Validation of CERES Edition 4 Angular Distribution Models

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Ed4ADM delivered

- Ed4ADM was delivered in November 2013
- Data management team and data center have finished testing of the inversion code
- Production of Ed4SSF is scheduled to begin on May 2, 2014
- ADM methodology paper is almost done
- Validation of the CERES instantaneous fluxes
  - Direction integration
  - CERES-MODIS flux consistency test
  - CERES-MISR flux consistency test
  - CERES-C3M scene identification

Direct integration for SW flux

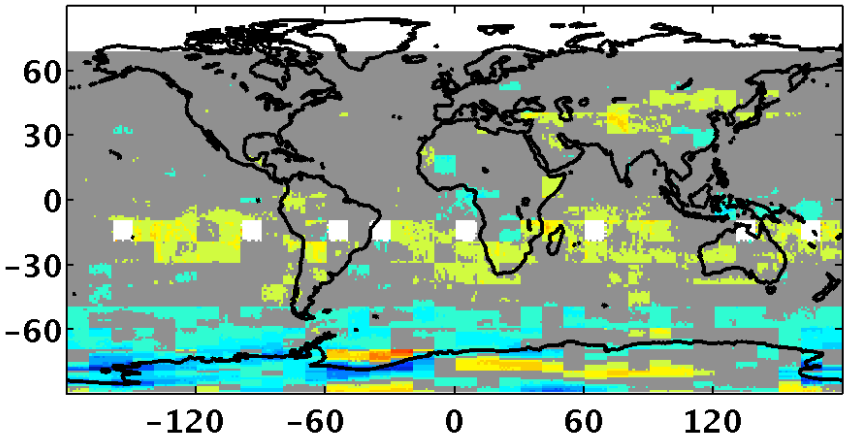
- Construct two sets of regional (10° X 10°) all-sky ADMs by season (e.g. DJF, MAM, JJA, and SON) from
  - CERES measured radiances $I_o \rightarrow F(\theta_0) = \dfrac{\pi I_o(\theta_0, \theta, \phi)}{R(\theta_0, \theta, \phi)}$
  - ADM predicted radiances $\hat{I} \rightarrow R(\theta_0, \theta, \phi) = \dfrac{\pi \hat{I}(\theta_0, \theta, \phi)}{\hat{F}(\theta_0)}$
- Both sets of regional all-sky ADMs have the same sampling
- Apply regional ADMs to crosstrack data of the middle month of the season to determine the fluxes
- Compare fluxes derived from these two sets of ADMs

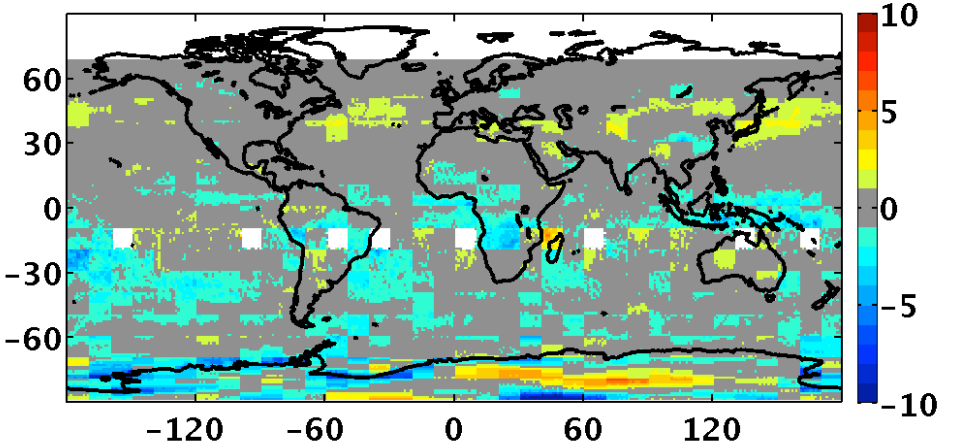
Direct integration SW flux error for 2002 Terra FM1 (flux from predicted radiance ADM – flux from observed radiance ADM)

Direct integration using Ed4ADM

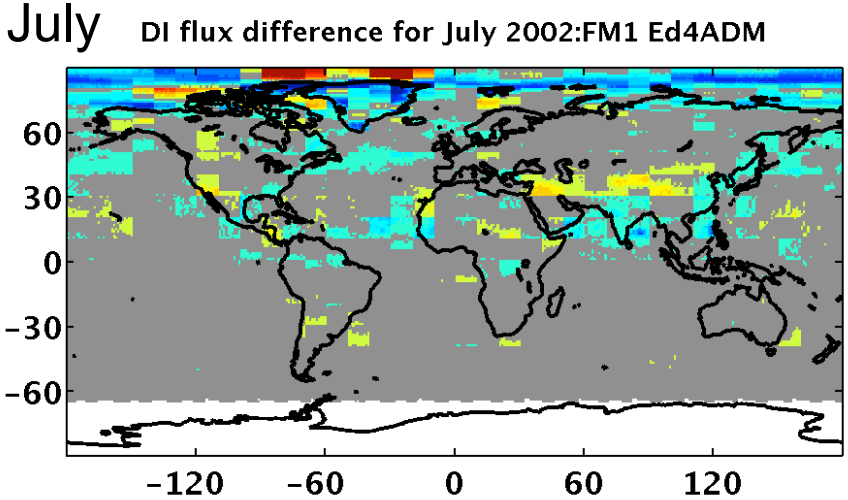
Direct integration using Ed2ADM

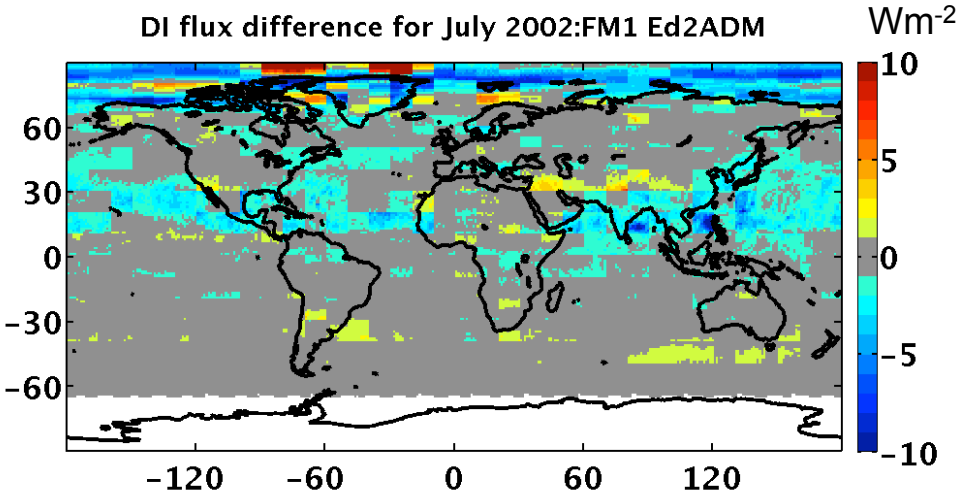
Jan



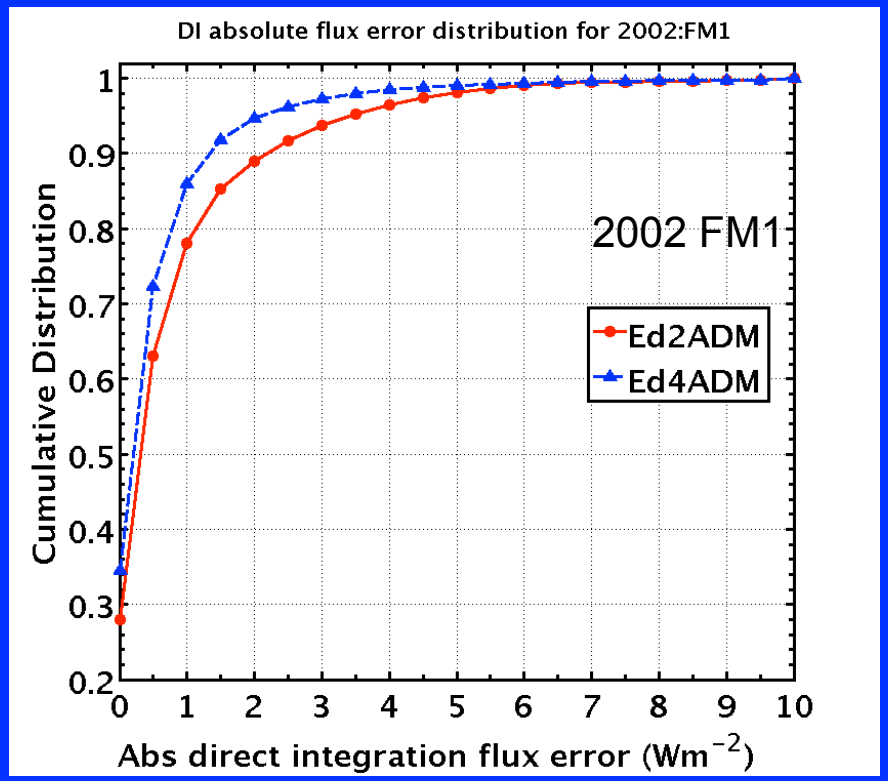


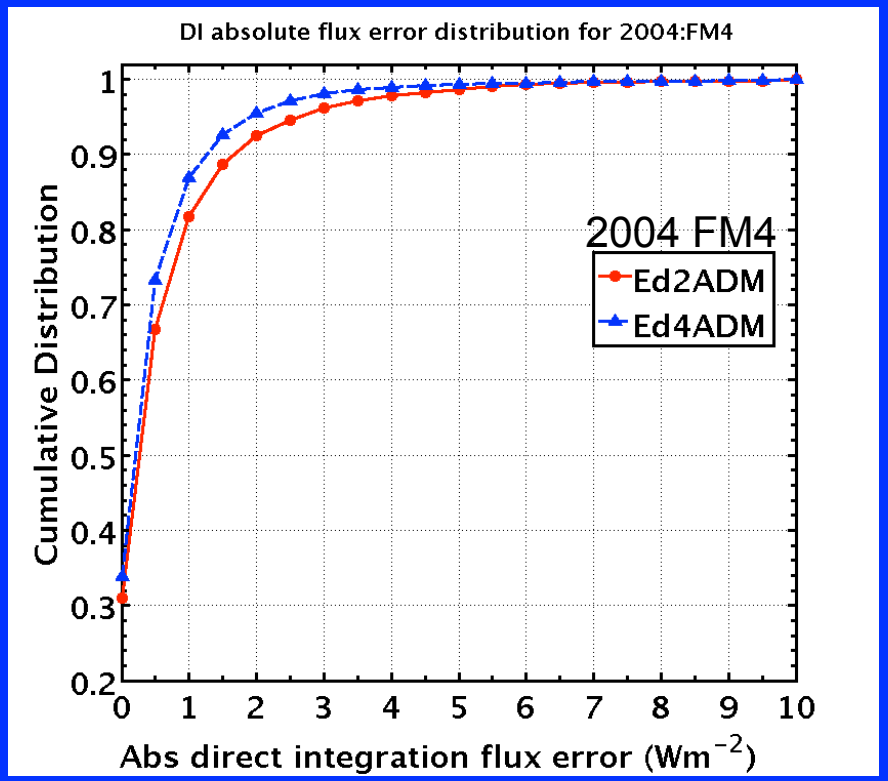
July





SW flux error is less than 2 Wm^{-2} for 95% of the 1° x 1° region

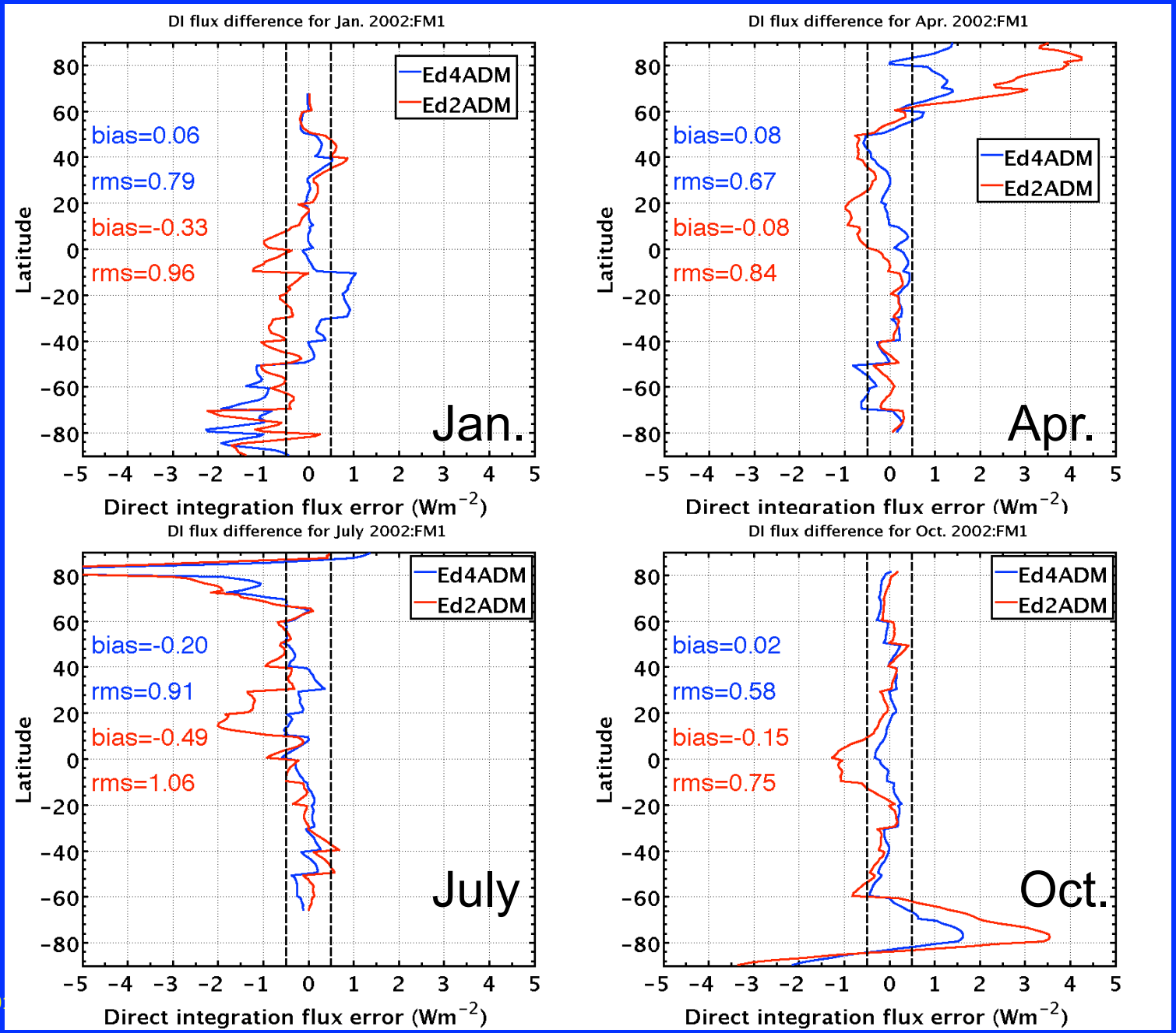




Abs. flux error (Wm-2)	Ed4ADM (%)	Ed2ADM (%)
<1	86.0	78.1
<2	94.7	89.0
<5	99.0	98.1
<8	99.7	99.6

Abs. flux error (Wm-2)	Ed4ADM (%)	Ed2ADM (%)
<1	86.9	81.7
<2	95.6	92.5
<5	99.3	98.7
<8	99.8	99.7

Zonal mean SW flux error for 2002 Terra FM1



Direct integration for LW flux

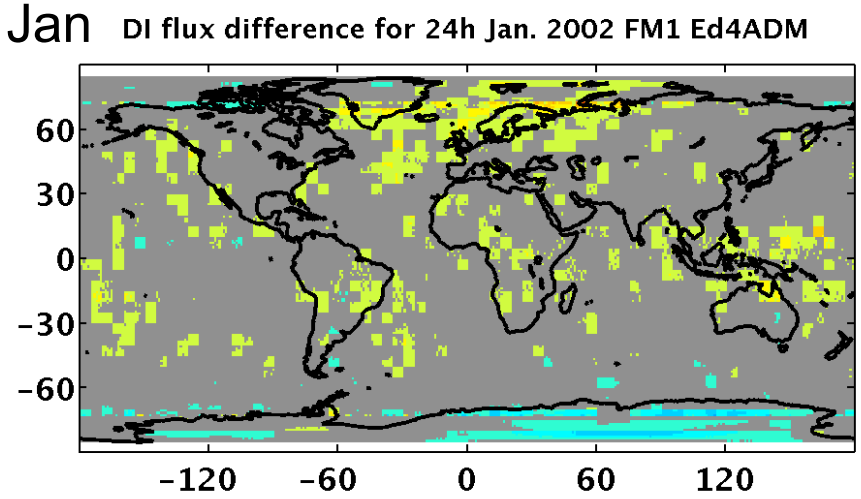
- LW flux is a weak function of solar zenith angle
- Use standard direct integration for LW flux
- Done separately for daytime and nighttime observations
- Weight the daytime and nighttime flux error by fraction of daylight at each latitude for each month to derive the 24h-averaged flux error

