

MODIS Total Precipitable Water Vapor

Operational MODIS algorithm MOD07

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Water Vapor

Makes our planet unique in solar system

(is up to 0.04% of atmosphere by volume)

Is the key molecule in radiation transfer

atmospheric physical energy transfer

atmospheric chemical processes

...

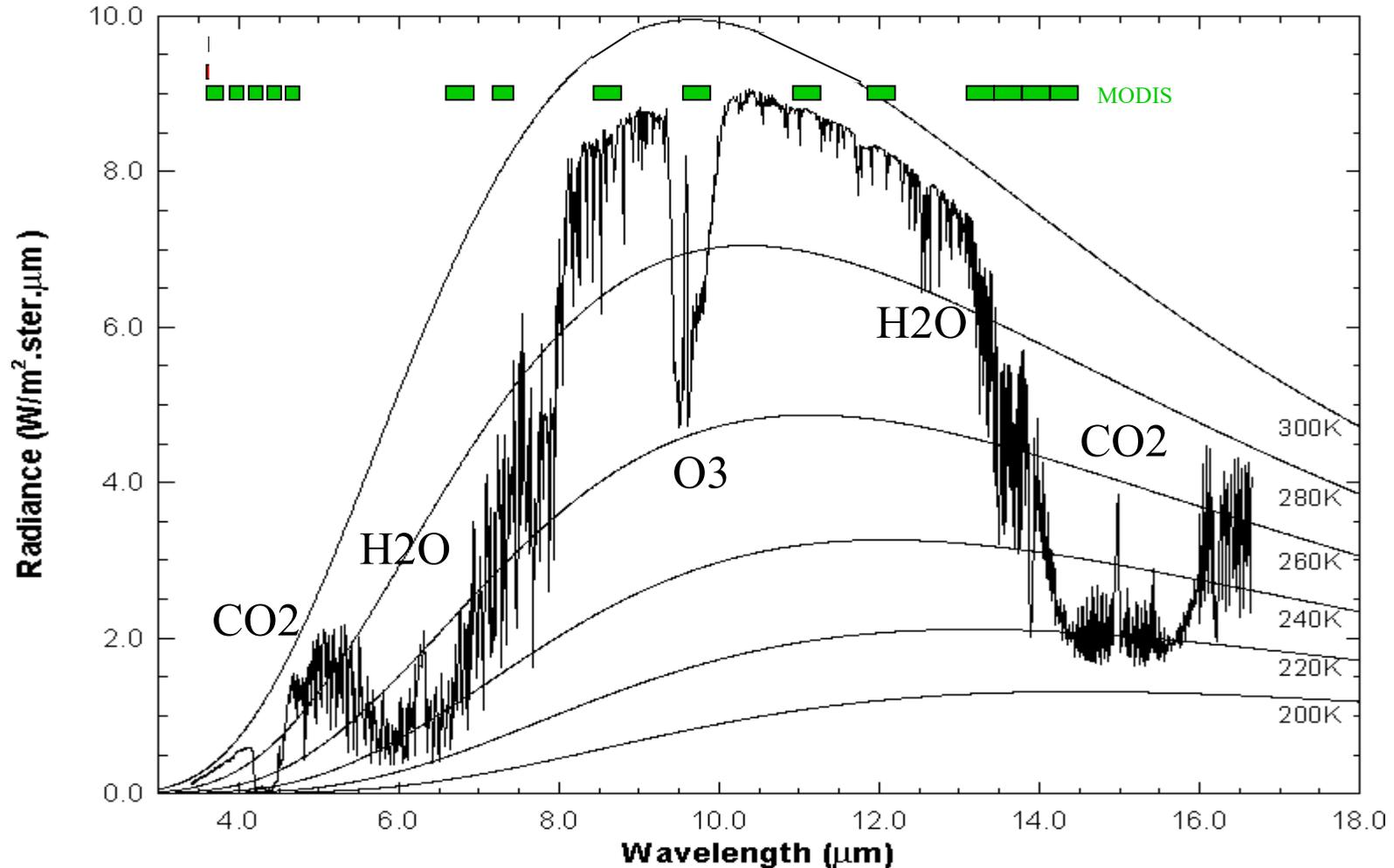
Is changing on small temporal and spatial scales

Is needed to correct remote sensing views of earth surface

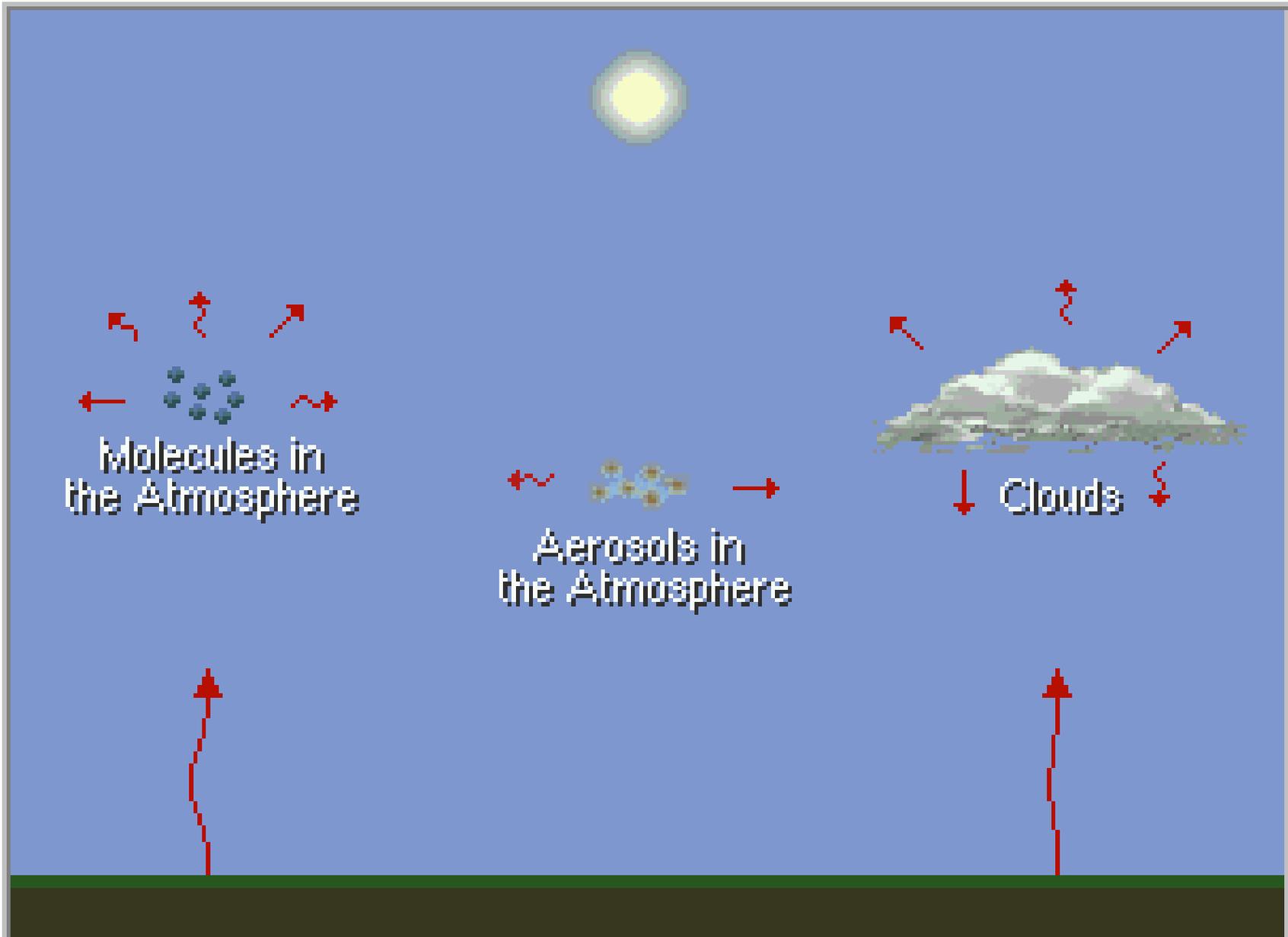
Will be a measure of climate change in next century

MODIS IR Spectral Bands (HIRS like sounder on Terra)

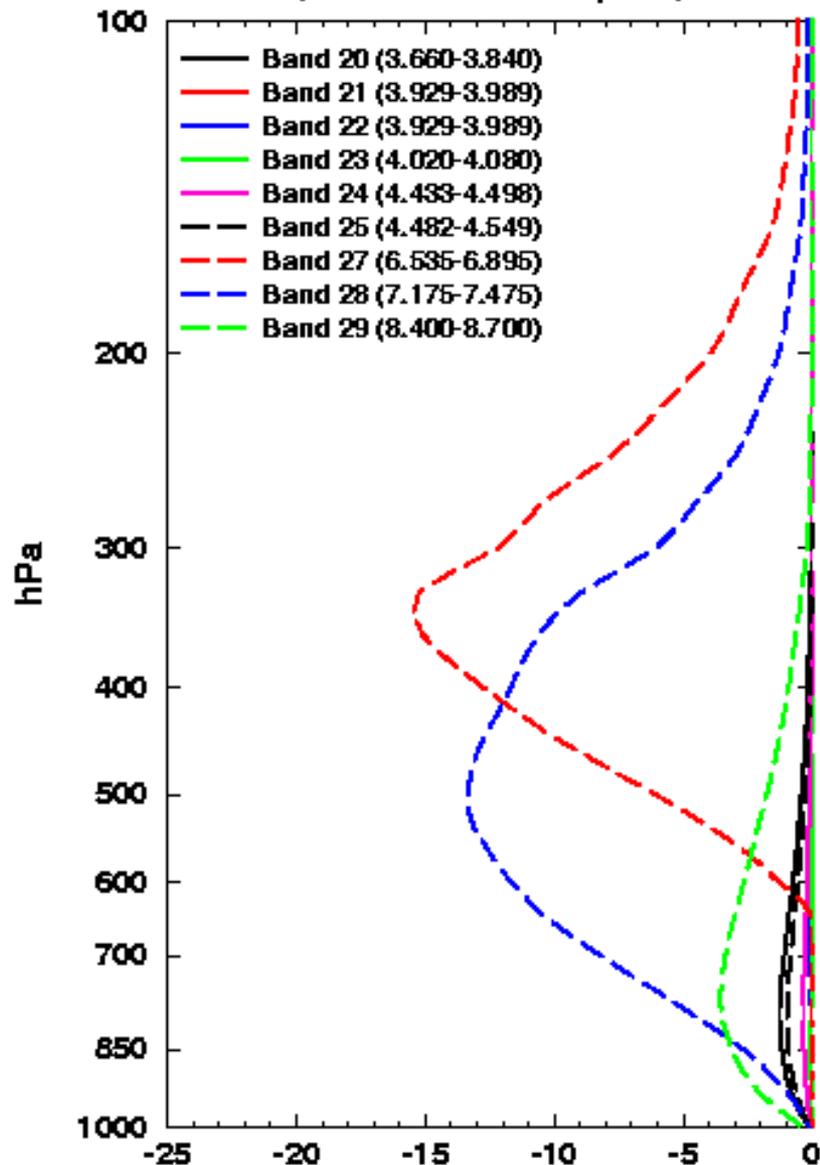
High resolution atmospheric absorption spectrum
and comparative blackbody curves.



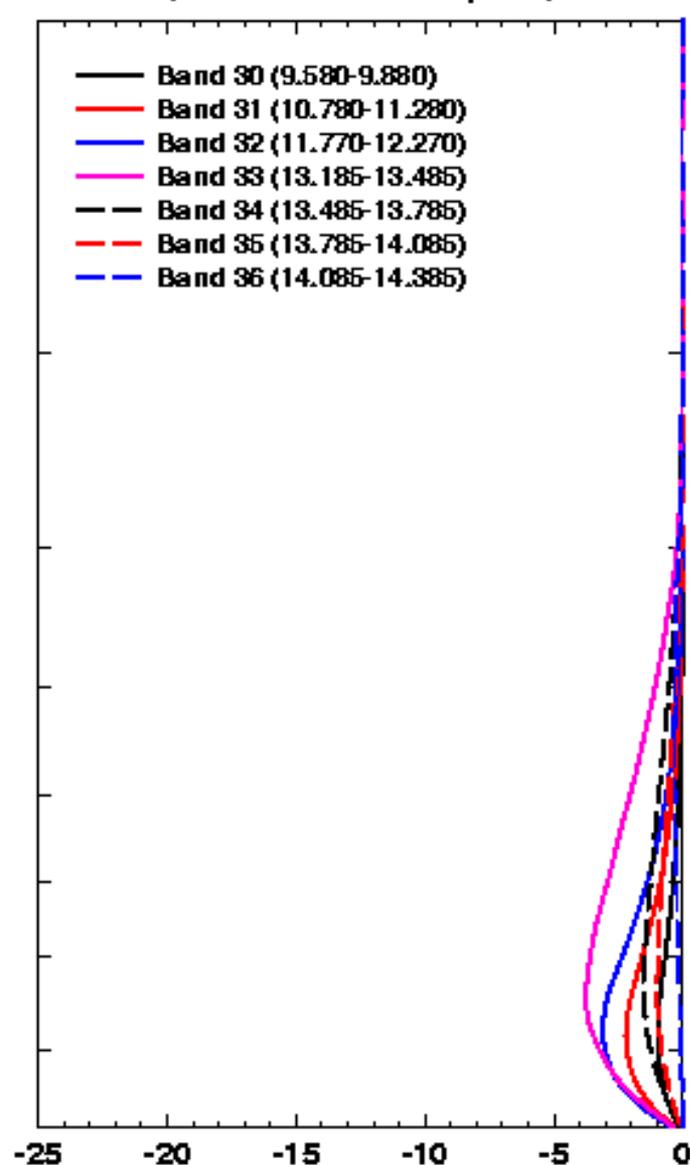
Re-emission of Infrared Radiation



WV Mixing Ratio Weighting Functions
(U.S. Standard Atmosphere)



WV Mixing Ratio Weighting Functions
(U.S. Standard Atmosphere)



6.7

7.3

Aqua MODIS images over Salt Lake City 18 August 2002

8.6

11.0

Total Water Vapor Retrieval from MODIS IR Radiances

$$I_{\lambda} = \varepsilon_{\lambda}^{\text{sfc}} B_{\lambda}(T(p_s)) \tau_{\lambda}(p_s) - \int_0^{p_s} B_{\lambda}(T(p)) [d\tau_{\lambda}(p) / dp] dp .$$

