



Atmosphere Monitoring

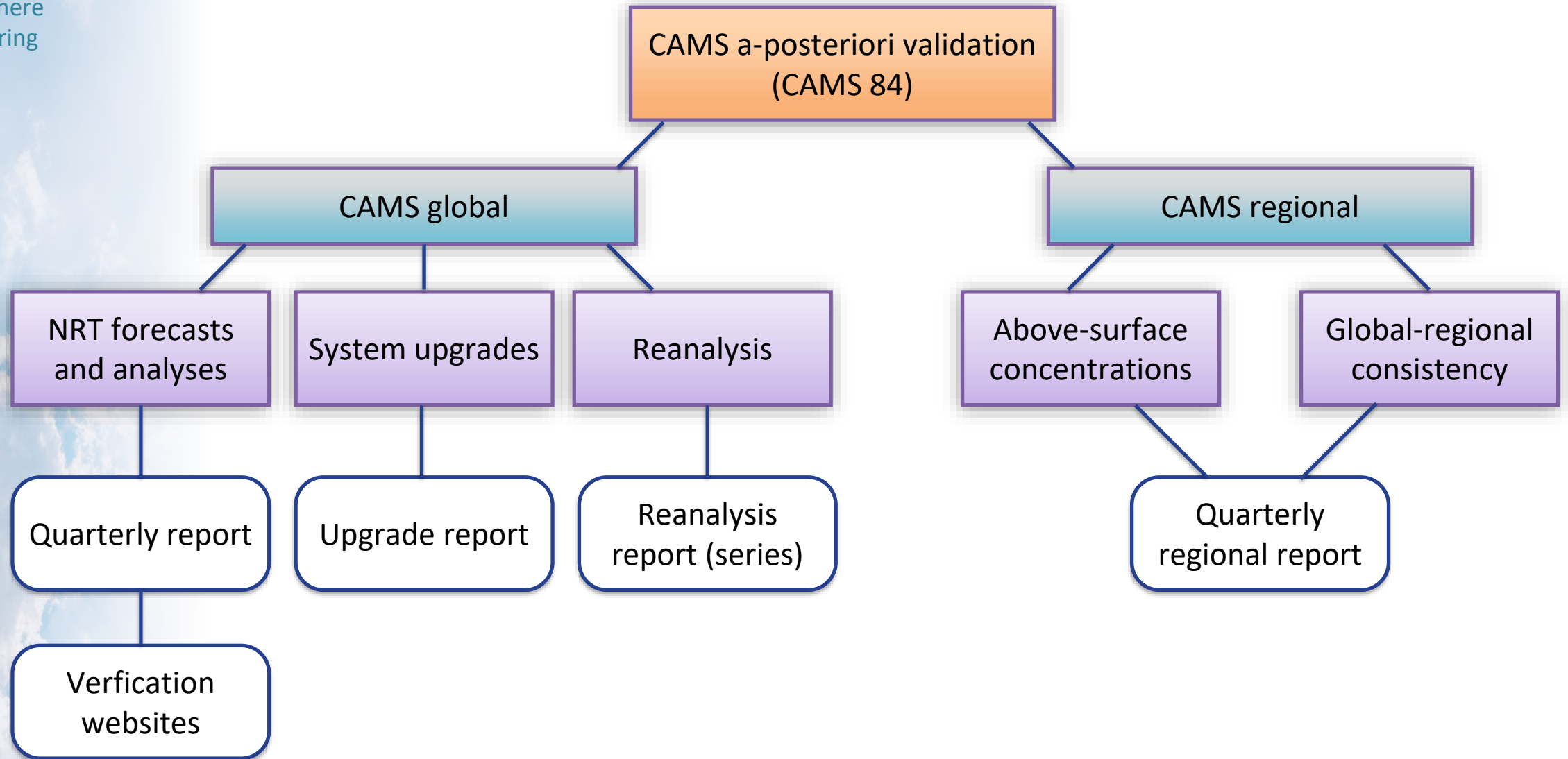
# CAMS Forecast and Reanalysis Evaluation using Chemical Observations

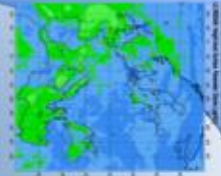
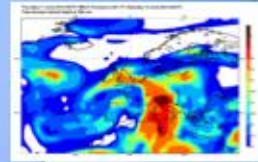
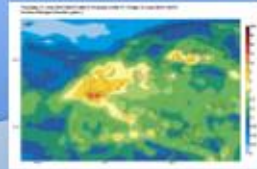
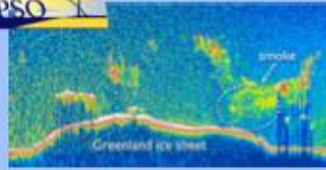
Henk Eskes, KNMI,  
Netherlands



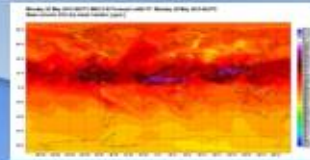
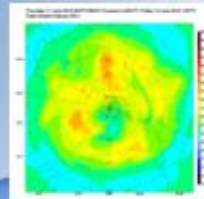
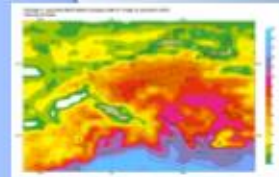


# CAMS a-posteriori validation activities





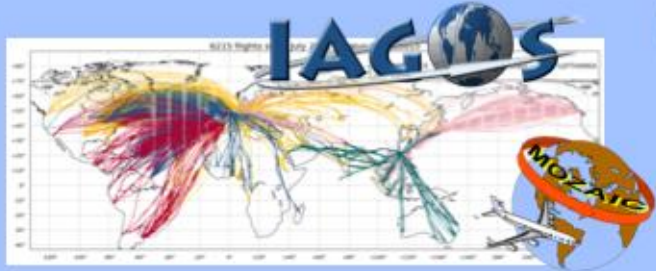
CAMS84 validation



European Environment Agency



ICOS integrated carbon observation system



TCCON total carbon column observing network



NDACC NETWORK FOR THE DETECTION OF ATMOSPHERIC COMPOSITION CHANGE



Observatories





Atmosphere  
Monitoring

# CAMS use of real-time observations

Timeliness

Real Real-Time  
< 2-3 hours

Near-Real-Time  
< 2-3 days

A posteriori  
< 1 month

Final  
< 1 year

QC/QA

Automated  
Filtering, flagging

Semi-automated

Manual, Expertise  
Semi-validated

Expertise+  
Validated

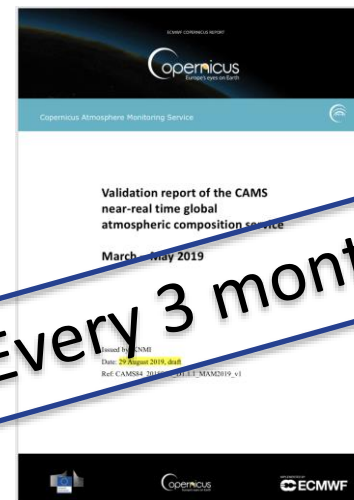
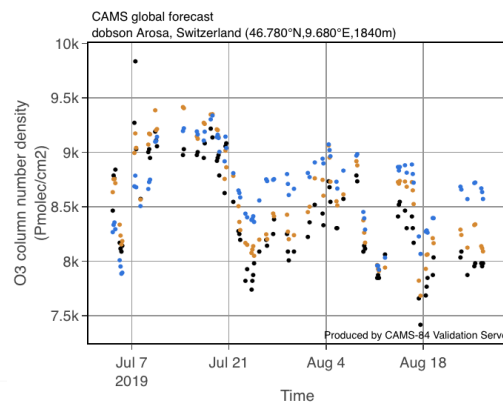
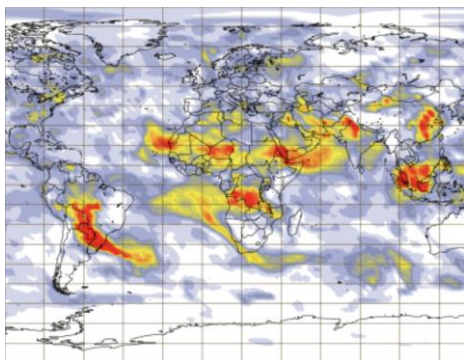
CAMS products

