The Sentinel-4 Mission:
Instrument Description and Atmospheric Composition Products

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Constellation Sentinel-4, -5, -5 Precursor

- The Sentinel missions are developed by ESA for the operational needs of the GMES (Global Monitoring for Environment and Security) programme
- Sentinel-4, -5, and -5 Precursor are dedicated to the GMES Atmosphere Services (GAS)
  - o **Air Quality Near-Real Time Applications**
  - o **Air Quality Protocol Monitoring**
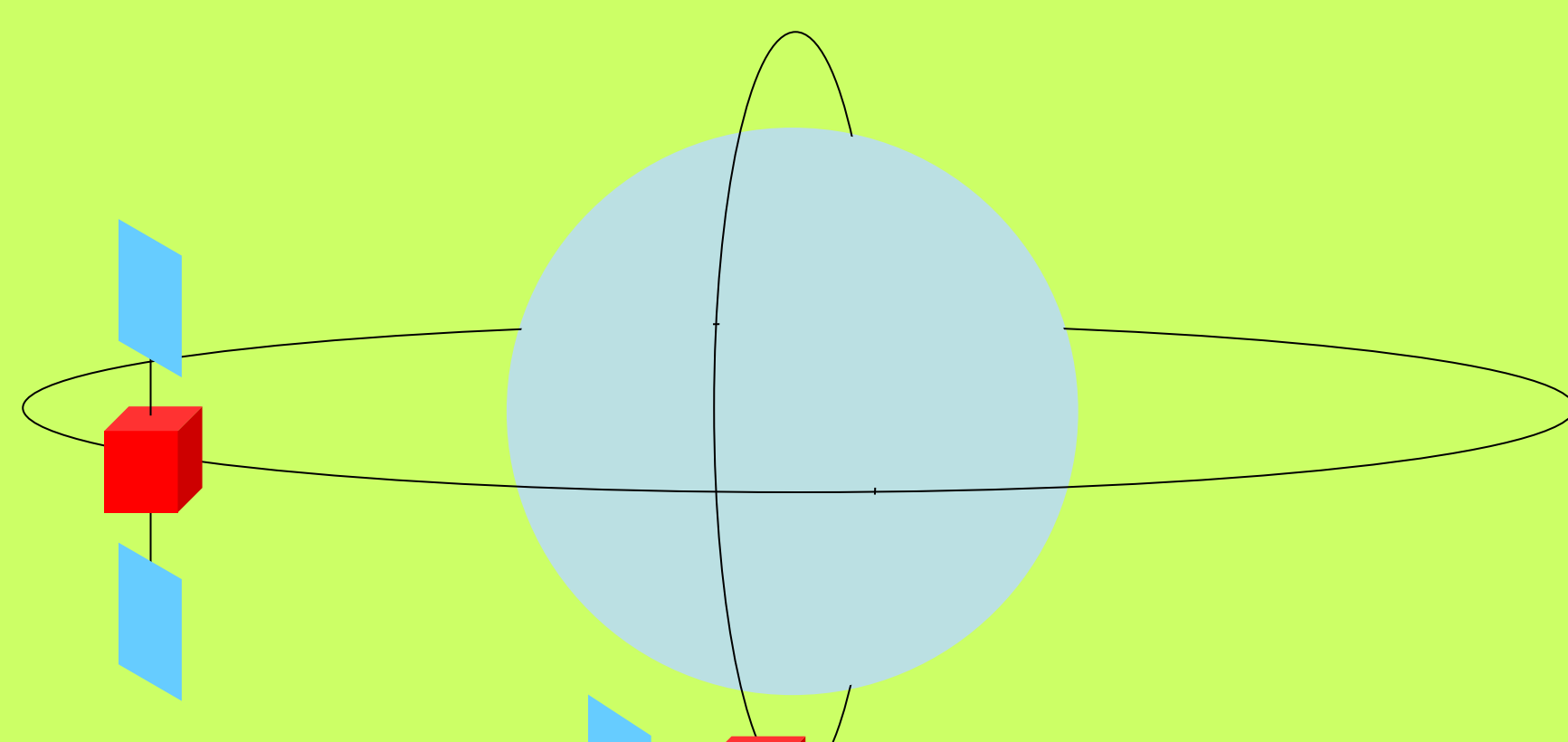 - o **Climate Protocol Monitoring**
- Meeting the needs of the GAS requires a constellation of GEOstationary and Low Earth Orbiting instrumentation
  - o **Hourly revisit time over Europe**
  - o Mainly air quality   → **GEO**
  - o **Diurnal cycle** of tropospheric composition

  - o **Daily revisit time** with **global coverage**
  - o Climate, air quality, ozone & UV   → **LEO**
  - o Tropospheric & stratospheric composition

UV	Ultra violet
Vis	Visible
NIR	Near InfraRed
SWIR	Short-Wave InfraRed
UVN	UV - Vis - NIR
UVNS	UV - Vis - NIR - SWIR

Sentinel-4 (S4) defined as

- **UVN spectrometer** on the **GEOstationary** MTG-S platforms (Meteosat Third Generation Sounding), launch of MTG-S1 ~2019
- Utilisation of data from IRS (InfraRed Sounder) on MTG-S
- Utilisation of data from FCI (Flexible Combined Imager) on MTG-I (Meteosat Third Generation Imaging)

