Toward producing a level 4 surface (EBAF) gridded monthly irradiance product

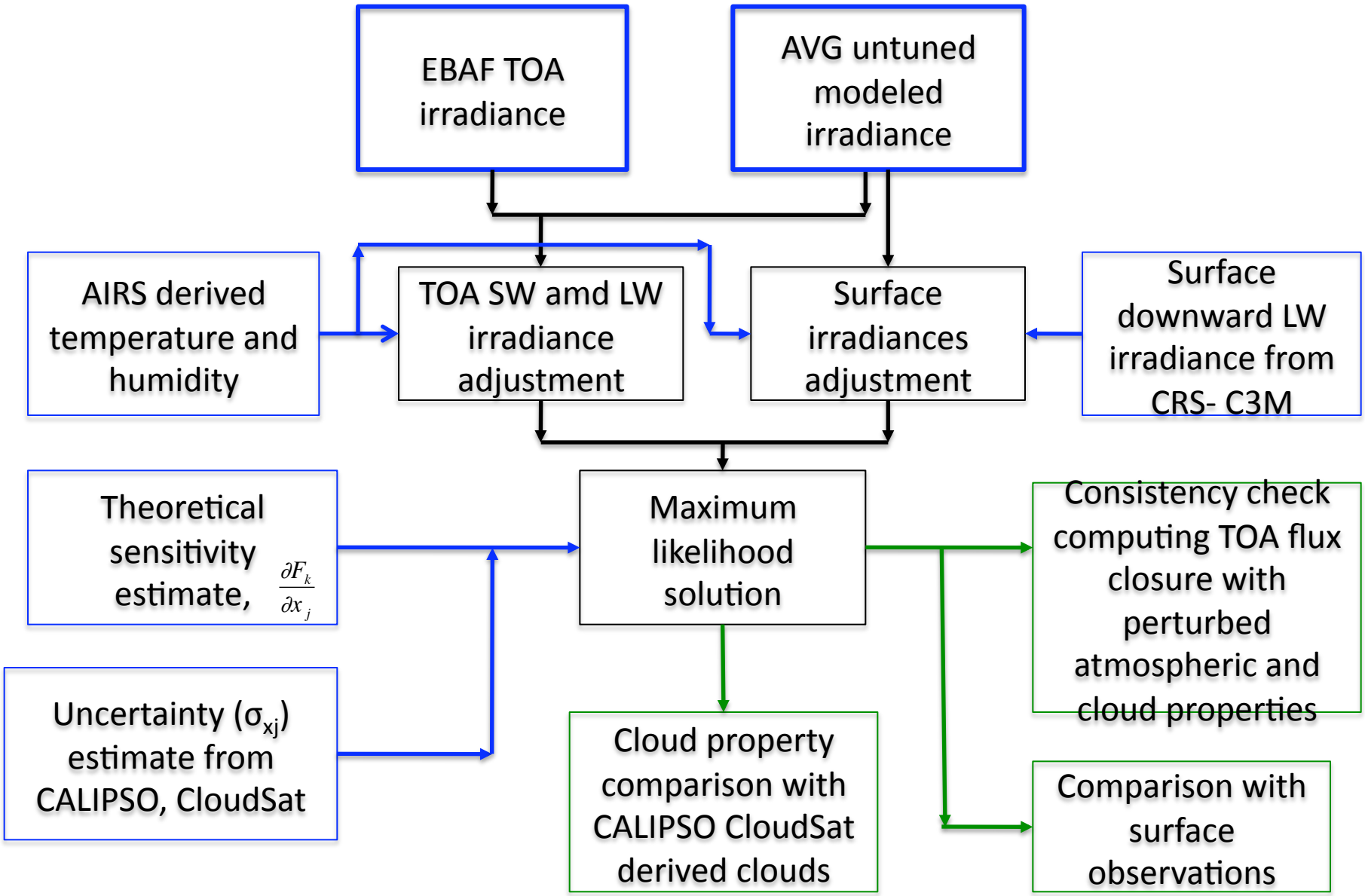
Seiji Kato, Fred Rose, Norman Loeb, David Doelling, Sunny Sun-Mack, Walt Miller,

Yan Chen, and David Rutan

Objectives of surface EBAF product

- Generate a Level 4 surface irradiance monthly gridded product that is consistent with the TOA irradiance adjustment used in the TOA EBAF product.
- Adjustment needs to be within the uncertainty of surface irradiances.
- Irradiance adjustments are achieved by adjusting atmospheric and cloud properties using a radiative transfer model (e.g. achieve consistency among atmospheric and cloud properties and irradiances).

Flow chart of the process

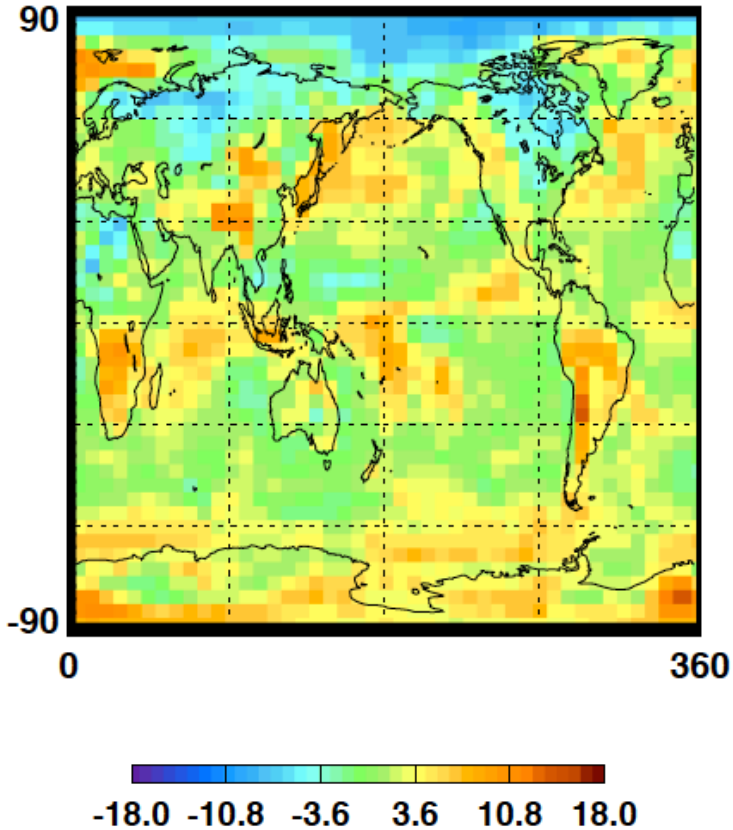


TOA and surface flux adjustments

- Use AVG untuned surface irradiances as initial values
- Difference between AVG untuned TOA SW and LW fluxes and EBAF (TOA) are adjustments.
- Further adjustments are added using the difference between AIRS derived upper tropospheric humidity and the upper tropospheric relative humidity from MOA converted to TOA and surface fluxes.
- Difference of the surface downward longwave irradiance computed with and without CALIPSO and CloudSat us used as adjustments

AVG (Ed 2) versus EBAF

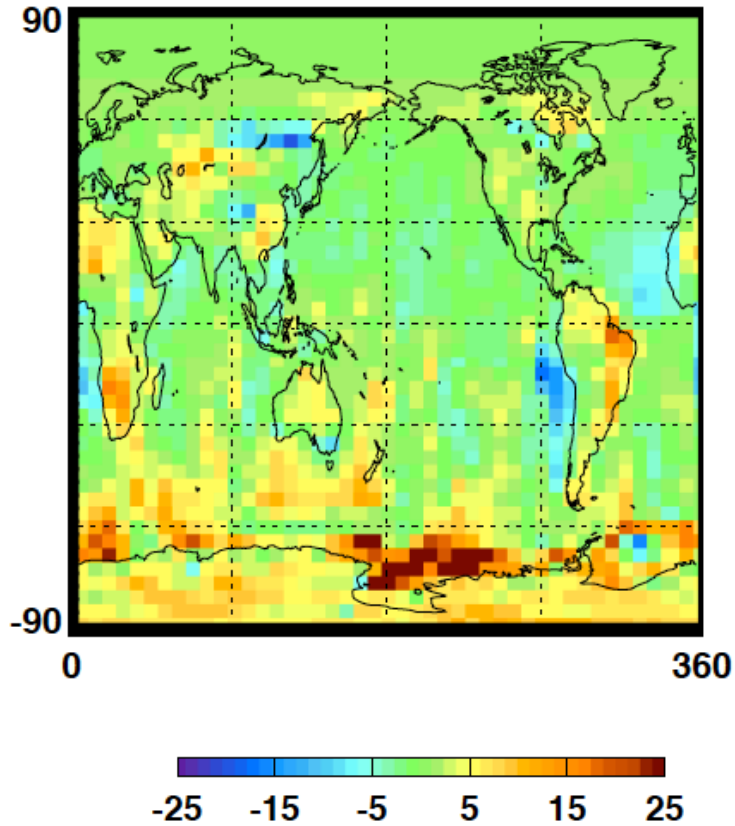
LW TOA, AVG – EBAF (200301)



N= 44012.

