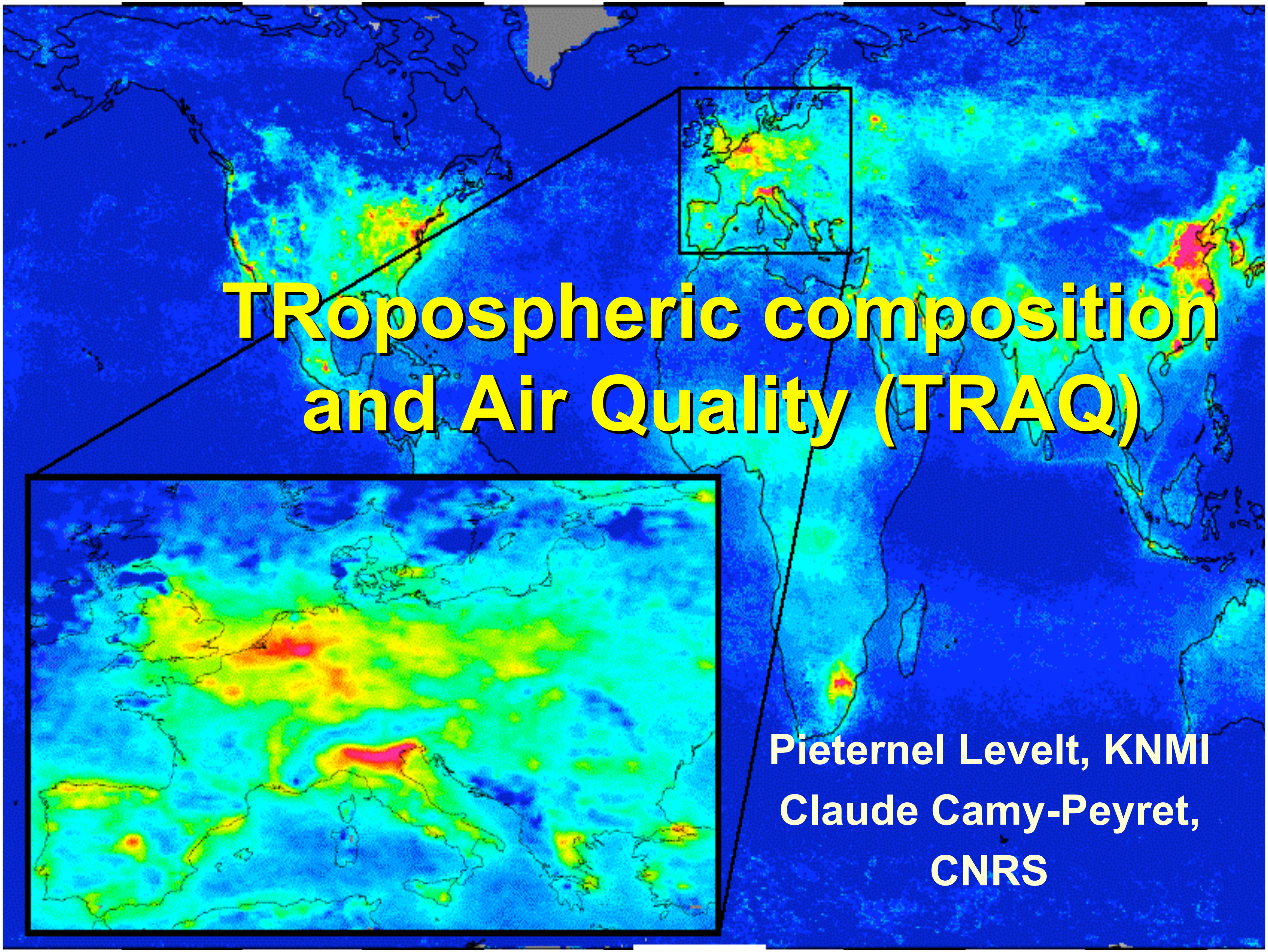
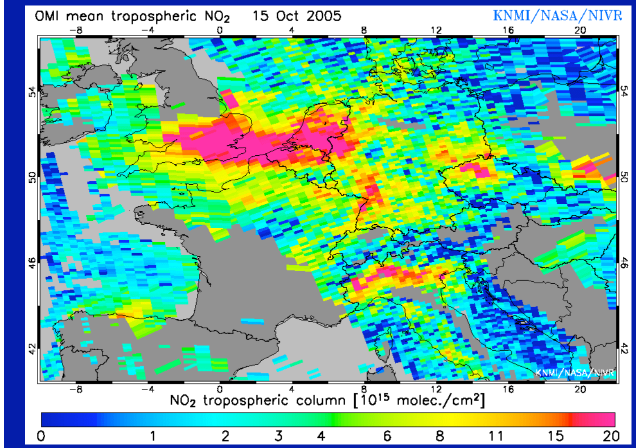
TRopospheric composition and Air Quality (TRAQ)



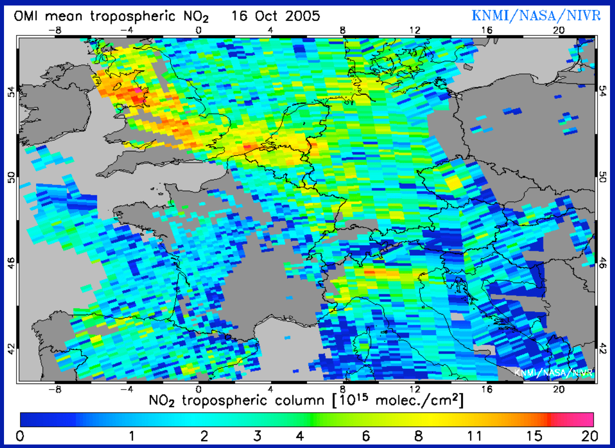
Pieternel Levelt, KNMI
Claude Camy-Peyret, CNRS

TRAQ Science Objectives

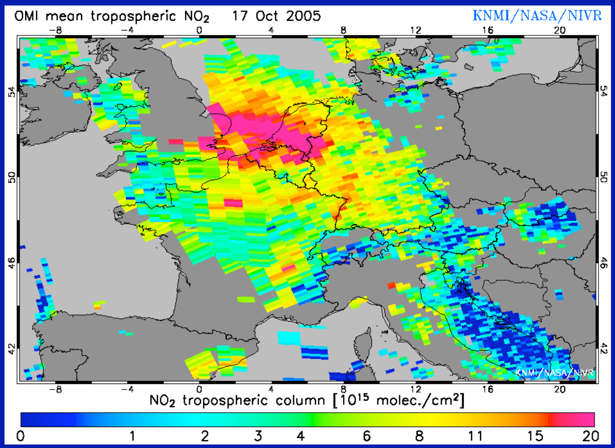
- How fast is air quality changing on a global and regional scale?
- What is the strength and distribution of the sources and sinks of trace gases and aerosols influencing air quality?
- What is the role of tropospheric composition in global change?



Saturday 15 October 2005



Sunday 16 October 2005

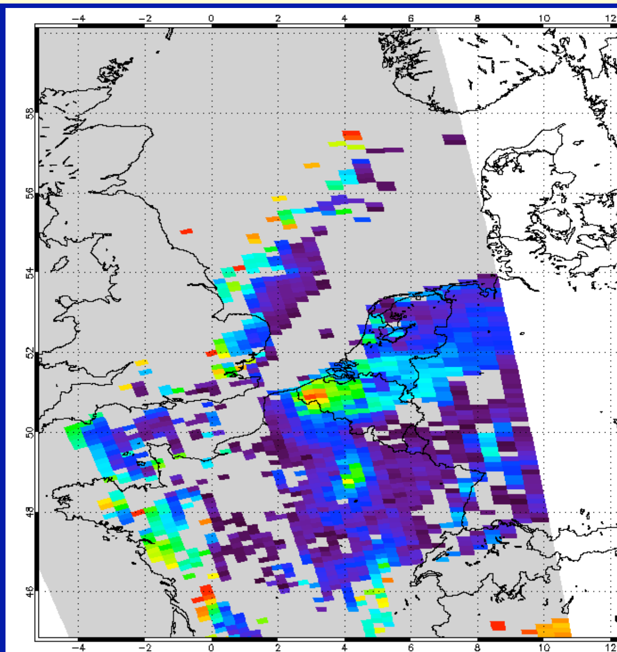


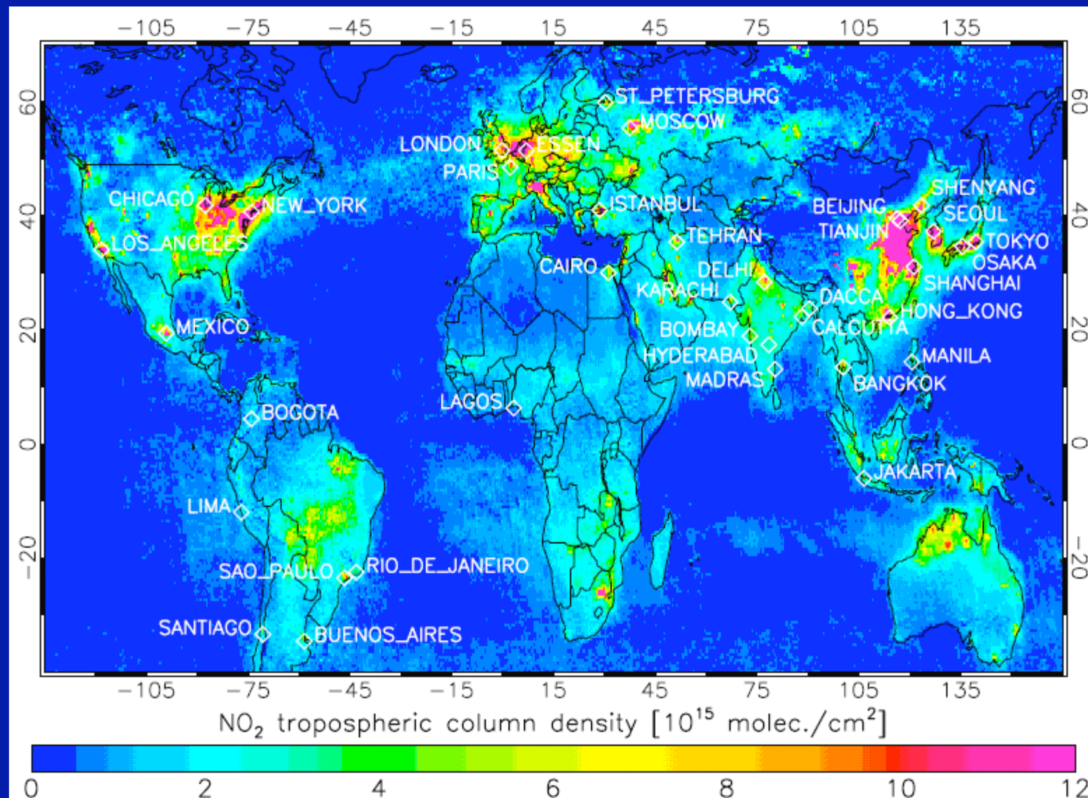
Monday 17 October 2005

Air Quality:

diurnal cycle; vertical and horizontal scales; hemispheric transport and background pollution