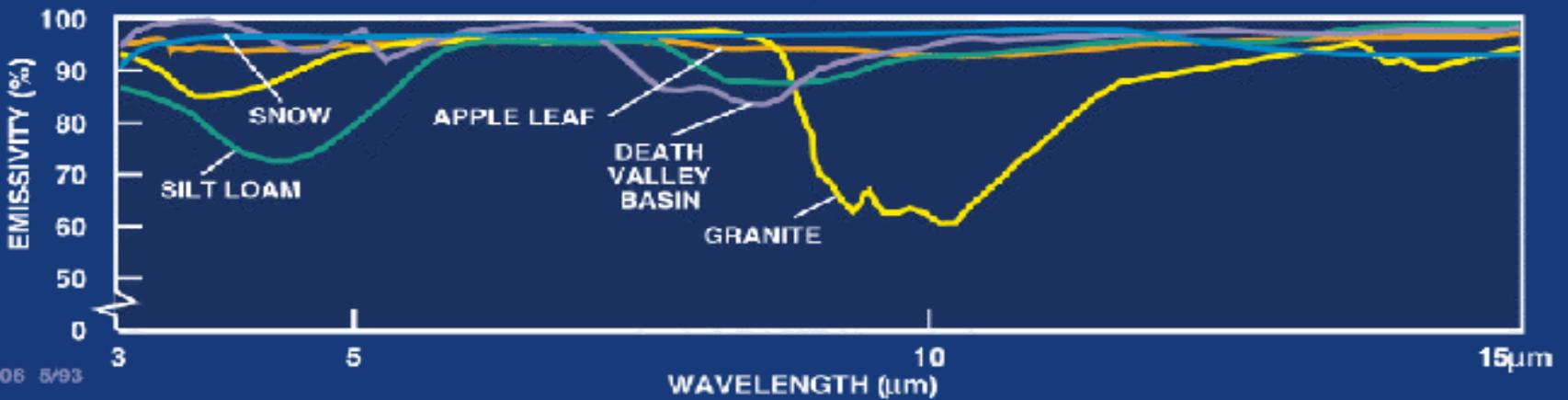
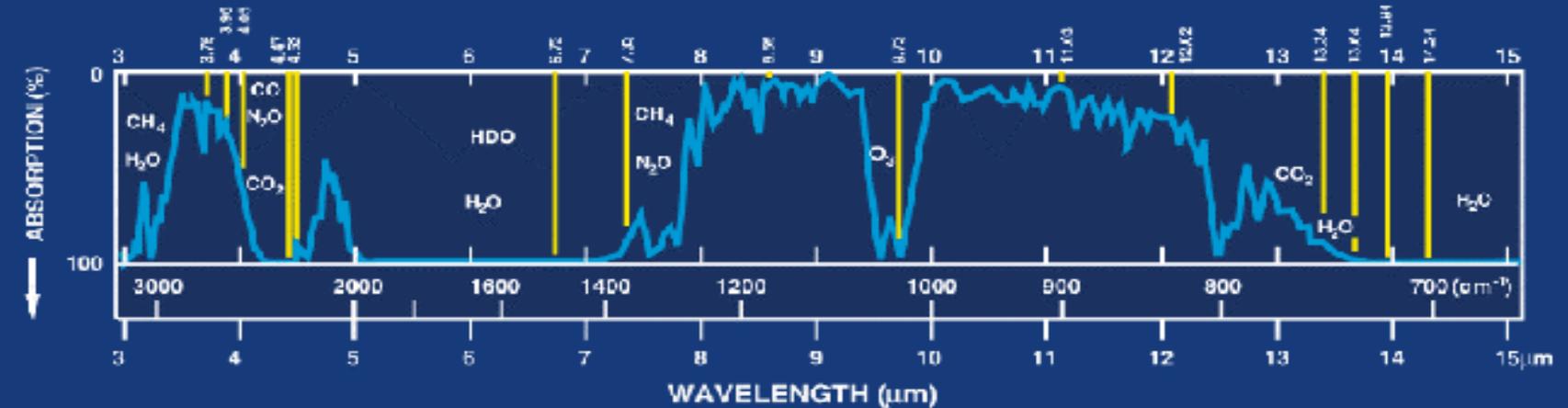
I24, I25, I27, , I36 are measured with MODIS
P(sfc) and T(sfc) come from ground based observations
 $\tau_{\lambda}(p)$ are calculated with physics models

Regression relationship is inferred from (1) global set of in situ radiosonde reports, (2) calculation of expected radiances, and (3) statistical non-linear regression of observed Raob TPW and calculated MODIS radiances (brightness temperatures)

Need RT model, estimate of $\varepsilon_{\lambda}^{\text{sfc}}$, and MODIS radiances



LAND - THERMAL RADIATION



MODIS TPW algorithm is based on **regression using NOAA-88 data set containing 7500+ global profiles** of temperature and moisture to determine regression coefficients.

Calculation of MODIS spectral band radiances is performed for each training profile using **Pressure layer Fast Algorithm for Atmospheric Transmittances (PFAAST)** transmittance model (with 101 pressure layer vertical coordinates from 0.1 to 1050 hPa). MODIS instrument noise is added to calculated spectral band radiances.

Observed RAOB temperature-moisture-ozone profile and calculated MODIS radiances are used to create the statistical regression relationship.

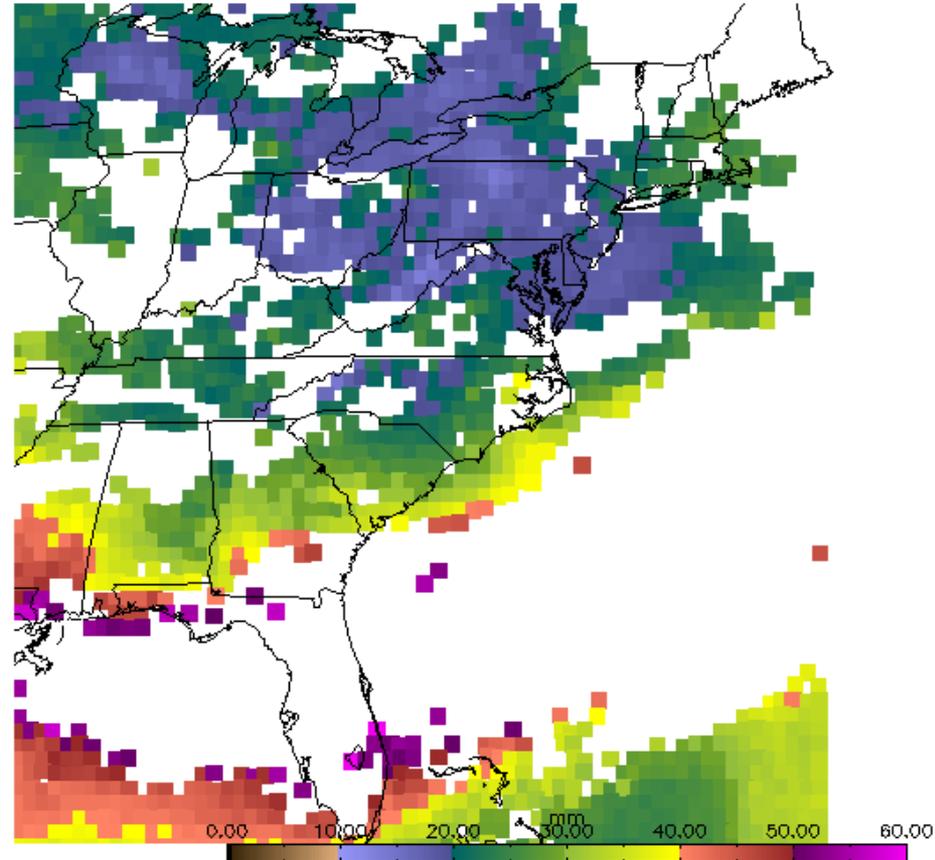
Measured MODIS radiances must then be adjusted for **bias between observed and calculated radiances** and used in regression relationship to generate TPW product.

Physical retrieval follows in direct broadcast processing.

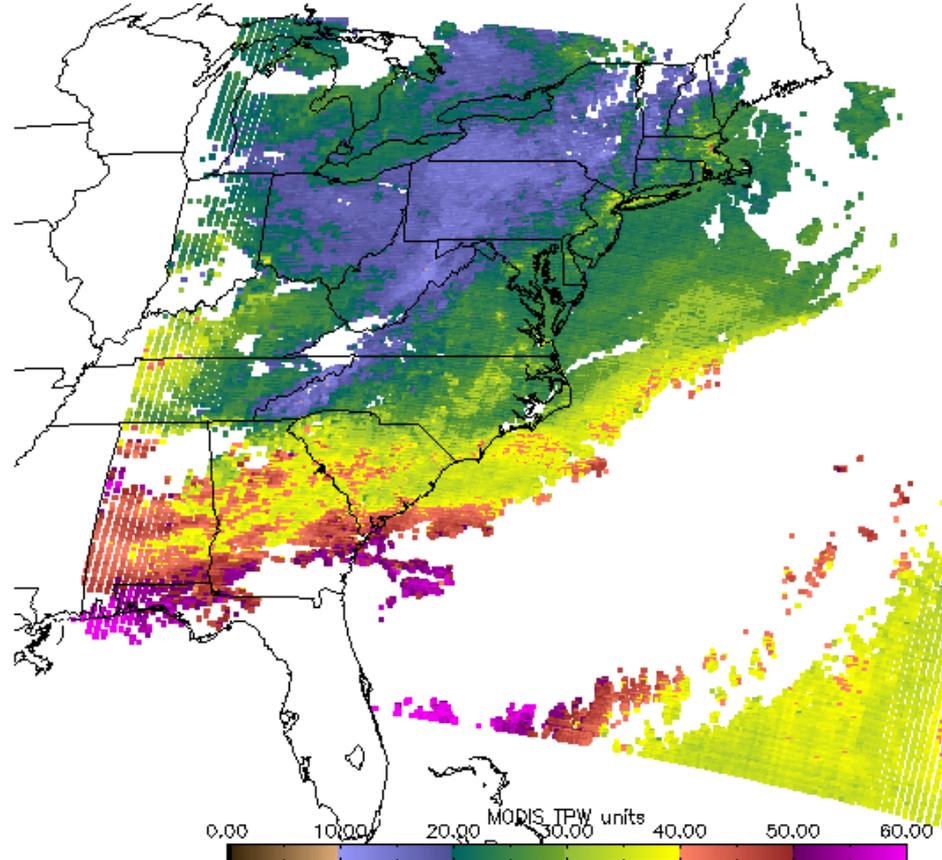
GOES vs. MODIS 2000/06/30 1600 UTC

Total Precipitable Water (mm)

