ESA CCI+ Phase 2 – Atmosphere

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Science questions in Atmosphere

Changes in Earth's atmosphere are driving climate change. However, crucial feedback mechanisms are playing out through water vapour, clouds, aerosol and greenhouse gases which affect climate sensitivity and are not yet well understood.

Major science questions include:

- How can we use atmospheric observations to understand climate sensitivity and biogeochemical feedback processes in the Earth system?

- How can we use atmospheric observations in a process-oriented manner to evaluate and constrain model behaviour?

- How can we best contribute with atmospheric EO ECV data products to Paris-related assessments?

Aerosol

Goals CCI+ Aerosol Phase I:

improve the quality and **consistency** of the **dual view CDR**
(AOD, FM-AOD)

R&D topics:

demonstrate **joint aerosol / cloud retrieval** in twilight zone
Improve surface modelling to **reduce SLSTR AOD bias**
Improve and validate **uncertainty propagation**

Products (released 4/2020 + 4/2021 + 7/2022):

Demonstrator data:
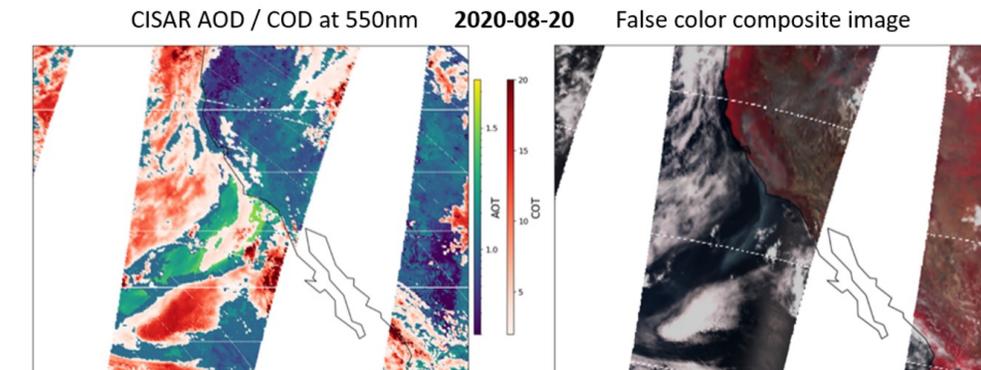Swansea algorithm: ATSR-2 (1998), AATSR (2008),
SLSTR / 3A and 3B (2019, 2020)
CISAR / Rayference algorithm: SLSTR / 3A (1029, 2029

Use cases:

Radiative forcing in decadal steps
SLSTR **data assimilation** into CAMS reanalysis

Discussions on new **WMO climate indicator** "Aerosol cooling offset"

year	sensor	Algorithm version	area	bias	stdv	Pearson corr	GCOS Fraction [1)
2008	AATSR	SU_v4.33	land / Southern hemisphere	0.06	0.10	0.83	34.9
2008	AATSR	SU_v4.35	land / Southern hemisphere	0.04	0.09	0.79	40.1
2008	AATSR	SU_v4.33	ocean / Northern hemisphere	0.03	0.12	0.84	56.2
2008	AATSR	SU_v4.35	ocean / Northern hemisphere	0.02	0.08	0.88	56.6
2019	SLSTRA	SU_v1.11	land	0.05	0.15	0.73	35.2
2020	SLSTRA	SU_v1.14	land	0.03	0.12	0.80	42.7
2019	SLSTRA	SU_v1.11	ocean	0.05	0.08	0.86	40.3
2020	SLSTRA	SU_v1.14	ocean	0.04	0.08	0.83	52.4
2019	SLSTRA	RF_v2.0.0.	land	0.08	0.41	0.17	23.0
2020	SLSTRA	RF_v2.1.1	land	0.00	0.14	0.45	38.6
2019	SLSTRA	RF_v2.0.0.	ocean	0.14	0.35	0.28	19.0
2020	SLSTRA	RF_v2.1.1	ocean	0.05	0.11	0.59	38.7