Sentinel-5 (S5) defined as

- **UVNS spectrometer** expected on the **Low Earth Orbiting (LEO)** Metop-SG platforms (Meteorological Satellite - Second Generation), launch ≥2020
- Implementation of atmospheric composition requirements in addition to numerical weather prediction requirements for the IRS on Metop-SG
- Utilisation of imager data from Visible/Infrared Imager (VII) on Metop-SG
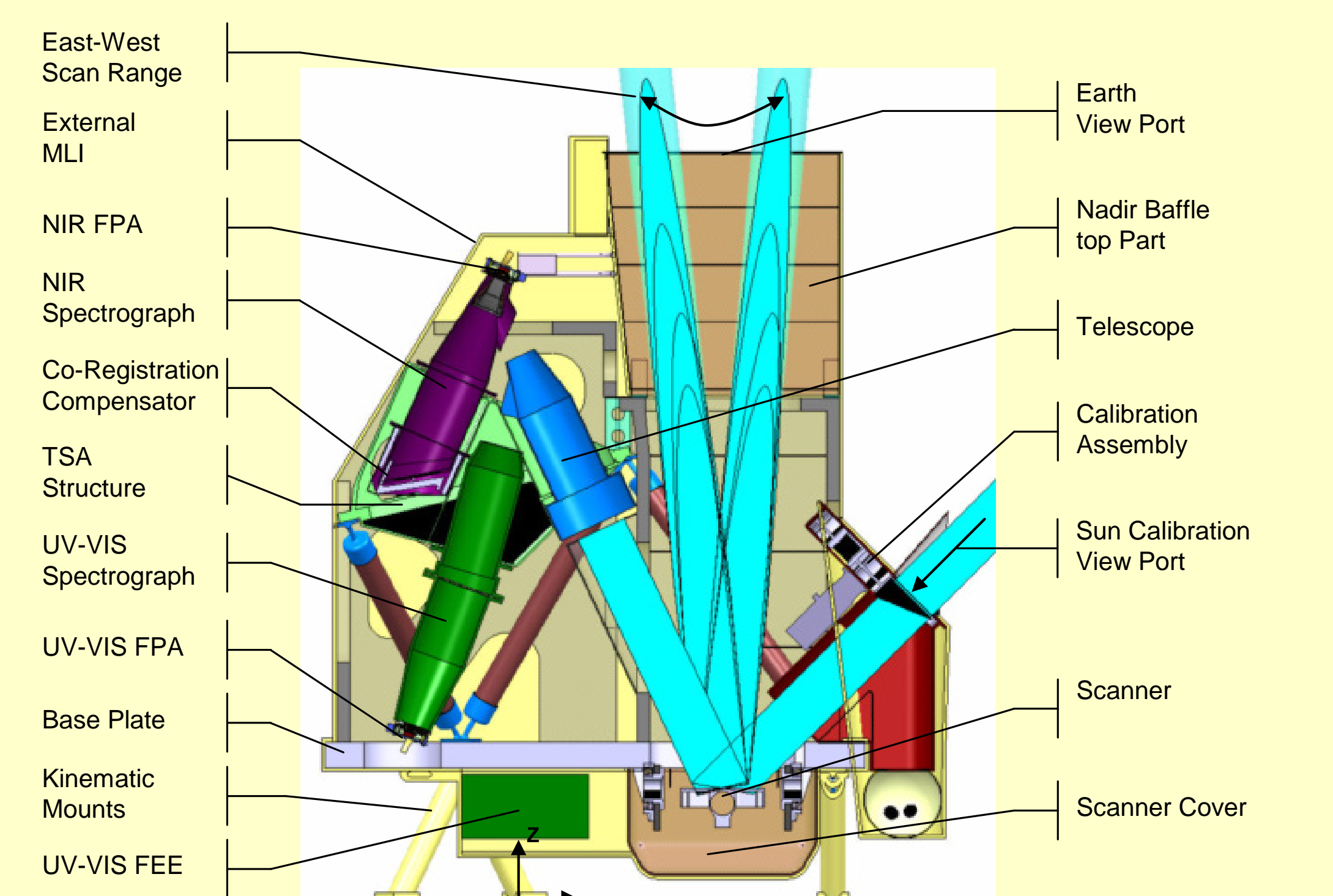- Utilisation of aerosol data from 3MI (Multi-viewing, -channel, -polarisation Imager) on Metop-SG

Sentinel-5 Precursor (S5P) defined as

- **UVNS spectrometer (TROPOMI)** on a dedicated **LEO** platform, launch ≥2014
- Utilisation of data from VIIRS (Visible Infrared Imager Radiometer Suite) on NPP (National Polar-orbiting Partnership)

Geographic Coverage

- Geographical Coverage Area (GCA): Europe + part of Sahara and Atlantic, Observation Zenith Angle < 75°
- Reference Area (RA): subset of GCA
- Push-broom in E/W direction by scan mirror
- Seasonal shift of GCA/RA: southward steps of 5° up to 10° latitude

Scanning scenario (East->West), Jun 21, SZA_max = 92°, RC_min = 10 min

Figures: courtesy Astrium/Deimos

Sentinel-4/UVN Spectrometer

- Imaging spectrometer
- 2 grating spectrometers
- 2 bands: UV-Vis and NIR
- CCD detectors cooled <220 K
- High performance on board calibration sources
- Low sensitivity to polarization <1%
- Low level of spectral features 0.05%
- High radiometric accuracy < 3%
- Spatial resolution 8 km at 45°N
- Revisit time ≤1 h over Europe

