TM5-MP-4DVAR, AND SOMETHING ON CH4 SINKS

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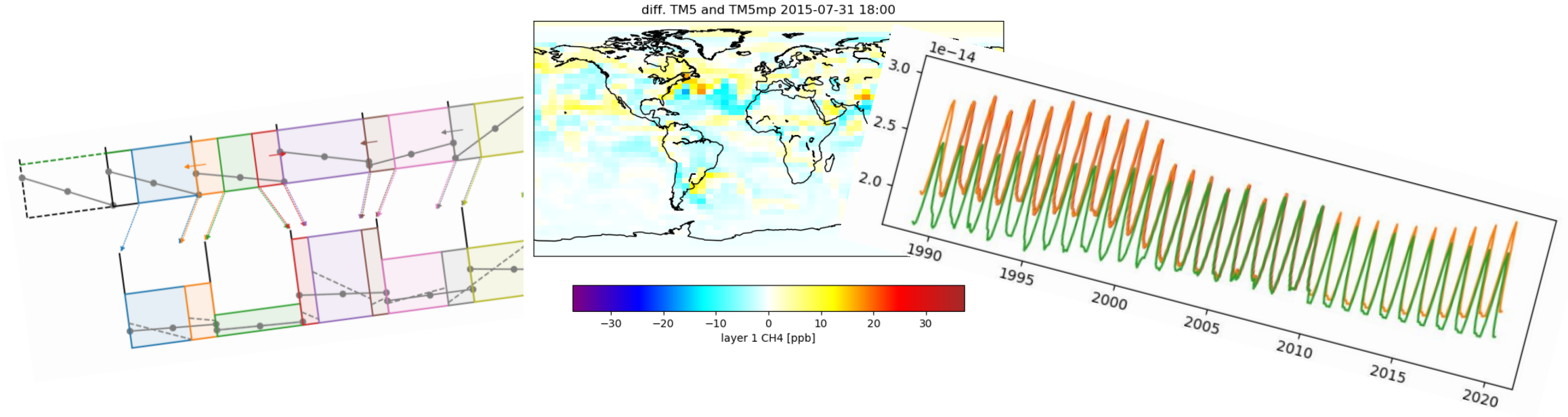

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

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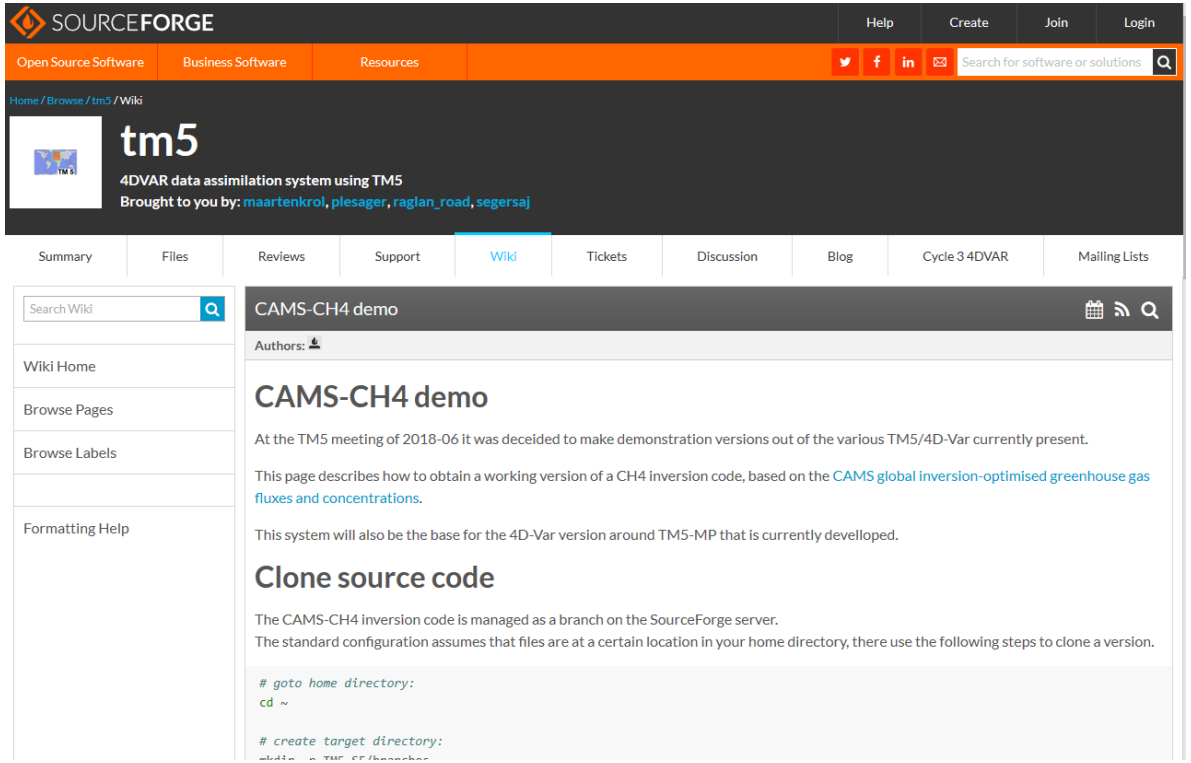
TNO innovation for life

