HIRS Daily OLR Climate Data Record – A Challenge to Homogenize Operational Satellite Observations for Climate Applications

Hai-Tien Lee

University of Maryland, College Park, Maryland, USA

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Introduction

- OLR is a component of the earth radiation budget and one of the 50 *Essential Climate Variables* (GCOS/WMO) that is routinely applied to climate variation monitoring, seasonal weather forecast, precipitation, tropical dynamics diagnostics, numerical model assessment, etc.
- Long continuous observational OLR product (30yr+) can only be generated from operational satellites observations
- Requires special cares to satisfy climate applications' demands in **accuracy**, **continuity** and **stability**

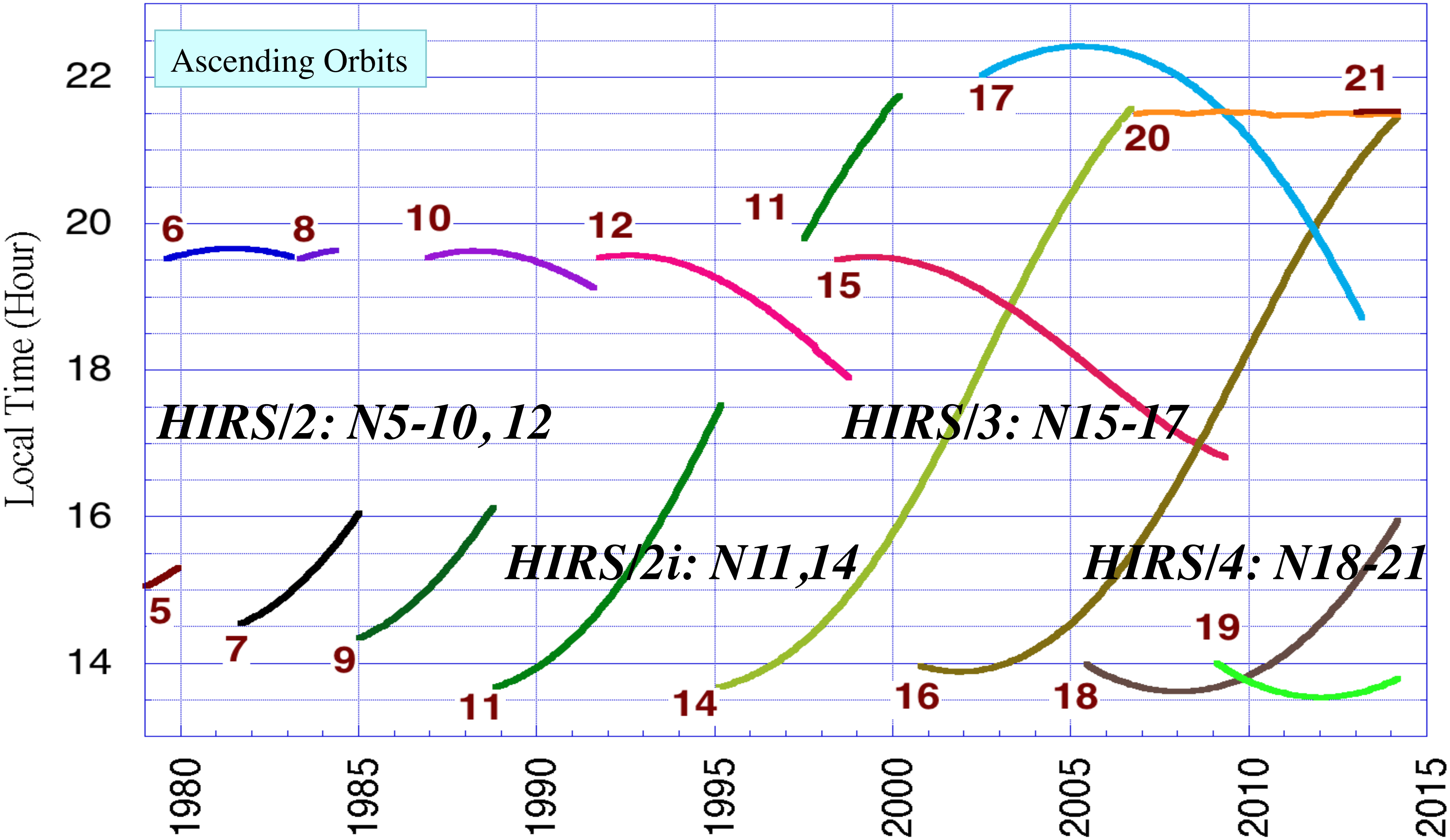
Observing Systems
and
Challenges

Operational Observing Systems

Infrared Observations

- **HIRS** (High-resolution Infrared Radiation Sounder)
  - US NOAA Polar-Orbiting Environmental Satellites (POES) ***TIROS-N Series*** (1978-present)
  - ESA ***MetOp*** A/B satellites (2006-present)
- **Imagers**
  - Multi-national geostationary satellites (1978-present)

