MERRA-2/AIRS/MODIS Temperature/Humidity Comparisons

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NASA Langley Research Center, Hampton, VA
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Outline

- Clear Sky OLR and Surface LW Down sensitivity to temperature and humidity
- Level by Level GMAO and ERA-I .vs. Airs (T&Q)
- Skin Temperature
  - Airs , Modis
- Sfc Air Temperature
  - Airs, CRU
- Ed4_SYNI (G541,MERRA2_Airs,MERRA2_NOAirs)
  - Clear and Total Sky OLR,ULF,DLF
  - Model –Obs Clear OLR
- Chou and Fu-Liou LW code biases

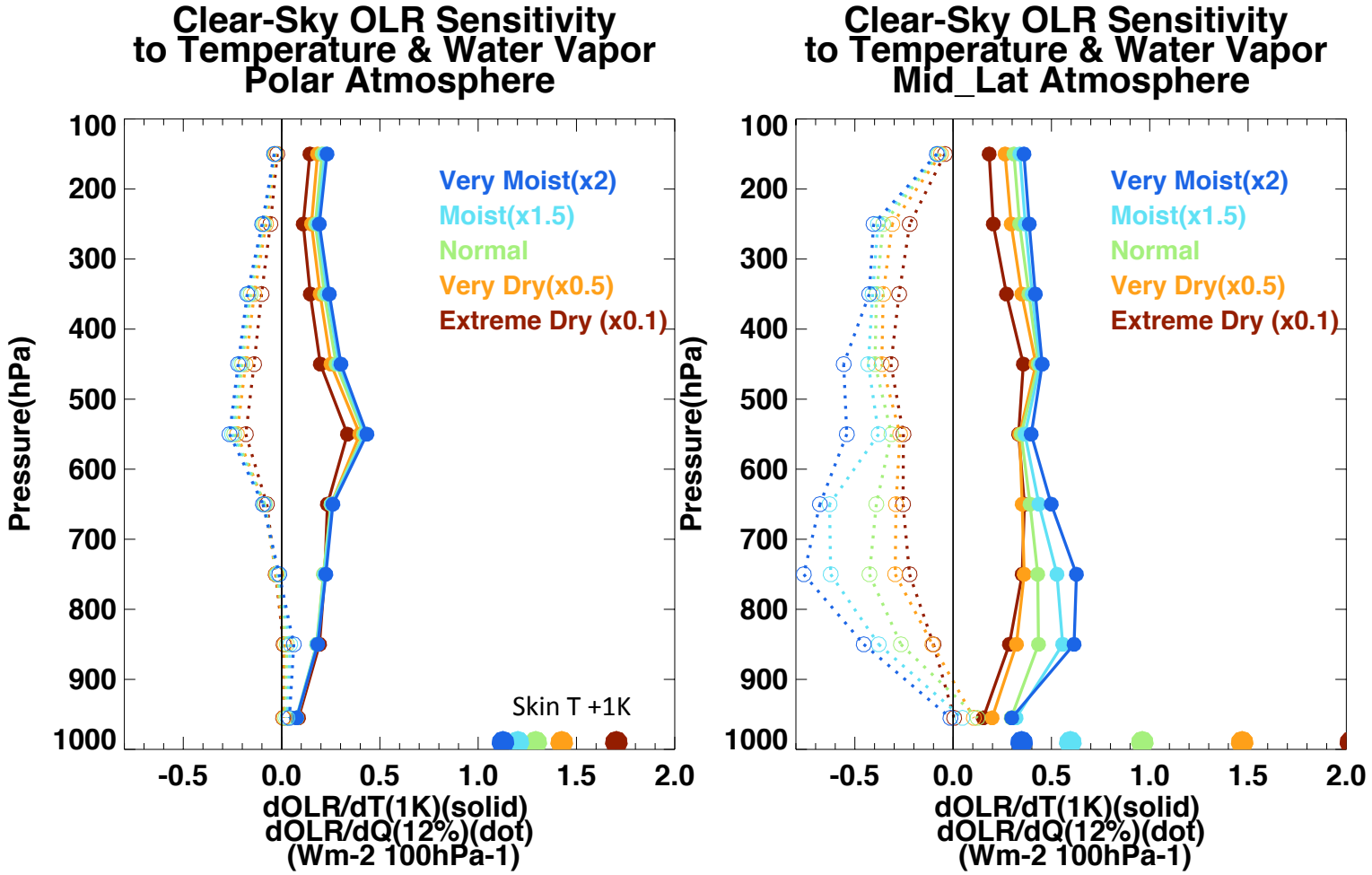
Clear Sky TOA and SFC Longwave Sensitivity to Water Vapor and Temperature Perturbations.

Clear Sky Outgoing Longwave Sensitivity

Fu-Liou code for a wide range of temperature and water vapor conditions.

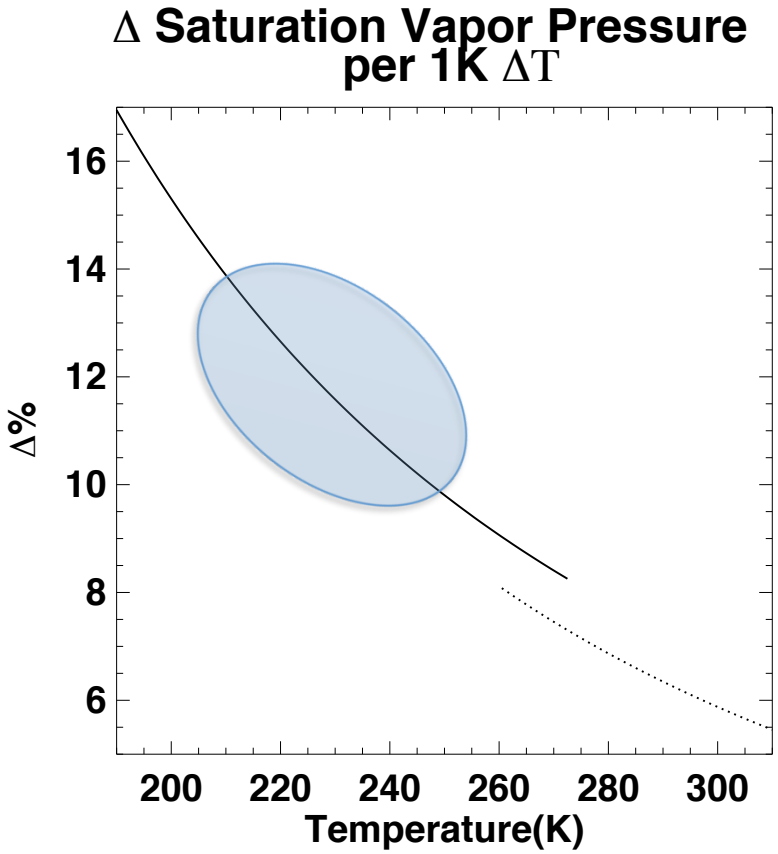
For a 100hPa thick layer : ΔT 1.0 K -or- ΔQ -12% = 0.4 Wm^{-2} ΔClear Sky OLR

ΔT 2.5 K -or- ΔQ -30% = 1.0 Wm^{-2}



Interestingly / Coincidently

- The Clausius–Clapeyron relationship gives roughly a ~12% increase in saturation vapor pressure per 1K temperature increase in the upper troposphere.
- So a line of constant relative humidity in dQ /dT error space over a 100hPa thick layer would be similar to that of constant Clear Sky OLR

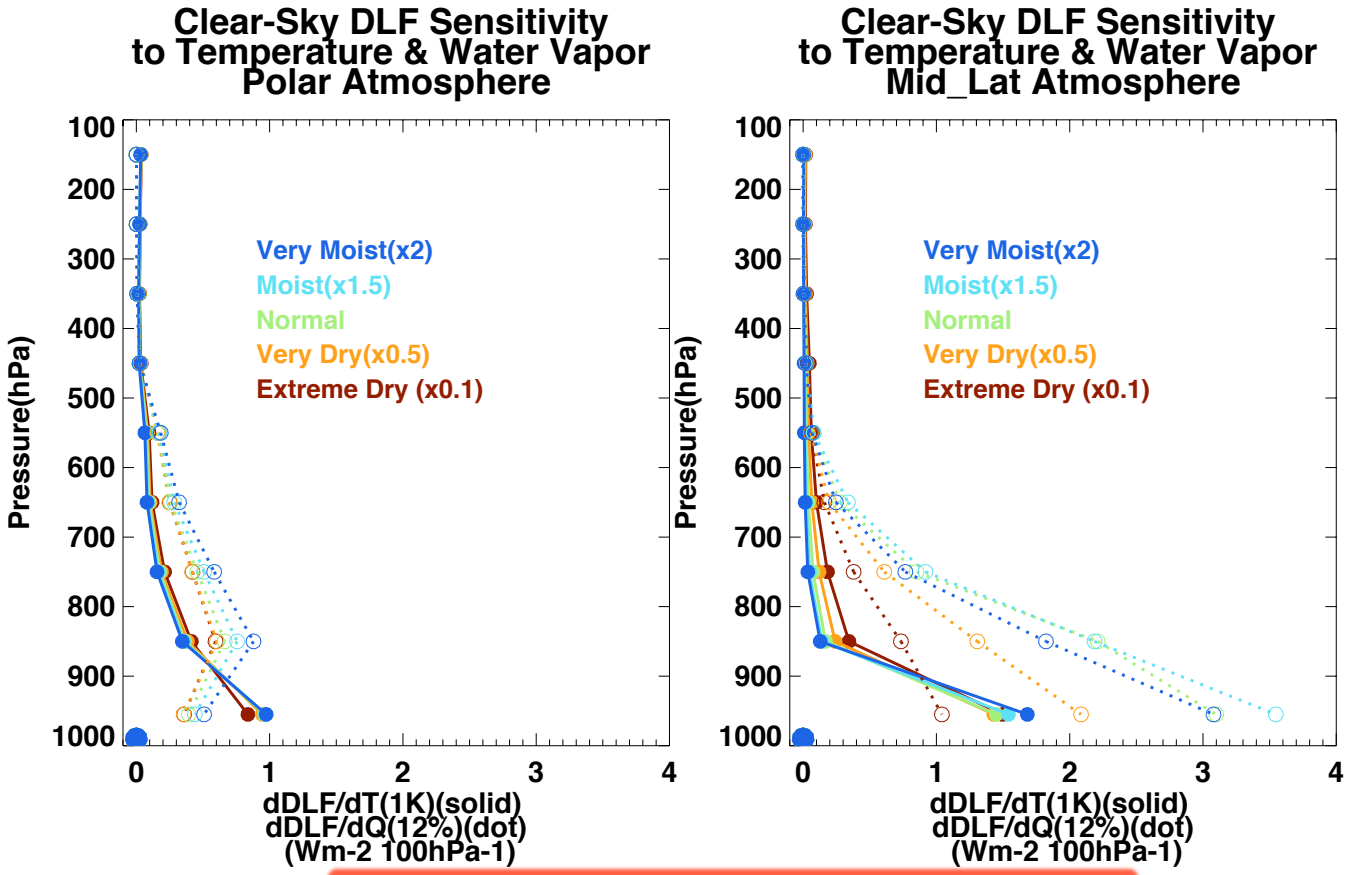


Clear Sky Surface Downward Longwave Sensitivity

Fu-Liou code for a wide range of temperature and water vapor conditions.

Clear DLF is most sensitive to lower troposphere T & Q , near surface has largest sensitivity.

Later we adopt Dilley & O'Brien parameterization of Clear DLF sensitivity which uses surface air temperature and total precipitable water differences.



