

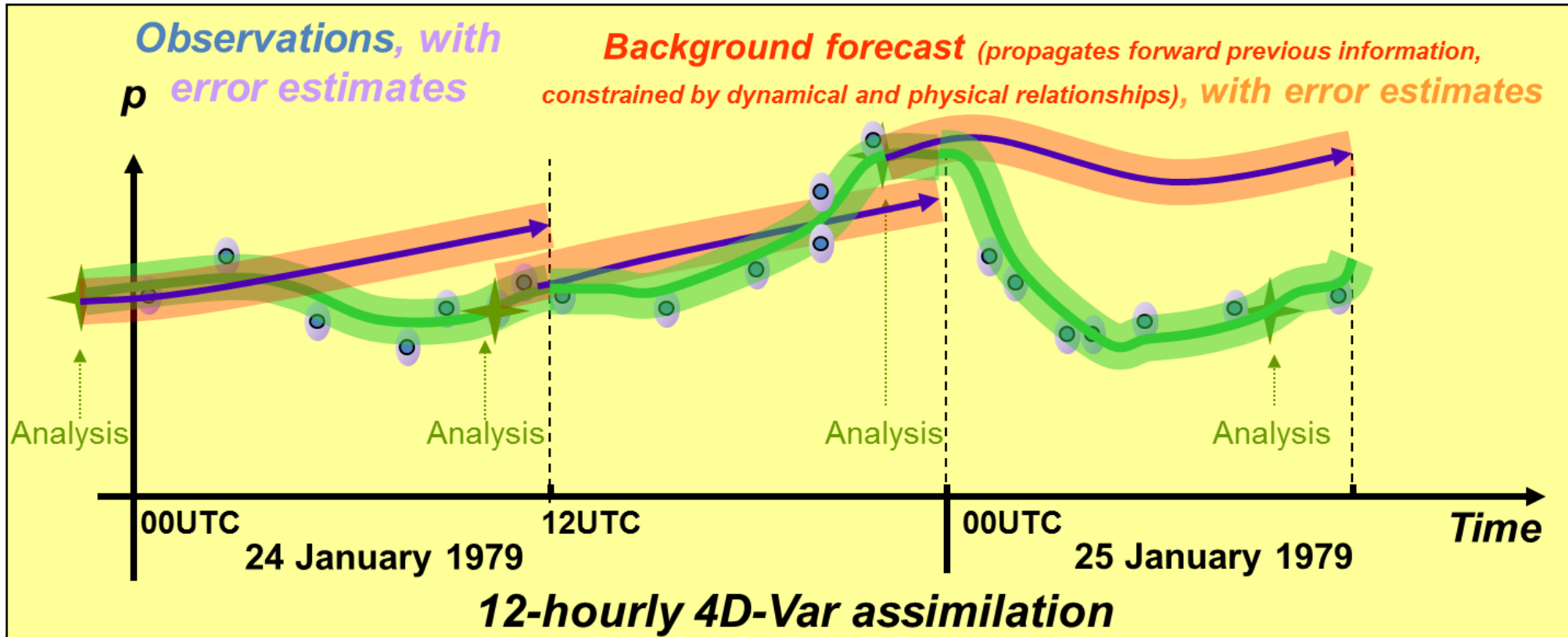
Assimilating Satellite Data in the Copernicus Atmosphere Monitoring Service Global Data Assimilation System: Current Status and Prospects for the Sentinel Era

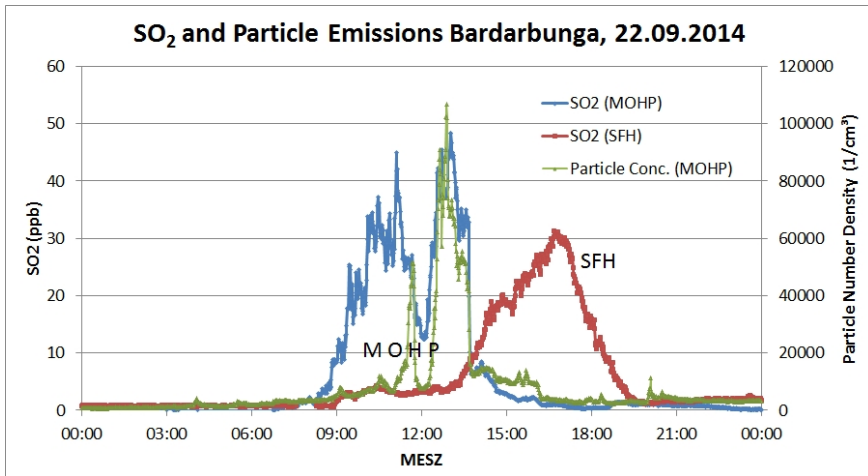
Richard Engelen

Thanks to: Anna Agusti-Panareda, Angela Benedetti, Marijana Crepulja, Johannes Flemming, Antje Inness, Luke Jones, Sebastien Massart, Mark Parrington, Vincent-Henri Peuch, Miha Razinger, Martin Suttie, Xiaobo Yang & MACC partners

ESA ATMOS, Heraklion, 12 June 2015

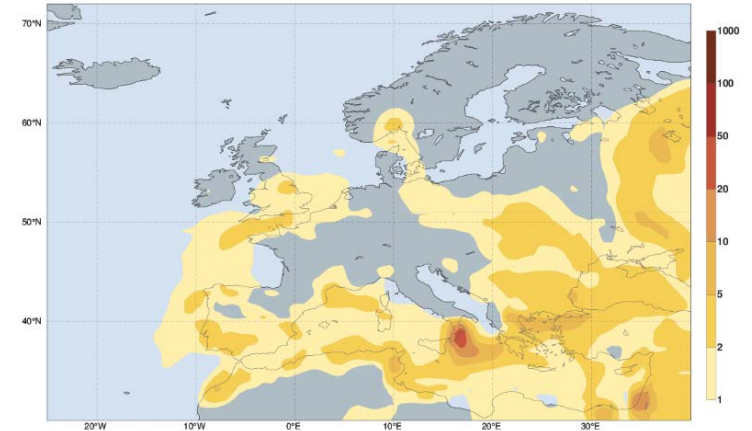
Data Assimilation – merging model forecast with observations





