COOPERATIVE INSTITUTE FOR CLIMATE STUDIES (CICS)

Comparison of HIRS OLR With ERBE and CERES

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Outline

- Construction of HIRS OLR Data Set
- Comparison with ERBE Non-scanner
- Comparison with ERBE Scanner, and CERES Scanner

Construction of HIRS OLR Time Series

1. Reprocessing of HIRS Radiance
2. OLR Regression Coefficients
3. Inter-satellite Calibration
4. Empirical Diurnal Model

***Climate Data Record**: "A time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change."* – Committee on Climate Data Records from NOAA Operational Satellites, NRC/NAS, 2004.

Multi-spectral HIRS OLR Algorithm

Ellingson et al. (1989)

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

a_i=regression coefficients
θ=local zenith angle

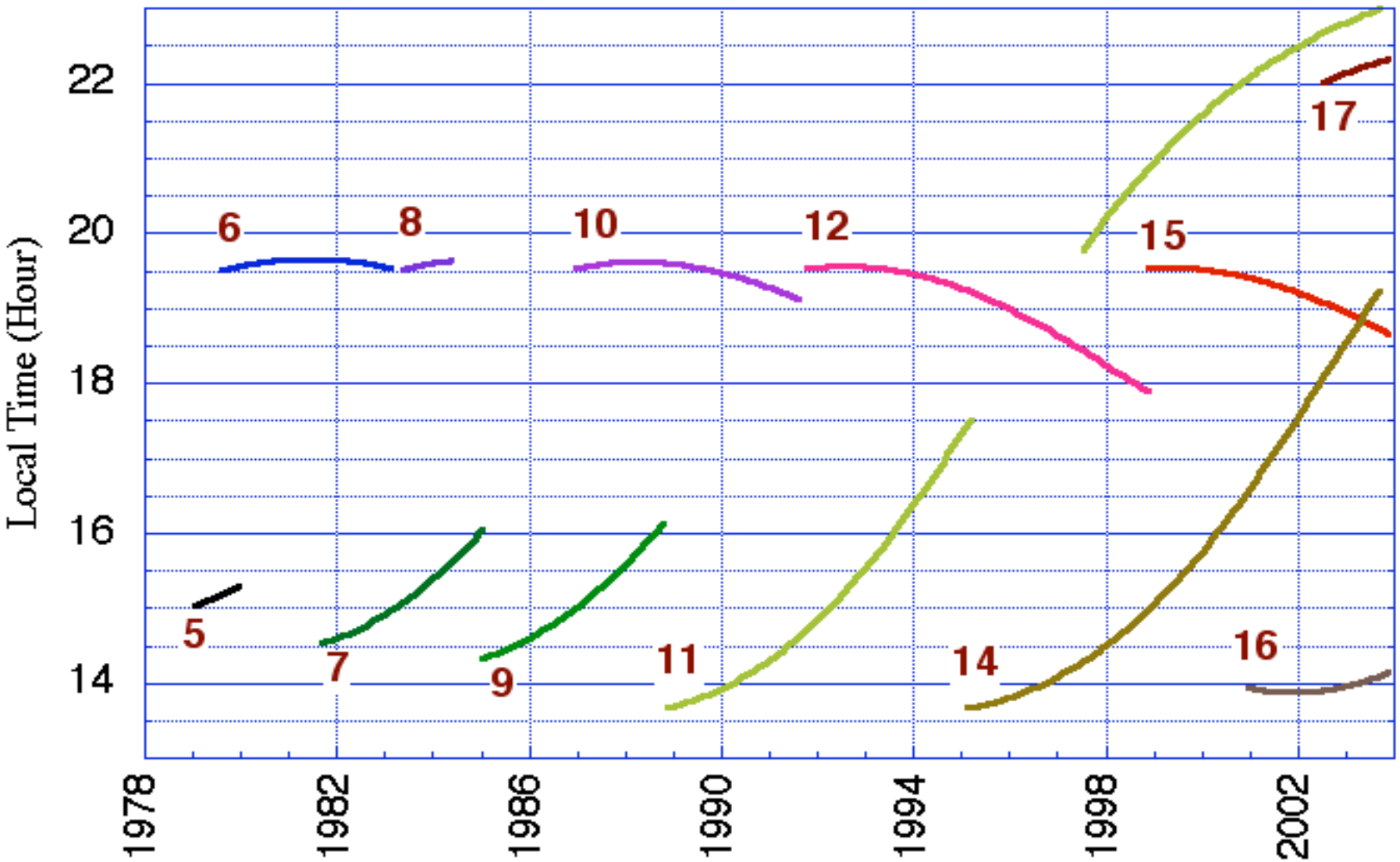
$$I_\nu^\uparrow(z_t;\mu,\phi) = \varepsilon_\nu^* B_\nu^*(0) T_\nu(z_t,0;\mu,\phi) + \int_0^{z_t} B_\nu(z') \frac{\partial T_\nu(z_t,z';\mu,\phi)}{\partial z'} dz'$$

$$OLR = \int_0^\infty \int_0^{2\pi} \int_0^1 I_\nu^\uparrow(z_t;\mu,\phi)\mu \mathrm{d}\mu d\phi \mathrm{d}\nu$$

$$N_i(\mu) = \int_{\Delta\nu_i} I_\nu^\uparrow(z_t,\mu) f_i(\nu) d\nu$$

$$\mu = \cos(\theta)$$

Equator Crossing Time for NOAA Polar Orbiters



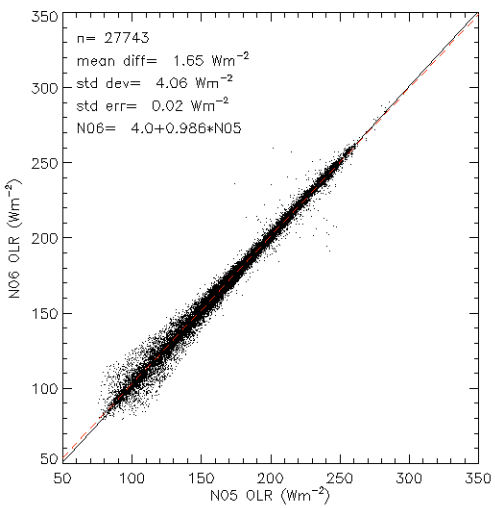
Inter-satellite Calibration

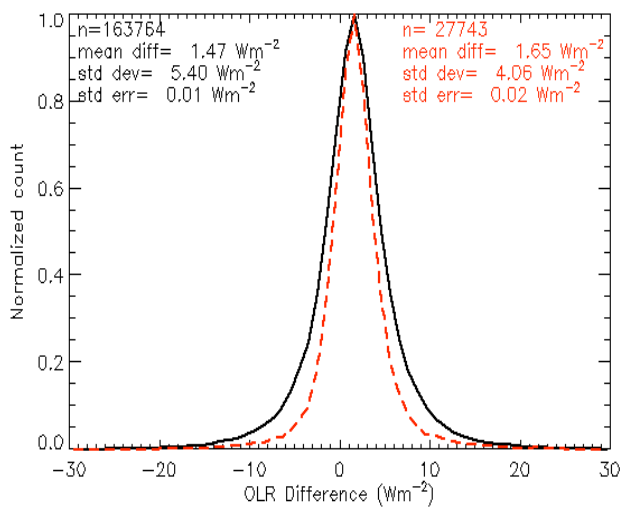
Collocation:

- 1°x1° lat/lon
- ±30 minutes

Homogeneity filter:

- Std error of mean OLR < 1 Wm^{-2}





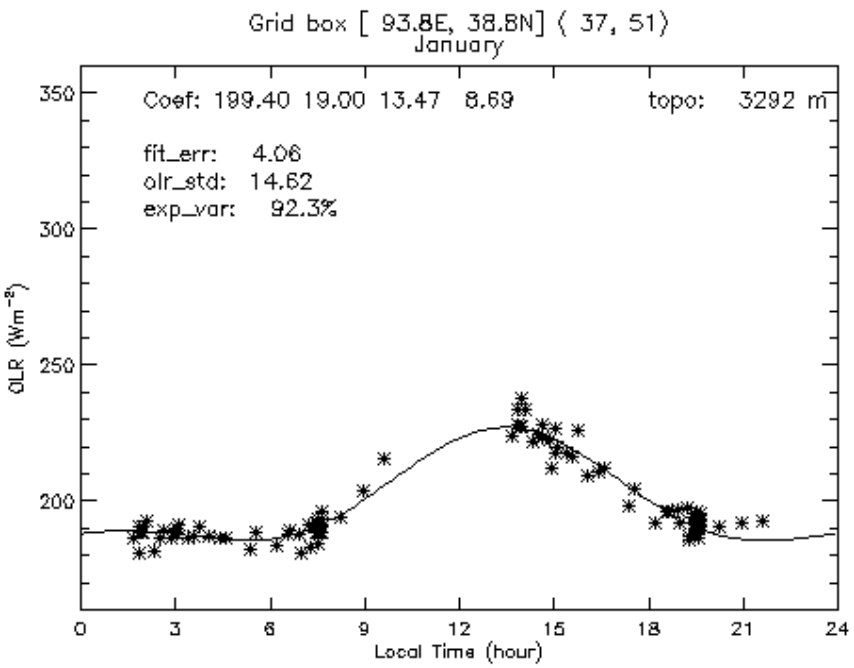
Satellites	Bias (Wm^{-2})
TN	0.15
N06	1.80
N07	2.13
N08	2.03
N09	Reference
N10	0.53
N11	-5.36
N12	-2.42
N14	-5.14
N15	-3.65
N16	-3.25

OLR Empirical Diurnal Model

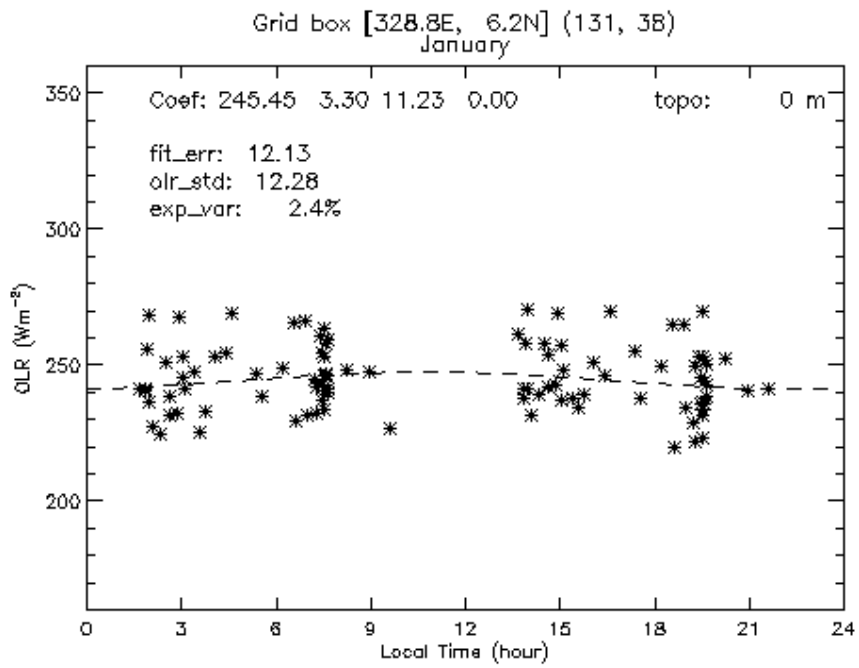
$$OLR = a_0 + a_1 COS\frac{\pi(t-t_0)}{12} + a_2 COS\frac{2\pi(t-t_0)}{12}$$

