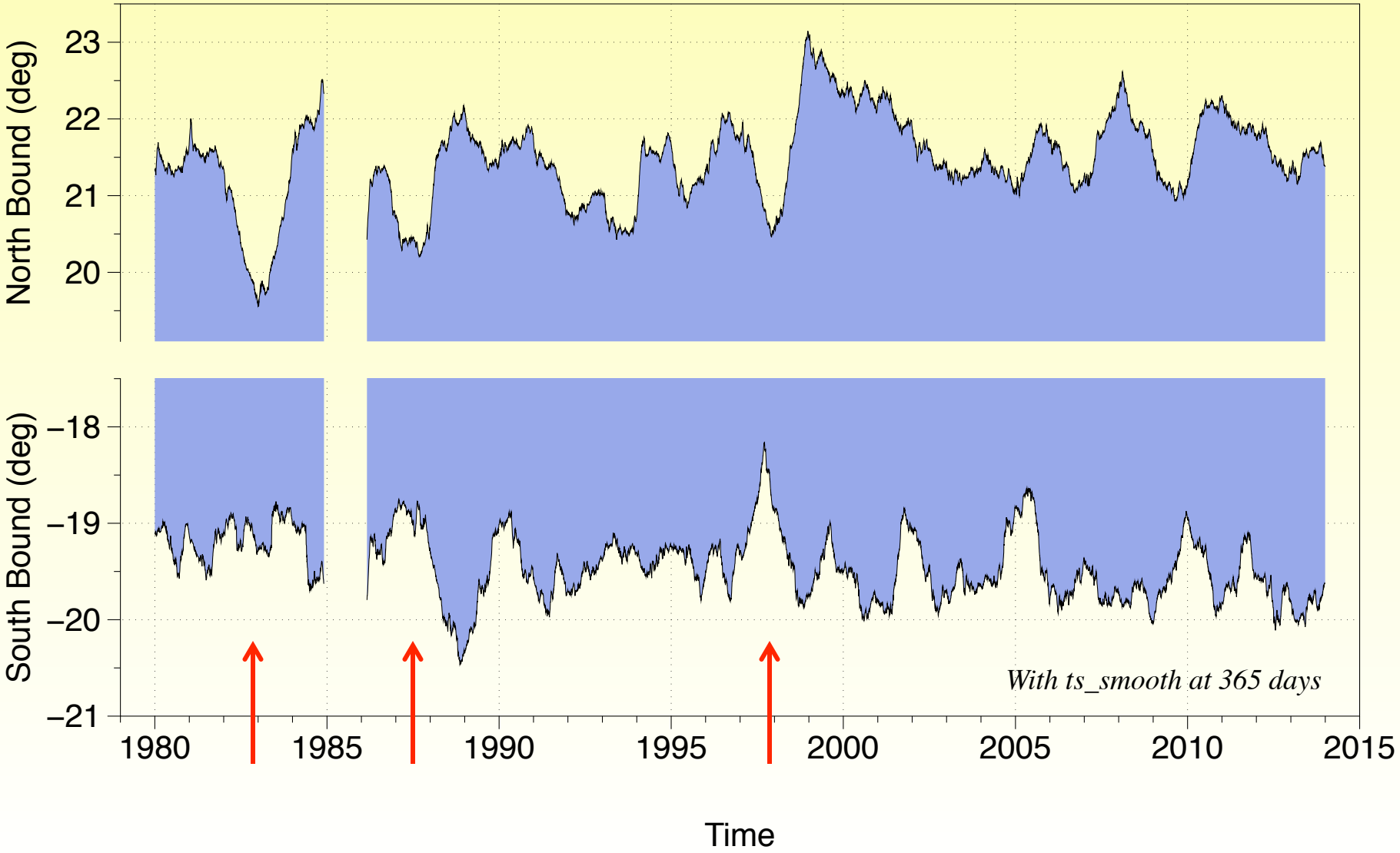
Daily Zonal Mean OLR for 1979-2012



Variations in the locations and tropical widths derived from the Daily OLR CDR v01r02 time series.