Band	Spectral range [nm]	resolution [nm]
UV-Vis	305-500	0.5
NIR	750-775	0.12

East-West Scan Range
External MLI
NIR FPA
NIR Spectrograph
Co-Registration Compensator
TSA Structure
UV-VIS Spectrograph
UV-VIS FPA
Base Plate
Kinematic Mounts
UV-VIS FEE

Earth View Port
Nadir Baffle top Part
Telescope
Calibration Assembly
Sun Calibration View Port
Scanner
Scanner Cover

Yaw-flip at equinox

Sentinel-4/UVN

IRS

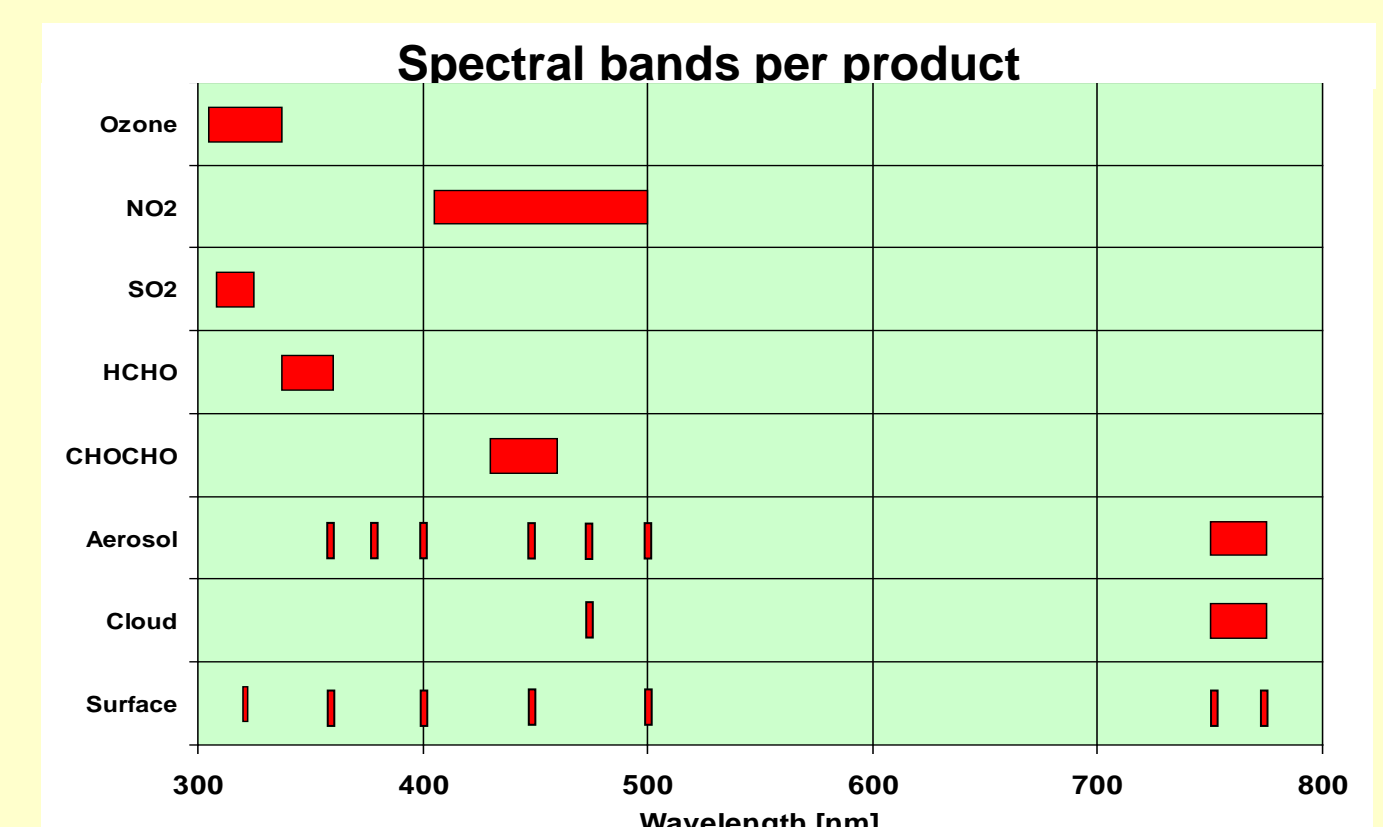Figures: courtesy Astrium

S4 Level-2 Products

- Focus on diurnal cycle of tropospheric composition
  for Air Quality Protocol Monitoring and Near-Real Time applications

Target Products	Application			Comment
	Air Quality	Climate	Surface UV	
O₃ total & trop. column	x		x	
O₃ profile	x		x	Synergy with infrared data from IRS
NO₂ total & trop. column	x			
SO₂ total column	x			volcanic eruptions, temporal averages
CHOCHO total column	x			
CH₂O total column	x			
Aerosol extinction coeff. profile, column optical depth / type / index	x	x		Also for volcanic eruptions. Also auxiliary for other S4 products. Synergy with imager data from FCI
Cloud optical thickness, fraction, altitude			x	Mainly auxiliary for other S4 products. Synergy with imager data from FCI
Surface reflectance daily map			x	Mainly auxiliary for other S4 products