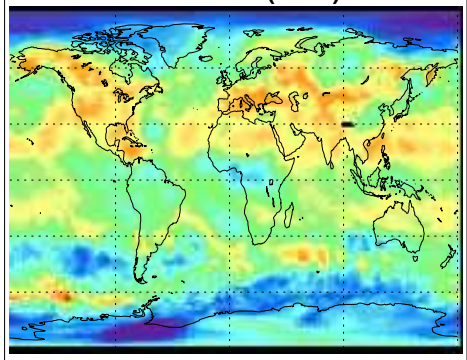
$$\Delta \mathrm{DLR} = 6\beta\left(\frac{T}{T_*}\right)^5\frac{\Delta T}{T_*} + \frac{1}{2}\gamma\left(\frac{w}{w_*}\right)^{-1/2}\frac{\Delta w}{w_*}. \qquad (2)$$

Comparison of
GEOS 5.4.1
MERRA2(with Airs)
MERRA2(No Airs)
to AIRS Product AIRX3STM.006
TQ Joint Temperature / Humidity
Retrievals (Single Month JULY 2004)

ΔT(K) @ 200 hPa

200407 Cloud Mask = 90%

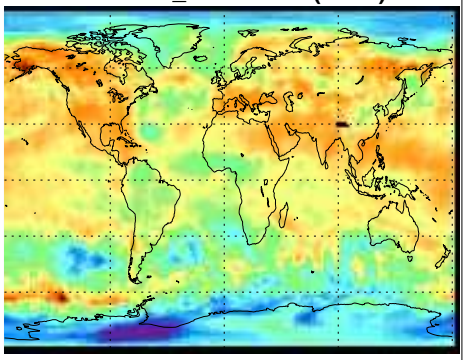
G541 - AIRS(V006)



-2.5 -1.5 -0.5 0.5 1.5 2.5
Δ T(K)

N= 43996. Mean (StdDev)
Δ T(K) 0.006 (0.659)

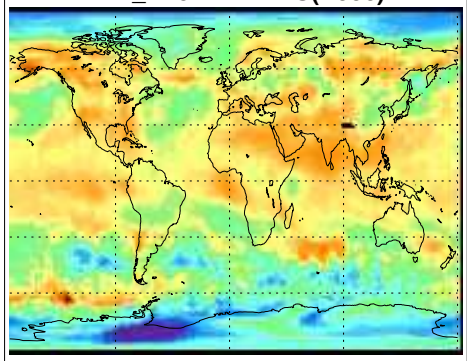
MERRA2_airs - AIRS(V006)



-2.5 -1.5 -0.5 0.5 1.5 2.5
Δ T(K)

N= 43996. Mean (StdDev)
Δ T(K) 0.403 (0.607)

ERA_Interim - AIRS(V006)



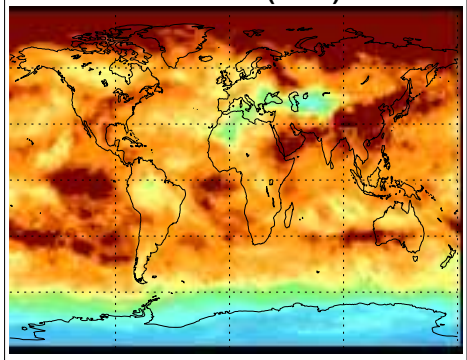
-2.5 -1.5 -0.5 0.5 1.5 2.5
Δ T(K)

N= 43996. Mean (StdDev)
Δ T(K) 0.411 (0.562)

ΔQ(%) @ 200 hPa

200407 Cloud Mask = 90%

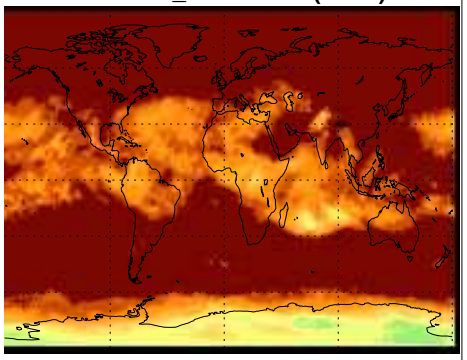
G541 - AIRS(V006)



-100 -60 -20 20 60 100
Δ Q(%)

N= 43996. Mean (StdDev)
Δ Q(%) 53.3 (34.4)

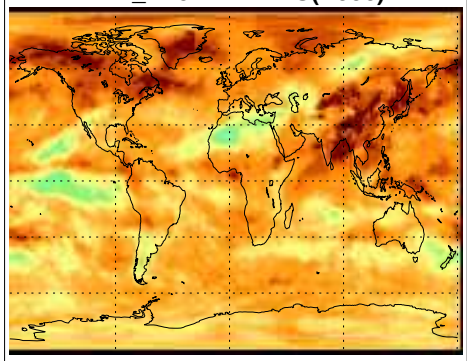
MERRA2_airs - AIRS(V006)



-100 -60 -20 20 60 100
Δ Q(%)

N= 43996. Mean (StdDev)
Δ Q(%) 107. (47.3)

ERA_Interim - AIRS(V006)



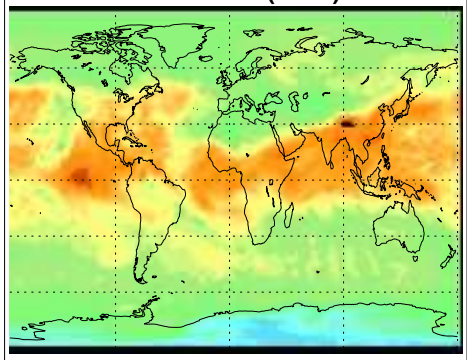
-100 -60 -20 20 60 100
Δ Q(%)

N= 43996. Mean (StdDev)
Δ Q(%) 47.5 (21.2)

ΔRH @ 200 hPa

200407 Cloud Mask = 90%

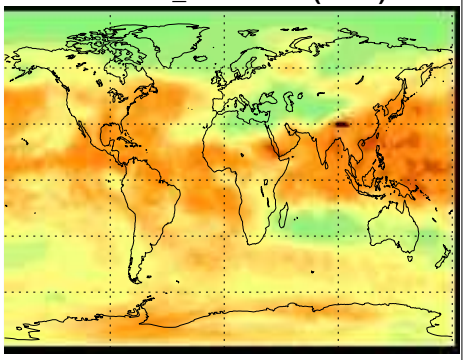
G541 - AIRS(V006)



-60 -36 -12 12 36 60
Δ RelHum(%)

N= 43996. Mean (StdDev)
Δ RelHum(%) 12.3 (11.5)

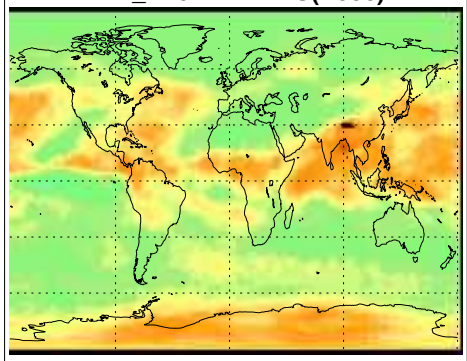
MERRA2_airs - AIRS(V006)



-60 -36 -12 12 36 60
Δ RelHum(%)

N= 43996. Mean (StdDev)
Δ RelHum(%) 19.4 (10.8)

ERA_Interim - AIRS(V006)



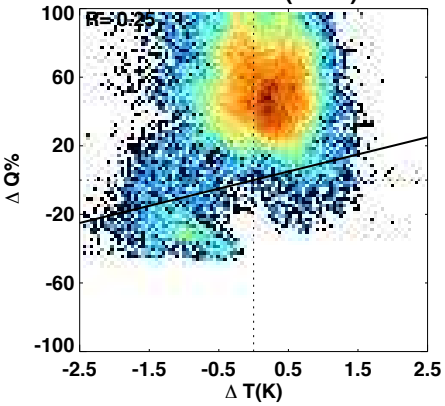
-60 -36 -12 12 36 60
Δ RelHum(%)

N= 43996. Mean (StdDev)
Δ RelHum(%) 10.3 (9.30)

Δ Q% vs Δ T(K) @ 200 hPa

200407 Cloud Mask = 90%

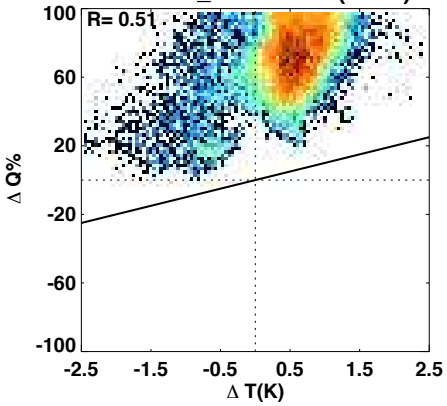
G541 - AIRS(V006)



0.000 0.395 0.789 1.184 1.579 1.973
Log10(Population)

N= 43996. Mean (StdDev)
Δ T(K) 0.006 (0.659)
Δ Q% 53.3 (34.4)

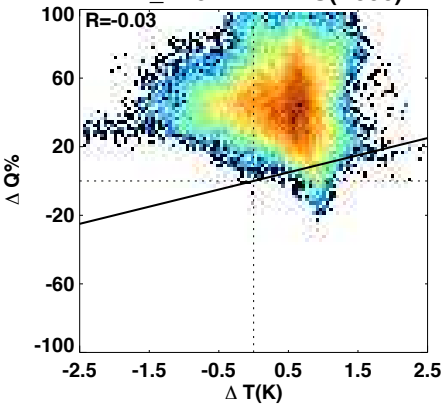
MERRA2_airs - AIRS(V006)



0.00 0.37 0.74 1.11 1.49 1.86
Log10(Population)

N= 43996. Mean (StdDev)
Δ T(K) 0.403 (0.607)
Δ Q% 107. (47.3)

ERA_Interim - AIRS(V006)



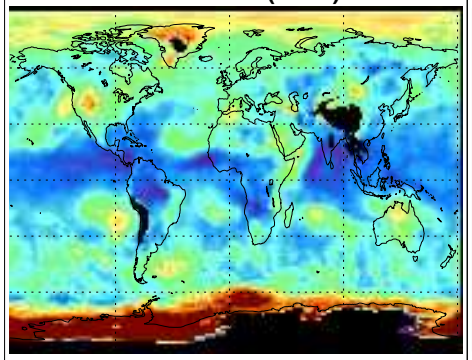
0.00 0.42 0.83 1.25 1.67 2.09
Log10(Population)

N= 43996. Mean (StdDev)
Δ T(K) 0.411 (0.562)
Δ Q% 47.5 (21.2)

ΔT(K) @ 700 hPa

200407 Cloud Mask = 90%

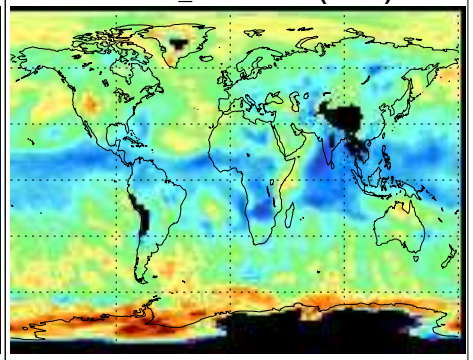
G541 - AIRS(V006)



-2.5 -1.5 -0.5 0.5 1.5 2.5
Δ T(K)

N= 42981. Mean (StdDev)
Δ T(K) -0.678 (0.945)

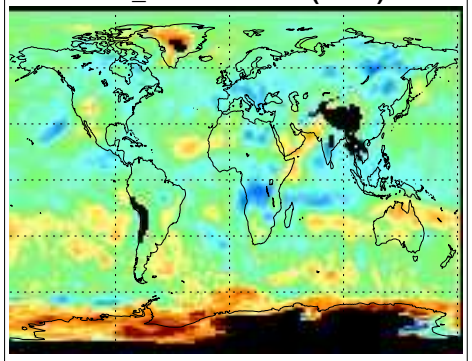
MERRA2_airs - AIRS(V006)



-2.5 -1.5 -0.5 0.5 1.5 2.5
Δ T(K)

N= 43021. Mean (StdDev)
Δ T(K) -0.327 (0.840)

ERA_Interim - AIRS(V006)



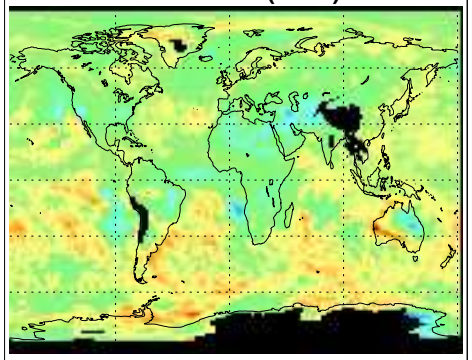
-2.5 -1.5 -0.5 0.5 1.5 2.5
Δ T(K)

N= 42981. Mean (StdDev)
Δ T(K) -0.095 (0.575)

ΔQ(%) @ 700 hPa

200407 Cloud Mask = 90%

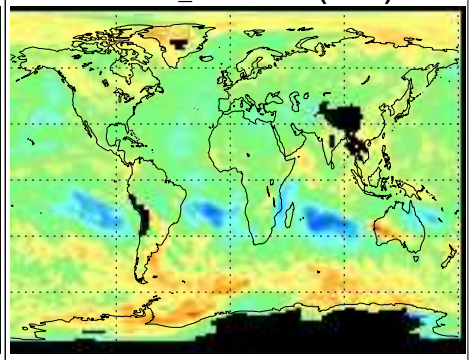
G541 - AIRS(V006)



-100 -60 -20 20 60 100
Δ Q(%)

N= 42929. Mean (StdDev)
Δ Q(%) 9.18 (13.4)

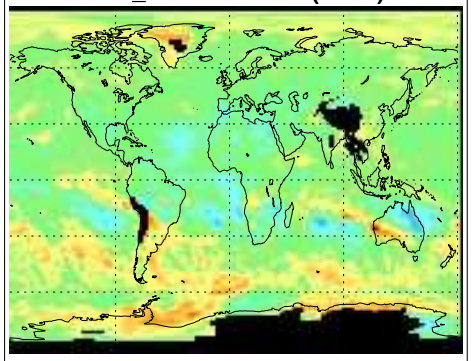
MERRA2_airs - AIRS(V006)



-100 -60 -20 20 60 100
Δ Q(%)

N= 42962. Mean (StdDev)
Δ Q(%) 2.78 (16.5)

ERA_Interim - AIRS(V006)



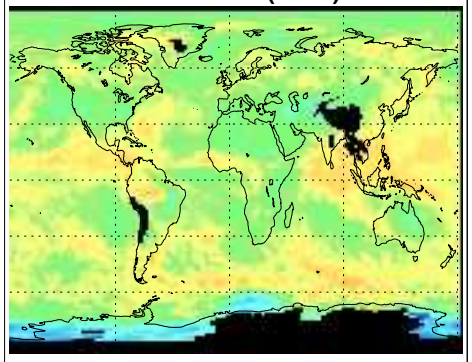
-100 -60 -20 20 60 100
Δ Q(%)

