DEVELOPMENT OF THE 4D-VAR CODE / PLANS FOR THE CAMS/CH4-FLUX PROJECT

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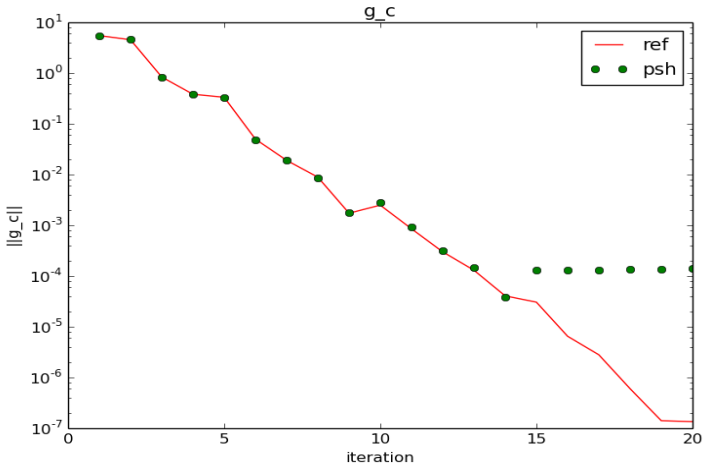
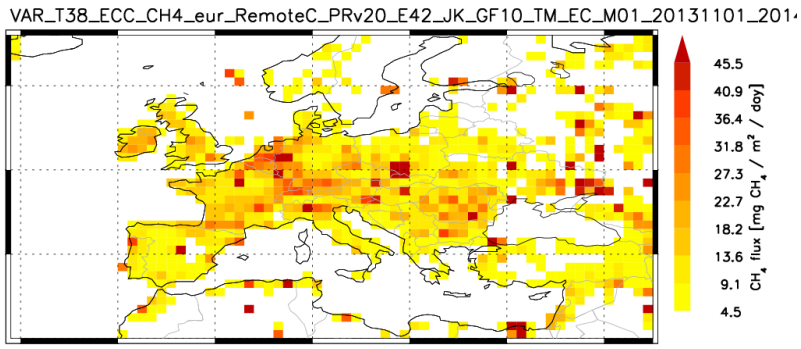
Peter Bergamaschi (JRC), Mihai Alexe (JRC)