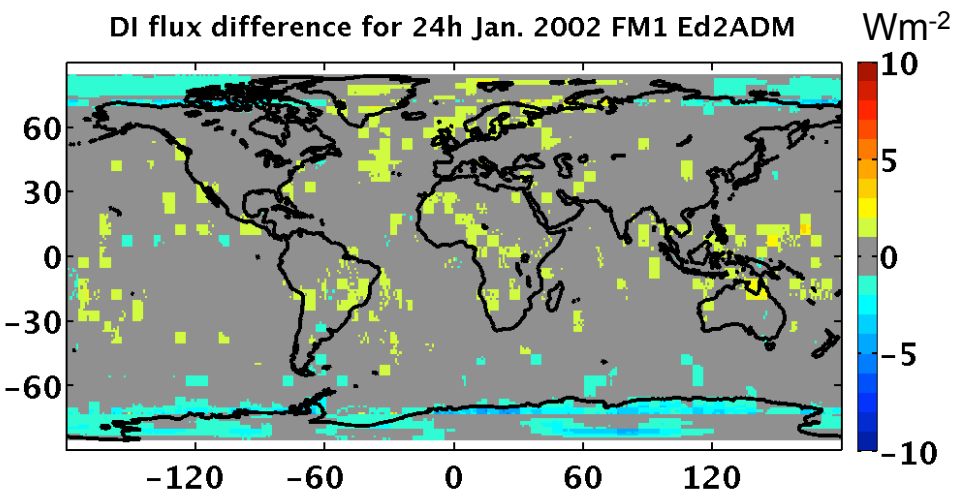
Direct integration LW flux error for 2002 Terra FM1 (ADM flux – DI flux)

Direction integration using Ed4ADM

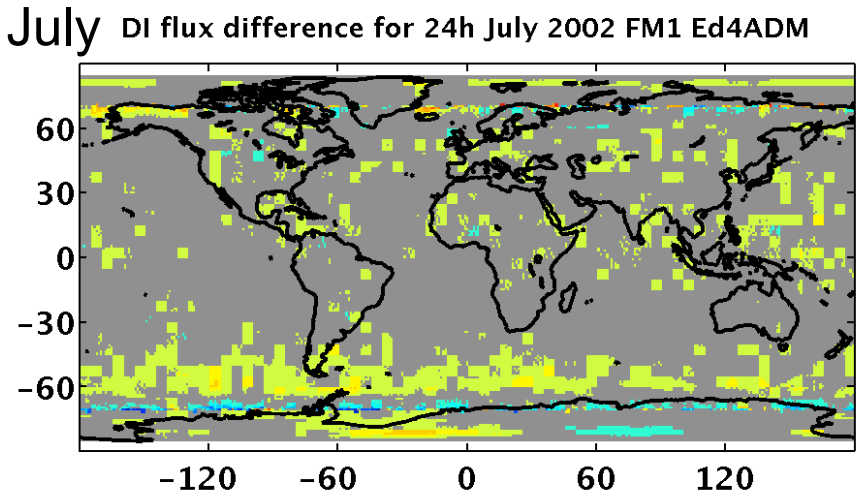
Direction integration using Ed2ADM

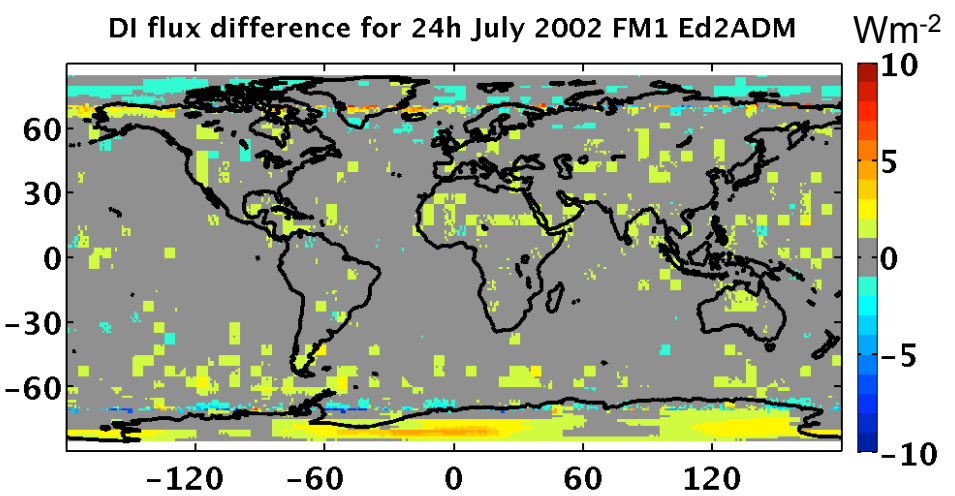
Jan



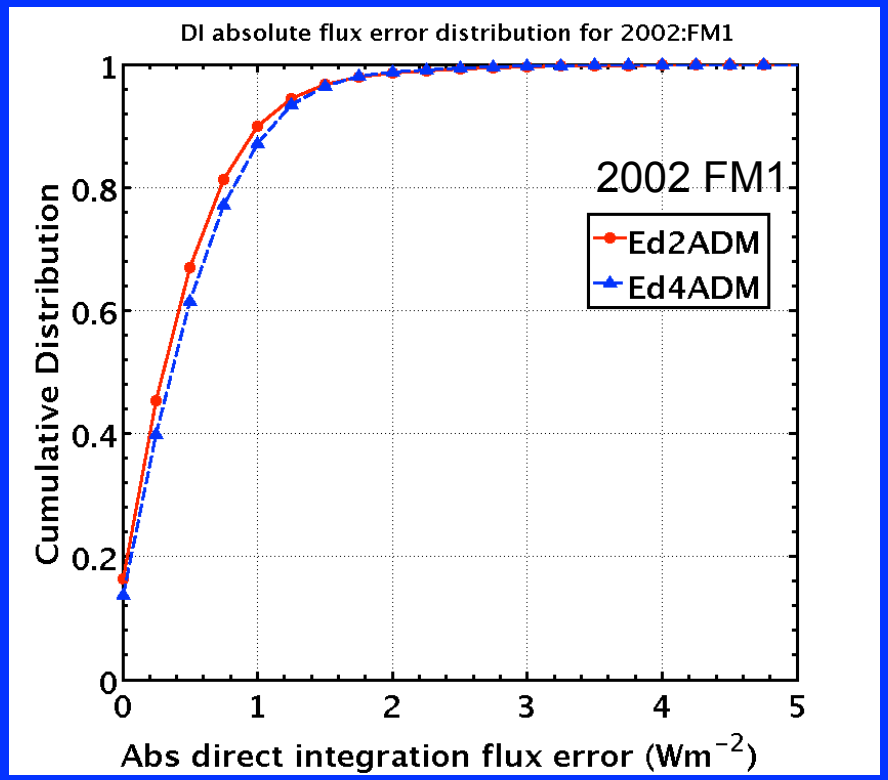


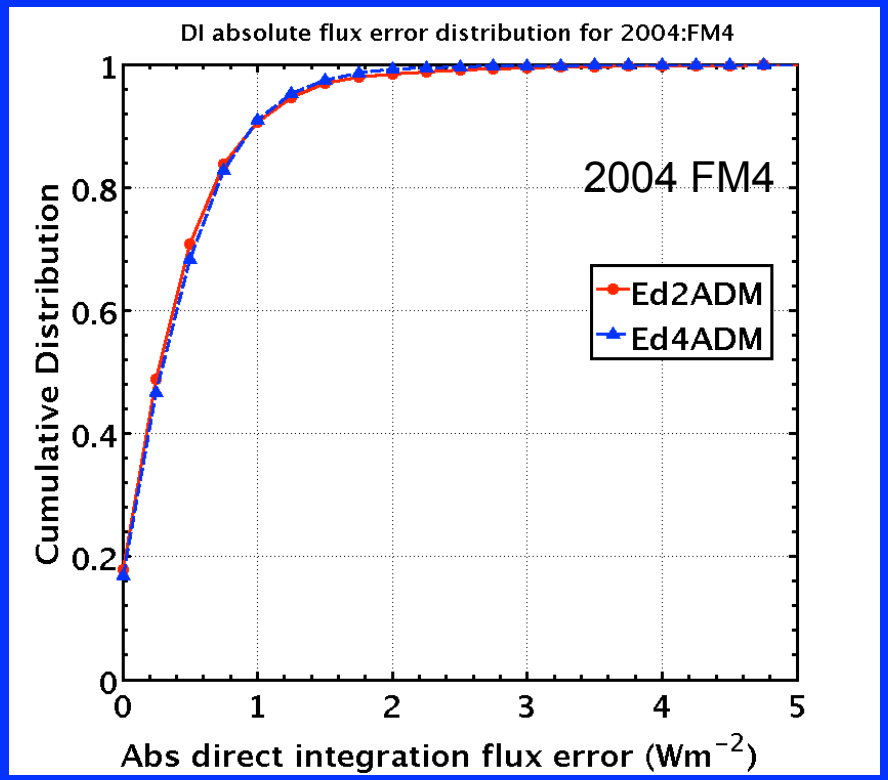
July





LW flux error is less than 2 Wm^{-2} for 99% of the 1° x 1° region

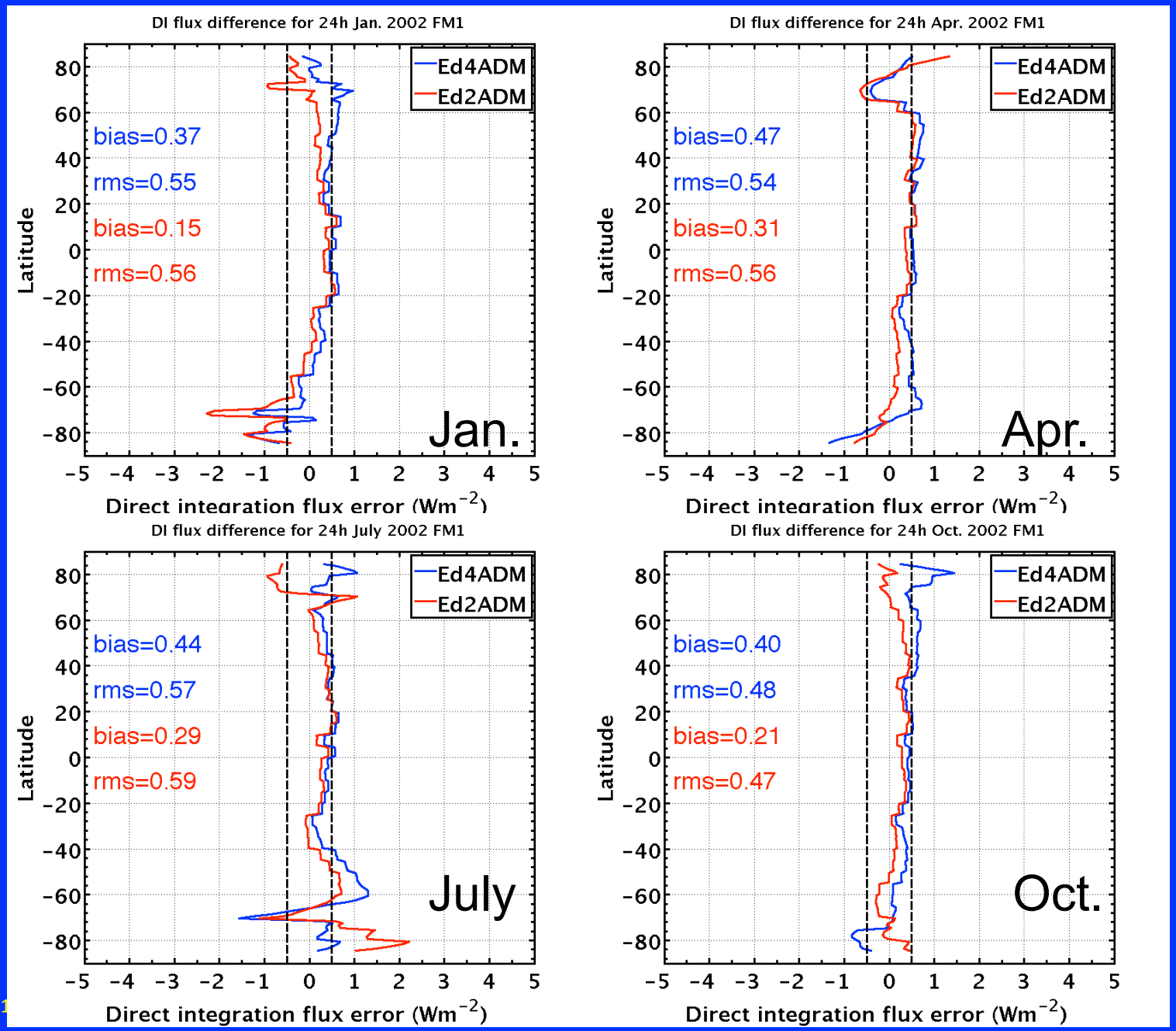




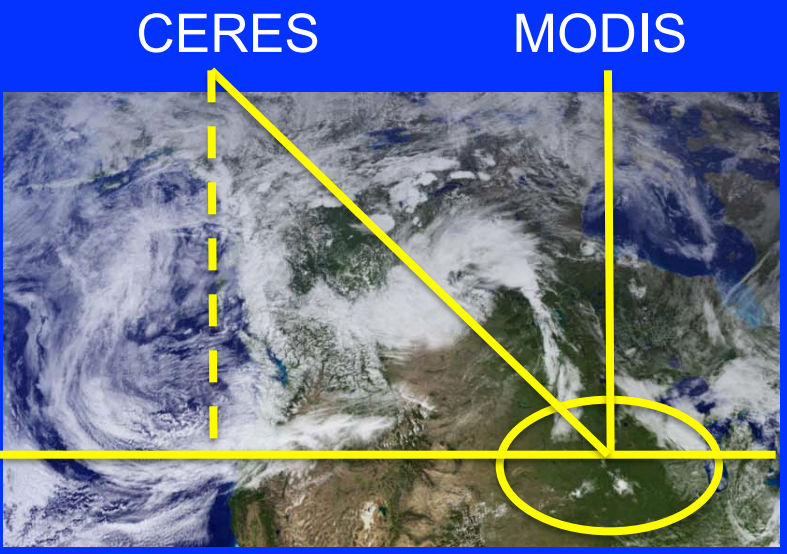
Abs. flux error (Wm-2)	Ed4ADM (%)	Ed2ADM (%)
<1	87.1	89.9
<2	98.8	98.6
<4	99.9	99.9

Abs. flux error (Wm-2)	Ed4ADM (%)	Ed2ADM (%)
<1	91.0	90.7
<2	99.2	98.5
<4	99.9	99.8