Assimilation  
(Verification)

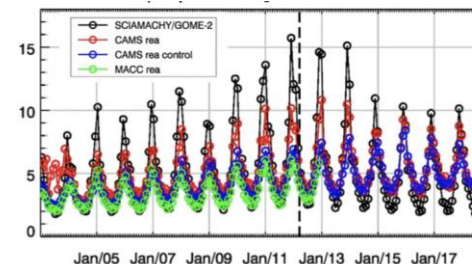
Verification  
(Assimilation)

Validation  
(Interim re-analyses)

Re-analyses  
(Validation)



Every 3 months



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



ECMWF COPERNICUS REPORT

**copernicus**  
Europe's eyes on Earth

Copernicus Atmosphere Monitoring Service

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

Evaluation of the e-suite for the  
CAMS upgrade of July 2019;  
e-suite experiments h4x1, h4xd (2017);  
e-suite run January-May 2019

Issued by: KNMI  
Date: 04-07-2019  
Ref: CAMS84\_2018SC1\_D3.2.1-201907\_esuite\_v1

<http://doi.org/10.24380/fcwq-yp50>

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

**Last upgrade:** July 2019

60L -> 137L

**Criteria for upgrade advice:**

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

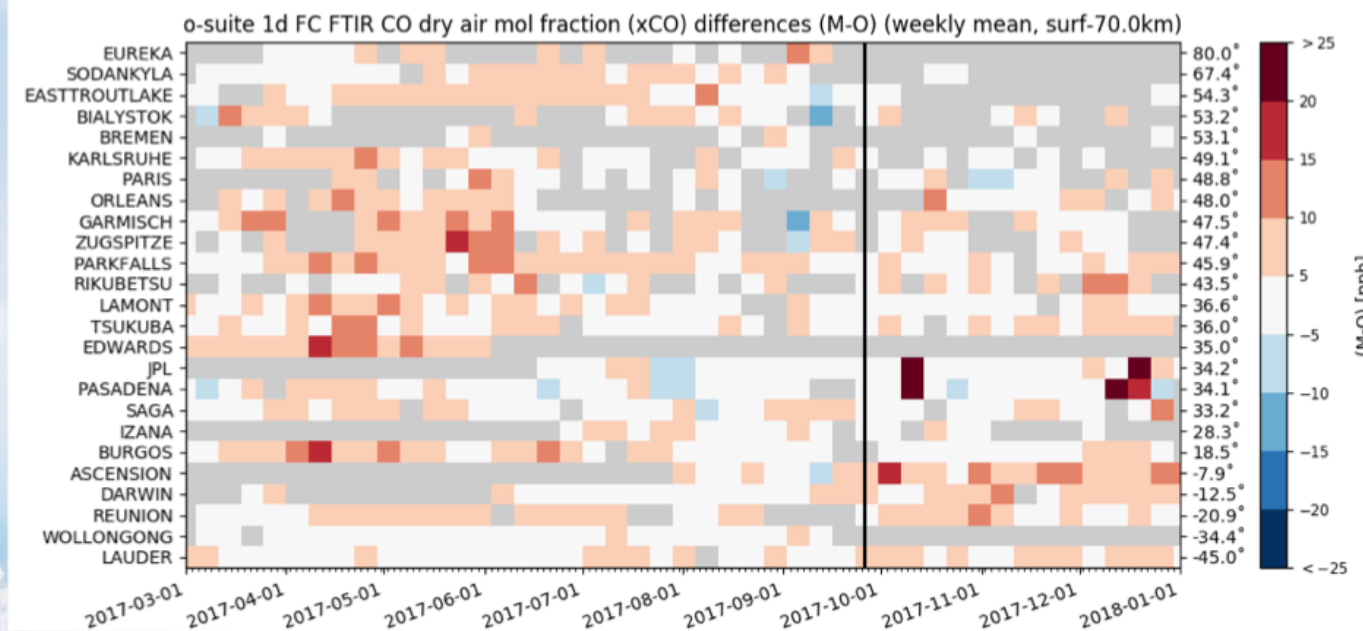


shutterstock.com · 208668481



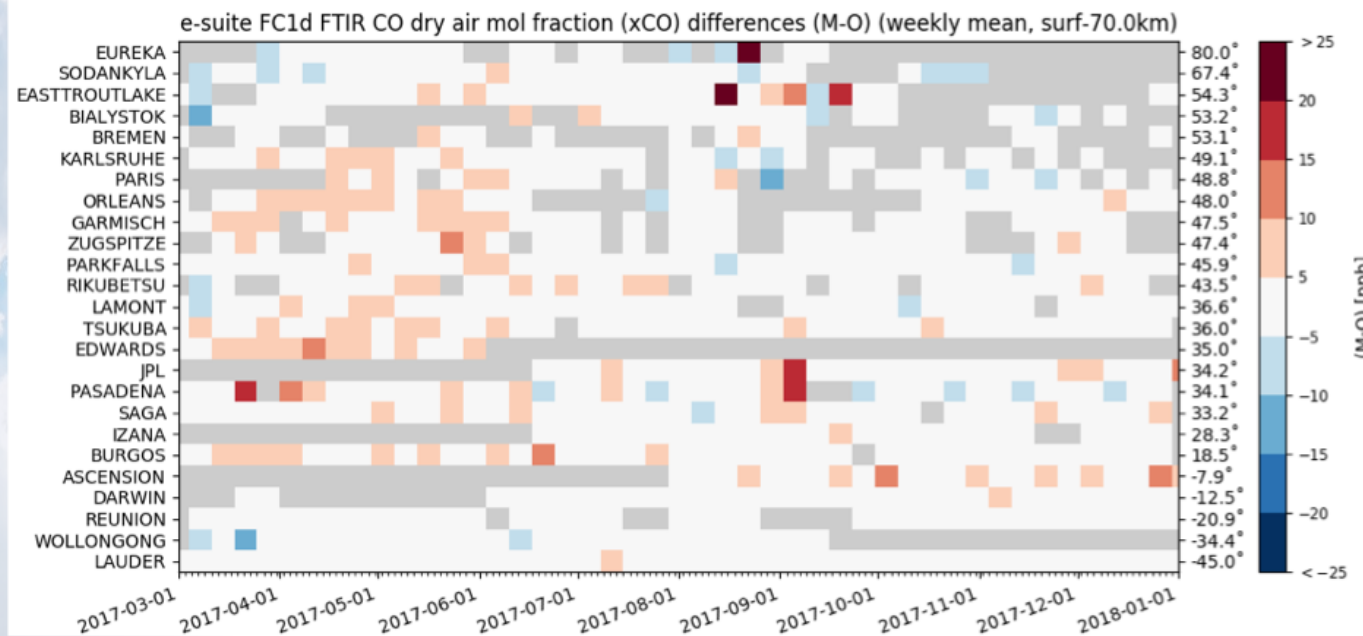
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# The 46R1 e-suite validation report