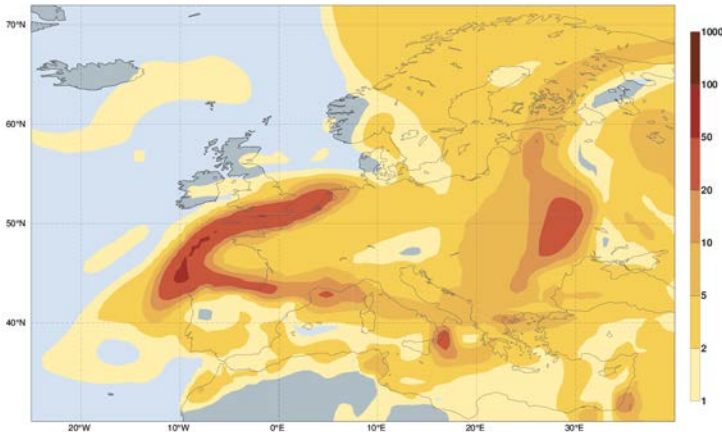
Credit: Deutsche Wetterdienst

Monday 22 September 2014 00UTC MACC_C-IFS Forecast t+036 VT: Tuesday 23 September 2014 12UTC
Total Column Sulphur Dioxide [10¹⁵ molecules / cm²] mean: 0.6 max: 51.6

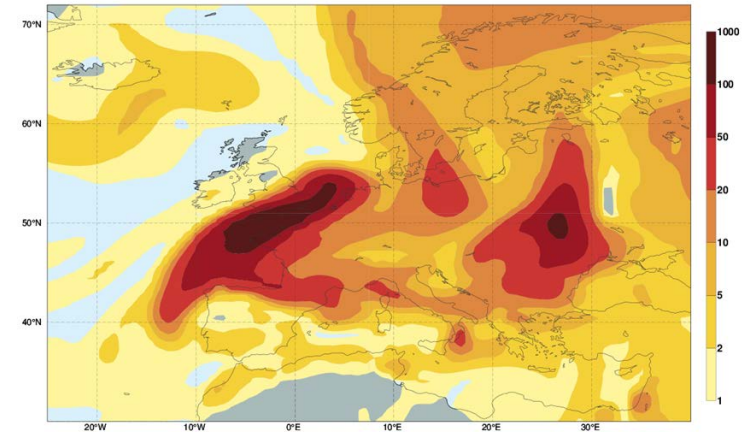


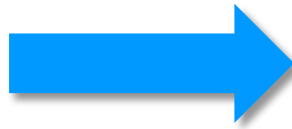
September 2014:
unusual SO₂
concentrations
detected across
Europe.

Monday 22 September 2014 00UTC MACC_C-IFS Forecast t+036 VT: Tuesday 23 September 2014 12UTC
Total Column Sulphur Dioxide [10¹⁵ molecules / cm²] mean: 1.8 max: 131.3



Monday 22 September 2014 12UTC MACC_C-IFS Forecast t+024 VT: Tuesday 23 September 2014 12UTC
Total Column Sulphur Dioxide [10¹⁵ molecules / cm²] mean: 3.1 max: 163.3

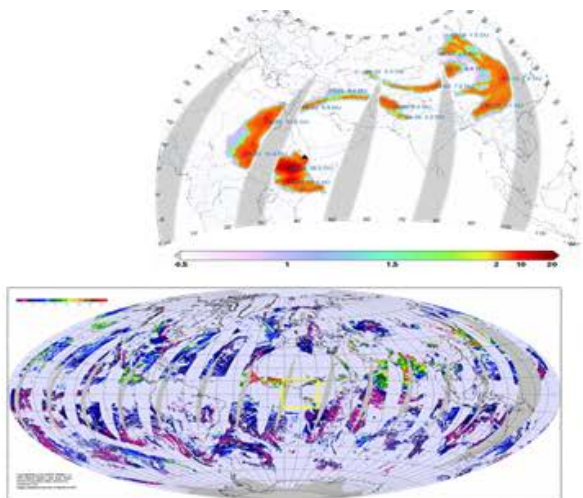




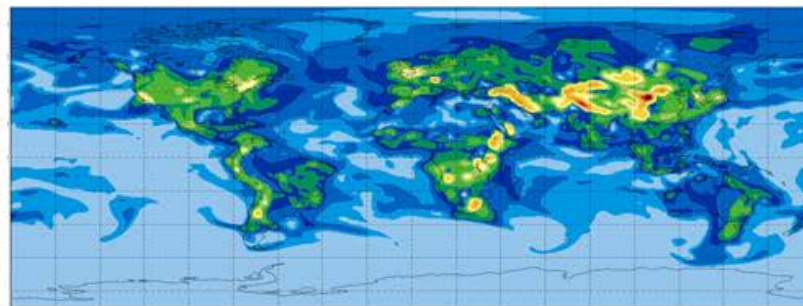
Copernicus Atmosphere Monitoring Service (CAMS)

- Operational delivery of atmospheric composition services
- Global and European regional scale
- Initial period from 2015 – 2020
- ECMWF is in charge of implementation

