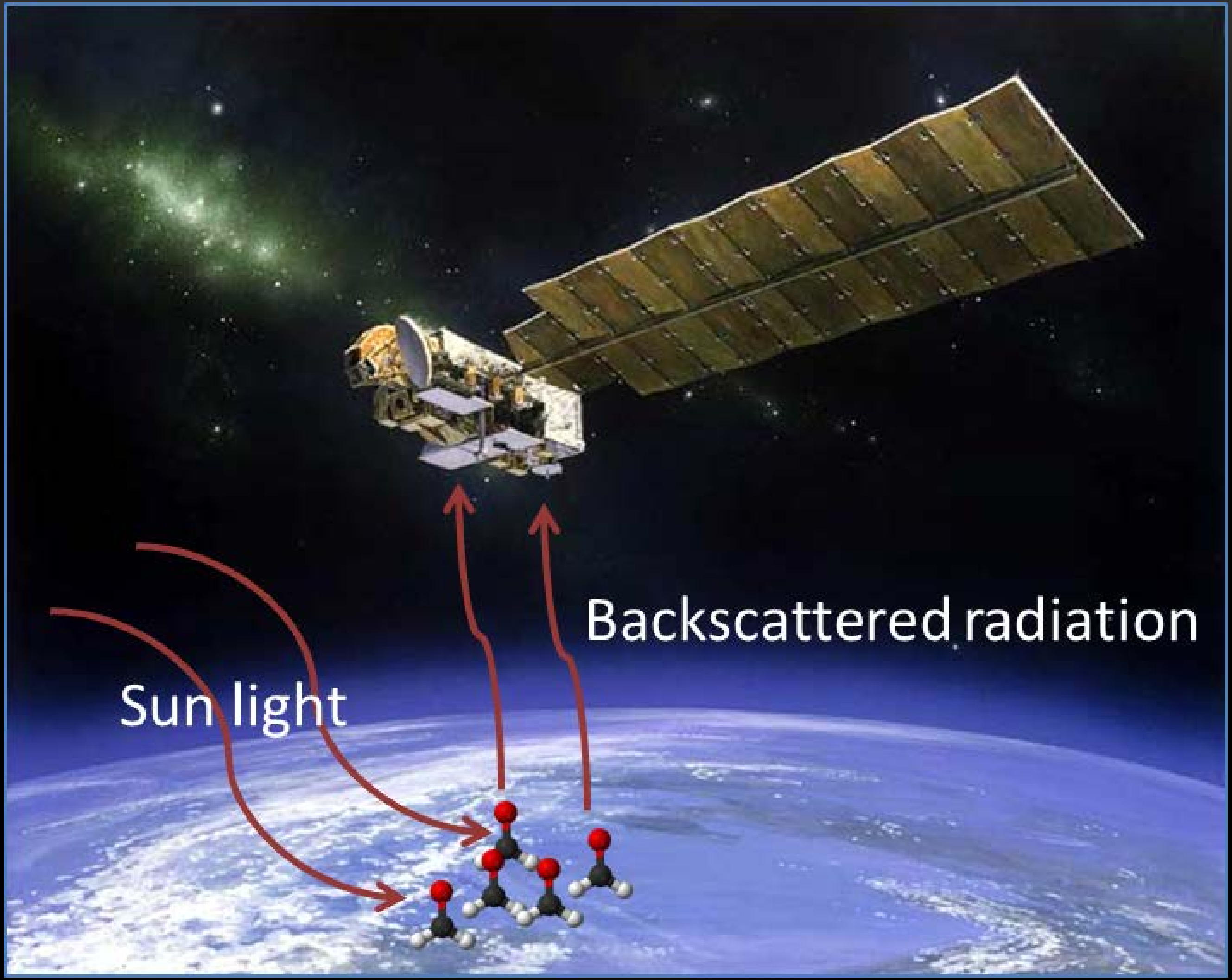
UV/VIS BACKSCATTERED SUN LIGHT RETRIEVALS FROM SPACE BORN PLATFORMS

G. Gonzalez Abad

With a lot of help from K. Chance, X. Liu, C. Miller and others

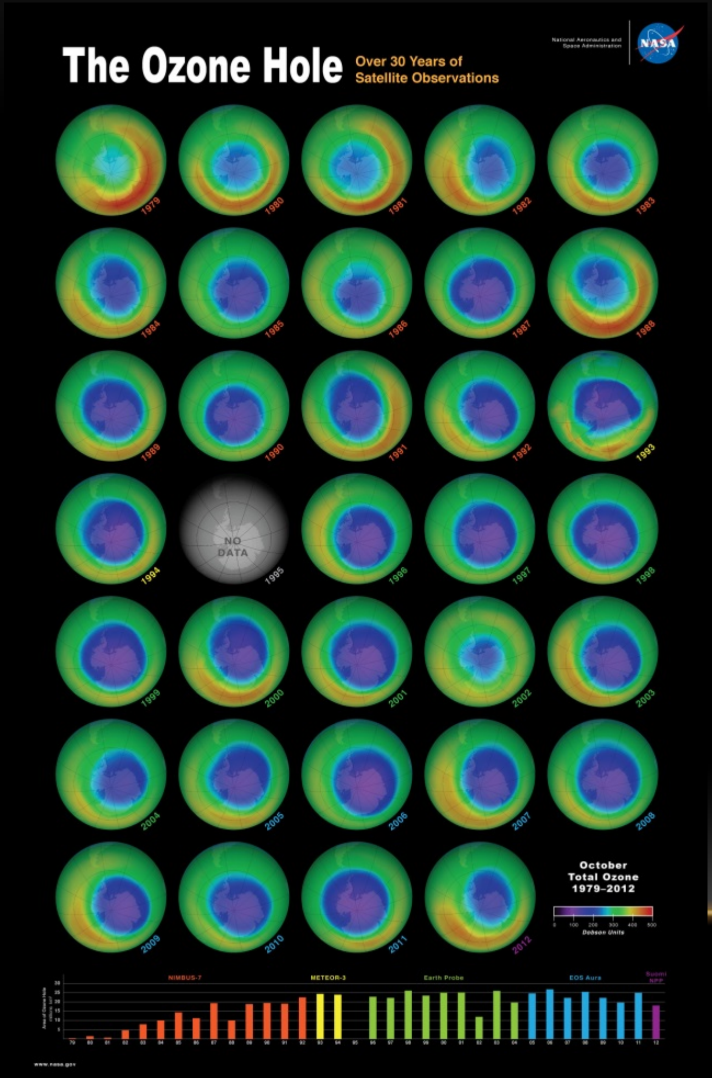

Backscattered radiation
Sun light

OVERVIEW

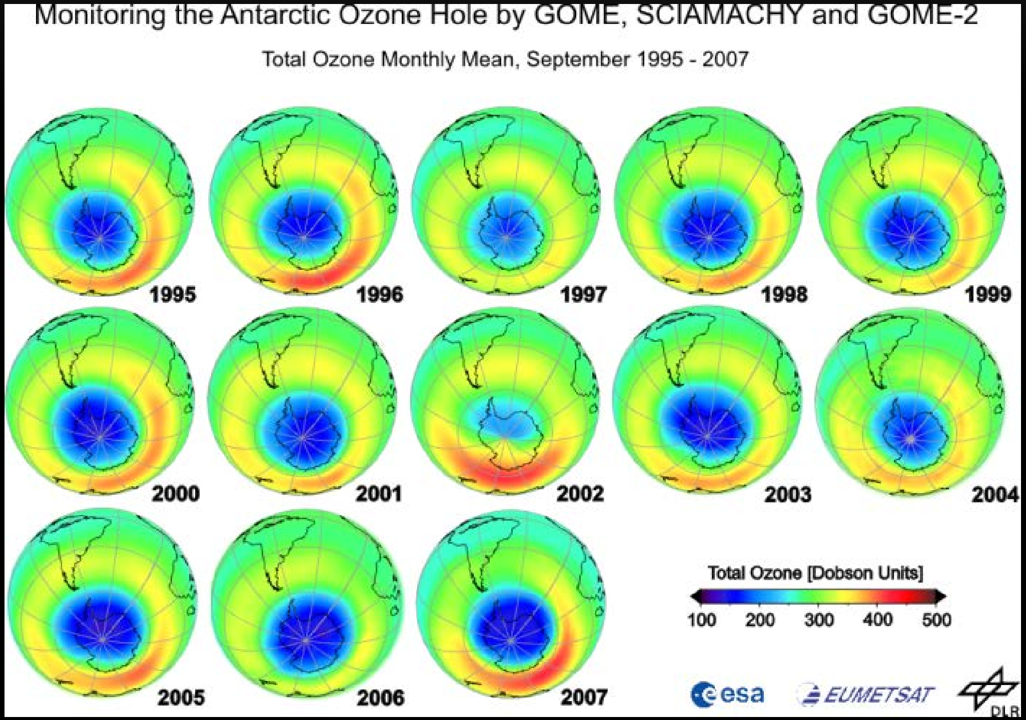
- A bit of history on UV-VIS backscatter spectrometers
  - Past, present and future instruments (as far as I know)
  - TOMS vs. OMI
  - GOME vs. OMI
  - The GEO constellation
- Slant column retrievals
  - The equations: BOAS
  - To have in mind (solar spectrum, cross sections, ring, undersampling, …)
  - Examples
- Slant column to vertical column
  - Equations
- Vertical columns: examples from OMI

HISTORY: THE DISCOVERY OF THE OZONE HOLE FUELLED THE INTEREST IN THE ATMOSPHERIC CHEMISTRY AND COMPOSITION DURING THE 1970S

USA



Europe



HISTORY & PRESENT: USA

Instrument	Satellite (Agency)	Period
BUV	Nimbus-4 (NASA)	1970-1980
SBUV	Nimbus-7 (NASA)	1978-1993
TOMS	Nimbus-7 (NASA) Meteor-3 (NASA) (Russian) Earth Probe (NASA)	1978 1993 1996-2007
SBUV/2	NOAA 9,10,11,13,14,17,16,18,19 (NOAA)	1984 – present
OMI	AURA (NASA/KNMI)	2004-present
OMPS	SUOMI-NPP (NOAA)	2011-present

HISTORY & PRESENT: EUROPE & CHINA

Instrument	Satellite (Agency)	Period
GOME	ERS-2 (ESA)	1995-2011
SCIAMACHY	ENVISAT (ESA)	2002-2012
OMI	AURA (KNMI/NASA)	2004-present
GOME2	Metop-A (EUMETSAT) Metop-B (EUMETSAT)	2006-present 2012-present
TOU/SBUS	FY-3A (NRSCC) FY-3B (NRSCC) FY-3C (NRSCC)	2008-present

FUTURE INSTRUMENTS

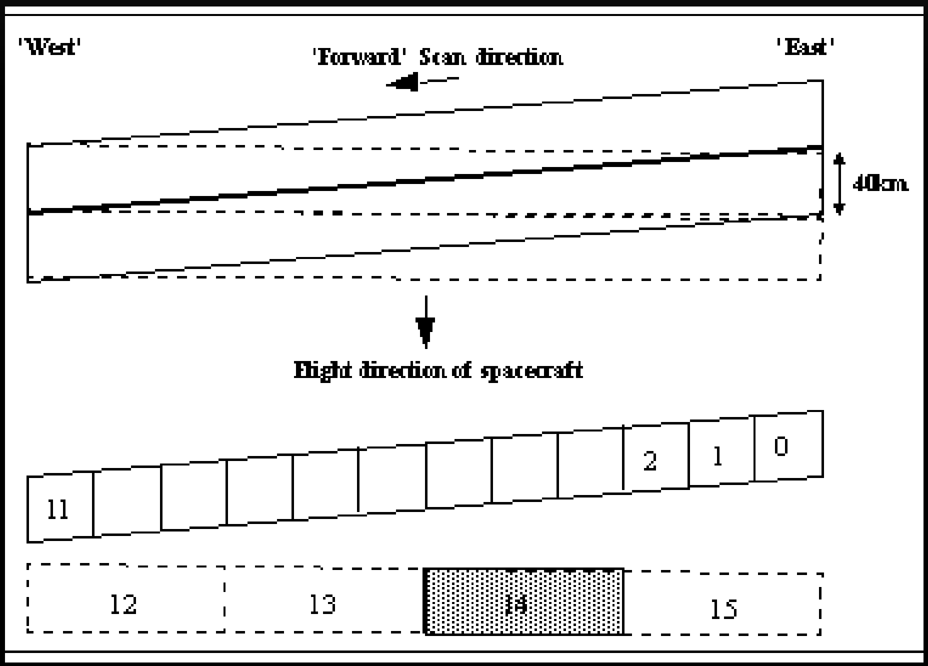
Instrument	Satellite (Agency)	Orbit
OMPS	JPSS1 (NOAA) JPSS2 (NOAA)	LEO LEO
TROPOMI	SENTINEL 5P (ESA)	LEO
GOME-2	Metop-C (EUMETSAT)	LEO
UVAS	Seosat-Ingenio (CDTI)	LEO
UVN	SENTINEL 4 (ESA)	GEO
GEMS	MP-GEOSAT (KORA)	GEO
TEMPO	TBD (NASA/SMITHSONIAN)	GEO

TOMS VS. OMI

	TOMS (Nimbus-7)	OMI
Spectral coverage	312.5 nm 317.5 nm 331.3 nm 339.9 nm 360.0 nm 380.0 nm	UV1: 270-314 nm UV2: 306-380 nm VIS: 350-500 nm
Bandwidth, resolution	1.1 nm	0.63 – 0.45 nm
Ground pixel size (nadir)	50 x 50 km^2	13 x 24 km^2
Global coverage	Daily	Daily