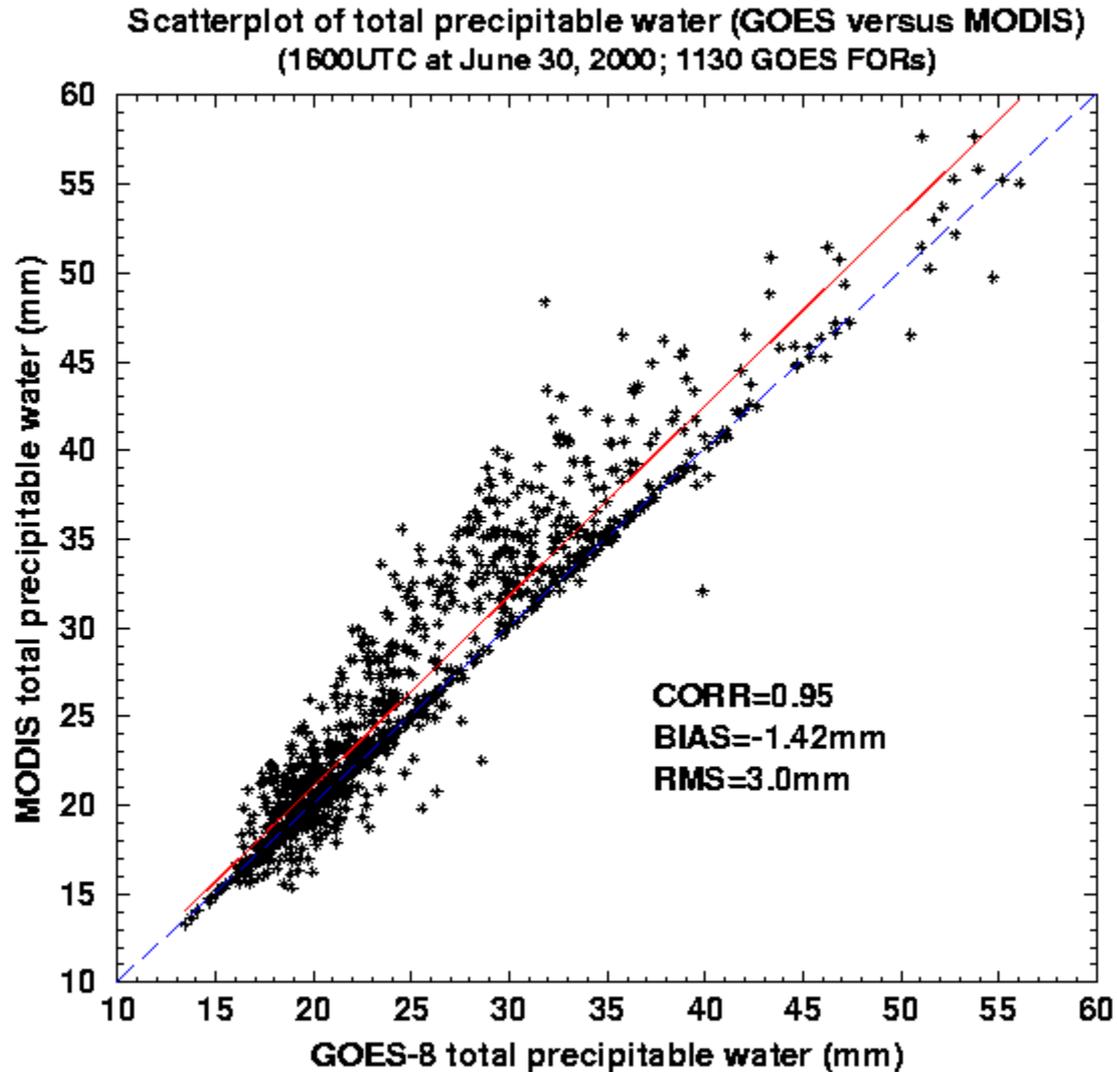
GOES-8 TPW 2000-0630-1600



MODIS TPW for 6-30-2000 at 1600 UTC

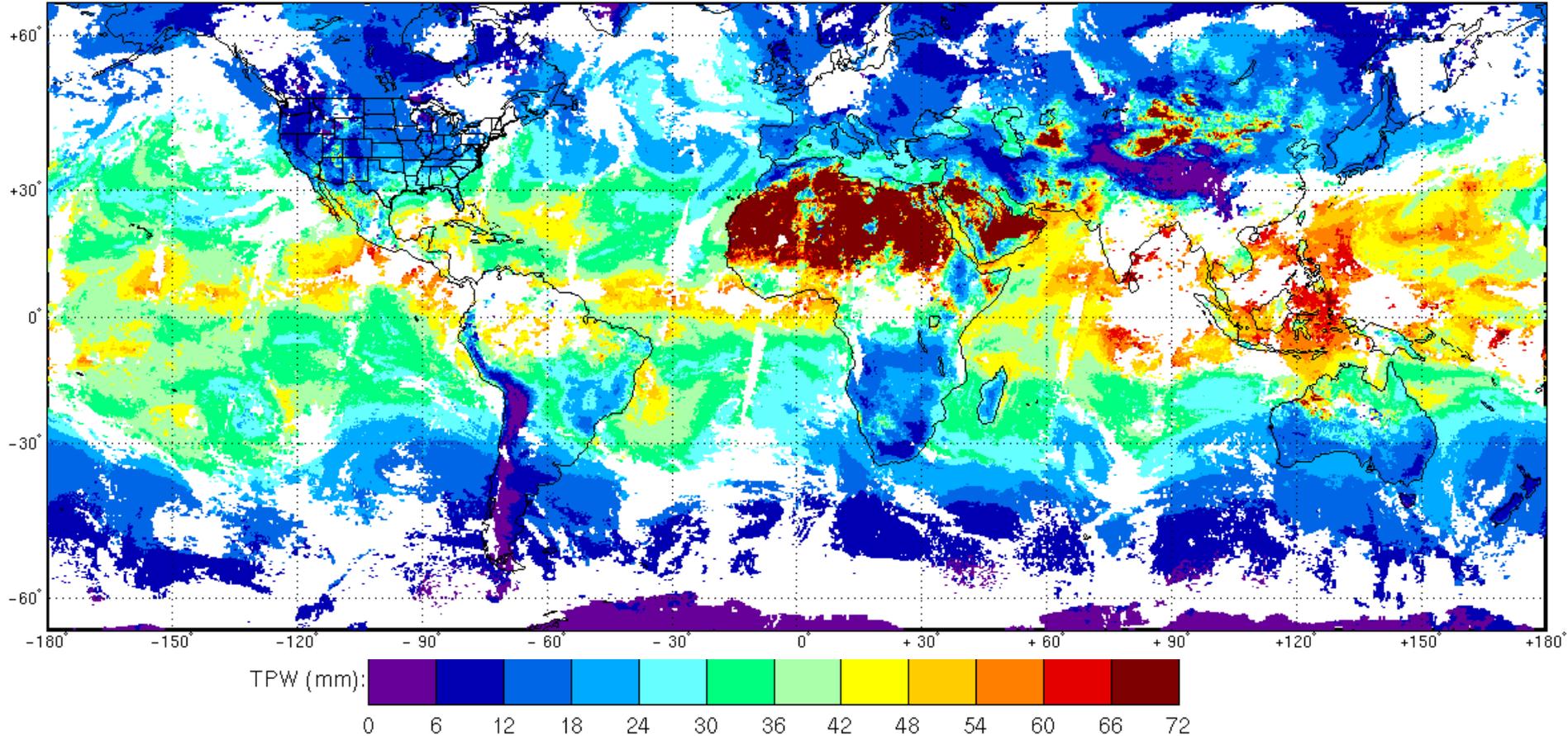


**MODIS total precipitable water vapor shows a wet bias wrt GOES;
bias 1.5 mm and rms of 3 mm; bias will be removed after more validation**





MODIS TPW June 2, 2001: Initial Algorithm



SWIR daytime reflection causing wet atm over African desert



Mitigating Problems in Initial MODIS TPW Algorithm

*** Changed predictors band 24 and 25 (4.4 and 4.5 um) brightness temperatures to their BT difference to remove surface effects:**

Old algorithm had 12 predictors:

individual bands 24, 25, and 27 through 36.

New algorithm has 11 predictors:

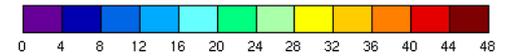
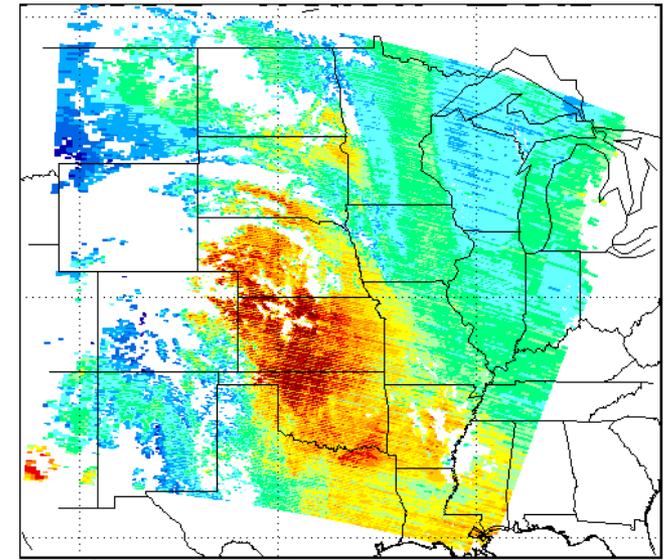
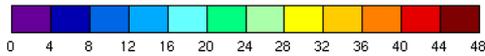
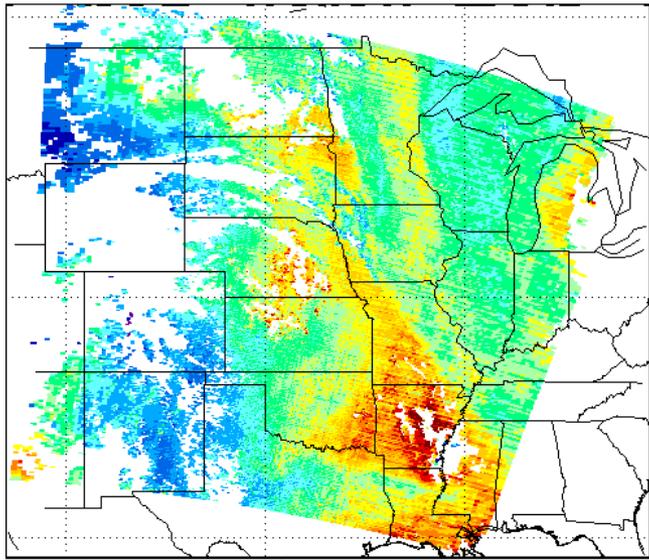
**band 25 - 24 BT difference and
individual bands 27 through 36.**

*** Separated training into seven regression BT zones to include a broader range of moisture regimes**

*** Used regression guess for surface skin temperature**

*** Implemented global radiance bias corrections.**

*** Applied post-launch NEdT in place of pre-launch.**

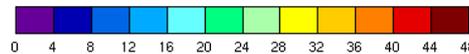
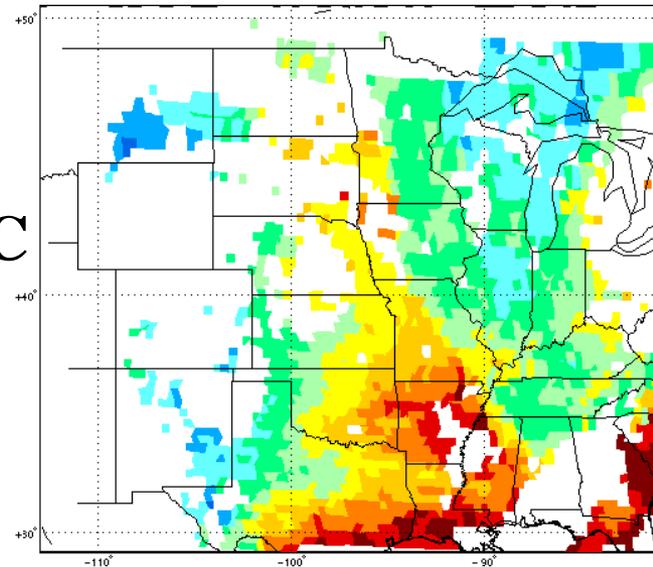


MODIS new

TPW

20 Aug 2001 18 UTC

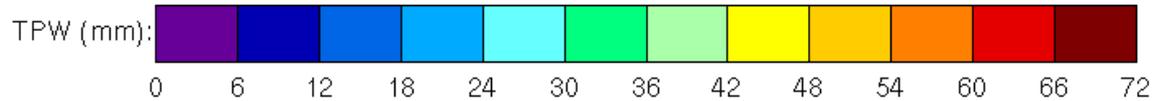
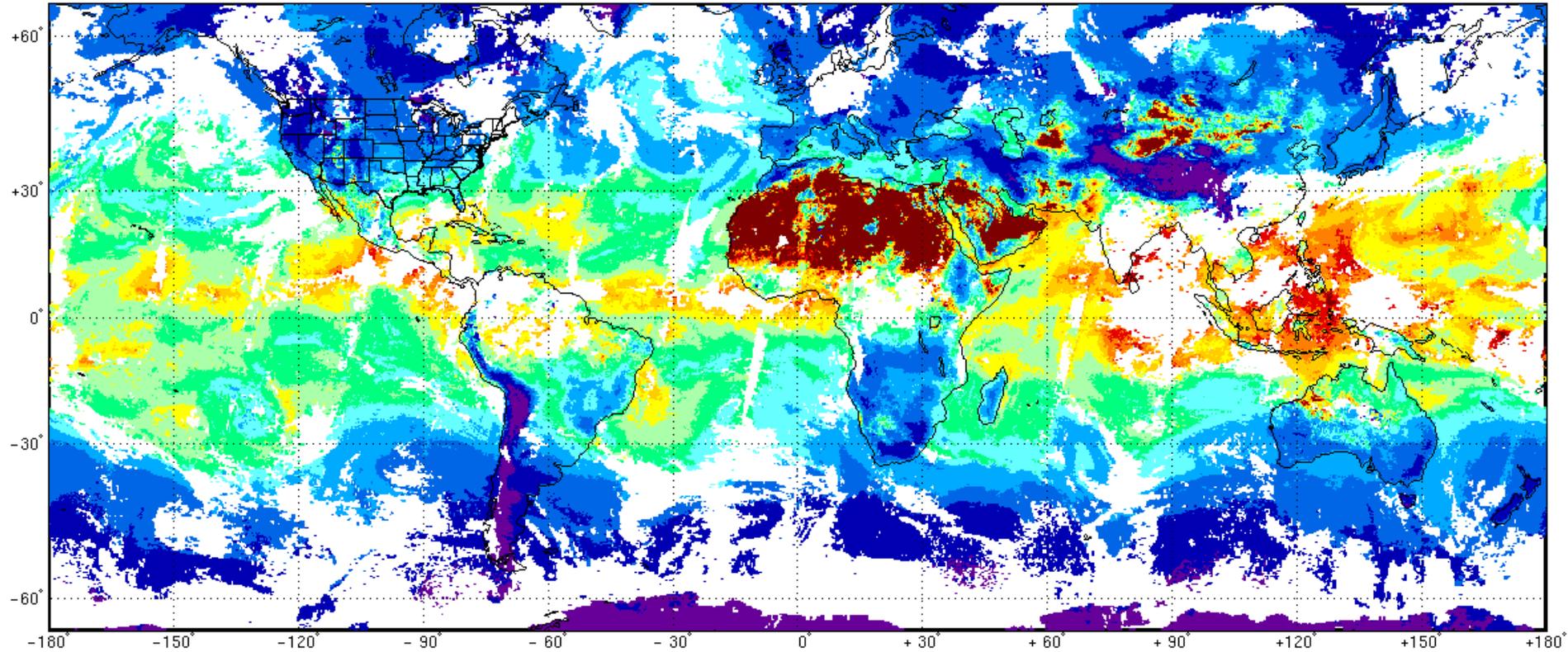
GOES -8



**MODIS wo BT11
partitioning**

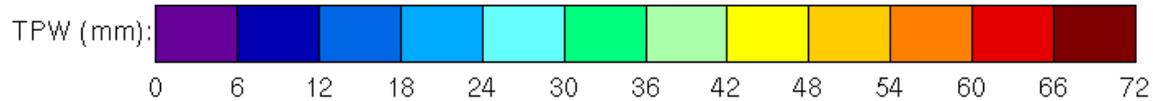
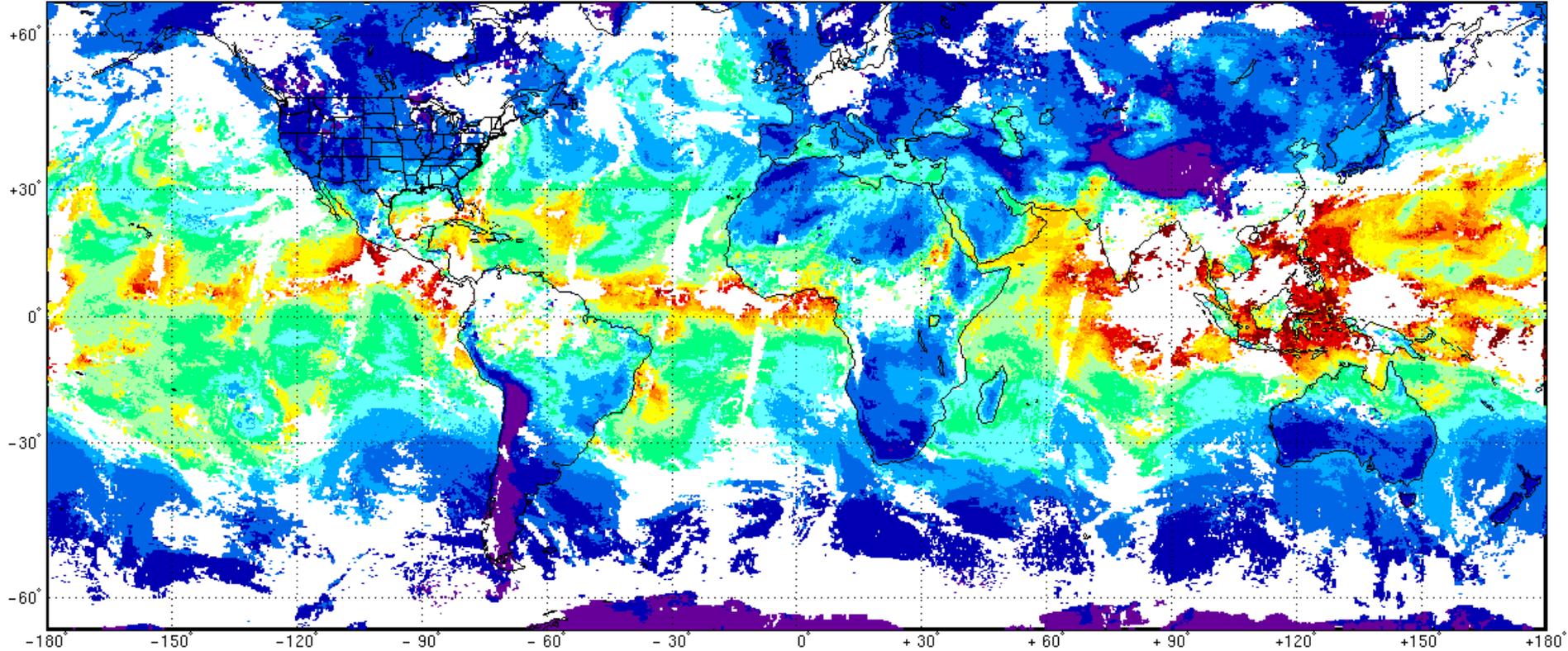