25 Years of Monthly 'Hourly' Mean OLR Composite

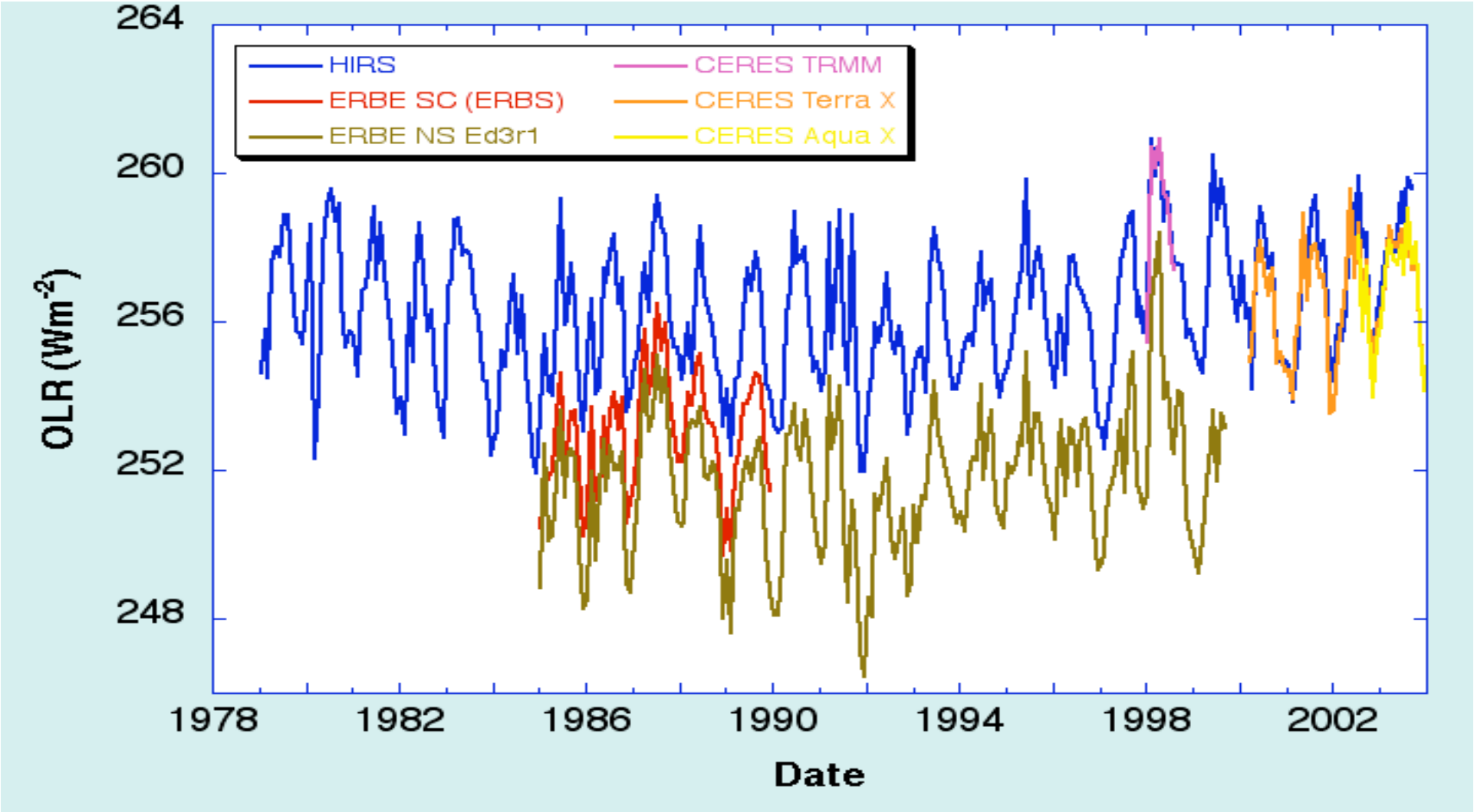
Tsaidam Basin



Western Pacific

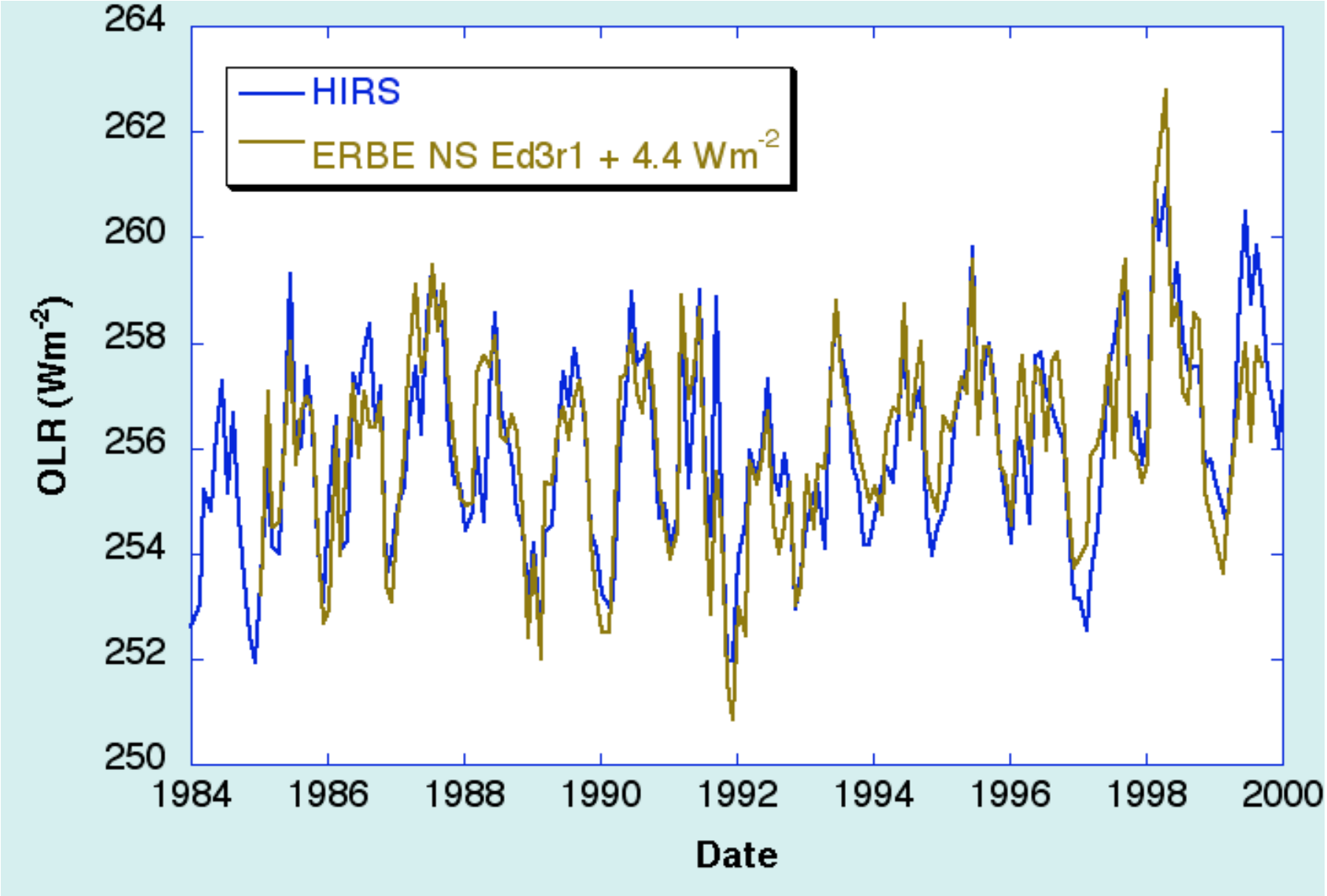


Tropical Mean OLR 1979-2003

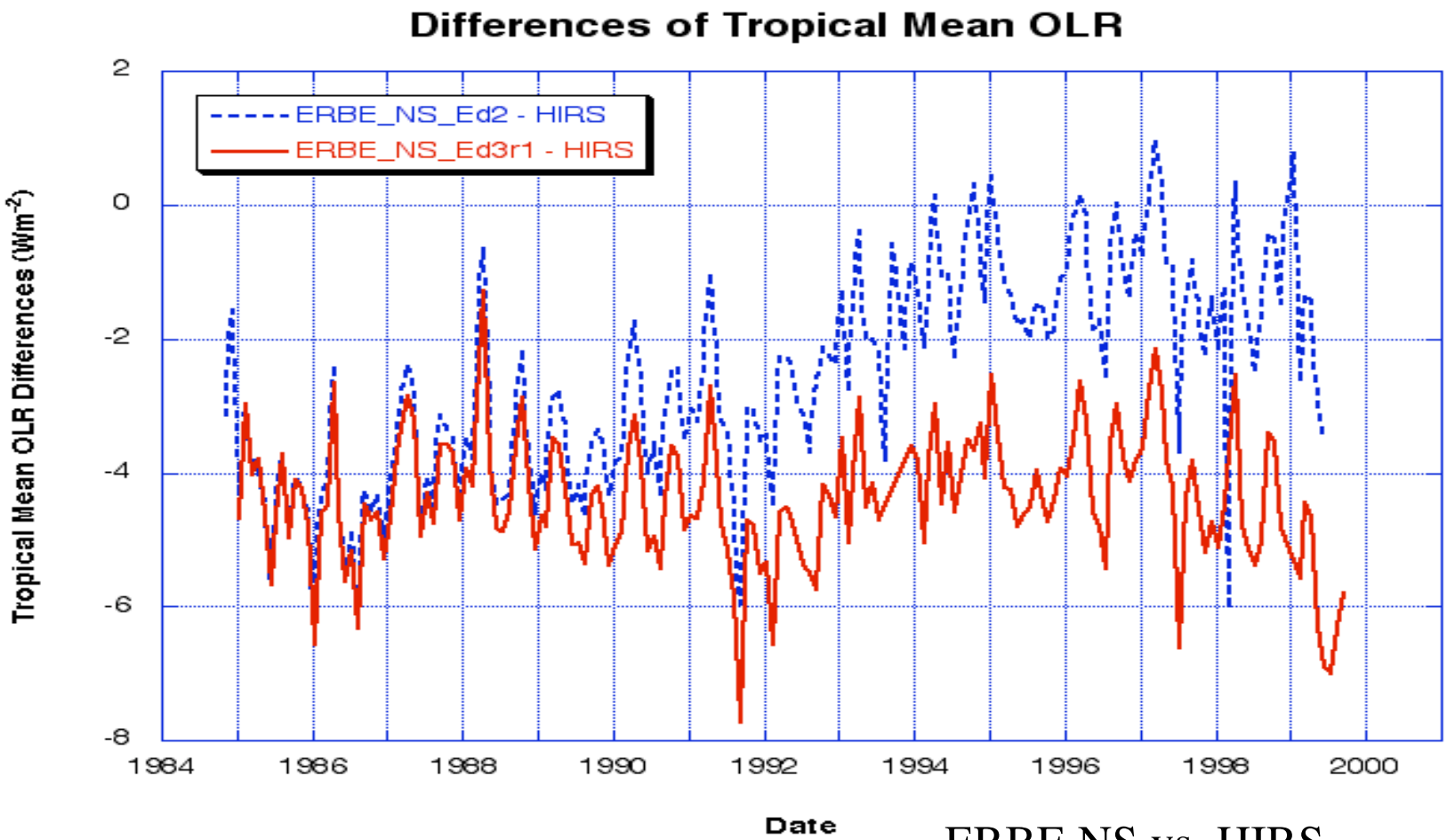


Comparing HIRS OLR with ERBE Non-scanner

ERBE Non-scanner and HIRS 1985-1999



ERBE Non-scanner and HIRS 1985-1999



HIRS product is as stable as ERBS-NS.