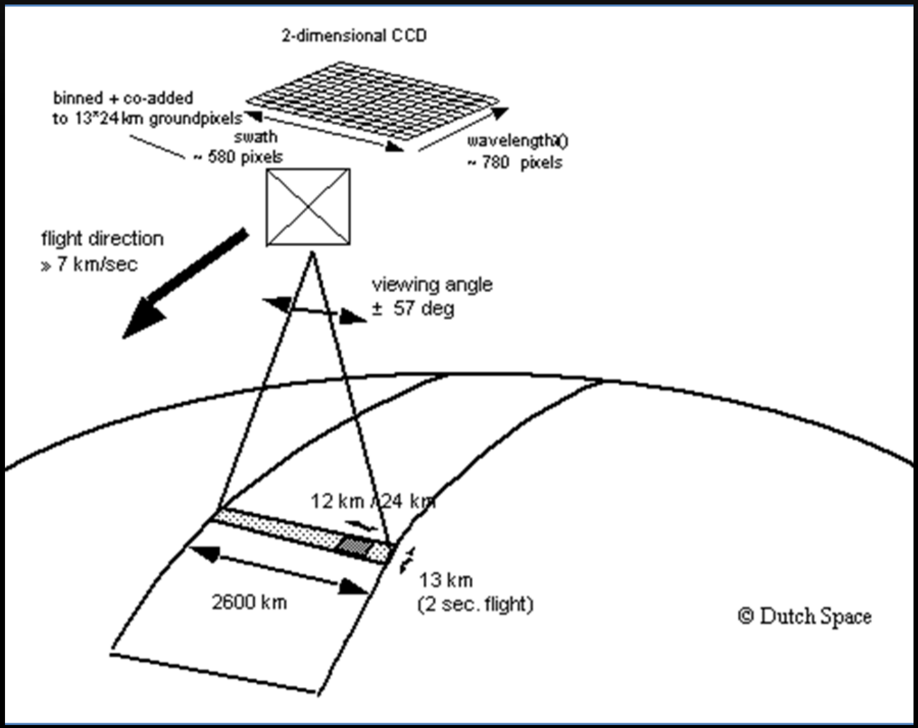
GOME VS. OMI

GOME



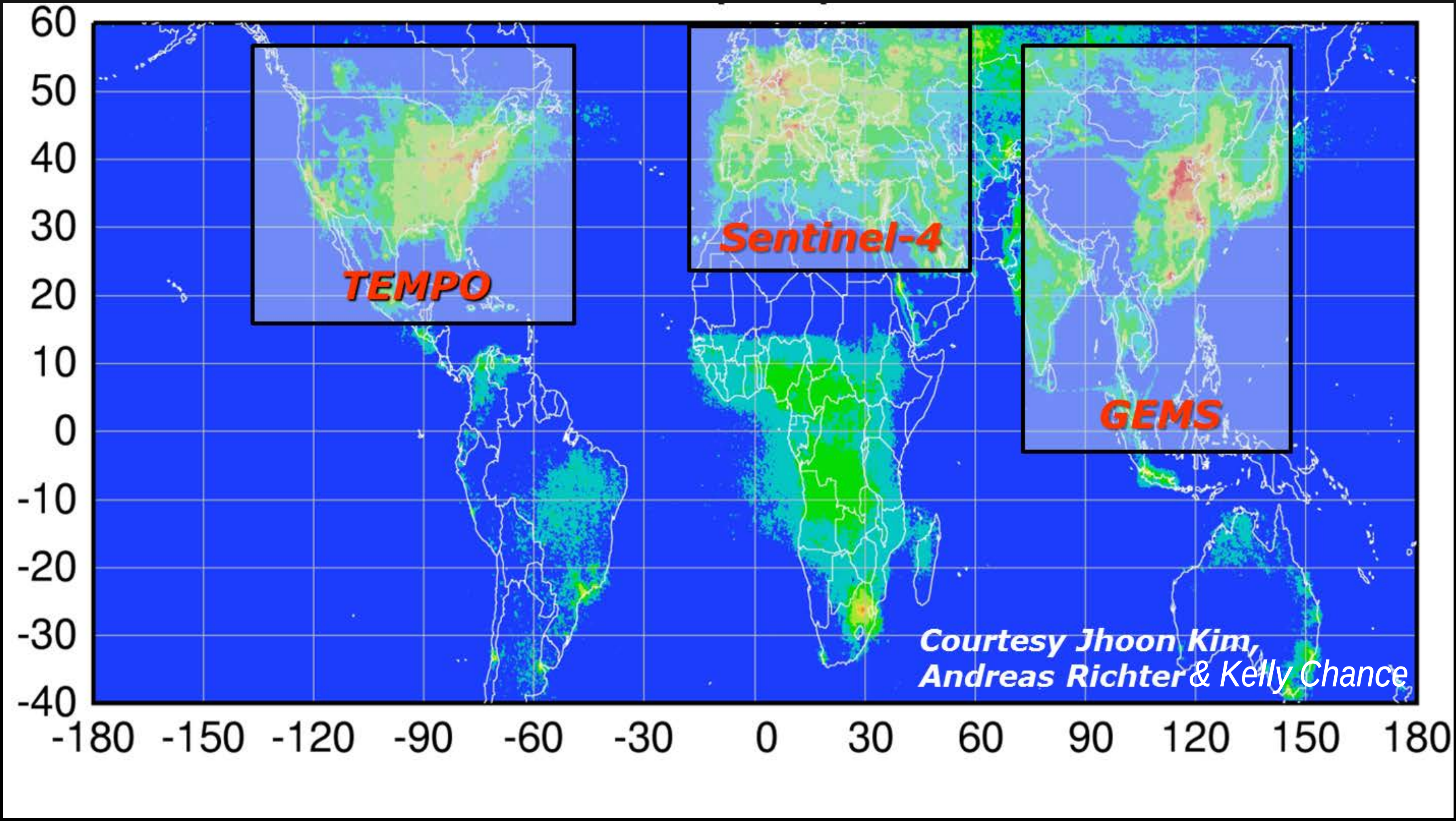
Photodiode detectors 1024 pixels

OMI

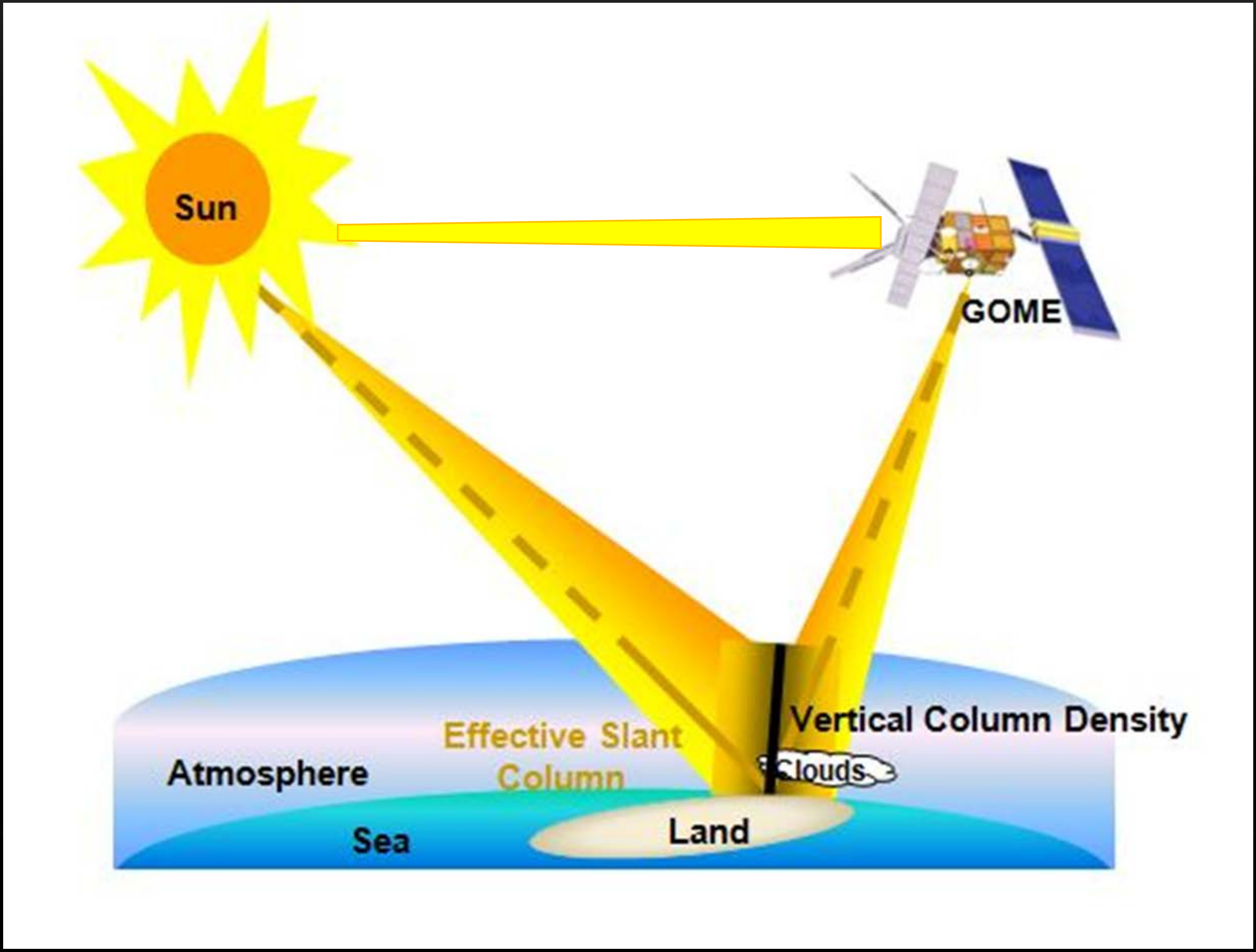


2D CCD detector

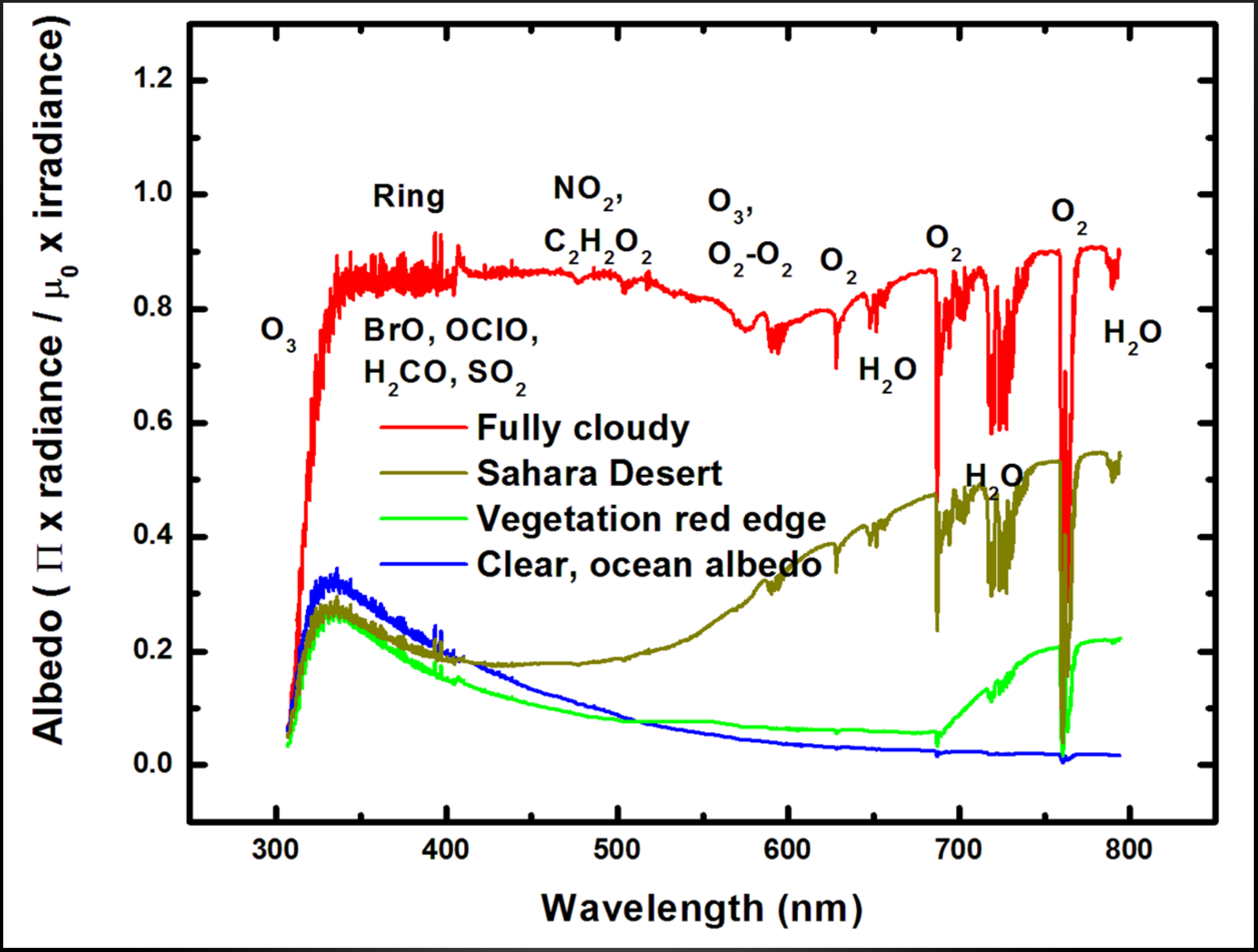
THE GEO CONSTELLATION



SLANT COLUMN RETRIEVAL



SLANT COLUMN RETRIEVAL



SLANT COLUMN RETRIEVAL: BOAS

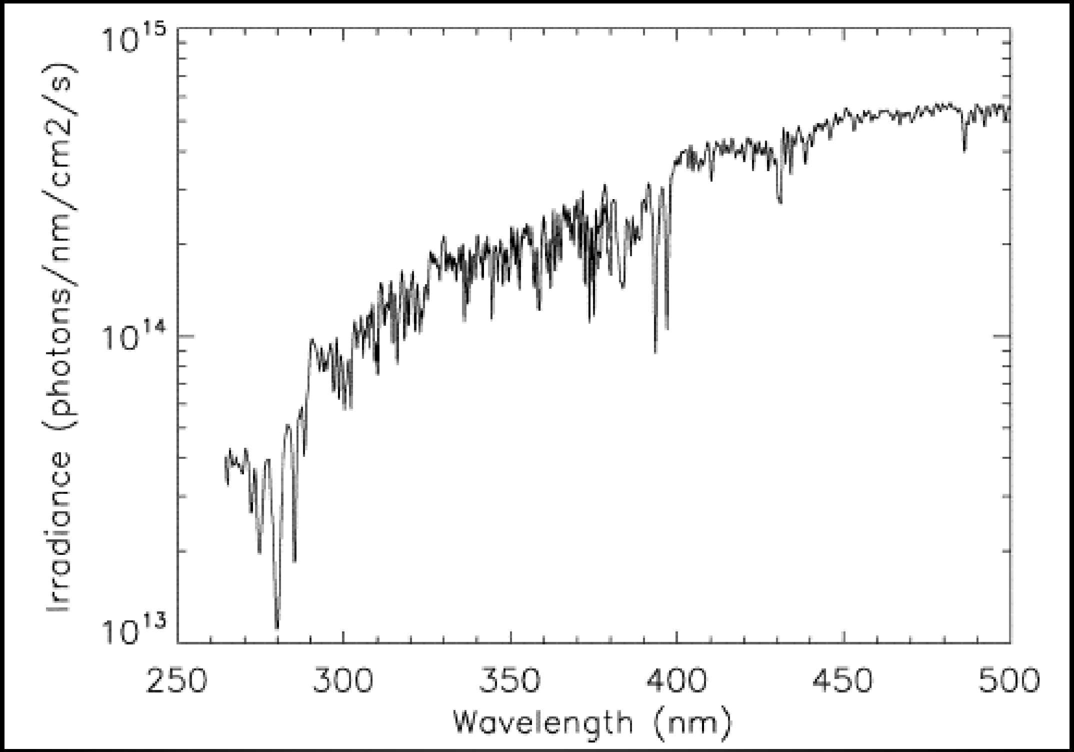
$$\chi^2 = \sum_i (y_i - f(\lambda_i, \beta))^2$$

