MODIS Science Team Meeting, Land Discipline
(Jan. 27, 2010)

Land Surface Radiation Budgets from Model Simulations and Remote Sensing

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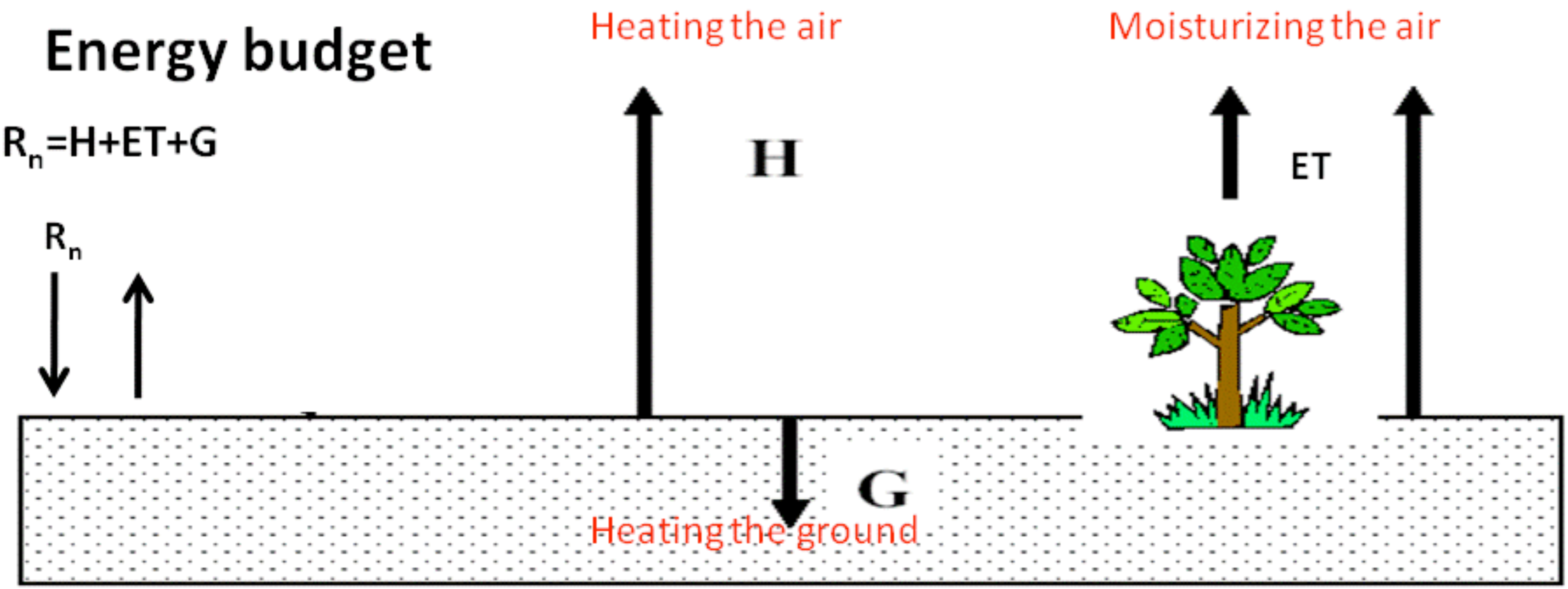


$$R_n = R_n^s + R_n^l = (1-\alpha)F_d^s + \varepsilon F_d^l - \sigma\varepsilon T^4$$