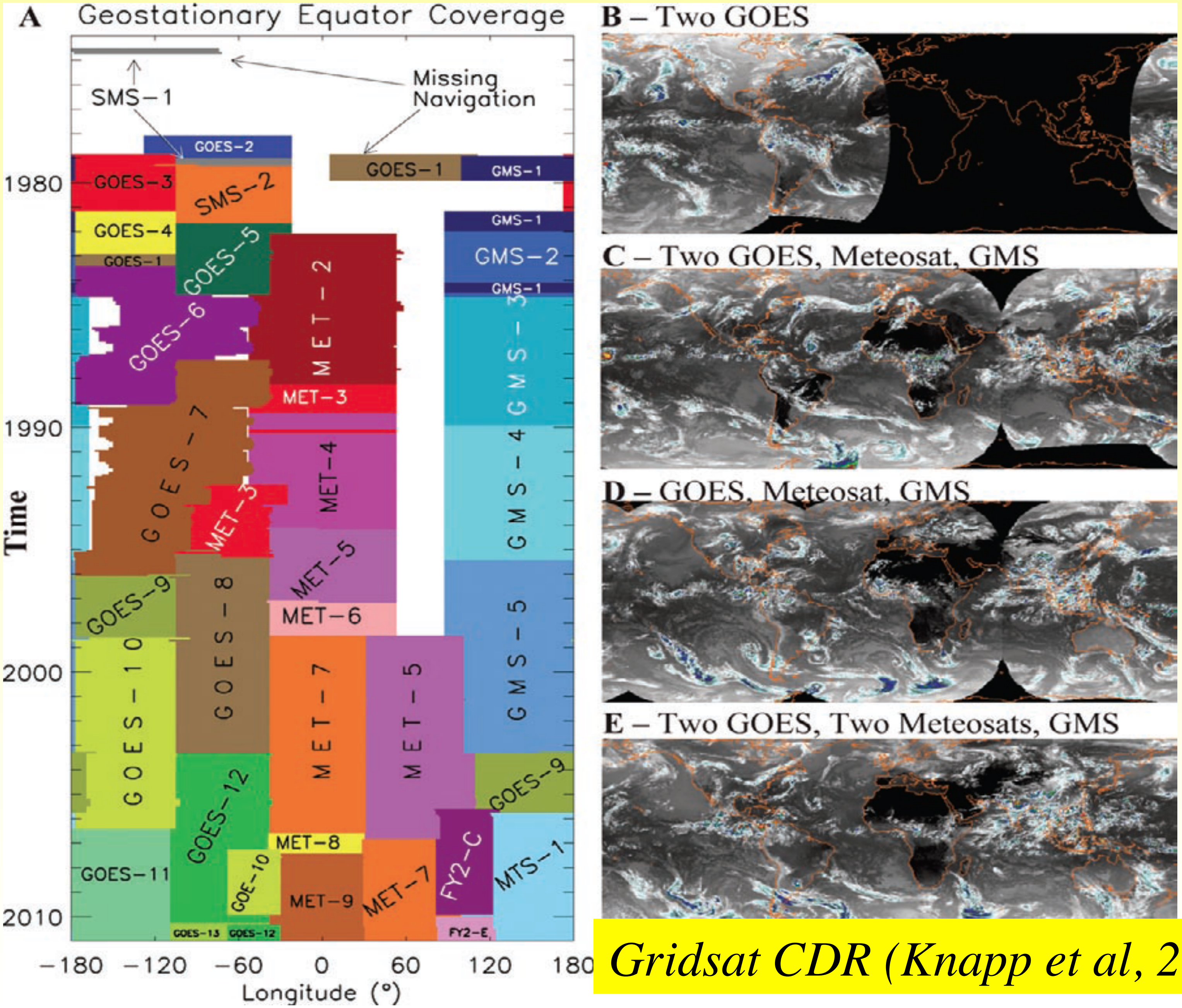
HIRS Revisions and Orbital Drift



5=TIROS-N; 6-19: NOAA; 20=MetOp-2, 21=MetOp-1

Level-1B data (NCDC CLASS)

"Mosaic" of Imagers



Gridsat CDR (Knapp et al, 2011)

Solutions for Generating Daily OLR CDR

New HIRS Multi-spectral OLR Algorithm

$$OLR = a_0(\theta) + \sum_i a_i(\theta) \cdot N_i(\theta)$$

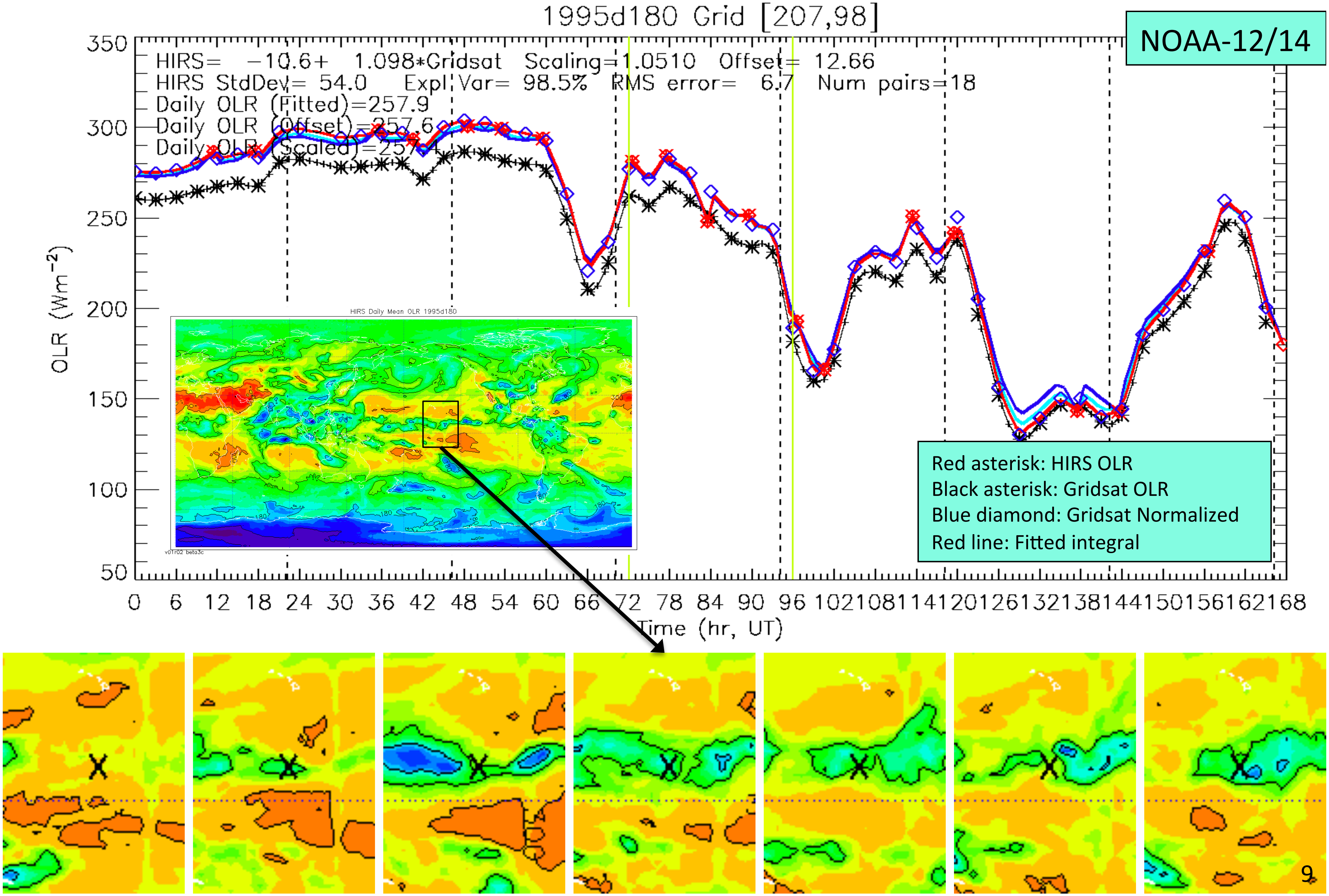
Adapted from Ellingson et al. (1989)