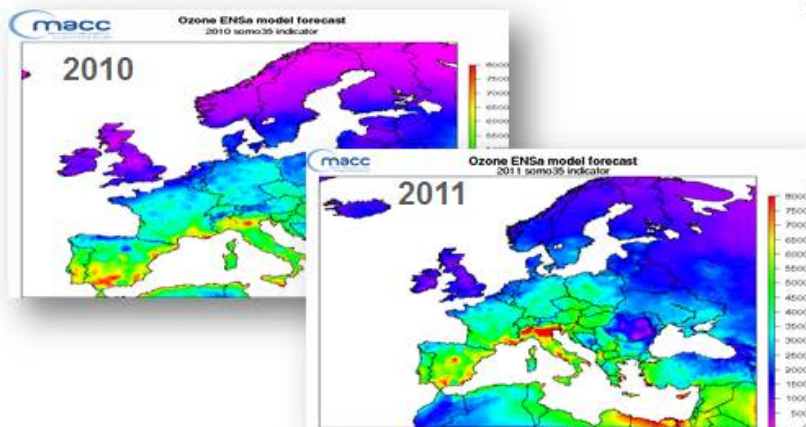
From EO to policy-relevant products



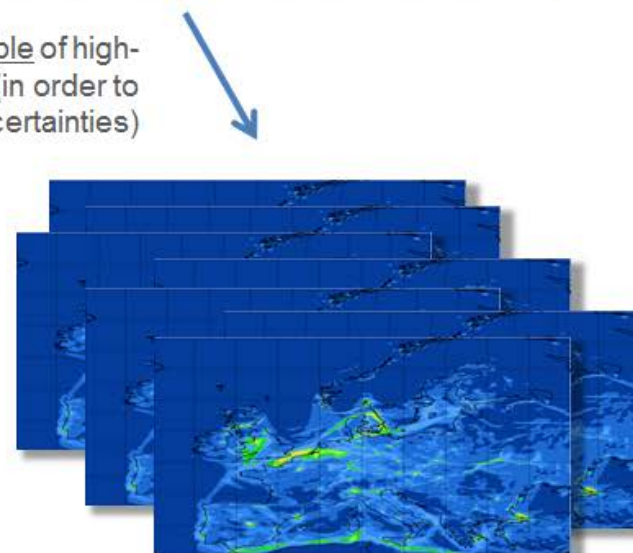
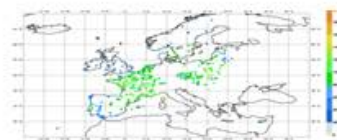
Over 70 EO instruments are assimilated in the global system



Boundary conditions feed an ensemble of high-resolution European AQ systems (in order to assess uncertainties)