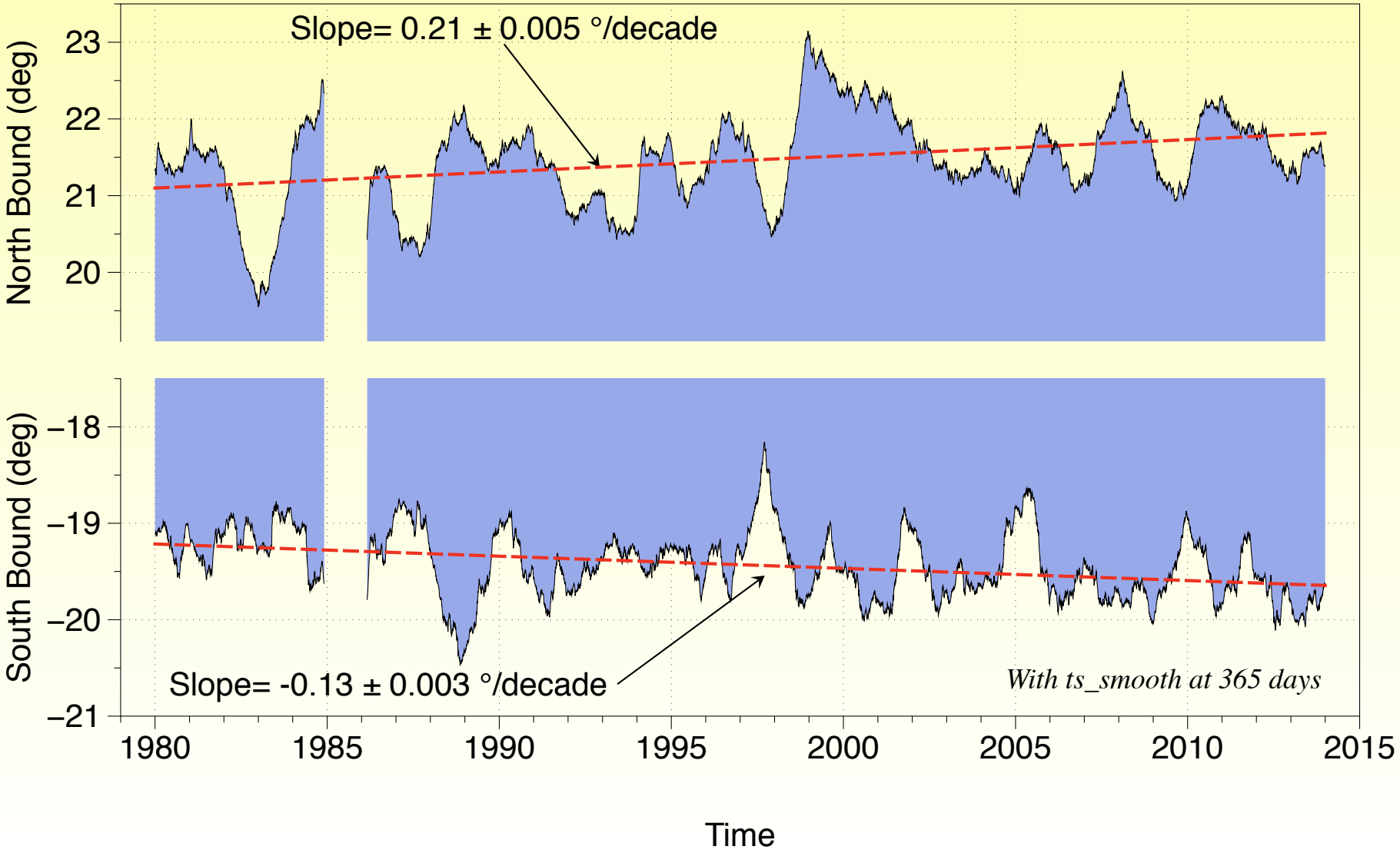
Variation in Tropical Bounds

1980-2014



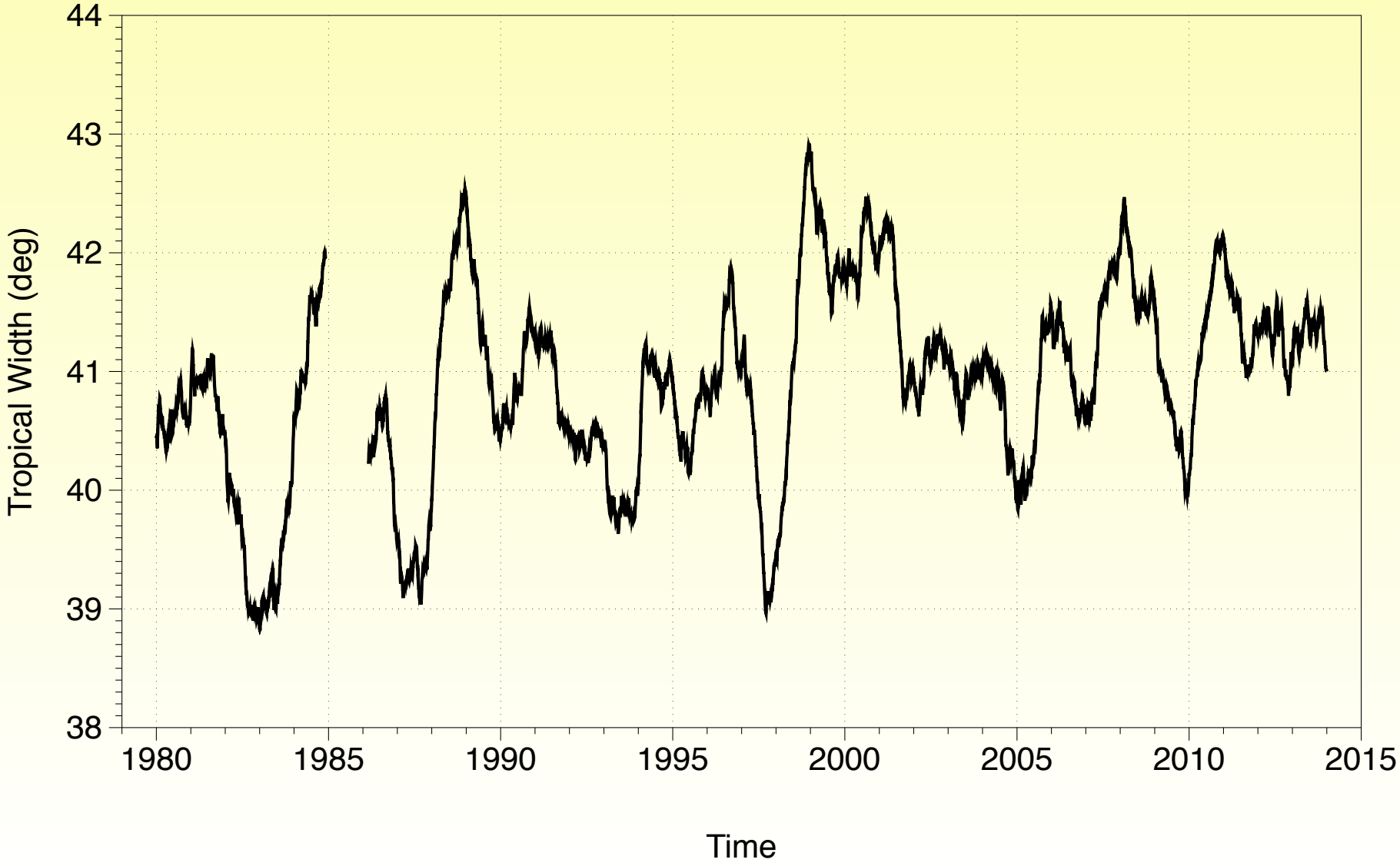
Trend in Tropical Bounds

1980-2014



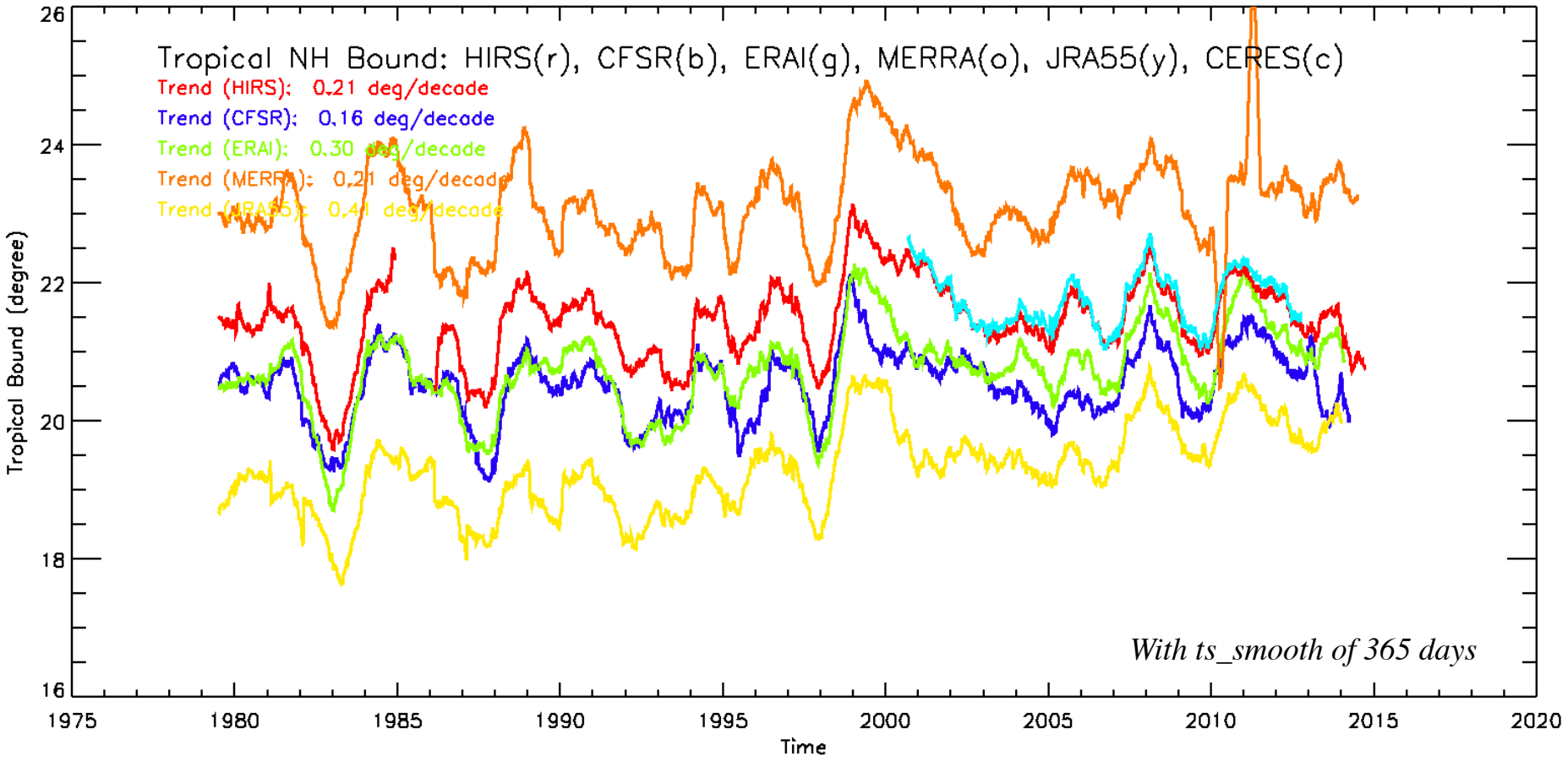
Variation of Tropical Width

1980-2014



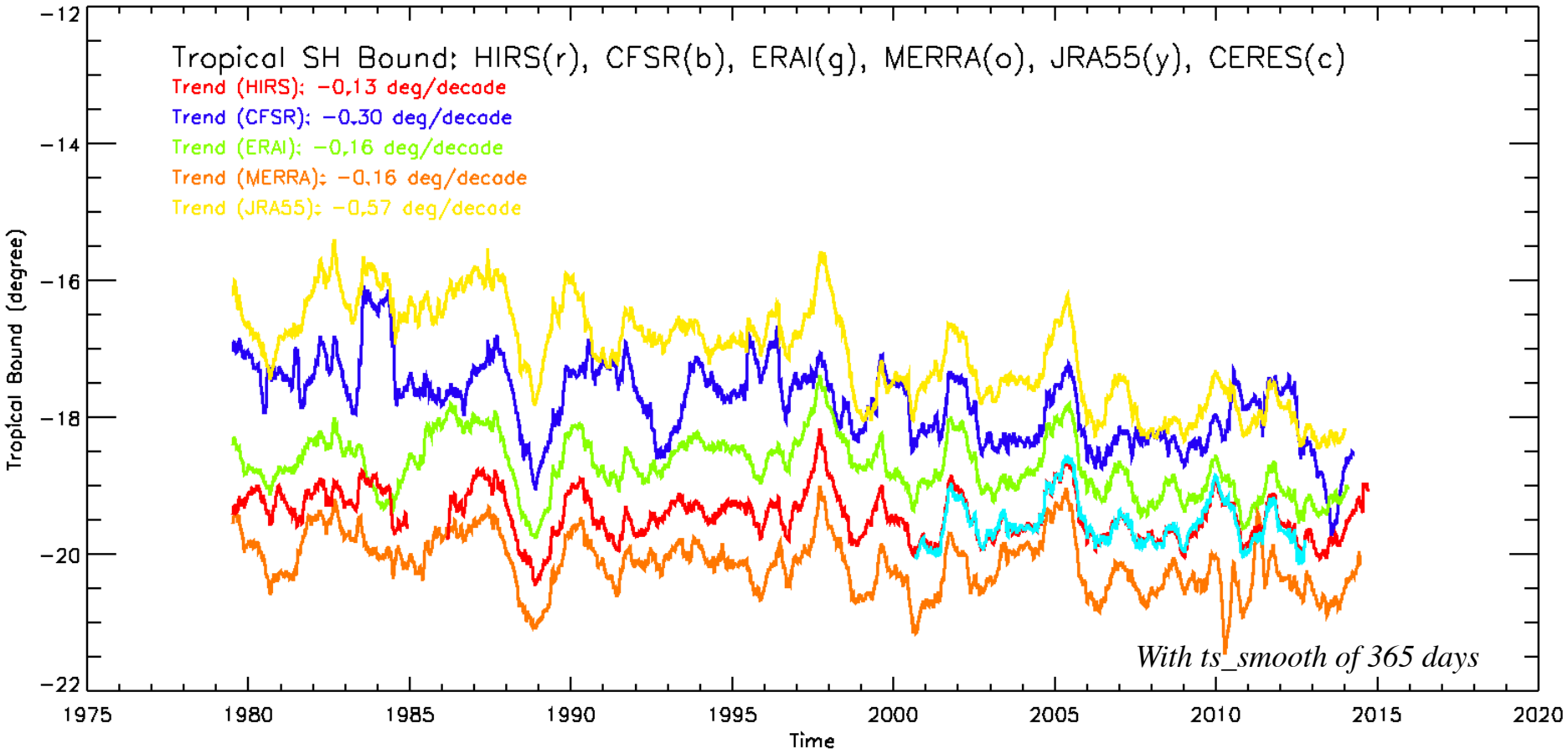
Satellite Observations
vs
Reanalysis Products

Tropical N.H. Bound



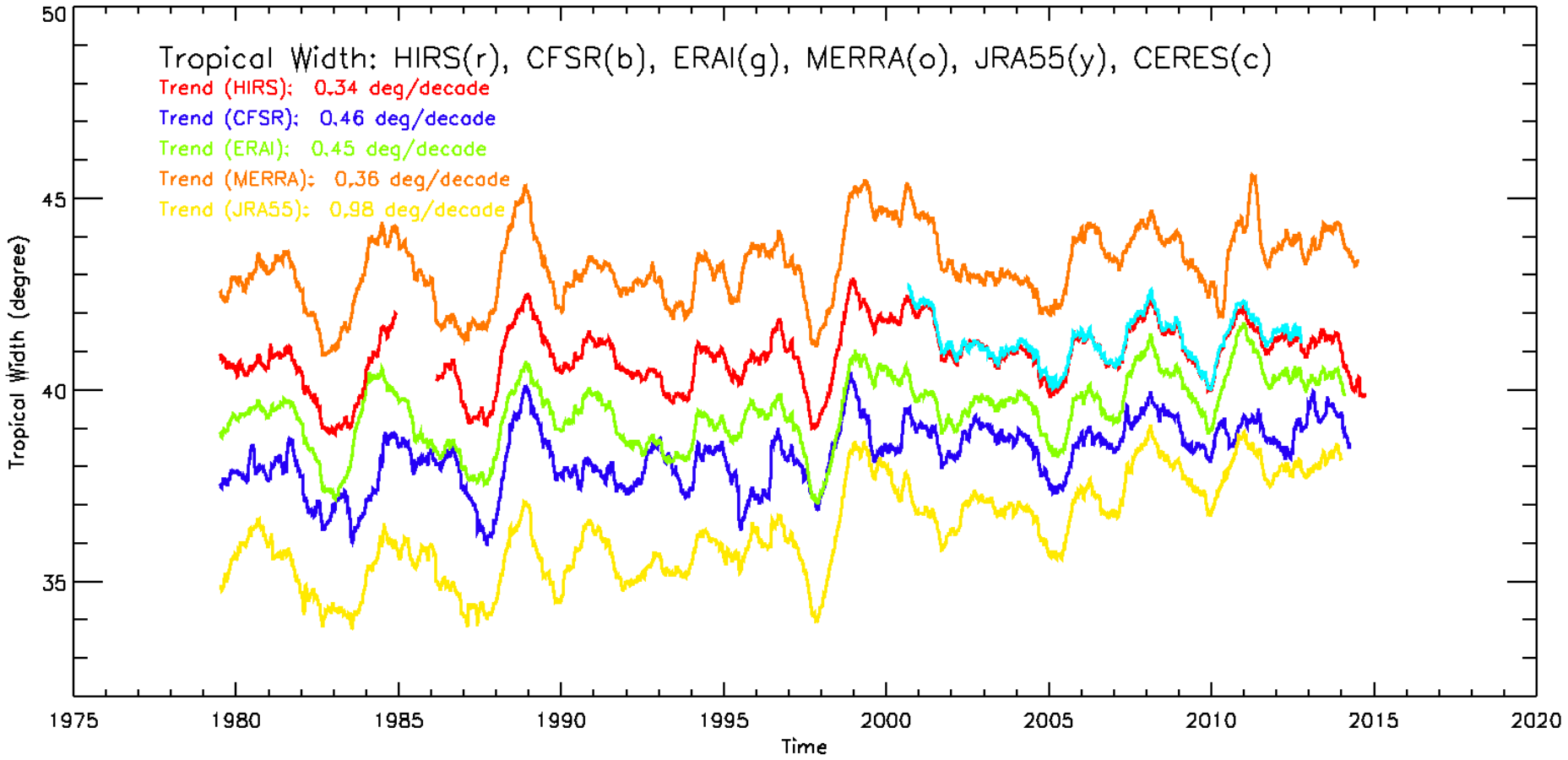
Comparison of tropical bound for northern hemisphere between the observed and the reanalysis. There are systematic differences in the peaking latitudes, nevertheless, with fairly good correlations.

Tropical S.H. Bound



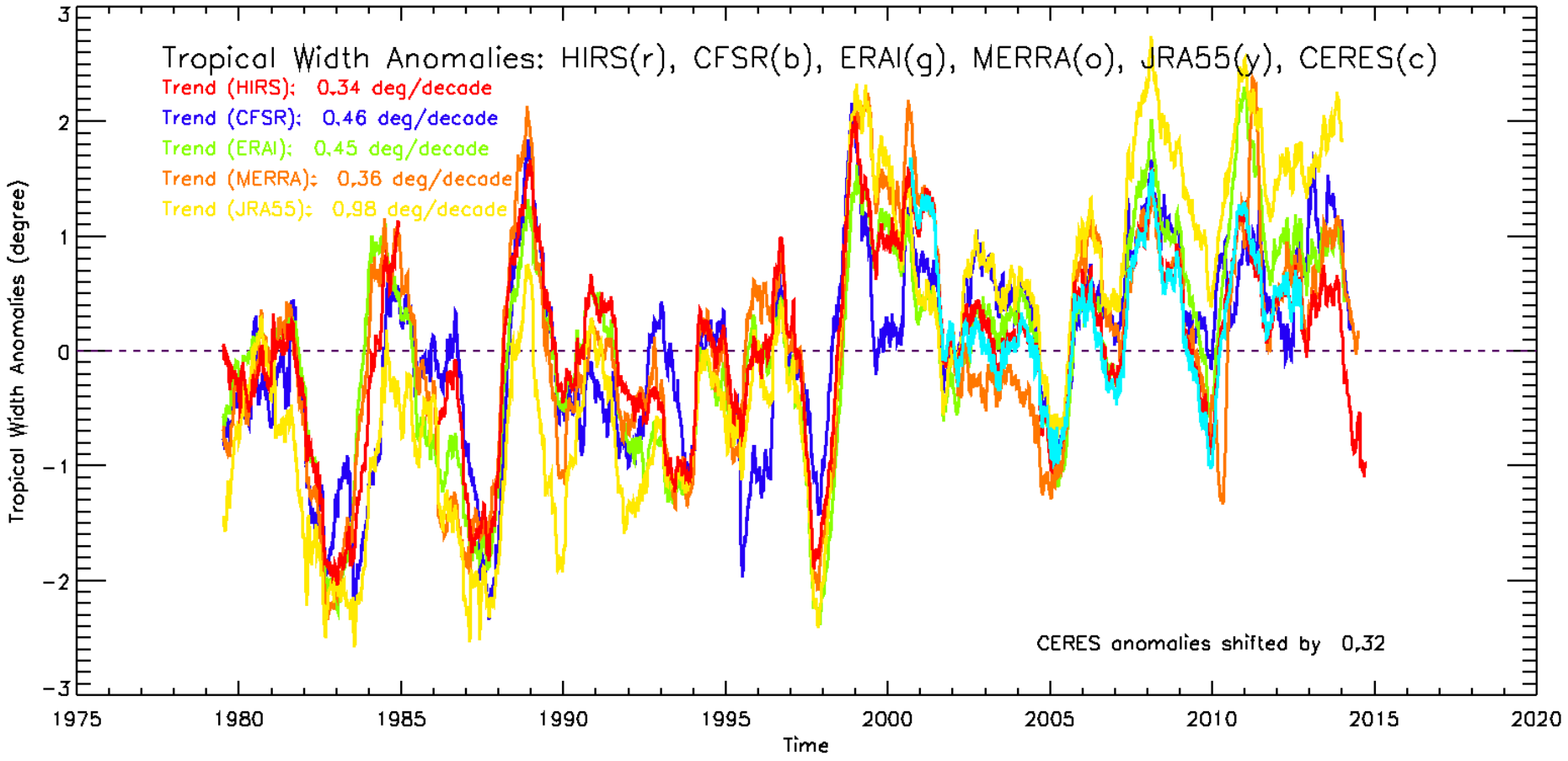
Less divergent, but still with sizeable systematic differences

Variation of Tropical Width



Very good correlation in the variations in tropical width described by observation and reanalysis. Reanalyses have larger rates of tropical expansion, 0.36-0.46 (0.98 for JRA) degrees per decade, versus 0.34 degrees per decades estimated by the OLR CDR for 1980-2013.

