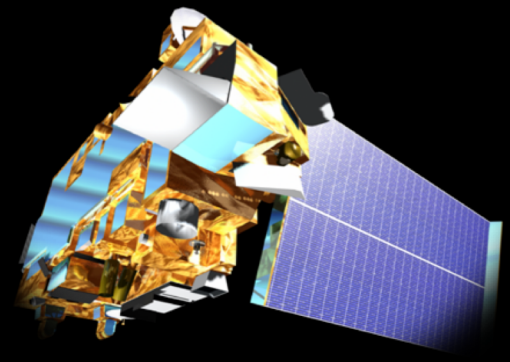

Satellite IR observations for air quality

David Edwards (NCAR)

with input from

Cathy Clerbaux, Maya George (CNRS), Juying Warner (UMD),
Helen Worden, Rebecca Buchholtz, Forrest Lacey (NCAR),
Antonia Gambacorta, Chris Barnet (NOAA),
Yasko Kasai (NICT), Juan Cuesta (LISA)

CEOS AC-VC-15, Tokyo, Japan, June 10-12 2019

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Thermal hyperspectral sounders

Currently 5 operational thermal sounder suites

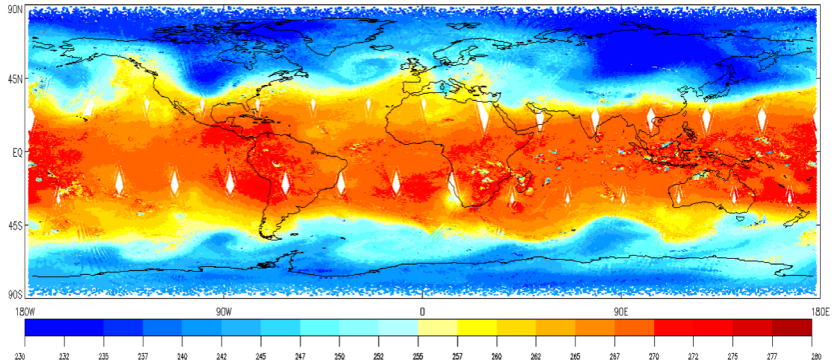
Satellite	Instruments	Overpass	Launch dates
Aqua	AIRS, AMSU	1:30	2002
Metop –A, -B, -C	IASI, AMSU, MHS	9:30	2006, 2012, 2018…
S-NPP, NOAA-20	CrIS, ATMS	1:30	2011, 2017, …

- Under the Joint Polar System Agreement, NOAA and EUMETSAT split responsibility for the two primary orbits: EUMETSAT satellites cover the mid-morning orbit while NOAA are responsible for the afternoon orbit; agreement covers NOAA's planned JPSS-2, -3, and -4 satellites and EUMETSAT's second-generation Metop satellites
- There are numerous (albeit small) differences in these sounding suites:
  - Instruments are different in spectra resolution, sampling and noise, spatial sampling and degradation over time
  - Algorithm are different in training datasets used, e.g. 9:30/1:30 orbits co-location w/in situ is different; several different processing suits in use at the different agencies
- Resultant product differences both instrumental, algorithmic and physical, e.g. sensitivity to meteorology, clouds at 9:30 vs 1:30 am/pm

NOAA NUCAPS operational & experimental products

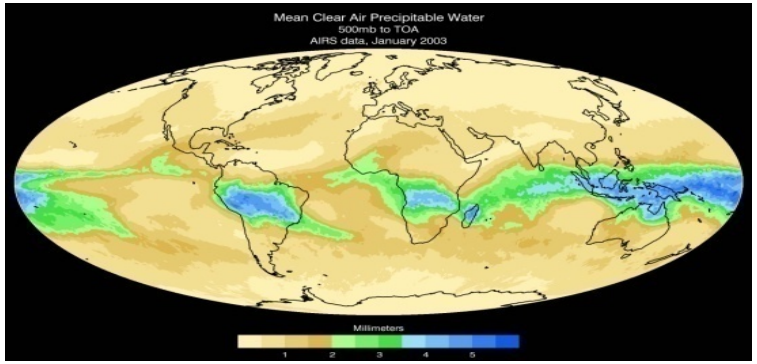
Retrieval Product	Spectral Region(s) Used (cm^{-1})
Cloud Clearing Parameters (4 *linear* parameters)	660 – 750 2200 – 2400
Cloud fraction and Cloud Top Pressure and Temperature	660 - 750
Surface temperature (LST, SST), emissivity and solar reflectivity	800 – 950, 1210 – 1230, 2400 – 2550
~10 to 1000 hPa Temperature, T(p) (Note: also use 57 GHz microwave)	660 - 750 2200 – 2400
~200 to 1000 hPa Water Vapor, q(p) (Note: also use 20, 35, 89, 183 GHz)	780 – 1090 1200 – 1750
Lower stratosphere Ozone	990 – 1070
Mid-tropospheric Carbon Monoxide, CO(p)	2155 – 2220
Mid-troposphere Methane, CH_4(p)	1220 - 1350
Mid-troposphere Carbon Dioxide, CO_2(p)	660 – 760, 980, 2200 - 2400
Lower-stratosphere Nitrous Oxide, N_2O(p)	1290 - 1300 2190 - 2240
Mid-troposphere Nitric Acid, HNO_3(p)	760 - 1320
Volcanic mid-tropospheric Sulfur Dioxide, SO_2(p)	1343 - 1383

500 hPa Temperature

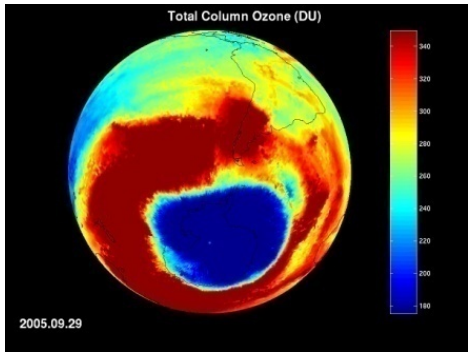


(January 5th 2014 Polar Vortex Anomaly)

