EE-11 candidate CAIRT

Scientific motivation, goals and mission requirements

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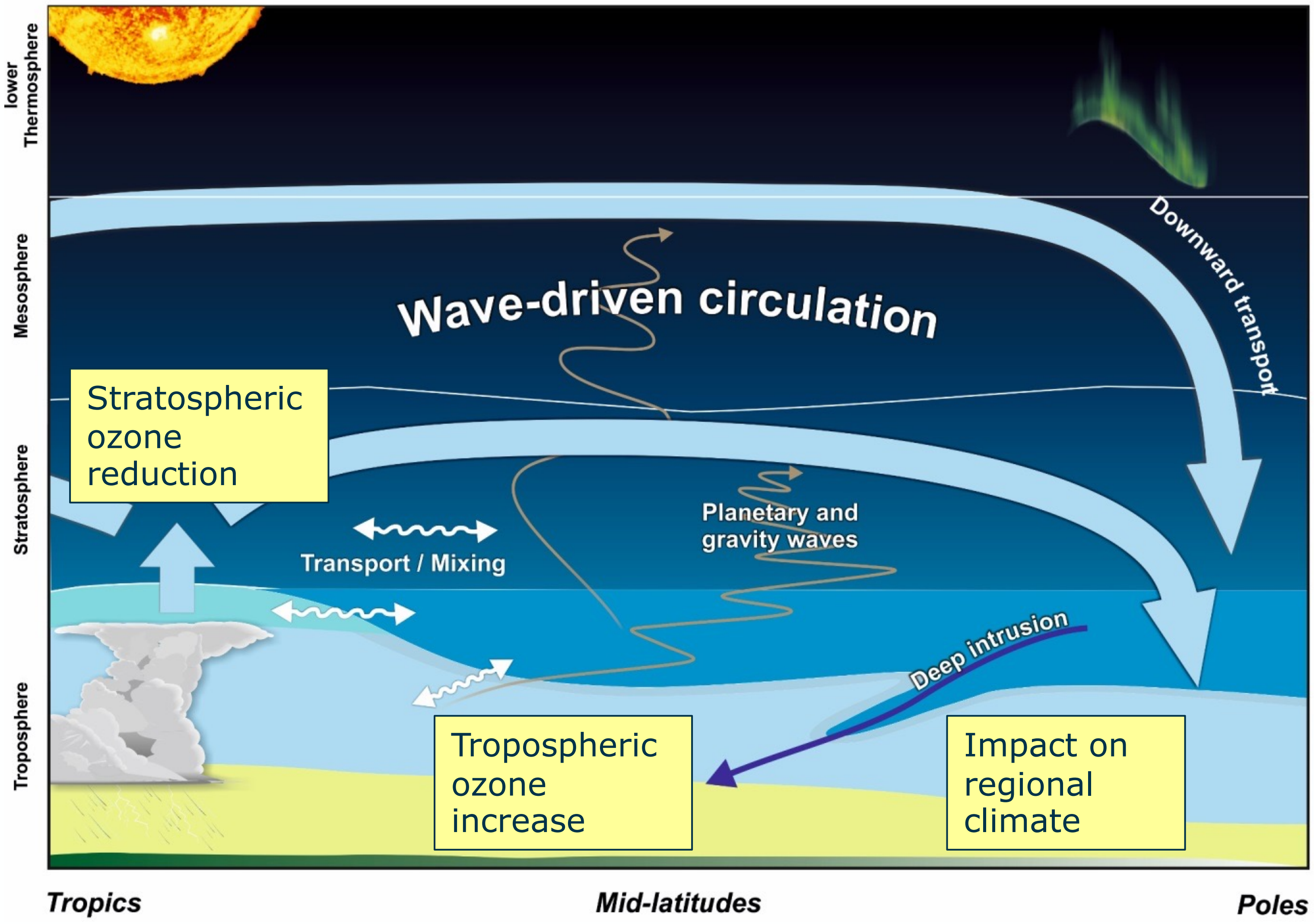
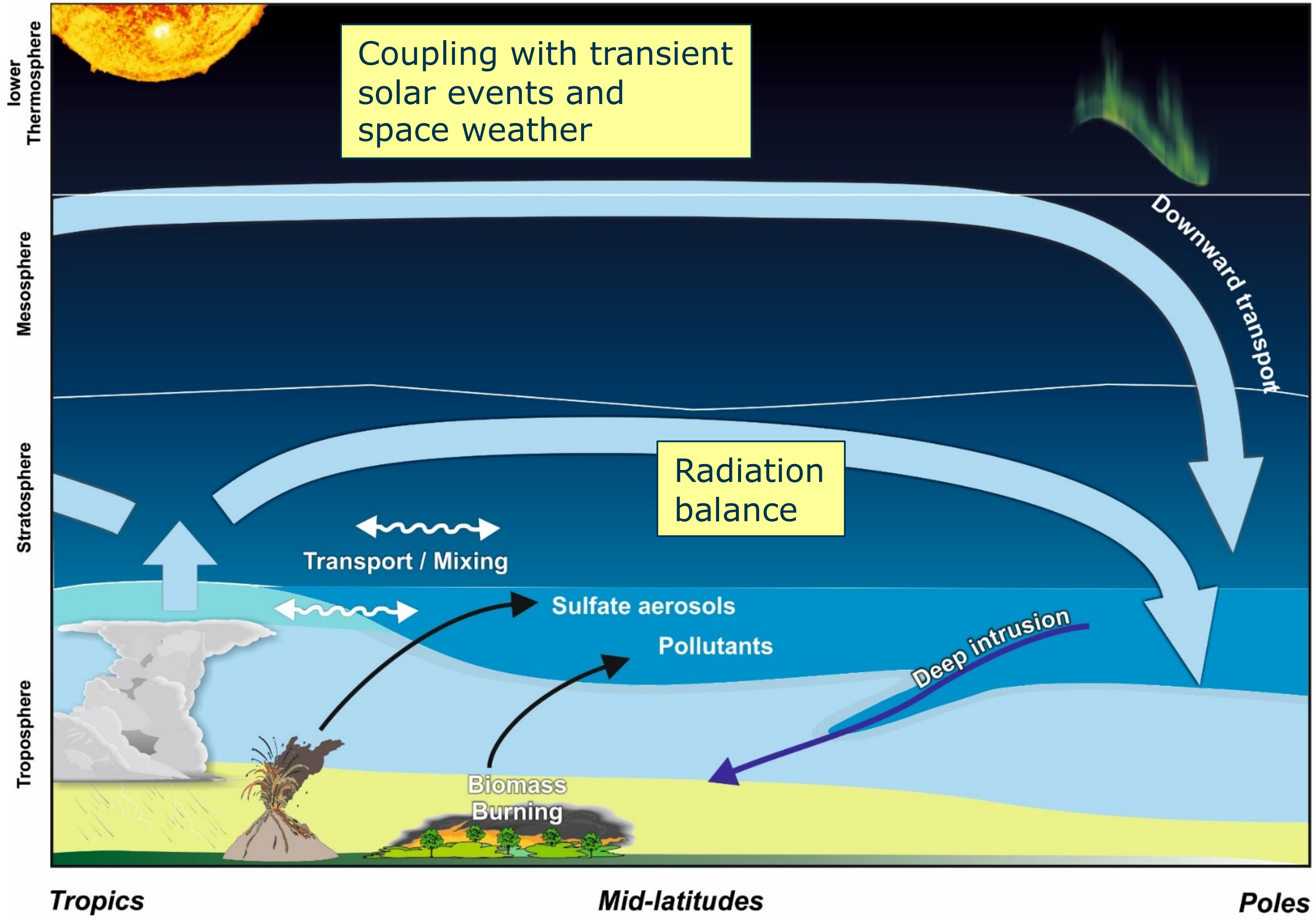
Scientific Motivation and Goals



