CECMWF



Commission

A

The road from Sentinel-5p to Paris

Richard Engelen ECMWF

acve → ATMOSPHERIC COMPOSITION VALIDATION AND EVOLUTION

18-20 October 2016 | ESA-ESRIN | Frascati (Rome) Italy









By how much will Sentinel-5p improve the air quality forecast for Paris?













Number of days that ECMWF weather forecasts provide useful information









Forecast sensitivity



From: Cardinali and Prates, 2009





COPERNICUS







Copernicus Atmosphere Monitoring Service

Combine observations with state-ofthe-art data assimilation and forecasting systems to provide air quality information on the global and regional scale.







CAMS IN A NUTSHELL





Space Agencies





In-situ component



CAMS



Tuesday 24 May 2016 00UTC MACC-RAQ Forecast t+000 VT: Tuesday 24 May 2016 00UTC Model: ENSEMBLE Height level: Surface Parameter: PM10 Aerosol [μg/m3]

> Tuesday 24 May 2016 00UTC MACC-RAQ Forecast t+000 VT: Tuesday 24 May 2016 00UTC Model: ENSEMBLE Height level: Surface Parameter: PM10 Aerosol [µg/m3]

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The challenge for ACVE

THE SPACE SEGMENT





SATELLITE DATA







Characterization of satellite observation errors is the first step in the chain.







FROM L1 TO L2







Buchwitz et al., 2013







Using NWP principles for atmospheric composition forecasting

THE GLOBAL ELEMENT





CAMS - GLOBAL





ernicus

Space Agencies









Fire emissions



Anthropogenic emissions









2
$$J(x) = (x - x_b)^T B^{-1} (x - x_b) + (H(x) - y)^T R^{-1} (H(x) - y)$$







SATELLITE DATA USED















Species	Instruments
Global system	
O ₃	OMI, SBUV, GOME-2, MLS, OMPS, S5p
CO	IASI, MOPITT, S5p
NO ₂	OMI, GOME-2, S5p
SO ₂	OMI, GOME-2, S5p
Aerosol	MODIS, PMAp, VIIRS, S3
CO ₂	GOSAT, OCO-2
CH ₄	GOSAT, IASI, S5p
GFAS fire emissions	MODIS, GOES, SEVIRI, VIIRS





SYSTEMATIC ERRORS





opernicus





GLOBAL FORECAST











VALIDATION – PART 1











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

System evolution and performance statistics Status up to 1 June 2016

Issued by: KNMI Date: 21/09/2016 REF.: CAMS84_2015SC1_D.84.1.4_201609









Seven know more than one

THE REGIONAL ELEMENT





CAMS - REGIONAL







In-situ component







Anthropogenic emissions



Tuesday 24 May 2016 00UTC MACC-RAQ Forecast t+000 VT: Tuesday 24 May 2016 00UTC Model: ENSEMBLE Height level: Surface Parameter: PM10 Aerosol [µg/m3]





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Model ensemble







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Regulatory Observations







Annual mean PM10 concentrations for 2013

European Environment Agency







EMISSIONS







All CAMS regional AQ models use the same emissions





Meteorology









Winter smog (PM, NOx, SO₂...) Photochemical smog (O₃, PM...)

All CAMS regional models are driven by the same meteorological fields from the operational ECMWF NWP system.





Chemical modelling







Ensemble





Pm10 Aerosol - 20130508 00UTC to 20130515 00UTC



Validation – part 2







The ensemble median consistently outperforms any individual model!!!





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Global to regional

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How is the CAMS information being used

APPLICATIONS









CAMS outputs are used as input for national and city-scale forecasts, combined with local expertise, AQ models and observations.



Downstream applications









max of 8hr mean 22JUL2016



Arianet arl - CC BY-NC-ND - o3 - run 20160722



2016-07-21-23:41











What can we do to estimate end-to-end uncertainty?

EVOLUTION





Regional





CAMS EPSGRAM

Roma(41.9°N, 12.48°E)

Forecast Sunday 16 October 2016 00 UTC



The ensemble spread provides an indication of the uncertainty.

This is especially useful when values approach or overshoot regulatory thresholds.

Is it likely or is it just one model forecasting these high values?

Does not account for uncertainties in boundary conditions, meteorology, emissions, ...



Estimating global errors





Estimate Analysis error within 4D-Var

Ensemble data assimilation

 $J' = B^{-1} + H^{T}R^{-1}H = A^{-1}$

Minimization provides one eigenvector per iteration (with limitations).



Ensemble forecasting

All methods need estimates of:

- Background errors
- Observation errors
- Errors in emissions
- Model errors









Ensemble data assimilation can estimate flow dependent analysis and background errors, but there is a limit to the ensemble size.











Scores based on anomaly correlations need an accurate climatology and are focused on the random error component.

35

Atmospheric composition forecasts contain significant systematic errors.





Systematic errors



Carbon monoxide



CAMS CIFS/TM5 AN GAW intercomparison Hohenpeissenberg Ozone September 2016 bias [ppb] D0: 2.4 D1: 2.2 D2: 2.0 D3: 2.5 MNbias [%] D0: 7 D1: 7 D2: 6 D3: 7



Chemistry tends to find an equilibrium driven by the emissions.

Aerosol Optical Depth







WHAT TO DO?



Monday 23 May 2016 00UTC CAMS Forecast (+036 VT: Tuesday 24 May 2016 12UTC



Space Agencies





WHAT TO DO?





Space Agencies



In-situ component



Observation System Simulation Experiment (OSSE)

- Characterize all errors
- Complex
- Unknown error sources
- Unclear how to propagate all error elements



day 24 May 2016 00UTC









By how much will Sentinel-5p improve the air quality forecast for Paris?











AA

European Commission

Thank you