Net radiation

albedo

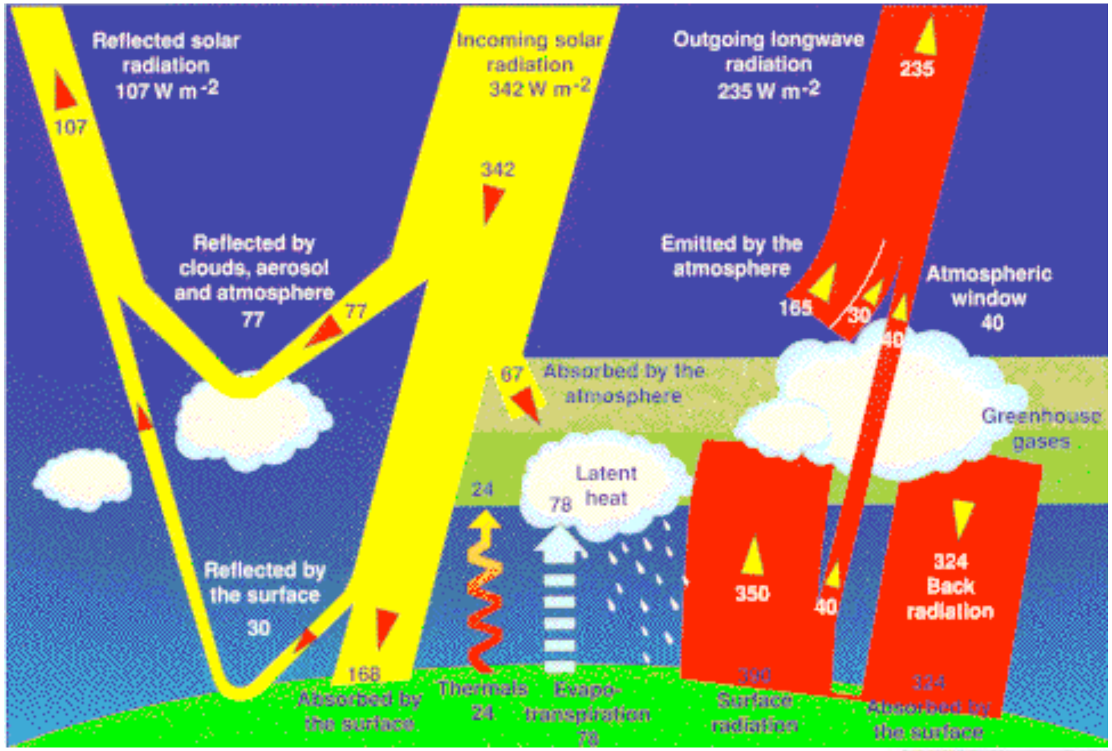
Insolation

Emissivity

Longwave downward radiation

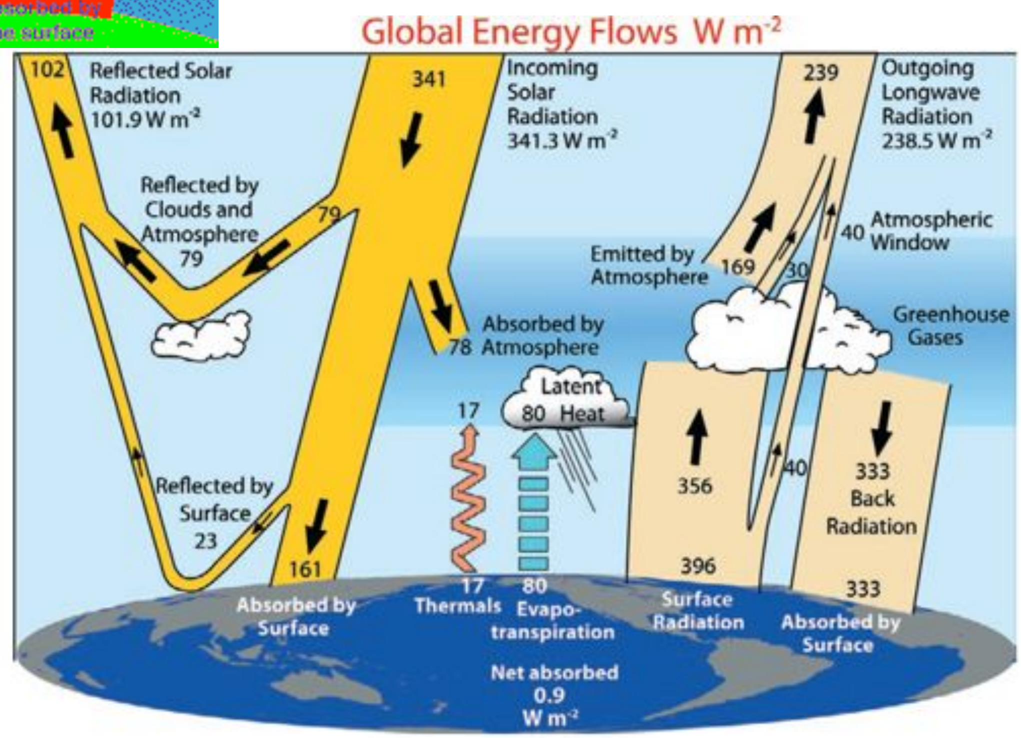
Skin temperature

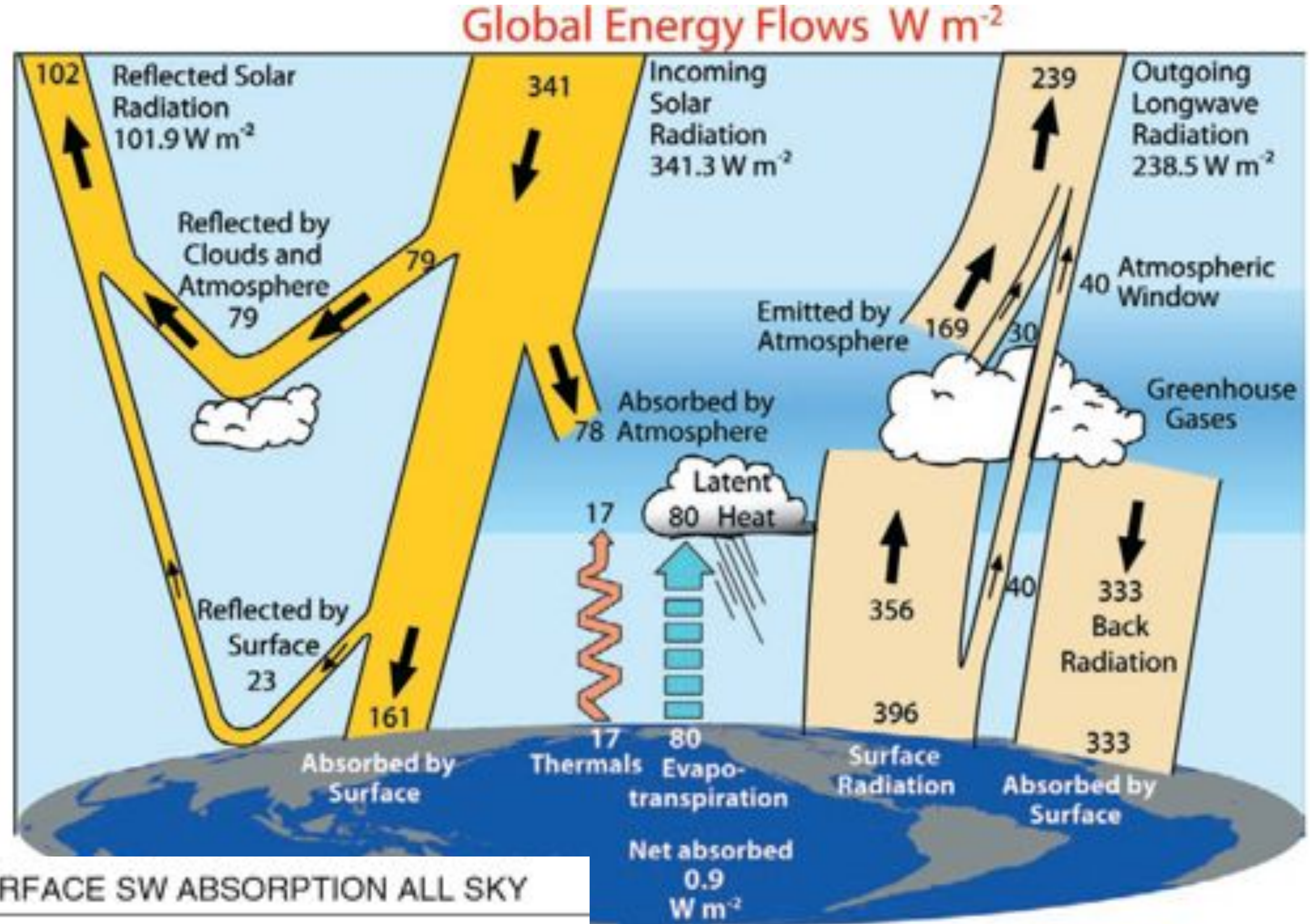
Radiation budget

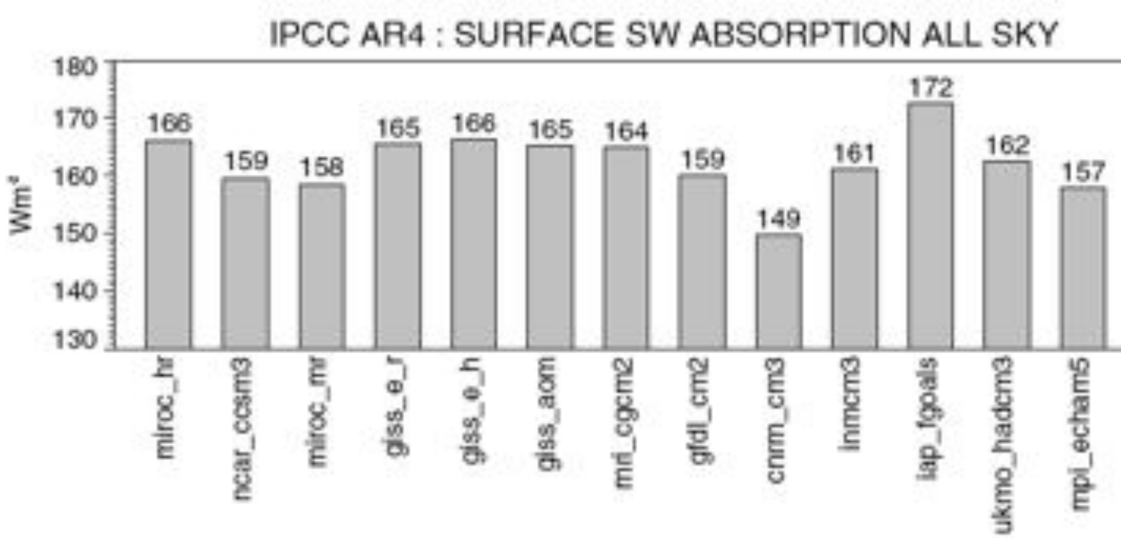


Kiehl and Trenberth (1997)

Trenberth et al. (2009)

