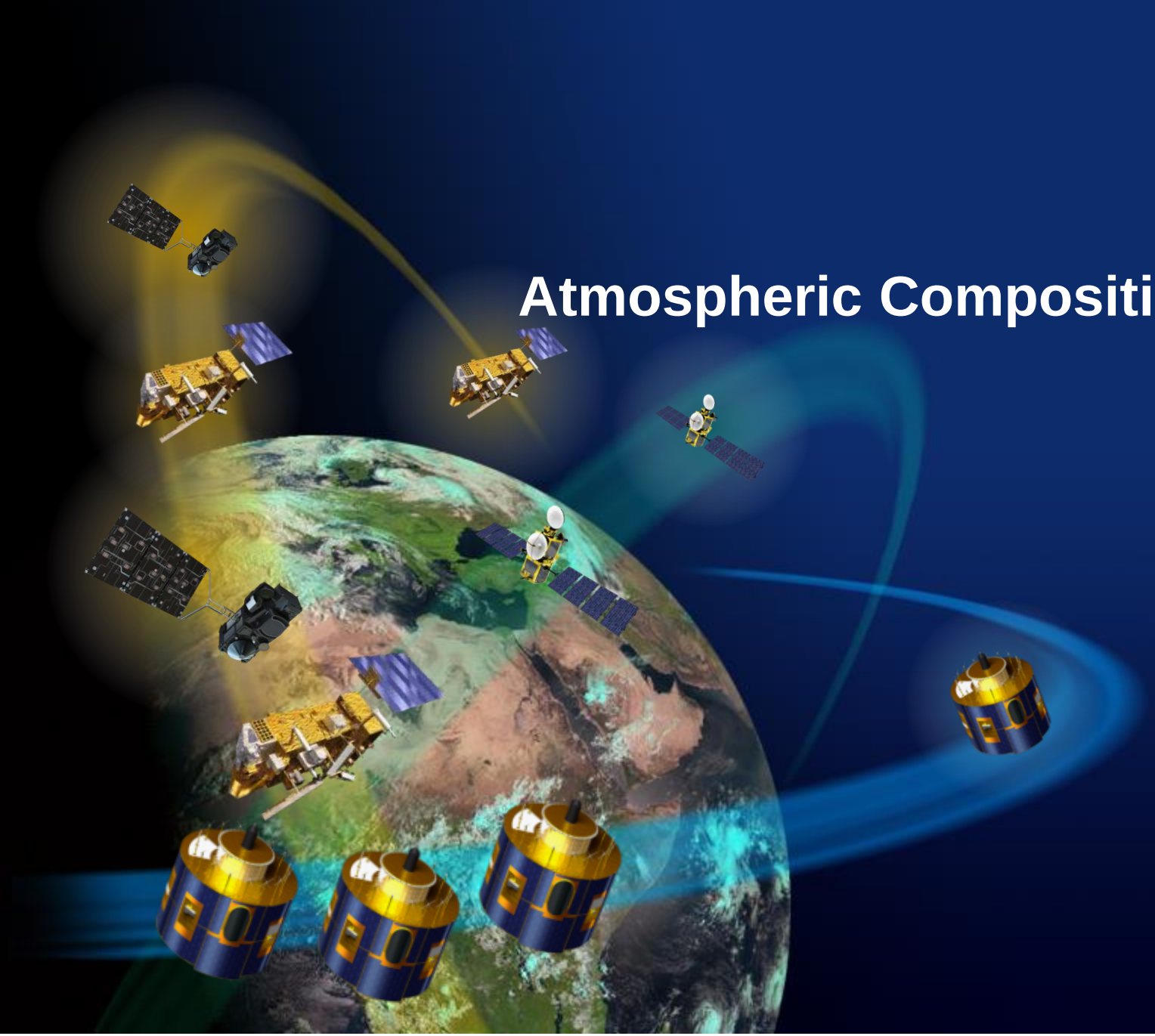


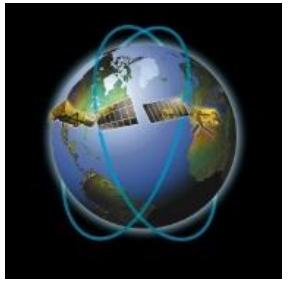
Atmospheric Composition products using IASI-NG and MTG-IRS

Dorothee Coppens

For the hyperspectral Infrared scientific team

Introduction

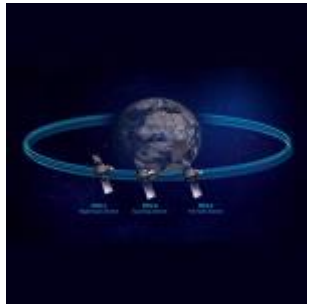
Future Hyperspectral Infrared instruments operated by EUMETSAT will be flying on two kind of satellites:



On a Polar orbiting satellite: sun-synchronous orbit at an altitude of 817 kilometers, to provide more detailed observations of the global atmosphere, oceans and continents.

- ✓ **EPS (EUMETSAT Polar System) program with three flying IASI instruments on the Metop satellites which operate in unison for as long as Metop-A's available capacities bring benefits to users**
- ✓ **Future EPS-SG program with the IASI-NG (New Generation) instruments, on three satellites from 2023 onwards.**

On a geostationary orbit: The Meteosat Third Generation (MTG) will include a state-of-the-art atmospheric sounding service providing measurements in the infrared spectrum. MTG will see the launch of six new geostationary satellites from 2021 onwards. The satellite series will be based on 3-axis platforms and comprise:



- ✓ **Four Imaging Satellites (MTG-I) (20 years of operational services expected)**
- ✓ **Two Sounding Satellites (MTG-S) (15.5 years of operational services expected)**

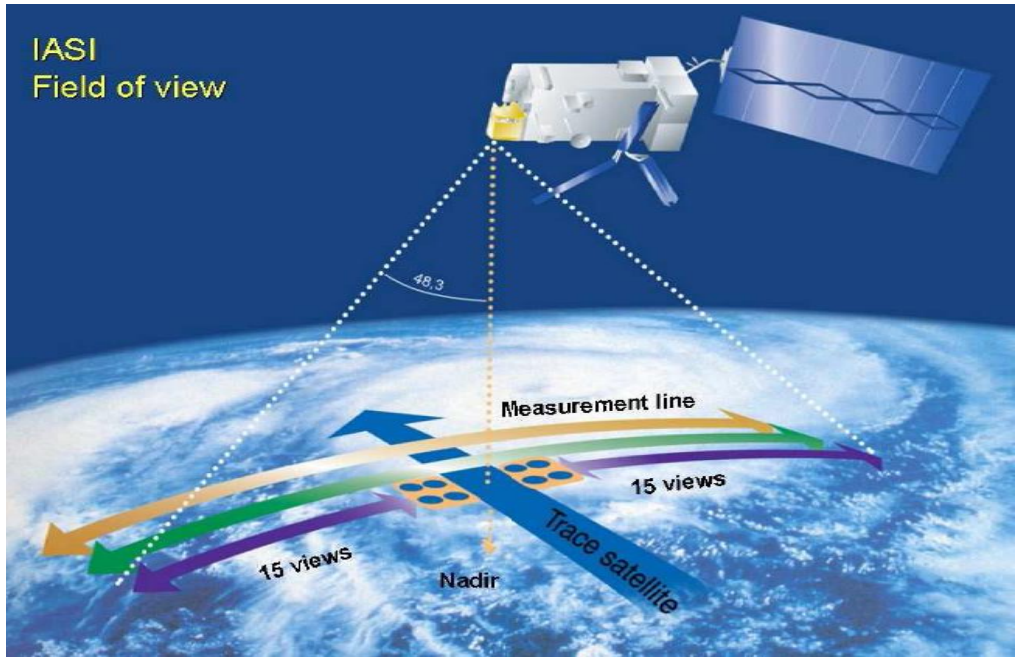
MTG-IRS will be flying on MTG-S satellites.