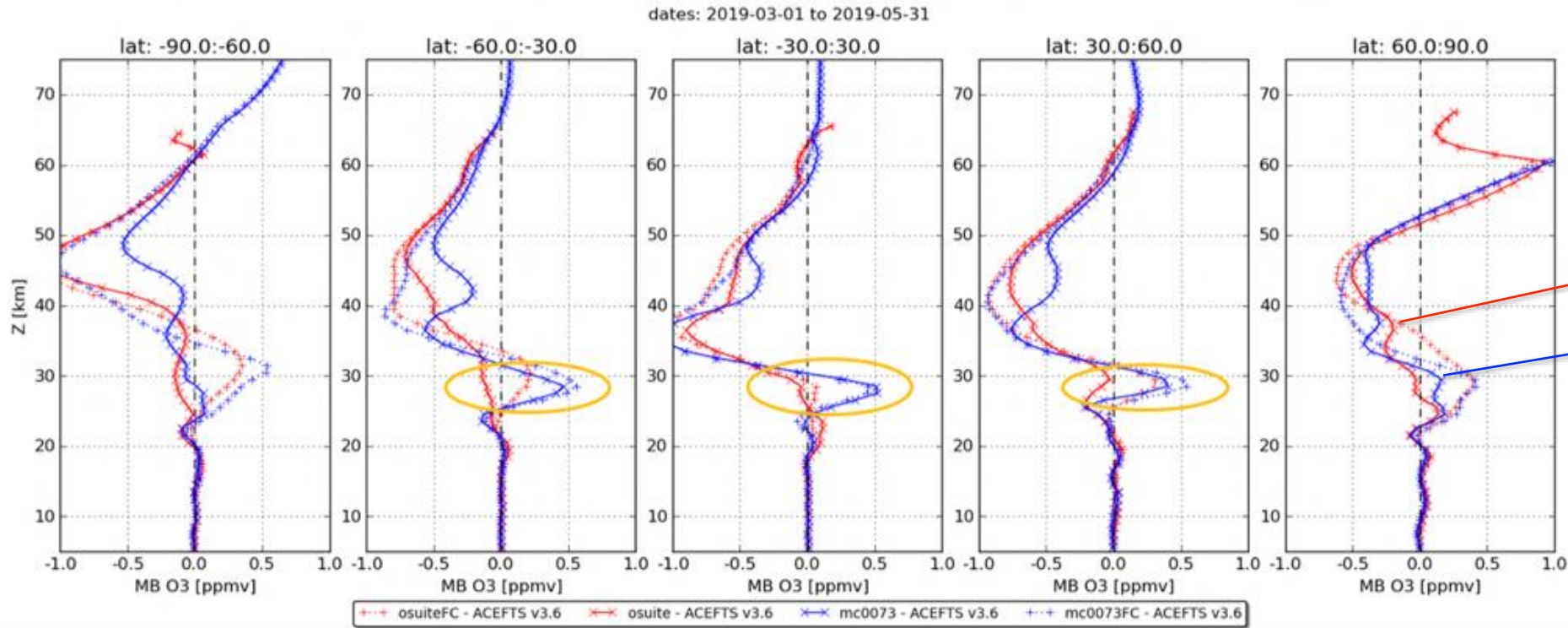


**CO comparisons  
against TCCON  
for 2017**

o-suite, 60L



e-suite, 137L



## Stratospheric ozone comparisons against ACE-FTS

o-suite  
e-suite

Pronounced bias peak around 20 hPa  
But also improvements in upper stratosphere

July 2019 upgrade of CAMS-global  
60 layers -> 137 layers





## Evaluation of CAMS European forecasts in boundary layer and free troposphere

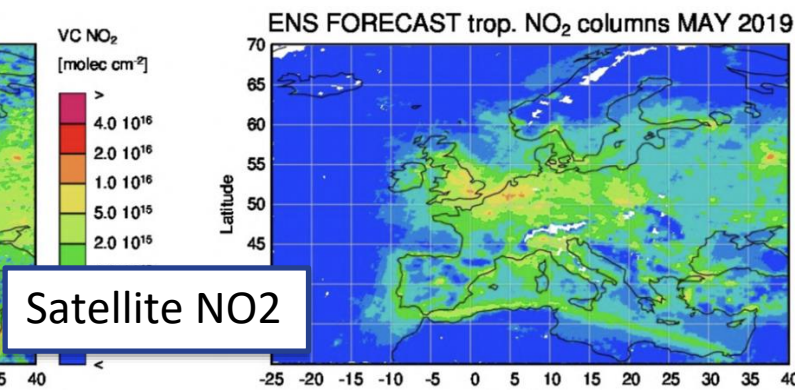
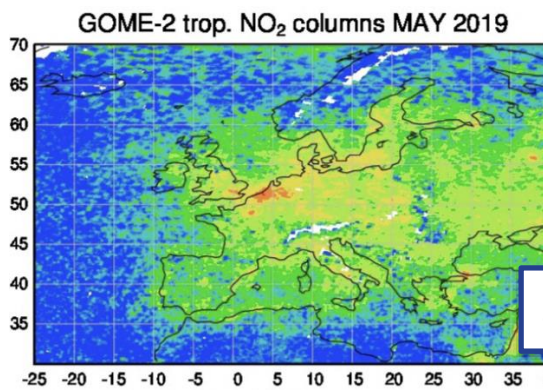
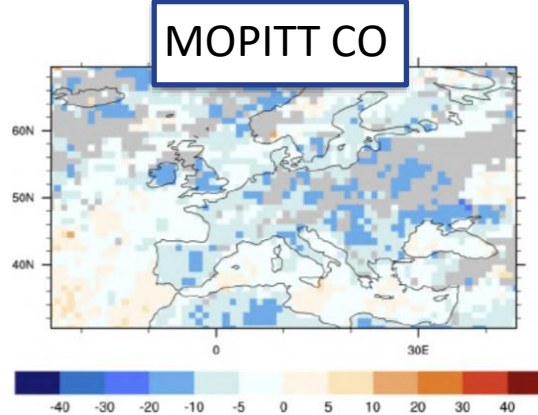
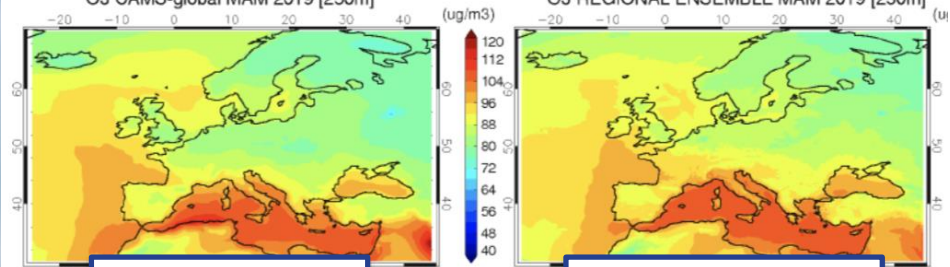
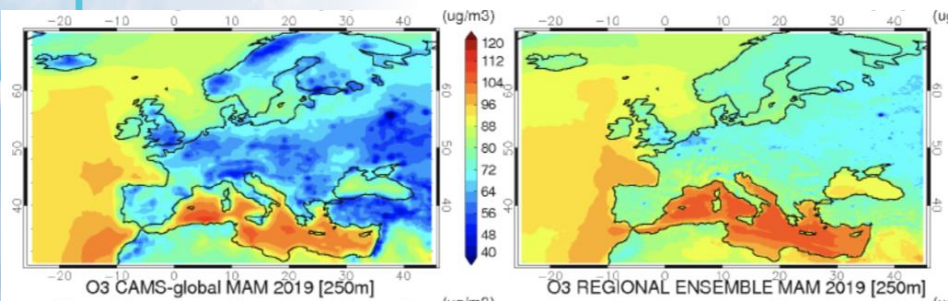
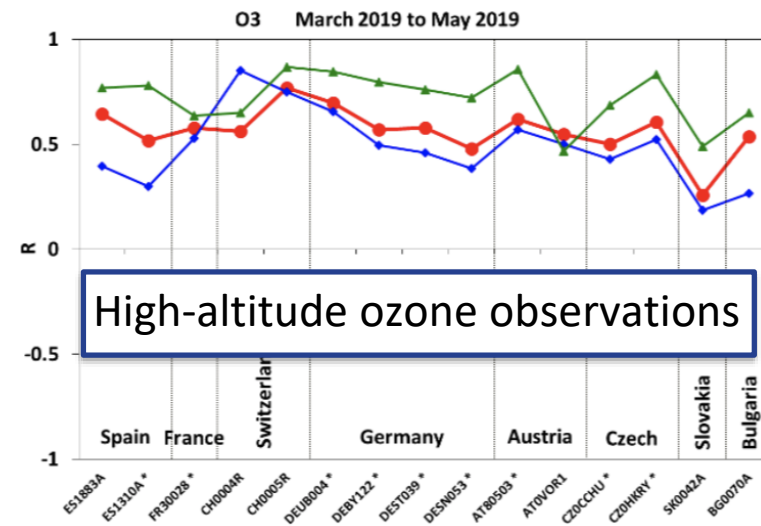
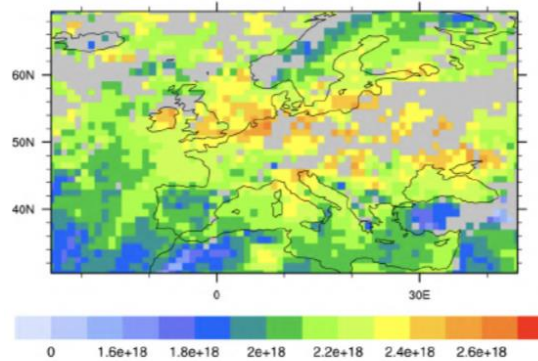
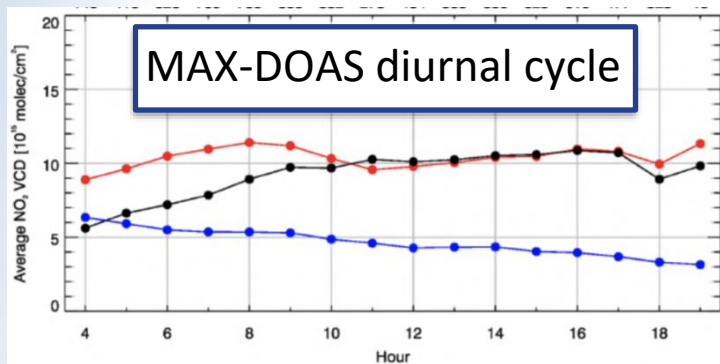
- AERONET - Aerosol optical depth
- EARLINET Lidar - Aerosol profiles
- Ozone sonde - Ozone profiles
- IAGOS O3 and CO - Aircraft decent, ascent
- MAX-DOAS - NO2 column in troposphere (boundary layer)
- Satellite NO2 (GOME-2), CO (MOPITT)
- High-altitude AIRBASE - Ozone in-situ
- GAW stations - Ozone and CO in-situ