CISAR AOD / COD at 550nm   2020-08-20   False color composite image
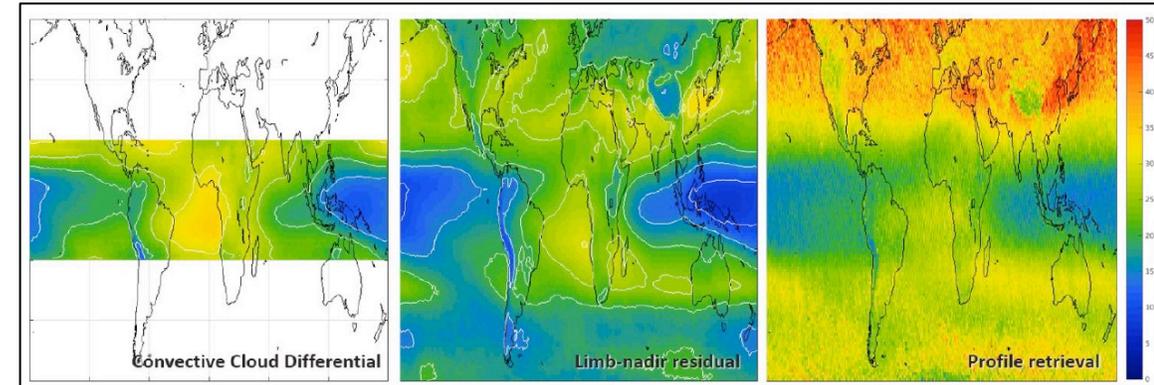
Ozone

Science questions

- Increase confidence in assessments of distribution and changes in **tropospheric O$_3$** (TOAR-I 2018, IPCC AR6).
- Independent nadir profile CDR may further **constrain stratospheric trends** & horizontal structure (LOTUS, 2019).
- Are observed **trends** in the total, stratospheric and tropospheric columns **consistent** (WMO/UNEP 2022)?

R&D and products
(Scheduled release : Dec 2023 – Jun 2024)

- Total ozone : Improve resolution MSR-2 in 1957-1978.
- Tropospheric ozone (reintroduced)
  - Develop 4+ CDRs spanning two decades using 3 complementary techniques.
  - Detailed intercomparison that considers differences in sampling/smoothing of troposphere.

- Nadir profile : Improve L2, first release of merged GOME-type CDR (1995-…) & merged IASI CDR (2008-…).
- Limb profile : Bias-correct L2, increase resolution of L3 and prototype retrieval OMPS-LP on JPSS-2.

Use cases

- Comparison of observed & modelled changes and variability in **tropospheric ozone**.
- Analysis of added value of backward-extended MSR for **ozone monitoring**.

Water Vapour

Main scientific question:

How can we ensure **homogeneity of WV climate data records** in the face of inhomogeneous sensors?

R&D topics:

- **Improve the quality of Phase 1 data records:**
  - Understand/remove jumps and shifts in long term TCWV time series (CDR-1)
  - Remove seasonal and spatial inhomogeneities in VRWV-strato (CDR-3)

- **Extend spatial and temporal coverage:**
  - Extend long-term time series backward and forward in time (all CDRs)
  - Generate regional, temporally limited, high-resolution (~0.01º) (CDR-1)

- **Update and extend input data:**
  - MERIS L1 (3rd → 4th reprocessing); Sentinel 3-B OLCI and MODIS Aqua (CDR-1)
  - HOAPS v5 (until 2020) will become available during Phase 2 (CDR-2)
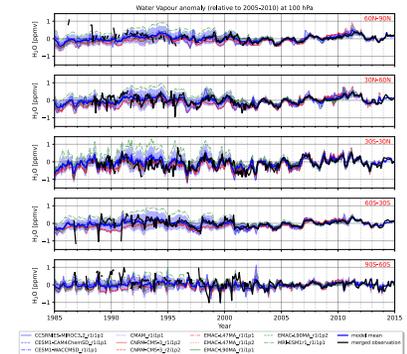 - Historical data rescue (CDR-3) / IMS MetOp A/B (CDR-4)