N= 42929. Mean (StdDev)
Δ Q(%) 2.55 (14.1)

ΔRH @ 700 hPa

200407 Cloud Mask = 90%

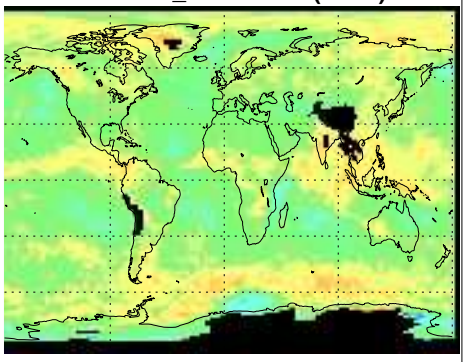
G541 - AIRS(V006)



-60 -36 -12 12 36 60
Δ RelHum(%)

N= 42929. Mean (StdDev)
Δ RelHum(%) 6.29 (7.07)

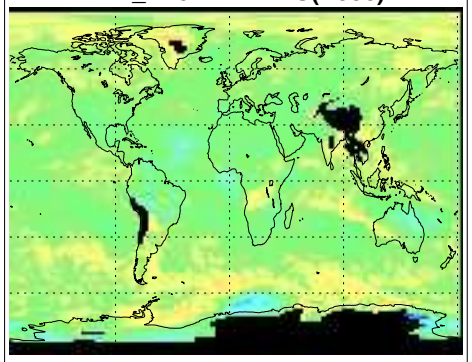
MERRA2_airs - AIRS(V006)



-60 -36 -12 12 36 60
Δ RelHum(%)

N= 42962. Mean (StdDev)
Δ RelHum(%) 3.51 (6.74)

ERA_Interim - AIRS(V006)



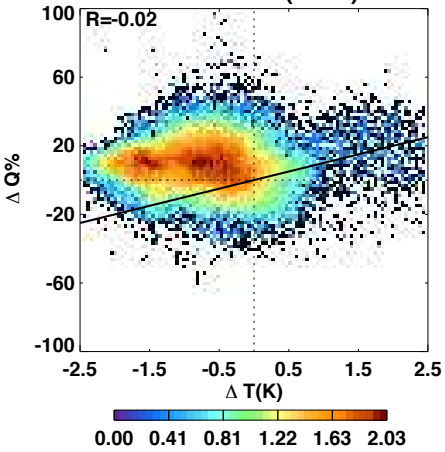
-60 -36 -12 12 36 60
Δ RelHum(%)

N= 42929. Mean (StdDev)
Δ RelHum(%) 1.75 (5.36)

Δ Q% vs Δ T(K) @ 700 hPa

200407 Cloud Mask = 90%

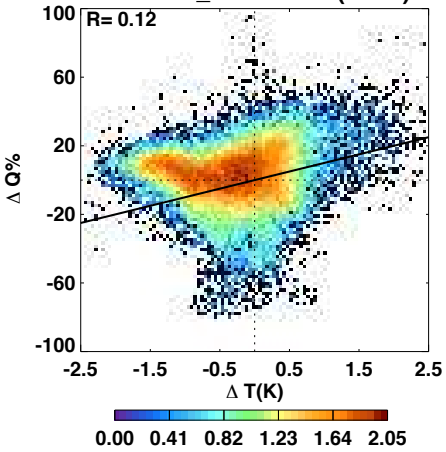
G541 - AIRS(V006)



0.00 0.41 0.81 1.22 1.63 2.03
Log10(Population)

N= 42981. Mean (StdDev)
Δ T(K) -0.678 (0.945)
Δ Q% 9.18 (13.4)

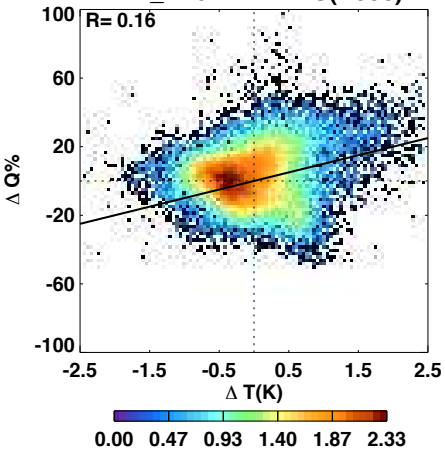
MERRA2_airs - AIRS(V006)



0.00 0.41 0.82 1.23 1.64 2.05
Log10(Population)

N= 43021. Mean (StdDev)
Δ T(K) -0.327 (0.840)
Δ Q% 2.78 (16.5)

ERA_Interim - AIRS(V006)



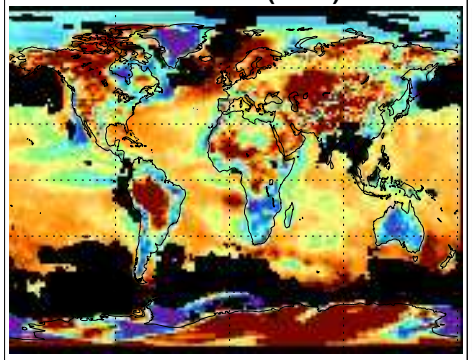
0.00 0.47 0.93 1.40 1.87 2.33
Log10(Population)

N= 42981. Mean (StdDev)
Δ T(K) -0.095 (0.575)
Δ Q% 2.55 (14.1)

ΔT(K) @ Surface

200407 Cloud Mask = 90%

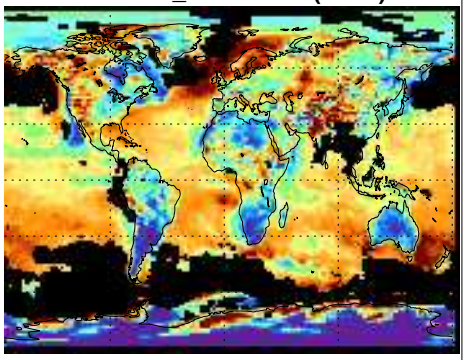
G541 - AIRS(V006)



-2.5 -1.5 -0.5 0.5 1.5 2.5
ΔT(K)

N= 37569. Mean (StdDev)
ΔT(K) 0.851 (1.73)

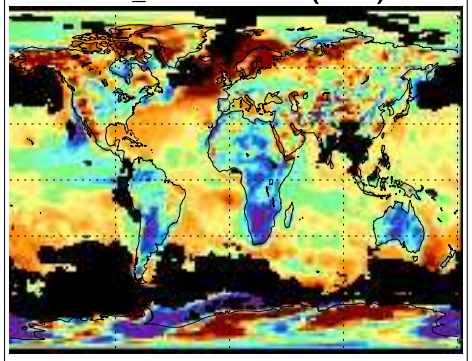
MERRA2_airs - AIRS(V006)



-2.5 -1.5 -0.5 0.5 1.5 2.5
ΔT(K)

N= 37569. Mean (StdDev)
ΔT(K) 0.450 (1.61)

ERA_Interim - AIRS(V006)



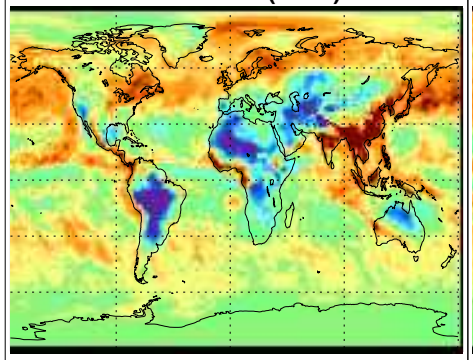
-2.5 -1.5 -0.5 0.5 1.5 2.5
ΔT(K)

N= 37569. Mean (StdDev)
ΔT(K) 0.376 (1.44)

ΔPW(mm)

200407 Cloud Mask = 90%

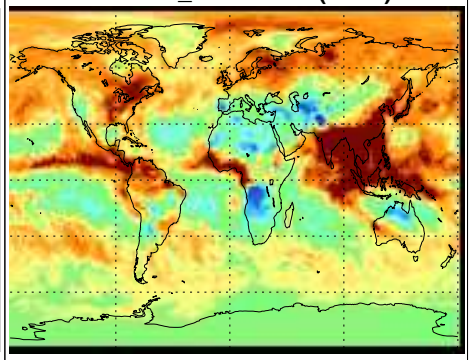
G541 - AIRS(V006)



-5 -3 -1 1 3 5
ΔPW(mm)

N= 44012. Mean (StdDev)
ΔPW(mm) 0.762 (2.02)

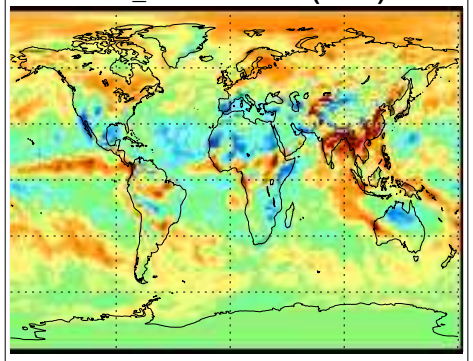
MERRA2_airs - AIRS(V006)



-5 -3 -1 1 3 5
ΔPW(mm)

N= 44012. Mean (StdDev)
ΔPW(mm) 1.49 (1.98)

ERA_Interim - AIRS(V006)



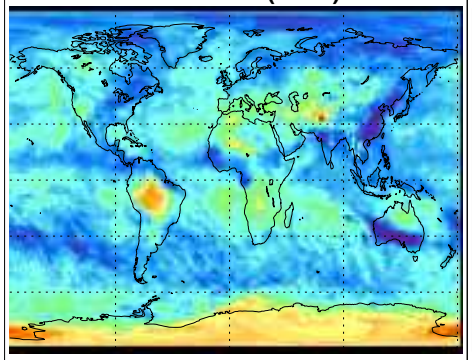
-5 -3 -1 1 3 5
ΔPW(mm)

N= 44012. Mean (StdDev)
ΔPW(mm) 0.617 (1.73)

Δ Clear OLR using (2.5K,33%Q)

200407 Cloud Mask = 90%

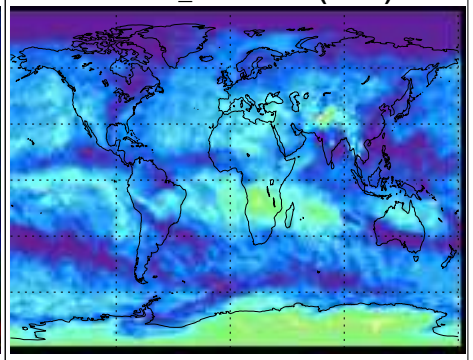
G541 - AIRS(V006)



-10 -6 -2 2 6 10
ΔOLR(wm^{-2})

N= 44012. Mean (StdDev)
ΔOLR(wm^{-2}) -3.62 (2.56)

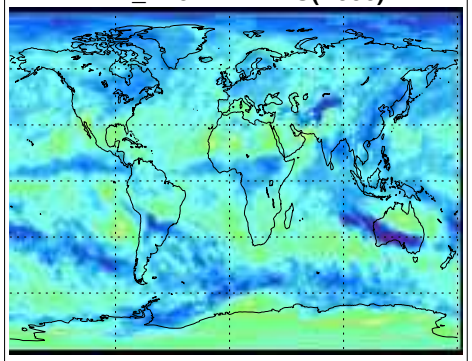
MERRA2_airs - AIRS(V006)



-10 -6 -2 2 6 10
ΔOLR(wm^{-2})

N= 44012. Mean (StdDev)
ΔOLR(wm^{-2}) -6.20 (2.74)

ERA_Interim - AIRS(V006)



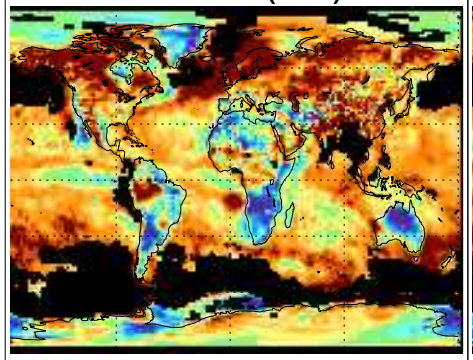
-10 -6 -2 2 6 10
ΔOLR(wm^{-2})

N= 44012. Mean (StdDev)
ΔOLR(wm^{-2}) -3.28 (2.05)

Δ Clear DLF using DilleyObrien

200407 Cloud Mask = 90%

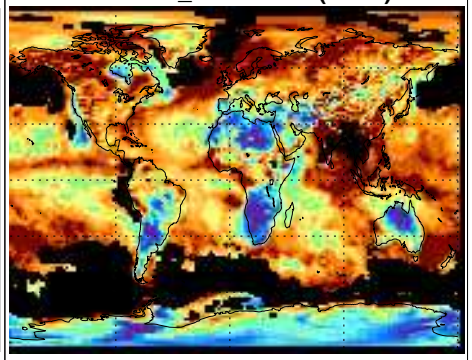
G541 - AIRS(V006)



-10 -6 -2 2 6 10
ΔDLF(wm^{-2})

N= 37569. Mean (StdDev)
ΔDLF(wm^{-2}) 4.10 (5.86)