Evidence for profound changes in:

- Atmospheric circulation
- Wave driving
- Transport and mixing
- Impact on
  - atmospheric composition
  - surface climate

Scientific Motivation and Goals



Evidence for profound changes in:

- Atmospheric circulation
- Wave driving
- Transport and mixing
- Impact on
  - atmospheric composition
  - surface climate
- Coupling with upper atmosphere / space weather
- Stratospheric aerosol budget
- Radiative balance

Mission Objectives

- **Objective A:** Quantify the middle-atmosphere circulation from the upper troposphere to the lower thermosphere by providing accurate and high-resolution observations of age-of-air, temperature and long-lived trace gases

- **Objective B:** Quantify the atmospheric gravity wave momentum flux and wave driving through temperature observations at unprecedented scales

- **Objective C:** Attribute changes in stratospheric ozone due to circulation and chemistry by providing observations of the relevant chemical species

- **Objective D:** Quantify the flux of reactive nitrogen species from the upper atmosphere into the stratosphere to improve our understanding how transient solar events and space weather affect stratospheric ozone and natural climate variability

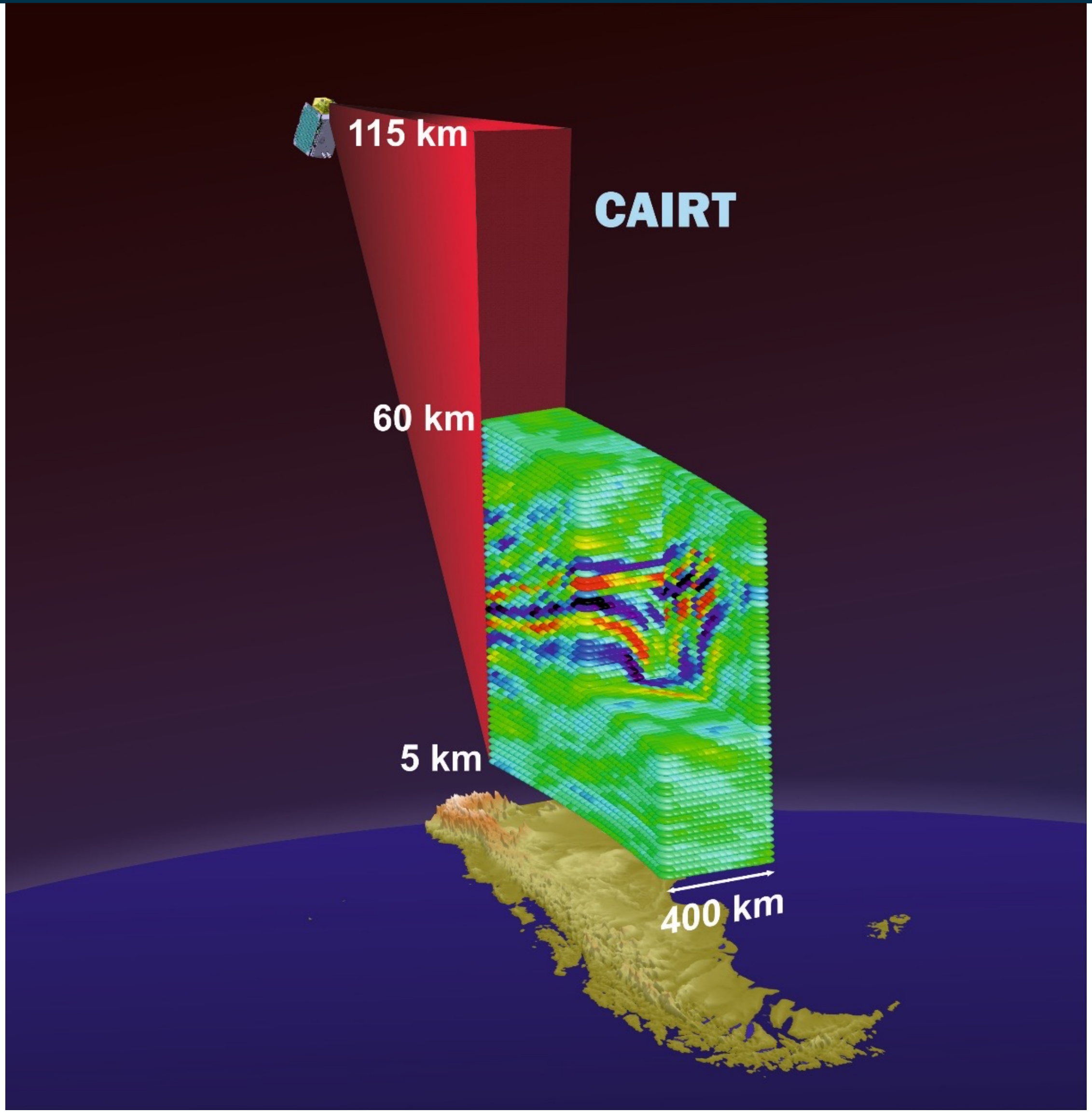
- **Objective E:** Quantify the upper troposphere and lower stratosphere (UTLS) aerosol composition and precursor gases

