~~TM5-4DVAR DEVELOPMENTS~~

EVERYTHING YOU (N)EVER WANTED TO KNOW ABOUT 4DVAR

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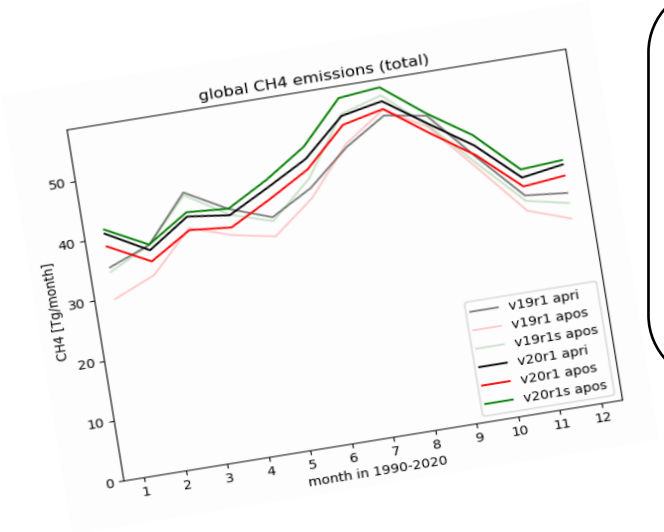
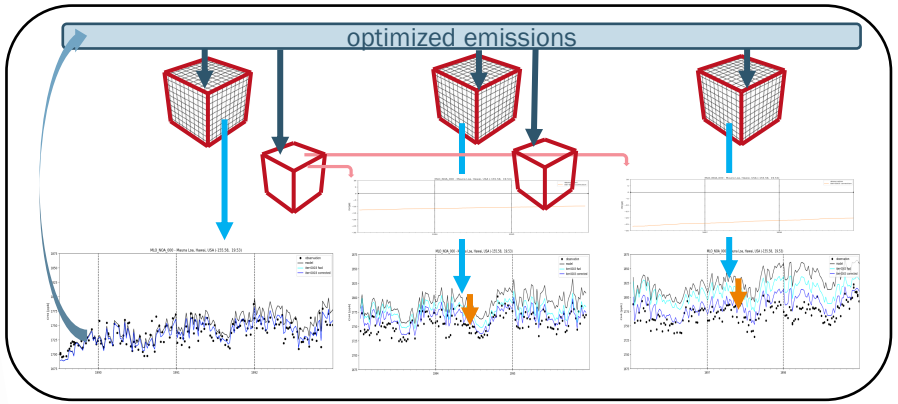
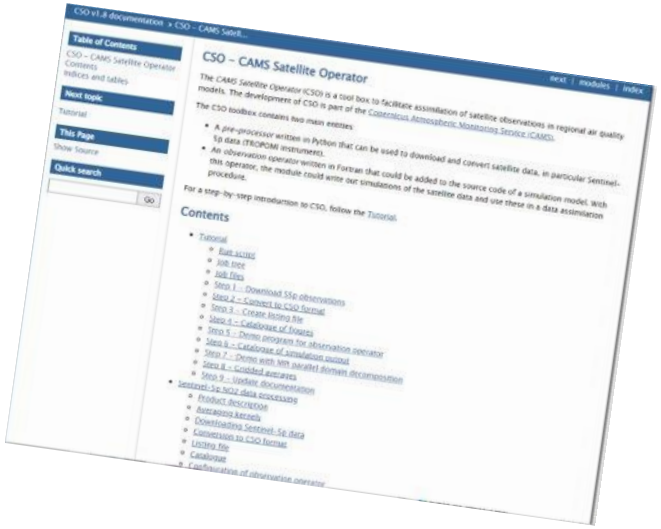
Sander Houweling (VU), Sudhanshu Pandey (NASA)



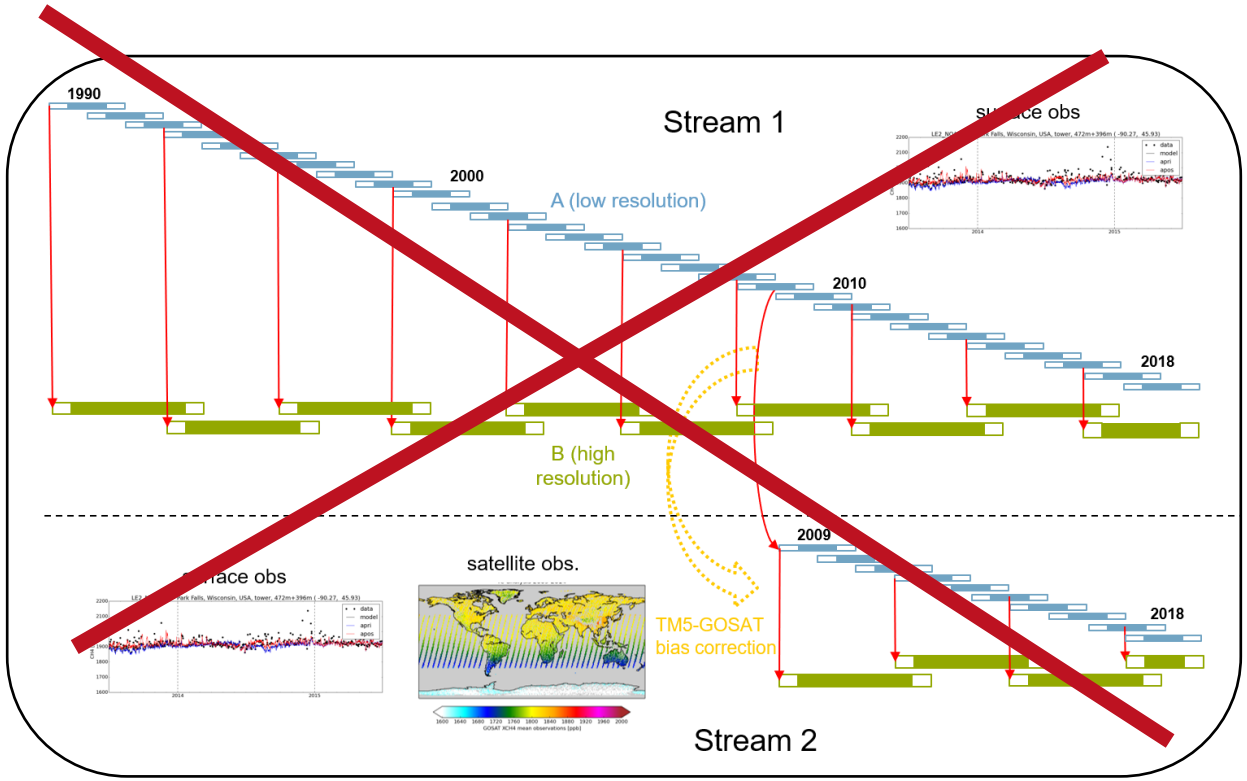




4DVAR "PP" - PHYSICAL PARALLELIZATION

CAMS multi-decadal CH_4 inversions:

- Old: combination of serial inversions on coarse resolution and serial inversions on high resolution

