



Atmosphere Monitoring

Validation of the Copernicus Atmosphere Monitoring Service global forecasts and reanalyses

Henk Eskes (KNMI, Netherlands)



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Persons involved in the CAMS validation contract:

S. Basart (BSC), N. Benas (KNMI), Y. Bennouna (CNRS-LA), A. Benedictow (MetNo),
A. Blechschmidt (IUP-UB), G. Brasseur (MPG), S. Chabrillat (BIRA-IASB),
Y. Christophe (BIRA-IASB), J. Claas (KNMI), E. Cuevas (AEMET), J. Douros (KNMI),
Q. Errera (BIRA-IASB), H. Eskes (KNMI), H. Flentje (DWD), P. Fritsche (DWD),
K. M. Hansen (AU), U. Im (AU), J. Griesfeller (MetNo), J. Kapsomenakis (AA),
E. Katragkou (AUTH), B. Langerock (BIRA-IASB), S. Niemeijer (S&T),
M. Ramonet (CEA-LSCE), M. Razinger (ECMWF), A. Richter (IUP-UB), M. Schulz (MetNo),
N. Sudarchikova (MPG), W. Thomas (DWD), V. Thouret (CNRS-LA), M. Vrekoussis (AA),
A. Wagner (MPG), T. Warneke (UBC), C. Zerefos (AA)

Many thanks to all the groups providing the (real-time) measurements

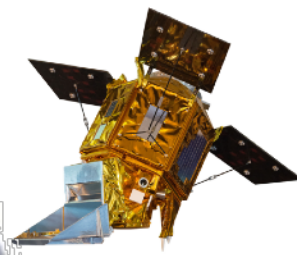


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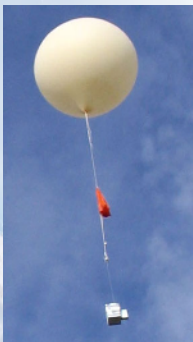
The global observing system



Airplanes



Satellites



Balloons



Ships



Ground-based stations





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CAMS-global quarterly real-time validation reports



**Validation report of the CAMS
near-real time global
atmospheric composition service**

Period March – May 2021

Issued by: KNMI
Date: 30 September 2021
Ref: CAMS84_2018SC3_D1.1.1_MAM2021

doi:10.24380/qq5m-dg18

CAMS-global real-time forecast/analyses validation reports

- Every 3 months
- Evaluation of forecasts/analyses plus control run without assimilation
- Reactive gases, aerosols and greenhouse gases
- Event studies
- About 200 pp of figures & validation results
- Stand-alone summary

Need for “real-time” observations, available within 1 month after real time

Importance of quarterly updates:
document the latest upgrade of the CAMS system



Species, vertical range	Assimilation	Validation
Aerosol, optical properties	MODIS Aqua/Terra AOD PMAp AOD	AOD, Ångström: AERONET, GAW, Skynet, MISR, OMI, lidar, ceilometer
Aerosol mass (PM10, PM2.5)	MODIS Aqua/Terra	European AirBase stations
O ₃ , stratosphere	MLS, GOME-2, OMI, OMPS, TROPOMI	Sonde, lidar, MWR, FTIR, OMPS, ACE-FTS, SAGE3-ISS and BASCOE analyses
O ₃ , UT/LS	MLS	IAGOS, ozone sonde
O ₃ , free troposphere	Indirectly constrained by limb and nadir sounders	IAGOS, ozone sonde, IASI
O ₃ , PBL / surface		Surface ozone: WMO/GAW, NOAA/ESRL-GMD, AIRBASE
CO, UT/LS	IASI, MOPITT	IAGOS
CO, free troposphere	IASI, MOPITT	IAGOS, MOPITT, IASI, TCCON
CO, PBL / surface	IASI, MOPITT	Surface CO: WMO/GAW, NOAA/ESRL
NO ₂ , troposphere	OMI, GOME-2, partially constrained due to short lifetime	TROPOMI, SCIAMACHY, GOME-2, MAX-DOAS
HCHO		TROPOMI, GOME-2, MAX-DOAS
SO ₂	GOME-2, TROPOMI (Volcanic eruptions)	
Stratosphere, other than O ₃		NO ₂ column only: SCIAMACHY, GOME-2
CO ₂ , surface, PBL		ICOS
CO ₂ , column	GOSAT	TCCON
CH ₄ , surface, PBL		ICOS
CH ₄ , column	GOSAT, IASI	TCCON

The table columns:

- Species / vertical range
- Datasets assimilated (satellite)
- Validation datasets

NRT validation:

62 datasets are used !