Use cases:

- **Eiras-Barca et al.,** *QJRMS* 2022 → Analysis of moisture source regions
- **He et al.,** *ACP* 2022 → Evaluation of tropical WV in CMIP6
- **Cross-ECV study** linking SSTs, WV, and clouds **(new)**
- **Stratospheric water vapour** trends, drivers, and radiative forcing **(new)**
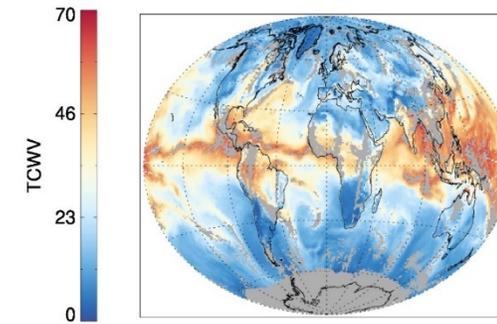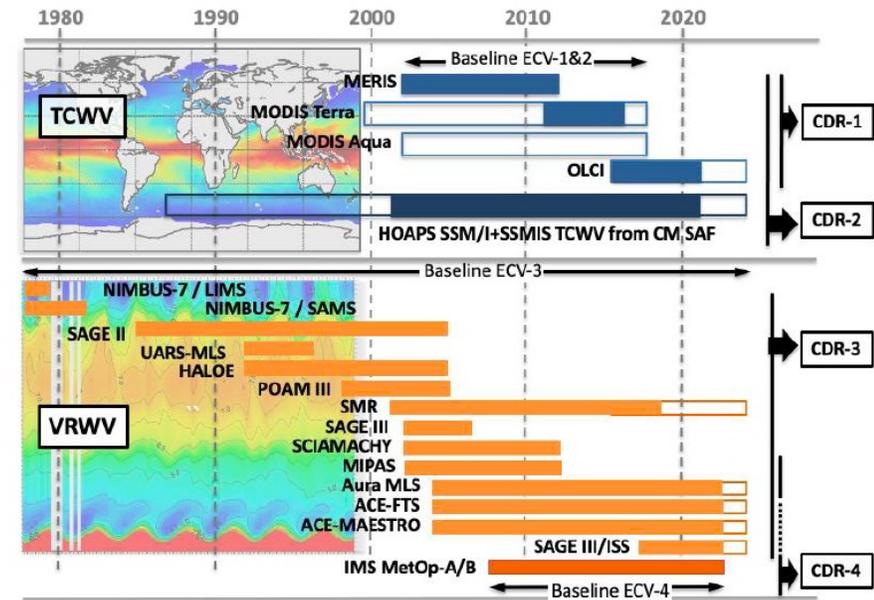
CDR-2/TCWV-combi   **CDR-3/VRWV-strato**

Release date: June 2025
CDR-1 (2002-2023) / **CDR-2** (2002-2020)
CDR-3 (1979-2023) / **CDR-4** (2007-2023)

Clouds

Goals CCI+ Clouds Phase I:
Exploiting the **additional spectral information** available from **SEVIRI and SLSTR** compared to the AVHRR heritage channels used previously in CCI Clouds

R&D topics:
Improve on **cloud detection** and **cloud phase** determination; Improve on spectral properties of modelling **cloud droplet and ice crystal** habits; Use of advanced spectral information for better **cloud height** assignment; Determining the sampling uncertainty of SLSTR.

Products:
Demonstrator data for SEVIRI and SLSTR covering the year 2019 including cloud and radiative flux properties. **Test products** for an innovative multi-layer retrieval.