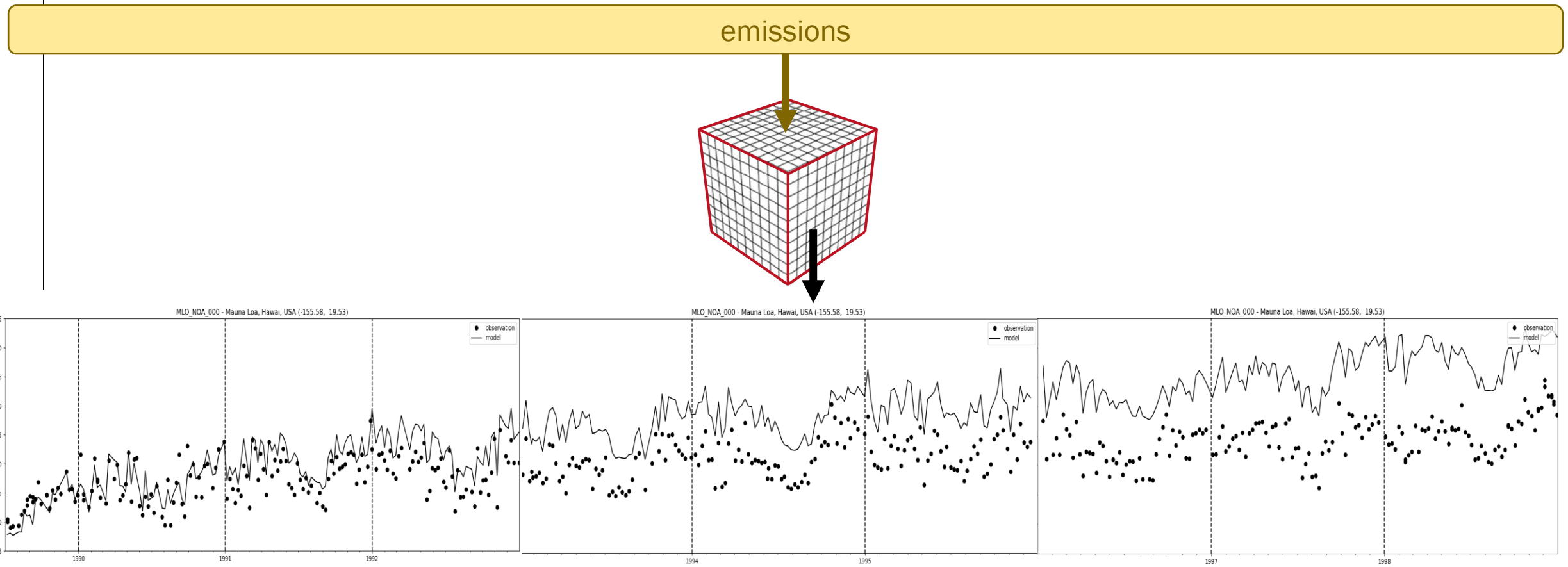


- New: Physical Parallelization scheme following Pandey et al (2022), GMD (accepted for publication)

doi:10.5194/gmd-2021-339

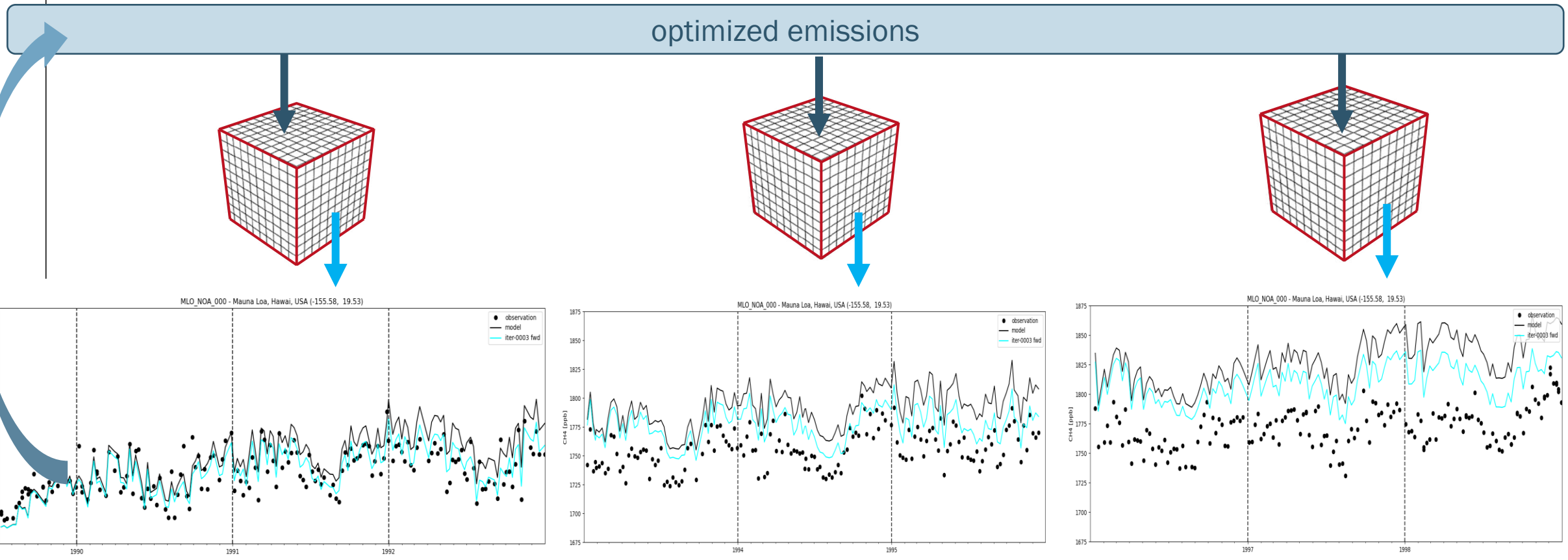
4DVAR "PP" - PHYSICAL PARALLELIZATION

- Goal: single inversion over entire period
- Iteration simulations take too long …



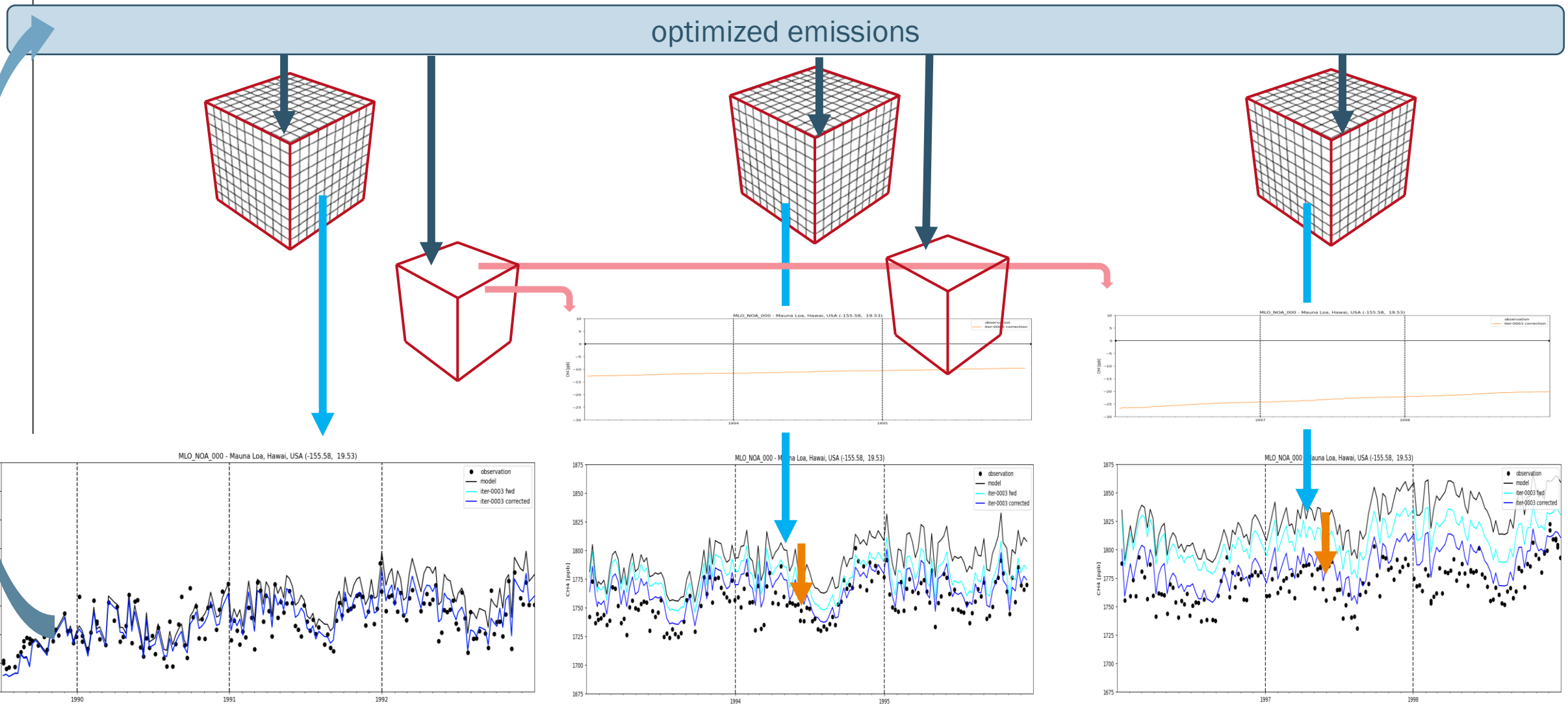
4DVAR "PP" - PHYSICAL PARALLELIZATION

- PP: split model simulation period in blocks, run blocks in parallel
- initial concentrations not optimized but taken from *a priori* model simulation
- how to take emission changes in previous blocks into account?



