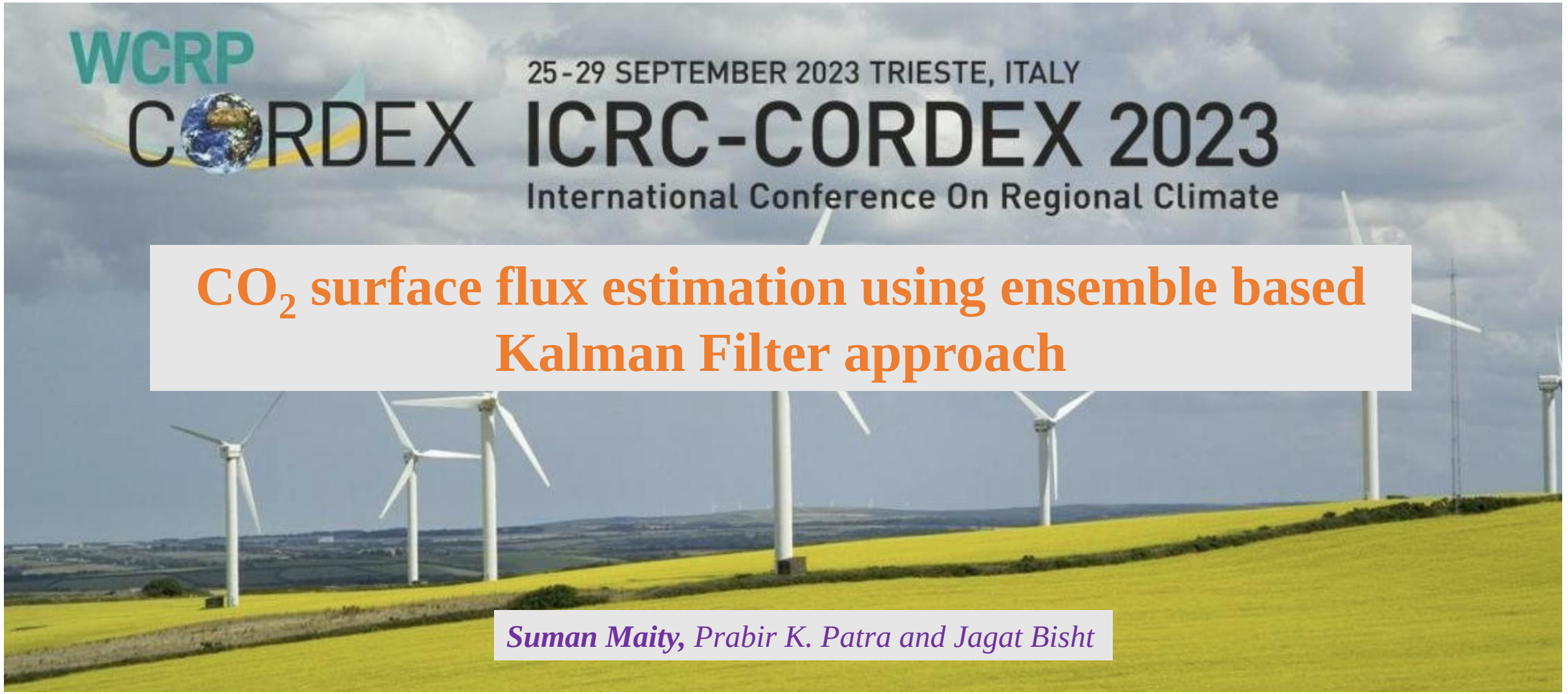

CO_2 surface flux estimation using ensemble based Kalman Filter approach

Suman Maity, *Prabir K. Patra and Jagat Bisht*

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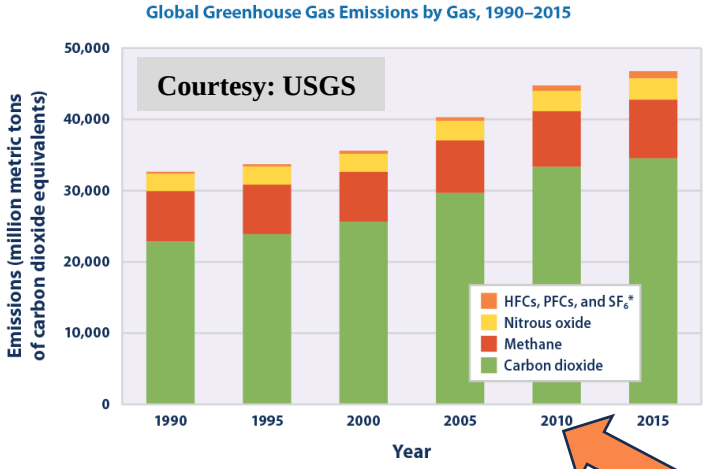
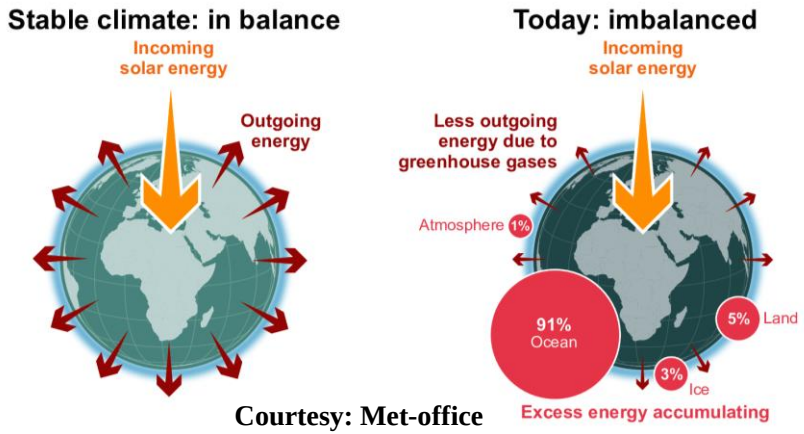
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Introduction

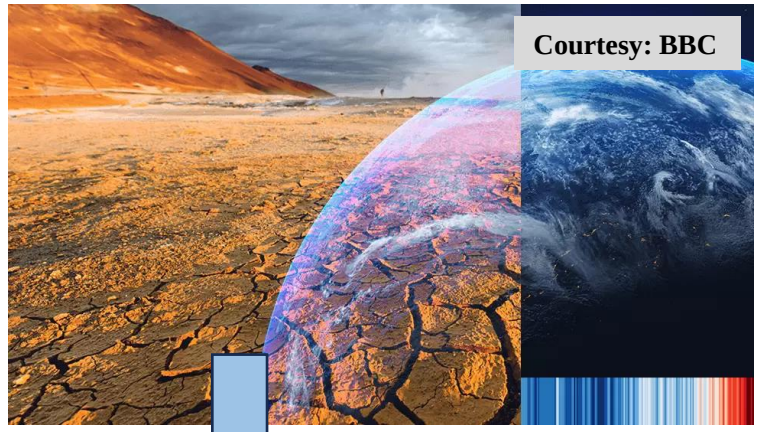
Global GHG emission is gradually increasing





Courtesy: Met-office