Tropical Width Anomalies



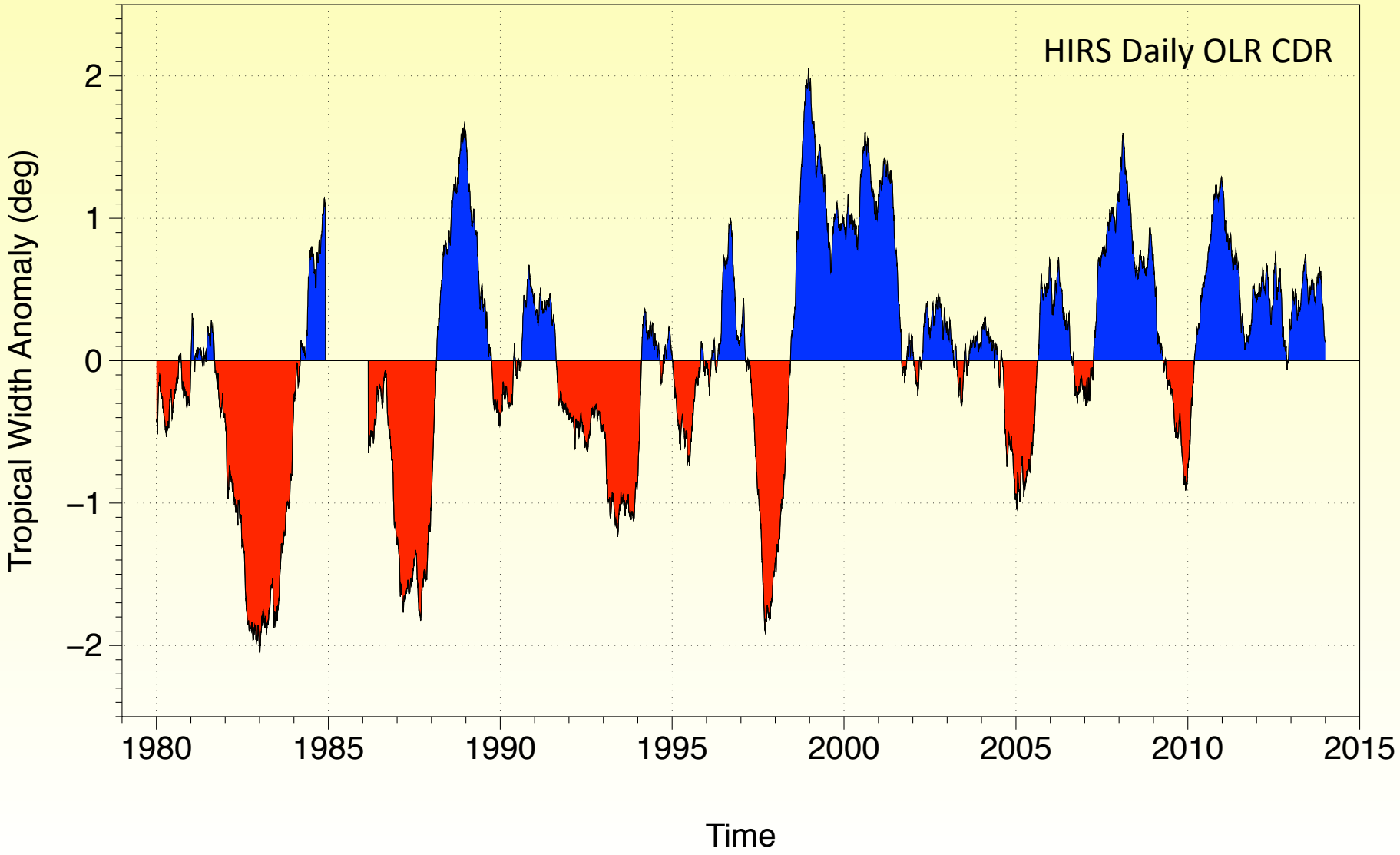
Very good agreement in the tropical width variations, both in phase and magnitude. Apparent deviations suggest data problems. Likely spurious trend in JRA55.

Tropical Expansion, ENSO/PDO

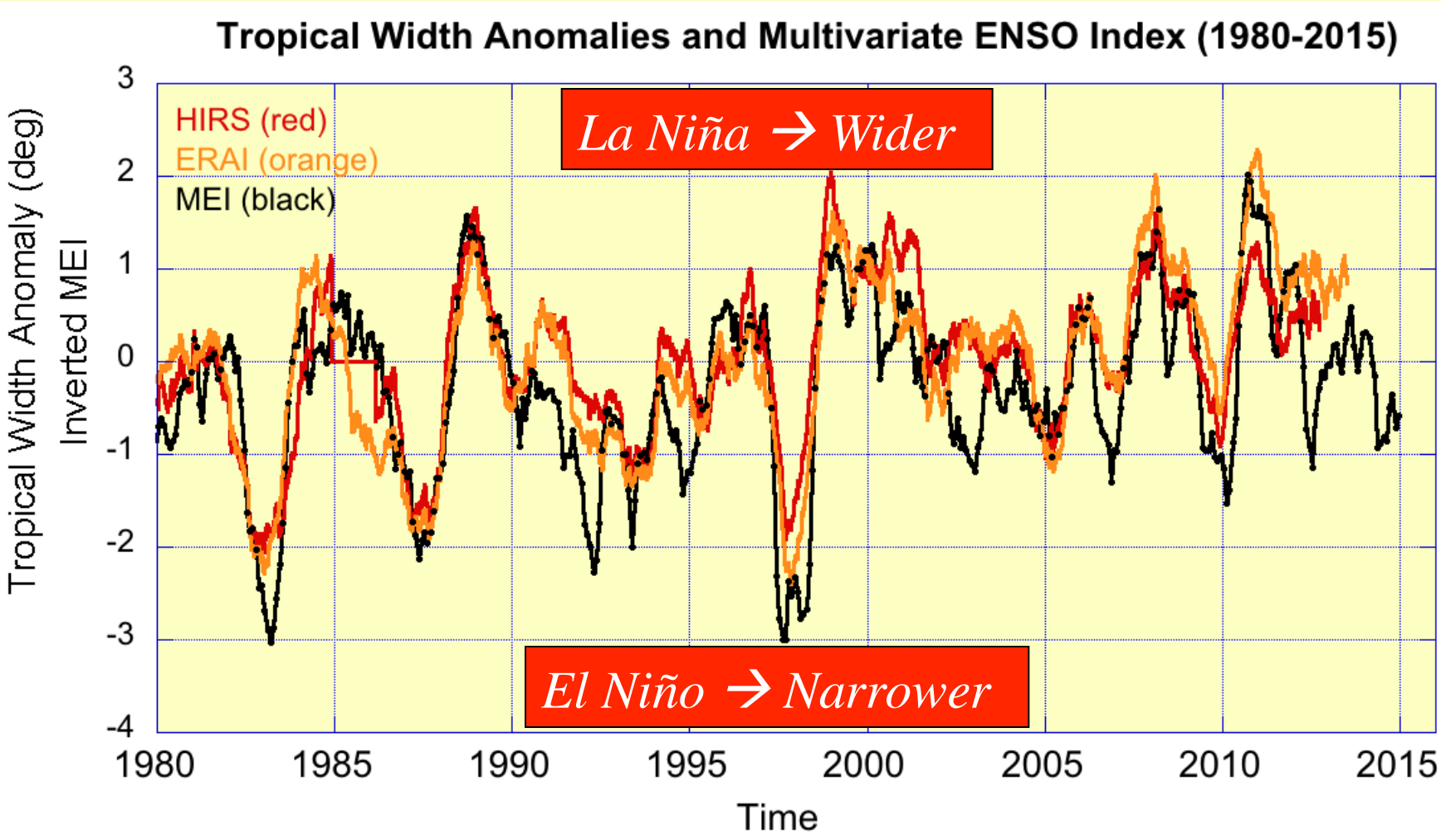
in the perspective of Global Warming

Tropical Width Anomalies

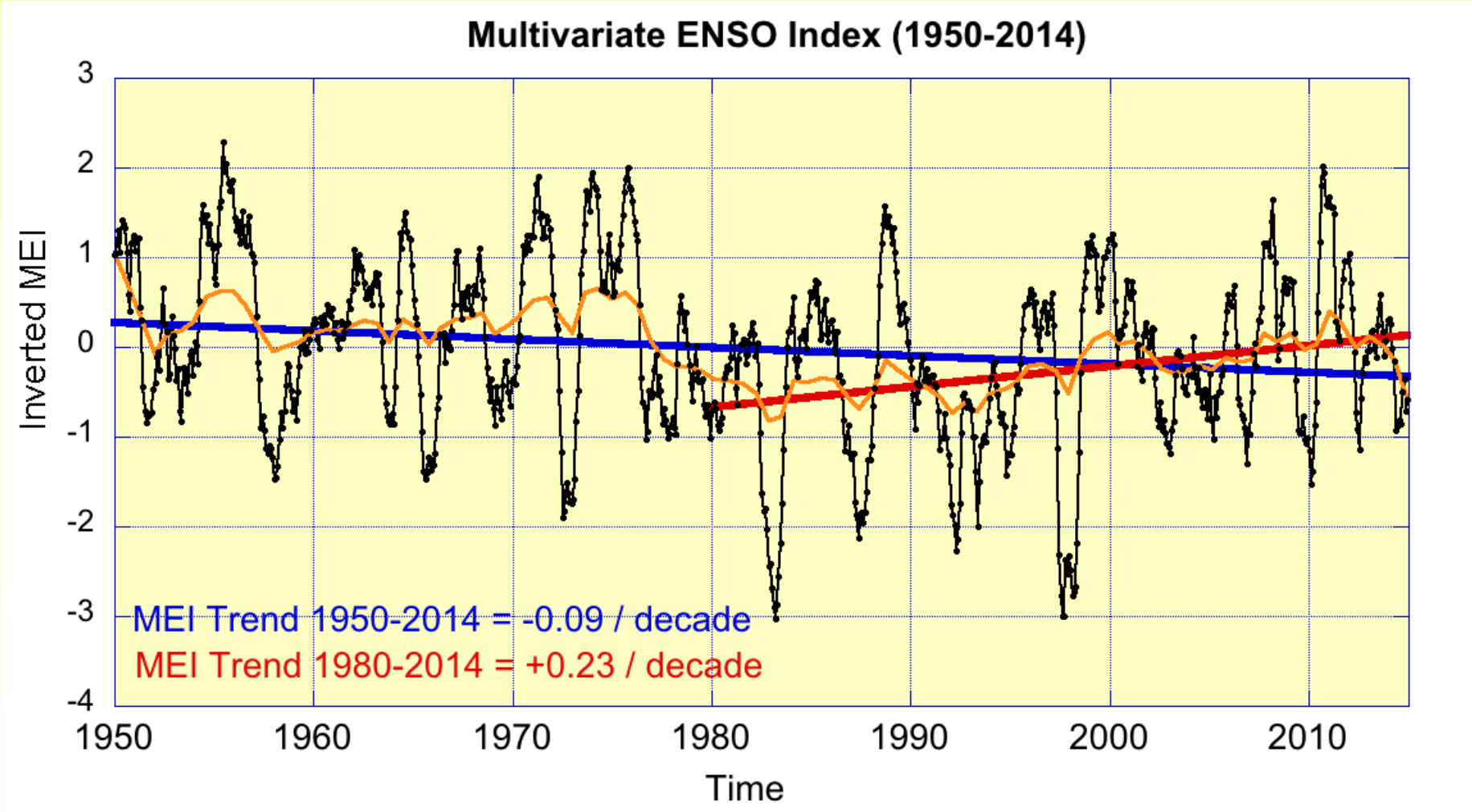
1980-2014



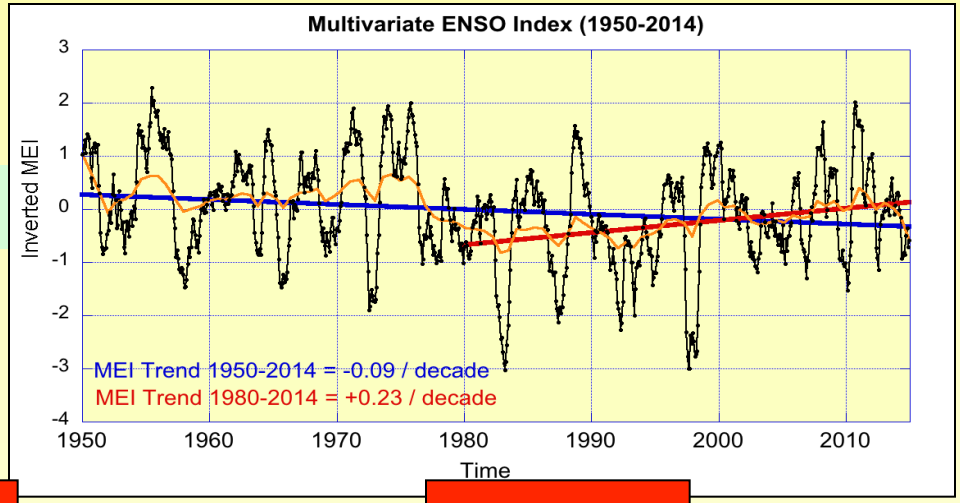
Tropical Width Anomaly and MEI



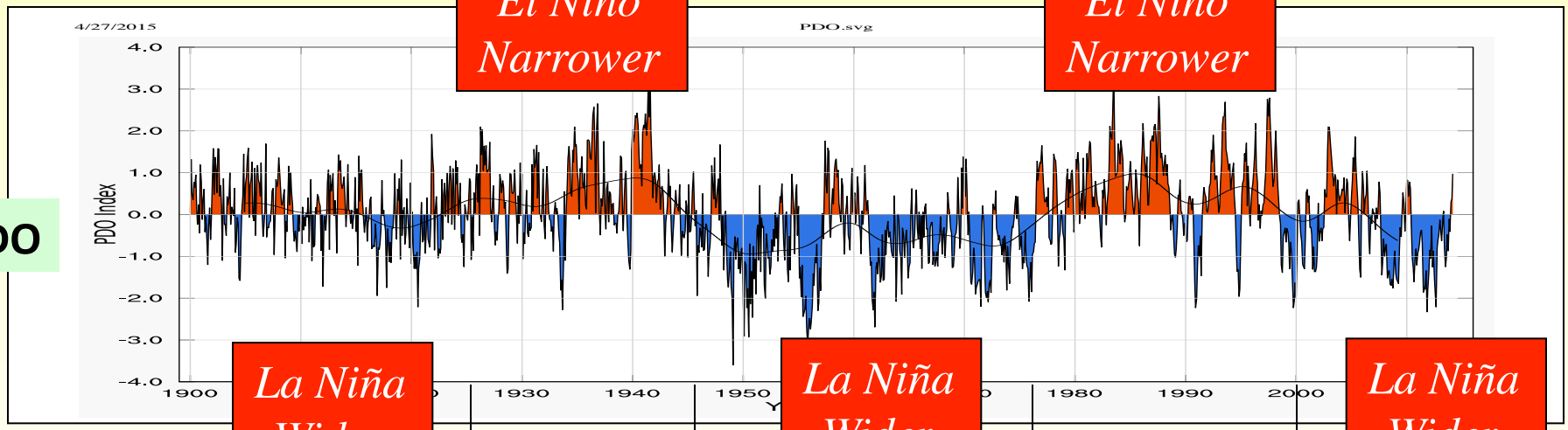
“Local” Trends in MEI (and Tropical Width)