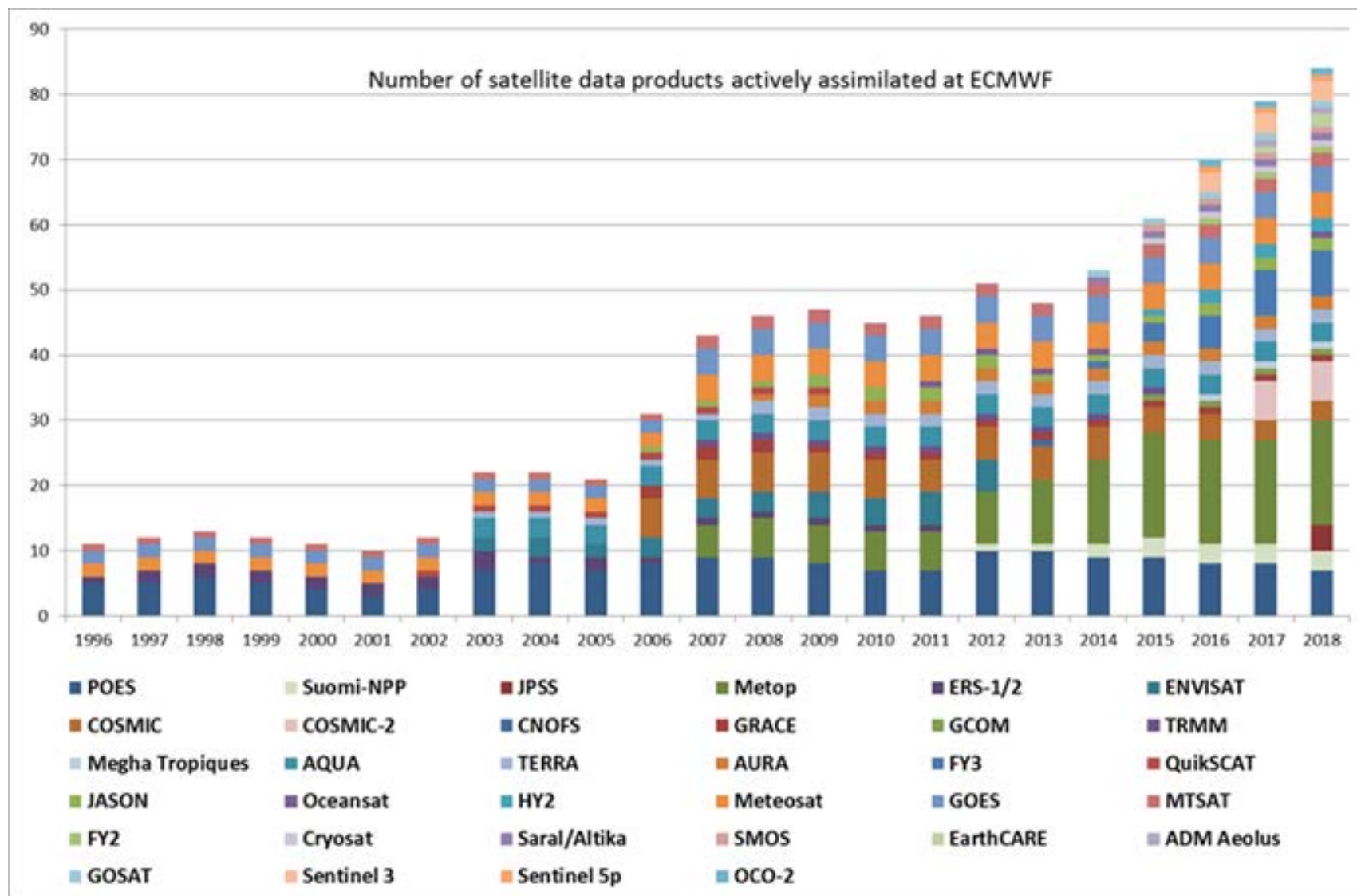


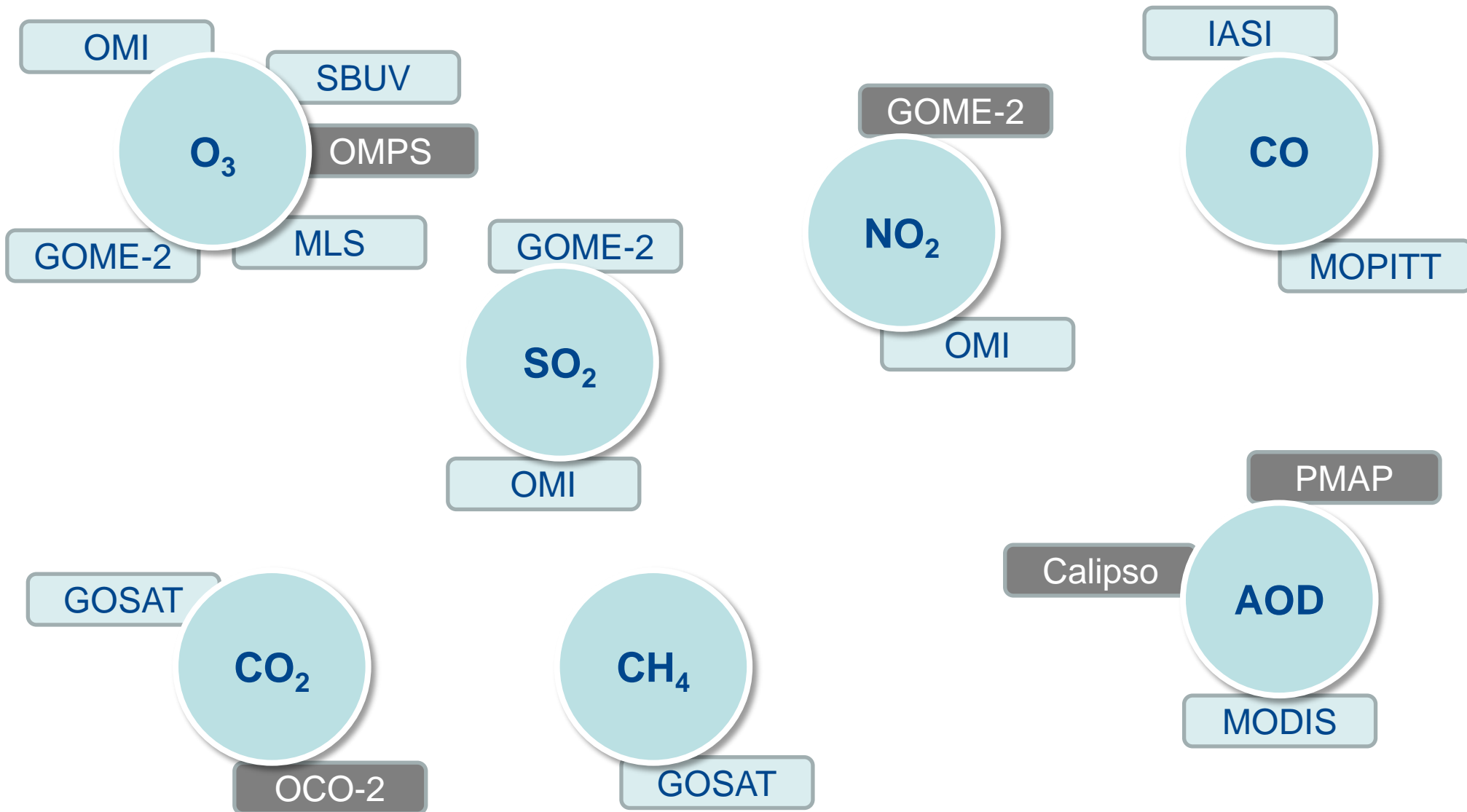
More data are assimilated (in particular hourly surface AQ concentrated by EEA/EIONET)



Policy-relevant (here health indicator for ozone) products are delivered. They are “maps with no gaps”, which observations alone don't provide and are essential to assess impacts.