Use cases:
Designing a "**Sunny Vacation Map**" (completed); **Convection life cycle** in the Congo Basin (ongoing)

GHG
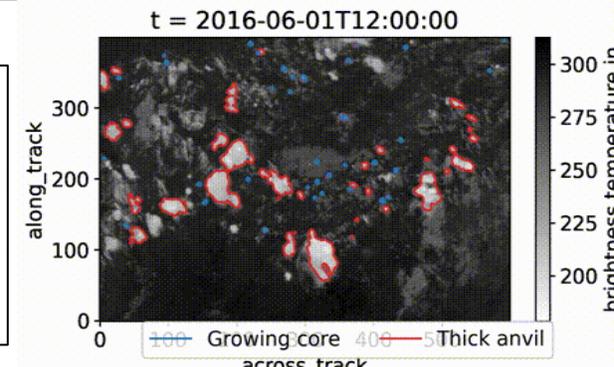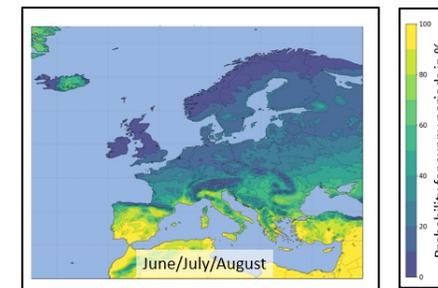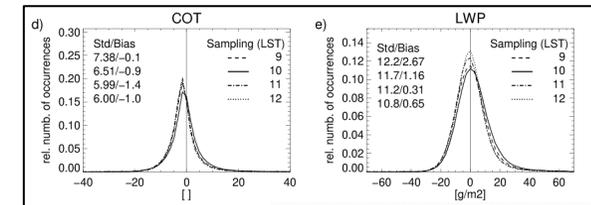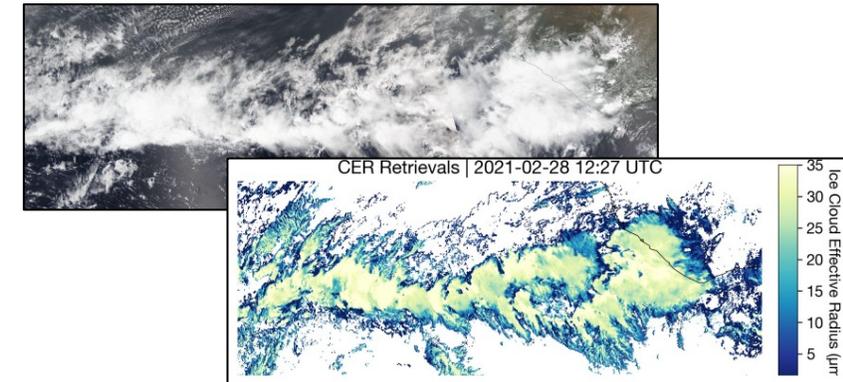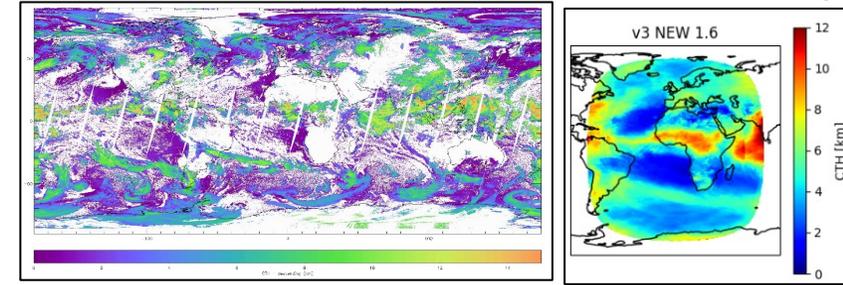
Main Science Question addressed in CCI+ Phase-2

- How to further improve the data quality in terms of **bias reduction** and yield enhancement as needed for the challenging CO_2 and methane sources & sinks applications (including „Paris" & high latitude applications)

R&D topics

- Retrieval algorithm improvements for all products but especially for the **3 (quite new) GOSAT-2 products**, where CCI R&D very useful also for CAMS and C3S (as quality of GOSAT products not yet achieved)
- Other: See Use Cases listed below