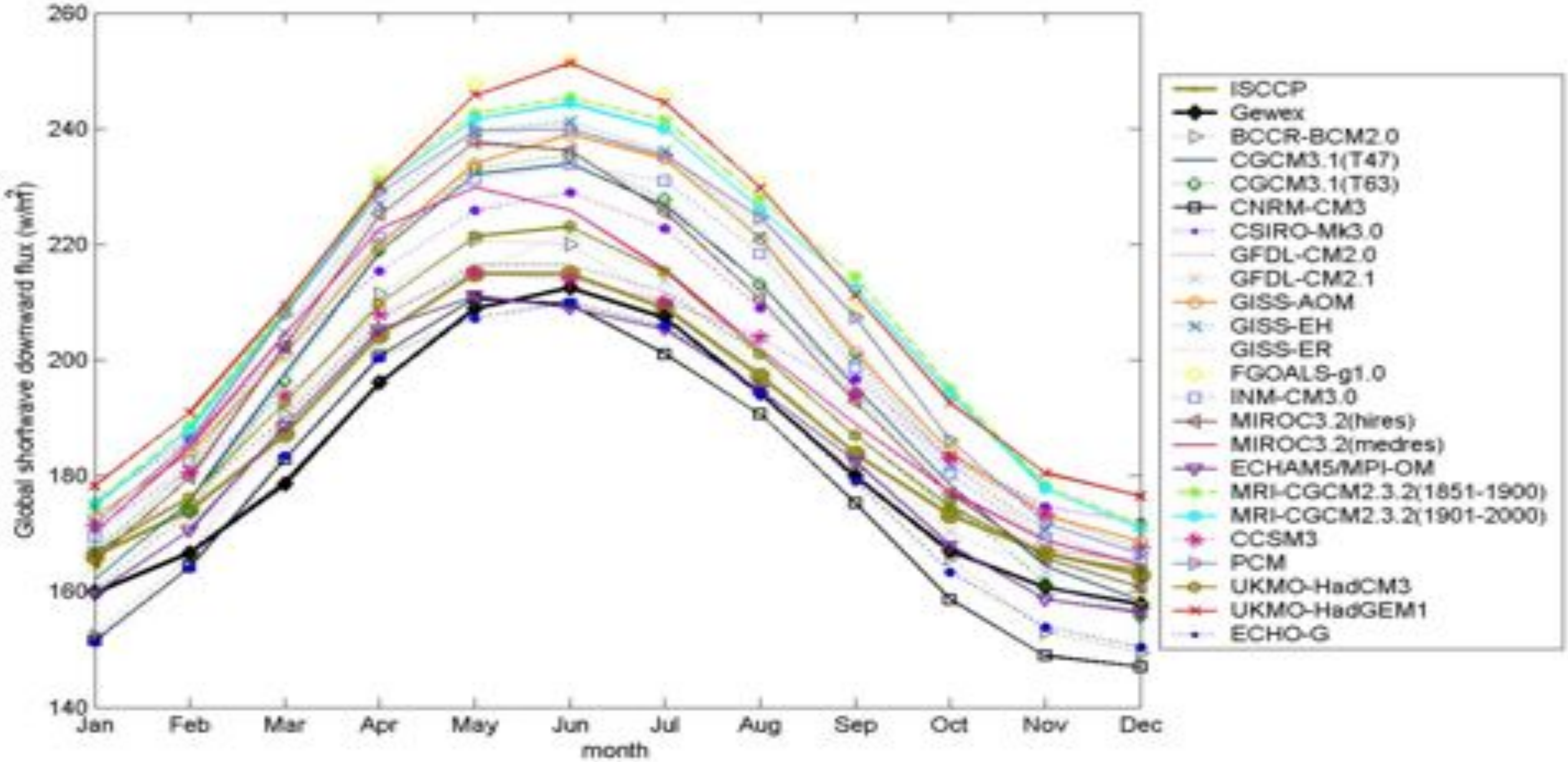






Radiation budgets in IPCC AR4 GCMs

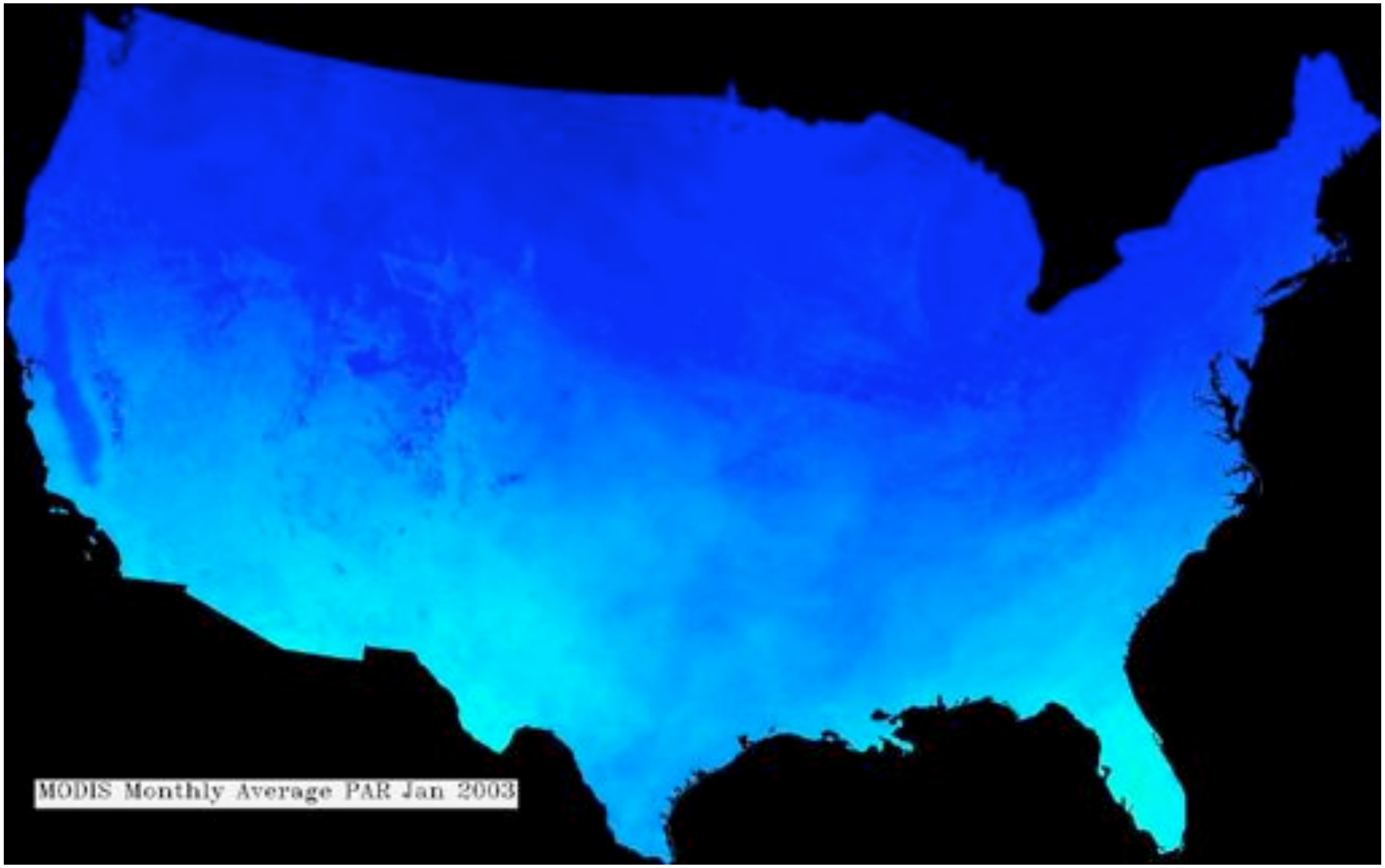
Wild 2005, Geophys. Res. Lett. 32
Wild 2008, Tellus



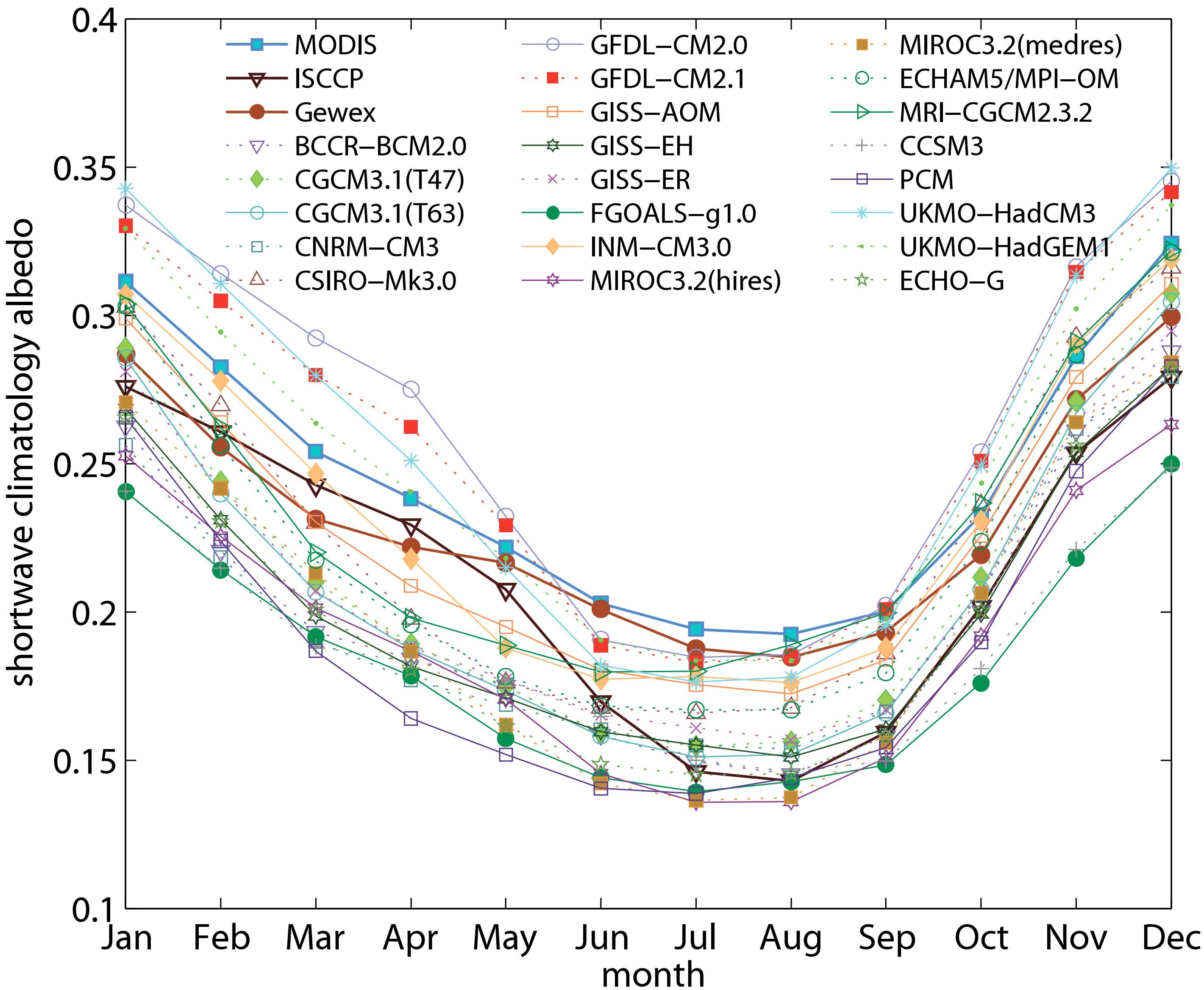
IPCC AR4 GCM model simulations and two satellite products

Table 1 Estimated averaged Insolation over land surfaces (Wm^{-2})

dataset	ISCCP-FD [125]	NRA [125]	ERA-40 [125]	JRA [125]	Trenberth et al. [125]	AMIPII GCMs mean [140]	GEBA mean [140]	IPCC AR4 GCM mean	GEWEX
Feb. 1985- April 1989	190.1	224.1	177.2	206.4		178	169	175	
Mar 2000 – May 2004	188.8	225.4	-	207.4	184.7				182.4



Liang, S., T. Zheng, R. Liu, H. Fang, S. C. Tsay, S. Running, (2006), Estimation of incident Photosynthetically Active Radiation from MODIS Data, *Journal of Geophysical Research – Atmosphere.* 111, D15208, doi:10.1029/2005JD006730.

