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Update of CTE-CH_4 and activities at FMI

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Outline

1. Methane emission estimates for NHL with CTE-CH_4

2. New covariance propagation scheme with CTE-CH_4

3. Other activities at FMI

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Methane emission estimates for NHL with CTE-CH_4

TM meeting 16-27.01.2017, video conference

CTE-CH_4 for NHL

- Optimize CH_4 emission based on ensemble data assimilation
- TM5 zoom grid over Europe
  - Gregory ('convec') convection
- Weekly optimization of anthropogenic (EDGAR v4.2 FT2010) and biospheric (LPX-Bern) emissions
- **Grid-by-grid (1°x1°) optimization on Europe**
- Elsewhere: Region-wise optimization based on modified TransCom regions and land-ecosystem (soil type) region
- **Additional observations from NHL assimilated (e.g. Russia & Finland).**

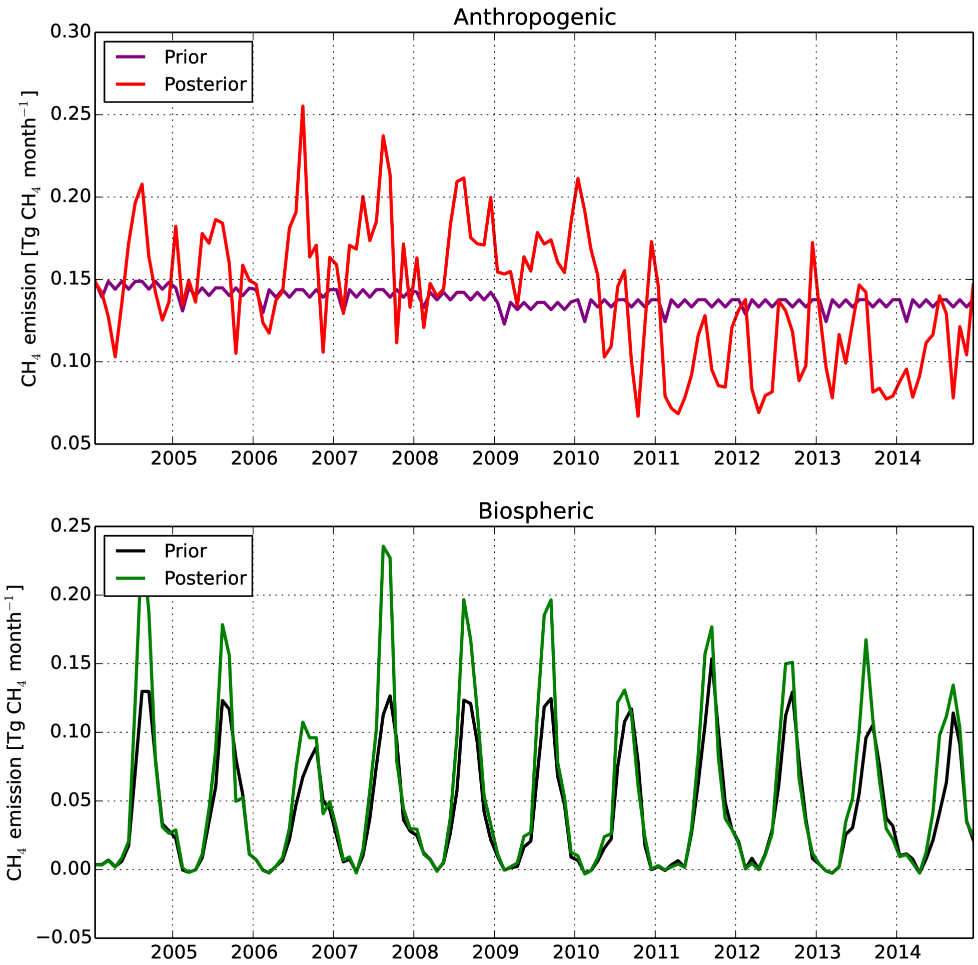
CTE-CH_4 for NHL

- Prior emissions
  - EDGAR v4.2 FT2010 (anthropogenic)
  - LPX-Bern dyptop (biospheric)
  - GFED v4 (fire) + Ito *et al.* (termites) + ocean

- Focus more on northern Europe
  - Level of anthropogenic and biospheric emission estimates
  - Seasonal cycle of biosphere emission