TM5-MP/4D-VAR
DEVELOPMENT STATUS

- CH_4 inversion, global 6°x4°, surface observations



sourceforge.net/projects/tm5

TM5-MP/4D-VAR
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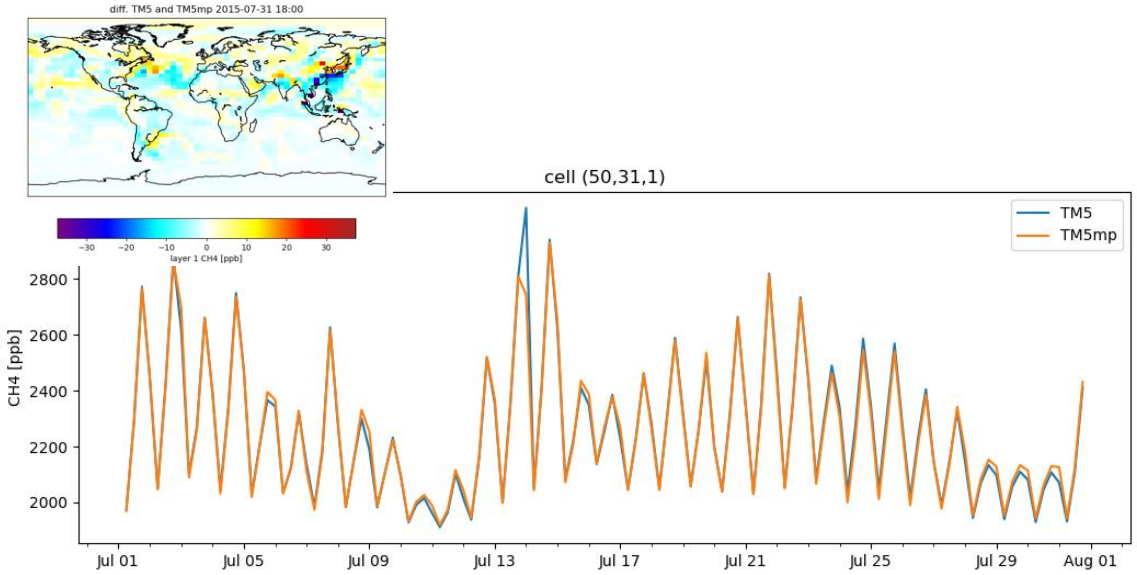
- TM5-MP forward model with same configuration [ok]
  - *small differences due to diverted models*



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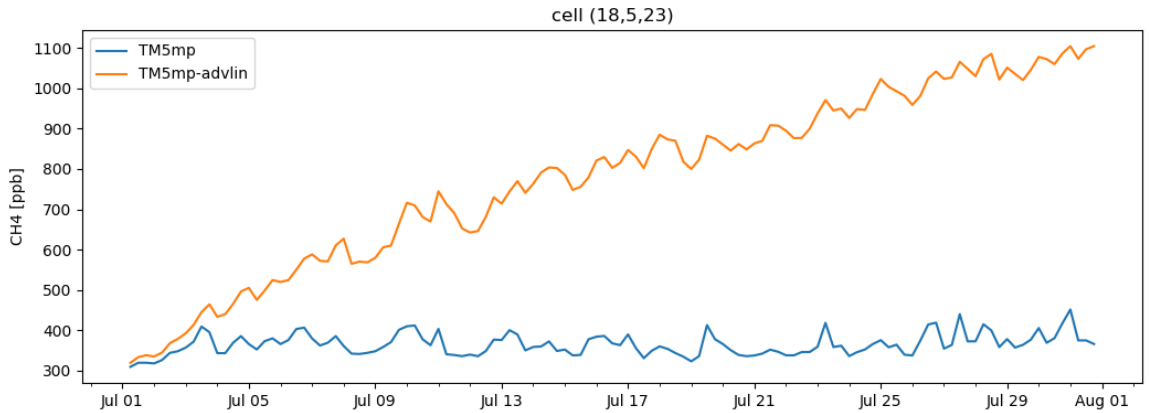