TRAQ will provide measurements of pollution at high horizontal resolution (10 km x 10 km) enabling detection of sub-mega city pollution





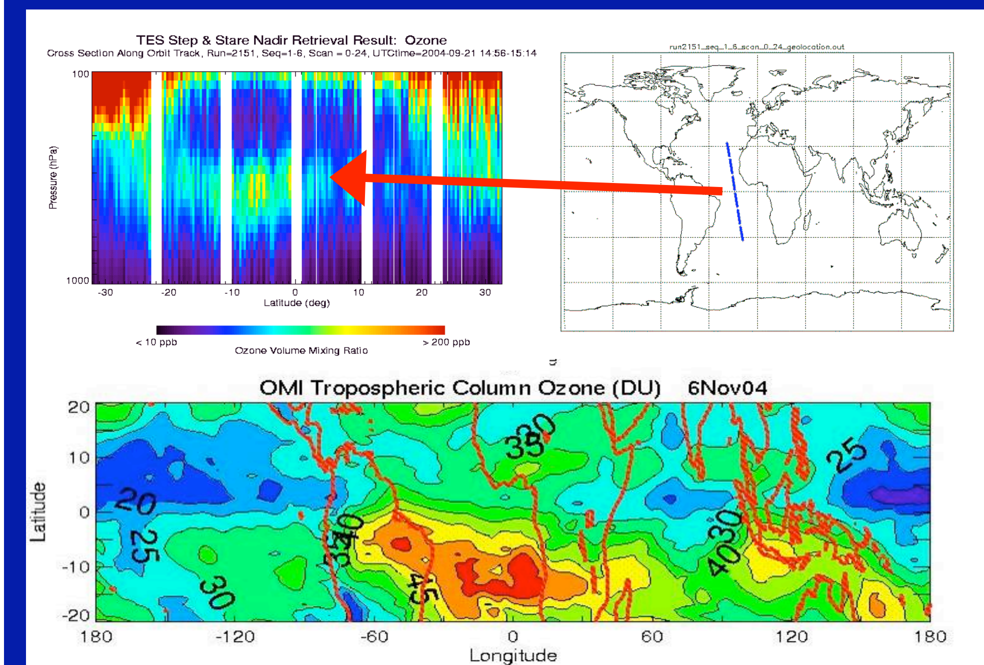
Top: Sciamachy annual average (2004) of tropospheric NO_2
Van der A, Boersma, KNMI

Left: OMI aerosol optical depth (15 June '05) (Veefkind, Curier)

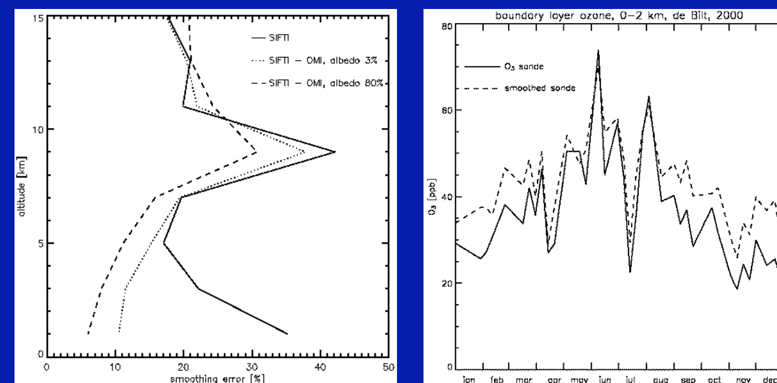
Air Quality:

diurnal cycle; vertical and horizontal scales; hemispheric transport and background pollution

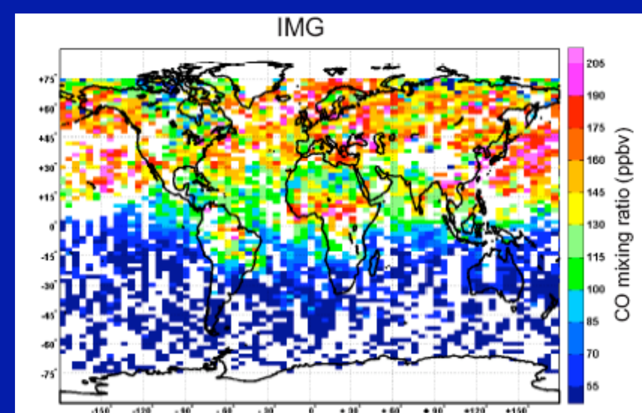
TRAQ will be able to measure vertical transport of boundary layer pollution of CO and O_3 to the free troposphere



Region of high tropospheric ozone periodically observed in South Atlantic. Measurements by OMI and TES (Ziemke, Beer)

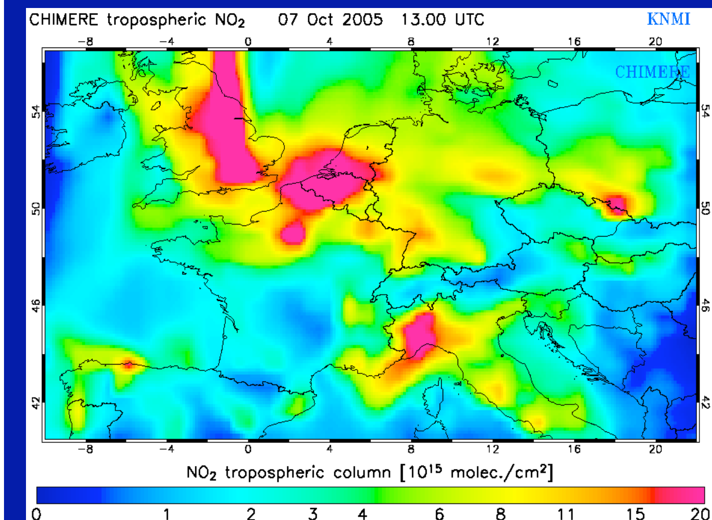


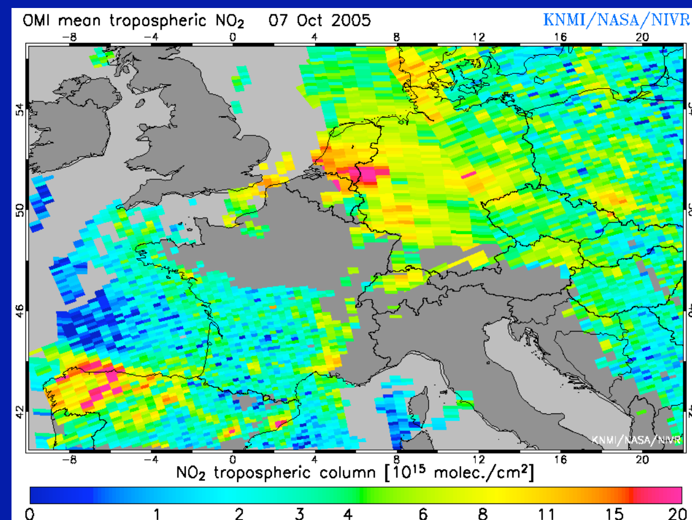
O_3 profile retrieval based on UV, VIS and TIR retrieval, Landgraf et al.



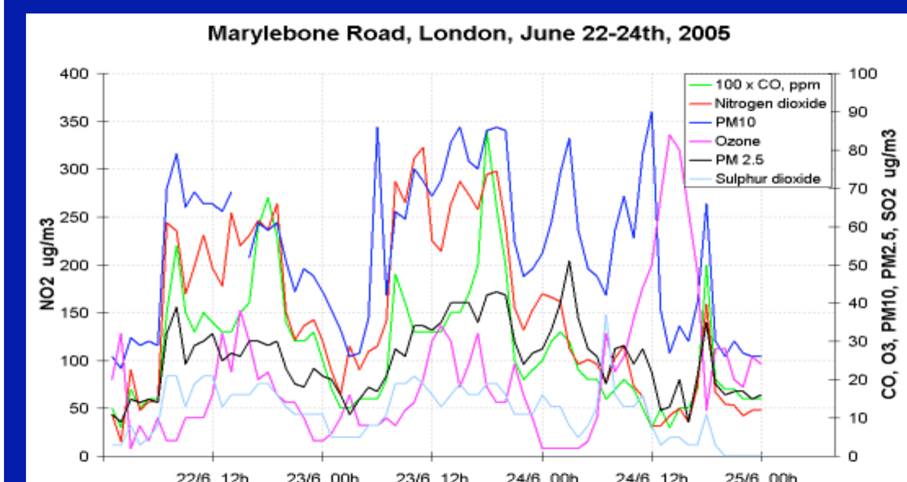
Coheur et al., CO boundary layer , IMG

Air Quality:
diurnal cycle; vertical and horizontal scales; hemispheric transport and background pollution





OMI tropospheric NO_2 and Chimere model output. Courtesy: Boersma, Eskes, Blond, Van der A