## Products (new, updated…) to be generated in CCI+ Phase 2; planned release dates)

- 1st Phase 2 products (CRDP#8, until end of 2022):
  - Improved XCO_2 from **OCO-2 & GOSAT-2**
  - Improved XCH_4 from **GOSAT-2 and S5P**
  - Planned release: Sept. 2023 (end of year 1)

Use Cases (ongoing)

- **Inverse modelling** of CO_2 and methane surface fluxes including hot spot emissions esp. from S5P (GHG CRG but also data provider & cooperations including other projects)
- Studies related to **methane growth rate** and methane at high latitudes

Existing Phase 1 CRDP#7 data products
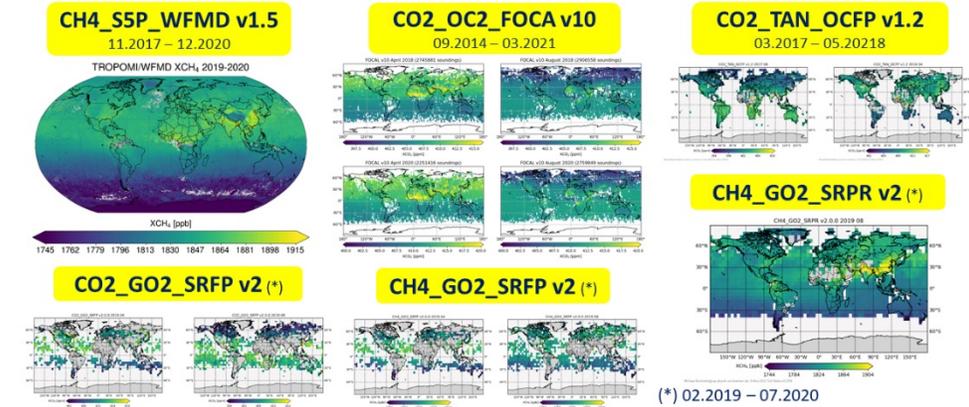
New Phase 2 TROPOMI/S5P methane product (processing ongoing for CRDP#8)

Precursors for ozone and aerosol
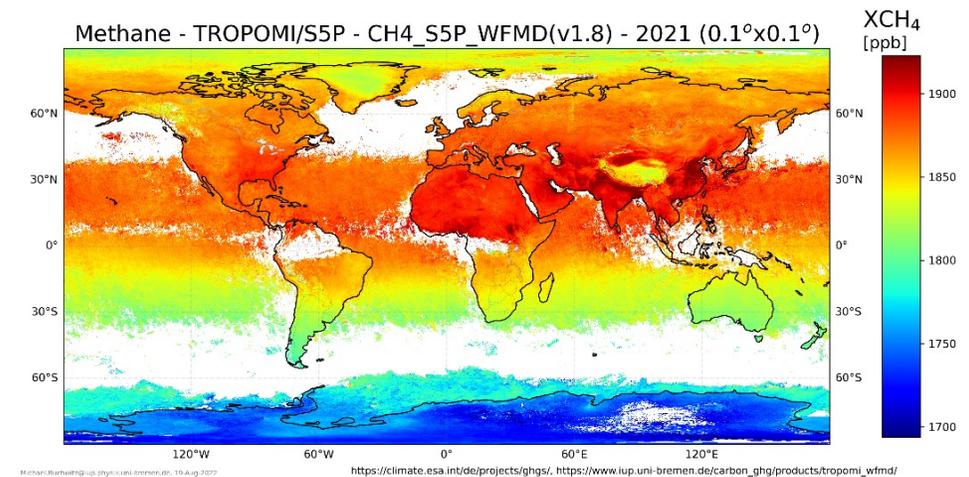
Science questions

- What is the impact of variability and long-term changes of precursors on **tropospheric ozone**?
- How do SO_2 emissions affect radiative forcing through the **formation of sulfate aerosols**?
- What is the role of **nitrogen emission and deposition** on soil, air quality and climate?

