Ed4 Energy Balanced and Filled (EBAF)–Surface

Sept 26th 2017

CERES Science Team Meeting
Nasa Goddard B34 Rm W150 ,Greenbelt Md

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Ed4 EBAF-Surface Outline

1. Algorithm description

2. Terra 6.7um MODIS anomaly, SfcEbaf 4.1 Terra-Aqua Night Cryosphere correction

3. Great Lakes ice issue

4. Future Ed5 plans (exploratory)?
   - Mitigate temporal GEO boundaries using GEO vs Modis clouds.

5. Comparison of atmospheric net anomalies versus precipitation anomalies

Surface EBAF :: What is it.

Surface Energy Balanced & Filled ED4_SFC_EBAF is a monthly, 1°x1^{o} deg surface broadband flux product that is made consistent with CERES (TOA_EBAF) SW and LW fluxes, using uncertainty estimates of input properties (clouds, atmosphere and surface) and TOA and surface fluxes

It uses a 1d radiative transfer (Fu-Liou) framework for its adjustment and initial flux computations which are based on inputs of MODIS and Geostationary cloud properties, GMAO GEOS 5.4.1 assimilation, MATCH aerosols.

Ed4 Surface EBAF: Summary

- Ed4 CERES input products
  - Hourly gridded RT model (Fu_Liou) computations using Geo(1hr) and Modis cloud properties. (Ed4 SYN1deg_hour)
  - Temperature, humidity and ozone profiles from Geos5.4.1 which replaces mix of Geos4 & Geos5.2 used in Sfc_Ebaf Ed2.8
    - No discontinuity in 2008.
  - Aerosols from MATCH Ed4 MODIS col5.

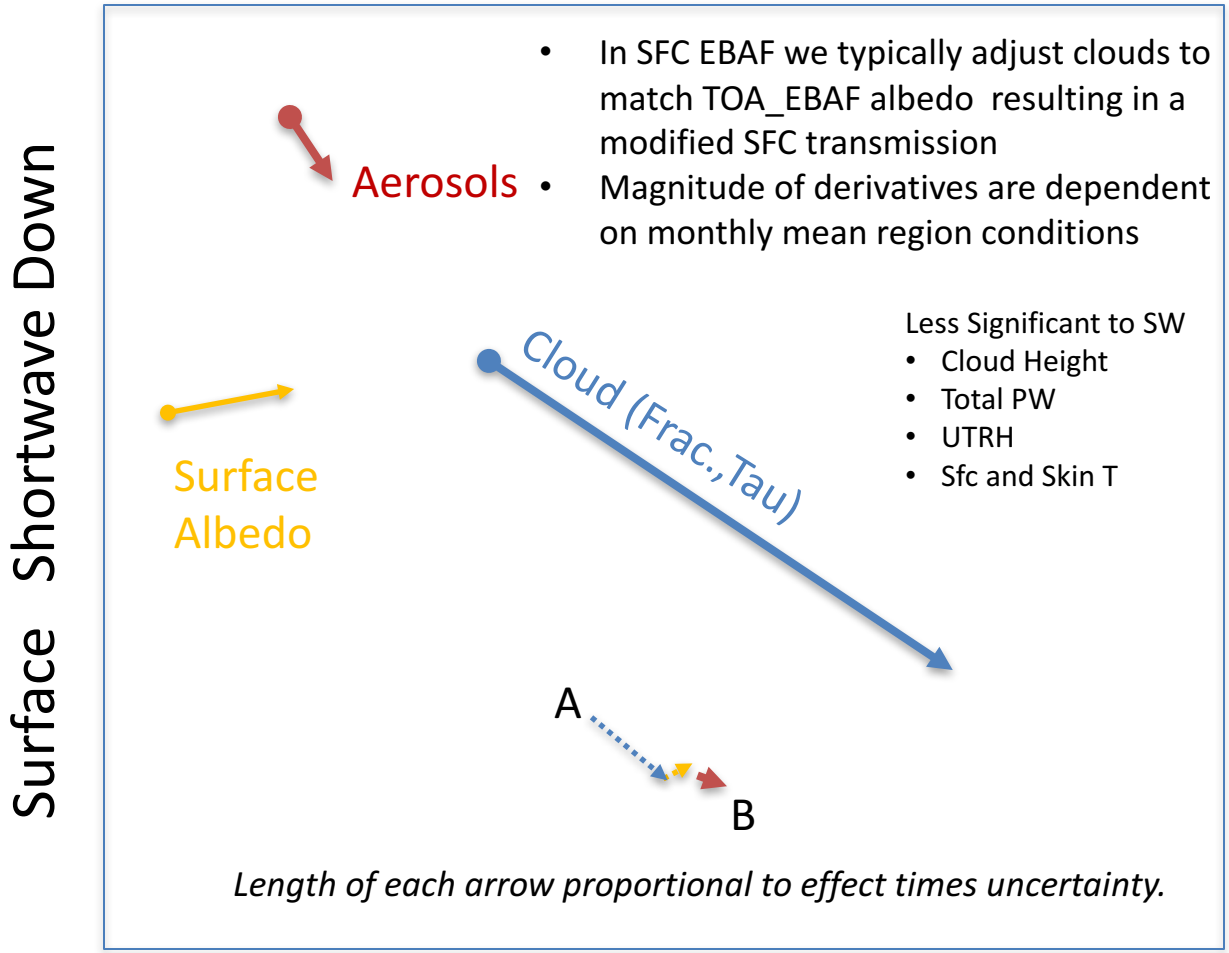
- ED4 has a modified bias adjustment procedure.

- Assignment of surface flux uncertainties based on unadjusted model Ed4-Ed3 differences

Surface EBAF:: Ed4 Process

- Surface EBAF consists of two basic sub processes
  1. Bias Corrections
  2. Lagrange Multiplier Adjustments
- Ed4 has Enhanced Bias correction adjustments
  - Clear and All sky OLR from Upper Troposphere Temperature and Humidity.
    - dOLR/dT(z) and dOLR/dQ(z) adj. to AIRX3STM.006 (AIRS_ IRonly after Sep2016)
  - Surface LW Down from Bottom view Cloud Fraction and base:
    - GEO/Modis → Calipso/CldSat zonal monthly climatology
    - dSFC_LWdn /dCloud_Fraction
    - dSFC_LWdn /dCloud_Base
  - All Sky Surface SW Down and TOA SW Up from Top view low cloud frac
    - GEO/Modis → Calipso/CldSat *top* view cloud low cloud fraction over ocean as a zonal relative percentage adjustment applied on the monthly grid scale to bias correct
    - dSW_TOA/dCF, dSFC_SWdn/dCF , dOLR/dCF