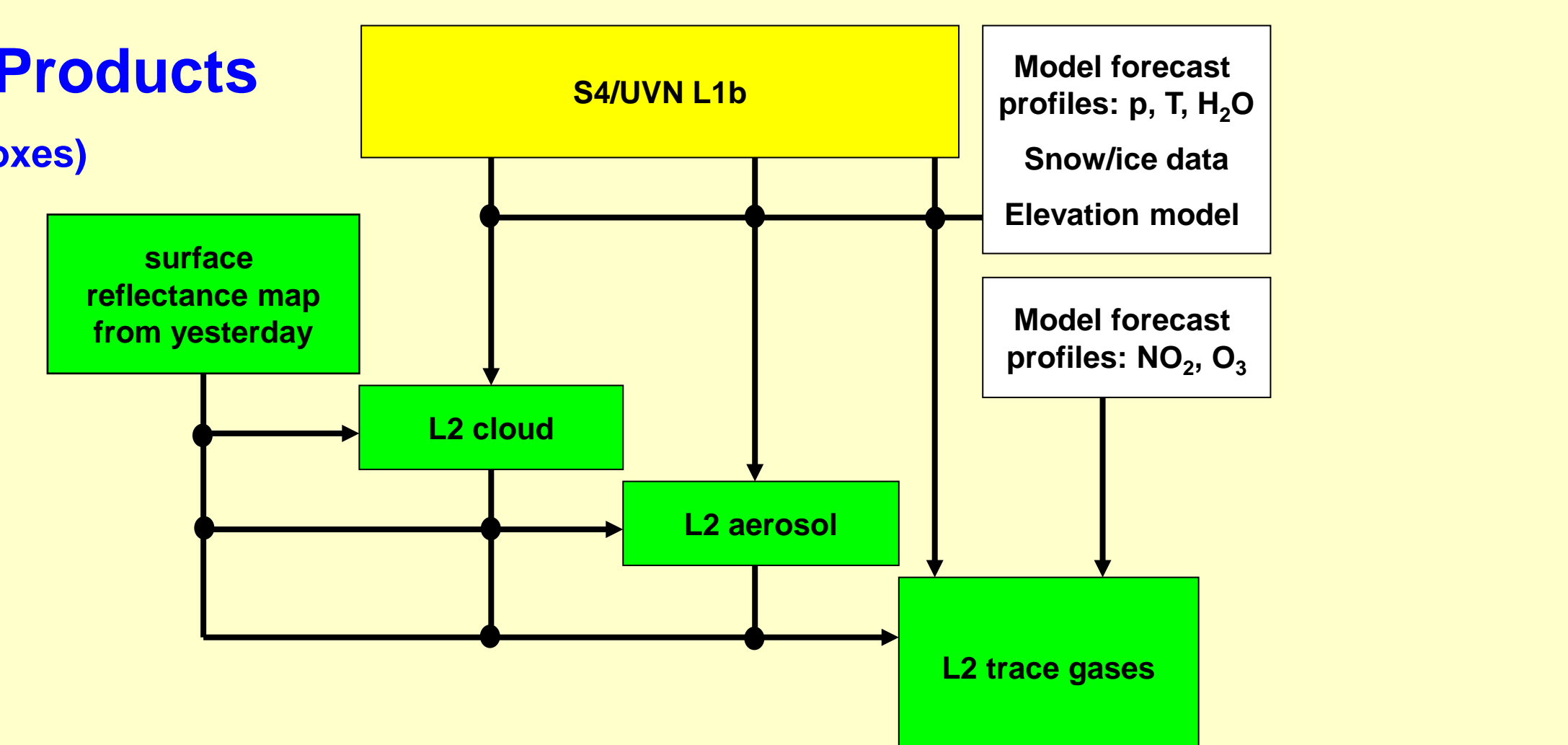IRS-alone products (eg O₃, CO) assumed to be developed by Eumetsat

Challenges

- Monitoring diurnal cycles requires that directionality of the surface reflectance is taken into account to avoid diurnal biases depending on illumination geometry
- Aerosol profile from O₂-A band
- Slant viewing geometries
- …

Spectral bands per product

Core Products
(green boxes)

S4/UVN L1b
Model forecast profiles: p, T, H₂O
Snow/ice data
Elevation model
surface reflectance map from yesterday
L2 cloud
L2 aerosol
Model forecast profiles: NO₂, O₃
L2 trace gases

