The estimation of CO_2 fluxes with a coupled meteorology and tracer transport model

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Objectives :

Extend the EC-EnKF to estimate CO_2 and CO and their fluxes for forecasting on weather timescales.

Since the winds are coupled to the tracer the forecast CO_2 spread includes uncertainty due to winds. This is an important advantage of coupled models over offline models in ensemble estimation/forecasting

Setup for modifications :

- GEM-MACH-GHG (*Polavarapu et. al.*) model with 0.9 degree resolution and 75 levels is used as the forward model.
- In-situ data (flask, tower and aircraft) is assimilated along with radiosonde observations.
- Ensemble size = 64
- Data are assimilated every 6 hours.

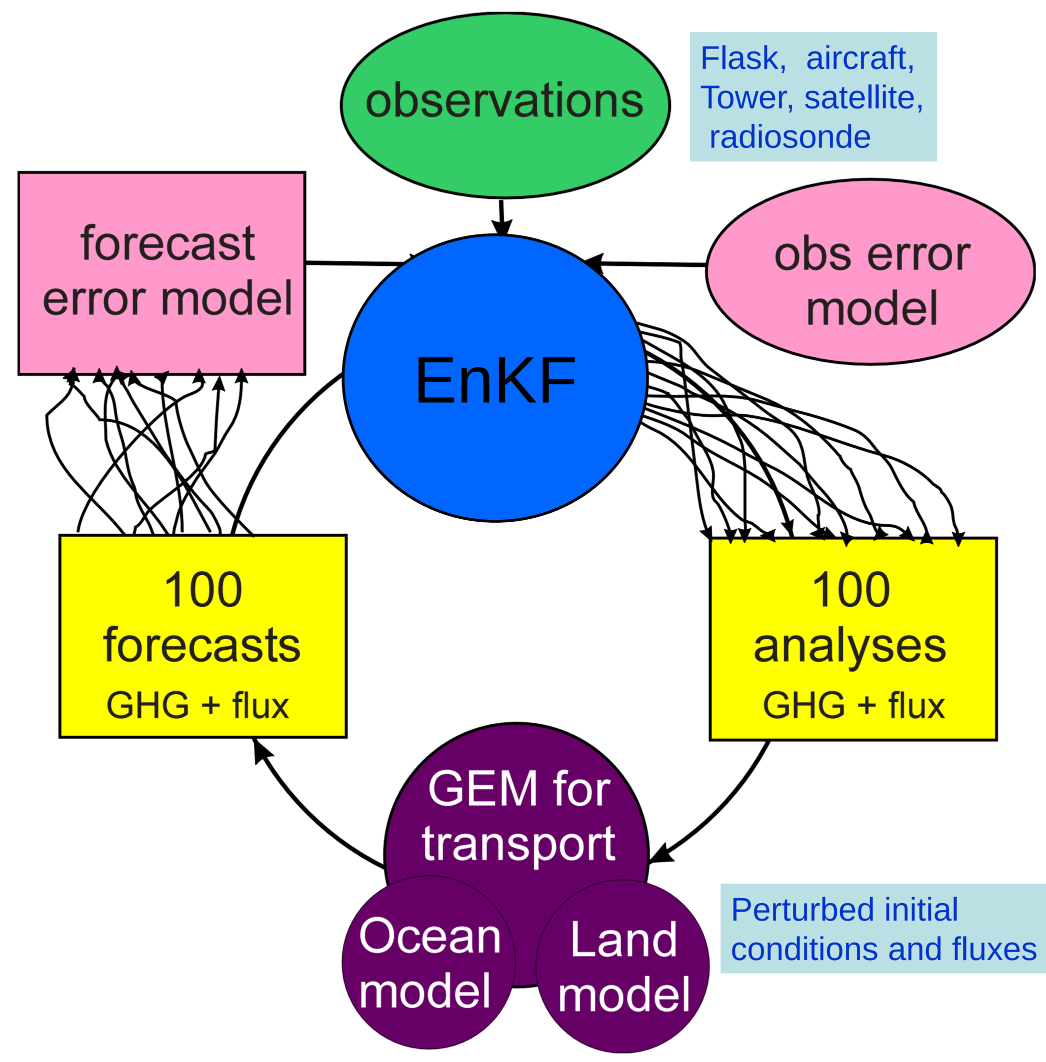
Modifications completed :

