climate change initiative

→ CLIMATE MODELLING USER GROUP

CMUG PHASE 3 – Cross-ECV Climate Science Study proposal: Cloud and Aerosol Analysis Study

cmug cci

Institutes: BSC, ECMWF, (DLR for a potential follow up study)

Leads: Angela Benedetti, Enza Di Tomaso, Jeronimo Escribano, (Axel Lauer)

Proposal study at a glance

Aim: fully exploit AEROSOL and CLOUD ESA CCI data in the context of Earth system model assimilation using the ECMWF 4D-Var system (cloud/aerosol analysis) and the BSC LETKF (ensemble-based) system (dust aerosol analysis)

WPs:

1. Dust aerosol analysis with the BSC system
2. Cloud/Aerosol analysis with the ECMWF system

Potential follow up study:

3. Evaluation using the ESMValTool and internal tools at BSC/ECMWF

ECVs involved: Aerosol, Cloud, (Soil Moisture, Water Vapour)

ECMWF system: Copernicus Atmosphere Monitoring Service

ECMWF system: Copernicus Atmosphere Monitoring Service

ECMWF system: Numerical Weather Prediction and monitoring the Earth system

ECMWF

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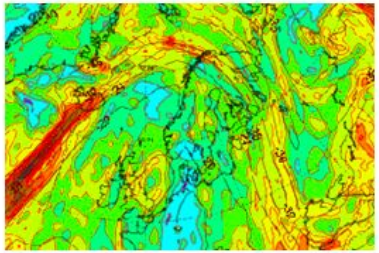


Charts

Our Integrated Forecasting System (IFS) provides forecasts and associated verification at different resolutions and for multiple time ranges. The verification provides essential feedback on the quality of the forecasting system.

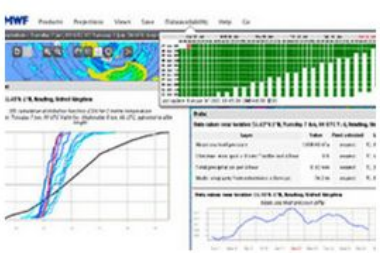
Datasets

Real-time and archive forecasts, analyses, climate re-analyses, reforecasts and multi-model datasets.

Real-time datasets

Monitoring of the observing system

We continually monitor the quality and availability of the different components of the global observing system used at ECMWF.



The Integrated Forecasting System

Key characteristics of the Integrated Forecasting System (IFS), documentation on specific areas, and description of our forecasts.

ECMWF system: Numerical Weather Prediction and monitoring the Earth system

ECMWF

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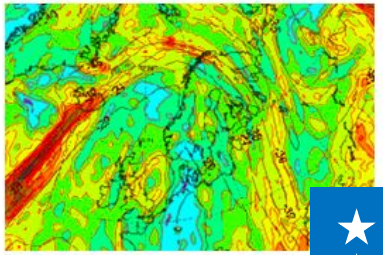


★ currently including the assimilation of MW all-sky radiances
★ interaction of aerosols and clouds with radiation