ERBE NS vs. HIRS

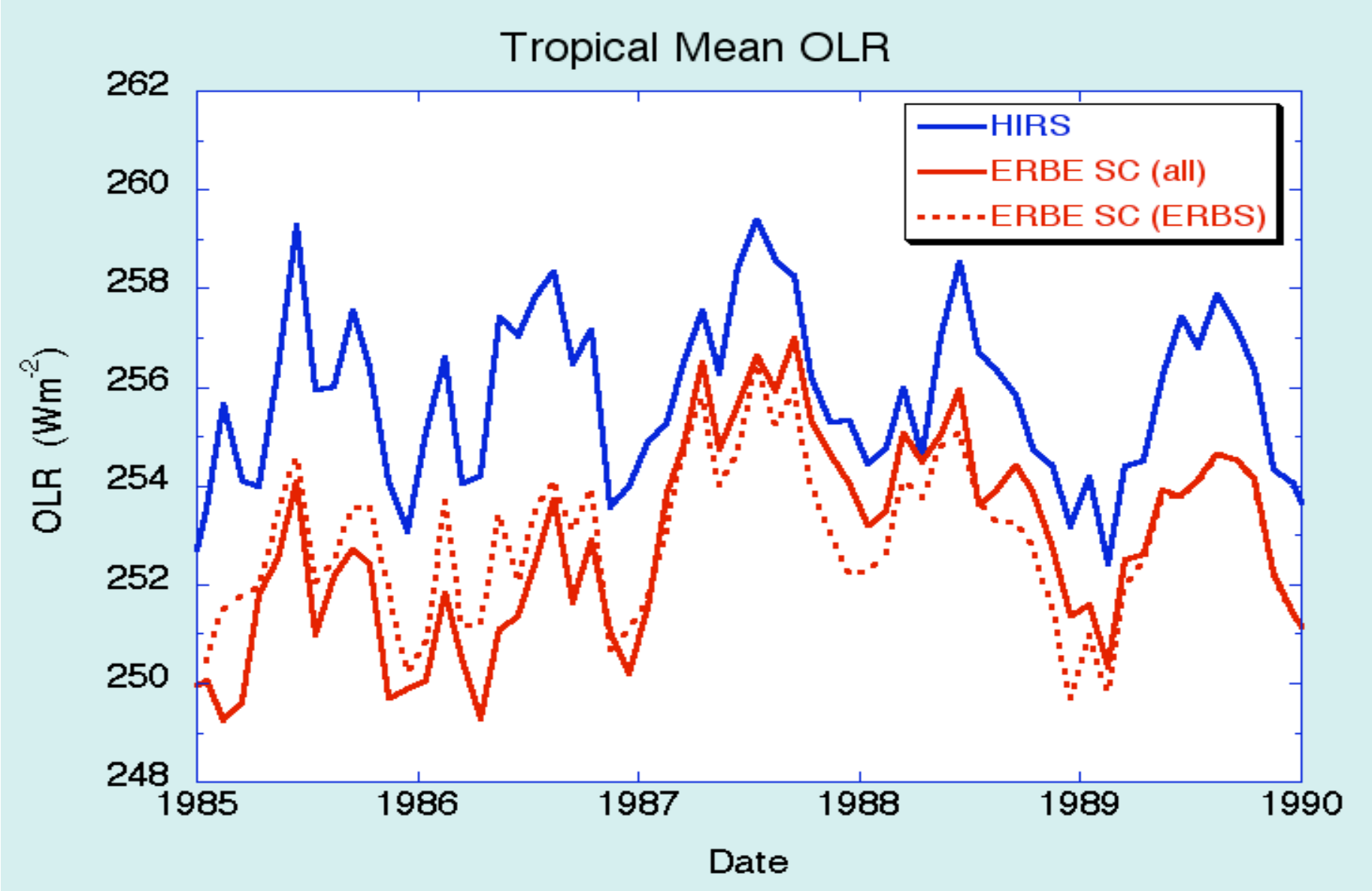
Best-fit line slope = 0.998

STD = 0.97 Wm^{-2}

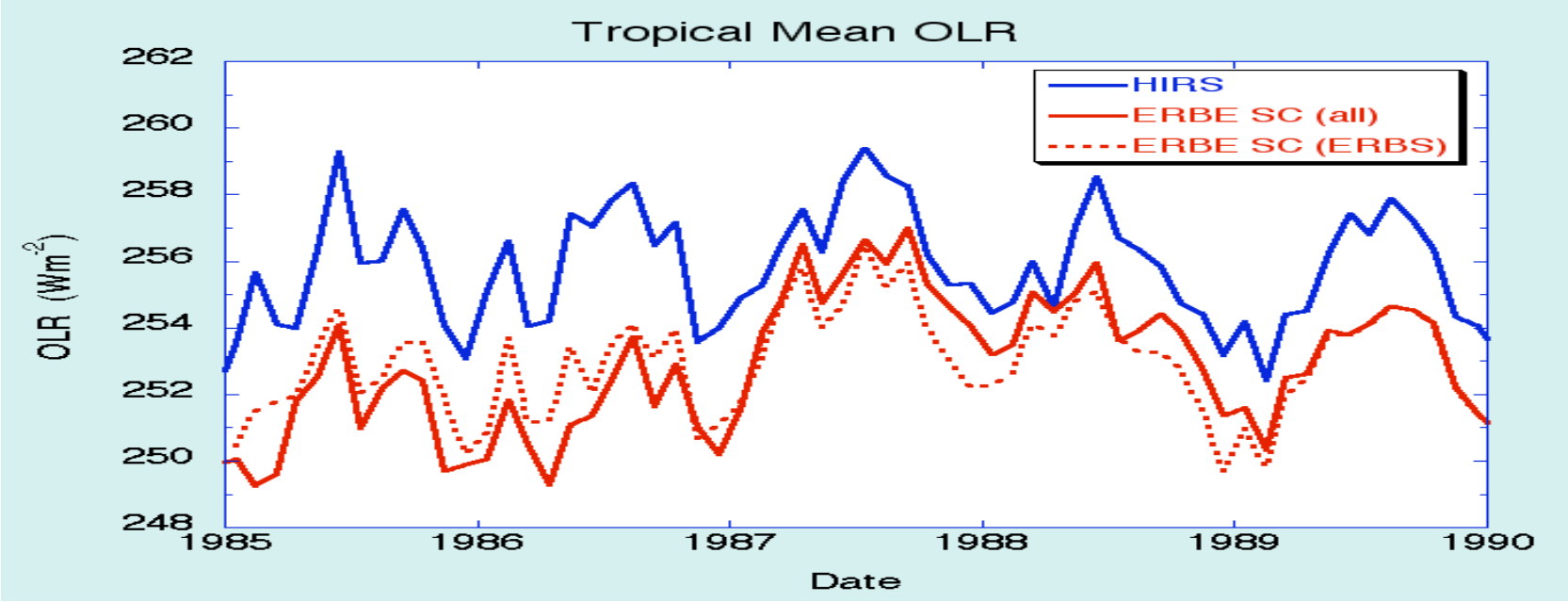
r = 0.86

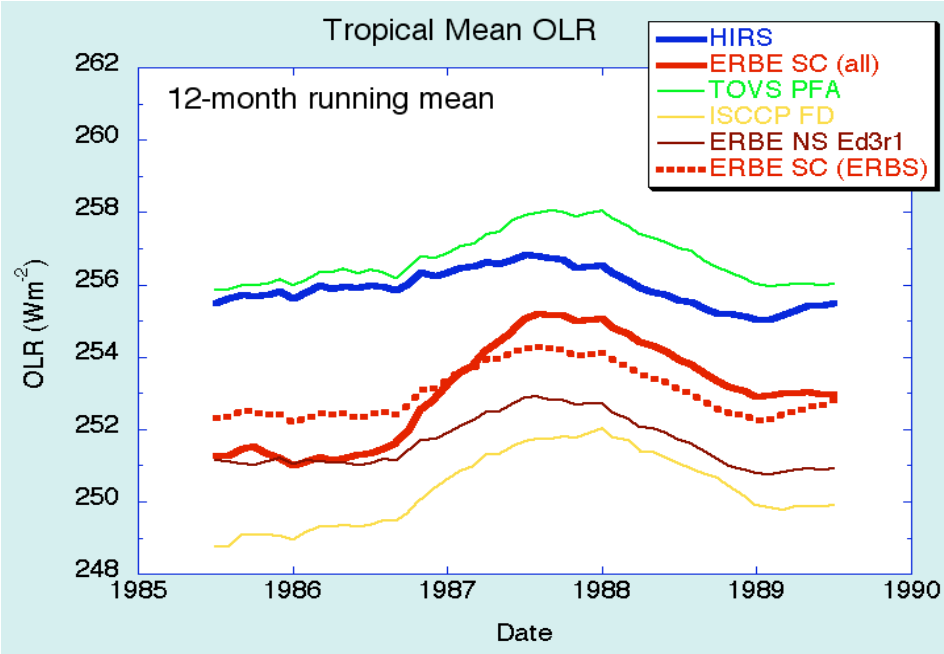
Comparing HIRS OLR with ERBE Scanner

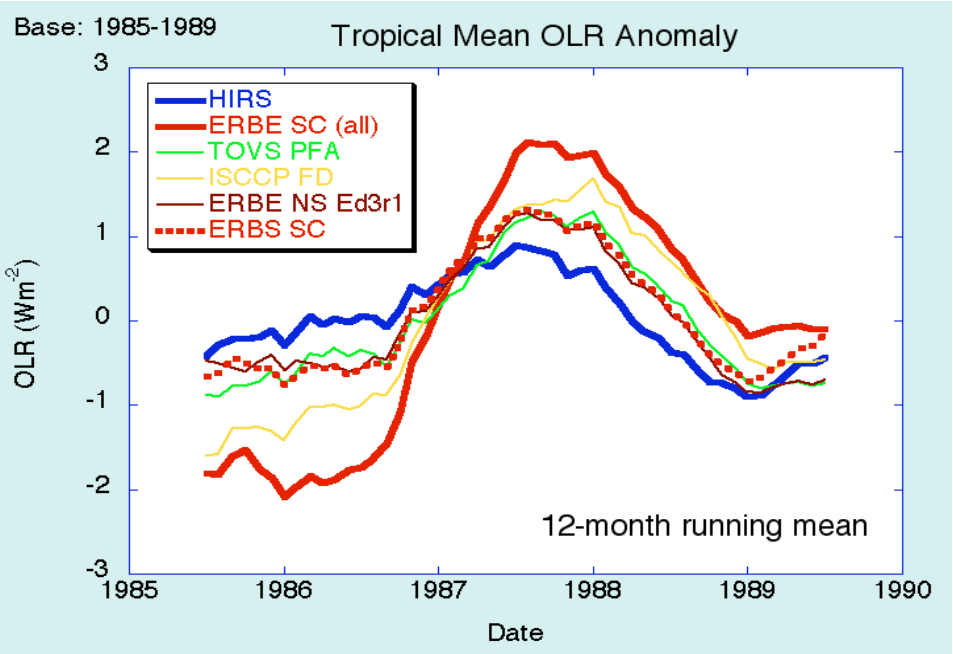
ERBE Scanner and HIRS 1985-1989



ERBE Scanner and HIRS 1985-1989

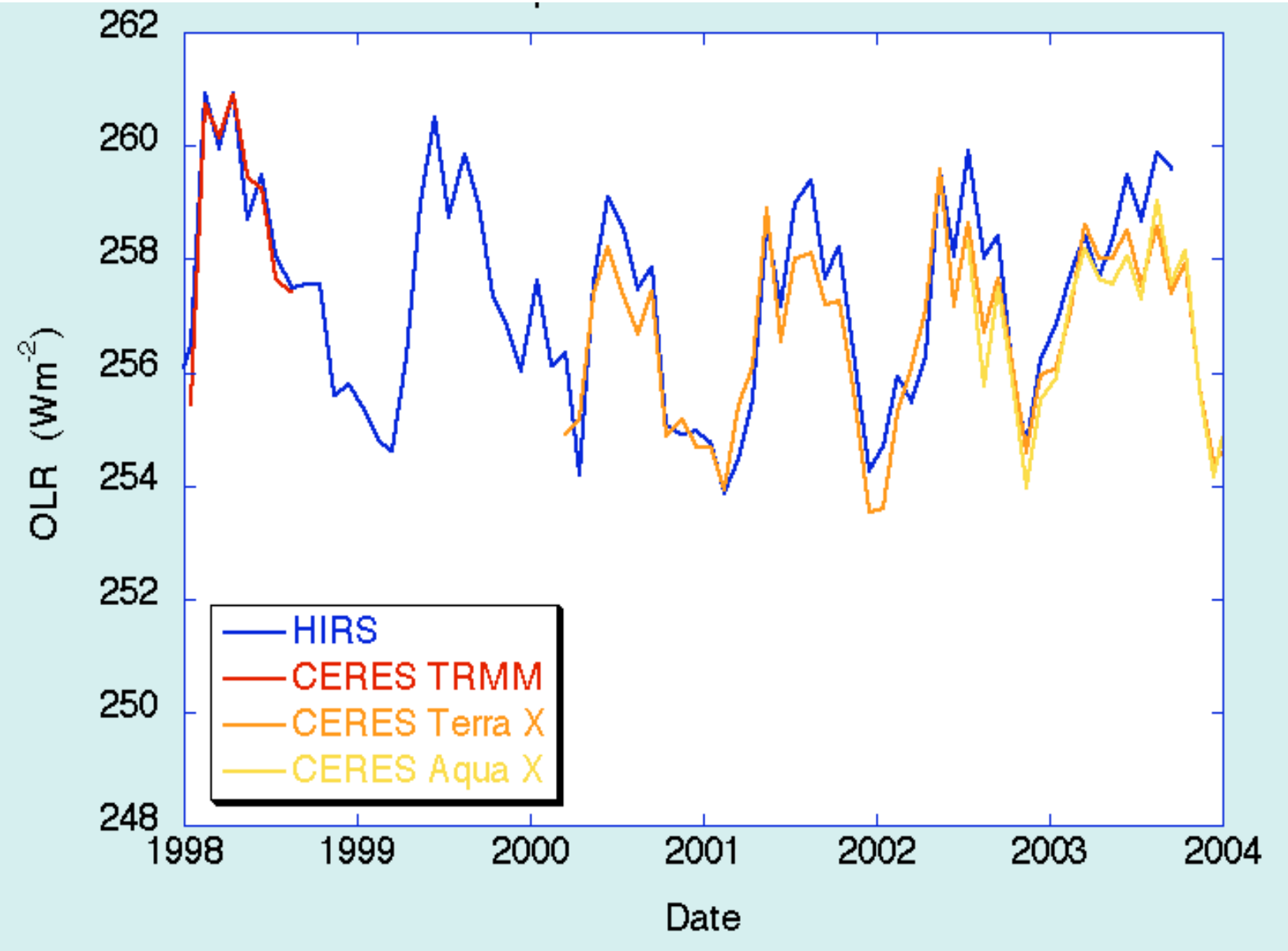




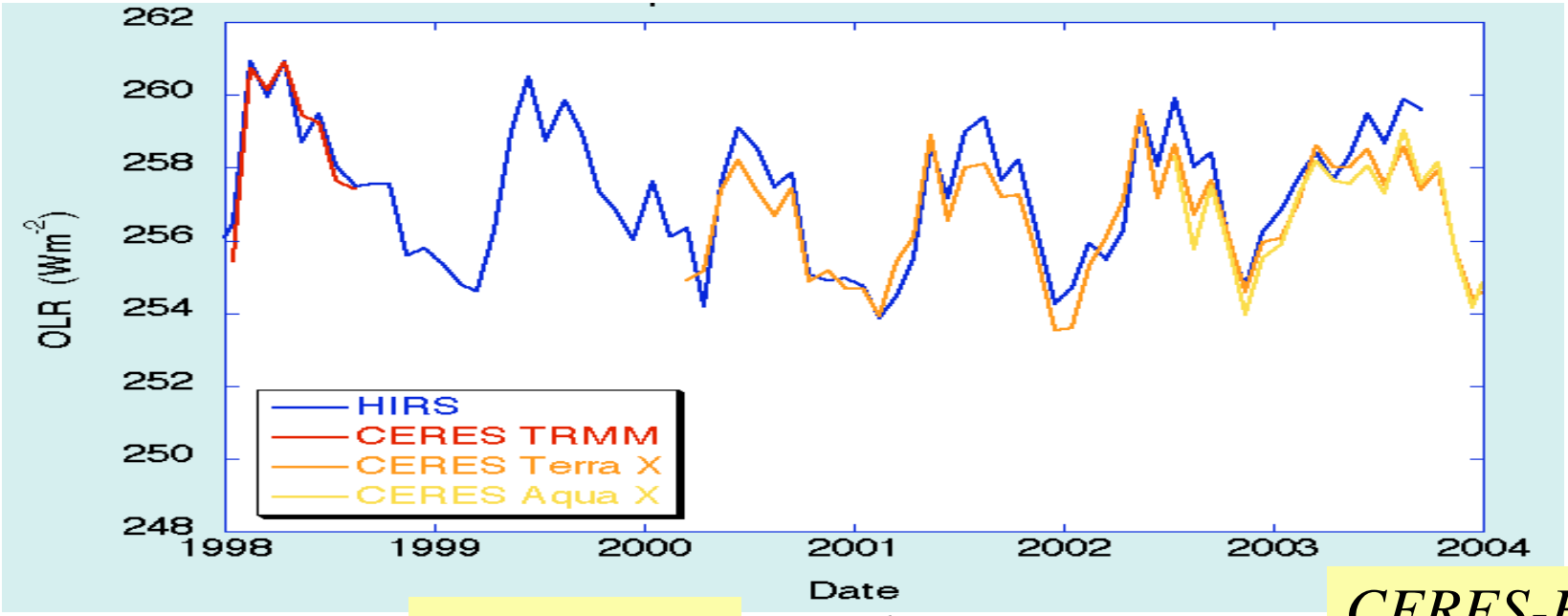


Comparing HIRS OLR with CERES Scanner

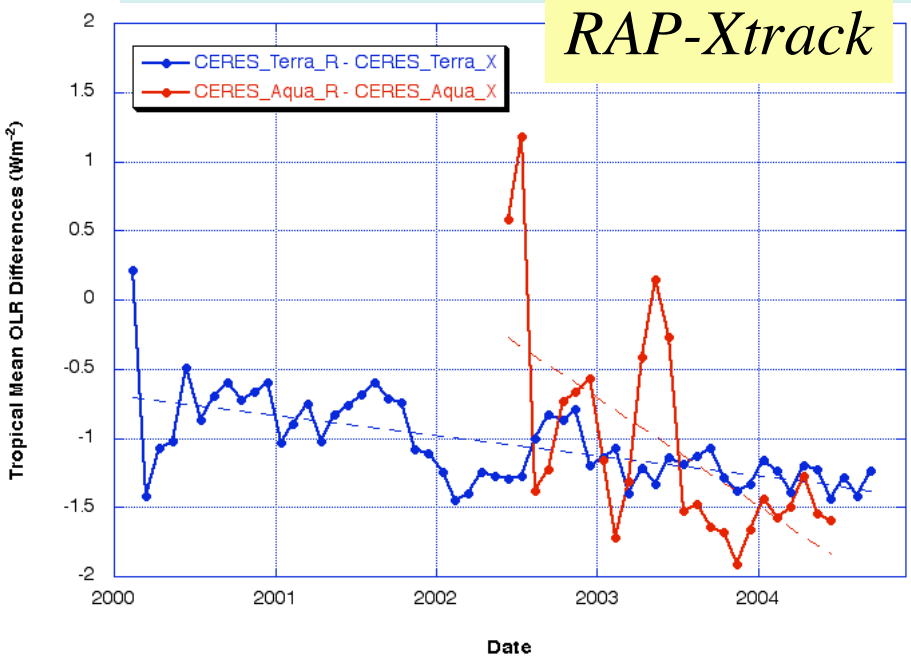
CERES Scanner and HIRS 2000-2003



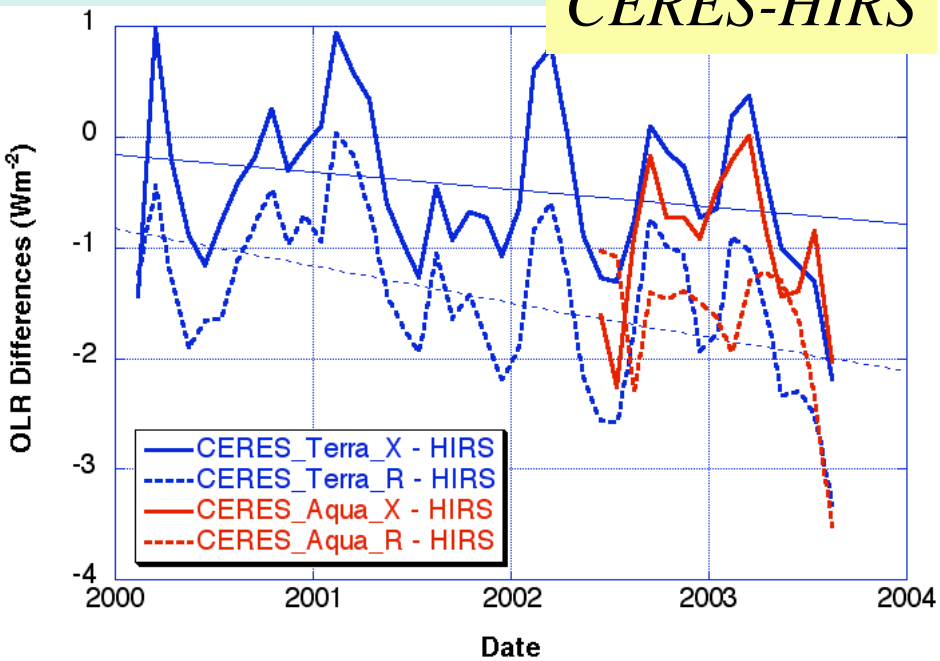
CERES Scanner and HIRS 2000-2003



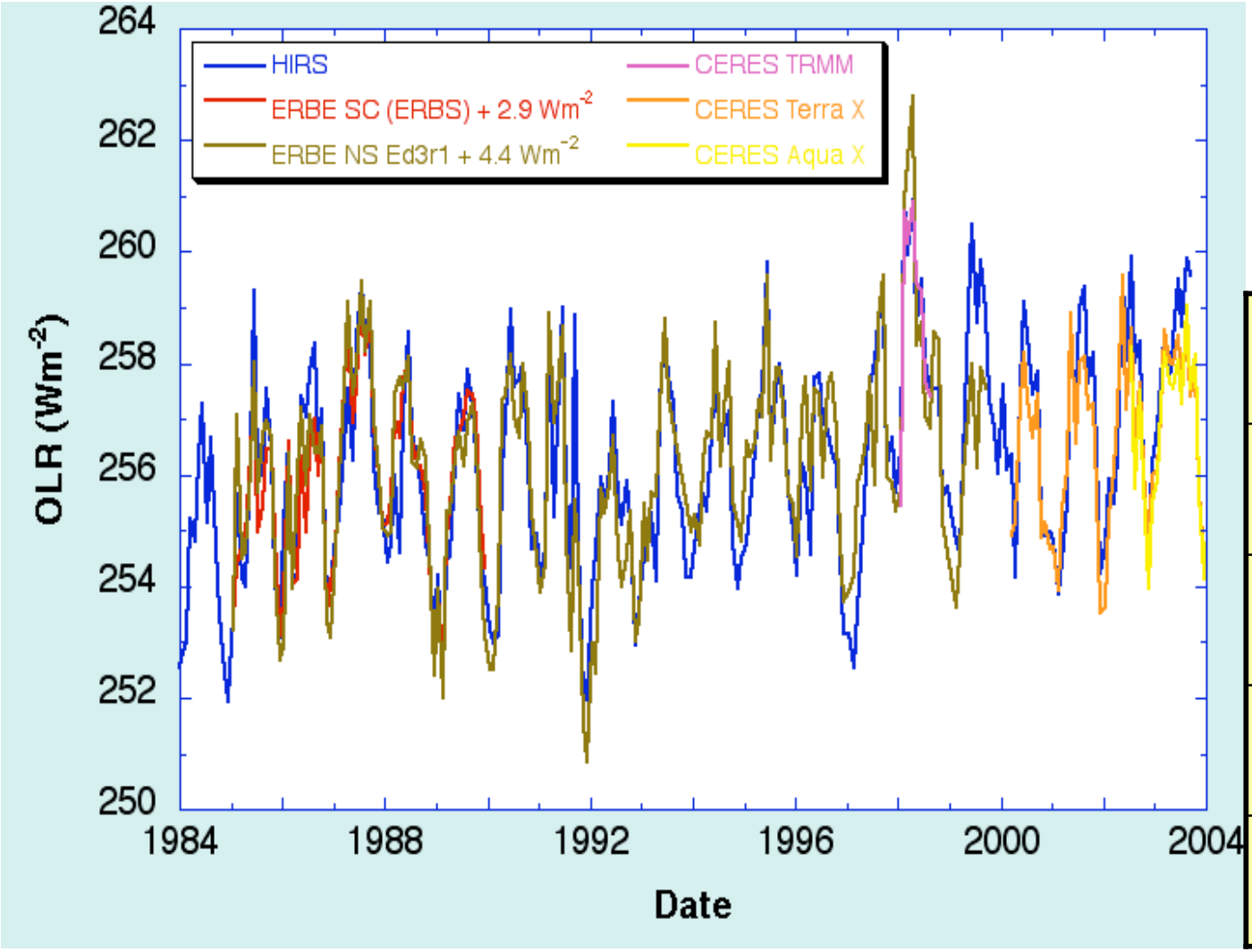
RAP-Xtrack