- **Objective F:** Quantify UTLS variability, stratosphere-troposphere exchange and its impact on tropospheric composition and air quality

Mission Objectives: L2 products

- **Objective A:** Long-lived tracers (**N_2O**, **CH_4**, **SF_6**, **CF_4, CO**) will provide information on **transport, mixing and circulation changes**
- **Objective B:** High-resolution measurements of temperature will provide **momentum flux**, phase speed and direction of **atmospheric gravity waves**
- **Objective C:** Ozone depleting substances (nitrogen: **NO, NO_2, HNO_3**, chlorine: **CFCs, HCFCs, $ClONO_2$, ClO**, bromine: **$BrONO_2$**)
- **Objective D:** Observations of **NO** and **CO,** from the stratosphere to the lower thermosphere, to derive flux of reactive nitrogen from the upper atmosphere and coupling with solar activity
- **Objective E:** Budget of stratospheric sulfur (**OCS**, **SO_2**, and **H_2SO_4** aerosols)**,** UTLS aerosols (**NH_4NO_3**) and aerosol precursors (**NH_3**) and reactive trace gases (e.g., **PAN**, **HCN**, **C_2H_2**)
- **Objective F:** Flying in formation with Metop-SG will provide **synergies with IASI and Sentinel-5** for measuring tropospheric composition (e.g., **O_3**, **NO_2**, **CH_4**, **N_2O**)

Mission Measurement Concept

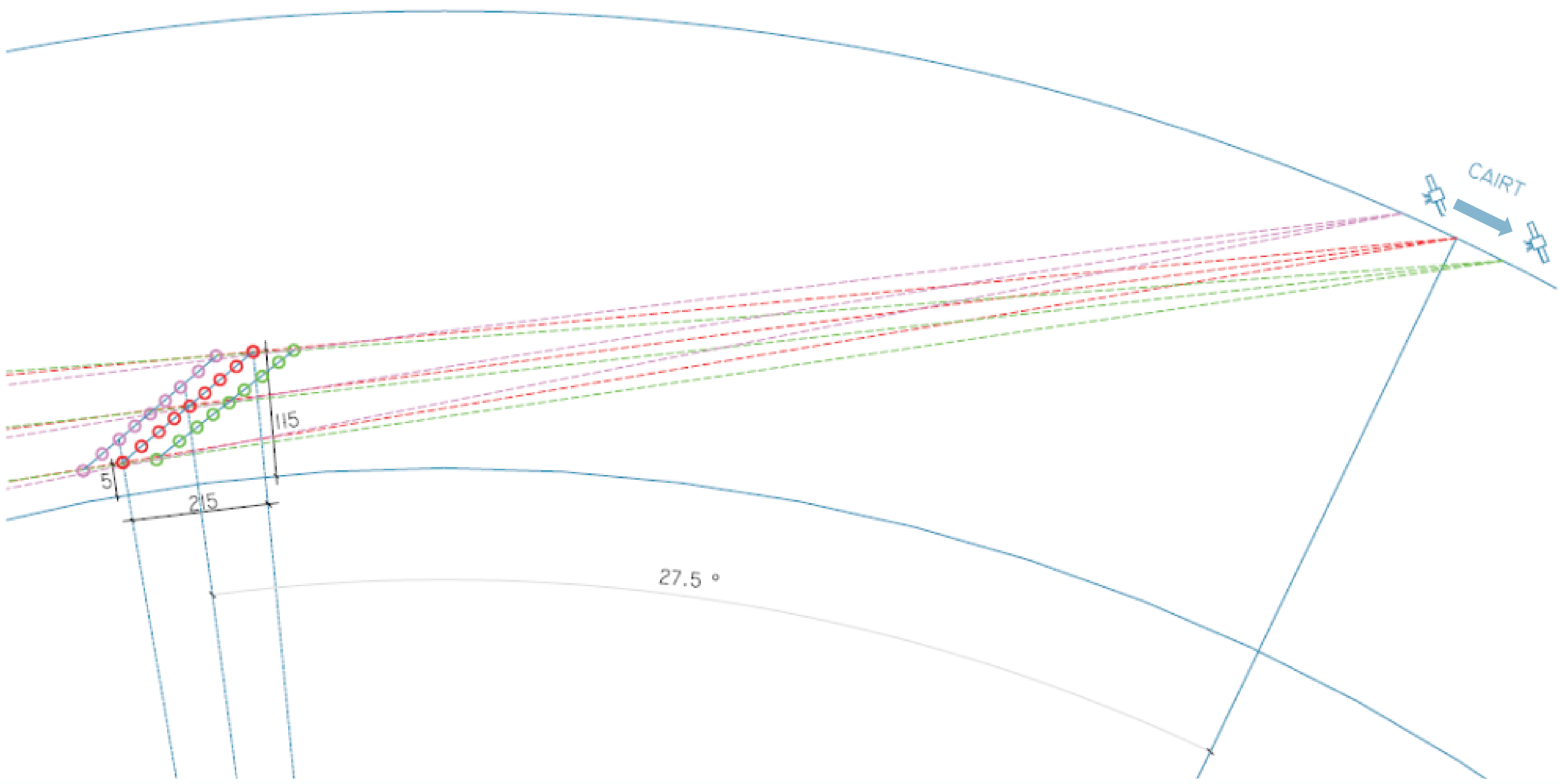


Tomography by infra-red limb imaging

- Imaging Fourier-Transform Spectrometer
- Measuring in the thermal IR with high spectral resolution
- Subsequent images/interferograms can be combined in a tomographic retrieval to get high spatial resolution volumetric temperature and trace gas observations