Mean (StdDev)
1.86(3.74)

SW TOA, AVG – EBAF (200301)

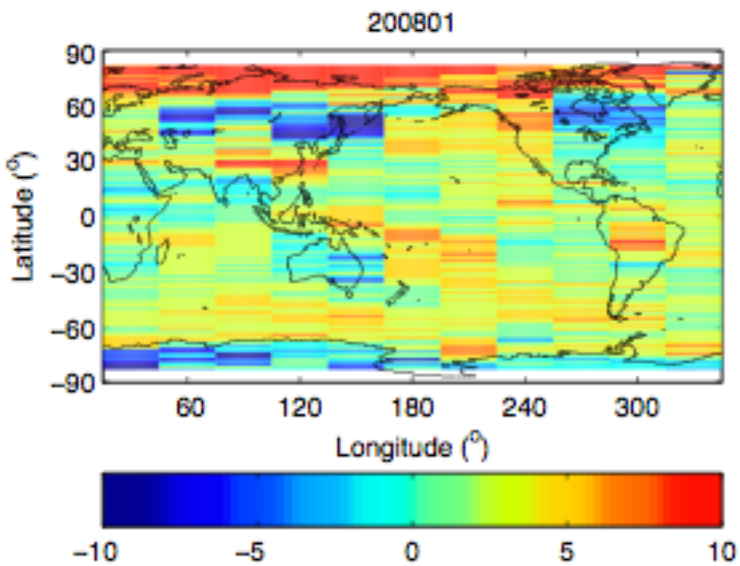


N= 44012.

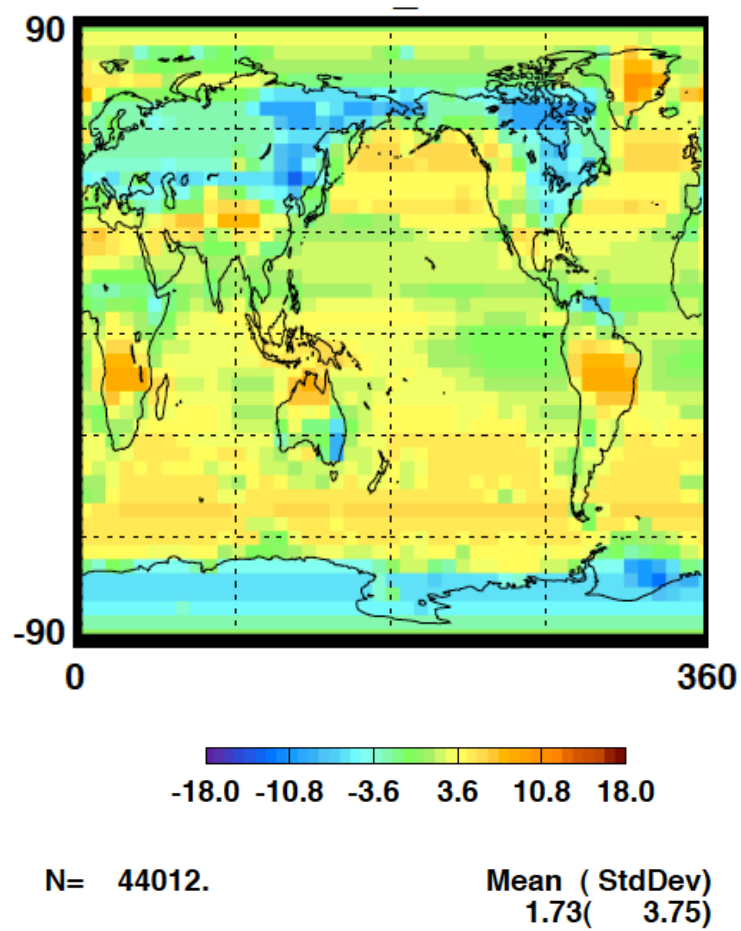
Mean (StdDev)
0.943(5.90)

Surface downward longwave irradiance

Without CALIPSO & CloudSat
- With CALIPSO & CloudSat



Surface LW down constraint derived
From monthly, 1°zonal cloud type
dependent table

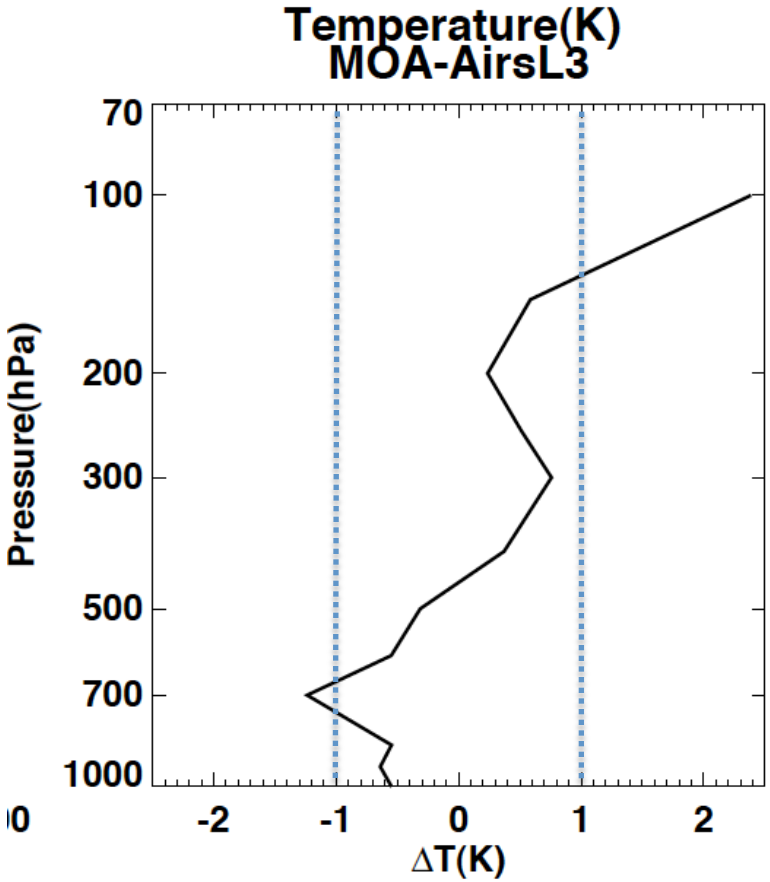


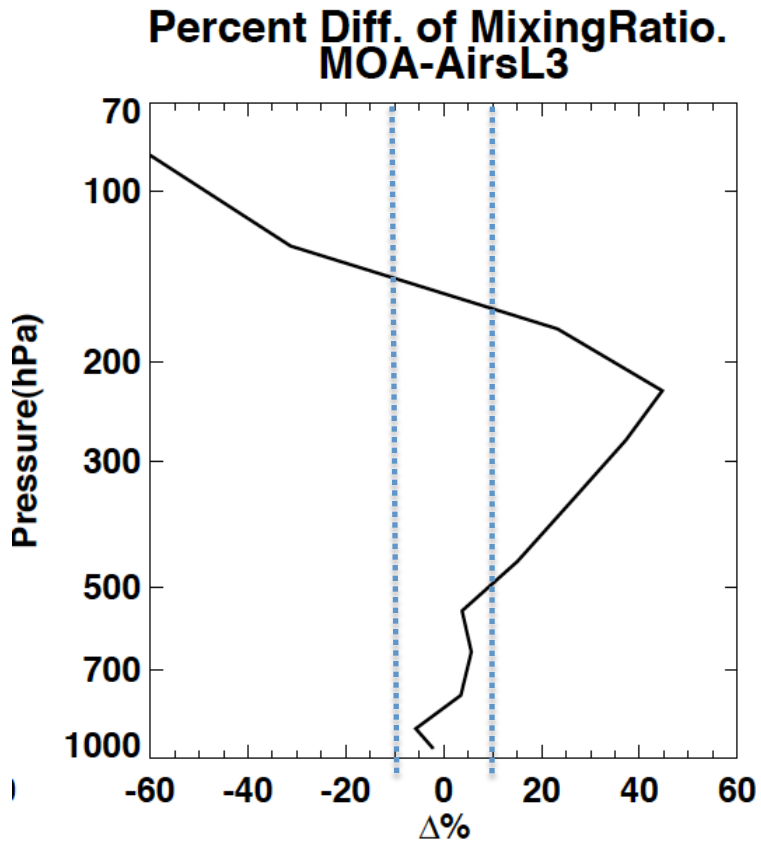
Adjusting algorithm

- Set up 6 equations, $\Delta F = \mathbf{a}^{\mathrm{T}}\mathbf{x}$ for TOA SW up and TOA LW up, Surface SW up and down, and Surface LW up and down, where elements of **a** are flux sensitivity and **x** is perturbed amount of atmospheric and cloud properties.