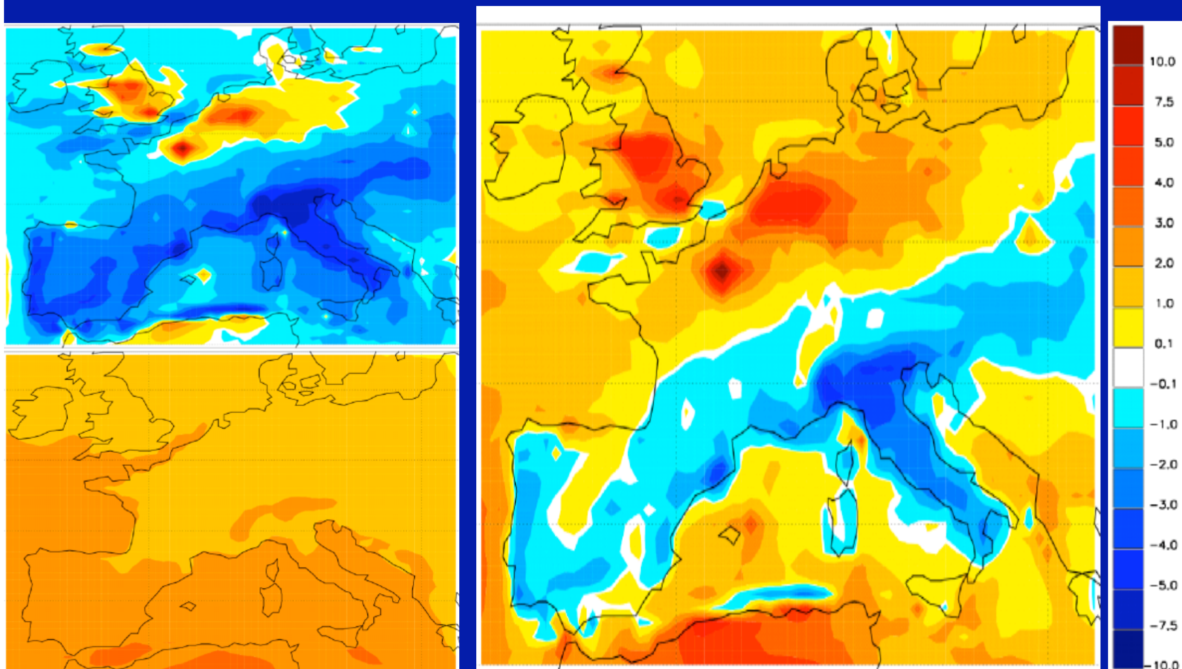


- TRAQ will detect pollution up to 5 times a day
- TRAQ will be able to measure the diurnal cycle

Left: Diurnal cycle of air pollutants and aerosols in London at street-level (Courtesy I. Kilbane-Dawe, CERC)

Air Quality:

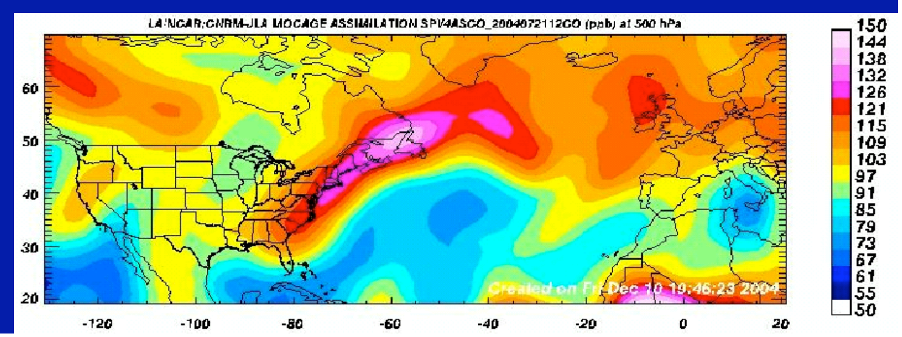
diurnal cycle; vertical and horizontal scales; hemispheric transport and background pollution



Model simulation of O_3 in July 2030 (Hauglustaine et al)
<u>Right</u>: O_3 change in ppb in 2030 under IIASA "current legislation scenario"
<u>Upper left</u>: O_3 reduction due to corresponding decrease of NO_x, CO and VOC emissions over Europe
<u>Lower left</u>: O_3 increase due to long range transport from USA and Asia causes O_3 increase over Europe

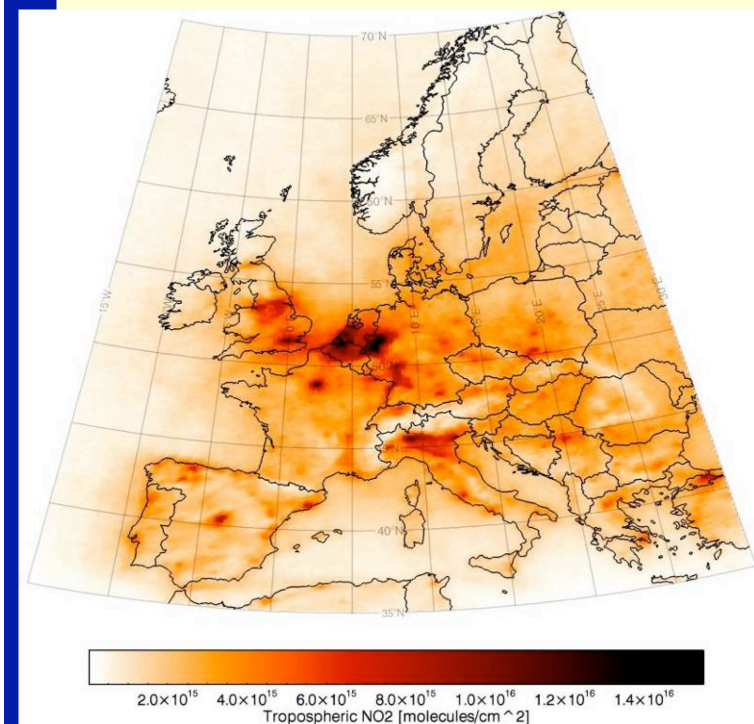
TRAQ will help determining to what extent Europe's background pollution is caused by global transport of pollution from other continents

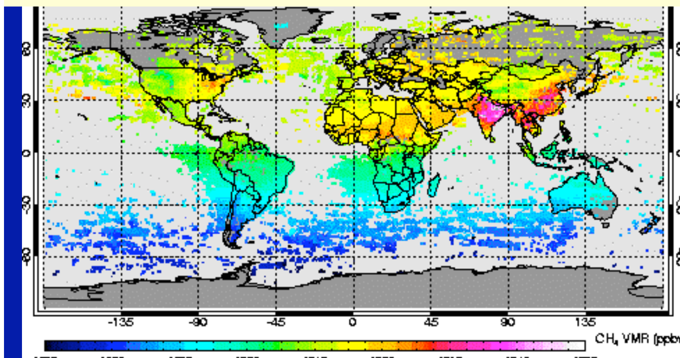
<u>Below</u>: Long range transport of CO over ocean : Terra-MOPITT CO assimilated in MOCAGE model (Attié et al.)



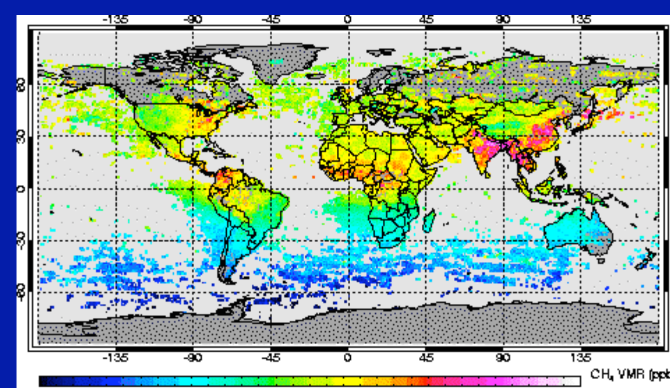
Sources and sinks : Emission estimates

- TRAQ will be able to constrain natural sources and sinks
- TRAQ will be able to constrain anthropogenic emissions
- TRAQ enables estimates of seasonal and interannual variations in emissions together with the geographical distribution of emissions
- TRAQ contributes to improved understanding of sinks: Oxidizing capacity (via OH budget: trop O_3, NO_x and CO, CH_4) and deposition (aerosols)





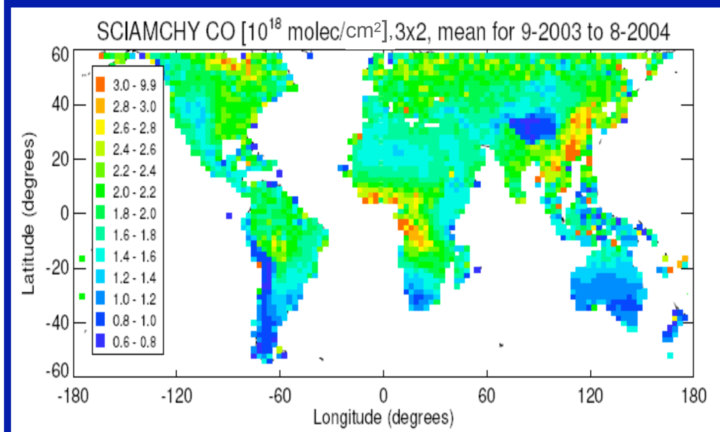
Left: Model CH_4 (TM3)
Bottom: SCIA CH_4,
Frankenberg et al., Science, 2005

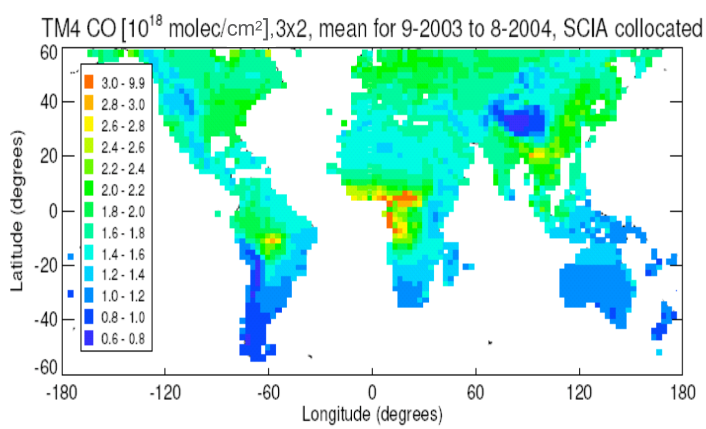


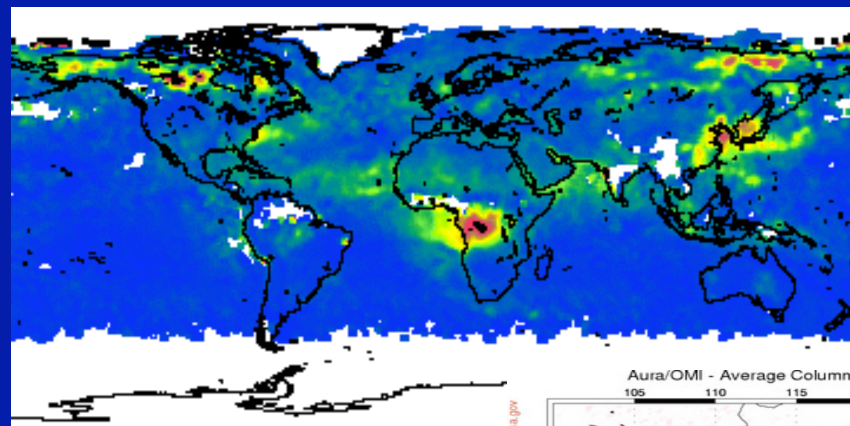
Veefkind et al. OMI Trop. NO_2 May-September 2005 average