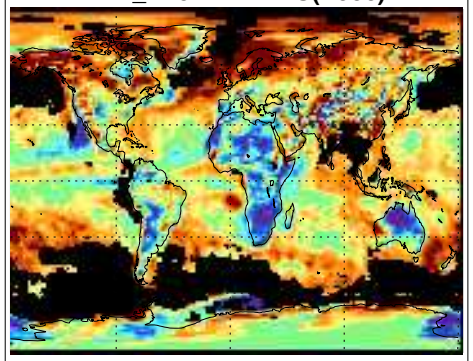
MERRA2_airs - AIRS(V006)



-10 -6 -2 2 6 10
ΔDLF(wm^{-2})

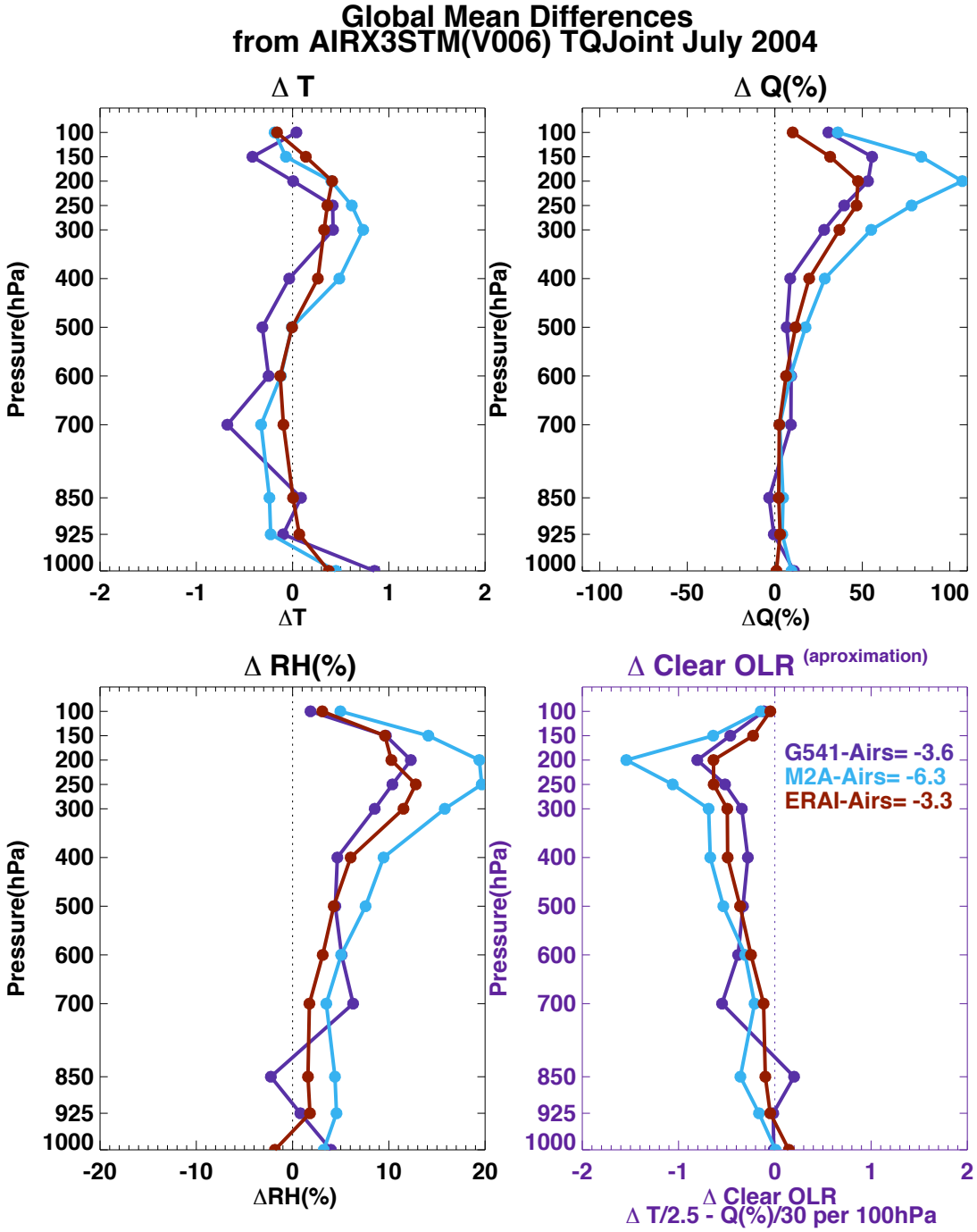
N= 37569. Mean (StdDev)
ΔDLF(wm^{-2}) 4.37 (6.01)

ERA_Interim - AIRS(V006)



-10 -6 -2 2 6 10
ΔDLF(wm^{-2})

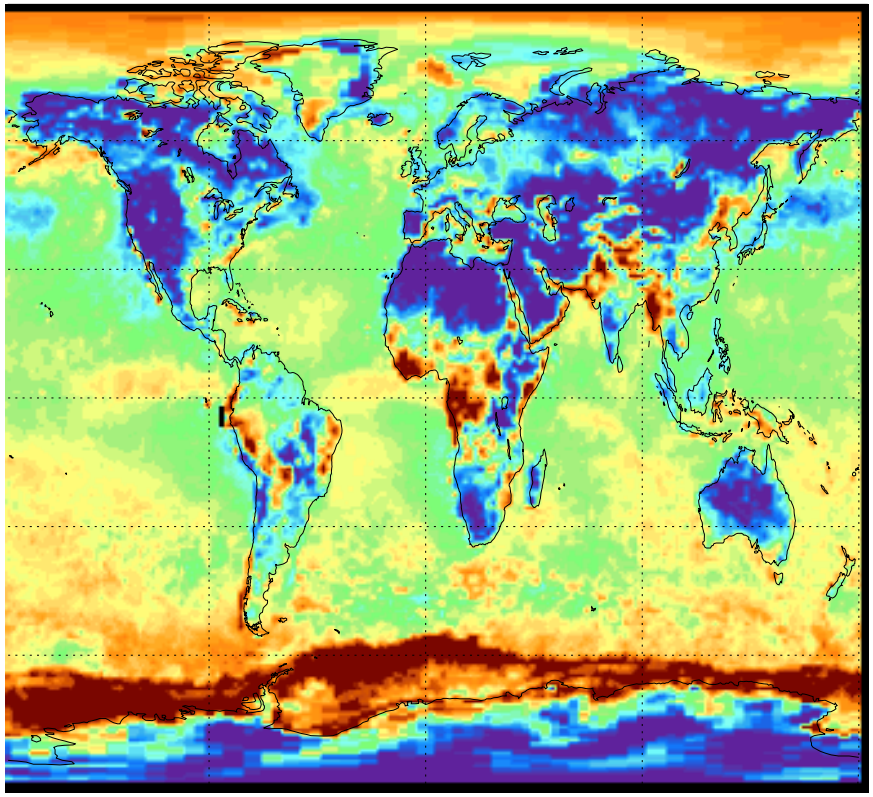
N= 37569. Mean (StdDev)
ΔDLF(wm^{-2}) 2.41 (6.31)

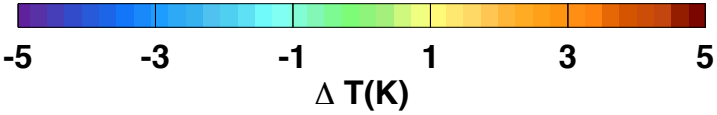

Global Mean Differences
from AIRX3STM(V006) TQJoint July 2004
Δ T
Δ Q(%)
Δ RH(%)
Δ Clear OLR (aproximation)
Pressure(hPa)
100
150
200
250
300
400
500
600
700
850
925
1000
-2
-1
0
1
2
ΔT
-100
-50
0
50
100
ΔQ(%)
-20
-10
0
10
20
ΔRH(%)
G541-Airs= -3.6
M2A-Airs= -6.3
ERAI-Airs= -3.3
Δ Clear OLR
Δ T/2.5 - Q(%)/30 per 100hPa

Skin Temperature

- MERRA2 (w/Airs)
- AIRS Retrieval AIRSX3STM(V006) “TQ_Joint”
- MODIS 10.8um TOA Brightness Temperature

ASCENDING Orbit “DAY”
MERRA2_Airs – AIRX3STM
Skin Temperature

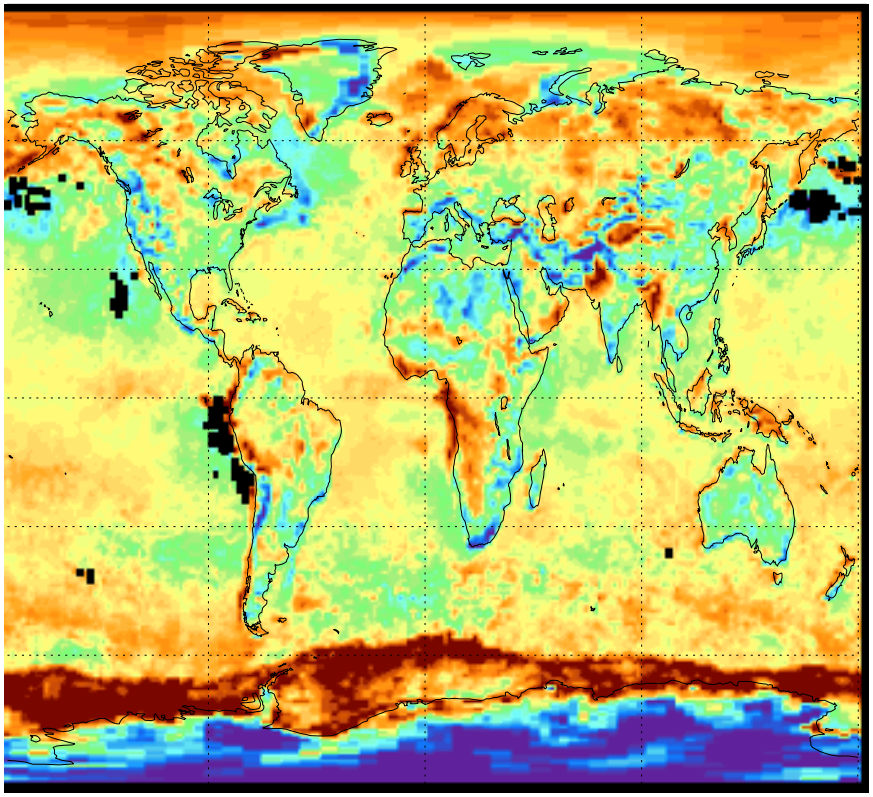


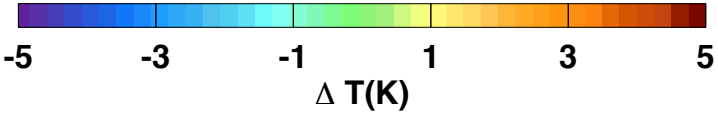


N= 44008.

Mean (StdDev)
Δ T(K) -0.128(2.93)

DESCENDING Orbit “NIGHT”
MERRA2_Airs – AIRX3STM
Skin Temperature

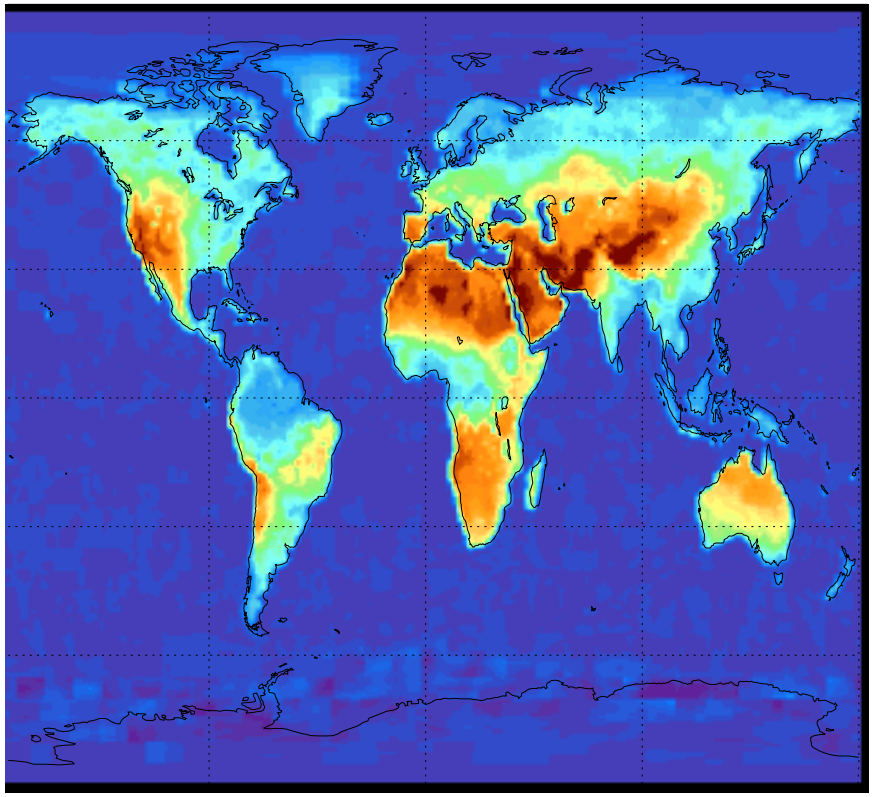




N= 43813.

