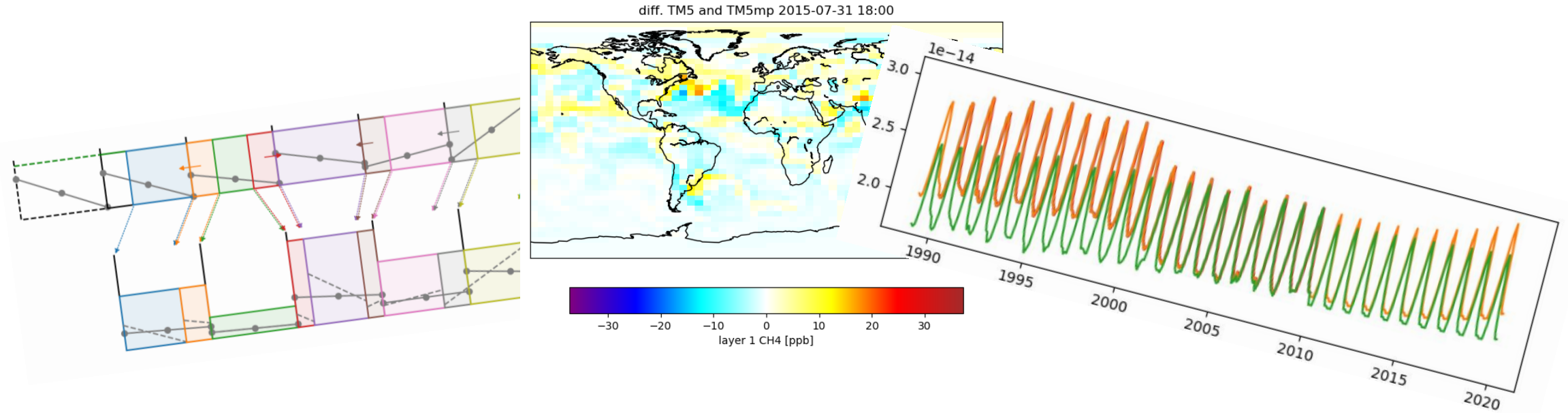


TM5-MP-4DVAR, AND SOMETHING ON CH4 SINKS

Arjo Segers, Janot Tokaya (TNO)

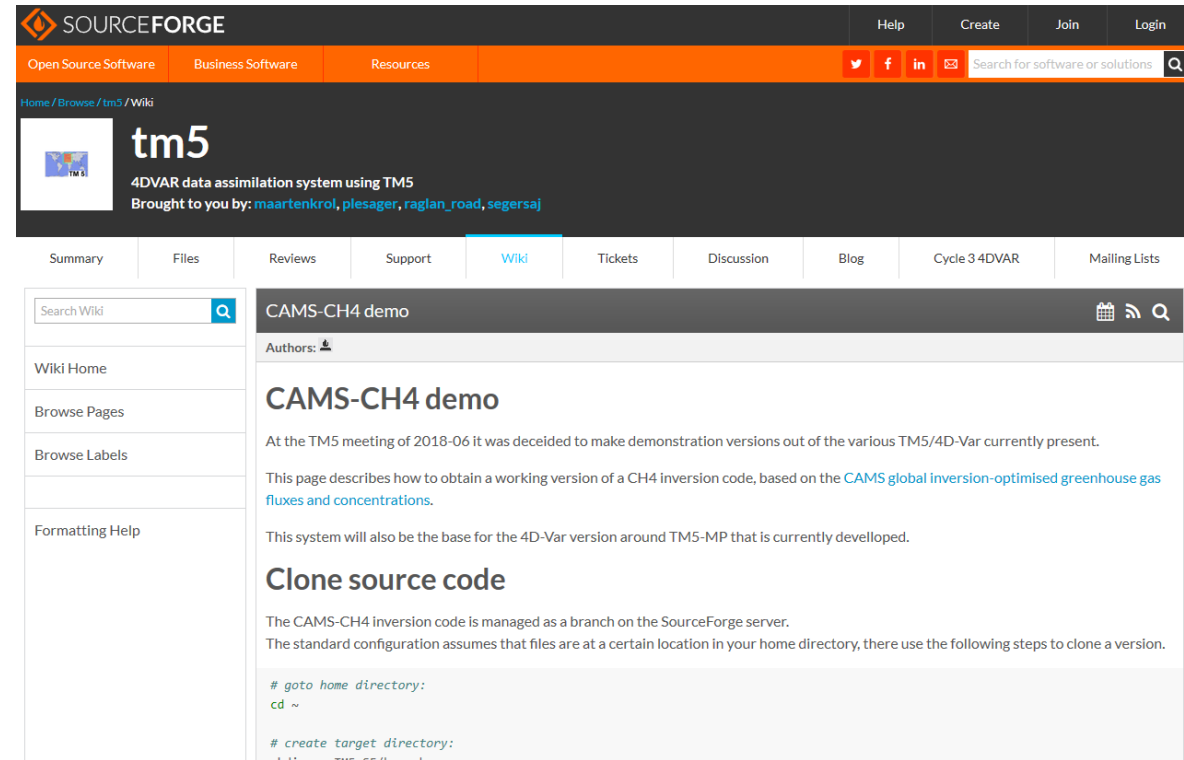
Sander Houweling, Jacob van Peet (VU)