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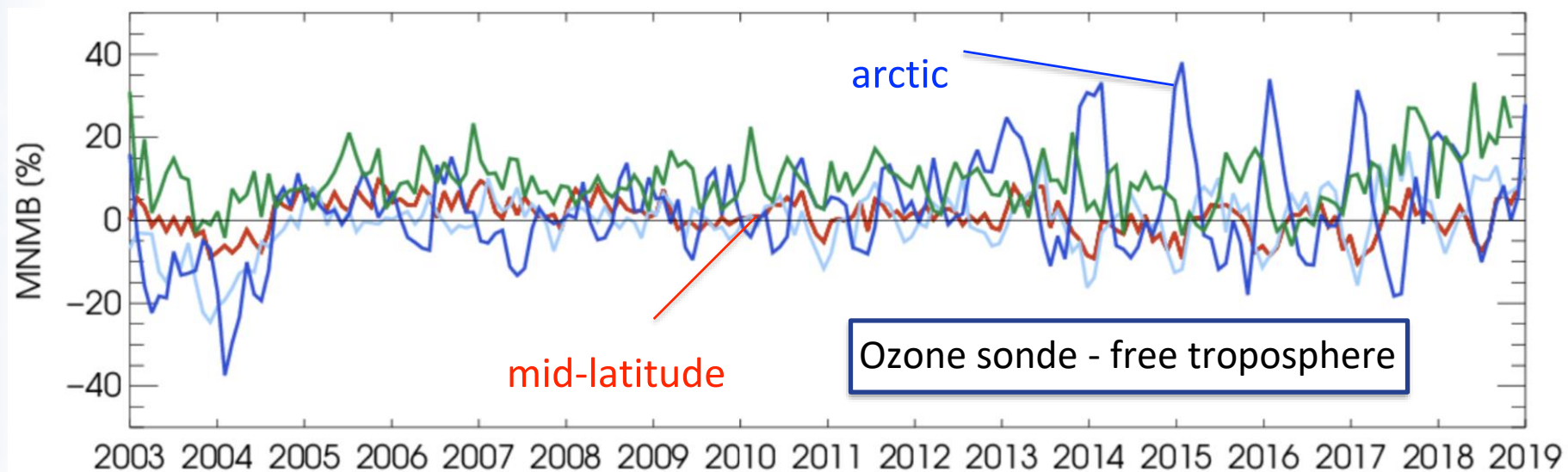
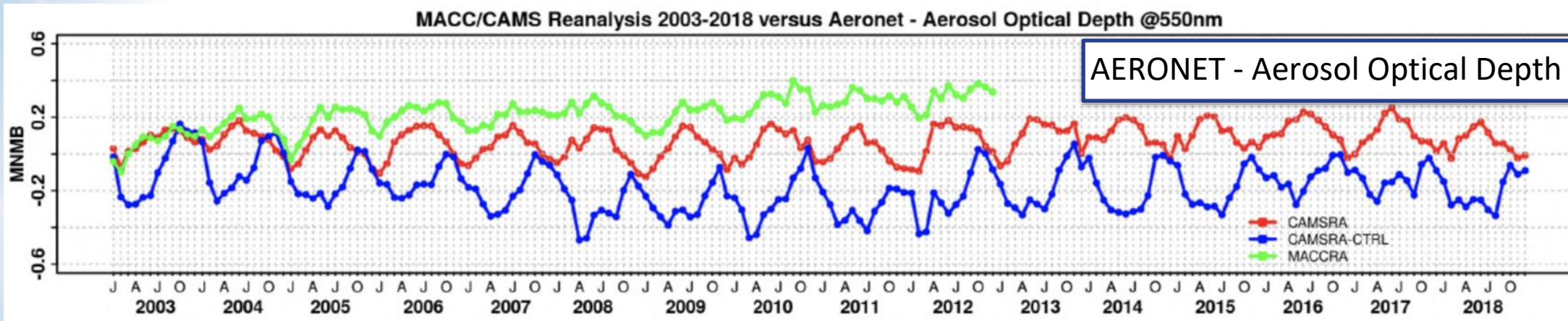
# Regional AQ forecasts: Evaluation above the surface