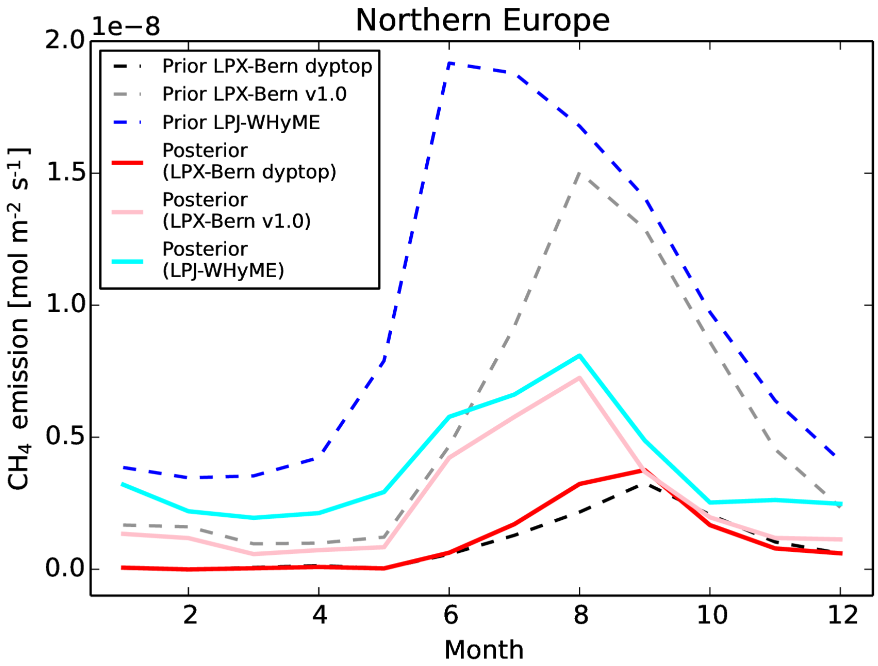
CTE-CH_4 for northern Europe

- Anthropogenic emission level lowers after 2010
  - Kumpula observation starts
- Higher biospheric emission during summer
  - Observations from Pallas probably play major role, but those from Sodankylä, and Hyytiälä can also contribute.



CTE-CH_4 for northern Europe

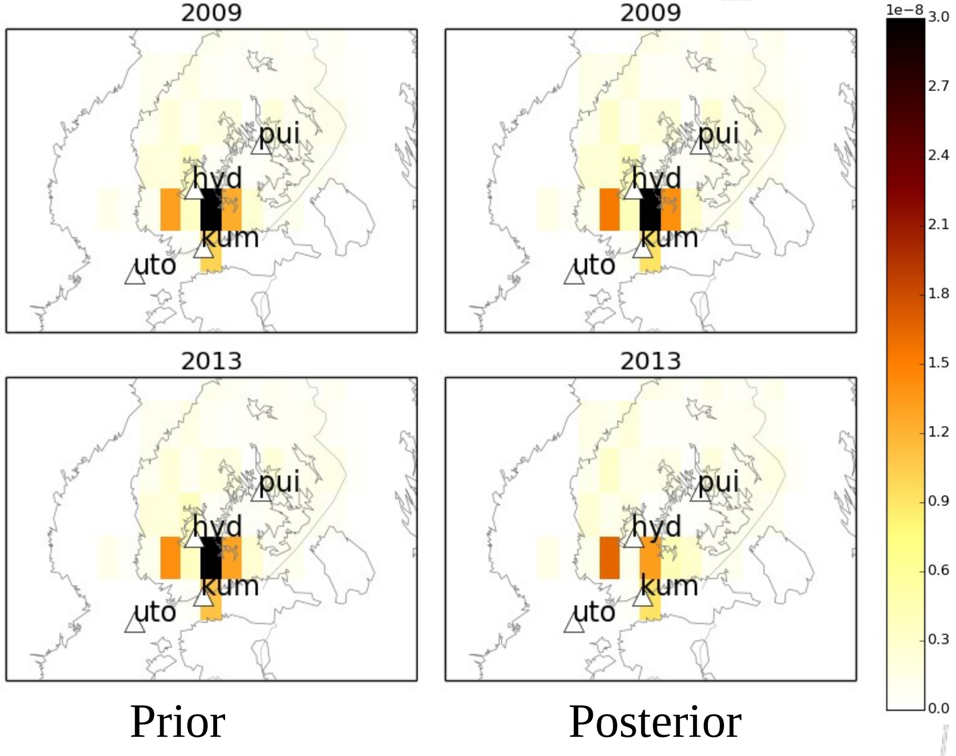
- Biospheric emission estimates over northern Europe differs a lot between different ecosystem models
  - Prior annual emission: 0.54 – 5.4 Tg CH_4 yr^{-1} (10 times!!)
  - Summer maximum: May-September
- Inversion suggests estimates to be somewhere in between, but prior influence is still high.
  - → Increase prior uncertainty to allow more variability in posterior