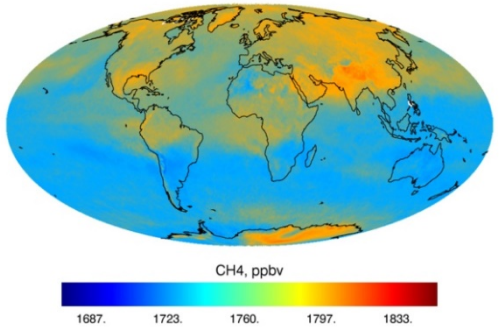
500 hPa Water Vapor



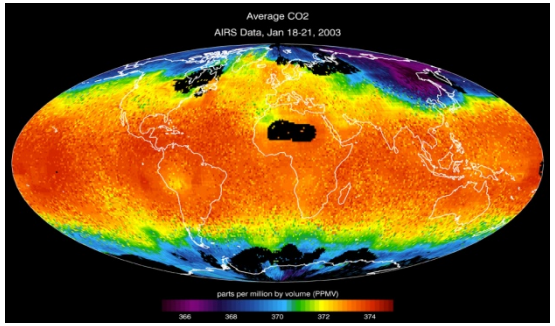
Ozone



Methane



Carbon Dioxide



NUCAPS NOAA Unique Combined Atmospheric Processing System

IASI/MetOp-A, -B and C

Brightness Temperature (K)

30
28
26
24
22
20
18

Now 31
measure

Concentrated plumes (6)	HCl, H_2S, C_3H_6, C_4H_4O, HONO, *HCHO*

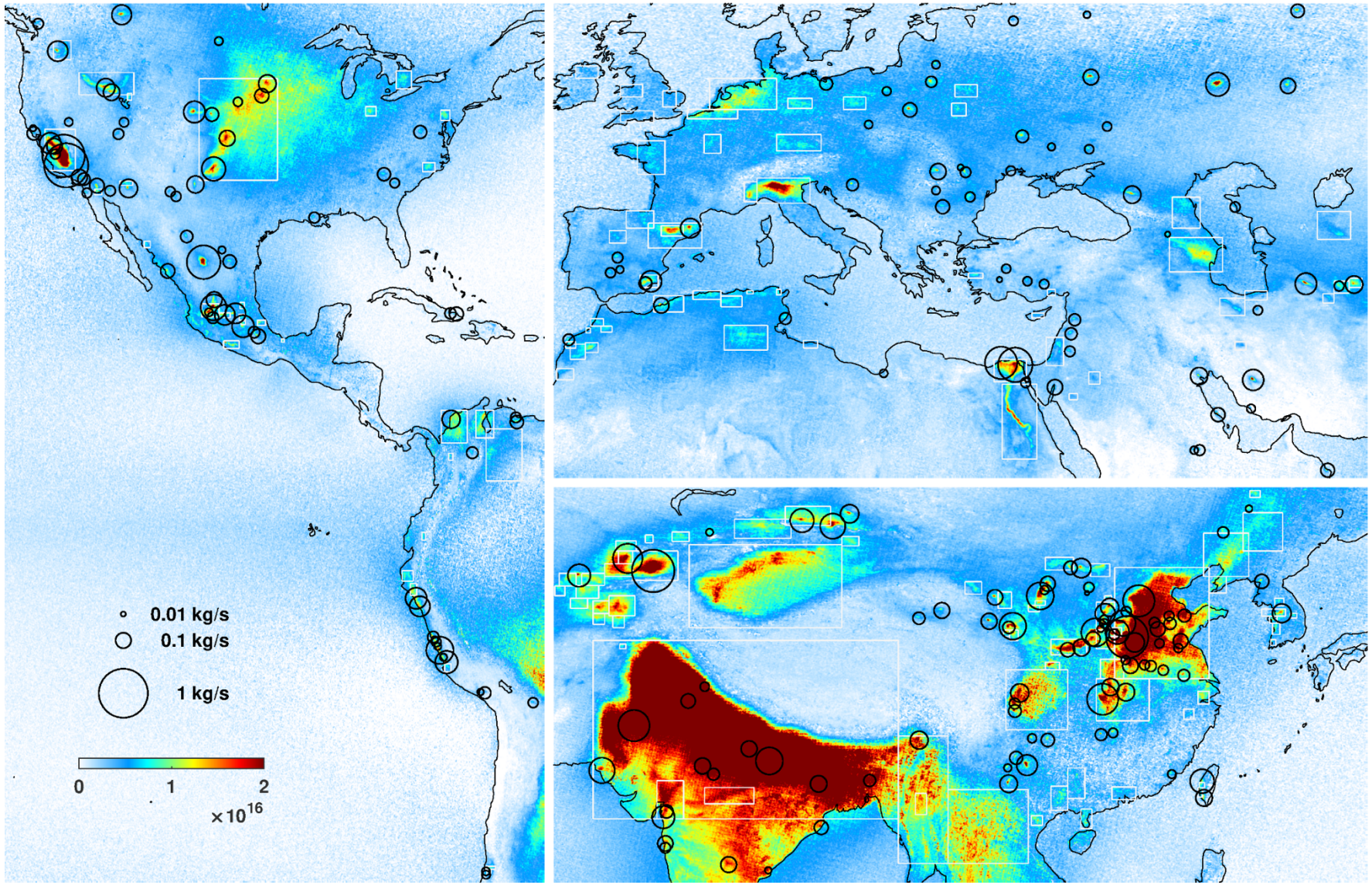
ULB LATMOS

Hotspot identification / categorization / quantification

IASI-NH_3

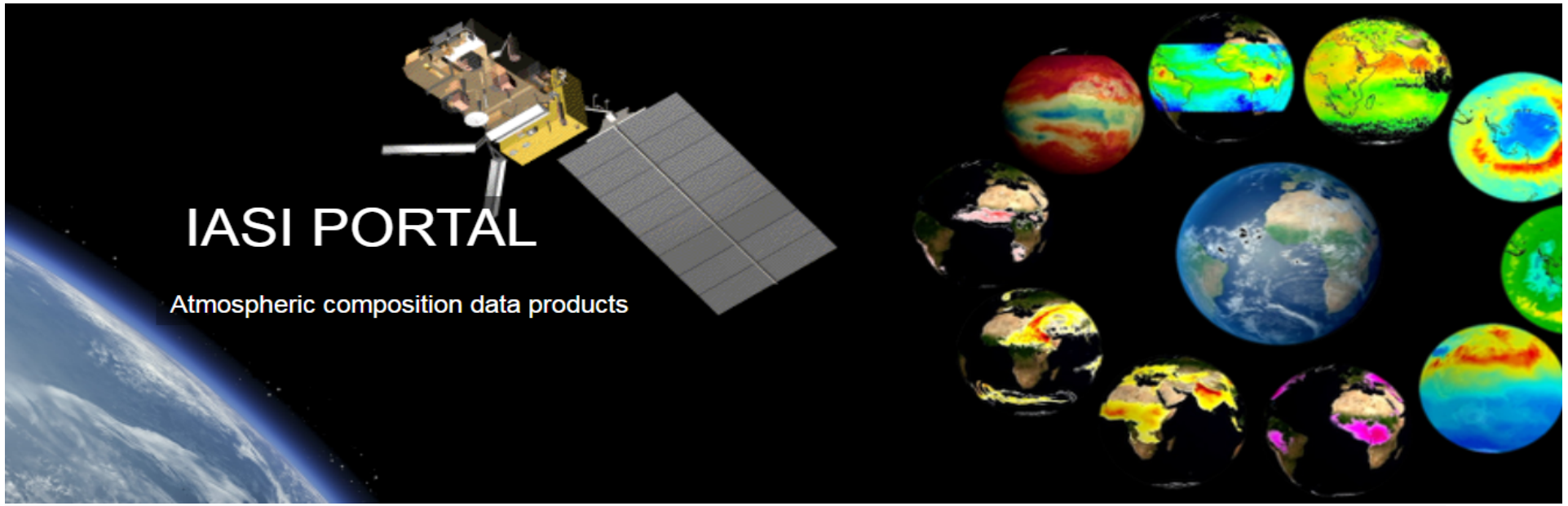
2008-2016
oversampled (1 km^2)
distribution:

- **>240 hotspots identified (+ >170 source regions)**
- 3 classes:
  - Agricultural (83)
  - Industrial (158)
  - Natural (1)
- Flux quantification

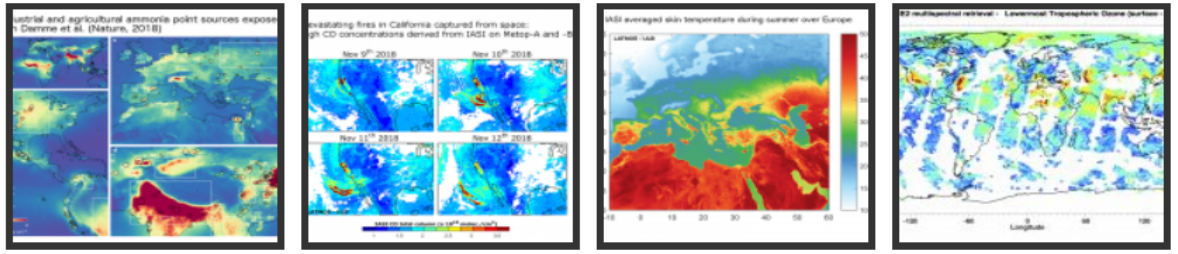


Martin Van Damme et al. Nature, 2018

IASI data access



AERIS data base : Data download + image gallery



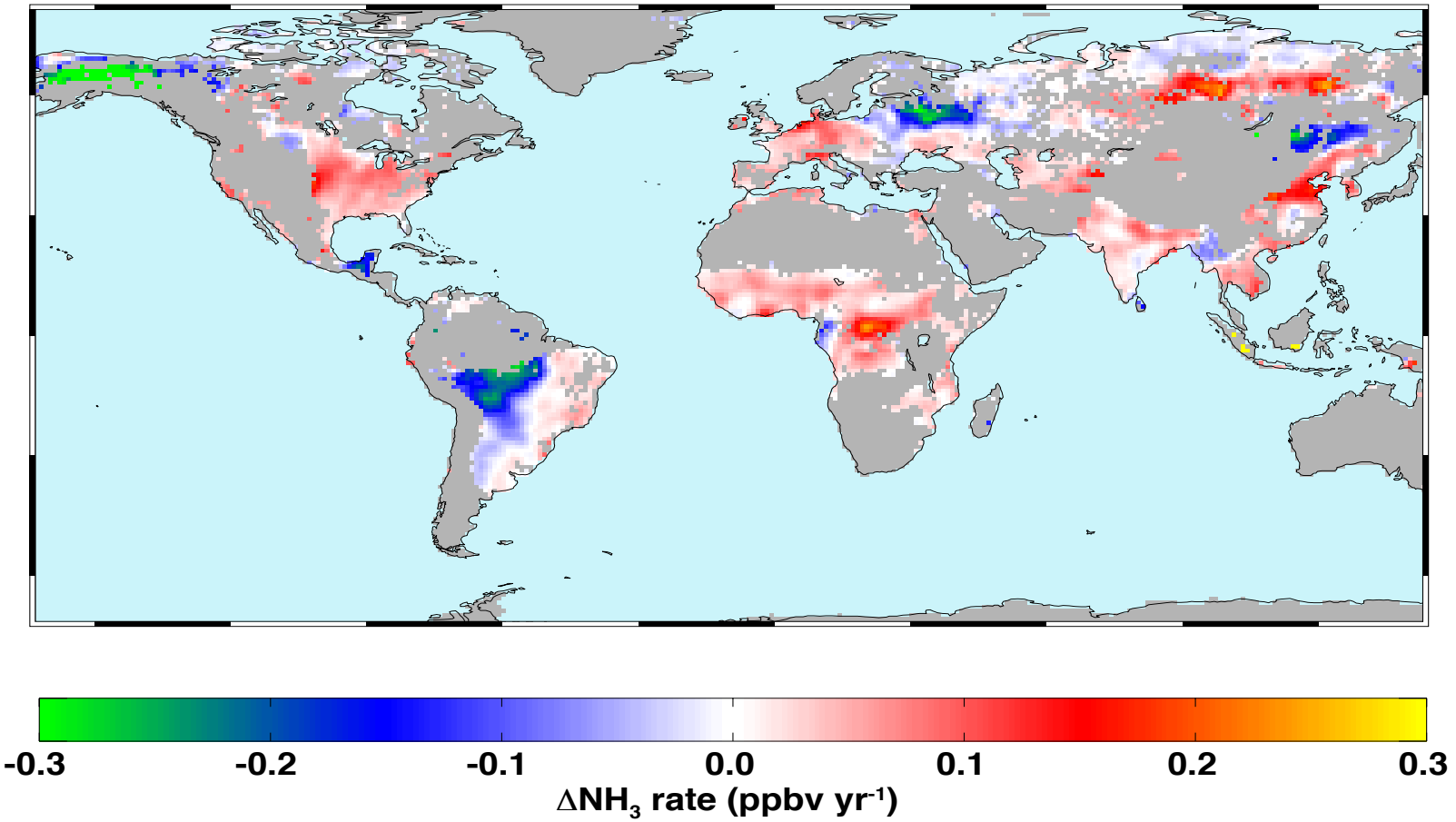
http://iasi.aeris-data.fr/CO/
http://iasi.aeris-data.fr/NH3/
http://iasi.aeris-data.fr/HCOOH/
http://iasi.aeris-data.fr/O3/
http://iasi.aeris-data.fr/SO2/

ULB LATMOS

Aqua/AIRS NH_3 trend 200209 to 201608

- Global trends in atmospheric NH_3 VMR at 918 hPa for each 1x1 grid
- Increases due to agricultural emissions and reduced scavenging by acid aerosols
- Decreases due to possibly reduced agricultural burning and fewer wild fires