Outline

- ✓ IASI a step forward to the infrared sounding
- ✓ IASI-NG mission
  - ✓ Presentation of IASI-NG mission
  - ✓ Strong heritage with IASI
  - ✓ Requirements regarding the AC products
- ✓ MTG-IRS mission
  - ✓ Presentation of the MTG-IRS mission
  - ✓ Situation of the requirements for AC products
  - ✓ How the IRS could contribute to the AC?
- ✓ Conclusion with possible synergies

IASI mission

IASI is a Michelson Interferometer flying on Metop satellites



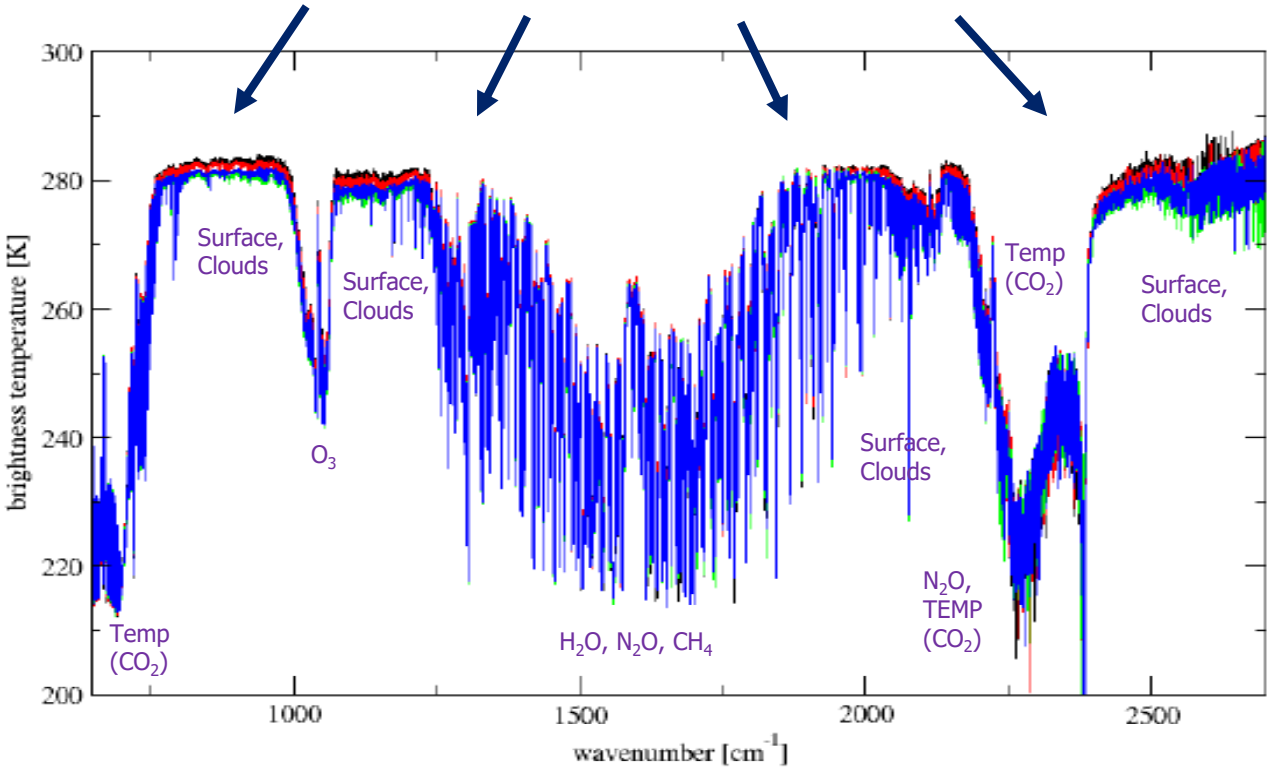
Normal Operation Mode
- ✓ Scanning the swath
- ✓ (30 Earth views + 2BB + 2CS) / 8 seconds

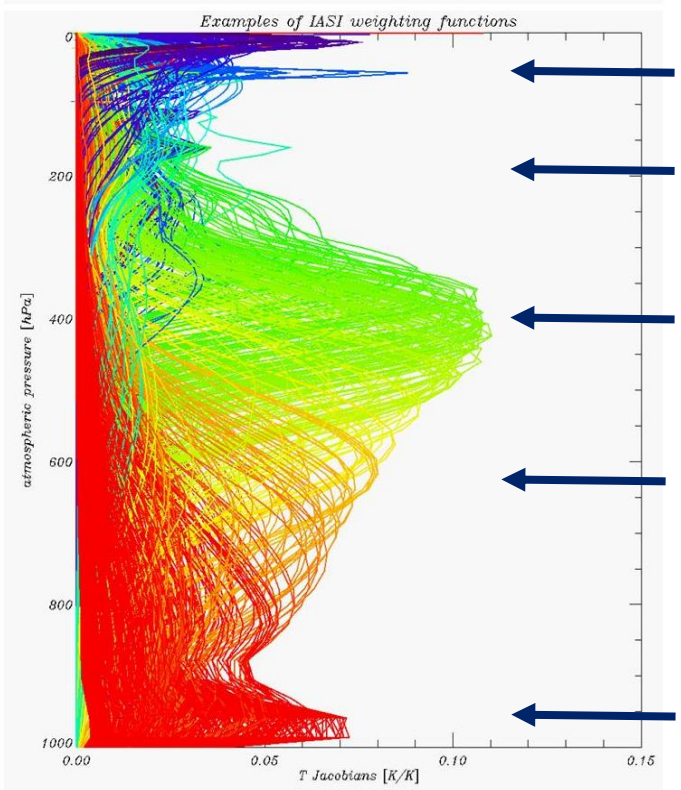
IASI	
Spectral characteristics	
Maximum OPD	2 cm
Spectral resolution	0.5 cm^{-1}
Spectral sampling	0.25 cm^{-1}
Spectral coverage	645-2760 cm^{-1} (3 bands are merged)
Spectral accuracy	< 2 ppm
Radiometric characteristics	
Radiometric noise	0.5 K
Geometric characteristics	
Field of view	12 km
Swath width	2200 km
Detector matrix	2x2 pixels covering 50x50 km^2

- ✓ **Flying IASI: 3 polar orbiting instruments on:**
  - ✓ Metop-A since October 19th, 2006
  - ✓ Metop-B since September 17th, 2012
  - ✓ Metop-C since November 7th, 2018