Monthly CH4 emission estimates for 2011

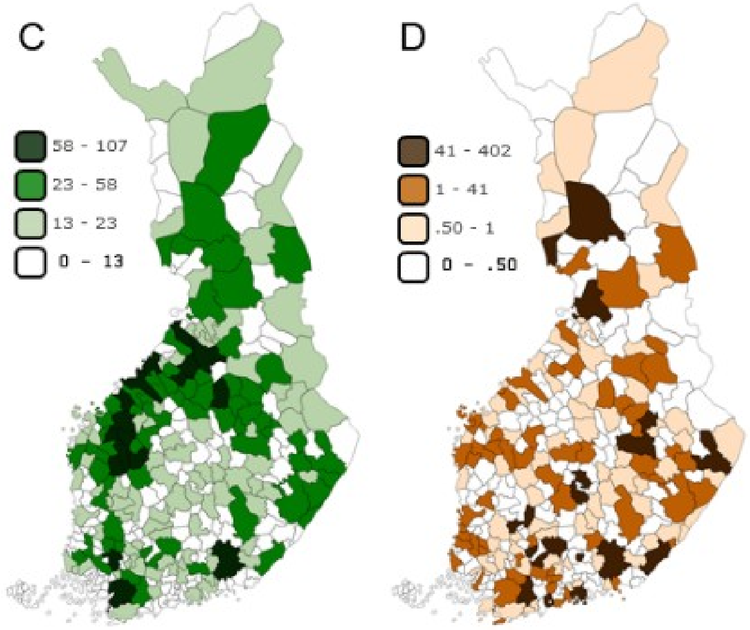
CTE-CH_4 for northern Europe

- Spatial distribution of anthropogenic emission
- Before 2010
  - similar pattern to prior
- After 2010
  - major reduction on north of Helsinki region
  - Slight increase on hot spot of north west of Kumpula.
- → Kumpula observations seem to influence larger region than its own grid