Irradiance	ΔF
TOA SW up	AVG (monthly 1°×1°) – EBAF TOA
TOA LW up	AVG (monthly 1°×1°) – EBAF TOA
Surface SW up	0
Surface SW down	0
Surface LW up	0
Surface LW down	CRS-CCCM (monthly, cloud, land/ocean)

MOA versus Airs (200301, 0 to 10°S)

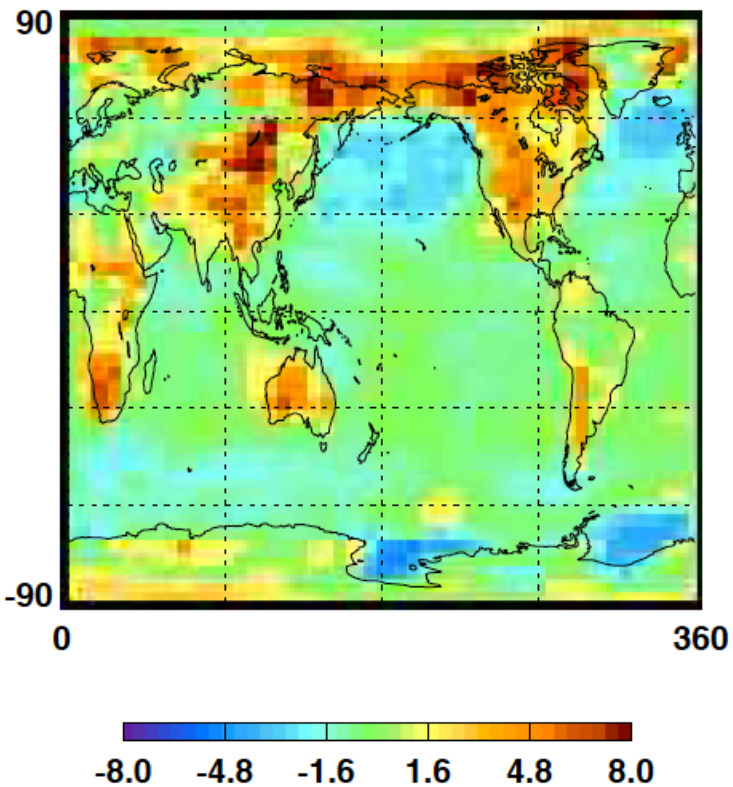




AIRS goal: Air temperature 1K RMS in 1 km layer below 100 hPa
water vapor concentration 10% RMS in 2 km layer below 100 hPa

MOA versus AIRS (cont.)

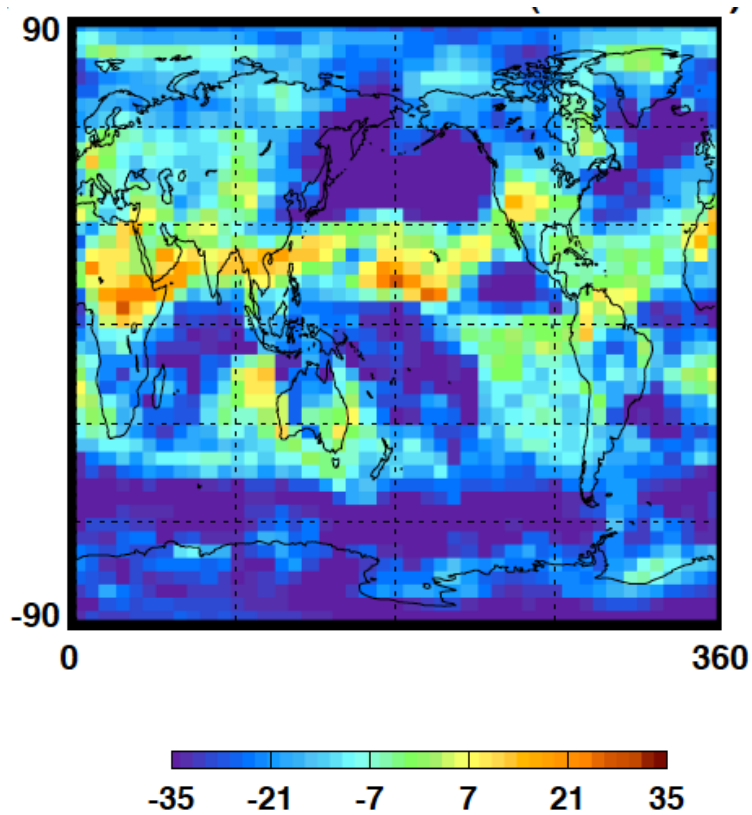
Surface air temp. AIRS - MOA



N= 44012.

Mean (StdDev)
0.098(2.22)