Zonal mean LW flux error for 2002 Terra FM1



CERES-MODIS instantaneous TOA flux consistency test



θ=50°-60° θ<10°

$$I_{sw}^{c} \qquad I_{sw}^{md} = d_0 + d_1 I_{0.65} + d_2 I_{0.86} + d_3 I_{1.63}$$

$$I_{lw}^{c} \qquad I_{lw}^{md} = \alpha_0 + \alpha_1 I_{11}$$

↓ CERES ADM ↓

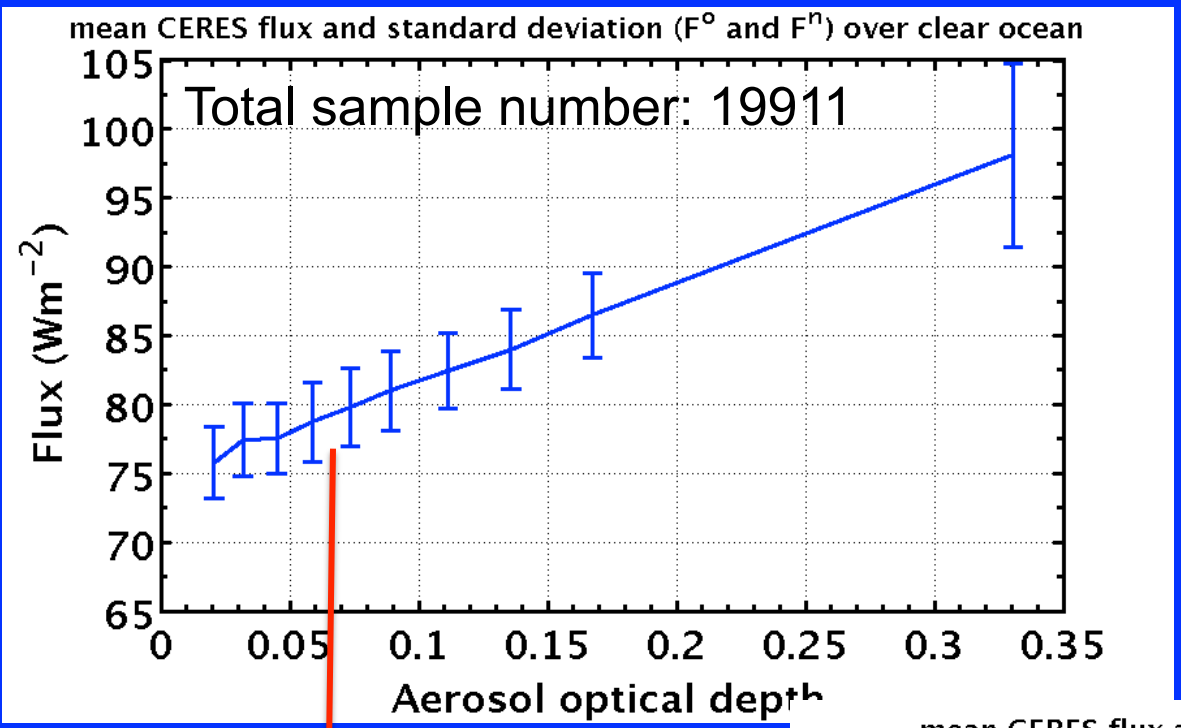
$$F(\theta^o) \qquad F(\theta^n)$$

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[F(\theta_i^n) - F(\theta_i^o)\right]^2} \qquad \psi = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[F(\theta_i^n) - F(\theta_i^o)\right]^2}}{\frac{1}{N}\sum_{i=1}^{N} F(\theta_i^o)} \times 100\%$$

Bias and RMS error between CERES and MODIS fluxes

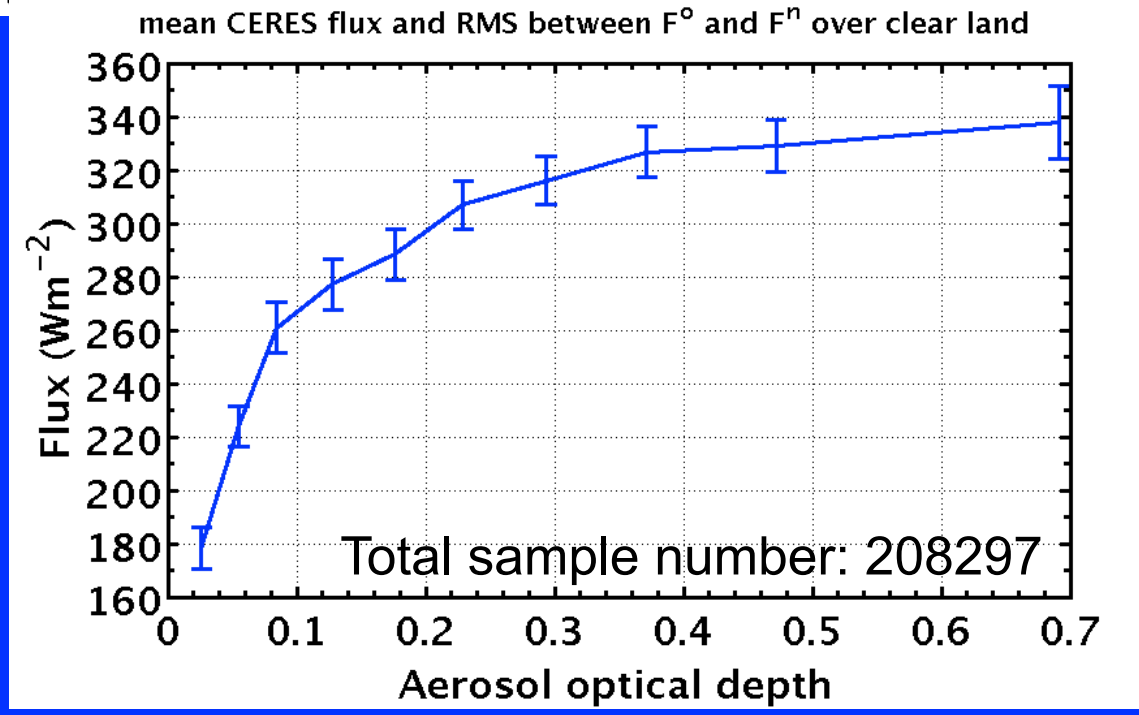
Clear-sky	Ocean		Land		Snow/Ice	
	Bias (Wm^{-2})	RMS (Wm^{-2})	Bias (Wm^{-2})	RMS (Wm^{-2})	Bias (Wm^{-2})	RMS (Wm^{-2})
SW	**0.0**	**3.4**	**3.4**	**9.6**	**0.0**	**8.8**
LW day	**-1.6**	**2.5**	2.0	4.2	**-0.5**	**2.1**
LW night	-2.0	2.3	-1.5	2.0	-0.3	1.5

All-sky	Ocean		Land		Snow/Ice	
	Bias (Wm^{-2})	RMS (Wm^{-2})	Bias (Wm^{-2})	RMS (Wm^{-2})	Bias (Wm^{-2})	RMS (Wm^{-2})
SW	**-0.7**	**15.1**	**2.6**	**16.1**	**-2.0**	**17.9**
LW day	**-1.7**	**5.9**	1.3	5.0	**-1.0**	**3.5**
LW night	-1.2	3.3	-1.5	3.2	-0.4	2.4

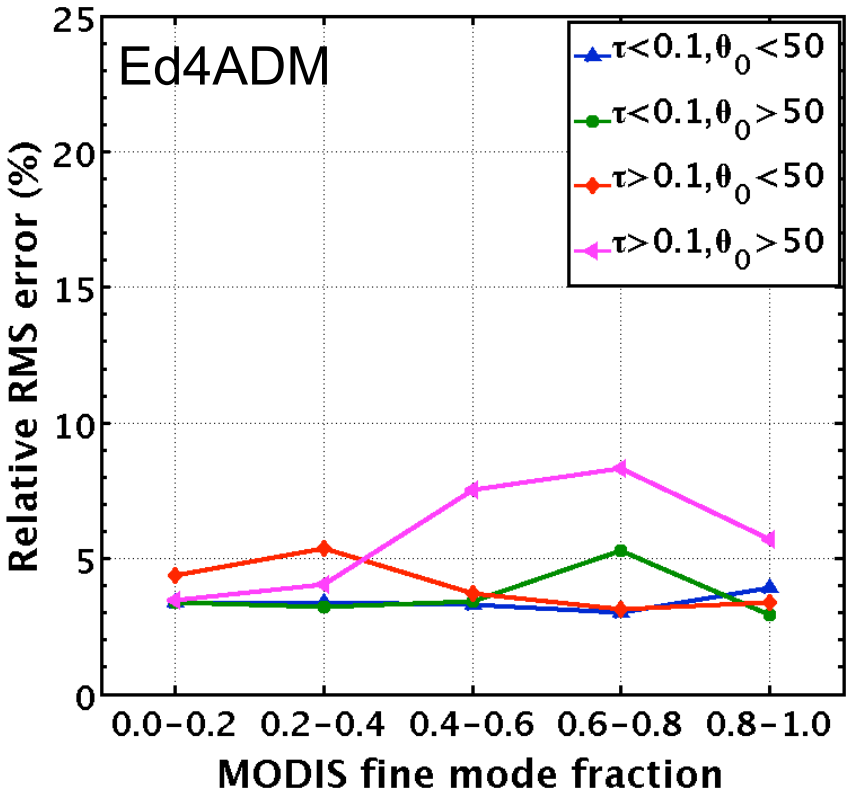


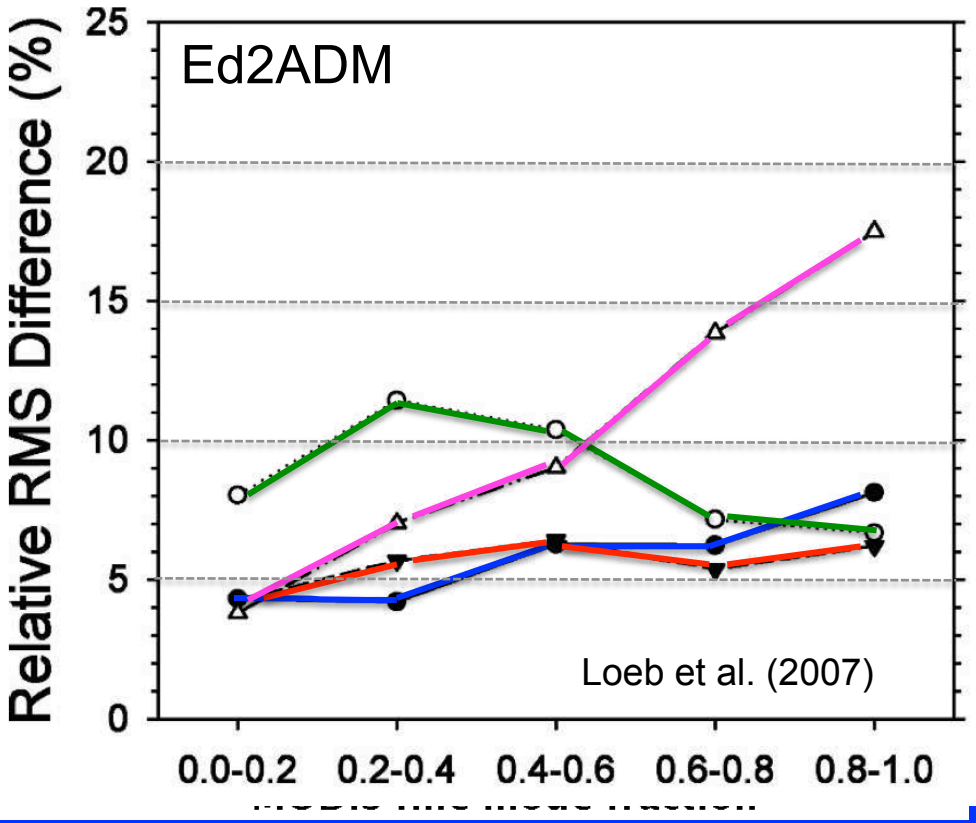
SW flux RMS error shows very little dependence on aerosol optical depth over ocean and land

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[F(\theta_i^n) - F(\theta_i^o)\right]^2}$$

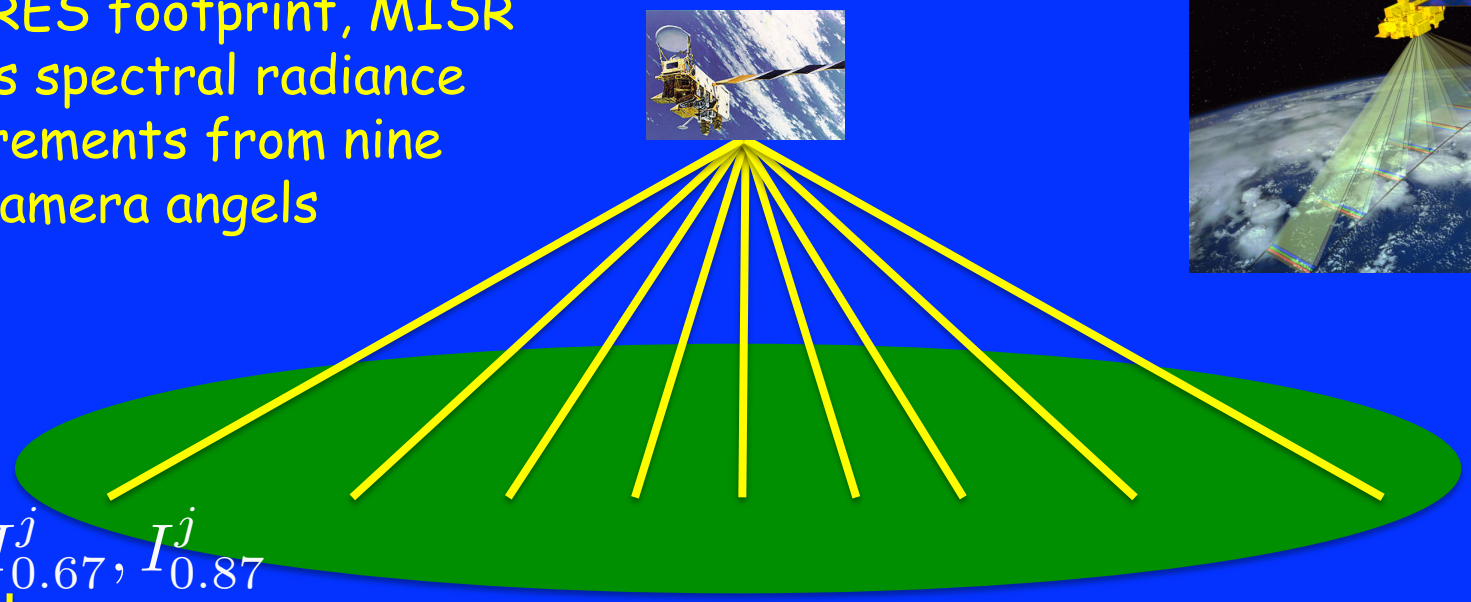


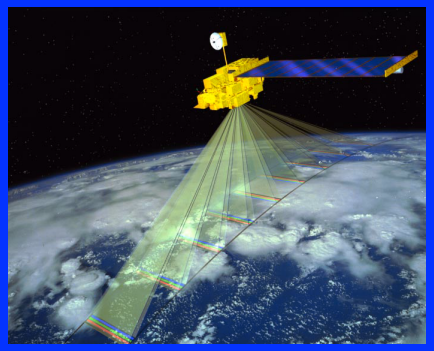
CERES-MODIS flux consistency over clear ocean: dependence on MODIS fine mode fraction is smaller than using Ed2ADM





For a CERES footprint, MISR provides spectral radiance measurements from nine camera angels





$$I^j_{0.45}, I^j_{0.67}, I^j_{0.87}$$

$$\downarrow \; I^j_{sw} = c_0 + c_1 I^j_{0.45} + c_2 I^j_{0.67} + c_3 I^j_{0.87}$$

$$I^j_{sw}$$

$$\downarrow \; \text{CERES ADM}$$

$$F^j_{sw} \longrightarrow \overline{F_{sw}} = \frac{\sum_{j=1}^{9} F^j_{sw}}{9} \longrightarrow s = \sqrt{\frac{\sum_{j=1}^{n} (F^j_{sw} - \overline{F_{sw}})^2}{n-1}}$$