Charts

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d Forecasting System

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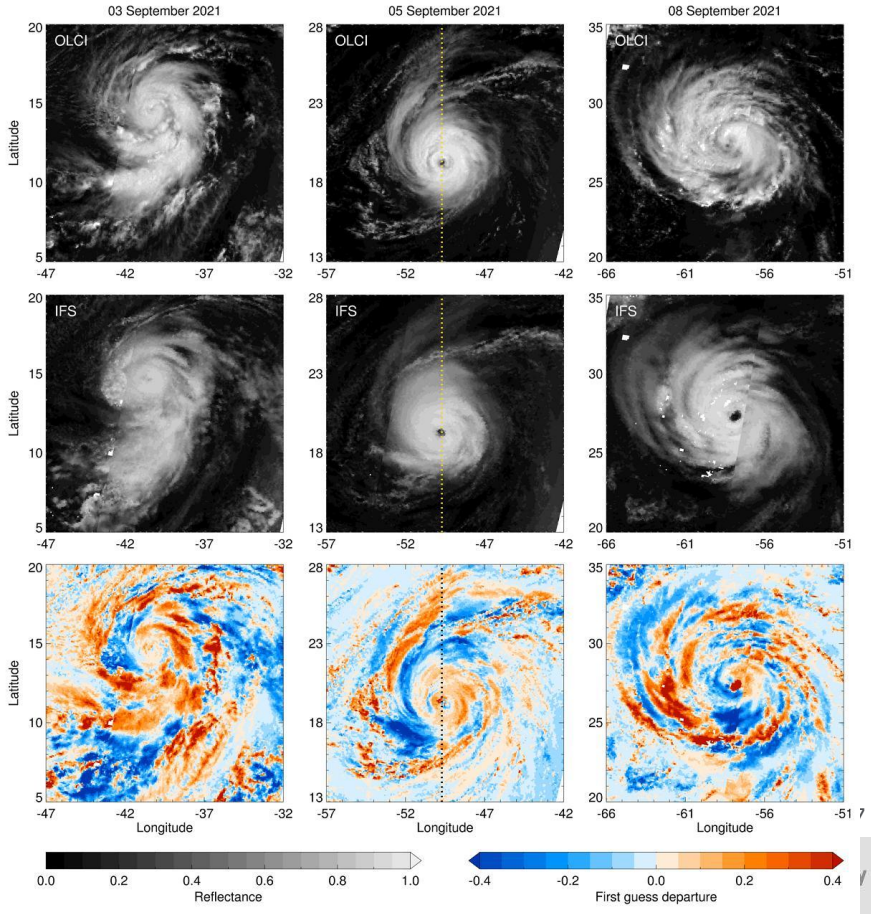
ECMWF monitoring of cloudy visible radiances

Reflectances from the OLCI observations

short-term IFS predictions

First-guess departures
(observations minus model background)



Credits: Liam Steele

BSC system: CAMS regional production

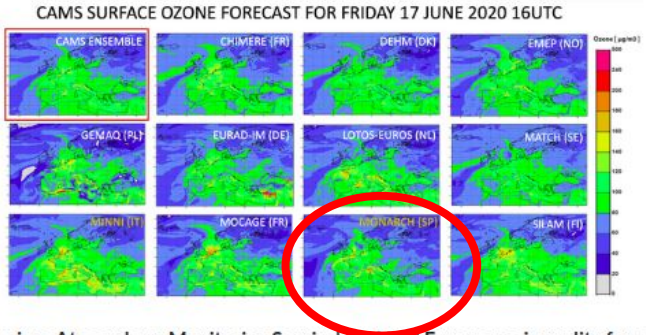
Atmosphere Monitoring Service

Data About us What we do

CAMS ENSEMBLE CHIMERE (FR) DEHM (DK) EMEP (NO)

The CAMS European air quality ensemble forecasts welcomes two new state-of-the-art models

CAMS SURFACE OZONE FORECAST FOR FRIDAY 17 JUNE 2020 16UTC



MONARCH will contribute also to CAMS regional reanalysis

Credits: https://atmosphere.copernicus.eu/cams-european-air-quality-ensemble-forecasts-welcomes-two-new-state-art-models

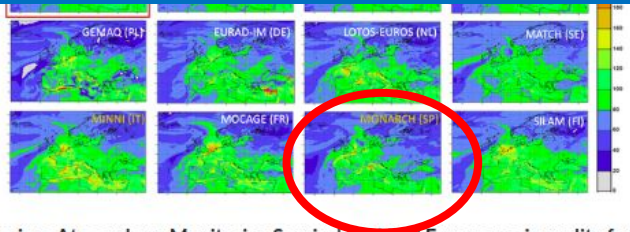
Starting 15 June, the Copernicus Atmosphere Monitoring Service's (CAMS) European air quality forecasts are composed of an ensemble of eleven individual models instead of nine previously.