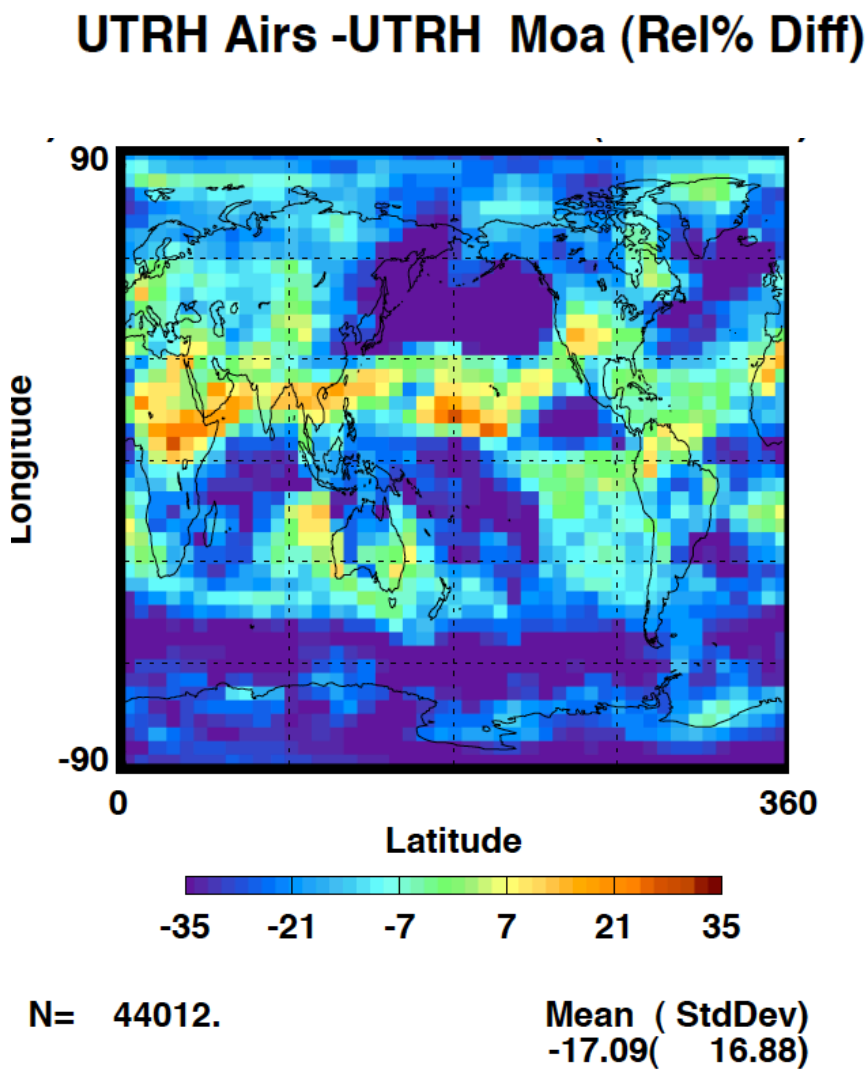
Upper Trop. WV, 100×(AIRS-MOA) / AIRS



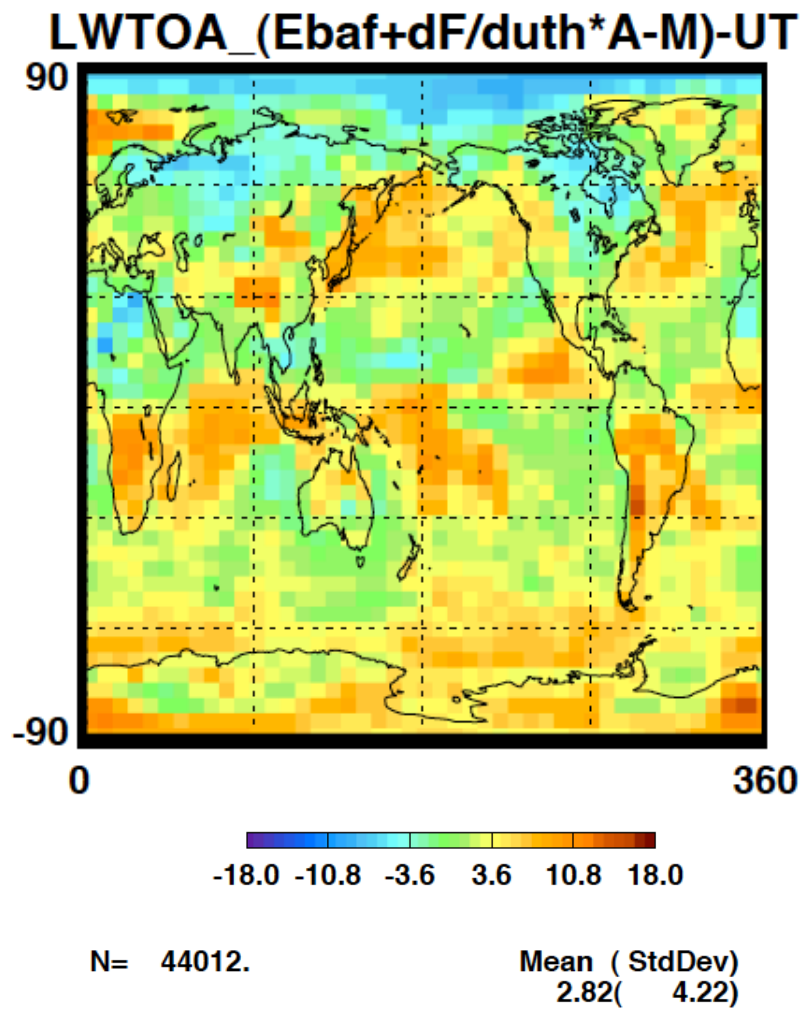
N= 44012.

Mean (StdDev)
-17.09(16.88)

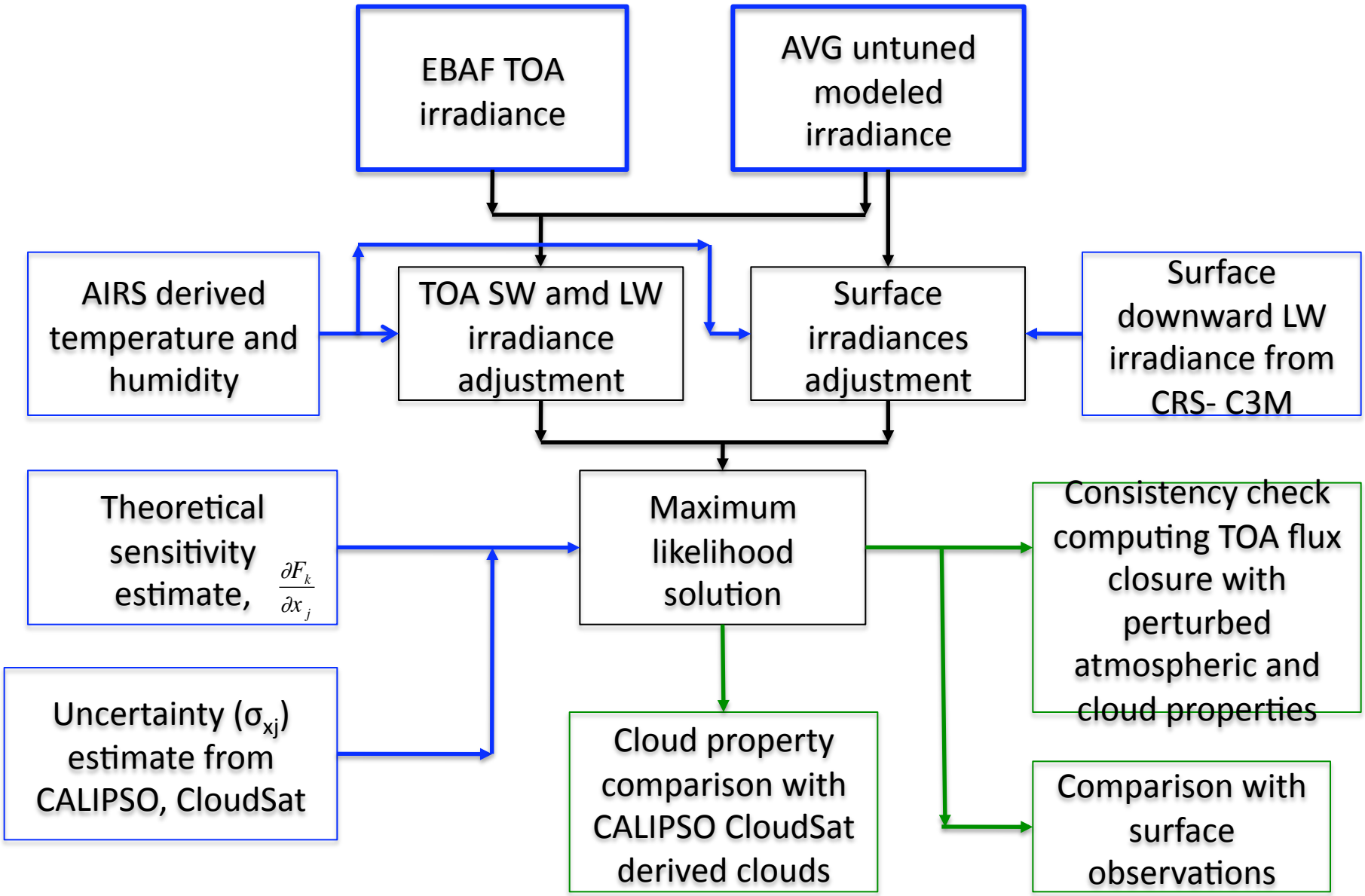
Upper tropospheric relative humidity change



Including the UTRH difference contribution to TOA LW



Flow chart of the process



Adjusting algorithm (cont.)

- Given 6 equations and uncertainties for key atmospheric and cloud properties, obtain the maximum likelihood solution (minimum of the sum of the square of the perturbation divided by the uncertainty and Lagrangian multiplier terms) of atmospheric and cloud properties.
- Compute flux changes using the atmospheric and cloud property solution by, $\Delta\hat{F} = \mathbf{a}^{\mathrm{T}}\mathbf{x}$ (algorithm is used for CRS and TOA EBAF).
- Add $\Delta\hat{F}$ to AVG monthly 1°×1° fluxes.

Constraints and uncertainties

Atmospheric and cloud properties	Source	
Skin temperature[1]	MODIS, CALIPSO, CloudSat	Uncertainty[3]
Surface air temperature[1]	0.5 × Skin temp. uncertainty	Uncertainty[3]
Precipitable water[2]	AIRS	Uncertainty[3]
Upper tropospheric relative humidity[2]	AIRS	Constraint
Cloud fraction[1]	CALIPSO, CloudSat	Uncertainty
Cloud optical thickness[1]	MODIS, CALIPSO, CloudSat	Uncertainty
Cloud top height[1]	CALIPSO, CloudSat	Uncertainty
Cloud base height[1]	CALIPSO, CloudSat	Uncertainty
Surface LW down irradiance[1]	MODIS, CALIPSO, CloudSat	Constraint
Surface SW down irradiance[1]	MODIS, CALIPSO, CloudSat	Uncertainty
Surface SW up irradiance[1]	MODIS, CALIPSO, CloudSat	Uncertainty

Uncertainty tables:

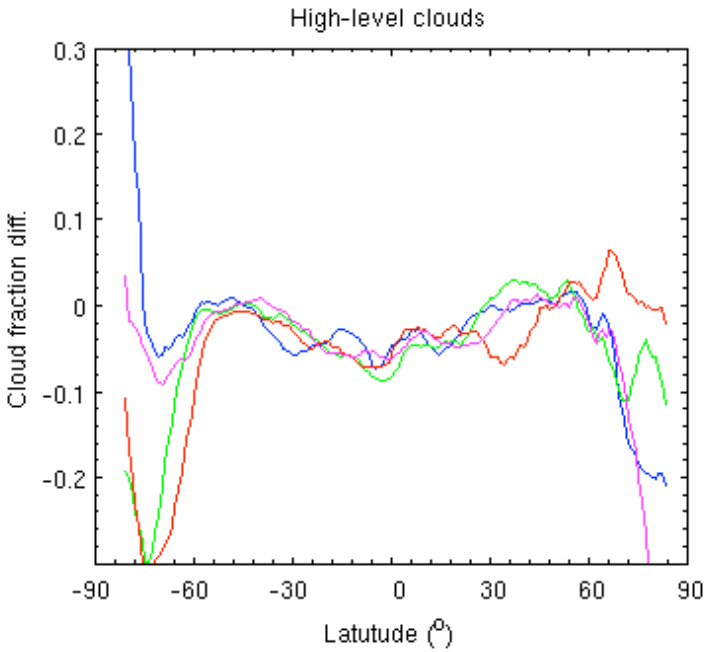
[1] Clear, high-, mid-, and low-level clouds Land and ocean, monthly 1° zonal

