CERFACS

CENTRE EUROPÉEN DE RECHERCHE ET DE FORMATION AVANCÉE EN CALCUL SCIENTIFIQUE

SEEDS

Sentinel EO-based Emission and Deposition Service

WP4: Improved Assimilation Schemes

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WP4: general objective

To develop a novel algorithm (4DEnVar) for the operational assimilation of ground (hourly) air quality measurements and to test it on selected pollution episodes (2-3 weeks periods both for a winter and a summer pollution case) using a model from the CAMS regional services (MOCAGE).

Data Assimilation in CAMS models

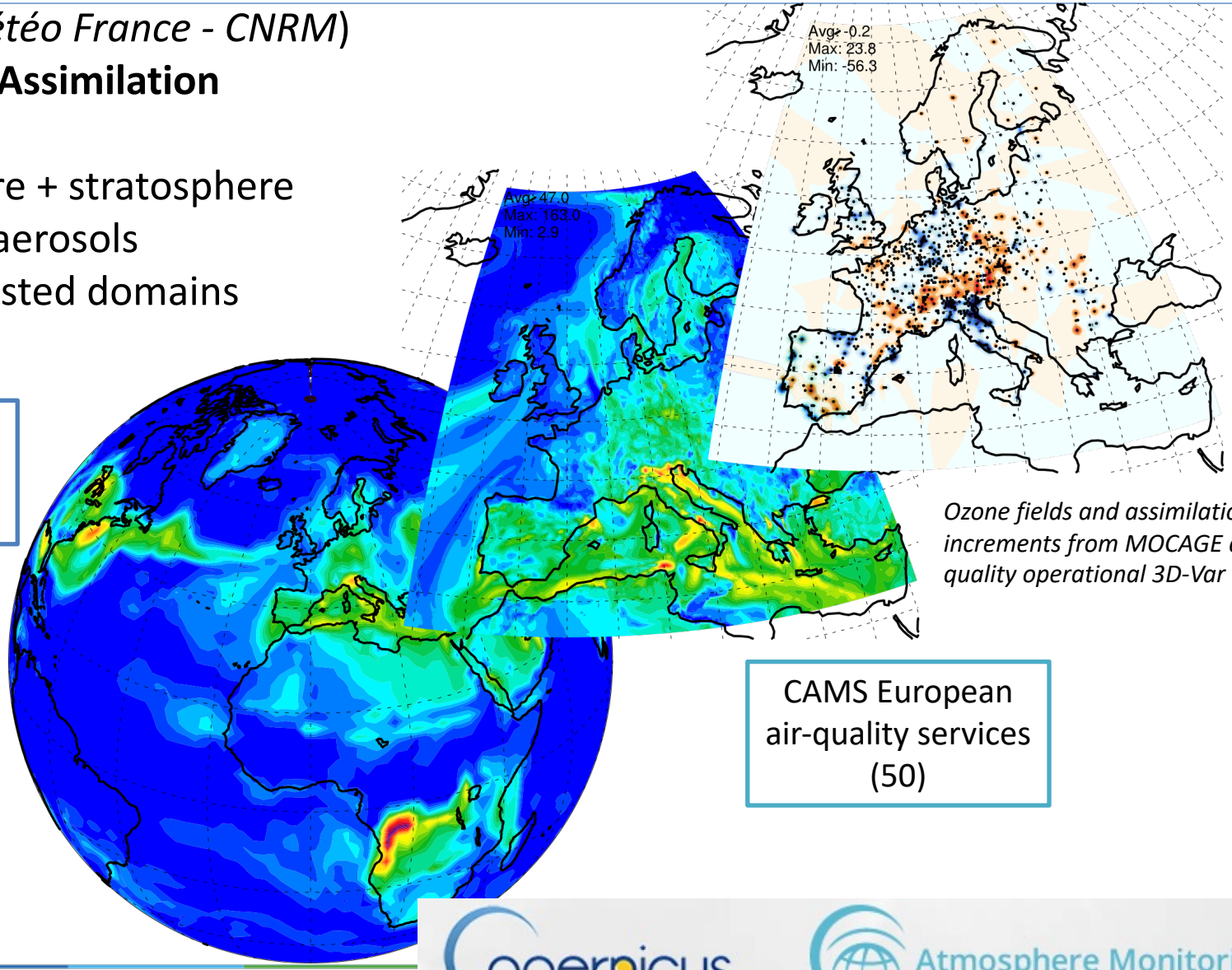
MODEL	ASSIMILATION ALGORITHM	ASSIMILATED OBSERVATIONS
CHIMERE	Kriging	O_3, NO_2, PM_{10}, $PM_{2.5}$
EMEP	3D-Var	O_3, NO_2, SO_2, PM_{10} + OMI NO_2
EURAD-IM	3D-Var	O_3, NO_2, PM_{10}, $PM_{2.5}$ + SATELLITE NO_2, SO_2, CO
LOTOS-EUROS	EnKF	O_3, NO_2, PM_{10}, $PM_{2.5}$ + OMI NO_2
MATCH	3D-Var	O_3, NO_2, SO_2 CO, PM_{10}, $PM_{2.5}$
MOCAGE	3D-Var	O_3, NO_2, PM_{10}, $PM_{2.5}$
SILAM	3D-Var	O_3, NO_2, SO_2, CO, PM_{10}, $PM_{2.5}$
DEHM	Optimal Interpolation	O_3, NO_2
GEM-AQ	Optimal Interpolation	O_3, NO_2, SO_2 CO, PM_{10}, $PM_{2.5}$