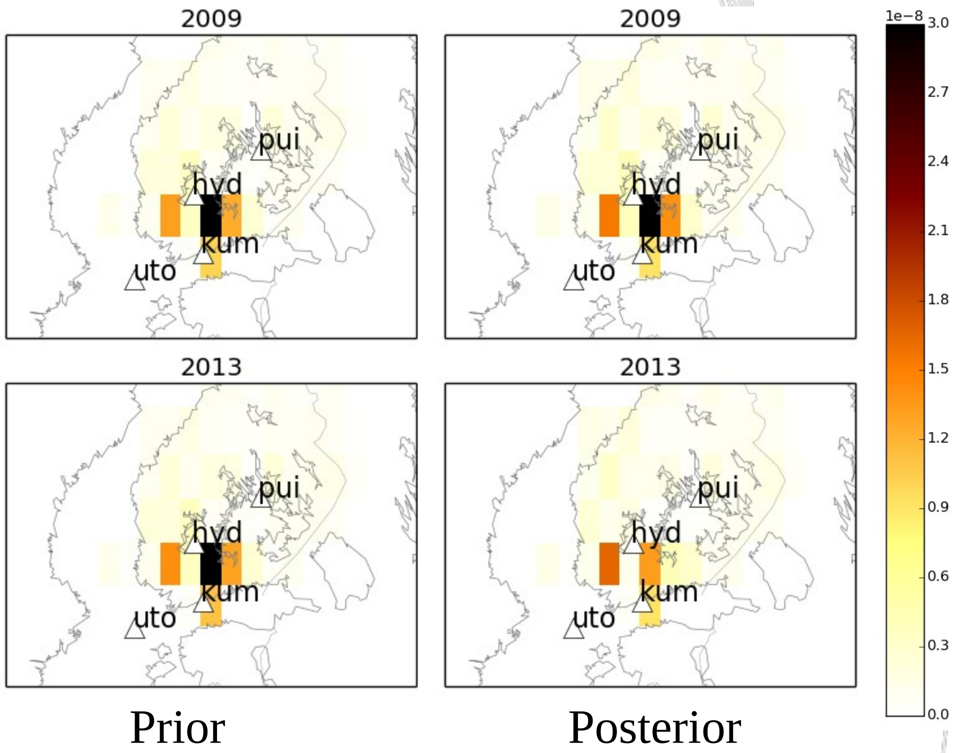


CTE-CH_4 for northern Europe

- Compared to national inventory



Source: Greenhouse gas inventory unit, Statistics Finland

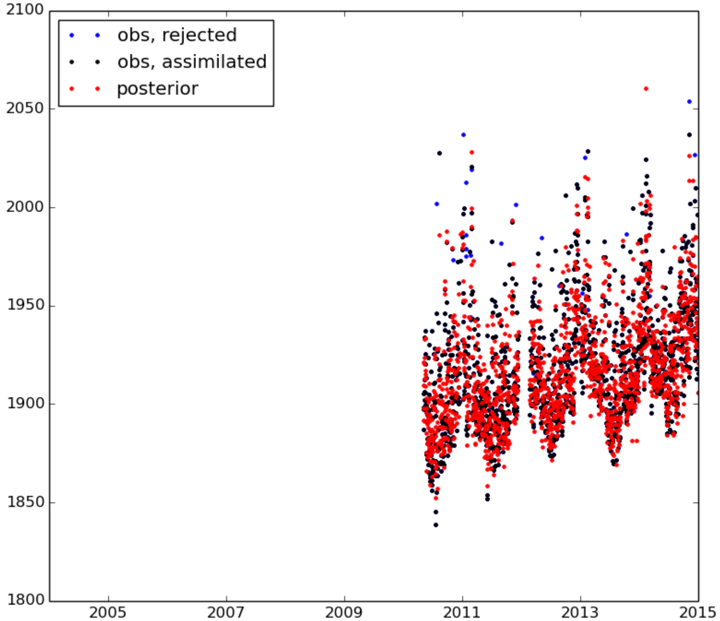


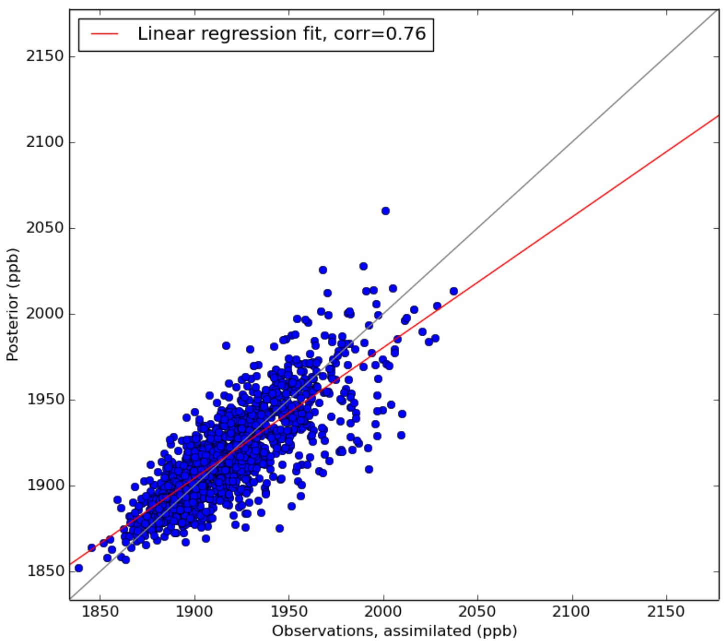
In Finland, anthropogenic emission is mainly from waste and agriculture.

CTE-CH_4 for northern Europe

- Atmospheric CH_4 at in-situ observation sites
- Generally good correlation
- Negative bias of 0~9 ppb