MODIS TPW June 2, 2001: Algorithm using IR ch 24 → 36



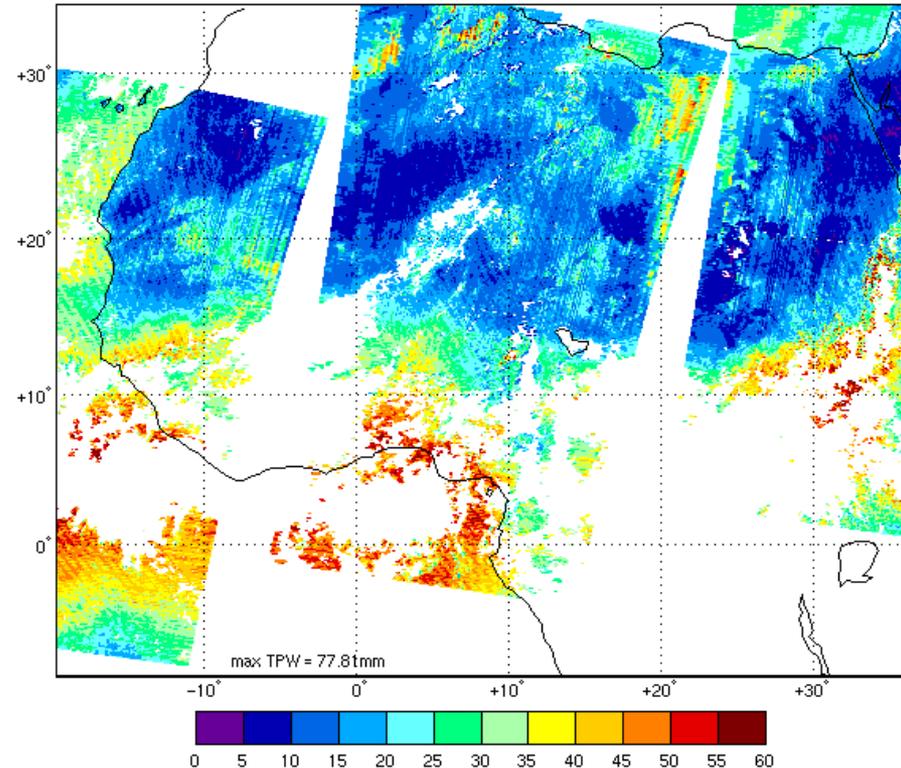
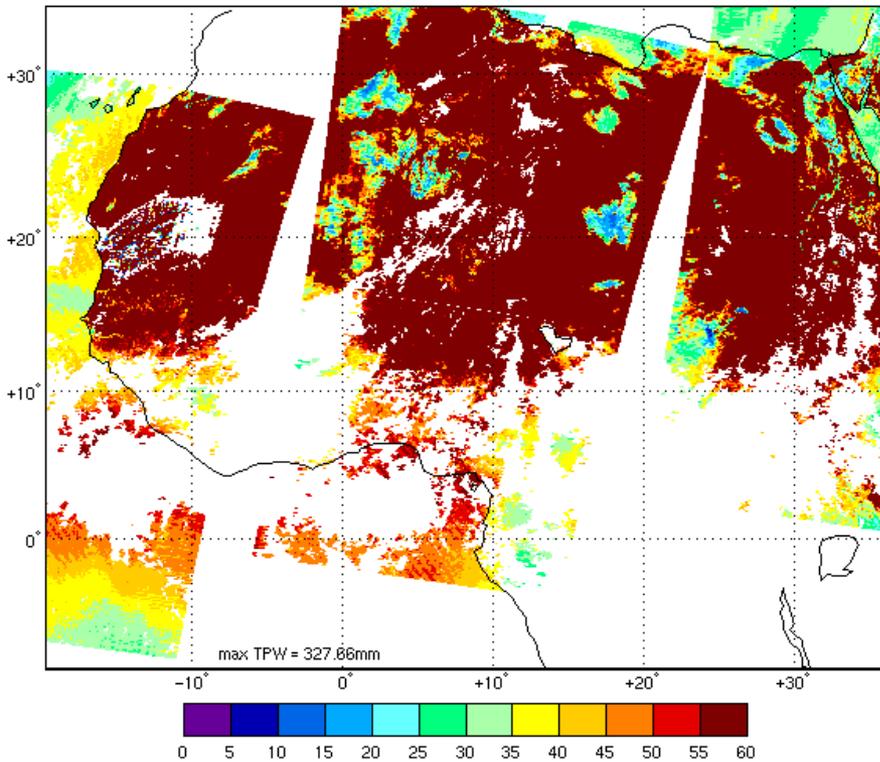


MODIS TPW June 2, 2001: Improved algorithm using Ch 24 - 25, 27 → 36



Improvement in Desert TPW: North Africa

June 2, 2001: 0830, 0835, 1010, 1015, 1150, 1155 UTC

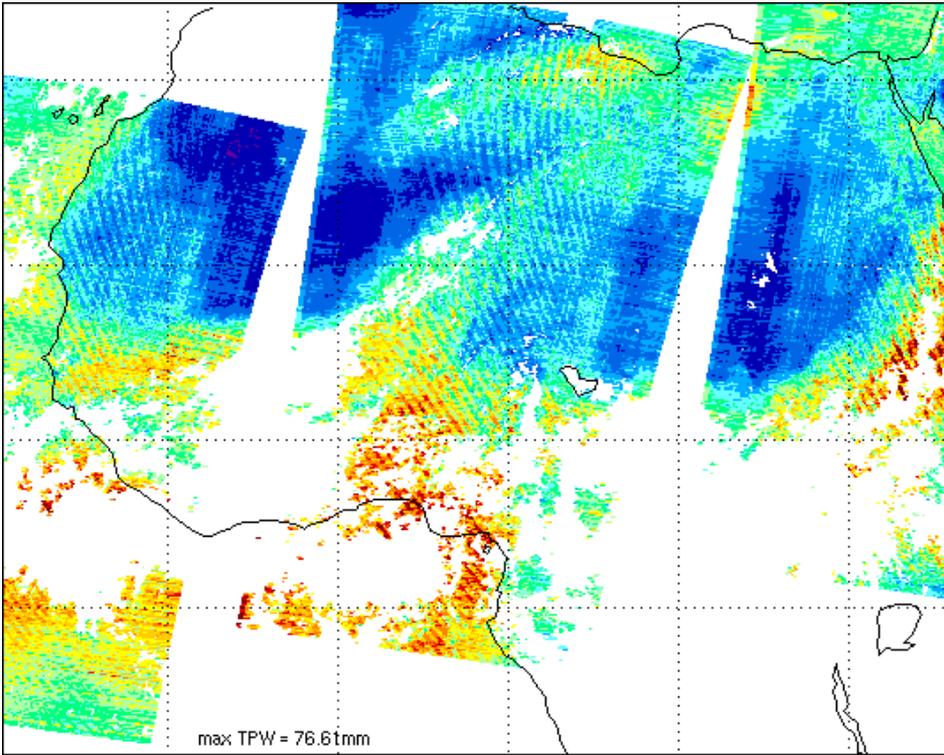




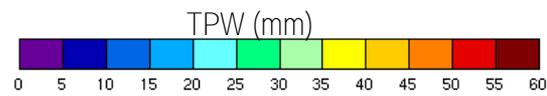
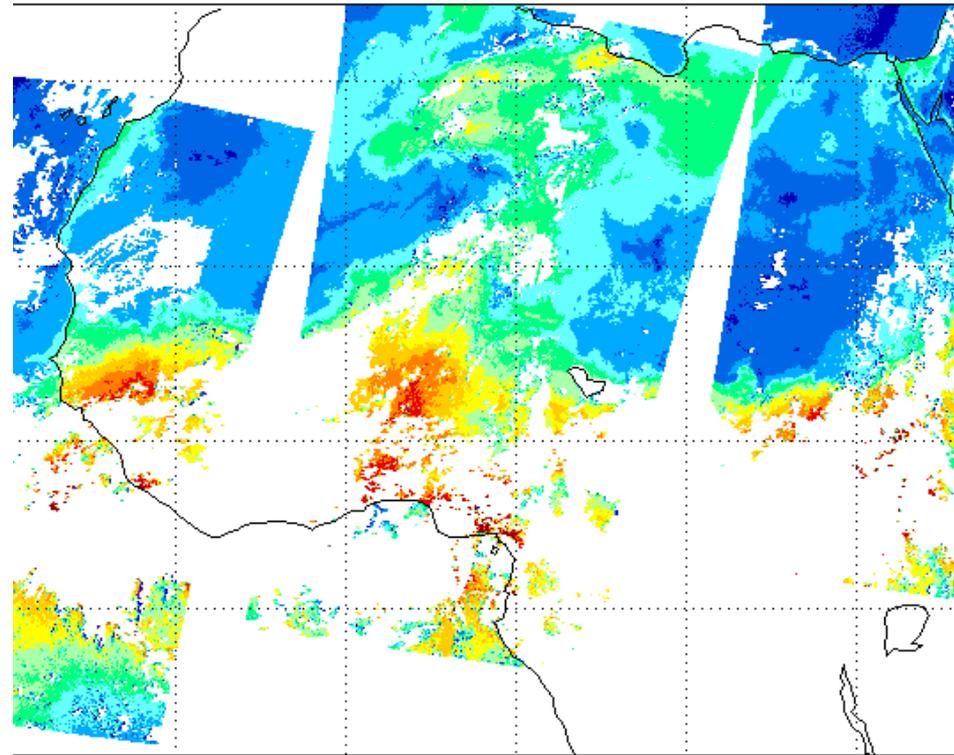
Comparison with MOD05: North Africa

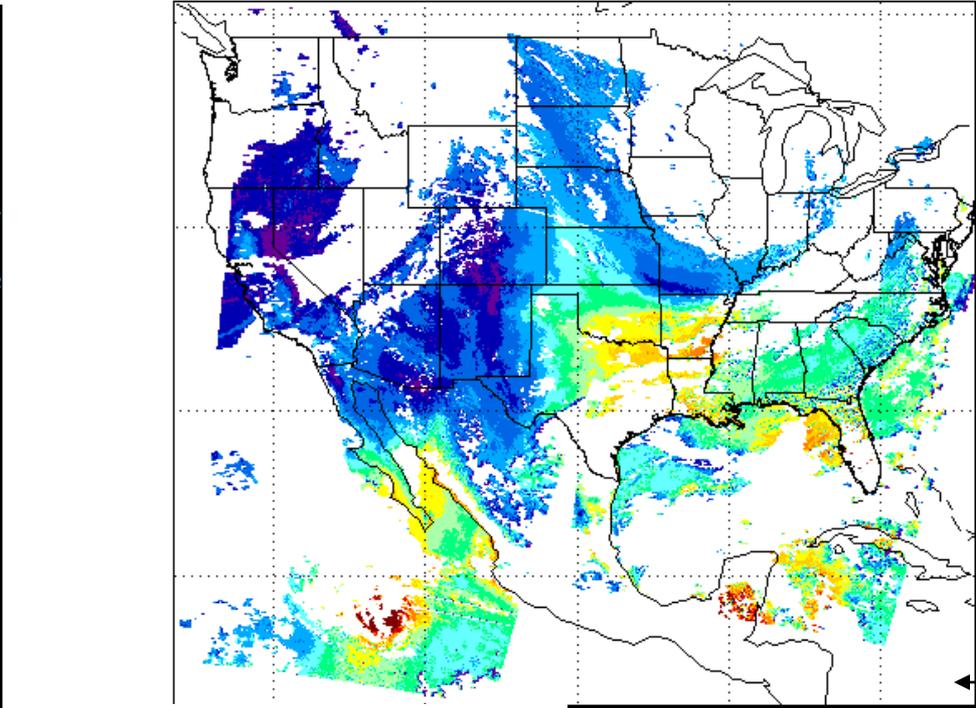
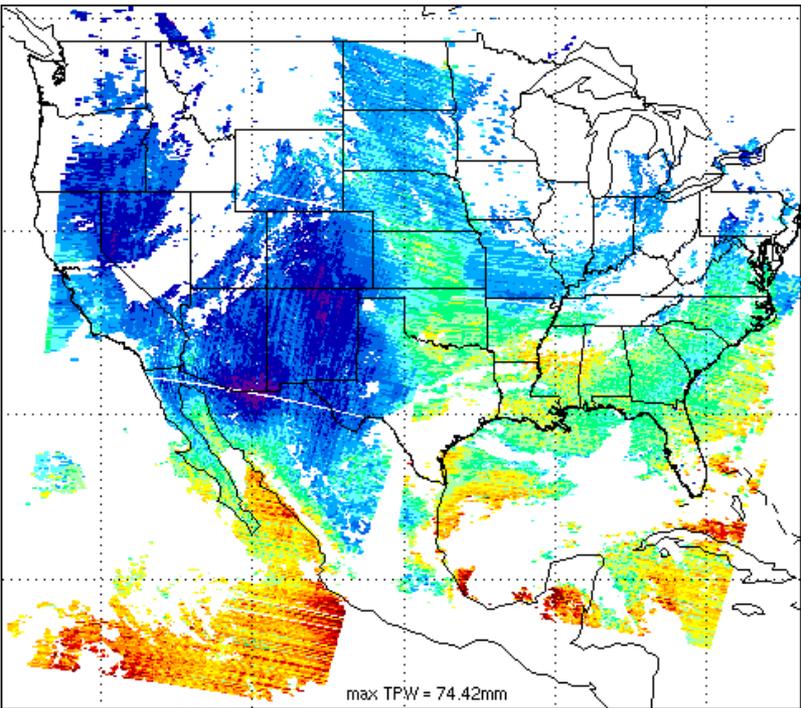
June 2, 2001: 0830, 0835, 1010, 1015, 1150, 1155 UTC

