Quantification of transport error using a coupled meteorological and constituent transport model with an Ensemble Kalman Filter (EnKF)

Vikram Khade[a,b], Saroja Polavarapu[a], Michael Neish[a], Pieter Houtekamer[a] and Dylan Jones[b]

[a]*Environment and Climate Change Canada*

[b]*University of Toronto*

GMAC-2019

Boulder, 21-22 May

Objectives :

Extend the ECCC-EnKF to estimate CO_2, CH_4, CO and their fluxes (EC-CAS).

Since the winds are coupled to the tracer the forecast tracer spread includes uncertainty due to winds. This is an important advantage of coupled models over offline models. Results relating to Carbon monoxide (CO) are shown here.

Basic Setup :

- GEM-MACH-GHG (*Polavarapu et. al.*) model with 0.9˚ grid spacing and 81 levels
- Simulated meteorological observations (radiosonde, surface, aircraft, GPS-RO and scatterometer) are assimilated at their real locations and times.
- Data are assimilated every 6 hours.
- Ensemble size = 64
- Flux perturbations correlated over 1000 km are used.
- Model error is sampled by using 64 different physics parametrizations.

Modifications and testing :

➢ Variable localization (*Kang et. al.*) has been implemented in the EnKF. This ensures that the meteorological observations do not update GHG and their flux. Similarly the GHG observations do not impact the meteorogical variables.

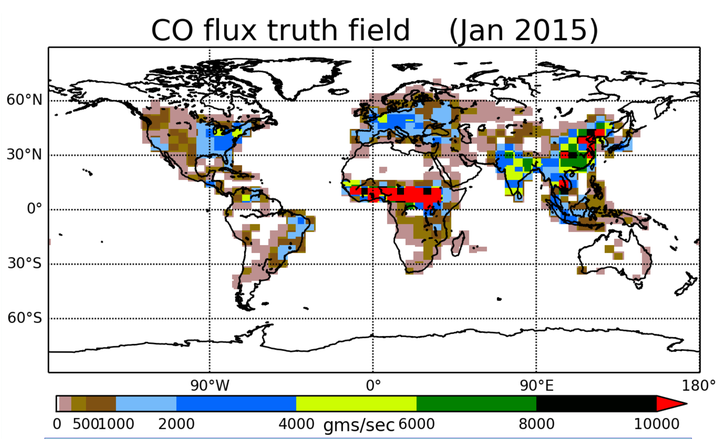
➢ These modifications are tested in a simulated observation framework. The 65th ensemble member is designated the *truth*. Observations are drawn from the truth run.

➢ Experiments with assimilation of meteorological observations only are run to ascertain the contribution of various error sources to the CO RMSE. Sources of uncertainty in estimated CO are:

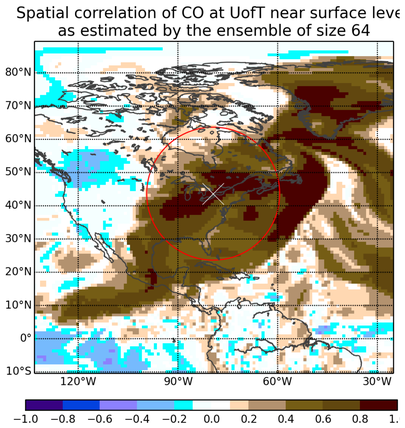
- Uncertainty in Initial Conditions (met. fields, CO)
- Imperfections in the meteorological model
- Imperfections in the surface flux of CO
- Errors in chemistry - reaction with OH (sink) and conversion from CH_4 to CO. These are assumed to be perfect.

➢ Experiments with assimilation of both meteorology and simulated CO observations are run to obtain estimates of improvements.