The two new operational systems are MINNI, developed and operated by ENEA (Italy) and the Barcelona Supercomputing Centre's MONARCH (Spain).

BSC system: CAMS regional production

★ currently BSC assimilates in-situ observations
★ plans to use of Sentinel data

ARCH will contribute also
MS regional reanalysis



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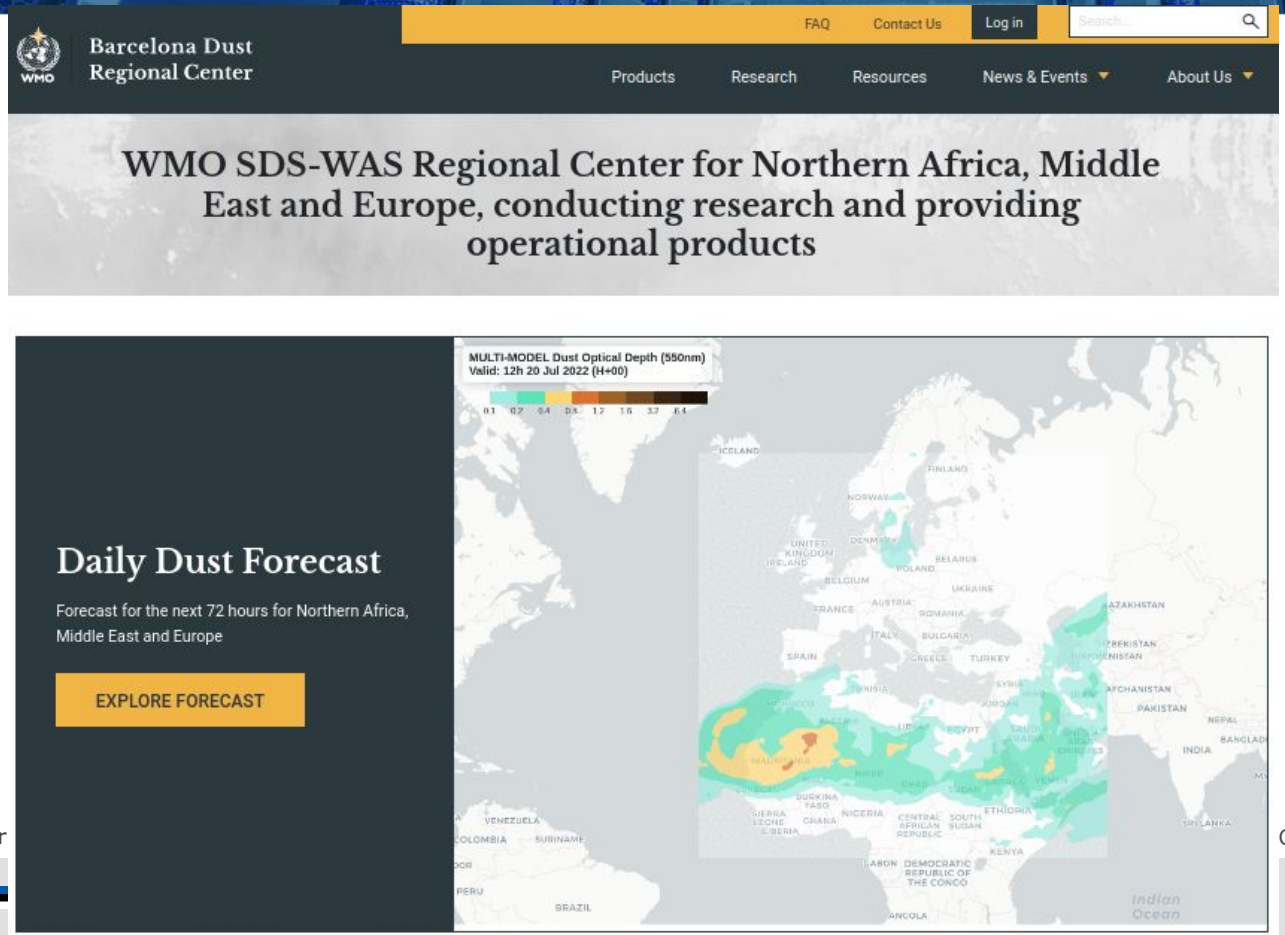
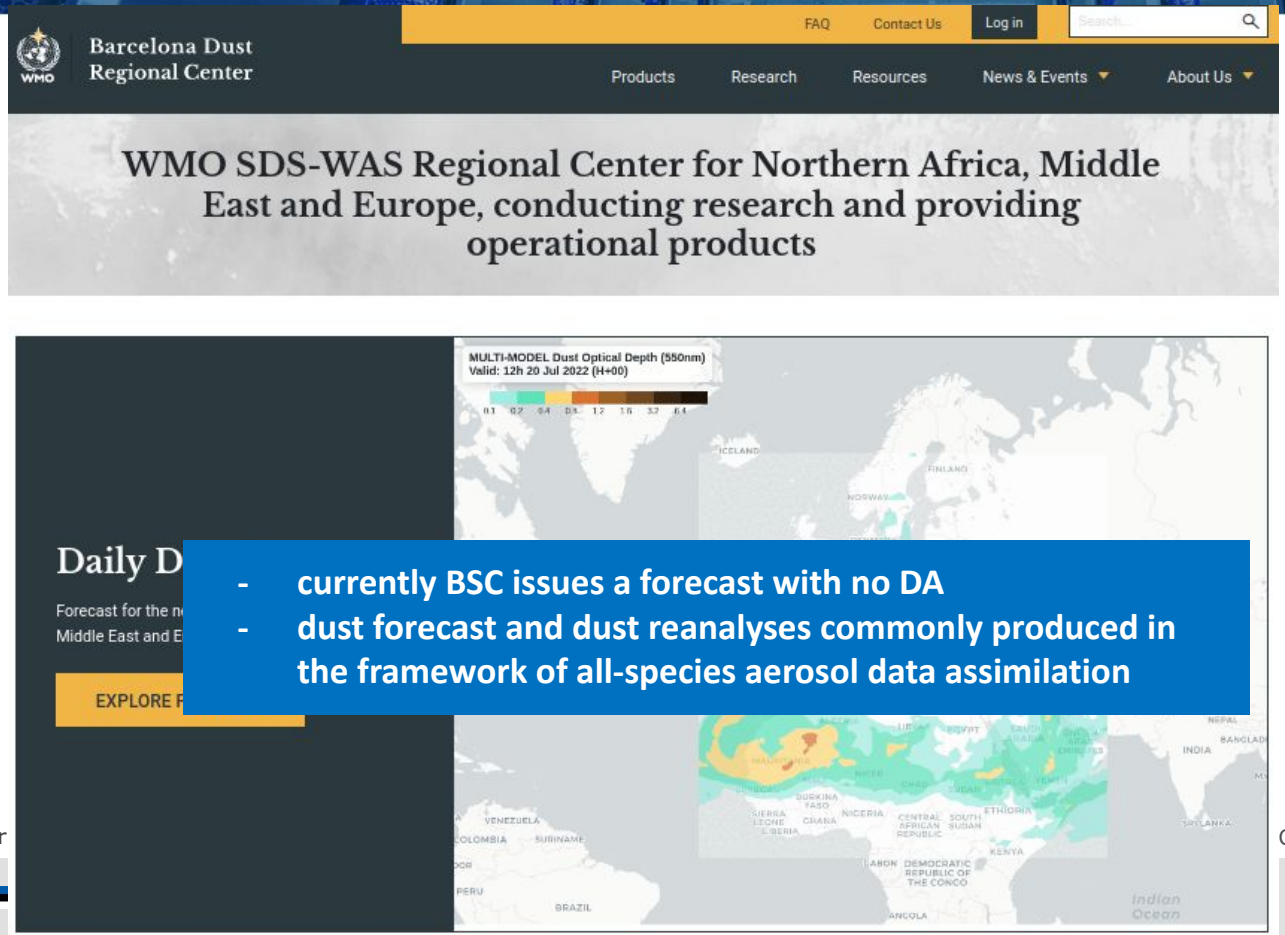
BSC system: WMO dust regional center



