OMI operational water vapor retrieval

Huiqun Wang, Xiong Liu, Kelly Chance,

Gonzalo Gonzalez Abad, Christopher Chan Miller

Smithsonian Astrophysicsl Observatory

Water Vapor Importance

- Active player in hydrological cycle
- Important factor for the weather
- Most abundant greenhouse gas
- Participates in atmospheric chemistry

It is important to monitor the spatial and temporal distribution

Water Vapor Remote Sensing

- Microwave – AMSU, AMSR-E, SSM/I, SSMI/S
- Radio wave – GNSS
- Thermal IR – MODIS, TES, IASI
- Near-IR – MODIS, MERIS, SCIAMACHY
- Red – GOME, GOME-2
- Blue – GOME-2, OMI

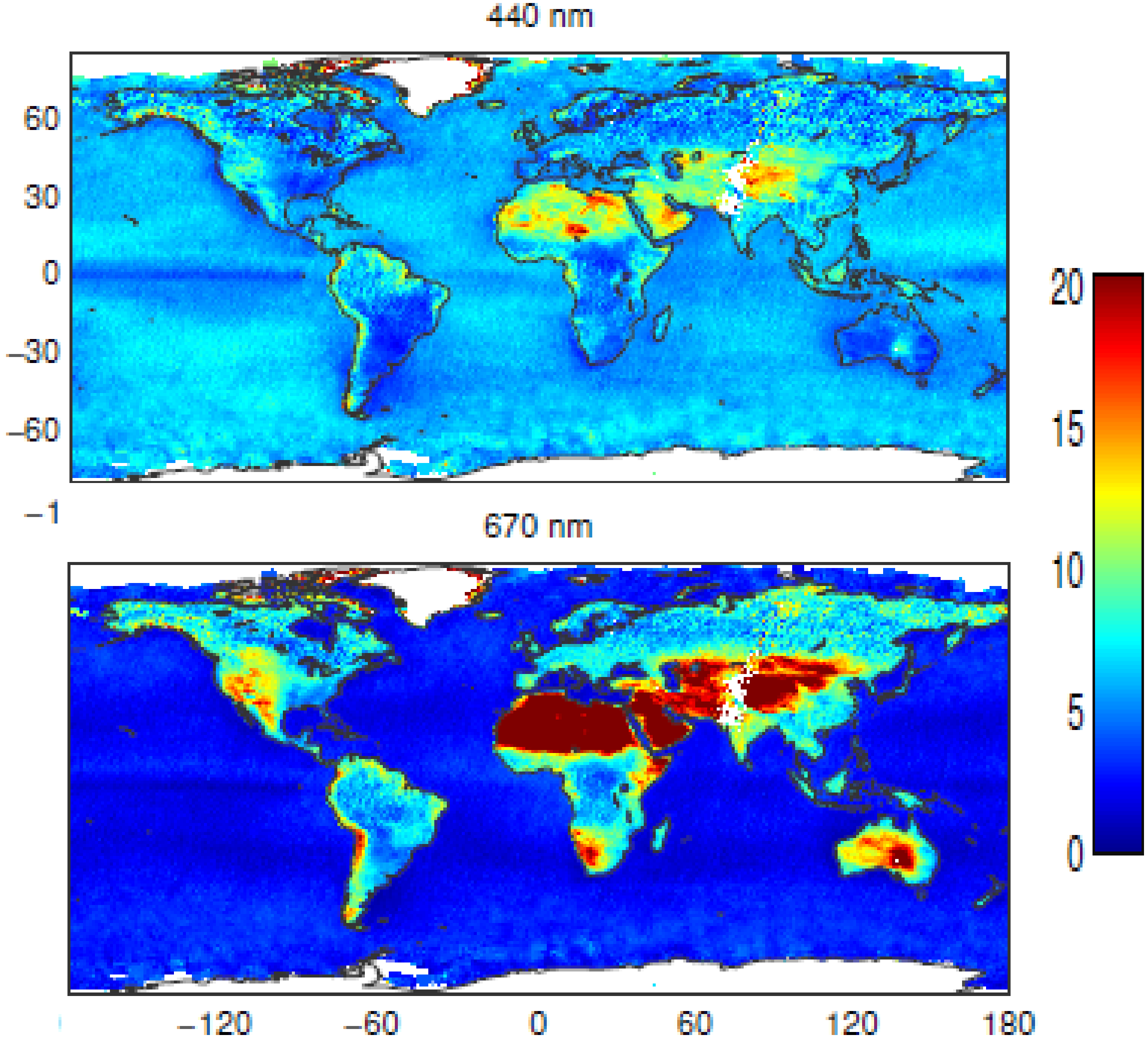
Water Vapor Remote Sensing

- Microwave – possible in the presence of clouds
  generally ocean only
- Thermal IR – both land & ocean with profiles
  limited sensitivity to PBL,
  strongly affected by clouds
- Near-IR & Red – sensitive to PBL
  strongly affected by clouds and
  low albedo over the ocean
- Blue – no saturation, land-ocean uniformity
  affected by clouds, larger uncertainty

GOME annual mean Surface Albedo

blue

red



[Koelemeijer et al., 2003]

Large land-ocean contrast at longer wavelengths

Ocean is brighter and Land is darker at shorter wavelengths

Ozone Monitoring Instrument (OMI)

On board NASA EOS-Aura launched in July 2004.

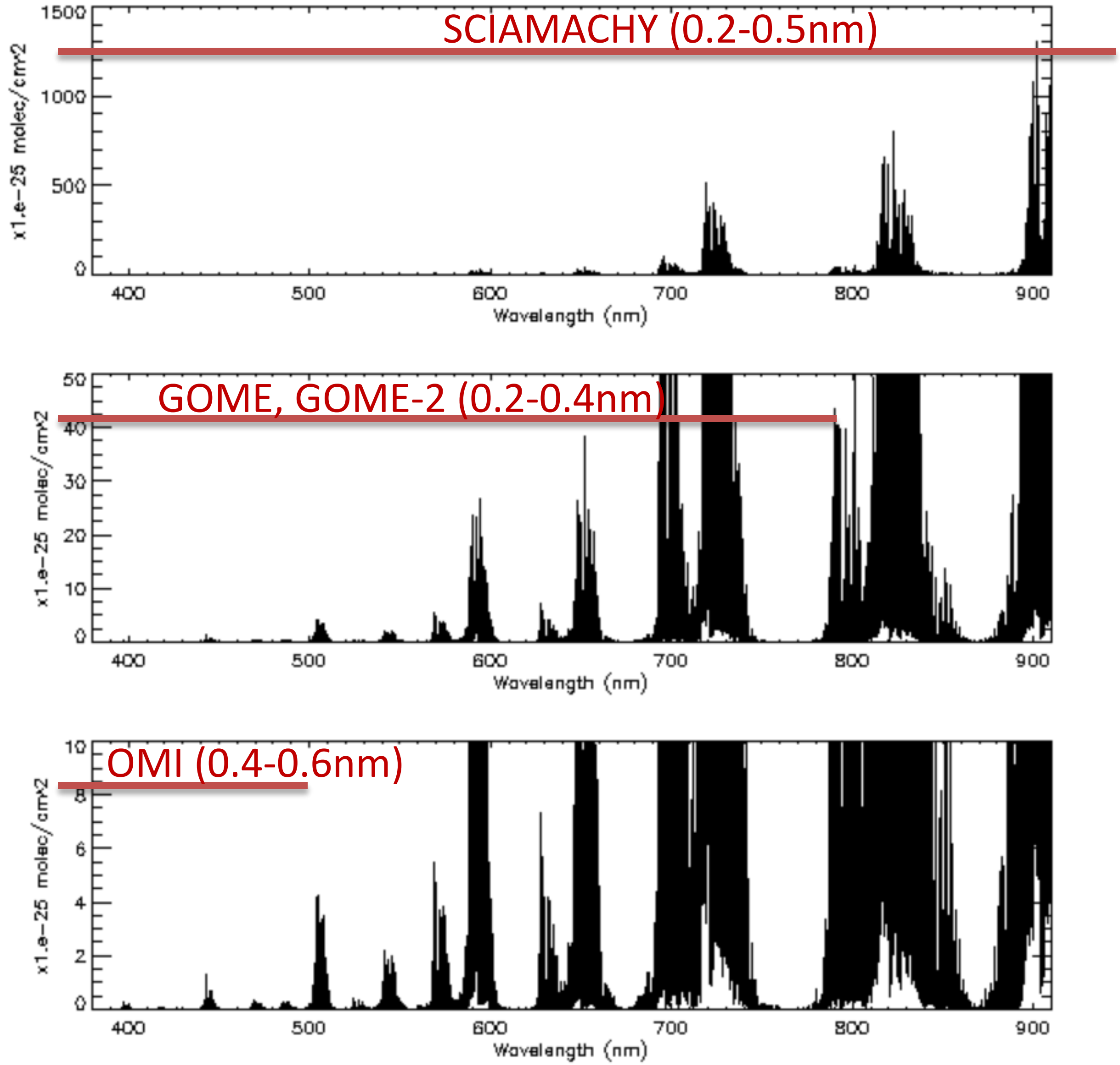
UV1 (270-310nm), UV2(310-365nm), VIS (365-500nm) @ 0.42 nm, 0.45nm, 0.63nm spectral resolution

2600 km swath, 13x24 km^2 spatial resolution at nadir

~15 orbits / day cover the entire globe

O_3, BrO, OClO, NO_2, HCHO, SO_2, $C_2H_2O_2$, H_2O

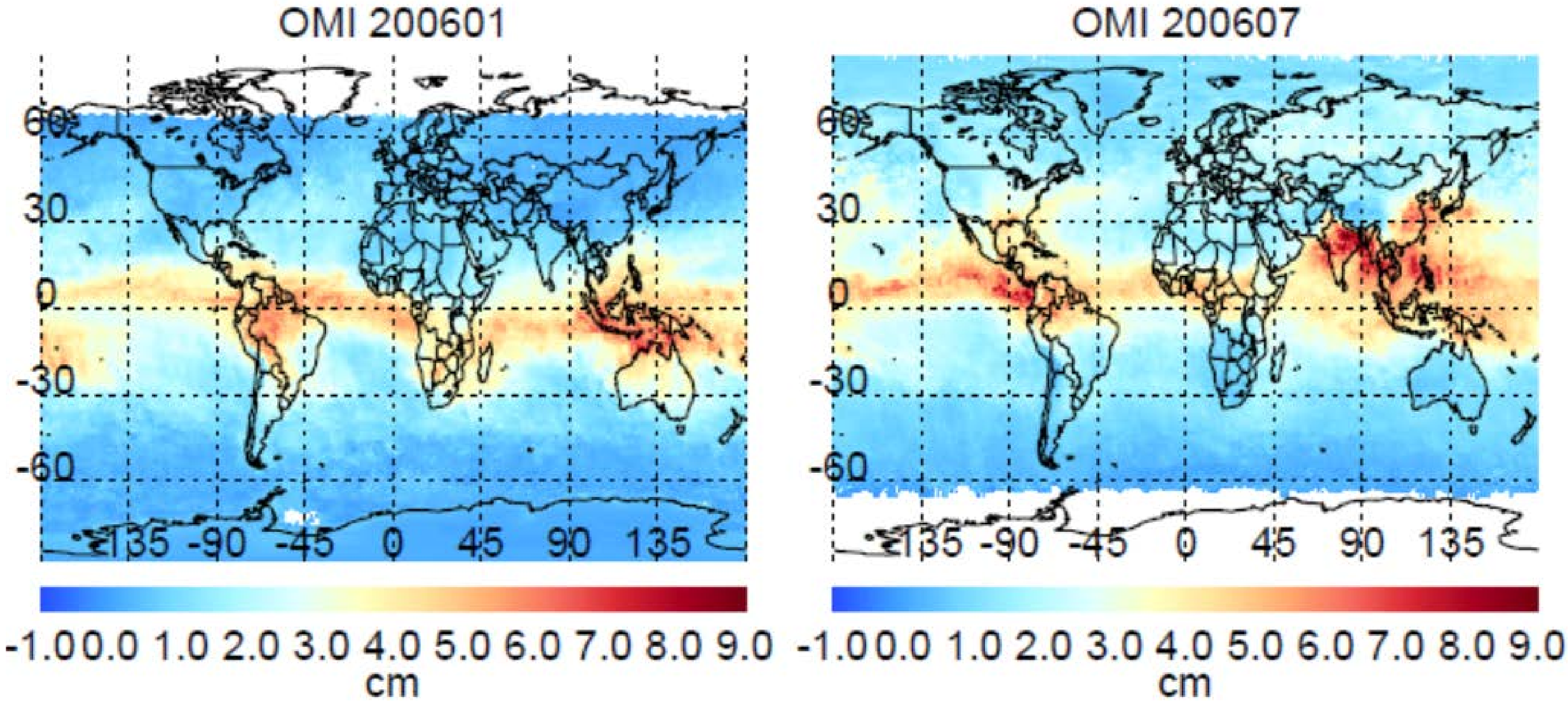
Water Vapor Spectrum



Much stronger absorption at longer wavelengths.