Kumpula, Finland

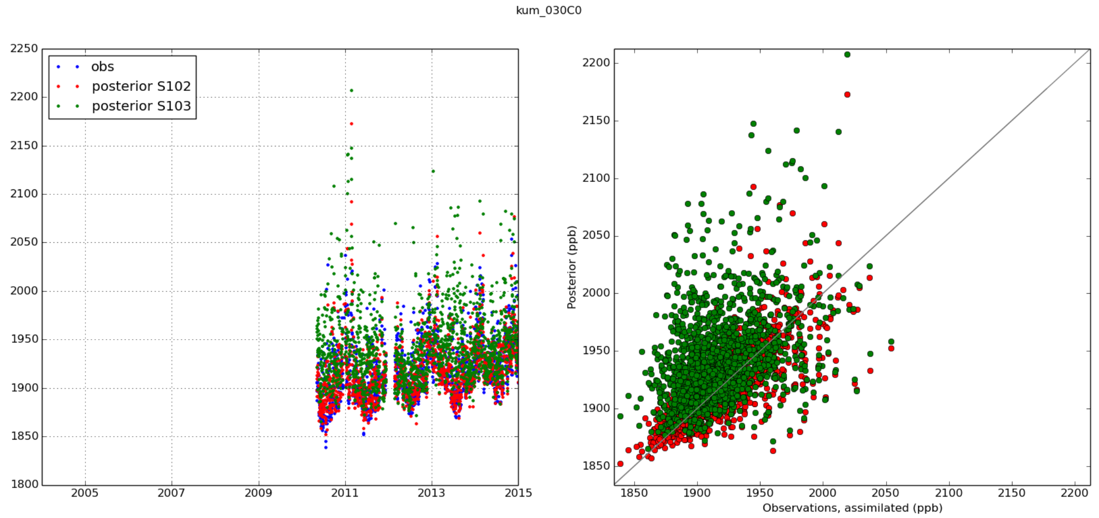




CTE-CH_4 for northern Europe

Sensitivity tests to observations

- Without city observations (Kumpula & Puijo) assimilated
  - Emission over northern Europe is higher
  - Agreement of with in-situ observations at Kumpula is much worse
  - Other sites show little effect, but slightly worse: the other sites mainly capture signals from biospheric emission



New covariance propagation scheme with CTE-CH_4

TM meeting 16-27.01.2017, video conference

New cov. propagation

Idea: introduce temporal correlation of state vectors (posterior emissions)

- Current version does not have propagation scheme

  i.e. no temporal correlation between state vectors from one week to another
- Resulting in large fluctuation of weekly estimates

  i.e. only monthly emission estimates have been reported
- We wish to better estimate short-term events

New cov. propagation

We tried several techniques...

1. Propagate all ensemble members, as is done for means
   - Too small prior std
   - Too small prior degree of freedom (dof)
2. Use of posterior covariance with inflation
   - Too small prior dof
3. Use of posterior covariance with partial replacement
   - Too much adjustments needed to carefully inflate/deflate covariance matrix and to reserve enough dof.

New cov. propagation

We tried several techniques...

1. Propagate all ensemble members, as is done for means
   - Too small 'prior' std

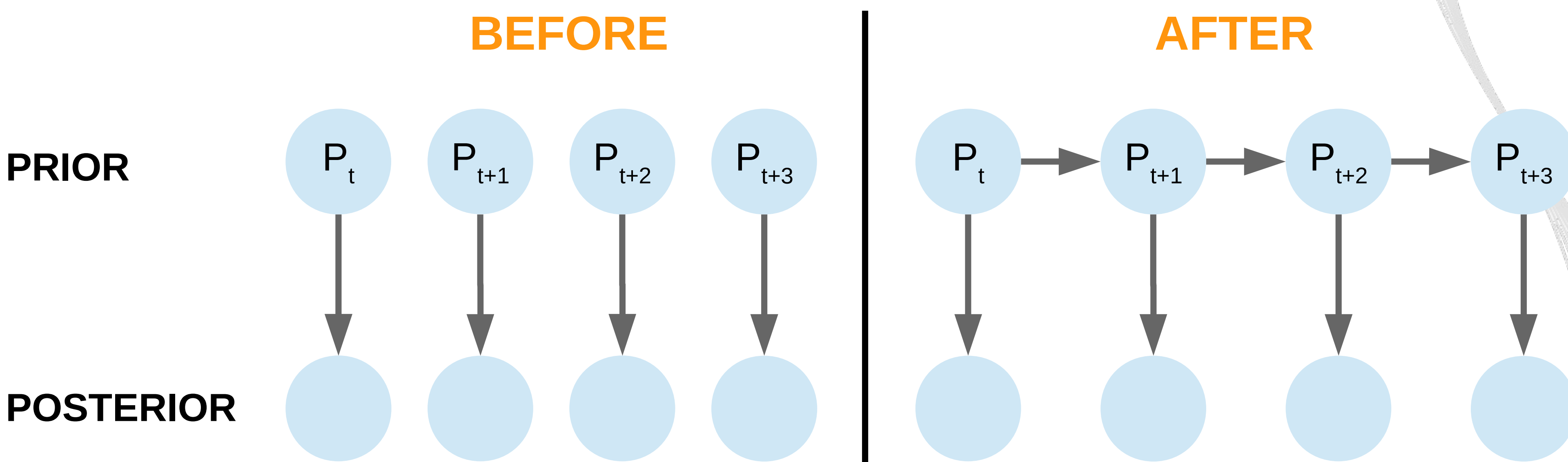
Non of them worked as well as we wish and would be easily applicable to different setups & versions.