$$I = \left[(aI_o + \sum_i \alpha_i X_i) e^{-\sum_j \alpha_j X_j} + \sum_k \alpha_k X_k \right] ScalPoly + BasePoly$$

$$\epsilon = \beta - \hat{\beta}$$

SLANT COLUMN RETRIEVAL: IRRADIANCE

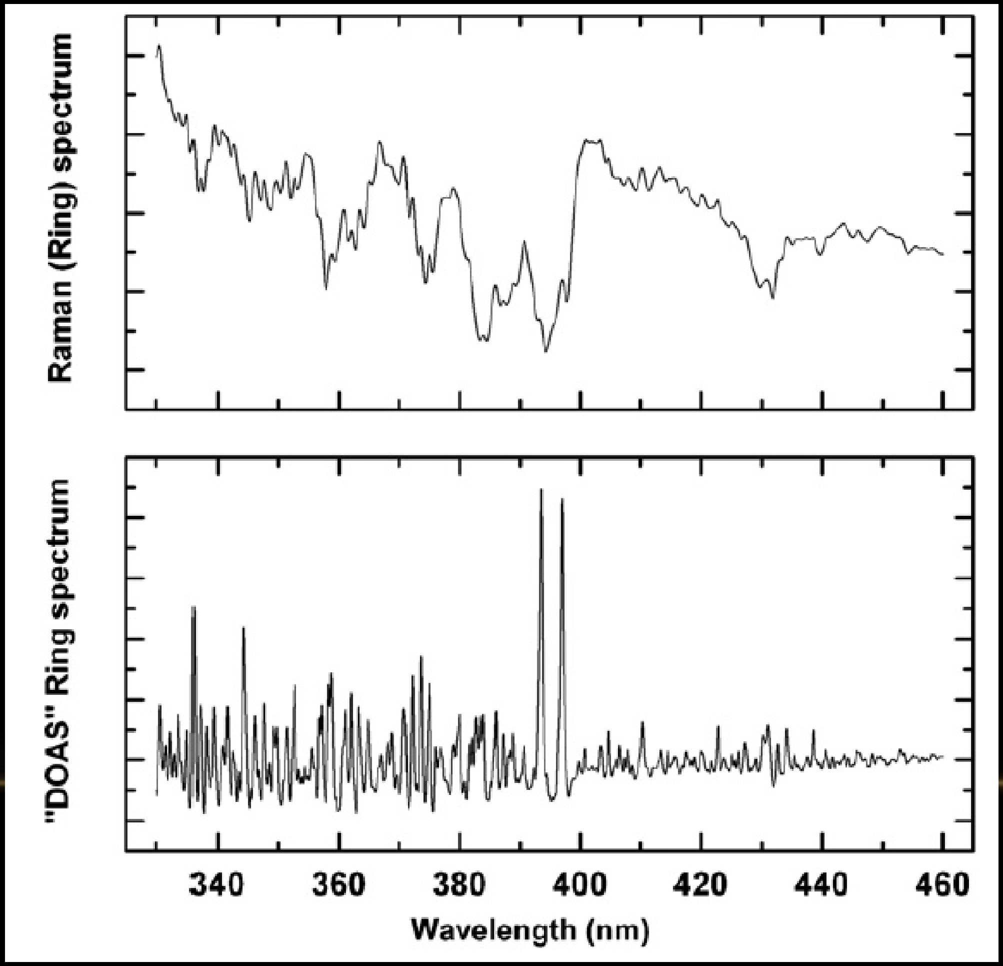
$$I = \left[(aI_o + \sum_i \alpha_i X_i) e^{-\sum_j \alpha_j X_j} + \sum_k \alpha_k X_k \right] ScalPoly + BasePoly$$



OMI irradiance, Dobber at al. 2006

SLANT COLUMN RETRIEVAL: RING SPECTRUM

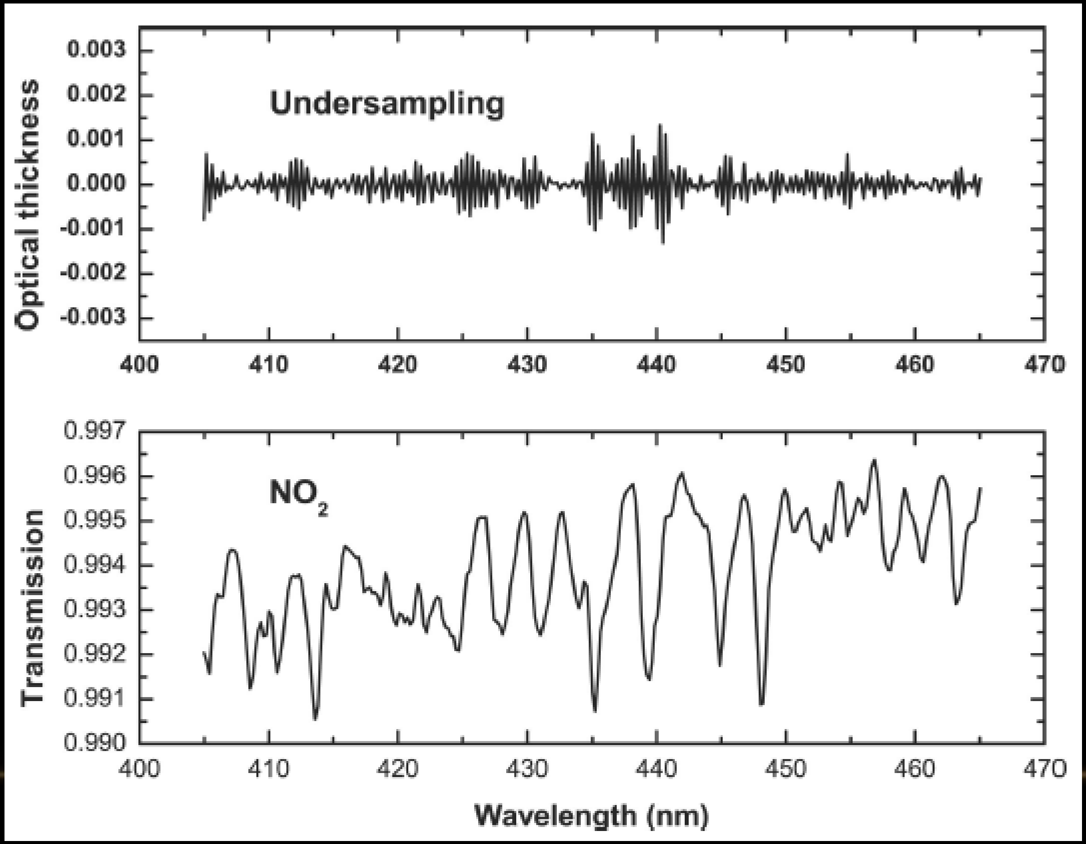
$$I = \left[\left(aI_o + \sum_i \alpha_i X_i \right) e^{-\sum_j \alpha_j X_j} + \sum_k \alpha_k X_k \right] ScalPoly + BasePoly$$



Chance and Kurucz 2010

SLANT COLUMN RETRIEVAL: UNDERSAMPLING

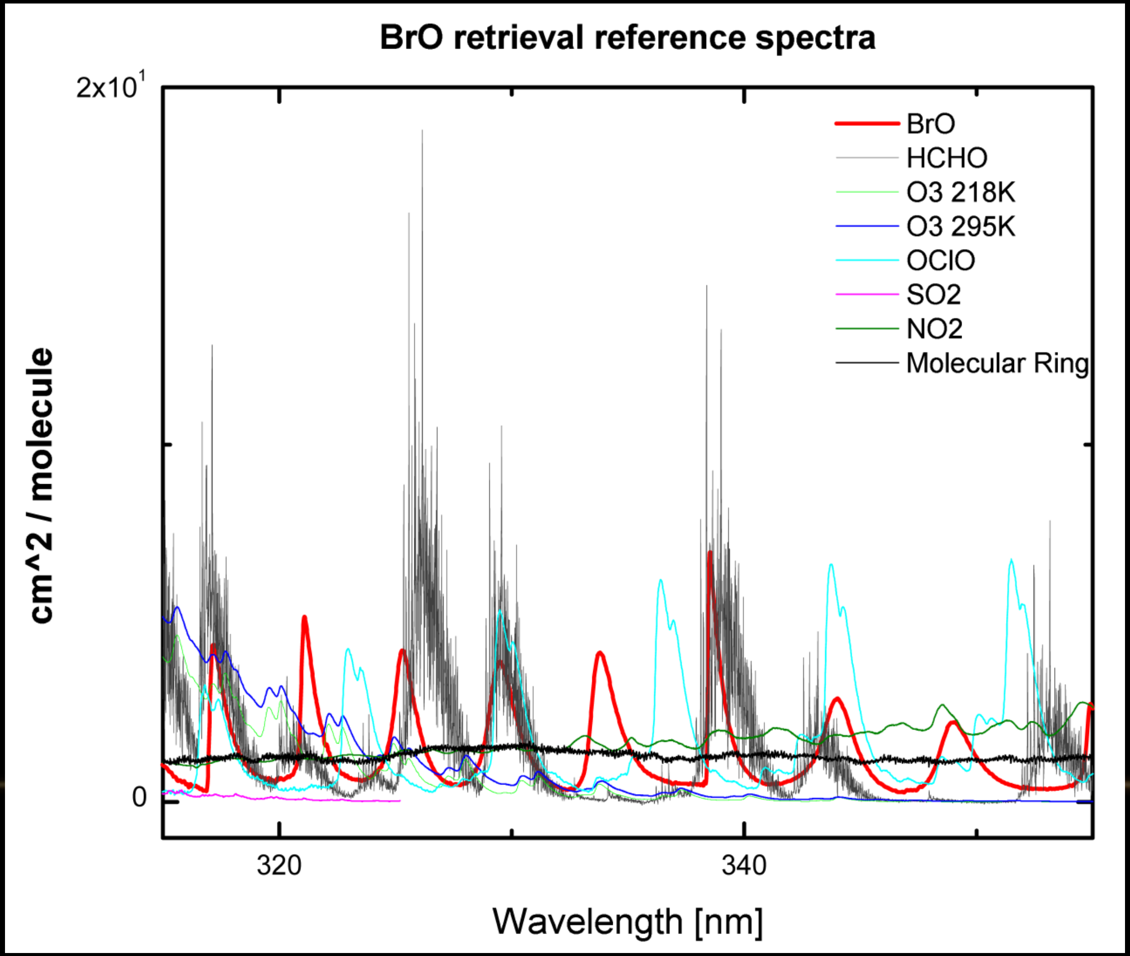
$$I = \left[\left(aI_o + \sum_i \alpha_i X_i\right) e^{-\sum_j \alpha_j X_j} + \sum_k \alpha_k X_k \right] ScalPoly + BasePoly$$



Chance et. Al, 2005

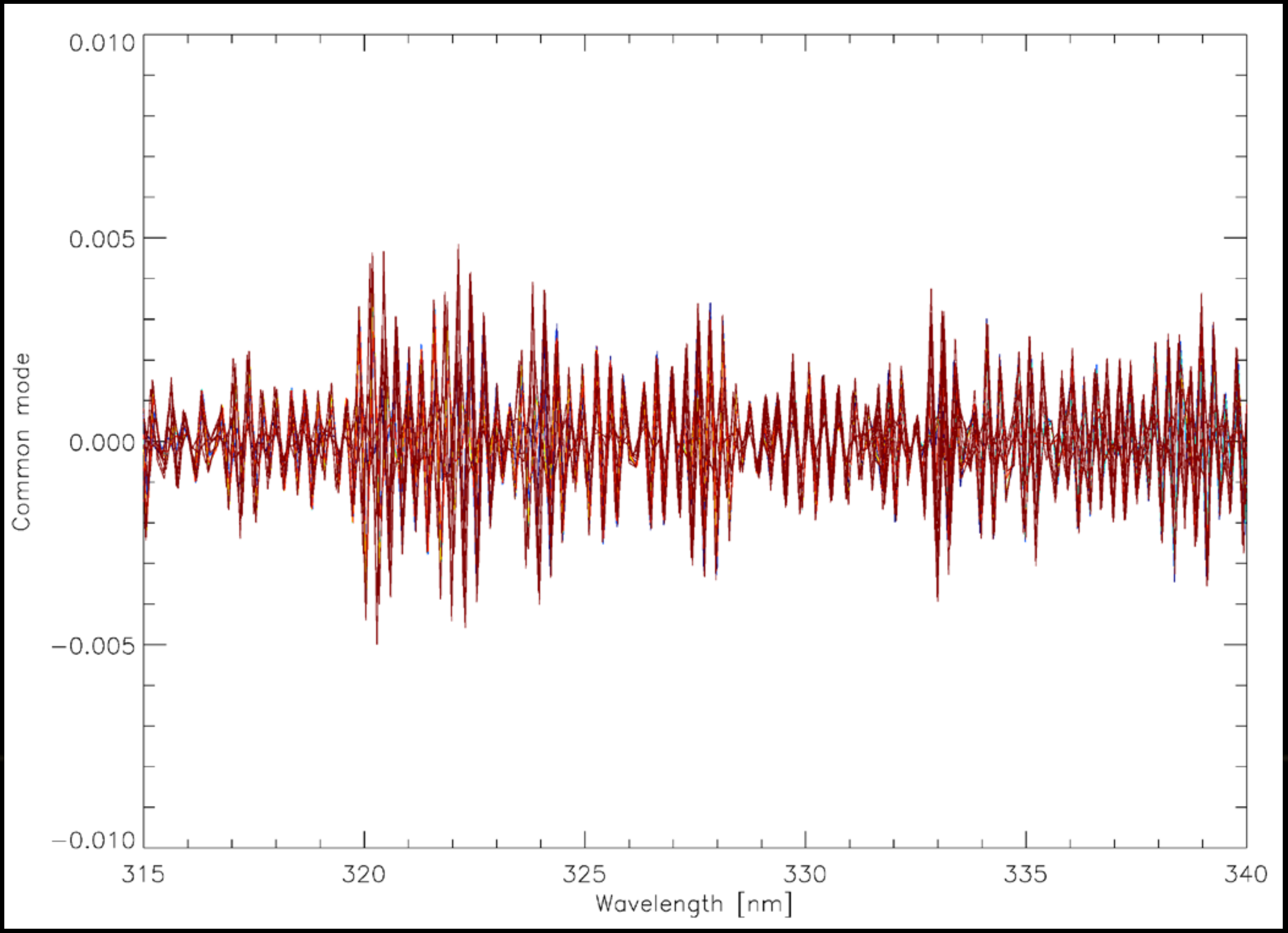
SLANT COLUMN RETRIEVAL: CROSS SECTIONS

$$I = \left[(aI_o + \sum_i \alpha_i X_i) e^{-\sum_j \alpha_j X_j} + \sum_k \alpha_k X_k \right] ScalPoly + BasePoly$$