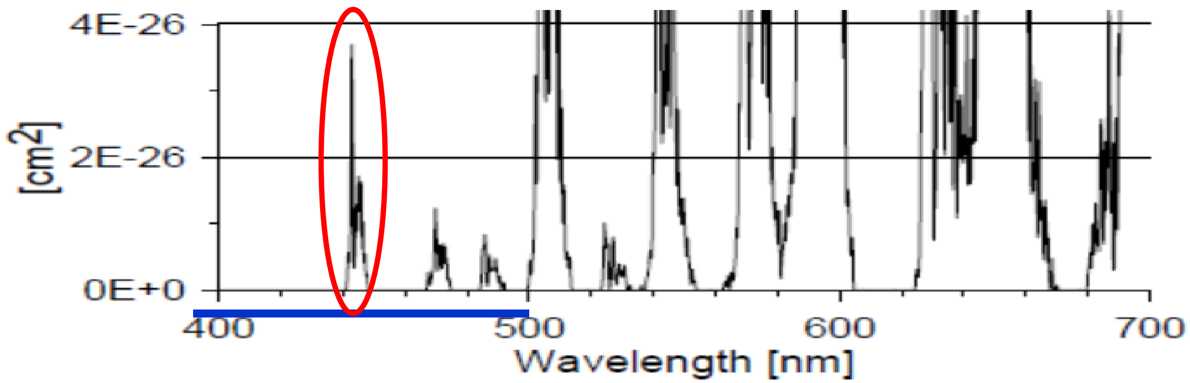
OMI visible spectrum covers weak water vapor features in blue range.

SAO OMI Water Vapor product



Abundant water vapor in ITCZ
Seasonal shift of ITCZ

Wagner et al. [2013] OMI H_2O Retrievals

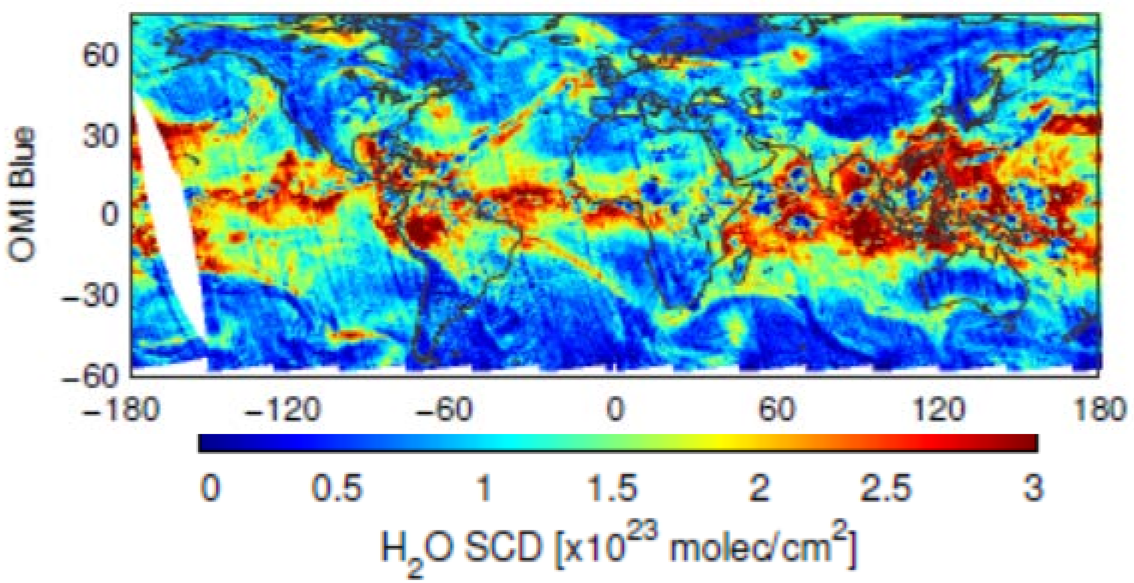


[430, 450] nm

H_2O, NO_2, O_3, Ring

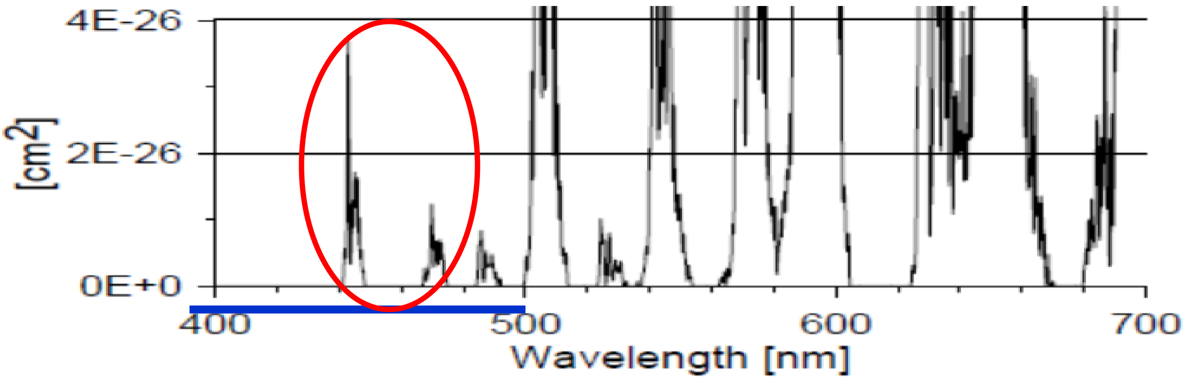
5th order polynomial

2007-06-01



Typical SCD uncertainty:
$(3 – 5) \times 10^{22}$ molec cm^{-2}

SAO OMI H_2O Retrievals



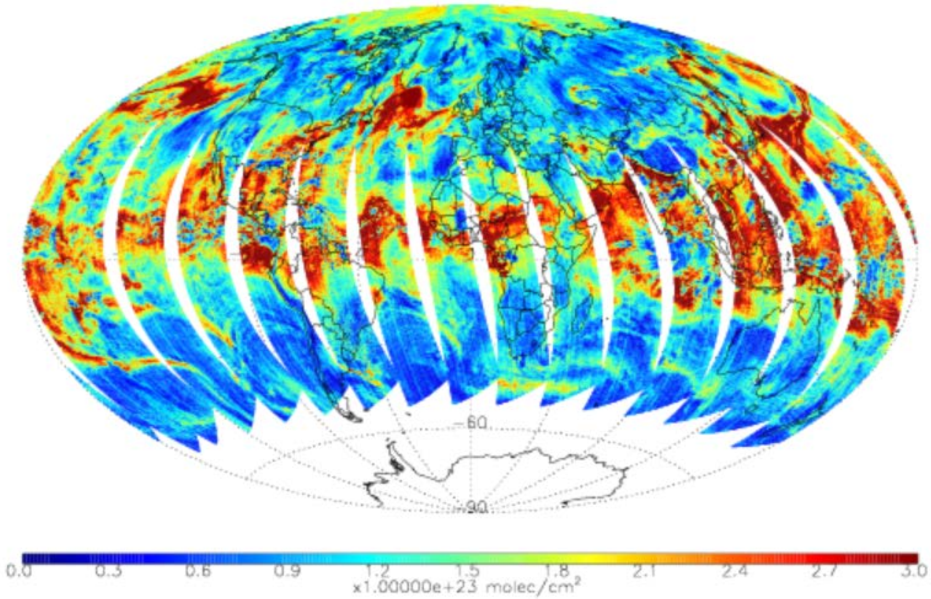
[430, 480] nm

H_2O, NO_2, O_3, Ring, &

Liquid water, water Ring, $C_2H_2O_2$

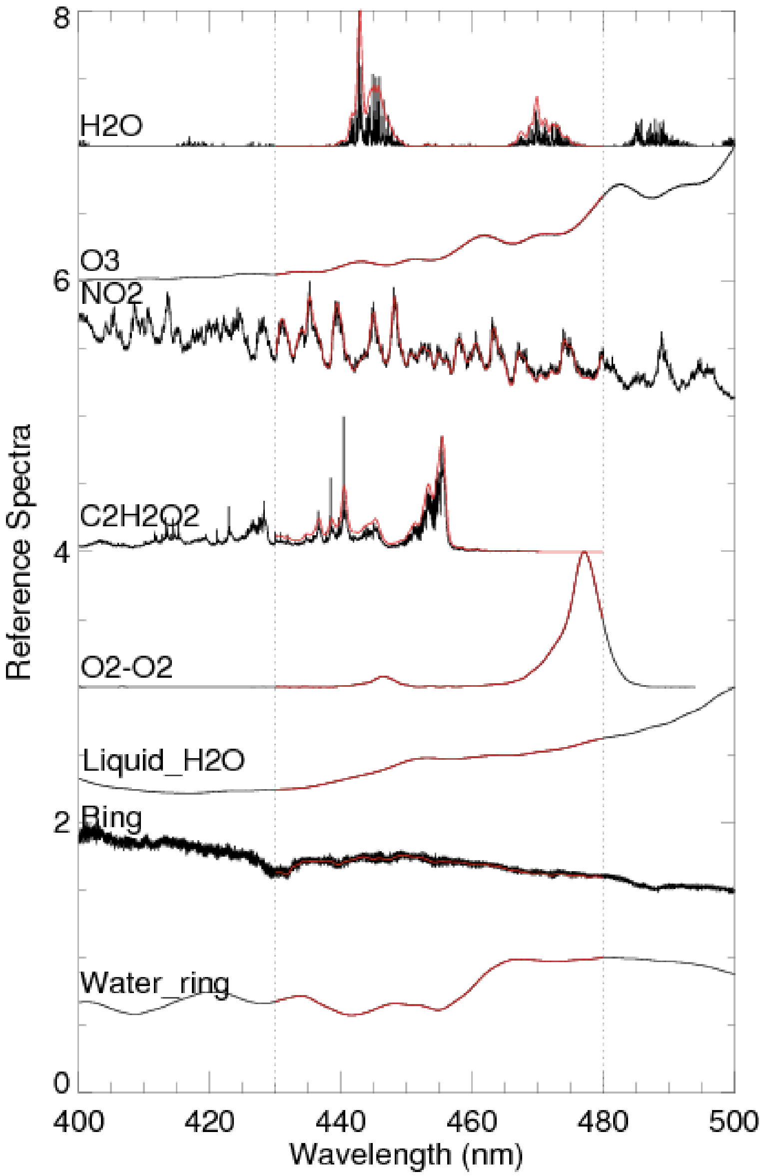
3rd order polynomials

2005-07-14



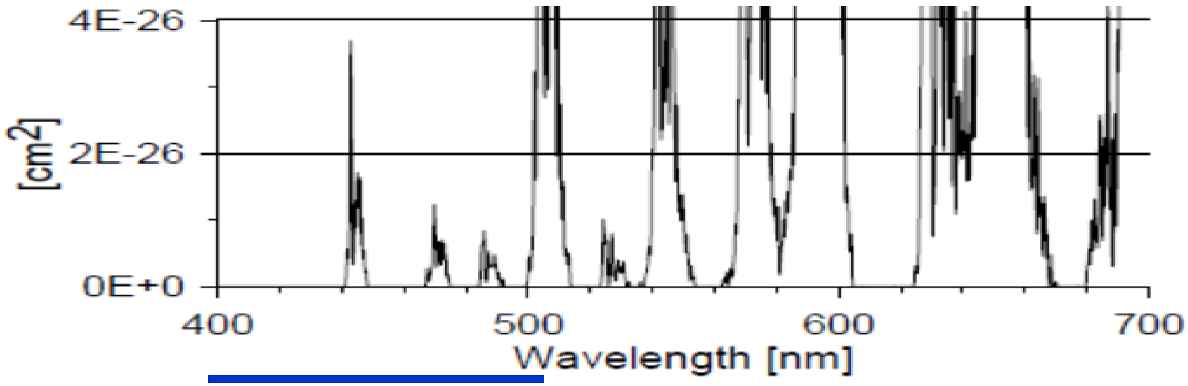
Typical SCD uncertainty:
(1.0-1.7)×10^{22} molec cm^{-2}

Reference spectrum for SAO OMI water vapor retrieval



Distinct spectral feature in the retrieval window

SAO OMI H_2O SCD sensitivity to retrieval window



Window Length (nm)	Retrieval Window (nm)	Median SCD (molecule cm^{-2})	Median Uncertainty (molecule cm^{-2})	Median Relative Uncertainty
20	[435, 455]	1.47×10^{23}	2.4×10^{22}	0.19
30	[432, 462]	1.43×10^{23}	2.0×10^{22}	0.17
40	[438, 478]	1.35×10^{23}	1.6×10^{22}	0.15
50 (standard)	[430, 480]	1.32×10^{23}	1.2×10^{22}	0.11
65	[430, 495]	1.23×10^{23} ~10%	1.5×10^{22}	0.12