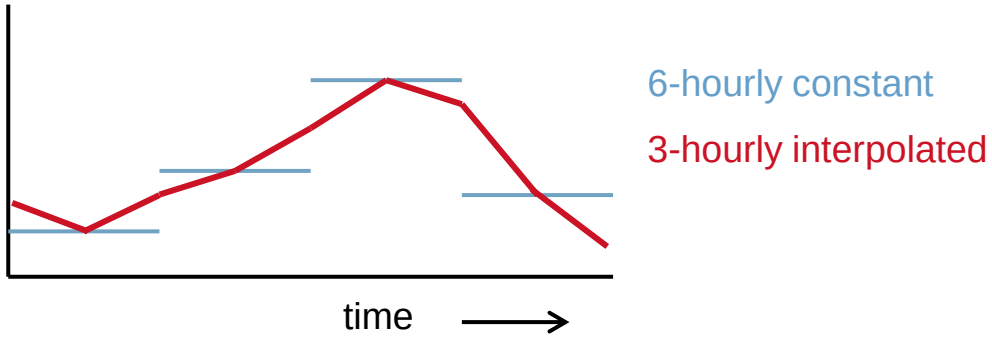




DEVELOPMENTS IN 4D-VAR

- Implemented under JRC Framework contract

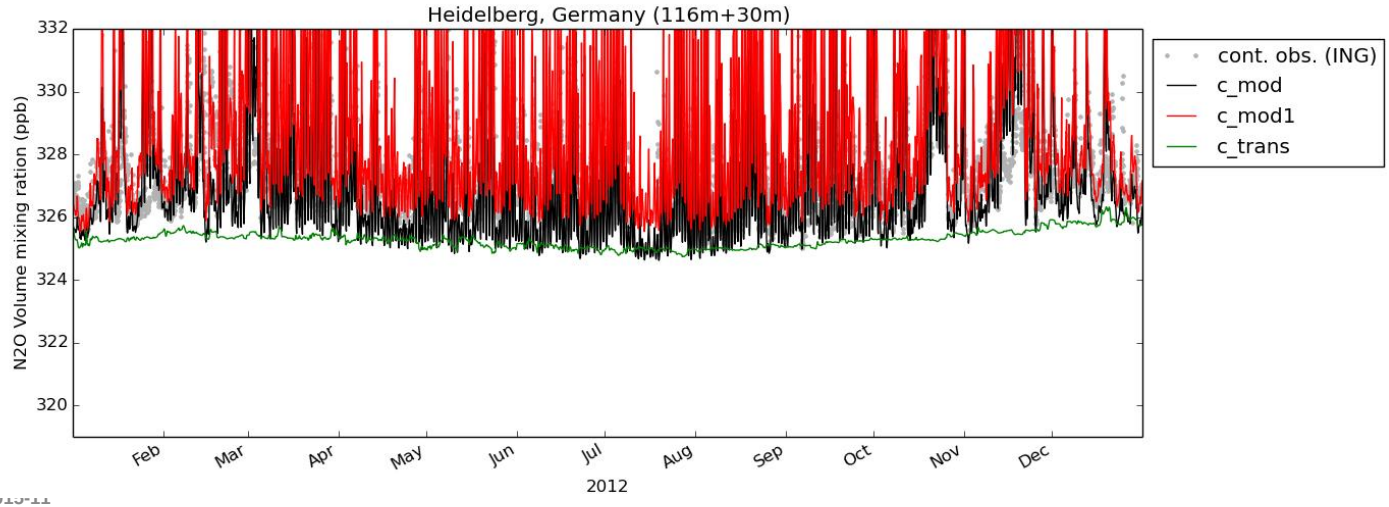
- **Temporal interpolation** of meteo in TM5 4D-var version:
  - originally only 6-hourly constant 3D-fields, and 3 hourly surface ("cy1")
  - new code with data structures of latest TM5
  - allows 3-hourly interpolated meteo
  - adjoint checked



DEVELOPMENTS IN 4D-VAR (2)

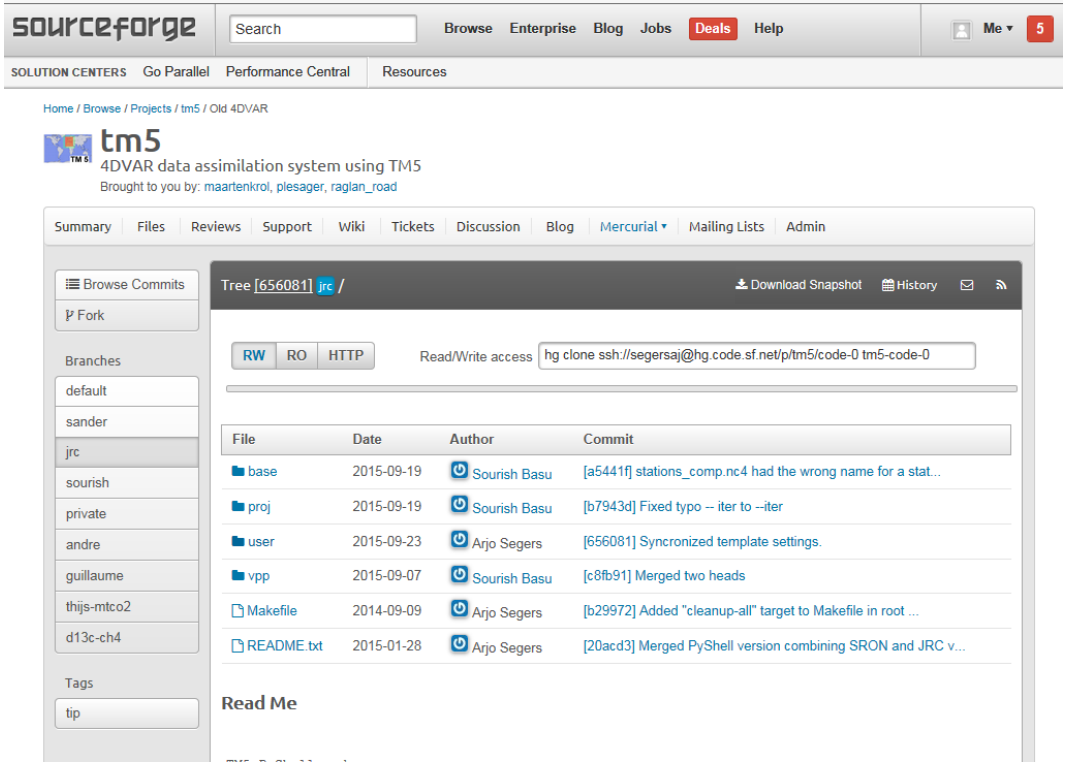
- Optimization of **bias correction** parameters for **station data** (N_2O)