-MEI



PDO



El Niño Narrower

El Niño Narrower

La Niña Wider

La Niña Wider

La Niña Wider

1924 1947 1977 ?

Summary

- Robust proxy of “tropical width” variation can be defined by the peaks of the zonal mean OLR, showing very agreeable features in observational and reanalysis data sets.
- Appearance of tendency depends on where the segment of data starts and ends. Global warming leads to **La Niña-like** states may be true, but requires much longer observational data to confirm.
- Be cautious on trends quantified from currently available satellite data because the slower oscillations (period >30yrs) cannot be resolved or accurately removed, easily leading to over or under-estimation.

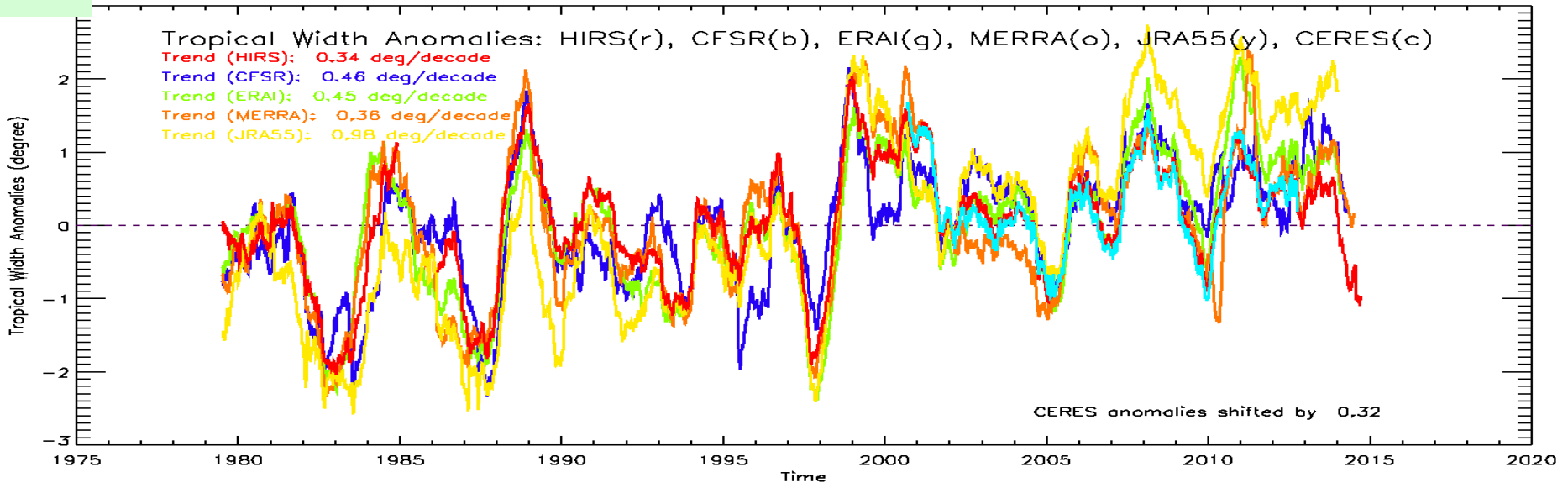
Acknowledgments

- Data sources: NCDC, LaRC, GSFC, NCEP, UCAR, ECMWF, JMA, ESRL
- Bill Lau, Michelle L'heureux, Shi-Keng Yang, Dian Seidel for their suggestions and discussions
- NOAA NCDC CDR Program for funding support

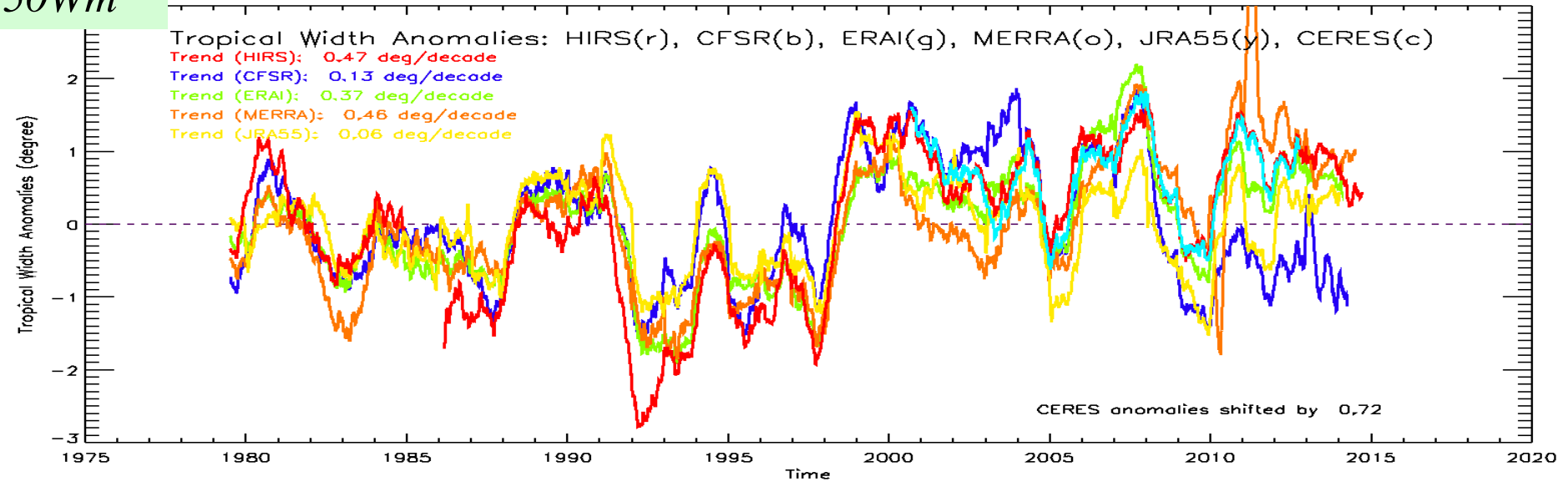
Backup slides

Tropical Width Anomalies

Peak



250Wm^{-2}



Changes in RH from CMIP5

4x CO_2 Simulation (1% increase for 140 years)

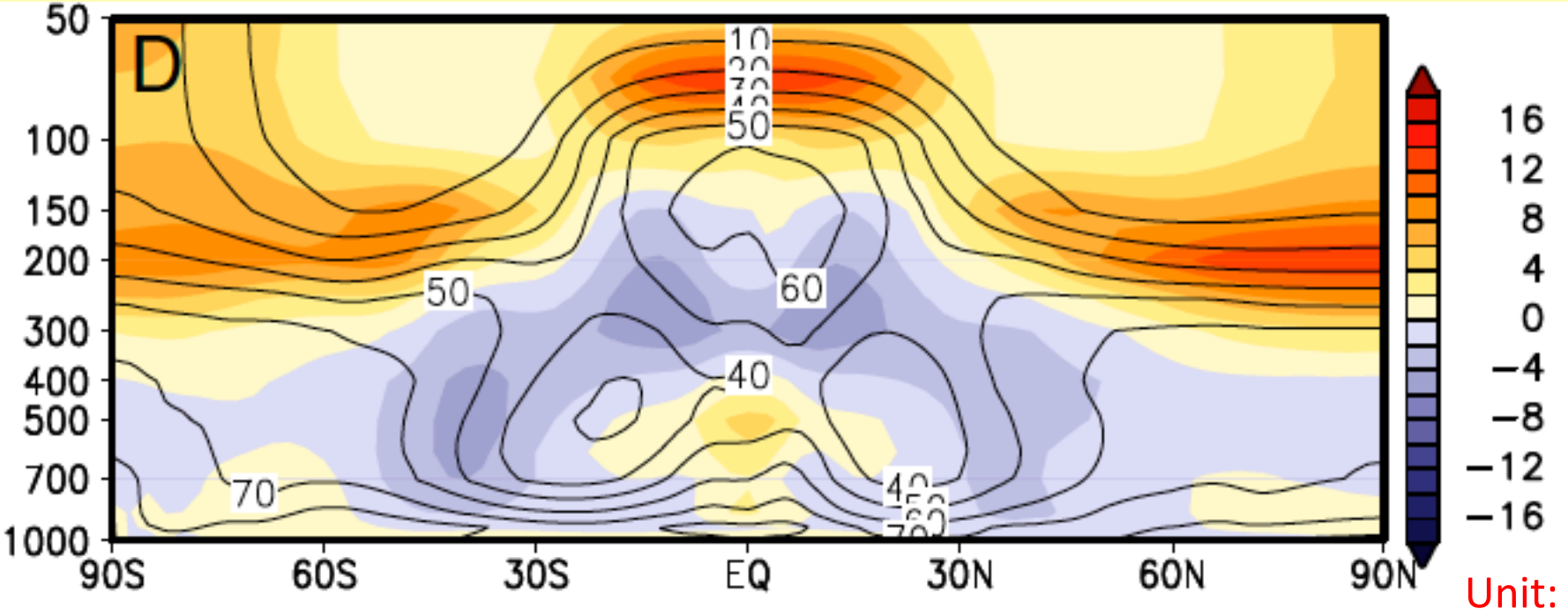
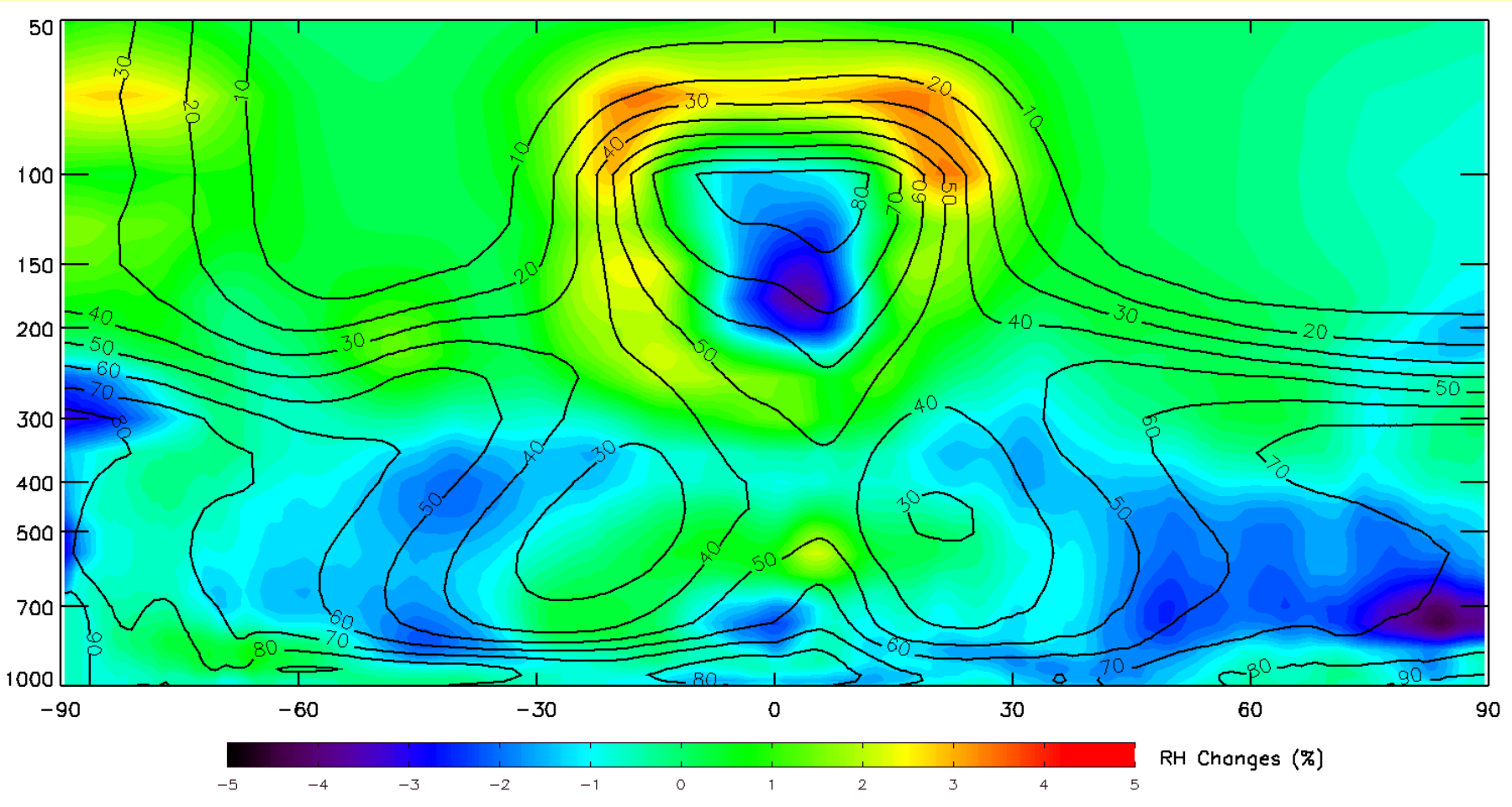


Fig. 3. Latitude–height cross section of (*A*) anomalous meridional zonal mean winds (meter per second) and (*D*) anomalous humidity (percent). The climatological mean is shown in contour, and anomaly is shown in color. Latitudinal profiles of components of moisture budget for (*B*) the control and (*C*) the anomaly. See Eq. **1** for explanation of symbols. Units in millimeters per day.