Mean (StdDev)
Δ T(K) 0.943(1.90)

Asc.-Des. Orbits “Day-Night”
MERRA2_Airs
Skin Temperature

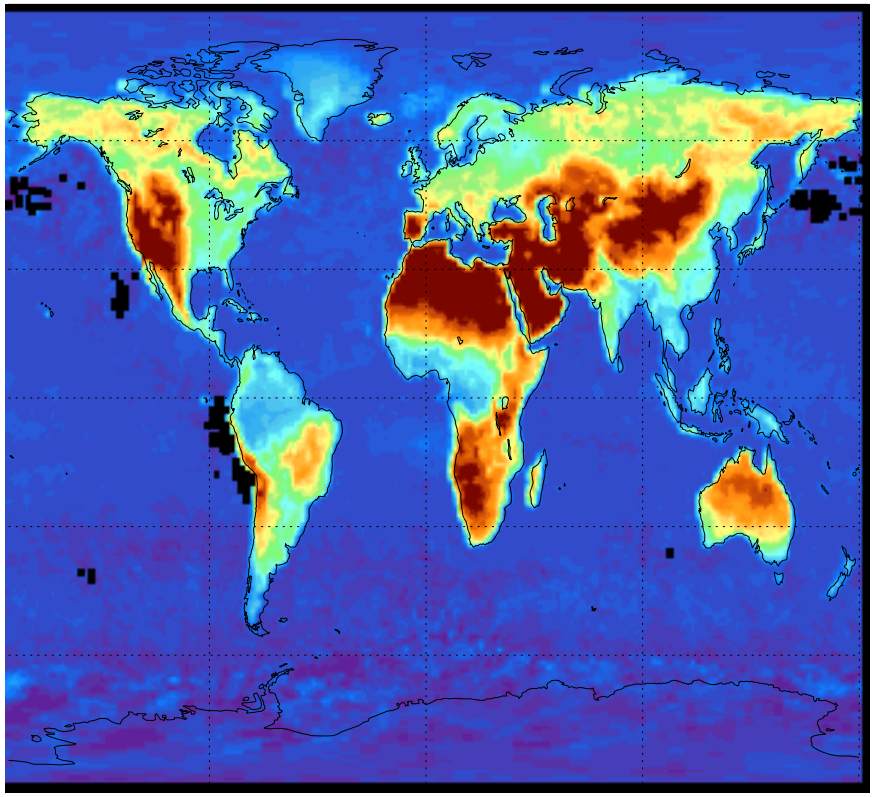


-2 4 10 16 22 28
Δ T(K)

N= 44012.

Mean (StdDev)
Δ T(K) 3.83(7.15)

Asc.-Des. Orbits “Day-Night”
AIRX3STM(V006)
Skin Temperature



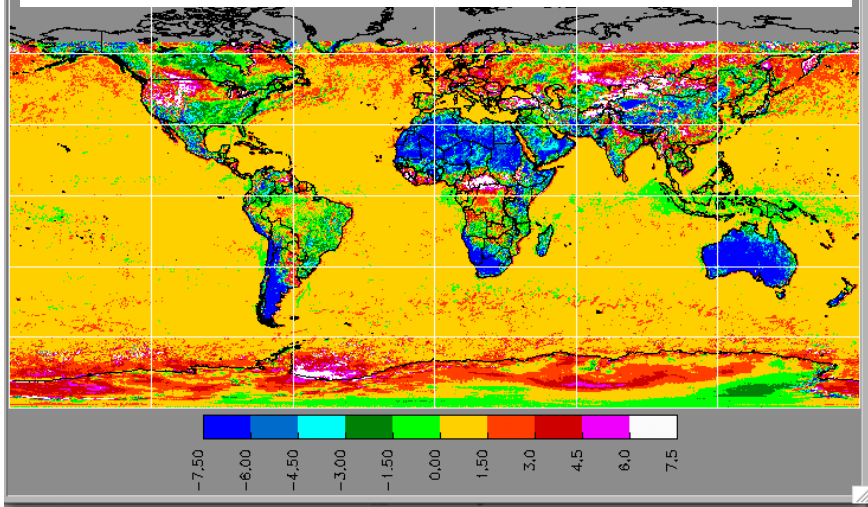
-2 4 10 16 22 28
Δ T(K)

N= 43813.

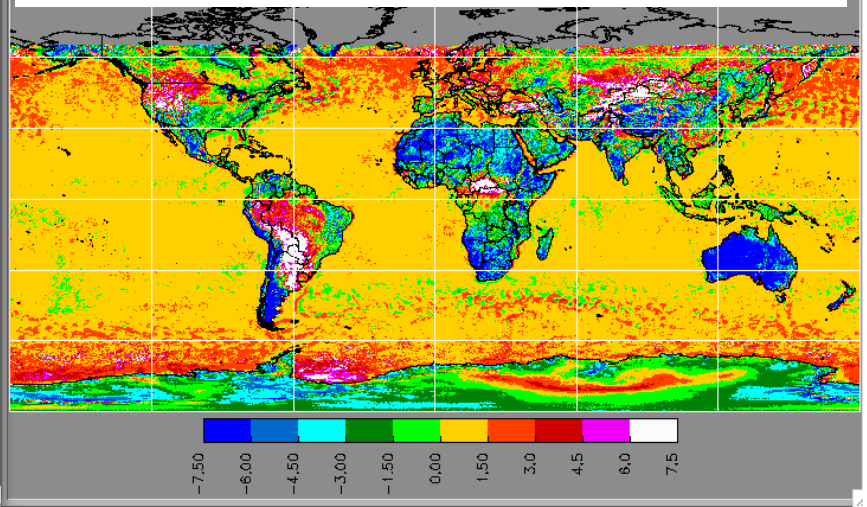
Mean (StdDev)
Δ T(K) 4.91(8.43)

Model Predicted – MODIS 10.8µ Observed
TOA Clear Sky Brightness Temperature (S.Mack)

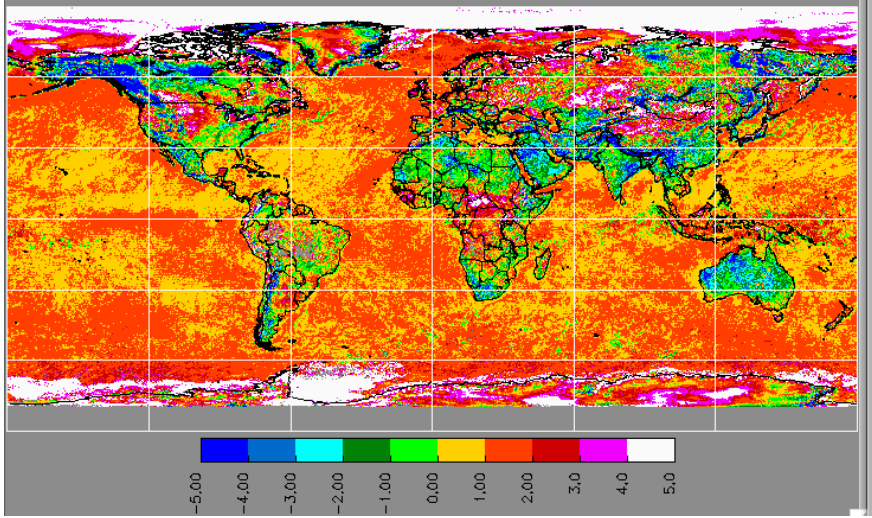
Merra2(noAirs) DAY



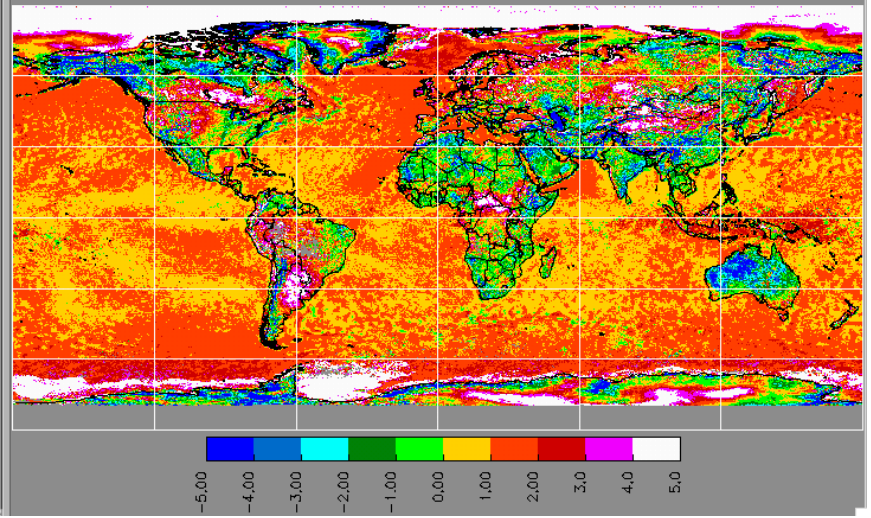
Geos541 Day



Merra2(noAirs) Night



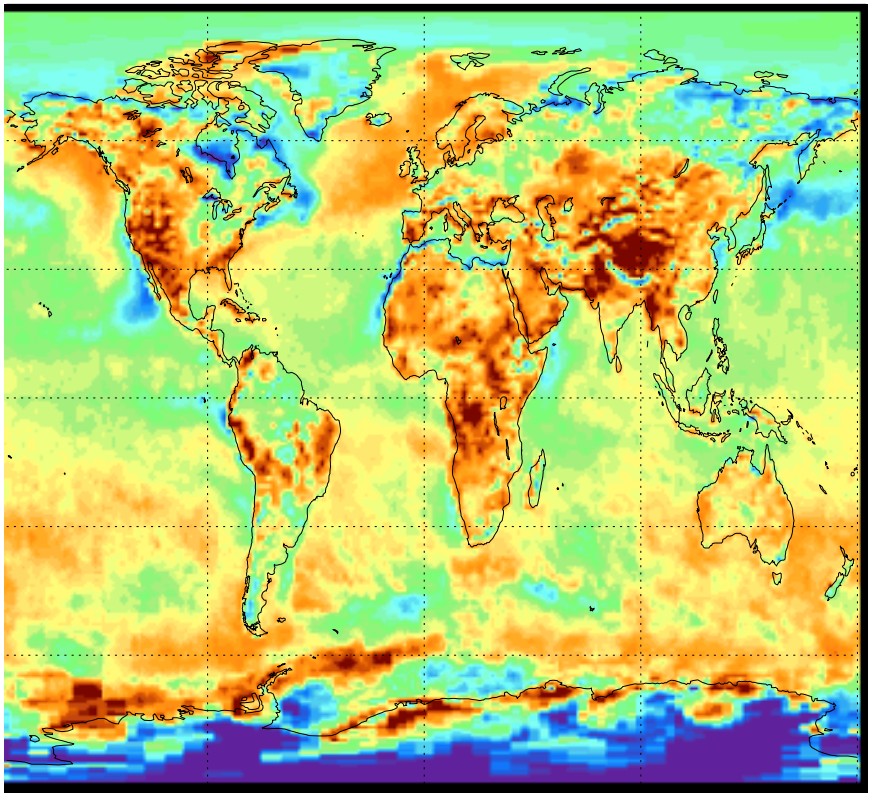
Geos541 Night

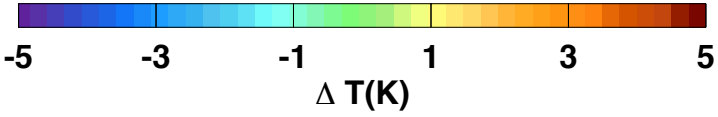


Surface Air Temperature

- AIRS Retrieval AIRSX3STM(V006) “TQ_Joint”
- Climate Research Unit (CRU) Diurnal Min/Max

ASCENDING Orbit “DAY”
MERRA2_Airs – AIRX3STM
Surface Air Temperature

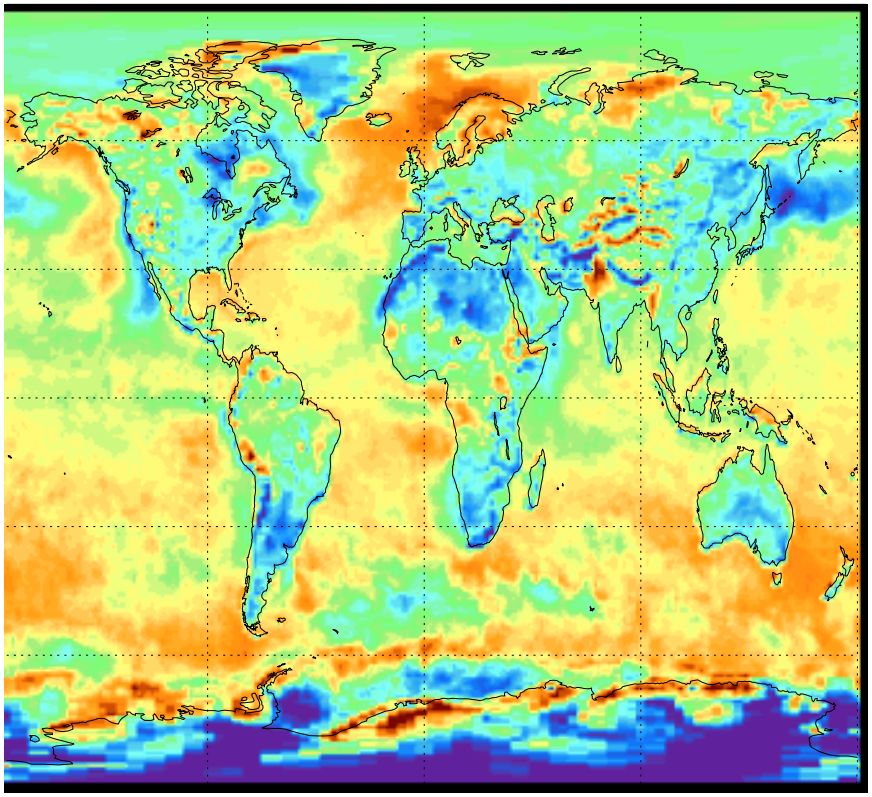


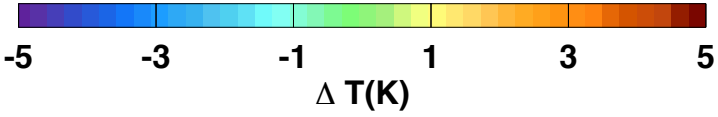


N= 44012.