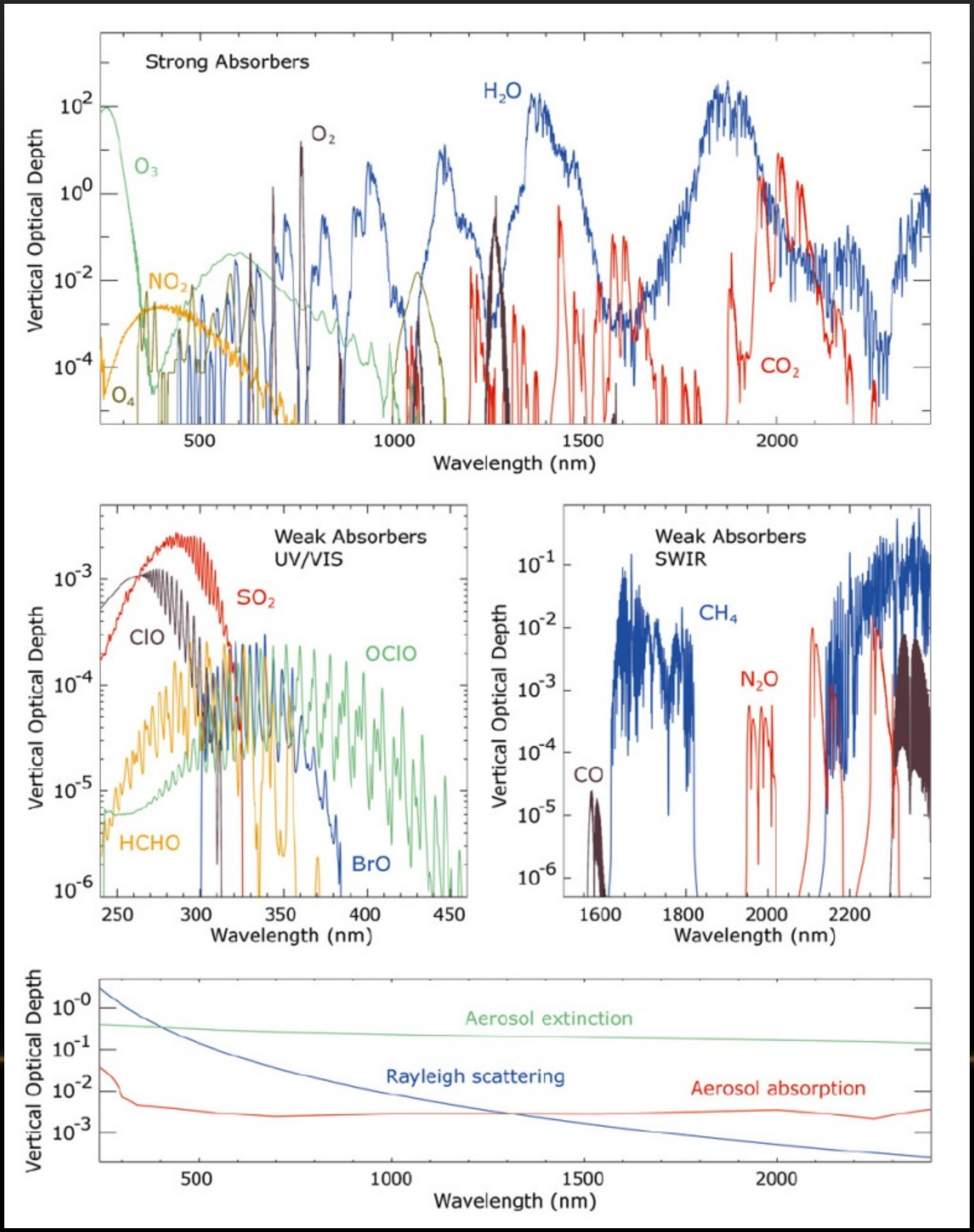


SLANT COLUMN RETRIEVAL: COMMON MODE

$$I = \left[(aI_o + \sum_i \alpha_i X_i) e^{-\sum_j \alpha_j X_j} + \sum_k \alpha_k X_k \right] ScalPoly + BasePoly$$