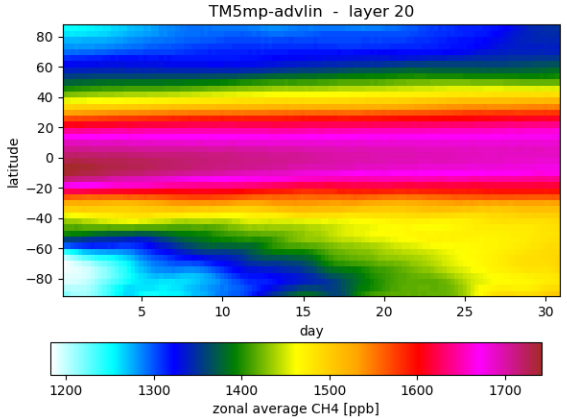

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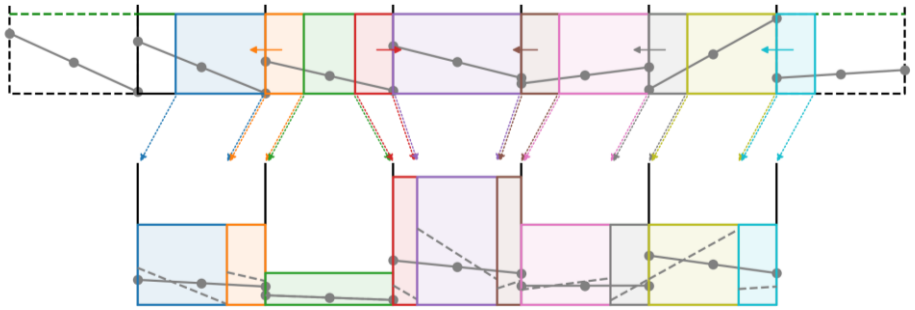

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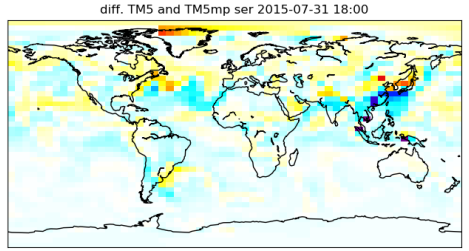