Météo France - CERFACS chemical forecasting system

MOCAGE (*Météo France - CNRM*)
+ **Variational Assimilation**
(*CERFACS*)

- troposphere + stratosphere
- gases and aerosols
- global + nested domains
- 3D-Var

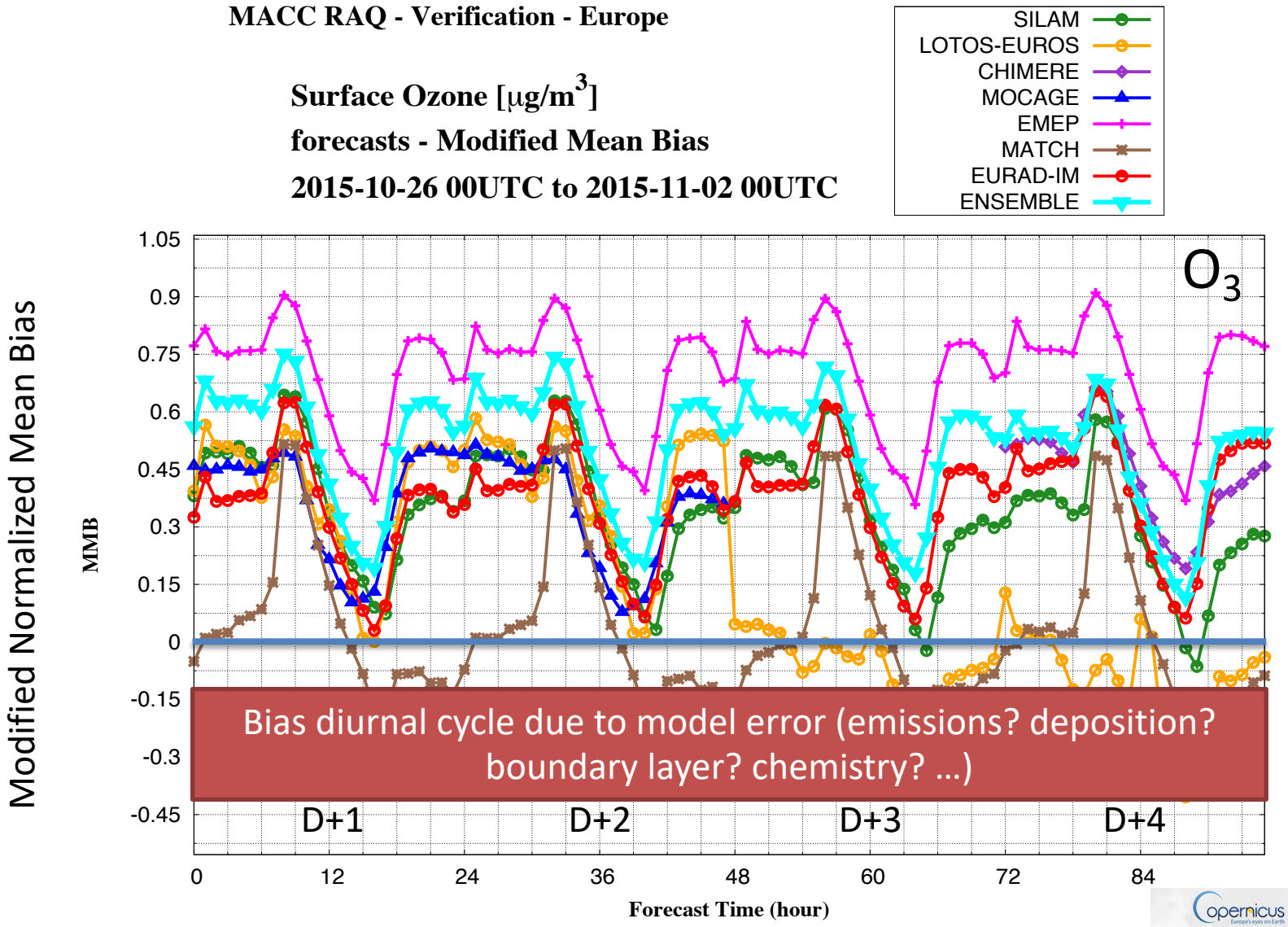
CAMS global reactive gases (42)