Satellite NO<sub>2</sub>

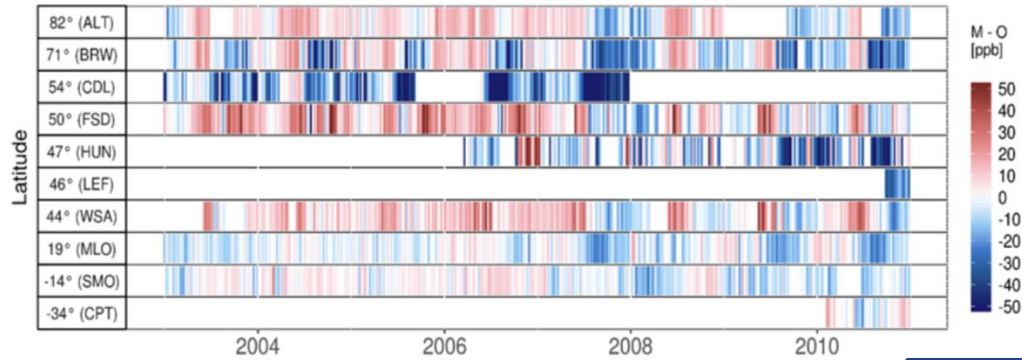


# CAMS reactive gas + aerosol reanalysis





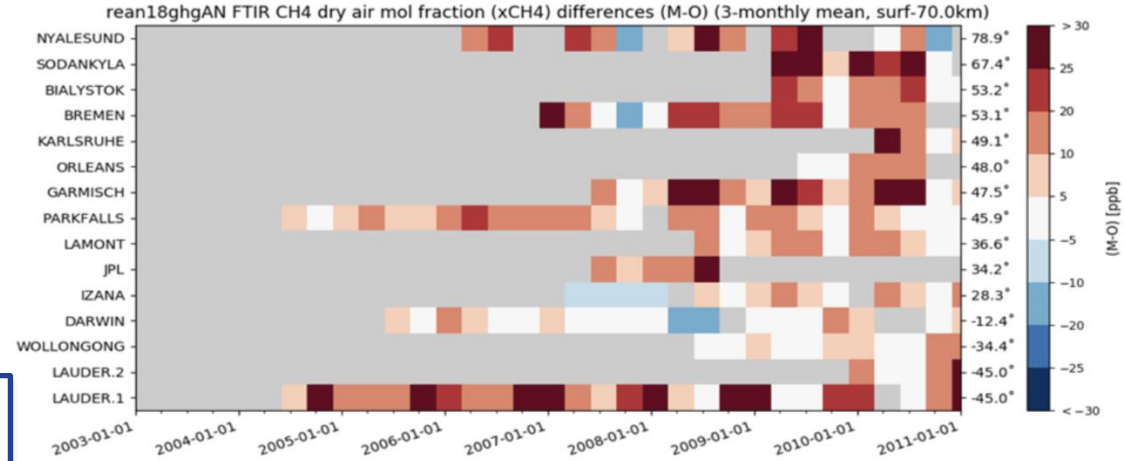
## Surface stations



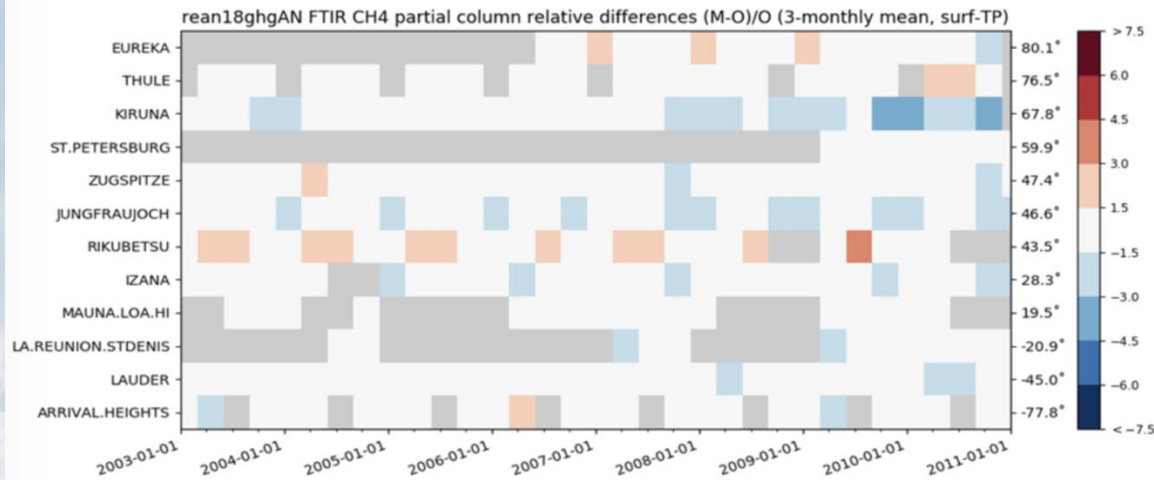
2003 - 2010

Methane

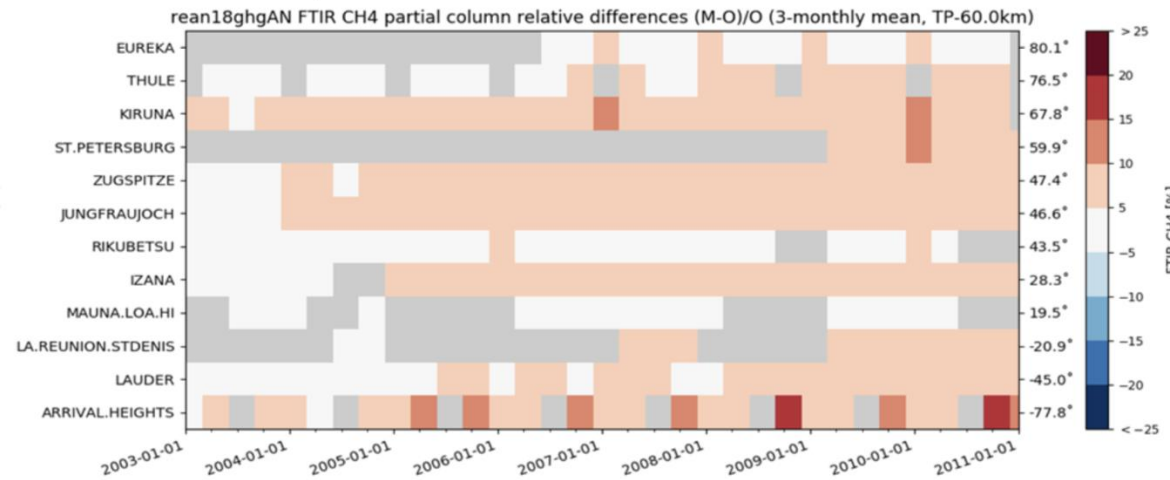
## Total columns at TCCON sites



## Tropospheric