Global Change

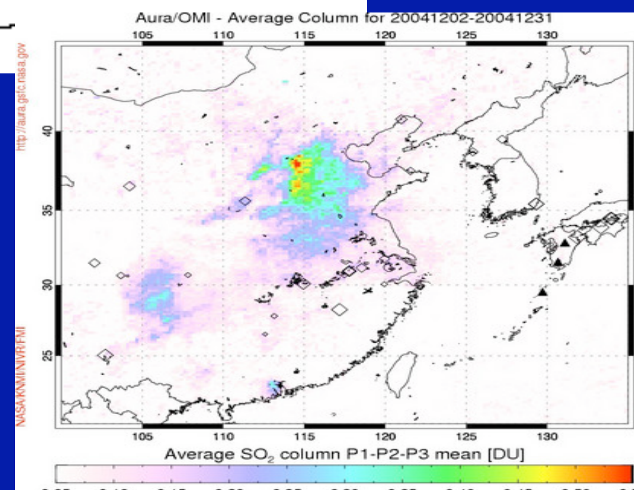
- TRAQ will be able to contribute to understanding the interaction between tropospheric composition and global change.
- The atmospheric components of bio-geo-chemical cycles of C,N and S
- Direct radiative forcing agents: CH_4, aerosols, tropospheric ozone
- Precursors of forcing agents: CO, CH_4, NO_2, SO_2, HCHO







Left: PARASOL, July 2005. Aerosols, Accumulation mode Courtesy: D. Tanré (LOA)



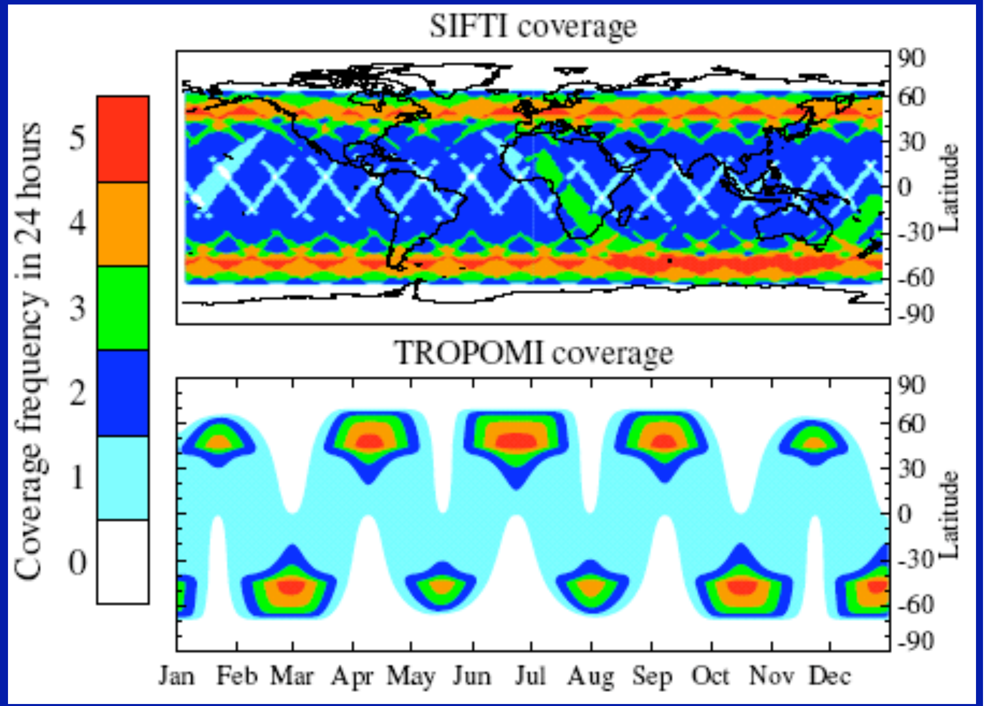
Left-top: SCIAMACHY CO, Left-Bottom: Model CO, Cloudemans et al.

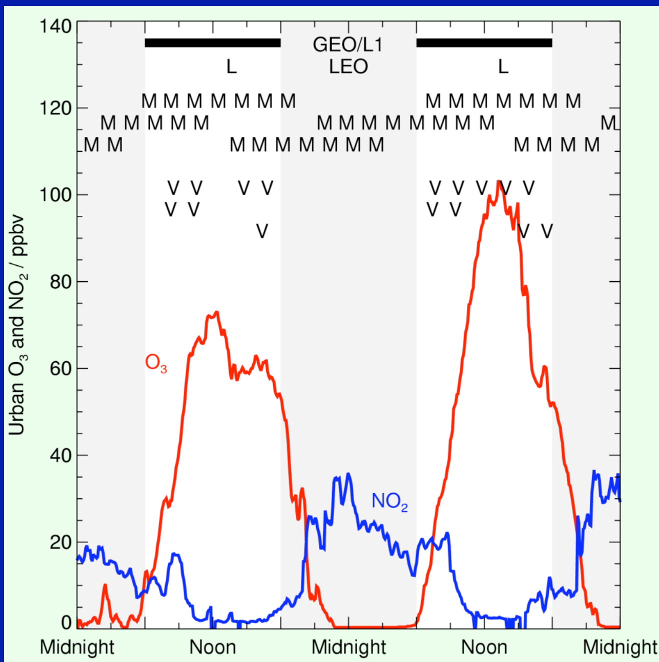
Right: OMI SO_2 over China, Carn, Krueger, et al.

Orbit

Non-sun synchronous LEO orbit:

- Measures air pollution at mid-latitude up to 5 times a day with 90 minutes interval
- Retains most of global coverage, except for poles





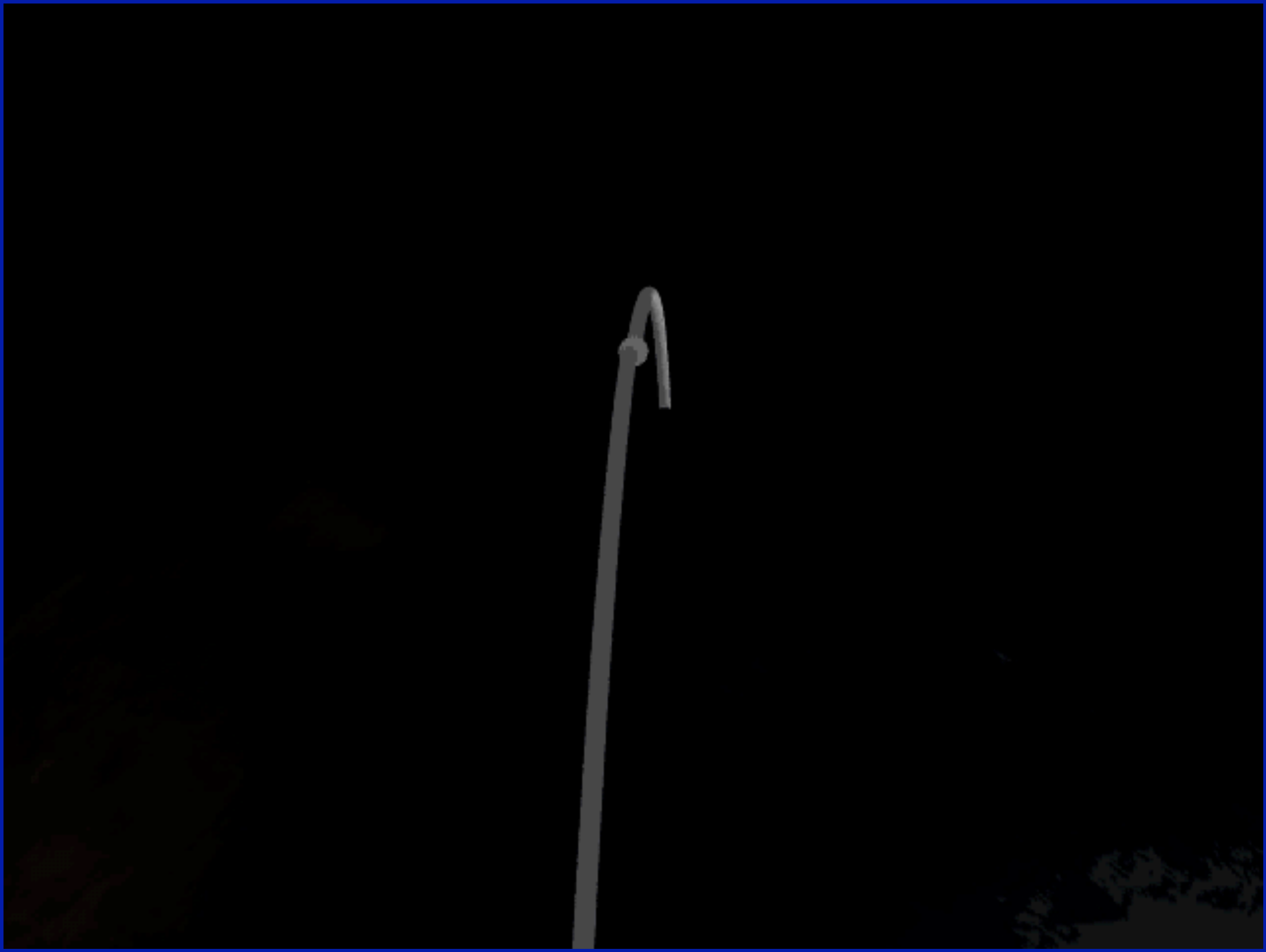
Range:

- Swath: 2000 – 2600 km
- Pixel sizes: 5 km × 5 km to 10 km × 10 km

LEO versus GEO

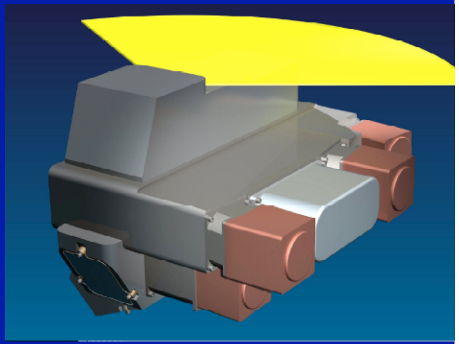
GEO does not provide global coverage and such detailed characteristics of aerosol