Vincent Huijnen (KNMI)



TM5-MP/4D-VAR DEVELOPMENT STATUS

› CH₄ inversion, global 6°x4°, surface observations



The screenshot shows the SourceForge project page for 'tm5'. The page title is 'tm5' and the subtitle is '4DVAR data assimilation system using TM5'. The page is categorized under 'Open Source Software'. The main content area is titled 'CAMS-CH4 demo' and contains the following text:

At the TM5 meeting of 2018-06 it was decided to make demonstration versions out of the various TM5/4D-Var currently present. This page describes how to obtain a working version of a CH4 inversion code, based on the [CAMS global inversion-optimised greenhouse gas fluxes and concentrations](#). This system will also be the base for the 4D-Var version around TM5-MP that is currently developed.

Clone source code

The CAMS-CH4 inversion code is managed as a branch on the SourceForge server. The standard configuration assumes that files are at a certain location in your home directory, there use the following steps to clone a version.

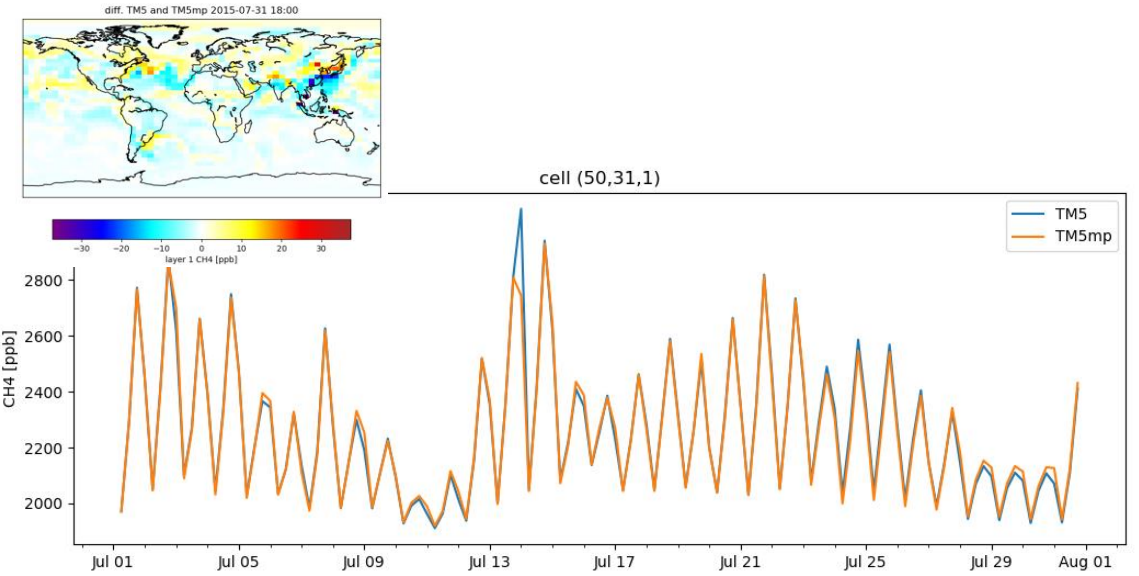
```
# goto home directory:
cd ~

# create target directory:
mkdir -p TM5/branches
```