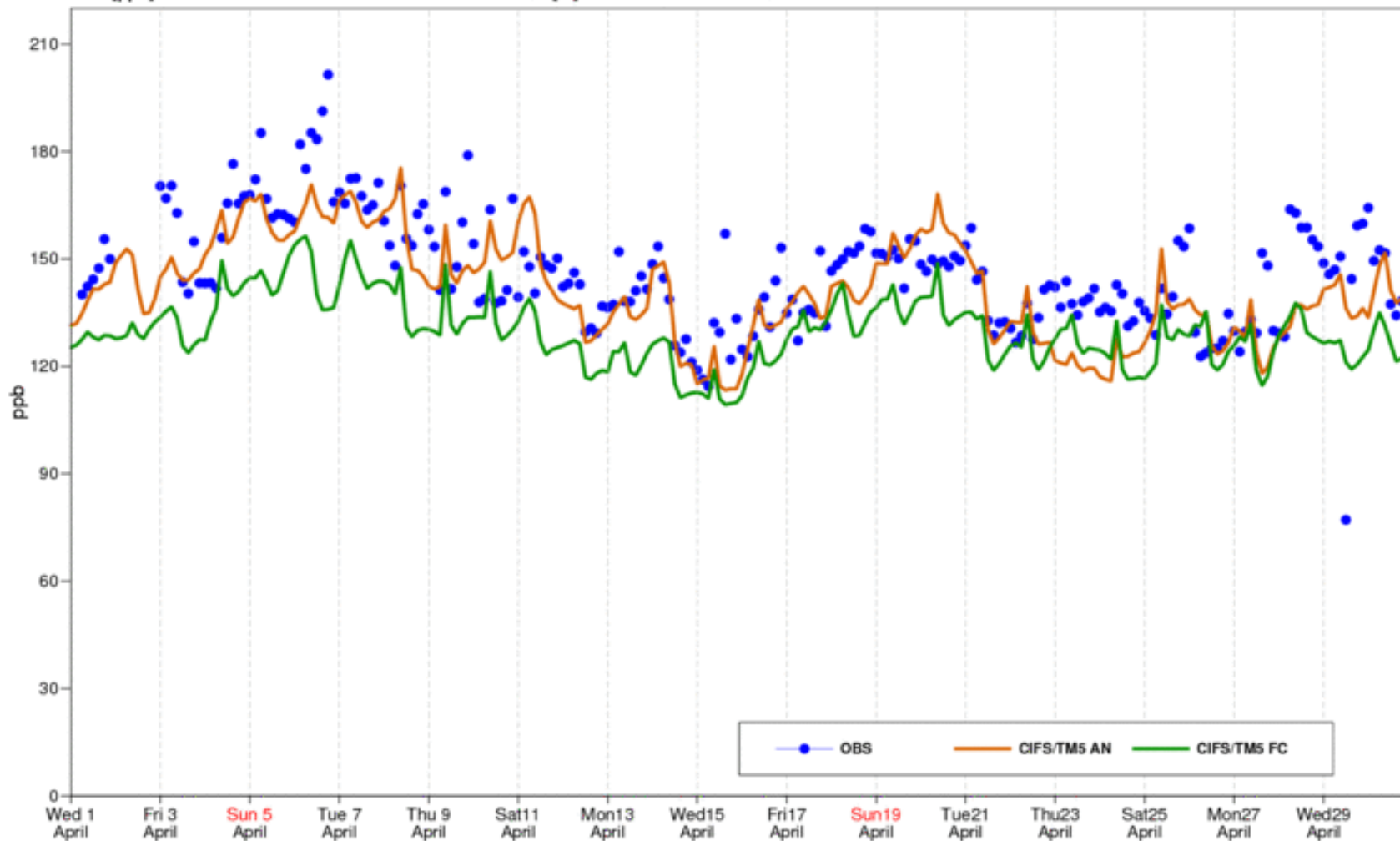




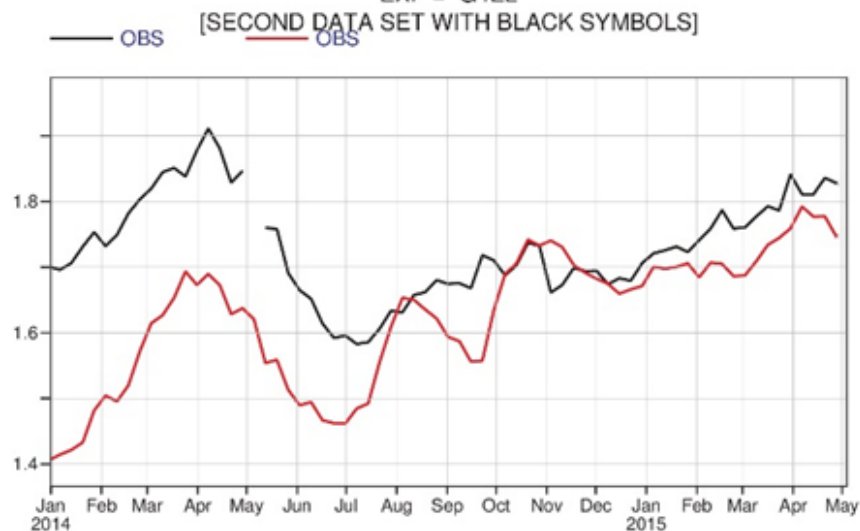


MACC GAW intercomparison Hohenpeissenberg Carbon monoxide April 2015

bias [ppb] CIFS/TM5 AN: -5.1 CIFS/TM5 FC: -16.7 MNbias [%] CIFS/TM5 AN: -3 CIFS/TM5 FC: -11



STATISTICS FOR CO FROM TERRA/ 90 VS METOP-A/221
LEVEL =0.00 - 1013.25 HPA, ALL DATA [TIME STEP = 168 HOURS]
Area: lon_w= 240.0, lon_e= 240.0, lat_s= -90.0, lat_n= 90.0 (over All_surfaces)
EXP = G4E2



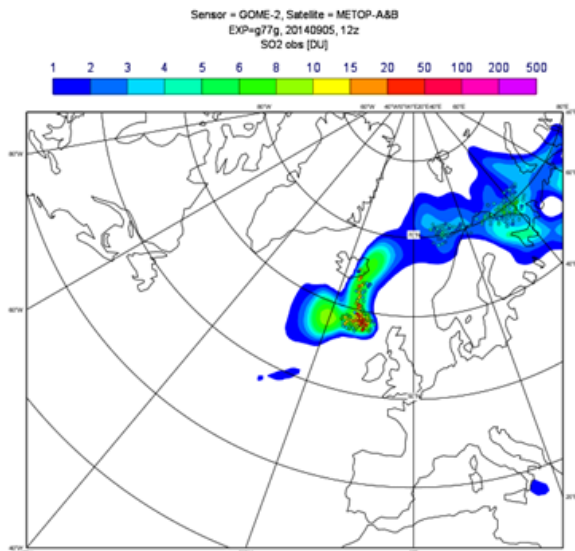
— MOPITT

— IASI

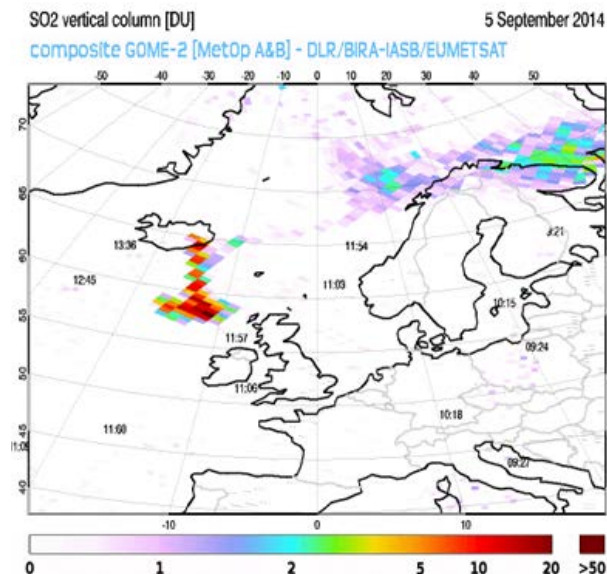
Both MOPITT and IASI have introduced new versions in their near-real-time data streams.

Agreement much better since November 2014, as clearly shown by operational monitoring.