Movie of orbit

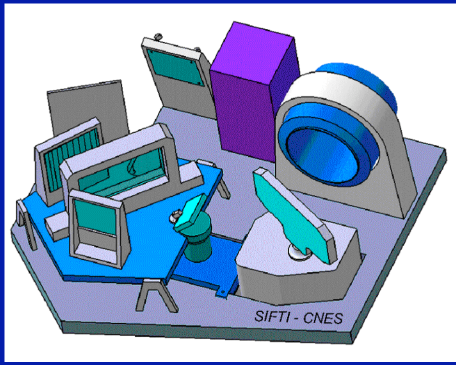


TRAQ Payload

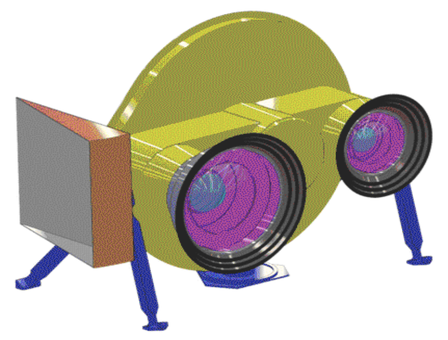
TROPOMI: Backscatter instrument (trop) columns of O_3, NO_2, SO_2, HCHO, aerosols & CO and CH_4.
Heritage: Aura-OMI, Envisat-Sciamachy



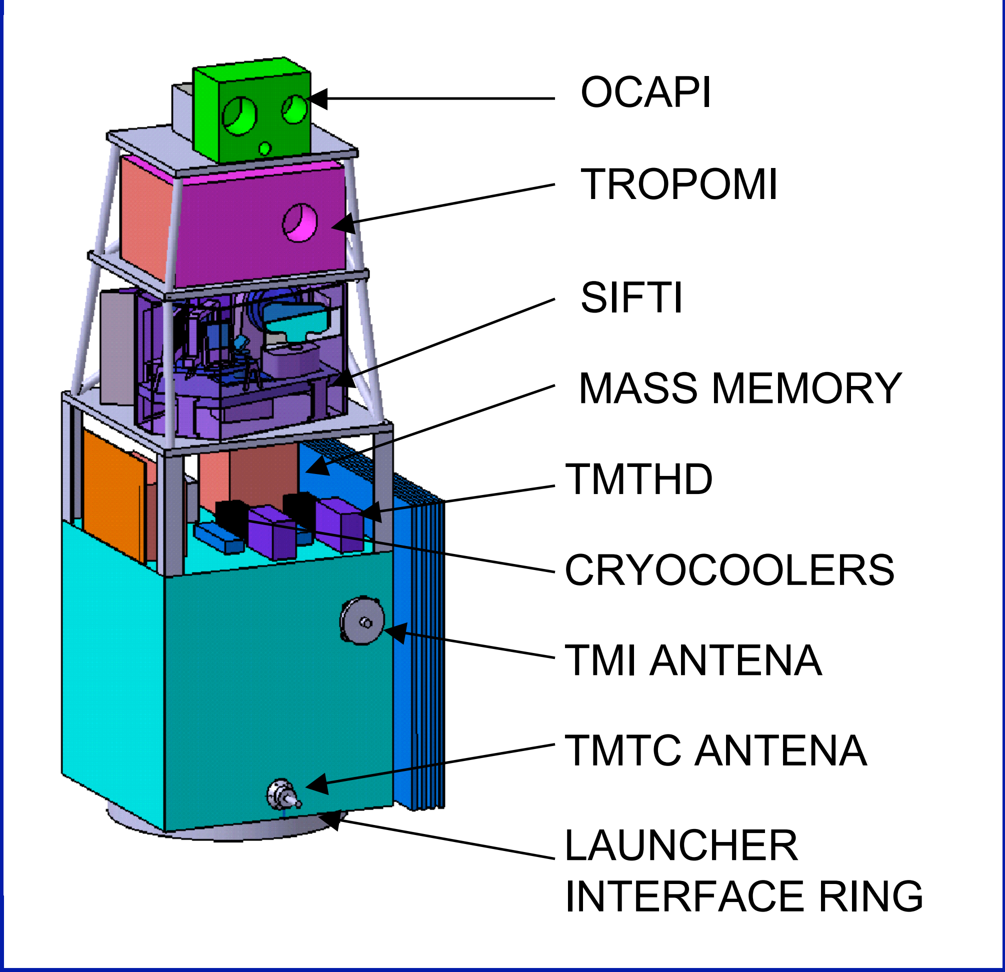
SIFTI (FTIR): O_3, CO, CH_4: trop columns and profiles with intelligent pointing for cloud free pixels.
Heritage: IASI

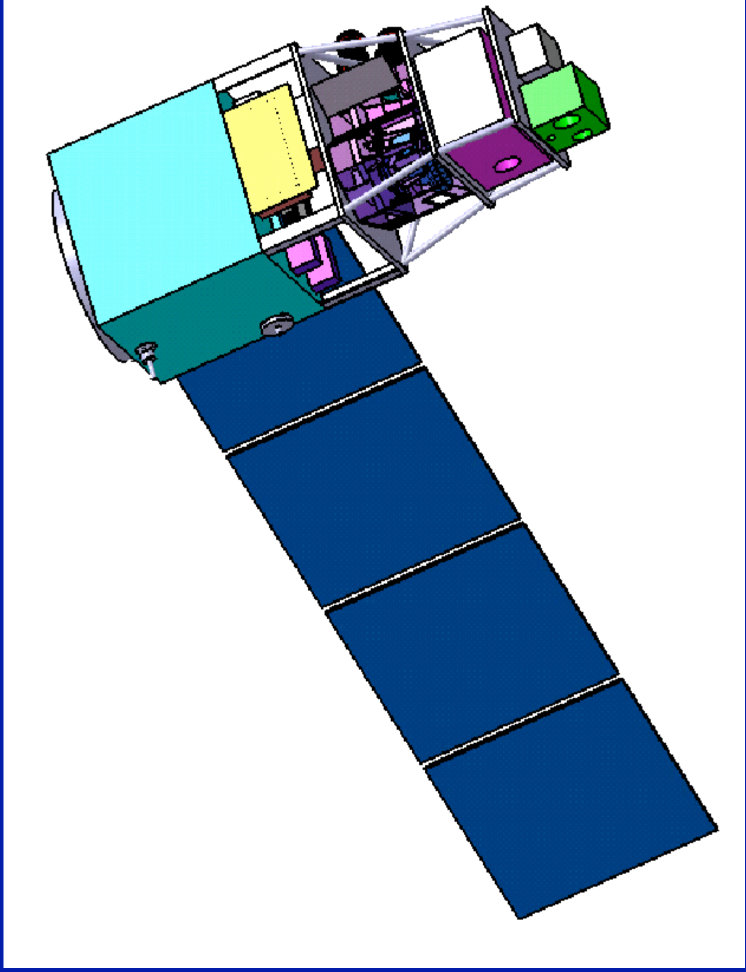


OCAPI: POLDER type of instrument:
AOD, single scattering albedo (ω_0), Air quality index (AQI), aerosol sizes and aerosol type.
Heritage: POLDER, PARASOL



TRAQ Satellite





TRAQ instrument and retrieval features

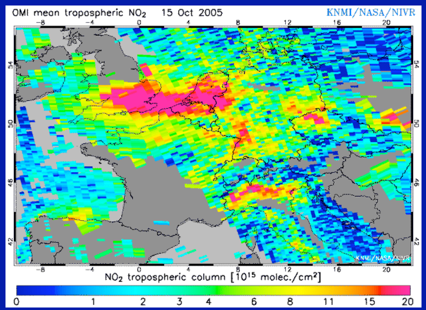
- **Improved retrieval of tropospheric pollutants** by small ground pixels and accurate determination of surface properties, cloud fraction and cloud top pressure (O_2-A band NIR channel of TROPOMI) and aerosol determination by OCAPI.
- **Combination of UV, SWIR and TIR retrieval** for CO and O_3 provides unique information on vertical distribution of O_3 and CO.
- **Almost daily global measurements of CO, CH_4** using imaging detectors for TROPOMI/SIFTI : enabling large coverage and high horizontal resolution
- **Unique cloud screening by SIFTI**, optimising detection of tropospheric pollutants, detecting the holes in the clouds deck.
- **Improved 2D detectors for UV/VIS/NIR** : S/N and radiation hardness

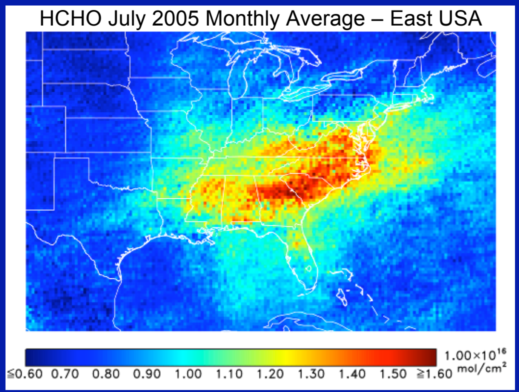
"Kernels and Clouds"

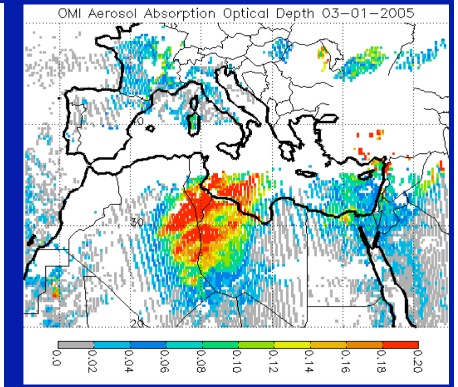
TRAQ Summary

- **TRAQ will contribute to tropospheric composition measurements:**
  - with high temporal resolution
  - high horizontal resolution
  - will track vertical transport of CO and O_3 (BL to the free troposphere)
  - enabling improved emission estimates
  - affecting the radiation balance
- **TRAQ has an innovative instrument suite combined with proven technology**
- **TRAQ's non-synchroneous LEO orbit combines high temporal resolution with global coverage.**

OMI measurements:
Left: Tropospheric NO_2
Middle: Formaldehyde
Right: Aerosol Opt. Depth
© Eskes, Kurosu, Torres







Acknowledgements

- The Netherlands:
  - H. Eskes, I. Aben, B. van den Oord, P. Veefkind, and M. van Weele
- France:
  - D. Tanré, T. Phulpin, P. Hebert, D. Hauglustaine, and C. Clerbaux

BACKUP SLIDES

Key Observables (1)

Product	Column	Instrument	Nadir ground-pixel (km^2)	Swath (km)	Uncertainties	
					Nom.	Min.
NO_2	Total	TROPOMI	8 × 10	2600	2%	3%
	Tropospheric	TROPOMI	8 × 10	2600	6%	13%
O_3	Total	TROPOMI SIFTI	16 × 40 10 × 10	2600 2000 *	0.5% 1%	2% 1%
	Tropospheric	TROPOMI SIFTI	8 × 10 10 × 10	2600 2000 *	15% 6%	35% 10%
CO	Total 1)	SIFTI SIFTI TROPOMI+SWIR	10 × 10 10 × 10 10 × 10	2000 * 2000 * 2600	5% 3% 6%	11% 15% 19%
SO_2	Total 1)	TROPOMI	8 × 10	2600	5%	10%
HCHO	Total 1)	TROPOMI	8 × 10	2600	25%	55%
CH_4	Total 1)	SIFTI TROPOMI+SWIR	10 × 10 10 × 10	2000 * 2600	0.4% 0.1%	2.5% 0.5%

1) = total column ≈ tropospheric column.
For SO_2 there is a stratospheric contribution during short periods after an volcanic eruption.