Aim: make use of all available high quality observations



Upgrade verification note for the CAMS near-real time global atmospheric composition service

Evaluation of the e-suite for the
CAMS 47R3 upgrade of 12 October 2021

Issued by: KNMI
Date: 8 October 2021
Ref: CAMS84_20185C3_D3.2.1-202109_esuite

doi:10.24380/hfvp-fq98

Last upgrades:

47R1: October 2020 (major)

47R2: May 2021 (minor)

47R3: 12 October 2021 (intermediate)

e-suite = candidate analysis system to replace the current CAMS operational system

Criteria for upgrade advice:

- On average, the e-suite should perform equally well or better (bias, rms, correlation)
- For specific cases, there should not be a major deterioration of the validation results



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<i>Property</i>	<i>Rel. score</i>	<i>Property</i>	<i>Rel. score</i>
Global AOD	+	CO surface	n
Ångström exponent	+	CO profiles (aircraft)	n
Dust AOD	n	CO columns (satellite, FTIR)	-
Dust PM10 Mediterranean	n	Tropospheric NO ₂ column	n
Surface PM10, Europe and US	n	HCHO column	n
Surface PM2.5, Europe and US	n	Surface ozone, Arctic	n
Ozone, free troposphere	n	Surface ozone, Midlatitude	n
Ozone stratospheric profile	n	Surface ozone, Antarctic	n
Ozone column	n	Surface ozone, Europe	n
CO ₂ surface concentrations	n	CH ₄ surface concentrations	+
CO ₂ column	n	CH ₄ column	+

Table S1. Scorecard for the relative performance of the e-suite versus the performance of the o-suite against independent observations. Meaning of the "relative score" symbols:

- ++ e-suite performs significantly better than the o-suite;
- + e-suite shows small improvements;
- n (neutral) no significant difference between o-suite and e-suite;
- score is somewhat degraded in the e-suite;
- e-suite performs significantly worse than the o-suite.

Scorecard for the 47R3 upgrade 12 October 2021

Comparing e-suite and o-suite, both against independent observations

Combining all aspects in one overview table

Green: major improvement

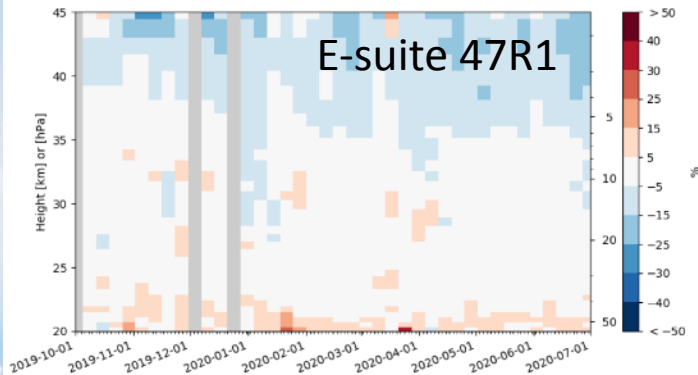
Light green: modest improvement

Light orange: score somewhat degraded

Red: score significantly lowered

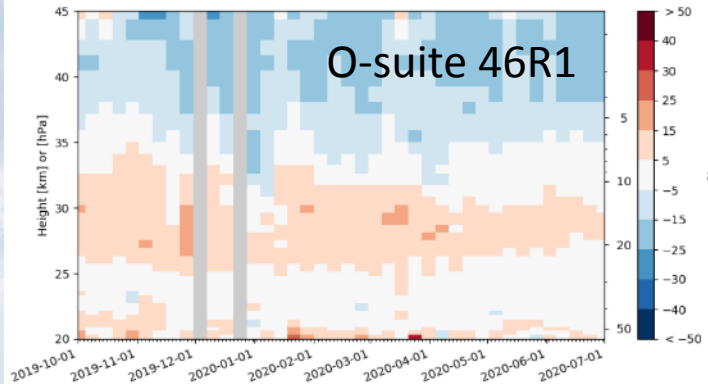


Table mountain ozone lidar



E-suite 47R1

LIDAR O₃ number density profile differences (M-O)/O
(weekly mean, 20.0km - 45.0km, o-suite 5d FC, TABLE.MOUNTAIN.CA (lat.=34.4°), 2019-10-01 till 2020-06-30, 158 meas.)



O-suite 46R1

47R1 upgrade:
stratospheric ozone profiles

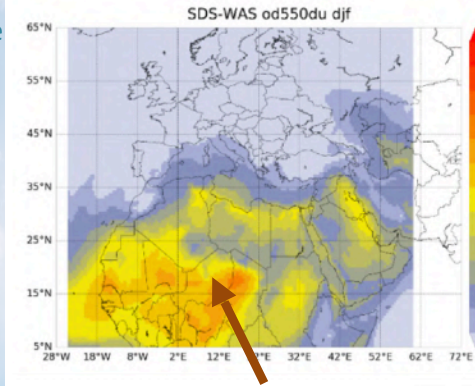
Major improvement observed in the profiles between 25-45 km altitude

Confirmed by:

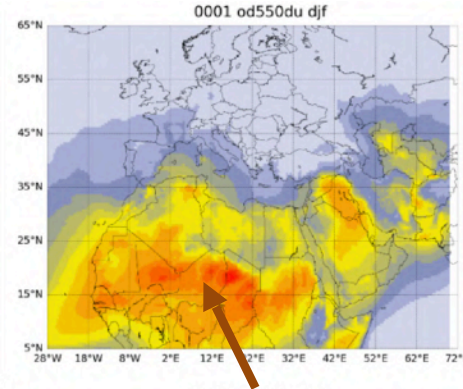
- NDACC profiles (ozone lidar)
- Ozone sondes
- Satellite ozone profiles (e.g. ACE-FTS)