Lau & Kim, 2015 PNAS

Changes in RH from ERA Interim

<1996-2012> minus <1979-1995>

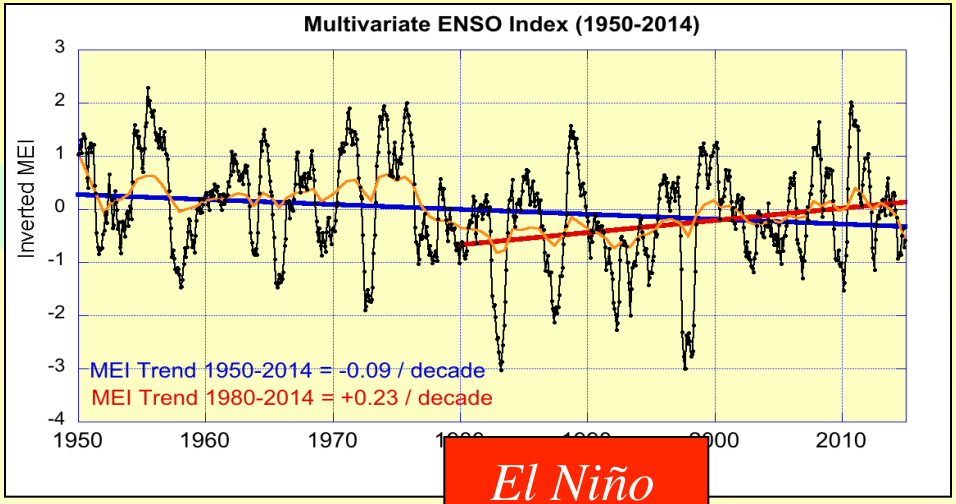


Contour: Climatology (1979-2012) of RH (%). Shaded: Changes of RH between the two 17-year periods [1979-1995] and [1996-2012].