4DVAR "PP" - PHYSICAL PARALLELIZATION

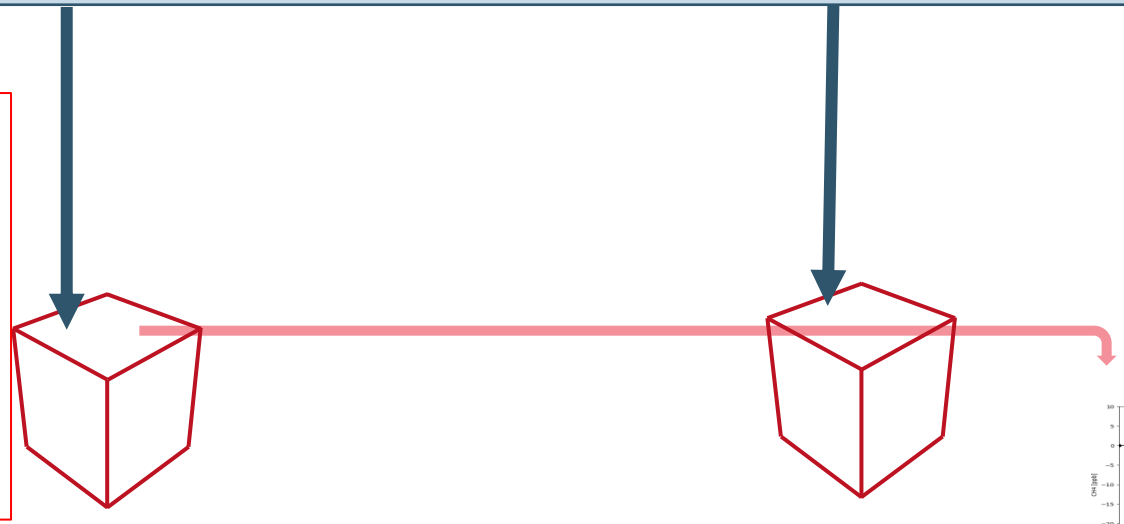
- simulated observations = TM5 simulation in block + box model correction for previous emission changes



4DVAR "PP" - PHYSICAL PARALLELIZATION

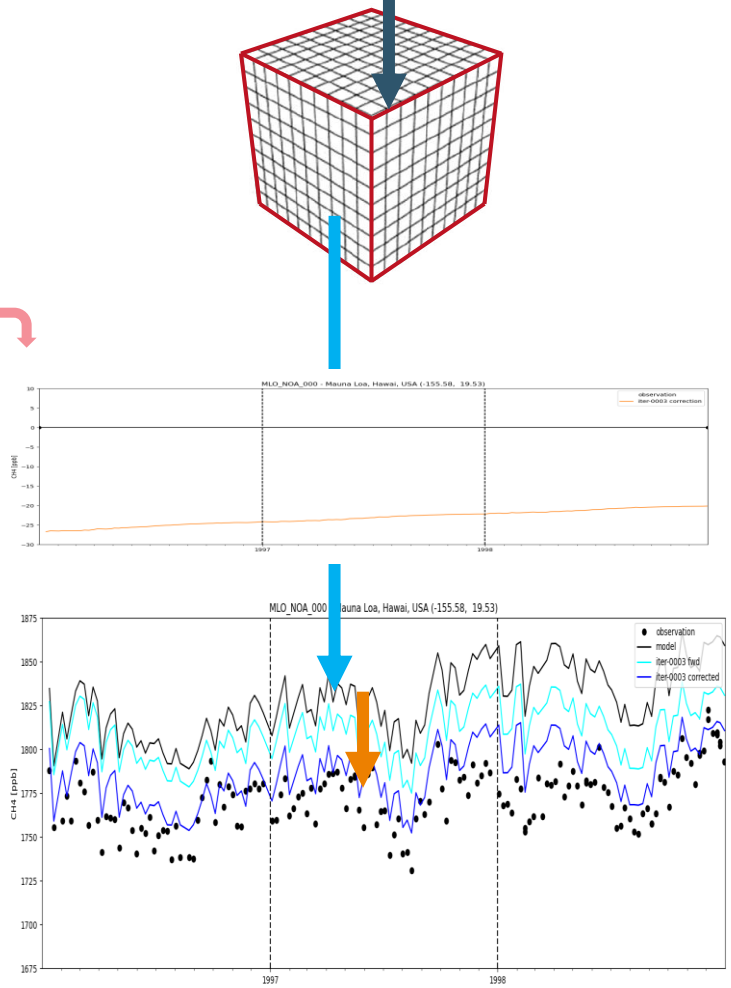
- Box model for impact of previous emission changes

optimized emissions



Box model:

- global concentration change due to emission change
- under impact of global averaged sink from sensitivity runs



Sensitivity runs per block:

- *initial concentrations of 1 ppb*
- *no emisisons*
- *3D sinks*
- *simulate observations*

"Evolution of 1 ppb iniconc under impact of sinks"