a_i=regression coefficients
N_i = radiance of channel *i* observed at local zenith angle θ

HIRS-2/2I/3/4:
Predicting Channels: 3, 7, 8, 11, 8^2, $11^{0.5}$, $12^{0.5}$

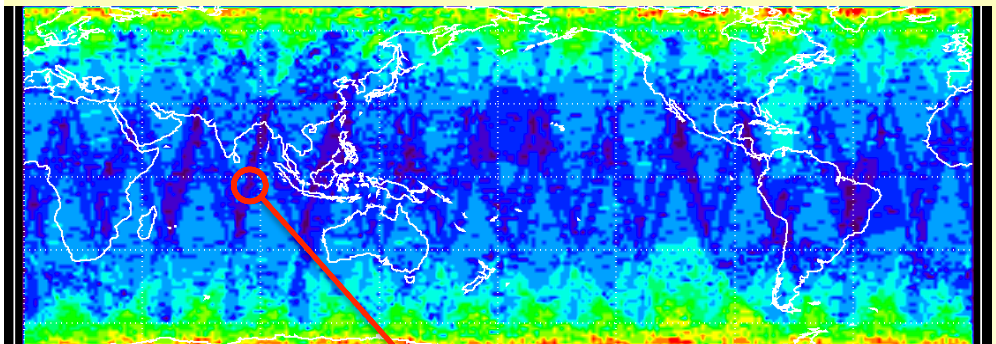
- *Channels are now common in all HIRS instruments*
- *Non-linear predictors reduce end-points biases*

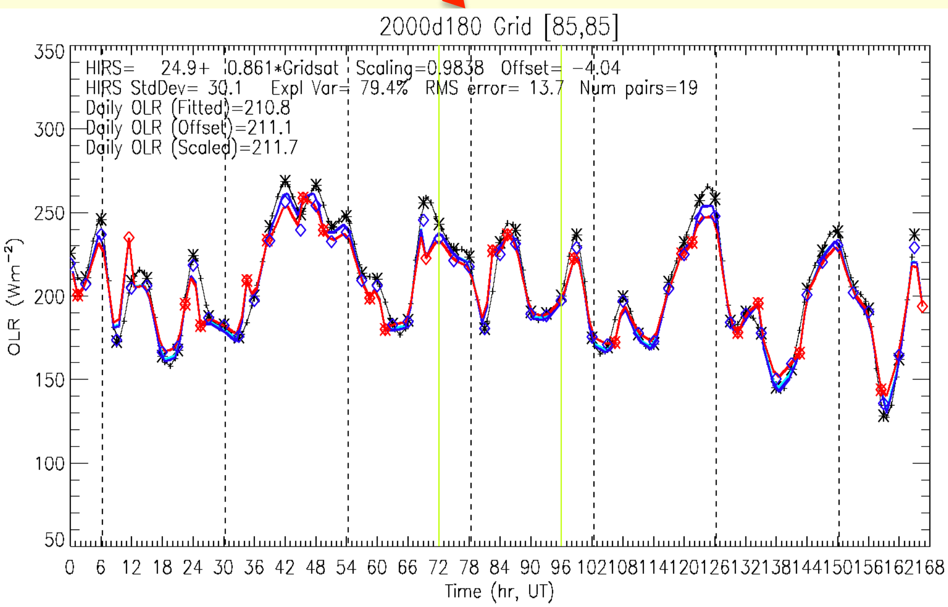
Radiometric Normalization and Temporal Integral



Inhomogeneity in HIRS Spatial Sampling

Number of HIRS Observations
2000 Day 180 (N0AA-14&15)