MOD07 TPW



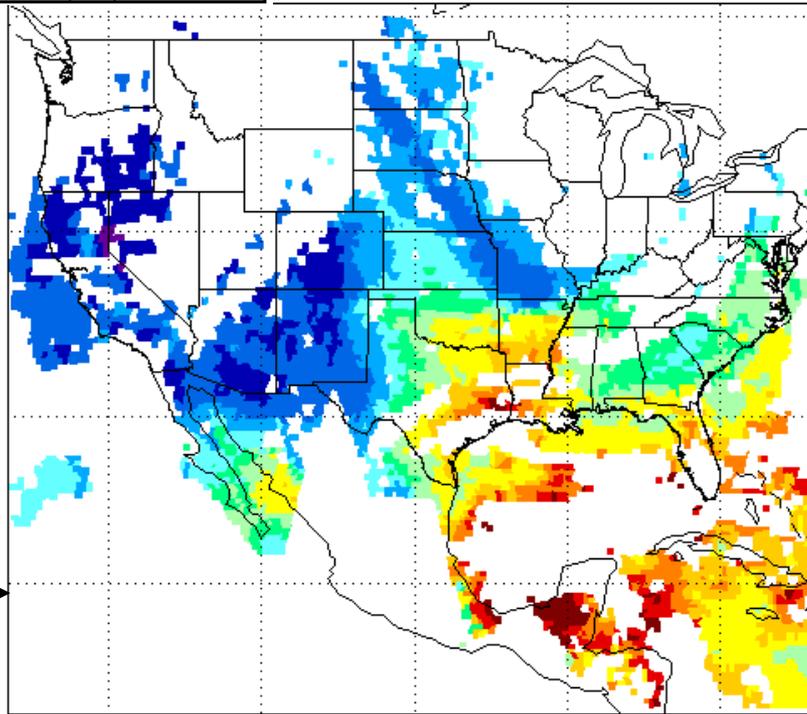
MOD05 TPW



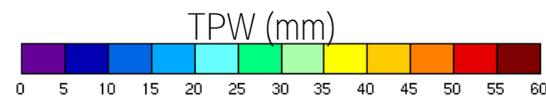


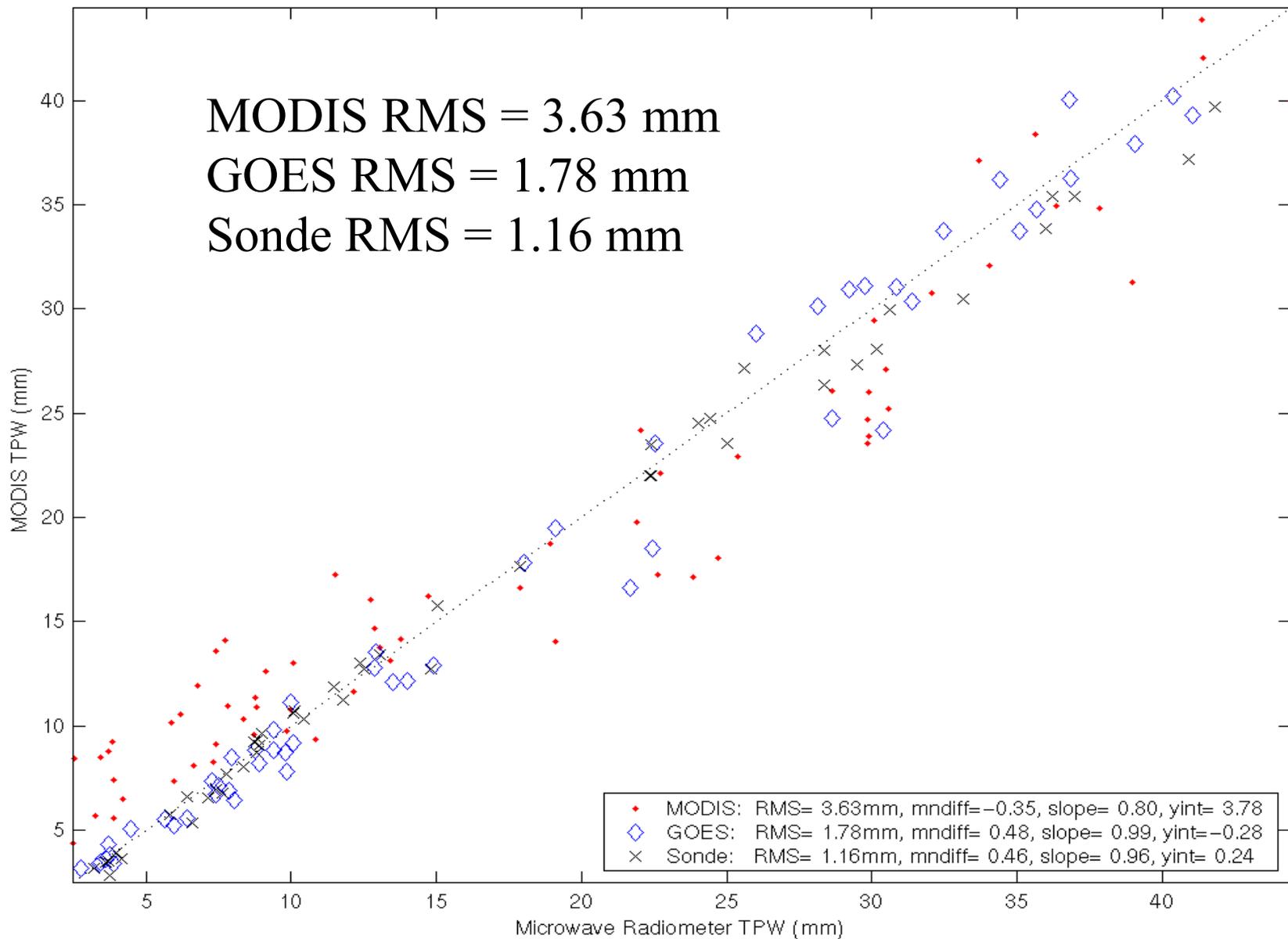
MOD 07 June 2, 2001:
1640, 1645, 1820, 1825 UTC

MOD 05 June 2, 2001:
1640, 1645, 1820, 1825 UTC

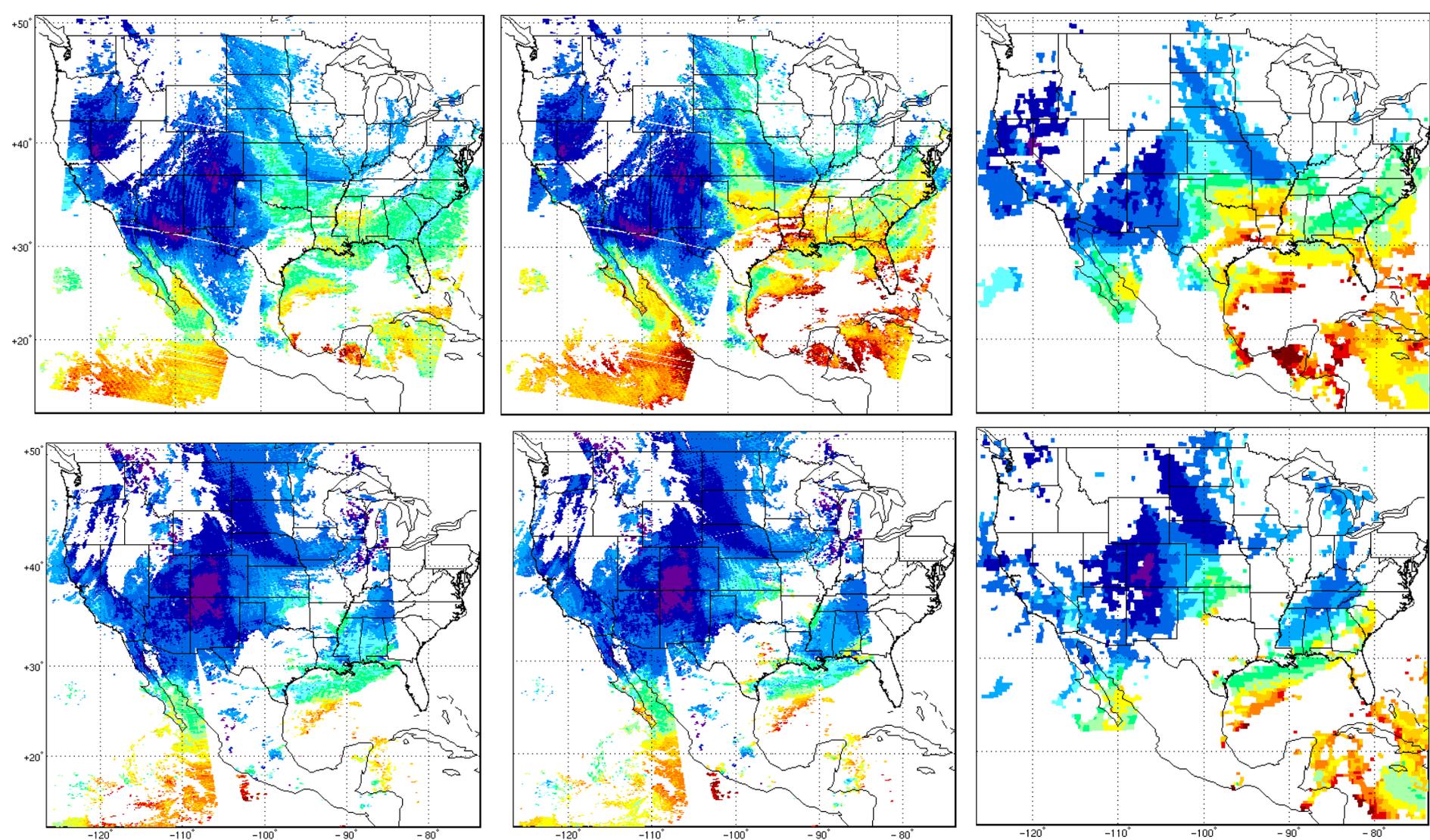


GOES 8 & 10
June 2, 2001:1800 UTC



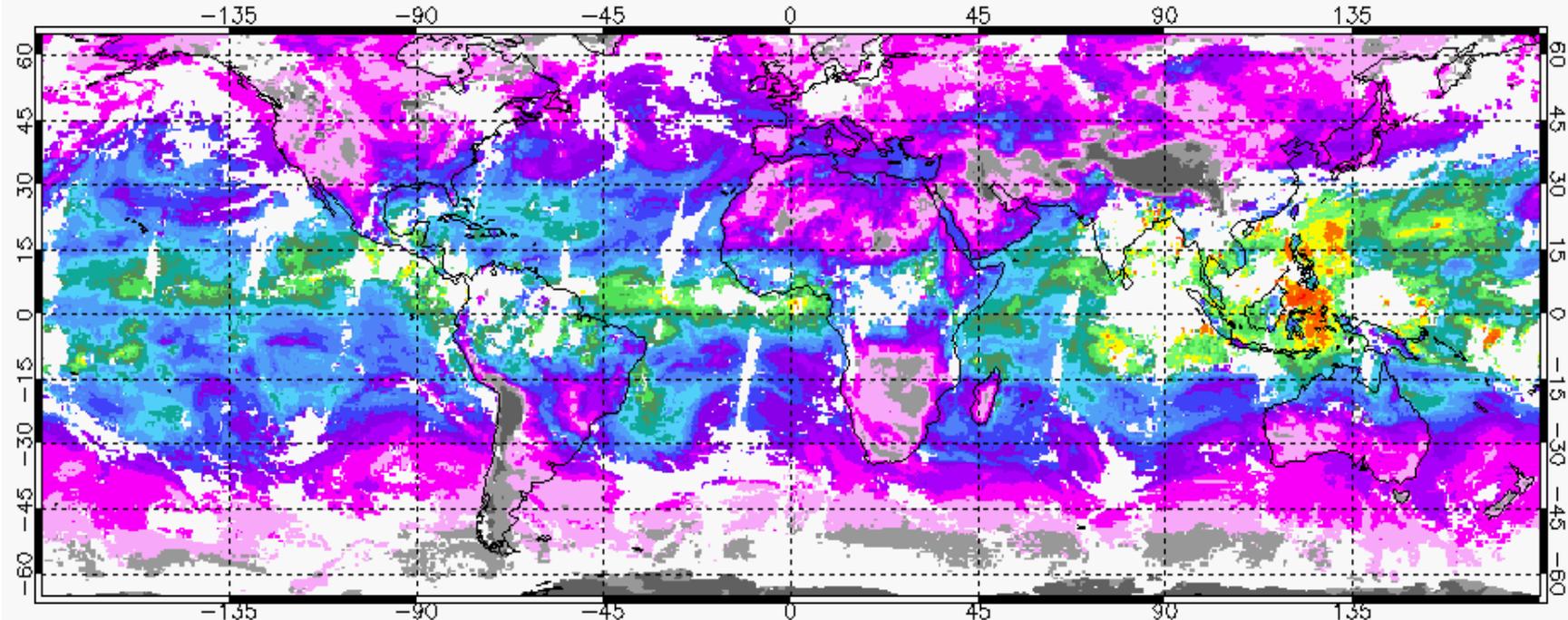


Comparison of TPW from MODIS regression (red dot), GOES-8 (blue diamonds), and radiosonde (black cross) with SGP ARM-CART microwave radiometer (MWR) in mm for 64 cases from April 2001 to June 2002



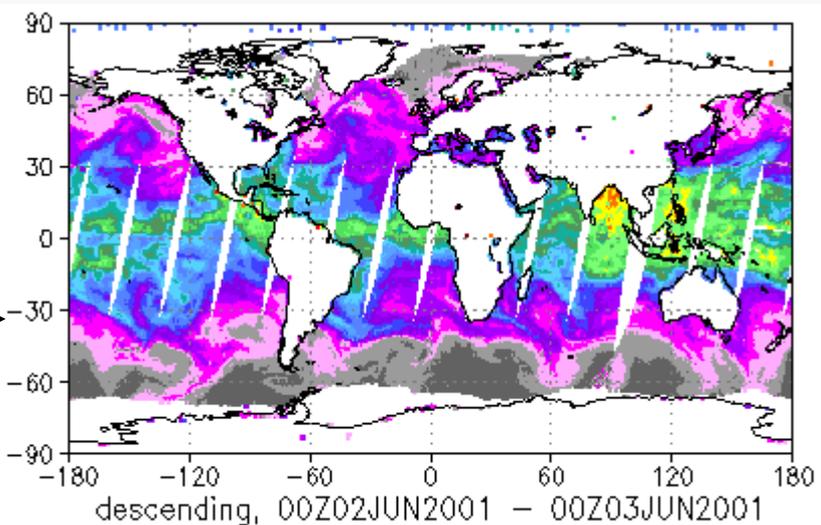
TPW (mm) for 02 June 2001 over North America retrieved by MODIS regression (left), MODIS physical (center), and GOES-8 and GOES-10 (combined, right). **Day** on top row and **night** on bottom row.