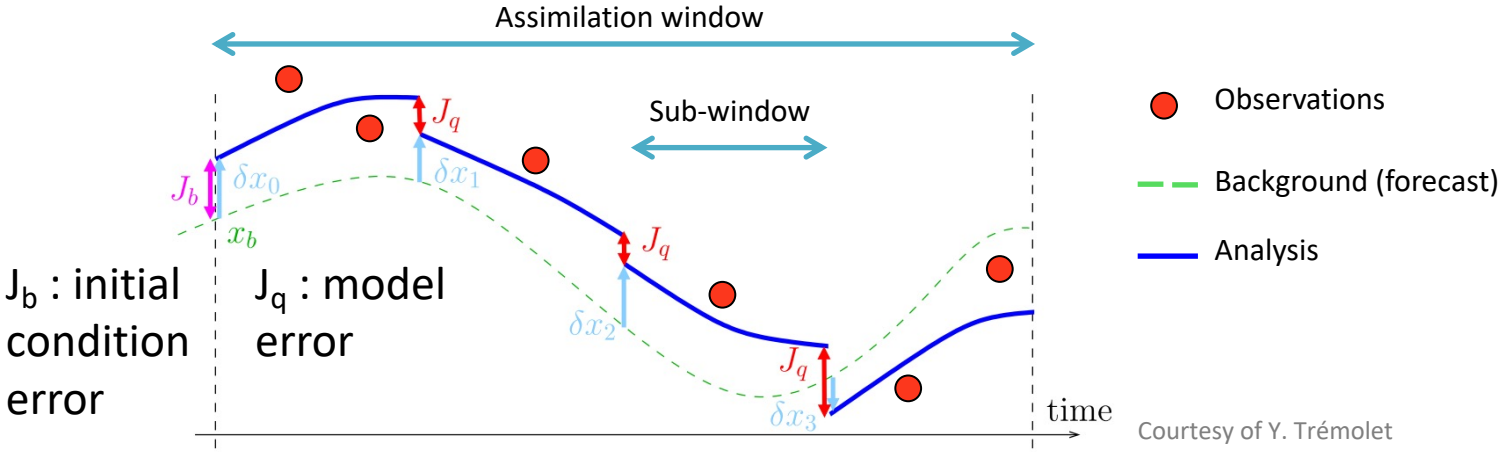
Ozone fields and assimilation increments from MOCAGE air-quality operational 3D-Var

CAMS European air-quality services (50)