sourceforge.net/projects/tm5

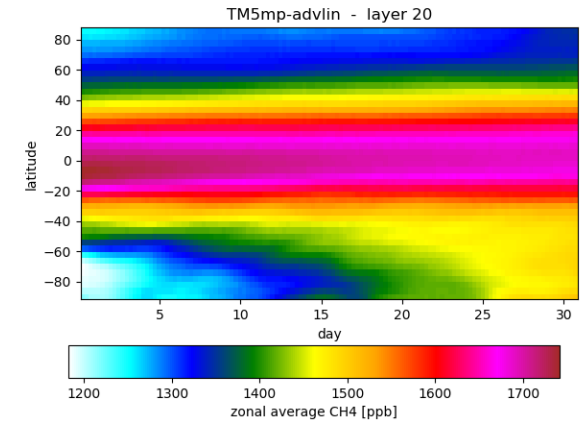
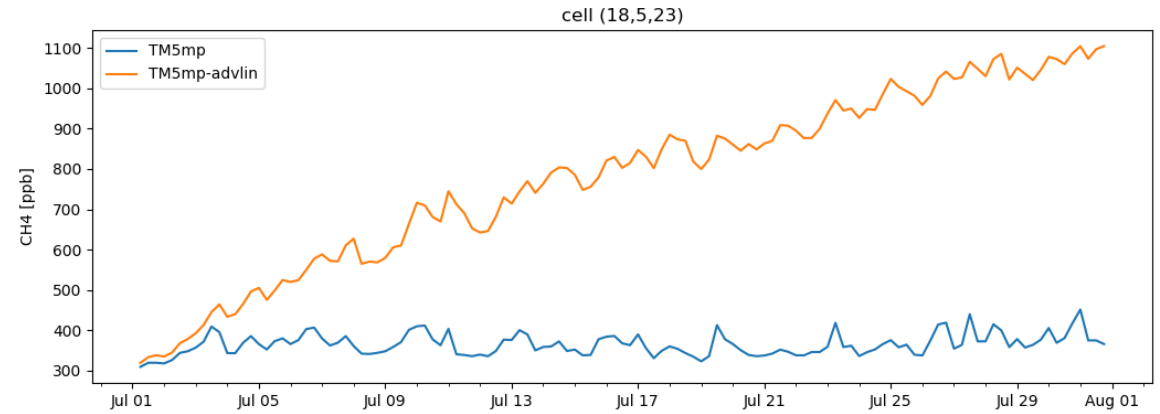
TM5-MP/4D-VAR DEVELOPMENT STATUS

- › CH₄ inversion, global 6°x4°, surface observations
- › TM5-MP forward model with same configuration [ok]
 - › *small differences due to diverted models*



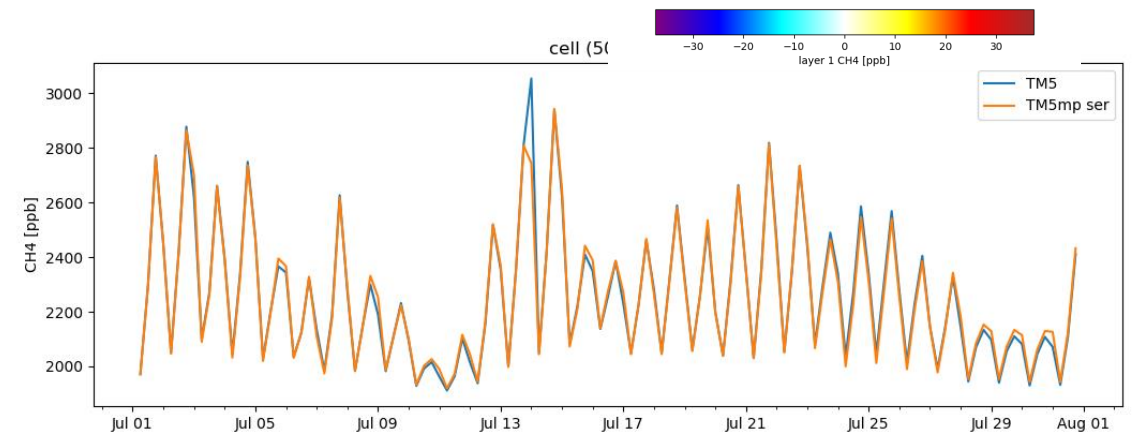
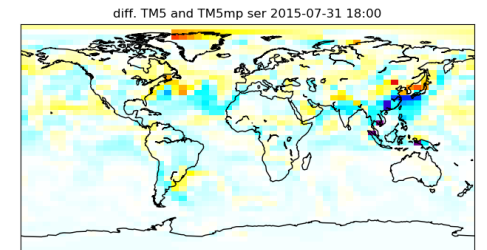
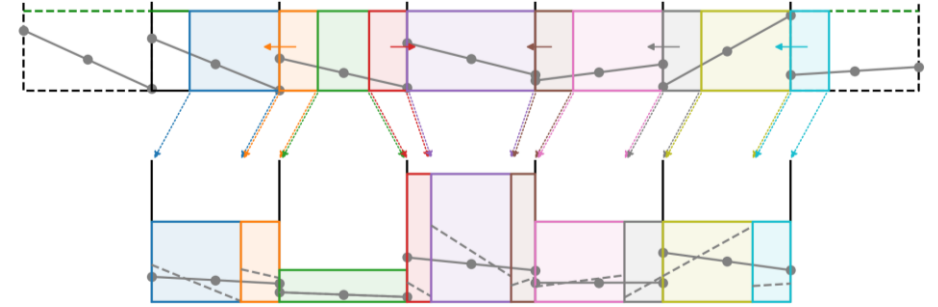
TM5-MP/4D-VAR DEVELOPMENT STATUS