BSC system: WMO dust regional center



- currently BSC issues a forecast with no DA
- dust forecast and dust reanalyses commonly produced in the framework of all-species aerosol data assimilation

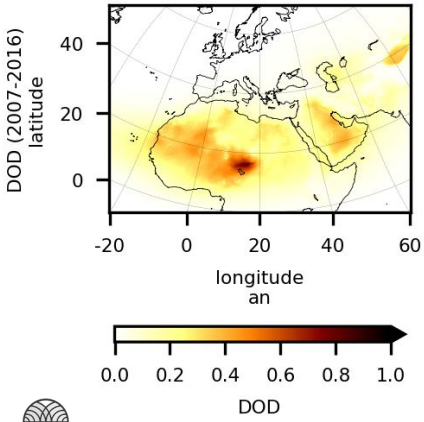
BSC system: dust regional reanalysis

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

MONARCH high-resolution reanalysis data set of desert dust aerosol over Northern Africa, the Middle East and Europe

A complete and consistent, four dimensional, regional reconstruction of desert dust in a recent decade (2007-2016)

- ✔ Unprecedented **high resolution**: 0.1º x 0.1º
- ✔ Specific **dust observational constraint**
- ✔ **Uncertainty estimates** in the reanalysis output
- ✔ Link to specific **air quality** and **climate services**
- ✔ **FAIR** data guidelines



Open access. To request access to the repository, please contact reanalysis.access@bsc.es

Dataset PID: http://hdl.handle.net/21.12146/c6d4a608-5de3-47f6-a004-67cb1d498d98

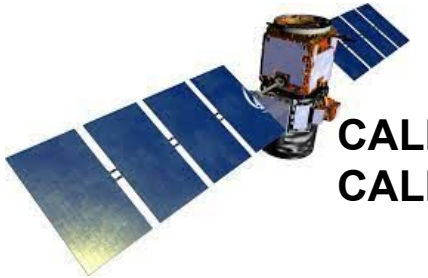
Climate Modelling User Group

Case study June 2020

Potential follow up: A variety of aerosol analyses produced for the same study period could be inter-compared

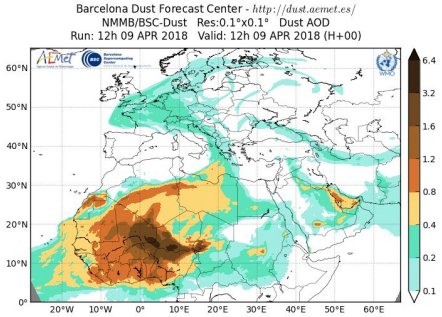
DOMOS

Metop
IASI

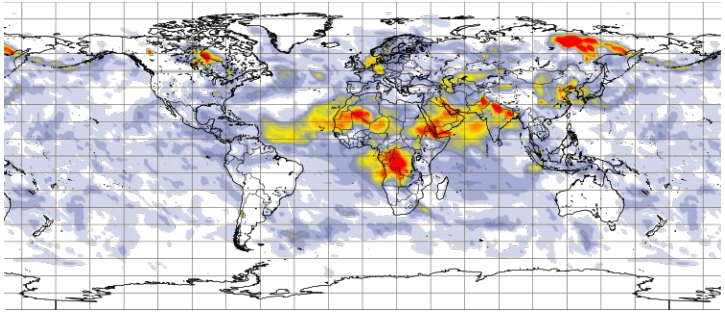


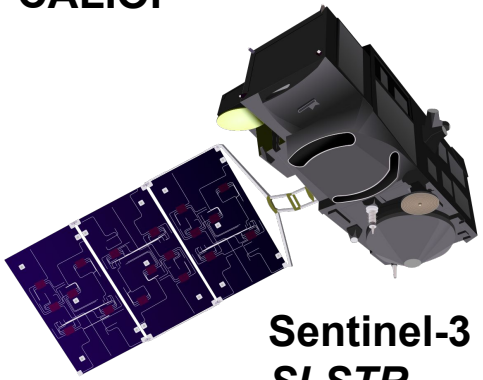
CALIPSO
CALIOP

MONARCH



IFS





Sentinel-3
SLSTR

Feasibility of the study w.r.t. the CCI ECV data

Which CCI data sets are required for use in the study?