Mission Measurement Concept

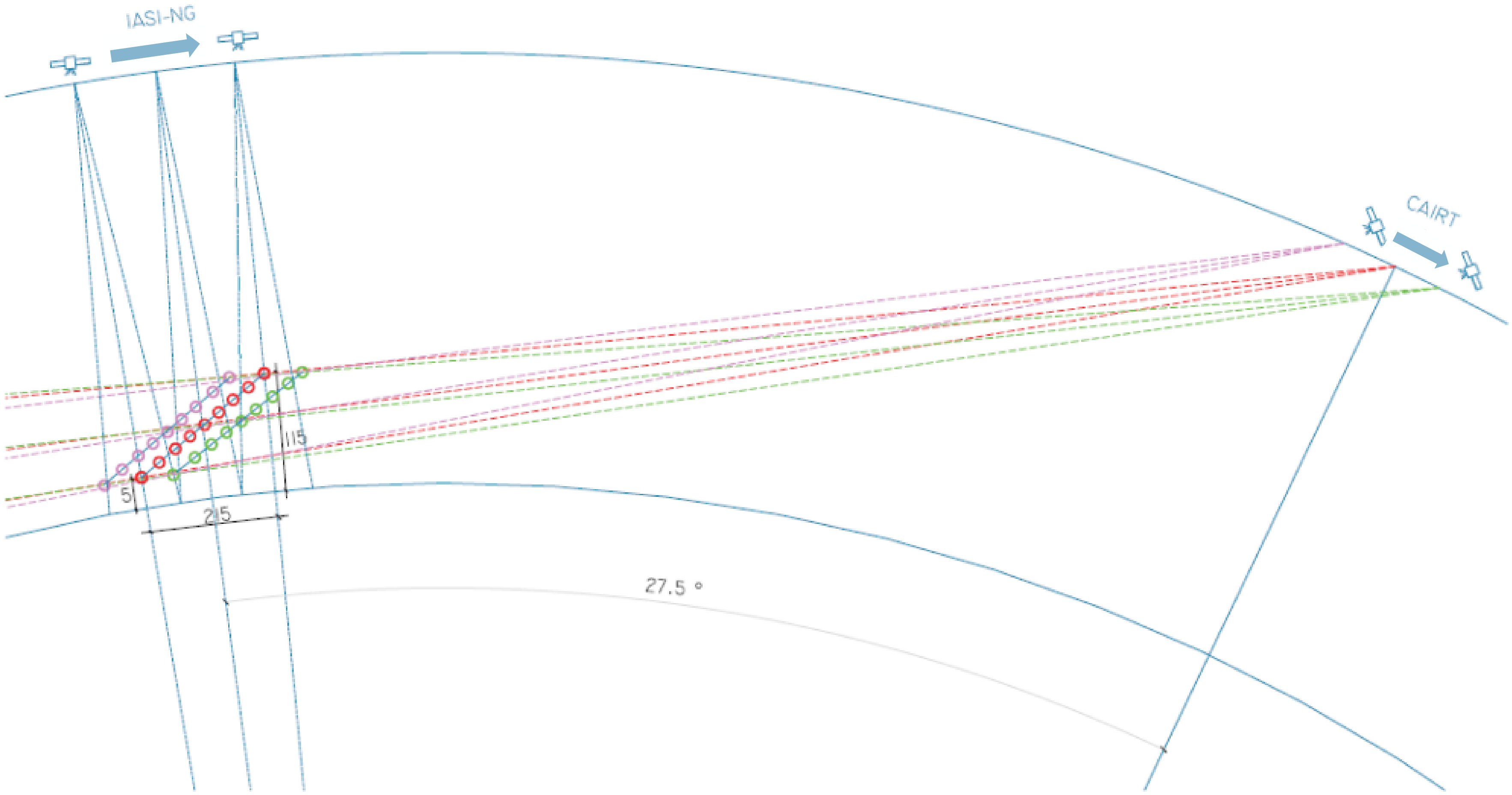
Limb imaging and tomographic retrieval concept



Mission Measurement Concept

Limb imaging and tomographic retrieval concept

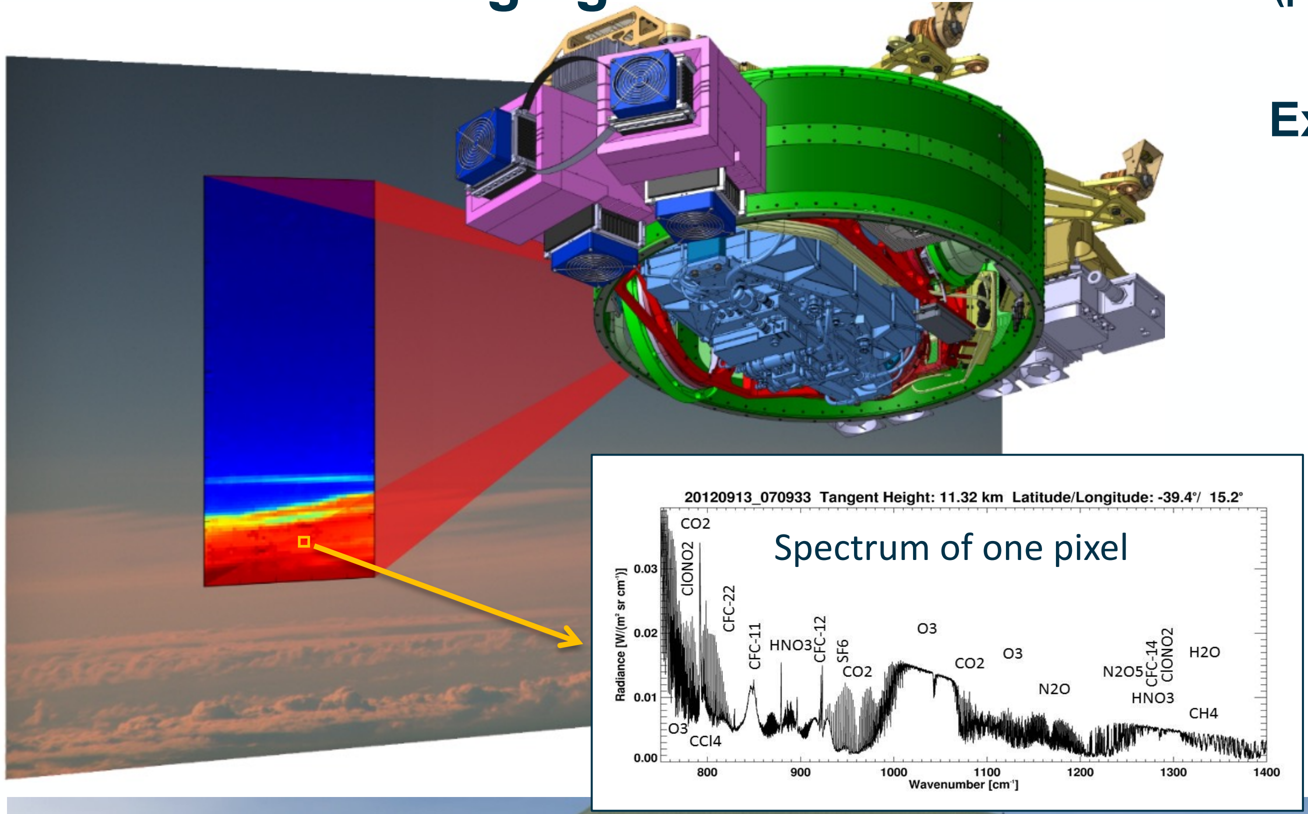
Flying in loose formation with MetOp-SG will provide synergies with IASI-NG