MODIS TPW Algorithm: Comparison with NOAA-15 Advanced Microwave Sounding Unit (AMSU) for June 2, 2001

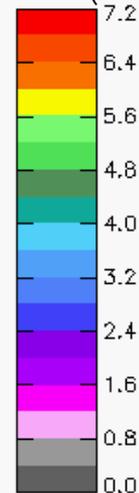


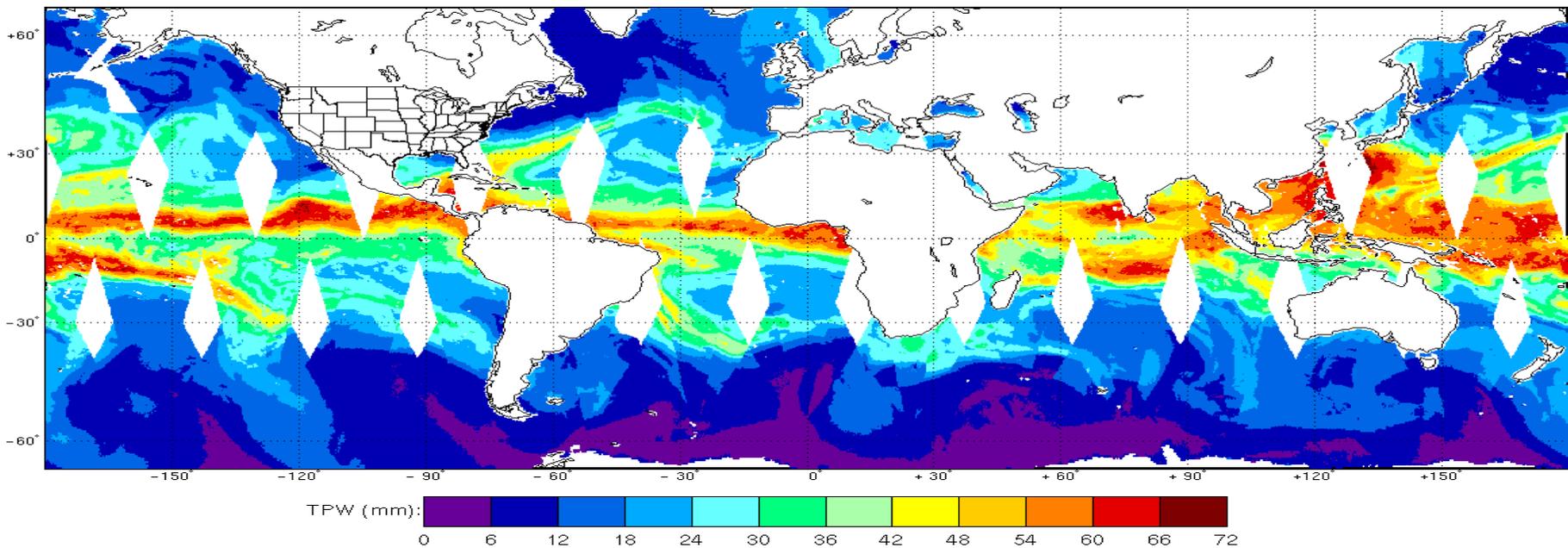
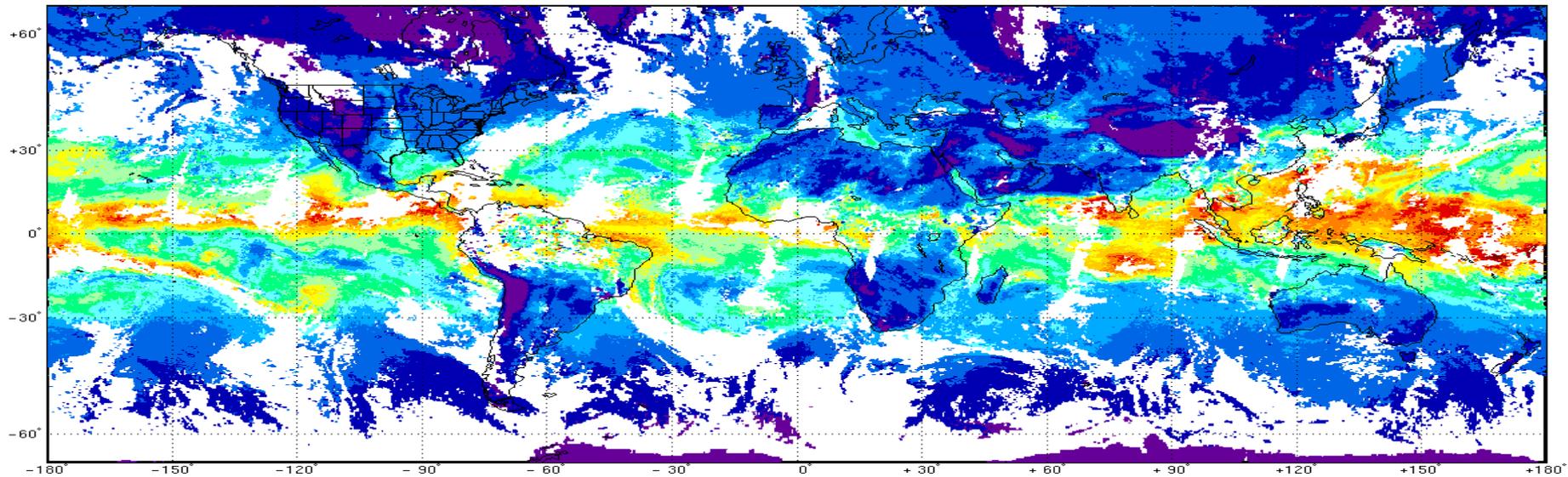
MODIS TPW (cm)
June 2, 2001

AMSU TPW (cm)
June 2, 2001



TPW (cm)



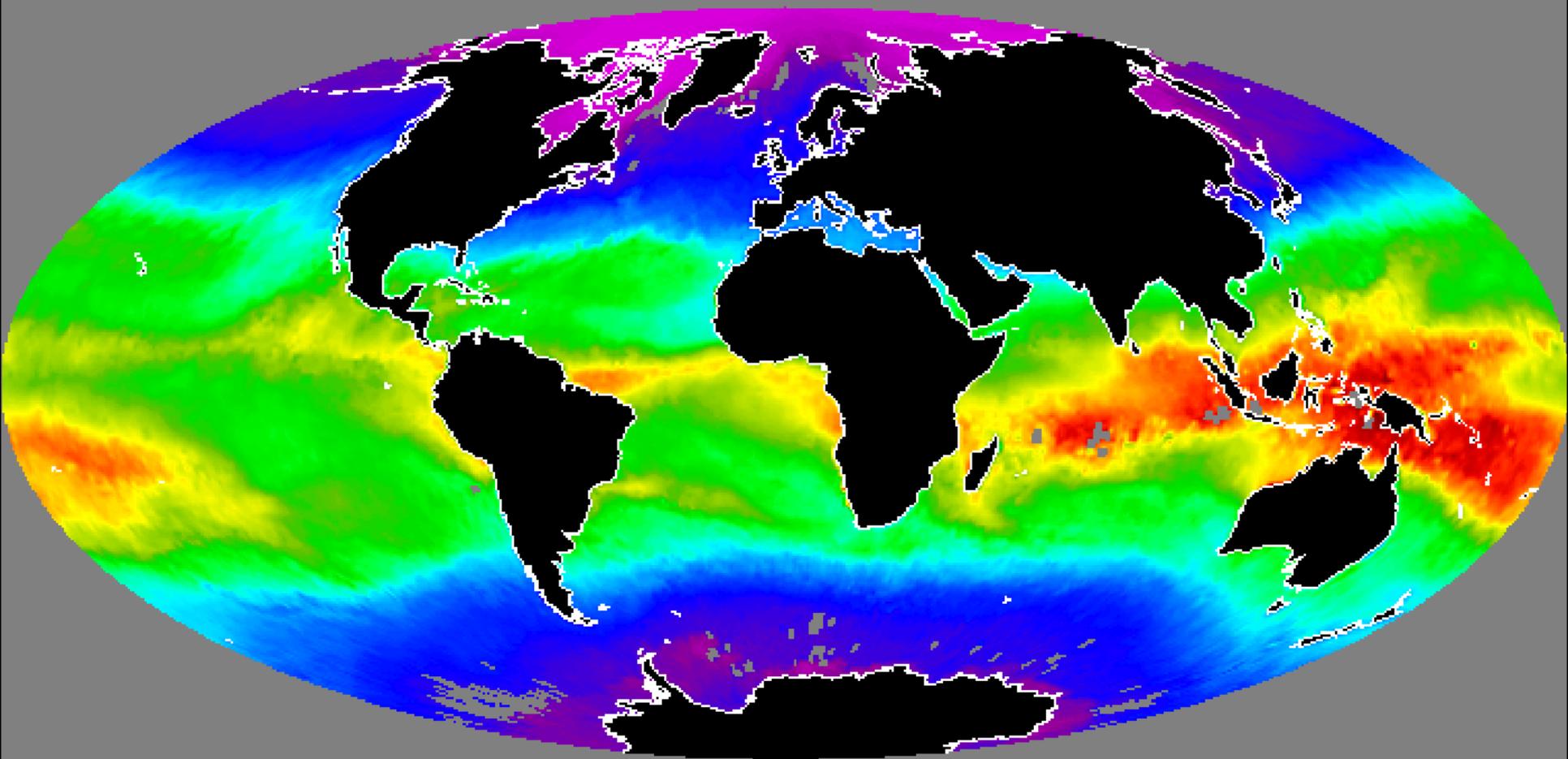


MODIS TPW (top) and SSM/I f-14 TPW (bottom) on 22 May 2002. Ascending and descending passes were averaged.

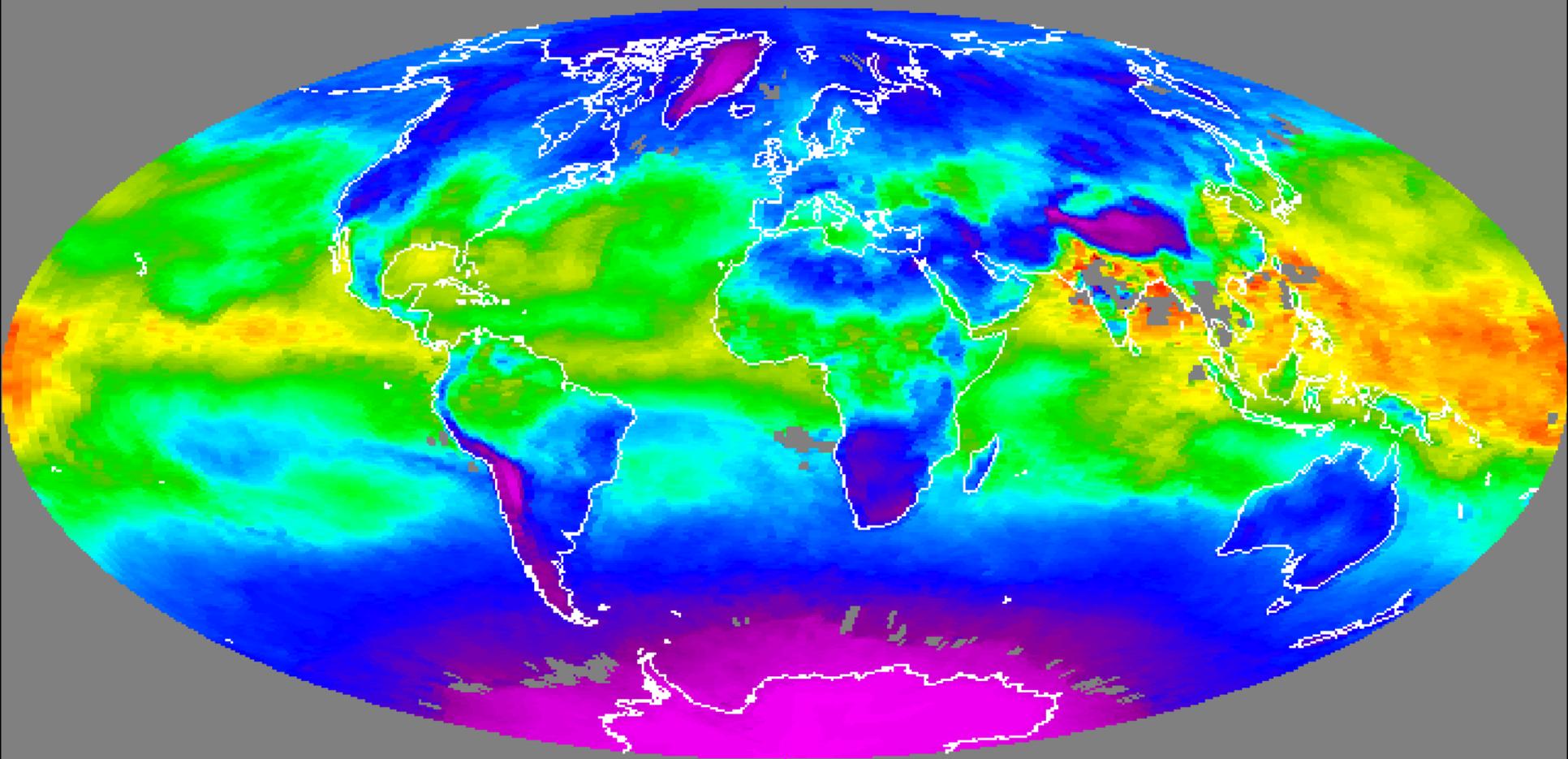
One year trends inferred from daily MODIS TPW

- * Continuous pulsing motion of moisture is evident
- * Global circulations are obvious esp around subtropical highs
(e.g. clockwise around Bermuda high in Jun,
counter clockwise around southern Pacific high in Dec)
- * Indian monsoon evident Jun-Jul-Aug
- * Gulf of Mexico moisture moving into central US appears May - Jun
- * Indonesian region has year round high moisture (often global max)
- * TPW follows the Sun – latitudinal moisture bands connecting
continents drift N & S with seasons
- * End of 2001 is drier than beginning?