Climate Change



Possible Linkage

- Heat and Cold Waves.
- Drought.
- Tropical storms.
- Heavy rainfall events

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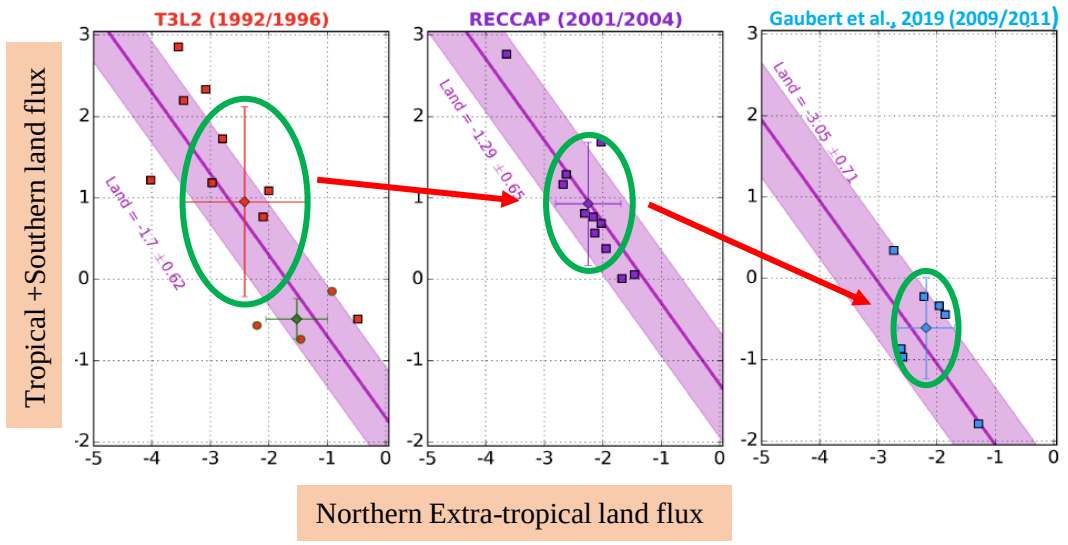
Background

CO_2 is the primary GHG having largest global warming potential (= 1, used as reference). Accurate quantification of CO_2 sink/source is extremely significant in understanding global commitment such as global stock take and the global carbon budget.