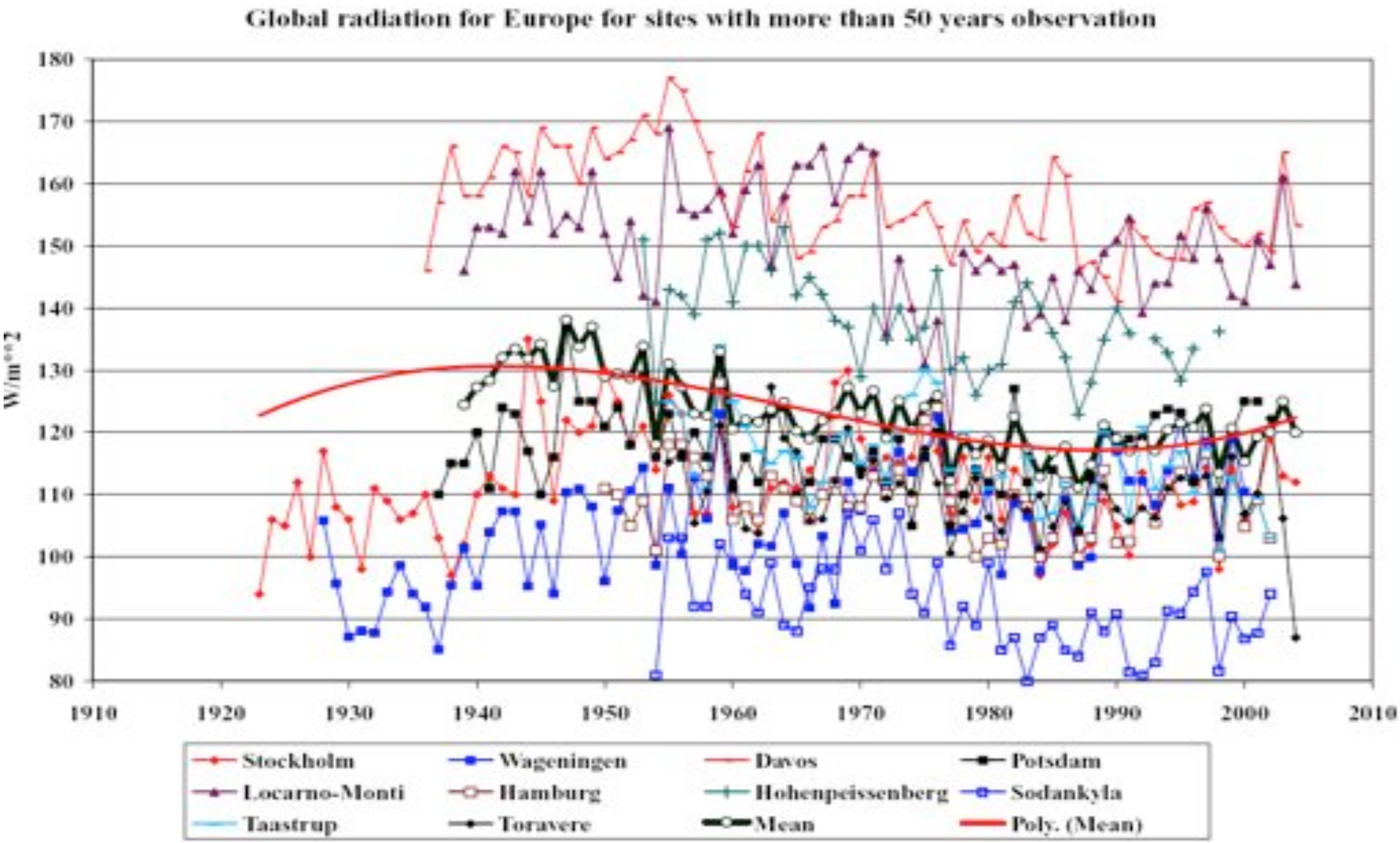


Model mean: 0.21

Standard dev.: 0.02

MODIS: 0.24

IPCC AR4 GCM model simulations and three satellite products

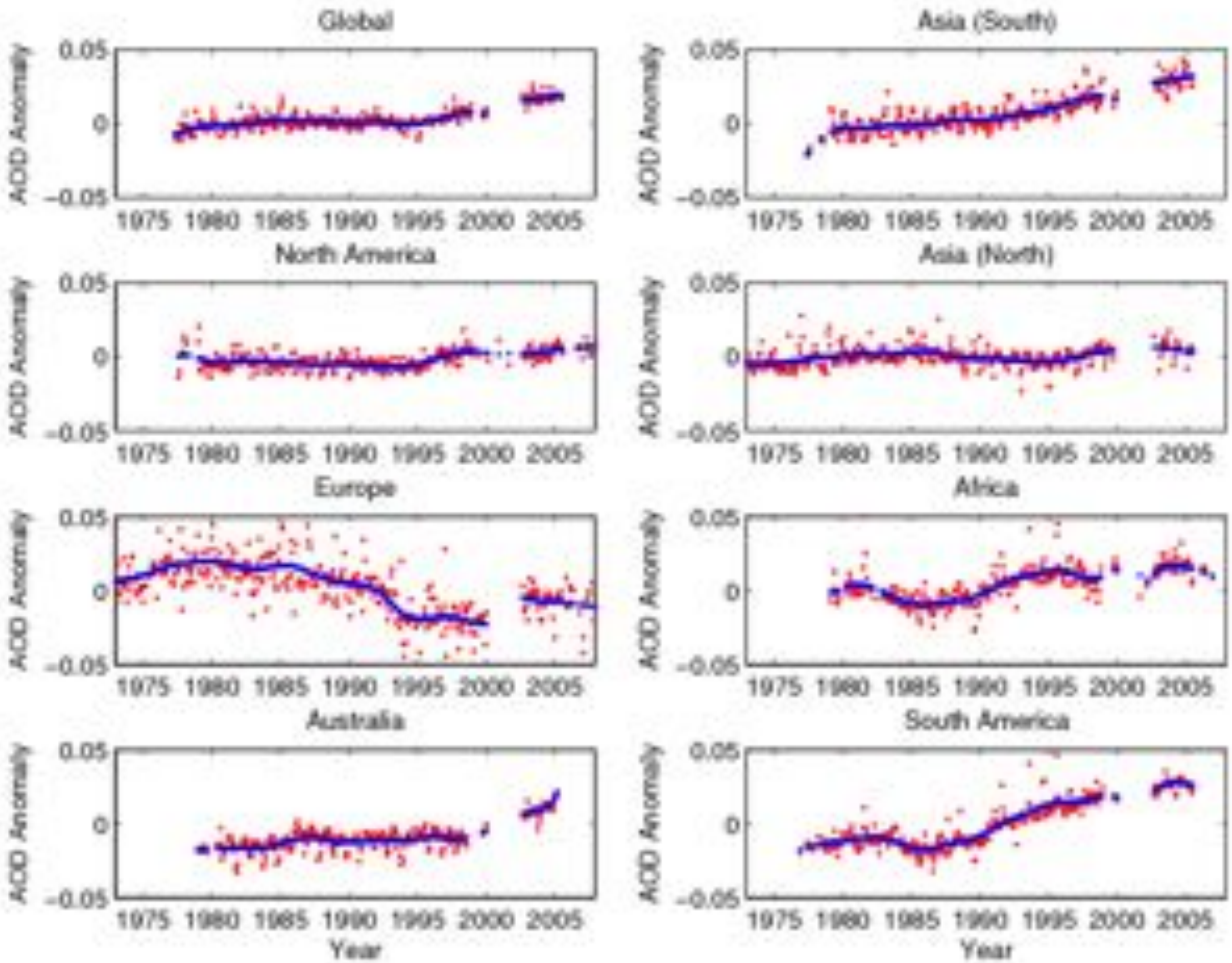


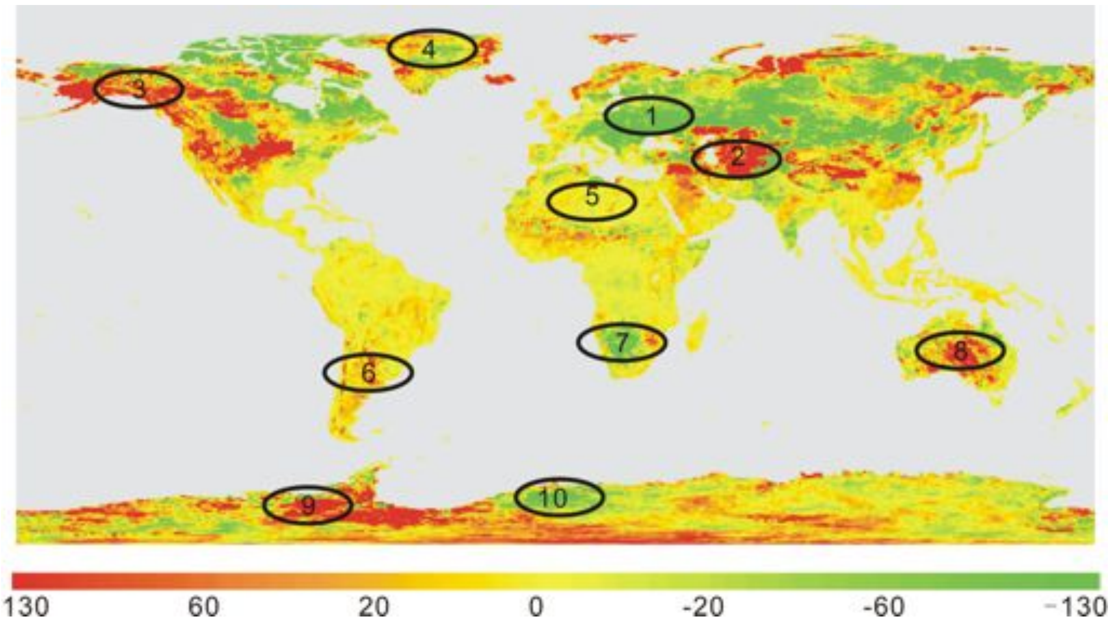
Ohmura (2006)

"**<u>global dimming</u>**" **:**Substantial decline in solar radiation the surface

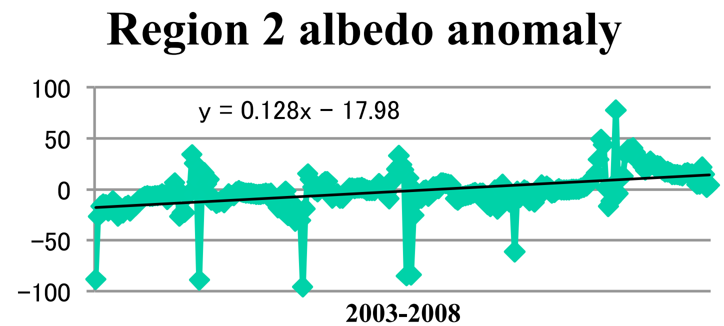
"**<u>global brightening</u>**"**:**Substantial increase in solar radiation the surface