TPW (CM)



1 JAN 2001



2 AUG 2002

Conclusions

MODIS IR TPW

- * captures TPW gradients very well
- * has been improved over daytime non vegetated land
- * is very sensitive to multi-spectral striping
- * agrees within 3 mm rms of GOES TPW
- * shows a wet bias wrt microwave for $TPW < 15\text{mm}$,
a dry bias for $TPW > 15\text{mm}$
- * bias will be removed after more validation.
- * vis-NIR TPW also available
- * Terra and Aqua offer opportunity for diurnal studies

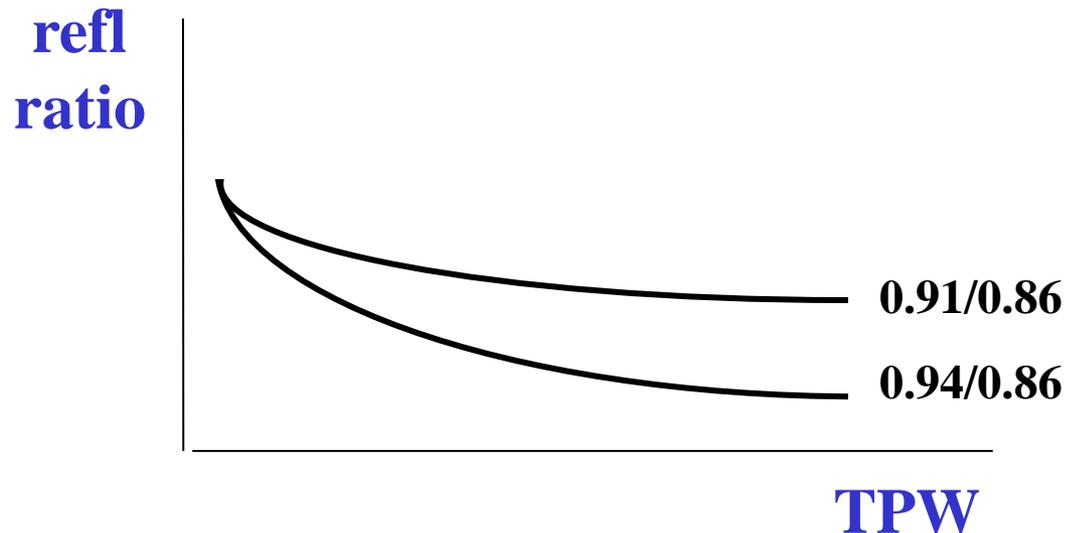
MODIS Polar WV loops

- * enable feature tracking
- * showing positive NWP impact

MODIS VIS NIR TPW

Ratios of on H2O line (0.91, 0.94 μm) and off H2O line (0.86 μm) are correlated with TPW

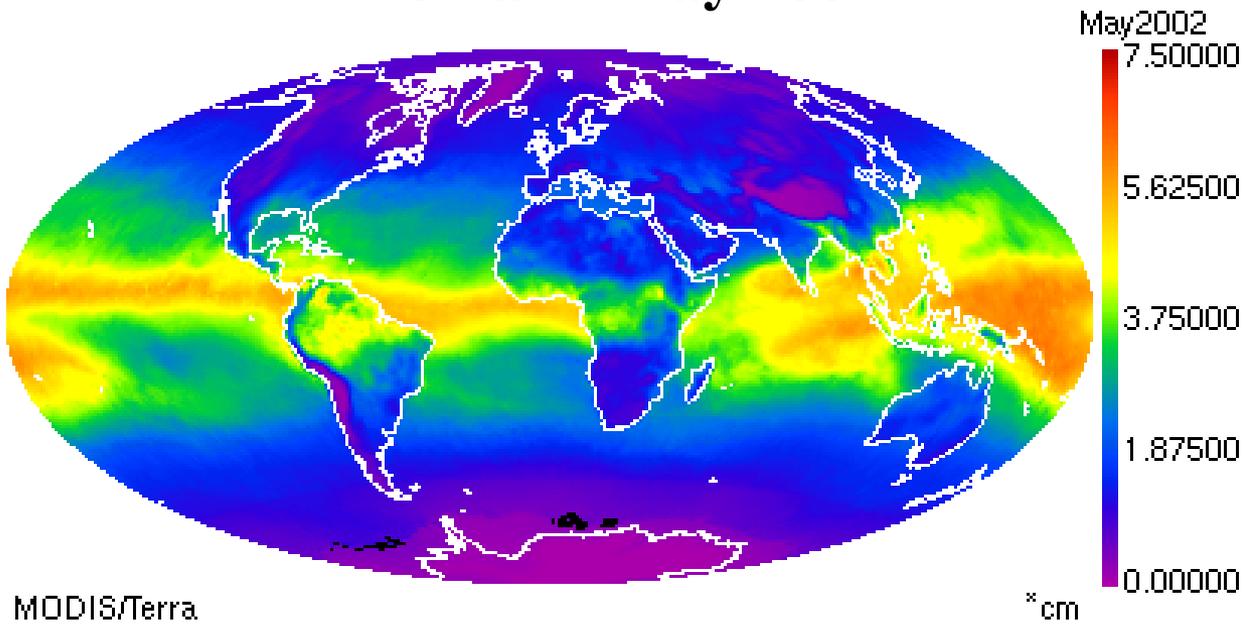
Two way transmittance through atmosphere calculated with HITRAN2000 (improvement over 1996)



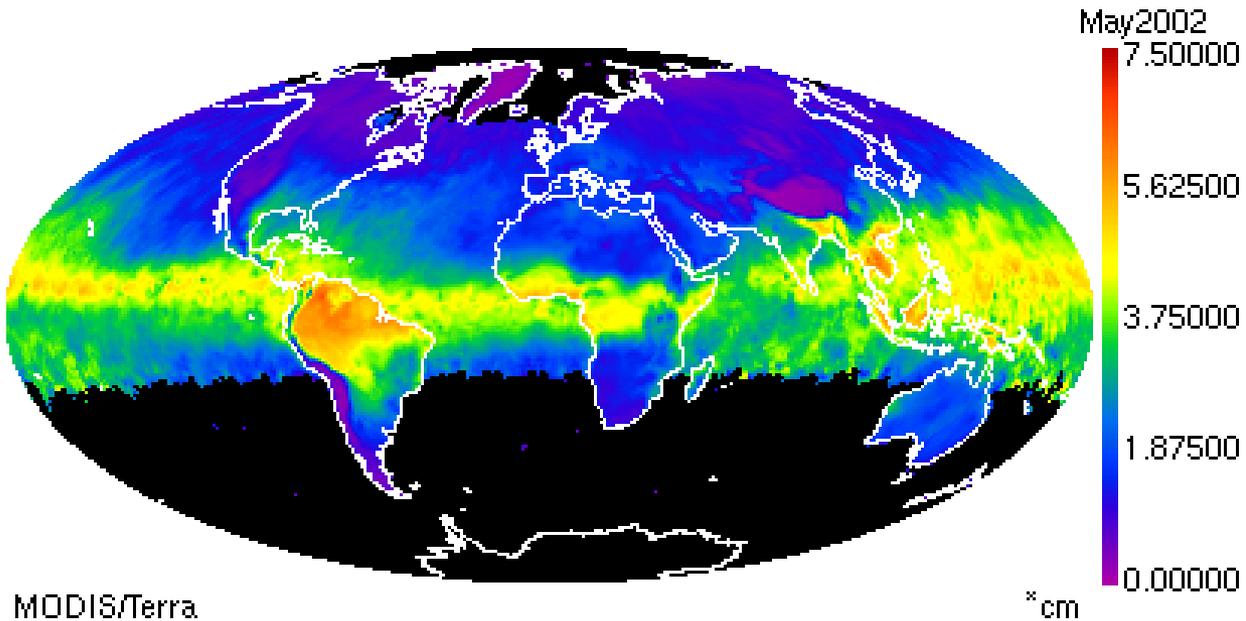
Comparison of MODIS WV Retrieval Techniques

Terra - May 2002

IR
Version



NIR
Version



Conclusions

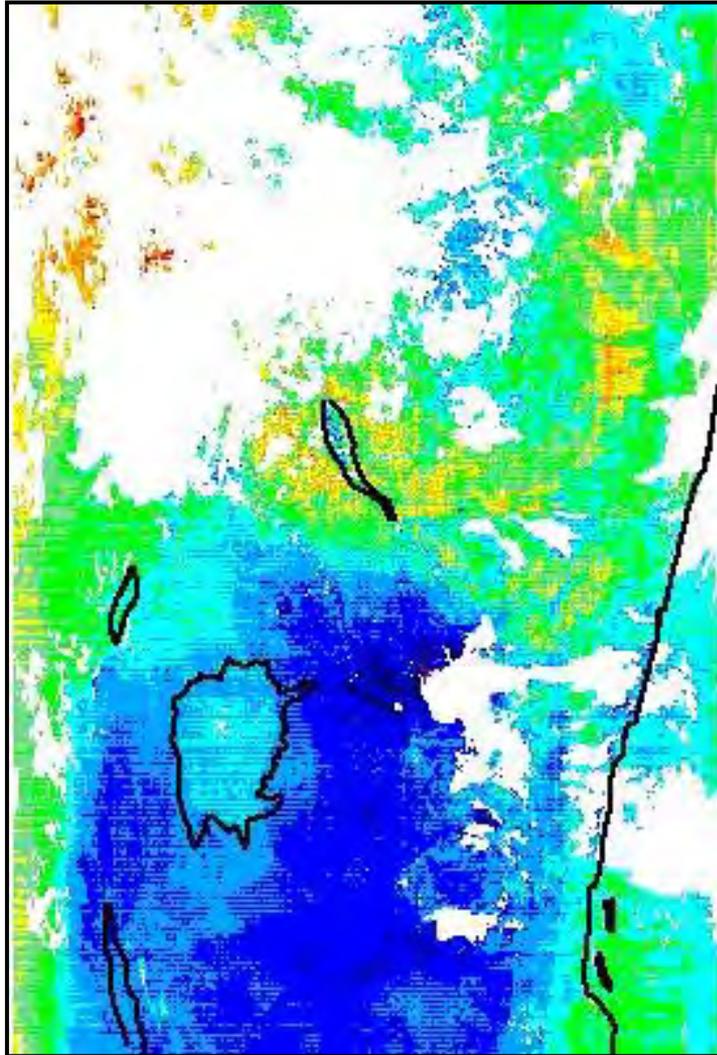
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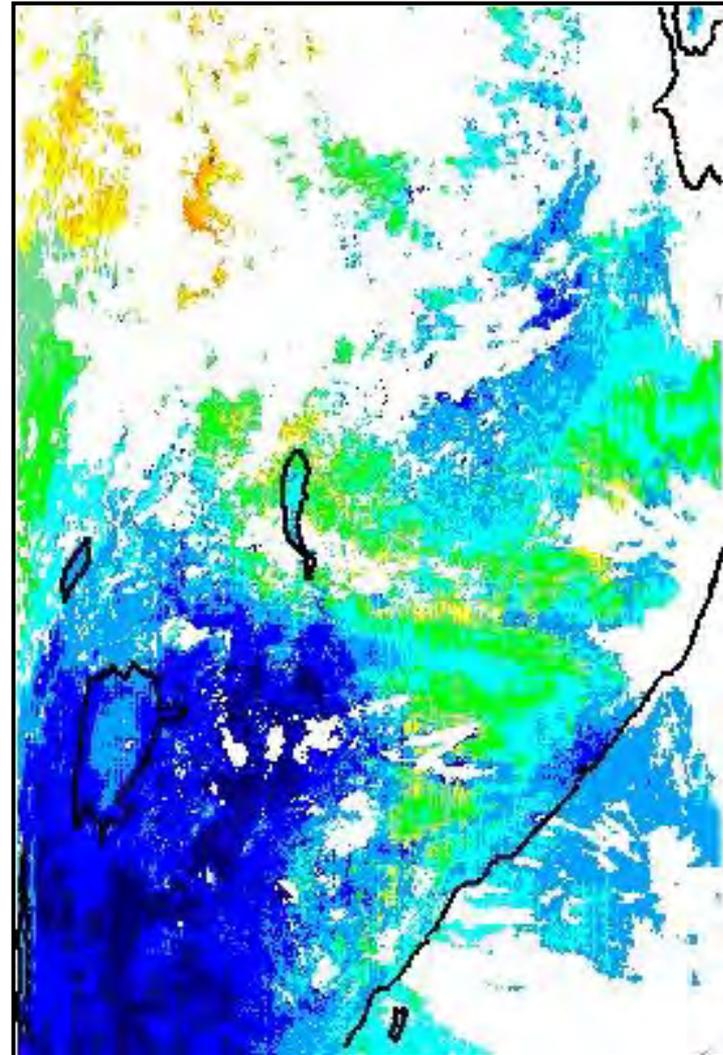
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TPW changes in 3 hours



Terra 08:05 UTC



Aqua 11:00 UTC

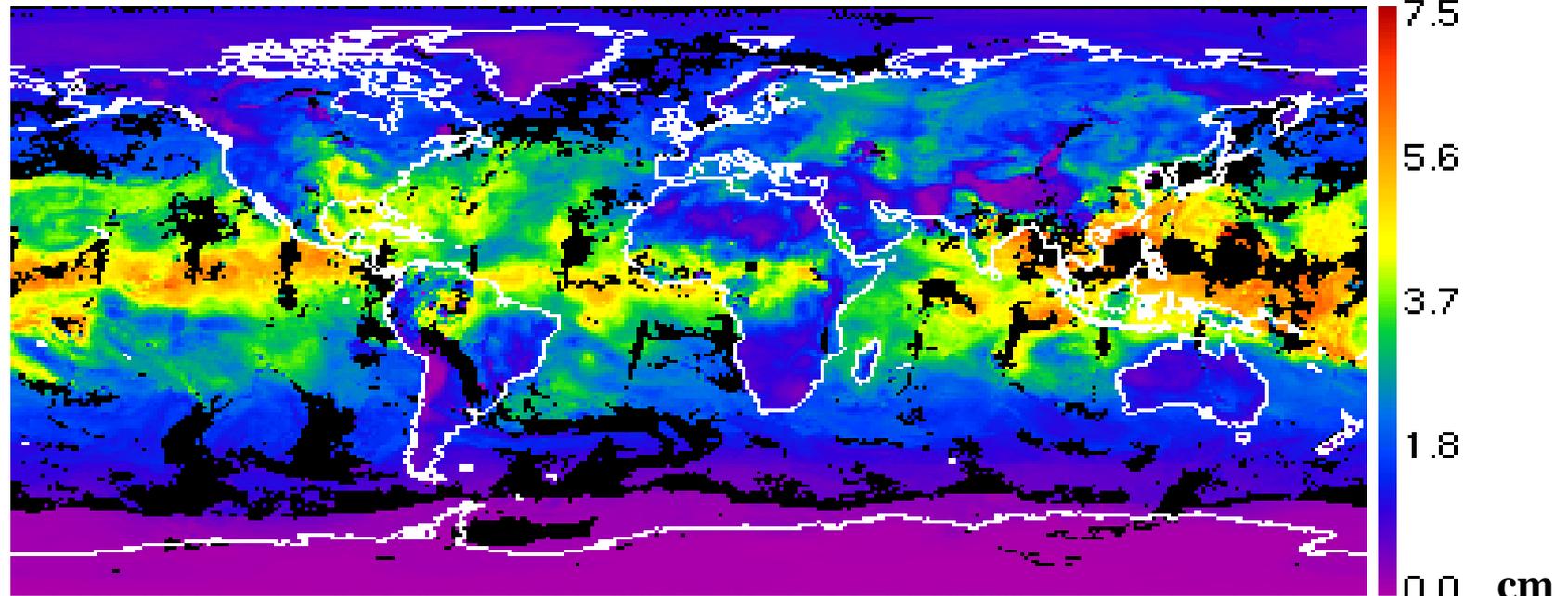
TPW (mm):