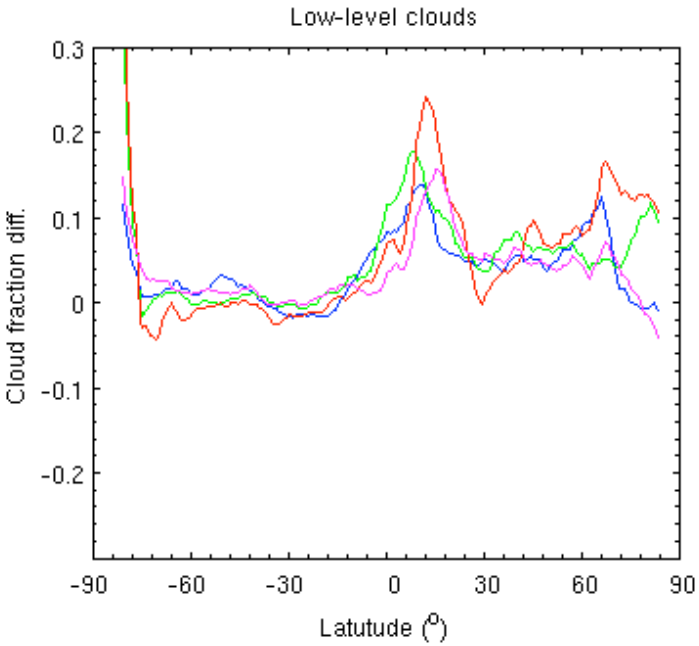
[2] 1°×1° monthly

[3] become constraints in the future work

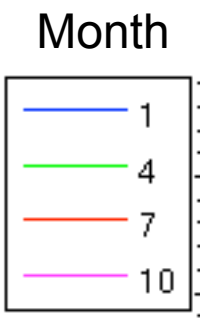
Aerosol optical thickness uncertainty is also treated

Uncertainty (cloud fraction)
MODIS – (CALIPSO+CloudSat)



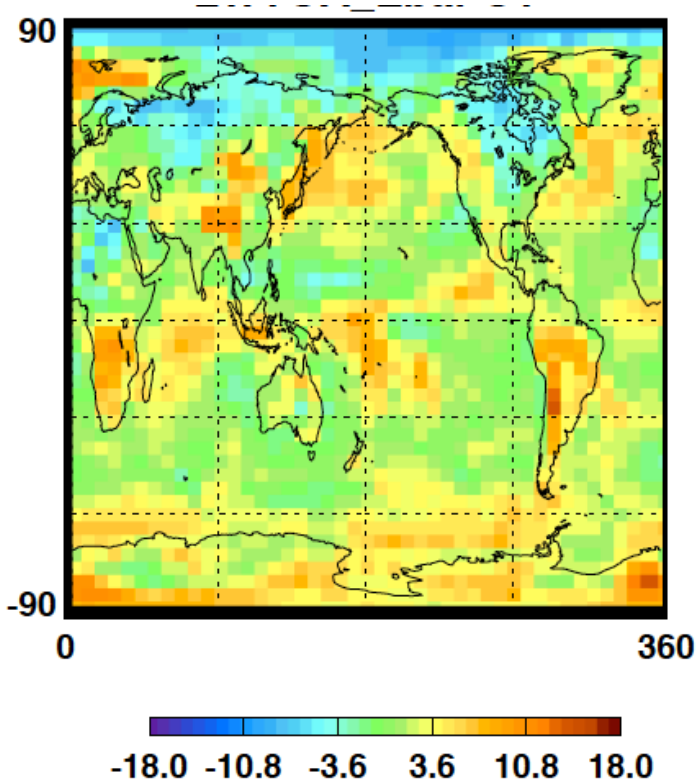


Regions with a large uncertainty allow to have a larger adjustment



Adjusted TOA LW (200301)

EBAF – AVG (200301)

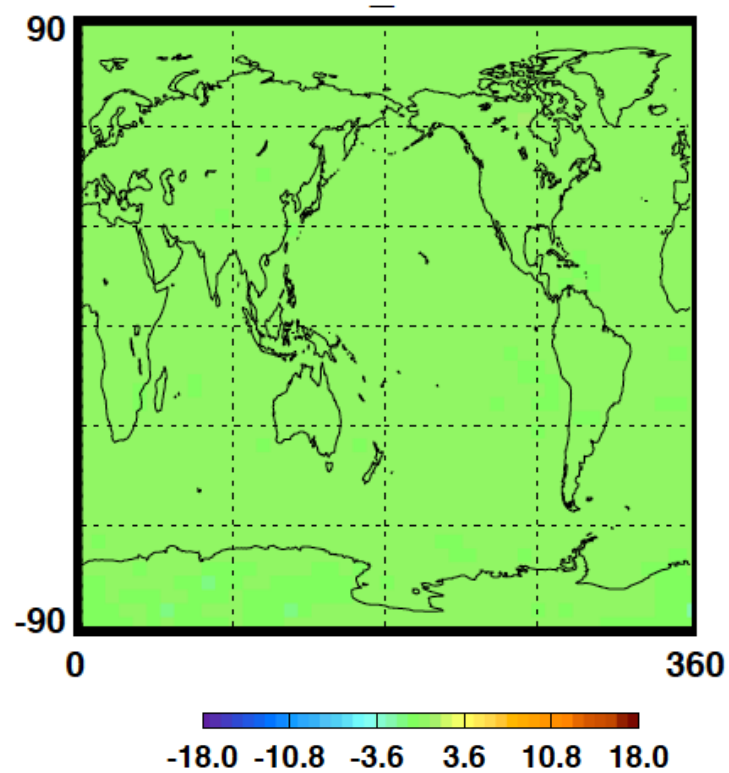


N= 44012.

Mean (StdDev)
1.86(3.74)

Before adjustment 234 Wm-2

EBAF – AVG adjusted



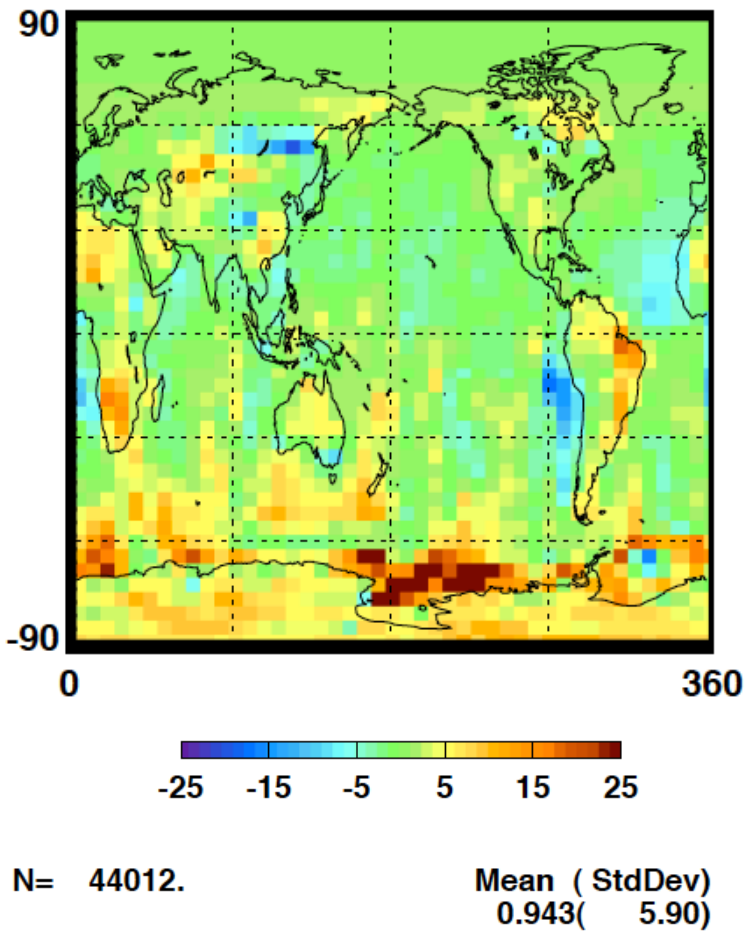
N= 44012.