columns at NDACC sites



## Stratospheric columns at NDACC sites

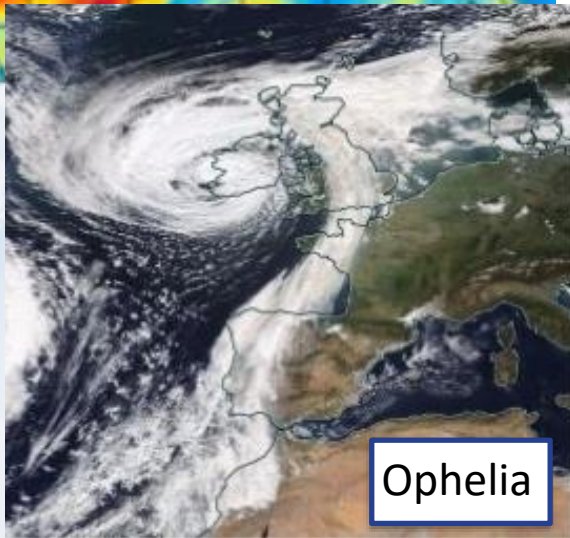
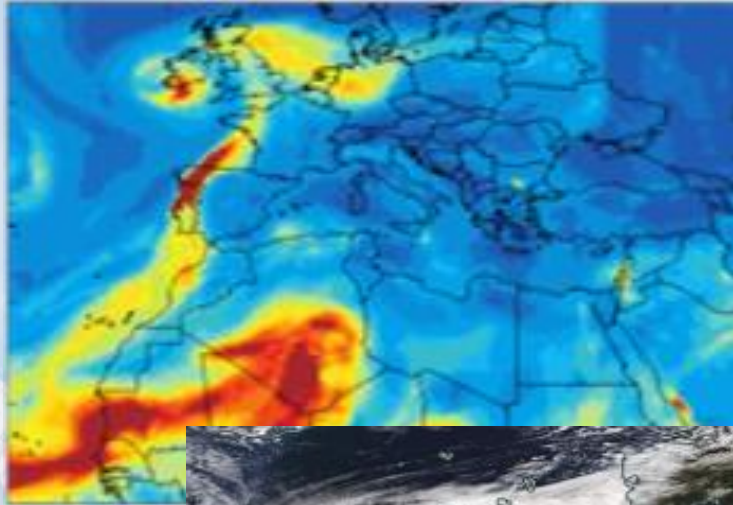




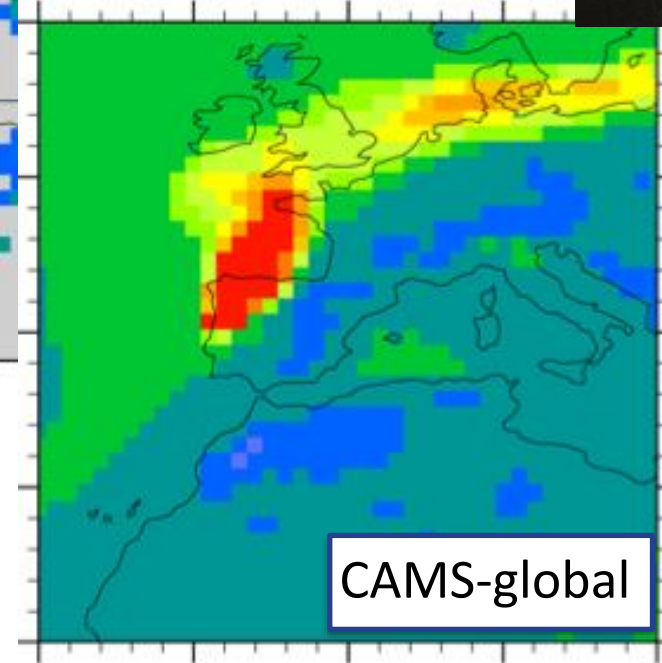
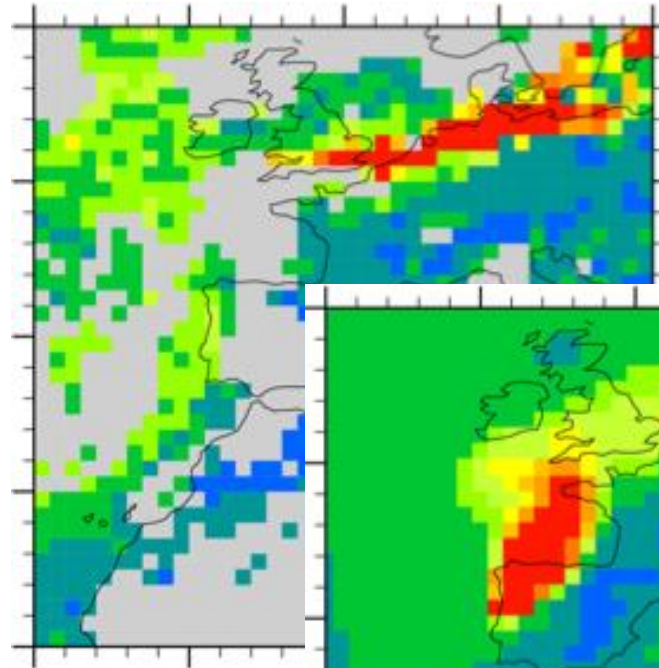
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# Case studies: dust and smoke over N-W Europe