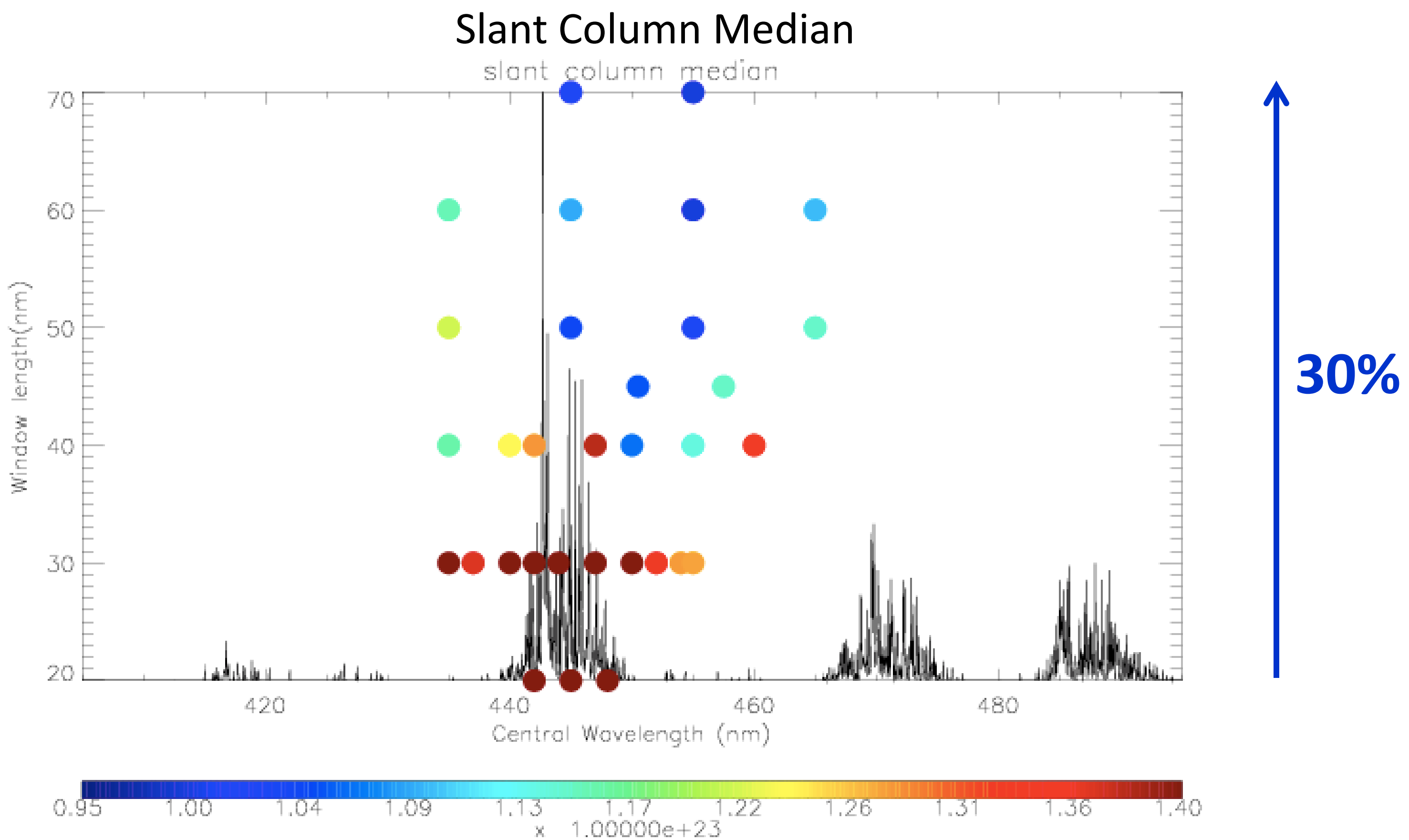
- SCD decreases by ~15% as window length increases from 20 nm to 65 nm.
- The smallest uncertainty is achieved by the standard window of [430, 480]nm.

SAO OMI H_2O sensitivity to interfering molecules

	Description	Median SCD (molecule cm^{-2})	Median uncertainty (molecule cm^{-2})	Median RMS	Number of negatives
	Standard	1.32×10^{23}	1.2×10^{22}	9.2e-4	1935
~10%	Without O_3	1.19×10^{23}	1.2×10^{22}	9.3e-4	7234
~10%	Without O_2-O_2	1.18×10^{23}	1.3×10^{22}	9.9e-4	5076
~20%	Without NO_2	1.05×10^{23}	1.2×10^{22}	9.3e-4	15666
~30%	Without liquid water	0.90×10^{23}	1.1×10^{22}	9.5e-4	50216
	Without $C_2H_2O_2$	1.34×10^{23}	1.2×10^{22}	9.2e-4	1780

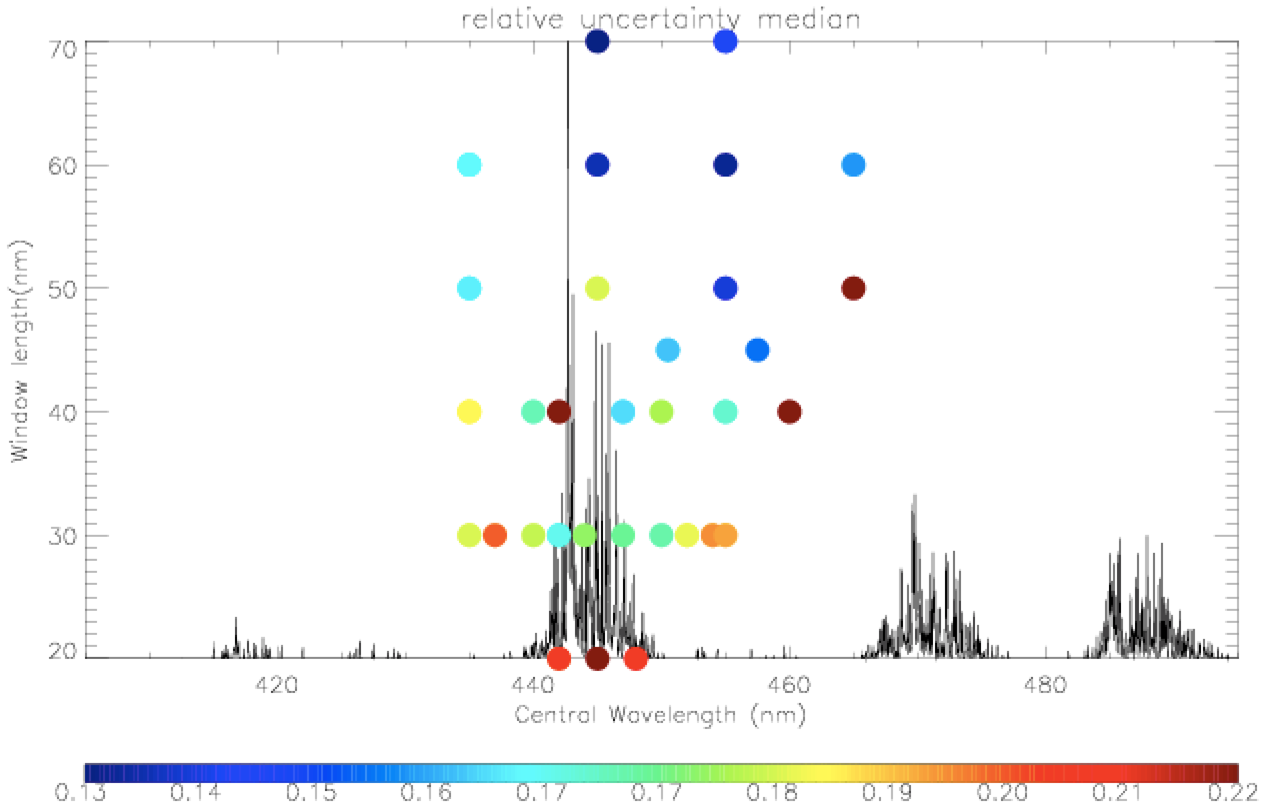
- The most important interfering molecules are liquid water, NO_2, O_3, O_2-O_2