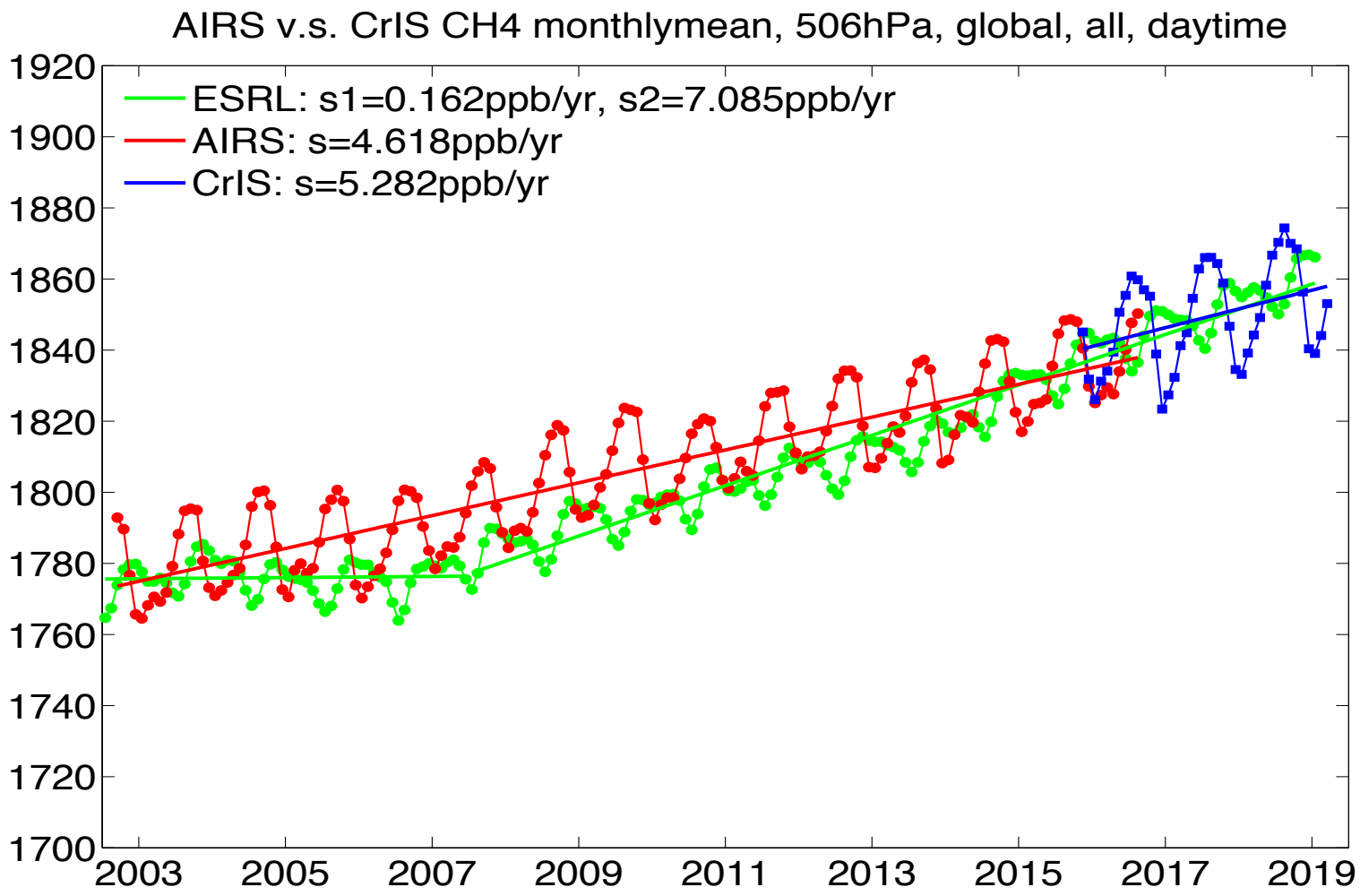
Warner et al. ACP, 2017



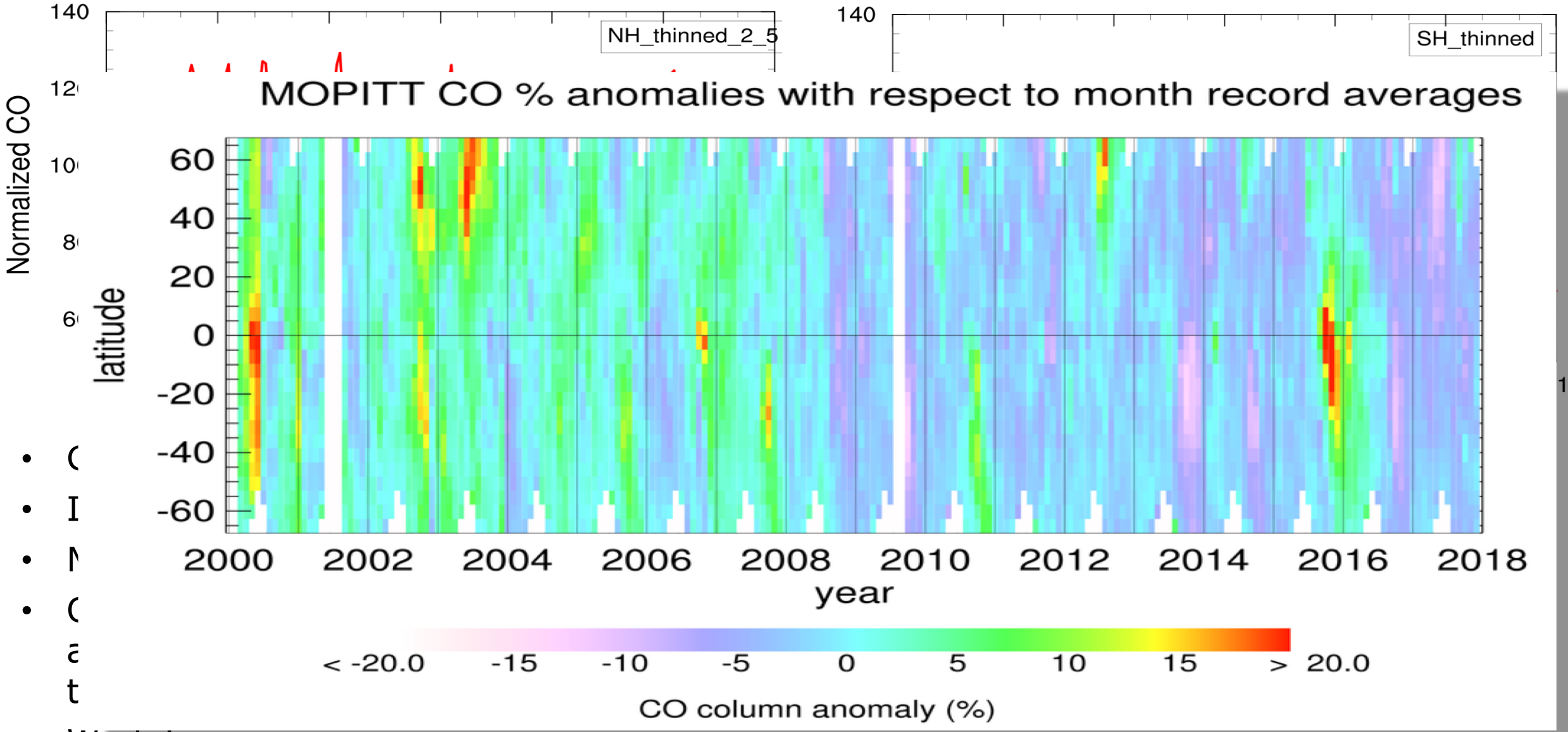
AIRS NH_3 Data Release at NASA GES DISC imminent https://disc.gsfc.nasa.gov/
doi: 10.5067/06YIT7GX74FN and the data set "shortname" AIRSAC3MNH3