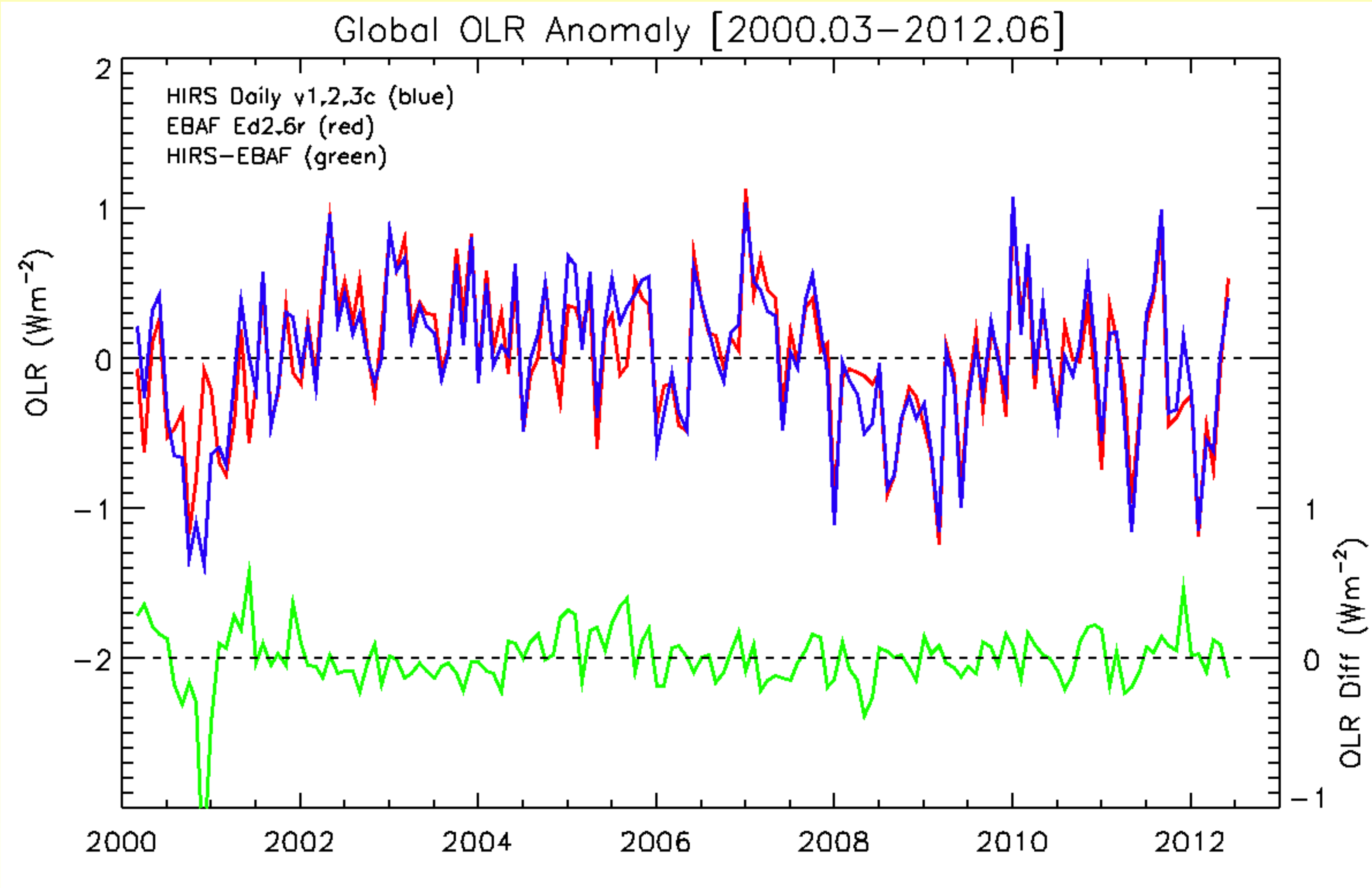
- Precession, scanning gaps and missing orbits create uneven spatial sampling. Diurnally symmetric observations over tropical areas are not always available.

- Daily OLR can still be accurately derived with Geo obs for regions with incomplete HIRS sampling – homogenizing spatial sampling, solving orbital gap issues, and effectively remove orbital drift effects.

Evaluations

Global OLR Anomalies (2000-2012)