- Support for "Rödenbeck" scheme to obtain **regional baselines**:
  - model runs with/without optimized emissions and/or masked region of interest
  - provides regional "global" background



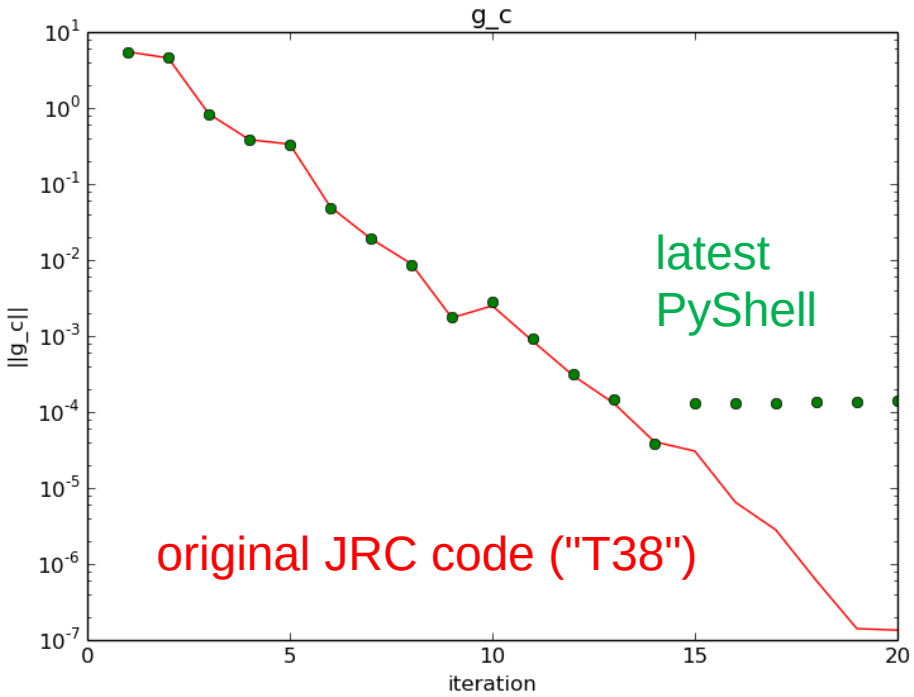
DEVELOPMENTS IN 4D-VAR (3)

- Version used by JRC, TNO, NOAA (Sourish)
- Code on SourceForge server under "jrc" branch, with "user" specific sources for "jrc" and "sron" (= Sourish)
- To be moved to the "default" branch?

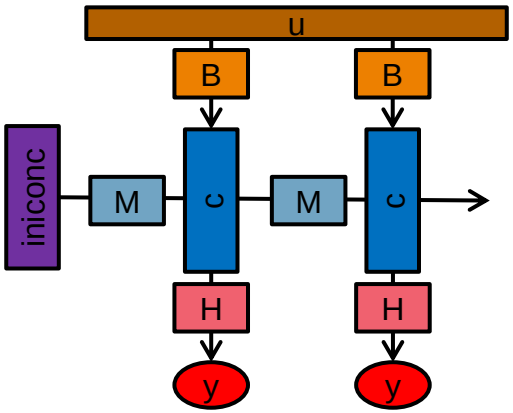


HOWEVER ...

- Problem discovered by Peter B.:
  while optimizing emissions and **initial concentrations**,
  norm of gradient is not reducing anymore after about 15 iterations:



- Possible reasons:
  - lack of precision in some steps?
  - adjoint not correct ?
  - ...



emissions

emission operator

model operator

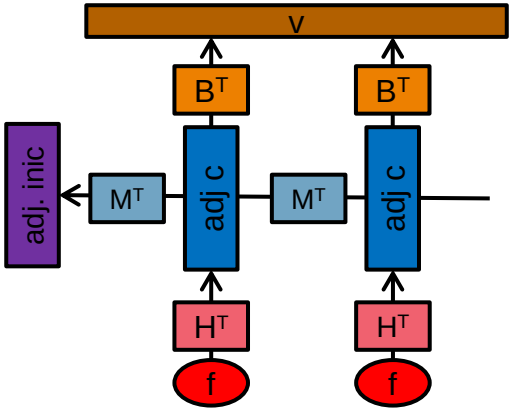
observation operator

observations

- Original adjoint test only related emissions and (point) observations:

forward run:

$\mathbf{y = H M B u}$



adj. emissions

adj. emission operator

adj. model operator

adj. observation oper.

adj. forcing

adjoint run:

$\mathbf{v = B^T M^T H^T f}$

In theory for the dot product holds:

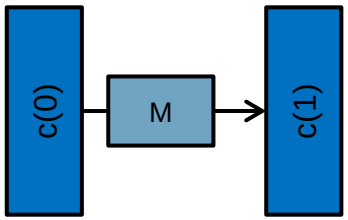
$\mathbf{f^T H M B u = u^T B^T M^T H^T f}$

$\mathbf{f^T y == u^T v}$?

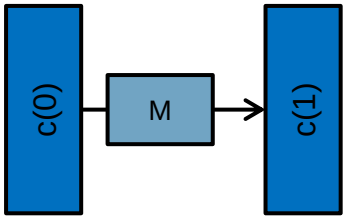
- Output of fulfilled adjoint test (original, only emis and point obs):

```
=========================================================================
adjoint test finished successfully
  || H dx || =  92.8714796013
  || d    || =  42.8138498125
  || dx   || =  14662.7577958
  || H' d || =  3078.75412786
test results:
  < H dx ,    d > =  -10.1152357114
  <   dx , H' d > =  -10.1152357114 , rel. difference =  1.40050575176e-12
=========================================================================
```

- Applied adjoint test on concentrations for sub-systems:
  - full model run : FAILED
  - model time step : FAILED
  - advection : FAILED
  - z-advection : FAILED



- Conclusion: something wrong with adjont model ...



- As test: re-implementation of z-advection:
  - Forward advection implemented as linear operator:

    c(t+dt) = A c(t)
  - Adjoint z-advection is now only 1 character different:

    call advectz('N', rm, rzm, ...) *! forward*

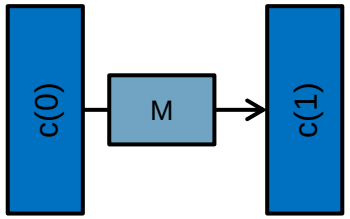
    call advectz('T', rm, rzm, ...) *! adjoint*
  - Small (but significant) difference with original result only in z-slopes

  - For new operator, adjoint test is fulfilled :

file keys : 'fwd_steps1' , 'adj_steps1'
time range: 2009-12-01 05:37:30 - 2009-12-01 06:00:00

region	mode	a(t1)'dx(t1)	dx(t0)'a(t0)	rel.diff.
glb600x400	rm	7.191329e+06	6.871351e+06	-4.550742e-02
glb600x400	rxm	0.000000e+00	0.000000e+00	0.000000e+00
glb600x400	rym	0.000000e+00	0.000000e+00	0.000000e+00
glb600x400	rzm	-1.864823e+04	3.013299e+05	2.263876e+00
all	all	7.172681e+06	7.172681e+06	-2.233300e-14

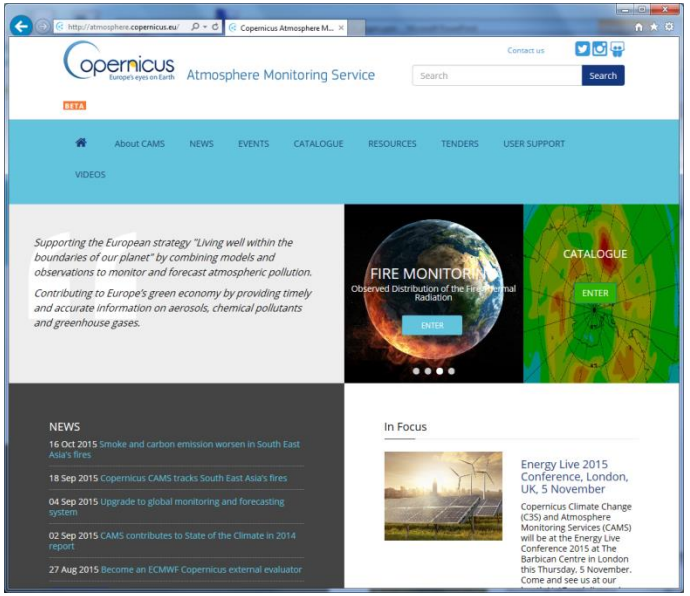
- Conclusions:
  - Adjoint operators in model are not completely correct ...
  - ... but are not that bad either; difference is in the details.
  - Adjoint test should be applied on model sub-systems, not on total application.