It remains a challenging task mainly due to:

- Spatio-temporal heterogeneity
- Measurement limitations
- Transport uncertainties

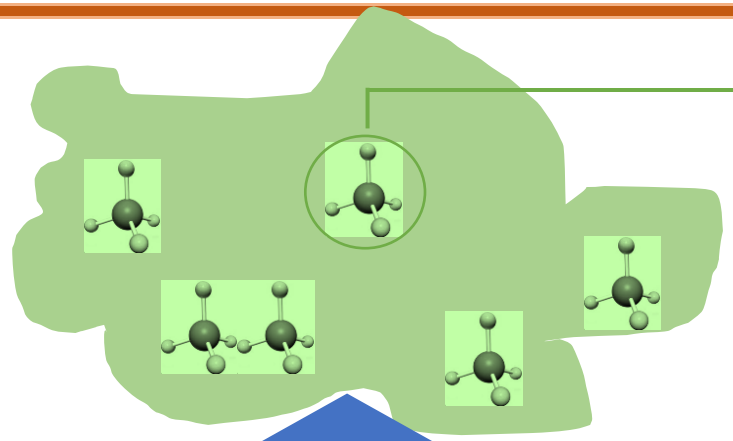


Although ensemble spread is reduced but still exist considerably??

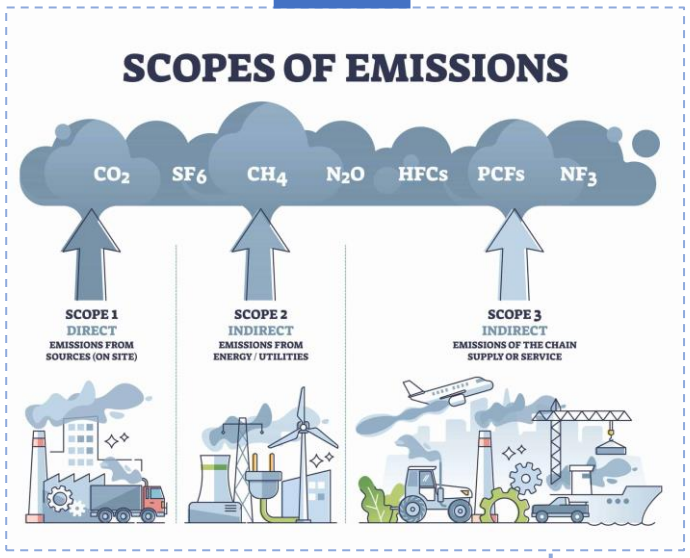
Courtesy: Gaubert et al., 2019

***T3L2**: TransCom version 3 level 2*
***RECCAP**: REgional Carbon Cycle Assessment and Processes.*

Background: Bottom-up vs. Top-down approach



GHG emission



Atmospheric Measumements

ACTM

Prior flux

Top-down Approach

Inverse modelling

Data Assimililation

Regional Emission

Bottom-up Approach

Emission factors

Consumption

Vehicle statistics, various chemical data etc.