- › CH₄ inversion, global 6°x4°, surface observations
- › TM5-MP forward model with same configuration [ok]
 - › *small differences due to diverted models*
- › New 3D advection code for TM5-MP: linear, sparse matrix operator [failed]
 - › *divergence of CH4 near south pole, operator too slow, difficult code, ...*



TM5-MP/4D-VAR DEVELOPMENT STATUS

- › CH₄ inversion, global 6°x4°, surface observations
- › TM5-MP forward model with same configuration [ok]
 - › *small differences due to diverted models*
- › New 3D advection code for TM5-MP: linear, sparse matrix operator [failed]
 - › *divergence of CH4 near south pole, operator too slow, difficult code, ...*
- › New 1D advection code: linear, easier code, closer to original TM5-MP [ok]
 - › *forward simulation very close to original*
 - › *same results between serial and domain decomposed*



TM5-MP/4D-VAR DEVELOPMENT STATUS

- › CH₄ inversion, global 6°x4°, surface observations
- › TM5-MP forward model with same configuration [ok]
 - › *small differences due to diverted models*
- › New 3D advection code for TM5-MP: linear, sparse matrix operator [failed]
 - › *divergence of CH4 near south pole, operator too slow, difficult code, ...*
- › New 1D advection code: linear, easier code, closer to original TM5-MP [ok]
 - › *forward simulation very close to original*
 - › *same results between serial and domain decomposed*
- › Adjoint advection [ok]
 - › *same results serial/parallel*
 - › *passed adjoint check*

```
[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
[INFO ] abs. diff.   : 0.000000e+00
[INFO ] rel. diff.   : 0.000000e+00          [OK   ]
[INFO ]
[INFO ] operator 0079 (0004): 2015-07-01 [02:37,03:00] dynamu
[INFO ]
[INFO ] dx^T g      : 2.034137e-09
[INFO ] f^T dz      : 2.034137e-09
[INFO ] abs. diff.   : 6.216262e-22
[INFO ] rel. diff.   : 3.055971e-13          [OK   ]
[INFO ]
[INFO ] operator 0080 (0003): 2015-07-01 [02:37,03:00] expand
[INFO ]
[INFO ] dx^T g      : 2.034137e-09
[INFO ] f^T dz      : 2.034137e-09
[INFO ] abs. diff.   : 0.000000e+00
[INFO ] rel. diff.   : 0.000000e+00          [OK   ]
[INFO ]
```