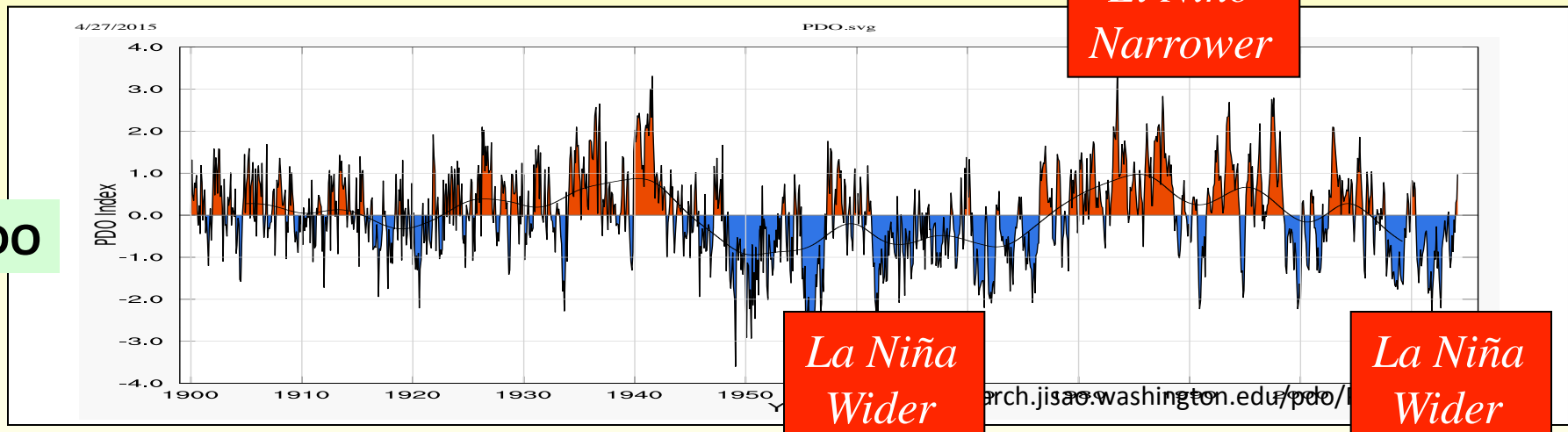
La Niña → Wider

El Niño → Narrower

-MEI



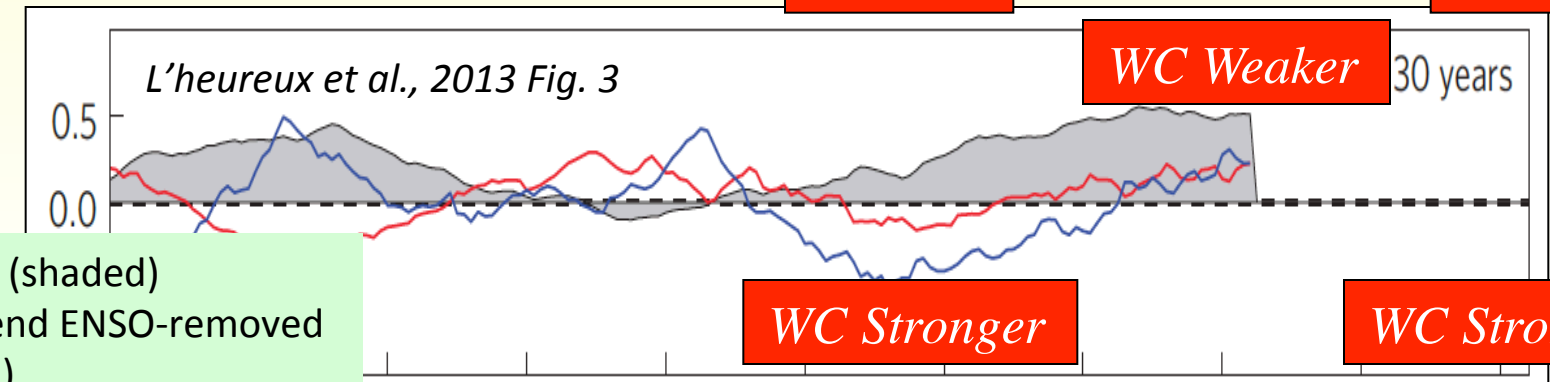
PDO



El Niño Narrower

La Niña Wider

La Niña Wider



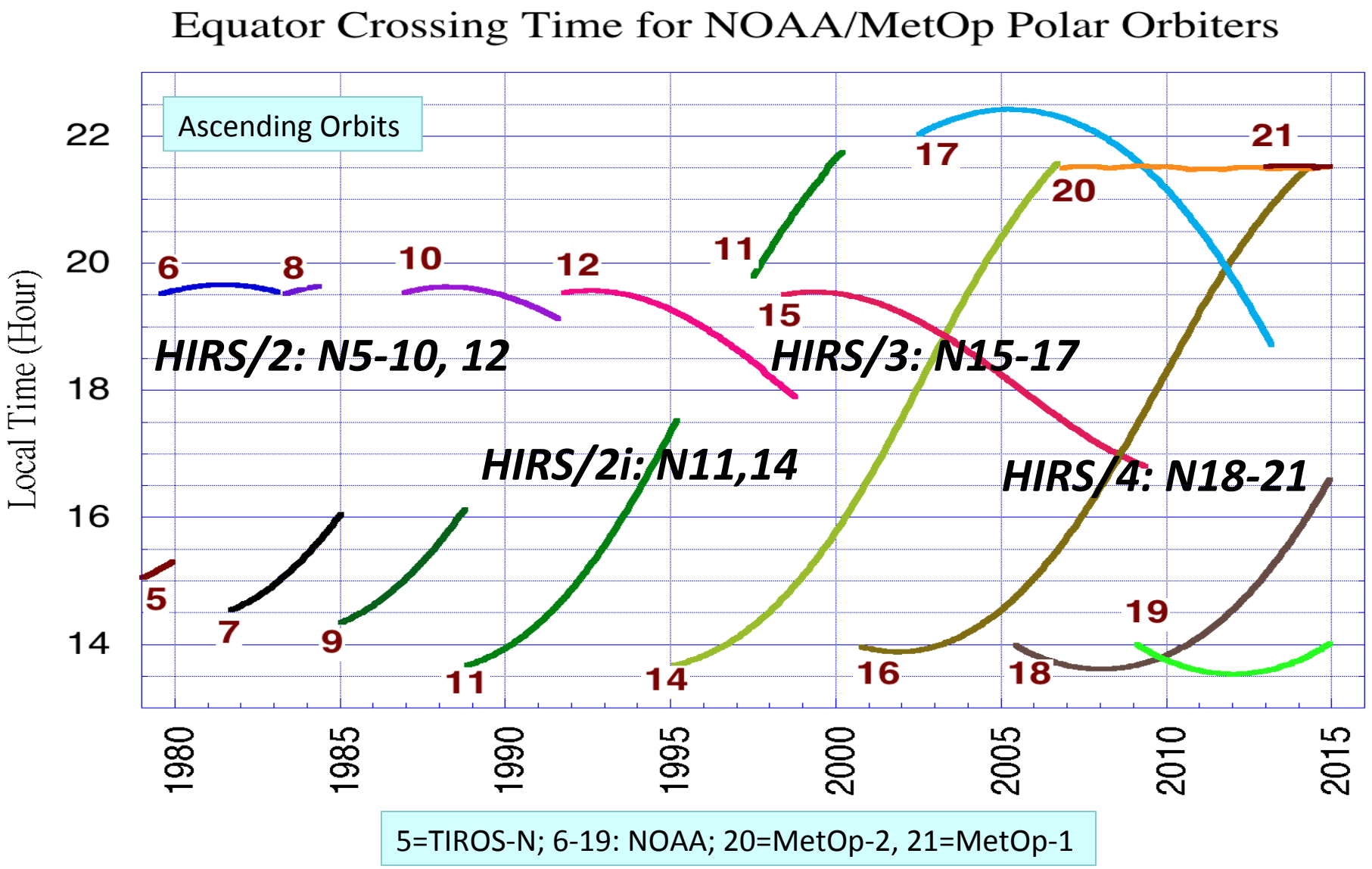
WC Weaker

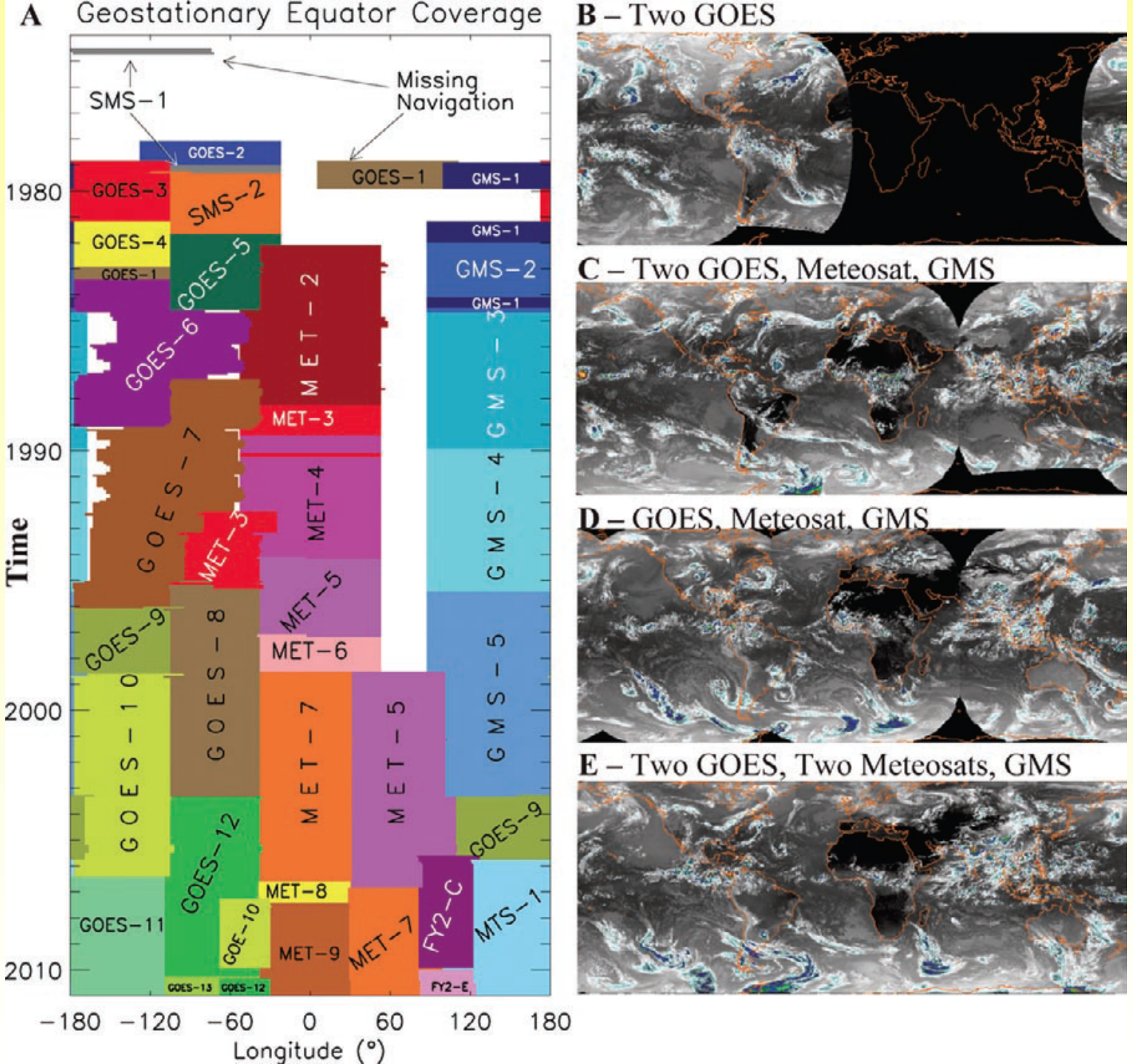
WC Stronger

WC Stronger

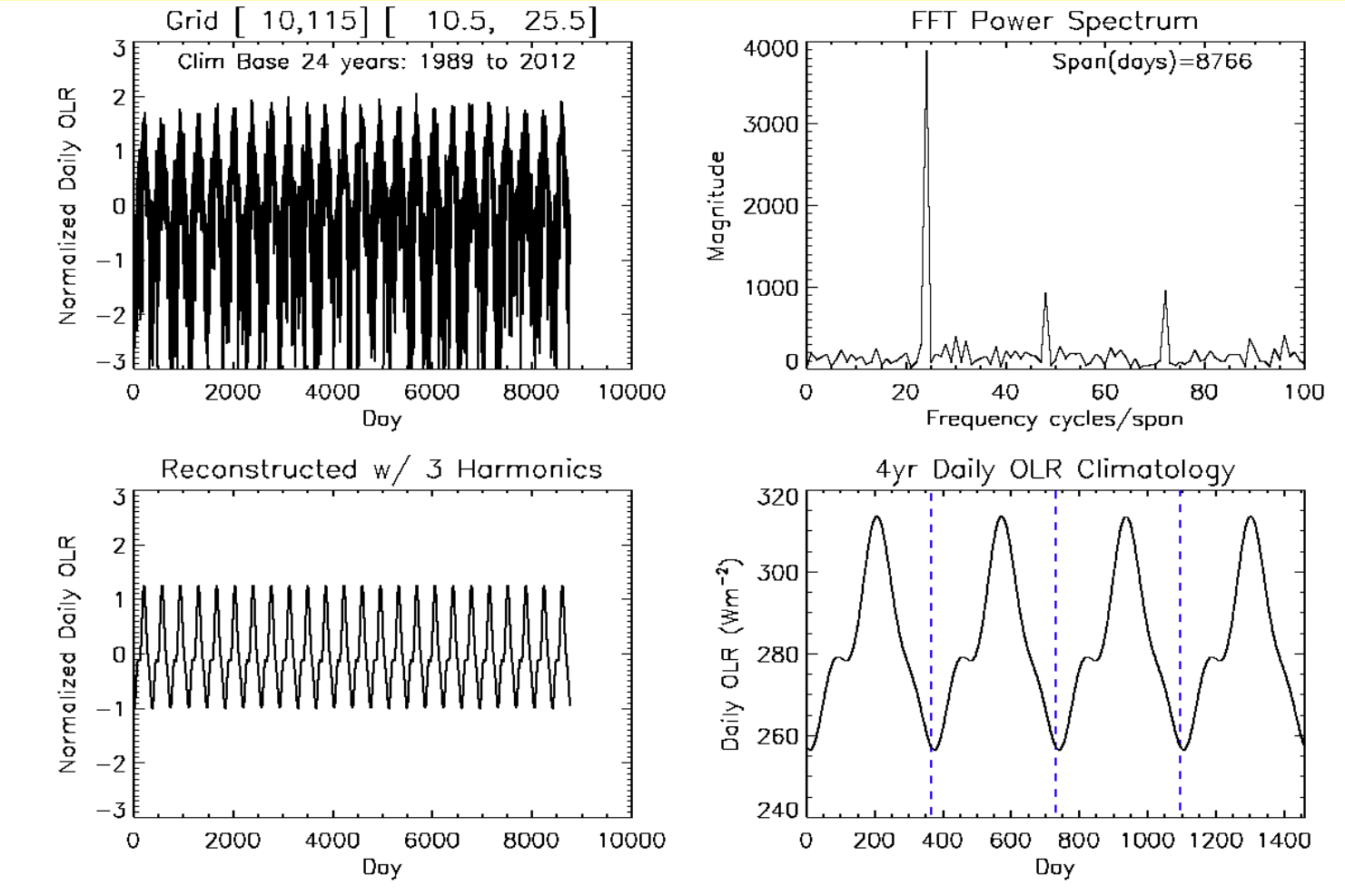
Global Temp (shaded)
SLP 30-yr Trend ENSO-removed
E.Pacific (red)

HIRS Variants and Time of Observations




A Geostationary Equator Coverage
SMS-1
Missing Navigation
GOES-2
GOES-3
SMS-2
GOES-1
GMS-1
GOES-4
GOES-5
GMS-2
GOES-6
MET-2
GMS-3
MET-3
GOES-7
MET-4
GMS-4
MET-3
MET-5
GOES-9
GOES-8
MET-6
GMS-5
GOES-10
MET-7
MET-5
GOES-12
GOES-9
MET-8
GOES-11
GOE-10
MET-9
MET-7
FY2-C
MTS-1
GOES-13
GOES-12
FY2-E
1980
1990
2000
2010
Time
−180 −120 −60 0 60 120 180
Longitude (°)
B – Two GOES
C – Two GOES, Meteosat, GMS
D – GOES, Meteosat, GMS
E – Two GOES, Two Meteosats, GMS

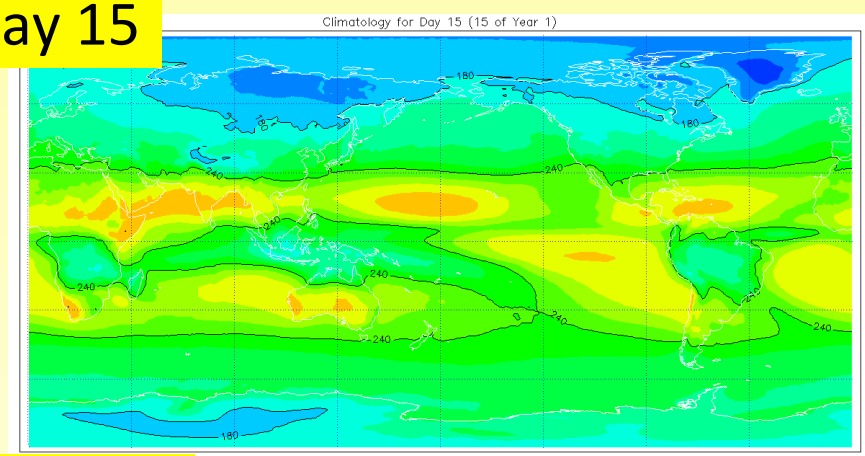
Daily OLR Climatology



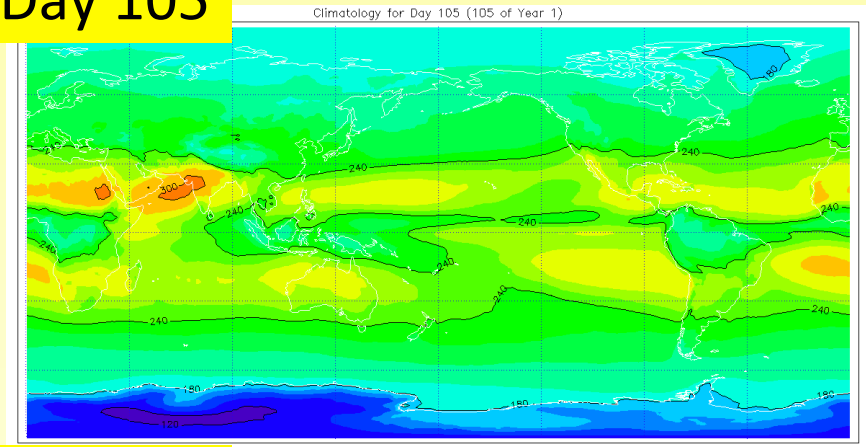
Daily climatology is derived for a 4-year (1461 days) cycles via FFT filtered by first 3 major harmonics representing annual, semi-annual and 1/3 annual cycles.
Climate base is 1989-2012 (24 years) for HIRS, CFSR and ERAI; 2001-2012 (12 years) for CERES.

Daily OLR Climatology (HIRS)