SFC EBAF Basic Concept
Shortwave : TOA Reflected vs SFC Downwelling

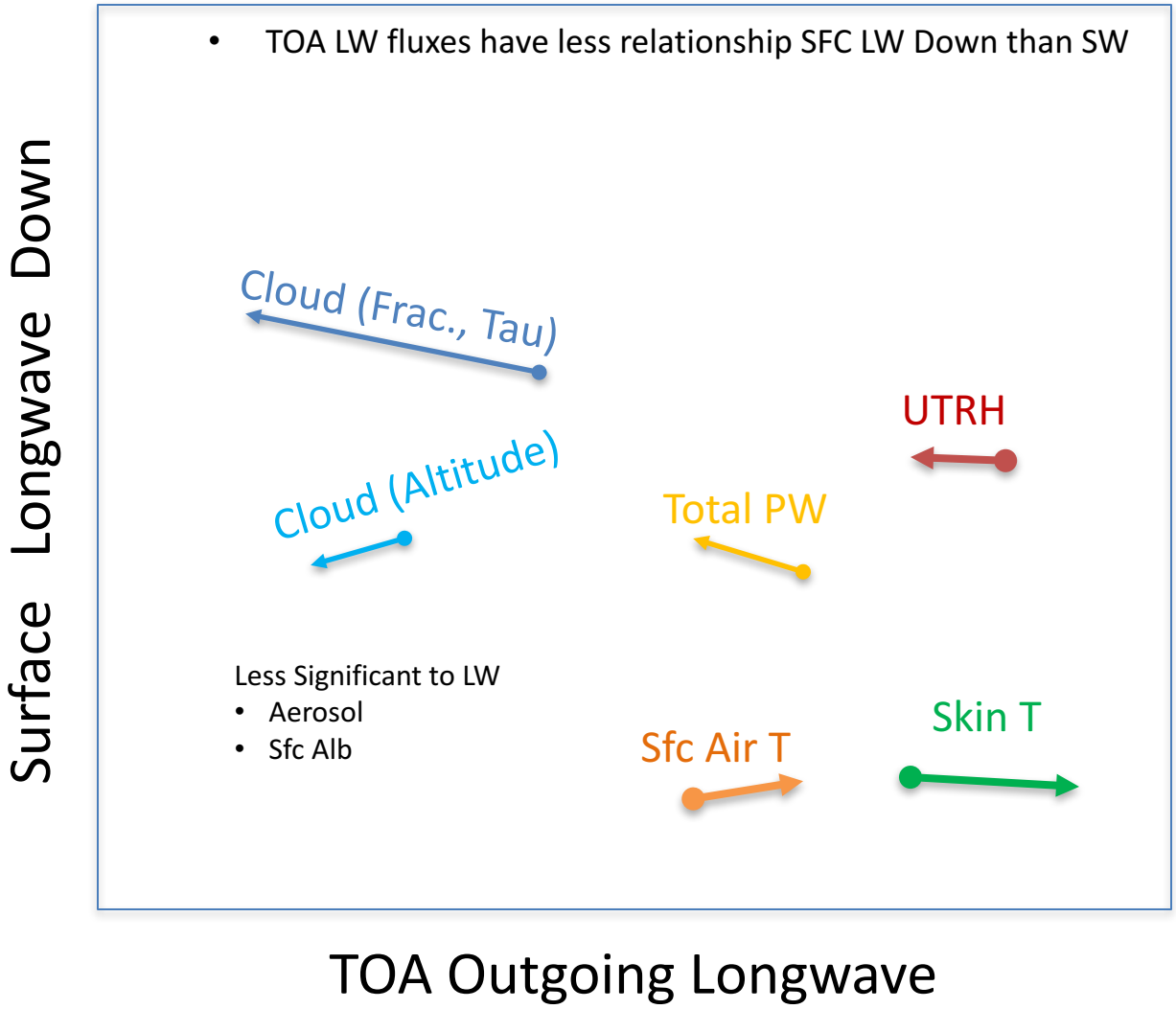


- In SFC EBAF we typically adjust clouds to match TOA_EBAF albedo resulting in a modified SFC transmission
- Magnitude of derivatives are dependent on monthly mean region conditions

Surface Shortwave Down

TOA Shortwave Reflected

SFC EBAF Basic Concept
Longwave: TOA OLR vs SFC Downwelling



Lagrange Multiplier Concept

$$\sum_{i=0}^{n} (Fki\ \Delta Ci\ ) + \sum_{i=0}^{n} Ci\ \sum_{j=1}^{m} ((\delta Fki/\delta \nu j)\Delta \nu j\ ) - \Delta Fk = \varepsilon Fk$$

ΔF*k* are the TOA Model – Observed *bias corrected* Flux differences

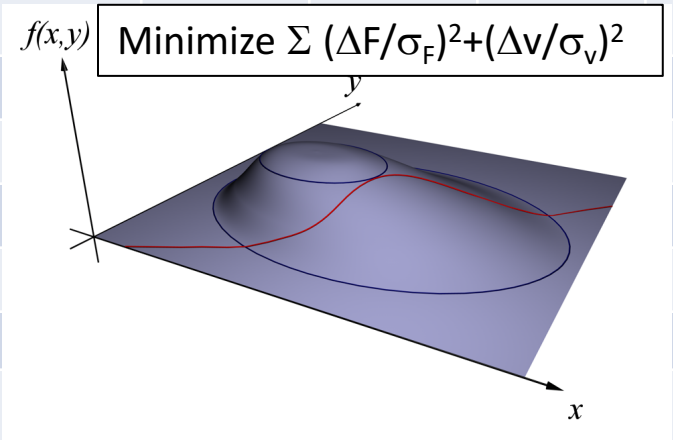
Surface differences assigned to zero after bias correction.

εF*k* are the 1sigma uncertainties assigned to flux component.

Resulting variable adj. $\Delta \nu j$ forces TOA agreement causing SFC flux modifications

Fluxes / Variables	SW TOA	LW TOA	SW Sfc Dn	SW Sfc Up	LW Sfc Dn	LW Sfc Up
SkinT	df/dv*δv*Δv					
SfcAirT						
PW(sfc:500)						
PW(200:500)						
AOT						
SfcAlbedo						
Cld Optical Depth						
Cld Top						
Cld Base						
Cld Fraction						

Minimize $\Sigma\ (\Delta F/\sigma_F)^2+(\Delta v/\sigma_v)^2$



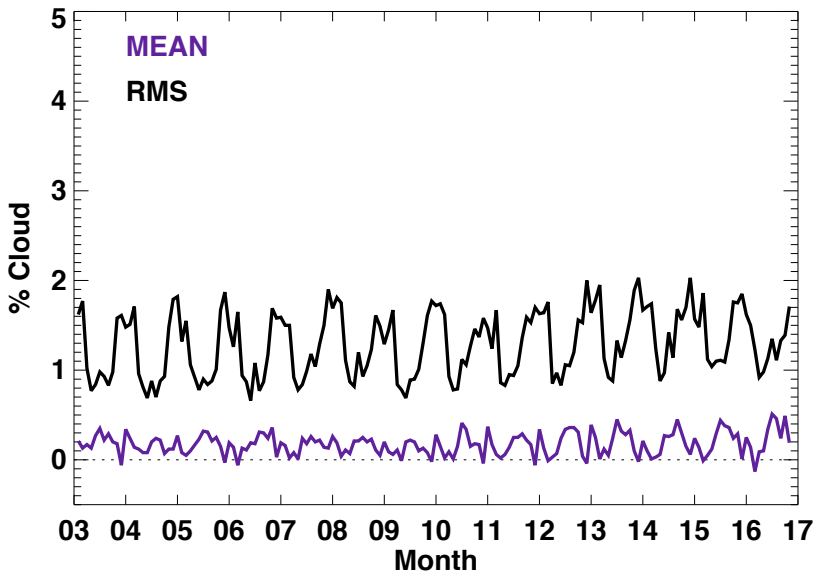
Method uses a set of Overcast-Sky and Clear-Sky Partial Derivatives