Global CH_4 trends: AIRS data record extended by CrIS

- Variability of CrIS and AIRS V6 mid-tropospheric (500 hPa) CH_4 records agree very well, and with also with near-surface ESRL https://www.esrl.noaa.gov/gmd/ccgg/trends_ch4/#global_data measurements
- ESRL CH_4 shows a sudden increase in 2008; not as obvious in AIRS data
- Work in progress



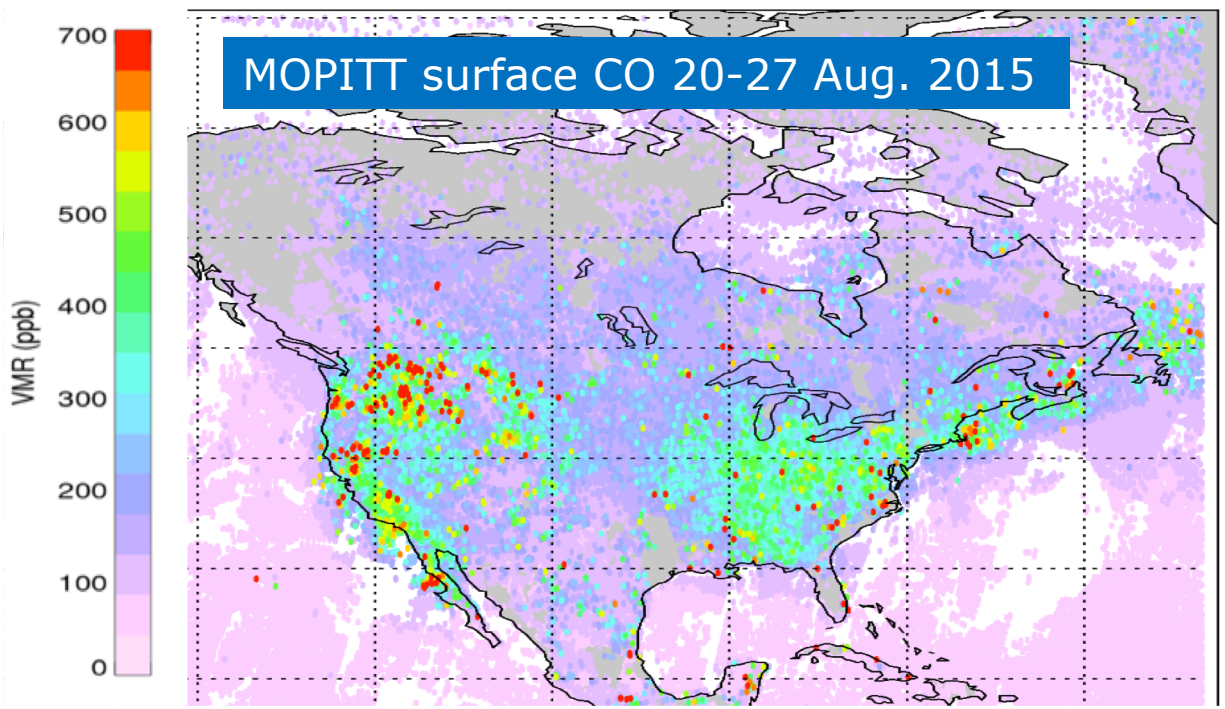
Global CO trends: MOPITT, AIRS & IASI

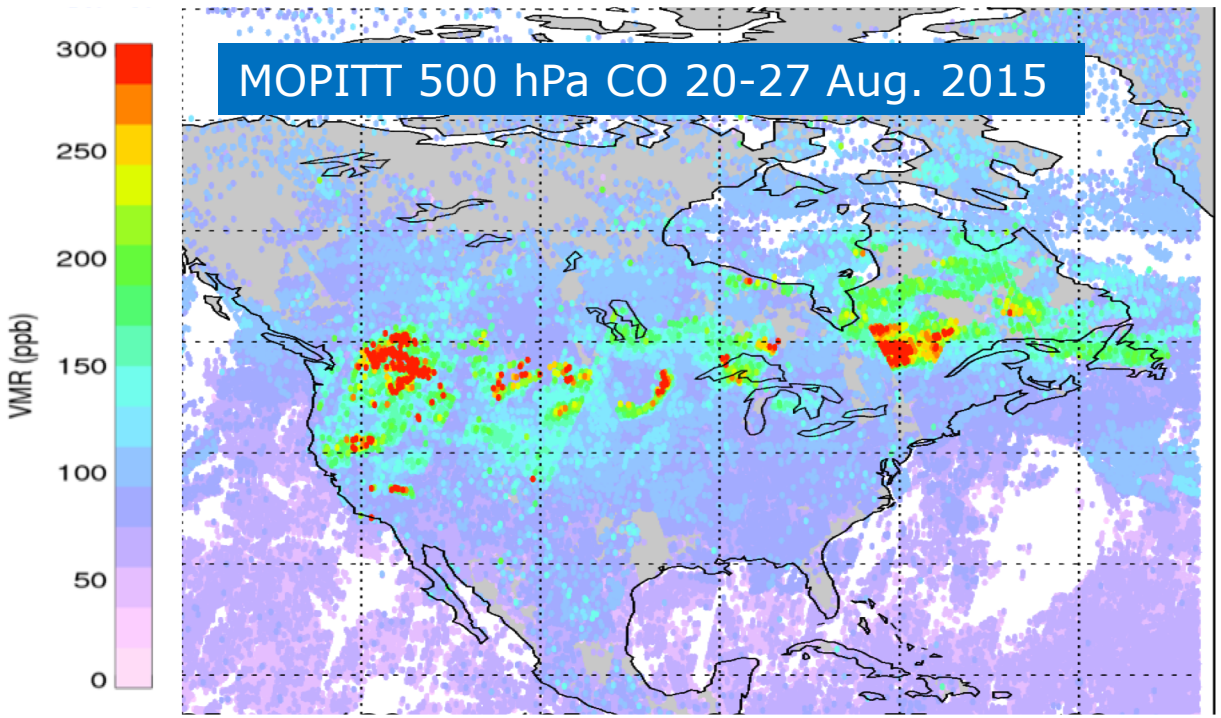


- C
- I
- M
- C
  a
  t
- Work in progress

Terra/MOPITT multispectral CO measurements

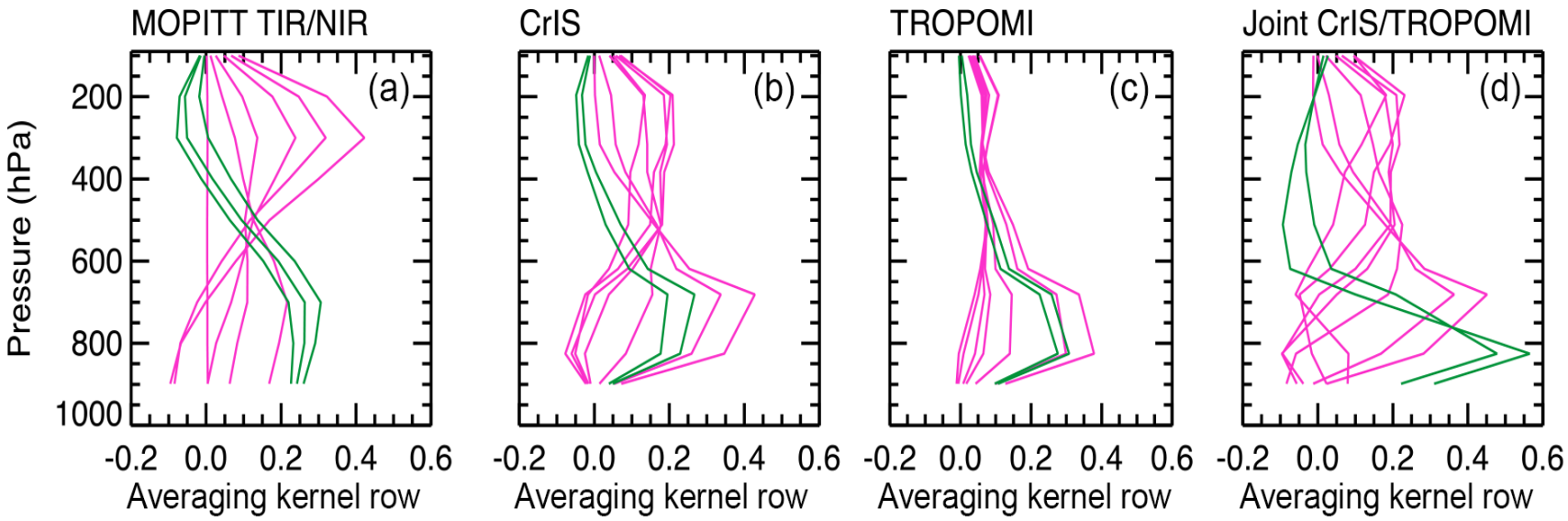