CERES-HIRS



Tropical Mean OLR 1984-2003



Relative to HIRS

ERBE SC (ERBS)	-2.9±0.1 n=60
CERES TRMM	-0.1±0.2 n=8
CERES Terra X	-0.5±0.1 n=56
CERES Aqua X	-1.0±0.2 n=25
ERBE NS	-4.4±0.1 n=170

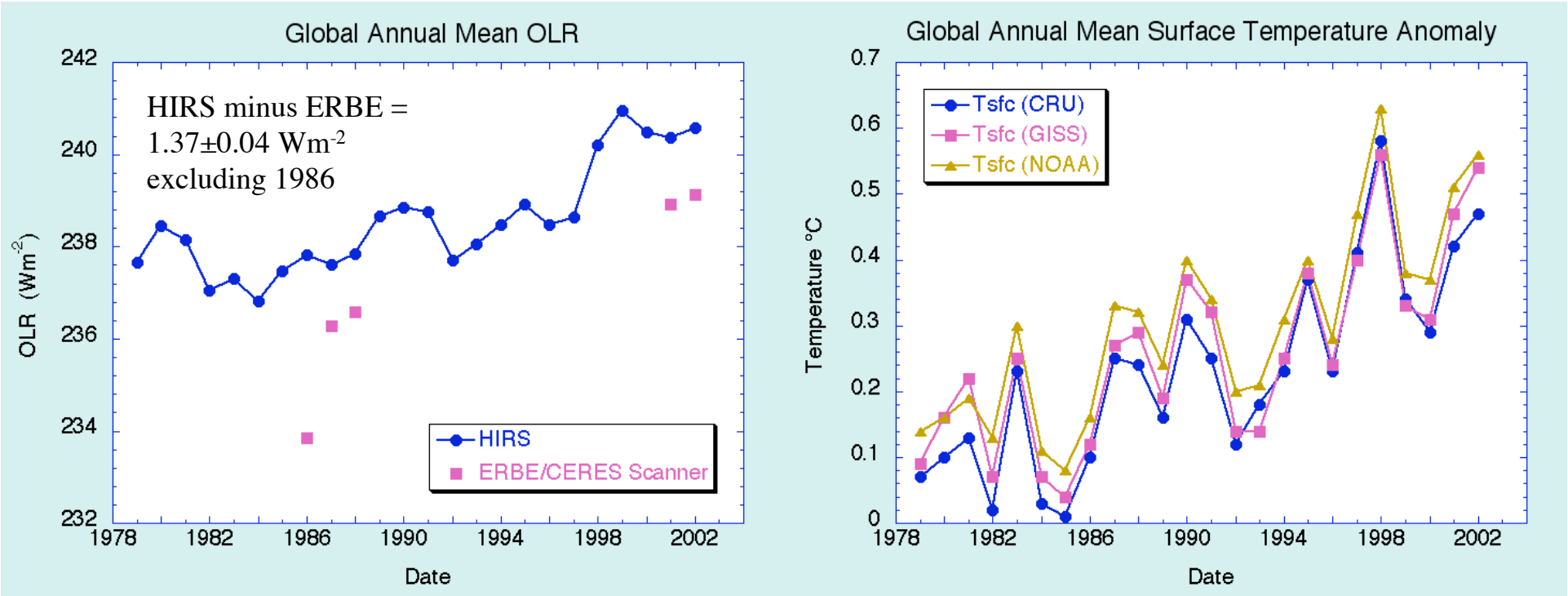
Summary

- New global HIRS OLR time series 1979 – 2003.
- Excellent agreement in tropical variation compared to ERBE and CERES with the stability comparable to ERBS-NS.
- HIRS anomaly is in-line with ERBS-SC, ERBS-NS, ISCCP FD, TOVS PFA; but smaller than ERBE-combined.
- Artificial trend in CERES Terra/Aqua LW?
- ERBE-SC and CERES-SC offset by about 3 Wm^{-2} in reference to ERBE-NS and HIRS.

Backup Slide

Trend in OLR, Surface Temperature, and Cloud Cover