2. U

3. Use of posterior covariance with partial replacement
   - Too much adjustments needed to carefully inflate/deflate covariance matrix and to reserve enough dof.

New cov. propagation

- Solution: introduce temporal correlation on 'prior' ensembles.



$$\boldsymbol{w}_{i,t} \sim N(1, \boldsymbol{P}^b),\ \boldsymbol{w}'_t \sim N(1,1)$$

$$\boldsymbol{x}^p_{i,t} = \boldsymbol{w}_{i,t} \quad \text{for } t \geq 0$$

$$\begin{aligned} \boldsymbol{z}_t &= \boldsymbol{w}'_t && \text{for } t = 0, \\ \boldsymbol{z}_{t+1} &= r\boldsymbol{z}_t + (1 - r^2)^{1/2}\boldsymbol{w}'_{t+1} && \text{for } t \geq 1. \end{aligned}$$

$$\boldsymbol{x}^p_{i,t} = \begin{cases} \boldsymbol{w}_{i,t} & \text{for } t = 0, \\ \boldsymbol{C} \cdot \boldsymbol{z}_{i,t} & \text{for } t \geq 1, \end{cases}$$

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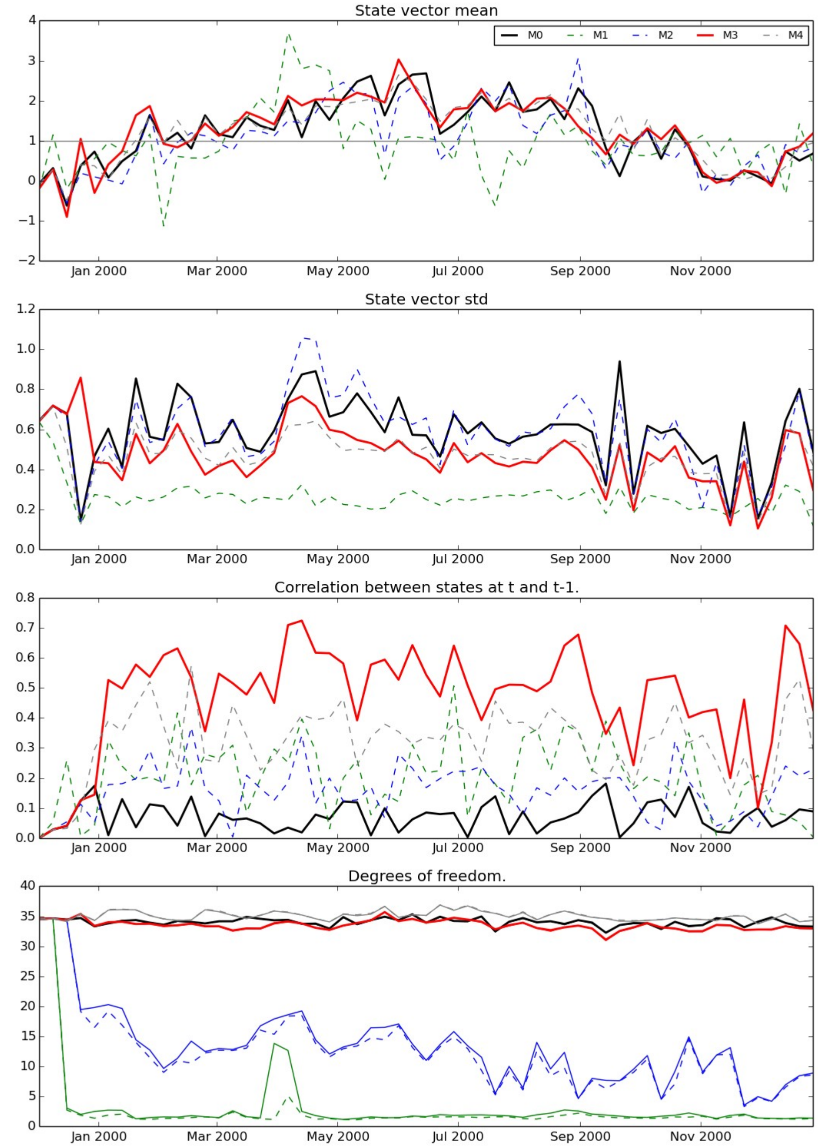
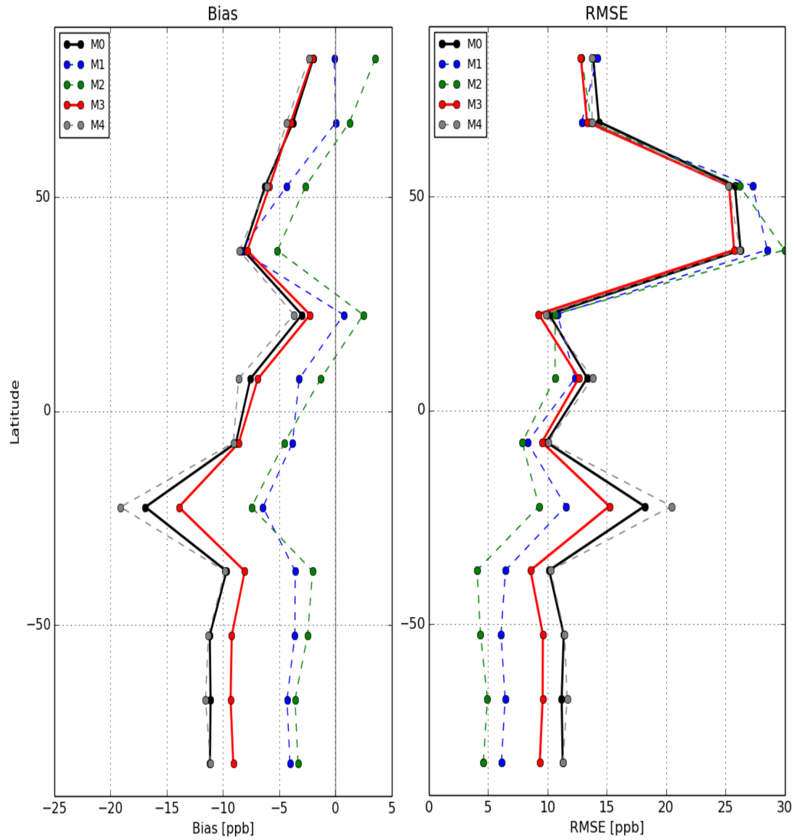
New cov. propagation