TM5-MP/4D-VAR DEVELOPMENT STATUS

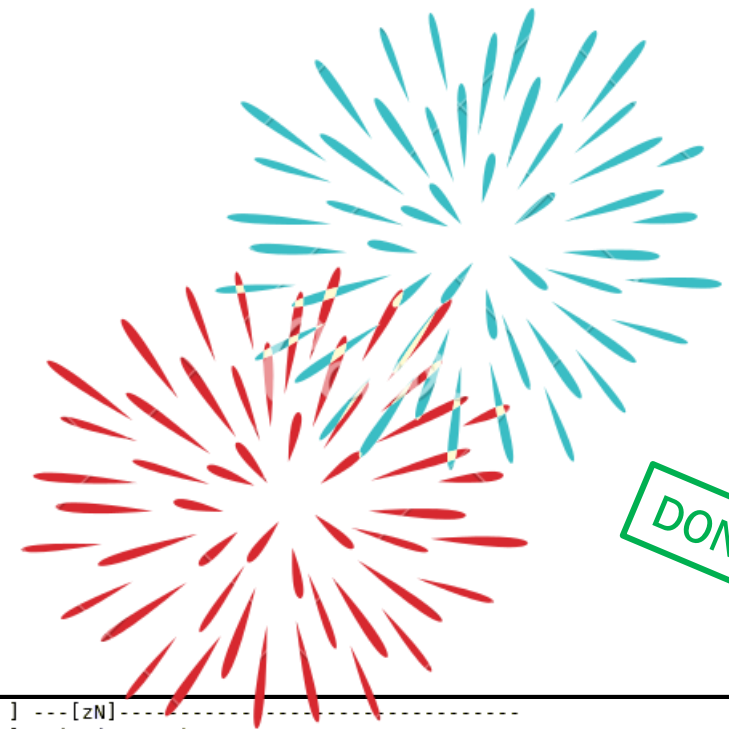
- › CH₄ inversion, global 6°x4°, surface observations
- › TM5-MP forward model with same configuration [ok]
 - › *small differences due to diverted models*
- › New 3D advection code for TM5-MP: linear, sparse matrix operator [failed]
 - › *divergence of CH4 near south pole, operator too slow, difficult code, ...*
- › New 1D advection code: linear, easier code, closer to original TM5-MP [ok]
 - › *forward simulation very close to original*
 - › *same results between serial and domain decomposed*
- › Adjoint advection [ok]
 - › *same results serial/parallel*
 - › *passed adjoint check*
- › Full adjoint version, incl. output/forcing [ok]
 - › *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  
[INFO ]  
[INFO ]  
[INFO ] ** end adjoint test (model part) **  
[INFO ]
```

[OK]

TM5-MP/4D-VAR DEVELOPMENT STATUS

- › CH₄ inversion, global 6°x4°, surface observations
- › TM5-MP forward model with same configuration [ok]
 - › *small differences due to diverted models*
- › New 3D advection code for TM5-MP: linear, sparse matrix operator [failed]