For M CERES footprints, we calculate the mean standard deviation:

$$\overline{\sigma} = \sqrt{\frac{\sum_{i=1}^{M} s_i^2}{M}}$$

and the overall relative consistency:

$$CV_T = \left(\frac{\sqrt{\frac{1}{M}\sum_{i=1}^{M} s_i^2}}{\frac{1}{M}\sum_{i=1}^{M} \overline{F_{sw}^i}} \right) \times 100\%$$

$$I_{0.45}^j, I_{0.67}^j, I_{0.87}^j$$

$$I_{sw}^j = c_0 + c_1 I_{0.45}^j + c_2 I_{0.67}^j + c_3 I_{0.87}^j$$

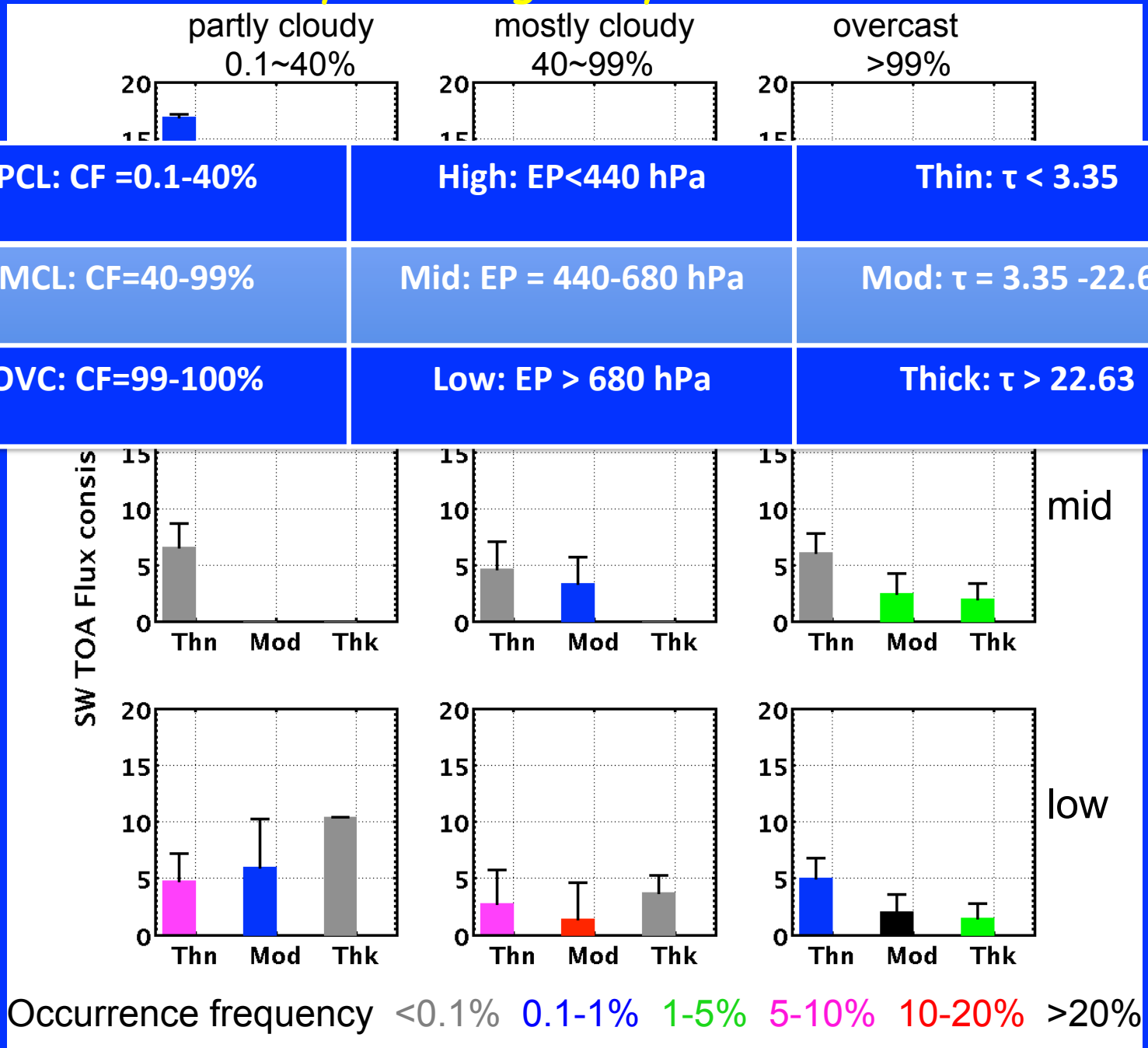
$$I_{sw}^j \; I_{sw}^c$$

CERES ADM

$$F_{sw}^j \; F_{sw}^c \longrightarrow CV_{NB} = \left(\frac{\sqrt{\frac{1}{m}\sum_{i=1}^{m} (F_{sw}^j - F_{sw}^c)^2}}{\frac{1}{m}\sum_{i=1}^{m} F_{sw}^c} \right) \times 100\%$$

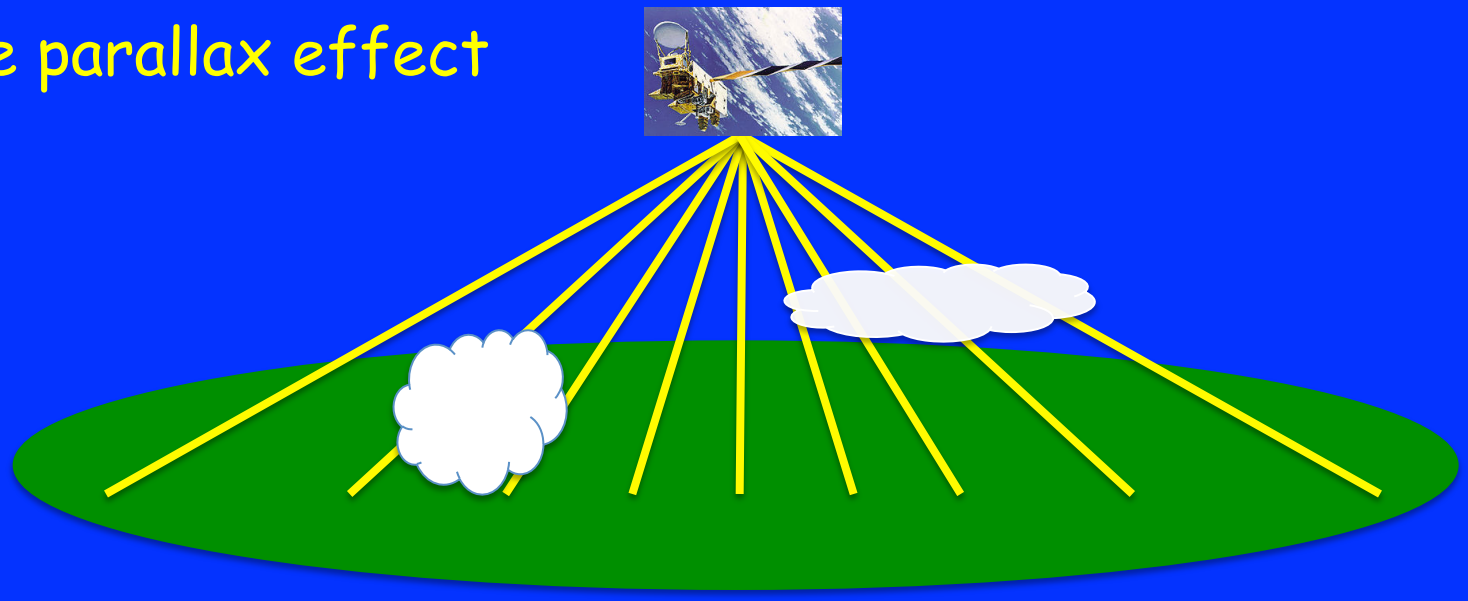
$$CV_{ADM} = \sqrt{CV_T^2 - CV_{NB}^2}$$

Flux consistency for single-layer clouds over ocean



PCL: CF =0.1-40%	High: EP<440 hPa	Thin: τ < 3.35
MCL: CF=40-99%	Mid: EP = 440-680 hPa	Mod: τ = 3.35 -22.63
OVC: CF=99-100%	Low: EP > 680 hPa	Thick: τ > 22.63

Quantify the parallax effect



- Surface is used as the reference level to collocate MISR Level 1B radiances with the CERES data:

$$CV_T^2 = CV_{ADM}^2 + CV_{NB}^2 + CV_{PX}^2$$

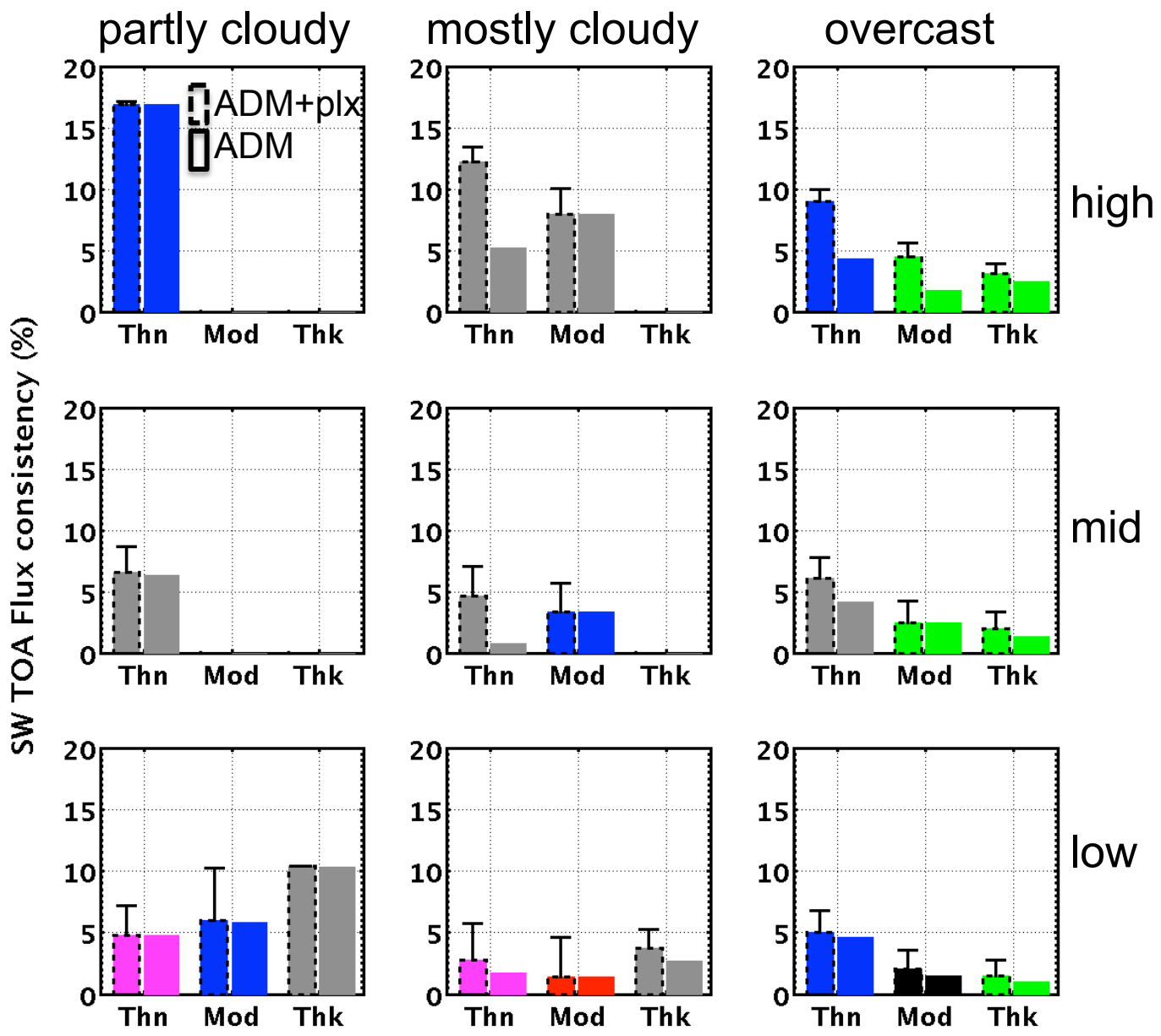
- MISR Level 2 data are projected on to the reflecting layer reference altitude:

$$CV2_T^2 = CV_{ADM}^2 + CV_{NB}^2$$

- Parallax effect can be quantified as:

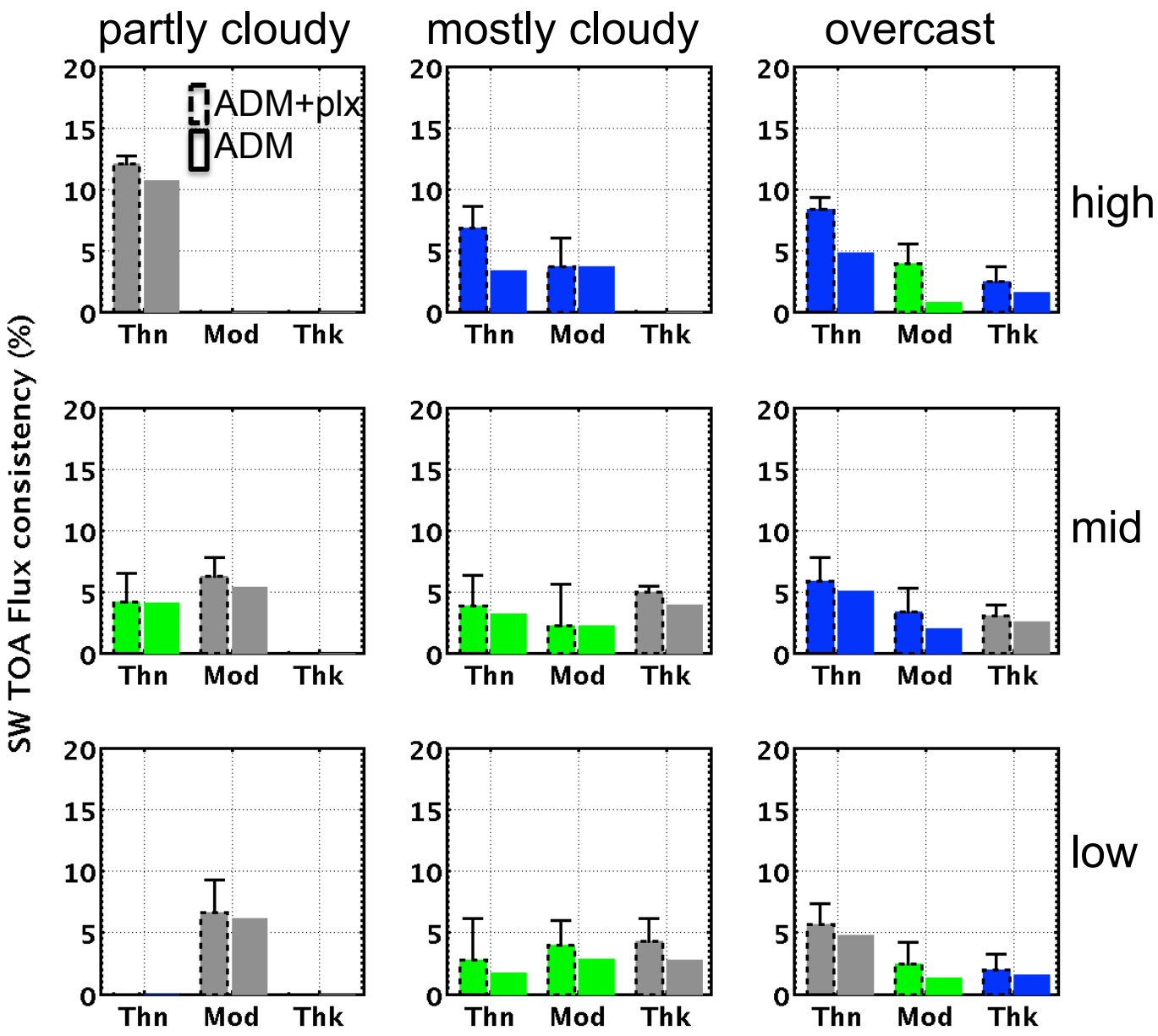
$$CV_{PX} = \sqrt{CV_T^2 - CV2_T^2}$$

Flux consistency for single-layer clouds over ocean



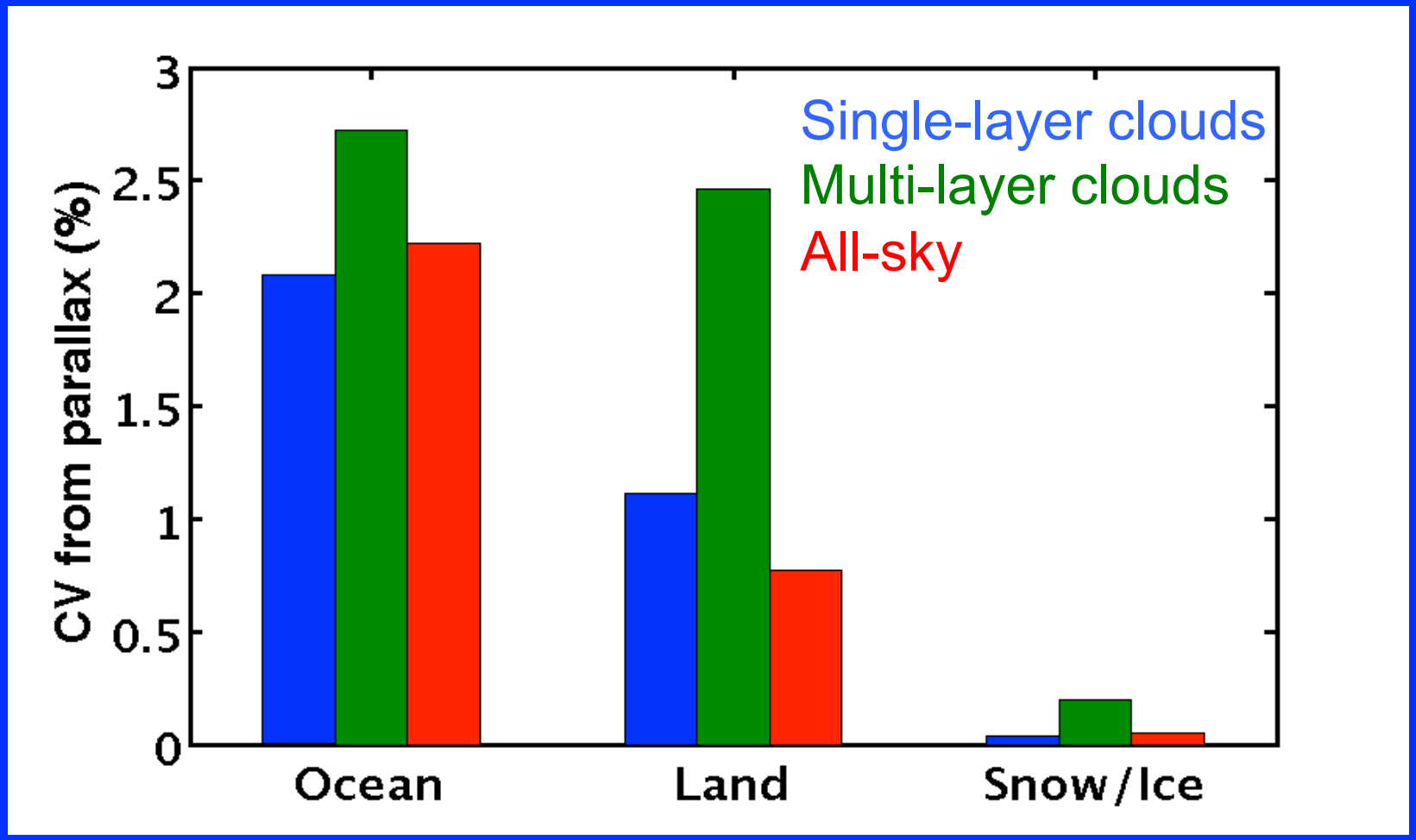
Occurrence frequency <0.1% 0.1-1% 1-5% 5-10% 10-20% >20%

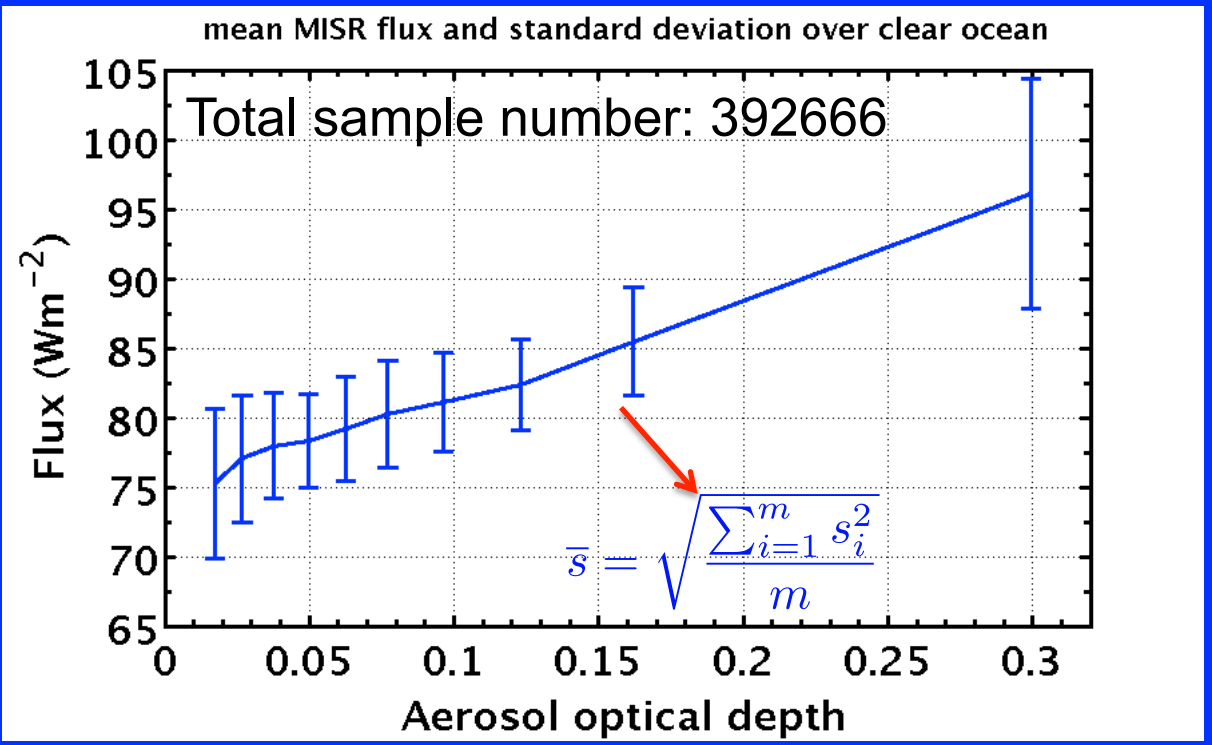
Flux consistency for multi-layer clouds over ocean



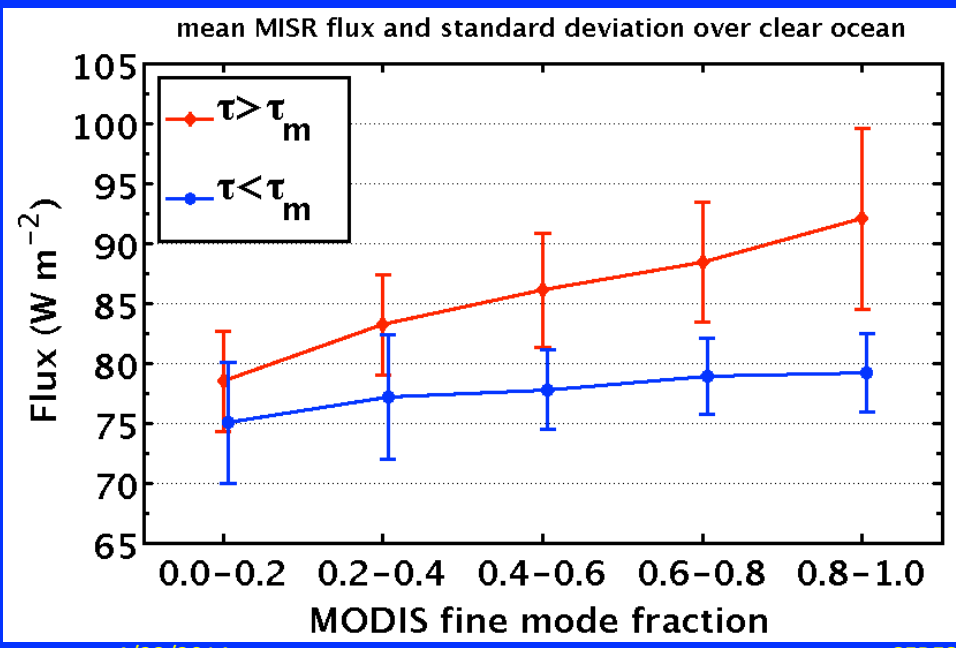
Occurrence frequency <0.1% 0.1-1% 1-5% 5-10% 10-20% >20%

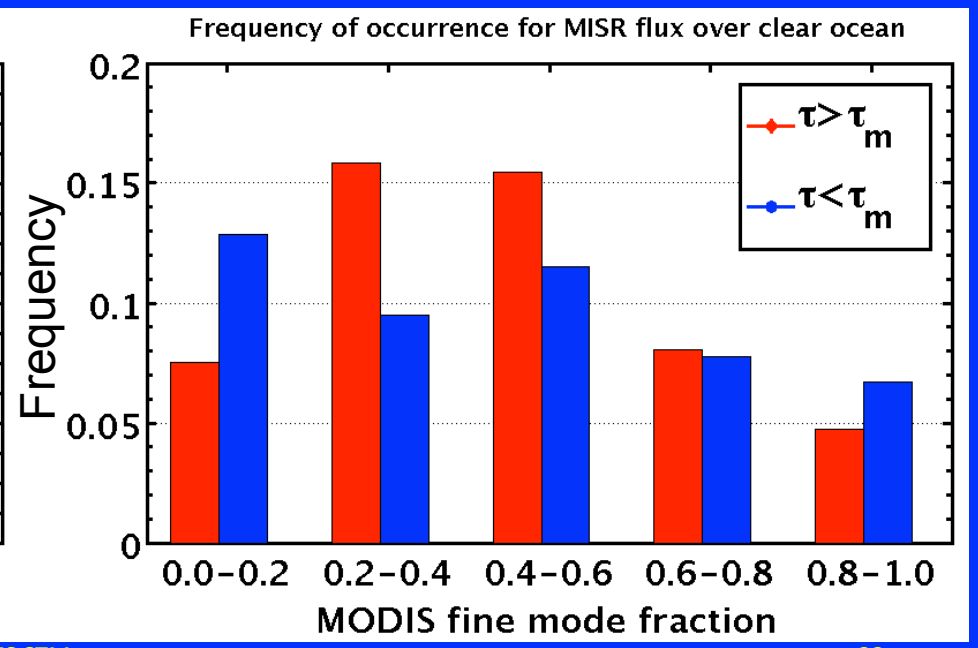
Uncertainty from Parallax is about 2% over ocean, 0.8% over land, and negligible over snow/ice under all-sky conditions

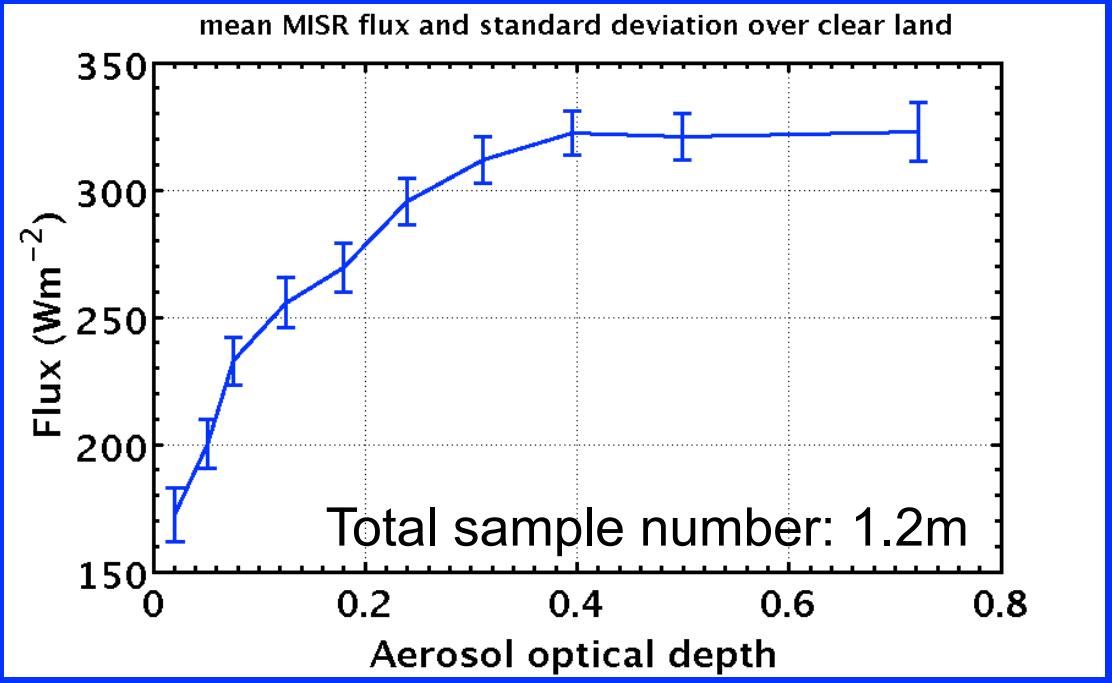




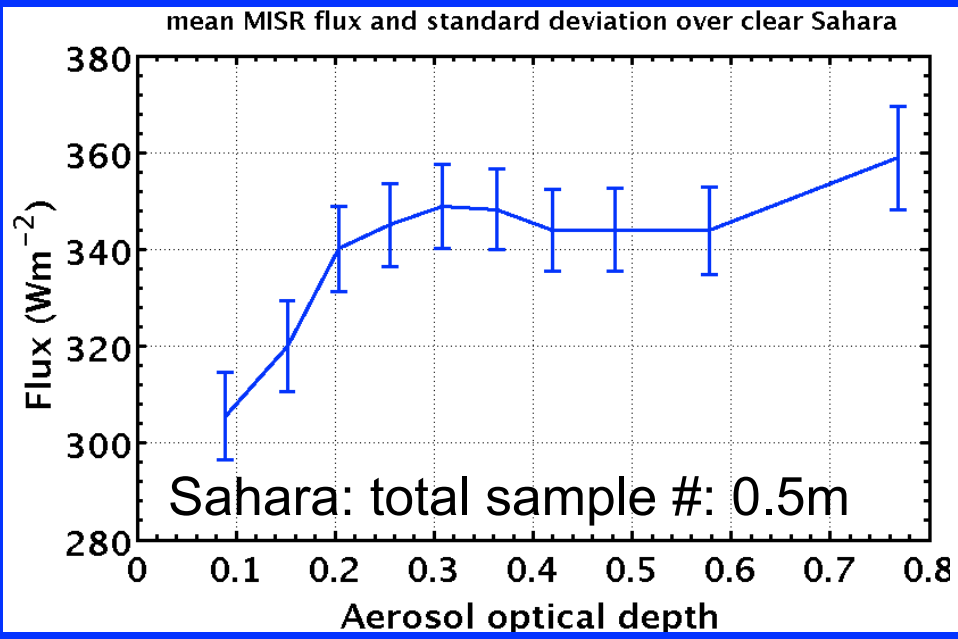
MISR flux consistency shows little dependence on aerosol optical depth and fine-mode fraction over ocean

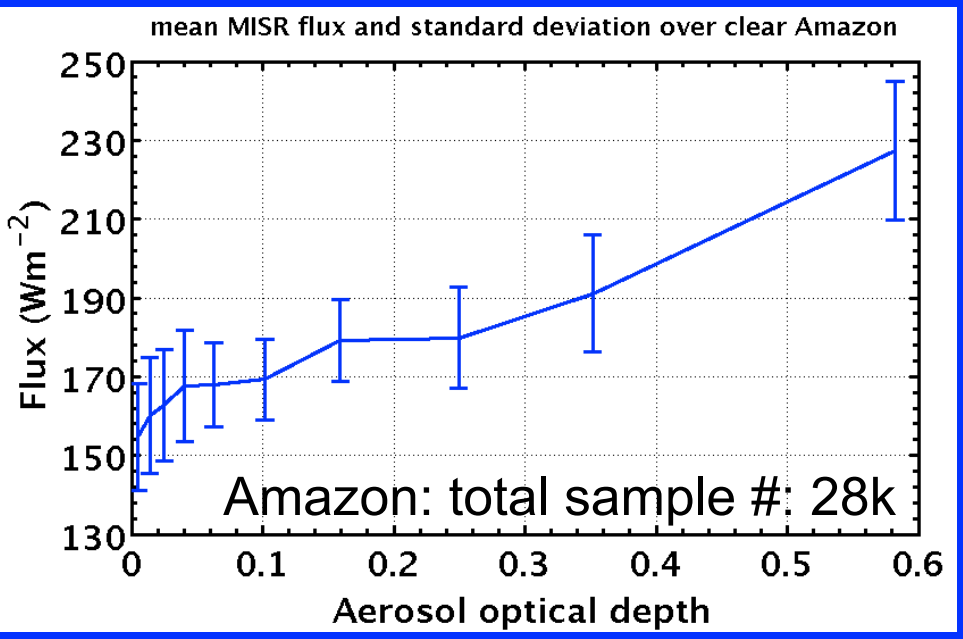




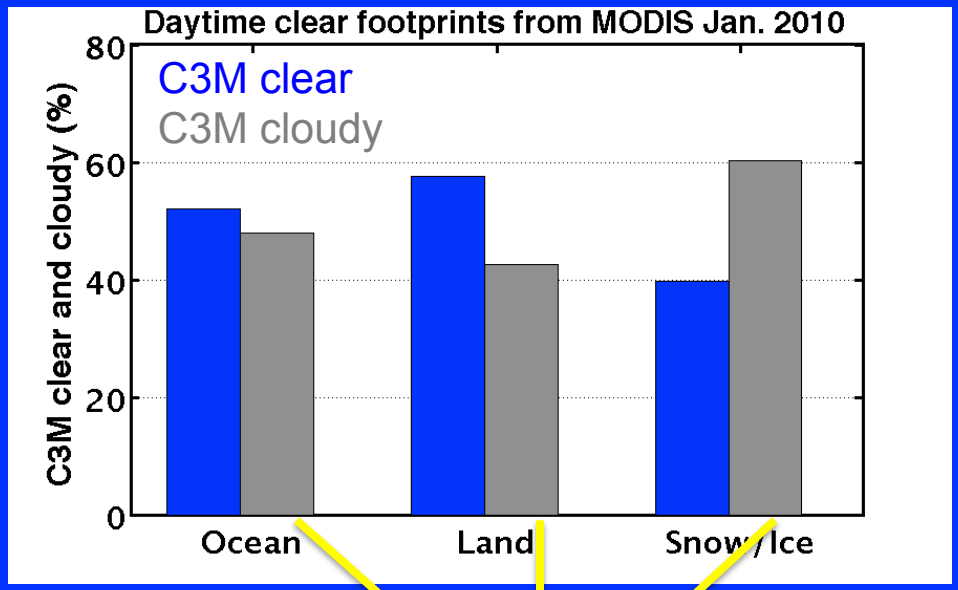


MISR flux consistency shows very little dependence on aerosol optical depth over land