- Longest satellite record of global CO observations (2000-2019) demonstrates interannual variability and long-term trends
- Unique multispectral measurements allow height-resolved retrievals with sensitivity to near-surface CO concentrations
- Surface retrievals identify source regions, mid-troposphere retrievals show transport



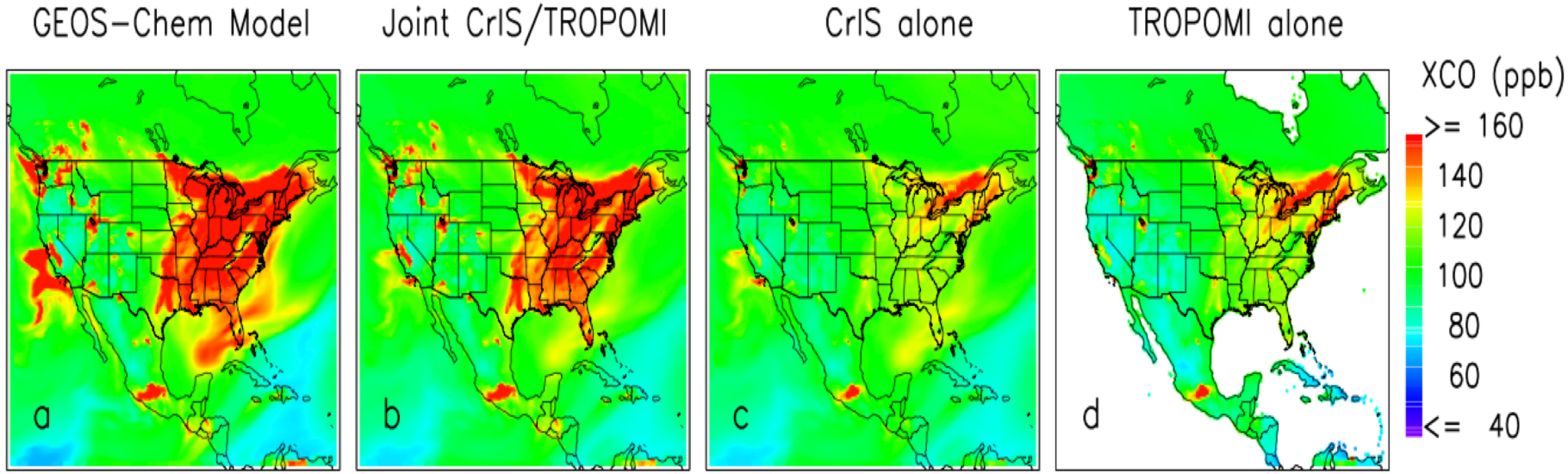


Extending the TIR+SWIR MOPITT CO record with SNPP/CrIS and S5P/TROPOMI

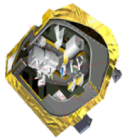
Averaging Kernels From Dejian Fu et al., *AMT*, 2016 – Using MUSES Algorithm for single pixel, OE retrievals



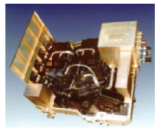
Simulated retrievals of surface layer CO (0-2km)