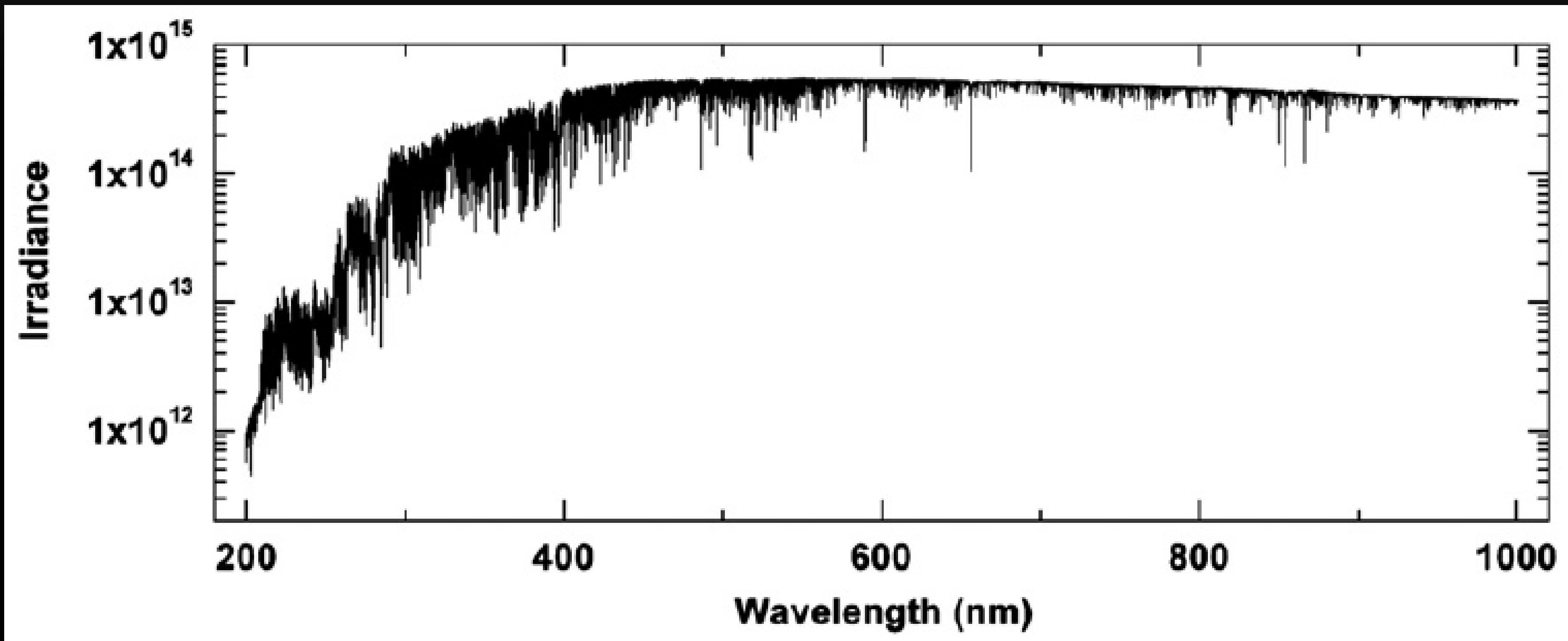


SLANT COLUMN RETRIEVAL: OPTICAL DEPTH



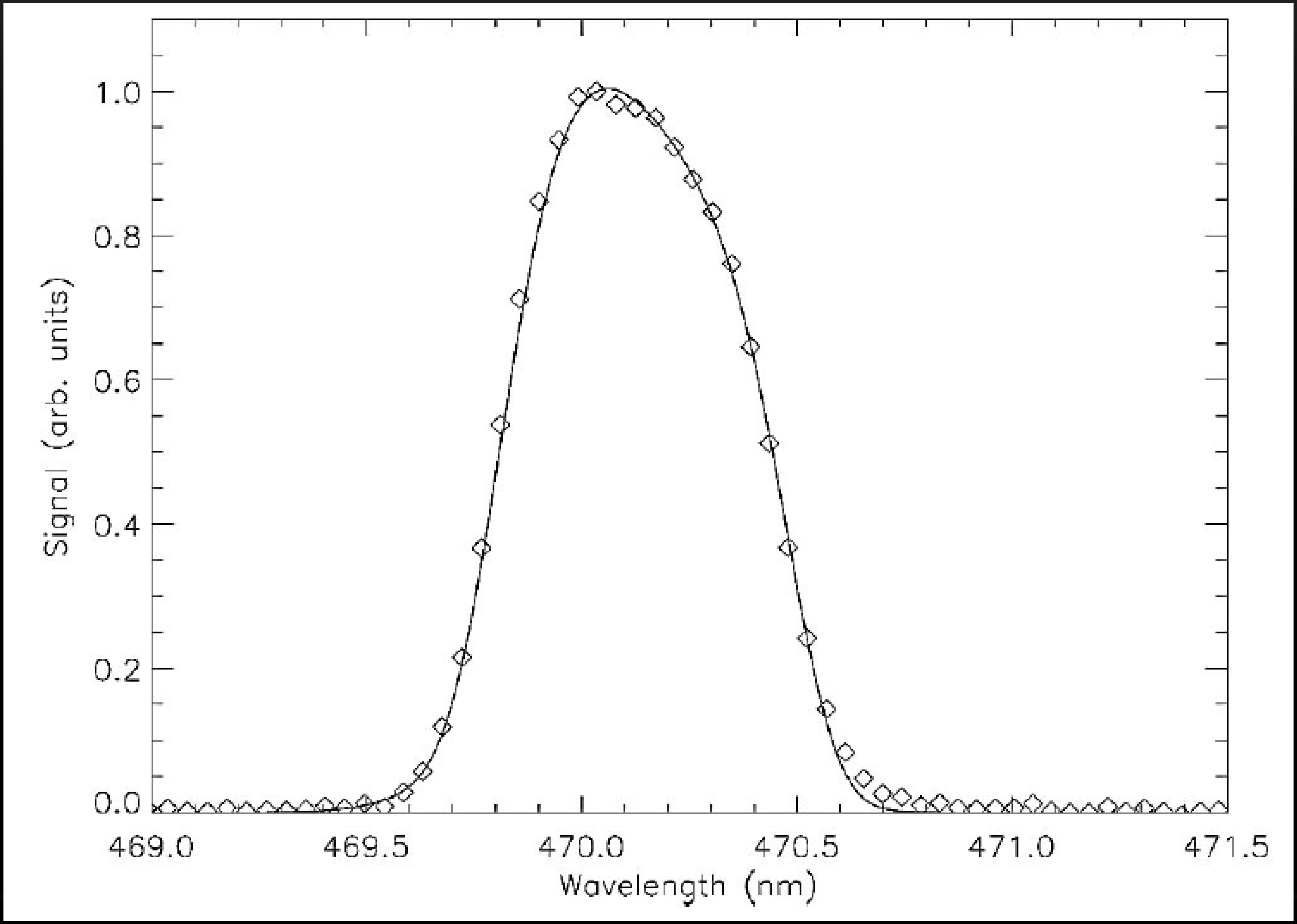
Courtesy: IUP-IFE, University of Bremen

SLANT COLUMN RETRIEVAL: HIGH RESOLUTION SOLAR SPECTRUM



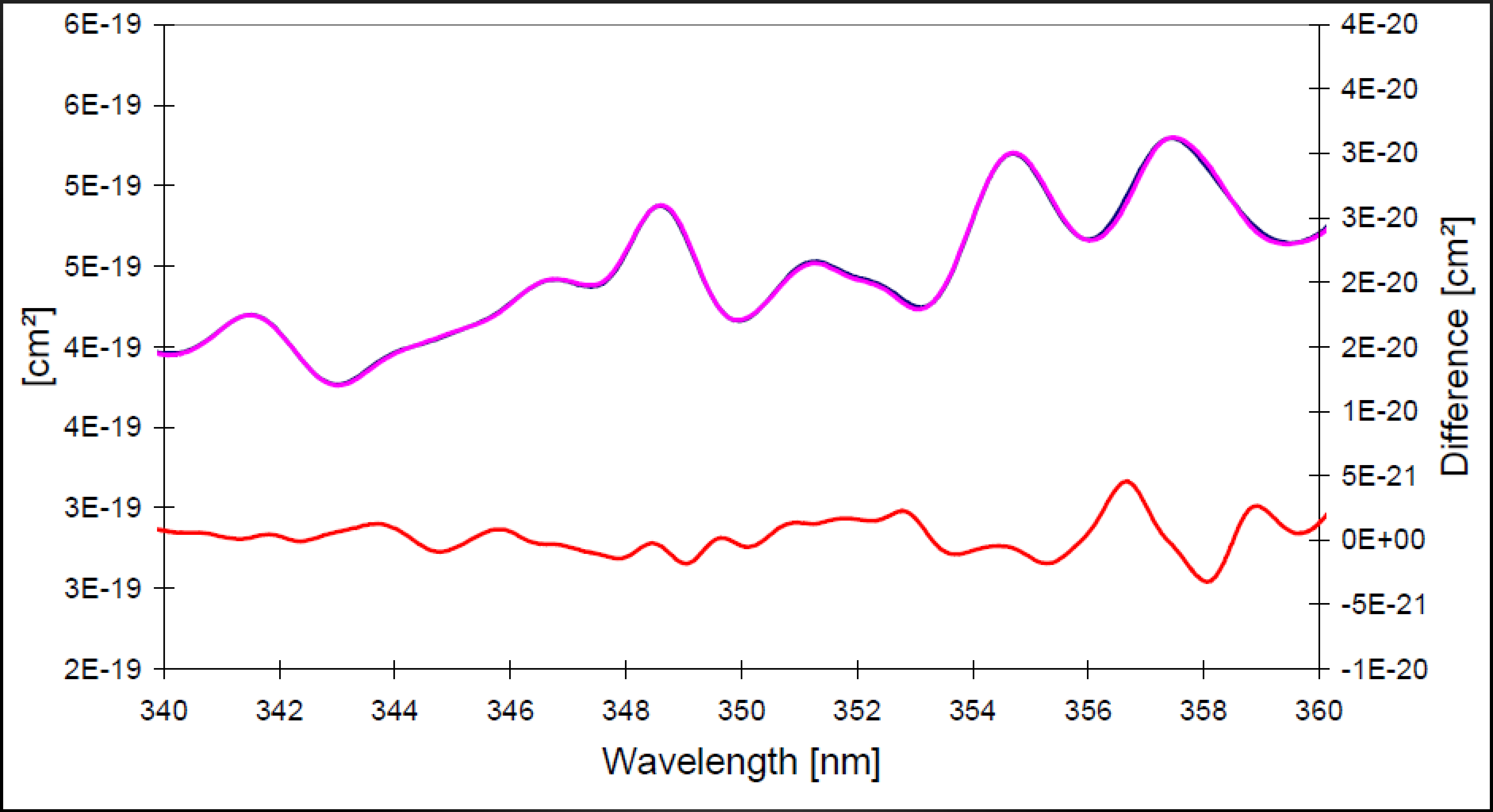
Chance & Kurucz, 2010

SLANT COLUMN RETRIEVAL: SLIT FUNCTION



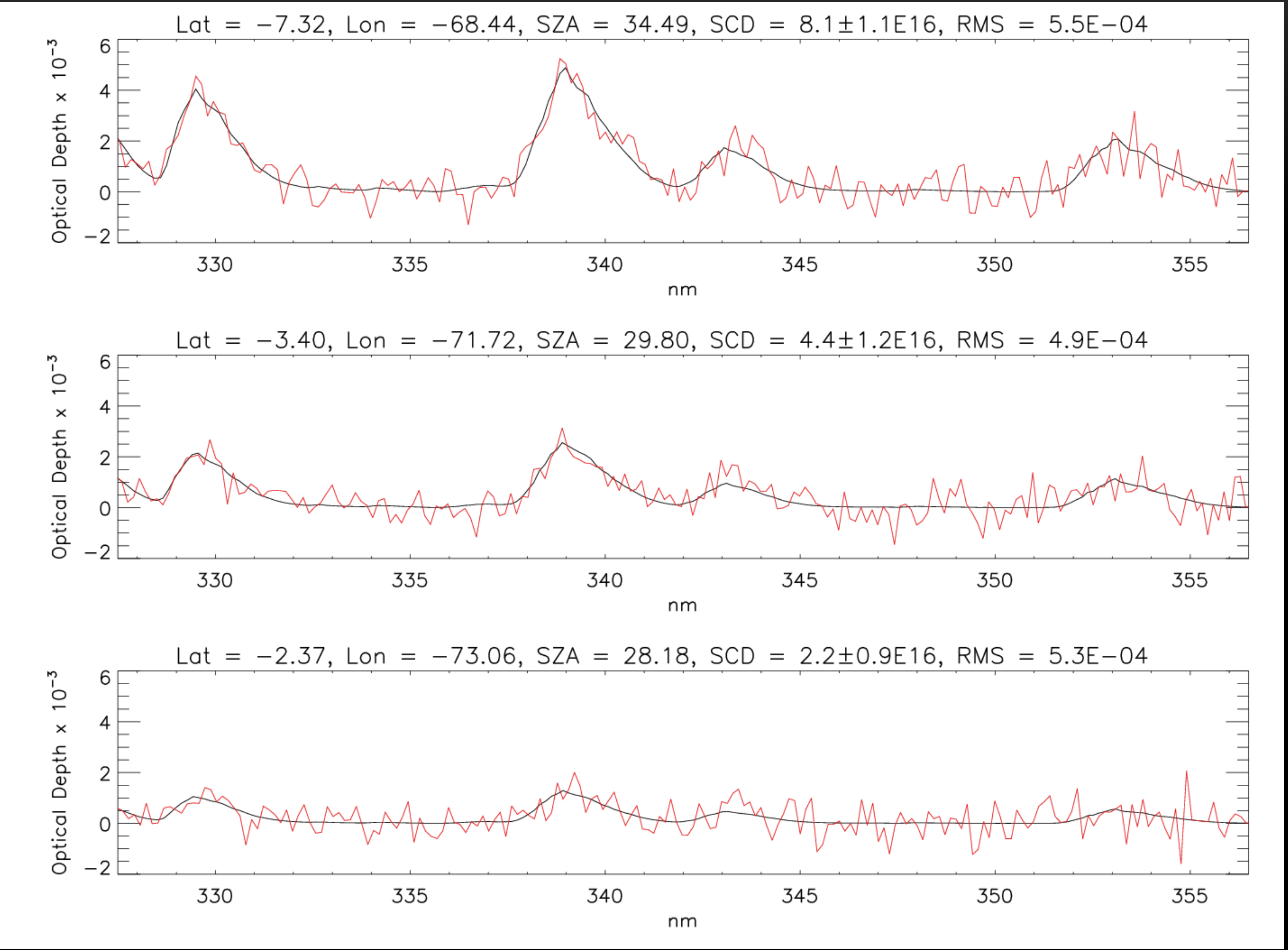
Dirksen et al. 2006

SLANT COLUMN RETRIEVAL: I_0 CORRECTION

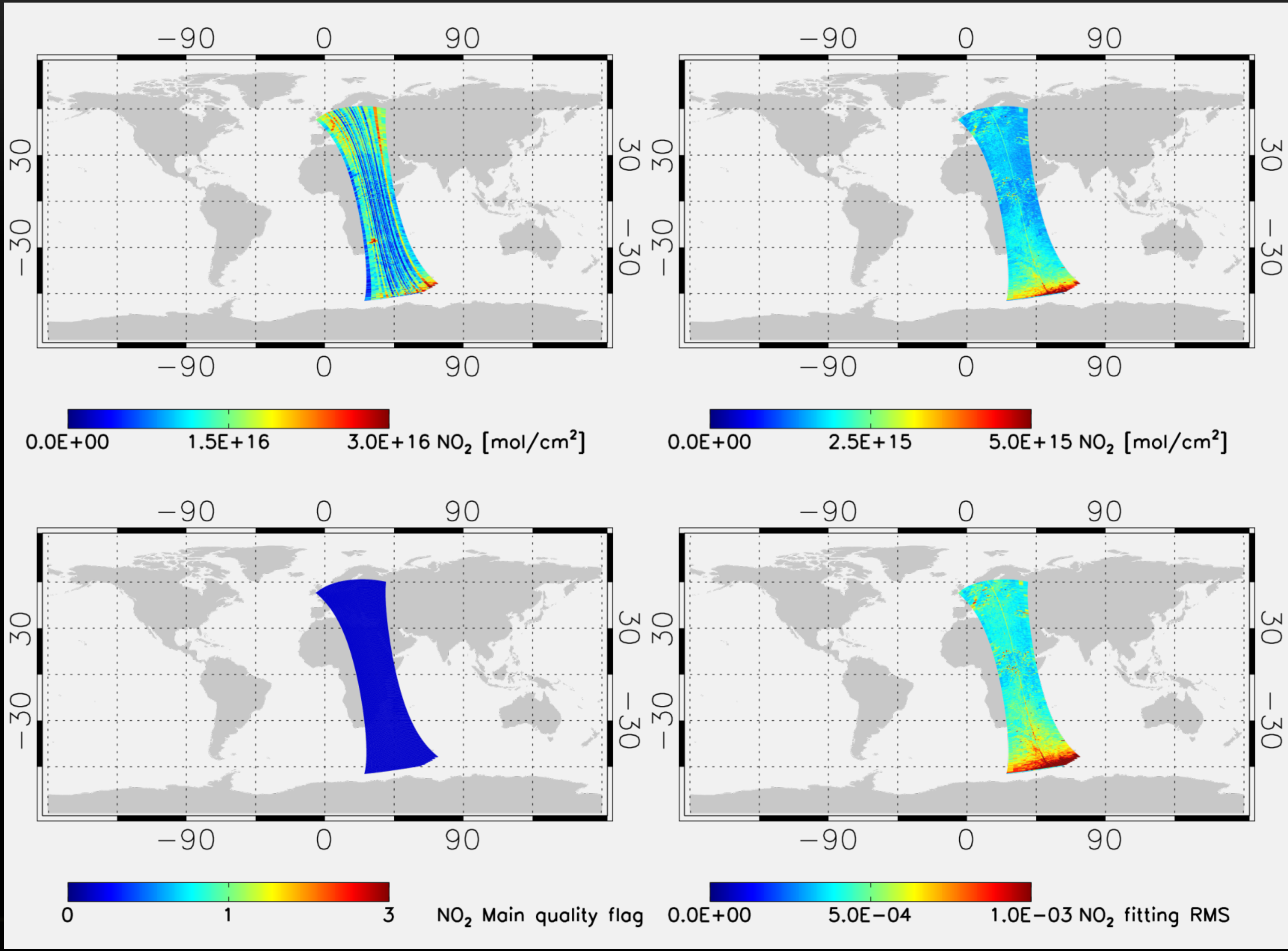


Wagner, Chance et al.