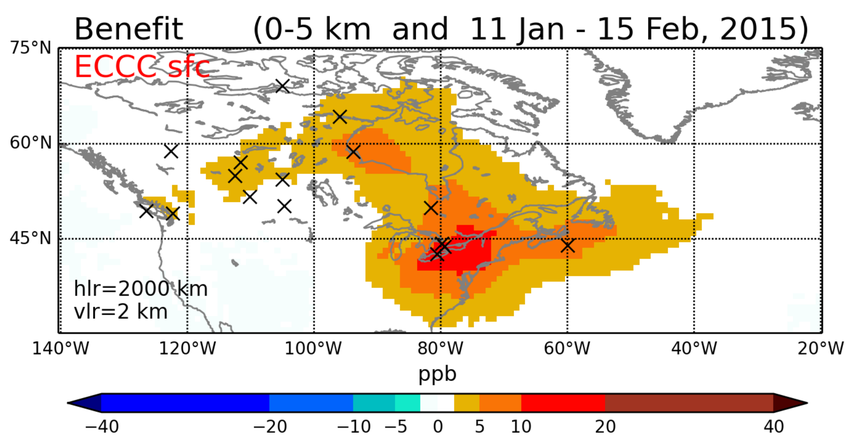
➢ Hypothetical in situ network, data from ECCC's CO surface network and retrievals from MOPITT are assimilated in separate experiments.



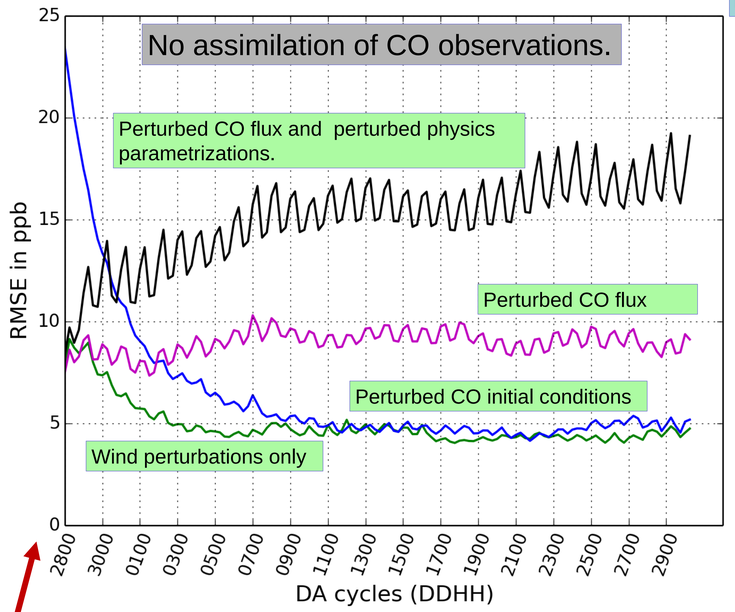
Sources of CO : Biomass burning, anthropogenic, biogenic, conversion of CH_4 to CO. Correlation length scale ~ 1000 km

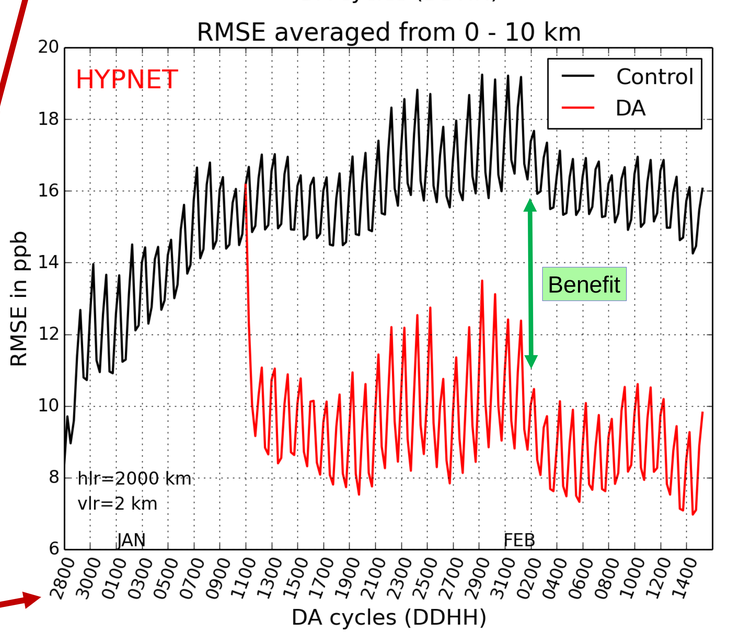


The forecast ensemble provides a state dependent estimation of correlation.
Flux error = 30%