IASI is a major step forward in infrared sounding

➔ **Many atmospheric variables…**



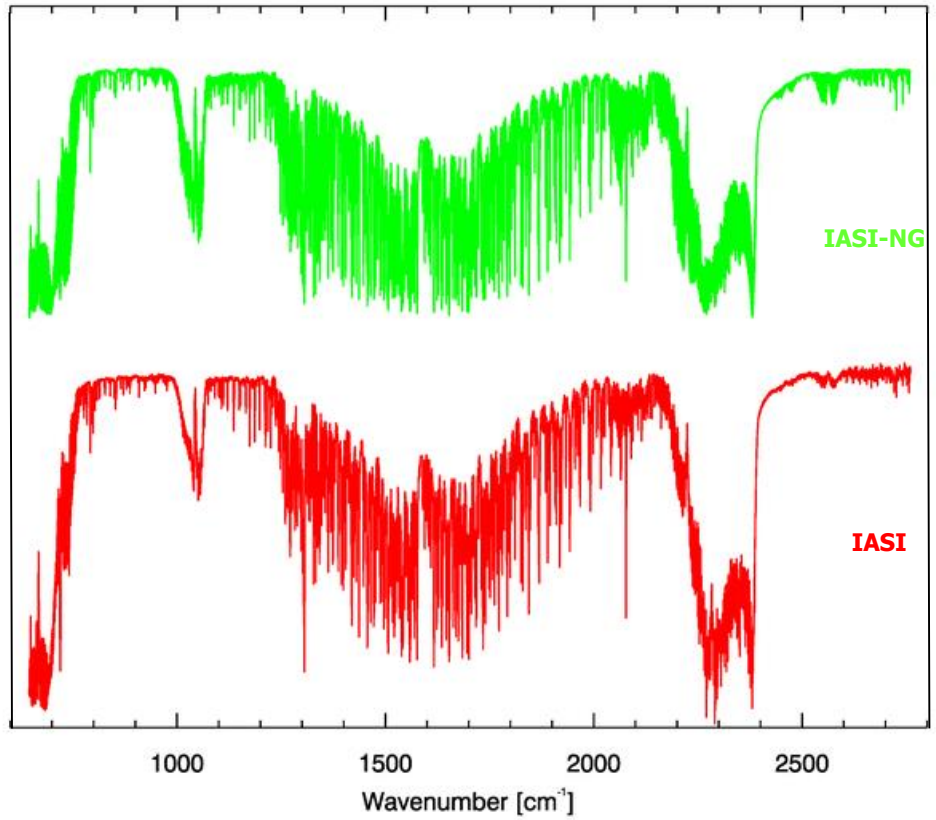


… located at different altitudes

IASI-NG mission

IASI-NG is a continuation of the IASI mission: Michelson interferometer + Mertz compensation:

- ✓ **Maximum OPD: 4 cm (on ground) i.e. a spectral sampling (0.125 cm^{-1}) and resolution of 0.25 cm^{-1} ➔ Better than IASI (0.25 cm^{-1} and 0.5 cm^{-1} respectively)**
- ✓ **Detector: 12 km resolution at nadir**
- ✓ **Spectral coverage: 645 - 2760 cm^{-1}**
- ✓ **Half of the IASI radiometric noise**

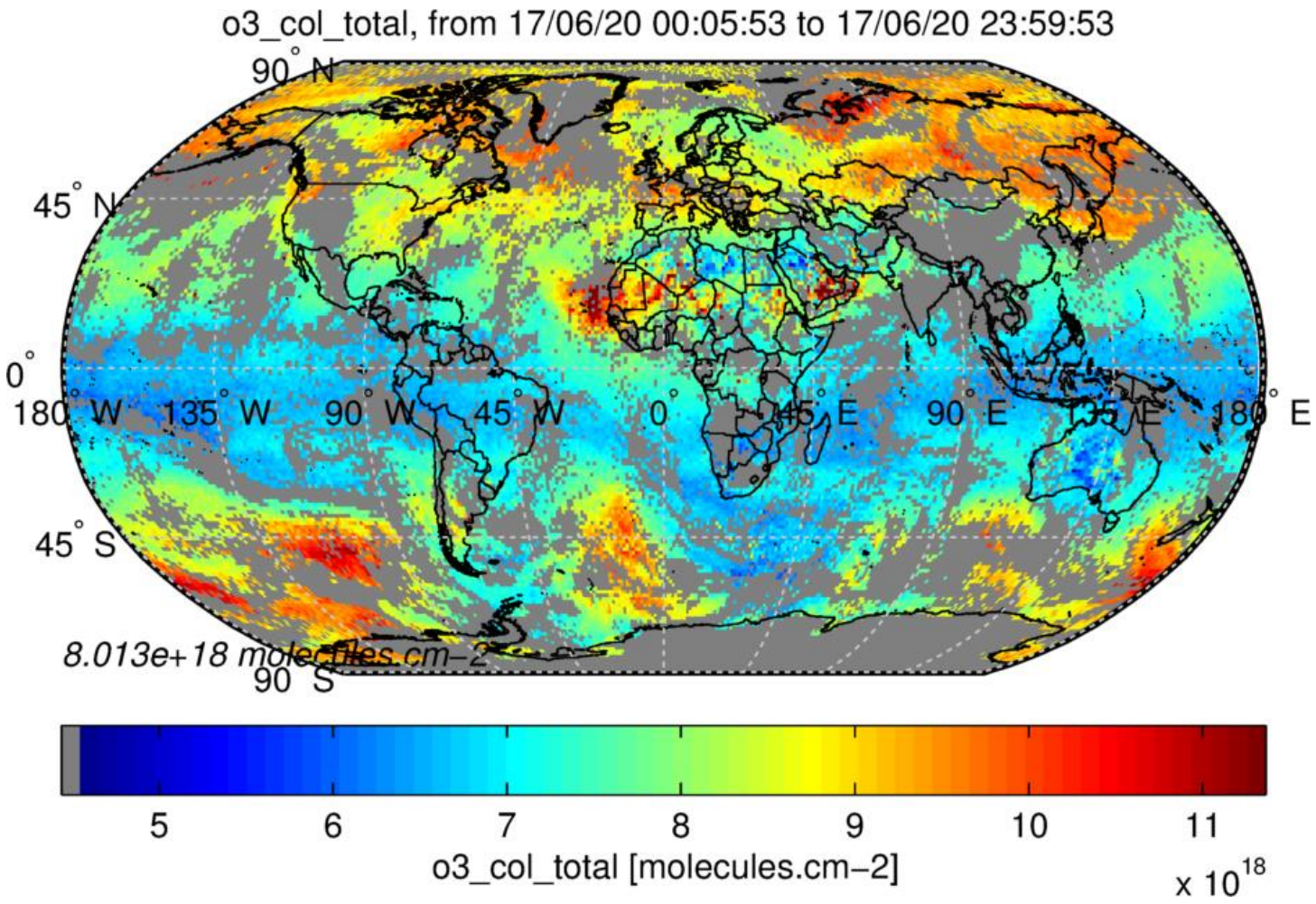


AC products with IASI-NG

AC Products	Developer	IASI heritage?
CO profile	AC SAF	Yes
CO partial column	AC SAF	Yes
Methane (CH_4) partial column	HQ	Yes
Nitric acid (HNO_3) partial column	AC SAF	Yes
Nitrous oxide (N_2O) total column	HQ	Yes
Ozone (O_3) profile	AC SAF	Yes
Ozone (O_3) total column	AC SAF	Yes
Sulphur dioxide (SO_2) total column	AC SAF	Yes