  - Implementation using linear (sparse) operators makes adjoint code only 1 character different from the forward.
  - Use this approach for TM5-MP ?

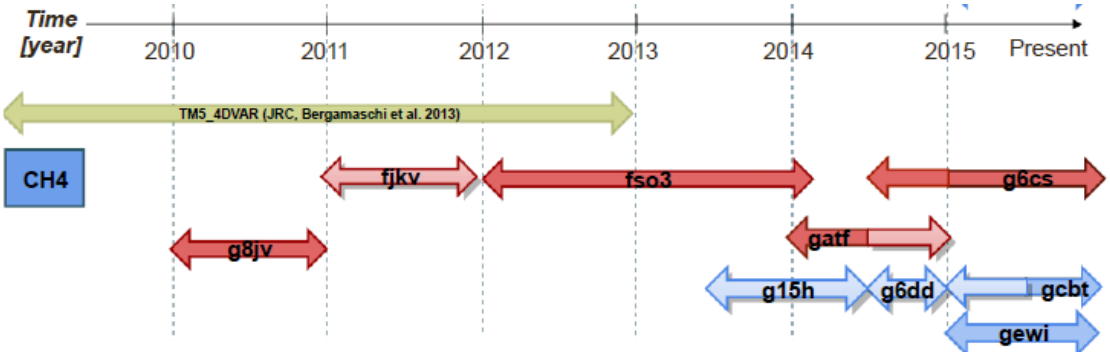
(problem with gradient norm postponed, adjont need to be corrected first)

COPERNICUS ATMOSPHERIC MONITORING SERVICE (CAMS)

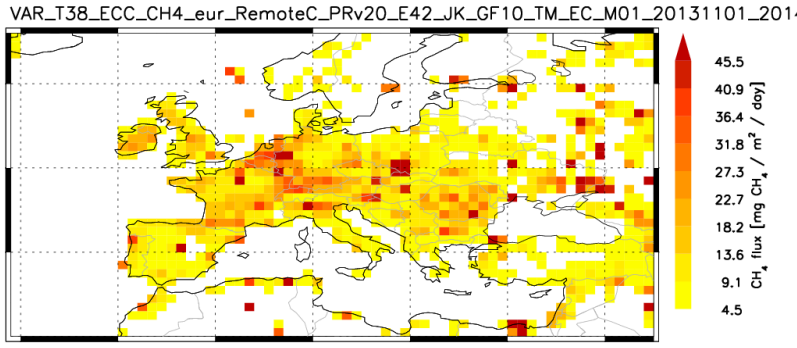


- Operational phase of MACC projects
- Intended (!) start date: October 1, 2015

- Services for GHG :
  - high-res forecasts of concentrations (ECMWF)
  - analysis incl. sat. data (ECMWF, < 1 month)
  - re-analysis of fluxes (external, < 1 year)