Forecast biases in CAMS models



4DEnVar



J_b : initial condition error

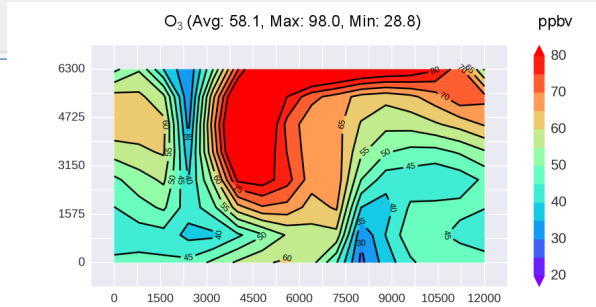
J_q : model error

Courtesy of Y. Trémolet

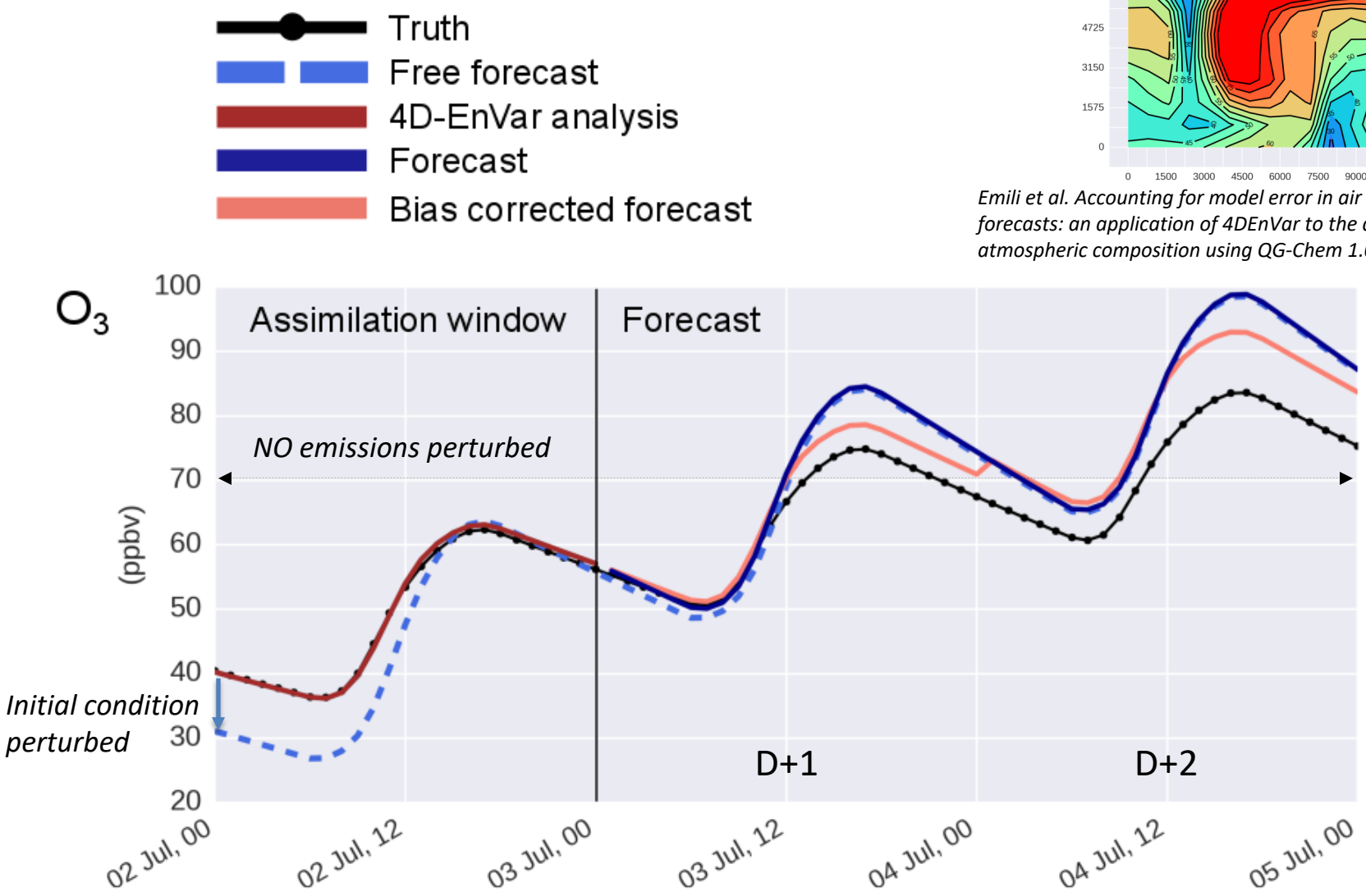
- 4DEnVar uses *ensembles* of perturbed forecasts to account for both initial and model errors of generic type (stochastic or parameterized)
- … without linearized and adjoint codes (costly model specific developments)
- … no need to construct and estimate complex error covariances operators **B**, **Q** (localization operator **C** needed instead)
- Physical-based specification of model error covariance (**Q**) through stochastic perturbation of model parameters (e.g. emissions and deposition)
- No need of ensemble inflation