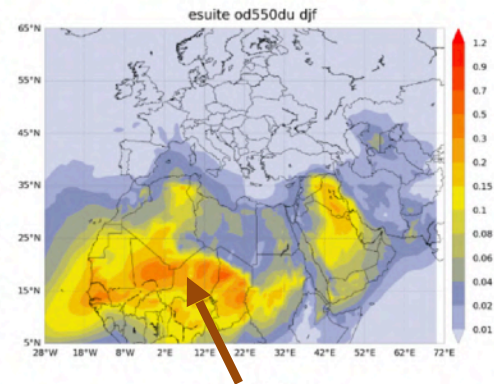
The 47R1 e-suite report: examples



SDS-WAS reference



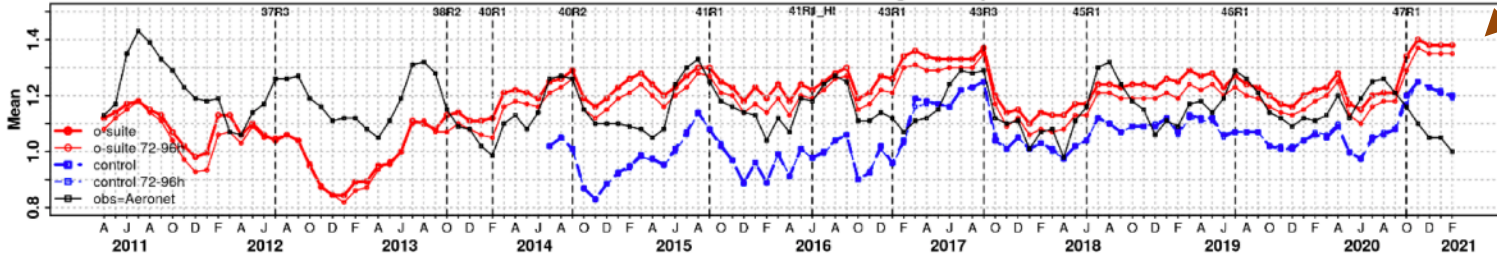
Too much dust in o-suite 46R1



Corrected in e-suite 47R1

47R1 introduced positive bias in Ångström exponent
 (too small particles)
 Improved in e-suite 47R3

MACC/CAMS 2011-2021 versus Aeronet - Ångström exponent





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The CAMS reanalysis validation report



**Validation report for the CAMS
global reanalyses of aerosols and
reactive trace gases,
years 2003 - 2020**

Issued by: KNMI
Date: 28 June 2021
Ref: CAMS84_2018SC3_D5.1.1-2020

doi: 10.24380/8gf9-k005

CAMS-global reanalysis, reactive gases and aerosol

Yearly updates of the reanalysis validation report.
Latest report covers 2003 – 2020

Inness et al, ACP (2019)

Just published:
Wagner et al, Elementa (2021)