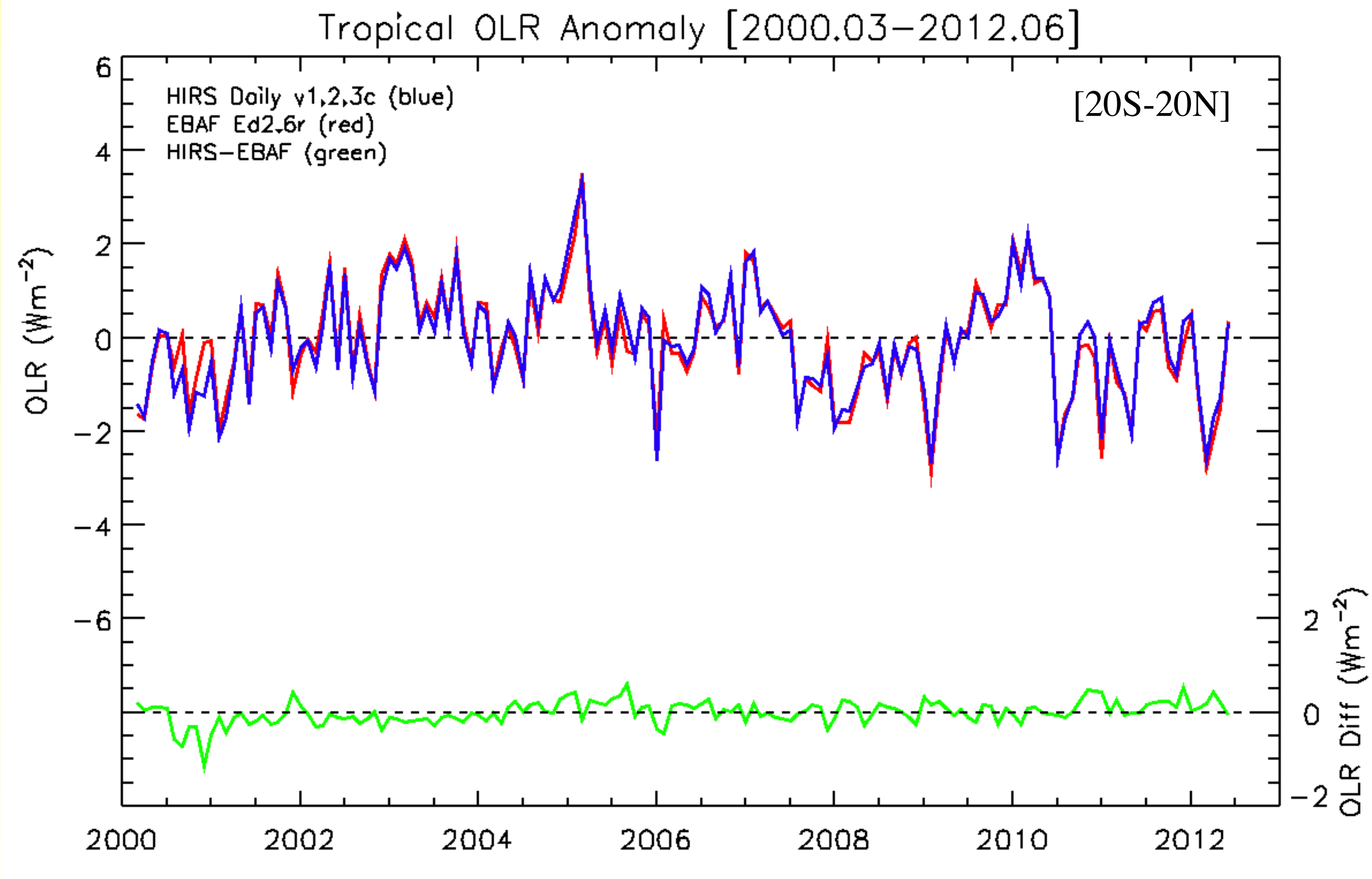
HIRS vs. CERES EBAF



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

Tropical OLR Anomalies (2000-2012)

HIRS vs. CERES EBAF



Slope of OLR anomalies diff = 0.28 ± 0.10 Wm^{-2}/decade at 2σ

Summary

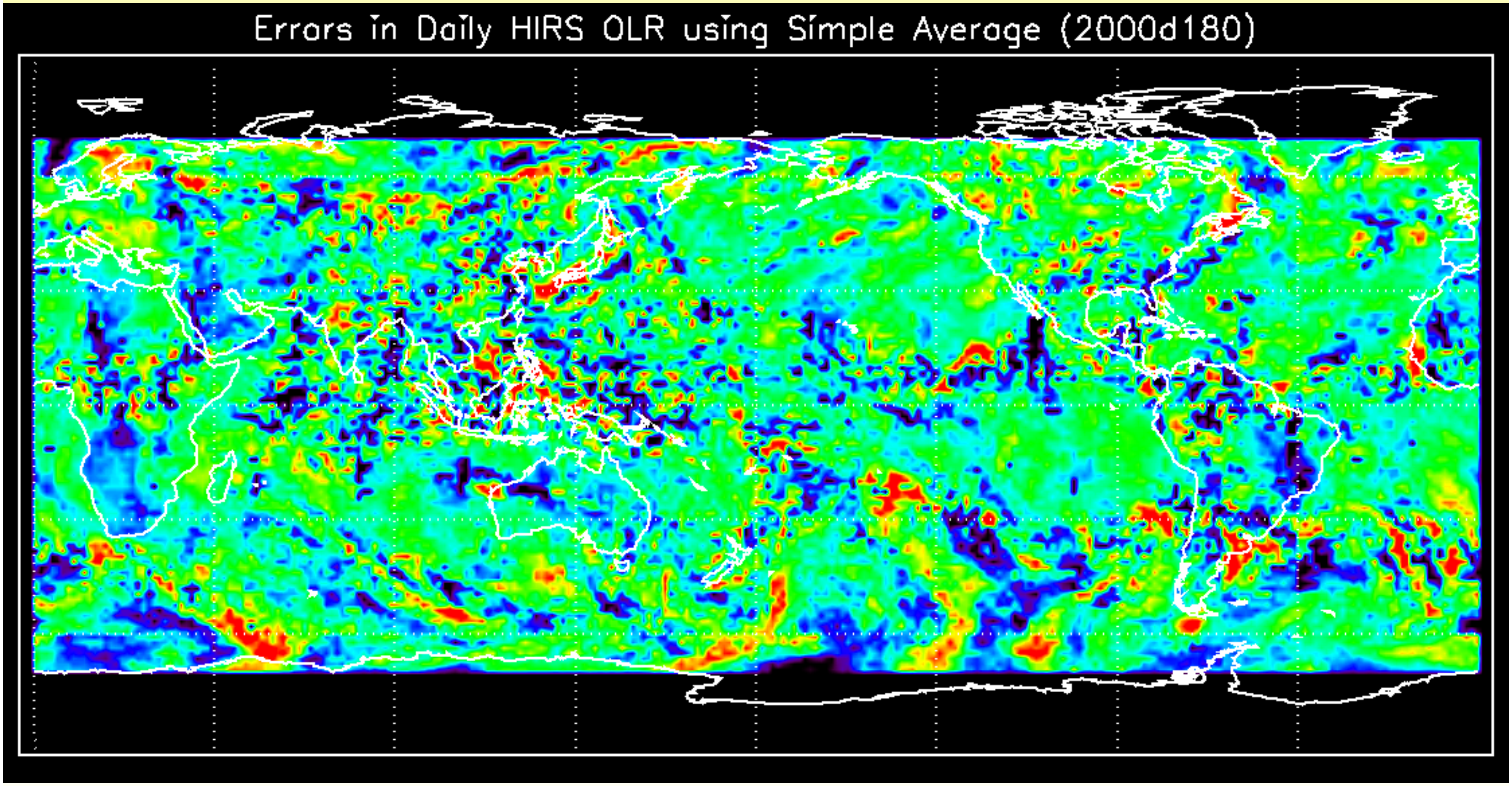
- *A new 1°x1° Daily OLR climate data record (1979-2012 as of now) were generated using observations from HIRS and Imager instruments onboard operational satellites.*
- *New OLR regression models improve accuracy and time series stability*
- *Geostationary data helps to improve temporal integration, and ultimately eliminate scanning gaps missing orbits, and orbital drift problems*
- *Compared very well with CERES EBAF products.*
- *Time series to be extended and near real-time (48hr) production to start in Summer 2014.*

Acknowledgments

- **NOAA NCDC Climate Data Record Program**
- **NOAA CLASS** (Comprehensive Large Array-Data Stewardship System) Data Center
- **NASA LaRC ASDC** (Langley Research Center Atmospheric Science Data Center)
- ***Robert G. Ellingson, Arnold Gruber, Ken Knapp, Carl Schreck, CERES Scientist Team***

BACKUP SLIDES

Errors in Daily OLR Without Geo Data



- Errors in daily OLR integral by simple averaging, e.g., (ascending+descending)/2, ranges from about ±80 Wm^{-2} even with two POES satellites. Areas shown in red/blue are those with errors exceed ±20 Wm^{-2}, respectively. The global mean and StdDev of differences are -0.6 and 8.7 Wm^{-2}, respectively.