2000 * = swath of 2000 km (1 pixel every 50 km + optional intelligent pointing)

Key Observables (2)

Aerosol Type	**Instr.**	**Nadir ground-pixel (km^2)**	**Swath (km)**	**Accuracy**
Aerosol Optical Thickness (AOT)	OCAPI	4 × 4	1700	0.03 × AOT + 0.03
AOT (fine fraction)	OCAPI	4 × 4	1700	0.03 × AOT + 0.03
Angstrom coefficient (total)	OCAPI	4 × 4	1700	0.2
Angstrom coefficient (fine)	OCAPI	4 × 4	1700	0.3
PM2.5 ($\mu g\ m^{-3}$)	OCAPI	4 × 4	1700	10
Eff. radius fine mode (μm)	OCAPI	4 × 4	1700	0.1
Eff. radius coarse mode (μm)	OCAPI	4 × 4	1700	0.3
Refractive index (real part)	OCAPI	4 × 4	1700	0.05
Aerosol type (% misassignment)	OCAPI	4 × 4	1700	8%
AOT (UV wavelengths)	TROPOMI	8 × 10	2600	15%
Single scattering albedo (UV wavelengths)	TROPOMI	8 × 10	2600	0.05
Aerosol absorption index	TROPOMI	8 × 10	2600	1%

Key Observables (3)

Profile products from SIFTI	Nominal			Minimum		
	DoF	Vertical Resolution	Unc.	DoF	Vertical Resolution	Unc.
O_3 Stratospheric profile	4.7	12-18 km 18-24 km 24-30 km	5% 3% 3%	3.8	12-18 km 18-24 km 24-30 km	9% 5% 4%
O_3 Tropospheric profile Can be improved by combining with TROPOMI measurements	2.6	0-6 km 6-12 km	10% 10%	2.3	0-6 km 6-12 km	23% 13%
CO Tropospheric profile	2.7	0-3 km 3-7 km 7–12 km	6% 5% 5%	1.8	0-3 km 3-12 km	16% 6%

DoF = Degrees of Freedom

Nadir ground pixel size = 10 km × 10 km

Swath = 2000 km (1 pixel every 50 km + optional intelligent pointing)

TROPOMI Fact Sheet

	UV1 (TBD)	UV2	VIS	NIR	SWIR
Range (nm)	270-320	300-400	380-490	710-775	2305-2385
Resolution (nm)	1.1	0.45	0.52	0.45	0.25
Sampling (nm)	~0.4	0.15	~0.18	0.15	0.125
Signal to Noise (minimum scenario)	100-1000	1000	1500	100-500	95
Ground pixel (km^2)	16 × 40	8 × 10			10 × 10
Swath	2600 km				2600 km
Dimension (m^3)	0.56 × 0.45 × 0.38				0.45 × 0.3 × 0.2
Mass (OPB+Detect.)	35 kg				17 kg
Temp. OPB	283 K				220 K
Temp. detector	233 K				165 K
Data rate	2 – 8 Mb/s				1 -3.5 Mb/s
Power (W)	90 (Nominal) – 150 (Peak)				15 (N) - 70 (P)

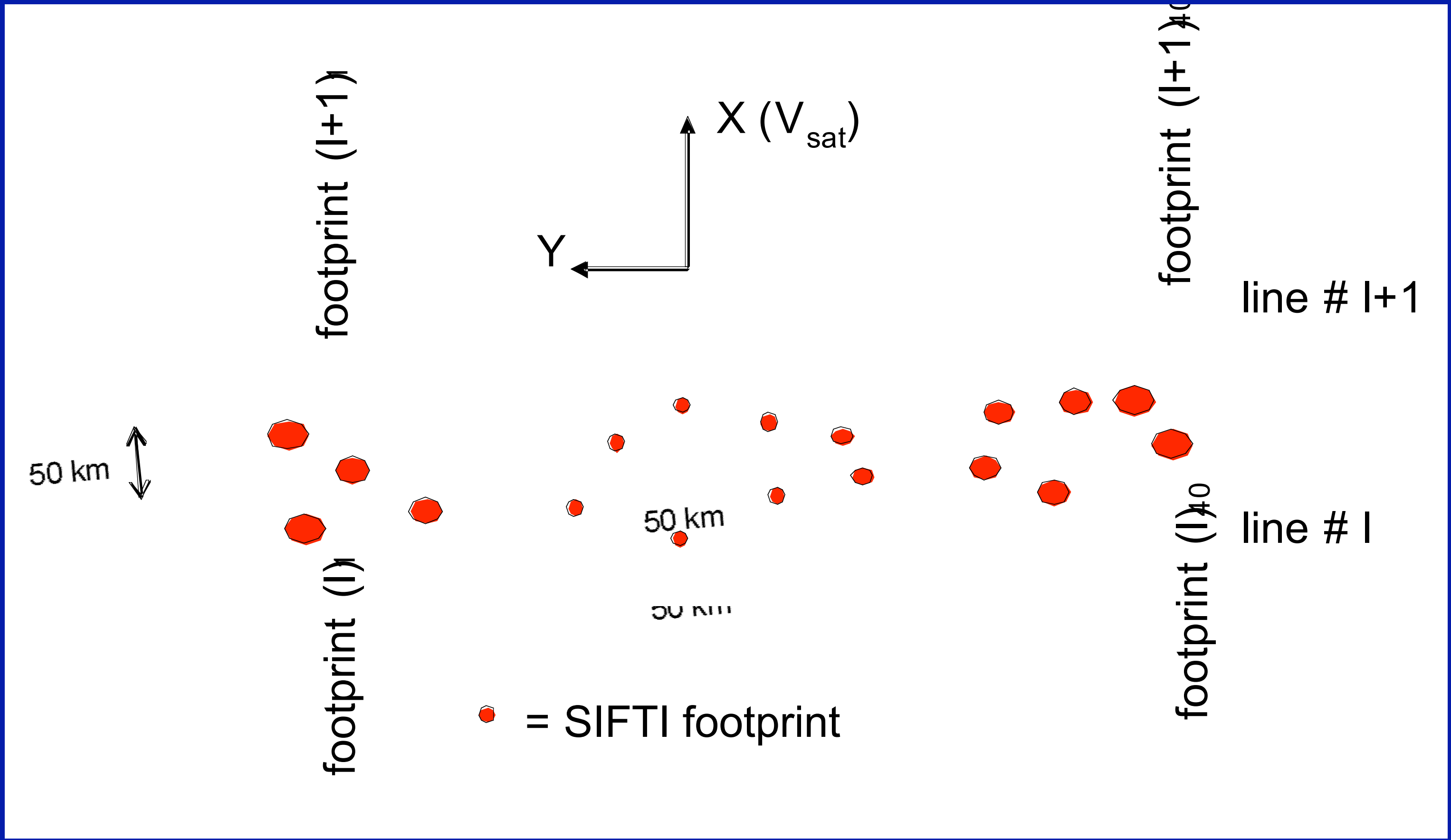
OCAPI Fact Sheet

	1	2	3	4 / 5 Option	6	7	8	9
Central wavelength (nm)	443	490	670	763 / 765	865	1370	1650	2130
width (nm)	20	20	20	10 / 40	40	40	40	40
Polarization		P	P				P	P
Signal to Noise	200 (minimum scenario)							
Number of viewing angles	15 successive angles							
Ground pixel	4 km × 4 km							
Swath	1700 km							
Dimension	0.40 m × 0.52 m × 0.36 m							
Mass	30 kg							
Data rate	3 Mb/s							
Power	30 W (Nominal)							

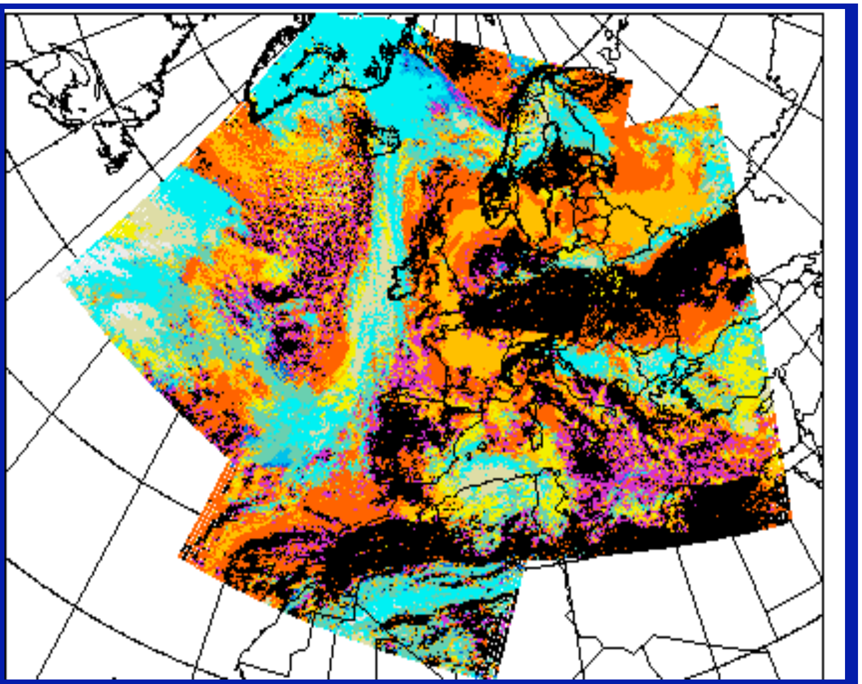
SIFTI Fact Sheet

	B1	B2	B3
Range (cm^{-1})	1026-1064	2100-2142	4270-4300
Resolution (cm^{-1})	0.125	0.125	0.150
Sampling (cm^{-1})	0.0625	0.0625	0.0625
Signal to Noise (minimum scenario)	800	350	100
Ground pixel	10 km × 10 km		
Horizontal sampling	1 pixel every 50 km + Intelligent pointing with CLIM (optional)		
Swath	1700 km		
Dimension	0.90 m × 0.60 m × 0.30 / 0.45 m (S / S+C)		
Mass	70 kg (SIFTI) + 8 kg (CLIM – optional)		
Temp. detector	65 K- 90 K		
Data rate	6 Mb/s		
Power	100 W (Nominal) – 150 W (Peak)		