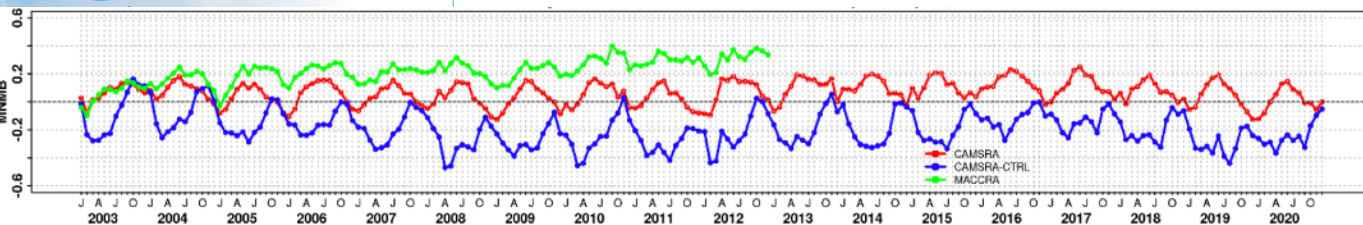
Copernicus
Europe's eyes on Earth

IMPLEMENTED BY
ECMWF



Copernicus
Europe's eyes on Earth

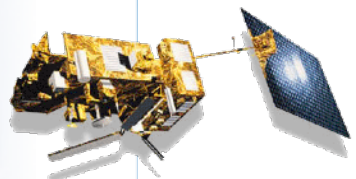
ECMWF



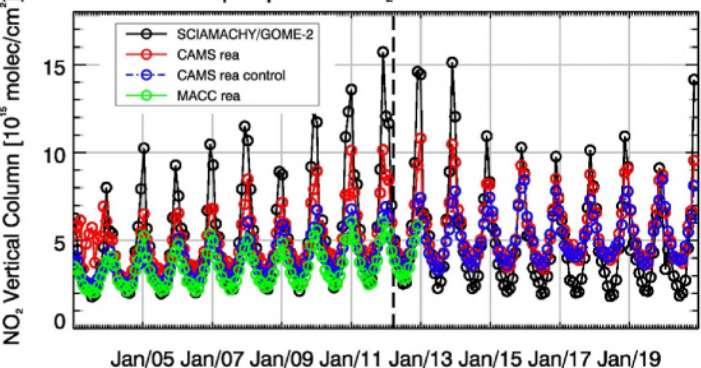
AERONET - Aerosol Optical Depth



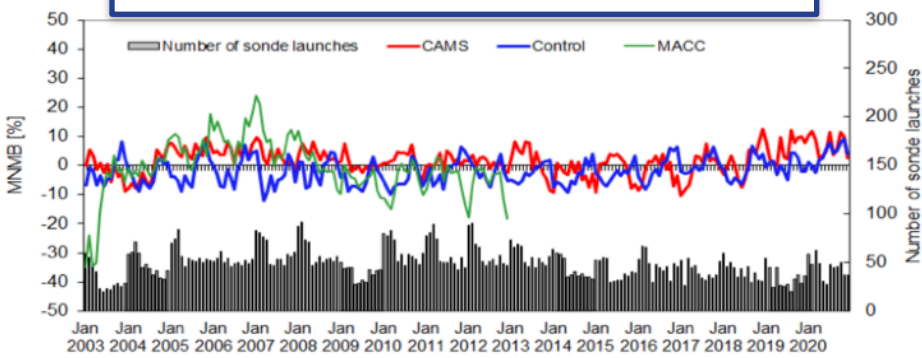
Tropospheric NO₂



Tropospheric NO₂ above East-Asia



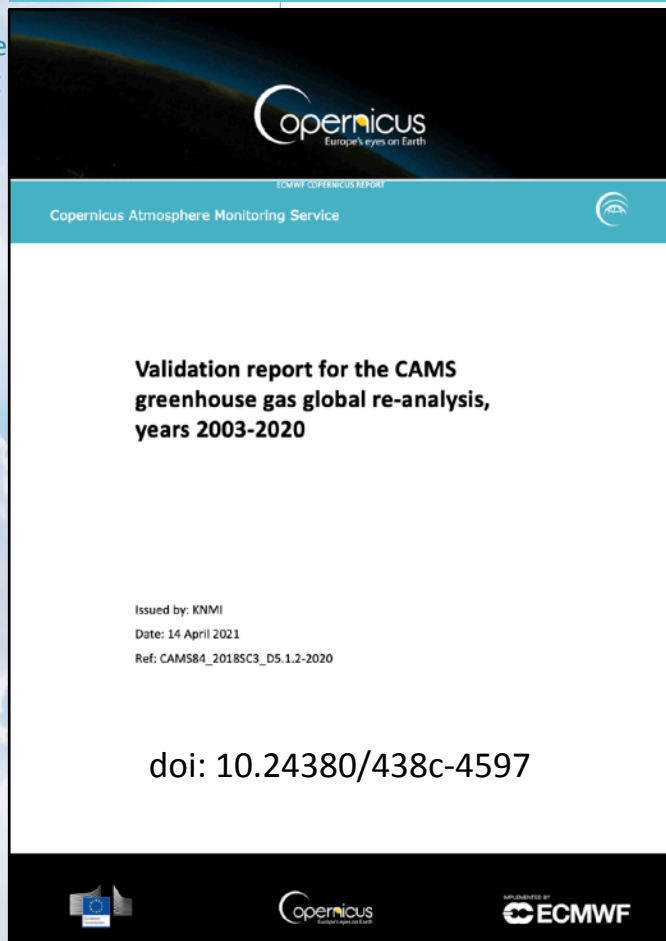
Ozone sonde - free troposphere mid-latitude





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CAMS greenhouse gas reanalysis



CAMS-global reanalysis, greenhouse gases CO₂, CH₄

Latest report covers 2003 – 2020

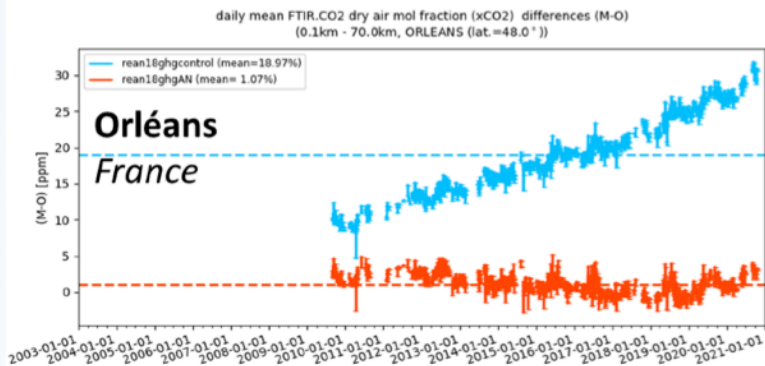
Validation based on TCCON, NDACC FTIR and
surface observations