Emission Inventory

Sectors

Process based models

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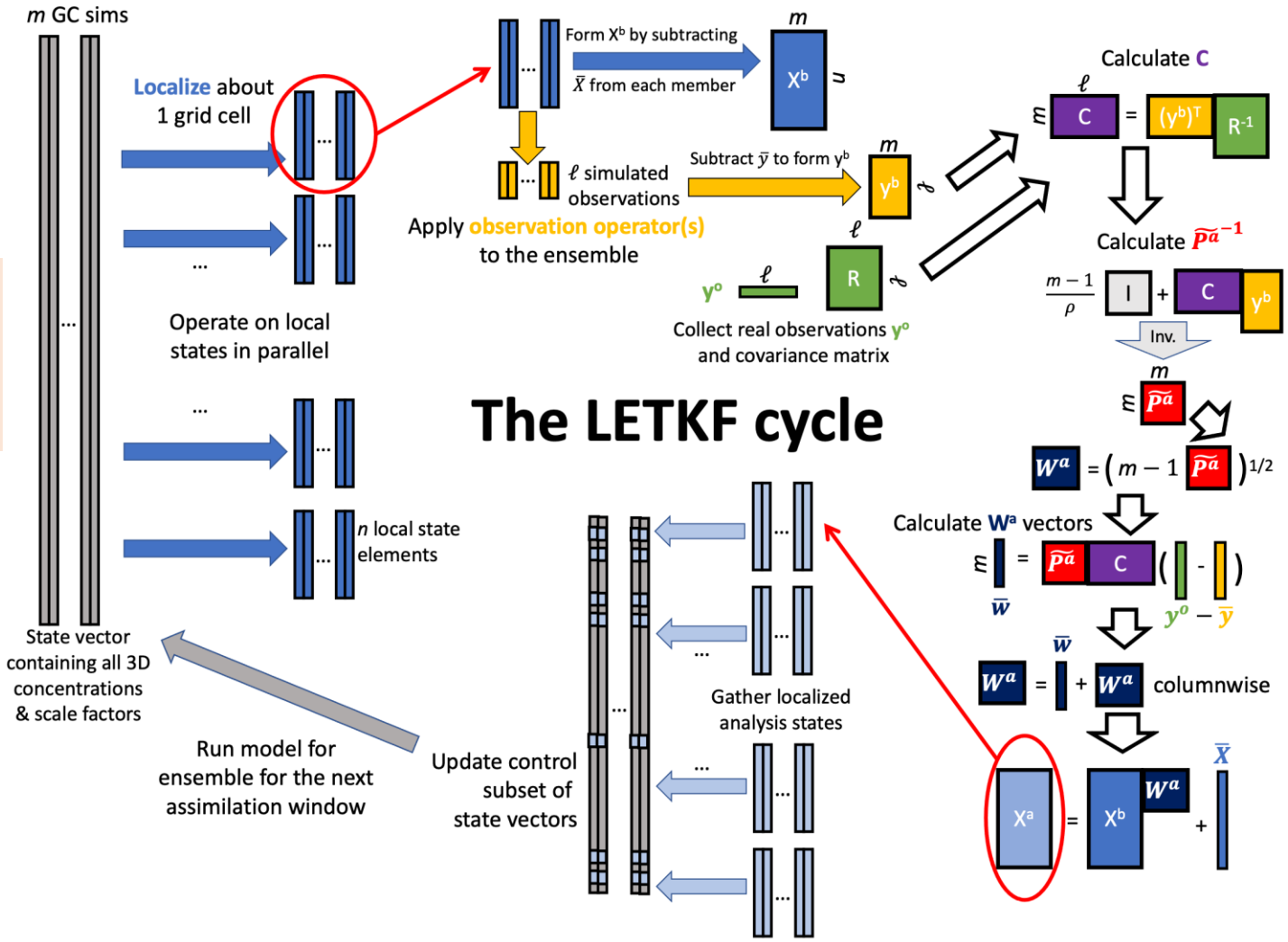
Local Ensemble Transform Kalman Filter (LETKF)

State vector

CO_2 *concentration and flux factors at each grid point.*



l : no. of points in observation space
m : no. of ensemble members
n : no. of points (lat x lon)
R : observation error covariance
$\boldsymbol{W^a}$*: Transport matrix*
$\widetilde{\boldsymbol{P^a}}$ *: Analysis error covariance*

Forward model:
MIROC4-ACTM

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MIROC4-LETKF OSSE Setup

OSSE : Observing System Simulation Experiment

First step for the implementation and testing of a DA system. It is useful to investigate the skill of the DA system using synthetic observation data before applying it to a real world problem.

To start an OSSE experiment using MIROC4-LETKF system, we need the following:

- *Synthetic observation data and its associated uncertainty.*
- *Prior flux and associated uncertainty.*
- *Initial CO_2 values.*

In our experiment:
Experinent year : 2015
No. of ensembles : 100
True flux: Fossil fuel (GridFED; Jones et al., 2021) + Land-biosphere (CASA monthly; Randerson et al., 1997) + Ocean (Takahashi et al., 2009) + Inversion flux (Chandra et al., 2022).
Apriori flux: Fossil fuel + Land-biosphere + Ocean + 75% Inversion flux.