New Imager OLR Algorithm

$$OLR = \sigma T_f^4$$

$$T_f^4 = (a_0 + a_1 T_{win}) \cdot T_{win} + (b_0 + b_1 T_{wv}) \cdot T_{wv}$$

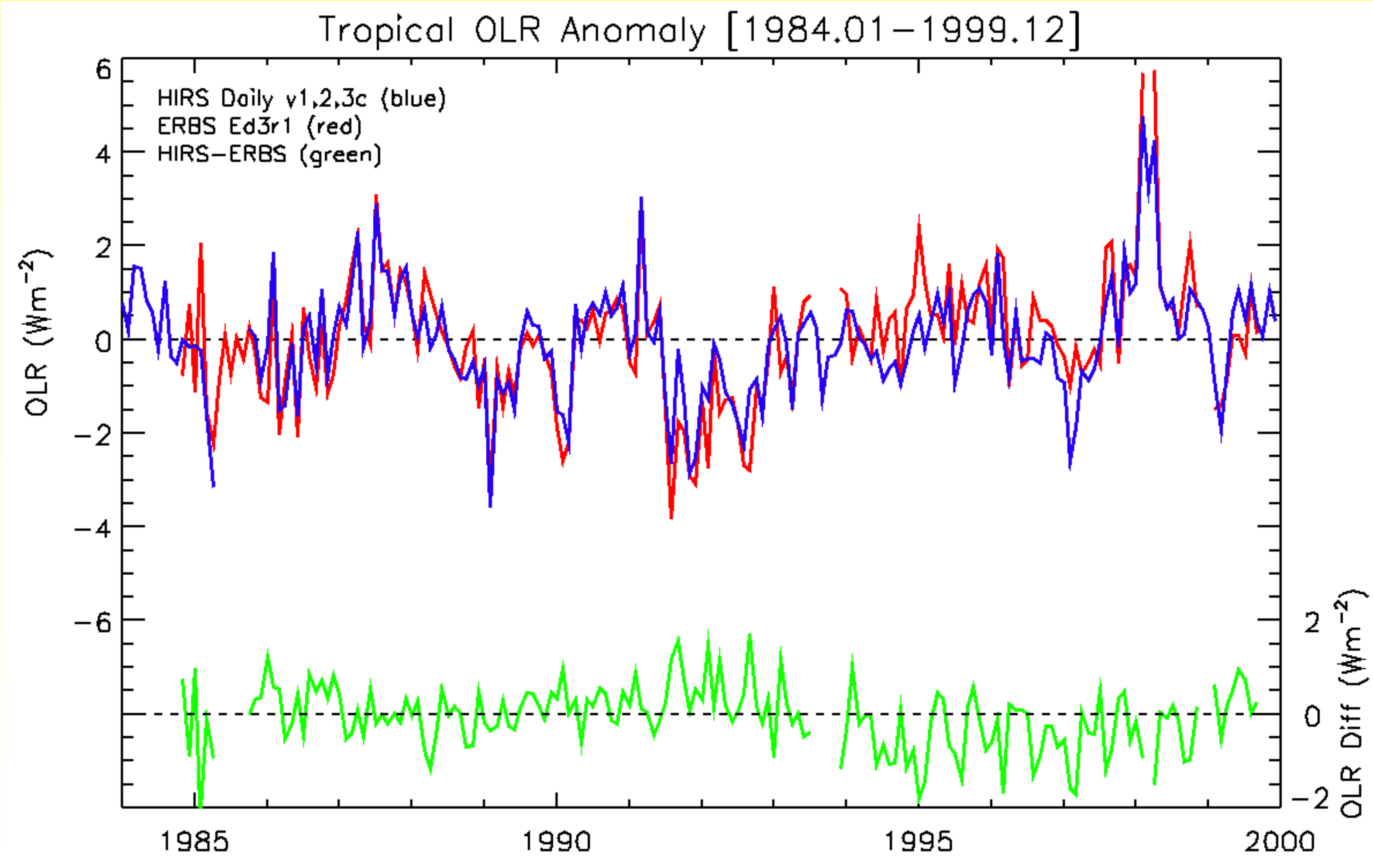
Adapted from Wark et al (1962)
cf. AVHRR OLR algorithm

a_i, b_i = Regression coefficients
T_f = Flux equivalent temperature
σ = Stefan-Boltzmann constant
T_{win} = Atmospheric window brightness temperature (nadir)
T_{wv} = 6.7 μm water vapor channel brightness temperature (nadir)