- Results
  - Smoother state vector
  - Std and dof stays similar to previous version (prior drawn from similar distribution)
  - Correlation increases (as expected)



New cov. propagation

- Results
  - Smoother state vector
  - Std and dof stays similar to previous version (prior drawn from similar distribution)
  - Correlation increases (as expected)
  -
- Agreement with observations became better 🙂



Other FMI activities

Other CTE activities...

- CTE-CH_4 with GOSAT
  - Under preparation: latitudinal bias found from a first test run will be taken into account
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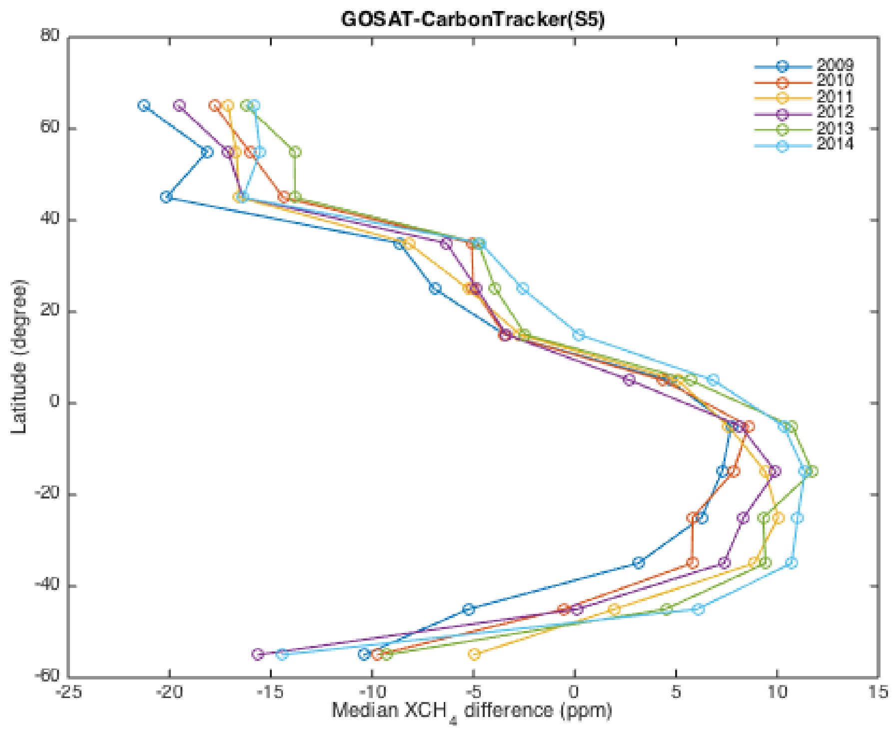