Window length: 3 days
Inflation: 10% fixed multiplicative
Gross error: 10
Horizontal correlation length = 2000 km
Vertical correlation length = 0.3 ln hPa

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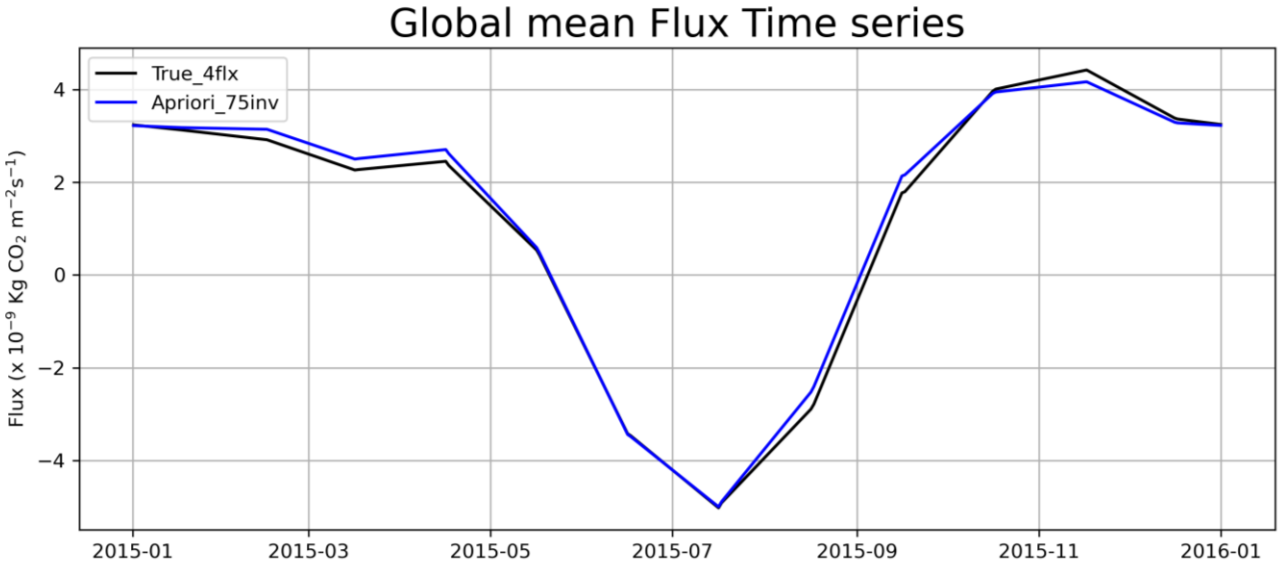
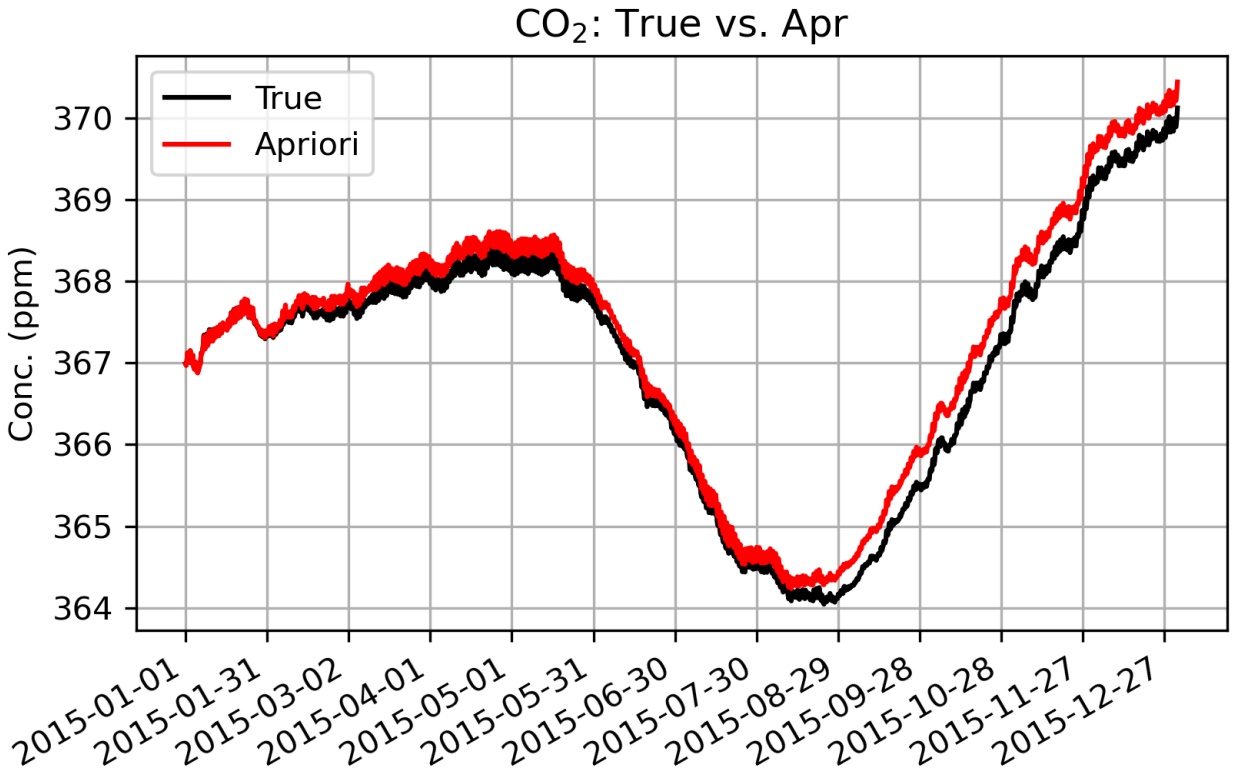
MIROC4-LETKF OSSE: Synthetic True vs. Apriori