Mean (StdDev)
Δ T(K) 0.952(1.78)

DESCENDING Orbit “NIGHT”
MERRA2_Airs – AIRX3STM
Surface Air Temperature

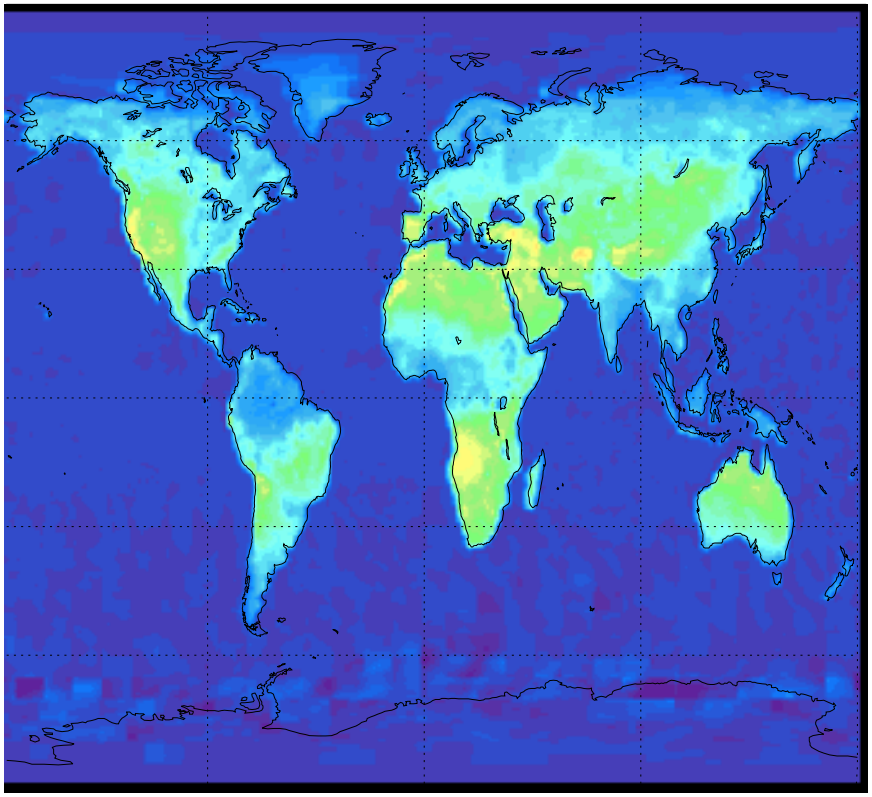


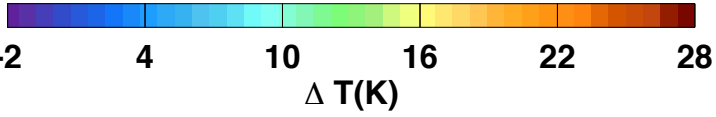


N= 44012.

Mean (StdDev)
Δ T(K) 0.420(1.71)

Asc.-Des. Orbits “Day-Night”
MERRA2_Airs
Surface Air Temperature

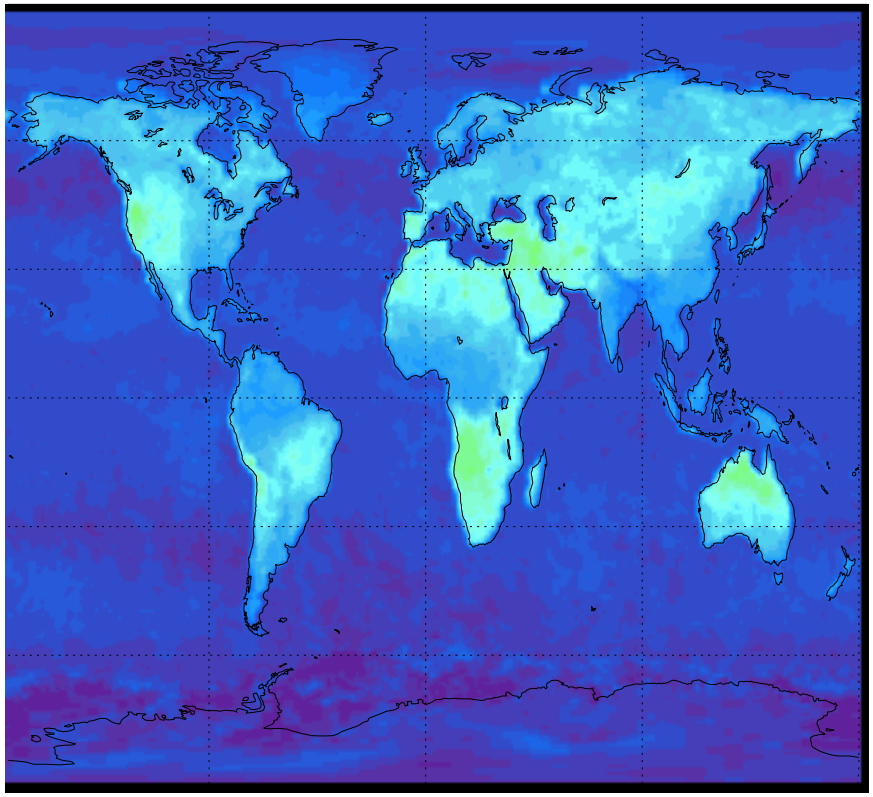


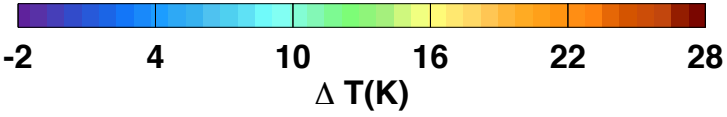


N= 44012.

Mean (StdDev)
Δ T(K) 2.64(4.49)

Asc.-Des. Orbits “Day-Night”
AIRX3STM
Surface Air Temperature





N= 44012.

Mean (StdDev)
Δ T(K) 2.11(3.26)

Climate Research Unit (CRU)

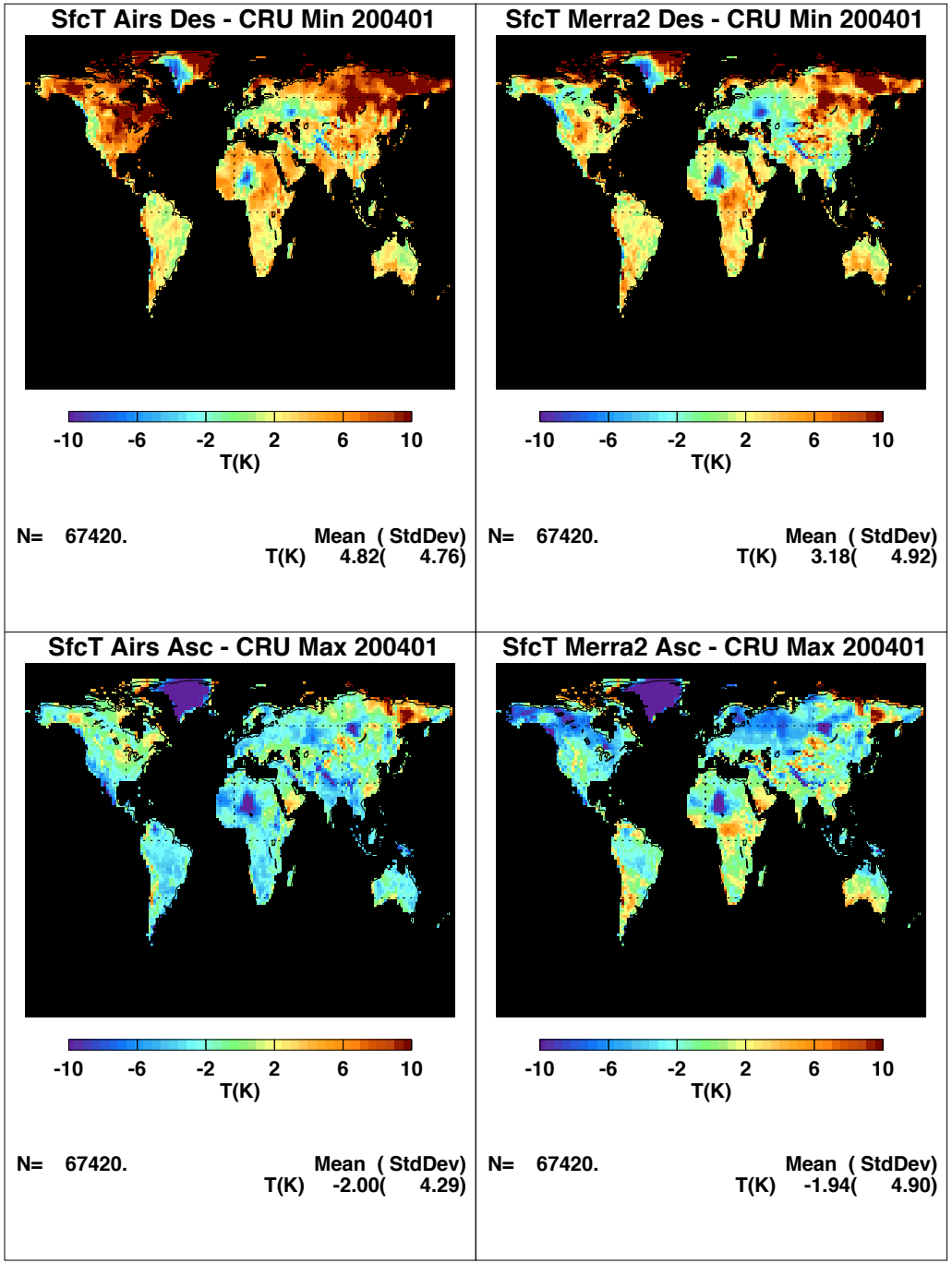
Night(Min) & Day(Max)

Land Surface Air Temperature

Comparison

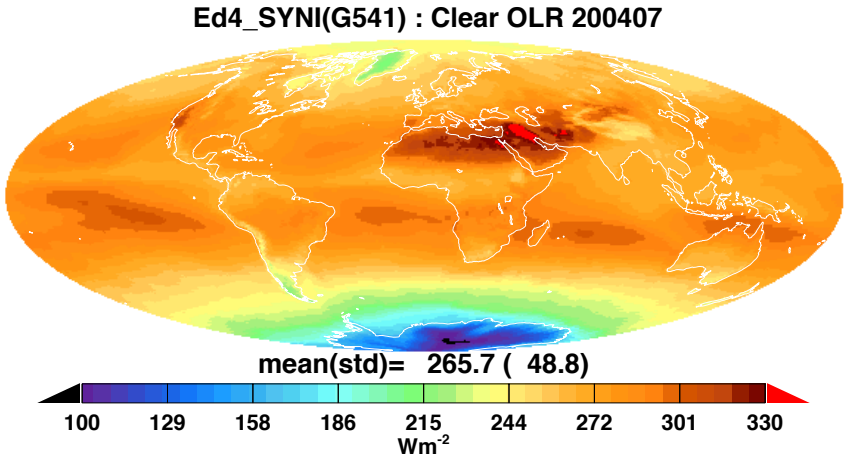
- AIRS and MERRA2 both have *-higher* Nighttime Min and *-lower* Daytime Max than CRU product.

- MERRA2 has slightly better agreement to CRU than AIRS

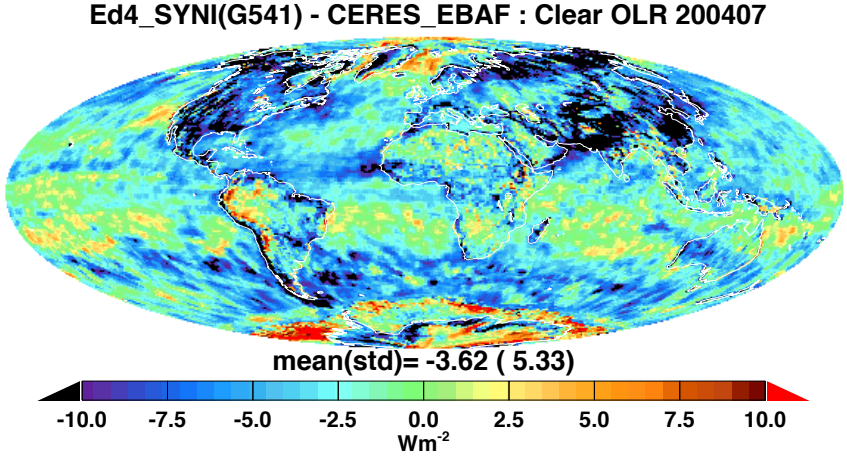


Computed Clear Sky Outgoing Longwave Radiation using Geos5.4.1 MERRA2(Airs) MERRA2(NOAirs) Compared to CERES TOA_EBAF Observed and ERA Interim.