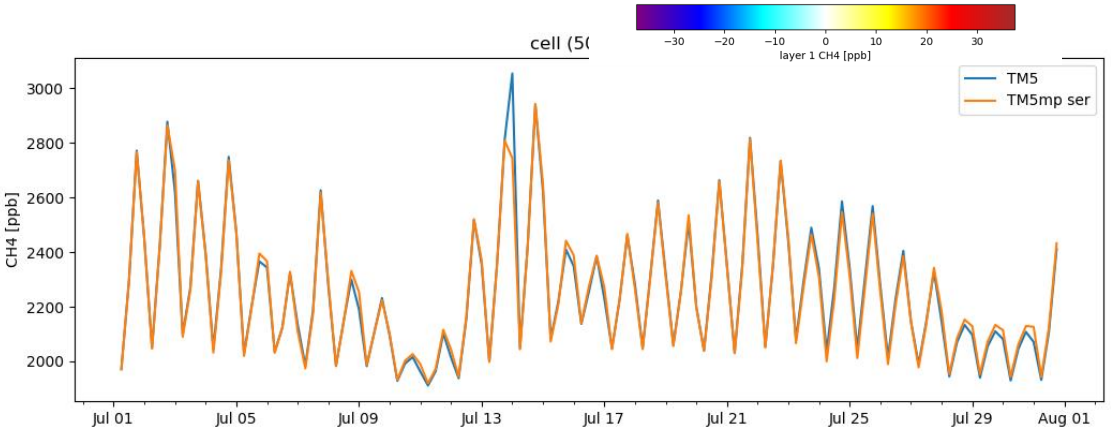

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```
[INFO    ]   f^T  dz          :      2.034137e-09
[INFO    ]   abs. diff.       :      6.216262e-22
[INFO    ]   rel. diff.       :      3.055971e-13                [OK       ]
[INFO    ]
[INFO    ] operator 0078 (0005):  2015-07-01 [02:37,03:00]  reduce
[INFO    ]
[INFO    ]   dx^T  g          :      2.034137e-09
[INFO    ]   f^T  dz          :      2.034137e-09
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[INFO    ]   rel. diff.       :      0.000000e+00                [OK       ]
[INFO    ]
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[INFO    ]
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[INFO    ]   abs. diff.       :      0.000000e+00
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[INFO    ]
[INFO    ]
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  - *full adjoint test over entire model passed*

```
[INFO    ] ---[zN]---------------------------------
[INFO    ] point(129, 1)
[INFO    ] -----------------------------------------
[INFO    ] ---[f]----------------------------------
[INFO    ] point(129, 1)
[INFO    ] -----------------------------------------
[INFO    ] ---[g]----------------------------------
[INFO    ] iniconc
[INFO    ]   iniconc.CH4(34, 90, 120)
[INFO    ] emis
[INFO    ]   CH4
[INFO    ]     emis.CH4.wetlands(1, 90, 120)
[INFO    ]     emis.CH4.rice(1, 90, 120)
[INFO    ]     emis.CH4.biomass-burning(1, 90, 120)
[INFO    ]     emis.CH4.other(1, 90, 120)
[INFO    ] -----------------------------------------
[INFO    ]
[INFO    ]   dx^T  g          :      3.999490e-05
[INFO    ]   f^T  dz          :      3.999490e-05
[INFO    ]   abs. diff.       :      2.995109e-18
[INFO    ]   rel. diff.       :      7.488726e-14                [OK      ]
[INFO    ]
[INFO    ]
[INFO    ] ** end adjoint test (model part) **
[INFO    ]
```

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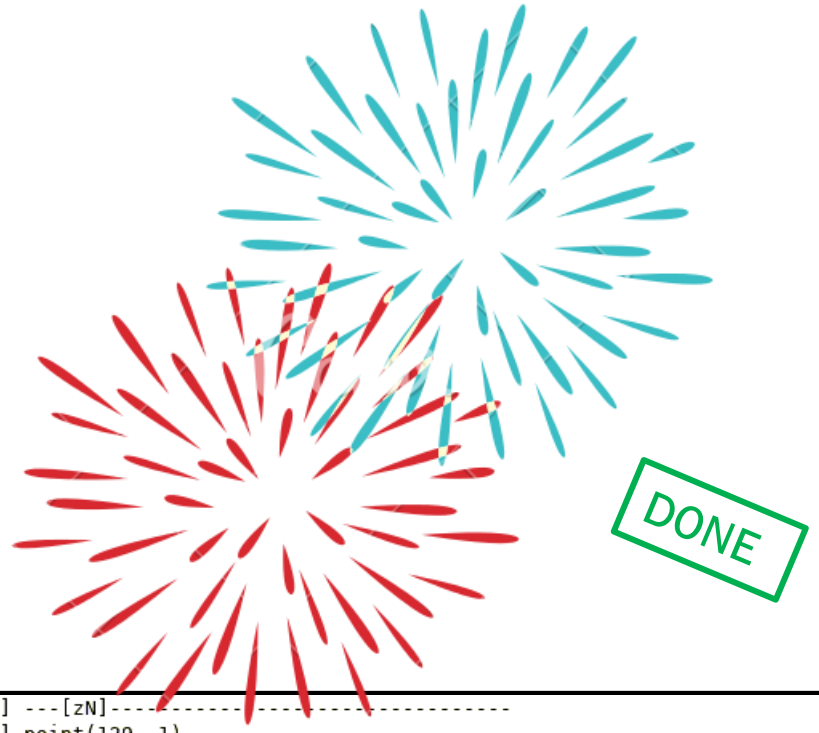