15-17 October 2017

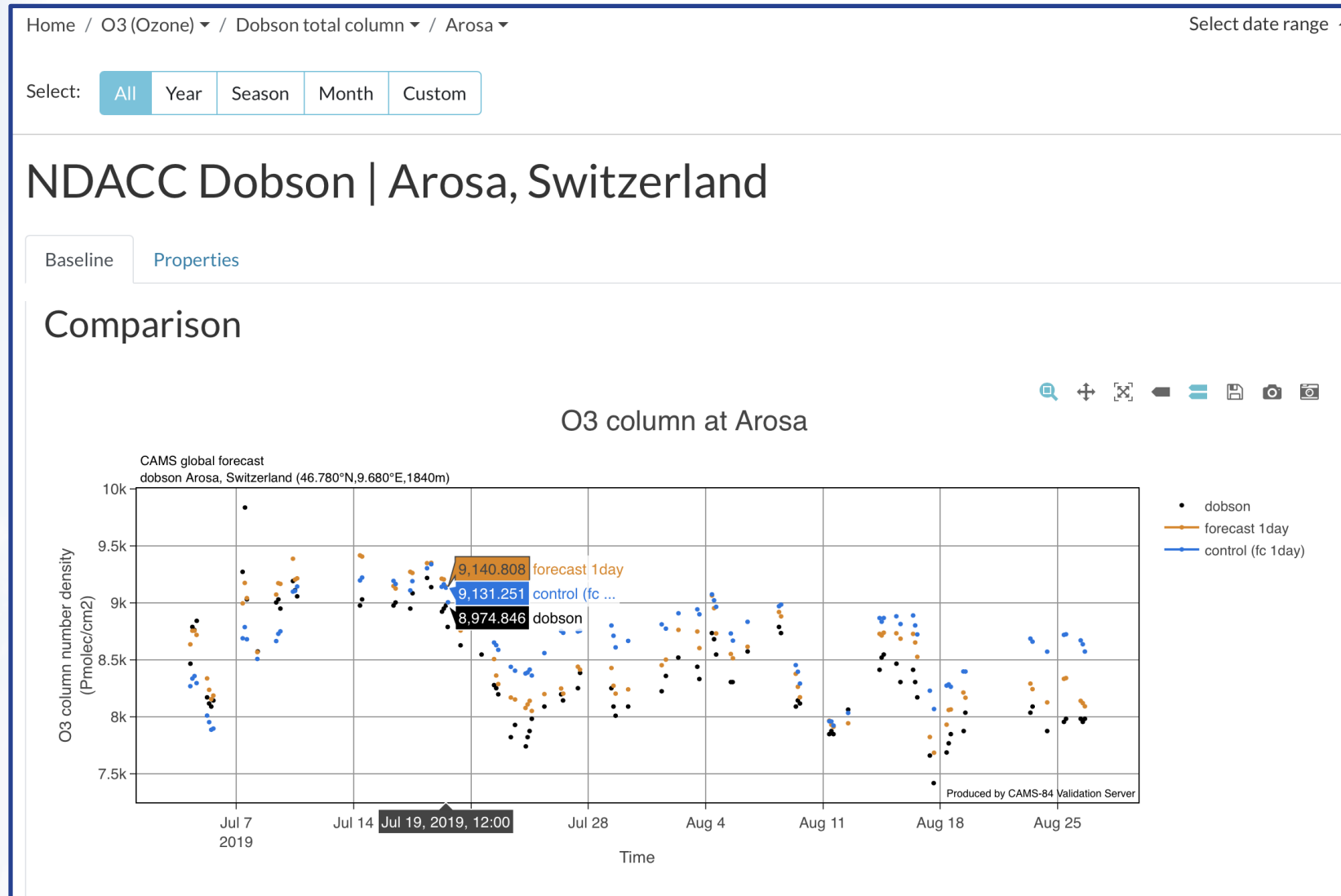


IASI CO observations



Sahara dust  
combined with  
fires in  
Portugal-Spain

-> Case study report available on CAMS website

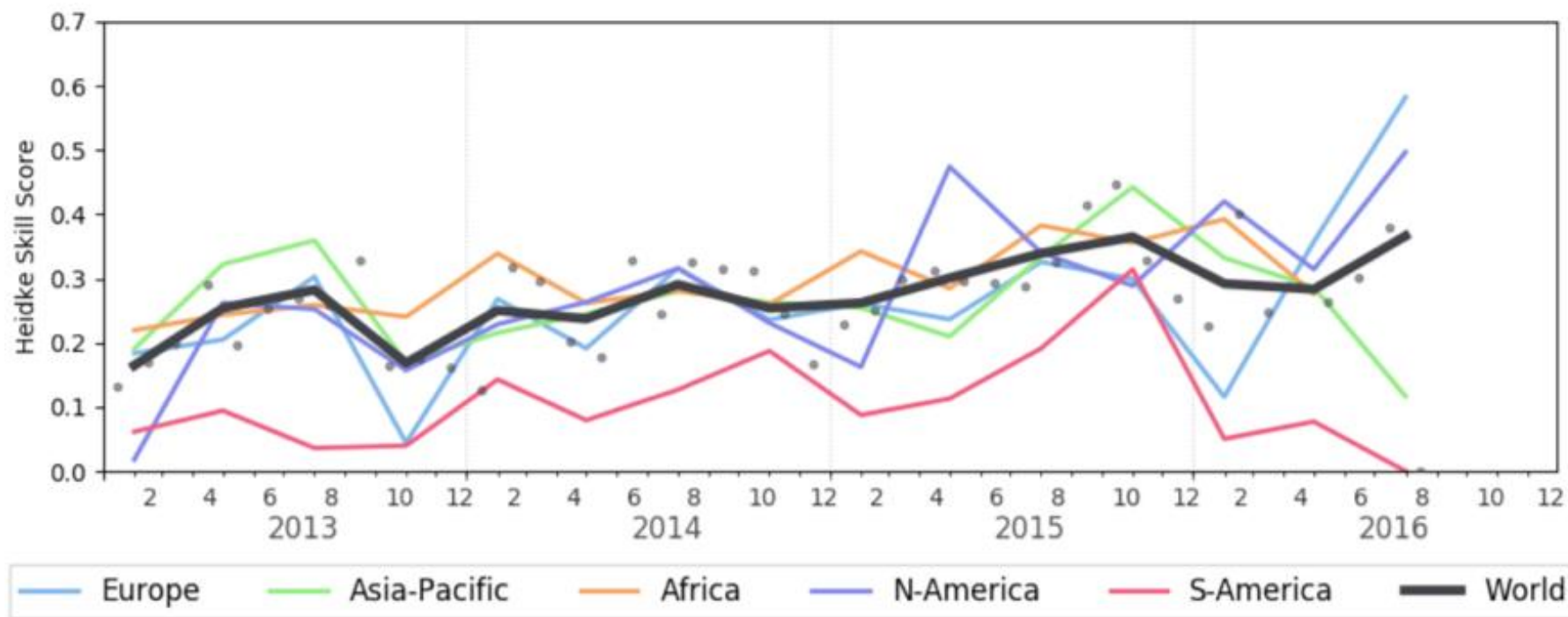




# Headline score developments

Headline scores: a few key scores to monitor the progress of CAMS with time

MetNo partner developed headline score for high aerosol concentration events



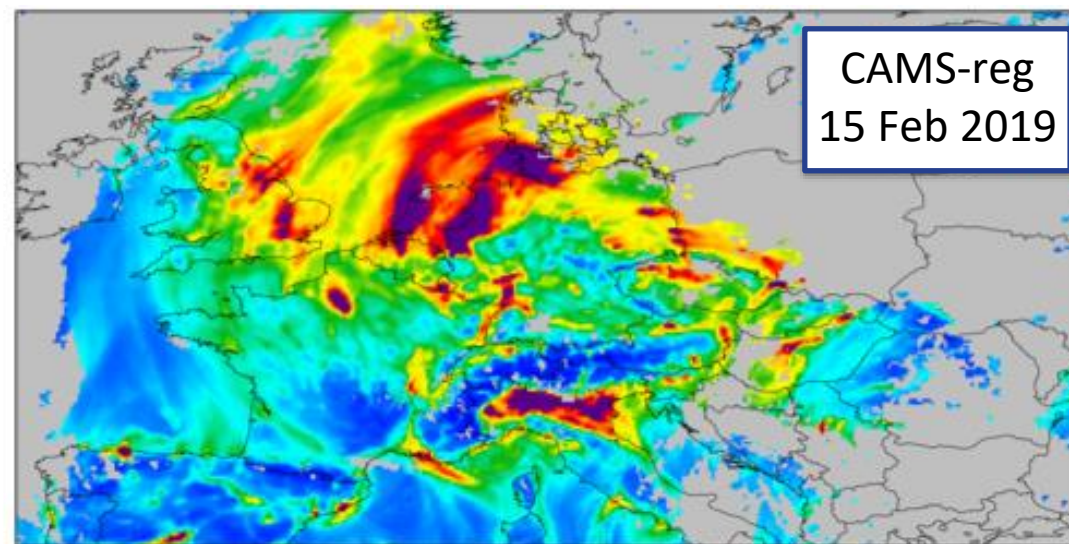
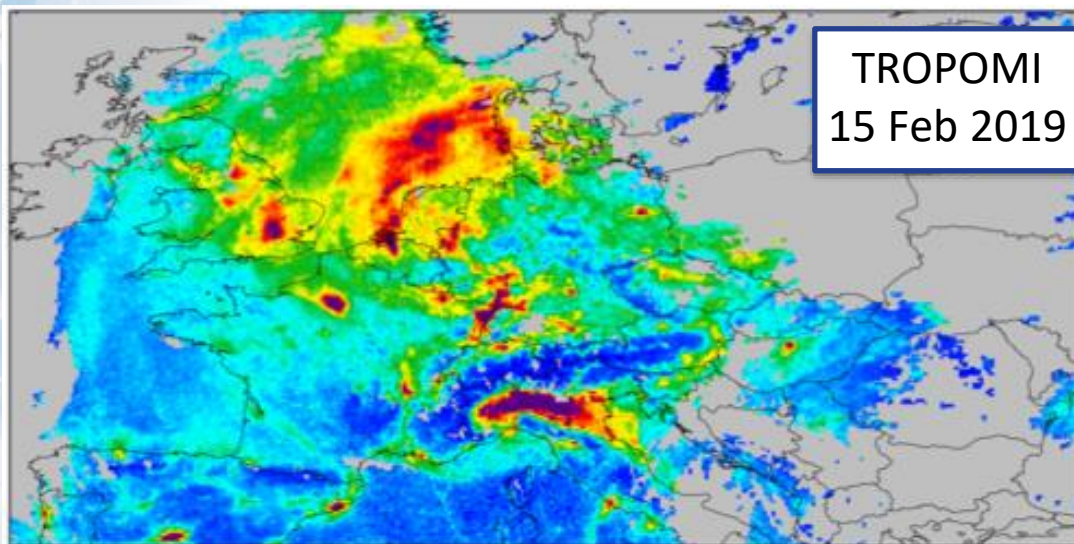
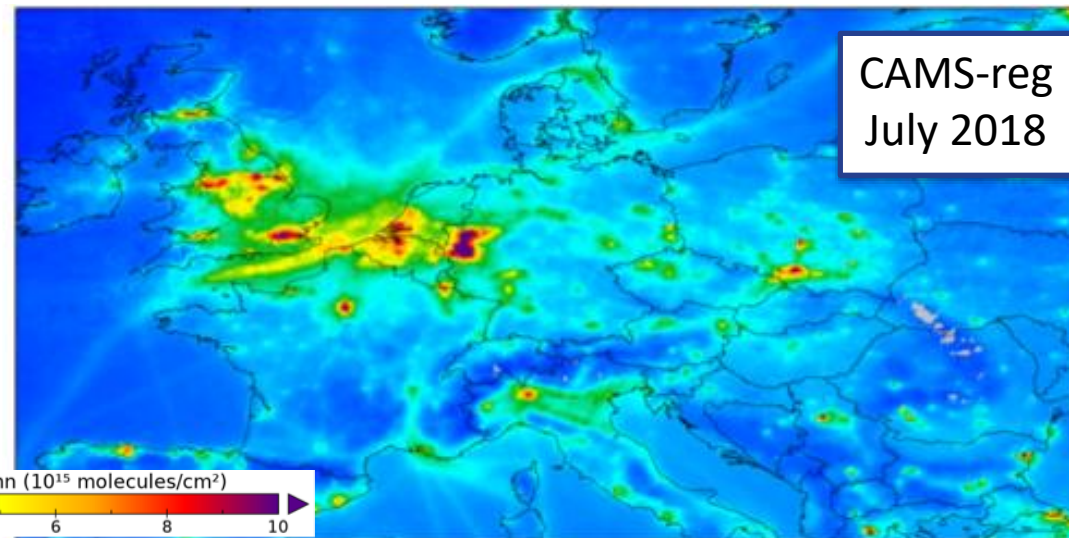
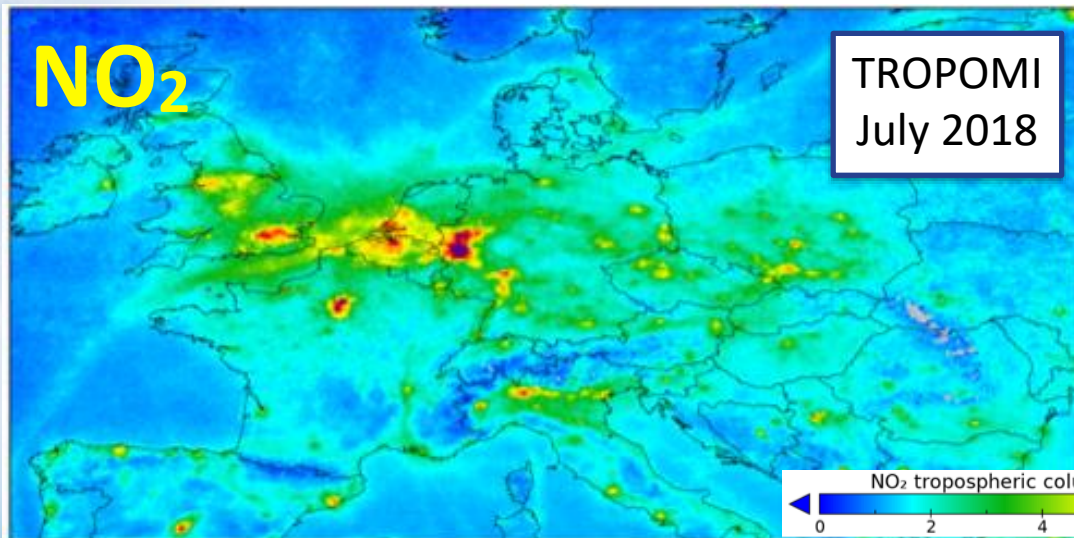
Michael Schulz (METNO)



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# Comparisons with Sentinel-5P TROPOMI

**NO<sub>2</sub>**



John Douros (KNMI)







## 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](http://global-evaluation.atmosphere.copernicus.eu)
- All validation reports available at [atmosphere.copernicus.eu](http://atmosphere.copernicus.eu)



## Persons involved in CAMS validation

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A. Blechschmidt (IUP-UB), S. Chabrillat (BIRA-IASB), Y. Christophe (BIRA-IASB),  
J. Claas (KNMI), H. Clark (CNRS-LA), E. Cuevas (AEMET), J. Douros (KNMI),  
H. Flentje (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), Y. Wang (MPG),  
T. Warneke (UBC), C. Zerefos (AA)

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



# The evaluation of the global NRT system

Variable	Instrument	Satellite	Product	Origin, period	AK
O3	SCIAMACHY	Envisat	TC	CCI; 20030101 - 20120408	no
O3	MIPAS	Envisat	PROF	ESA NRT: 20030127- 20030720 MARS ESA NRT: 20030721-20040326 CCI: 20050127-20120331	no