Globally, Apriori CO_2 is higher as the Aprioi flux is higher. It is because inversion sink is reduced in Apriori => it increases the total flux.

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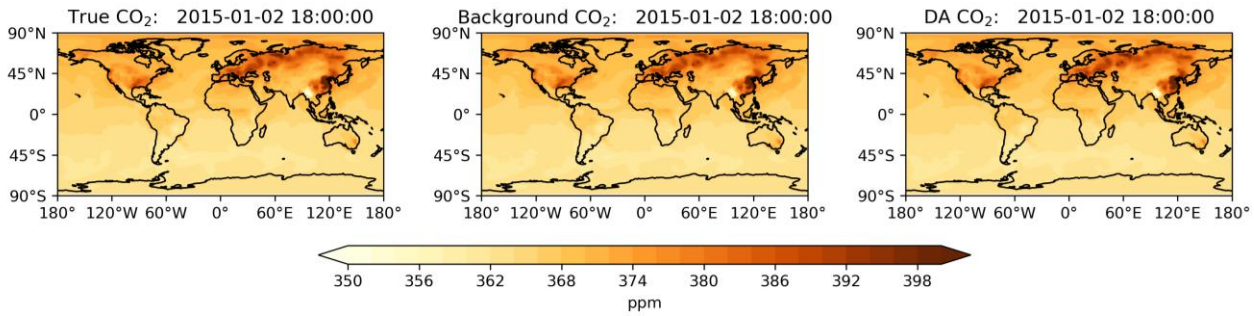
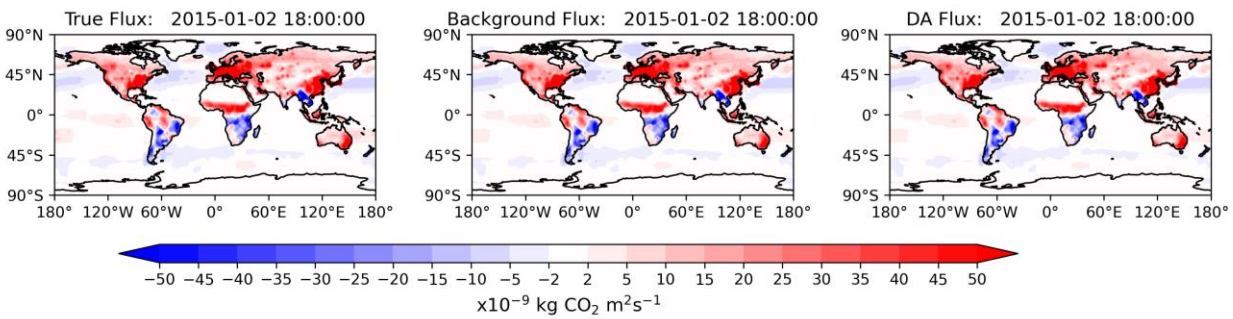
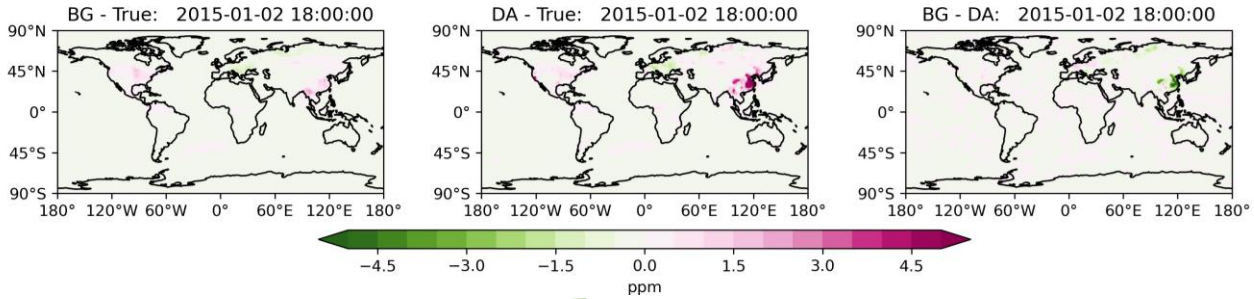
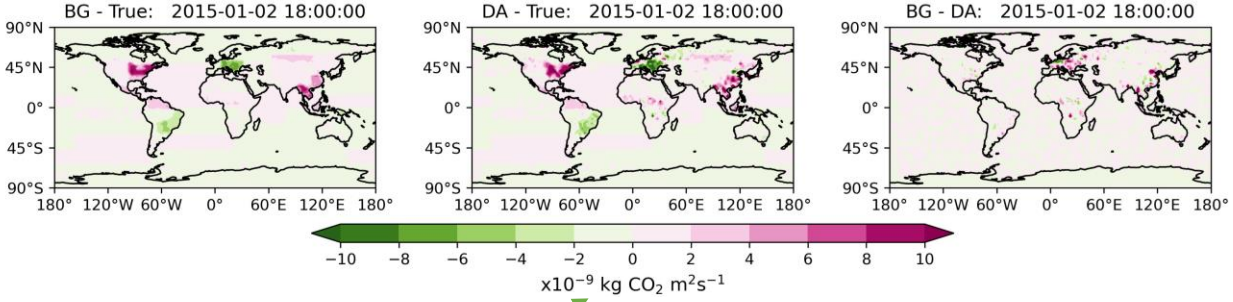
Results: Spatial distribution of analysed CO_2 and flux