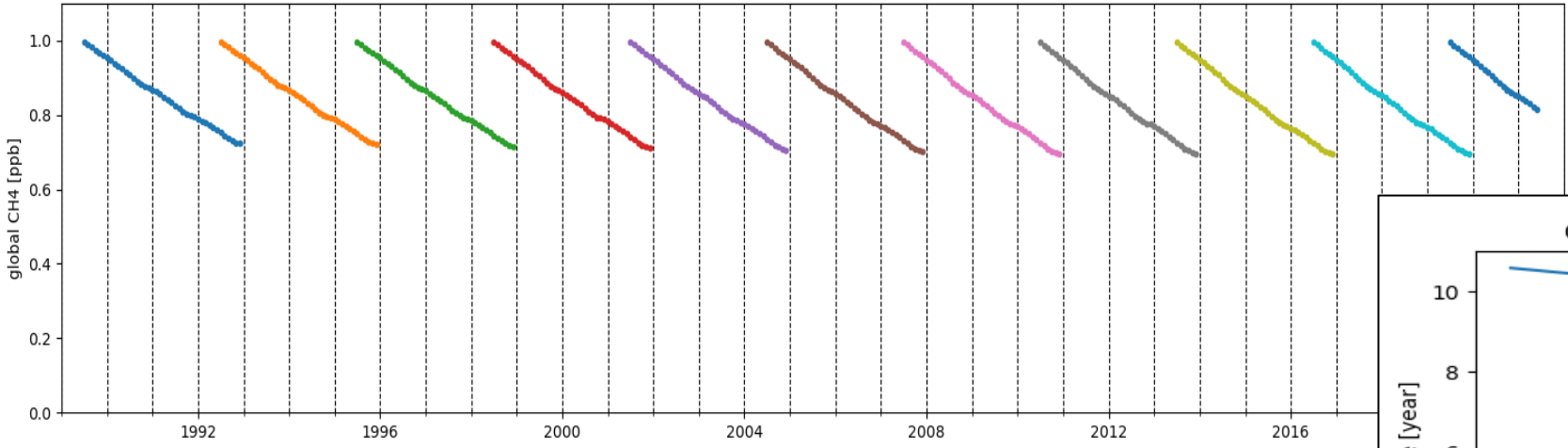
4DVAR "PP" - PHYSICAL PARALLELIZATION

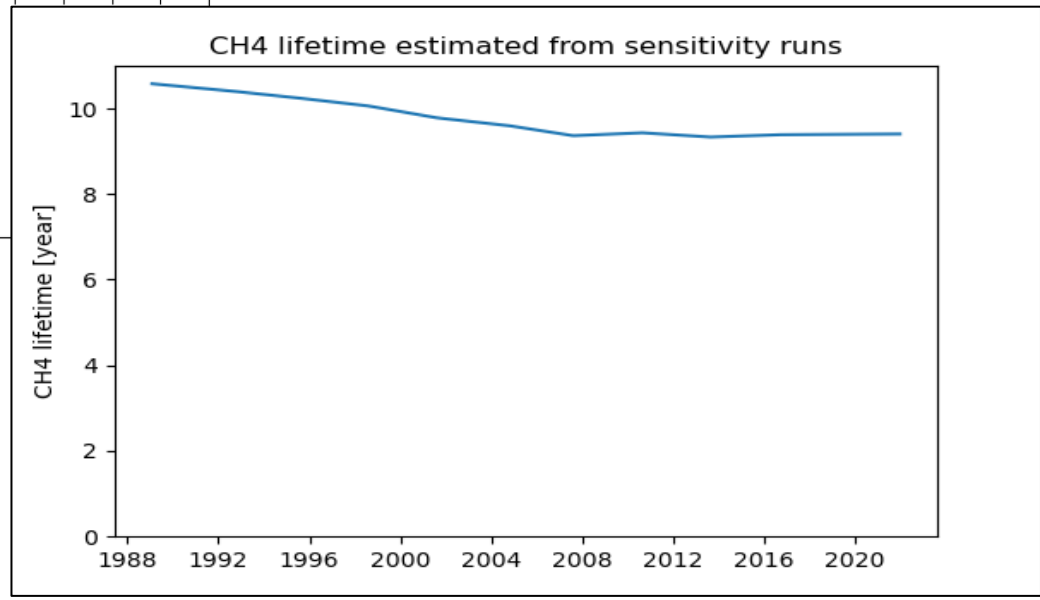
- Global CH_4 concentration change in 3-year blocks using CAMS sinks:

Sensitivity runs per block:

- *initial concentrations of 1 ppb*
- *no emisisons*
- *3D sinks*
- *simulate observations*

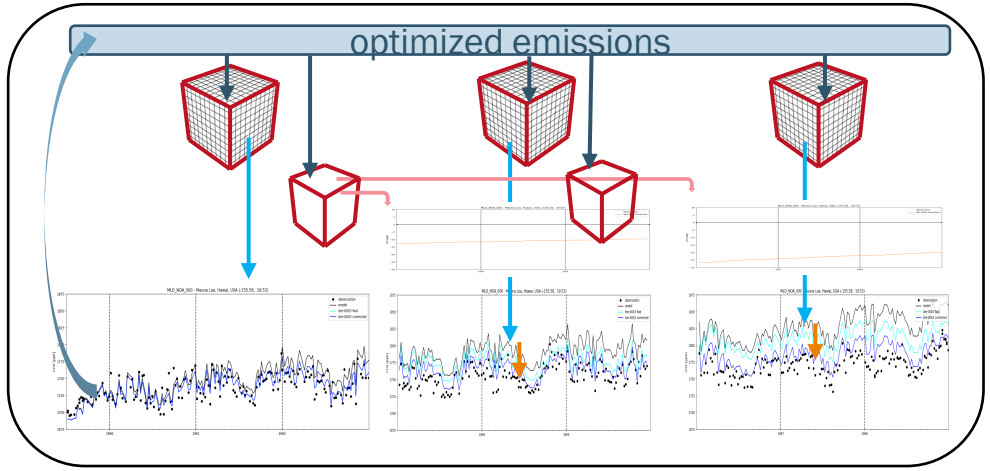
"Evolution of 1 ppb iniconc under impact of sinks"

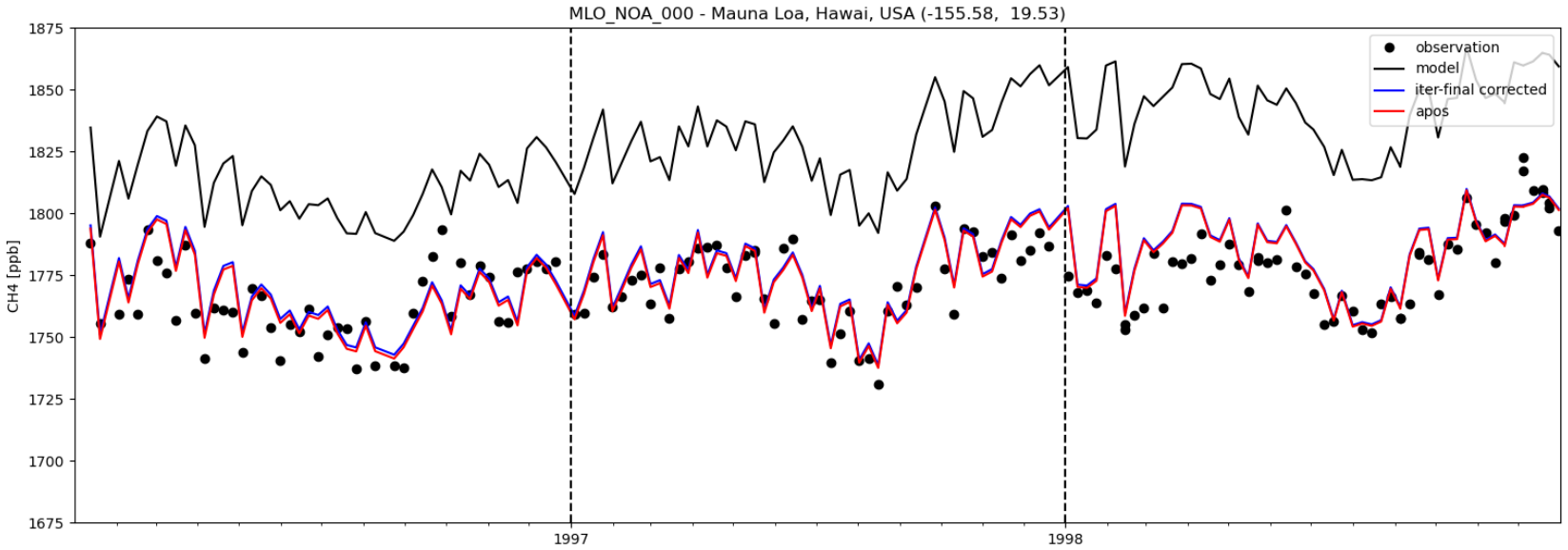




4DVAR "PP" - PHYSICAL PARALLELIZATION

- Implemented for latest CAMS inversions:
  - TM5-4DVAR changes: gather output from blocks, apply corrections
  - Minor changes in TM5-MP for sensitivity runs (zero emissions …)
- Simpler configuration than original coarse/high.resolution mixture
- Total run time comparable to inversion over single block
  (if on your computer all blocks take the same amount of time …)





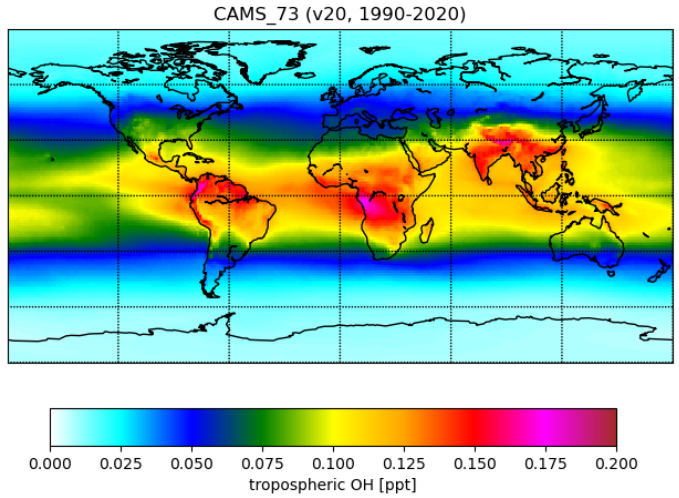
Only tiny differences between final iteration and serial posterior run