- The meteorological state has been augmented with CO_2 and the flux field.
- Variable localization (*Kang et. al.*) has been implemented in the EnKF. This ensures that the meteorological observations are not allowed to update CO_2 and the flux. Similarly the CO_2 observations are not allowed to impact the meteorogical variables.
- These modifications are tested by assimilating radiosonde observations and only two surface flask CO_2 observations.

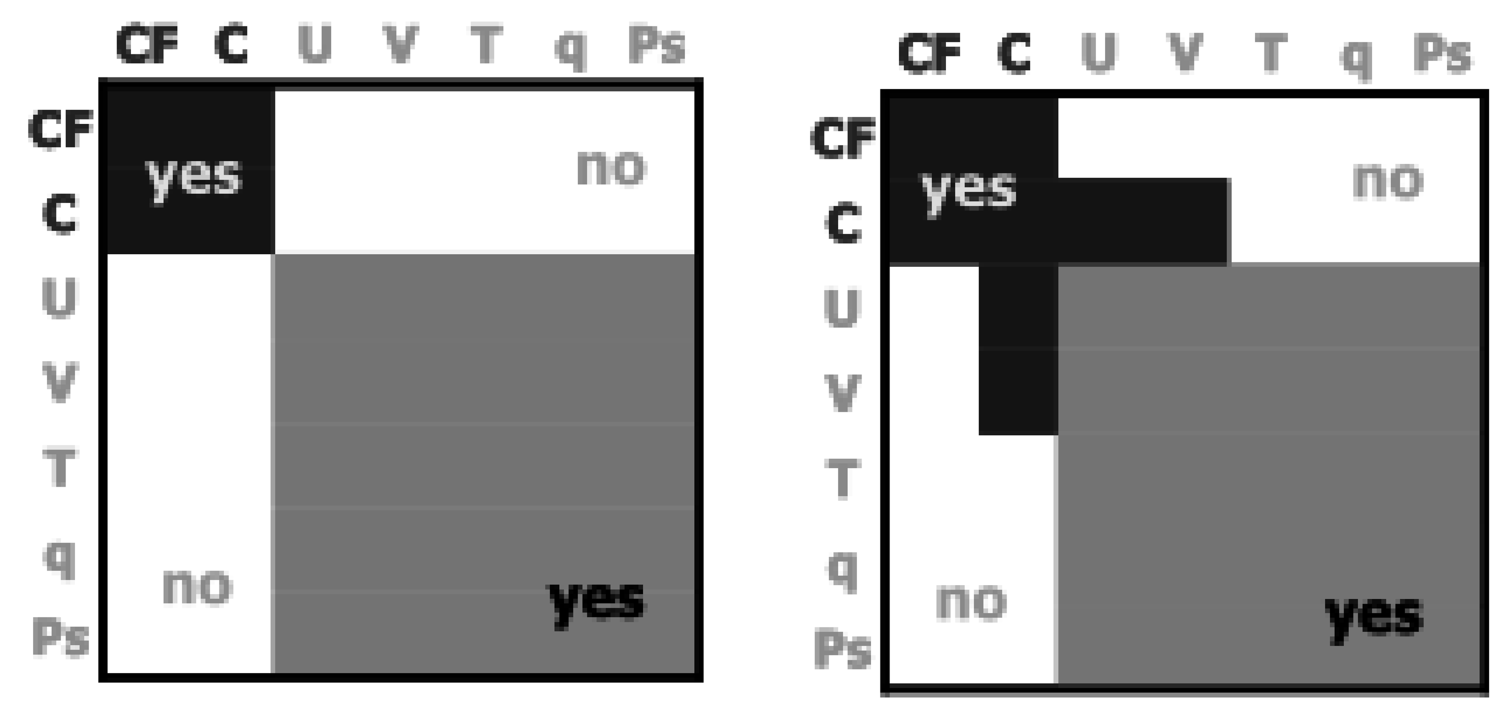
An ensemble based estimator is potentially better than flux inversion because the ensemble provides a state dependent estimate of covariance.