Modis Terra Anomaly

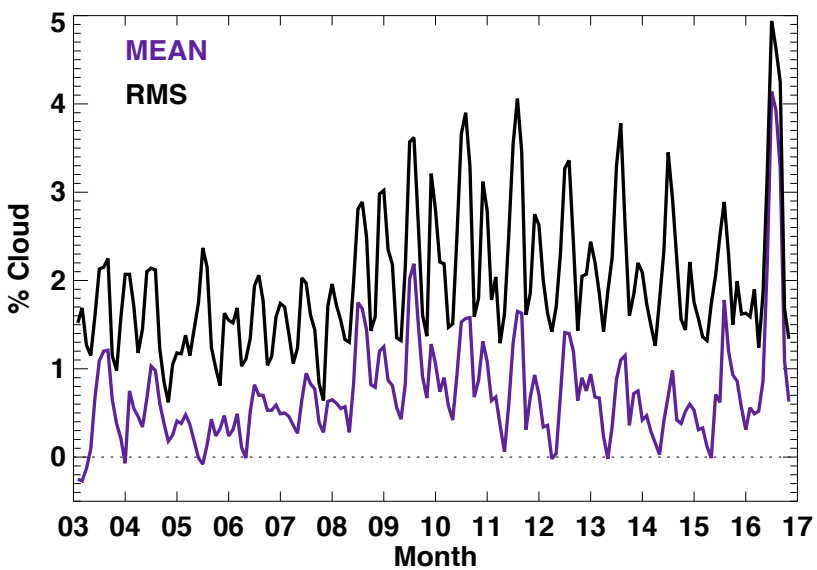
- Terra 6.7um and 8.5um channel anomaly and resulting Terra cloud fraction anomaly over nighttime and low sun (SZA >82deg) Cryosphere applied from March 2016 to Aug 2016
- Large anomaly occurred in Feb 2016 but a drift was seen already in 2008.
- Surface Longwave down has a large sensitivity to cloud fraction in cold dry regions.

Cloud fraction from Terra Vs. Aqua over Cryosphere Night

Aqua Only *minus* Aqua Cloud Fraction at times when Terra also available



AQUA *minus* Terra Cloud Fraction

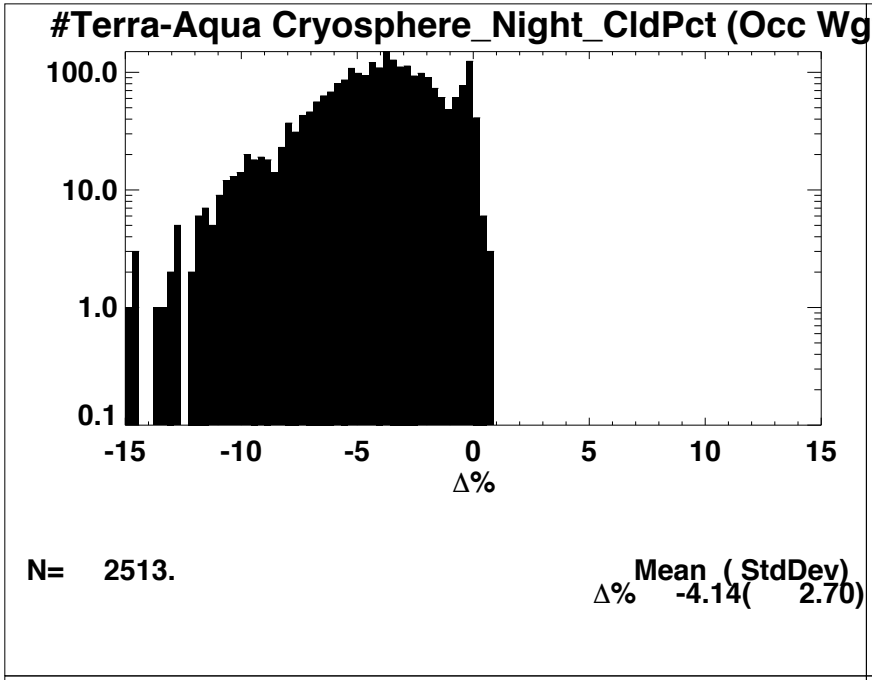


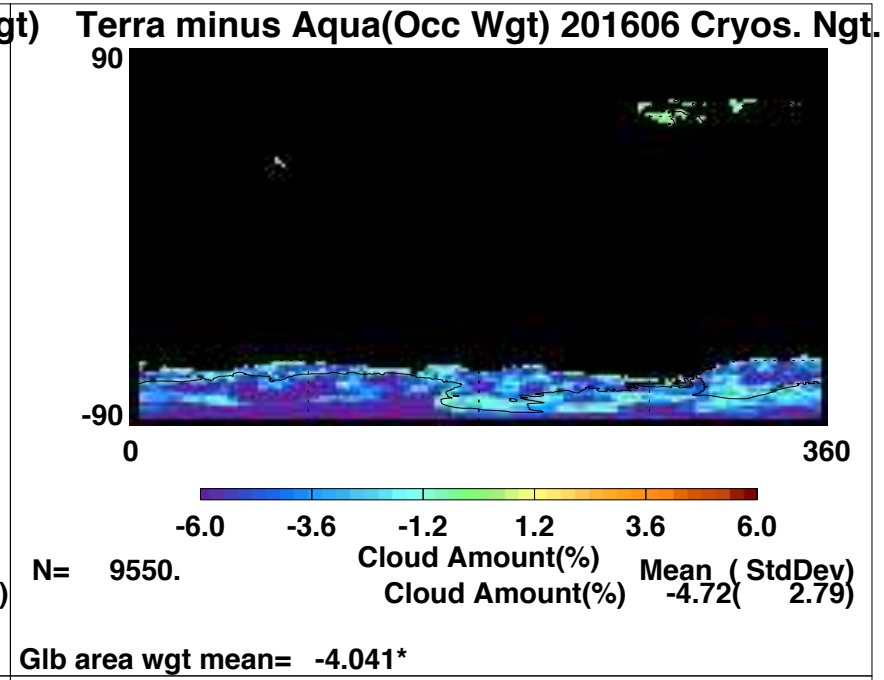
Correction Method

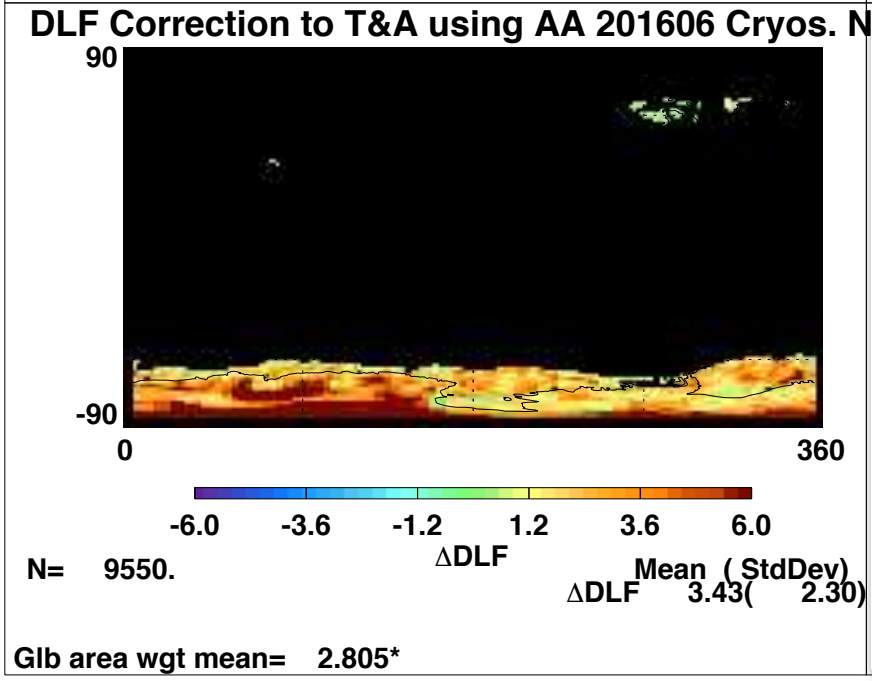
- Use Terra&Aqua TSI to obtain monthly grid box cloud fraction differences between Terra only and Aqua only times.
- Weight cloud fraction differences by