Desroziers et al. 2014. 4D-En-Var: link with weak-constraint 4D-Var and different possible implementations. QJRMS

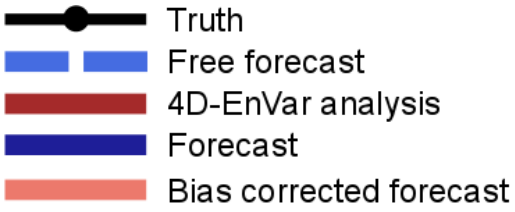
Ensemble based bias correction

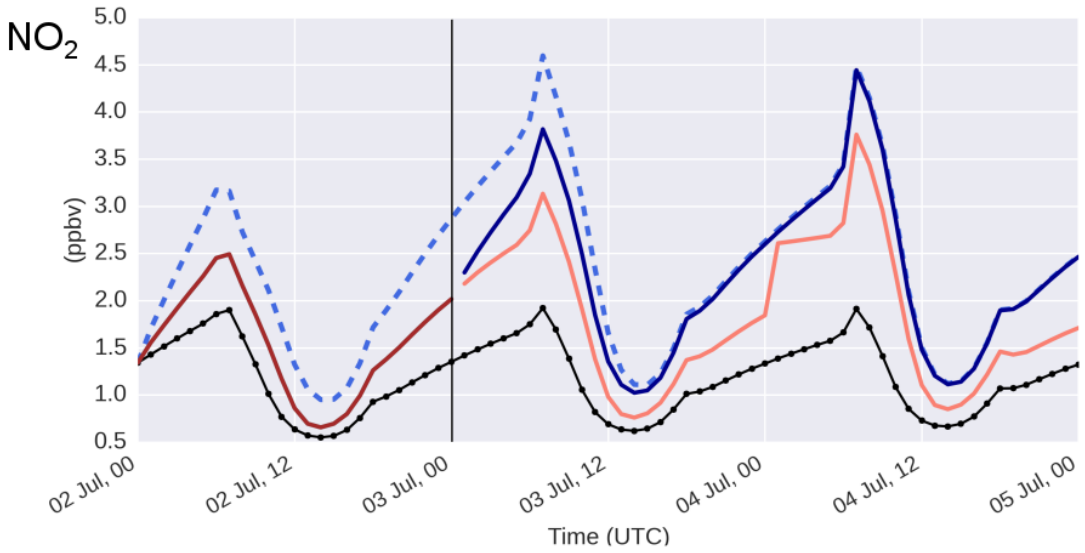


Emili et al. Accounting for model error in air quality forecasts: an application of 4DEnVar to the assimilation of atmospheric composition using QG-Chem 1.0, GMD, 2016