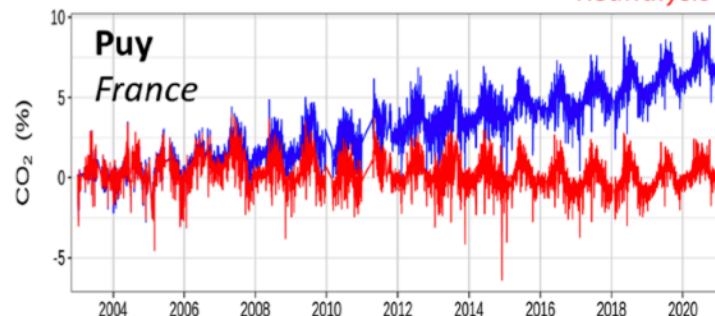
CO₂

TOTAL COLUMNS

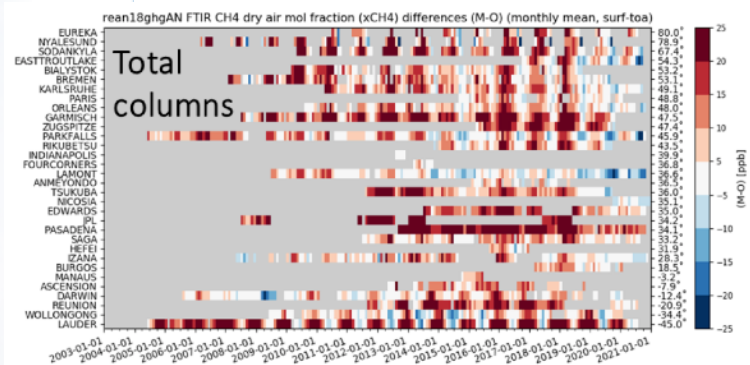


SURFACE

Control run
Reanalysis

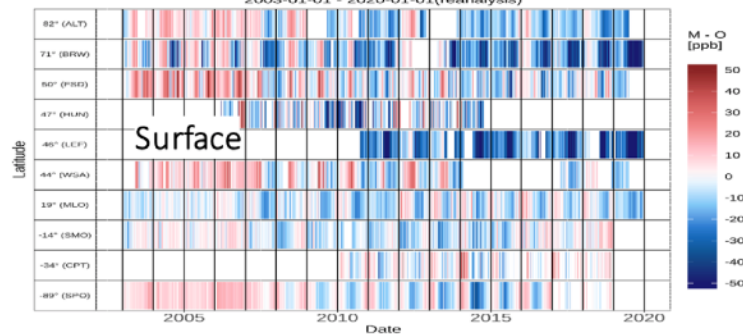


CH₄



CH4 weekly differences (model - obs)

2003-01-01 - 2020-01-01(reanalysis)



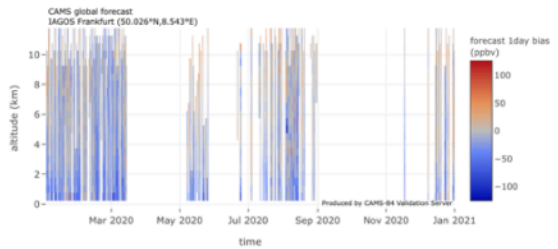
Observation locations

This validation is available for the following locations.

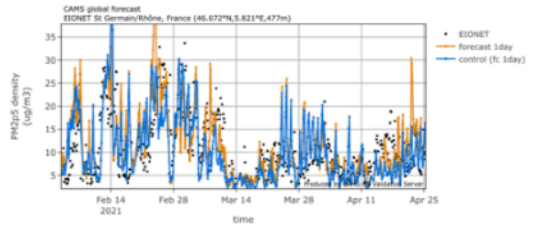


- Adeleide_Site_7
- AqilaMarina_Kyllatos
- Alta_Floresta
- AmazonATTO_Tower
- American_Samos
- Ames
- Amity_Islh_Gurgan
- Amsterdam_Island

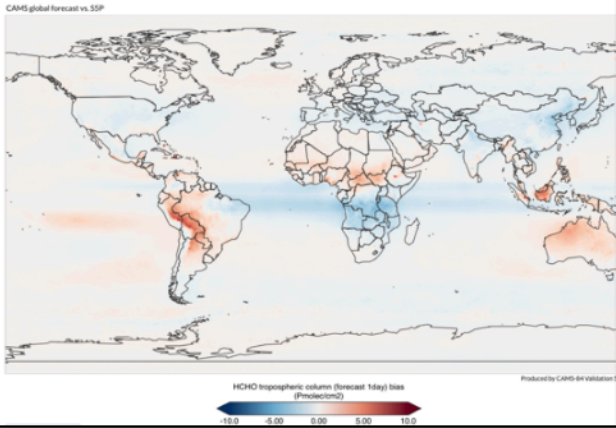
CO profile at Frankfurt [2020]



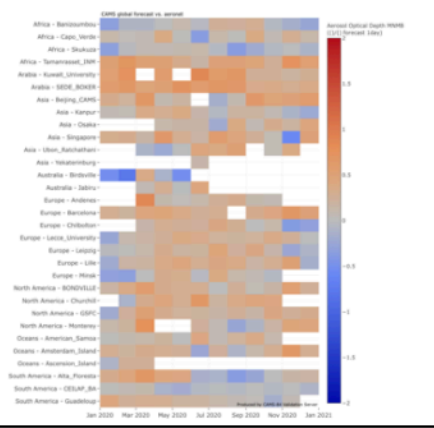
surface PM2p5 at St Germain/Rhone



HCHO tropospheric column (bias)



Aerosol Optical Depth statistics [2020]