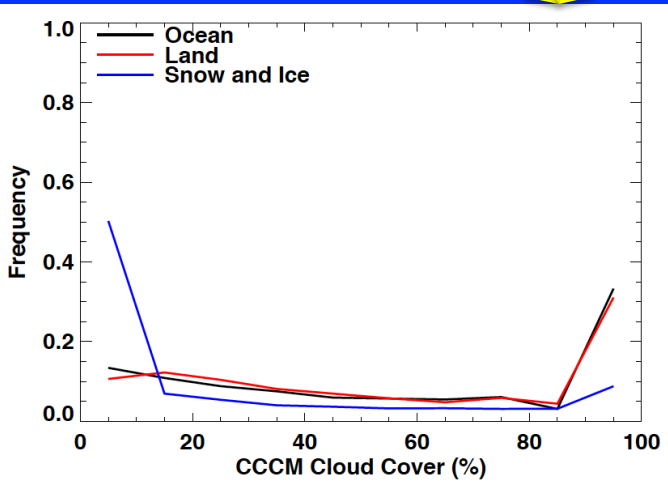


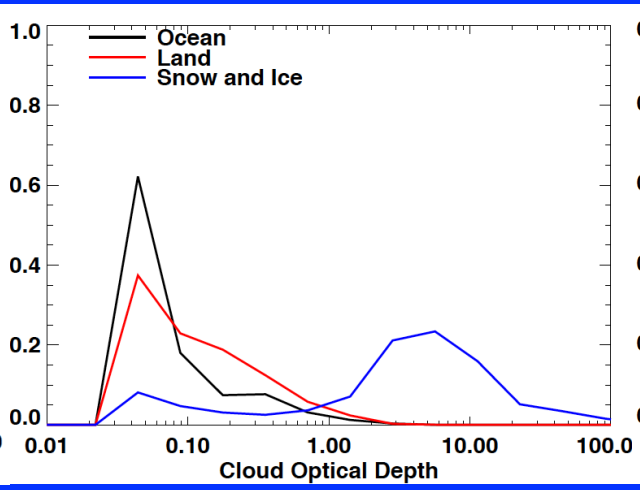


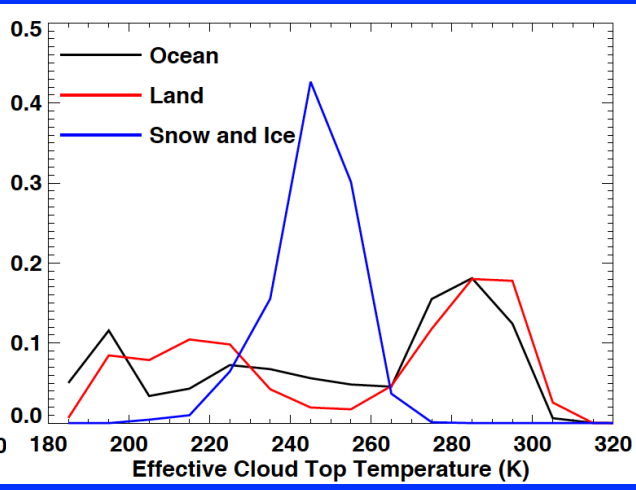
Daytime clear-sky LW flux uncertainty from scene identification



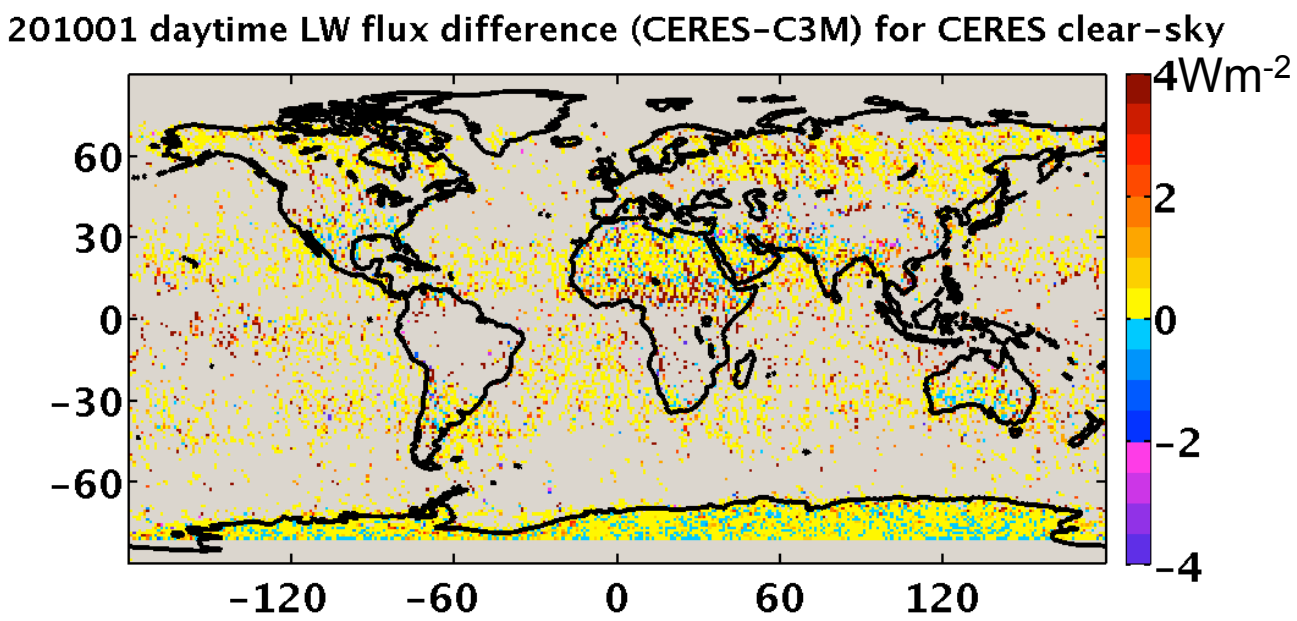
Daytime Sfc. Type	Δf (CERES-C3M) (%)	ΔLW (CERES-C3M) (Wm-2)
ocean	-12.9	0.7
land	-13.9	1.8
snow/ice	-10.8	0.3



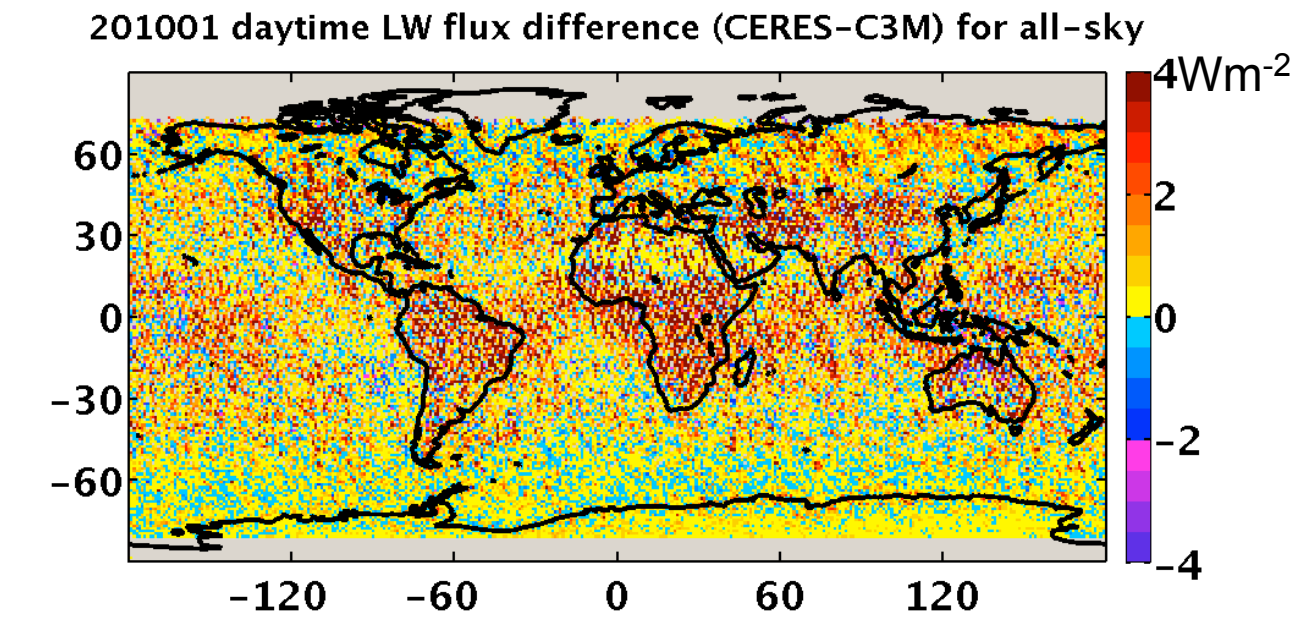




Daytime LW flux uncertainty from scene identification

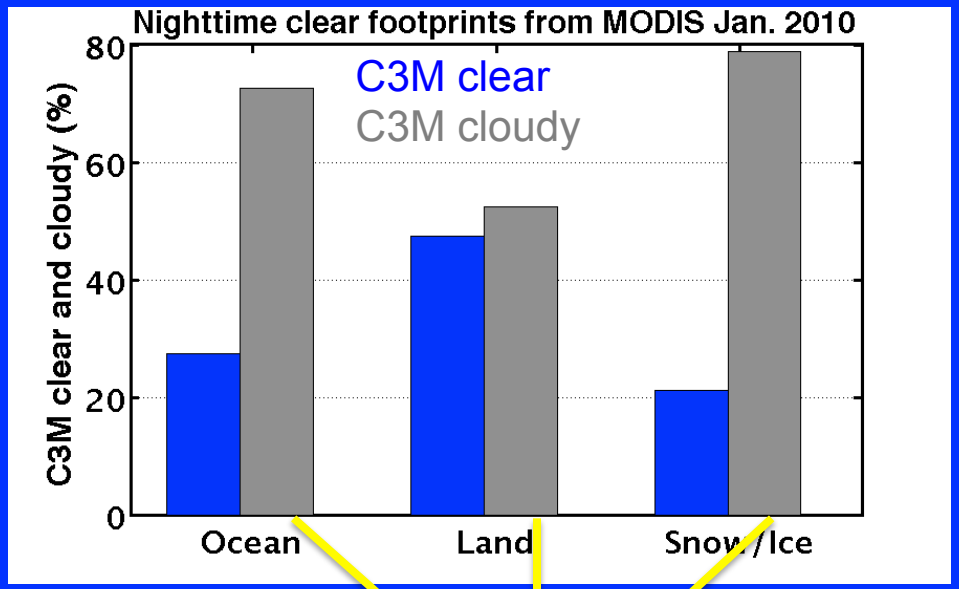


CERES overestimates clear-sky daytime LW flux by 1.2 Wm^{-2}

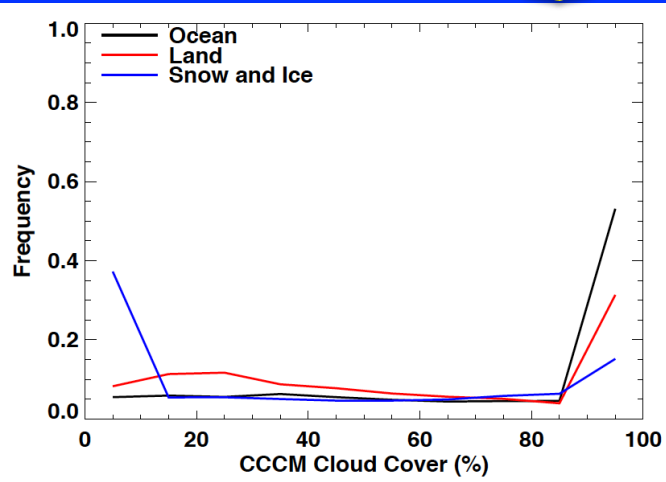


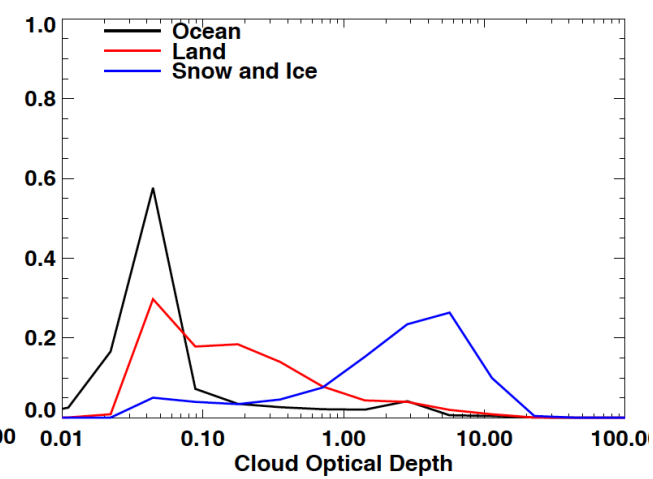
CERES overestimates all-sky daytime LW flux by 1.1 Wm^{-2}

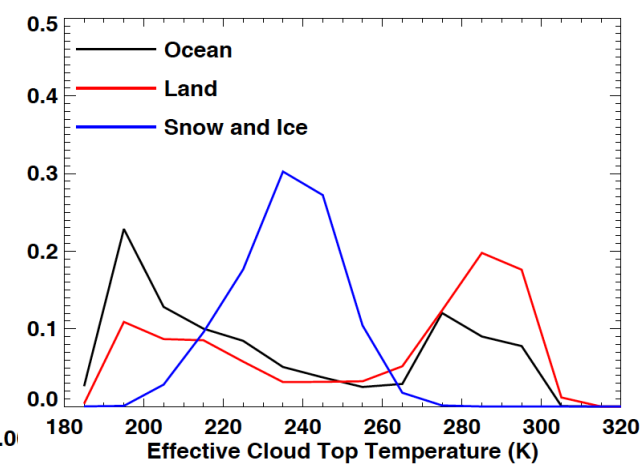
Nighttime clear-sky LW flux uncertainty from scene identification