Global Annual Mean



<u>1979-2002 Linear Trend</u>

OLR (HIRS): 1.34±0.21 Wm^{-2} per decade

Tsfc (CRU): 0.17±0.03 °C per decade
Tsfc (GISS): 0.15±0.03 °C per decade
Tsfc (NOAA):0.16±0.03 °C per decade

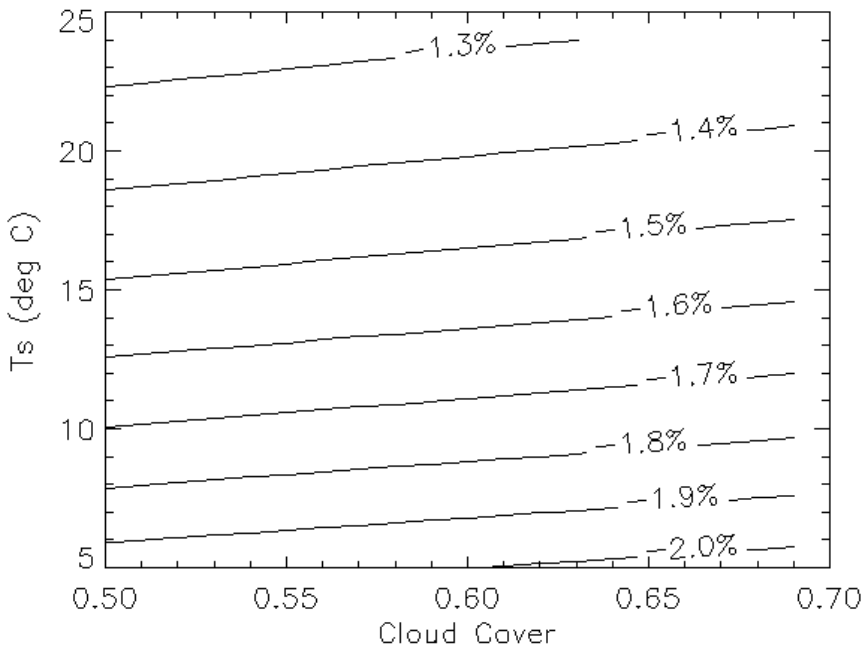
Linear Trends in OLR, T_{sfc} and Cloud Cover

Budyko (1969):

$$OLR = 226 + 2.26\,T_s - (48 + 1.62 T_s)\,A_c$$

Simulations
Monthly
206 stations

$$\frac{dOLR}{dt} = (2.26 - 1.62\,A_c)\,\frac{dT_s}{dt} - (48 + 1.62 T_s)\,\frac{dA_c}{dt}$$



Given 1979-2002 linear trends:
OLR: 1.34 Wm^{-2}/decade
Ts: 0.17°/decade

Estimated trend in Cloud Cover would be about -1.5% per decade for cloud cover at 60% and Tsfc at 15°C.