 - › *divergence of CH₄ near south pole, operator too slow, difficult code, ...*
- › New 1D advection code: linear, easier code, closer to original TM5-MP [ok]
 - › *forward simulation very close to original*
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 - › *same results serial/parallel*
 - › *passed adjoint check*
- › Full adjoint version, incl. output/forcing [ok]
 - › *full adjoint test over entire model passed*



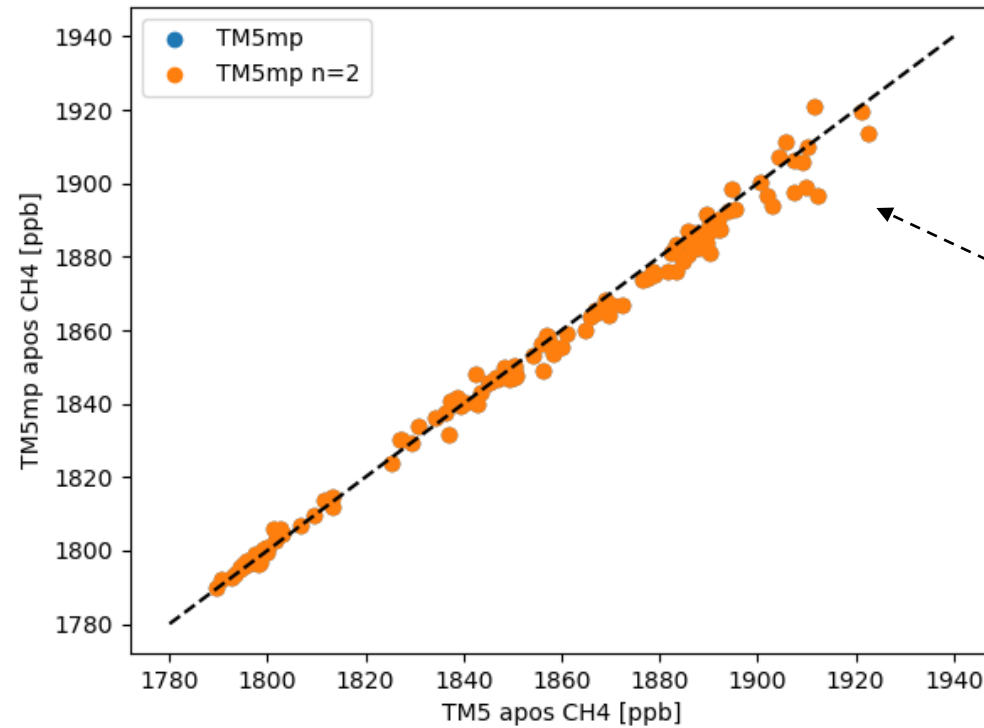
```
[INFO ] ---[zn]-----  
[INFO ] point(129, 1)  
[INFO ] -----  
[INFO ] ---[f]-----  
[INFO ] point(129, 1)  
[INFO ] -----  
[INFO ] ---[g]-----  
[INFO ] iniconc  
[INFO ]   iniconc.CH4(34, 90, 120)  
[INFO ] emis  
[INFO ]   CH4  
[INFO ]     emis.CH4.wetlands(1, 90, 120)  
[INFO ]     emis.CH4.rice(1, 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  
[INFO ]  
[INFO ]  
[INFO ] ** end adjoint test (model part) **  
[INFO ]
```

[OK]

TM5-MP/4D-VAR DEMO APPLICATION

› CH₄ inversion, 1 month, global 6°x4°, surface observations, 40 iterations

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

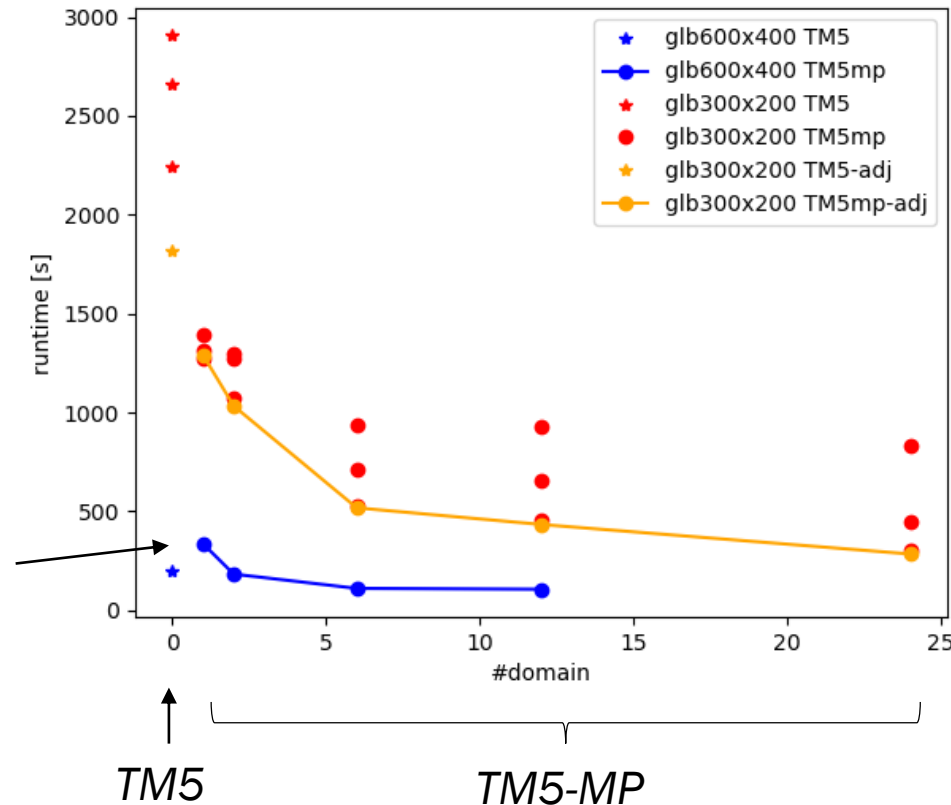