Fitting window dependence without liquid water

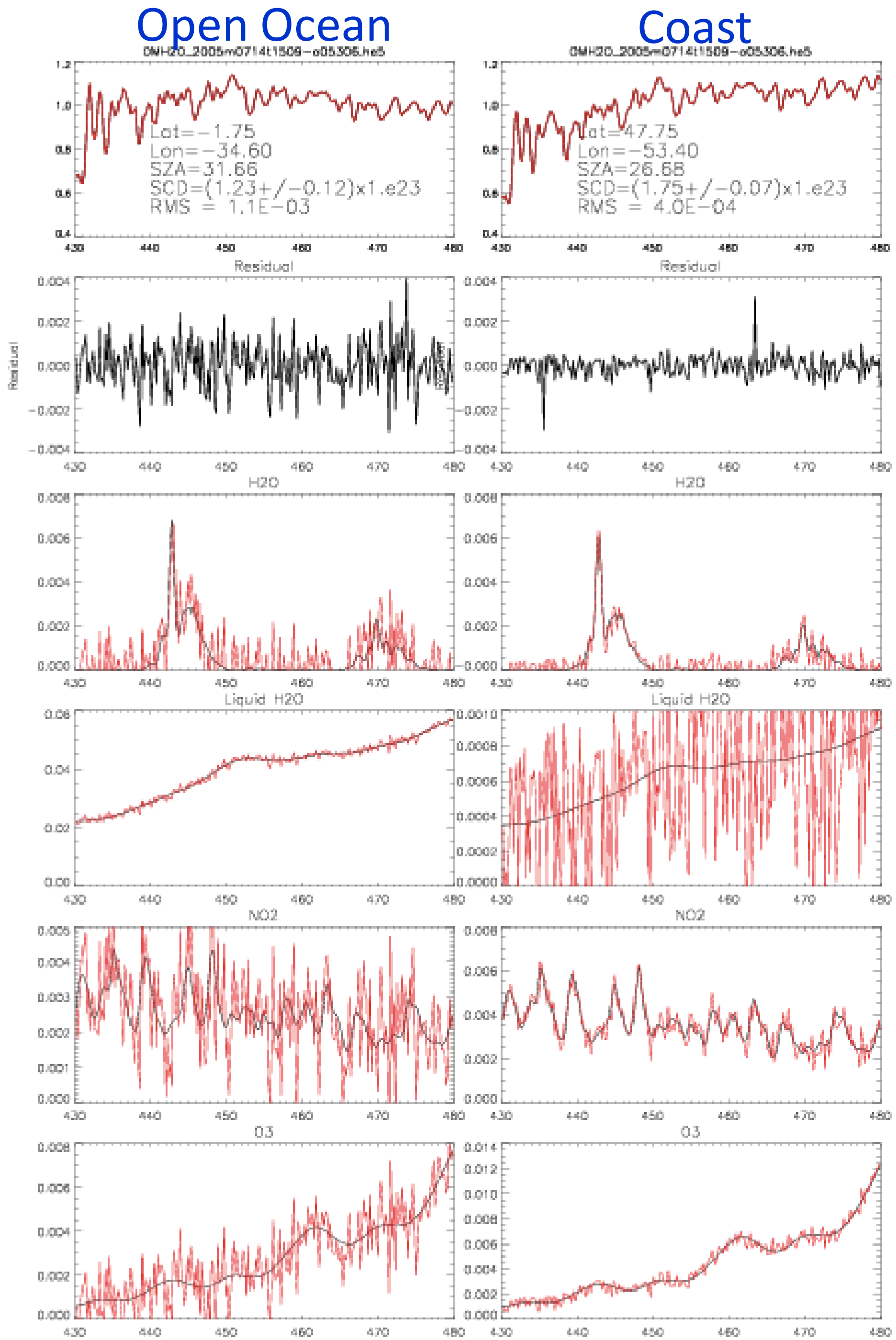


Fitting window dependence without liquid water

Relative Uncertainty Median



Example retrieval result



Measured & fitted spectra

Fitting residual

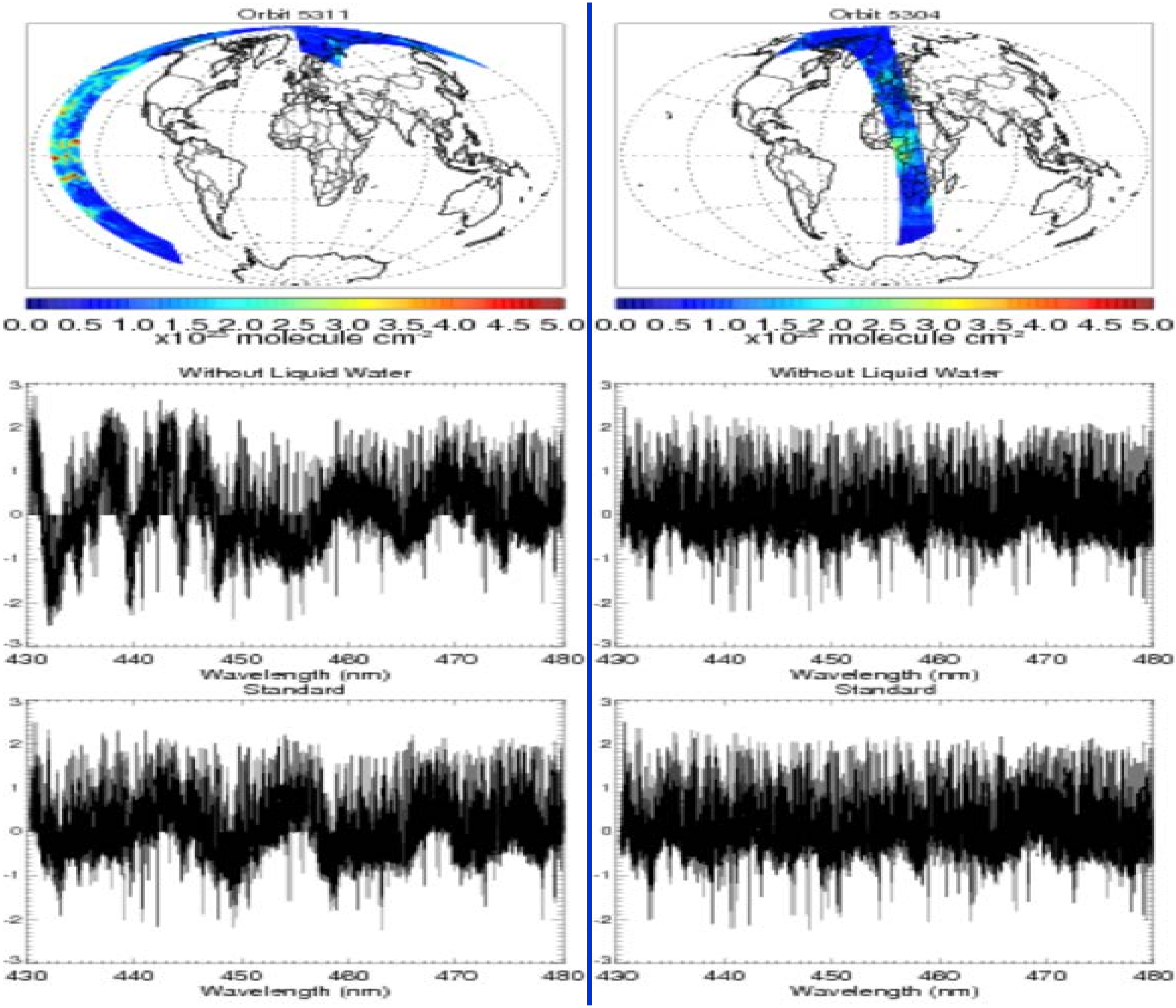
Fitted water vapor + residual

Fitted liquid water + residual

Fitted NO_2 + residual

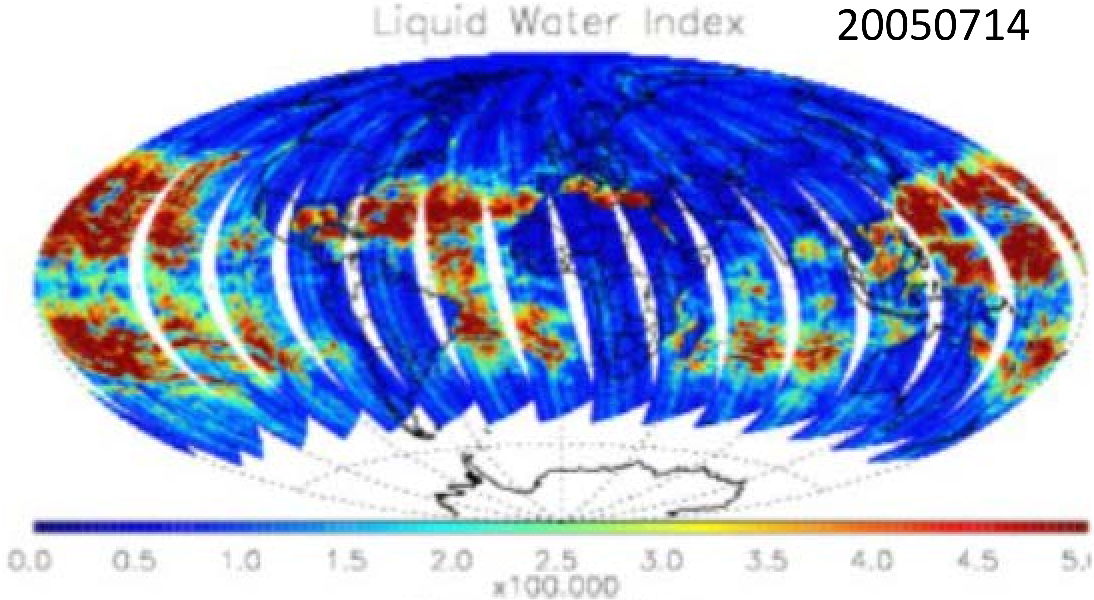
Fitted O_3 + residual

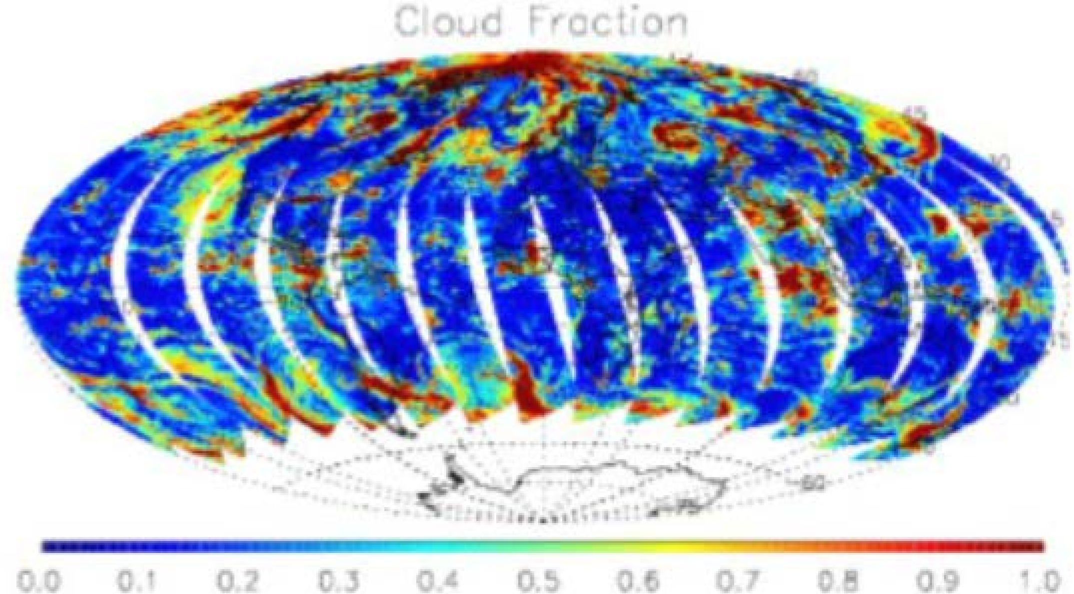
Common Mode over the ocean and land



More apparent structure over the ocean which is mitigated with liquid water

By-product of standard water vapor retrieval





SAO OMI H_2O sensitivity to Spectroscopy

Description	Median SCD (molecule cm^{-2})	Median uncertainty (molecule cm^{-2})	Median RMS	Number of negatives
Standard	1.32×10^{23}	1.2×10^{22}	9.2e-4	1935
Switch reference H_2O to 0.7atm and 265K	1.29×10^{23}	1.2×10^{22}	9.2e-4	1992
Switch reference H_2O to 1.0atm and 288K	1.34×10^{23}	1.2×10^{22}	9.2e-4	1918
Switch to [Rothman et al., 2013] HITRAN 2012 water vapor	1.24×10^{23}	1.2×10^{22}	9.2e-4	1816
Switch to [Thalman et al., 2013] O_2-O_2	1.31×10^{23}	1.2×10^{22}	9.2e-4	2185

Changes in SCD are < fitting uncertainty

Conversion from SCD to VCD

$$VCD = SCD / AMF$$

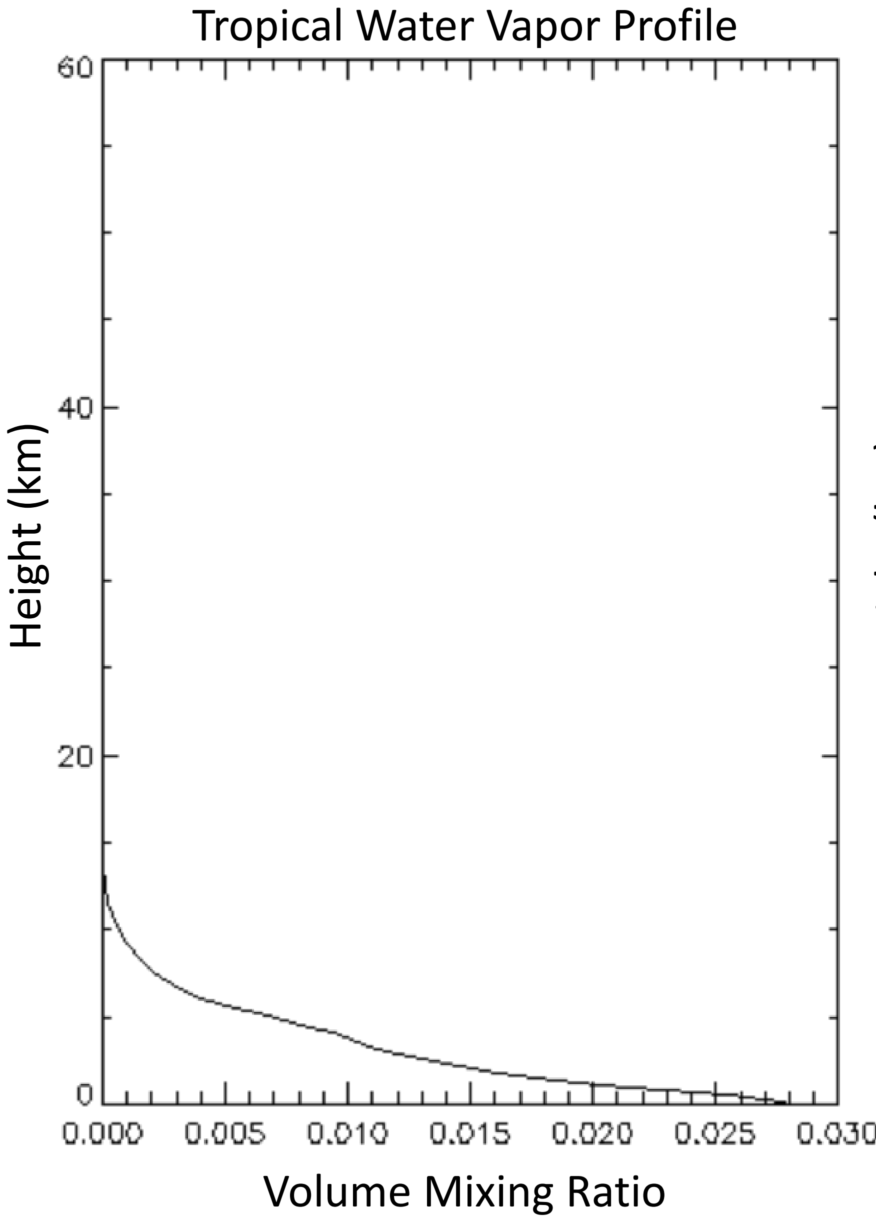
$$AMF = AMF_G \cdot \int_0^{\infty} w \cdot S dz$$