Lowermost tropospheric ozone from IASI+GOME2 multispectral synergism

IASI  **Thermal IR spectra**

+

GOME-2  **UV spectra**

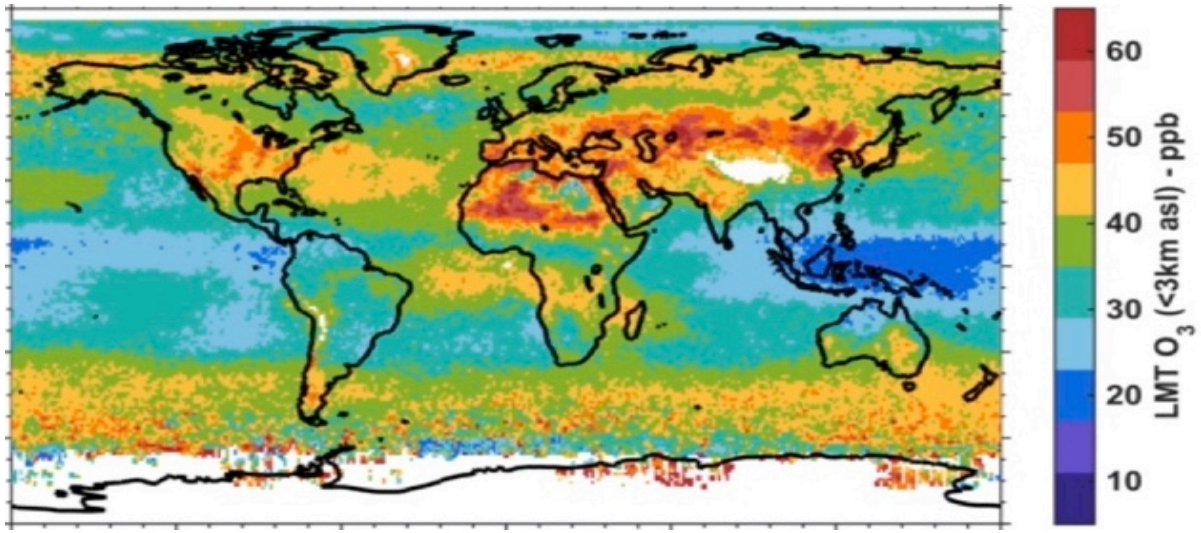
IASI+GOME2 multispectral synergism

First satellite observation of lowermost tropospheric O_3 (<3 km asl), with sensitivity peaking down to 2 km

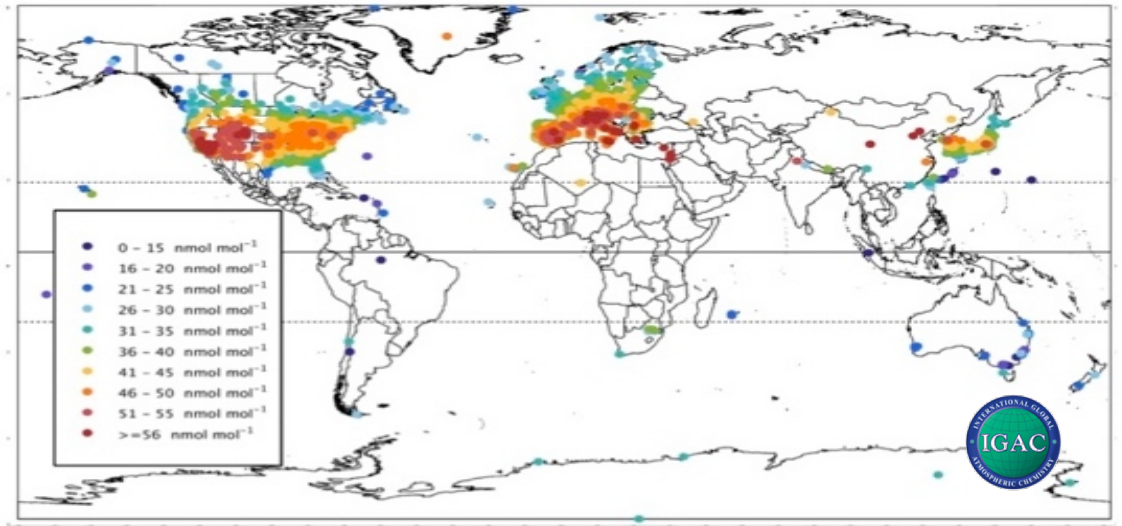
➔Air quality

Cuesta et al., ACP 2013, 2018

IASI+GOME2 lowermost tropospheric O_3 – JJA 2017



In situ surface O_3 – JJA 2010-2014



TOAR [Gaudel et al. Elementa 2018]