Are all required data sets expected to be available in time to perform the study?

Proposal study: ECVs involved

Aerosol ECVs:

Aerosol Optical Depth, (Fine mode Aerosol Optical Depth, Absorption Aerosol Optical Depth, Dust Aerosol Optical Depth)

-> aerosol_cci team willing to make available latested improved version

Cloud ECVs:

Cloud Optical Depth, (Cloud Top Height, Cloud Fraction, Ice Water Path, Liquid Water Path)

-> cloud_cci team willing to make available L2 retrievals for the study period (currently published up to 2016 and as Level 3 retrievals)

Optional evaluation tasks: **Soil Moisture, Water Vapour ECVs**

-> updates to latest version needed (SM) or inclusion of extended period (WV, to cover June 2020)

Feasibility of the study w.r.t. the CCI ECV data

Are the CCI data sets technically suitable for the study?

Technical aspects

Geophysical meaning of the satellite product vs. the equivalent model variable	Assumptions on extinction optical properties to link mass concentrations with optical depth (DA observation operator and model diagnostics for evaluation)
Snapshot in time vs. daily average	Model equivalent of the observations are calculated (Level 2 for DA; Level 2 and 3 for evaluation)
Clear sky or seasonal biases	Seasonality will not be analysed. Potential clear sky bias (for aerosol) is not deemed a first priority issue to be tackled. In more general terms, bias in observations and in models is a general issue more often abided than fully solved. Multiple reference data and inter-comparison help
Horizontal resolution *Vertical resolution* *Time resolution*	Observation resolution > model resolution –> superobing or thinning (or obs error correlations); Observation resolution < model resolution –> representation error characterization Model information only Model simulation value closest in time to satellite overpass (Level 2); use of 4DVar and 4D-LETKF
Gaps	Not a technical issue in DA (models cover data gaps). Use only model values collocated with observations.
Stability	Not an issue in relatively short case studies. A potential issue could be mitigated by a simple quality control
Accuracy	Use of observation uncertainty (and balanced model background uncertainty in DA); Multiple reference data and inter-comparison help.

CLOUD/AEROSOL BREAKOUT

- **Scientific questions**:
  - What is the impact of using COD and AOD level 2 data on the 4D-Var analysis both for air quality fields and for meteorological variables?
  - At which extent and under which assumptions can coarse mode AOD constrain desert dust simulations?
  - Are CCI (pixel-level) uncertainties realistic for assimilation applications?
  - How well do different analyses obtained by either distinct modeling systems or diverse observational constraints (column-integrated versus profile) compare?

- **Discussion from the integration meeting**:
  - How to best deal with observational bias (eg in SLSTR)

CLOUD/AEROSOL BREAKOUT

- **Feasibility of the study w.r.t. the CCI ECV data** (mostly fulfilled at the stakeholder meeting with the aerosol and cloud CCI teams - extra slides have all the details)

  - which data sets and version
  - availability
  - technically suitable for the study? (see table on technical aspects)
  - risk analysis

CLOUD/AEROSOL BREAKOUT DISCUSSION

- Thomas: SLSTR fine mode AOD is biased high, therefore coarse AOD, which is planned to be used by BSC for dust assimilation, will be underestimated (total - fine)

- Question about the bias of SLSTR: maps of varBC output from ECMWF from SLSTR assimilation to inform BSC's study to use coarse AOD, although it is model-specific and anchored on MODIS and for total AOD.