Linear Trends in OLR, T_{sfc} and Cloud Cover

Cess (1976):

$$OLR = 257 + 1.57\, T_s - 91\, A_c$$

Obs., annual zonal, N.H.
OLR - Ellis & Vonder Haar (1976)
Ts - Crutcher and Meserve (1970)
Cloud - London (1957)

$$\Rightarrow \quad \frac{dOLR}{dt} = 1.57 \frac{dT_s}{dt} - 91 \frac{dA_c}{dt}$$

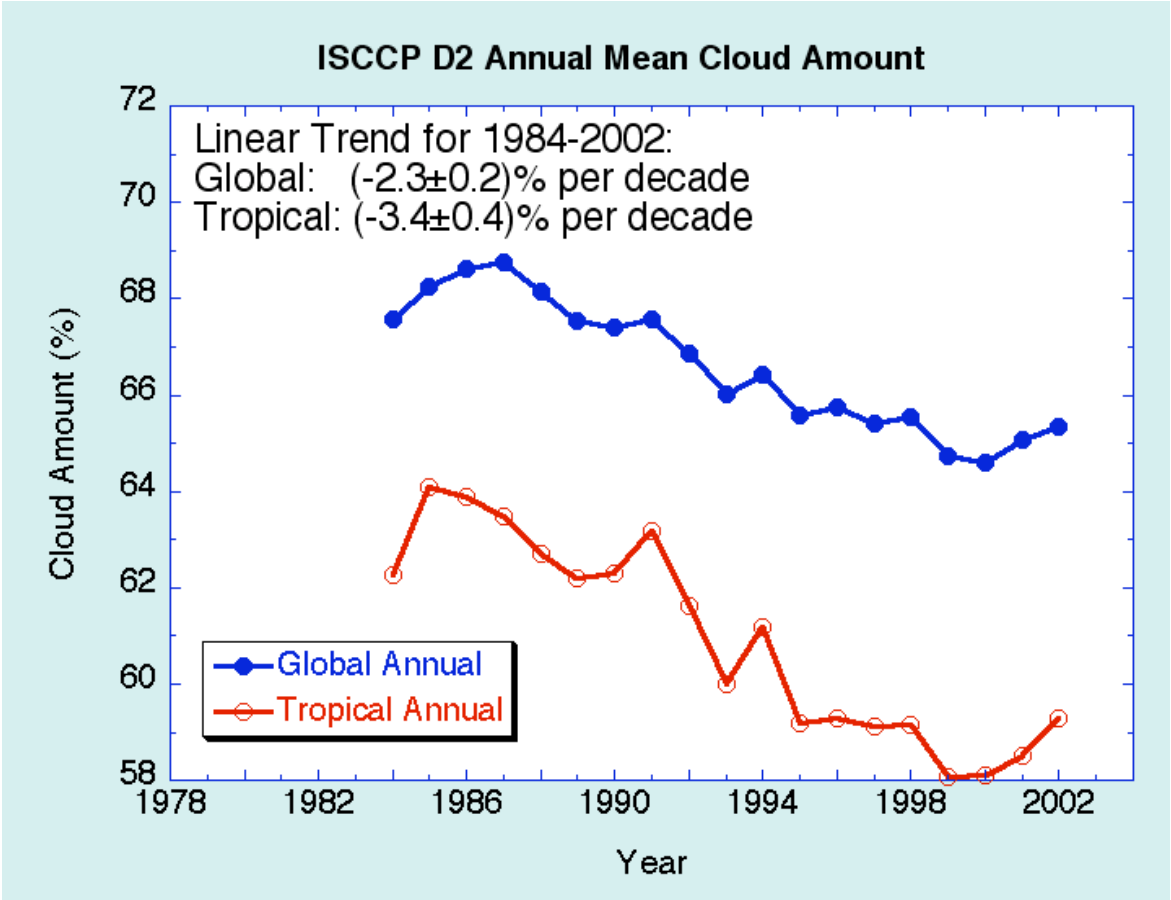
Given 1979-2002 linear trends:
OLR: 1.34 Wm^{-2}/decade
Ts: 0.17°/decade

Estimated trend in Cloud Cover would be about -1.2% per decade.

Coherency in Decadal Variation

Linear trend 1979-2002:
OLR 1.34 Wm-2
Tsfc 0.17°
\ Cloud Amount
-1.2 ~ -1.5 %

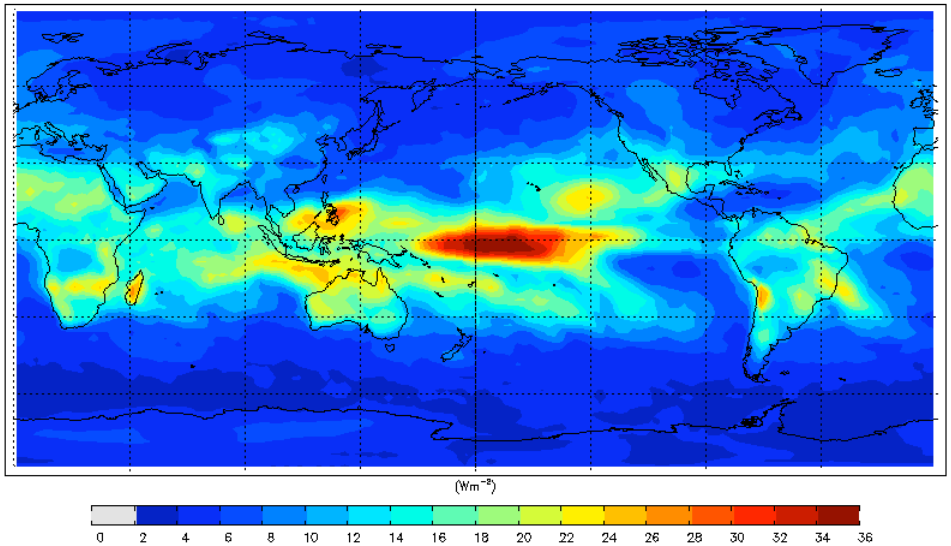
Linear trend 1984-2002:
OLR 1.88 Wm-2
Tsfc 0.21°
\ Cloud Amount
-1.7 ~ -2.2 %



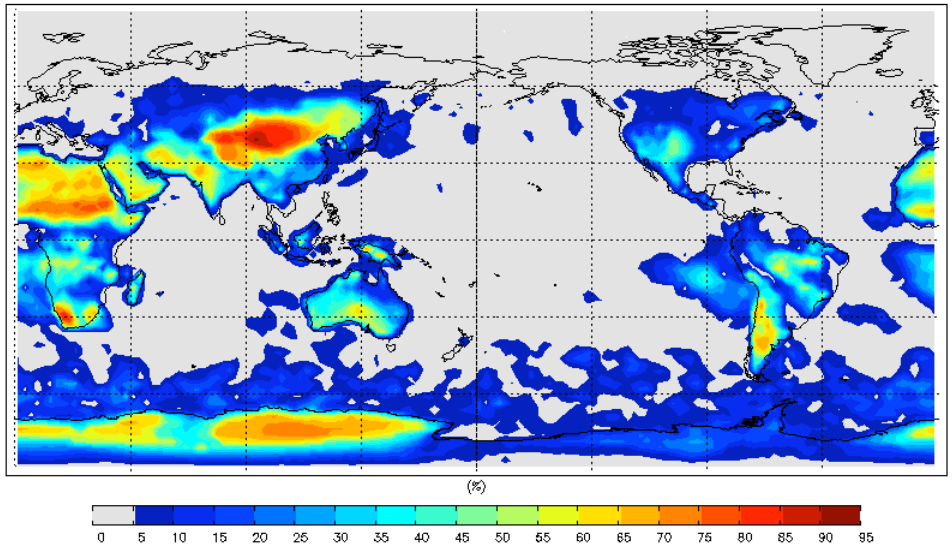
Rossow (Oct. 2005): "Not yet declared whether the long-term trend is real; Some artifacts being investigated that some claim explains this variation away".

January

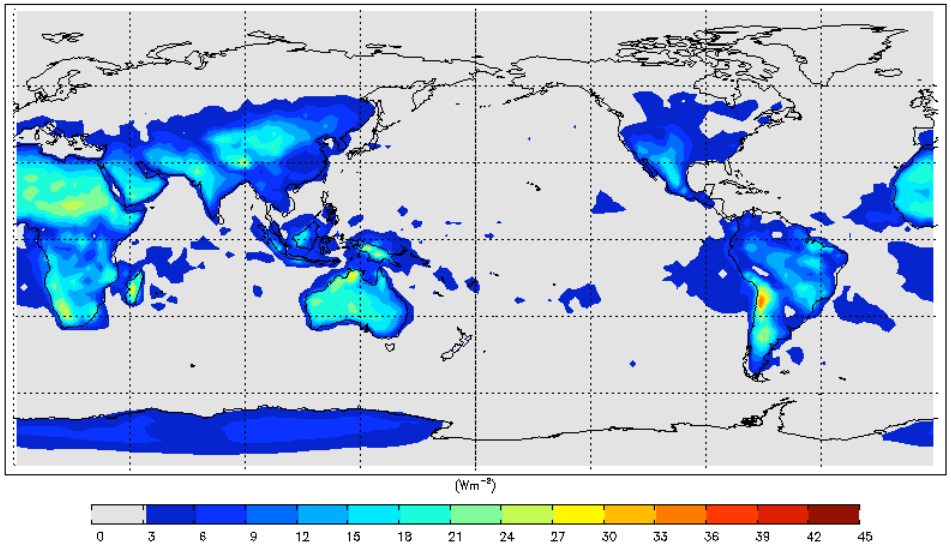
STD of OLR Diurnal Variation
January



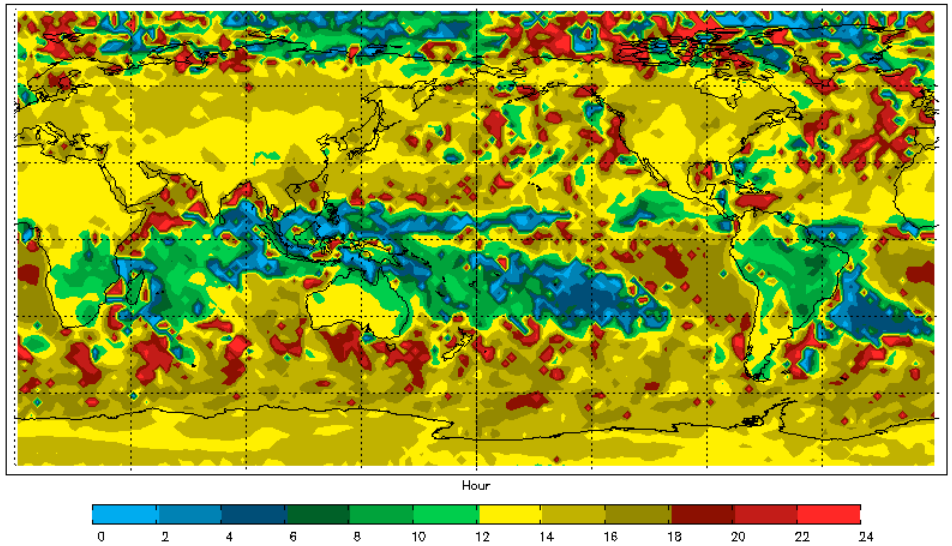
Explained Variance of OLR Diurnal Variation
January