CO_2

Flux

First Analysis step

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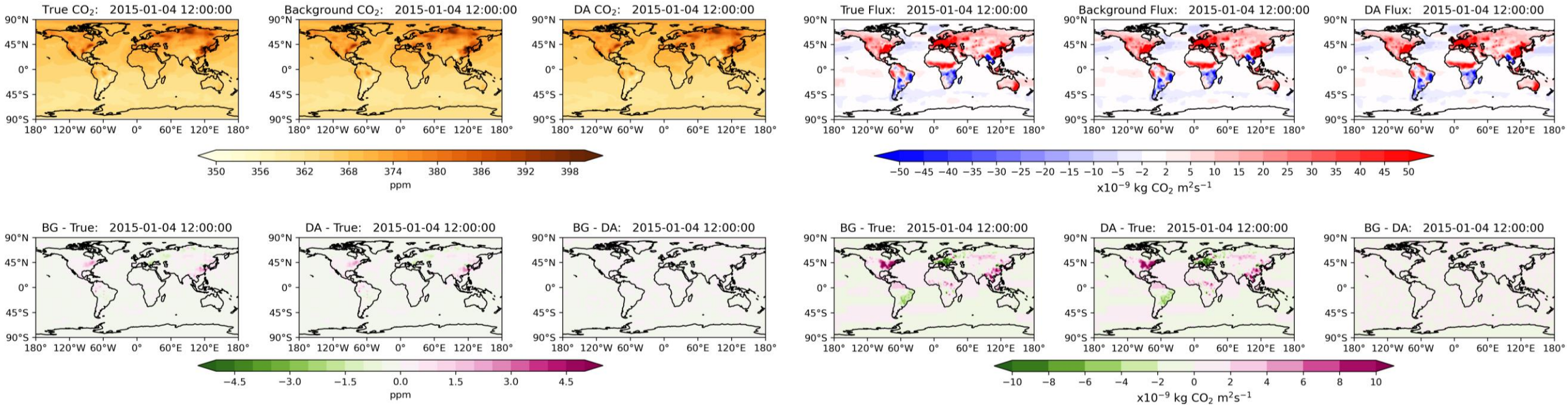
Results: Spatial distribution of analysed CO_2 and flux