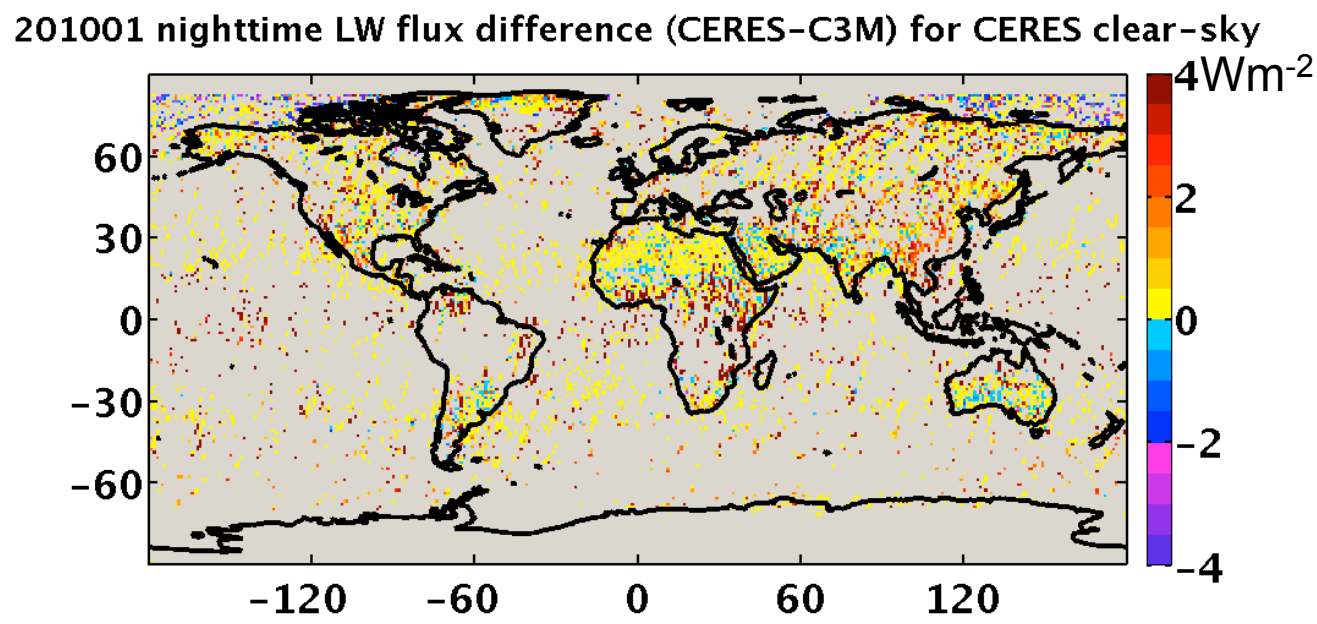
Nighttime Sfc. Type	Δf (CERES-C3M) (%)	ΔLW (CERES-C3M) (Wm-2)
ocean	-20.1	1.9
land	-20.1	2.0
snow/ice	-24.7	0.7



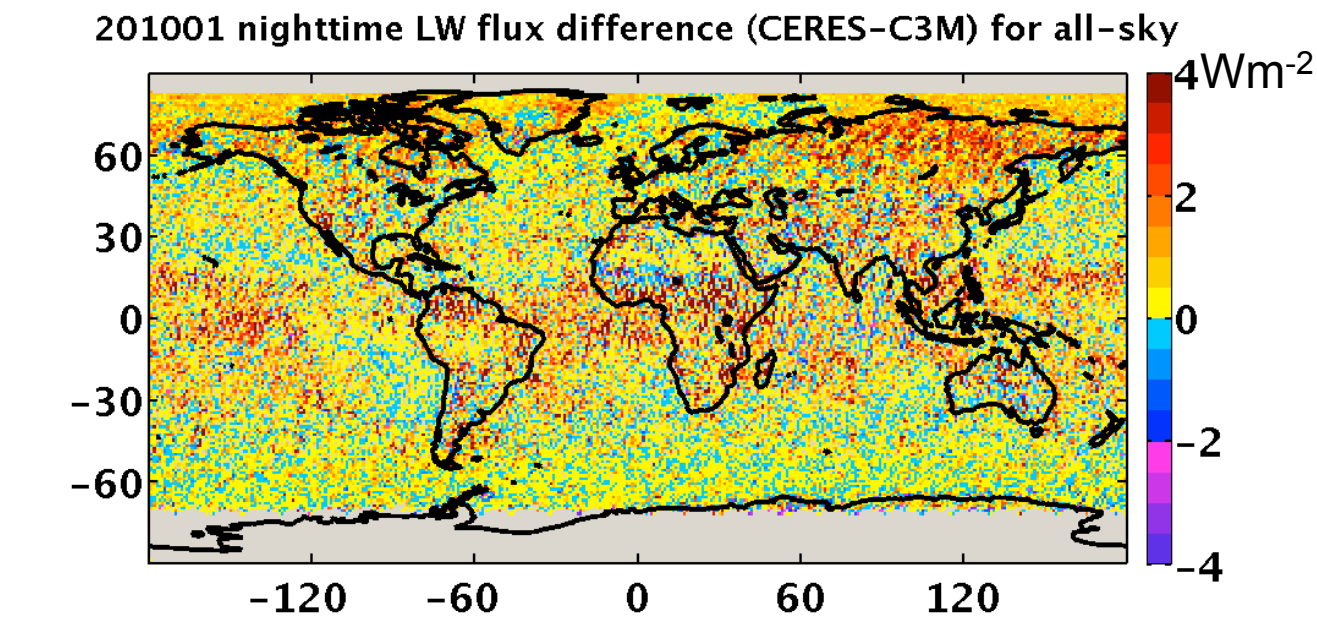




Nighttime LW flux uncertainty from scene identification



CERES overestimates clear-sky nighttime LW flux by 2.1 Wm^{-2}



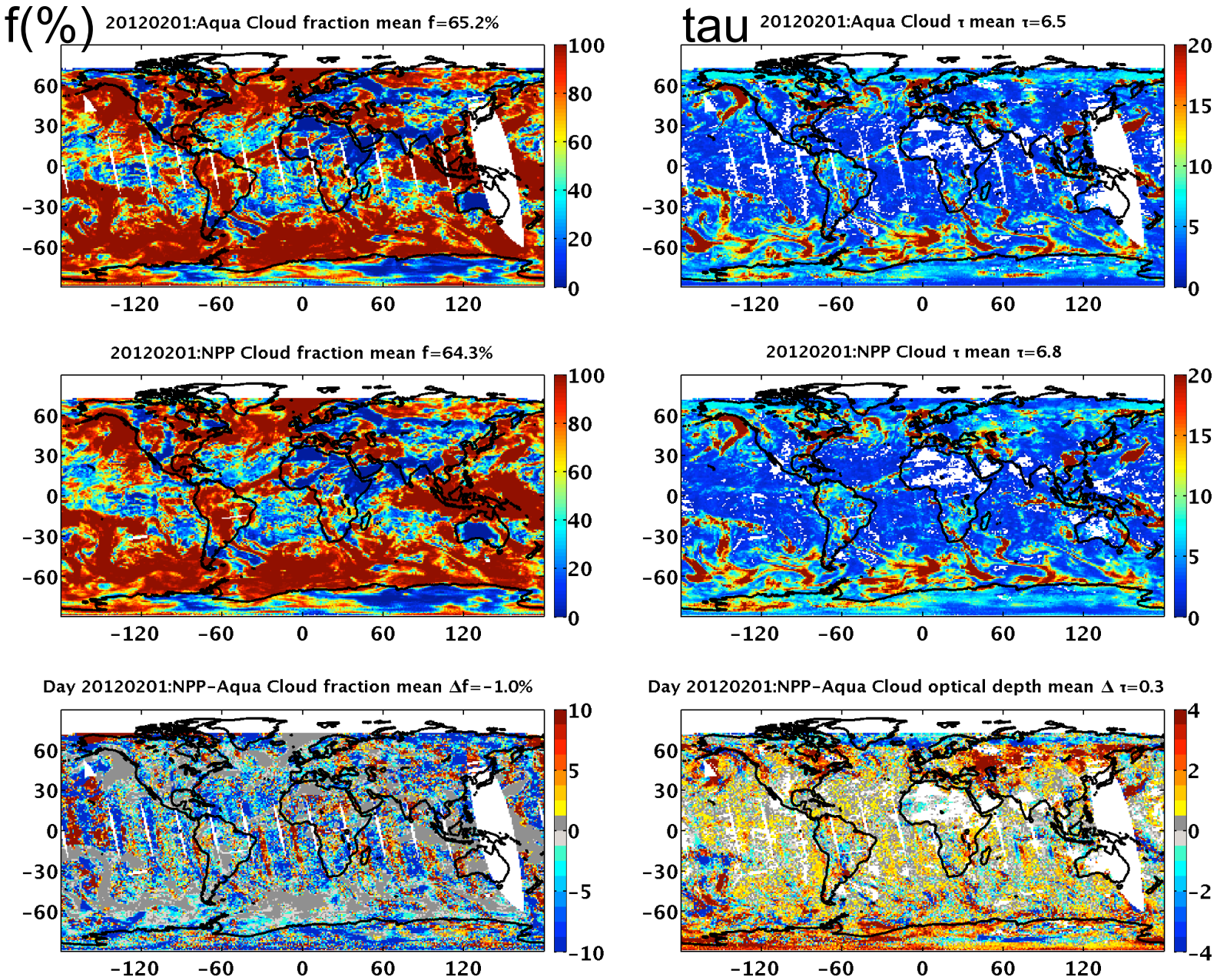
CERES overestimates all-sky nighttime LW flux by 0.8 Wm^{-2}

Comparison between Aqua and SNPP: Daytime cloud properties

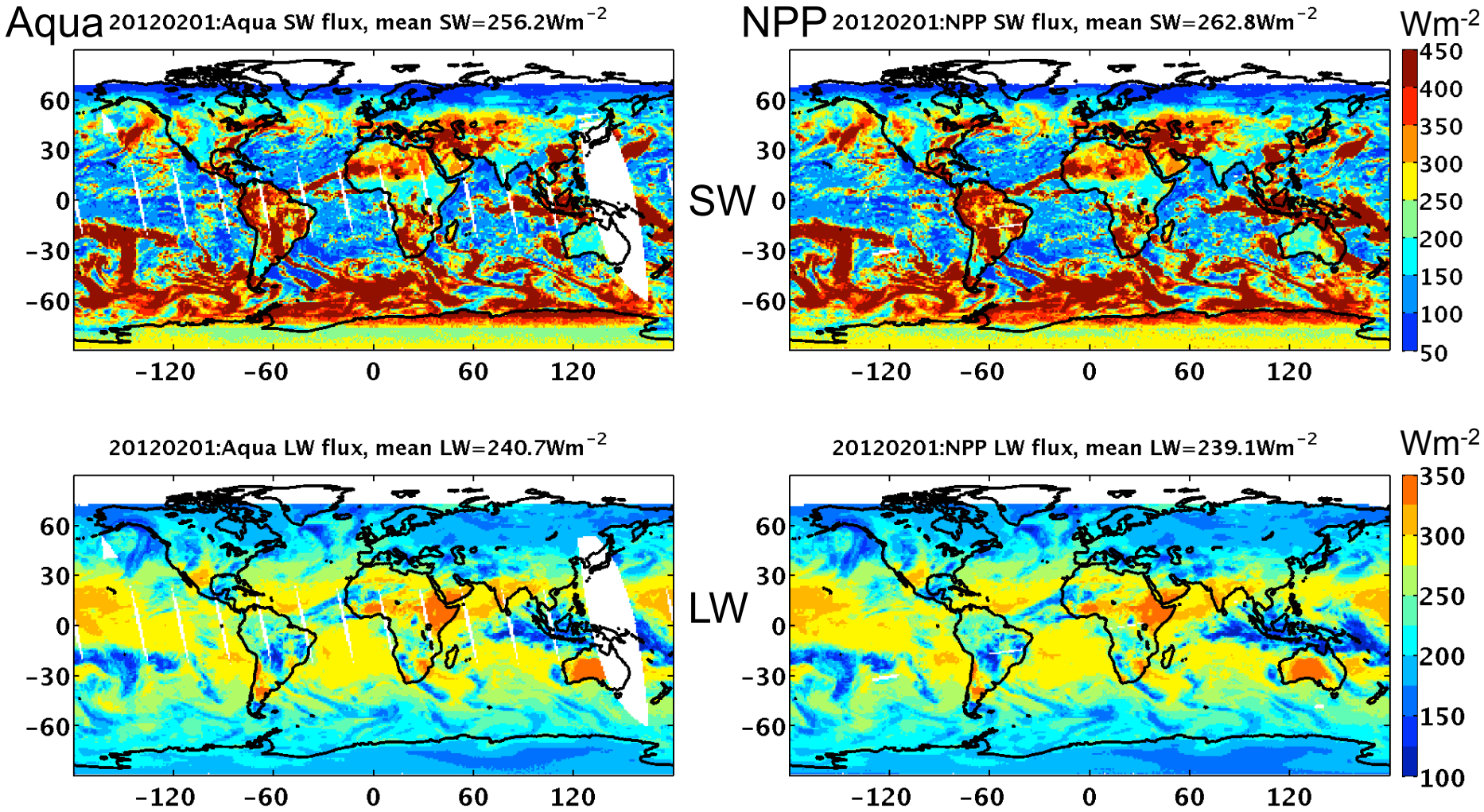
Aqua

SNPP

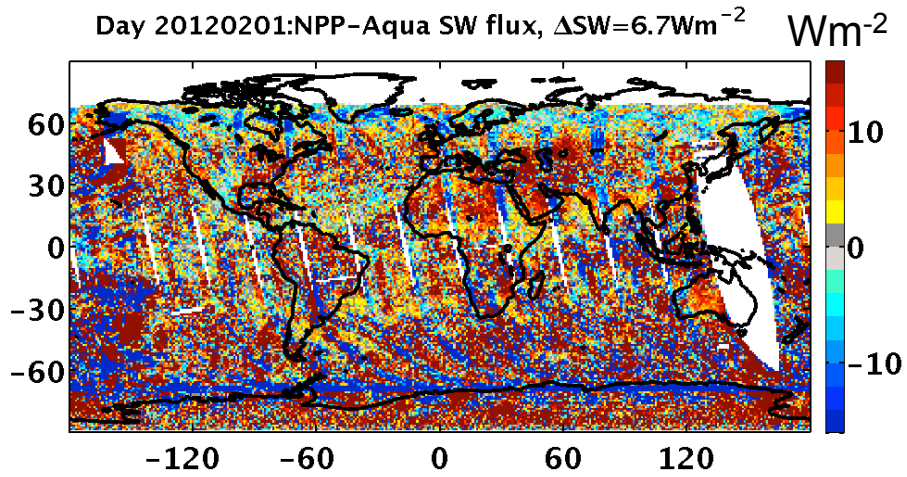
Diff.