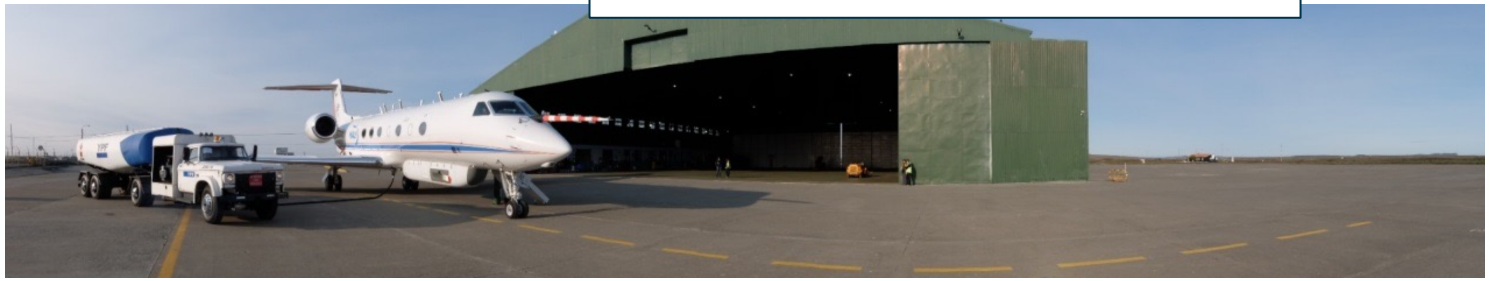


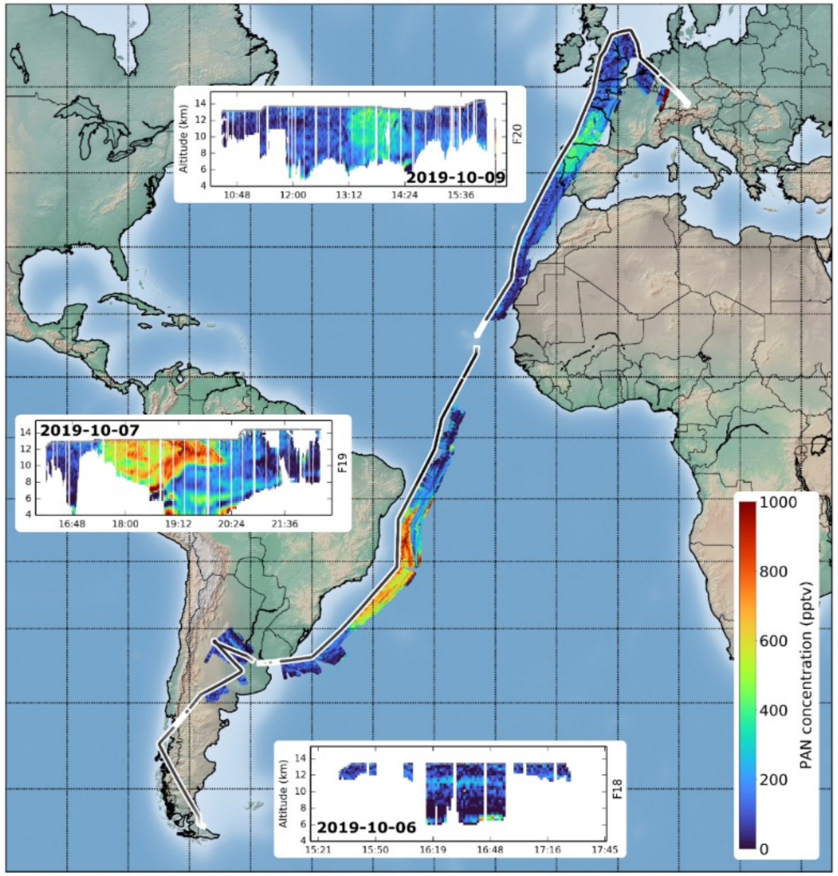
Mission Measurement Concept

Airborne Limb-Imaging Demonstrator GLORIA (providing partial evidence of SRL-4)