*only small difference
between TM5/4D-Var and
TM5-MP/4D-var posterior
simulations*

apos simulation using TM5/4D-Var

TM5-MP/4D-VAR RUN TIMES

- › measured for 1 month CH₄ simulation
- › sara/carthesius (24 cpu's per node)
- › multiple runs tested
- › global 6°x4° or 3°x2°



- 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 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 (CAM5 inversions, CH₄ demo)
- › Supports TM5 and TM5-MP

TM5-MP / 4D-VAR

Overview

The 4D-variational data-assimilation built upon TM5-MP.

	open	closed	Total
Bug	0	0	0
Feature	0	0	0
Support	0	0	0
Task	0	0	0

View all issues | Calendar | Gantt

Members

Manager: Arjo Segers, Philippe Le Sager

Developer: Andreas Hilboll, Arjo Segers, Henk Esk Williams, Maarten Krol, Michiel van Weele, Stelios Myriokefalitakis, Tommi Bergman, Twan van Noije Huijnen

Member: Andreas Hilboll, Arjo Segers, Henk Esk Williams, Maarten Krol, Michiel van Weele, Stelios Myriokefalitakis, Tommi Bergman, Twan van Noije Huijnen

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

- 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 CH₄ sinks:

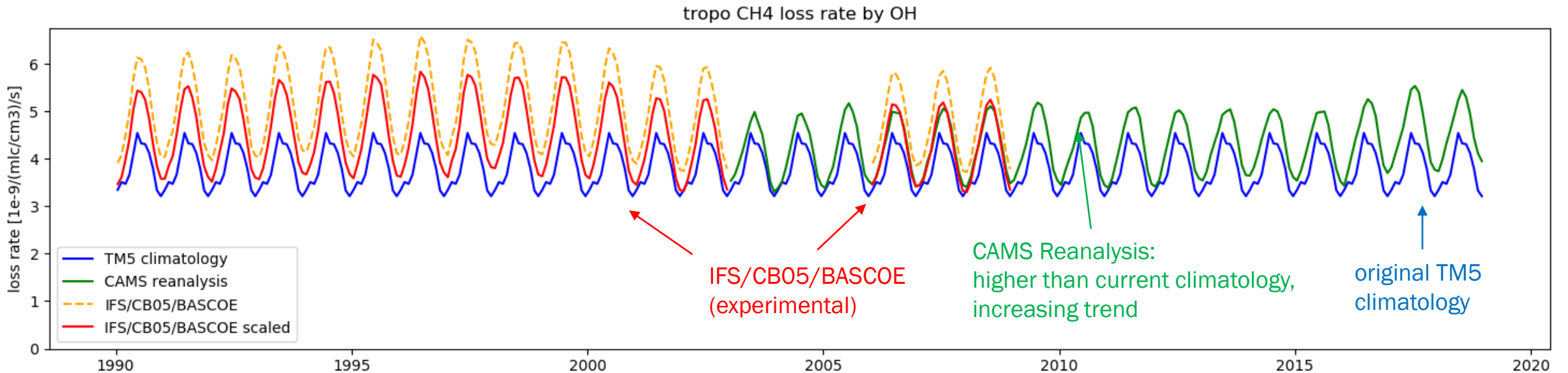
where	what	now	new?
stratosphere	OH	climatology	IFS-CB05-BASCOE simulations
	O ¹ D	ECHAM-MESSY	
	Cl ⁻	simulations	
troposphere	OH	climatology, TM5 full chemistry scaled with methyl-chloroform (Bergamaschi 2005)	IFS-CB05-BASCOE simulations CAMS re-analysis

› ATMOSPHERIC SINKS FOR CH₄ INVERSION REPLACING CLIMATOLOGIES

Combine/scale/extrapolate timeseries:

- › tropospheric 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/O¹D/Cl
 - › combination of 4 runs, some were reruns, changes NO_x emissions, ...
 - › should be in line with CAMS reanalysis for 2003-2008

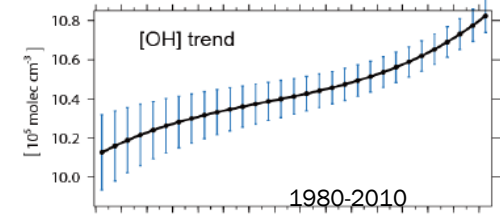
Early example of scaling tropospheric OH:



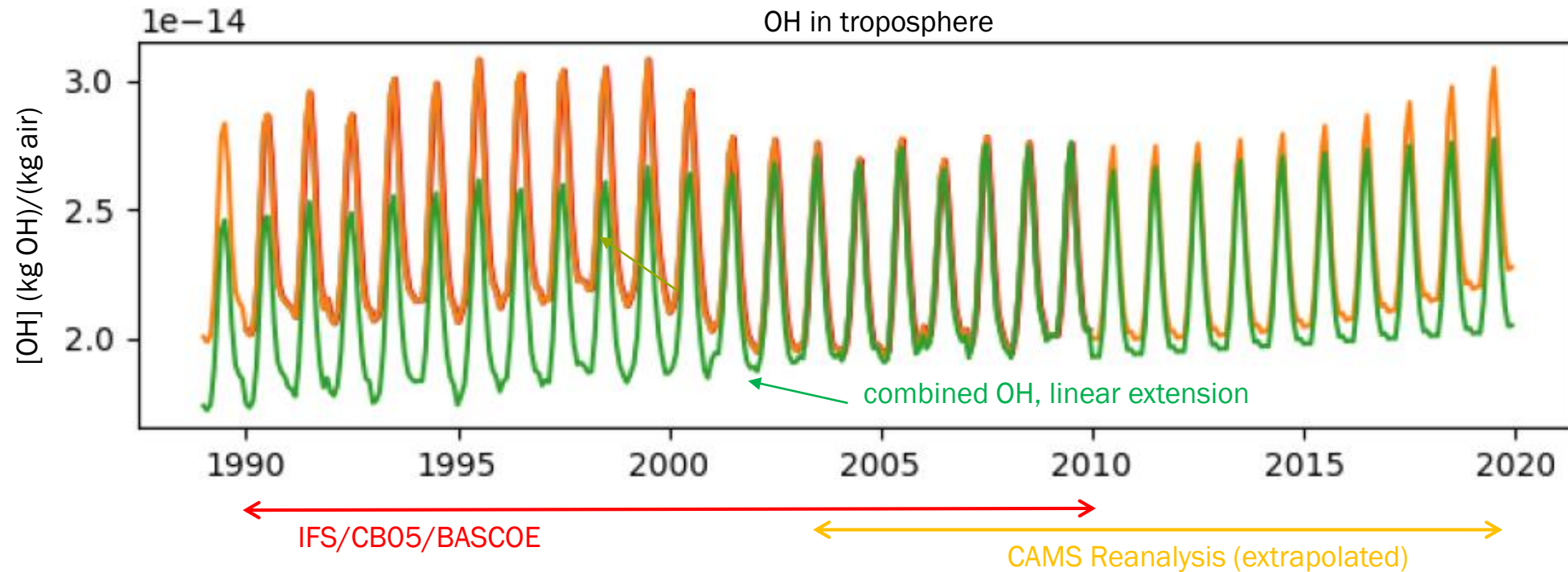
ATMOSPHERIC SINKS FOR CH₄ INVERSION REPLACING CLIMATOLOGIES

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

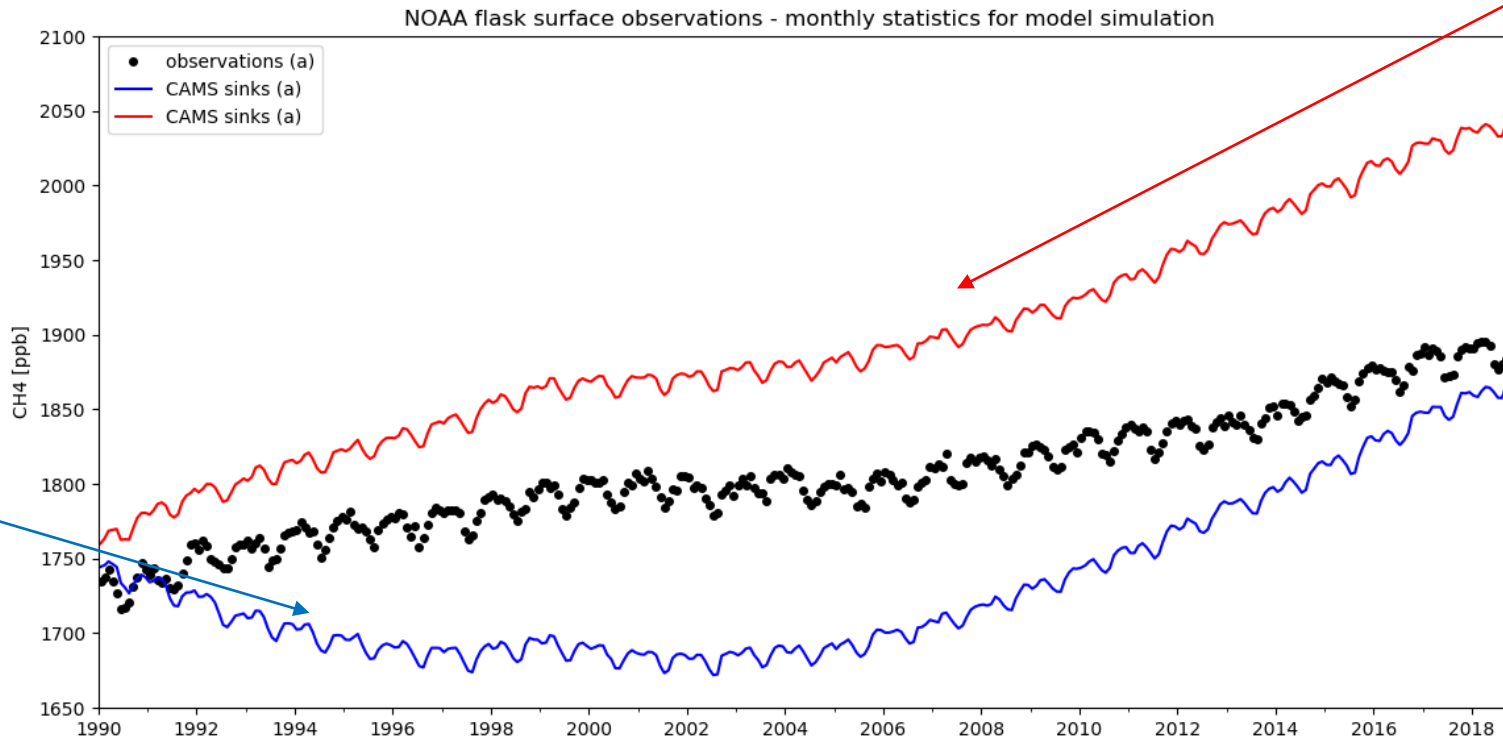


New trend in OH comparable to Zhao et al, 2020, ACP



› 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:

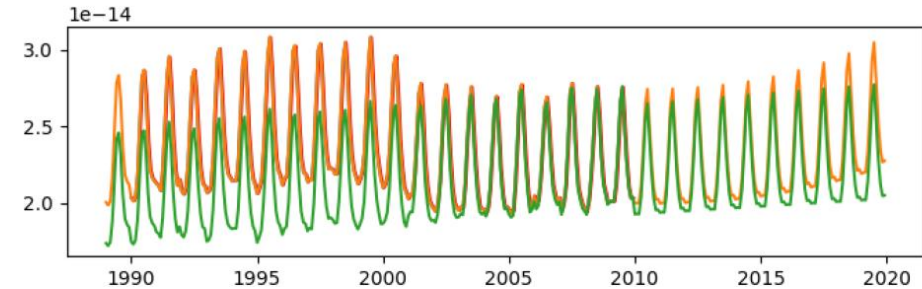
› CAMS CH₄ inversion "v19r1" (1990-2019)

› 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?)