  $(\#\text{Terra}_{\text{Cry Night Hours}} + 0.5*(\#\ \text{Interpolated}_{\text{Cry Night Hours}})$
  $/\ (\ \#\ \text{TOTAL}_{\text{Hours per month}}\ )$

- Obtain Grid box LW SFC DN multiply by
  - dDLF/ dCF
  - Typically 0.5 to 0.9 Wm-2/%Cloud in Polar regions





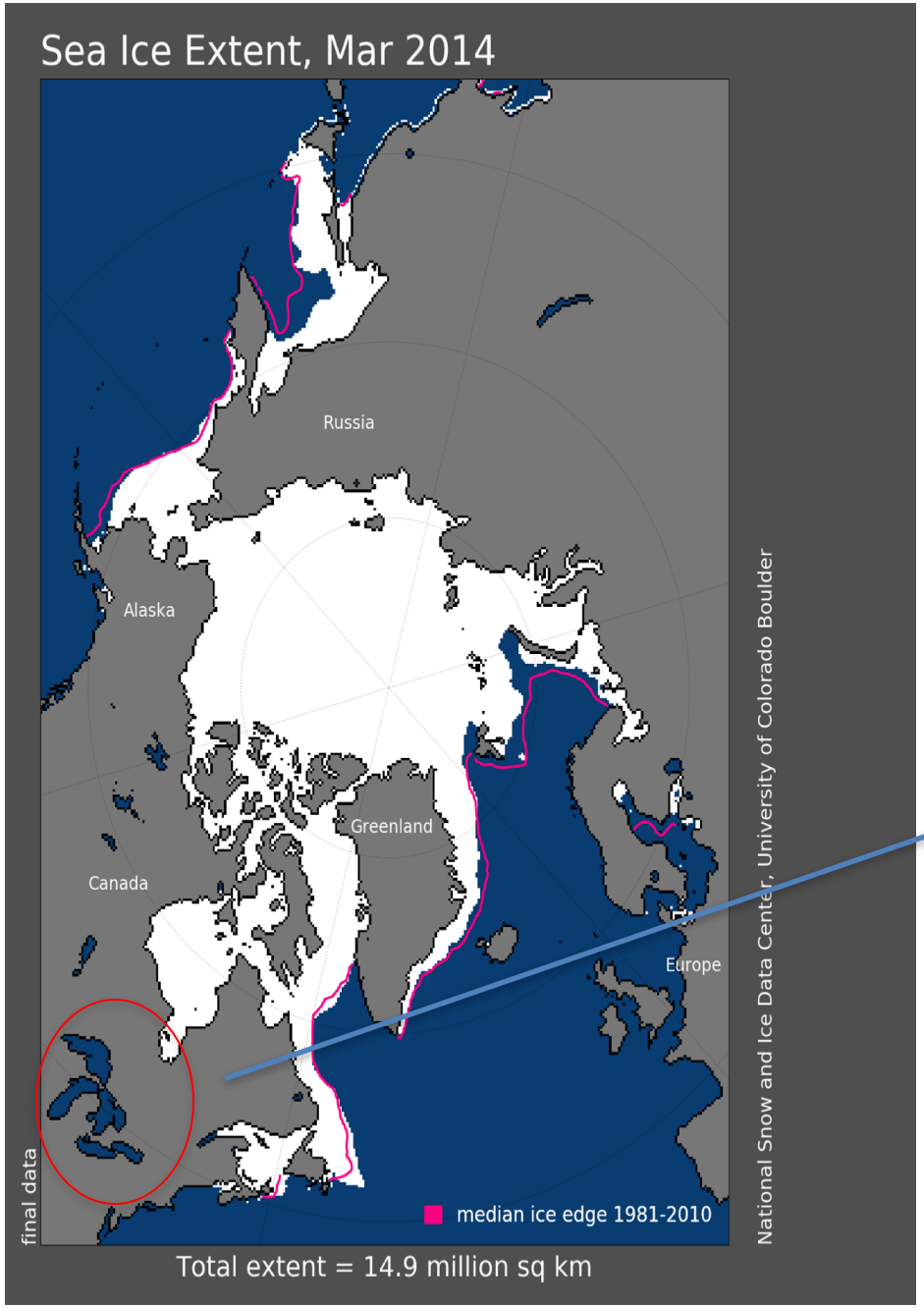


Time period : June 2016

Upper left : Histogram of Terra minus Aqua cloud fraction difference

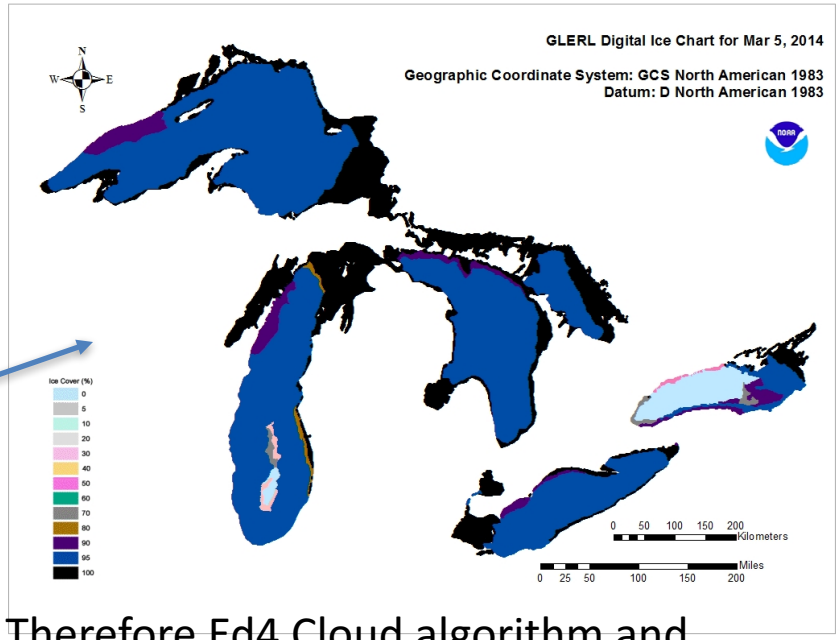
Upper Right: Global map of cloud fraction differences (Terra – Aqua)

Lower Left : Global map of Surface Longwave flux adjustment.