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[INFO    ]
[INFO    ]
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[INFO    ]
```
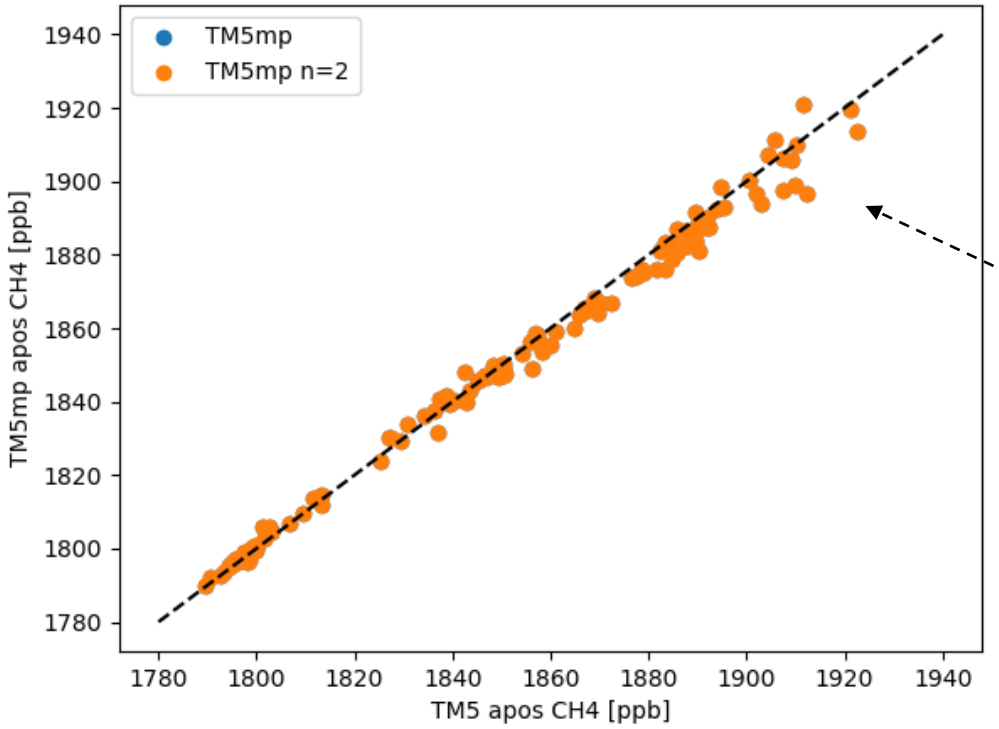

TM5-MP/4D-VAR
DEMO APPLICATION

- CH_4 inversion, 1 month, global 6°x4°, surface observations, 40 iterations

apos simulations using TM5-MP/4D-Var, serial or parallel

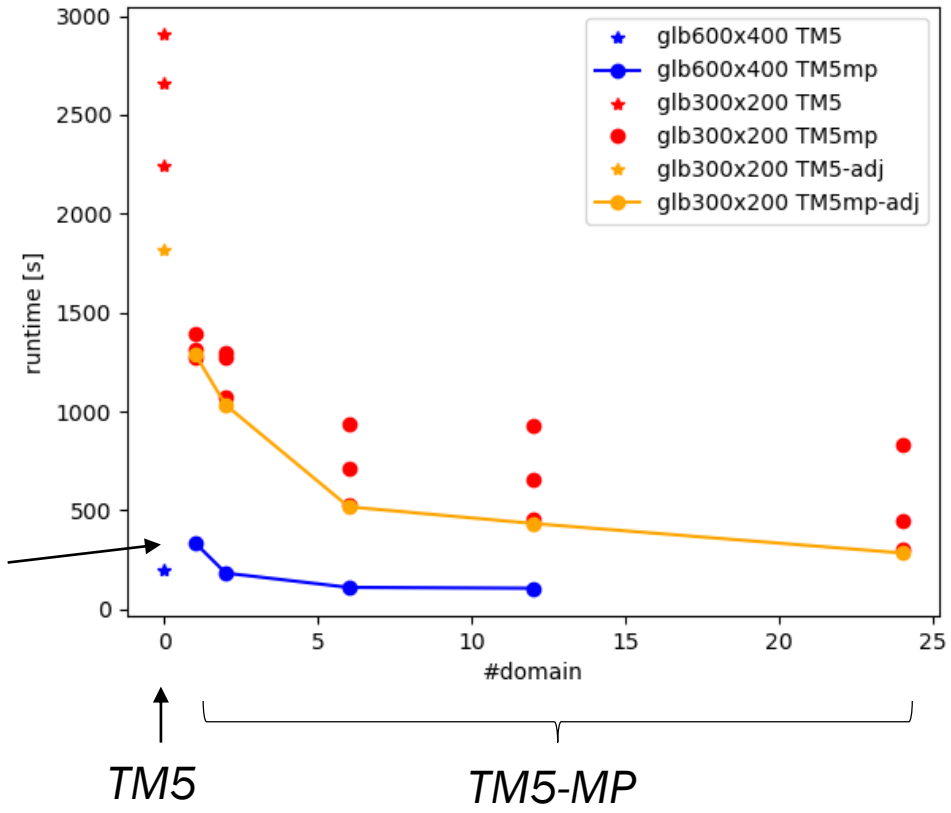


apos simulation using TM5/4D-Var

only small difference between TM5/4D-Var and TM5-MP/4D-var posterior simulations

TM5-MP/4D-VAR
RUN TIMES

- measured for 1 month CH_4 simulation
- sara/carthesius (24 cpu's per node)
- multiple runs tested
- global 6^ox4^o or 3^ox2^o

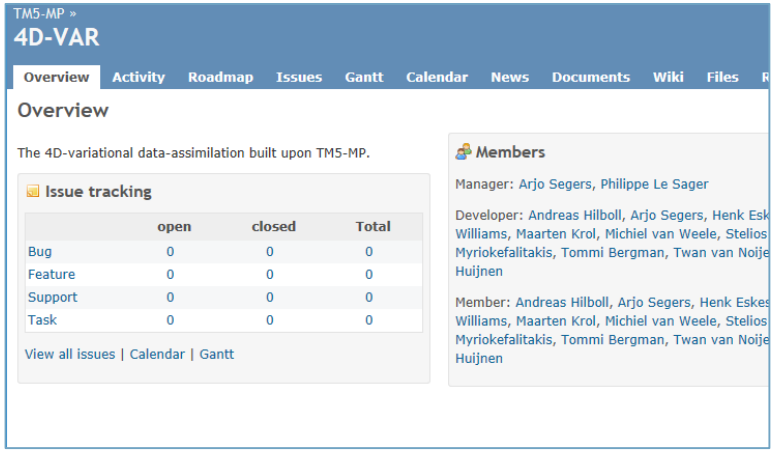


- *at 6x4, TM5-MP on 1 domain is actually slower than TM5 …*

3x2:

- TM5-MP could be 3-6 times faster than TM5