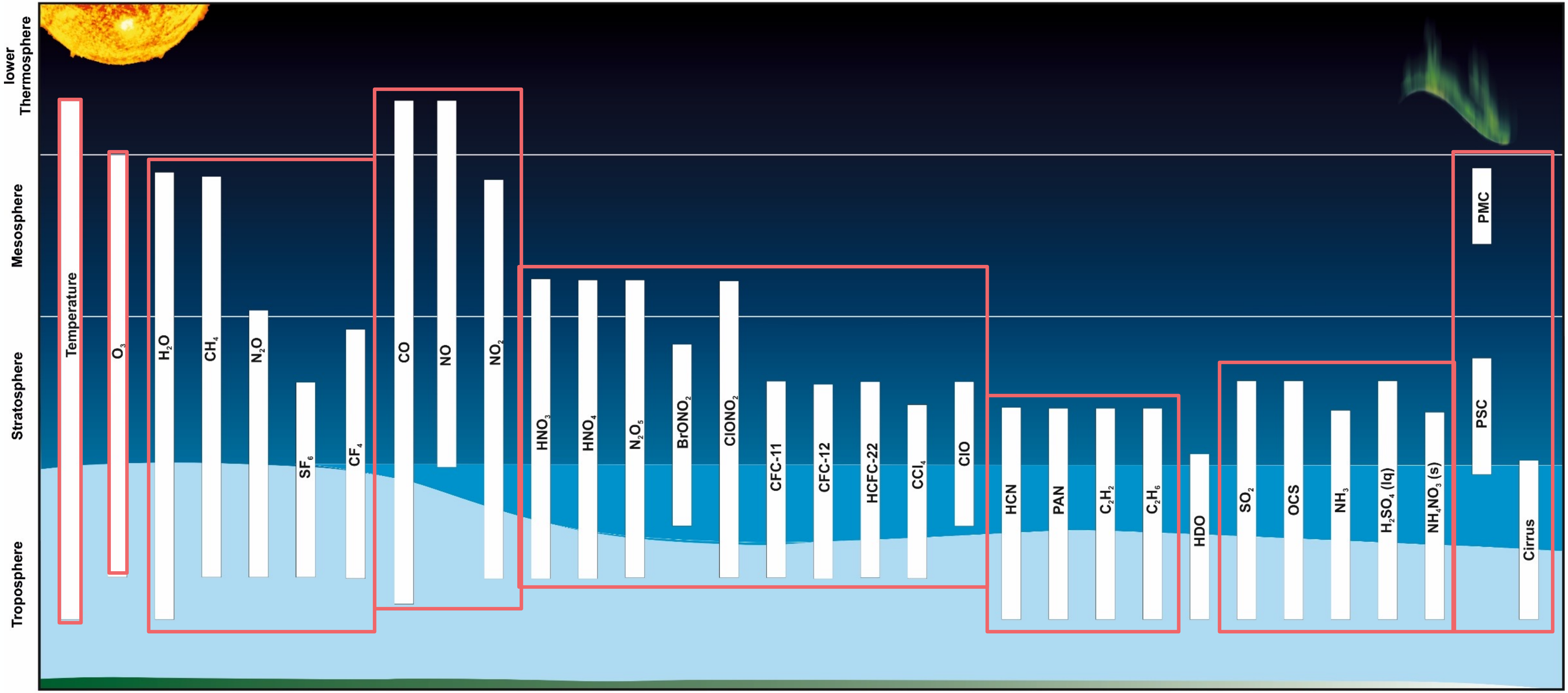
Example: Biomass burning pollution



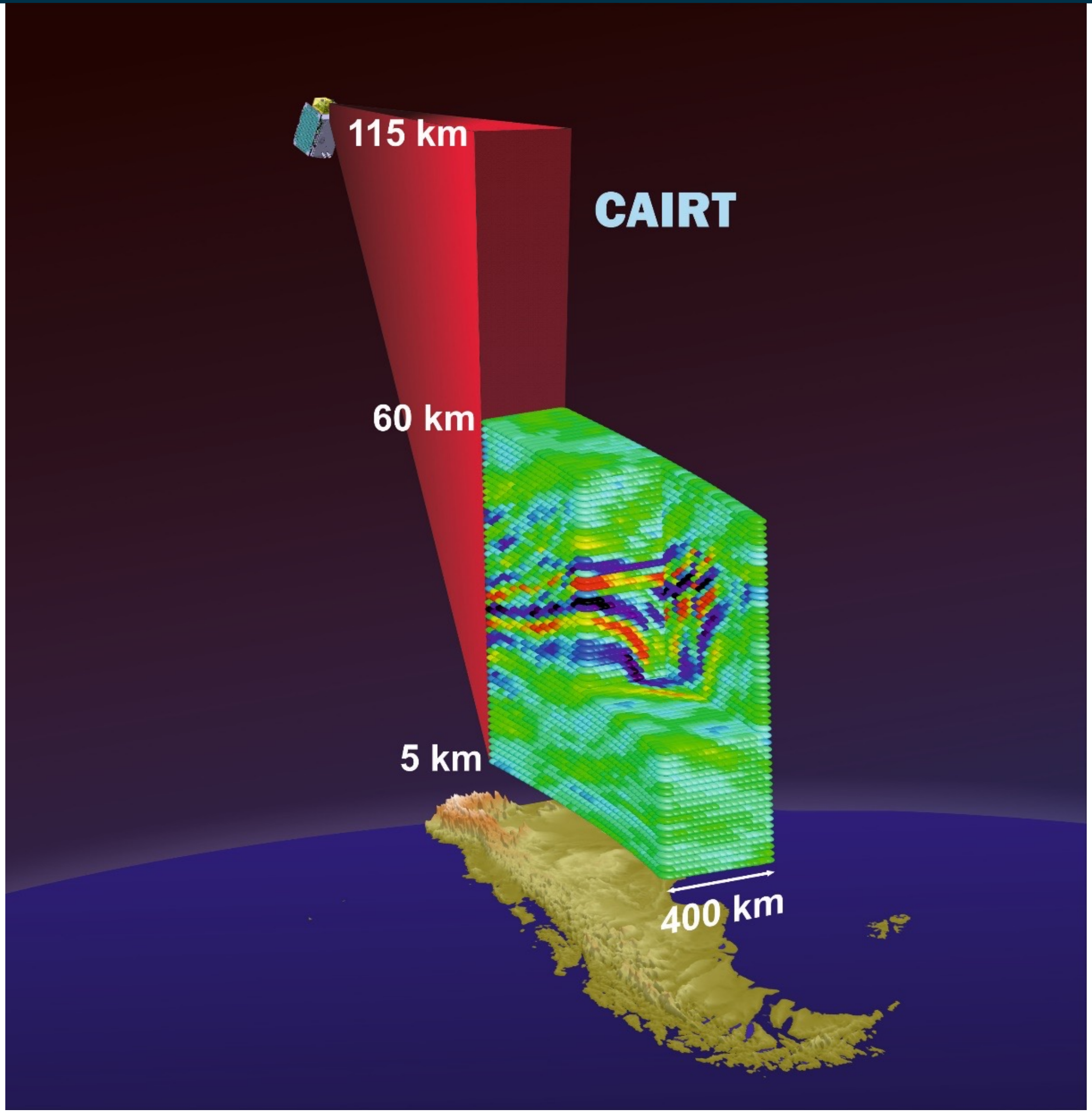




Mission Level 2 Products



Key Mission L2 Requirements



Required resolution of L2 products:

- Vertically ~1km
- Horizontally ~50 x 50 km
- Across track coverage ~ 500km

to detect small scale structures and waves

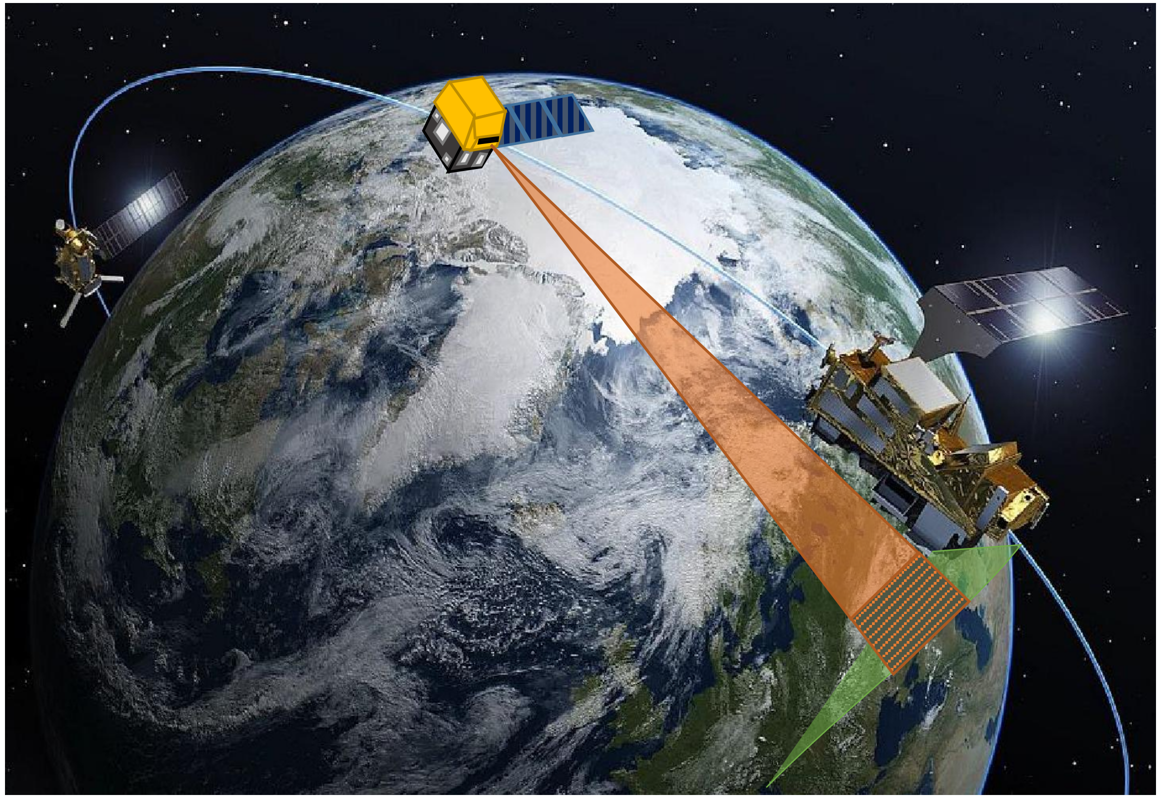
Mission L1 requirements

Requirement	Value Goals (all TBD)
Instrument	Imaging Fourier Transform Spectrometer
Observation mode	Limb viewing
Waveband	720 to 2200 cm^{-1} ~ 4.55 to 13.9 µm
Spatial coverage	V: **5-115 km** H: **500 km**
Spatial sampling	V: **1 km** and SEDF <1.2km H (ACT): **~50 km (with sub-sampling to ~25 km)** D (ALT): **~50 km**
Spectral sampling / resolution	OPD: **5 cm** Sampling: **0.1 cm^{-1}** ILS FWHM: **< 0.125 cm^{-1}**
Sensitivity (NESR)	**< 13** $nW.cm^{-2}.sr^{-1}.cm$ @ 800 cm^{-1} **< 3.3** $nW.cm^{-2}.sr^{-1}.cm$ @ 1650 cm^{-1}

Key System specification

Requirement	Value
Orbit	Loose formation with MetOp-SG (co-imaging with IASI-NG) ➔ SSO orbit @ ~835km 09:30 LTDN TBC
Lifetime	5 years (with 10 years consumables)

Requirement	Value
Launcher	Compatible with launcher policy *(VEGA-C or Ariane 6)*
Platform	• Follow tailored ESA standards for Earth-Explorer missions • Re-use of heritage platform encouraged • Compliant with CleanSpace “DIVE guidelines” for de-orbit and casualty risk



Mission technical challenges

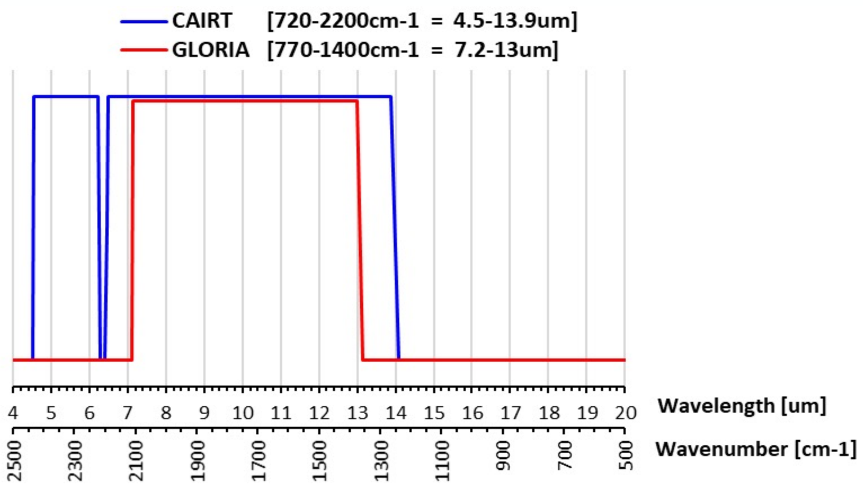
Classical mission architecture: 1 satellite, 1 payload, VEGA-C launcher

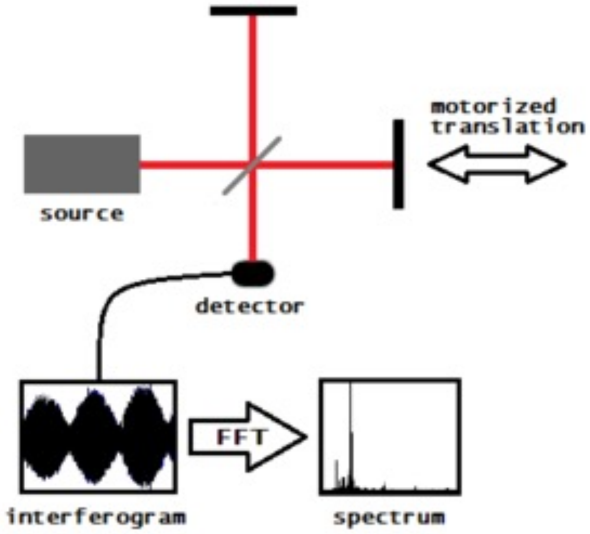
Mission and platform:

- Achieve spatial and temporal co-registration with MetOp-SG

Payload:

- Imaging Fourier Transform Spectrometer (IFTS) meeting performance and observation requirements:
    - Large waveband from MWIR to LWIR ➔ detector, optics
    - Spectral resolution and sampling
    - Large spatial coverage with a 1:5 ratio (Vertical 110km x Swath 500km)
    - Cooling subsystem ➔ mass, cost, complexity
    - Mechanisms ➔ microvibrations, synchronisation, life and reliability, operations
    - IFTS elements ➔ stability, metrology, straylight control
- Achieve the required TRL level for critical elements of the payload

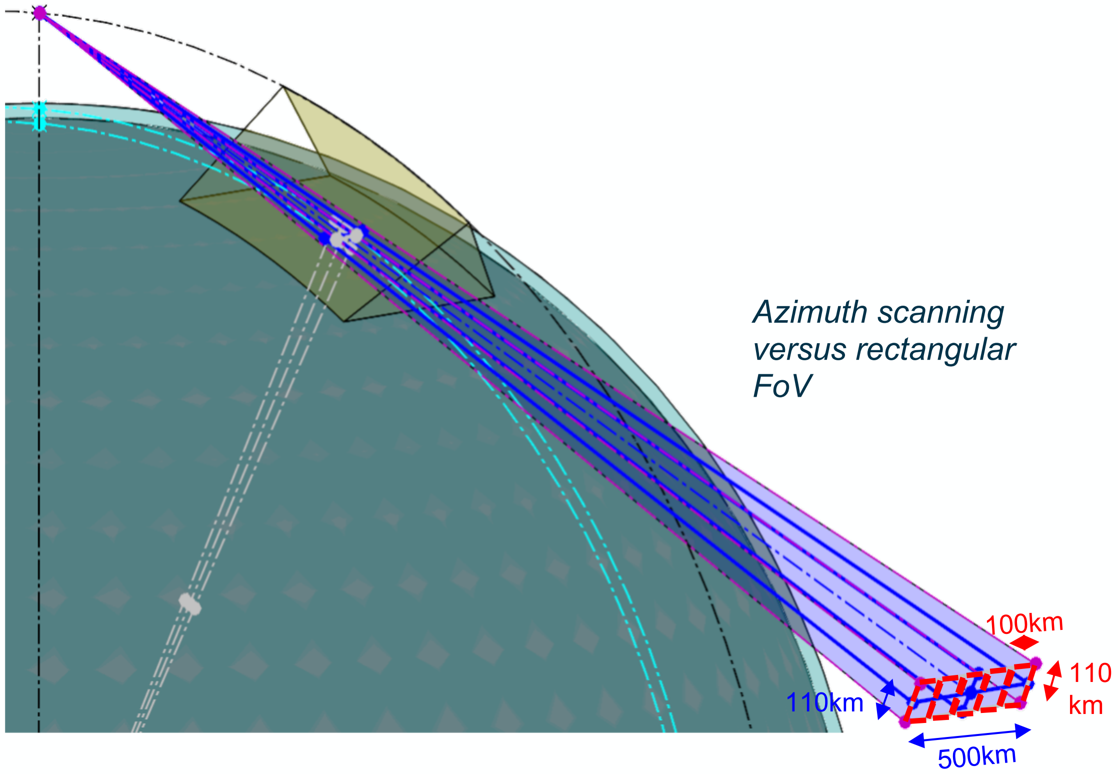




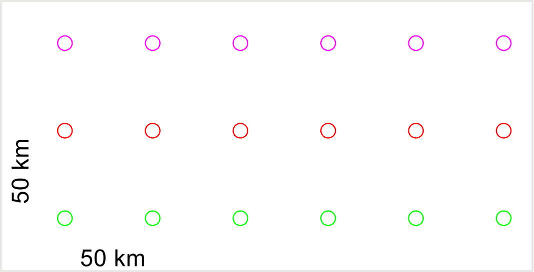
Principle of Fourier Transform spectrometer, for illustration only

Key payload trade-offs

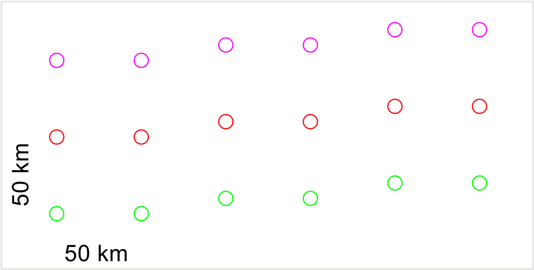
- **Payload architecture:**
  - Detector trade-off: technologies/materials, single sensor versus multiple sensors
  - Across Track swath coverage: Azimuth scanning mechanism versus rectangular FoV
  - Calibration: internal and external sources
  - Redundancy concept
- **IFTS configuration:**
  - Number of ports, dichroic
  - Scanning type: rotating or linear scanning, symmetrical and asymmetrical scanning, etc.
  - 1D or 3D metrology
  - Sizing: aperture, OPD, spatial sampling (binning), performance and stability
- **Cooling subsystem:**
  - Stirling cooler, Pulse tube cooler and Reverse Turbo Brayton
  - Cryostat, Integrated Dewar Cooler Assembly
- **Instrument processor:** on-board versus ground processing



Azimuth scanning versus rectangular FoV



Measurement pattern with 500x110km FoV



Measurement pattern with 100x110km FoV and azimuth scanning

Summary

CAIRT – Changing Atmosphere Infra-Red Tomography Explorer

- First **imaging IR limb sounder** in space
- First **comprehensive measurements** of the relevant processes from troposphere to lower thermosphere
- First **global 3D tomographic mapping** of the atmospheric structure at unprecedented scales
- A **three-dimensional picture of temperature and trace gases** profiles with near global coverage every two days
- Near real time **radiance inputs for weather prediction** and air quality models

➔ Understanding the atmosphere and regional climate change