R&D and products

- Round robin of UV-Vis retrievals :
  - Select optimal retrieval baseline generally applicable
  - Harmonise NO_2, HCHO and SO_2 products across sensors
- Carbon monoxide (CO) :
  - Create first merged long-term MOPITT-IASI data record
- Ammonia (NH_3) :
  - Develop improved retrieval baseline accounting for clouds
  - Produce consolidated IASI NH_3 product for Metop-A,B,C
- Product release scheduled: Jun – Dec 2024

Use cases

- Impact of CCI+ NO_2 and CO CDRs on **CAMS reanalysis**
- GEOS-CHEM **model validation** using CCI+ NO_2 and HCHO products
- Analysis of **HCHO variability over African rainforests** based on MAGRITTE model and CCI+ datasets

RECCAP-2
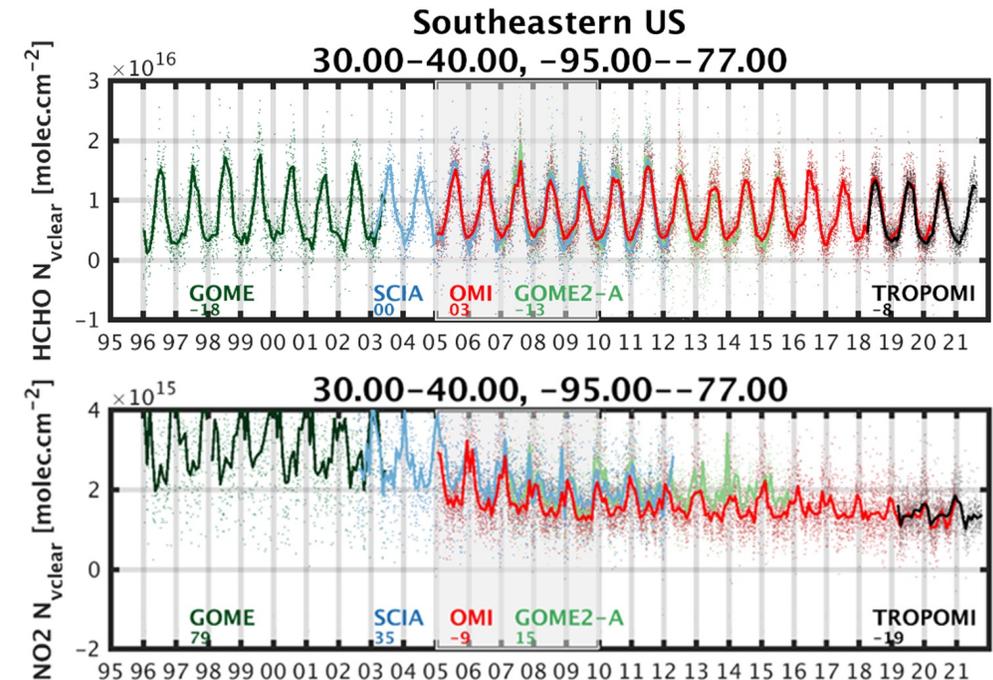
Goals :
Integration of **multiple EO over land, atmosphere and oceans**
to quantify **GHG budgets** from global to national scale and their
drivers. CCI+ GHG, Biomass, Fires, Land Cover

R&D topics:
Improve the **accuracy of GHG budgets** and the comparability
with bottom up inventories methods, in close collaboration with
National Inventory Agencies

Products:
new biomass change global estimates since 2010 from SMOS
SMAP L-band microwave passive remote sensing ; national GHG
budgets separated into anthropogenic and natural emissions ;
Dynamic Vegeration Model simulations of net C fluxes constrained
by CCI+ ECV ; New wetland area data from multiple sensors

Use cases:
large emitting countries, Brazil (land use change and forest
degradation), **Global Stock Take** contribution