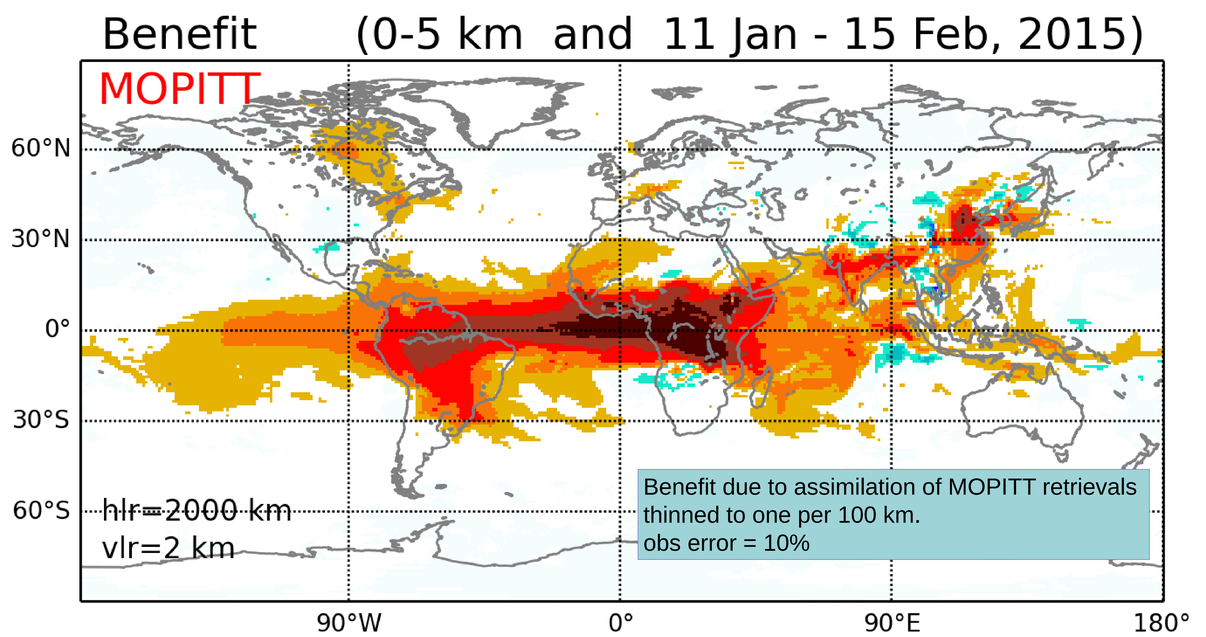


Observations at *each* of the 17 stations are available every hour.
Obs error = 10%





Control and DA experiments assimilate the same meteorological observations. DA experiment in addition assimilates HYPNET which has observations spaced horizontally every 1000 km at the 1 km, 5 km and 9 km levels.



Benefit due to assimilation of MOPITT retrievals thinned to one per 100 km.
obs error = 10%

- With a 30% prior flux uncertainty, the error in flux contributes ~ 5 ppb to RMSE in CO. The error in physics contributes about ~ 5 ppb.
- The EnKF-based assimilation of CO observations leads to a benefit of about 5 – 20 ppb. The benefit is proportional to the RMSE.

Future work :

- Estimate CO using real observations.
- Estimate fluxes of CO_2 and CO.
- Increase the observation window from a few hours to a few days .
- Allow observations of the winds to update CO_2 and CO.

Acknowledgement : We thank the Canadian Space Agency for funding this work.

References :

Polavarapu et al. (2016): Greenhouse gas simulation with a coupled meteorological and transport model: predictability of CO_2 , Atmos. Chem. Phys.

Kang et. al. (2011): Variable localization in an ensemble Kalman filter : Application to the carbon cycle data assimilation, JGR.

Barre et al. (2015): Assessing the impacts of assimilating IASI and MOPITT CO retrievals using CESM-CAM-chem and DART. JGR.