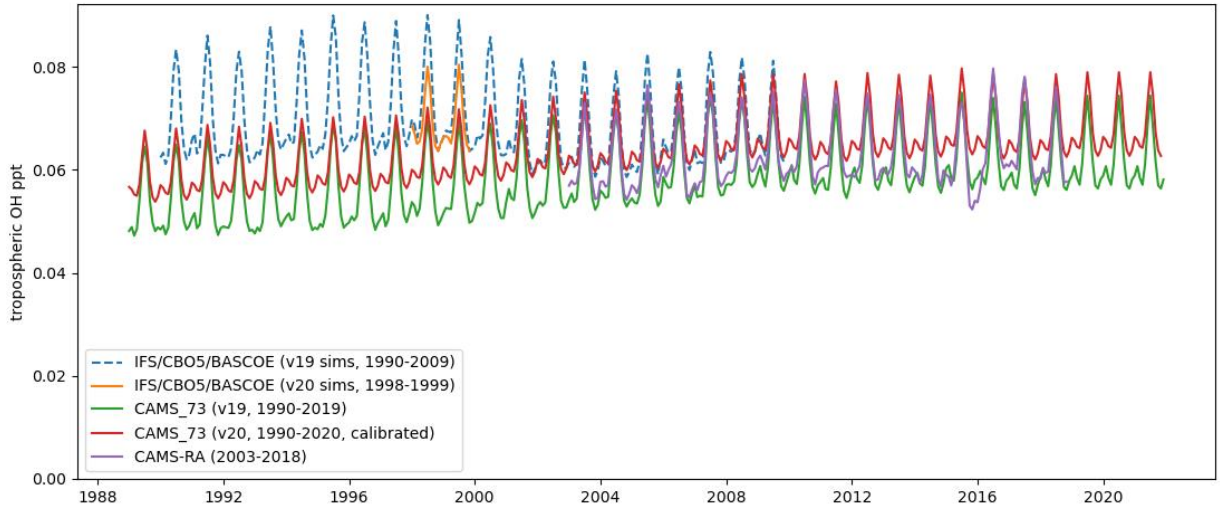
CAMS INVERSIONS

V20R1(S) INVERSIONS

Global CH_4 emission inversions, 3x2 deg.

- v20r1: 1990-2020, NOAA surface observations only
  v20r1s: 2009-2020, also using GOSAT XCH_4 observations (bias corrected)
- Production chain:
  - TM5-MP
  - "Physical Parallelization" scheme
- Input updates:
  - EDGAR v6.0 emissions, incl monthly profiles
  - sinks based on CAMS global IFS-TM5-BASCOE simulations for 1998-1999, scaling/extrapolations, and MCF calibration ;
    no up-to-date fields for 2020 "pandemic" impact