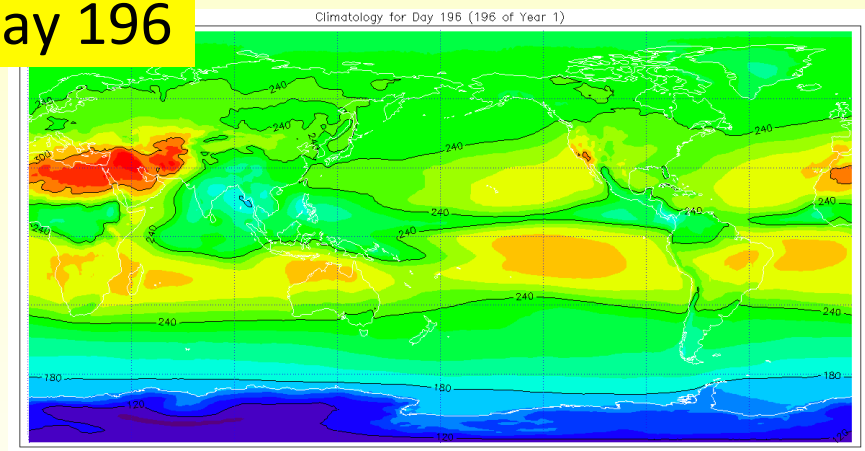
Day 15



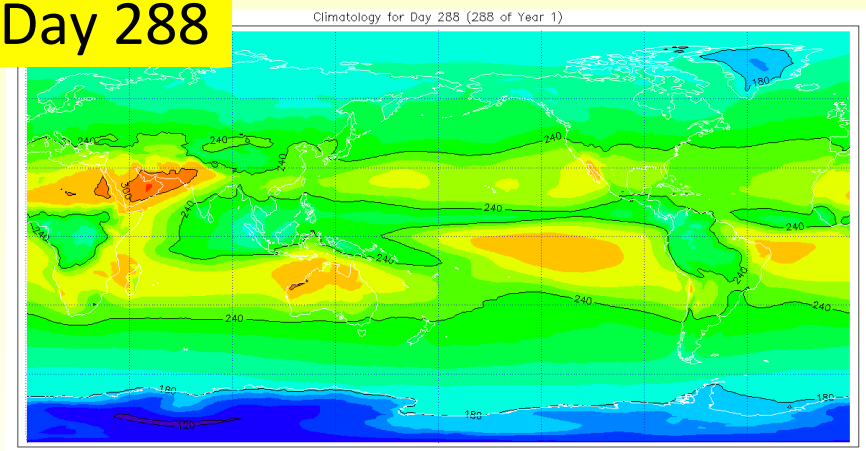
Day 105



Day 196

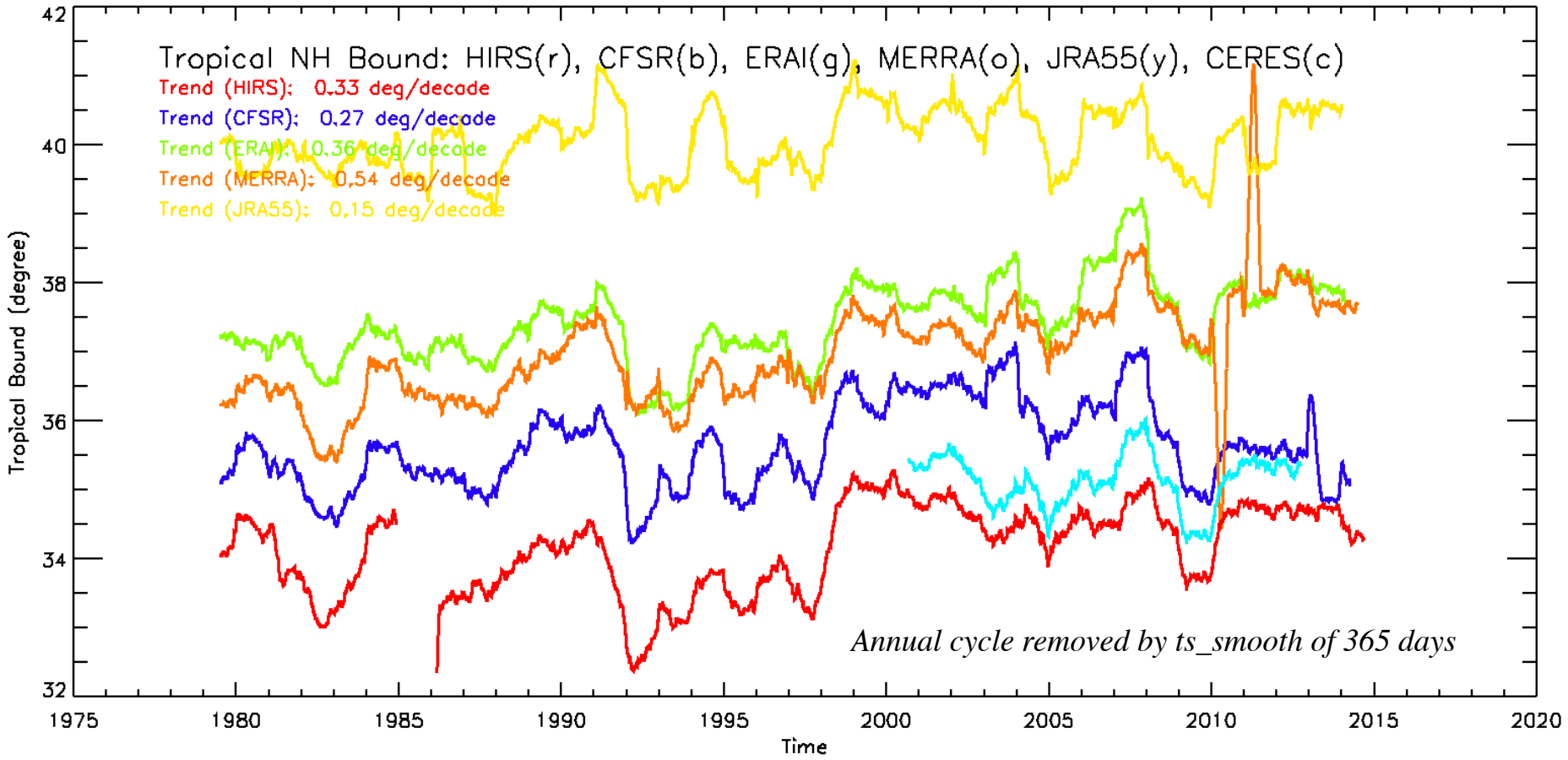


Day 288



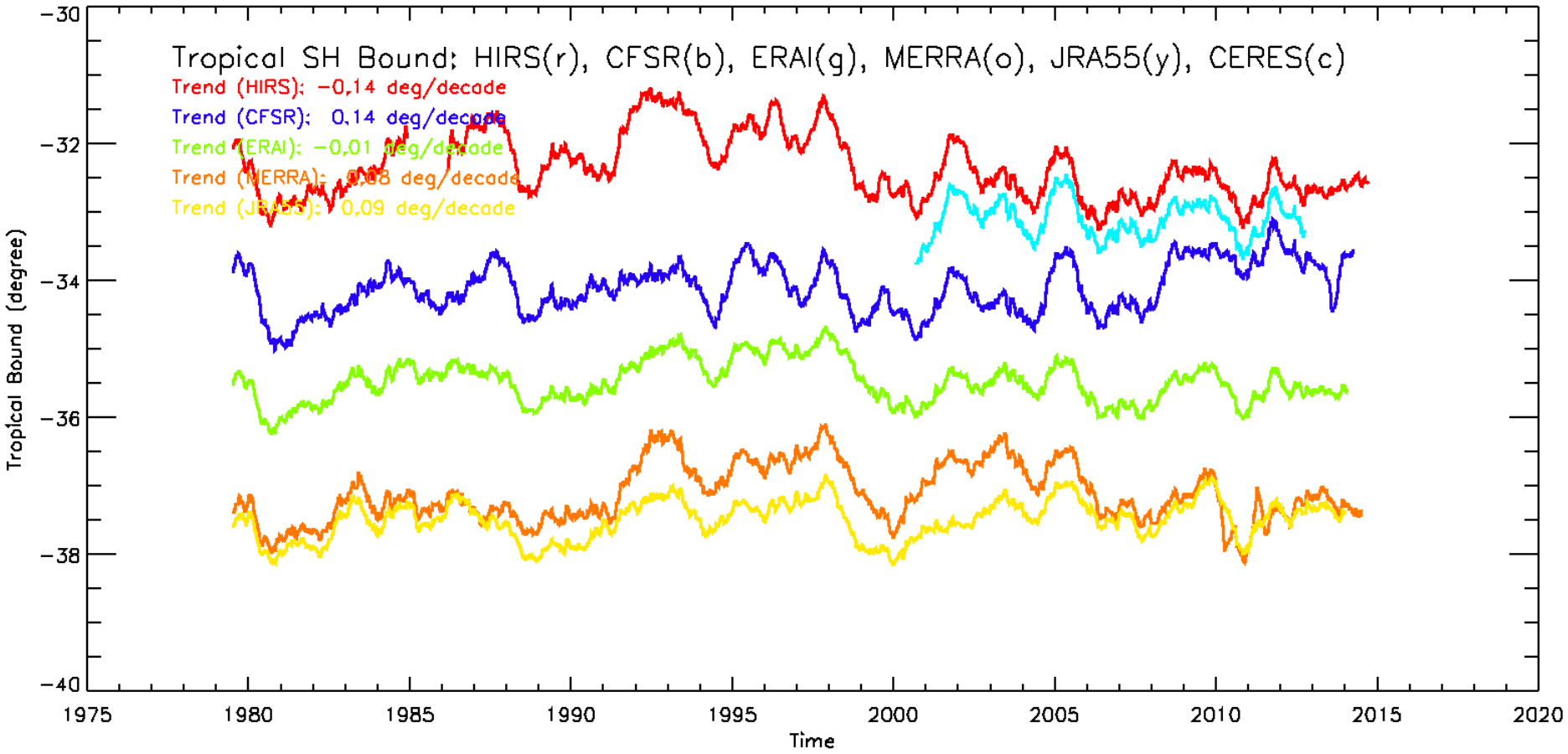
Sample daily OLR climatology maps.

N. H. Tropical Bound (250Wm^{-2})

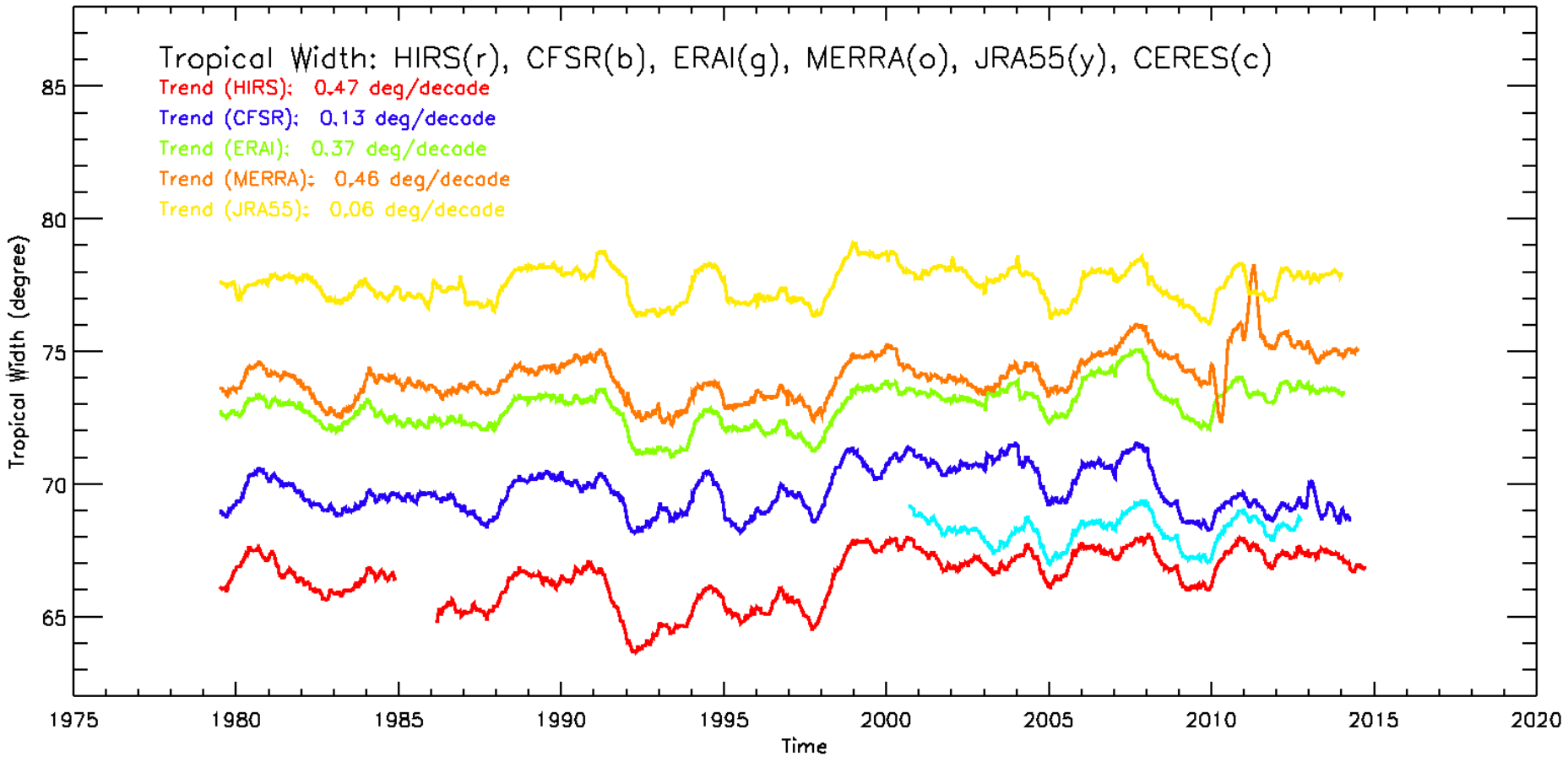


Hu & Fu, 2007 definition

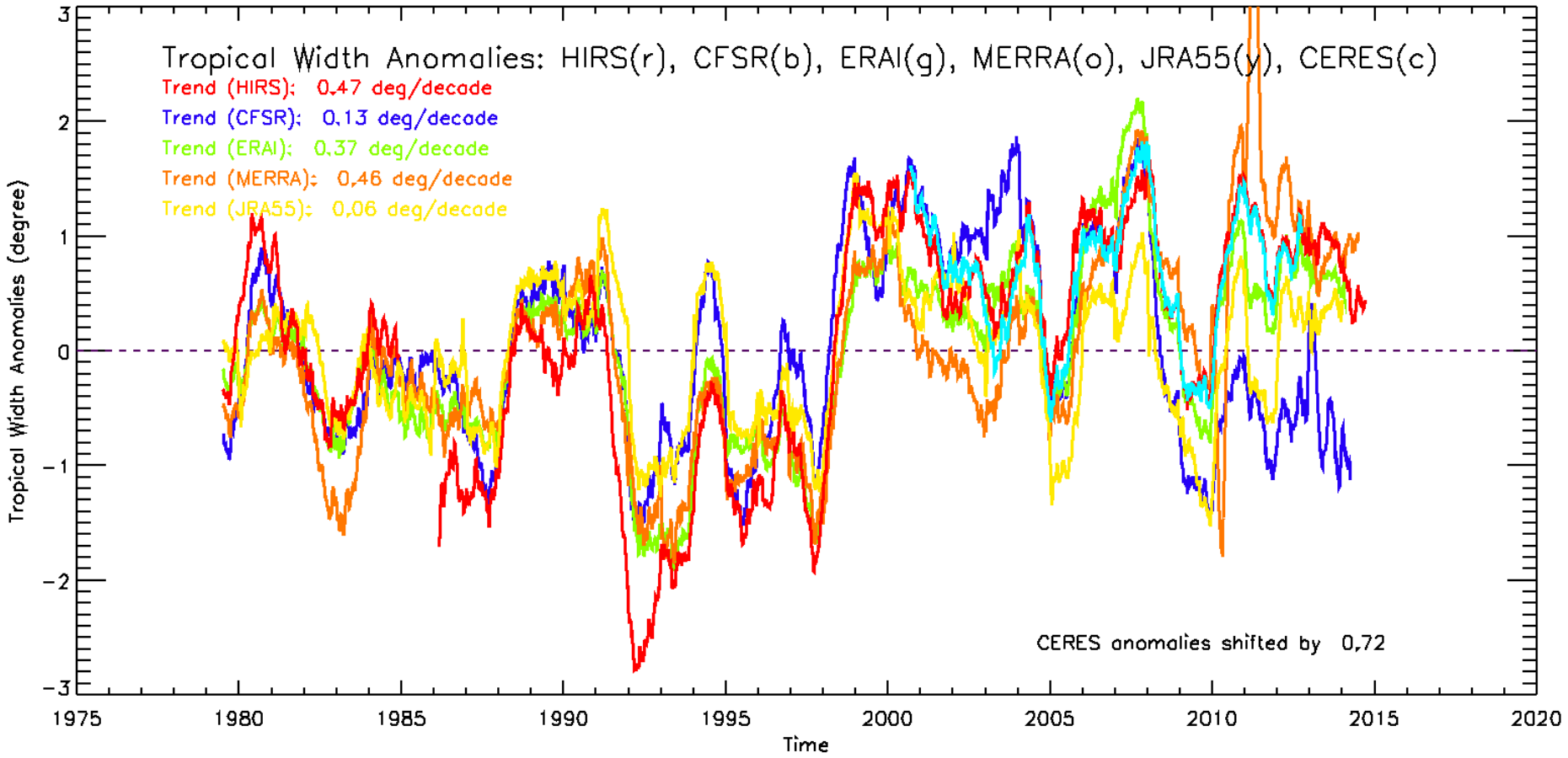
S. H. Tropical Bound (250Wm^{-2})