CO_2

Flux

Second Analysis step

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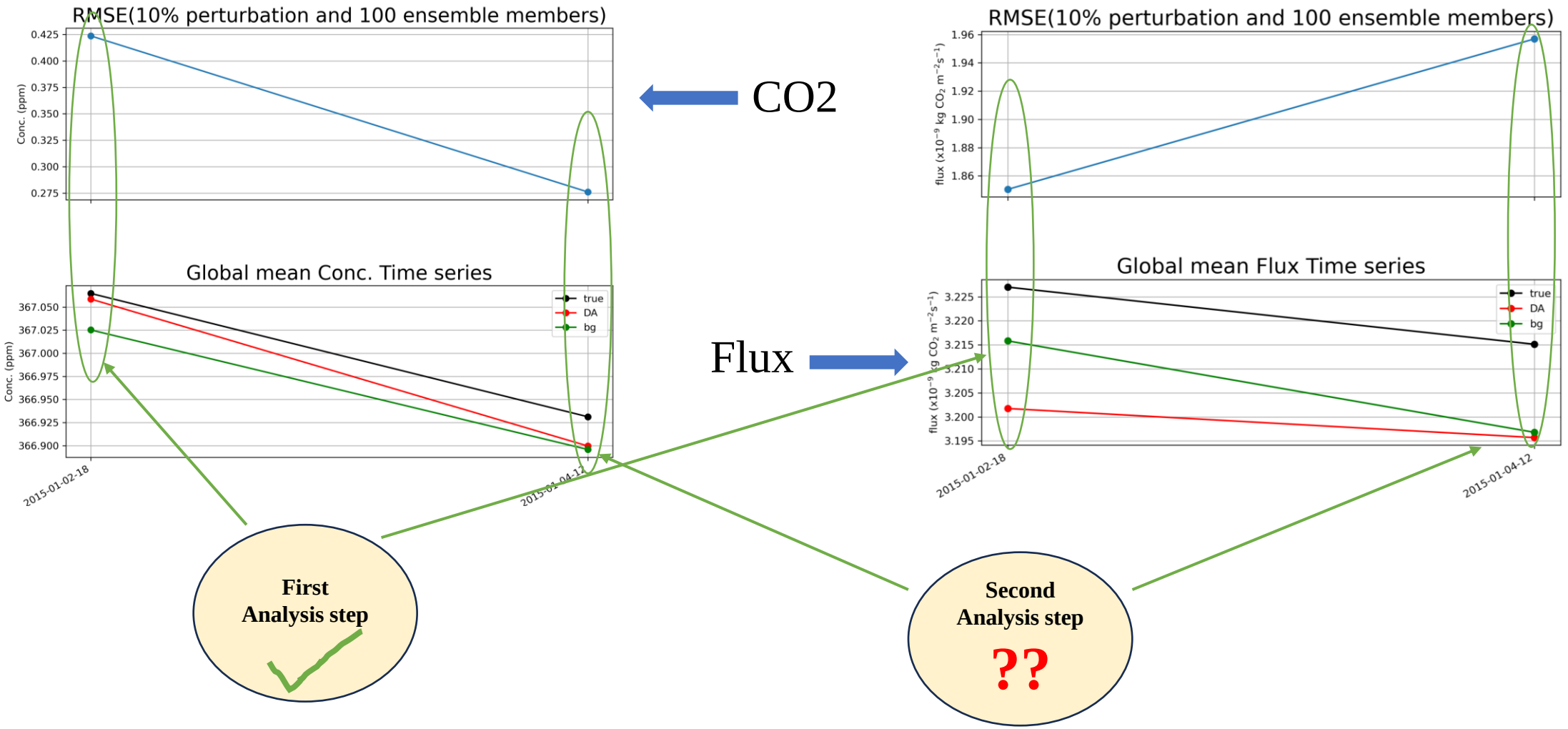
Results: Global RMSE of analysed CO_2 and flux



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Metric based on CO2 flux and concentration

Possible solution of this problem:

- *It is observed that LETKF is extremely sensitive to the prior flux and its uncertainty.*
- *Observation error is also an important factor for the convergence. Realistic error might help the system to converge.*
- *Theoretically, background error covariance is getting underdispersed over time. Therefore, we need to inflate it. This will help the LETKF system to maintain the background/prior flux uncertainty. There are various covariance inflation technique. One of such procudure is RTPS (relaxation-to-prior spread). In this method, we force the system to maintain a predefined (provided by the user) percentage of prior flux uncertainty for the following timesteps.*
- *More test simulation and diagnostics are needed.*

Concluding remarks

In this study, LETKF is tested for the optimization CO_2 flux and concentration. As of now,

- Technical implementation and testing of LETKF is finished and the system (MIROC4-LETKF) is working well.
- As observed earlier, CO_2 and flux are not optimized correctly from the second analysis window onwards due to inaccurate prior flux and its uncertainty as well as implementation of correct covariance inflation technique.

I am working on it……

Thank you

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