VLIDORT → *Scattering Weight*

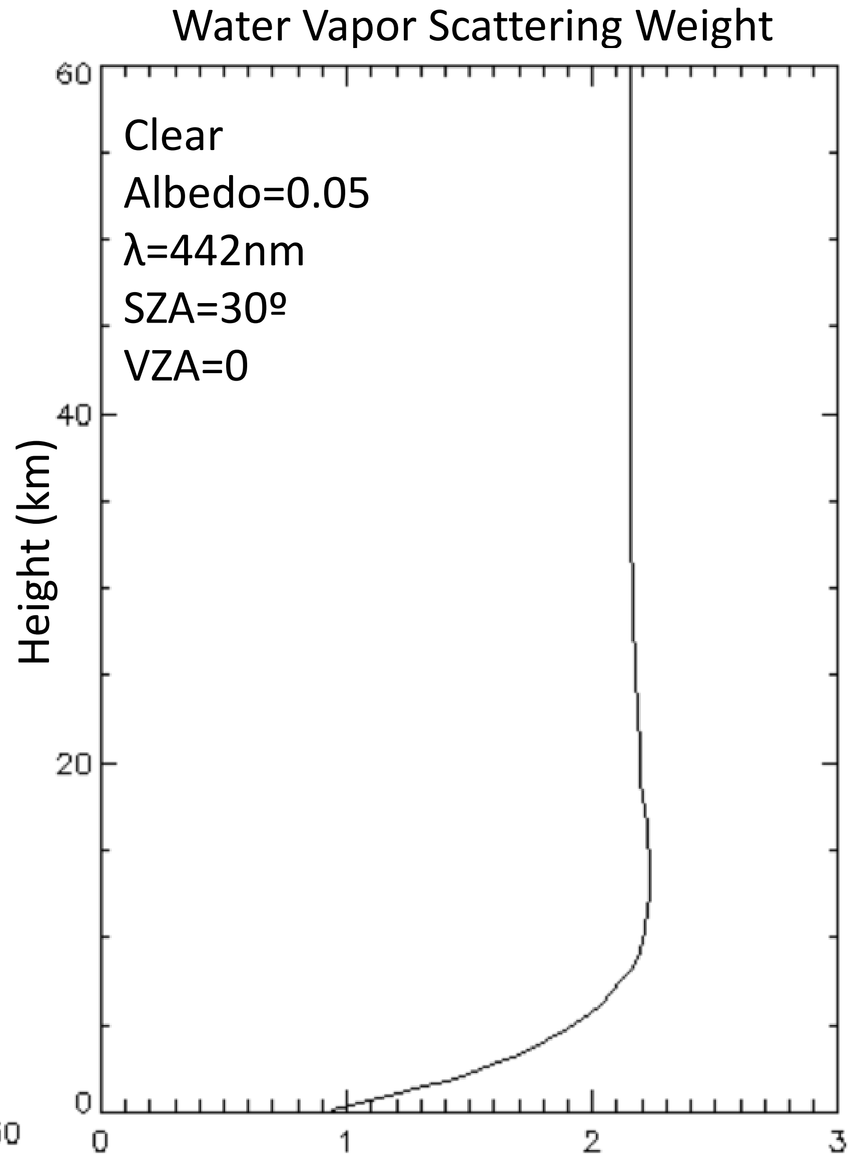
GEOS-Chem → *Shape Factor*

$$AMF_G = \frac{1}{\cos\theta_{sza}} + \frac{1}{\cos\theta_{vza}}$$

$$w = (1-\phi) \cdot w_{clear} + \phi \cdot w_{cloudy}$$

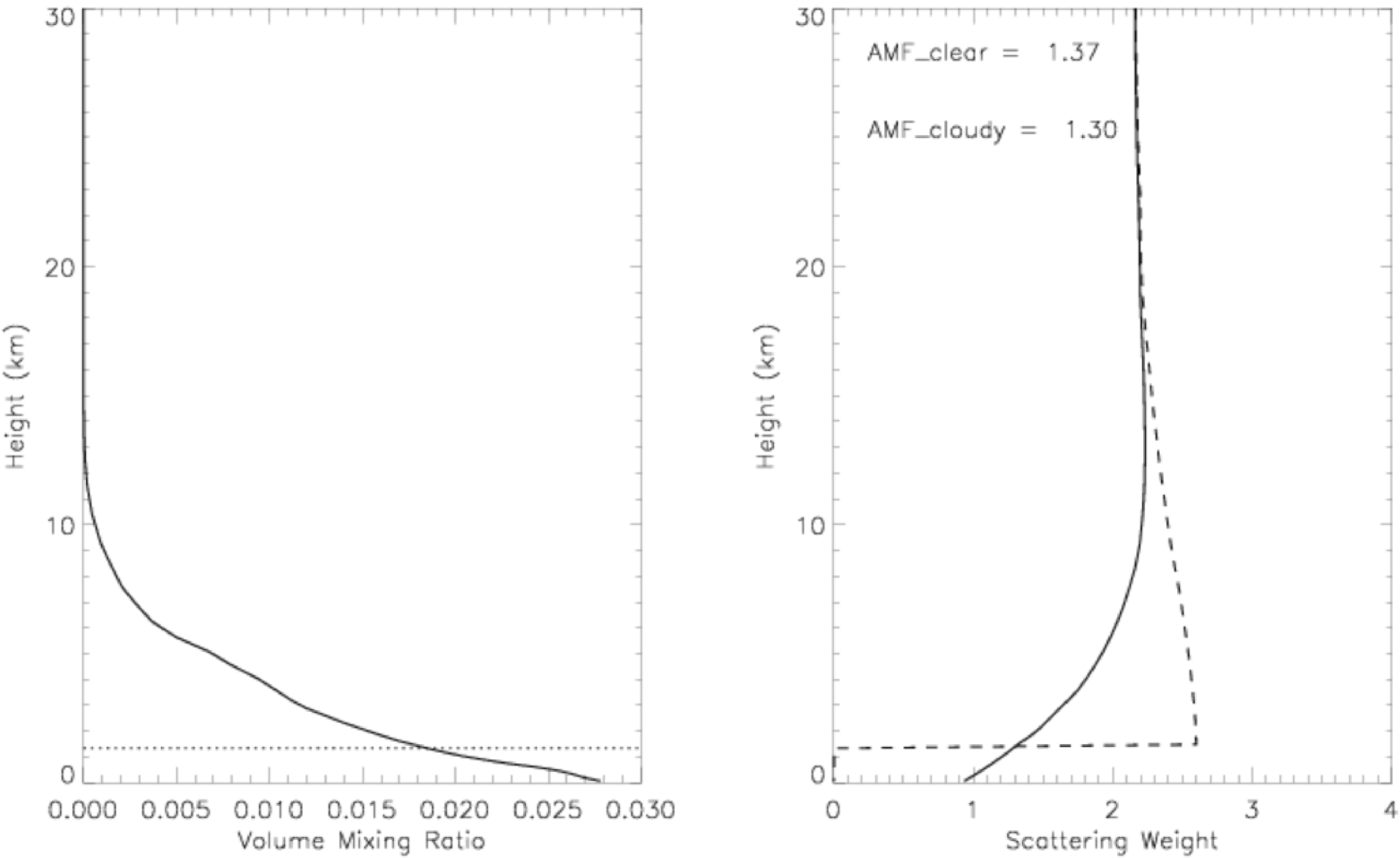


Tropical Water Vapor Profile
Height (km)
60
40
20
0
0.000
0.005
0.010
0.015
0.020
0.025
0.030
Volume Mixing Ratio



Water Vapor Scattering Weight
Clear
Albedo=0.05
λ=442nm
SZA=30º
VZA=0
Height (km)
60
40
20
0
0
1
2
3

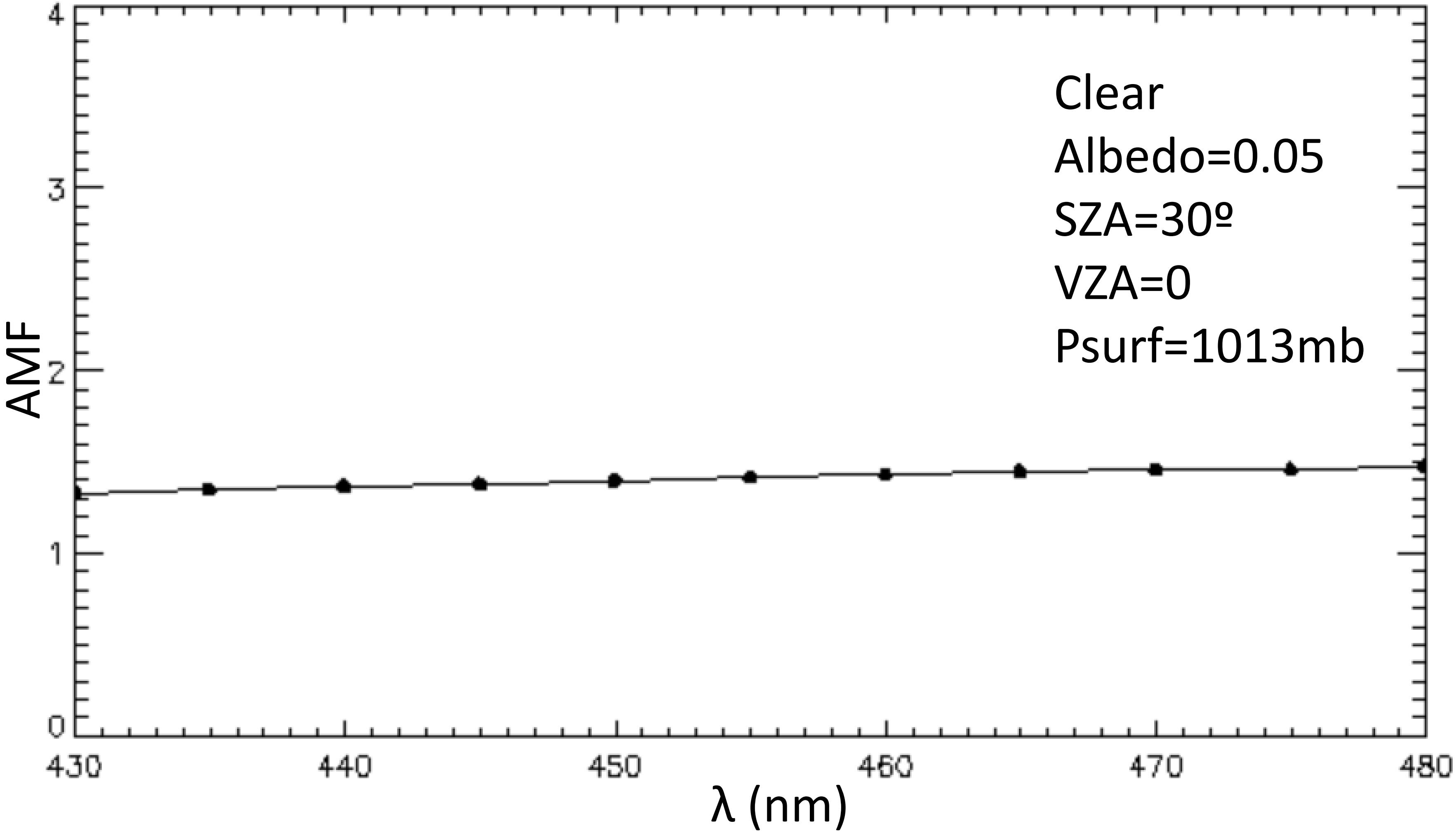
Influence of clouds on scattering weight



Model cloud as a reflective surface with albedo of 0.85 at 800mb

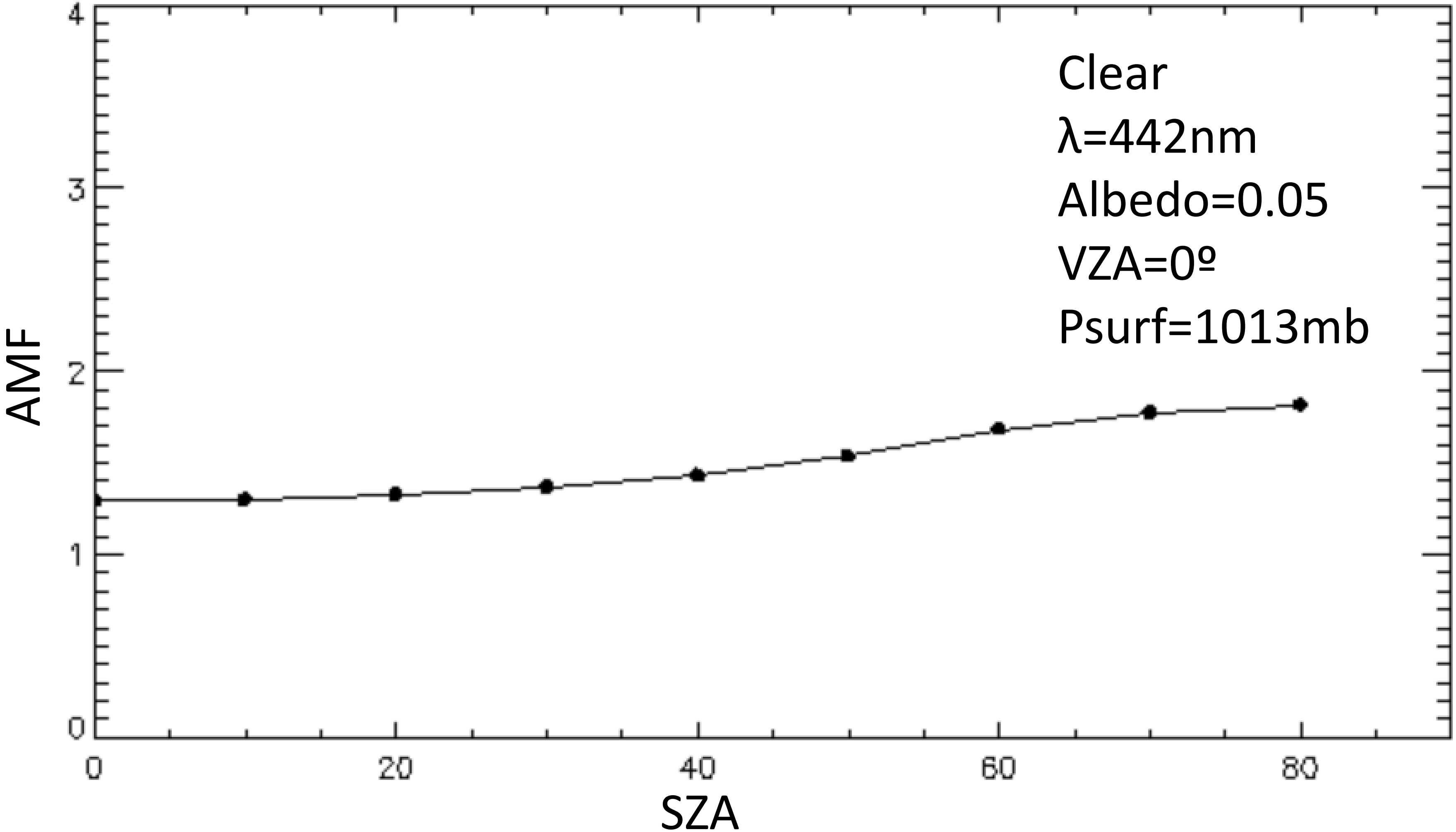
AMF sensitivity

$$AMF(\lambda, \theta_{sza}, \theta_{vza}, P_{surface}, Albedo, Cloud, Aerosol, Composition, ...)$$



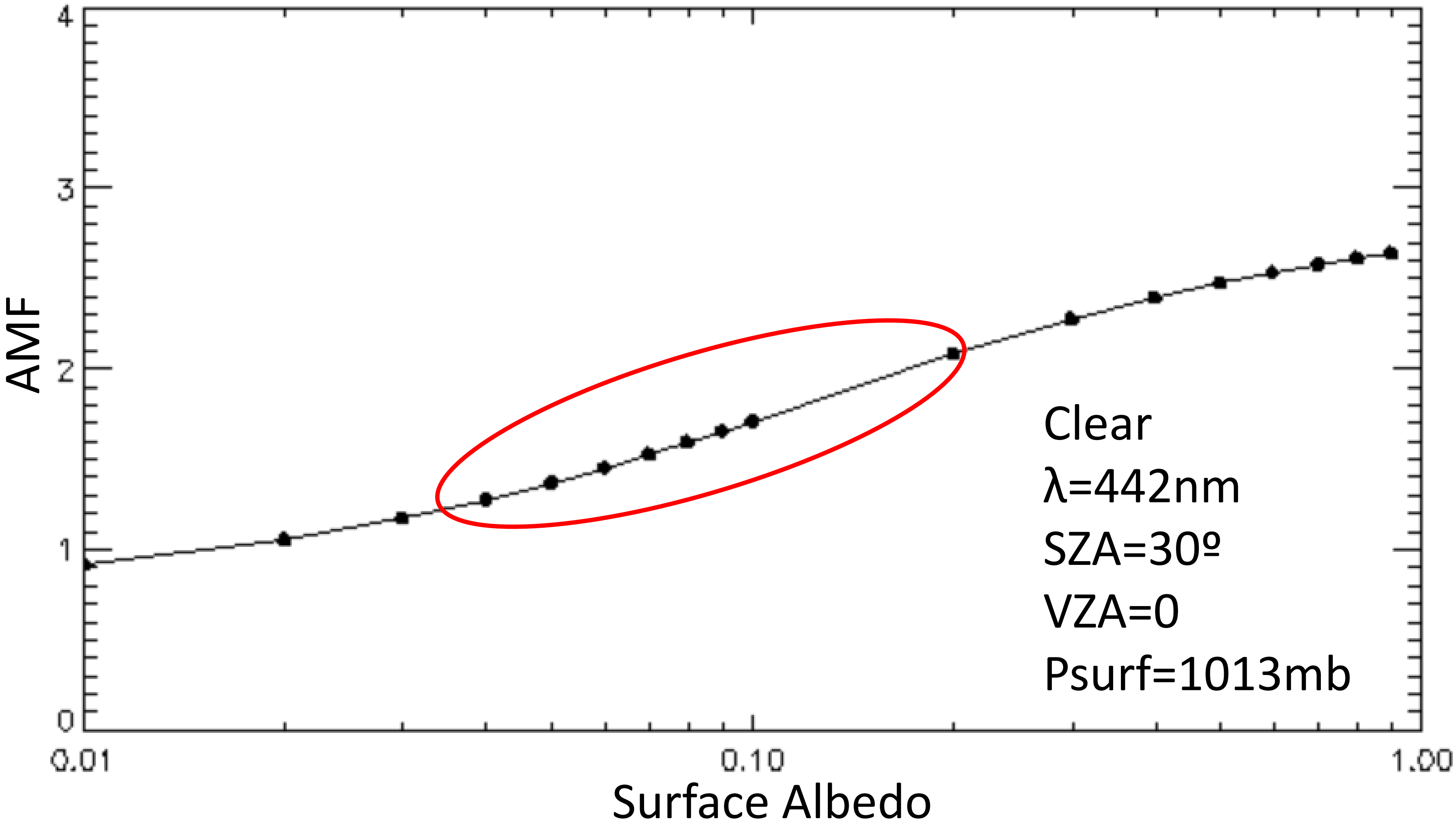
AMF sensitivity

$$AMF(\lambda, \theta_{sza}, \theta_{vza}, P_{surface}, Albedo, Cloud, Aerosol, Composition, ...)$$