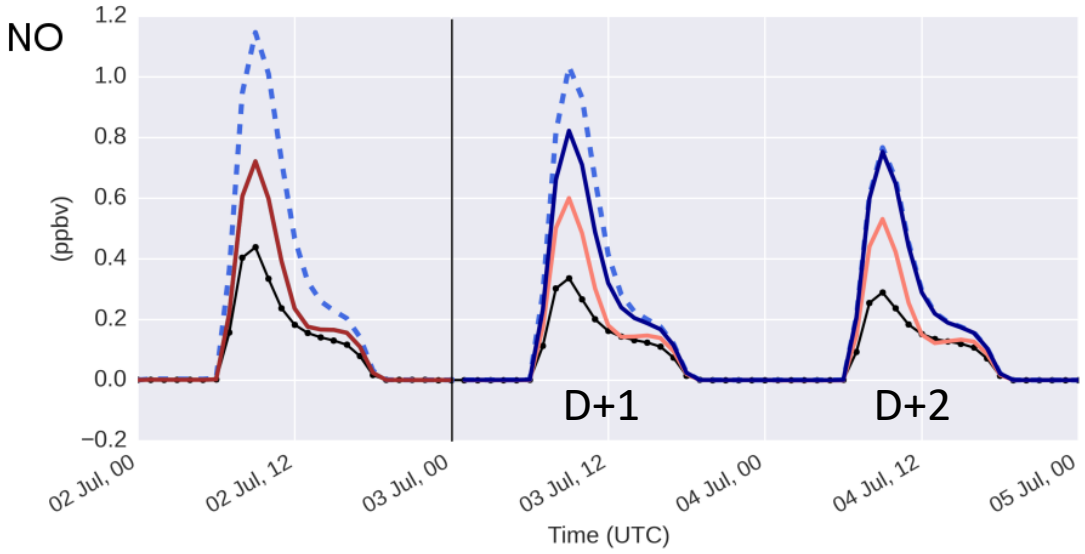


Multivariate chemical corrections





- Unobserved species can benefit from O_3 assimilation through multivariate ensemble covariances



Emili et al. Accounting for model error in air quality forecasts: an application of 4DEnVar to the assimilation of atmospheric composition using QG-Chem 1.0, GMD, 2016

WP4 Specific Goals

1. Evaluate ensembles of MOCAGE forecasts based on new SEEDS products (emissions, deposition) and the associated uncertainties.

2. Assess the added value of an assimilation scheme that includes model error (4DEnVar) with respect to the sequential filters used today in CAMS operations (use MOCAGE).

3. Provide an open-source assimilation code that can be adapted to other CAMS model that can provide ensemble forecasts, or to the CAMS ensemble itself.

WP4 method

Ensemble production (code and data)

- Ensemble generation specific to MOCAGE
- Ensemble driver built with ECFLOW (ECMWF) tool (under evaluation)
- Capacity to run 20-30 members of 96 hours forecasts using MOCAGE CAMS configuration on MF-CERFACS HPC resources

Assimilation algorithm (code)

- 4DEnVar assimilation code developed within the OOPS (ECMWF-MF) framework (under evaluation), 24-48 hours target assimilation window
- Observation operator for surface concentration based on MOCAGE assimilation code
- Localization operator (3D, multivariate) based on MOCAGE background covariance code
- Advection/estimation of the localization operator during the assimilation window to be developed

Tests with synthetic observation

1. Generate 'truth' simulation
2. Produce synthetic observations
3. Perturb the forecast model
4. Assimilate the synthetic observations
5. Compare to the 'truth'
6. Tune ensemble size, localization ..

Tests with real observations

1. Assimilate O_3, NO_2, PM_{10}, $PM_{2.5}$ measurements during a winter and a summer pollution episode (2-3 weeks).
2. Evaluate against 3D-Var using independent observations