Work in progress :

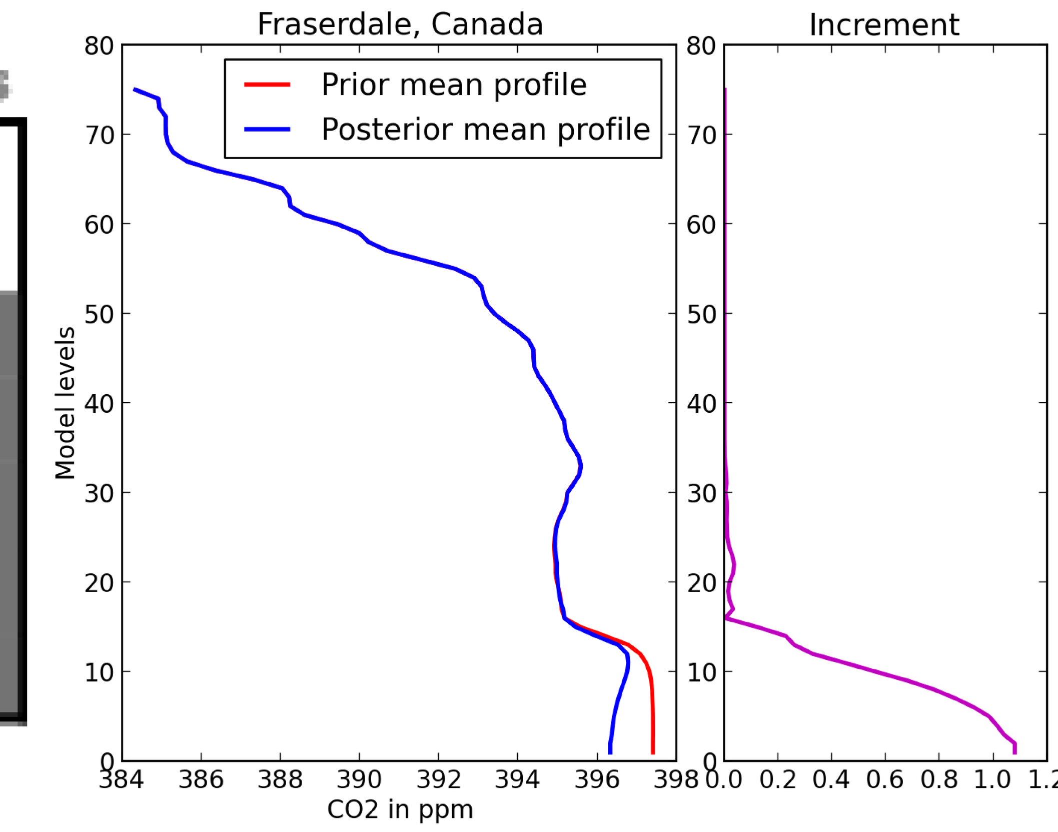
- Include CO and flux field in the augmented state.
- Implement an Observation System Simulation Experiment (OSSE).
- The OSSE will use simulated radiosonde observations and simulated CO_2 and CO observations.
- The simulated observations will be at the same time and locations as the real flask, tower and aircraft observations.