NESDIS "Sea Ice" maps (left) do not attempt to give values for fresh water lakes…

In reality NOAA GLERL Mar 2014 maps (below) have all of the Great lakes, except Lake Ontario at > 95% Cover

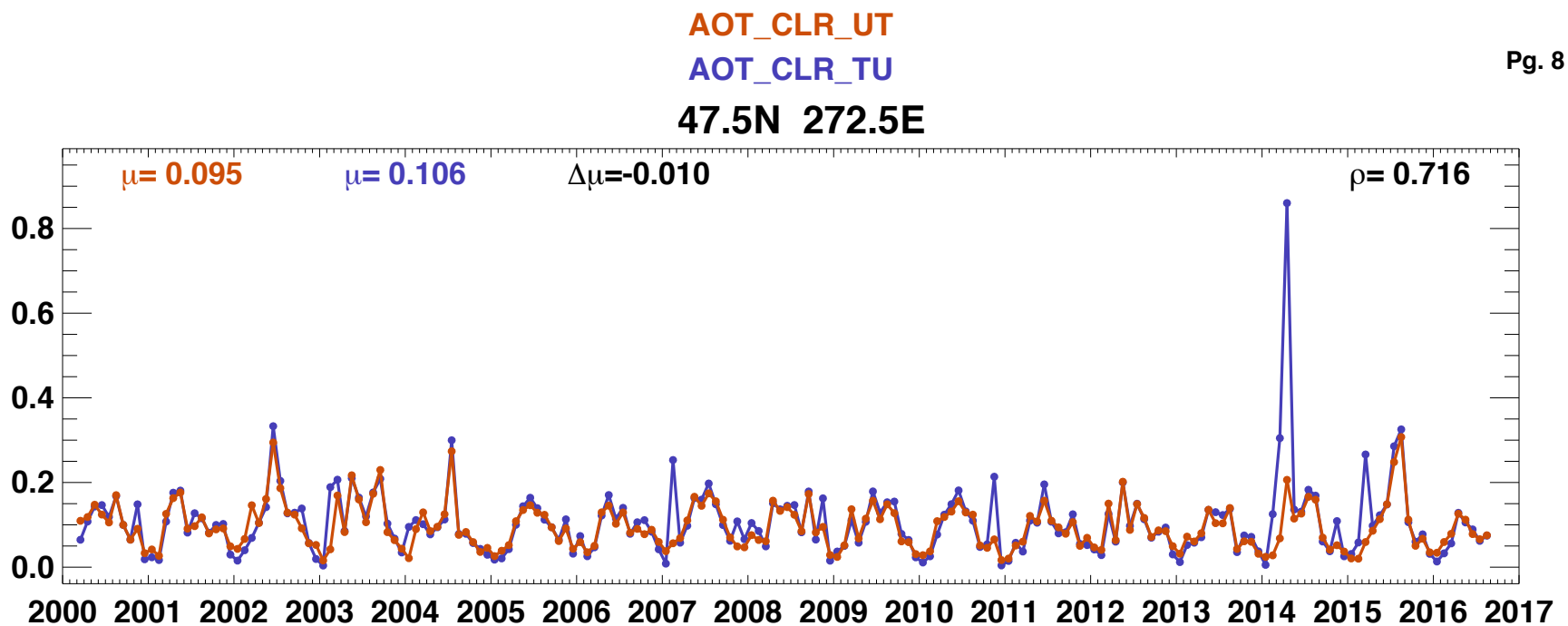


Therefore Ed4 Cloud algorithm and SFC EBAF follow incorrect algorithm paths giving incorrect Cloud Fraction and Flux data…..

Lake Ice Issue
Great Lakes Winter 2014

- Surface EBAF tunes to TOA EBAF SW All and Clear values successfully however..
  - All Sky required a moderate increase in cloud fraction.
  - Clear Sky erroneously increases Aerosol Optical Depth , Why?
  - Sea ice values used in Ed4 SYNI show NO ice for entire winter/spring season
  - GLERL Ice maps show nearly 100% values from February thru Mid April of 2014.

Time series of Tuned and UnTuned Aerosol optical depth
Over Lake Superior Grid box in Ed3 SFC_EBAF



Since Grid box has less than the 10% sea ice threshold it is considered to be water grid box with a high certainty of surface albedo.
Aerosol therefore has a larger uncertainty than surface albedo and AOT is erroneously adjusted to match TOA EBAF SW.

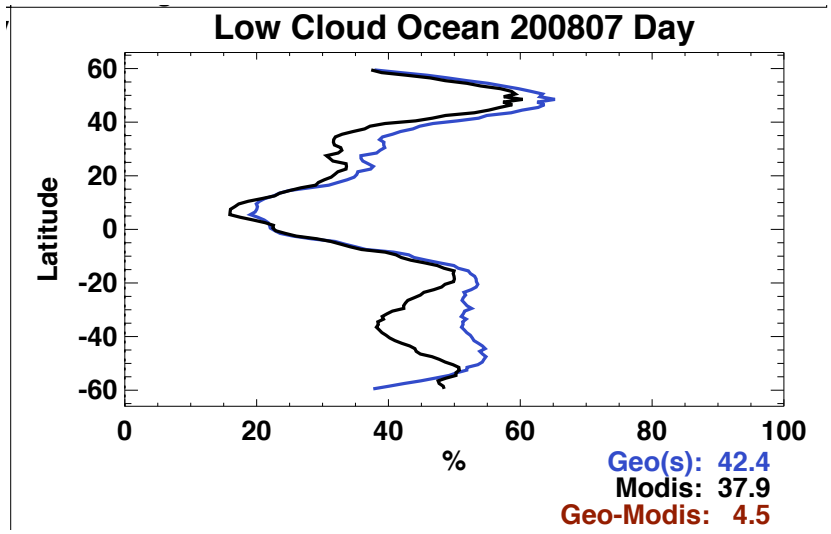
Ed5 Cloud Property adjustment plan

- Implement a **regional monthly** bias correction based upon monthly mean of near co-temporal MODIS and Geostationary cloud observations.
- Retains diurnal Geo cloud information.

Ed4 Low Cloud Ocean Adjustment

Ed4 :

- Low cloud fraction adjustment over ocean only.
  - Did not account for Geo to Geo retrieval differences
- Using a **seasonal zonal climatology** relative fraction correction
- $frac_{low}' = frac_{low} * fadj(lat,month)$



Ed4 Syn1deg_Hour product subset by observation source and adjacency of Modis and Geo observations.

- Hour : 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
- SatIdx : 2 20 10 20 2 2 2 2 20 10 20 2 2 2 2 2 2 0 2 2 2 20 10 20

- t_{10} Red Modis observation time with a Geo obs either + or – 1hr.
- t_{20} Green GEO observation within +/- 1hr of Modis obs.
- t_2 GEO observation > 1hour from Modis