*Data Source: **GridSat CDR** data from NCDC CDR Program*

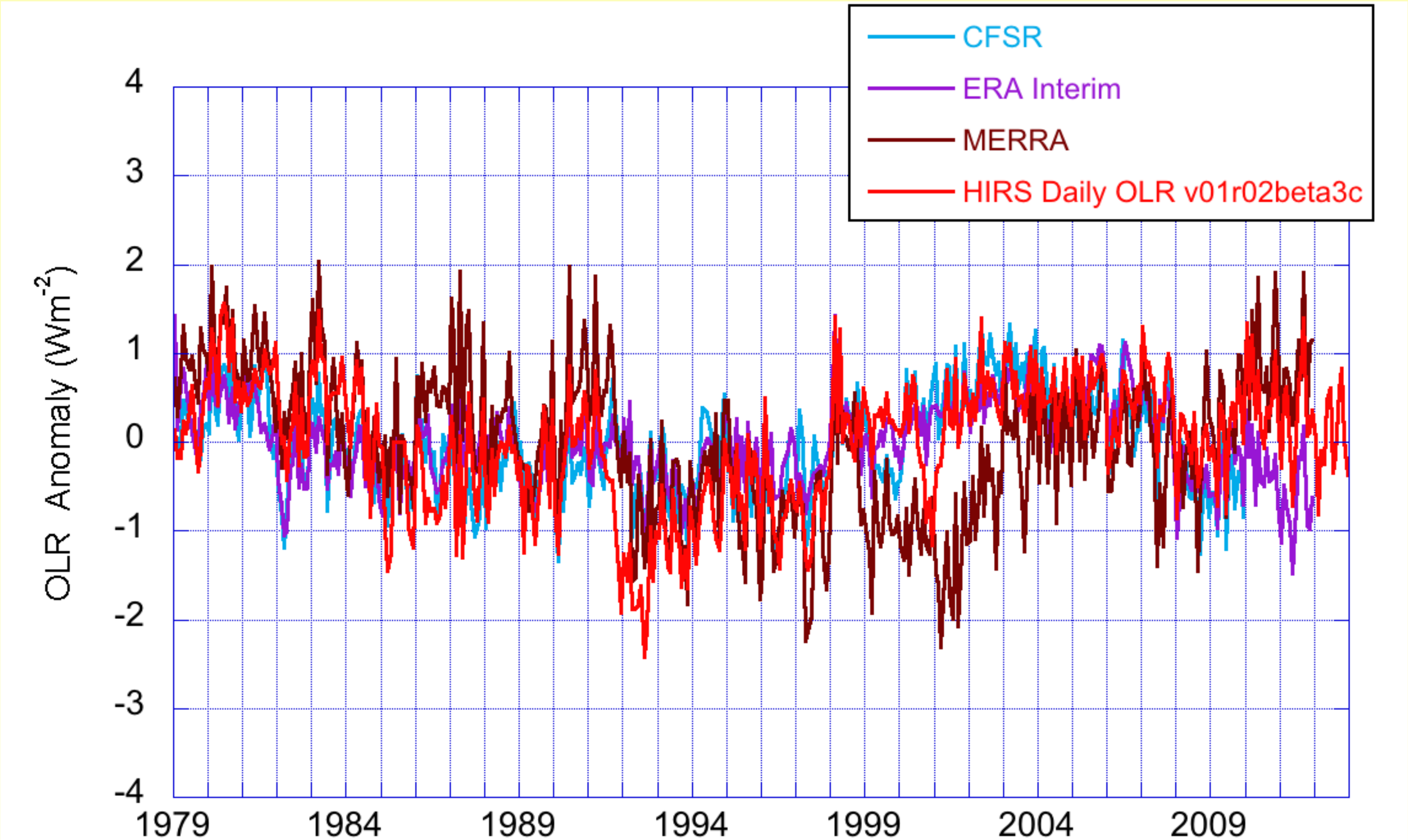
Tropical OLR Anomalies (1985-1999)

HIRS vs. ERBS non-scanner



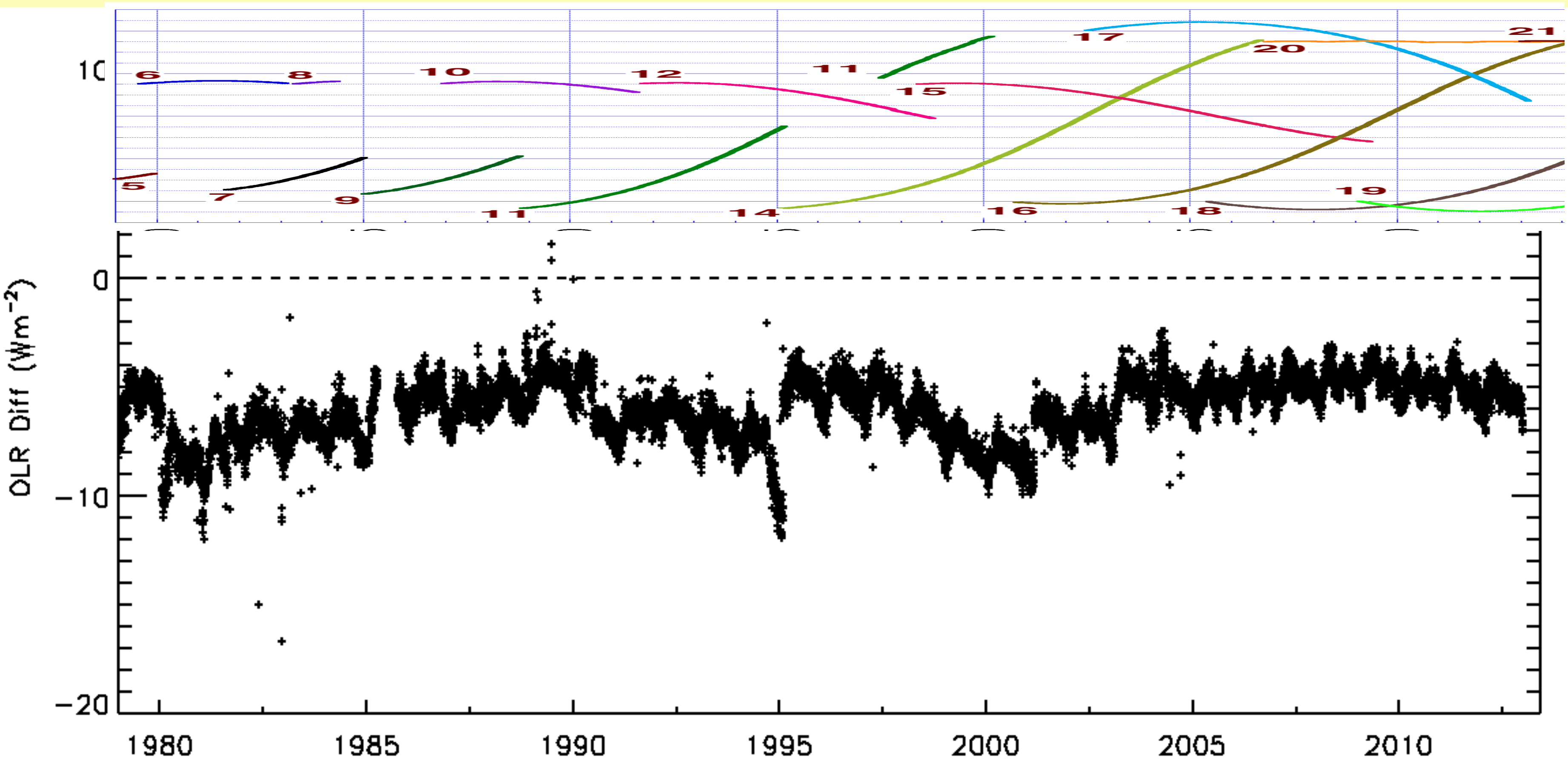
Slope of OLR anomalies diff = -0.34 ± 0.24 Wm^{-2}/decade at 2 σ