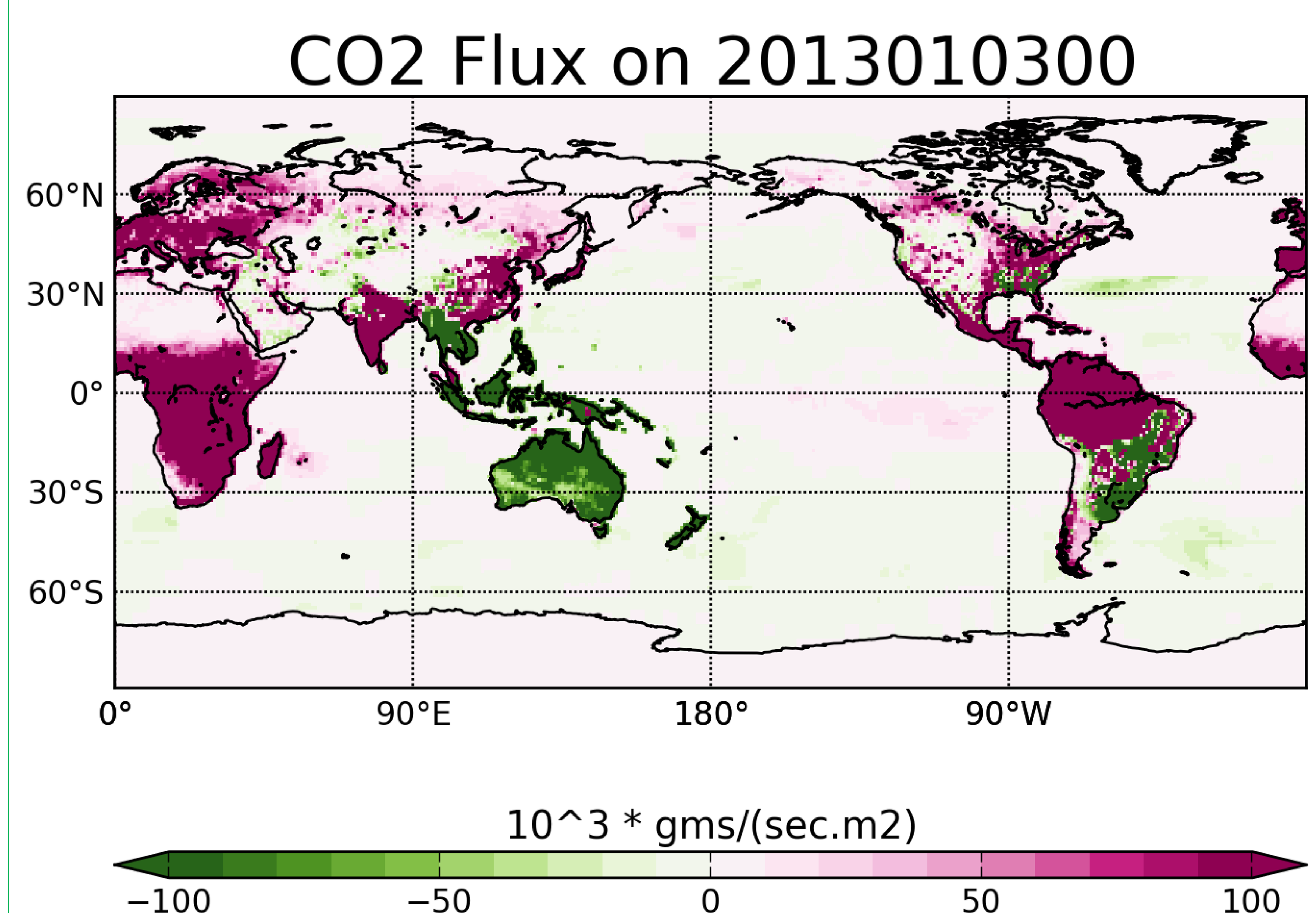
ECCC Carbon Assimilation System (EC-CAS)