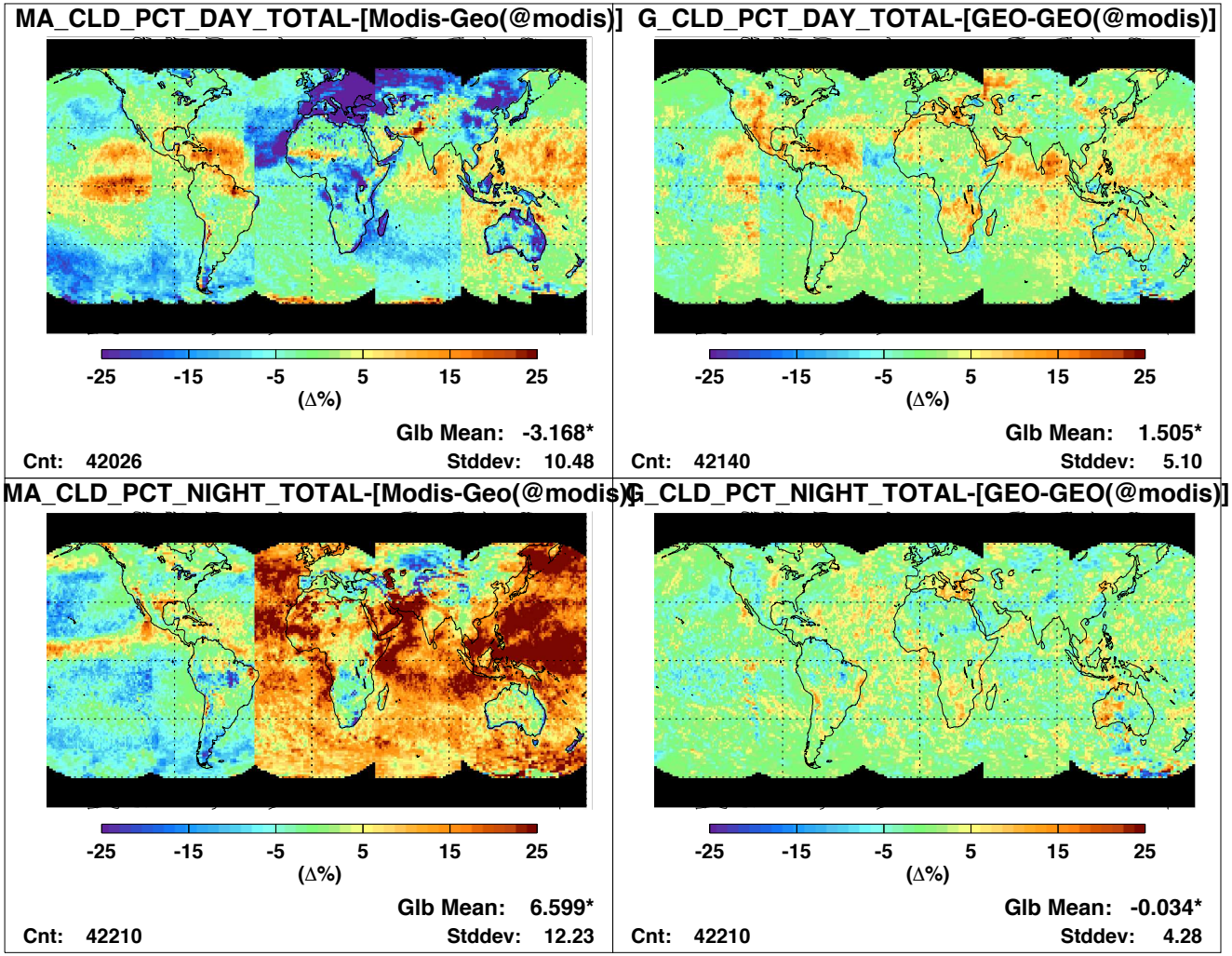
- Modis = Mean (cld(t_{10}))
- Geo(@modis) = Mean(cld(t_{20}))
- Geo(@other) = Mean(cld(t_2))