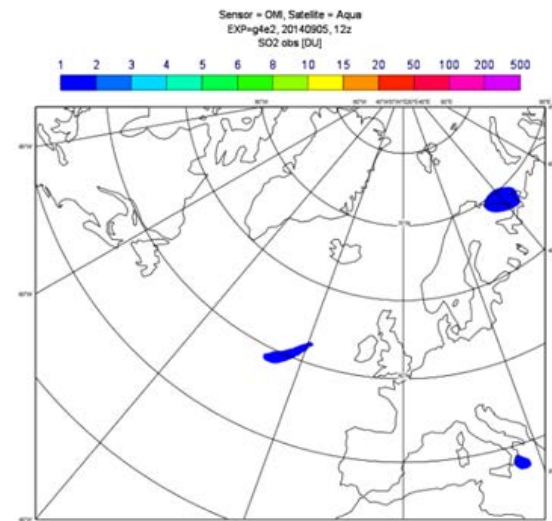
GOME-2 assimilation



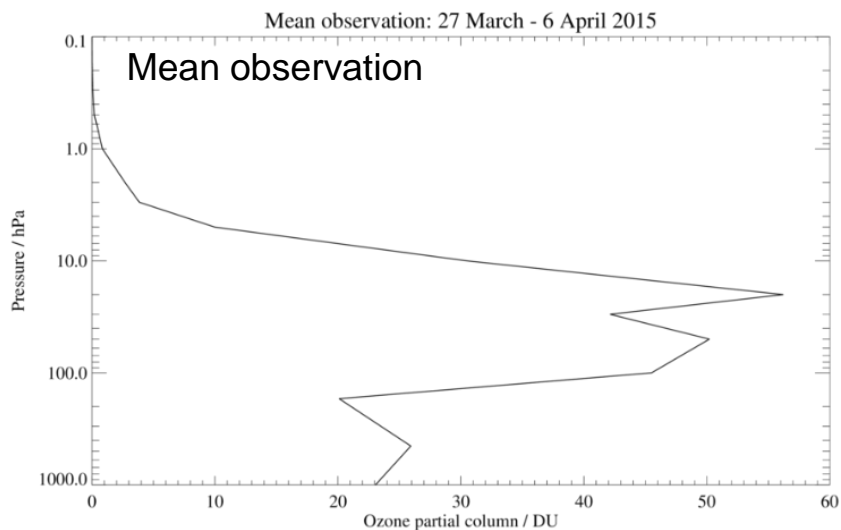
SACS composite



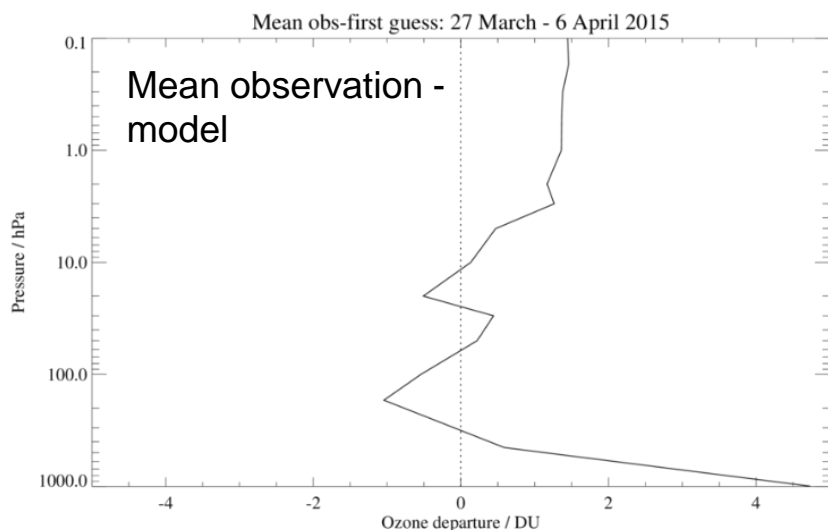
OMI assimilation



DLR provides a volcanic SO₂ flag as part of its SO₂ product. This allows better use of GOME-2 data. Much improved results compared to assimilation of OMI data only.



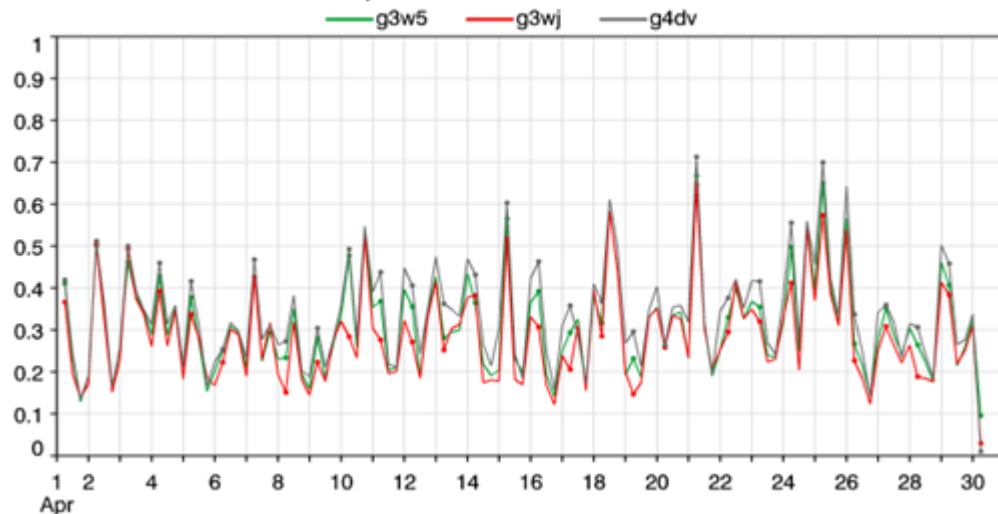
Assimilation of GOME-2 O₃ profiles (provided by RAL) is work-in-progress; successful assimilation should provide better constraint on vertical distribution.



First results show that use of averaging kernel for tropospheric profile is important.