WP4 tasks

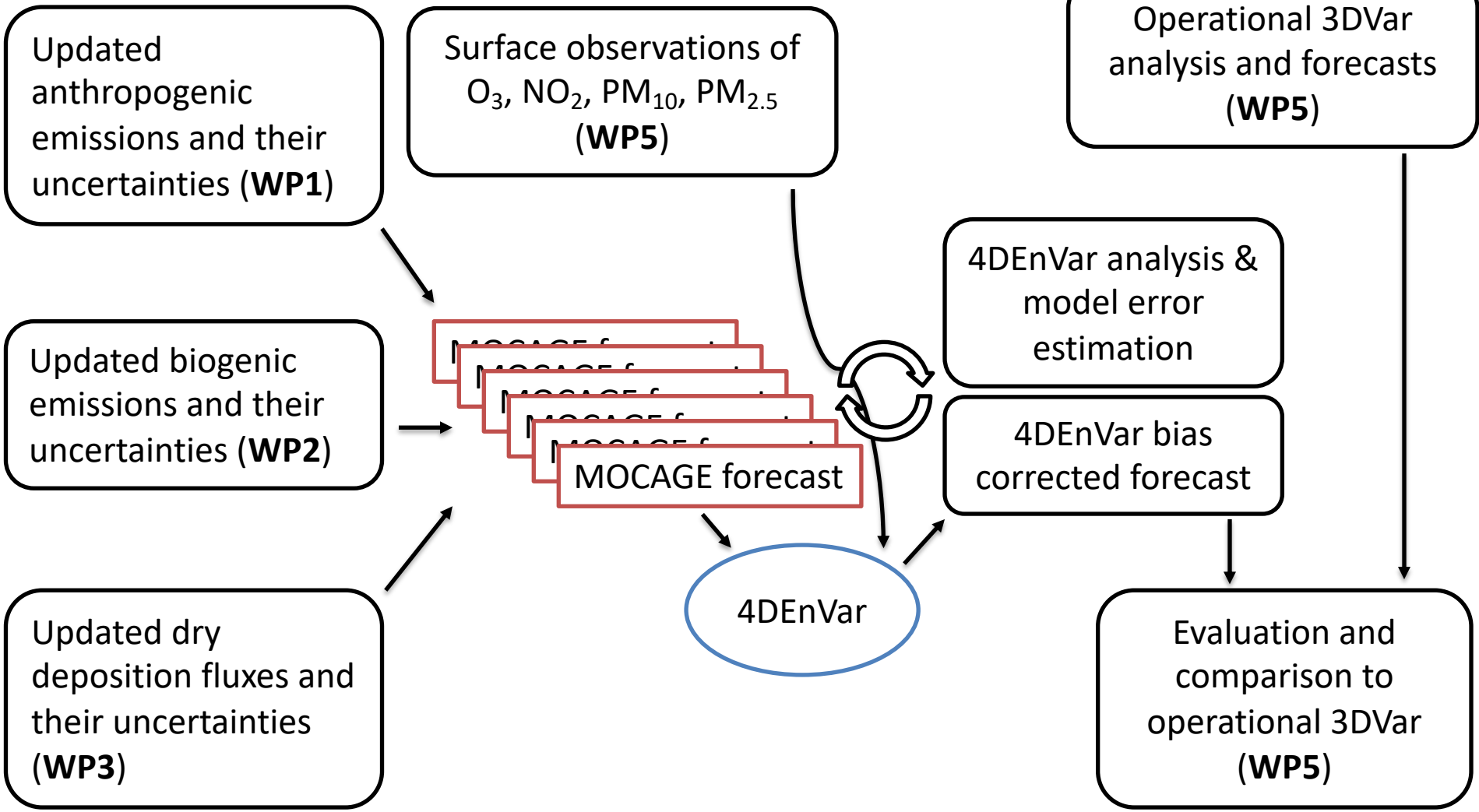
Task 4.1 Develop and evaluate ensembles of air quality forecasts with MOCAGE (Lead: CERFACS; MF-CNRM) **D M24**

Task 4.2 Develop an open source 4DEnVar code for the assimilation of ground air quality measurements (Lead: CERFACS) **D M18**

Task 4.3 Tests and optimization of the 4DEnVar algorithm with synthetic observations (Lead: CERFACS) **D M36**

Task 4.4 Perform 4DEnVar assimilation experiments with the operational MOCAGE configuration and comparison with 3DVar (Lead: CERFACS; MF-CNRM) **D M36**

WP4 links with other WPs



WP4 plan from M1 to M6

- Evaluate the availability/adaptability of existent community tools (ECFLOW) and start the development of MOCAGE ensembles
- Evaluate the availability/adaptability of existent community tools (OOPS) and start the development of the 4DEnVar code
- Discussion and definition of the setup for the assimilation experiments with real observations