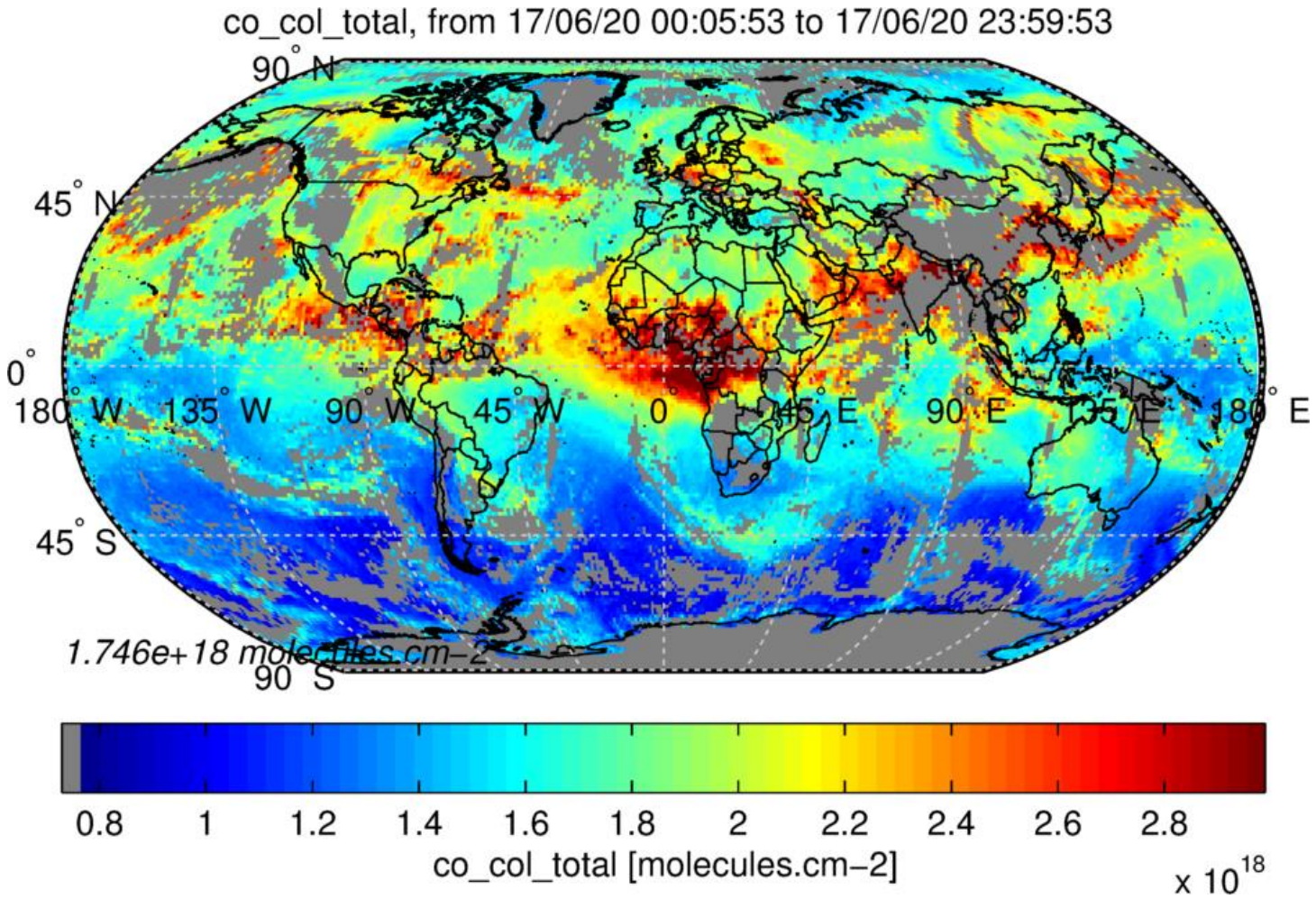
➔ **Few examples of current IASI AC products are provided in the next slides**