TOTAL Cloud Fraction July 2001 TERRA MODIS vs GEOSTATIONARY

Bias: coincident Modis minus GEO **Diurnal**: GEO(all) minus GEO at Modis

DAY

NIGHT

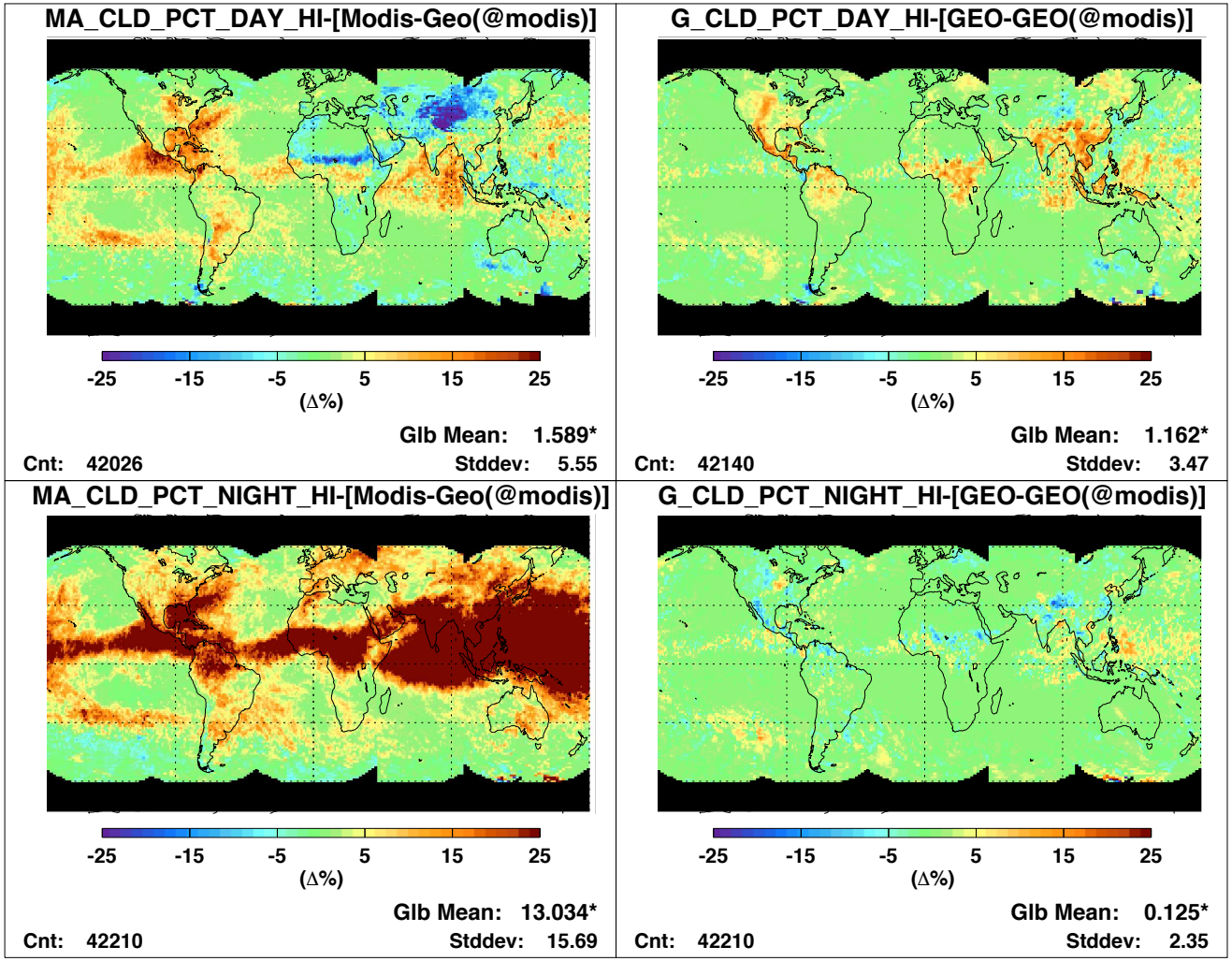


HIGH Cloud Fraction July 2001 TERRA MODIS vs GEOSTATIONARY

Bias: coincident Modis minus GEO **Diurnal**: GEO(all) minus GEO at Modis

DAY

NIGHT



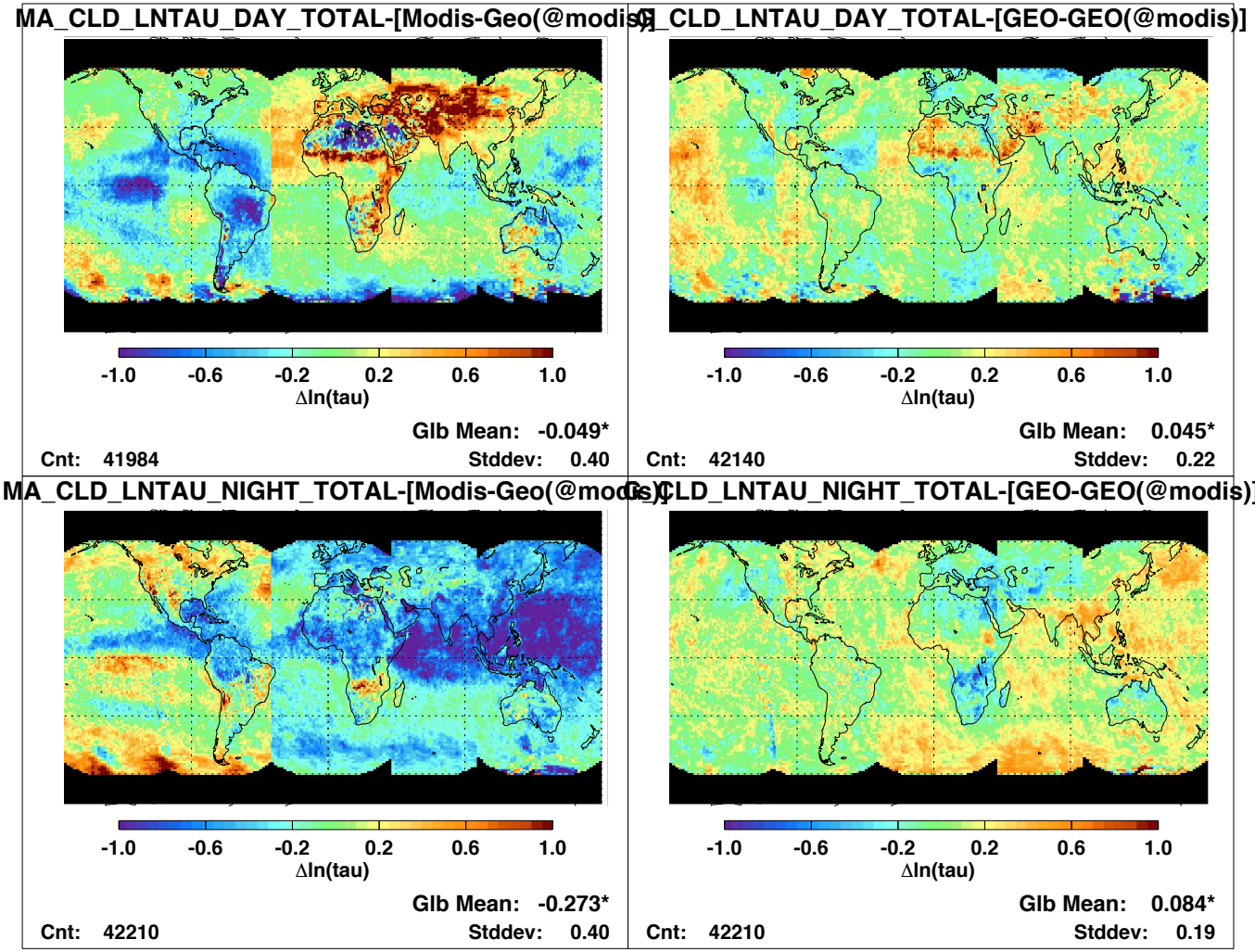
Total Cloud **Optical Depth** July 2001 TERRA MODIS vs GEOSTATIONARY