- SLSTR fine mode is estimated from the pre-defined fine mode size distribution, and is not related to emissions or deposition.

- A comparison with independent obs and analysis could be useful (DOMOS IASI runs)

- Simon wonders about what we mean with: Are CCI (pixel-level) uncertainties realistic for assimilation applications?

CLOUD/AEROSOL BREAKOUT DISCUSSION

- Enza explained the need to "compromise" in within the constraints of the assimilation and error might need to be adjusted.
- Thomas wonders if the adjustments made to the observation errors (for DA purposes) are something to share and discuss with them.
- Observation uncertainties are binned against differences with AERONET AOD and an histogram is created. A correction derived from this comparison can be applied to the observational error. In a way, they are "validated" with independent observations (true reference) and there is some confidence that they are reasonable.
- First assumption is always to go to observation error provided by the data provider, but not always it can be used meaningfully.

Extra slides discussed at the stakeholder meeting

Aerosol data products

For **assimilation or evaluation** (June 2020/September 2021 optional)

- Level 2: AOD550, D_AOD550, FM_AOD550 SU SLSTR (v1.12 data available at https://www.icare.univ-lille.fr/asd-content/archive/?dir=C3S-Aerosols/SLSTR_SU_v1.12/L2/ or v1.14 (i.e. an improved version that the aerosol ECV team is willing to make available for this study), D_AOD10000 IASI (v9, data available at https://www.icare.univ-lille.fr/asd-content/archive/?dir=C3S-Aerosols/IASI_ULB_v9/)
- AOD550, AAOD550, D_AOD550, FM_AOD550 ESACCI-L3C_AEROSOL-AER_PRODUCTS-AATSR_ENVISAT-SU_v4.3 implemented in ESMValTool, needs update to Swansea ATSR (v4.33) and SLSTR / 3A (v1.12) OR ensemble (ATSR v3.0 and SLSTR / 3A v2.2) v6.1 (data available on ICARE ftp archive)

Cloud data products

For **assimilation or evaluation** (June 2020/September 2021 optional)

- Level 2: COD v3.0 (requested to the cloud ECV team for this study period)

- cod, cth, cfc, iwp, lwp, toa_lwup, toa_lwup_clr, toa_sw_up, toa_swup_clr (ESACCI-L3C_CLOUD-CLD_PRODUCTS-AVHRR_*-fv3.0); CCI (L3C - monthly) already implemented into ESMValTool, adding L3U (daily)

Soil moisture and water vapour data products

For optional **evaluation** tasks (June 2020/September 2021 optional)

- sm (ESA CCI SM v07.1 COMBINED); v4.2 of CCI already implemented into ESMValTool – needs update to version v7.1 (daily data available via https://www.esa-soilmoisture-cci.org/)

- tcwv (ESACCI-WATERVAPOUR-L3S-TCWV-*-fv3.1); CCI already implemented into ESMValTool

Feasibility of the study w.r.t. the CCI ECV data

Are all required data sets (CCI and external) expected to be available in time to perform the study?

Aerosol data products

For **assimilation or evaluation** (June 2020/September 2021 optional)

- Level 2: AOD550, D_AOD550, FM_AOD550 SU SLSTR (v1.12 data available at https://www.icare.univ-lille.fr/asd-content/archive/?dir=C3S-Aerosols/SLSTR_SU_v1.12/L2/ or v1.14 (i.e. an improved version that the aerosol ECV team is willing to make available for this study), D_AOD10000 IASI (v9, data available at https://www.icare.univ-lille.fr/asd-content/archive/?dir=C3S-Aerosols/IASI_ULB_v9/)
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Cloud data products

For **assimilation or evaluation** (June 2020/September 2021 optional)

- Level 2: cod (requested to the cloud ECV team for this study period)

- cod, cth, cfc, iwp, lwp, toa_lwup, toa_lwup_clr, toa_sw_up, toa_swup_clr

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- tcwv (ESACCI-WATERVAPOUR-L3S-TCWV-*-fv3.1); CCI already implemented into ESMValTool (CDR-2)

Feasibility of the study w.r.t. the CCI ECV data

What is the backup solution in case the CCI data are not made available on time?