Current AC products with IASI – O_3 total column



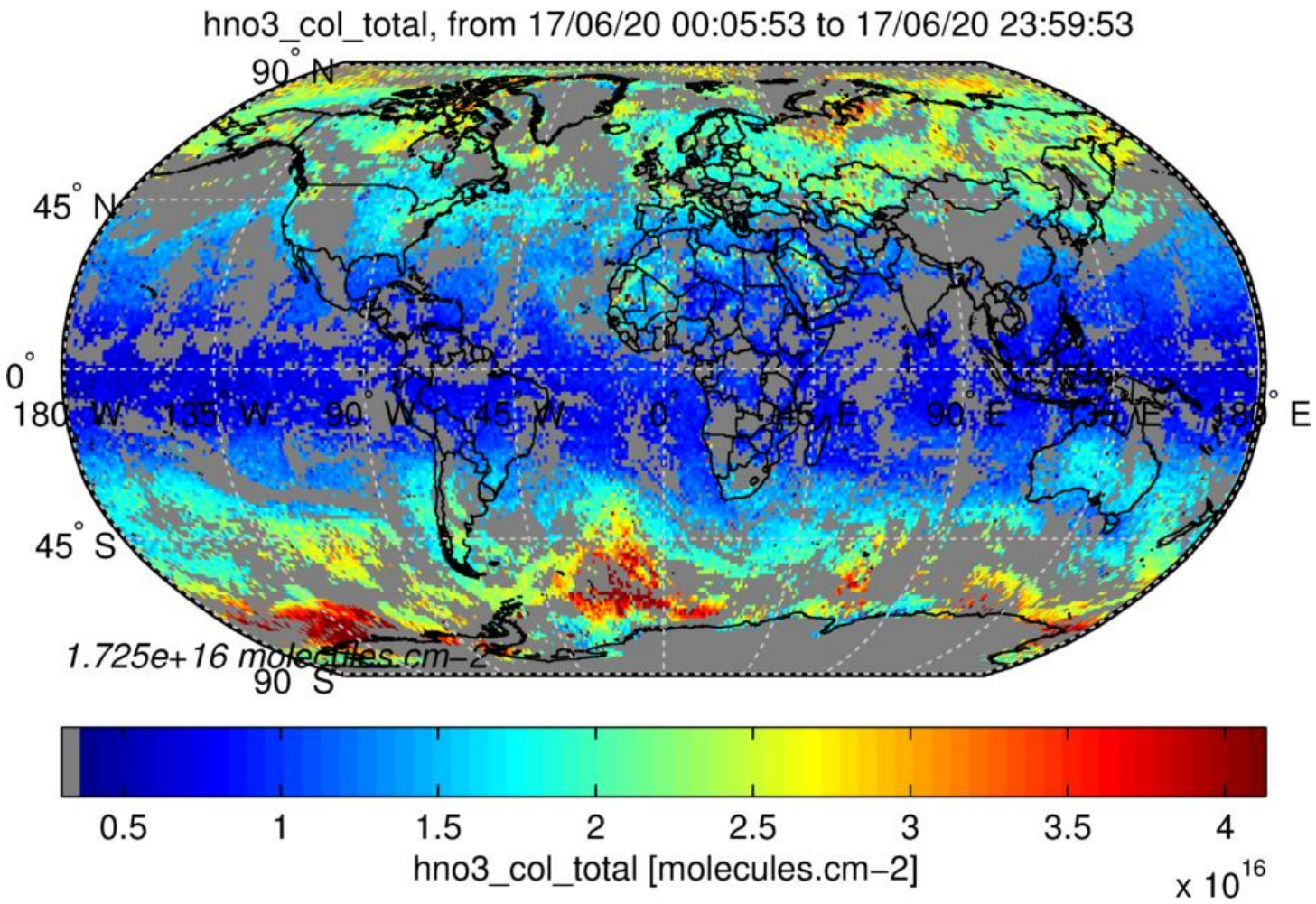
1 day

Current AC products with IASI – CO total column



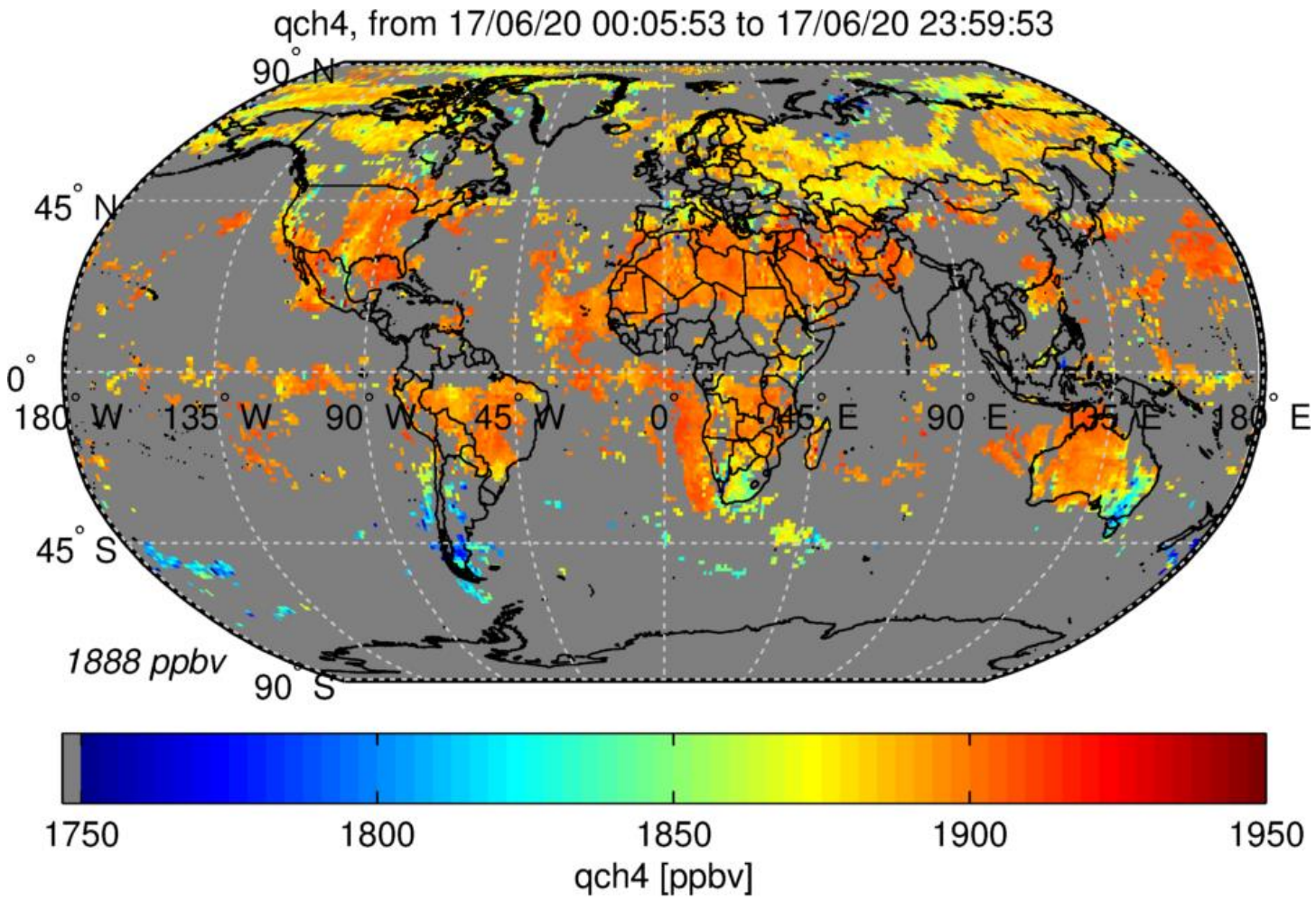
1 day

Current AC products with IASI – HNO_3 total column



1 day

Current AC products with IASI – CH_4 partial column



1 day

Improvements expected with IASI-NG

AC Products	With IASI		With IASI-NG	
	Vertical res.	Accuracy	Vertical res.	Accuracy
CO profile	N/A	20%	3 km	LT: 30% MT: 25% HT, S: 20%
CO partial column	N/A	20%	3 km	20 %
Methane (CH_4) partial column	N/A	20%	LT: 3km S: 5km	LT: 12% S: 30%
Nitric acid (HNO_3) partial column	N/A	20%	T, S	20%
Nitrous oxide (N_2O) total column	N/A	20%	N/A	10%
Ozone (O_3) profile	7 km at pressures < 30 hPa 10 km at pressures > 30 hPa	15 % at pressures < 30 hPa 50 % at pressures > 30 hPa	3 km	LT,MT, UT: 20% S: 10%
Ozone (O_3) total column	N/A	5%	N/A	5%
Sulphur dioxide (SO_2) total column	N/A	N/A	N/A	50%

(LT: Lower Troposphere, MT: Middle Troposphere, UT: Upper Troposphere, S: Stratosphere, LS: lower Stratosphere)

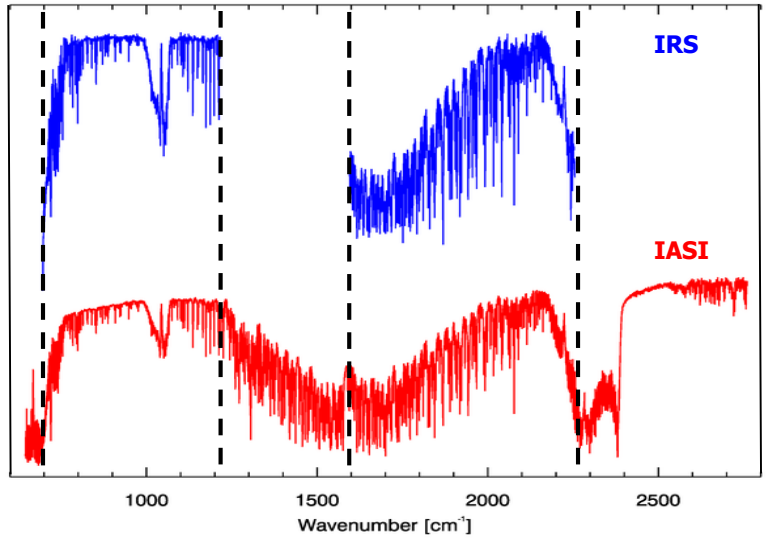
MTG-IRS instrument – New features compared to IASI

MTG-IRS is an imaging FTS, based on a Michelson interferometer:

- ✓ Corner cube mechanism (CCM) similar to IASI
- ✓ Multiple laser beams for monitoring the CCM speed variations as well as its 3D position
- ✓ Maximum OPD: 0.828 cm (on ground) i.e. a sampling of about 0.6038 cm^{-1}
- ✓ Detector: 160x160 pixels (640x640km) measured in 10 sec, with spatial resolution of 4 km
- ✓ Two spectral bands: 700-1210 and 1600-2175 cm^{-1} within IASI spectra