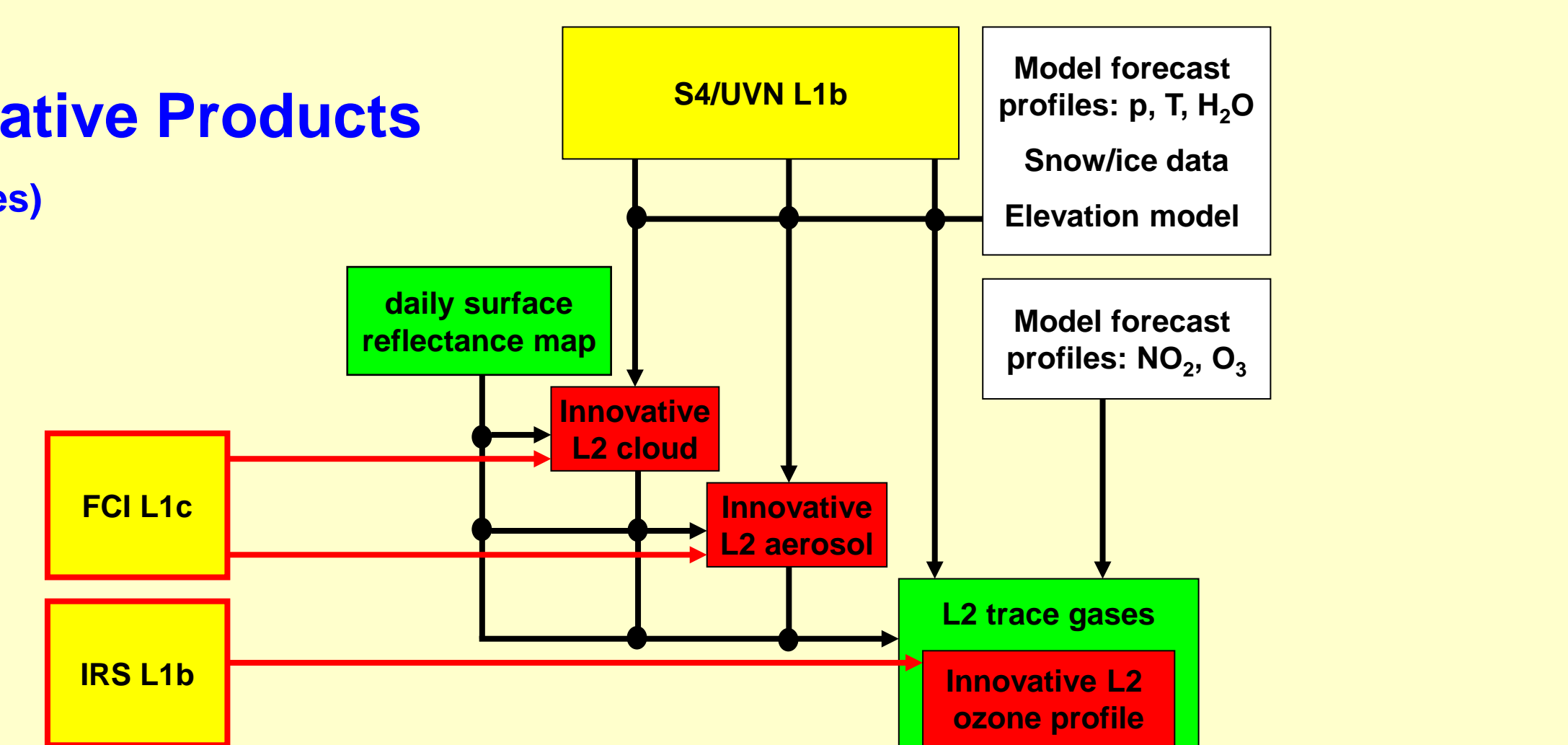### Synergies

- Vertical profiles for NO₂ and O₃: a-priori from forecast model fields used in S4/L2 algorithms
- Cloud info from FCI L2 products exploited in S4/L2 algorithms as optional input
- O₃ profile: synergy with IRS especially for pollution events and high thermal contrast; exploited in innovative synergetic product
- Cloud and aerosol: synergy with FCI exploited in innovative synergetic product
- Long-range transport: synergy with Sentinel-5/5P exploited in GAS using assimilation
- Stratospheric O₃: synergy with Sentinel-5/5P exploited in GAS using assimilation

Innovative Products
(red boxes)