Flux inversion systems
Analysis
High resolution forecast

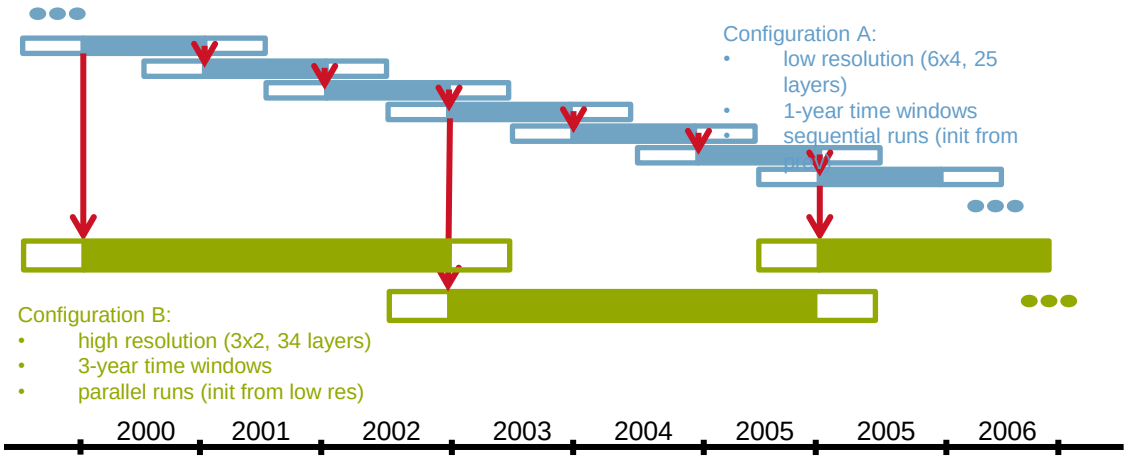


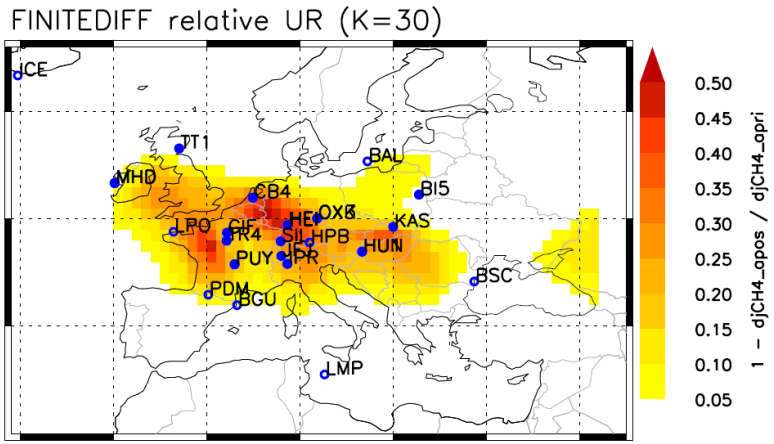
- CAMS sub-project on GHG fluxes re-analysis:
  - For CH4 continuation of re-analysis by JRC (Peter Bergamaschi)
  - Proposal of consortium lead by LSCE incl. TNO/SRON for CH4
  - Legal issues are currently under negotiation ...

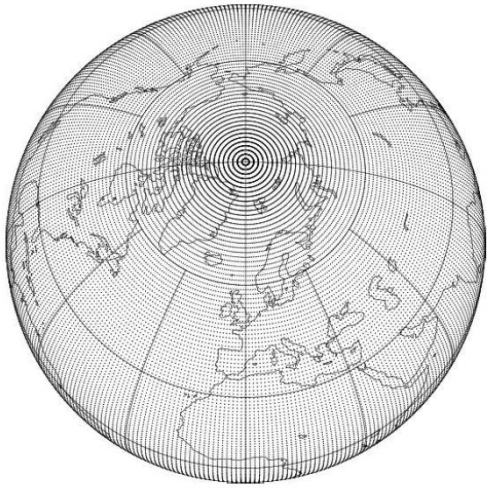
- Proposed 2 x 2 re-analys streams:
  - using NOAA flask observations only:
    - low res (glb 6x4), 1 year window + spinup/down , sequential
    - high res (glb 3x2), 3 year window + spinup/down, init from low res
  - idem incl. GOSAT too

- User input requested!

  User asks, CAMS does ...

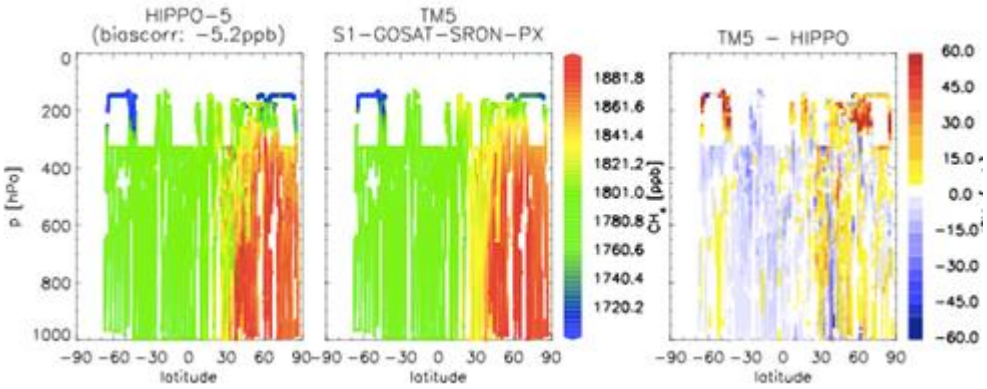






- Uncertainty quantification?

- Higher global resolution ?
  (N80 Era-Interim grid, ~1.125º)



- Improved latitudinal gradient ?