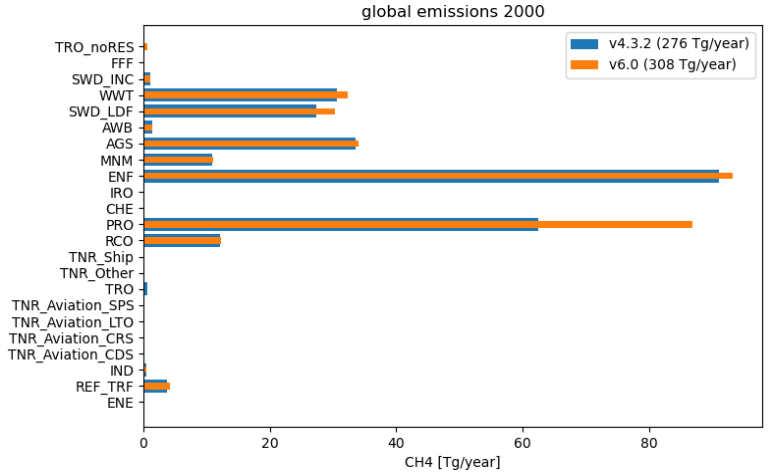


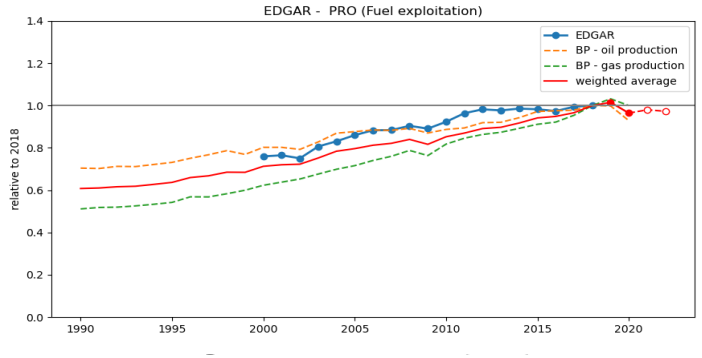
CAMS INVERSIONS
EMISSIONS

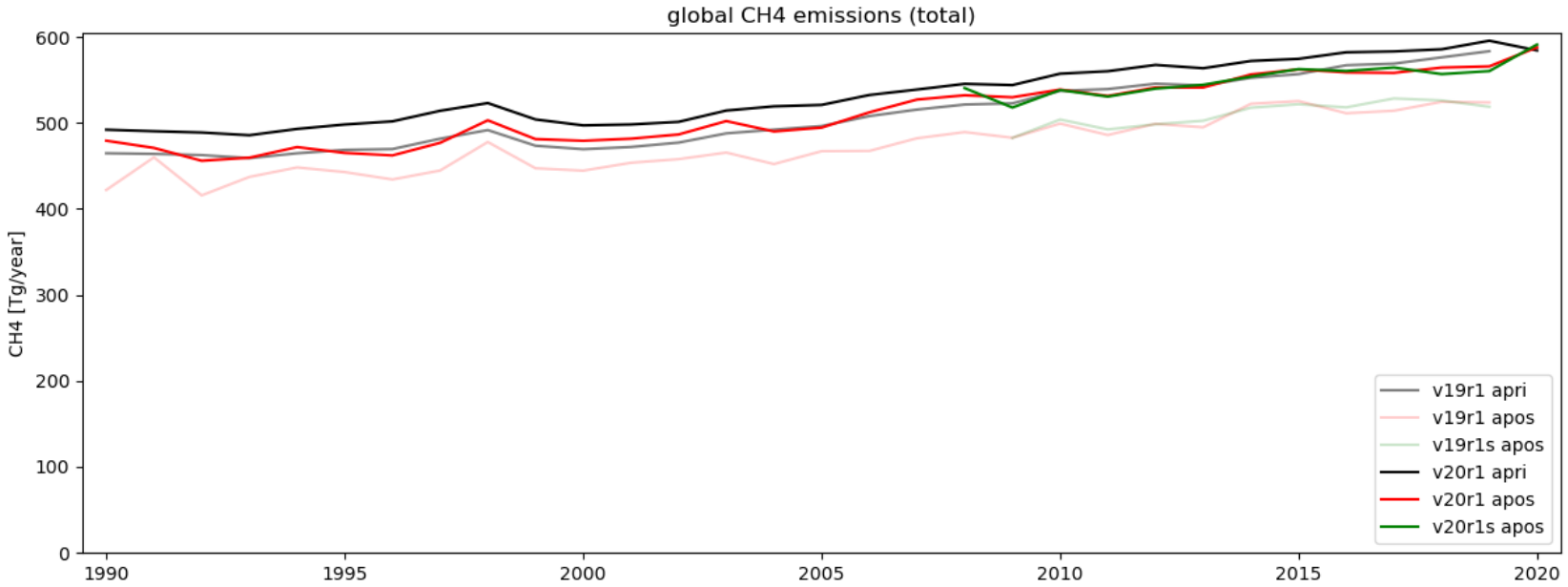
Prior emissions updated to EDGAR v6.0

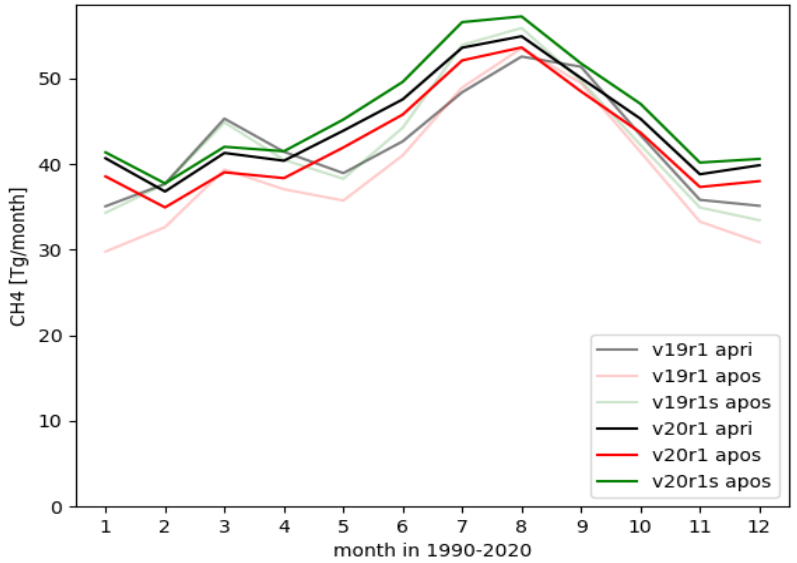
- ~ 30 Tg/year higher than previous, mainly due to "Fuel expoloitation (PRO)"
- updated monthly profiles, in better agreement with previous *posterior* profiles *(correction needed for number of days in month!)*
- extrapolation to 2020 based on oil/gas proxies show "pandemic" dip

Posterior emissions lower than *prior*, but higher than in previous release (higher sinks); for 2020 relative high





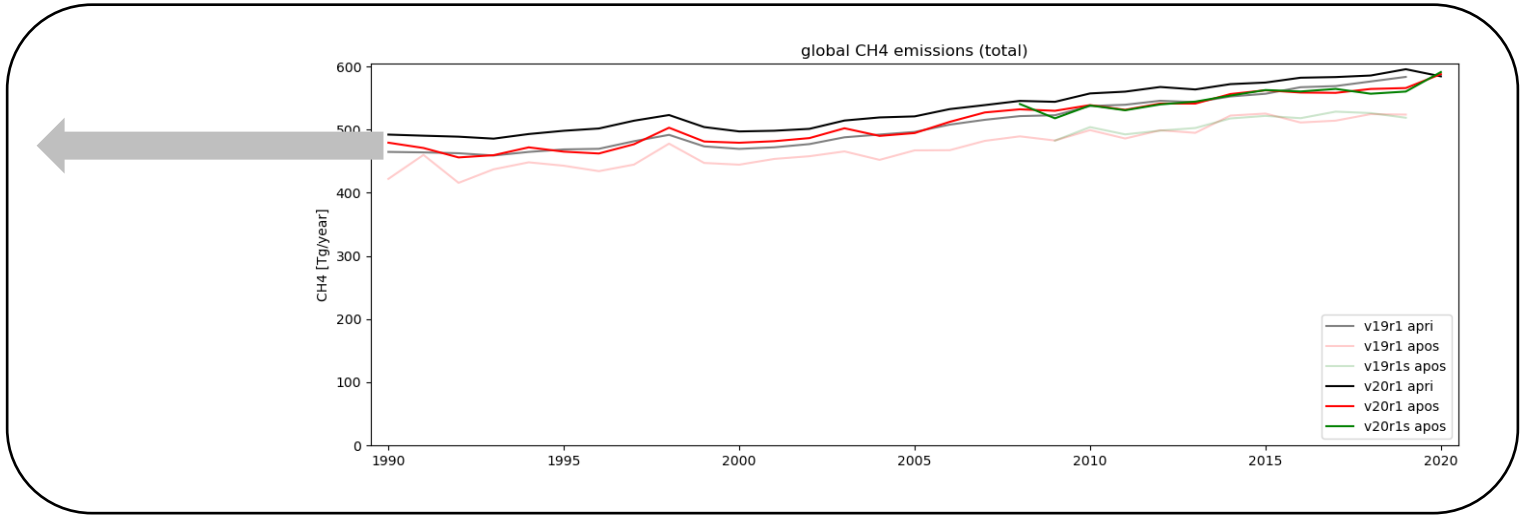


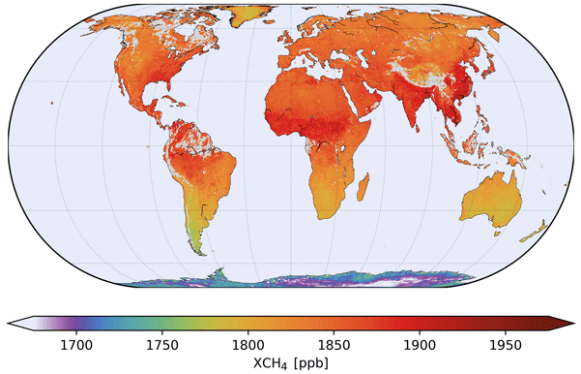


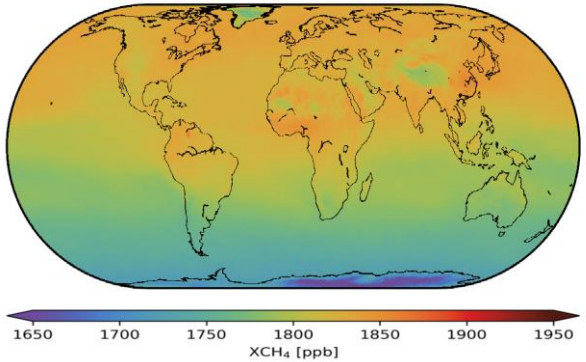
CAMS INVERSIONS OUTLOOK

v21 release (2022):

- time period **1979**-2021
  - ERA5 meteo archive extended
  - any observations <1983 ..?
  - sinks in 1980's ... ?
- extra streams including satellite data:
  - TROPOMI, IASI
- towards 1x1 resolution ...