S4/UVN L1b
Model forecast profiles: p, T, H₂O
Snow/ice data
Elevation model
daily surface reflectance map
Model forecast profiles: NO₂, O₃
Innovative L2 cloud
FCI L1c
Innovative L2 aerosol
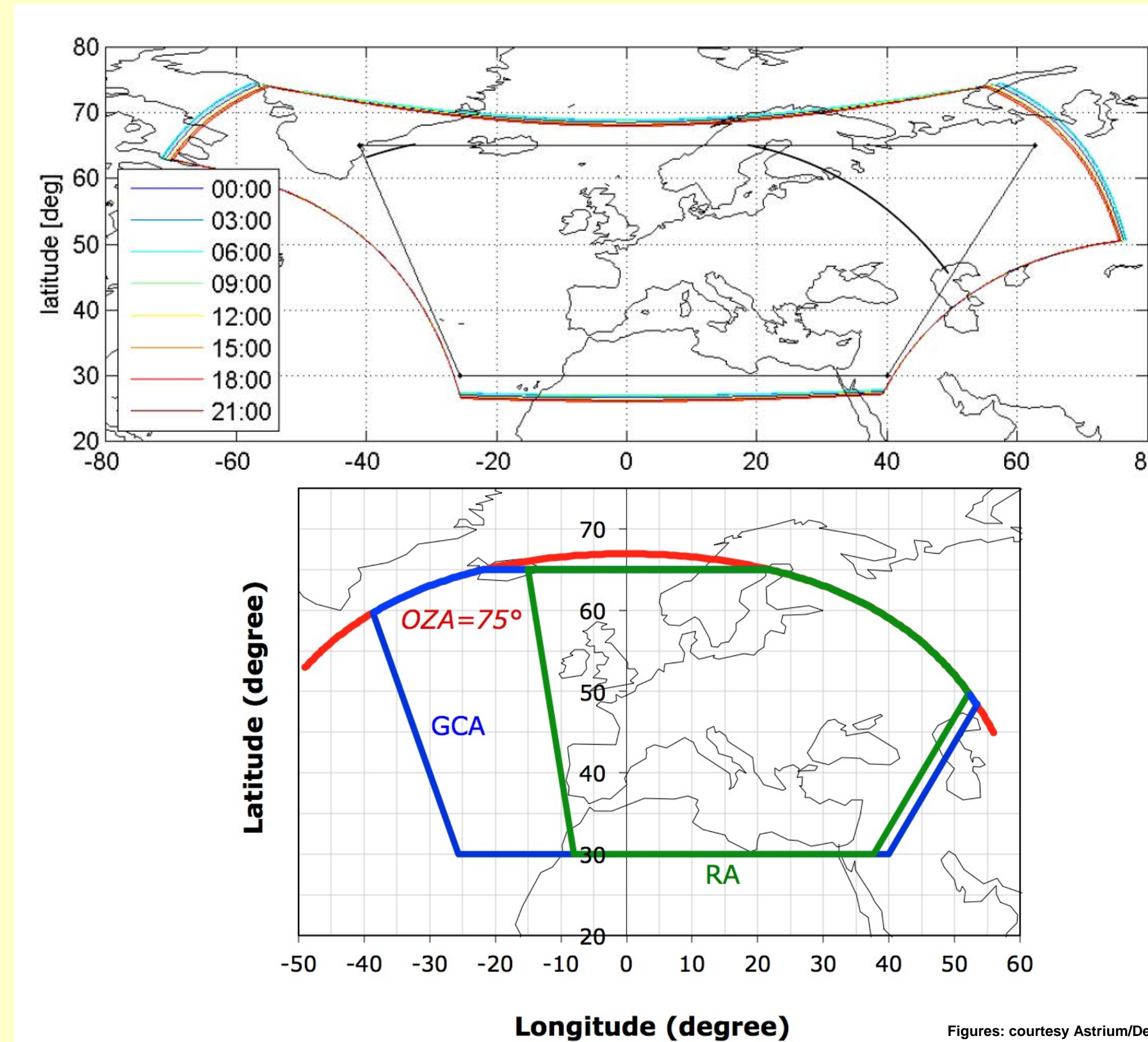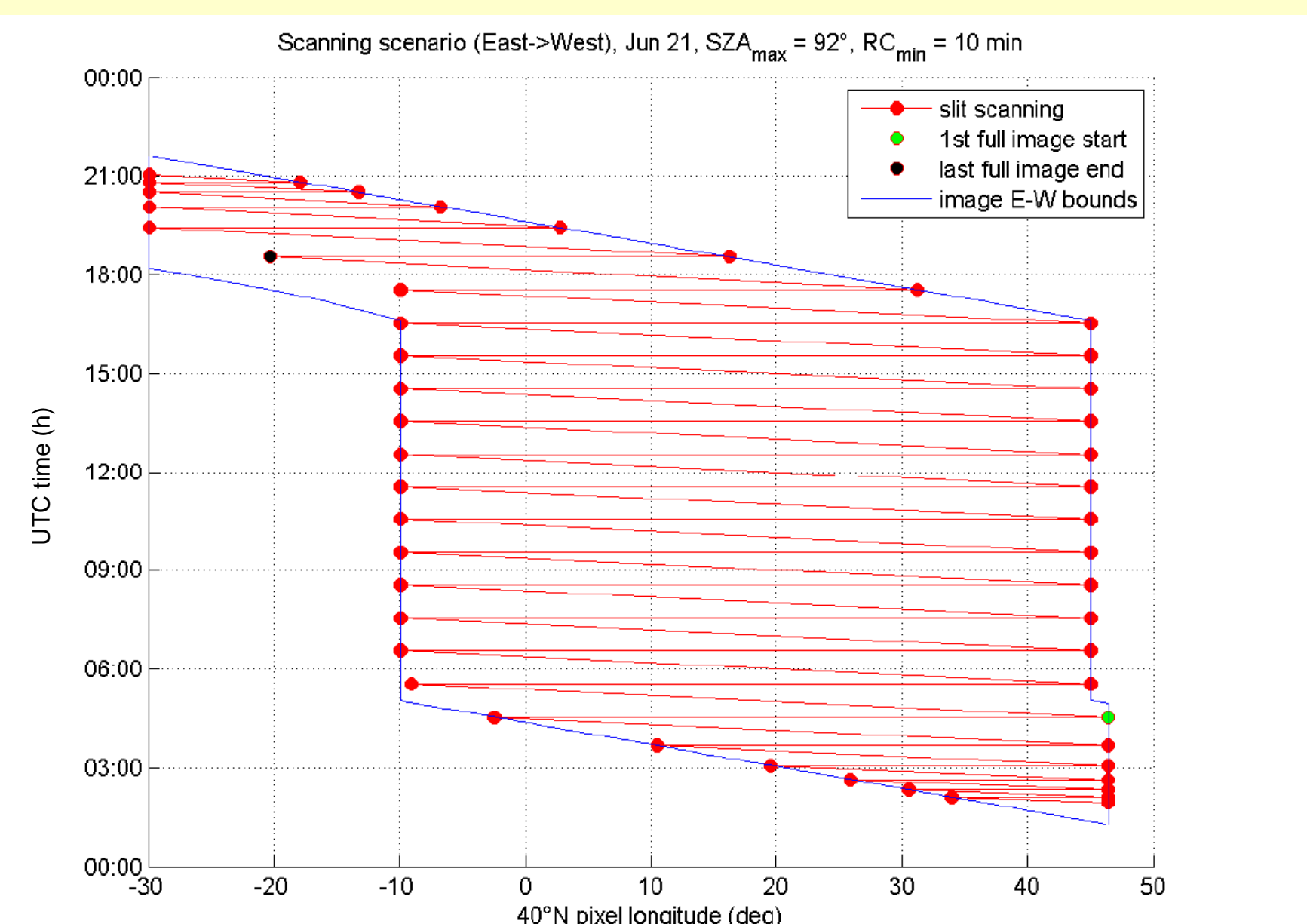IRS L1b
L2 trace gases
Innovative L2 ozone profile