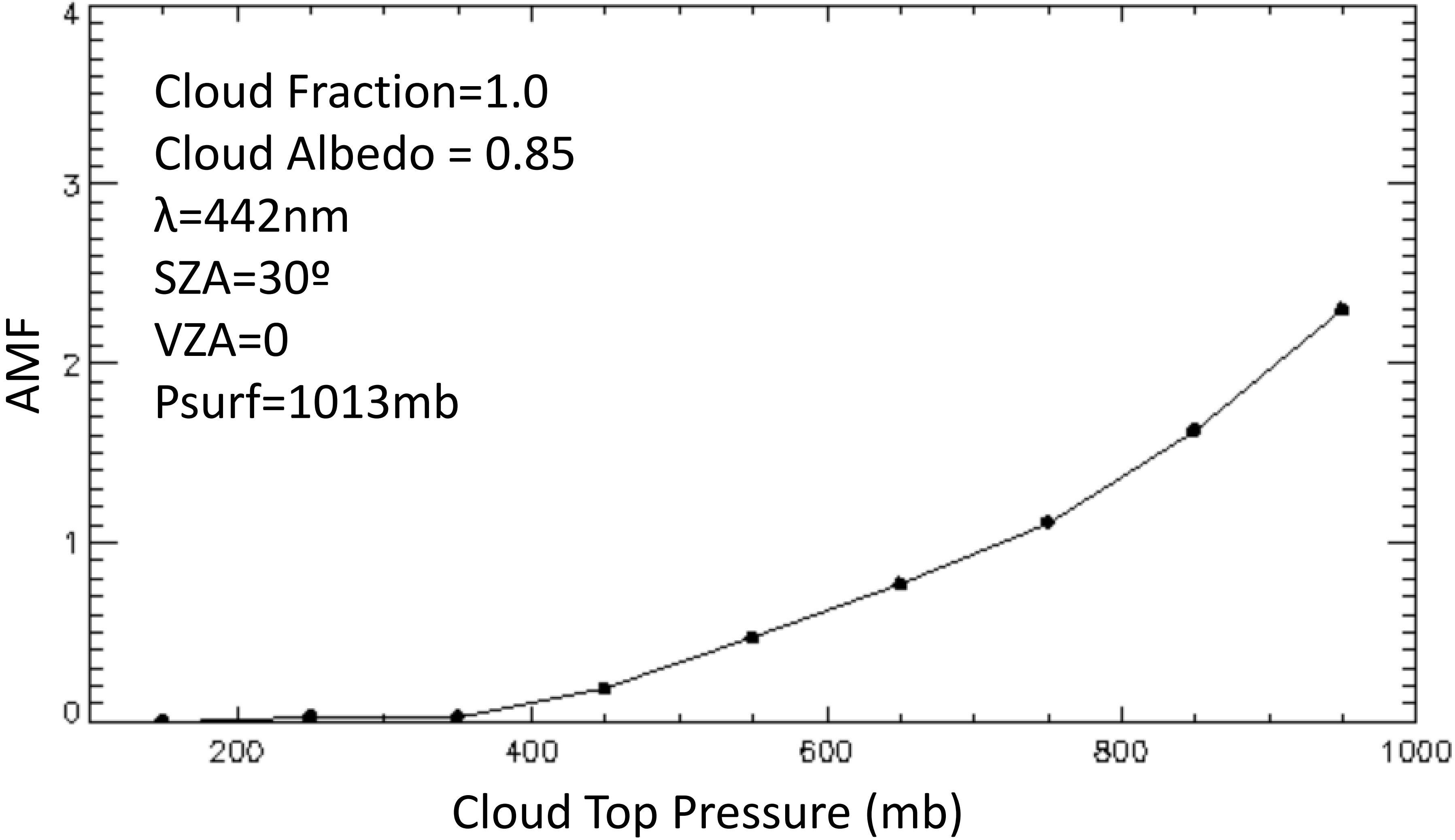
AMF sensitivity

$$AMF(\lambda, \theta_{sza}, \theta_{vza}, P_{surface}, Albedo, Cloud, Aerosol, Composition, \ldots)$$



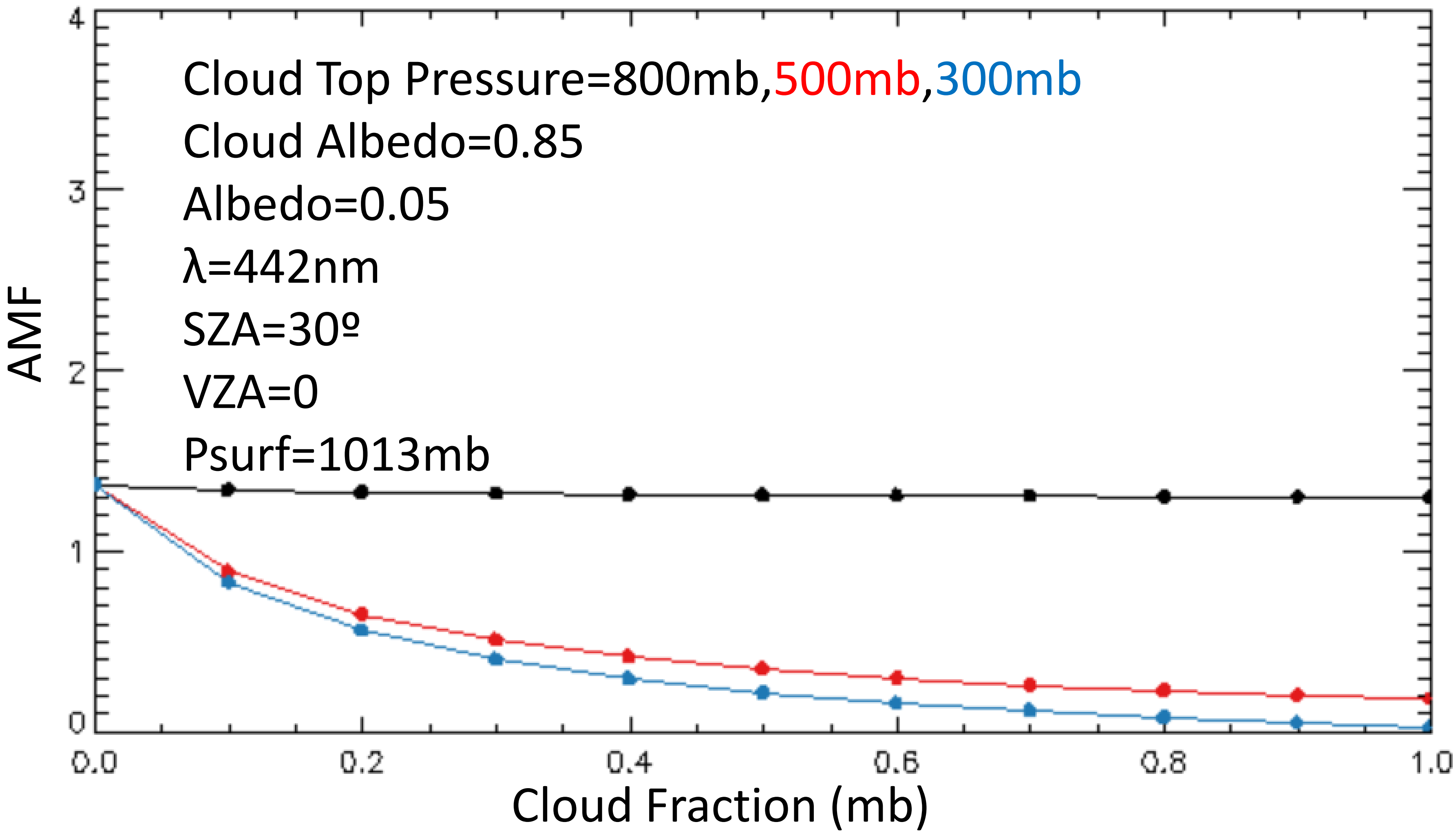
AMF sensitivity

$$AMF(\lambda, \theta_{sza}, \theta_{vza}, P_{surface}, Albedo, Cloud, Aerosol, Composition, ...)$$