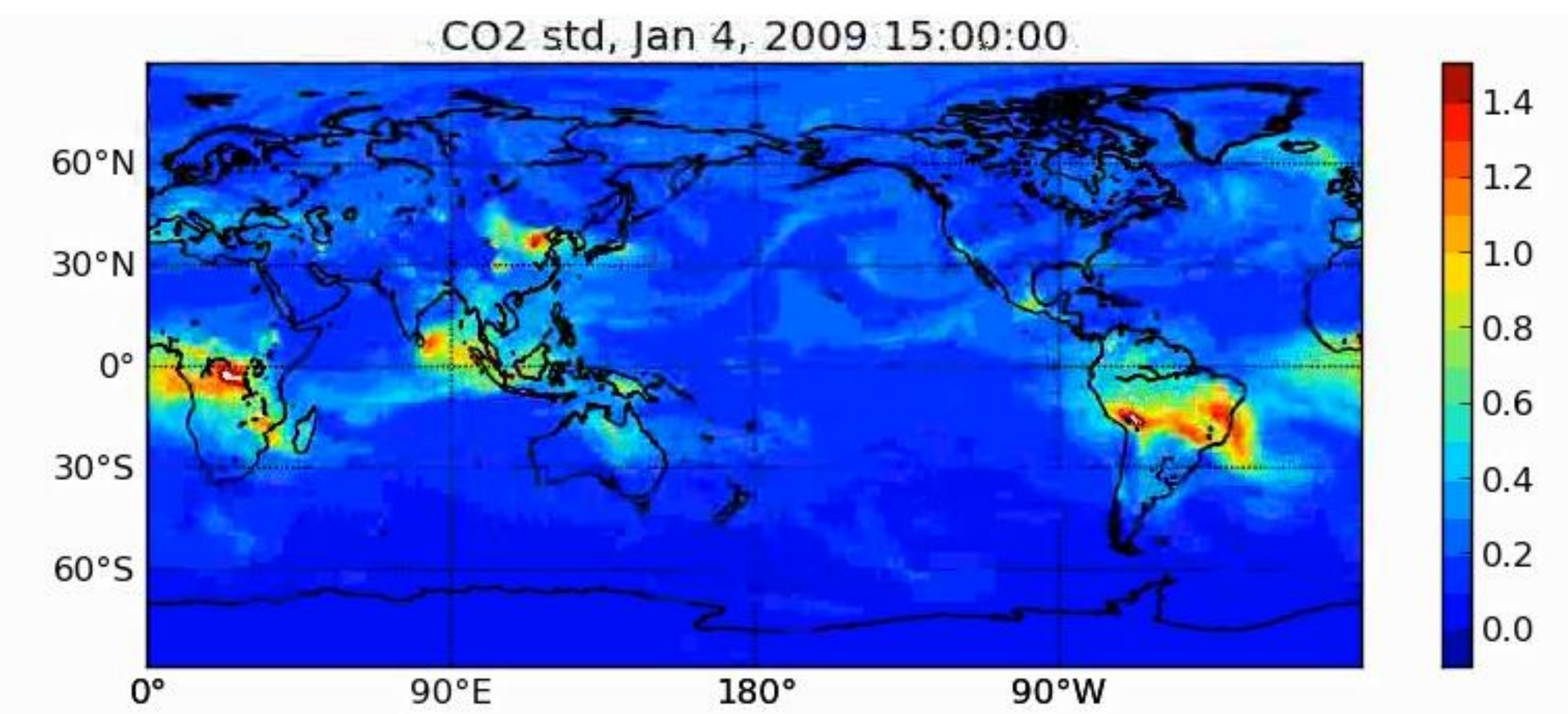


Variable localization : The left panel shows the scheme that has been implemented. The right panel shows the scheme that will be implemented in the future. This will allow the wind observations to constrain the CO_2 state.