SIFTI/CLIM Intelligent Pointing

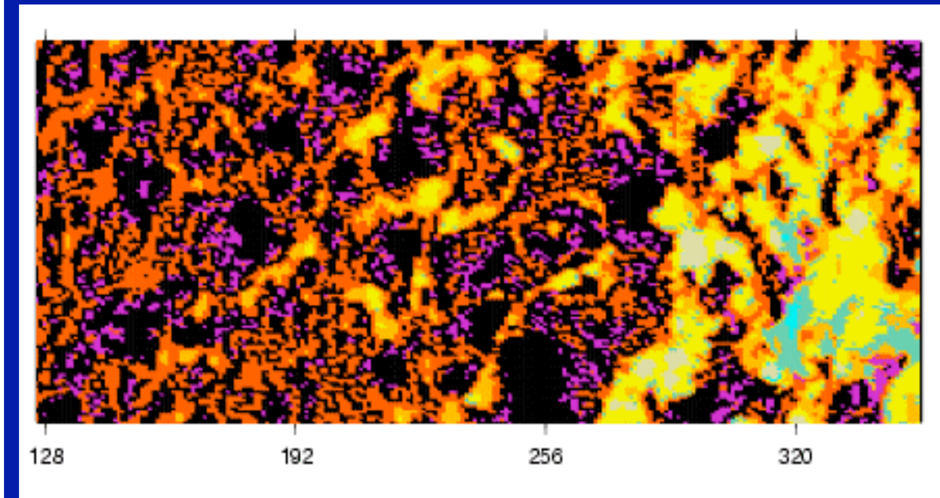


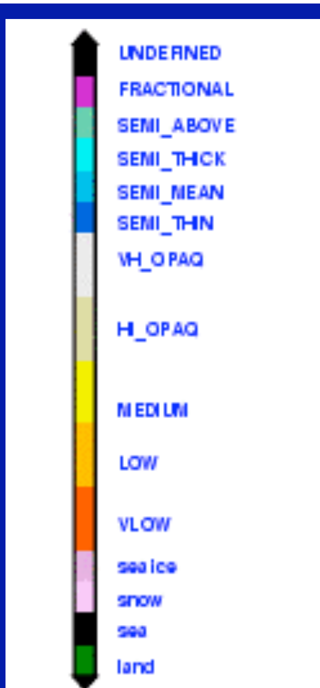
Hole hunting: Cloud-free pixels occurrence with optimized sampling (viewing in cloud holes)

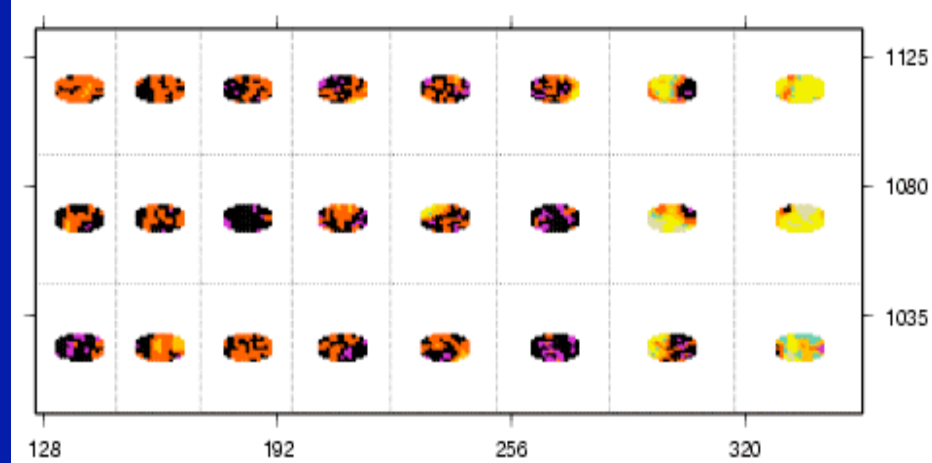


- All AVHRR acquisitions , 4 times a week (Dec., March, June, Sept.)
- CMS operational cloud mask
  - 5 channels: 0.6 μm, 0.8 μm, 3.7 μm, 11.0 μm, 11.8 μm
  - Forecast of Ts and CWV
  - Full resolution
  - Highest resolution
- 50 km × 50 km boxes (Fields of Regards) and each SIFTI pixel located at the center in a normal scan (regular sampling)
- Simulation of intelligent pointing → selection of the clearest location in each FOR

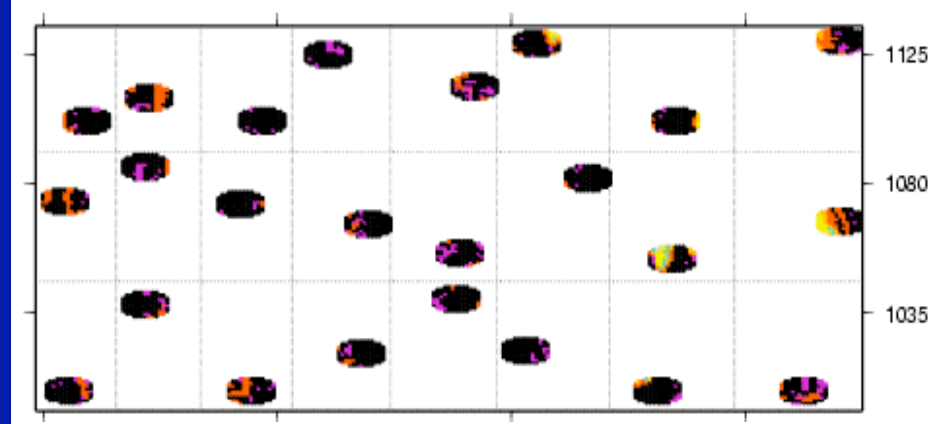
Edge of Orbit





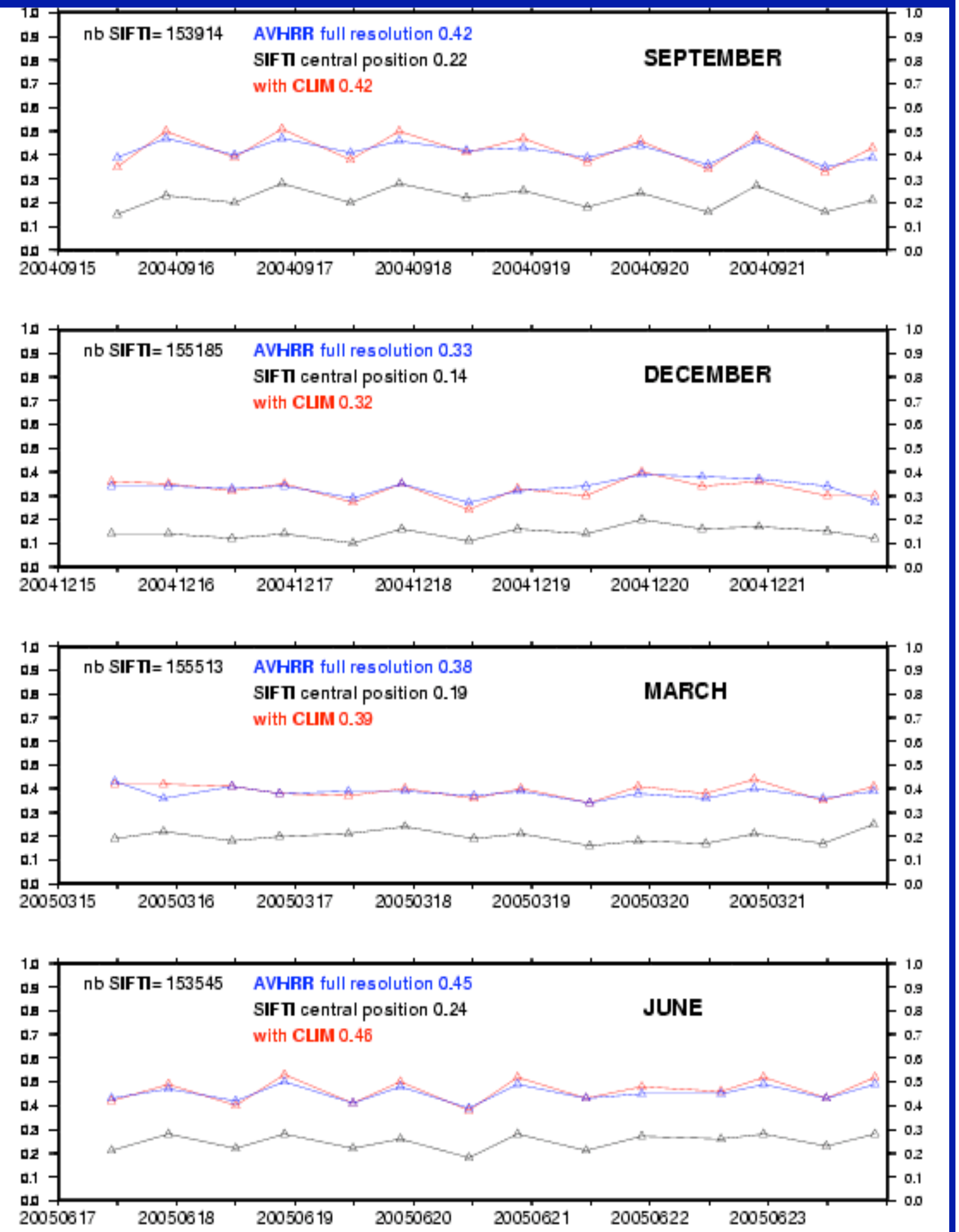


↑ Regular sampling

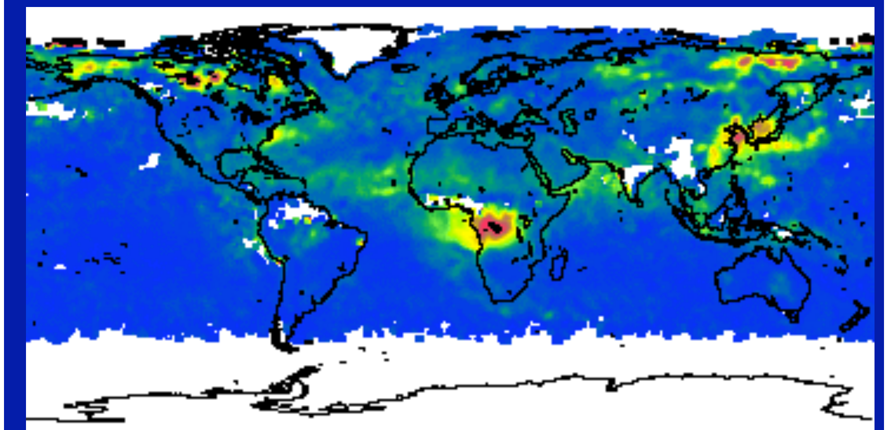


↑ Optimized sampling (hole hunting)