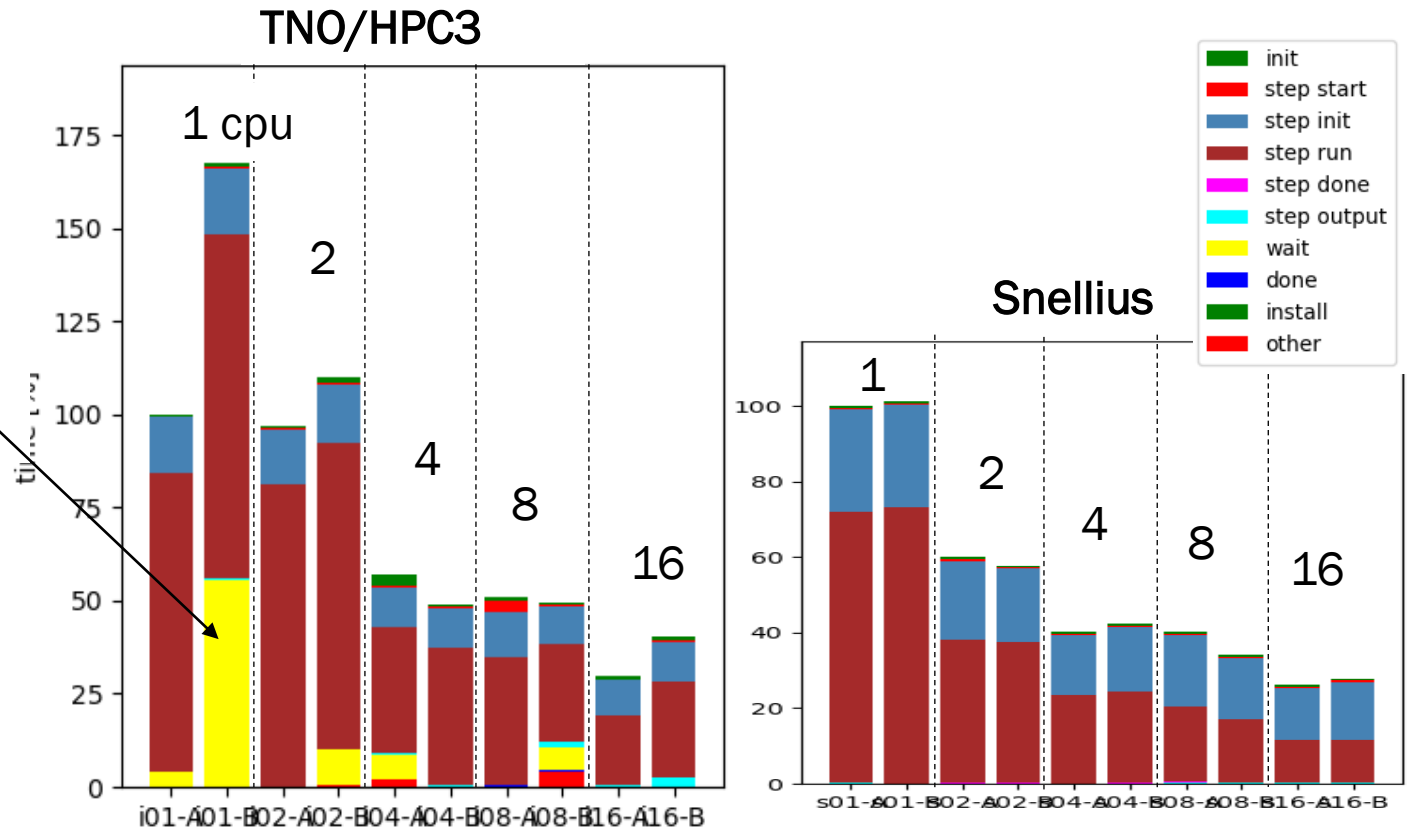


CAMS INVERSIONS
TOWARDS 1X1

Speed tests with TM5-MP: 3x2 degree, 34 layers

1 cpu used to copy input to fast ssd drive on node

Runs performed twice to check variability; occasionally, i/o is much slower in a particular run



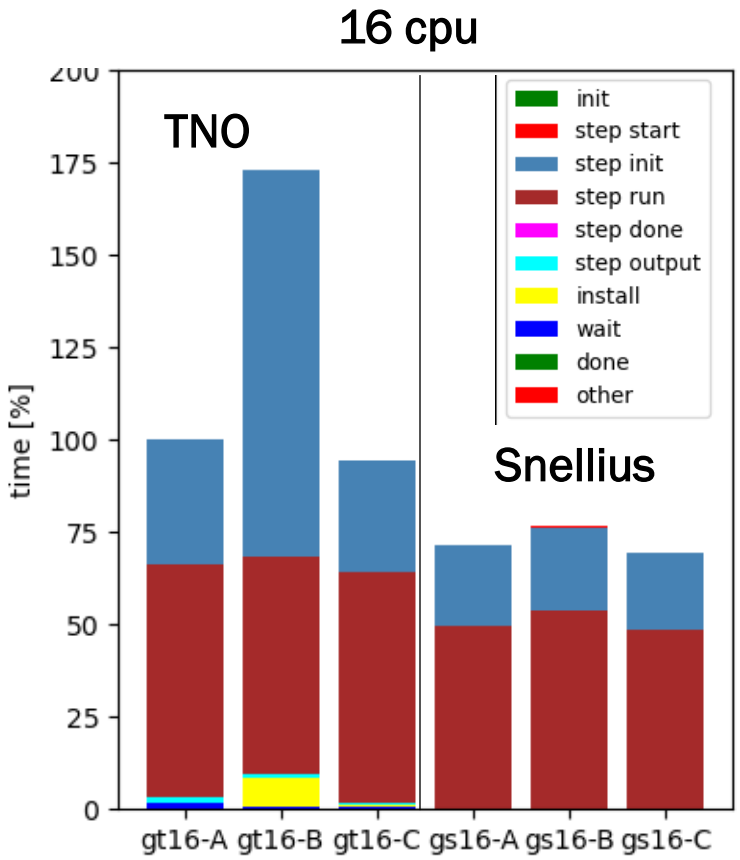
Limitted variability on Snellius

For 16 CPU:
speedup 4 for this resolution
50% time on i/o

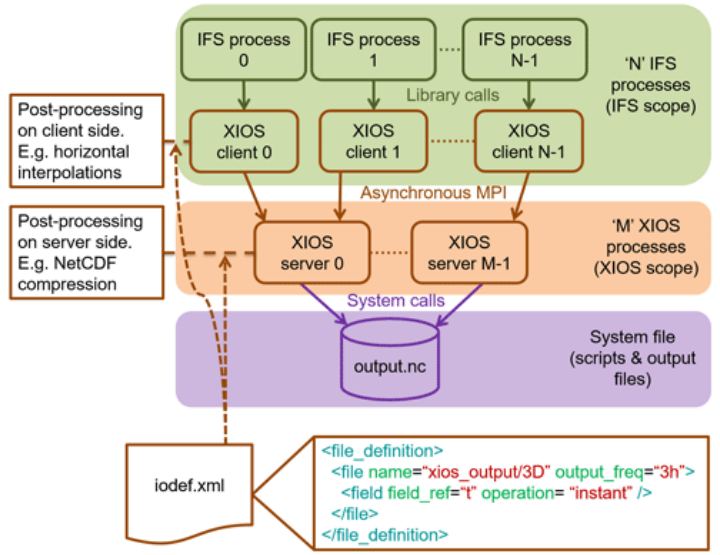
CAMS INVERSIONS
TOWARDS 1X1

TM5-MP on 1x1, 137 layers:

~3 hour for 1 week of simulation (2 days for 3-year block)



Testing: XIOS server to handle I/O:



XIOS server:
forge.ipsl.jussieu.fr/ioserver
Coupling XIOS to IFS:
doi:10.5194/gmd-15-379-2022

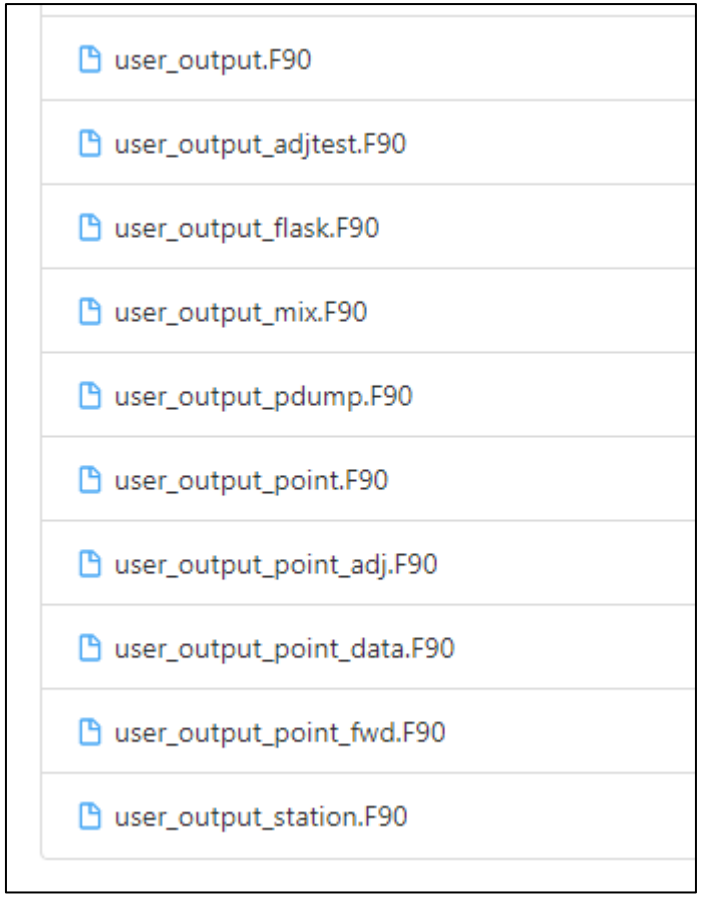
TM5-MP USER OUTPUT

TM5 "*per* user output":

- point simulations (incl adjoint forcing)
- profiles at satellite pixels (kernel application outside model)
- 3D fields, instant or averaged
- timeseries at station locations
- timeseries of profiles at station locations (FTIR)
- validation locations (ship tracks, aircraft flights)
- *… and probably many more*

Not all of this are actually parallel yet in TM5-MP!