O3	MLS	Aura	PROF	V4: 20040803-20180312 V4 NRT: 20180313-	
O3	OMI	Aura	TC	KNMI V003; reprocessed 20040803-20150531 NRT 20150601-	no
O3	GOME-2	Metop-A	TC	CCI BIRA (fv0100): 20070123-20121231 CCI BIRA (fv0300): 201301-201612 GDP4.8 ACSAF/DLR: 20170101 -20181231	no
O3	GOME-2	Metop-B	TC	CCI BIRA (fv0300): 201301-201612 GDP4.8 ACSAF/DLR: 20170101 -20181231	no
O3	SBUV/2	NOAA-14	PC 13L	NASA v8.6: 200407-200609	no
O3	SBUV/2	NOAA-16	PC 13L 21L	NASA v8.6: 200301-200706 20111201-20130708 NASA v8.6 NRT: 20130709-201406	no
O3	SBUV/2	NOAA-17	PC 13L	NASA v8.6: 200301-201108	no
O3	SBUV/2	NOAA-18	PC 13L	NASA v8.6: 200507-201211	no
O3	SBUV/2	NOAA-19	PC 13L 21L	NASA v8.6: 200903-20130708 NASA v8.6, NRT: 20130709-20181231	no
CO	MOPITT	Terra	TC	V6 (TIR): 2003-2016 V7 (TIR): 201701 onwards	yes
NO2	SCIAMACHY	Envisat	TRC	v1p: 20030101-20101231 v2: 20110101-20120409	yes
NO2	GOME-2	Metop-A	TRC	ACSAF GDP4.8: 20070418-20181231	yes
NO2	GOME-2	Metop-B	TRC	ACSAF GDP4.8: 20130101-20181231	yes
NO2	OMI	Aura	TRC	COL3: 20041001-20181231	yes
AOD	AATSR	Envisat	TC	CCI, 20030101-March2012	no
AOD	MODIS	Terra	TC	COL6; 20030101-20181231	no
AOD	MODIS	Aqua	TC	COL6; 20030101-20181231	no

Reanalysis:  
satellite  
observations  
used



## Global CAMS forecast validation report:

- Published every 3 months
- Last available report MAM 2018 (published October 2018)

## Why 3-monthly ?

- The CAMS analysis/forecast system is evolving, about 2 updates / yr
- Up-to-date validation results

## Approach

- Compare **o-suite** and **control** run against independent observations