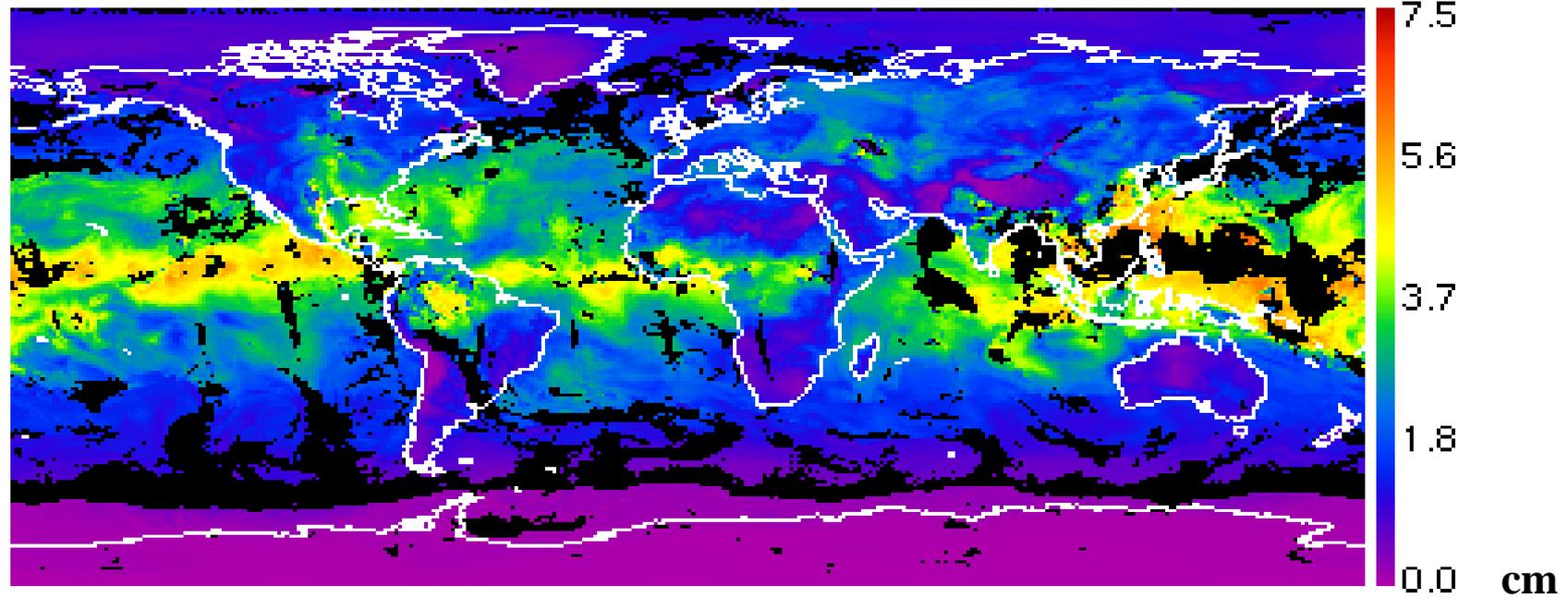
0 6 12 18 24 30 36 42 48 54 60 66 72

am & pm TPW from Terra and Aqua on 5 July 2002

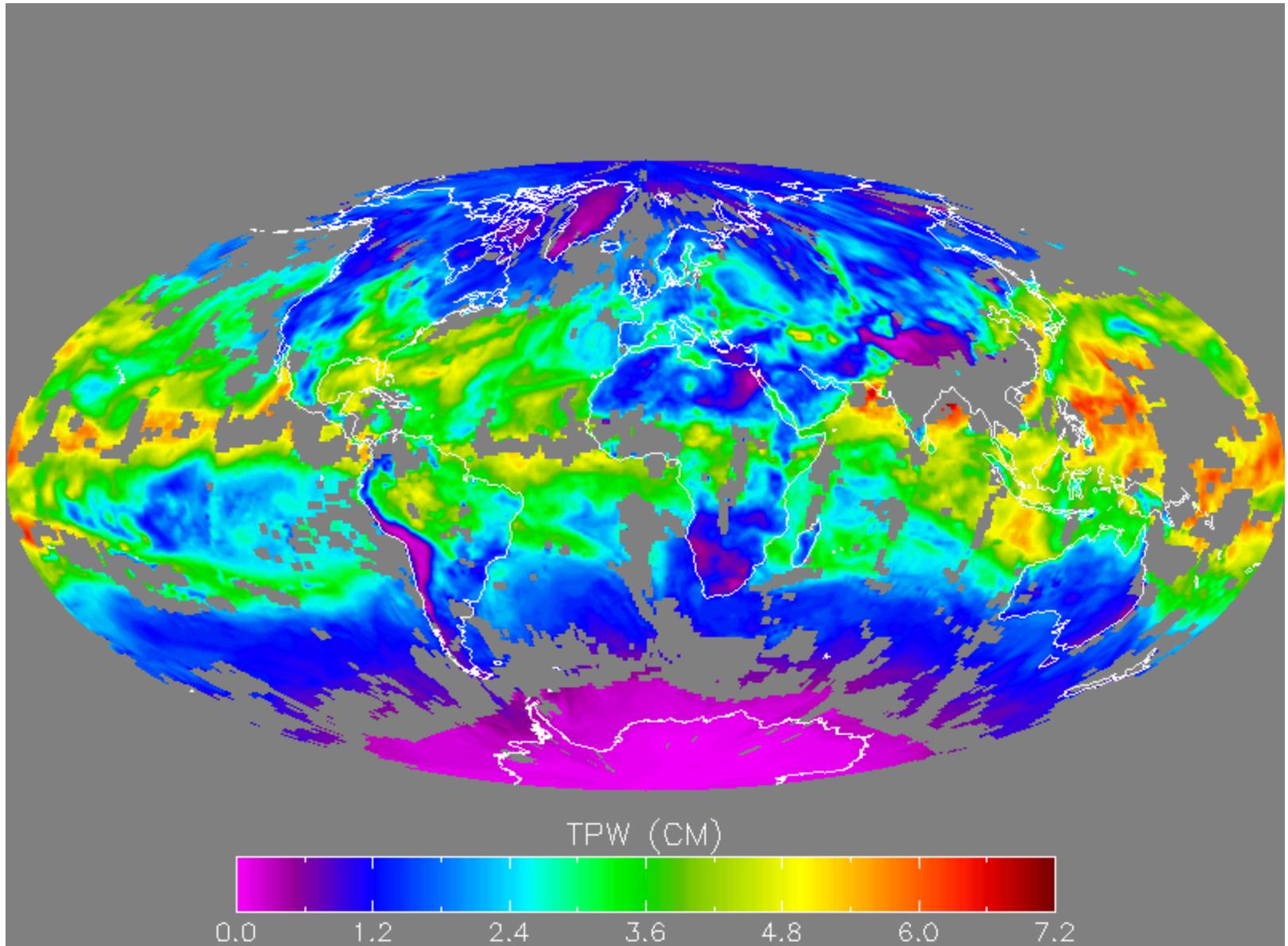
Terra



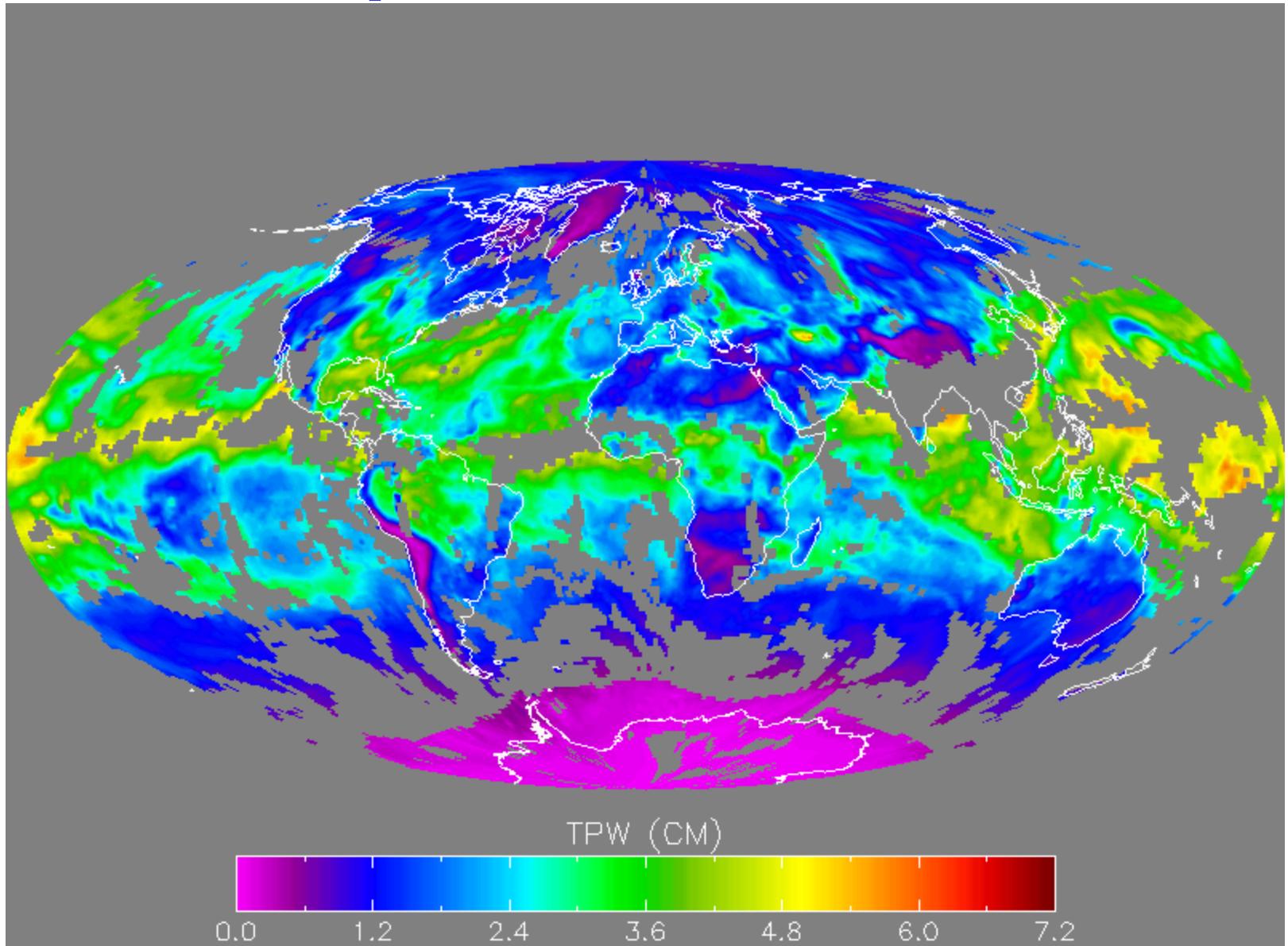
Aqua



Terra MODIS TPW 2002/07/20



Aqua MODIS TPW 2002/07/20



**With AIRS/AMSU on Aqua Q(p)
will be significantly improved**

**MODIS additional role be will be to
provide small scale info within
AIRS/AMSU footprint**

Conclusions

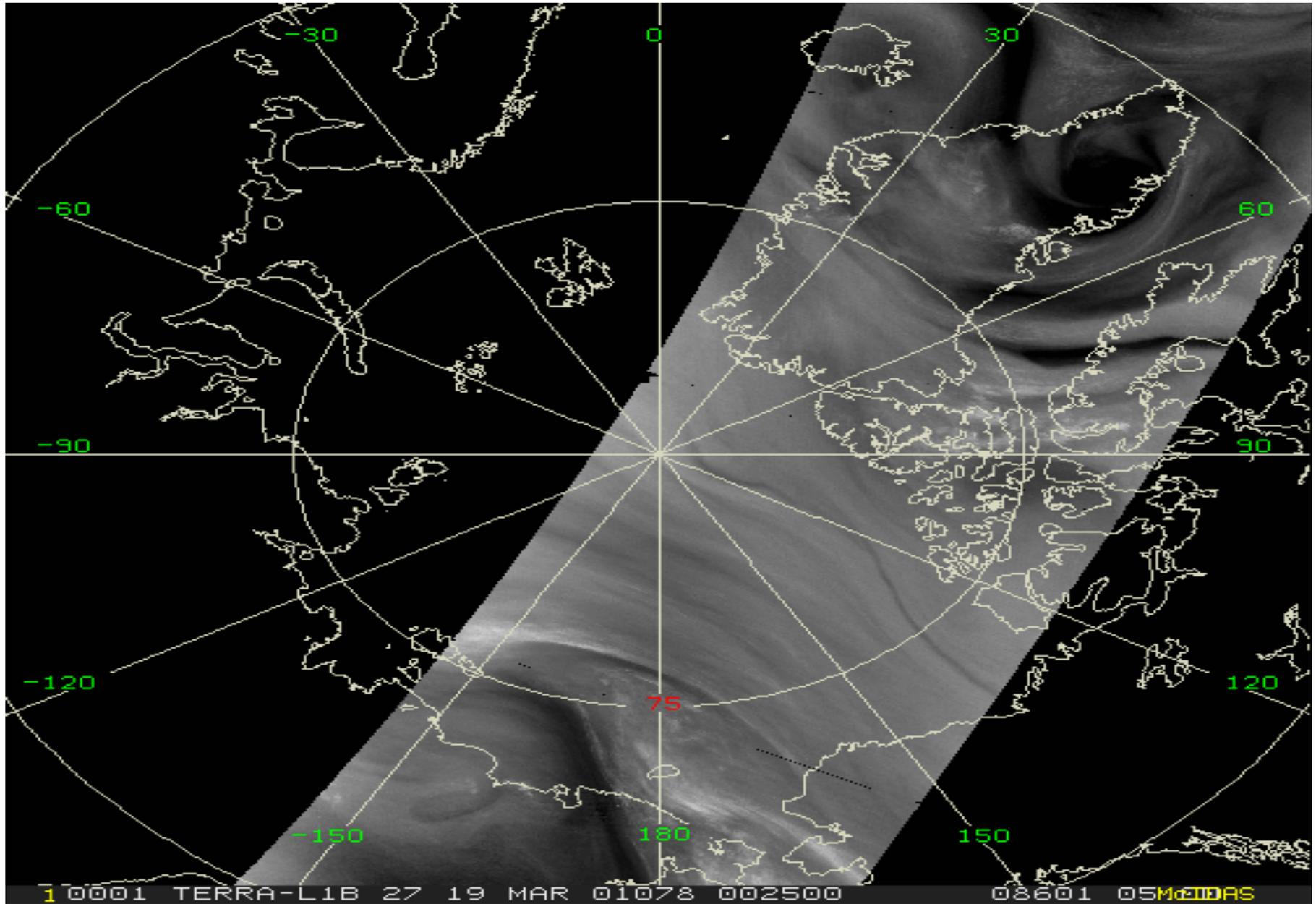
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- * **enable feature tracking**
- * **showing positive NWP impact**

Polar WV image loops enable feature tracking



Winds improve Wx Fcst