Maybe try to harmonize?

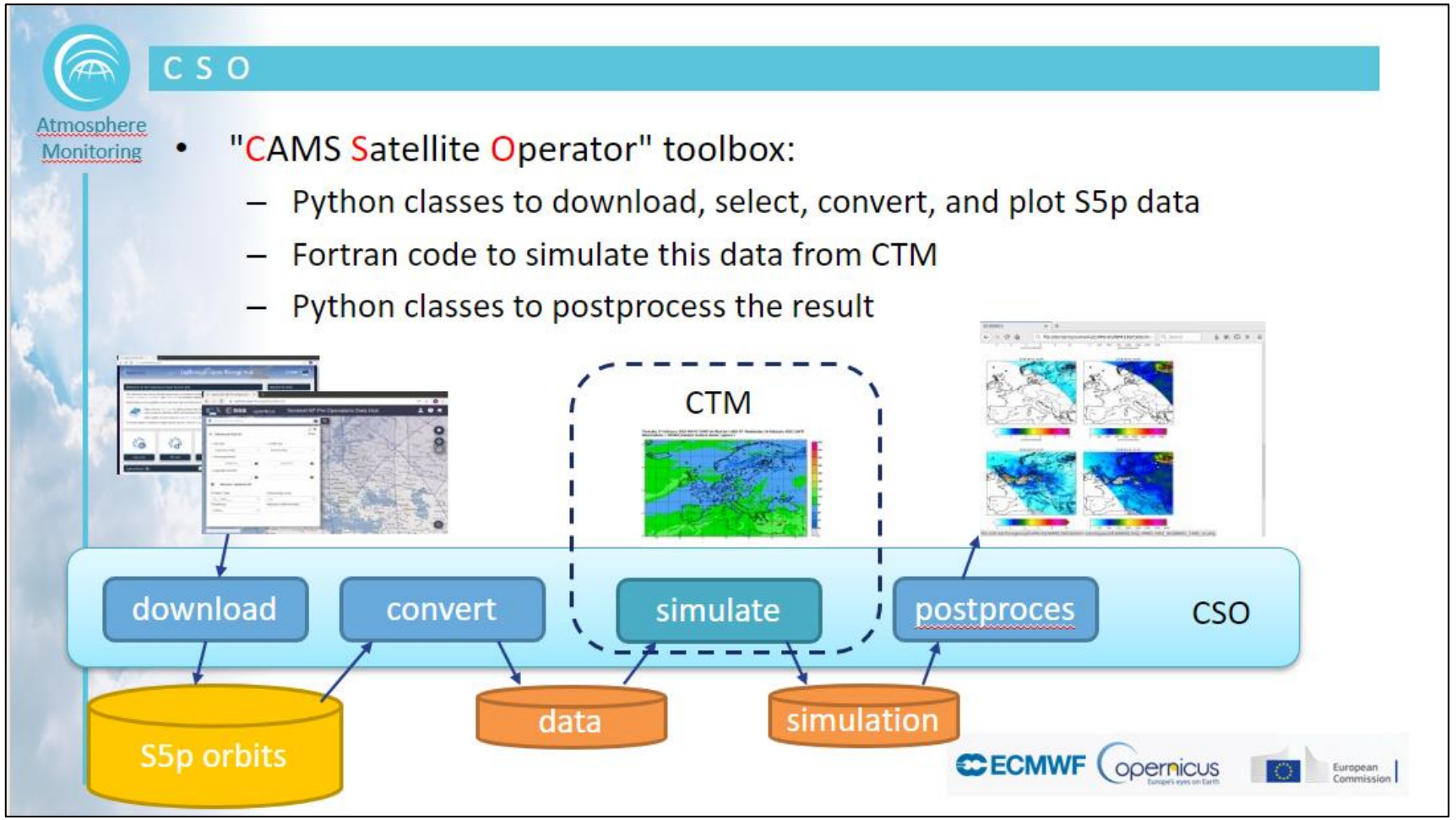


user_output files in "proj/4dvar_ch4"

TM5-MP USER OUTPUT

CSO TOOLBOX

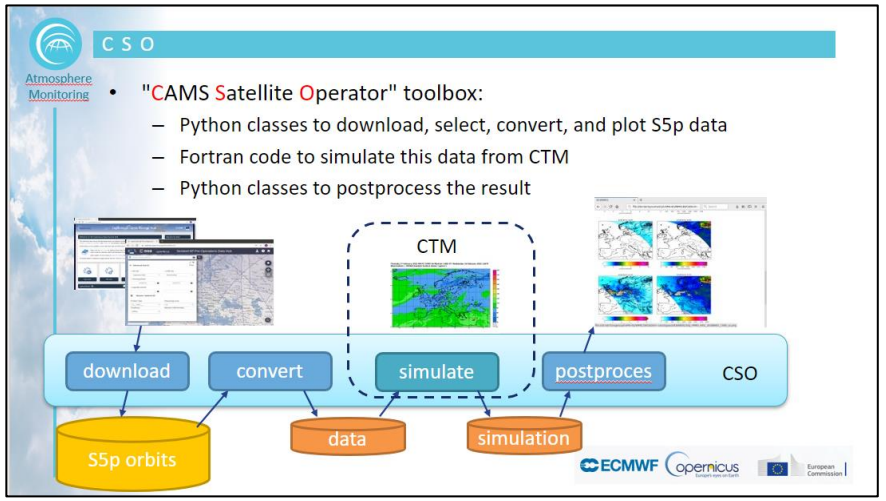
Development from "CAMS_61" project, to facilitate assimilation of Sentinel products in regional models:

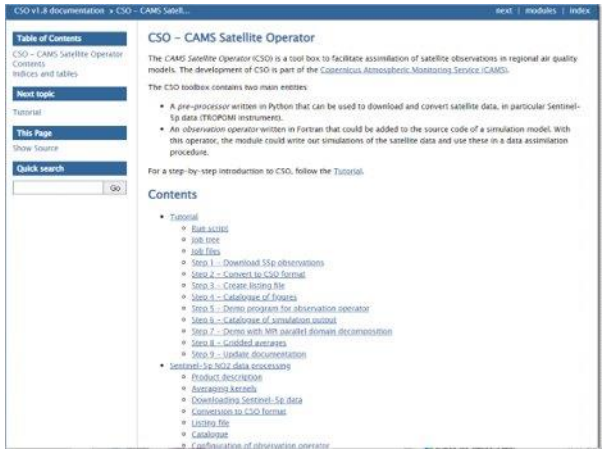


TM5-MP USER OUTPUT
CSO TOOLBOX

Coupled to TM5-MP via "user_output_cso.F90"

- operator takes care of:
  - domain decomposition (gather/scatter)
  - horizontal mapping (interpolation weights)
  - vertical mapping
  - postprocessing (kernel application)
  - input, output
  - documentation …
- Observation types for CAMS inversions:
  - GOSAT XCH4 (SRON product)
  - timeseries at NOAA surface stations
  - *t.b.d.: timeseries at TCCON locations*
  - *t.b.d.: validation data (ship tracks, aircraft flights)*





to be continued …