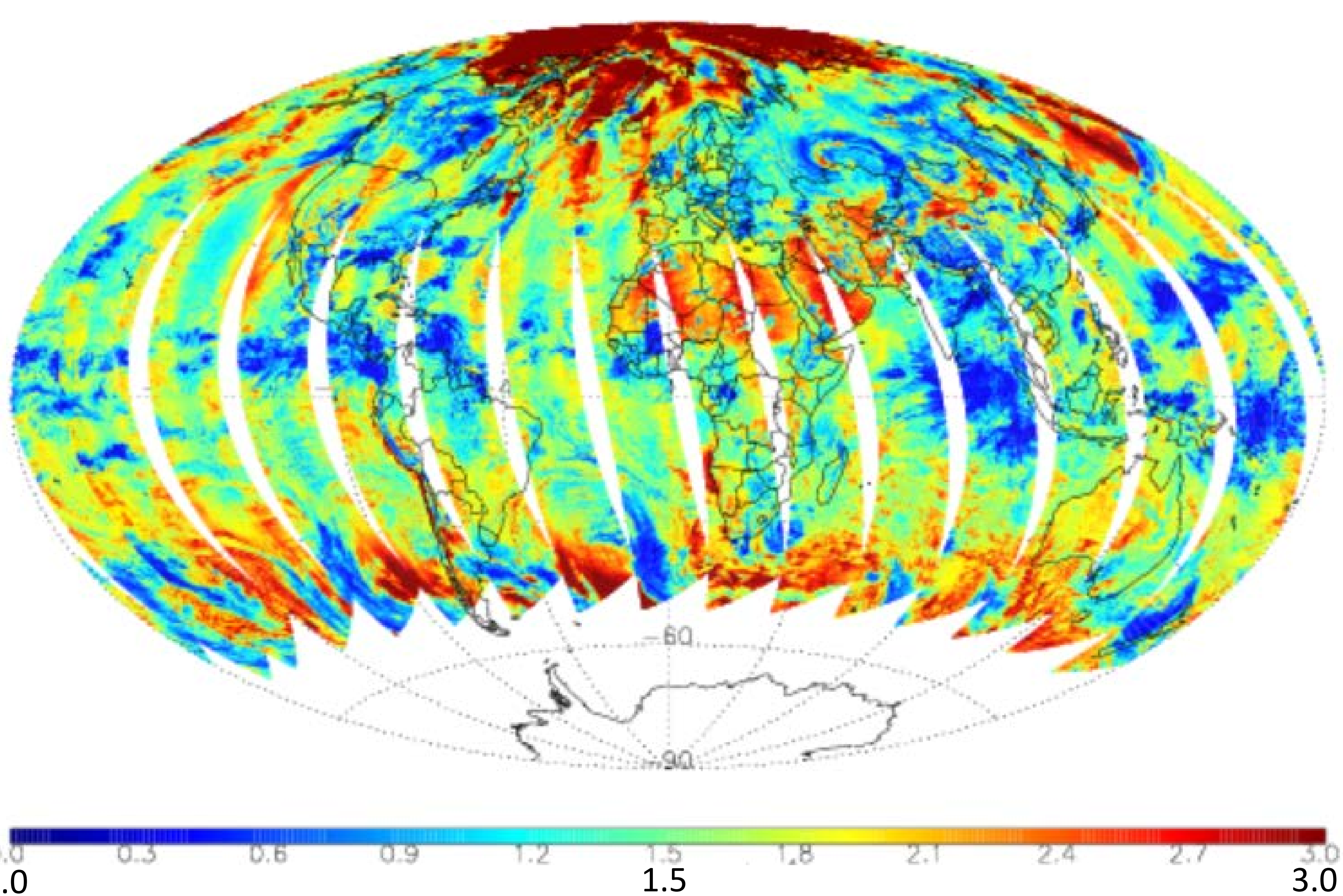


AMF sensitivity

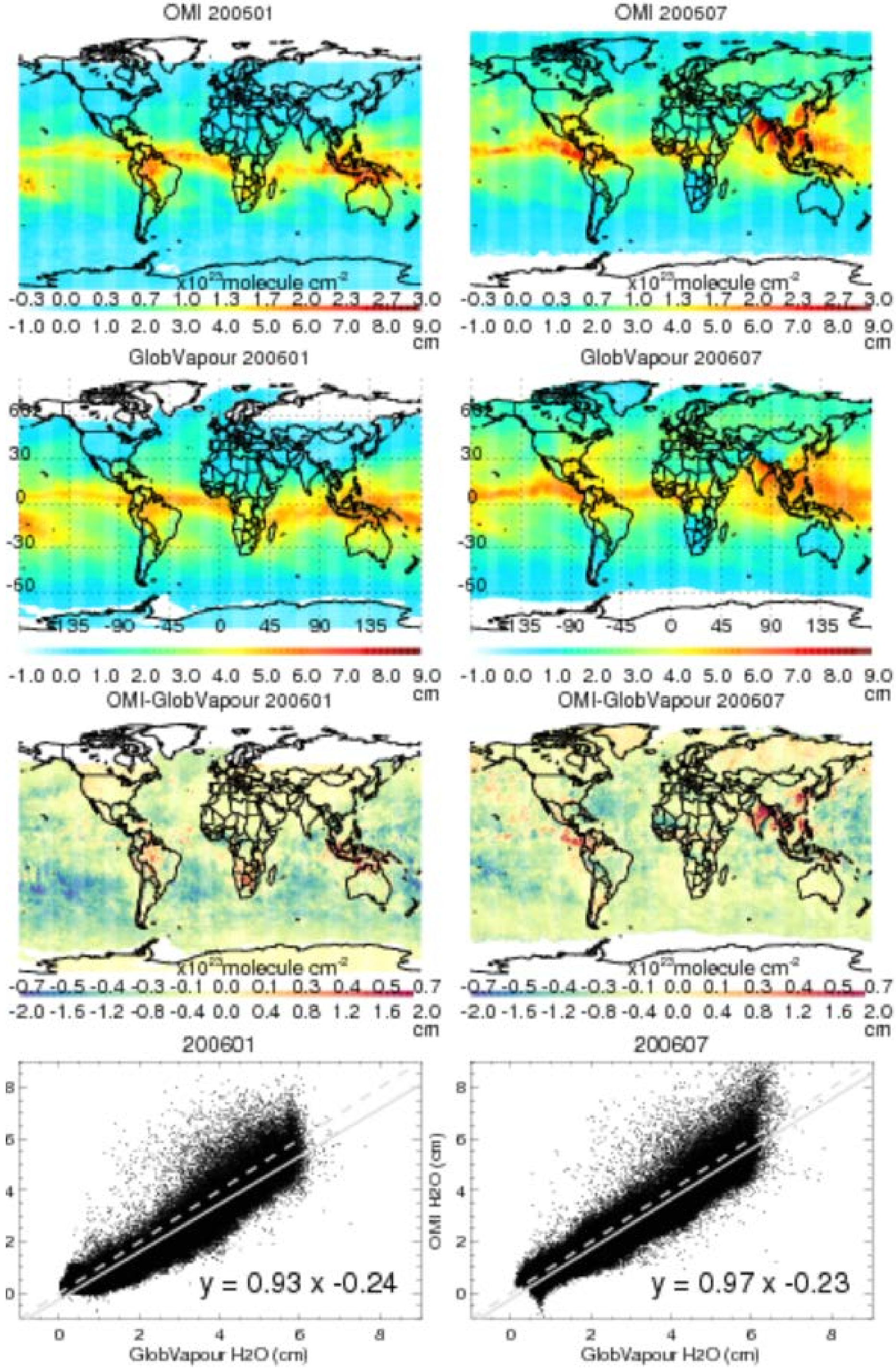
$$AMF(\lambda, \theta_{sza}, \theta_{vza}, P_{surface}, Albedo, Cloud, Aerosol, Composition, ...)$$