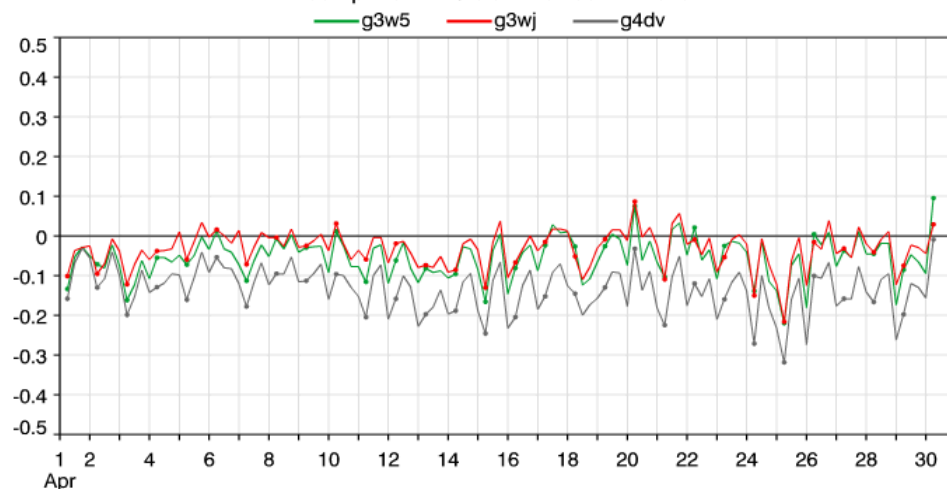


RMS error. Model AOT at 550nm against L1.5 Aeronet AOT at 500nm.
Voronoi-weighted mean over 272 sites globally ($r_{max}=1276km$).
1-30 Apr 2014. FC start hrs=00Z. T+6 to 24.



RMS error against Aeronet data

FC-OBS bias. Model AOT at 550nm against L1.5 Aeronet AOT at 500nm.
Voronoi-weighted mean over 272 sites globally ($r_{max}=1276km$).
1-30 Apr 2014. FC start hrs=00Z. T+6 to 24.

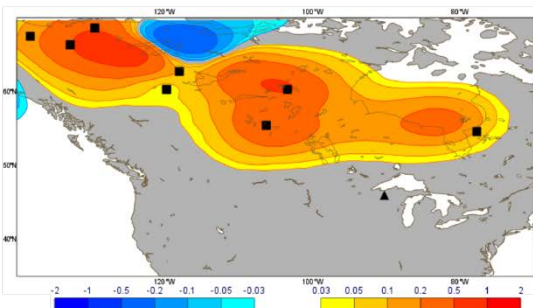


Bias against Aeronet observations

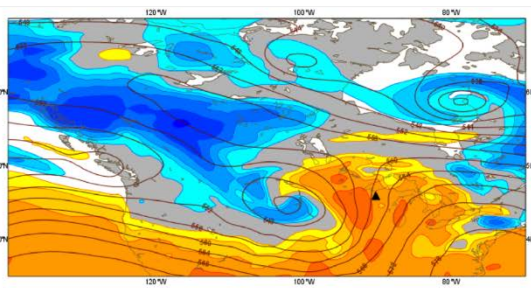
Assimilation of PMAP data (AOD based on GOME-2 and IASI) provides comparable quality to assimilation of MODIS data.

- Forecast-only run
- PMAP-only run
- MODIS-only run

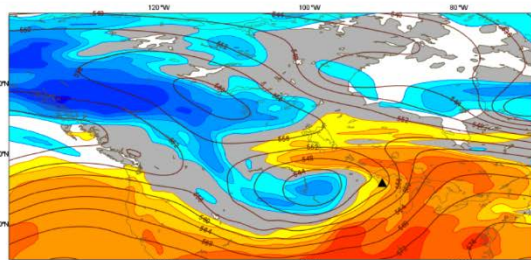
(a) XCO₂ increment 30 May 2013



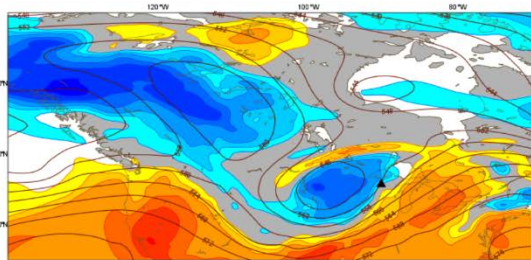
(b) XCO₂ analysis 31 May 2013 00:00



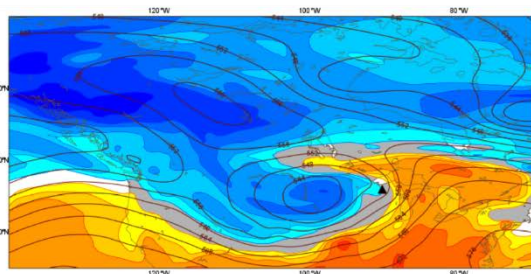
(c) XCO₂ analysis 31 May 2013 12:00



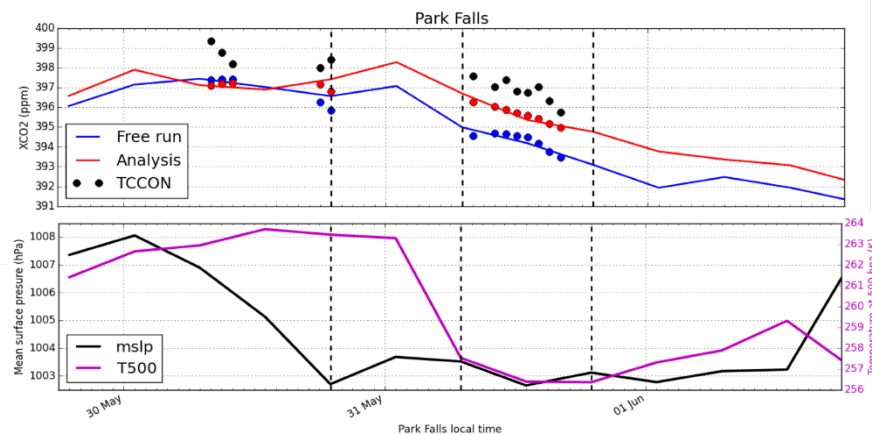
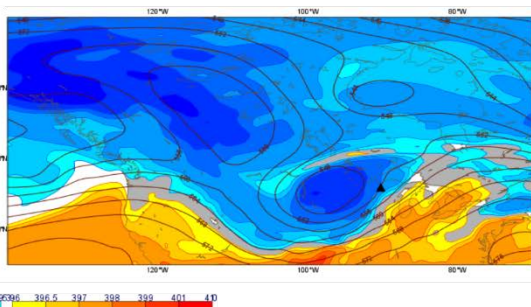
(d) XCO₂ analysis 1 June 2013 00:00