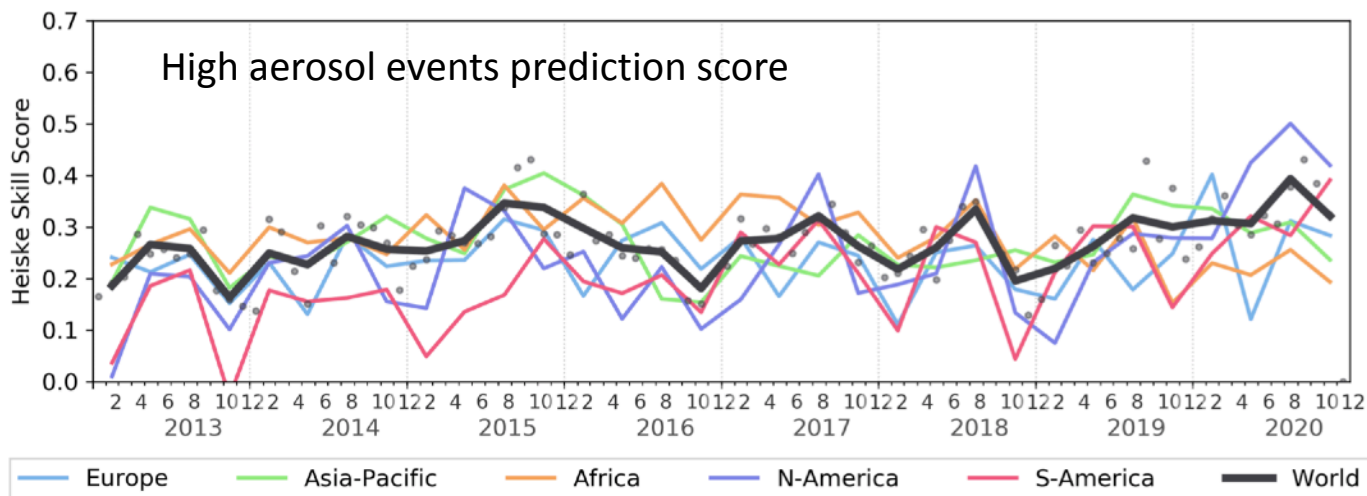
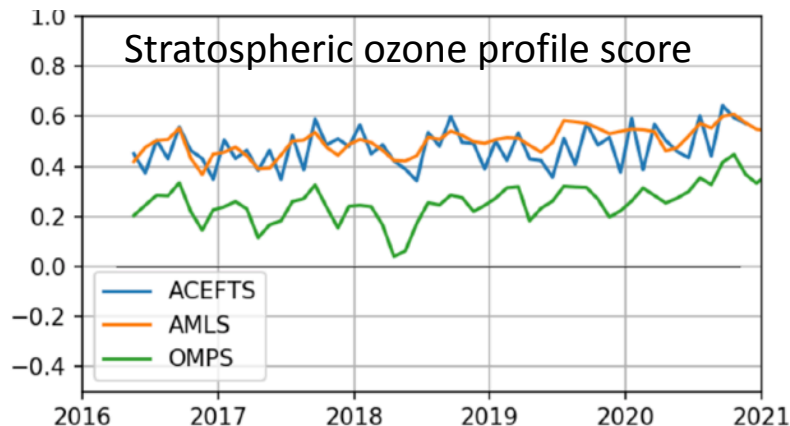
The CAMS validation server:
 a rich and flexible source of
 intercomparison between
 CAMS-NRT and a
 large number of
 independent datasets

global-evaluation.atmosphere.copernicus.eu



Headline scores:

A few scores to monitor progress made in the CAMS system with time to forecast/analyse user-relevant aspects. Facilitate comparisons with other atmosphere monitoring systems worldwide (Work in progress)





CAMS a-posteriori validation effort:

- Provide information on the quality of the CAMS service products to the users
- Team with strong links to “in-situ” observations, and some “distance” from ECMWF team and model developers (independent assessment)
- Evaluation of
 - CAMS-global analyses and forecasts
 - CAMS-global upgrades
 - CAMS-global reanalysis
 - Contributions to evaluation of CAMS-regional above surface, consistency CAMS-global and CAMS-regional
- Validation server: global-evaluation.atmosphere.copernicus.eu
- All validation reports available at atmosphere.copernicus.eu



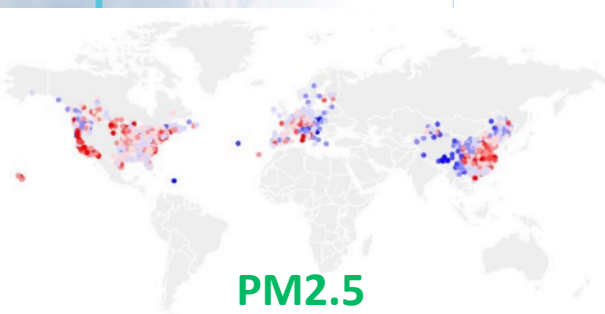
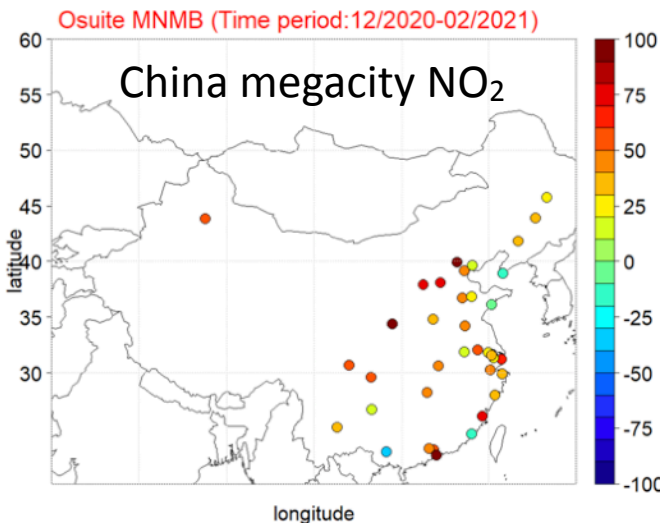
There is recently an increasing attention for surface air quality forecasts from CAMS-global.