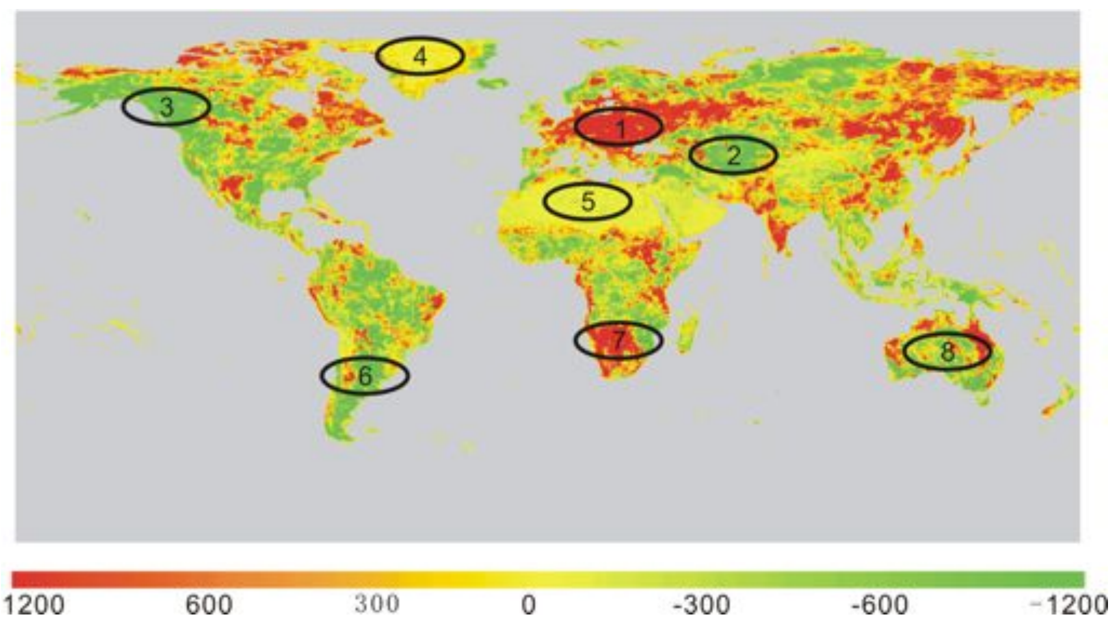
Wang, K., R. Dickinson and **S. Liang**, (2009), Clear sky visibility has decreased over land globally from 1973 to 2007,*Science*, 323, 1468-1470



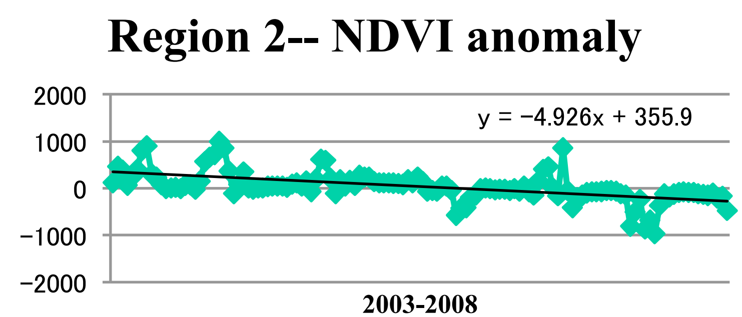


MODIS land surface albedo anomaly between 2003-2008 (%)





MODIS NDVI anomaly between 2003-2008 (X10000)



Longwave radiation budget

$RRRFFT_{nnndd}^{slsl} = = 2 + 2 \quad (1) \; \in J O J \qquad {}^{4}$

albedo

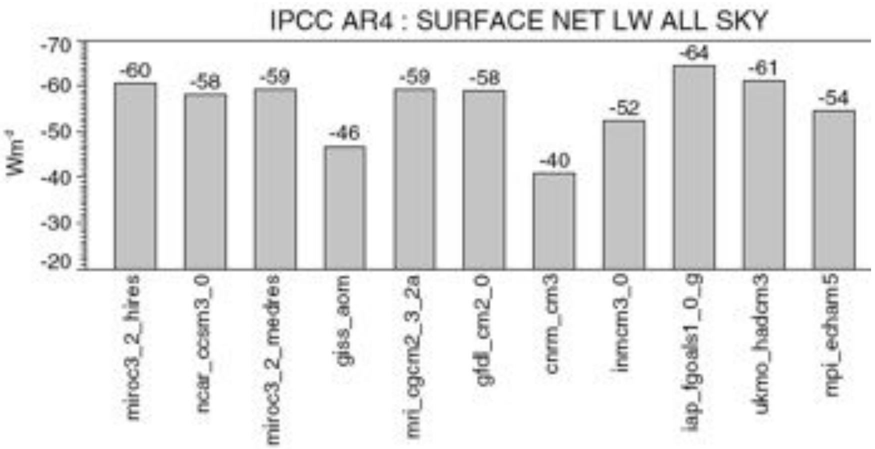
Insolation

Emissivity

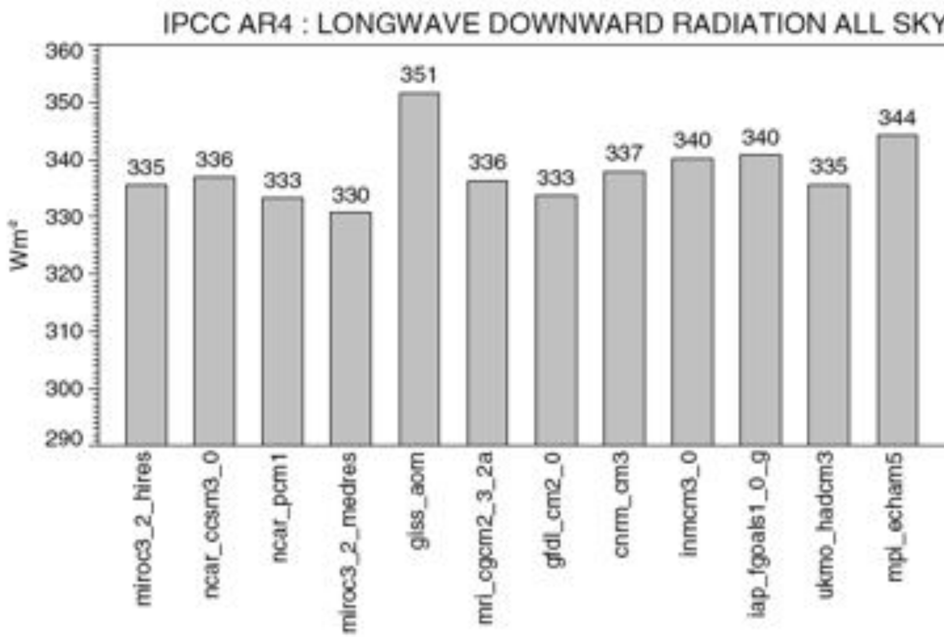
Longwave downward radiation

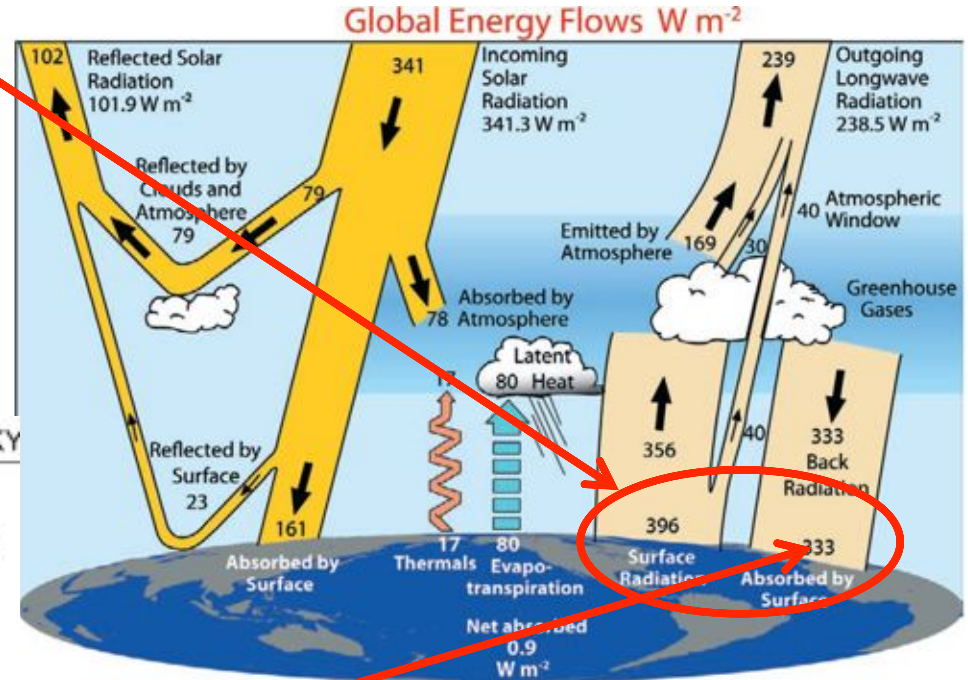
Skin temperature

Radiation budget



Radiation budgets in IPCC





Wild 2008, Tellus

Fig.1 Monthly averages of longwave downward radiation from two satellite products (ISCCP and GEWEX) and different GCMs in the IPCC AR4.