Global OLR Anomalies (1979-2012)
HIRS vs. Reanalysis



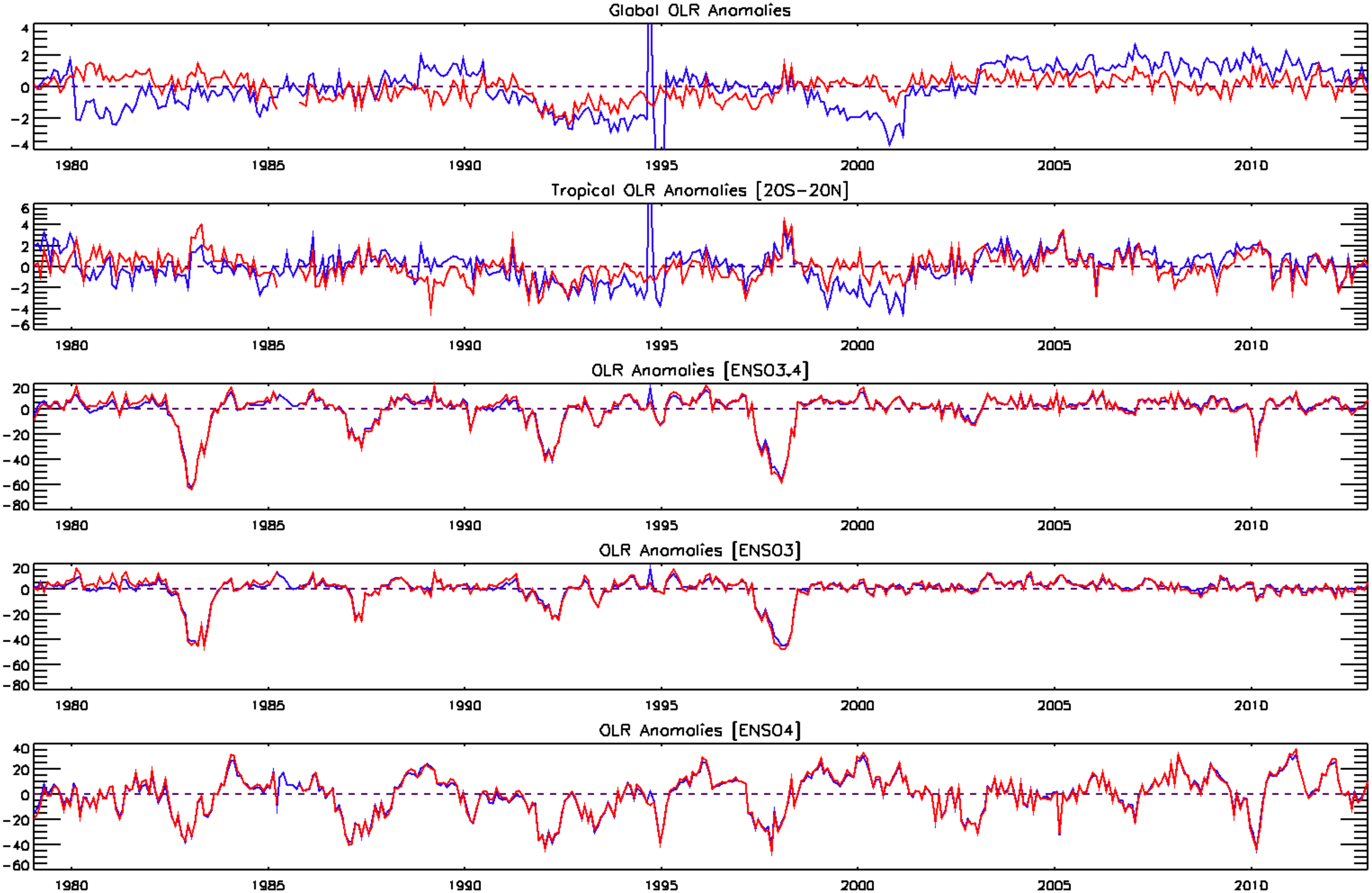
- *Problems in MERRA in several periods*
- *Problems in ERA Interim since 2009?*
- *1991-1993 negative anomalies in HIRS: aerosol or bad data?*

Differences of Global Mean Daily OLR
AVHRR minus HIRS



- *Satellite switching and orbital drift artifacts are apparent; most likely in AVHRR OLR*.

Daily OLR Anomalies (1979-2012)
HIRS (red) and AVHRR (blue)



Datasets

- **HIRS** Monthly OLR Climate Data Record v2.2/v2.3 and Daily OLR CDR v1.2.3c for 1979.01-2012.12 (*UMD-CICS/NCDC CDR Program*)
- CERES **EBAF Ed2.6r**, **Terra/Aqua SSF1deg Ed2.6, SYN1deg Ed3A**. 2000.03-2012.06 (*NASA LaRC ASDC*)
- NCEP Climate Forecast System Reanalysis (**CFSR**) 1979.01-2009.12 (*NCAR CISL Data Research Archive*)
- ECMWF European Reanalysis (**ERA**) Interim 1979.01-2011.12 (*ECMWF*)
- NASA Modern-Era Retrospective Analysis for Research and Applications (**MERRA**) 1979.01-2012.02 (*NASA GES DISC*)
- NOAA ESRL (Earth System Research Laboratory) Interpolated **AVHRR** OLR