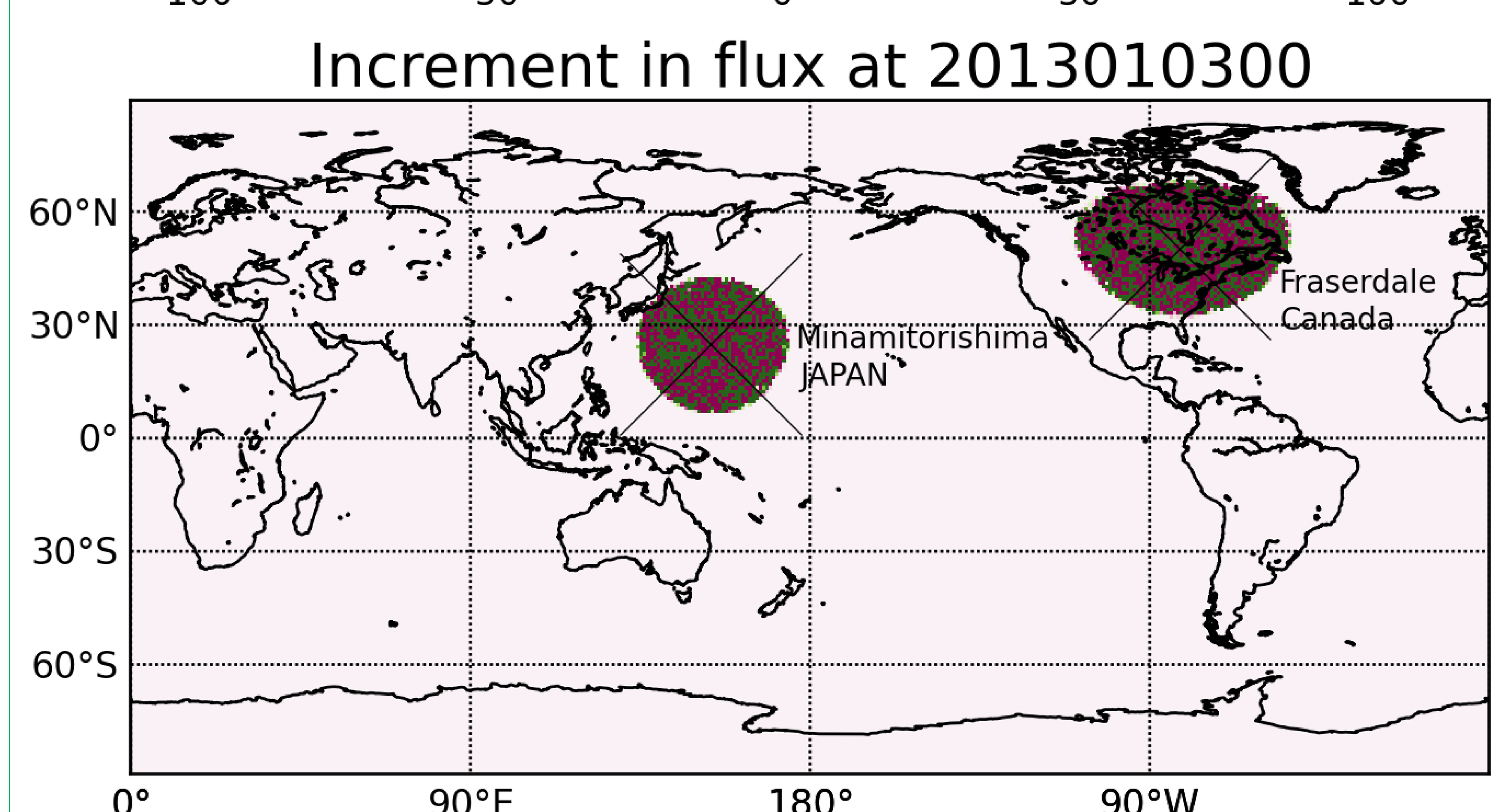


Testing of CO_2 estimation : Surface observations update the model profile near the surface.





CO_2 spread in ppm : The spread in winds induces a spread in CO_2 in regions of strong gradients.



Testing of flux estimation : Increments are localized to the regions in which the two CO_2 observations are located.

Future work :

- Allow observations of the winds to update CO_2 and CO.
- Use satellite observations (MOPITT, OCO-2) apart from in situ observations.
- Increase the observation window to few days from few hours.
- Estimate CH_4 and fluxes along with CO_2 and CO.

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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.