Mean (StdDev)
-0.012(0.169)

After adjustment 236 Wm-2

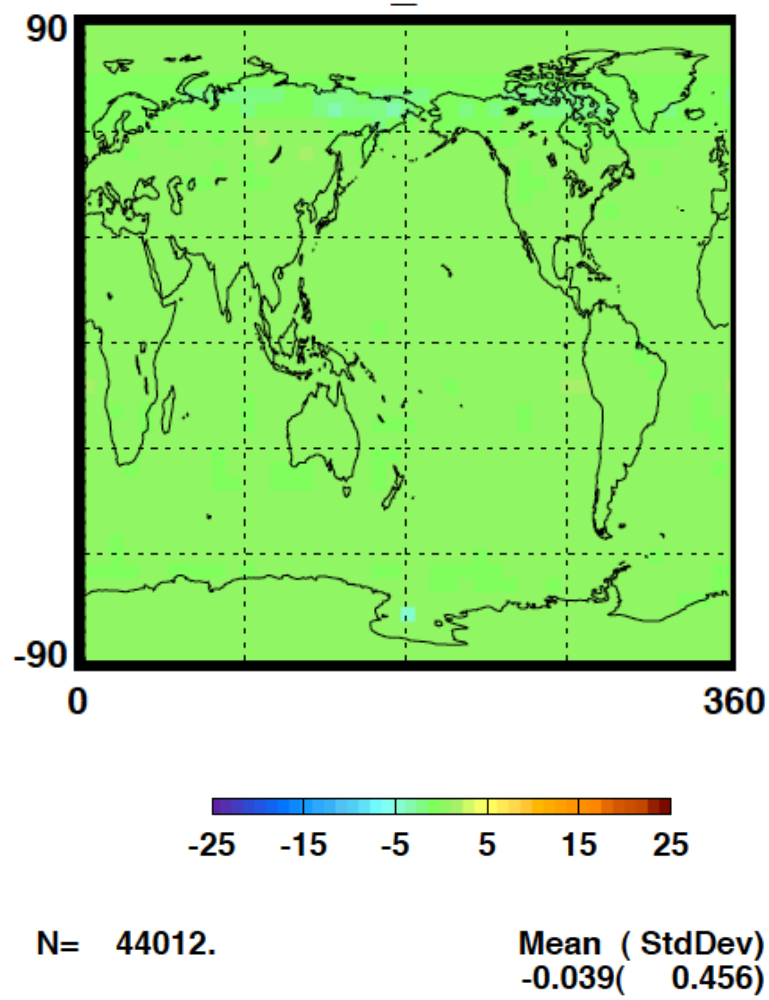
Adjusted TOA SW (200301)

EBAF – AVG (200301)



Before adjustment 102 Wm-2

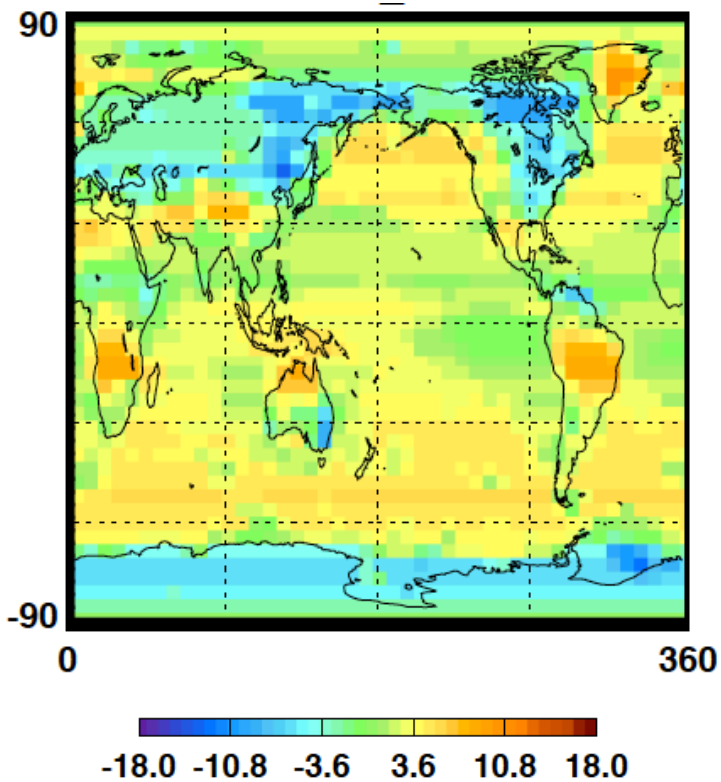
EBAF – AVG adjusted



After adjustment 103 Wm-2

Adjusted surface downward LW flux (200301)

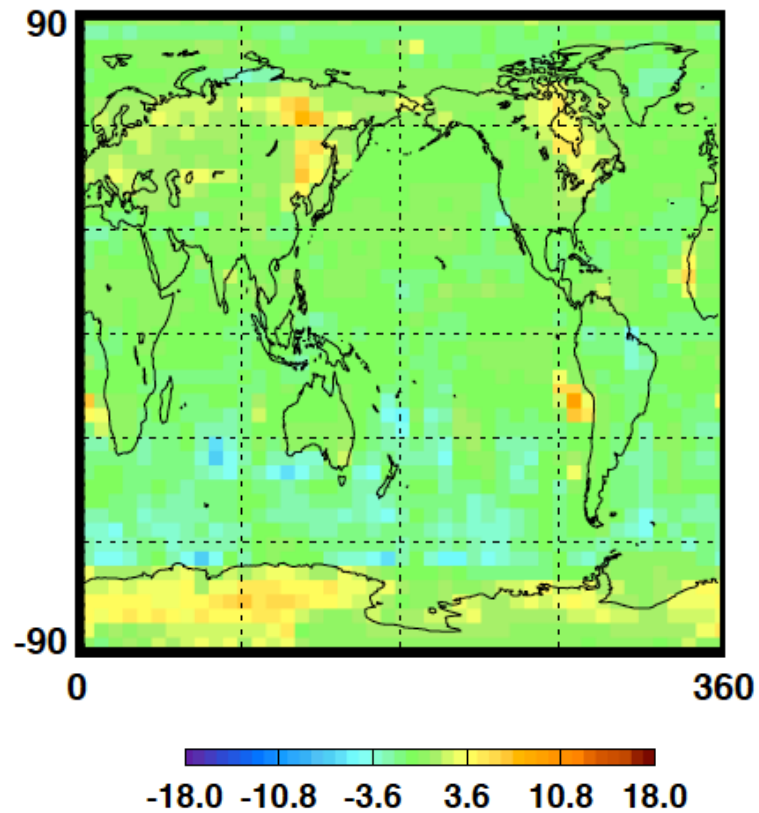
Downward LW added to AVG



N= 44012.

Mean (StdDev)
1.73(3.75)

Added LW – Adjusted LW



N= 44012.

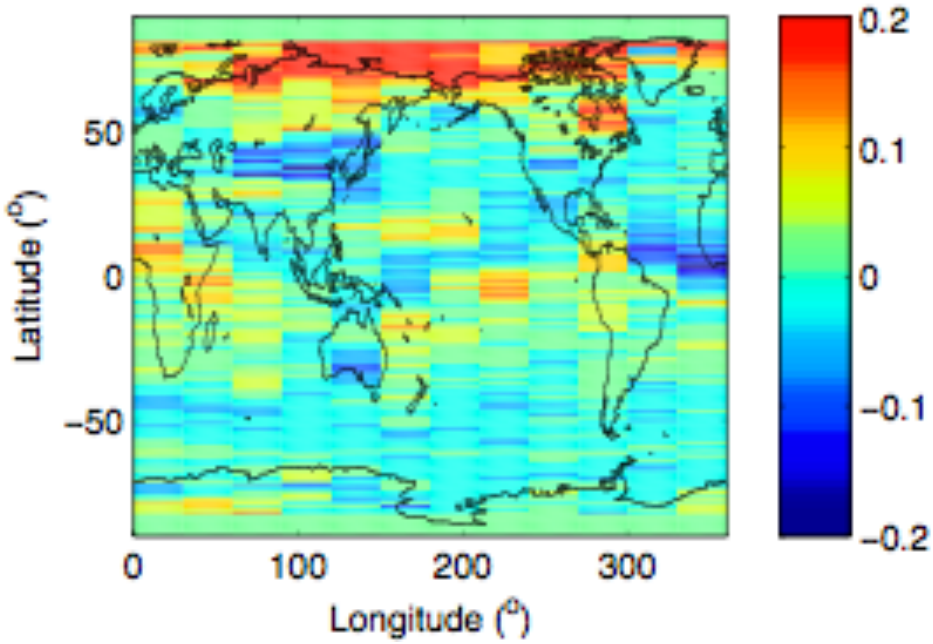
Mean (StdDev)
-0.414(1.98)

Before the tune 334 Wm-2

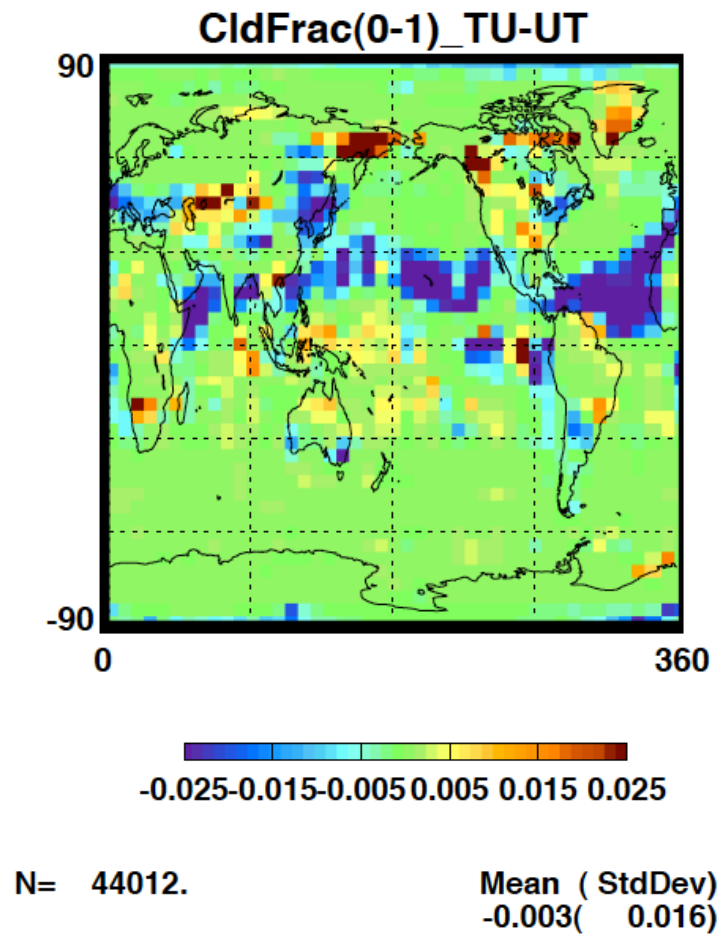
After the tune, 336 Wm-2

Cloud fraction change (200301)