Extend comparisons against regulatory AQ surface networks (Airnow, Airbase, China)

Data mining: additional datasets. (QC? Availability? Procedures? Documentation? Role WMO)



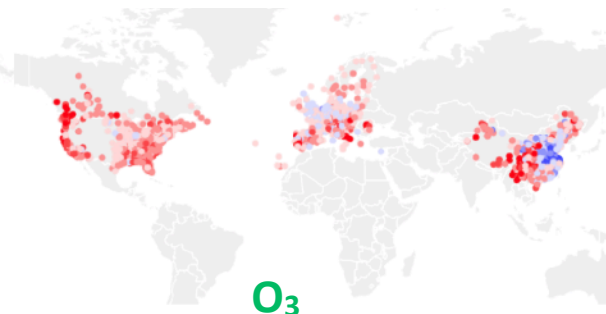
CNN



Statistic: NMB (%)
-100< -75 -50 -25 0 25 50 75 >100



Statistic: NMB (%)
-100< -75 -50 -25 0 25 50 75 >100



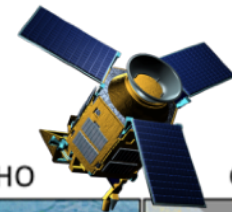


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Wealth of data from satellites (sentinels)

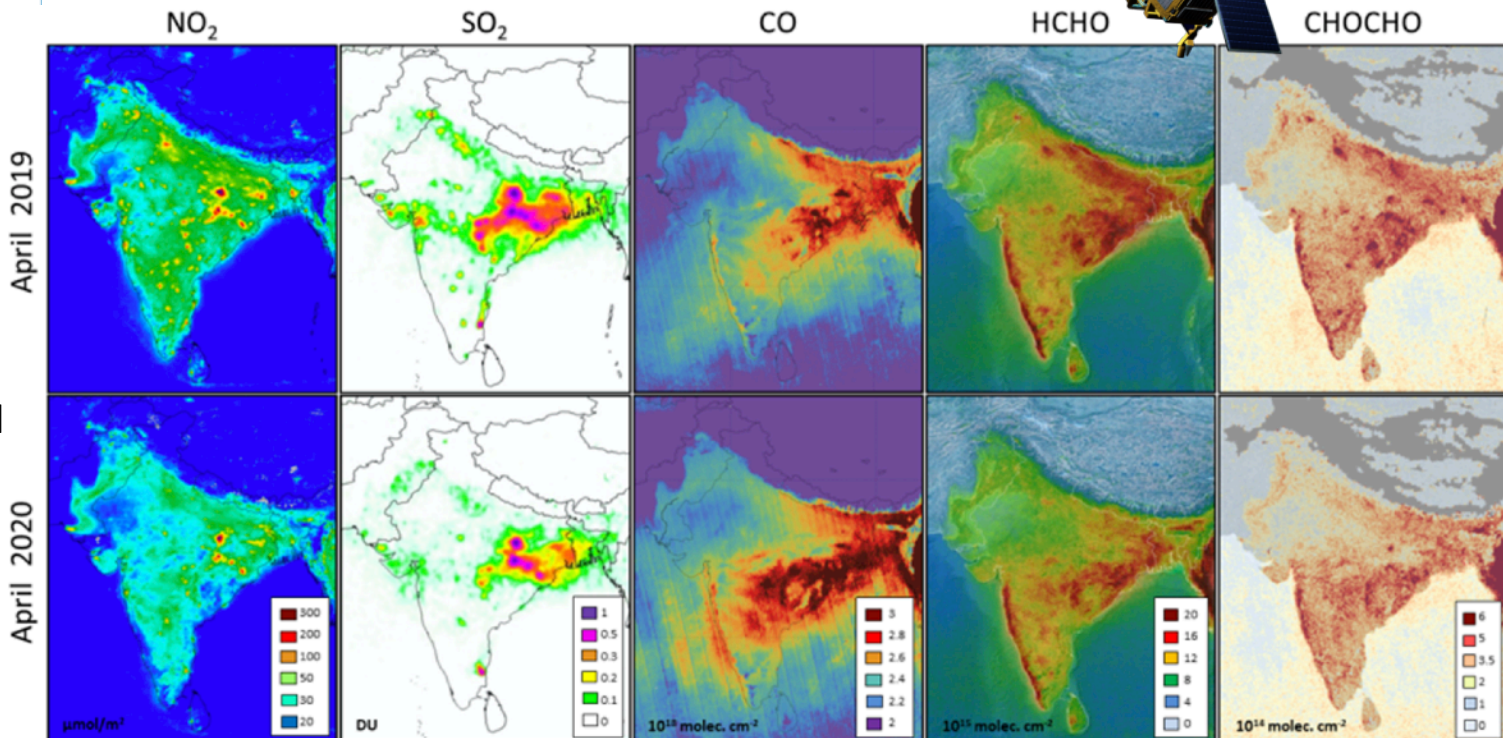
Make more use of satellite measurements for:

- Interpretation of in-situ observations
- Case study analysis: e.g. fires, dust, volcano (plume transport)
- Rapid emission changes, e.g. Covid



Sentinel-5P
Tropomi

COVID-19 related
concentration
reductions



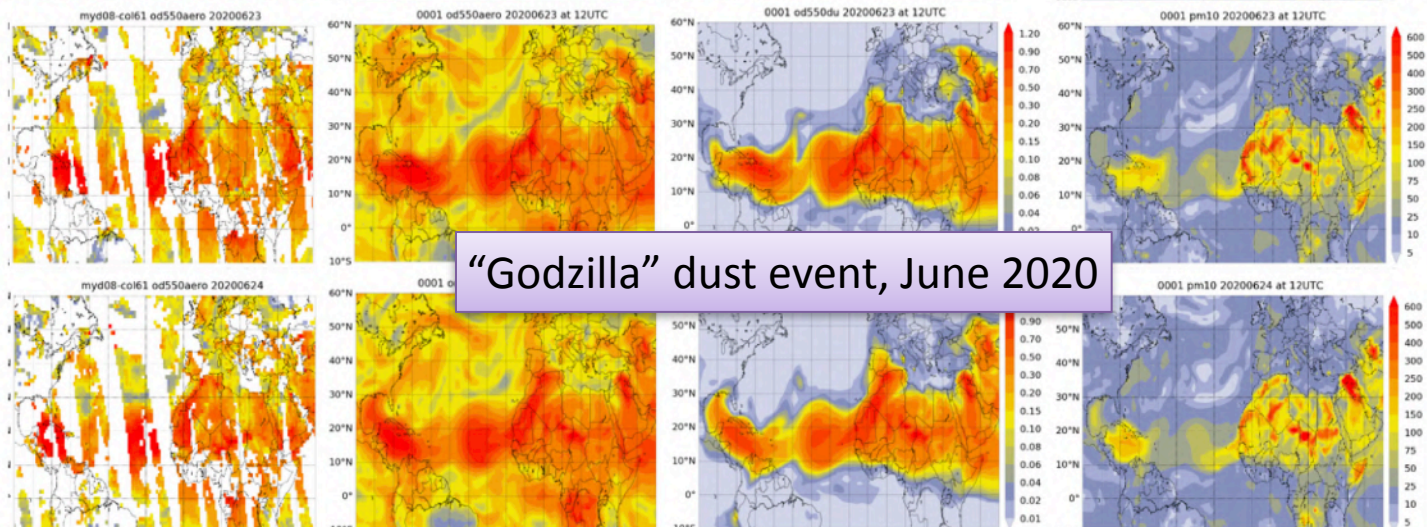


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Interaction with the CAMS weather room - case studies

Use major events identified by the CAMS Weather Room as examples in the validation reports
or: more real-time interaction between EQC and CWR activities

Note: Case studies are included in the CAMS-84 validation reports



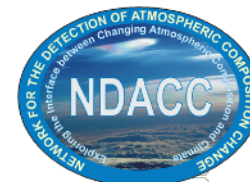


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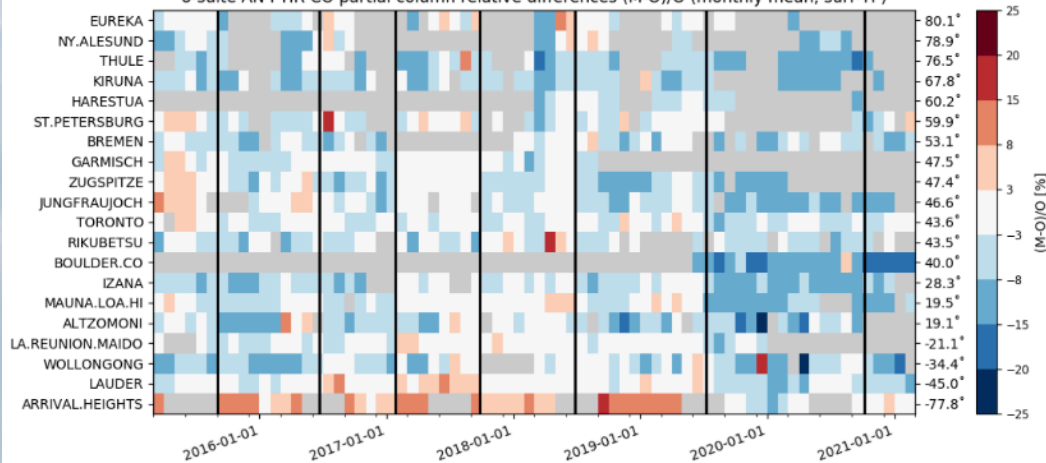
Make use of CAMS in-situ datasets (NRT)

The global validation activity will make more and more use of **contracts between CAMS and major in-situ networks** and Copernicus in-situ activity

For the NRT reports we need observations to be available *within one month* after sensing.



o-suite AN FTIR CO partial column relative differences (M-O)/O (monthly mean, surf-TP)



Example:
use of FTIR CO
tropospheric column
measurements from
NDACC contract