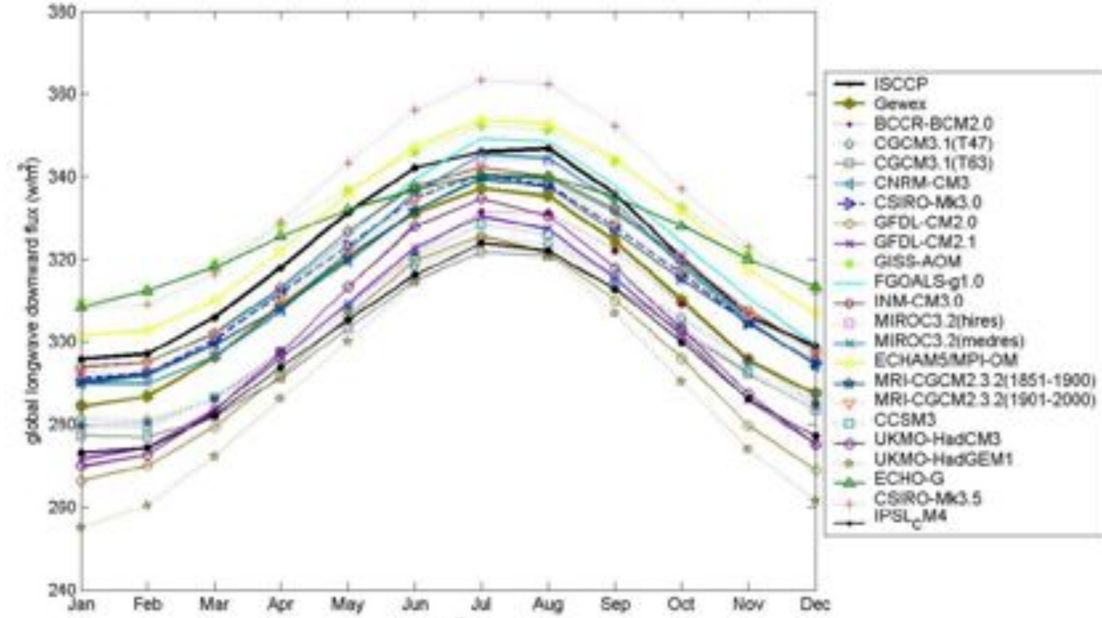
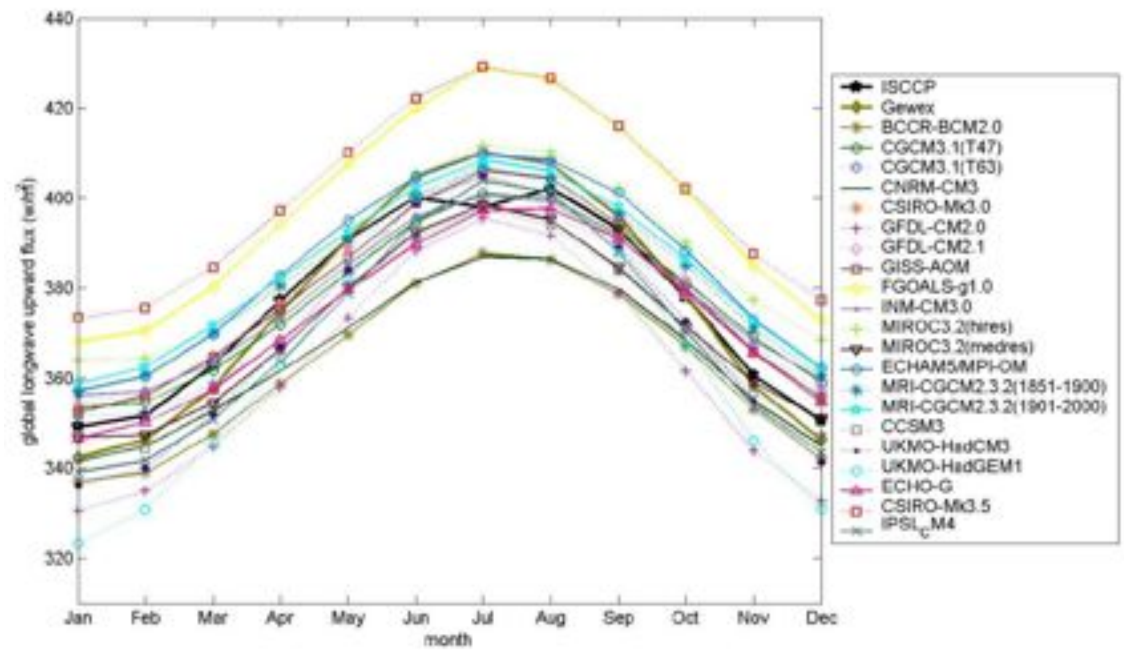
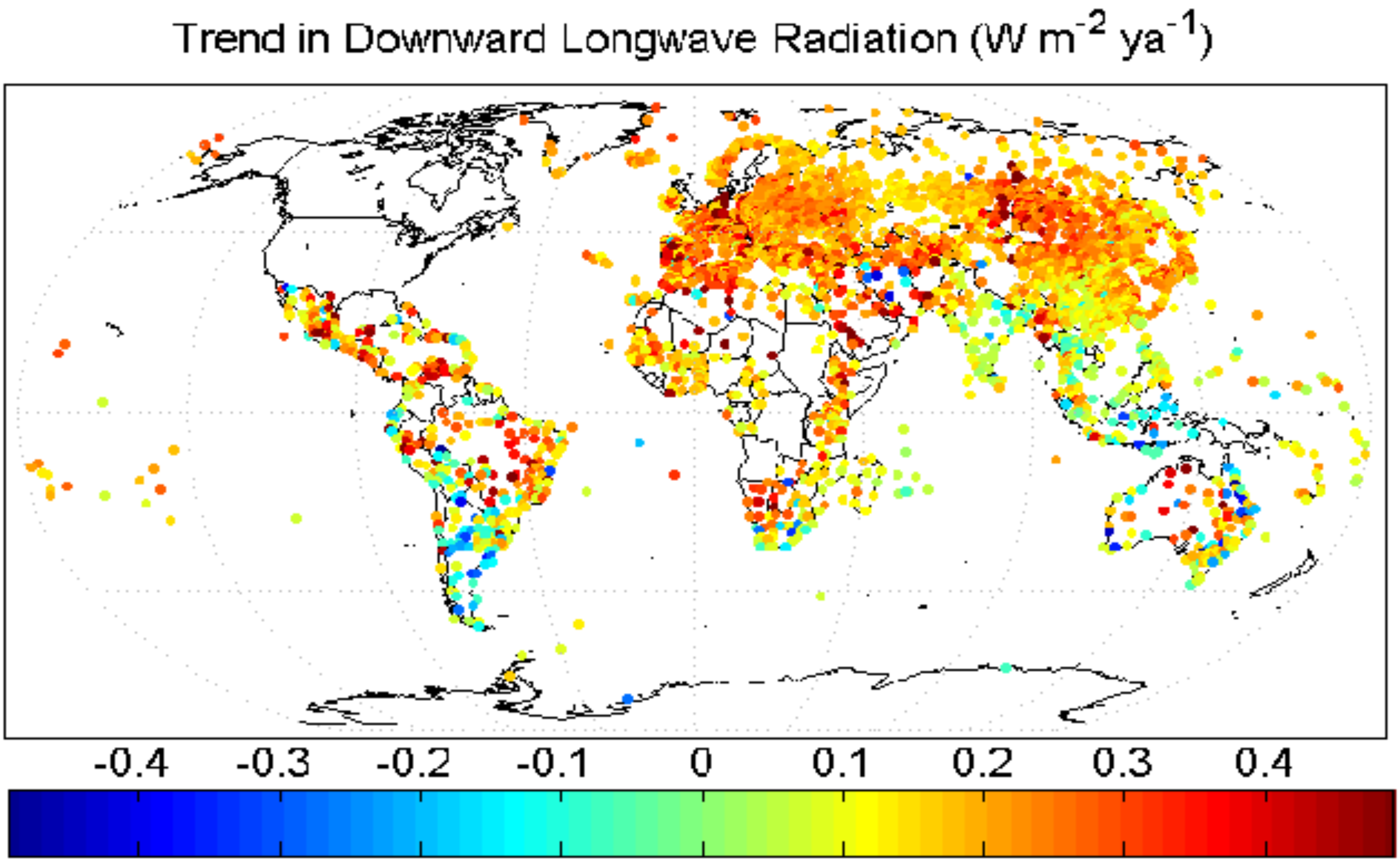


Fig.2 Monthly averages of longwave upwelling radiation from two satellite products (ISCCP and GEWEX) and different GCMs in the IPCC AR4.



Estimation of downward longwave radiation

1). Empirical methods
2). Calculating downward flux using atmospheric profiles
3). Calculating downward flux from TOA radiance directly



Linear trend of daily (L_d) over 3200 global weather stations where data are available for at least 300 months (25 years) during the period of 1973-2008.