(e) XCO₂ free run 31 May 2013 12:00



(f) XCO₂ analysis 1 June 2013 00:00

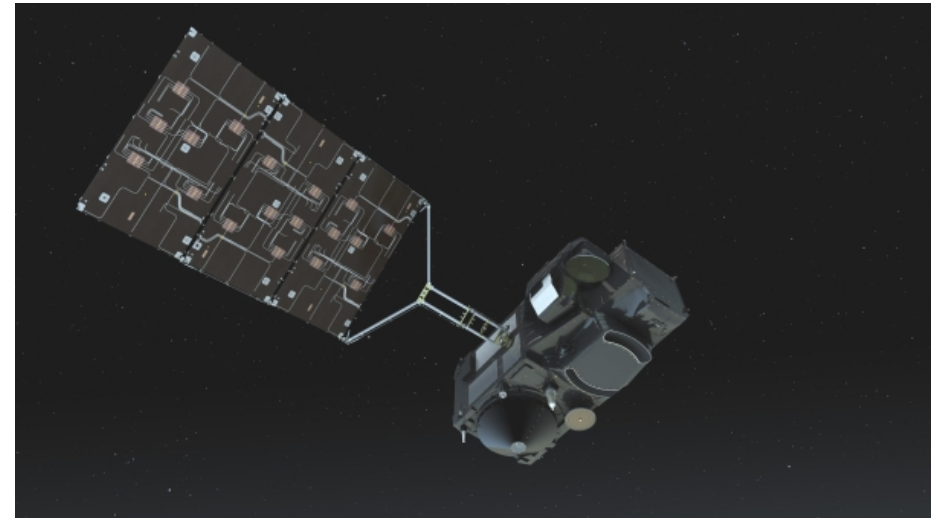


Park Falls data from TCCON network

Assimilating only a few GOSAT observations significantly improves the forecast of CO₂ concentrations over Park Falls.

OLCI – based on MERIS heritage

SLSTR – based on AATSR heritage



Discussions with ESA and EUMETSAT about provision of Aerosol Optical Depth and Fire Radiative Power from Sentinel-3.

These observations will be used to complement AOD and FRP from MODIS. Aim is to make observing system more robust.

TROPOMI

O₃

NO₂

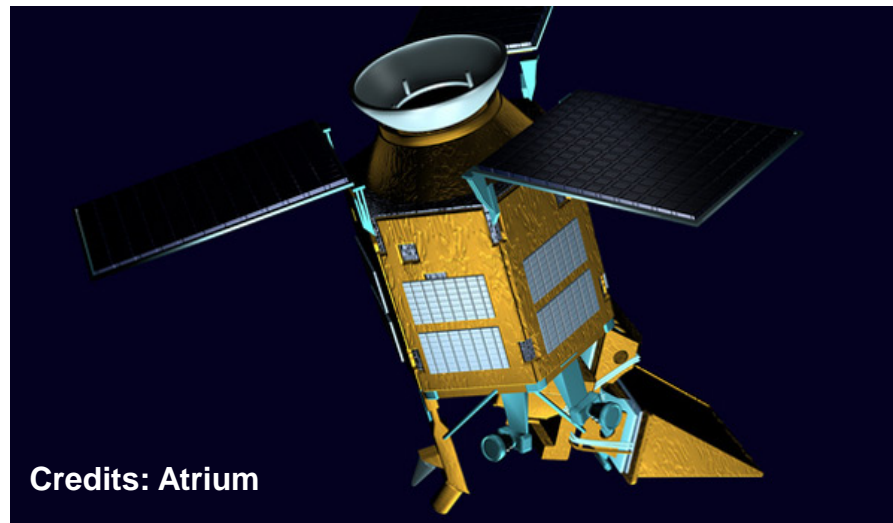
SO₂

HCHO

CO

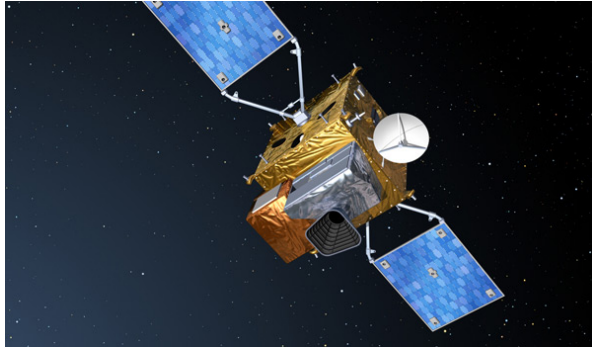
CH₄

Aerosol



Sentinel-5p will provide essential observations complementing OMI, GOME-2, MOPITT, IASI and others, and ensuring crucial observations for the coming years.

Exciting new instrument and CAMS will provide early feedback based on its own satellite data monitoring system.



- Geo-stationary Sentinel-4
- Information on diurnal cycle
- Might help with regional air quality modelling

- Polar orbiting Sentinel-5
- Continuation of crucial observational record of atmospheric composition into the future.



- OCO-2
- SNPP
- JPSS
- Metop-C

- GOSAT-2
- TANSAT
- Aeolus
- EarthCare

- GEMS
- TEMPO
- ...

- **MACC will enter its operational phase as CAMS on 1 July**
- **Using satellite data through data assimilation improves the global forecasts, which is also important for the regional air quality forecasts**
- **The Sentinel missions will play a crucial role for years to come by providing important observations of atmospheric composition; operational reliability and quality is key to the success of these missions for the Copernicus Atmosphere Monitoring Service**
- **CAMS will also make use of many other European and non-European research and operational missions in its data assimilation system**