Bias: coincident Modis minus GEO

Diurnal: GEO(all) minus GEO at Modis

DAY

NIGHT

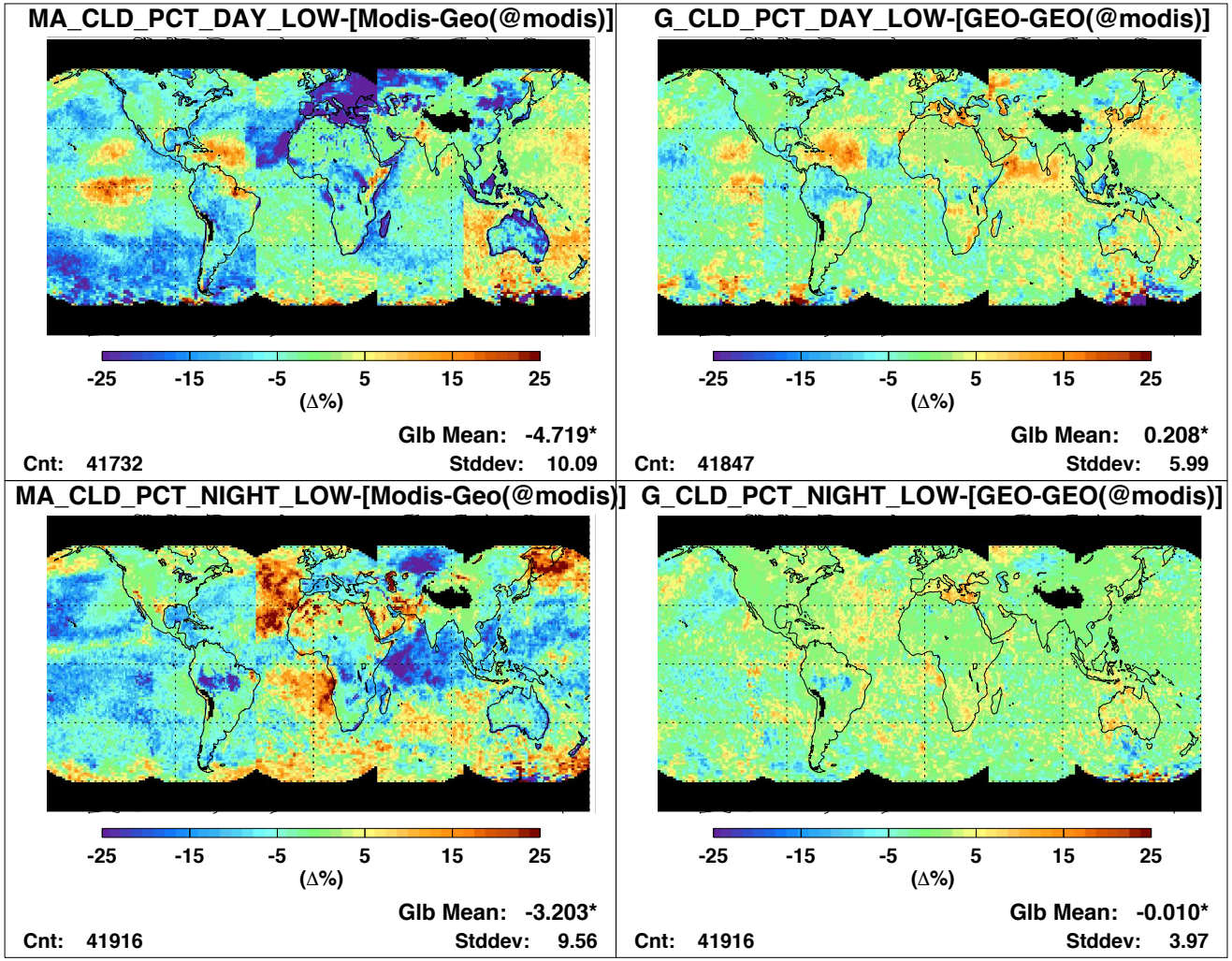


LOW Cloud Fraction July 2001 TERRA MODIS vs GEOSTATIONARY

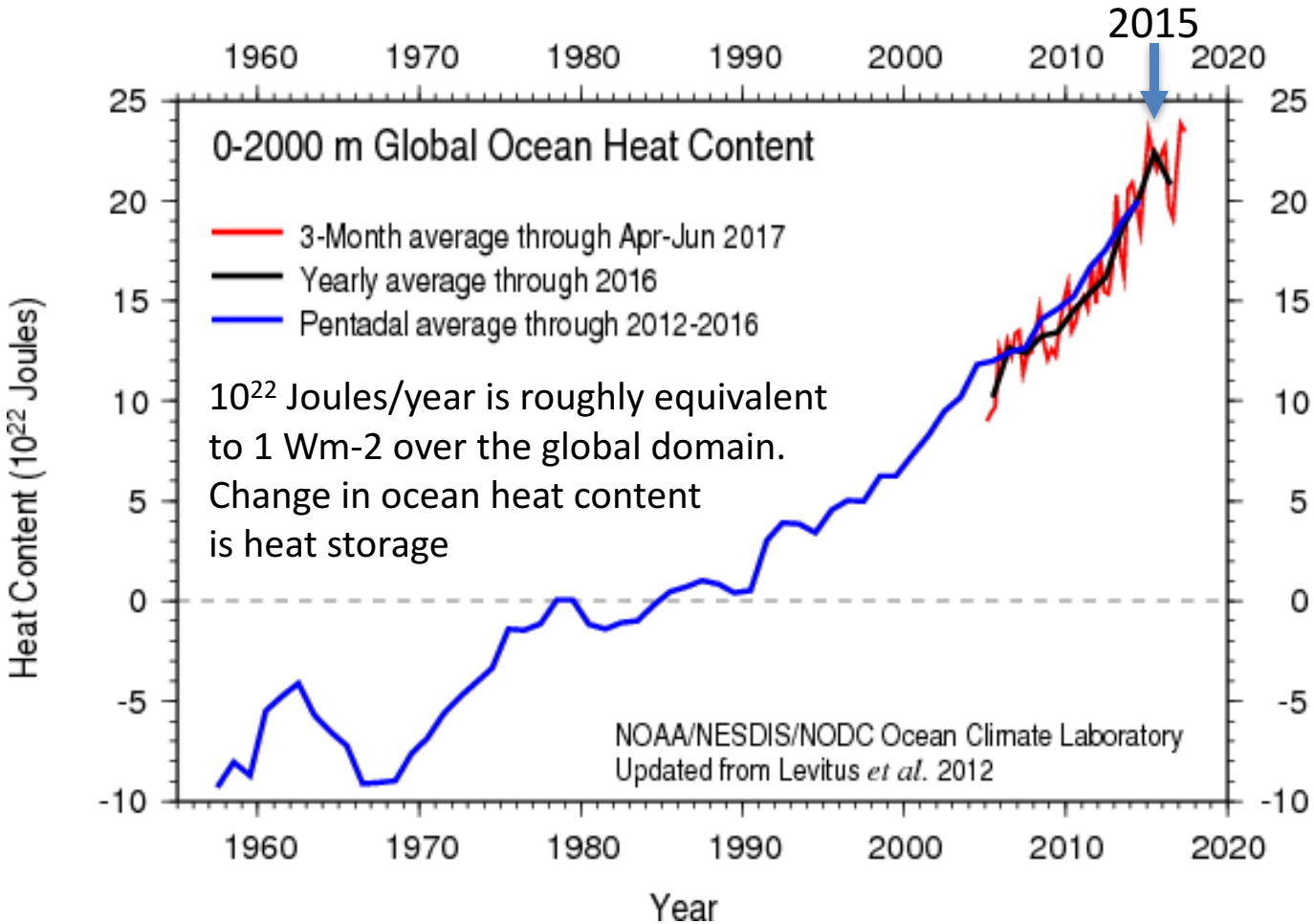
Bias: coincident Modis minus GEO **Diurnal**: GEO(all) minus GEO at Modis

DAY

NIGHT



Global Ocean Heat Content



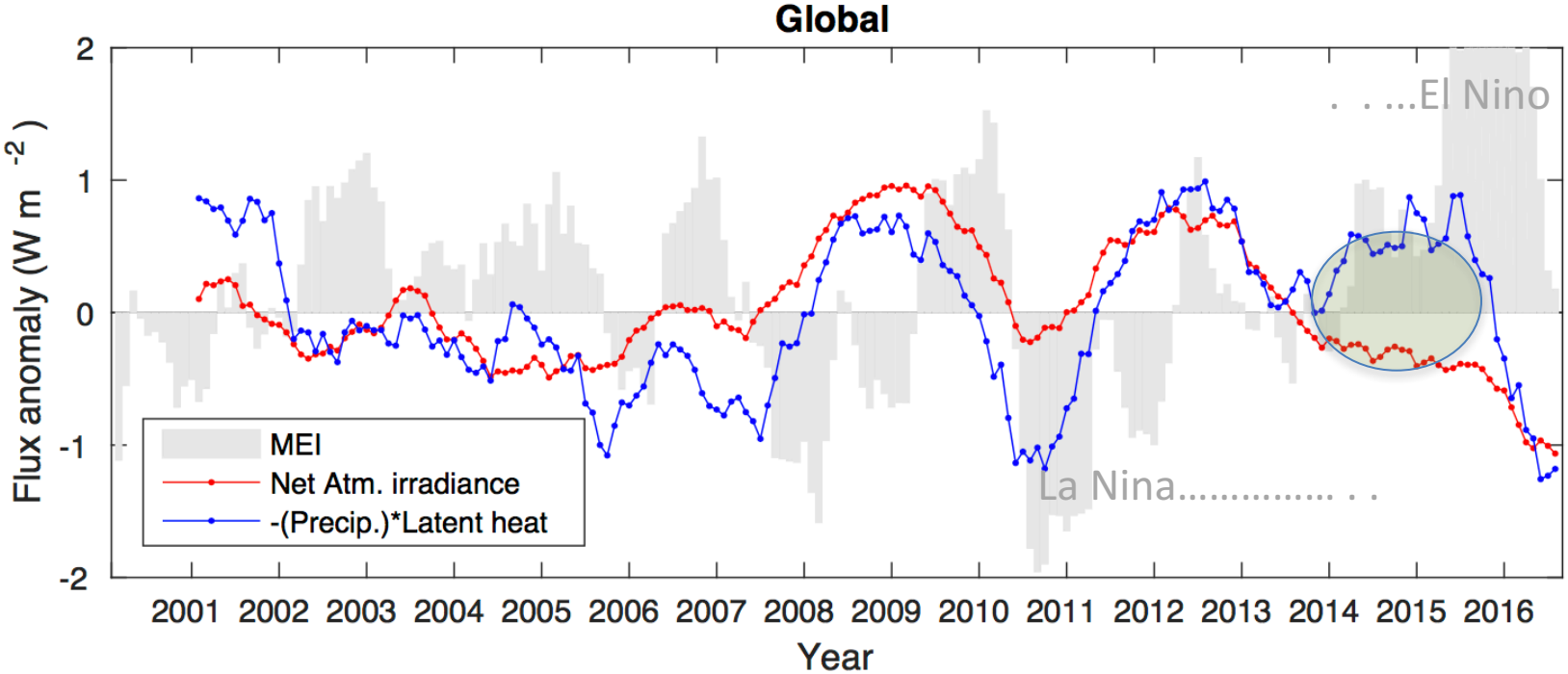
2015 coincides with the end of *La Nina*, ie. end of a large ocean heat storage period? Especially as *El Nino* magnified in the fall of 2015.

Atmosphere Net Radiation and Global Precipitation

Red: Ed4 EBAF(TOA-SFC)Global anomaly of Sw&Lw Atmosphere Net

Blue: GPCPv2.3 Global precipitation anomaly converted to Wm^{-2} (Sign Flipped) Lv =28.9 Wm-2/mm day^{-1}

Smoothed using a 12 month running mean



Atmosphere gains heat through latent heat release from condensation to form precipitation. Radiation acts to balance the precipitation induced atmospheric heat anomaly.

**Variability of Surface fluxes of Latent and Sensible heat not included here.*