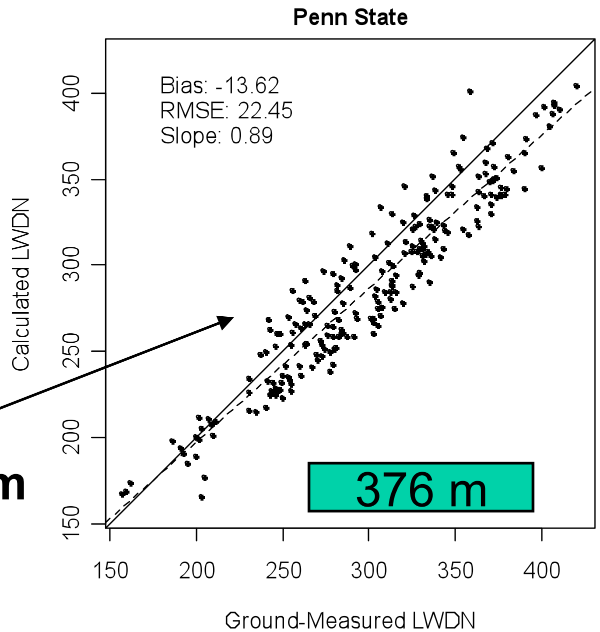
Wang, K., and **S. Liang**, (2009), Global atmospheric downward longwave radiation under all-sky conditions from 1973 to 2008, *Journal of Geophysical Research,* 114, D19101, doi:10.1029/2009JD011800

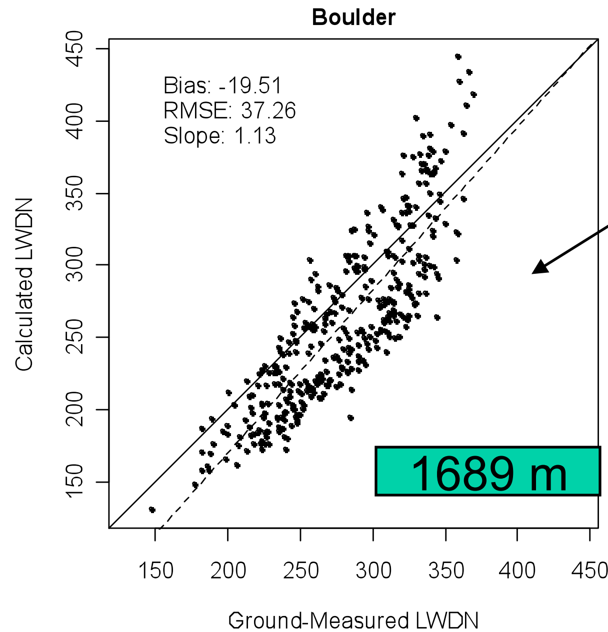
Estimating longwave downward radiation from MODIS

Physical Method

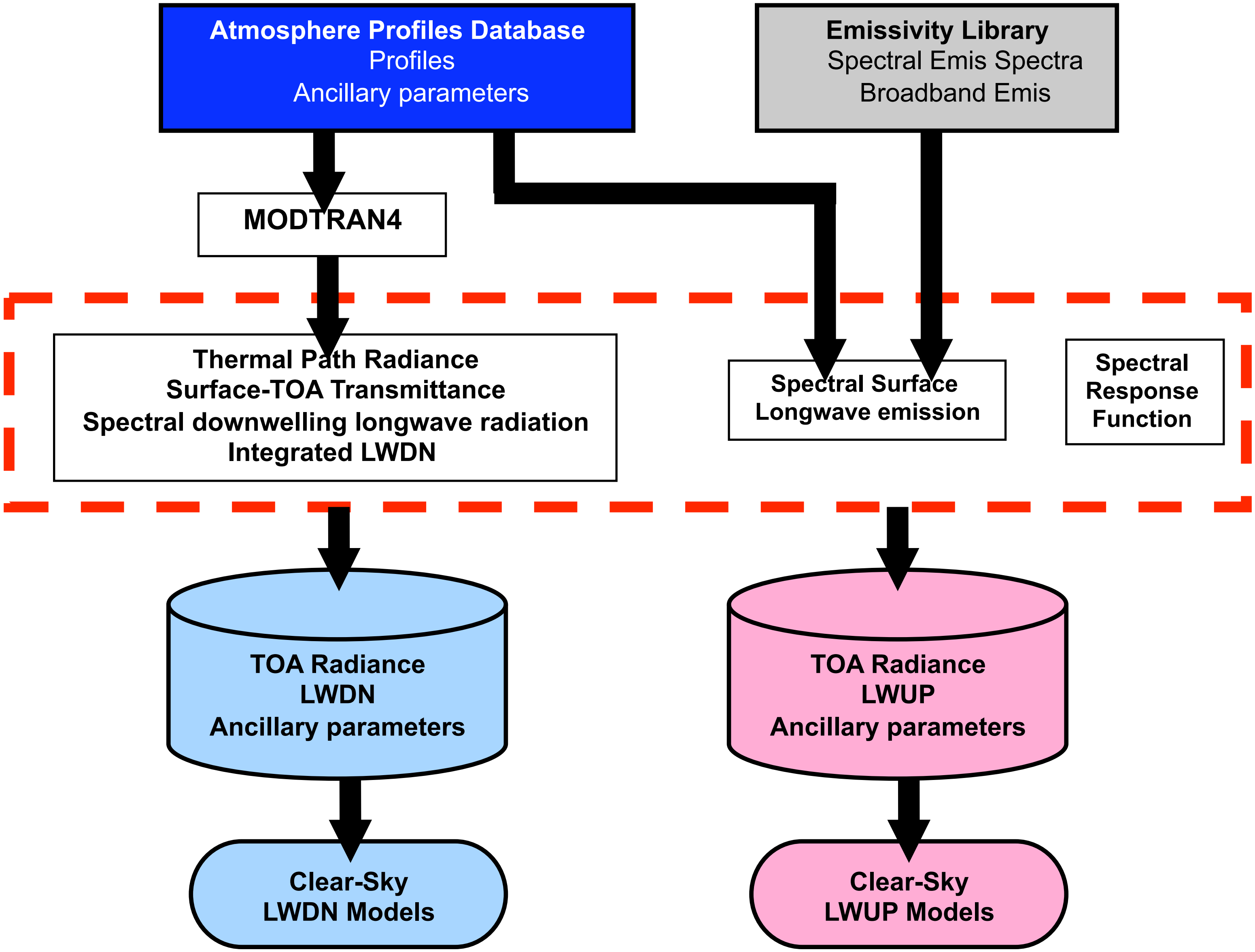
- ♣ Using MODIS Profiles & MODTRAN4
- ♣ Problems:
  - ✈ LWDN dominated by near surface temp. & moisture
  - ✈ MODIS profiles are coarse (20 levels)
    - 1000, 950, 920, 850, 800, 700, 620, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10, 5 hPa
  - ✈ Large errors, especially over high elevation sites

~4 layers below 500 m



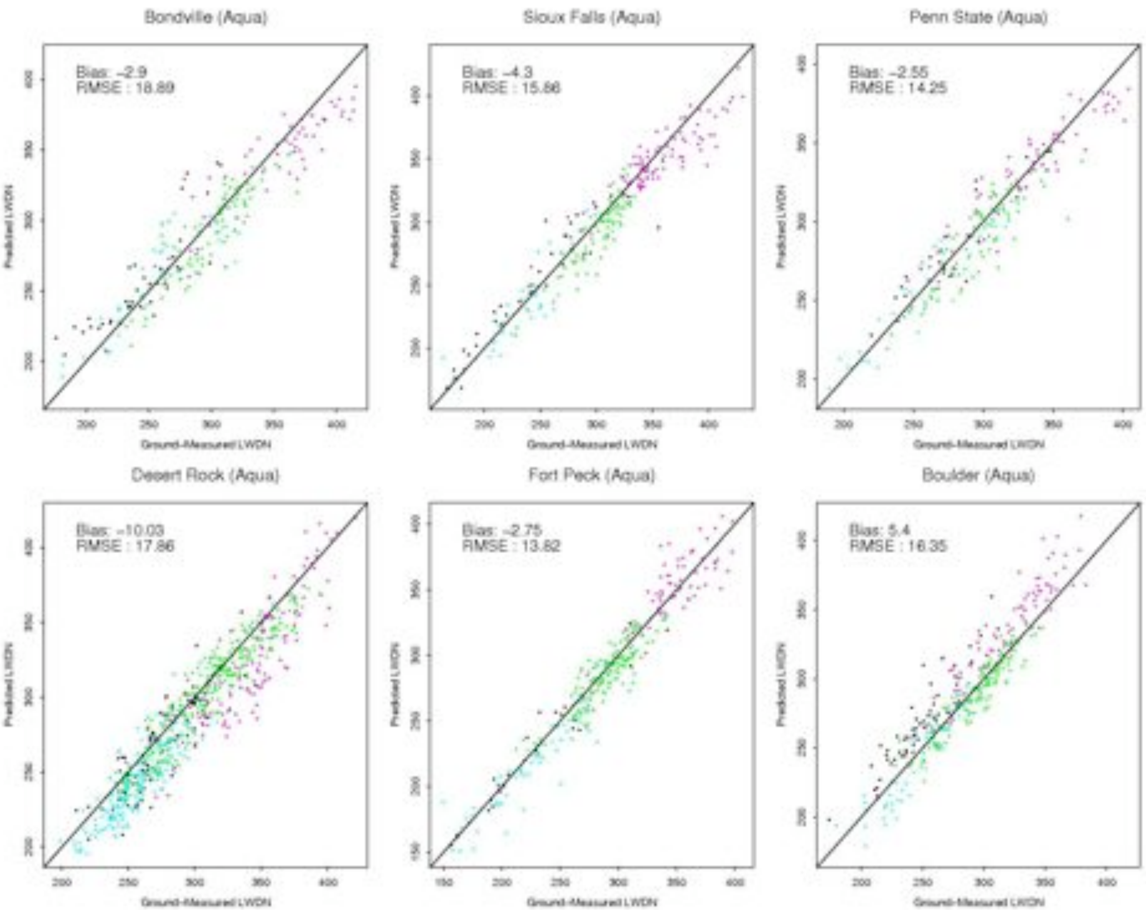


~3 layers below 500 m



Framework of Hybrid Methods

Validation



- ♣ Results similar to Terra
- ♣ Smaller RMSEs in Aqua-derived
  - ✈ Smaller systematic errors in Aqua *(Liu et. Al, 2006)*
  - ✈ *Diff. overpass times → diff. atmospheric conditions*

Avg. RMSE: 17.60 W/m2
Avg. Bias: -0.40 W/m2

Wang, W. & **S. Liang,** (2009), Estimating High-Spatial Resolution Clear-Sky Land Surface Downwelling and Net Longwave Radiation from MODIS Data, *Remote Sensing of Environment,* 113:745-754

day/fallwinter
night/fallwinter
day/springsummer
night/springsummer

Estimating longwave upwelling radiation (LWUP)