AMF for 20070714



Comparison with GlobVapour H_2O

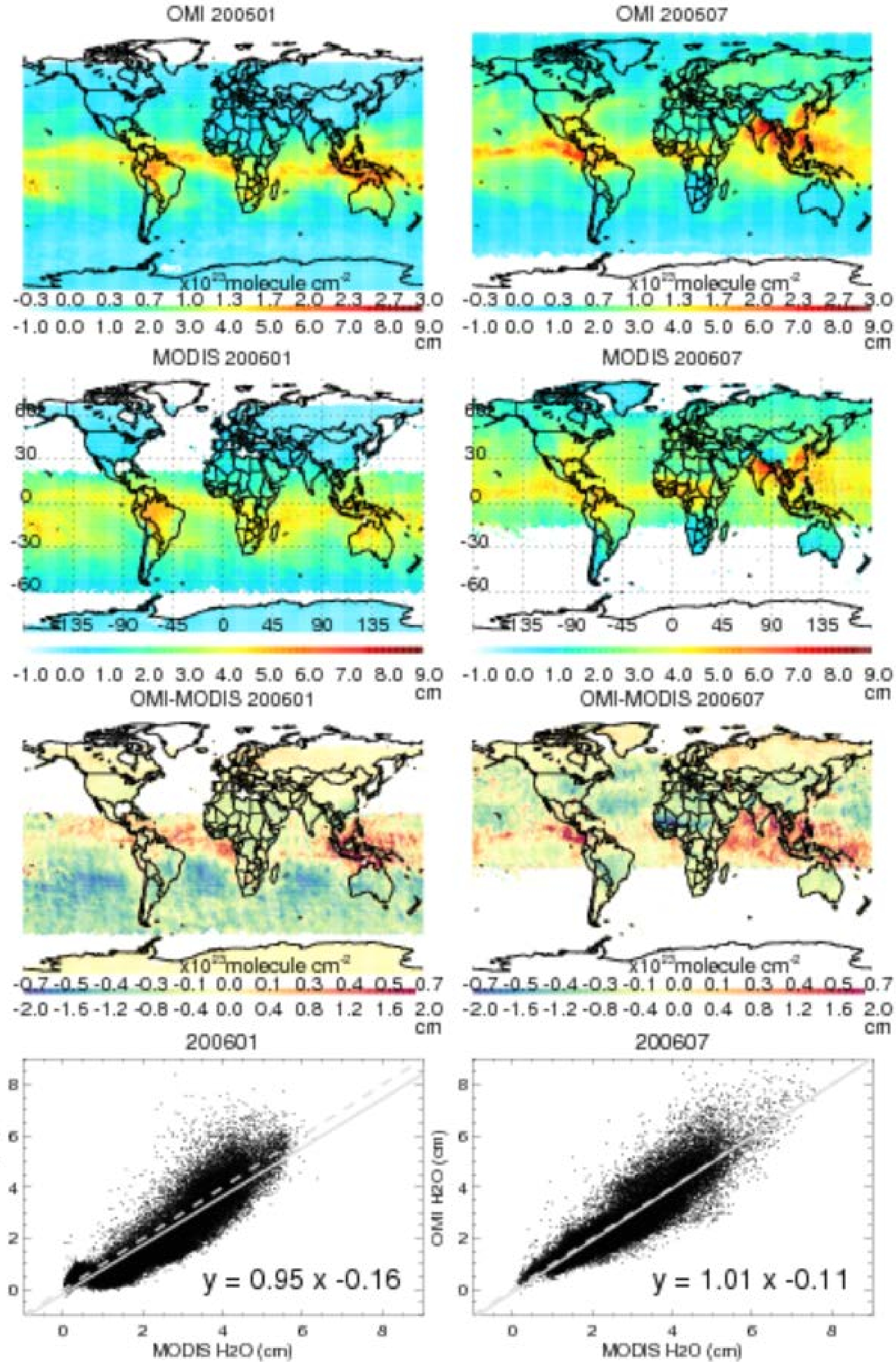


OMI
afternoon

GlobVapour
MERIS+SSMI
morning

OMI-GlobVapour

Comparison with MODIS near-IR H_2O

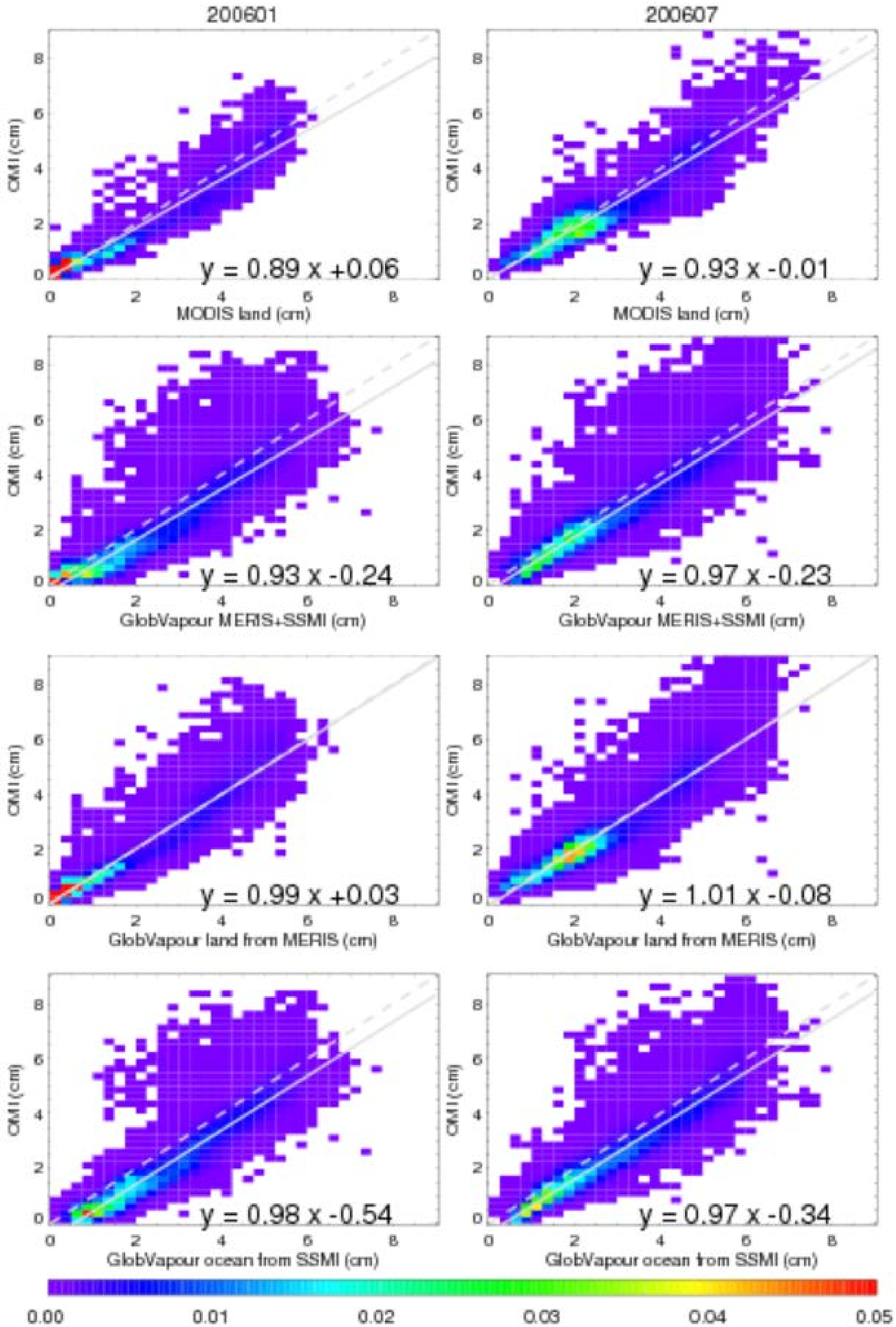


OMI
afternoon
Blue

MODIS
afternoon
Near IR

OMI-MODIS

Joint probability density distribution for land and/or ocean



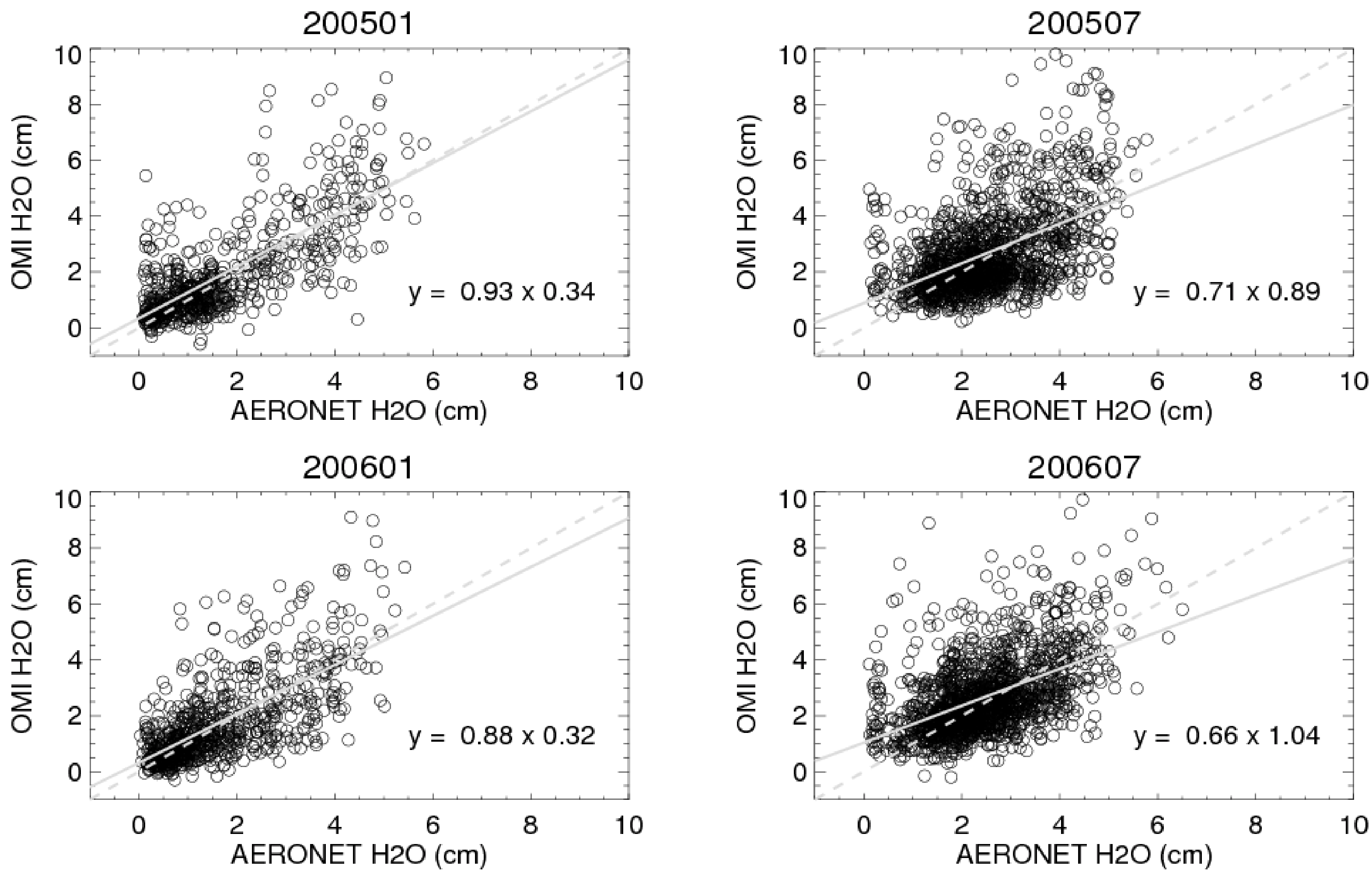
OMI-MODIS Land

OMI-GlobVapour Land+Ocean

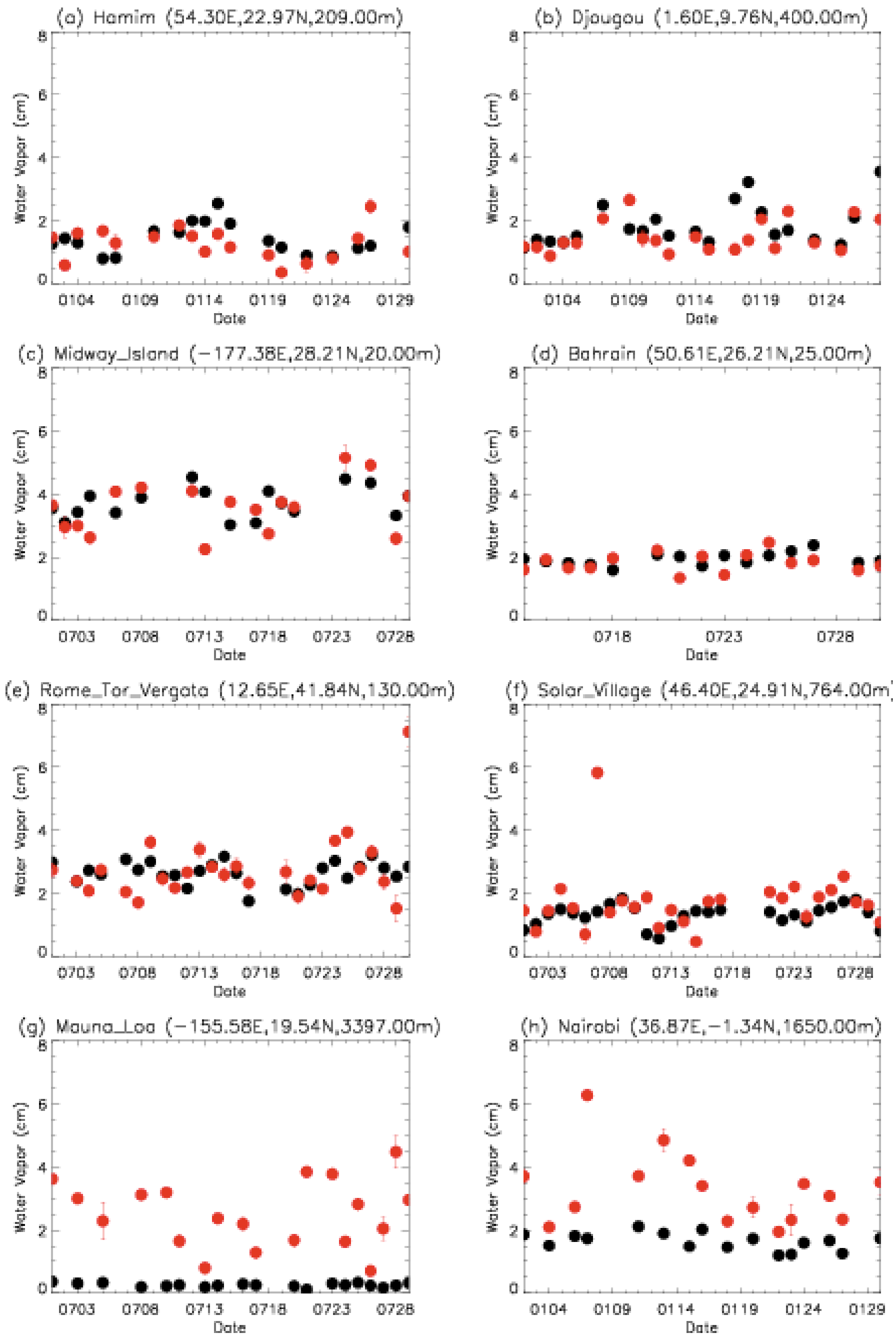
OMI-MERIS Land

OMI-SSMI Ocean

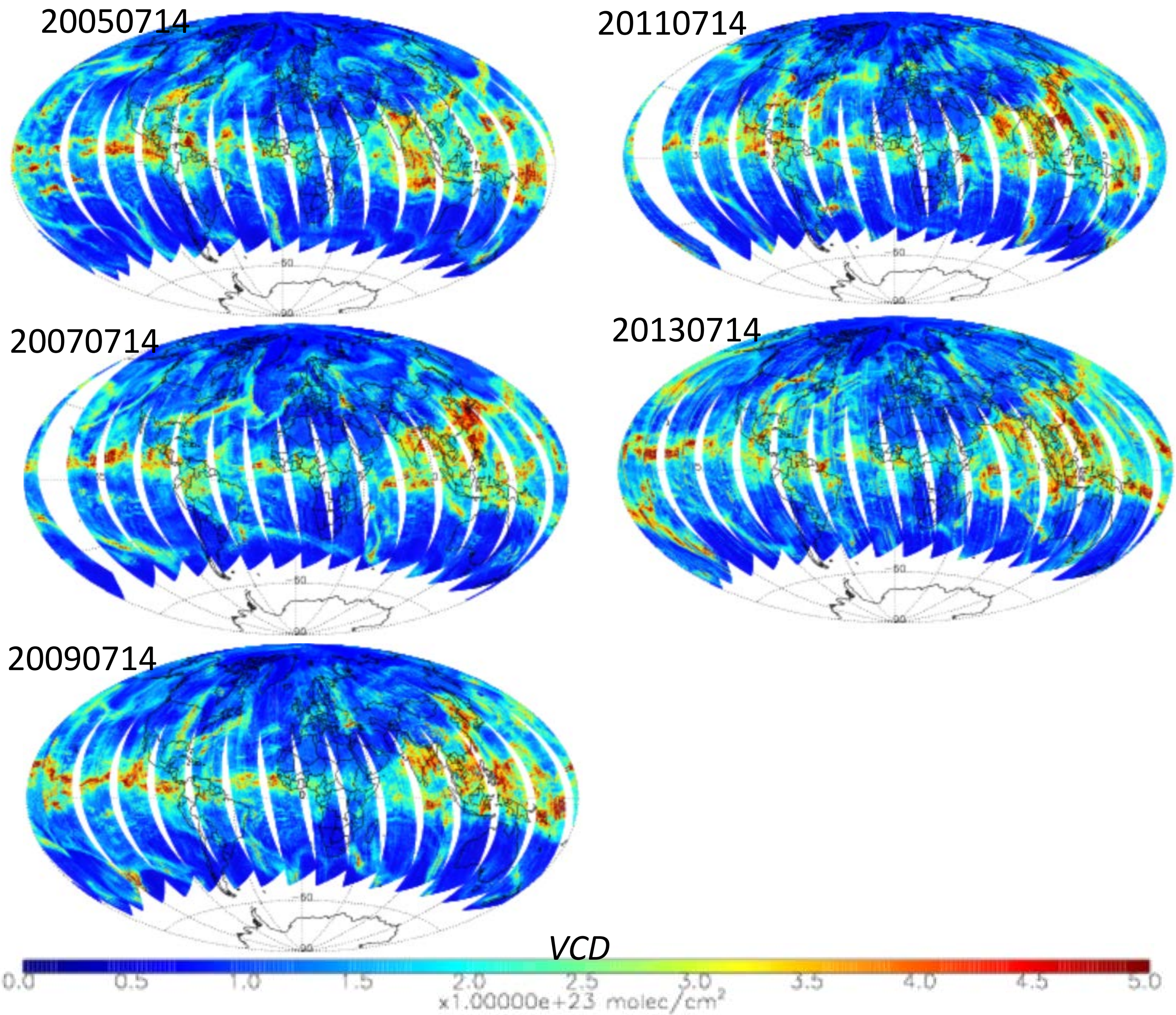
Comparison with AERONET H_2O



Comparison with AERONET time series



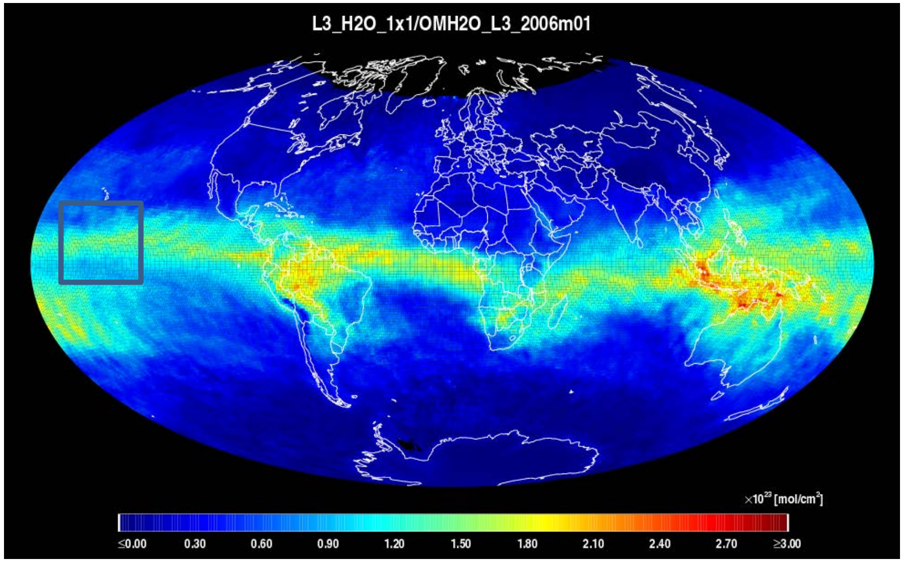
Long-term record of atmospheric water vapor

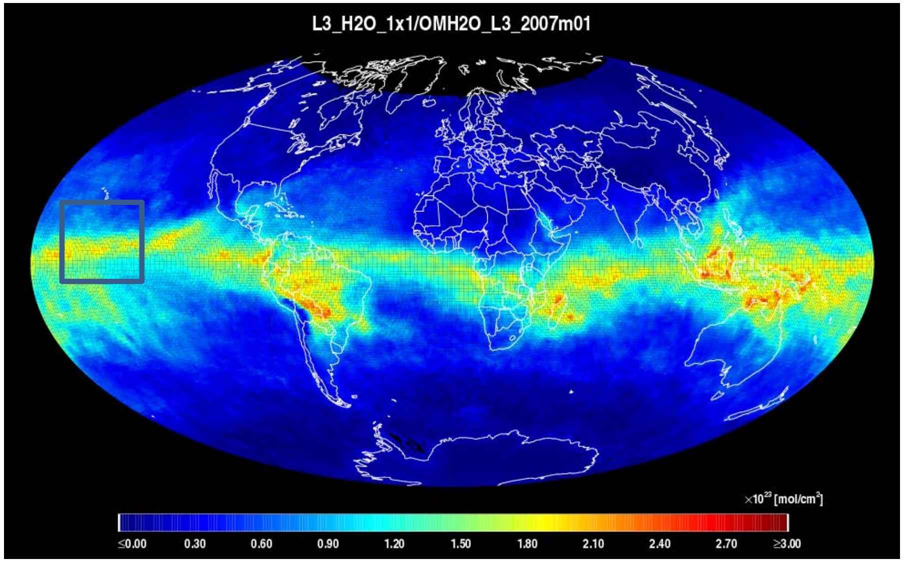


SAO L3 monthly OMI water vapor product

January 2006

January 2007





Oceanic Nino Index (ONI) = -0.9

ONI=0.7