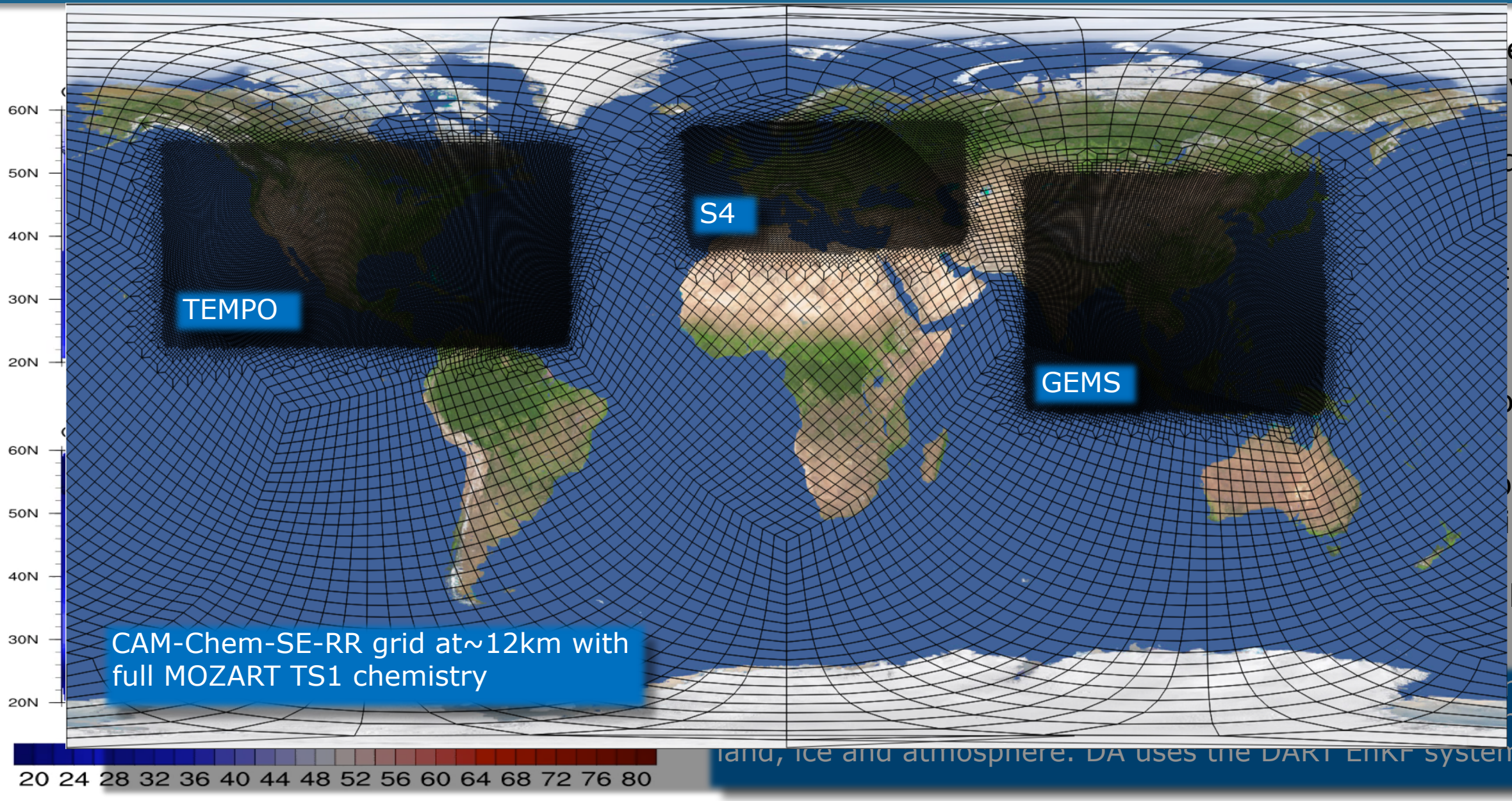
lisa

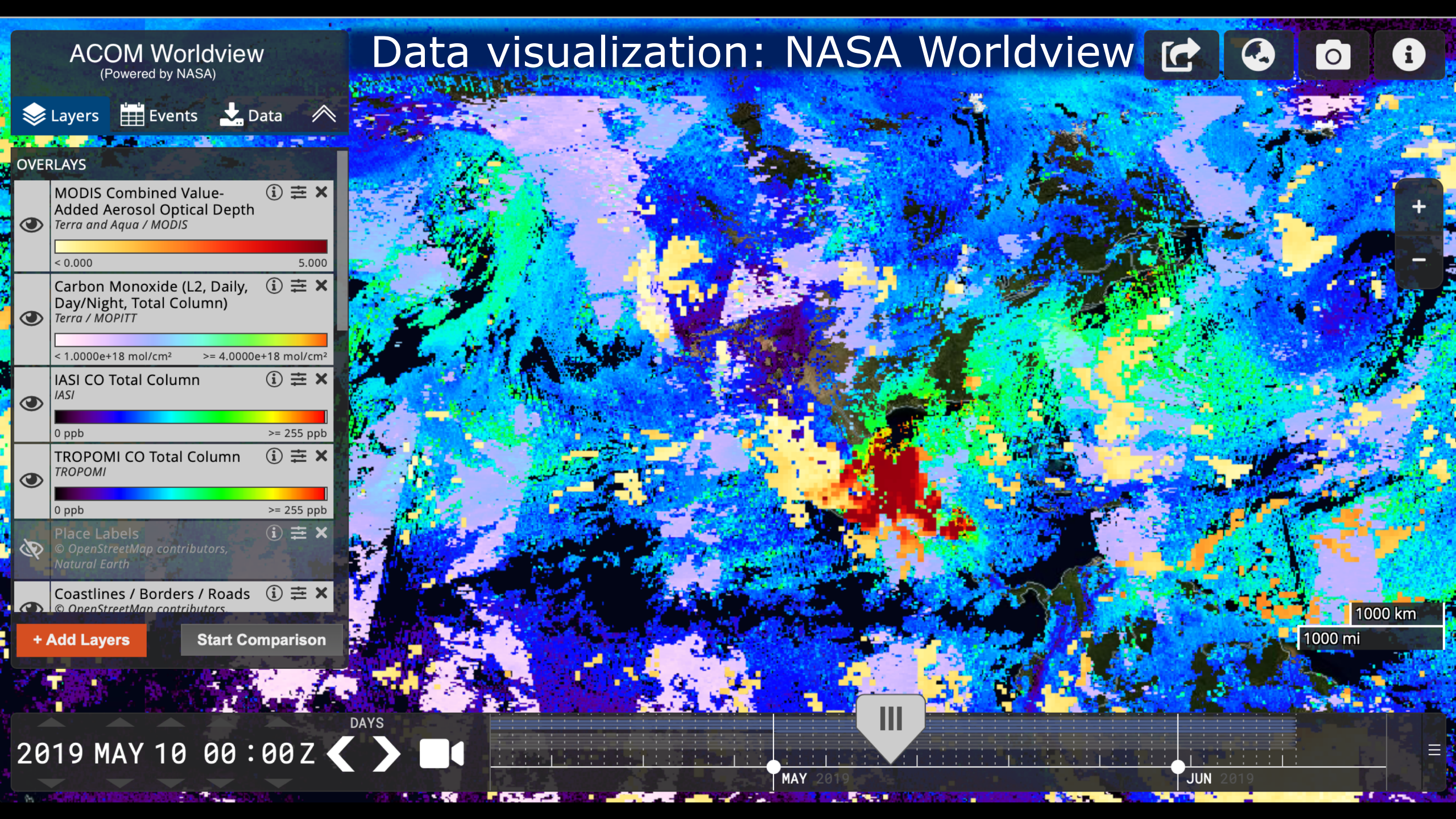
Global IASI+GOME2 data available at AERIS data centre

https://iasi.aeris-data.fr/ , cuesta@lisa.u-pec.fr

Ongoing comparisons with other observations and models (CAMS, CHASER)

IR as a component of the AQ constellation




ACOM Worldview
(Powered by NASA)
Layers
Events
Data
Data visualization: NASA Worldview
OVERLAYS
MODIS Combined Value-Added Aerosol Optical Depth
Terra and Aqua / MODIS
< 0.000
5.000
Carbon Monoxide (L2, Daily, Day/Night, Total Column)
Terra / MOPITT
< 1.0000e+18 mol/cm²
>= 4.0000e+18 mol/cm²
IASI CO Total Column
IASI
0 ppb
>= 255 ppb
TROPOMI CO Total Column
TROPOMI
0 ppb
>= 255 ppb
Place Labels
© OpenStreetMap contributors, Natural Earth
Coastlines / Borders / Roads
© OpenStreetMap contributors
+ Add Layers
Start Comparison
1000 km
1000 mi
DAYS
2019 MAY 10 00:00Z
MAY 2019
JUN 2019