CALIPSO CloudSat - MODIS



After – before adjustments



Summary

- Surface EBAF (L4) product will be generated using AIRS derived air temperature and humidity, CALIPSO, CloudSat, and MODIS derived skin temperature and cloud properties.
- Surface downward longwave irradiance computed with CALIPSO, CloudSat derived clouds is also used to constrain the model.
- Need further study to check the effect of GEO derived cloud properties and AIRS algorithm

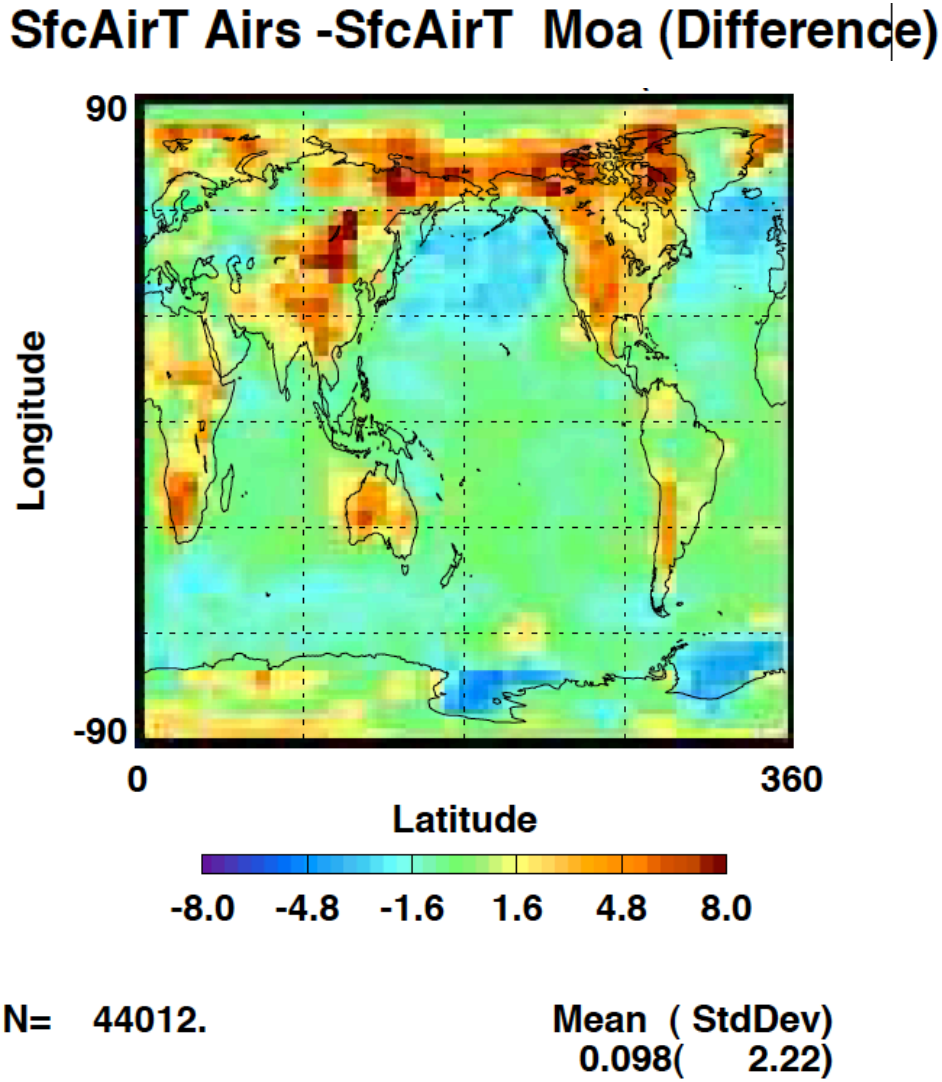
Back-ups

Adjusting algorithm

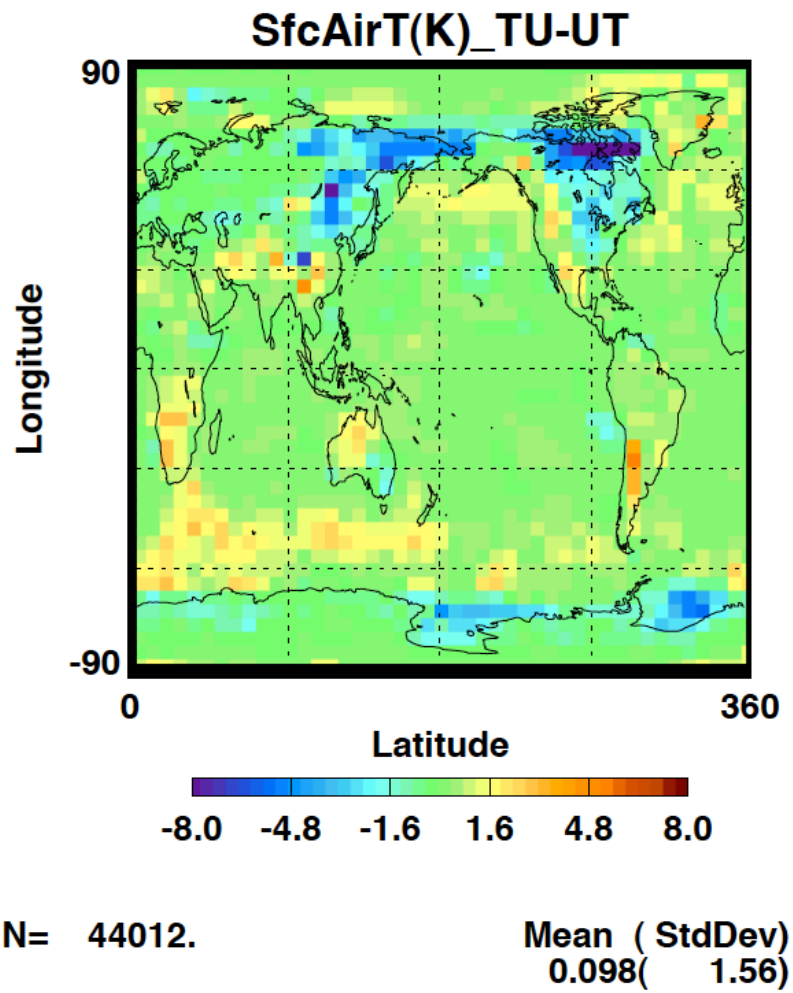
- Set up 6 equations, $\Delta F = \mathbf{a}^{\mathrm{T}}\mathbf{x}$ for TOA SW up and TOA LW up, Surface SW up and down, and Surface LW up and down, where elements of **a** are flux sensitivity and **x** is perturbed amount of atmospheric and cloud properties.