(1)Temperature-Emissivity Method

$$F_u = \varepsilon \int_{\lambda_1}^{\lambda_2} \pi B(T_s) d\lambda + (1-\varepsilon) F_d$$

T_s MODIS LST (MOD11_L2)

ε Broadband emis (derived from MOD11B1)

(2) Hybrid Method

- Following the framework for hybrid methods
  - Emissivity Effect
    - UCSB Emissivity Library (59 spectra)
    - ~2000 MODIS Profile
- Statistical Analysis
  - Linear SULR Models (R^2: 0.990, RMSE< 5.42 W/m^2)

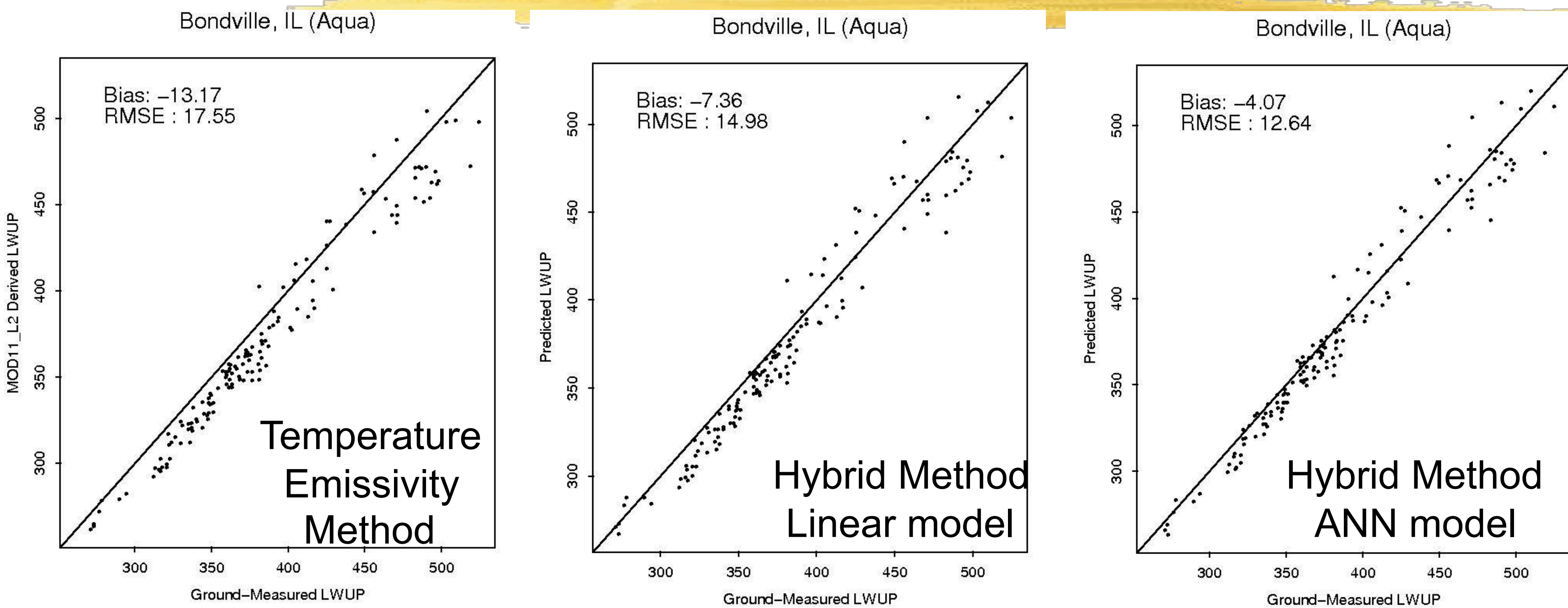
$$F_u = a_0 + a_1 L_{29} + a_2 L_{31} + a_3 L_{32}$$

  - Artificial Neural Network (ANN) Models (R^2: 0.996 RMSEs<3.7 W/m^2)

5 Models in total

θ	Model
0º	
15º	
30º	
45º	
60º	

Estimating LWUP: validation



Bondville, IL (cropland, elevation 213 m)

•Smaller RMSEs in Aqua

•Hybrid method outperforms temperature-emissivity method

• ANN model outperforms linear model

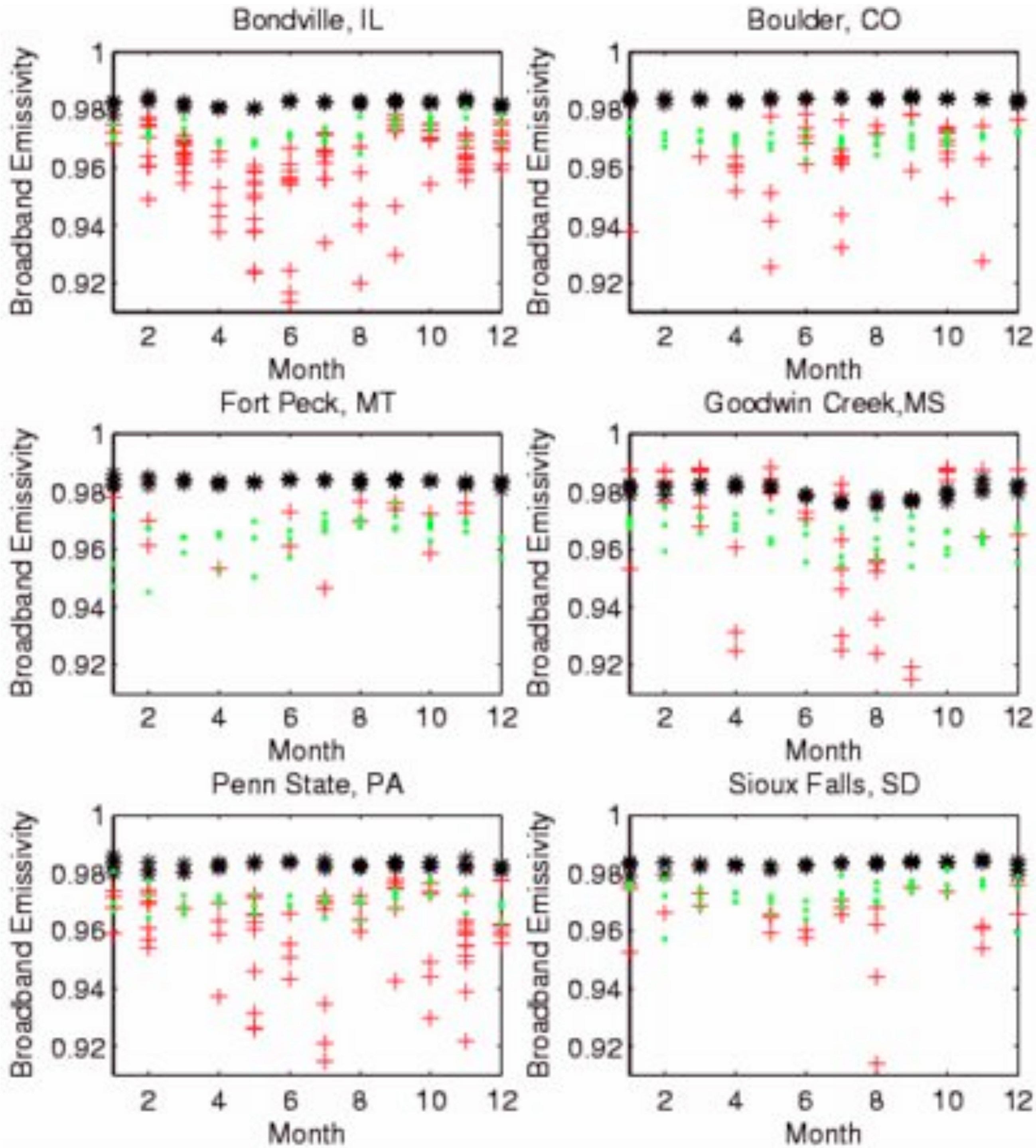
Wang, W., **S. Liang** & J. A. Augustine, *(2009),* Estimating Clear-Sky Land Surface Upwelling Longwave Radiation from MODIS Data. *IEEE Trans. Geosci. and Remote Sens.* 47(5):1555-1575

MODIS LST validation

Summary of validation results

Site	MOD11_L2 (°C)		MOD07_L2 (°C)	
	Bias (MOD-GT)	RMSE	Bias (MOD-GT)	RMSE
Brookings	0.62	1.63	1.30	1.97
Audubon	0.72	1.31	2.98	3.74
Canaan Valley	0.04	1.42	1.20	2.08
Black Hills	0.15	1.48	3.14	4.10
Fort Peck	−2.19	2.51	0.34	2.70
Hainich	−2.21	2.51	−2.12	2.58
Tharandt	−3.23	3.44	−3.38	3.73
Bondville	−3.09	3.41	−0.16	2.50

Wang, W., **S. Liang,** , and T. Meyer, (2008), Validating MODIS land surface temperature products, *Remote Sensing of Environment,*112:623-635



Broadband emissivity calculated from MODIS Collection 4 (green dot) and Collection 5 (black star) monthly emissivity products and ASTER daily emissivity products (red plus sign) at a resolution of 0.05° at six SURFRAD sites.

Wang, K., and **S. Liang**, (2009), Evaluation of ASTER and MODIS land surface temperature and emissivity products using surface longwave radiation observations at SURFRAD sites, *Remote Sensing of Environment*, 113:745-754

Summary

- ♣ human activities have greatly impacted land surface radiation budgets
- ♣ There is still a tremendous amount of variations in model simulations
- ♣ High-resolution satellite remote sensing can help determine land surface radiation budget more accurately

Thank you !