- adjoint run relative cheap (less output written?)

TM5-MP/4D-VAR
CODE AVAILABILITY



TM5-MP / 4D-VAR
dev.knmi.nl/projects/4dvar

TM5-MP adjoint code:

- main extension to standard model:
  - negative timestep allowed
  - support 4D-var files: iniconc, emissions, point observations
  - new advection routines
  - adjoint test codes
- TO BE DONE: merge into standard model?

TM5-MP/4D-var

- UTOPyA driver scripts (CAMS inversions, CH_4 demo)
- Supports TM5 and TM5-MP

Organize online coding event?
- *Introduction to TM5-MP/4D-Var*
- *Configuration on various servers*
- *Testing demo inversion*
- *…*

ATMOSPHERIC SINKS FOR CH4 INVERSION
REPLACING CLIMATOLOGIES

- Atmospheric CH_4 sinks:

where	what	now	new?
stratosphere	OH	climatology ECHAM-MESSY simulations	IFS-CB05-BASCOE simulations
	O^1D		
	Cl^-		
troposphere	OH	climatology, TM5 full chemistry scaled with methyl-chloroform (Bergamaschi 2005)	IFS-CB05-BASCOE simulations CAMS re-analysis

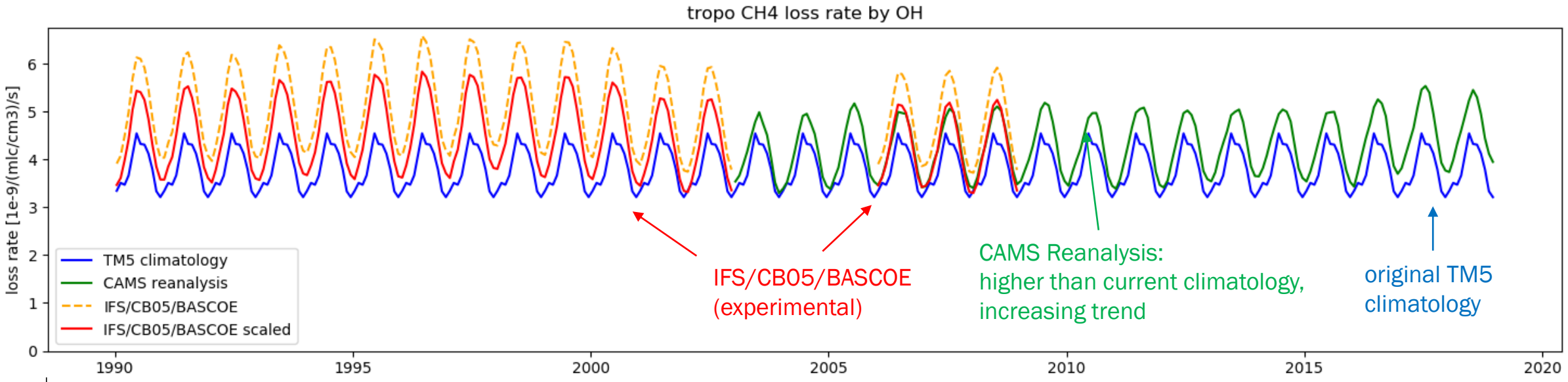
ATMOSPHERIC SINKS FOR CH4 INVERSION

REPLACING CLIMATOLOGIES

Combine/scale/extrapolate timeseries:

- troposperic OH 2003-2018 from CAMS reanalysis: IFS full chemistry, assimilated (satellite data)
- for 1990-2008: IFS/CB05/BASCOE simulations by CAMS42 team (Vincent Huijnen) provide tropospheric OH and stratospheric OH/O^1D/Cl^-
  - combination of 4 runs, some were reruns, changes NO_x emissions, …
  - should be in line with CAMS reanalysis for 2003-2008

Early example of scaling tropospheric OH:

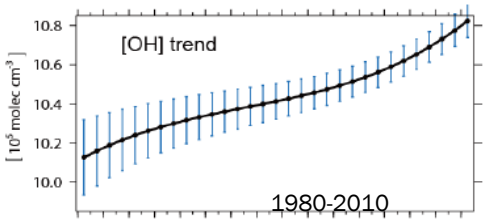


ATMOSPHERIC SINKS FOR CH4 INVERSION

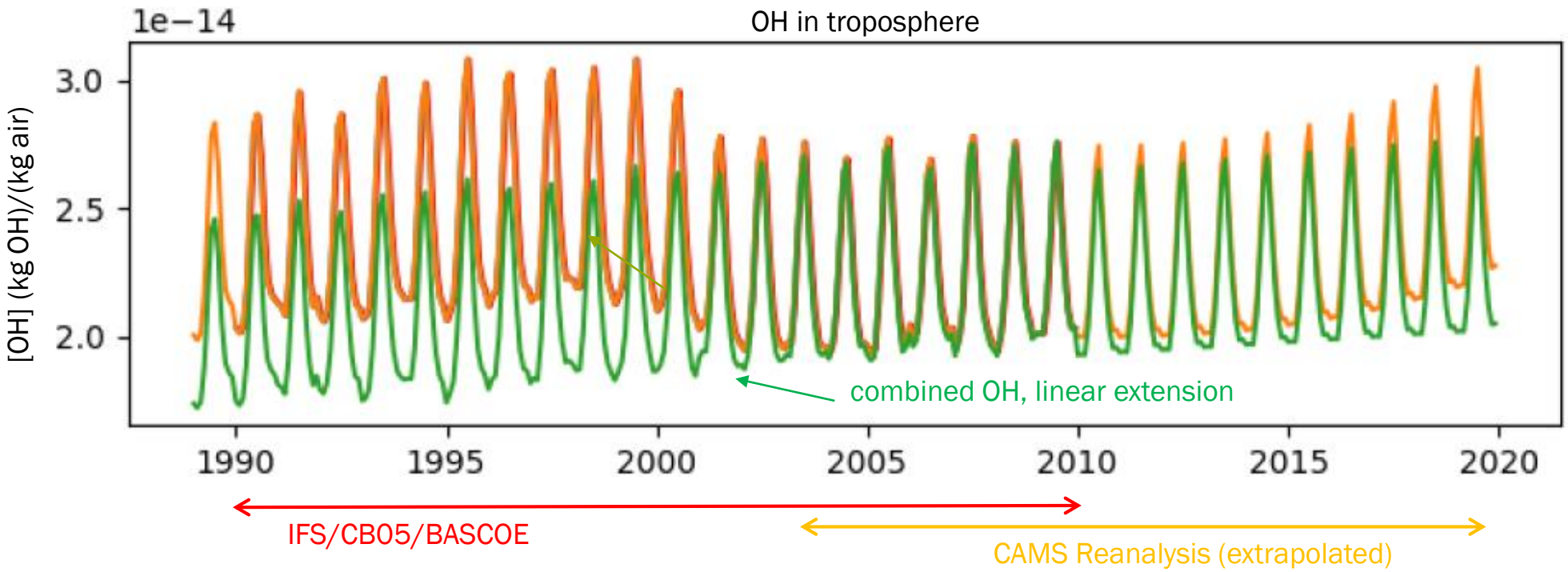
REPLACING CLIMATOLOGIES

After some trial and error …

- Calculate linear trend in tropospheric OH in CAMS reanalysis