Effect of polar vortex on xCH_4

- Motivation:
  - Better understanding of what the measurements of Arctic xCH_4 represent
    - e.g. when xCH_4 is assimilated to CT
    - derive tropo-xCH_4 from xCH_4, xHF and CH_4-HF relationship in the stratosphere
  - Suggestion for improved prior selection for the retrieval of xCH_4
    - Significant effect on methane profile during spring due to descent of air masses with low CH_4 concentration within the polar vortex
    - Set of improved prior profiles based on satellite data (HALOE, ACE)
  - CarbonTracker validation
    - Improved distribution of stratospheric methane in CT?

Arctic xCH_4

- Data:
  - Arctic xCH_4 data, (TCCON + NDACC stations)
  - Meteo data: ECMWF ERA-Interim, definition of vortex & tropopause height
  - Stratospheric profiles of CH_4 & HF (HALOE, ACE)
  - CH_4 profiles, AirCore
  - CH_4-CarbonTracker Europe

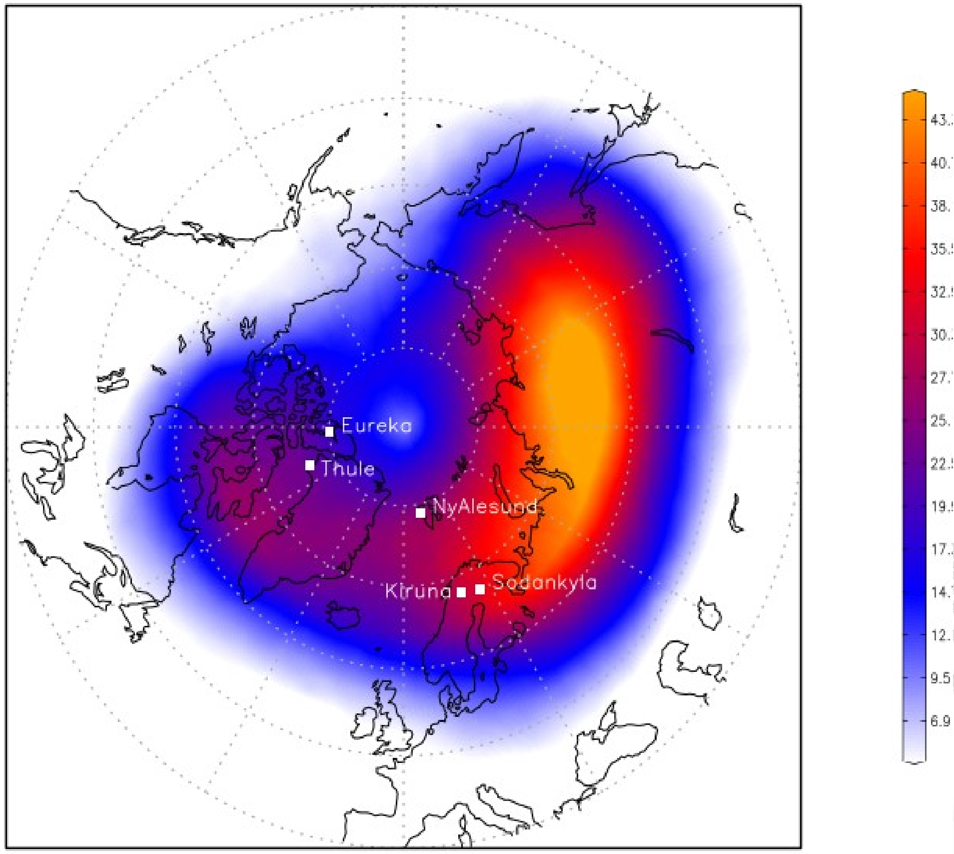

Fig: Average number of days influenced by the polar vortex during Feb-May (1995-2015) with SZA < 82°