Risk analysis

The CCI data sets (and versions) considered in this study are already all available with two exceptions:

(a) **COD retrievals** have been published up to 2016 and as Level 3 retrievals

- samples of COD Level 2 retrievals have been already shared by the ECV team with ECMWF
- a request has been put forward to the ECV team leader for COD retrievals to support the pilot case studies that we propose
- if this will not be possible by the start of the study, the pilot case study period will be changed to a period when COD retrievals are already publicly available (before 2017)

(b) **TCWV retrievals** are currently available only up to 2017

- an extension to cover 2020 globally and 2021 over land is planned in phase 2 of the WV project
- we have made the validation of TCWV an optional task, depending (also) on data availability within the course of this study

Earth System Model Evaluation Tool

International ESMValTool development team

- 17 funded projects
- 63 institutions
- 203 developers

scientific documentation

Righi et al., 2020
Technical overview

Eyring et al., 2020
Large-scale diagnostics

Lauer et al., 2020
Diagnostics for emergent constraints and future projections

Weigel et al., 2021
Diagnostics for extreme events, regional and impact evaluation

ESMValTool
Earth System Model Evaluation Tool

- Tool for fast and easy routine **evaluation and analysis** of Earth system models including provenance records for all results (**traceability and reproducibility**)
- Well-established analysis based on **peer-reviewed literature**
- Many diagnostics and performance metrics covering **different aspects of the Earth System** (dynamics, radiation, clouds, carbon cycle, chemistry, aerosol, sea-ice, etc.) and their interactions
- Extensive **documentation** (user guide, peer-reviewed papers, tutorial)
- Supported production of a subset of figures of the **IPCC WGI AR6**

https://www.esmvaltool.org/

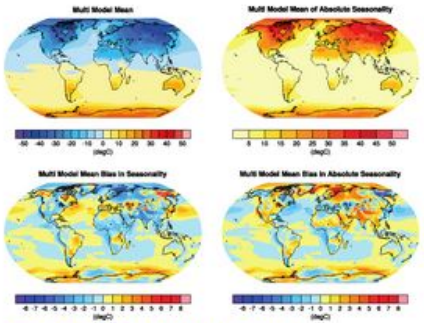
Earth System Model Evaluation Tool

ESMValTool
Earth System Model Evaluation Tool

HOME ESMVALTOOL TEAM DOWNLOAD

ESMValTool GALLERY » 1

ESMValTool examples



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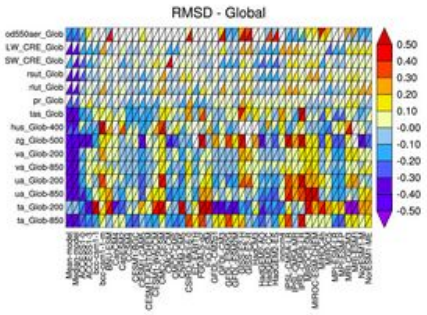

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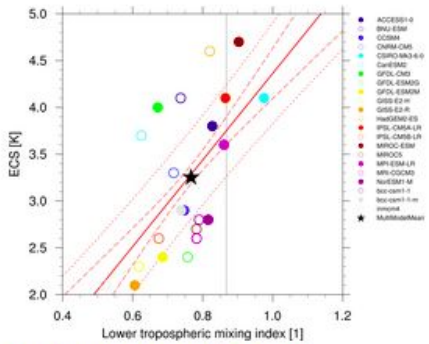

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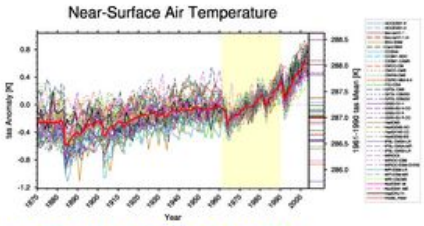

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