Amplitude of OLR Diurnal Model
January

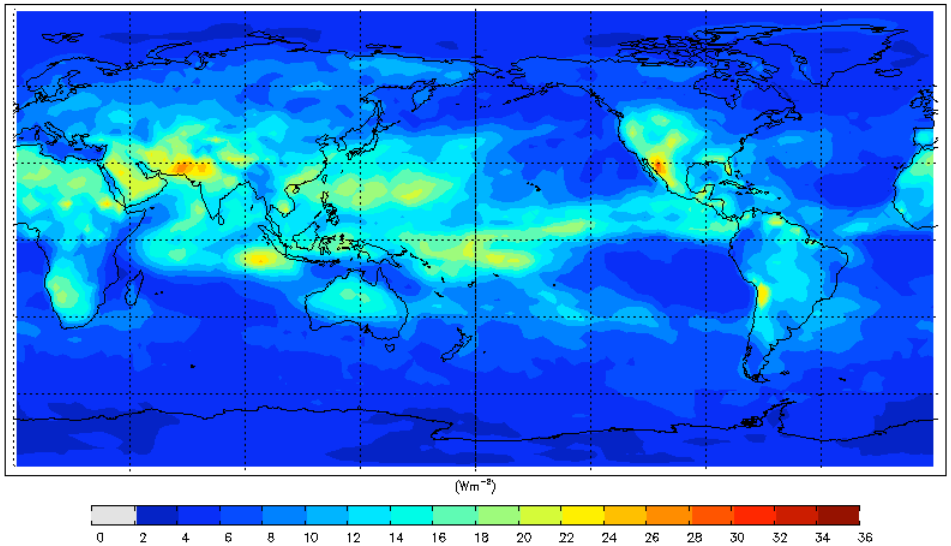


Phase of OLR Diurnal Cycle
January

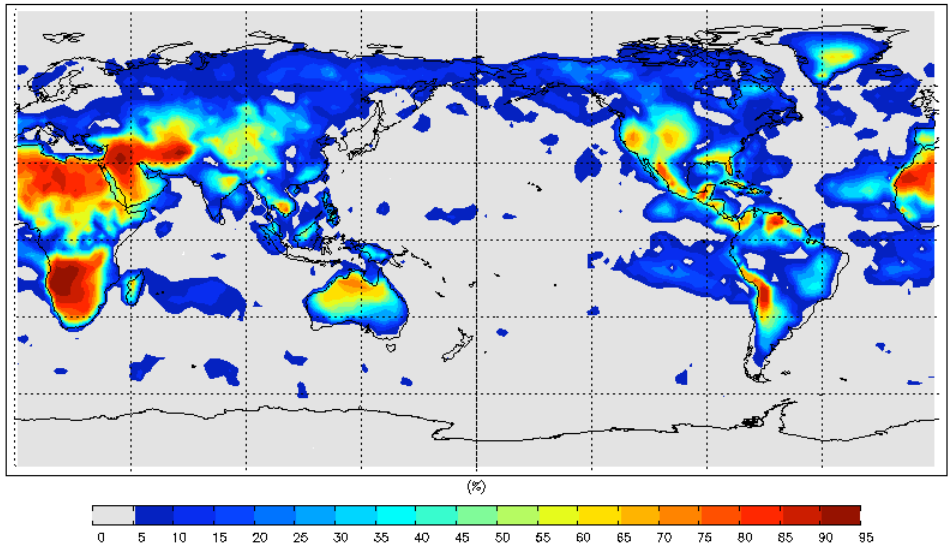


July

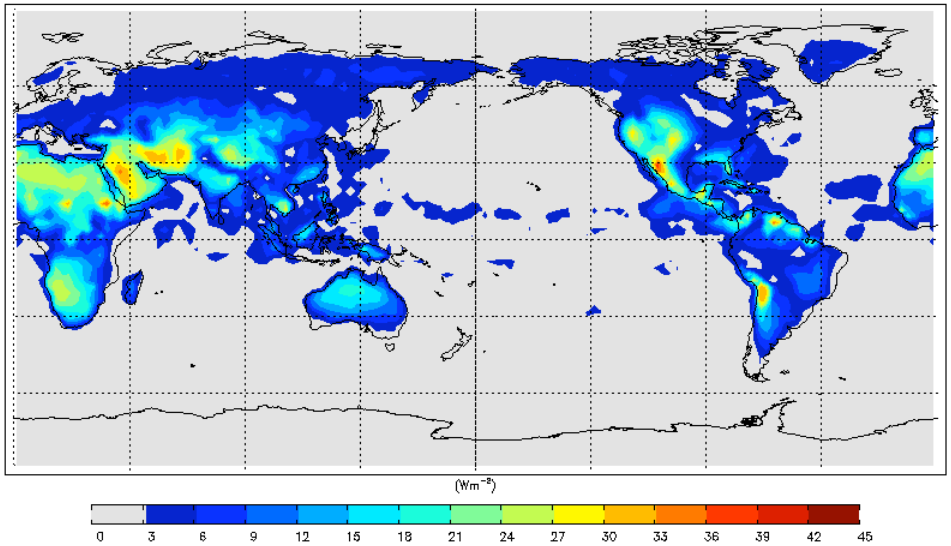
STD of OLR Diurnal Variation
July



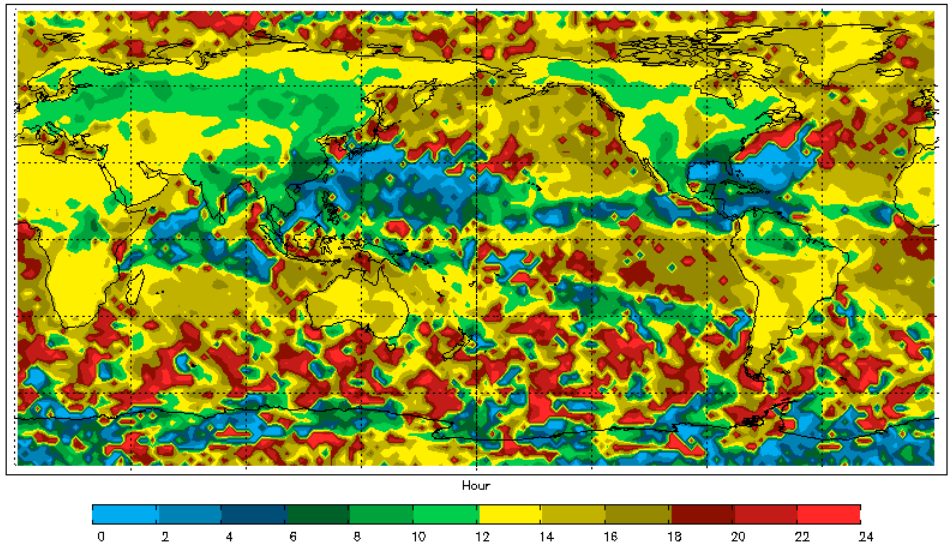
Explained Variance of OLR Diurnal Variation
July