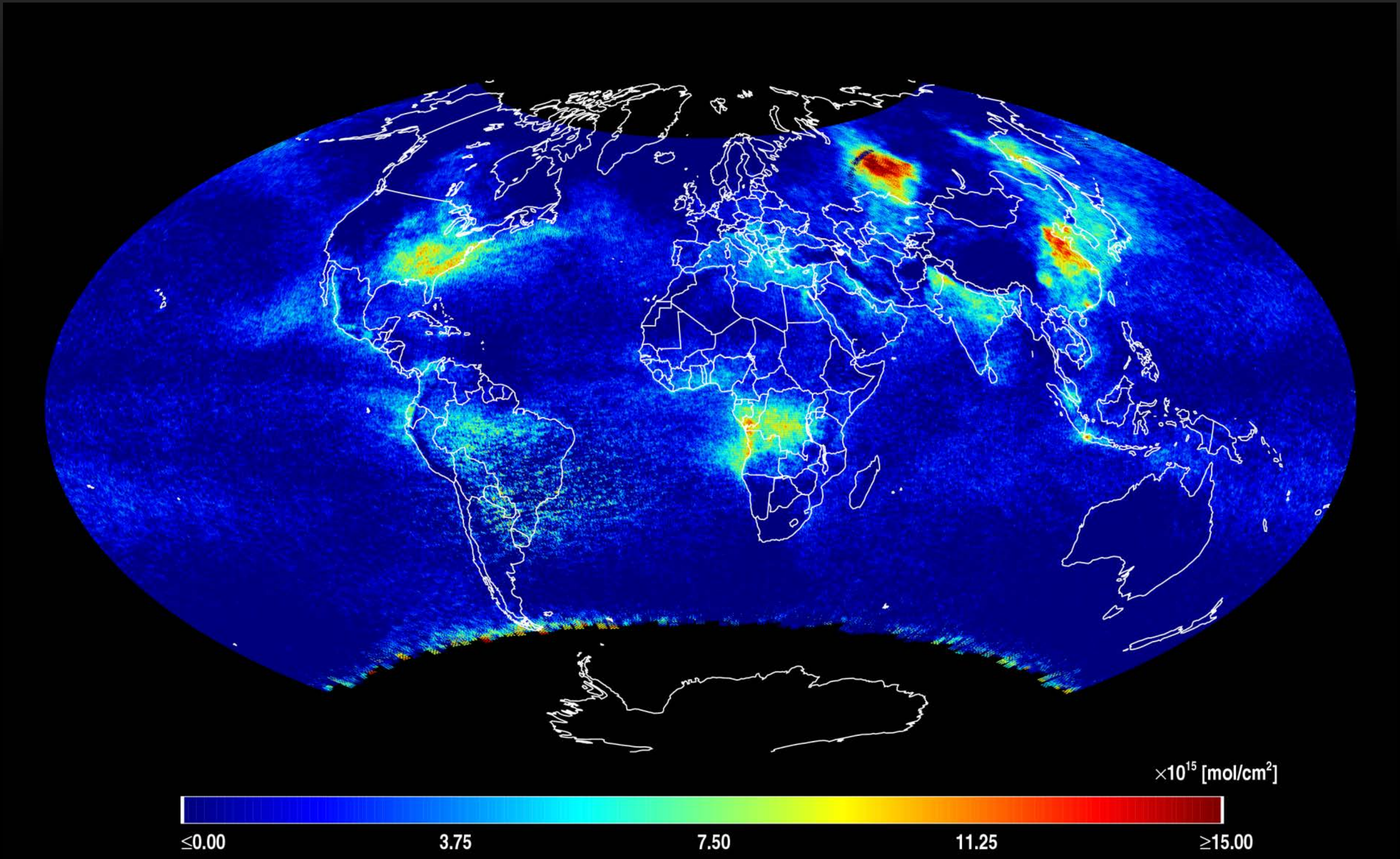
SLANT COLUMN RETRIEVAL: OMI C_2HO



SLANT COLUMN RETRIEVAL: OMPS NO_2



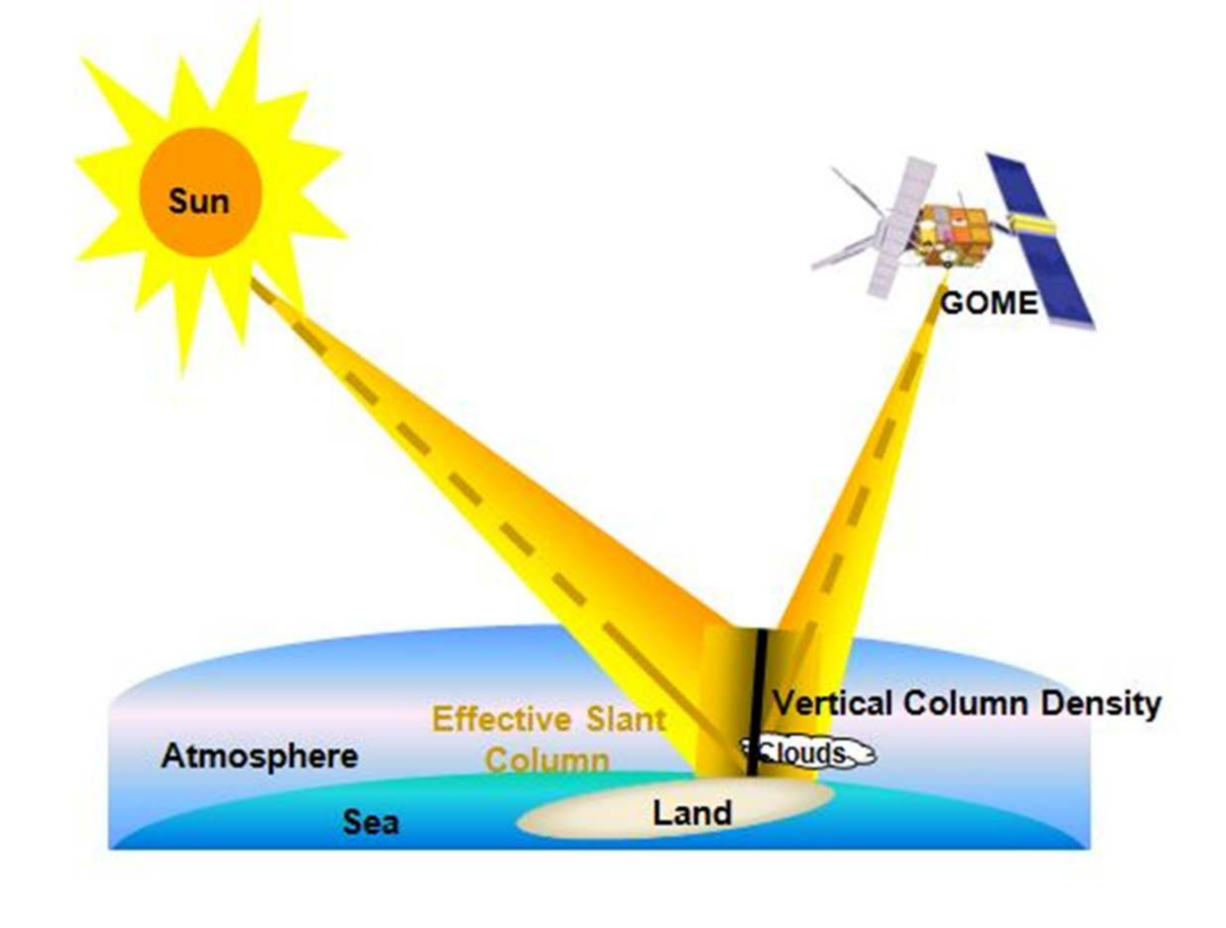
SLANT COLUMN RETRIEVAL: OMPS C_2HO



VERTICAL COLUMN: EQUATIONS

$$VCD = \frac{SCD}{AMF}$$

AMF (Air Mass Factor)