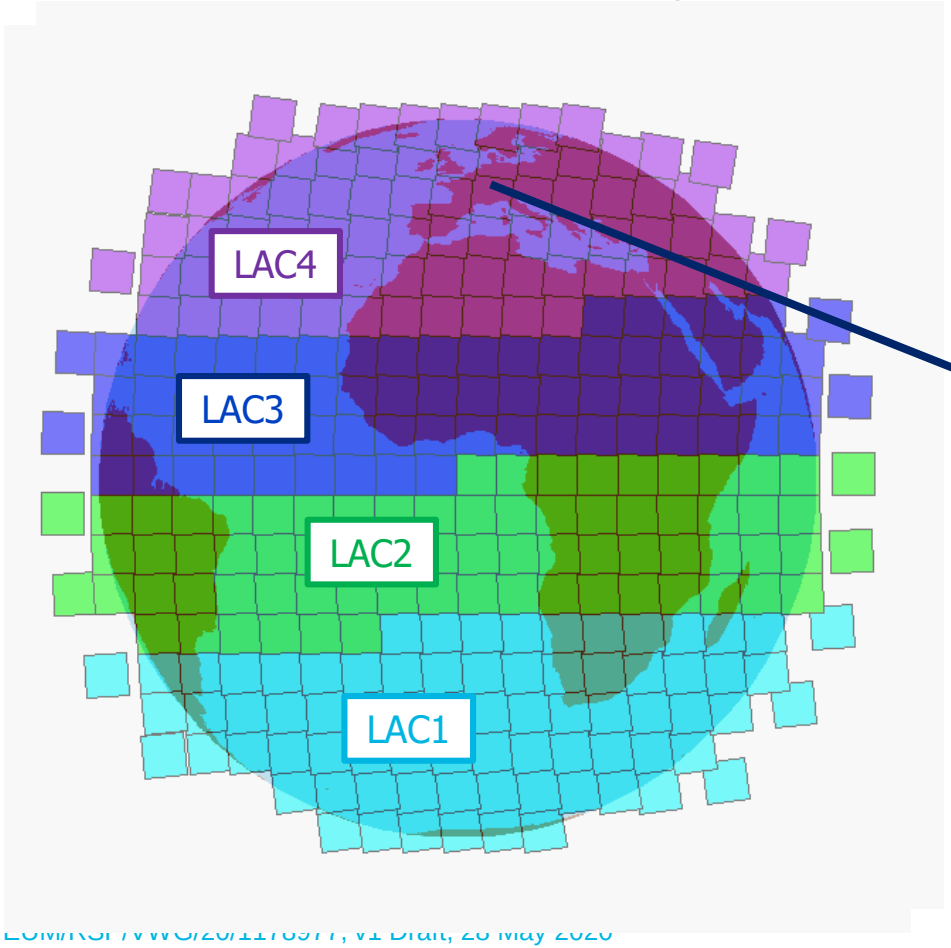
MTG-IRS is a step forward wrt. IASI:

- ✓ New technology
- ✓ Larger field, better spatial resolution
- ✓ Higher temporal repetition
- ✓ Additional user community (Nowcasting)
- ✓ Different instruments ➔ different calibration method

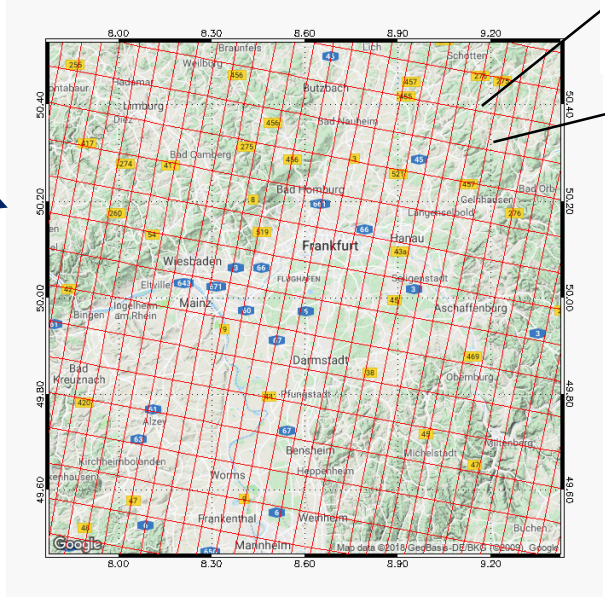


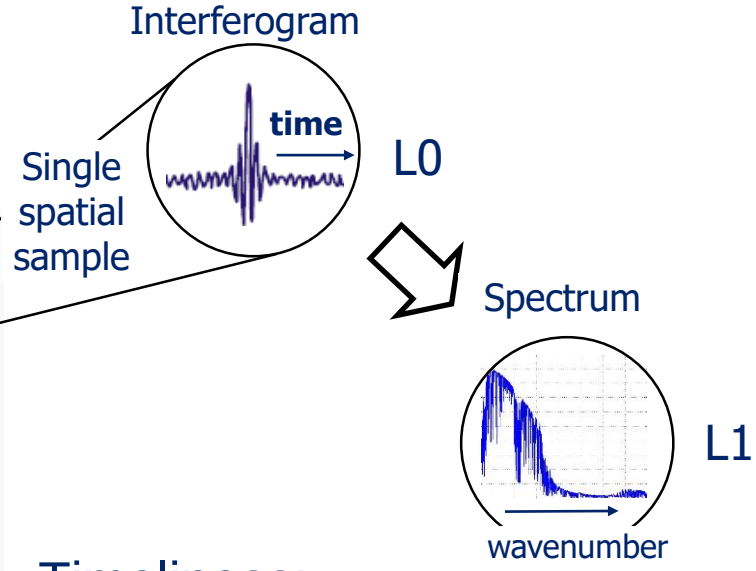
IRS scanning sequence and timeliness

- ✓ The Earth disk is split in 4 Local Area Coverage (LAC) zones, each of them covered in 15 min by a succession of “steps and stares” called dwells
- ✓ **LAC4** (northern mid-latitudes) will be covered **every 30 minutes**
- ✓ LAC1, 2, 3 will be alternatively viewed in-between



Each dwell consists of 160x160 pixels yielding a high spatial sampling





Timeliness:

- ✓ 25600 spectra covering 640x640 km² in **15 min**!
- ✓ Level 2 products in 30 min!

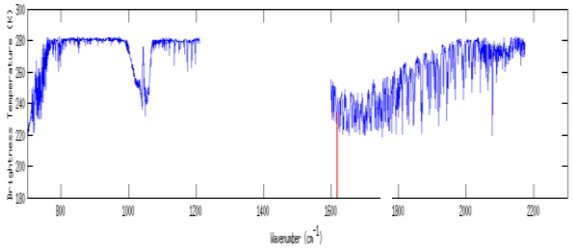
➔ **All products are disseminated in NetCDF**

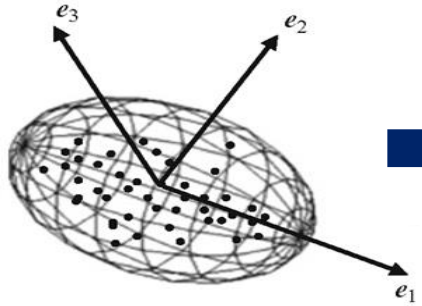
EUMETSAT

MTG-IRS Level 1b - dissemination

✓ **IRS L1 products will be disseminated in Principal Component (PC) scores only**

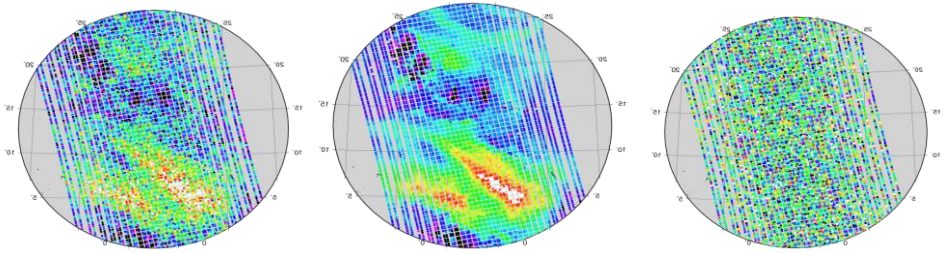
IRS L1b spectrum **eigenvectors**





PCS **Atmospheric signal** *+ noise*

Residuals **Noise**



✓ **An hybrid (between global and local PC) method will be used, i.e., we will distribute global PCs on a stable (fixed) basis + *5* local PCs to capture possible outliers.**

EUMETSAT is interacting actively with the AC user community to explain how to use reconstructed radiances from the PC and to learn about their constraints and problems.