Next Level-2 development steps

- Pre-development for aerosol profile from O₂-A band started
- Pre-development for surface reflectance map product started
- **Algorithm concept development to be set up in 2012**
- Prototype processor development
- Operational processor implementation in MTG ground segment
- Commissioning of Core Products (end of E1) and Innovative Products (later)
- Preparation of exploitation

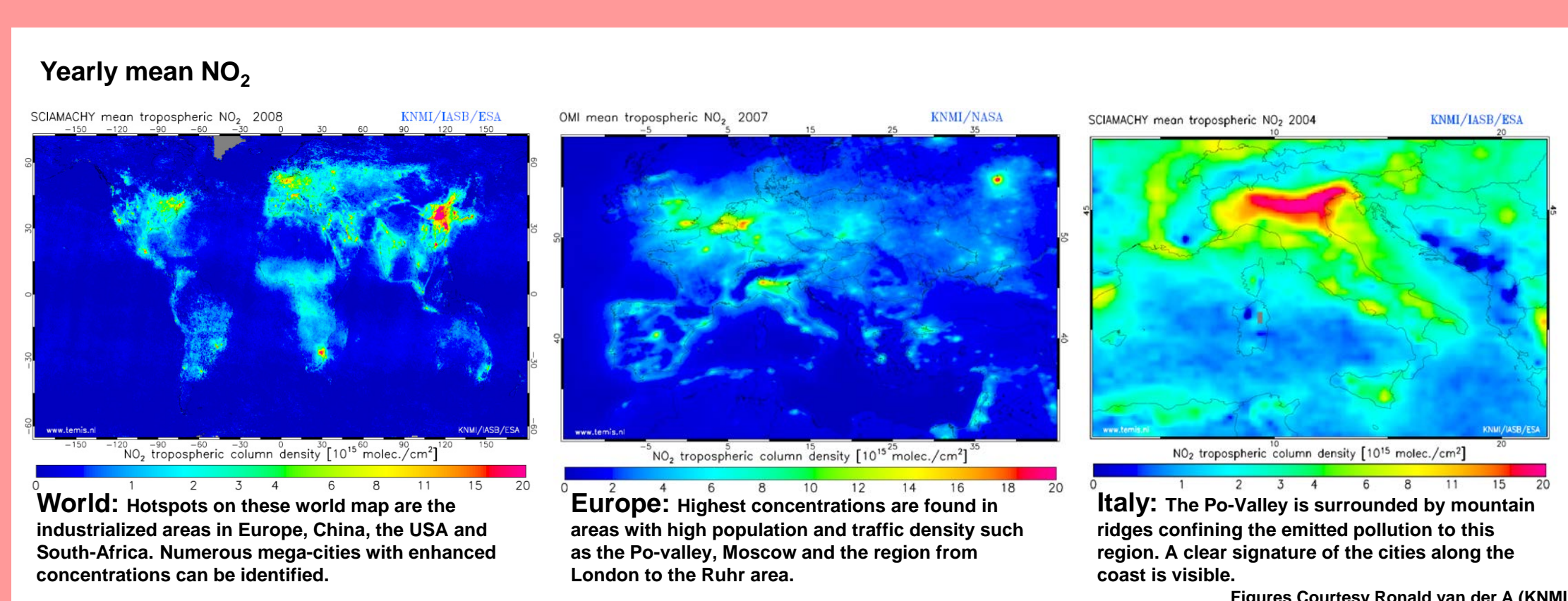## GMES Atmosphere Services (EU projects)

- Monitoring, forecast and reanalysis services dedicated to
- European Air Quality, Global Atmospheric Composition, Climate, UV and Solar Energy services
- Sentinel-4 products used mainly for European Air Quality Monitoring and Near-Real Time applications

MACC-II (Monitoring Atmospheric Composition and Climate Interim Implementation) www.gmes-atmosphere.eu
- Pre-operational GMES Atmosphere Service for global to European service lines

PASODOBLE Downstream Service Project for Air Quality
- Pre-operational downstream atmosphere service for regional to local service lines

Yearly mean NO₂

World: Hotspots on these world map are the industrialized areas in Europe, China, the USA and South-Africa. Numerous mega-cities with enhanced concentrations can be identified.

Europe: Highest concentrations are found in areas with high population and traffic density such as the Po-valley, Benelux and the region from London to the Ruhr area.