- Extrapolate trend to 1990's, scale OH from IFS/CB05/BASCOE to same yearly average



New trend in OH comparable to *Zhao et al, 2020, ACP*

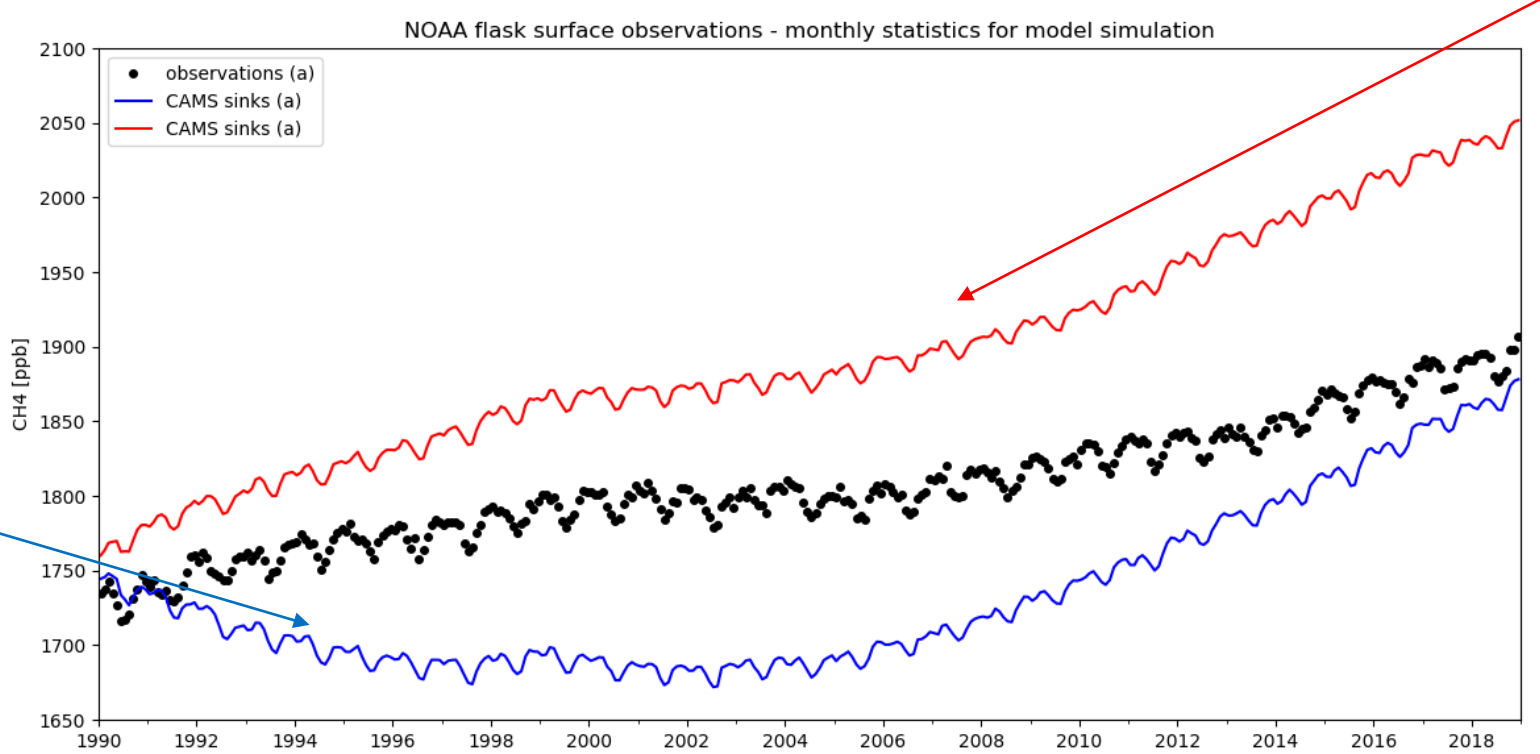


ATMOSPHERIC SINKS FOR CH4 INVERSION

REPLACING CLIMATOLOGIES

CH4 simulations with free running model
(monthly averages over NOAA surface observations)

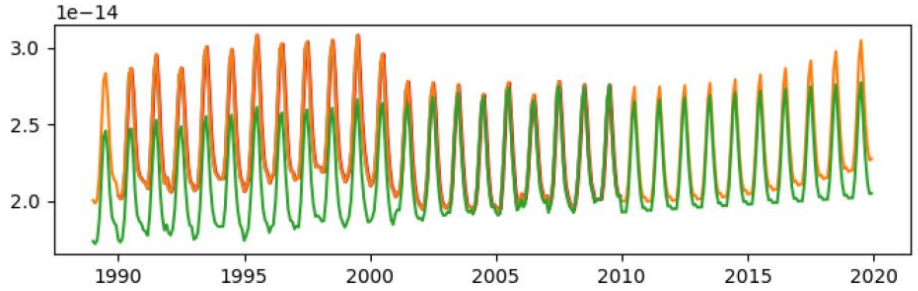
Using new sinks: simulations too high, but follow the observed trends



Using original sinks: simulations decrease in 1990's, strong increase after 2005

ATMOSPHERIC SINKS FOR CH4 INVERSION
OUTLOOK

- Currently running using new sinks:
  - CAMS CH4 inversion "v19r1" (1990-2019)



- Next year?
  - Full timeseries of IFS/CB05/BASCOE for 1990-2020 ?
  - TM5-MP/4D-Var
  - SCIT (Sudhanshu's Cool Inversion Trick)

(where shall we waste that time on?)