AC products with MTG-IRS

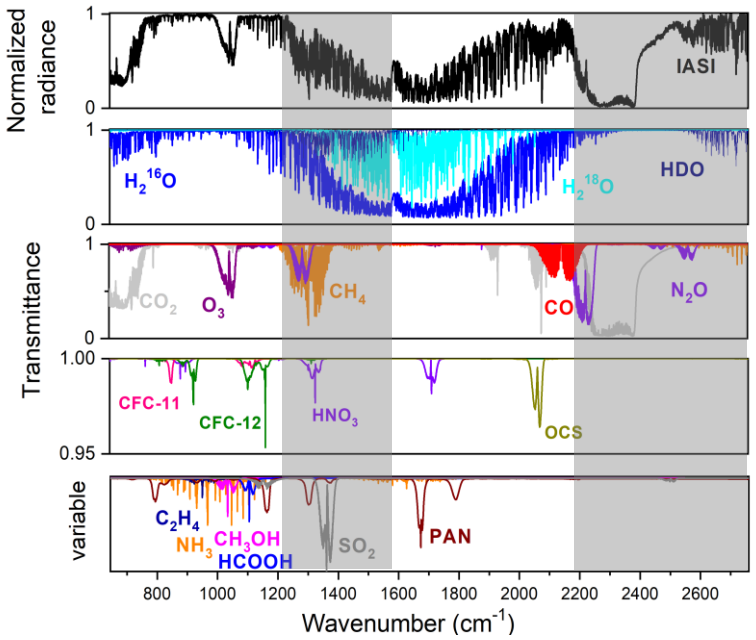
- ✓ **The situation for MTG-IRS is different**
- ✓ **There is no End-User requirements regarding the AC products**
- ✓ **Working with IRS Mission Advisory Group (MAG) members to define what could be done with MTG-IRS, what is possible and what needs to be studied or developed**
- ✓ **Next slides will show the outcome of the first discussion**

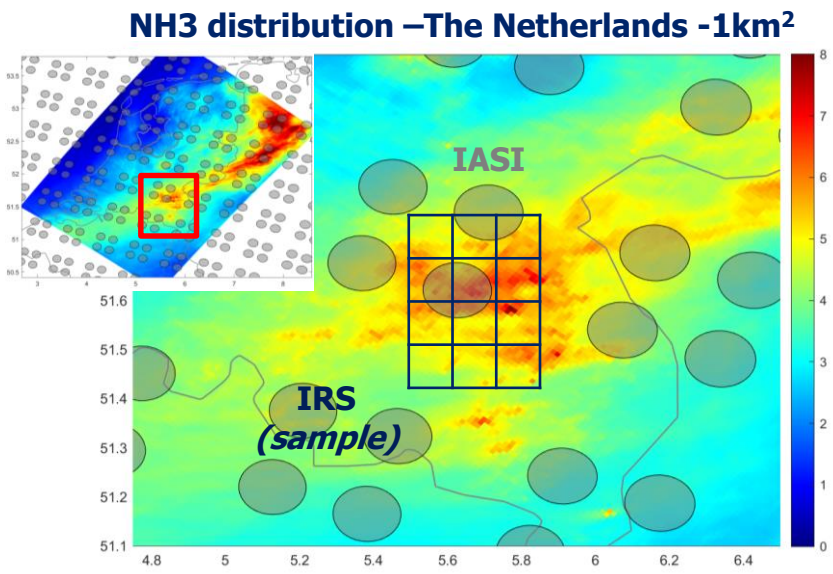
MTG-IRS possible contribution to AC

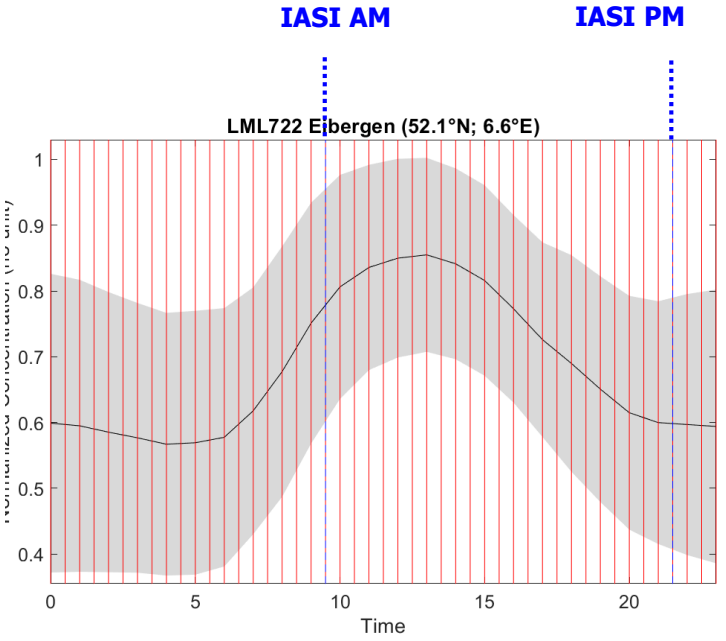
MTG-IRS vs. IASI and IASI-NG

- ✓**Reduced spectral coverage ➔ will miss CH_4, N_2O, SO_2 ν_3, HDO**
- ✓**Coarser spectral resolution and larger noise ➔ reduced vertical sensitivity + surface sensitivity**

- ✓**Continuous coverage ➔ Better mapping opportunities**
- ✓**Higher spatial resolution ➔ improved resolution of sources**
- ✓**High temporal sampling ➔ diurnal sampling; rapidly changing chemistry**







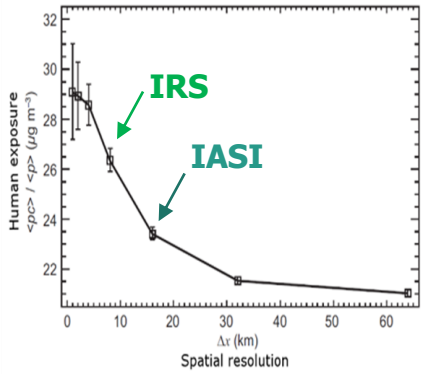
Credits: Pierre Coheur, IRS-MAG meeting

MTG-IRS possible contribution to AC

Air Quality

Limitations with polar sounders

- Spatial resolution: separating sources at city scale and improve exposure assessment



- Diurnal sampling

Opportunities for MTG-IRS

Time resolved measurements of CO, O_3, tropospheric/total columns, NH_3 columns at better spatial resolution over the Europe-Africa disc

but:

- Over polar sounders, IRS will have reduced vertical sensitivity in the troposphere for O_3 and CO
- Varying sensitivity to boundary layer as function of thermal contrast
- Anthropogenic SO_2 is unlikely to be measured (no coverage of ν_3 band) spectral range

Questions

- Will IRS allow resolving the diurnal cycle of pollution / emission?
- Is the reduced vertical sensitivity compromising AQ applications?
- Will operational assimilation system benefit from the diurnal measurements

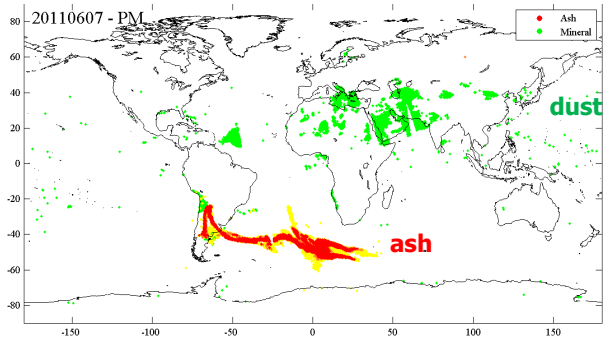
Credits: Pierre Coheur, IRS-MAG meeting

MTG-IRS possible contribution to AC

Events

Demonstrated with polar sounders

- Uses signature from SO_2, mainly in ν_3 band (ν_1 seen for large eruptions) or volcanic ash



- Fires with CO, NH_3 and VOCs

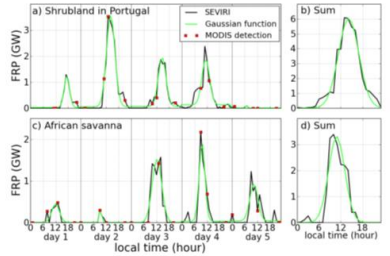
Opportunities for MTG-IRS

Volcanoes:

- SO_2 ν_3 band will not be accessible; alerts based on SO_2 will be possible using signal in ν_1, likely only for large eruptions
- Ash alerts will be possible and benefit from the improved spatial/temporal sampling

Fires:

- CO, NH_3 and VOCs at higher resolution with diurnal sampling



Questions

- Will IRS contribute to identifying/monitoring extreme events?
- Are there new operational applications to develop?
- Technical: Will these applications not be impacted by the use of PCs

Credits: Pierre Coheur, IRS-MAG meeting

MTG-IRS possible contribution to AC

Global stratos.