Italy: The Po-Valley is surrounded by mountain ridges confining the emitted pollution to this region. A clear signature of the cities along the coast is visible.
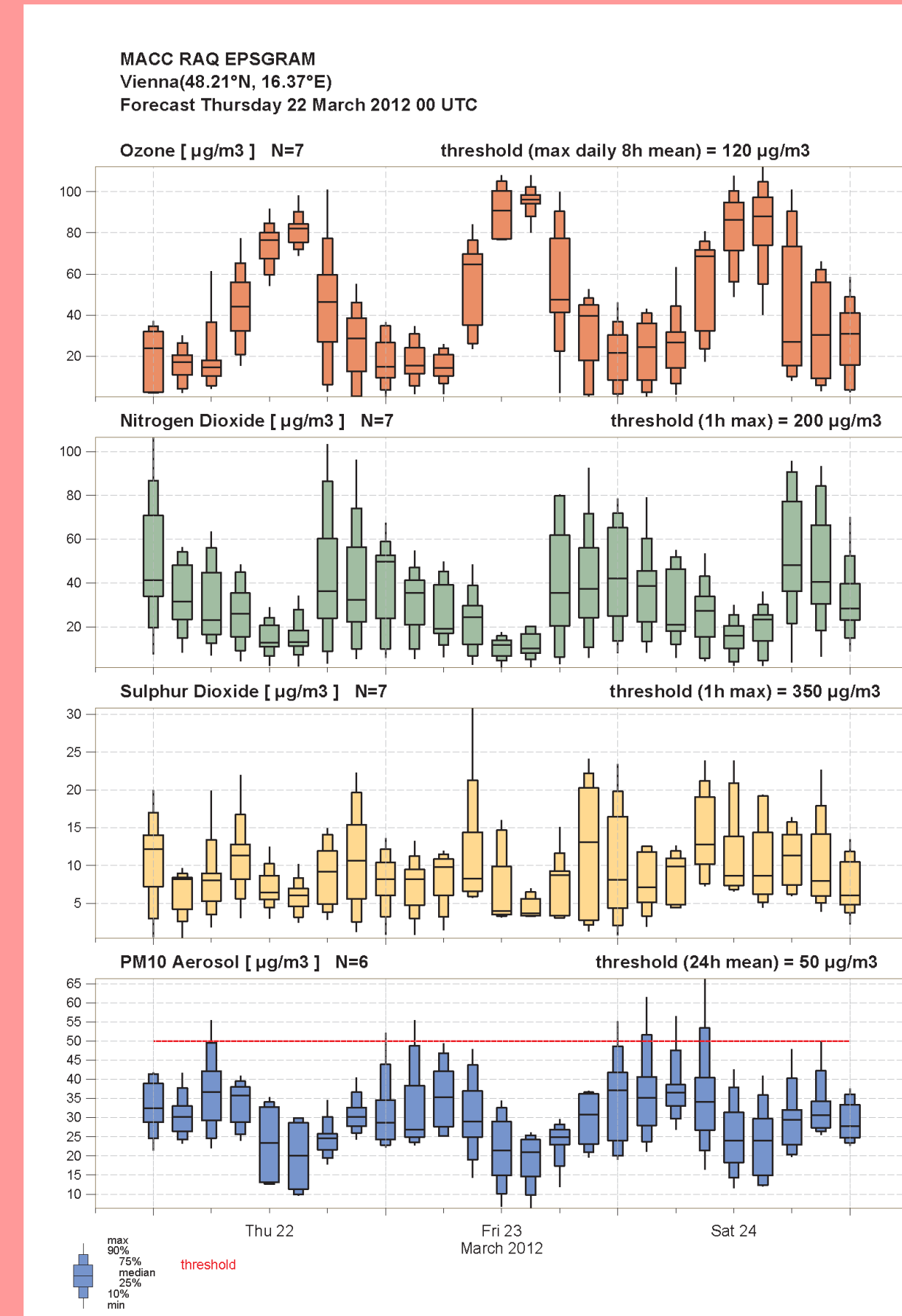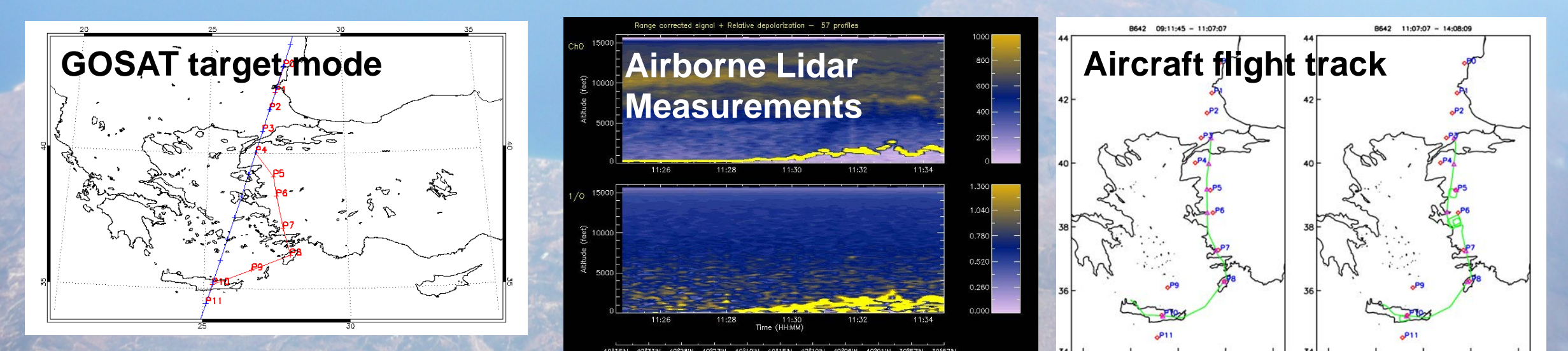
Figures Courtesy Ronald van der A (KNMI)

Figure Courtesy MACC-II

Level-2 Pre-development

- First activity just started
- Aerosol profile from O₂-A band
- Proxy data from GOSAT target mode measurements
- Validation using airborne lidar measurements
- Carbonexp campaign

GOSAT target mode
Airborne Lidar Measurements
Aircraft flight track

Figures: courtesy MetOffice