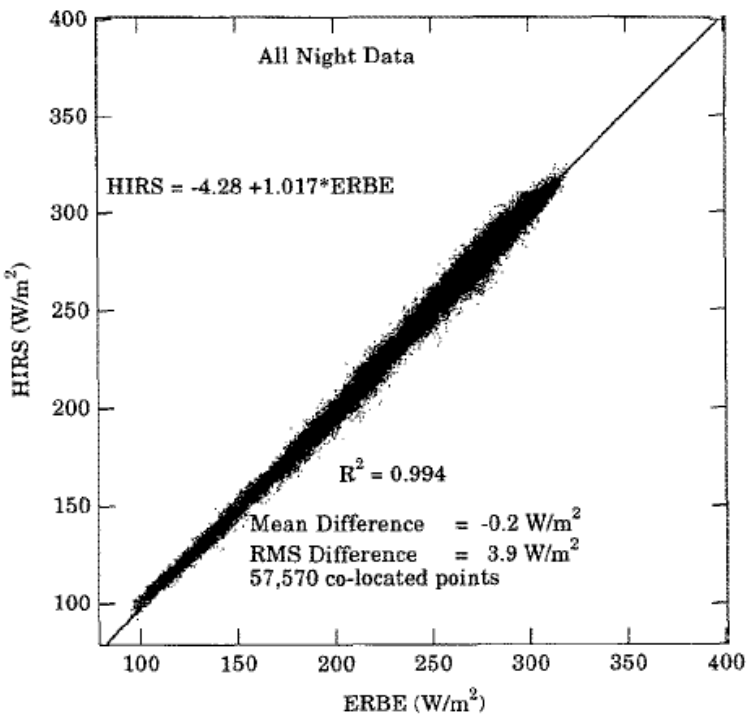
Amplitude of OLR Diurnal Model
July



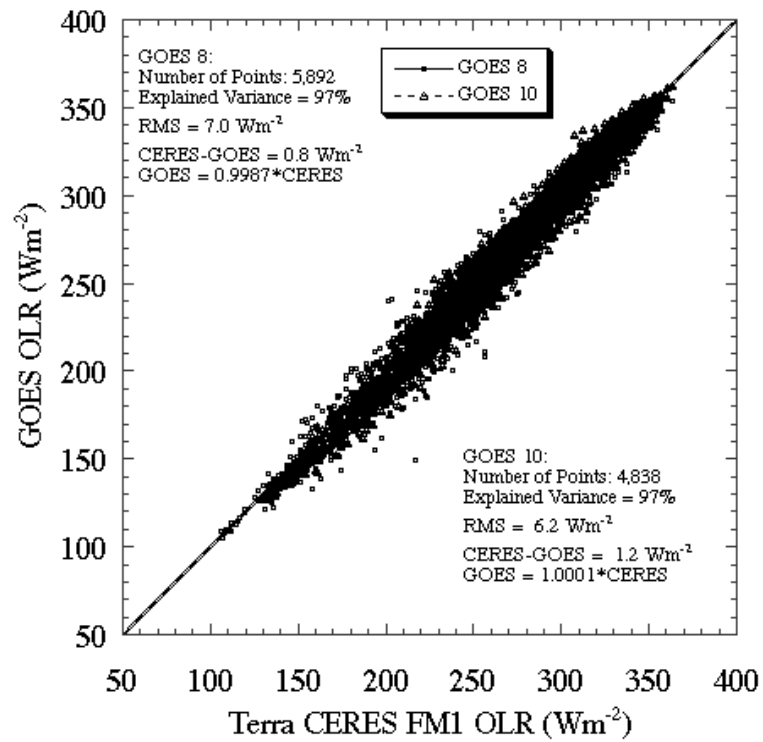
Phase of OLR Diurnal Cycle
July



Validation of Multi-spectral OLR Algorithms



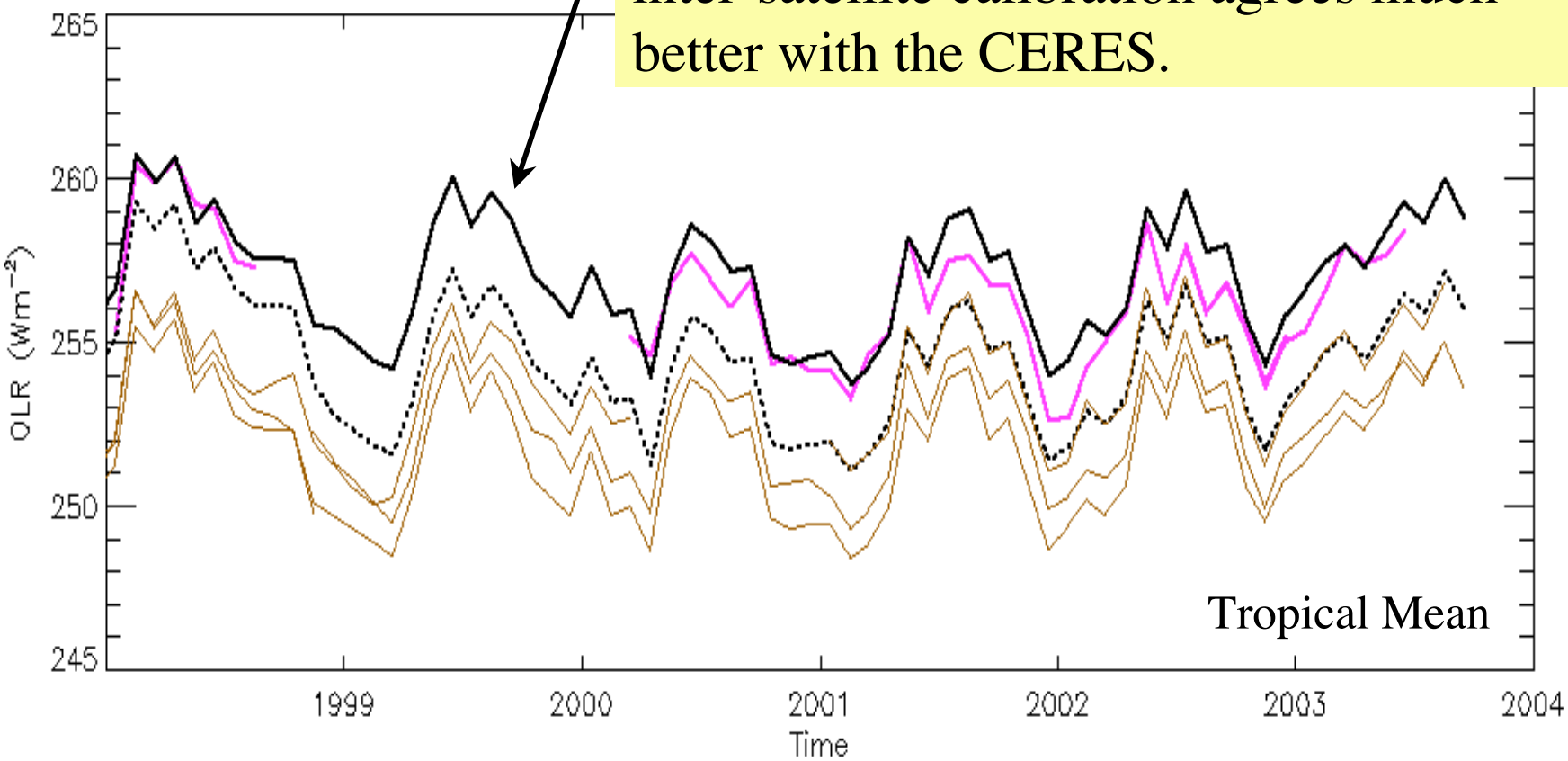
Ellingson *et al.*, 1994: Validation of a technique for estimating outgoing longwave radiation from HIRS radiance observations *J. Atmos. Ocean. Technol.*, **11,** 357-365.



Ba et al., 2003: Validation of a technique for estimating OLR with the GOES sounder. *J. Atmos. Ocean. Technol.*, **20,** 79–89.

Improvement by inter-satellite calibration

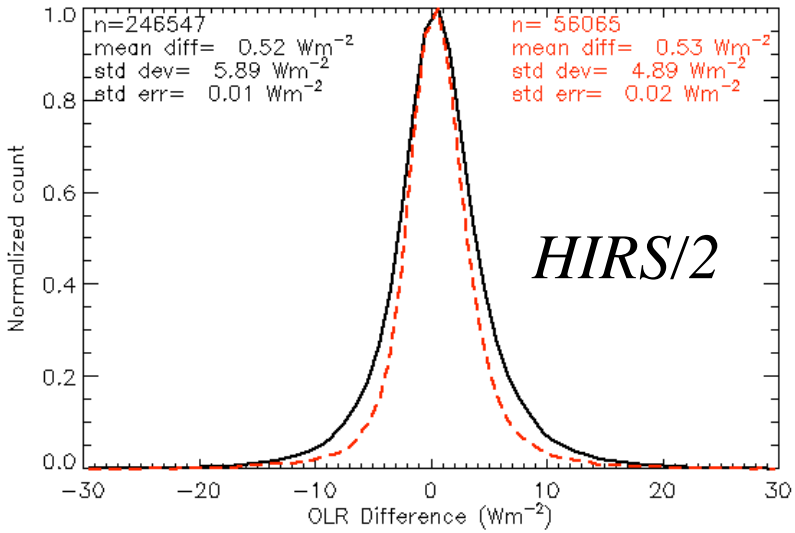
The blended HIRS monthly mean OLR data with the adjustments determined by inter-satellite calibration agrees much better with the CERES.



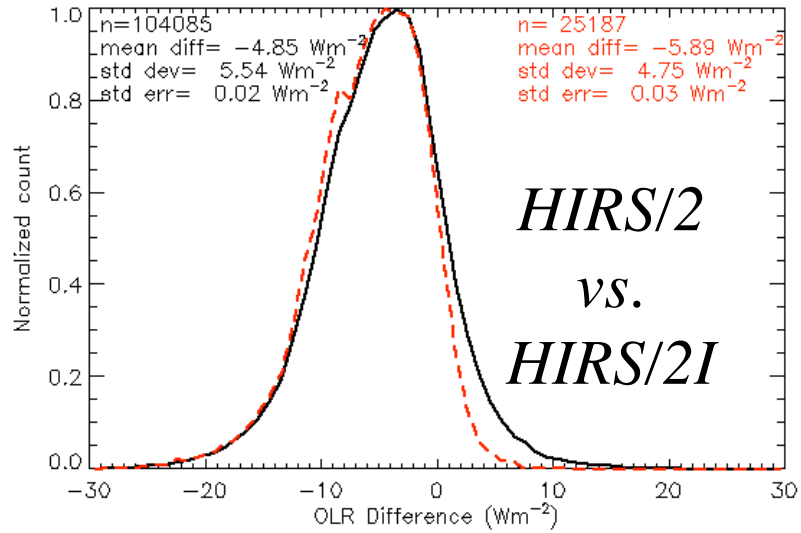
Magenta - CERES (TRMM, Terra, Aqua)
Black solid/dotted - HIRS, blended with calibration method 1/2
Brown - HIRS from individual satellites: NOAA11, 12, 14, 15, 16

Instrument Continuity & Algorithm Consistency

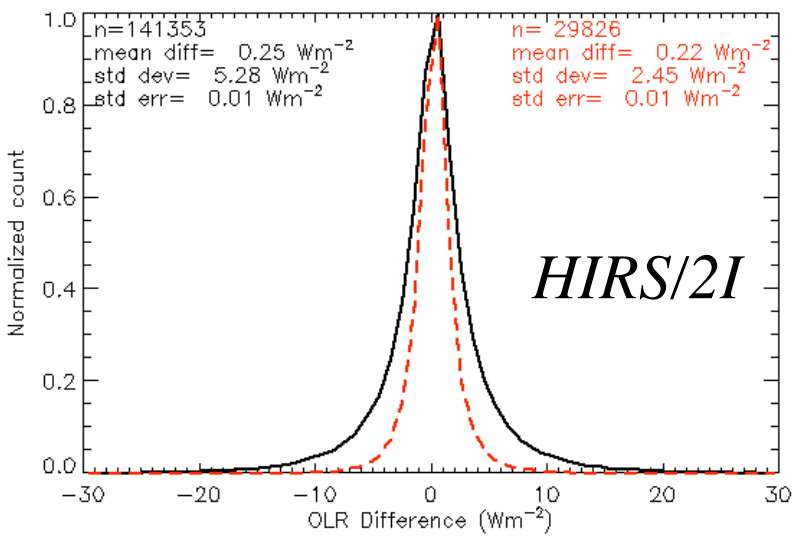
N10-N09



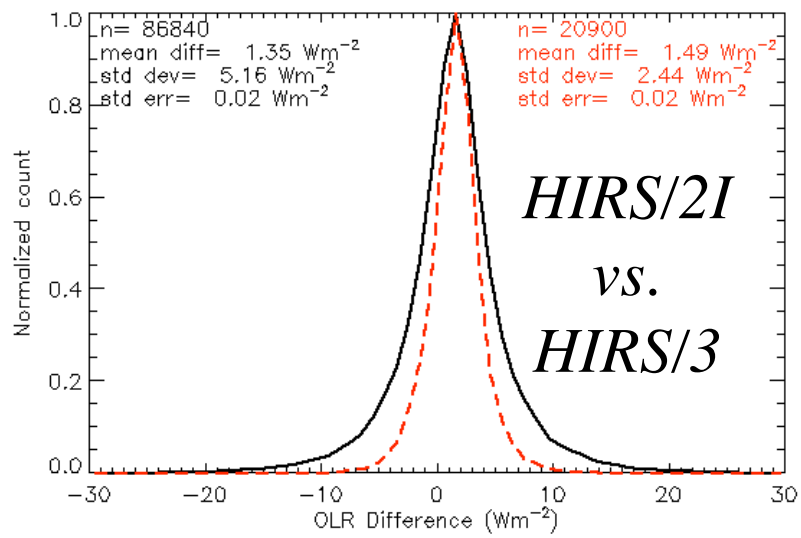
N11-N10



N14-N11



N15-N14



ERBE Scanner and HIRS

Puzzled Discontinuity