Global tropos.

Climate

Opportunities for MTG-IRS

The relevant species (O_3, CO, HNO_3, VOCs) for monitoring the global troposphere and stratosphere will be accessible with IRS. However,

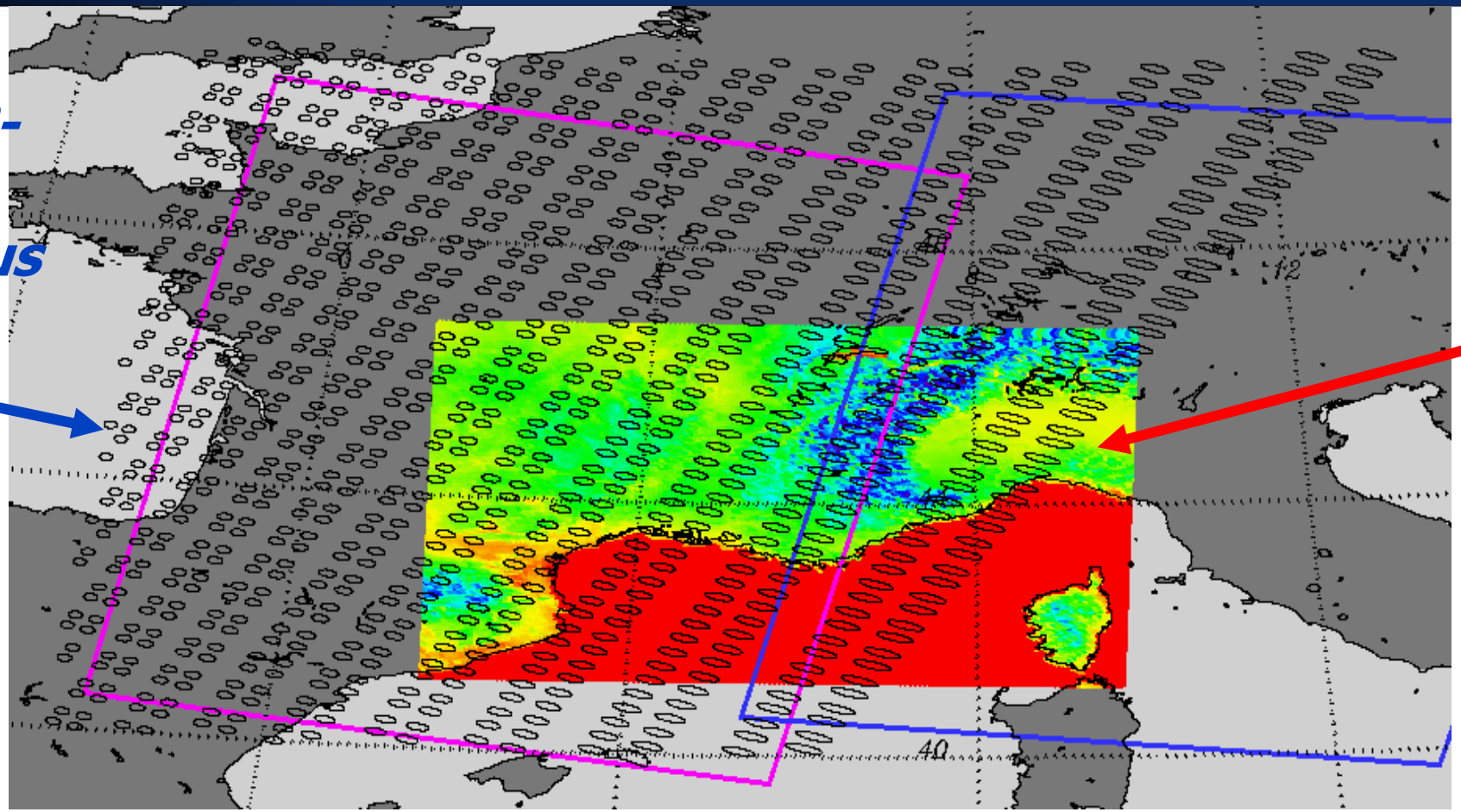
- ✓ **With less vertical sensitivity**
- ✓ **On temporal/spatial scales that are smaller than the processes currently looked at (most applications use averages, in time and space)**

Among the main long-lived greenhouse gases, only CO_2 will be measurable (not CH_4 and N_2O). Several short-lived or indirect climate forcers will be accessible but –as above- with less vertical sensitivity and accuracy.

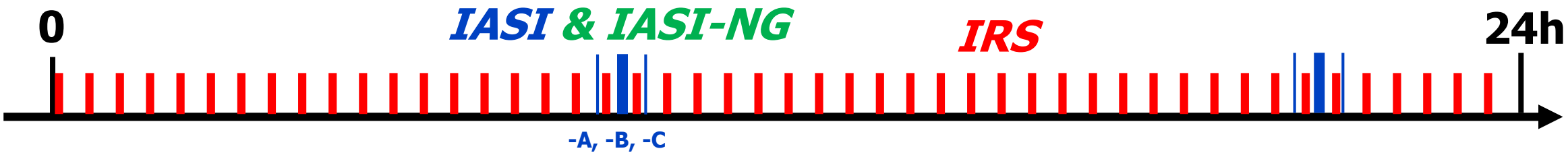
Credits: Pierre Coheur, IRS-MAG meeting

IASI/IASI-NG and MTG-IRS are very complementary

IASI-NG footprints 12-40km Not-contiguous 2x per day



IRS pixels ~7km Contiguous Every 30'



Conclusion - Opportunities for synergies

- ✓ **IASI-NG will provide:**
  - ✓ **high spectral resolution and coverage**
  - ✓ **Better radiometric noise**

→ **MTG-IRS and IASI-NG are then very complementary**

- ✓ **MTG-IRS will provide:**
  - ✓ **high spatial resolution and coverage**
  - ✓ **high temporal repetition**

The coming years we should look at:

- ➔ **Synergies for common species (O_3, CO, NH_3…)?**
- ➔ **How to exploit the complementarity of the different missions?**

+ Start to use the principal component score.

Thank you for your attention!

Acronyms

Acronyms	Definition
AC	Air Composition
AQ	Air Quality
EPS	EUMETSAT Polar System
EPS-SG	EUMETSAT Polar System – Second Generation
IASI	Infrared Atmospheric Sounding Interferometer
IASI-NG	Infrared Atmospheric Sounding Interferometer – New Generation
IRS	InfraRed Sounder
MAG	Mission Advisory Group
MTG	Meteosat Third Generation
OPD	Optical Path Difference (related to the spectral resolution)
PC	Principal Component