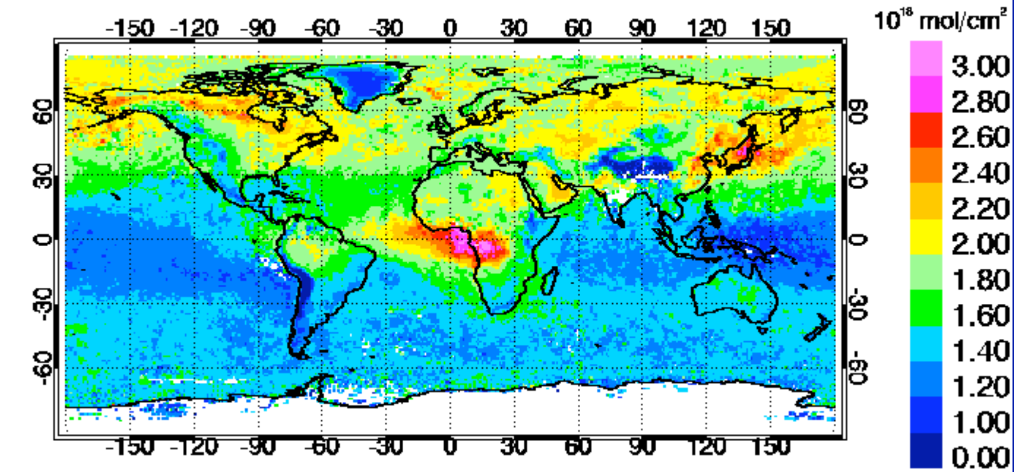
Cloud-free pixel occurrence with and without hole hunting



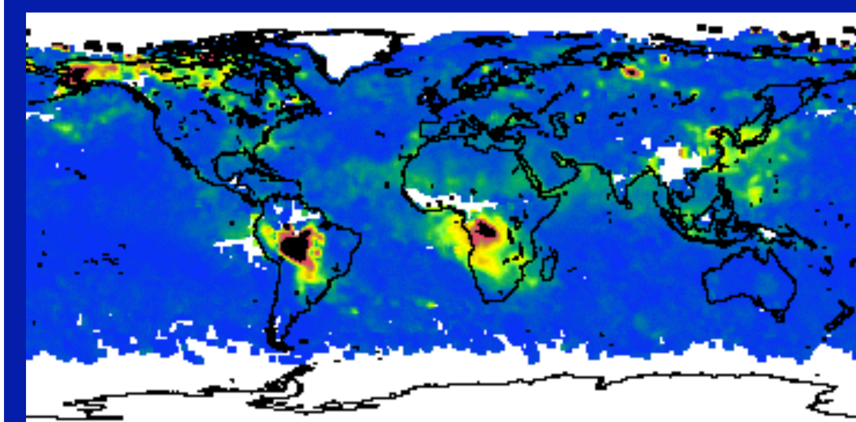
PARASOL, July 2005
Accumulation mode



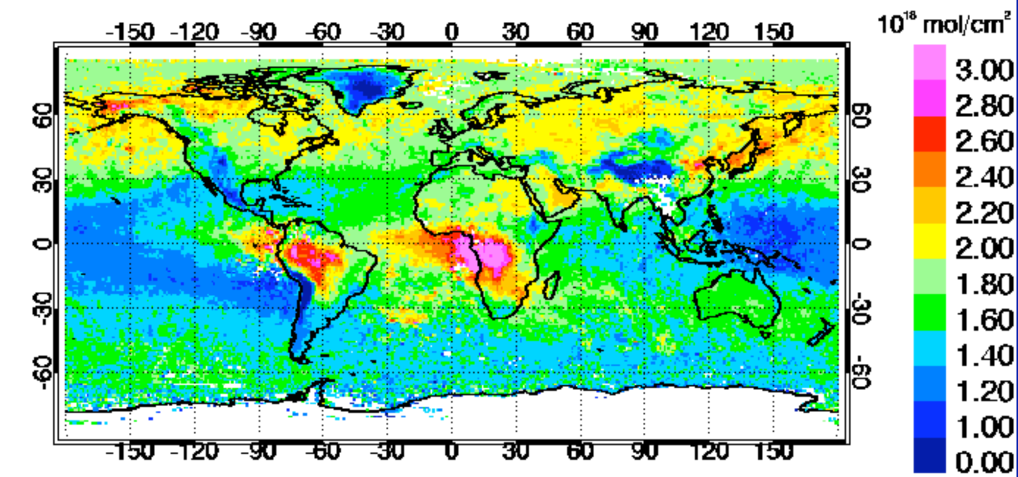
MOPITT CO (V3) Column Jul 1-31, 2005



PARASOL, August 2005
Accumulation mode



MOPITT CO (V3) Column Aug 1-31, 2005

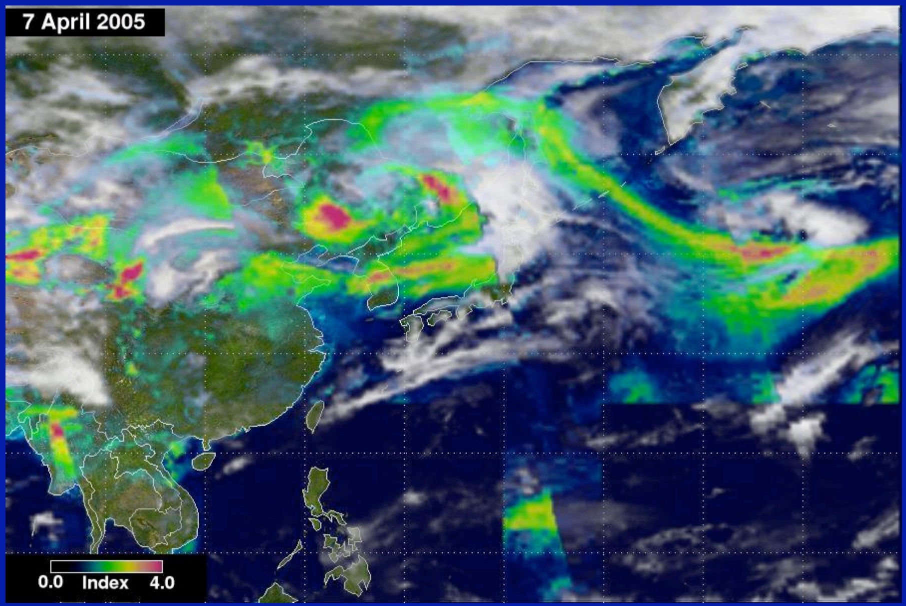


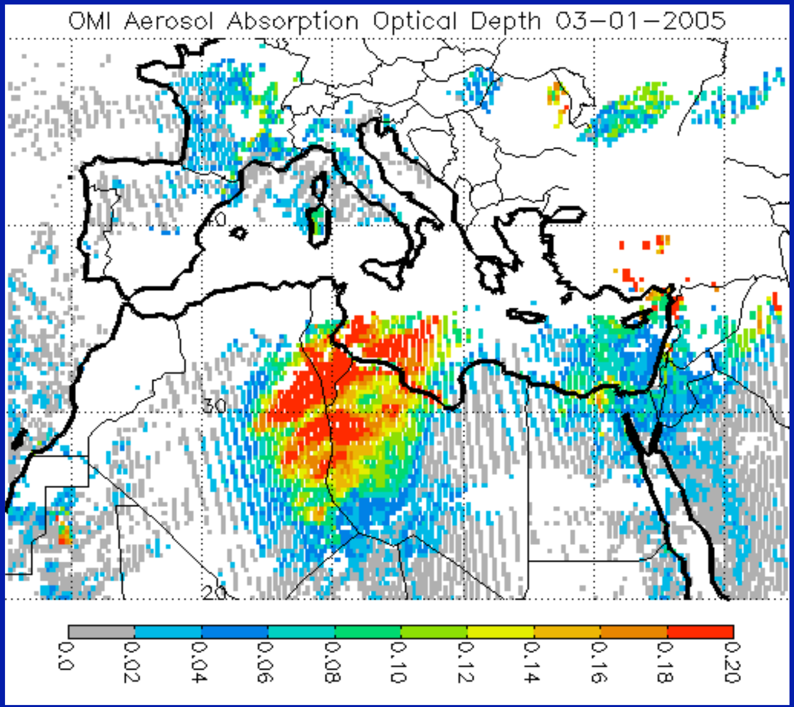
Gridded at 1x1deg from MOP02-20050831-L2V5.9.4.val.hdf (apriori fraction < 50%)

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

CENTRE NATIONAL D'ETUDES SPATIALES

Aerosol Detection in the UV: A Unique OMI Capability





Aerosol detection above clouds:
OMI Aerosol Index (color scale)
OMI reflectivity (gray scale)

Aerosol detection above land and ocean.

Distinguish between absorbing and non-abs. aerosols: biomass burning, dust, industrial aerosols
OMI Aerosol Optical Depth ;
Dust storm over Sahara

Torres, Bhartia, NASA GSFC