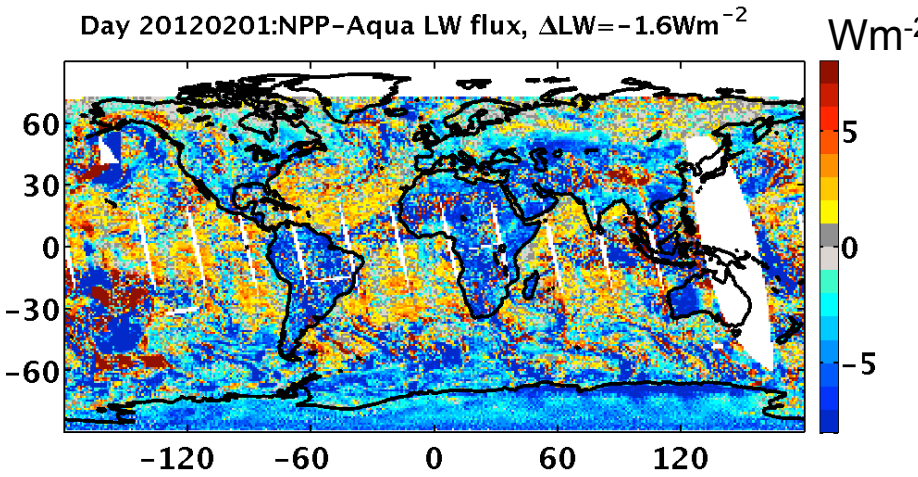


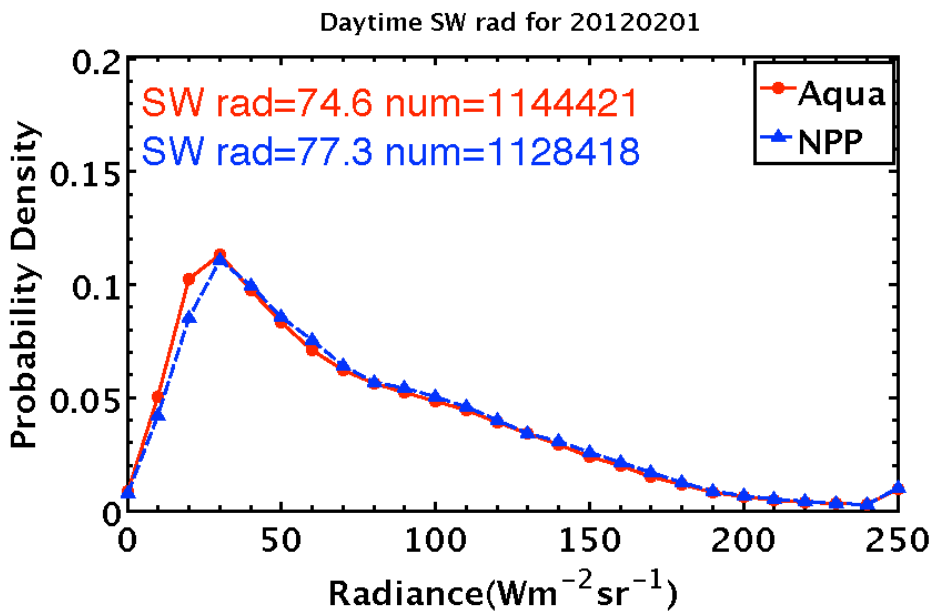
Comparison between Aqua and SNPP: Daytime SW and LW flux

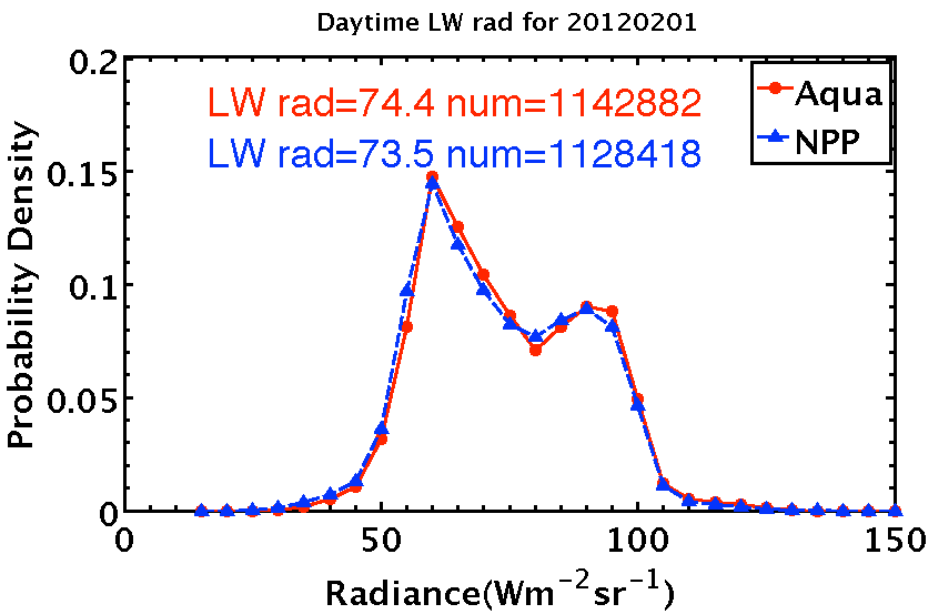


SNPP SW flux is higher than Aqua SW flux by 6.7 Wm^{-2}, and daytime SNPP LW flux is lower than Aqua LW flux by 1.6 Wm^{-2}







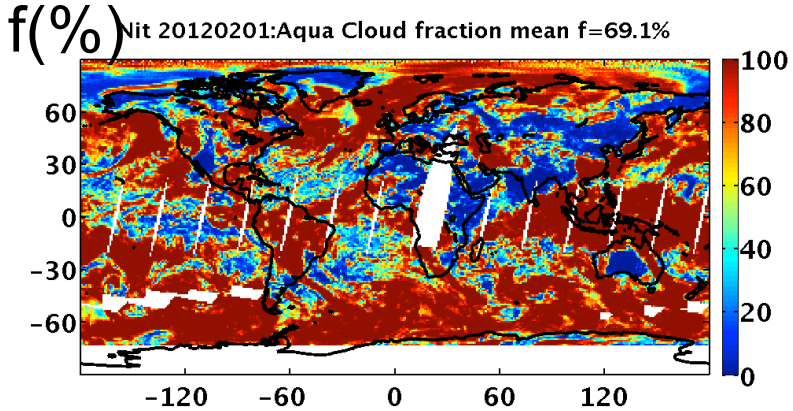


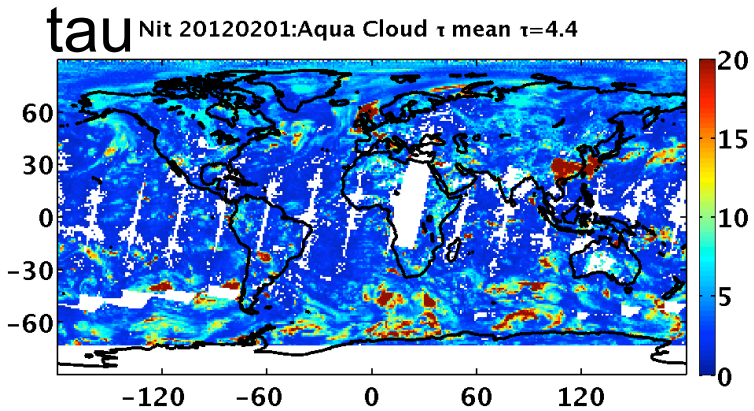
Comparison between Aqua and SNPP: Nighttime cloud properties

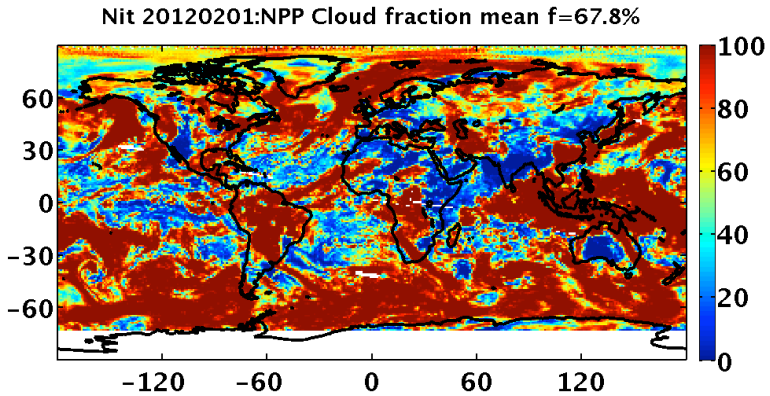
Aqua

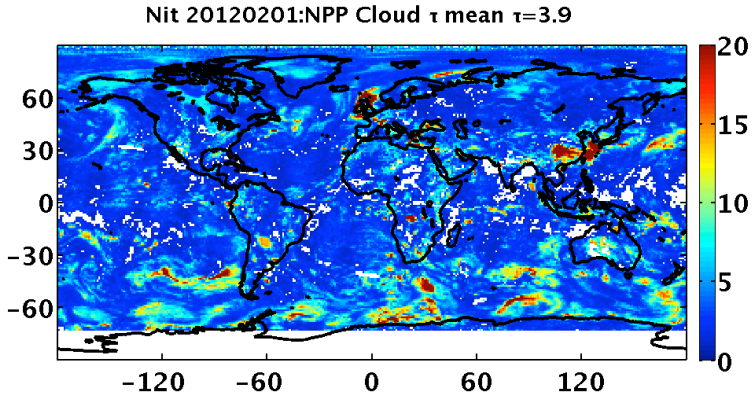
SNPP

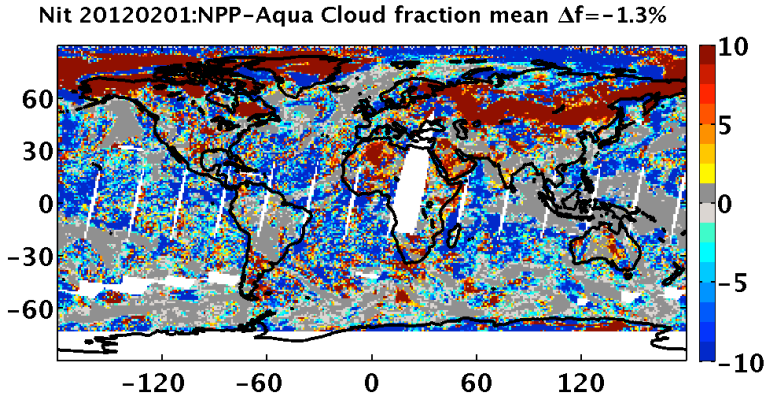
Diff.

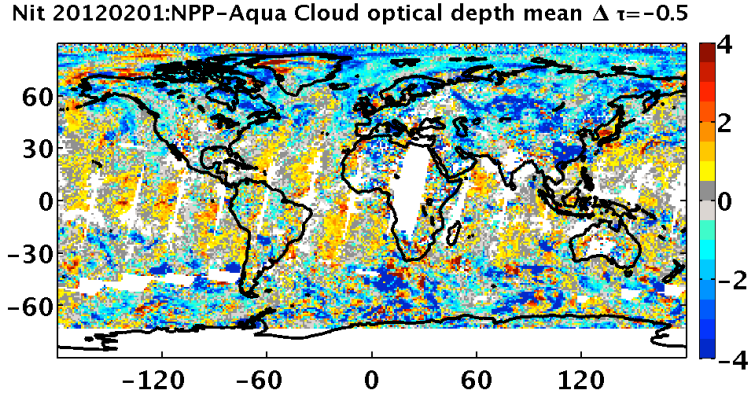




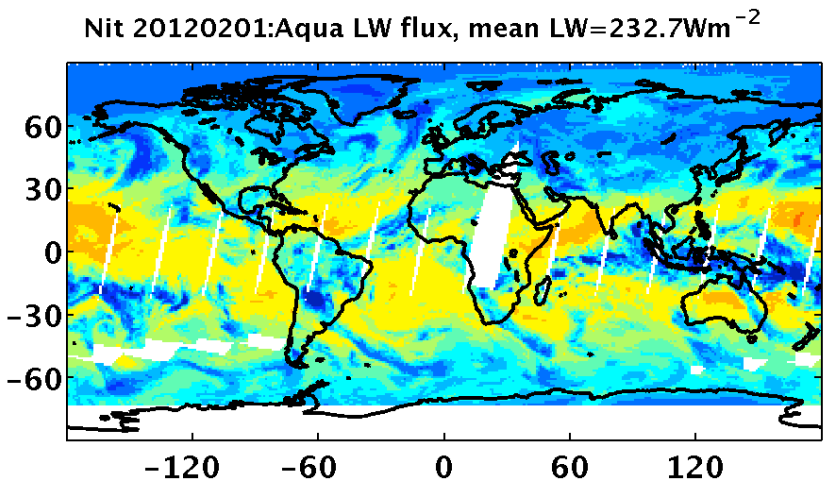


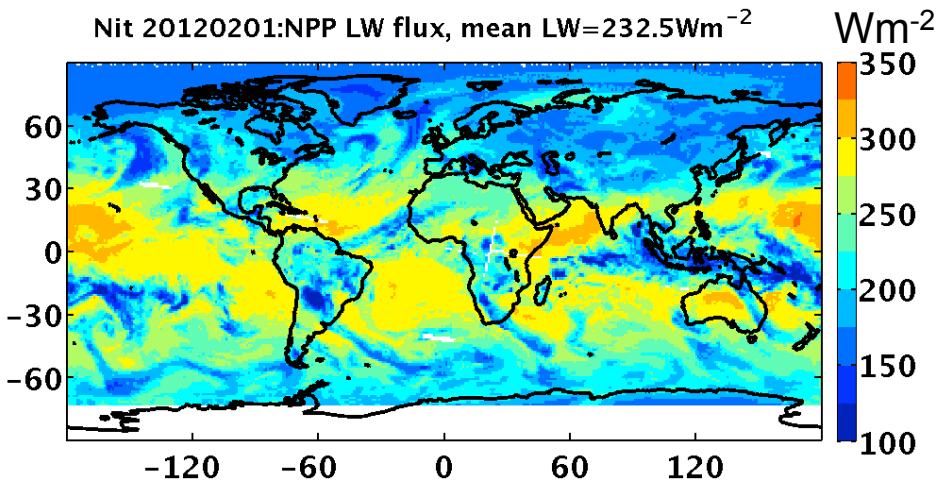


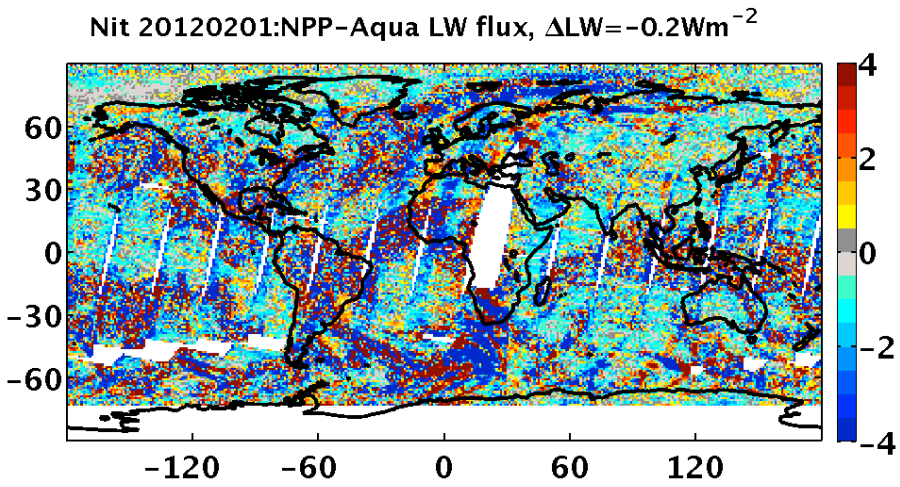


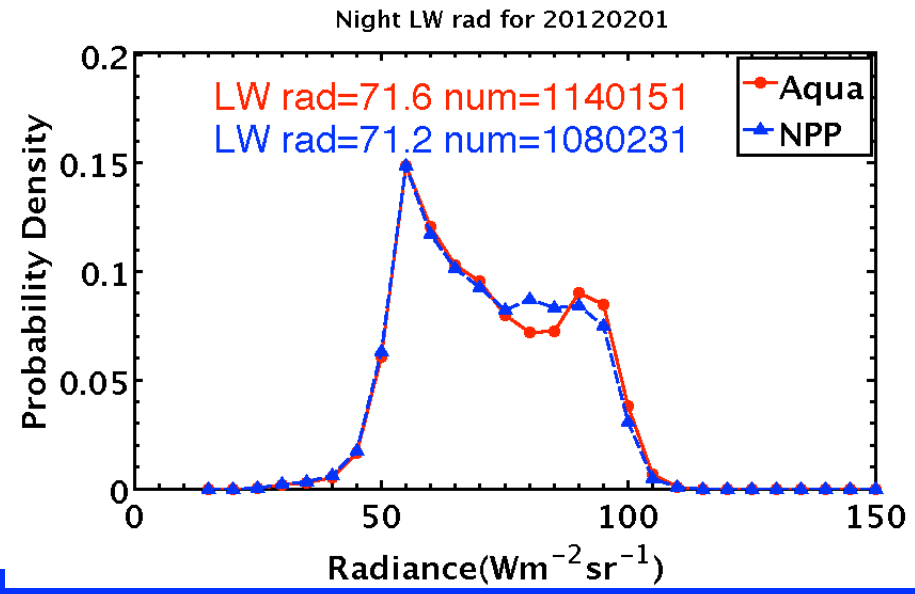


Nighttime SNPP LW flux is lower than Aqua LW flux by 0.2 Wm^{-2}









More talks on ADM

- Lusheng Liang: Edition 4 clear-sky shortwave angular distribution models over ocean
- Zach Eitzen: Uncertainty of LW fluxes due to scene identification
- Joe Corbett: Expanding the SSFM dataset for CERES ADM validation

Summary

- CERES TOA SW flux uncertainties
  - global mean uncertainty is less than 0.2 Wm^{-2}
  - instantaneous uncertainty is 15~18 Wm^{-2}
- CERES TOA LW flux uncertainties
  - global mean uncertainty is less than 0.4 Wm^{-2}
  - instantaneous uncertainty is 3~6 Wm^{-2}
- Clear-sky SW flux consistency tests show little dependence on aerosol optical depth over ocean and land
- LW flux uncertainty from scene identification is about 1 Wm^{-2}
- Global mean SW flux from SNPP is higher than that from Aqua by 2~3%, consistent with the SW radiance difference between SNPP and Aqua.
- LW fluxes from SNPP and Aqua are within 0.1%.