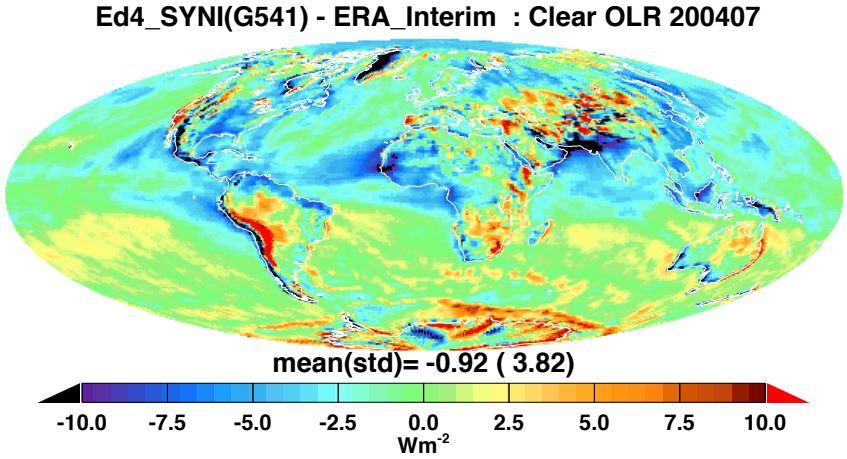
Computed Clear OLR using **Geos 5.4.1** in CERES Ed4 SYNI product using Fu-Liou



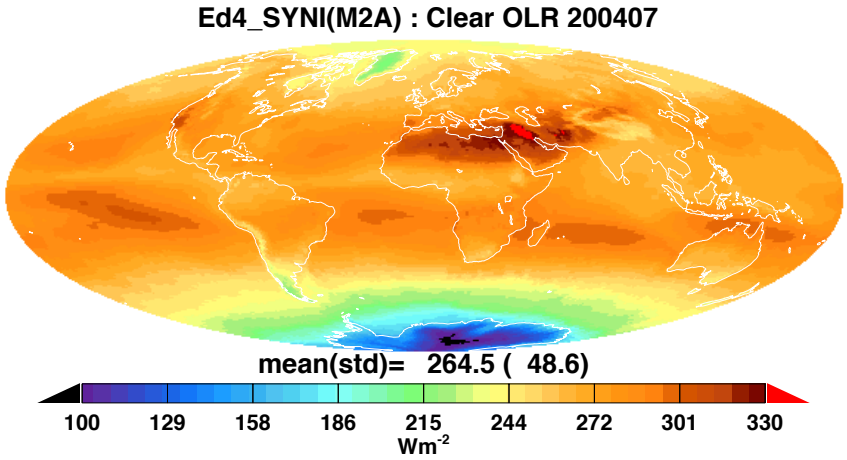
Compared with CERES TOA_EBAF



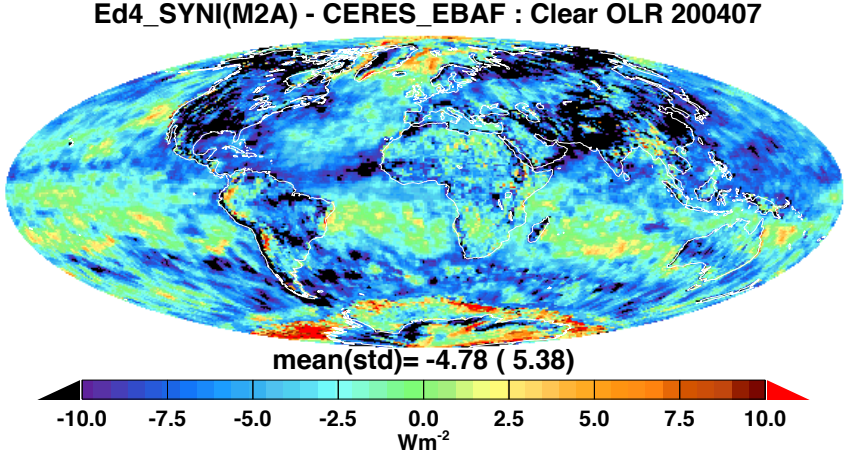
Compared with ERA_Interim



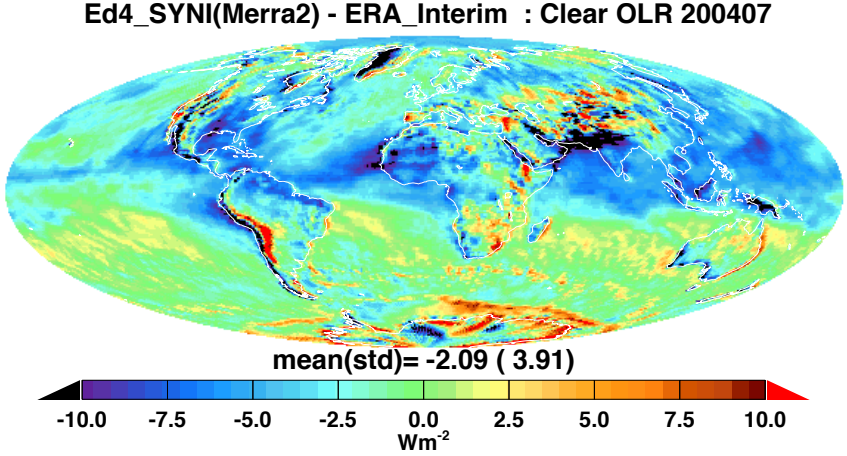
Computed Clear OLR using **Merra2_Airs** in CERES Ed4 SYNI product using Fu-Liou



Compared with CERES TOA_EBAF

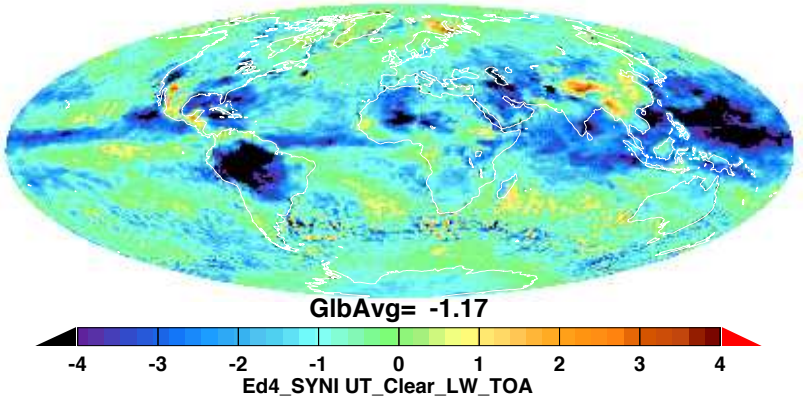


Compared with ERA_Interim

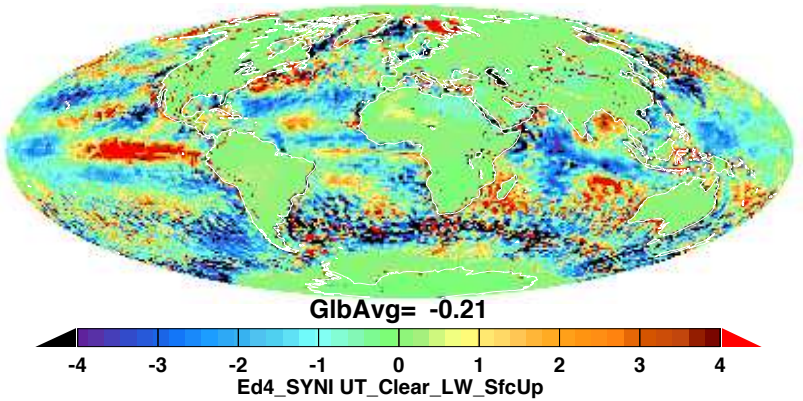


Ed4 SYNI Computations July 2004 :**MERRA2_AIRS** minus **GEOS 5.4.1**

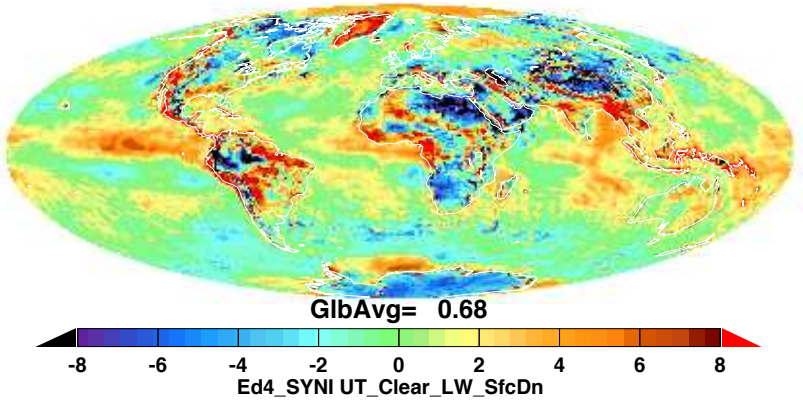
Clear-sky TOA OLR:
•The *simple* sensitivity calculation had predicted a difference of -2.7 Wm-2 which excluded SkinT differences



Clear-sky SURFACE LW UP:
•Ed4 SYNI uses MODIS/GEO SkinT retrievals over land and snow

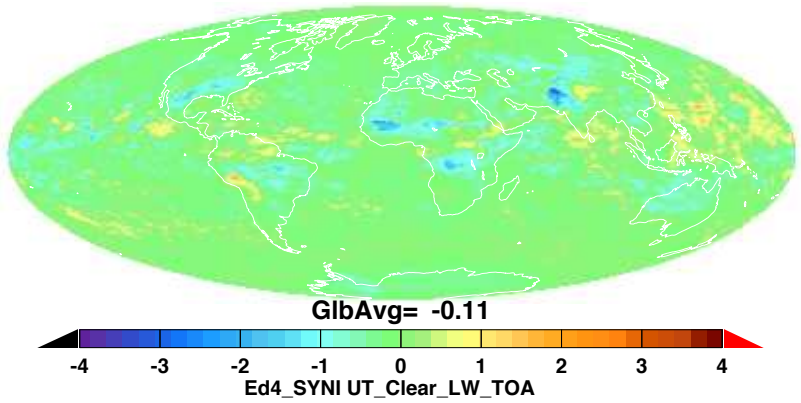


Clear-sky SURFACE LW DOWN:
•Dilley & O'Brien SfcT, PW sensitivity calculation predicted a difference of +0.3 Wm-2

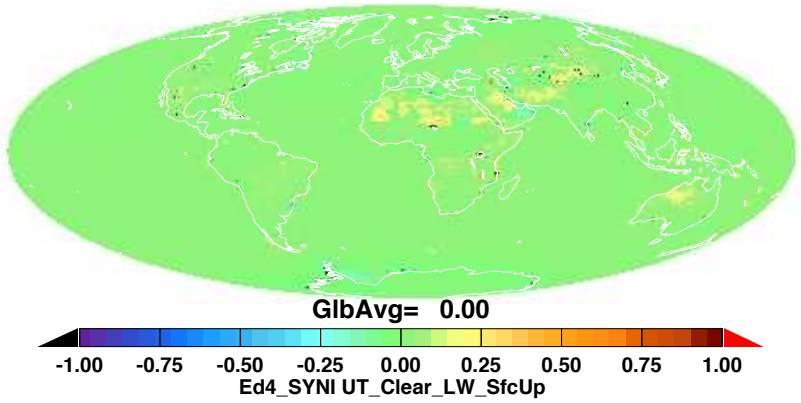


Ed4 SYNI Computations July 2004 :**MERRA2_AIRS** *minus* **MERRA2_NOAirs**

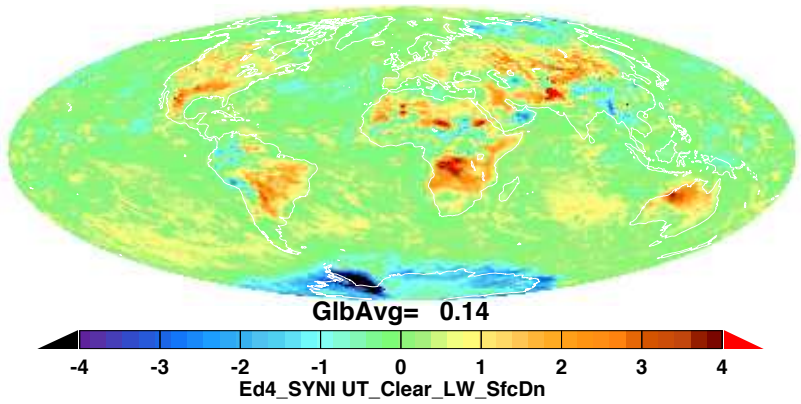
Clear-sky TOA OLR:
Only minor differences seen