	ΔF	Uncertainty
TOA SW up	AVG (monthly 1°×1°) – EBAF TOA	0.5 Wm^{-2}
TOA LW up	AVG (monthly 1°×1°) – EBAF TOA	0.5 Wm^{-2}
Surface SW up	0	CRS-CCCM relative diff.
Surface SW down	0	CRS-CCCM relative diff.
Surface LW up	0	2wm^{-2} (ocean), elsewhere 10Wm^{-2}
Surface LW down	CRS-CCCM (monthly, cloud, land/ ocean)	5 Wm^{-2}

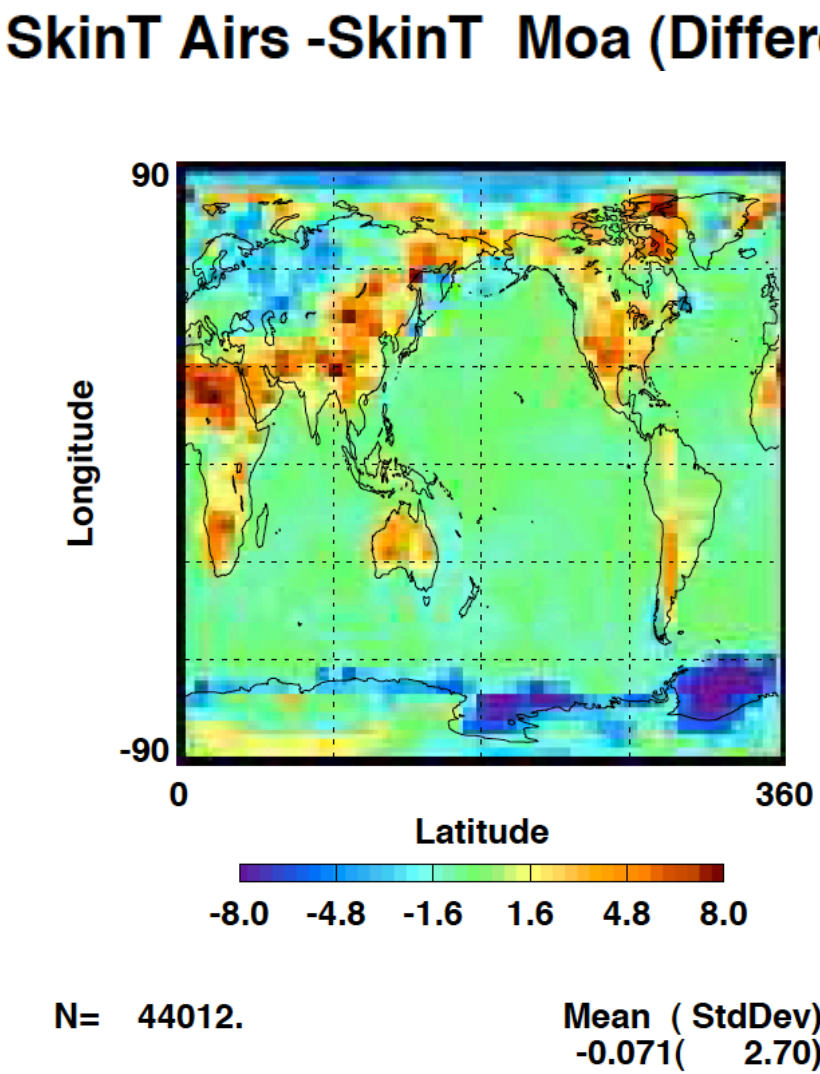
Surface air temperature change

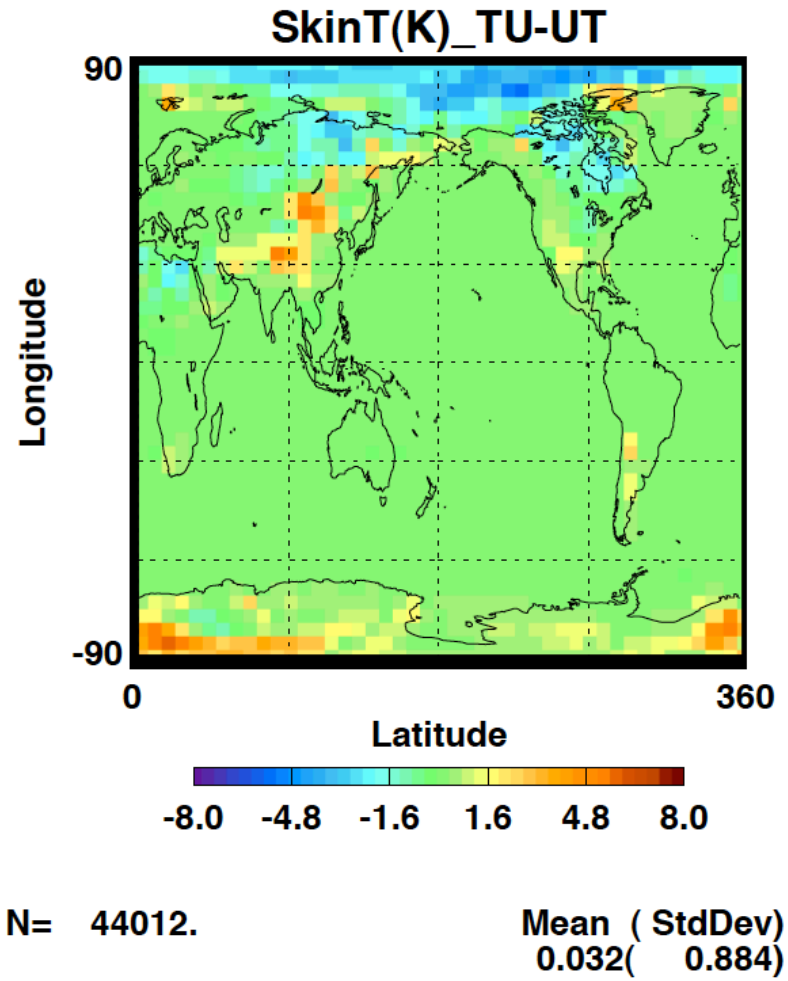


After – before adjustment



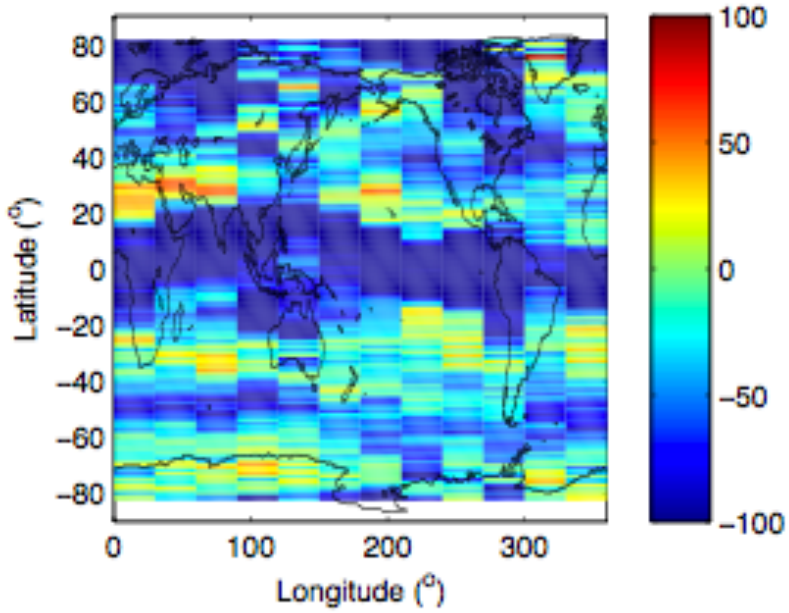
Skin temperature change

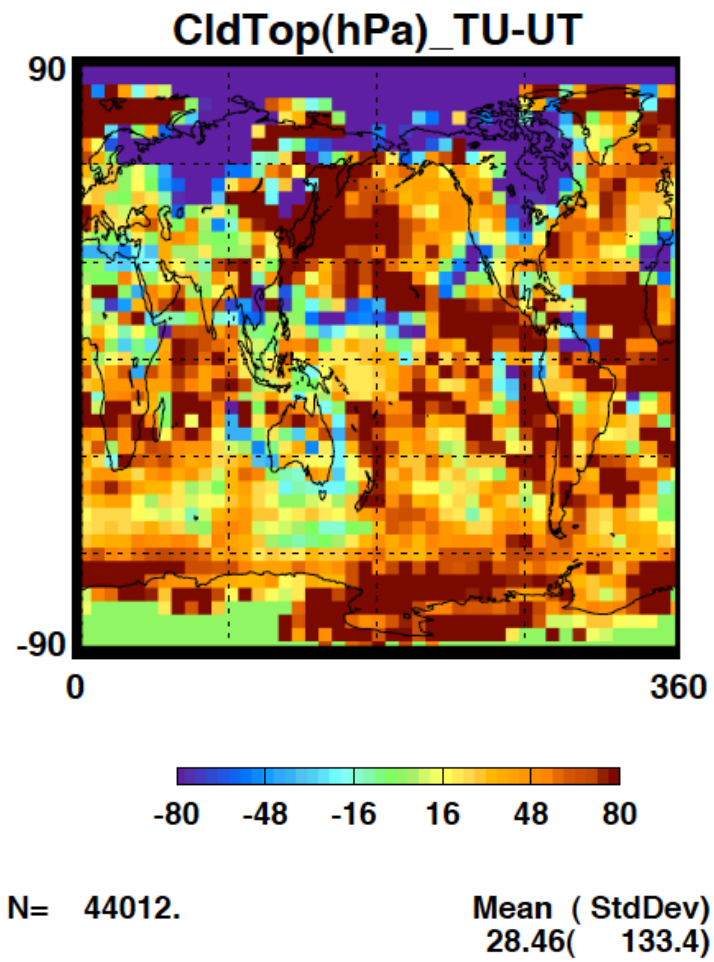




Cloud top height change

CALIPSO CloudSat – MODIS (hPa)





Cloud base height change

CALIPSO CloudSat – MODIS (hPa)