VERTICAL COLUMN: EQUATIONS

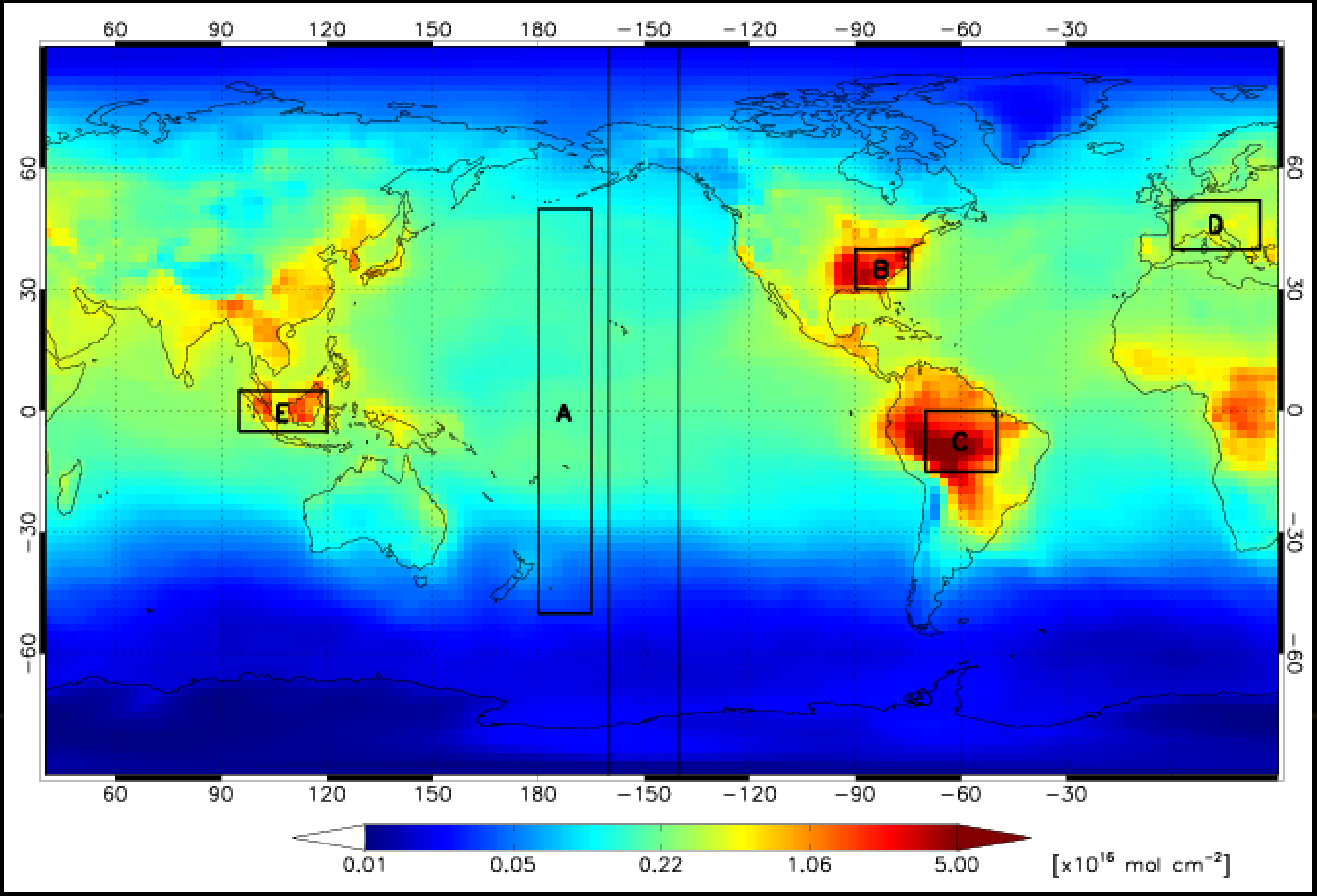
$$AMF = \int_{atm} w(z) S_z(z) dz$$

w(z) Scattering weights from Vlidort

S_x (z) shape factors from a climatology for example GEOS-Chem

VERTICAL COLUMN: EQUATIONS, SHAPE FACTORS

$$S(z) = \frac{x_a(z)}{\int_{atm} x_a(z)dz}$$



VERTICAL COLUMN: EQUATIONS SCATTERING WEIGHTS

$$w(z) = \frac{\partial I / \partial z}{I \sum x_z}$$

Cloudy SZA: 28°

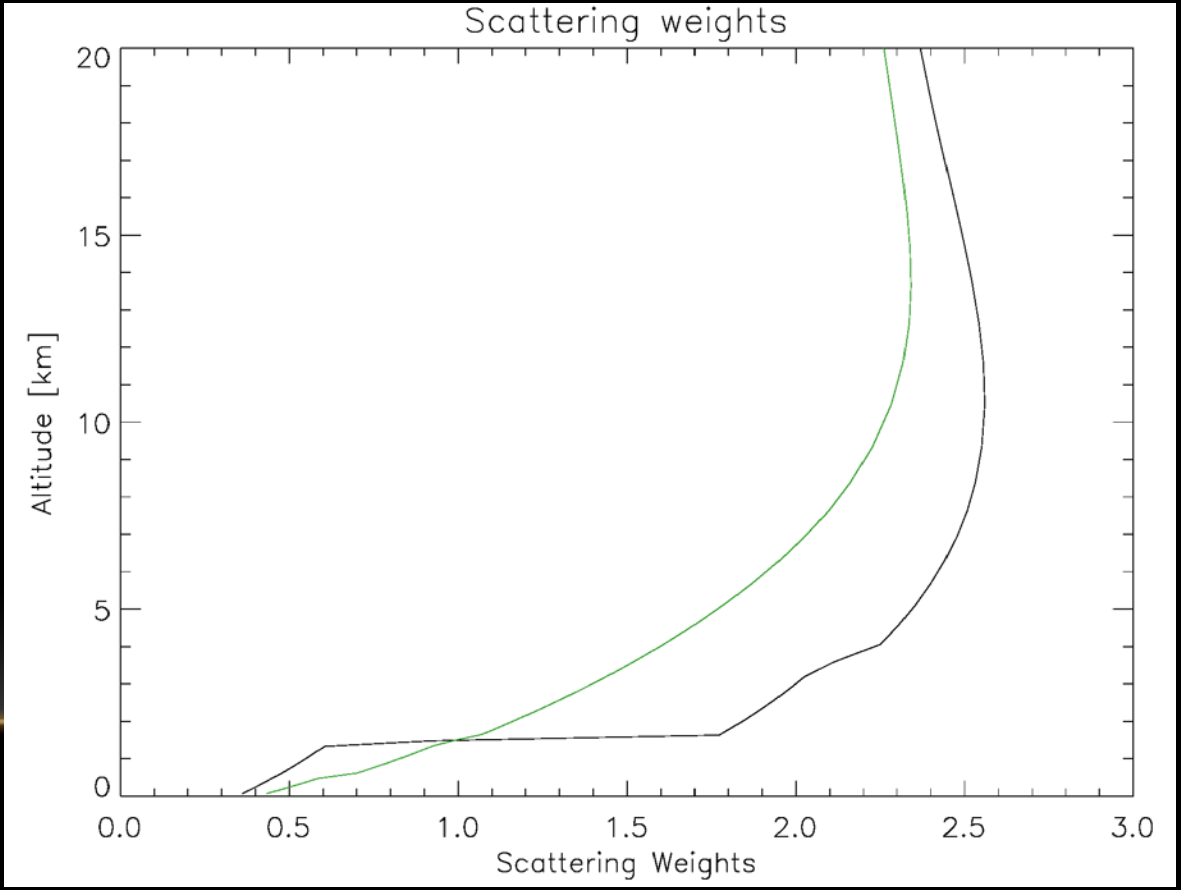
Clear SZA: 24°

Cloudy VZA: 16°

Clear VZA: 2.7°

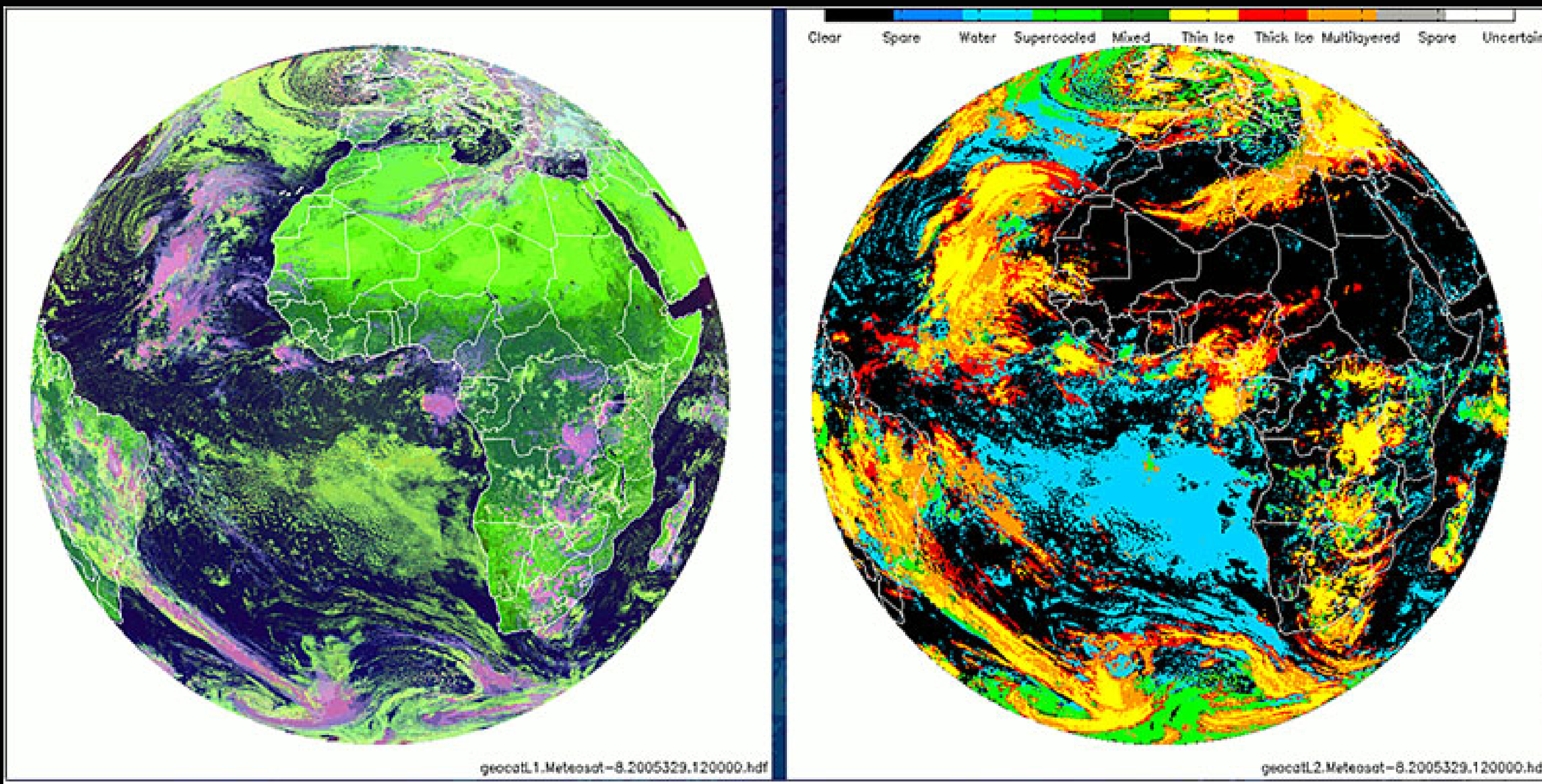
Cloudy cloud fraction: 0.2

Clear cloud fractions: 0.01



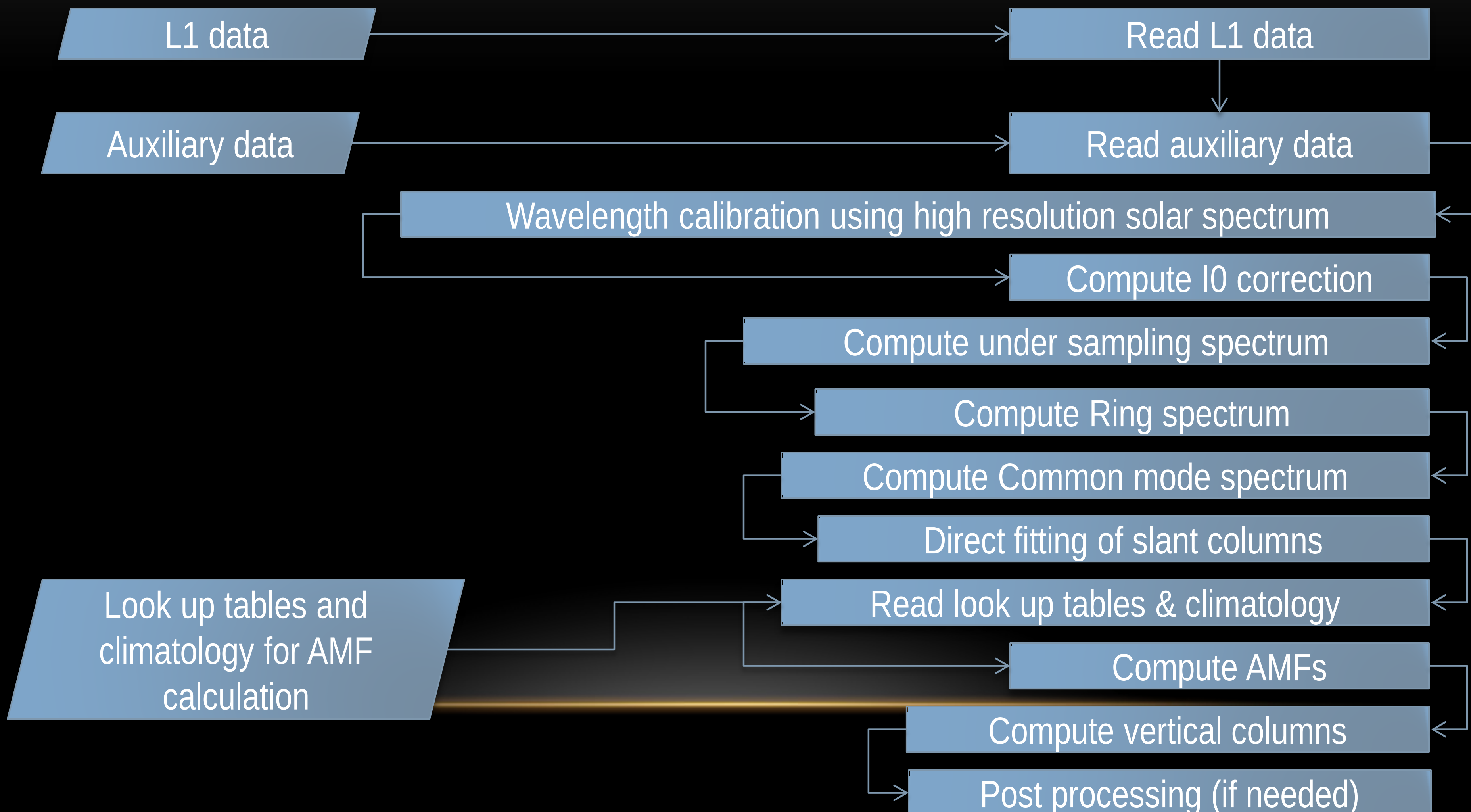
VERTICAL COLUMN: EQUATIONS SINGEL PIXEL APPROXIMATION

$$w(z) = (1 - \emptyset) w_{clear}(z, a_s, h_s) + \emptyset w_{cloud}(z, a_c, h_c)$$

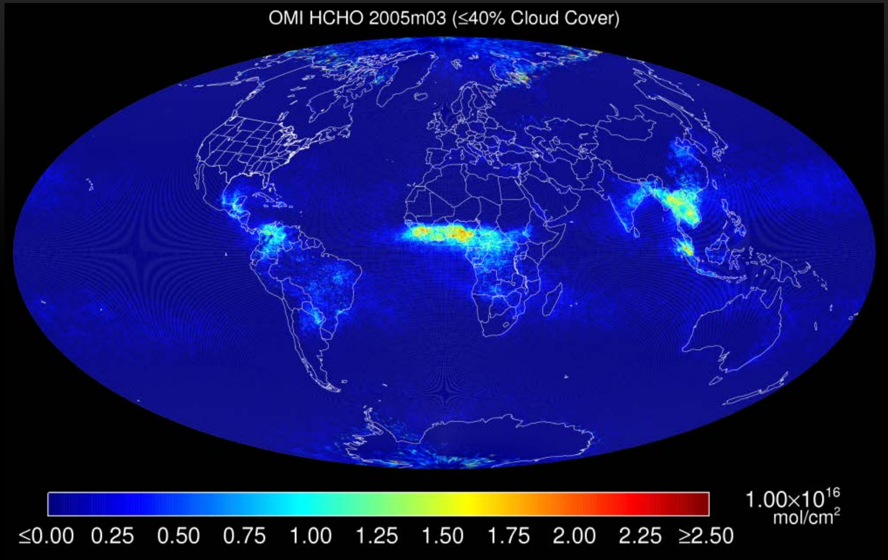


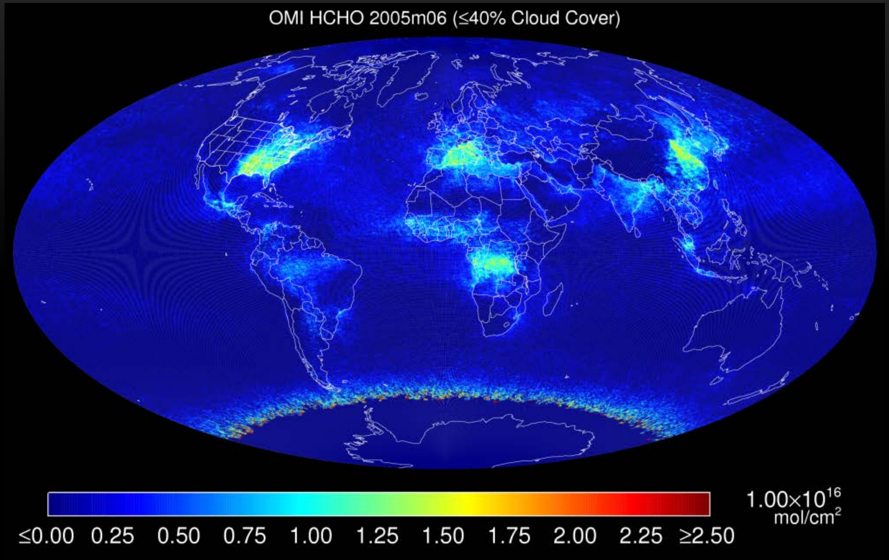
GENERIC RETRIEVAL FRAMEWORK

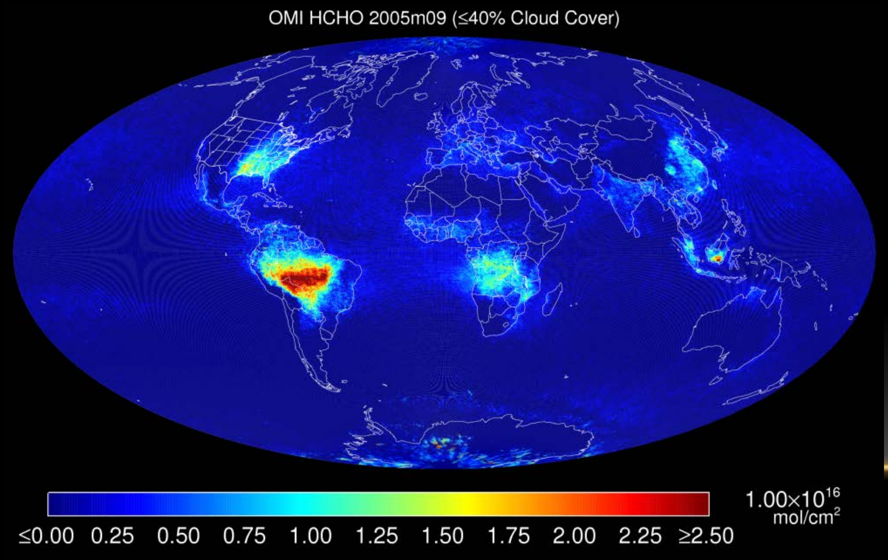
Typical retrieval flow chart for a retrieval