Clear-sky SURFACE LW UP:
Only very minor differences where lower surface emissivity allows DLF changes to affect ULF



Clear-sky SURFACE LW DOWN:
Few Wm-2 regional differences over land and snow

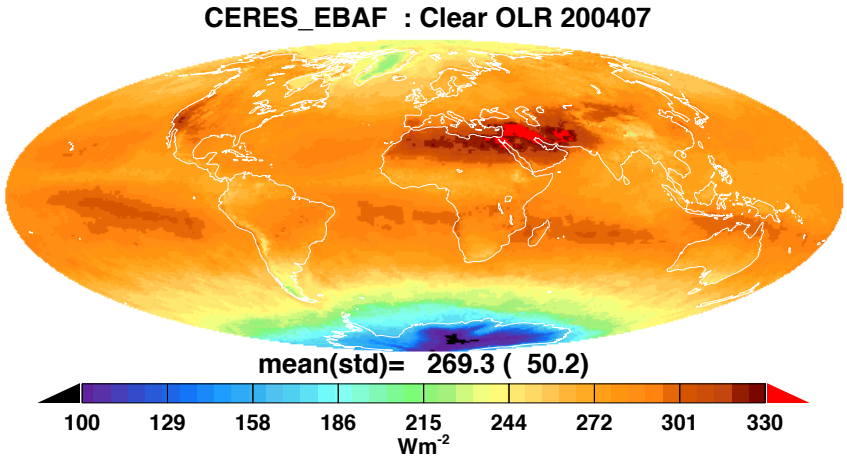


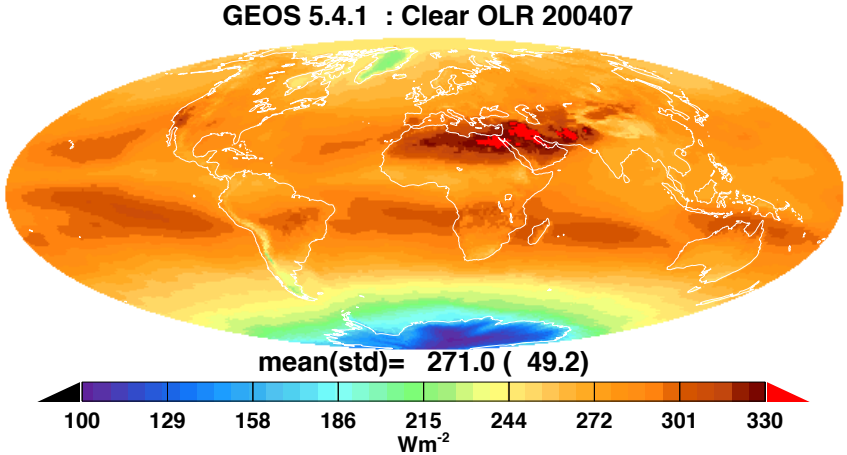
Comparison of GMAO GEOS 5.4.1 Clear Sky Longwave as computed by GMAO (Chou) to TOA/SFC EBAF and ERA-I

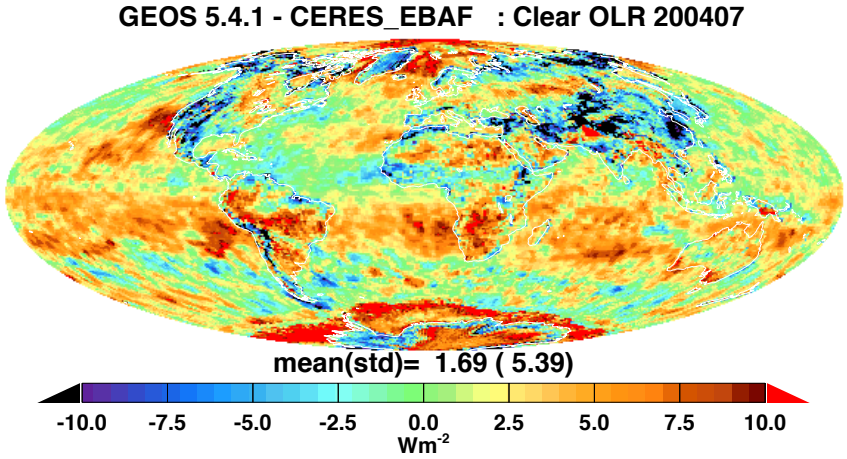
CERES TOA EBAF Clear-sky OLR

GMAO GEOS 5.4.1 Chou

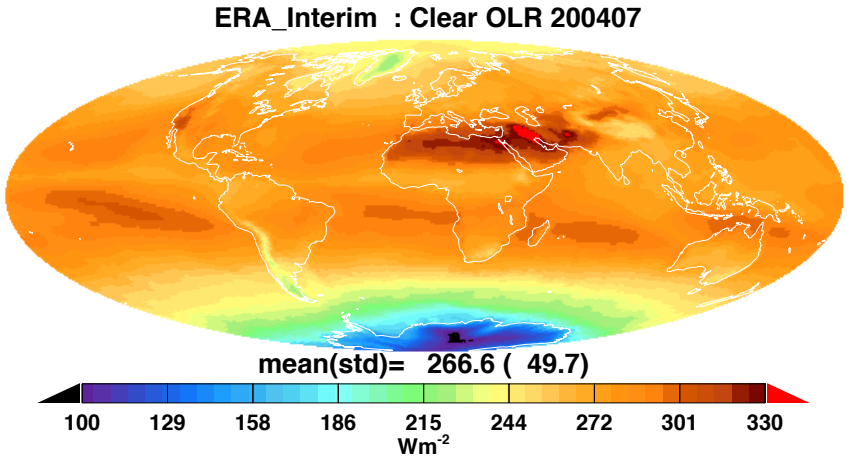
Difference of
GEOS 5.4.1 – TOA_EBAF



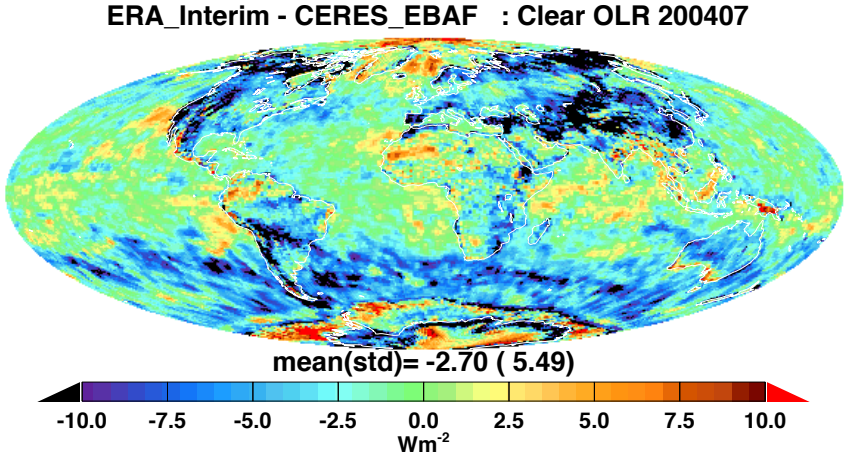




ERA_Interim Clear-sky OLR



Difference of
ERA_Interim – TOA_EBAF



Difference of
ERA_Interim - GEOS 5.4.1

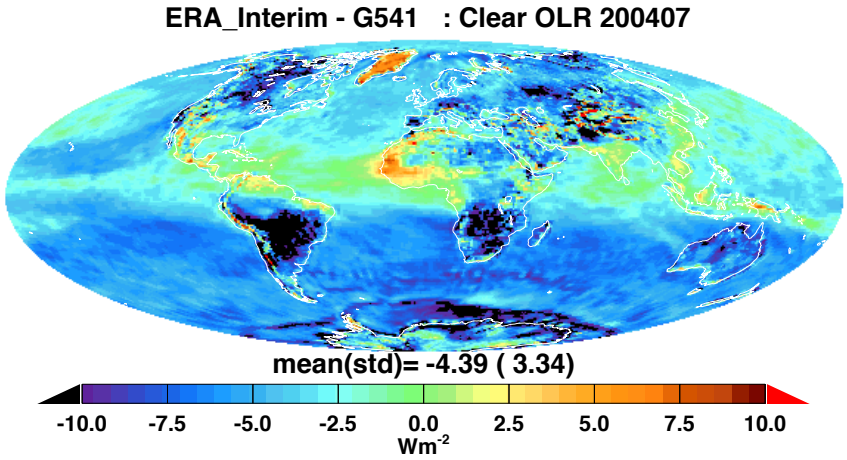
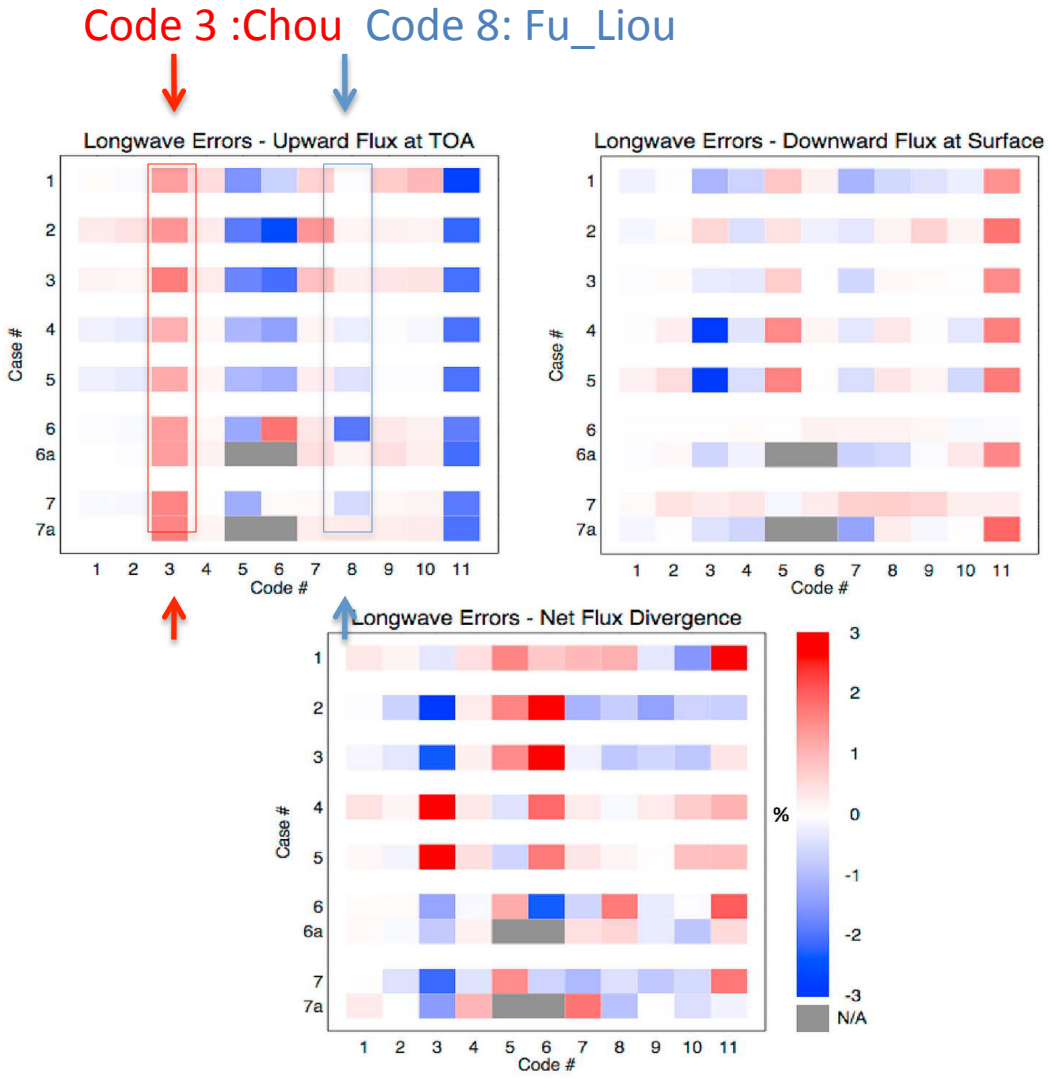


Fig 1: The Continual Intercomparison of Radiation Codes:
Results from Phase I (Oreopoulos 2012)



Clear OLR Biases

Source	Global Mean	Difference from TOAEBAF
GMAO(G541)	271.0	+1.69
TOA_EBAF	**269.3**	**Reference**
ERA_Interim	266.6	-2.70
Ed4SYNI(G541)	265.7	-3.62
Ed4Syni(Merra2 wo/Airs)	264.6	-4.67
Ed4SYNI(Merra2 w/ Airs)	264.5	-4.78

Summary

- Clear OLR Sensitivity +1K = -12%Q = 0.4 Wm-2 /100hPa
- GEOS 5.4.1 ~50% moister that AIRSXSTM V006 in the upper troposphere.
  - Merra2 even moister in Upper Trop. ~100%.
- Little sensible difference between Merra2 'with Airs assimilation' and Merra2 'without Airs'
- Merra2 has smaller SkinT, larger SfcAirT diurnal cycle than AIRSXSTM V006
- ~1 Wm-2 global mean clear-sky OLR reduction from GEOS5.4.1 to Merra2
- GMAO Chou LW code less absorptive than LaRC Fu-Liou
  - biases of 3-4 Wm-2 between code on order of UTH sensitivity.