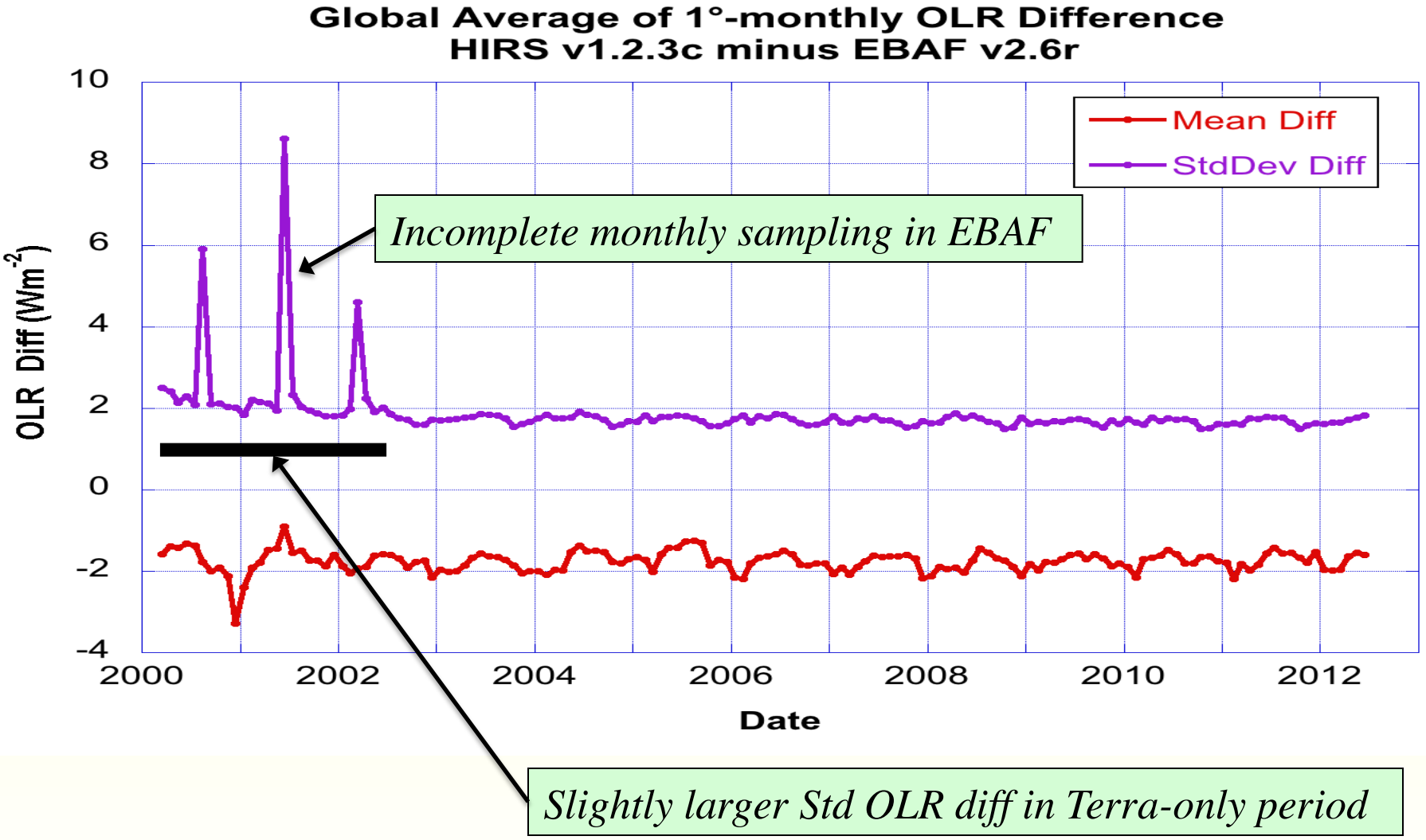
Variation of Tropical Width ($250Wm^{-2}$)



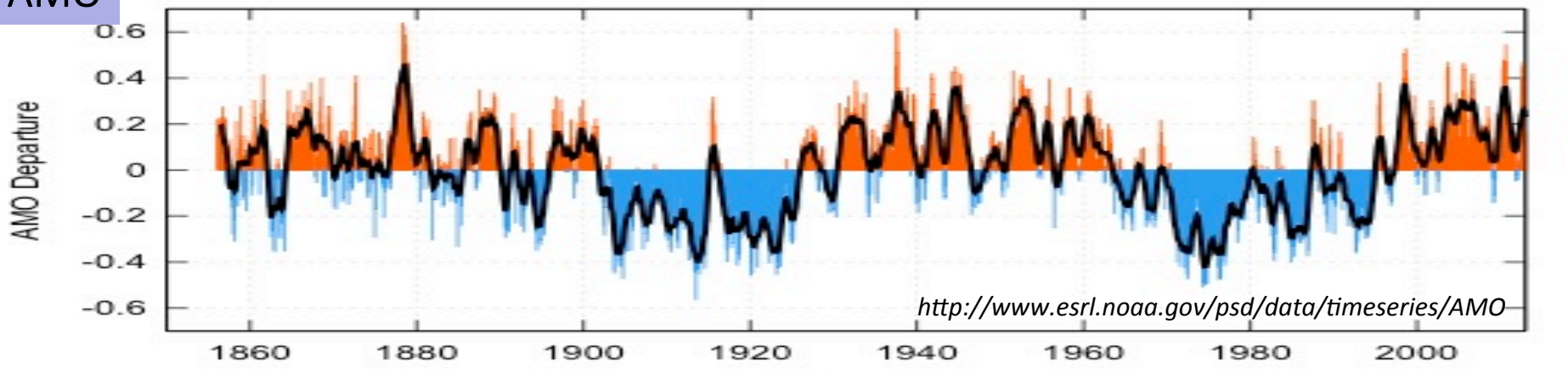
Anomalies in Tropical Width (250Wm^{-2})



HIRS-EBAF Monthly Global OLR Differences 2000-2012



AMO



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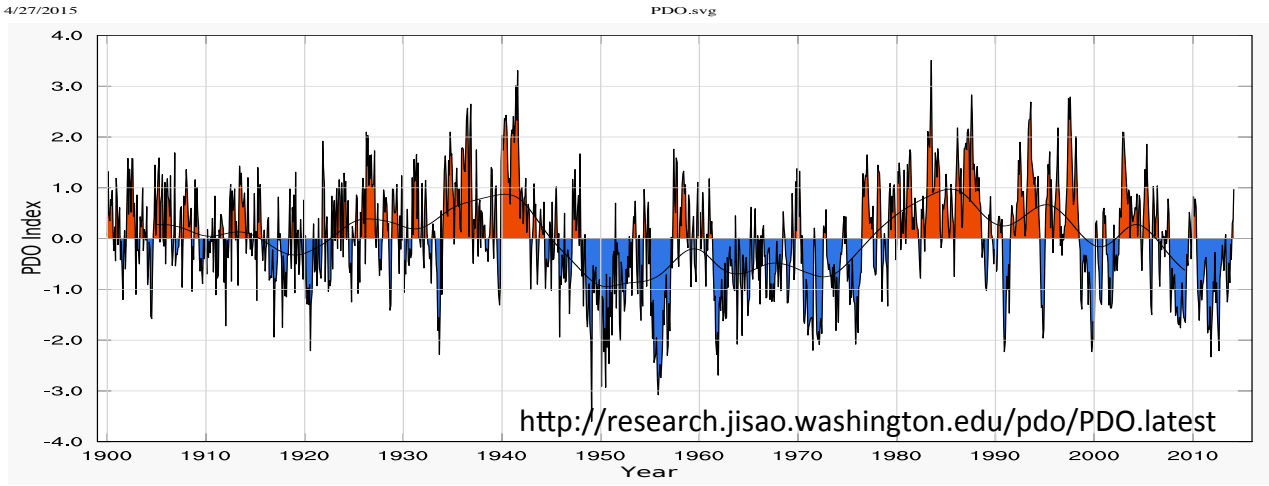
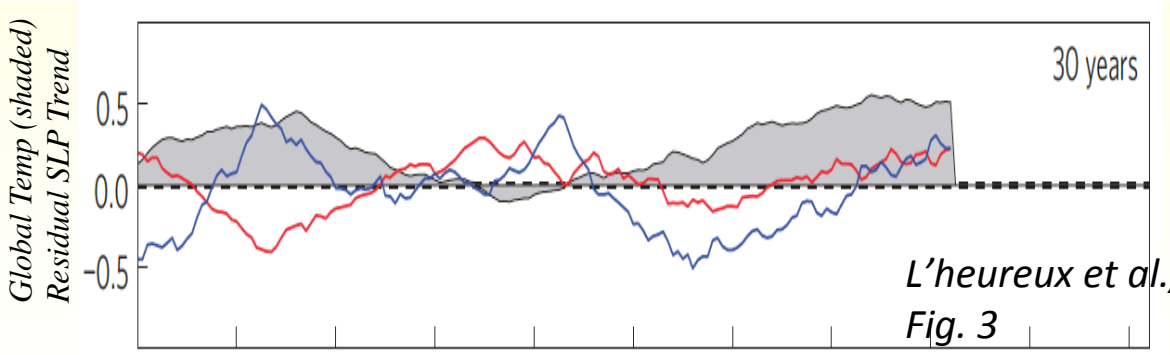
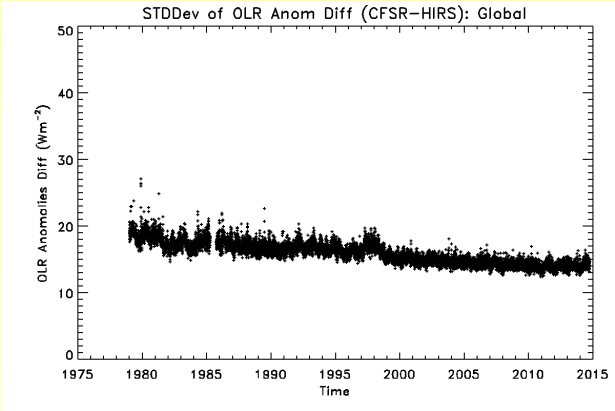


Global Temp (shaded)
SLP 30-yr Trend w/
ENSO-removed

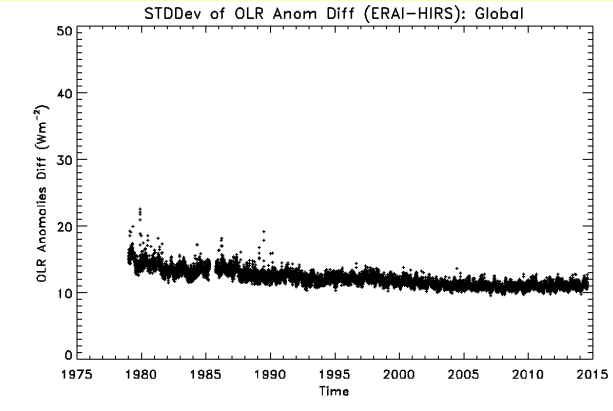


STD of Global Daily OLR Anomalies Differences

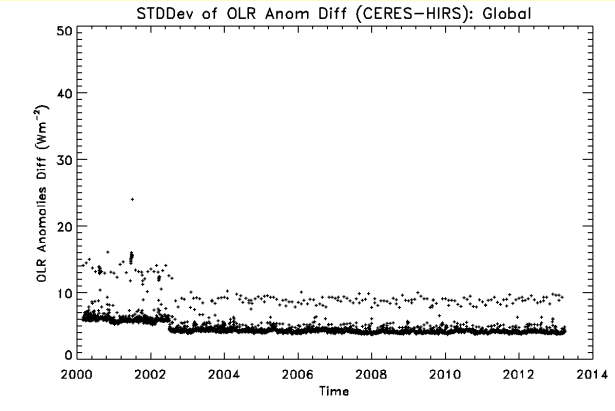
CFSR - HIRS



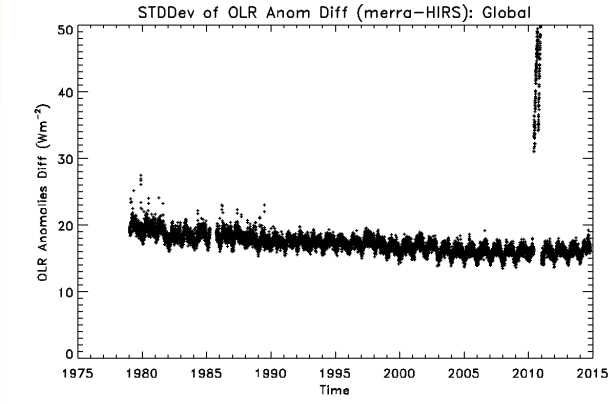
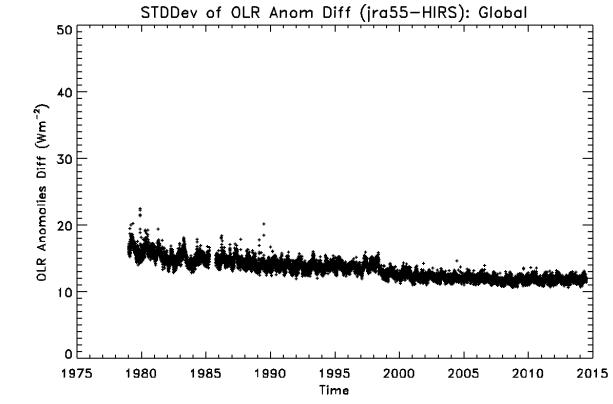
ERAI - HIRS



CERES - HIRS



MERRA - HIRS



JRA55 - HIRS