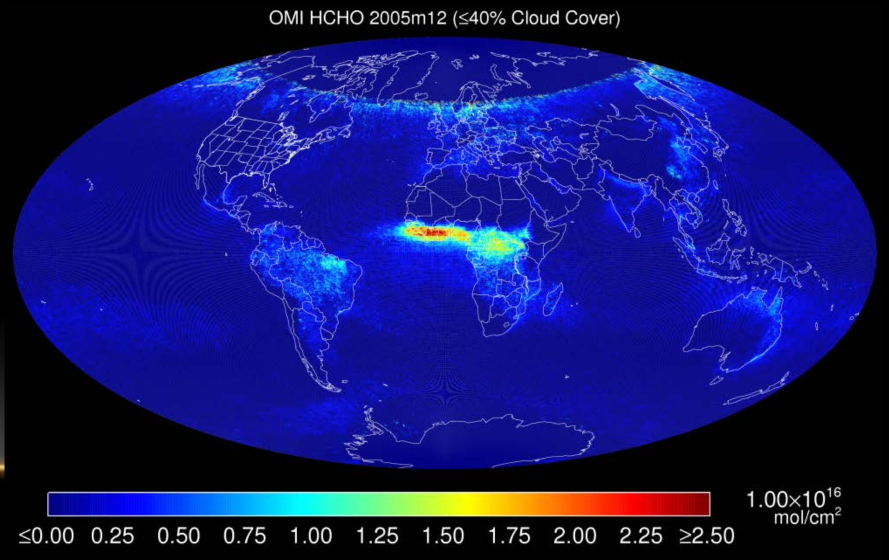


VERTICAL COLUMN RETRIEVAL: OMI C_2HO

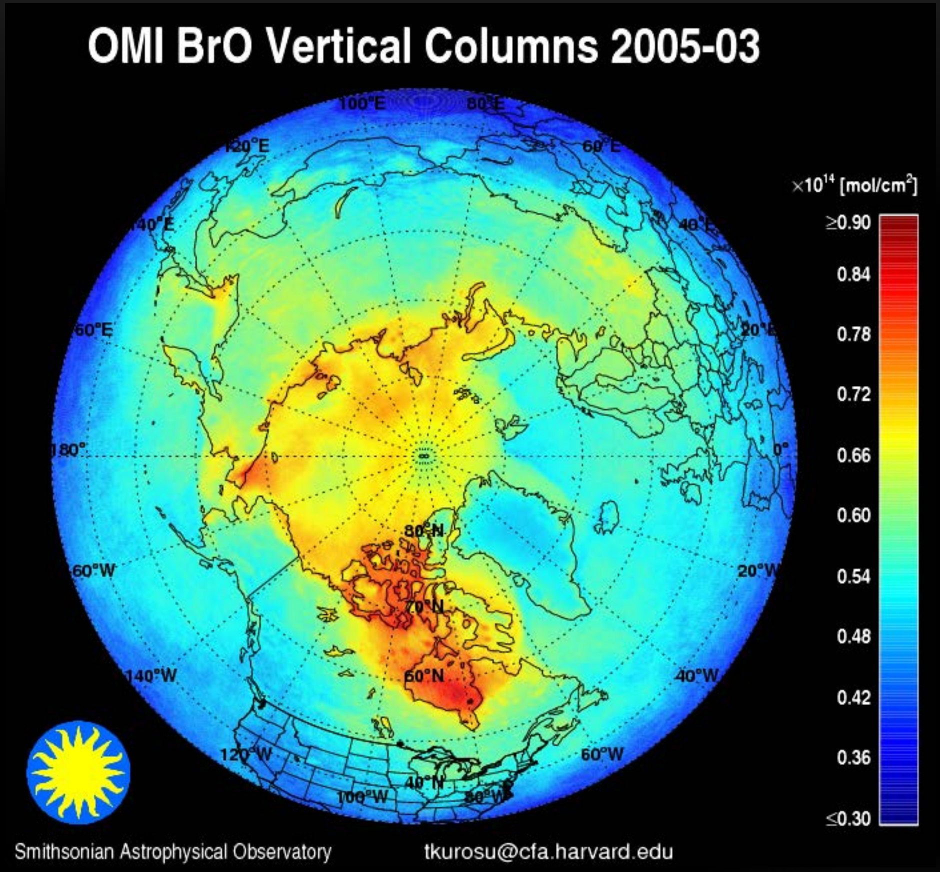


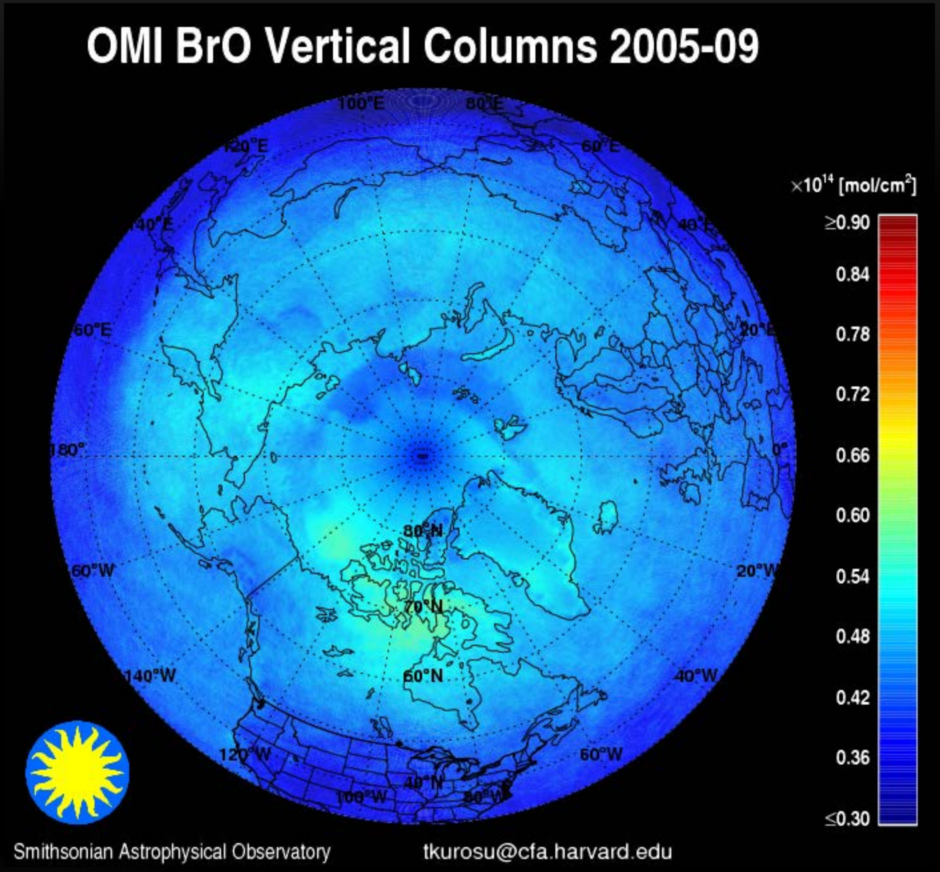




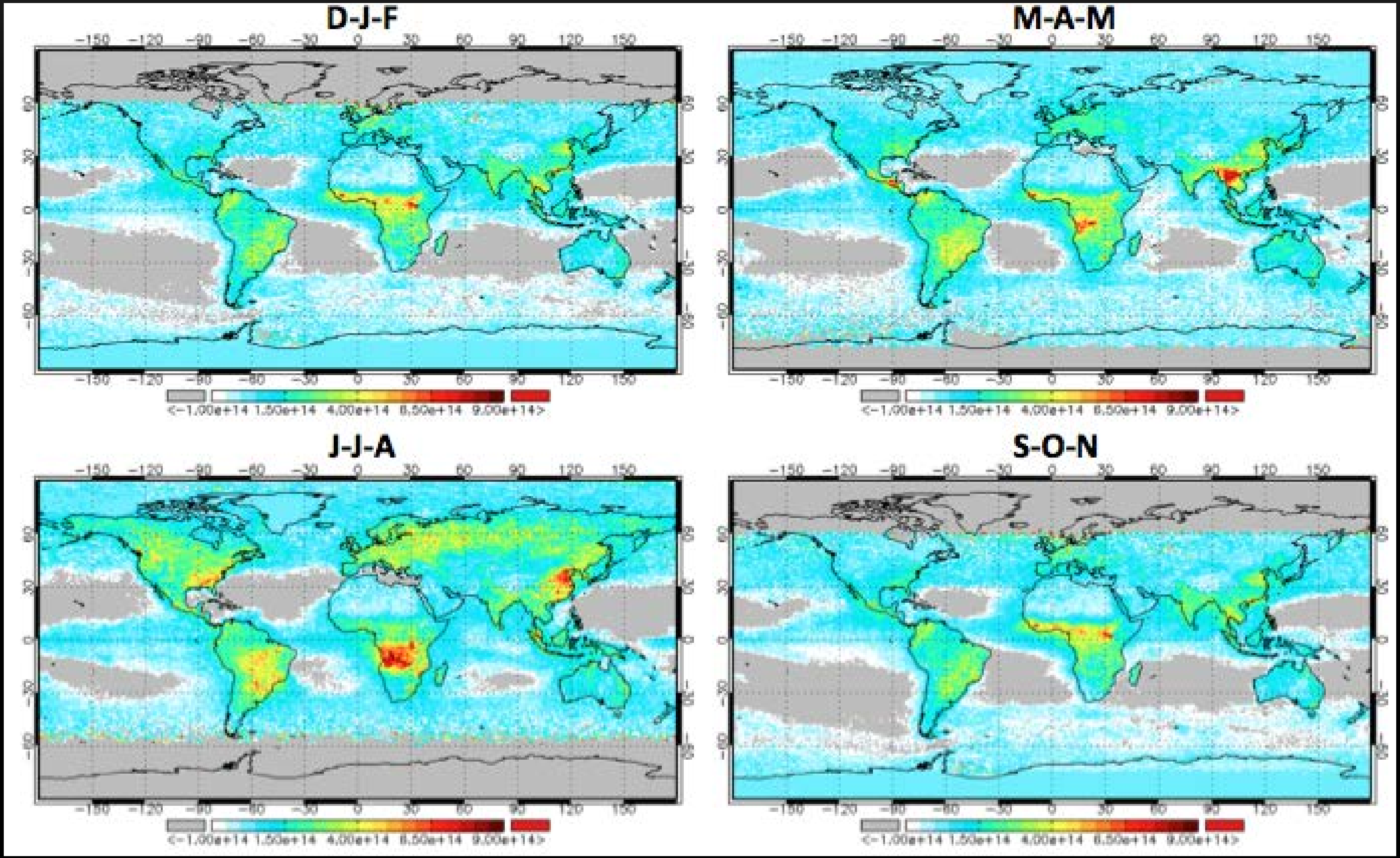


VERTICAL COLUMN RETRIEVAL: OMI BRO



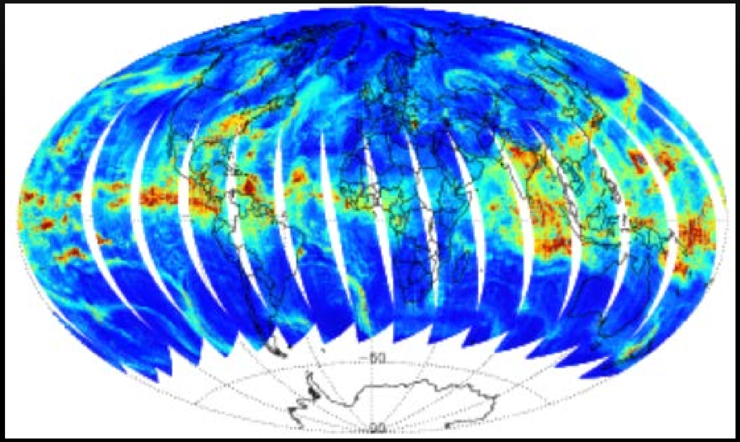


VERTICAL COLUMN RETRIEVAL: OMI $C_2H_2O_2$



VERTICAL COLUMN RETRIEVAL: OMI H_2O

20050714



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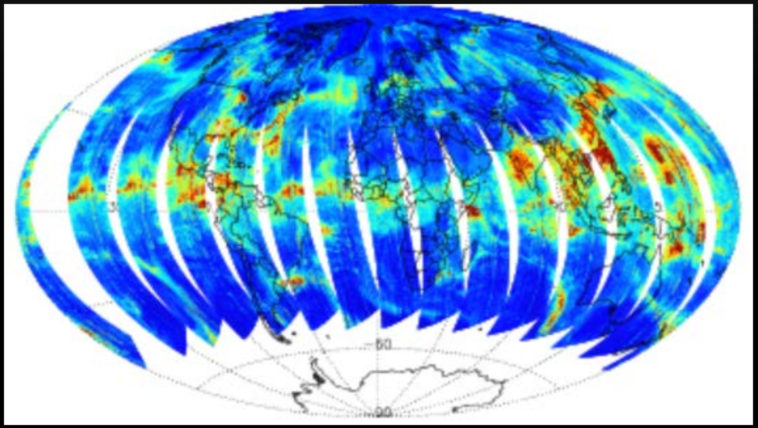

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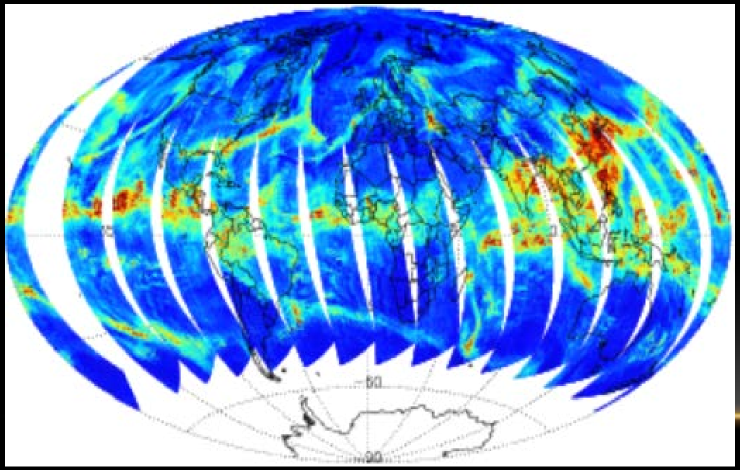

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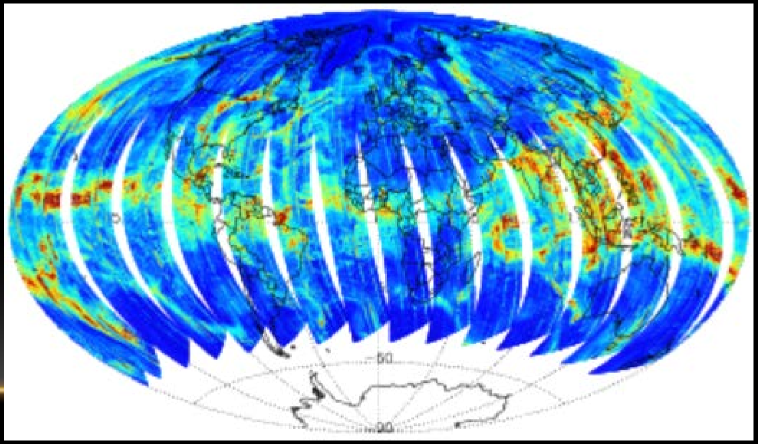

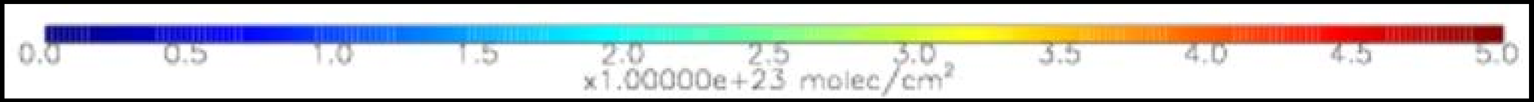

THE END

PLUS TEAM HANDBALL

OMI operational HCHO

Fitting window	327.5 – 356.5 nm
Baseline polynomial	3rd order
Scaling polynomial	3rd order
Instrument slit function	Hyper-parameterization of pre-flight measurements
Wavelength calibration	Spectral shift (no squeeze)
Solar Reference Spectrum	Chance and Spurr, 1997
HCHO cross sections	Cantrell et al., 1990; 300K
O_3 cross sections	Macilet et al., 1995; 228K
NO_2 cross sections	Vandaele et al., 1998 220K
BrO cross sections	Wilmouth et al., 1999; 228K
Molecular Ring cross sections	Chance and Spurr, 1997
Sampling correction	Computed on-line
Residual common mode spectrum	Computed on-line

OMI CHOCHO

Fitting window	431.5 – 469.5 nm
Baseline polynomial	4th order
Scaling polynomial	3rd order
Instrument slit function	Hyper-parameterization of pre-flight measurements
Wavelength calibration	Spectral shift (no squeeze)
Solar Reference Spectrum	Chance and Spurr, 1997
CHOCHO cross sections	Volkamer et al., 2005; 296K
O_3 cross sections	Macilet et al., 1995; 228K
NO_2 cross sections	Vandaele et al., 1998 220K
O_2-O_2 cross sections	Hermans BISA, 2006; 294K
H_2O cross sections	HITRAN 2008, 280K
Liquid H_2O cross sections	Pope and Fry, 1997
IO cross sections	Spietz et al., 2005; 298K
Vibrational Raman Spectrum	Chance and Spurr, 1997
Molecular Ring cross sections	Chance and Spurr, 1997
Sampling correction	Computed on-line
Residual common mode spectrum	Computed on-line

OMI operational BrO

Fitting window	319.0 – 347.5 nm
Baseline polynomial	4^{rh} order
Scaling polynomial	4^{th} order
Instrument slit function	Hyper-parameterization of pre-flight measurements
Wavelength calibration	Spectral shift (no squeeze)
Solar Reference Spectrum	Chance and Spurr, 1997
HCHO cross sections	Cantrell et al., 1990; 300K
O_3 cross sections	Macilet et al., 1995; 218K; 295K
NO_2 cross sections	Vandaele et al., 1998 220K
BrO cross sections	Wilmouth et al., 1999; 228K
O_2-O_2 cross sections	Hermans BISA, 2006; 294K
SO_2 cross sections	Hermans et al., 2009; 295K
OClO cross sections	Kromminga et al,. 2003; 213K
Molecular Ring cross sections	Chance and Spurr, 1997
Sampling correction	Computed on-line
Residual common mode spectrum	Computed on-line

OMI operational OClO

Fitting window	358.5 – 392.0 nm
Baseline polynomial	3^{rd} order
Scaling polynomial	3^{th} order
Instrument slit function	Hyper-parameterization of pre-flight measurements
Wavelength calibration	Spectral shift (no squeeze)
Solar Reference Spectrum	Chance and Spurr, 1997
O_3 cross sections	Macilet et al., 1995; 228K
NO_2 cross sections	Vandaele et al., 1998 220K
BrO cross sections	Wilmouth et al., 1999; 228K
O_2-O_2 cross sections	Hermans BISA, 2006; 294K
OClO cross sections	Kromminga et al,. 2003; 213K
Molecular Ring cross sections	Chance and Spurr, 1997
Sampling correction	Computed on-line
Residual common mode spectrum	Computed on-line

GOME2 SO_2

Fitting window	312.0 – 330.0 nm
Baseline polynomial	3rd order
Scaling polynomial	3rd order
Instrument slit function	Asymmetric Gaussian fitted online
Wavelength calibration	Spectral shift (no squeeze)
Solar Reference Spectrum	Chance and Spurr, 1997
SO_2 cross sections	Bogumil et al., 2003; 293K
HCHO cross sections	Meller and Moortgat et al., 2000; 298K
O_3 cross sections	Brion et al., 1993; 218K, 273K
NO_2 cross sections	Vandaele et al., 1998 220K
BrO cross sections	Wilmouth et al., 1999; 228K
Molecular Ring cross sections	Chance and Spurr, 1997
Sampling correction	Computed on-line
Residual common mode spectrum	Computed on-line