CarbonTracker update

Wouter Peters, Andy Jacobson, John Miller, Ken Masarie, Lori Bruhwiler, David Baker, Leif Backman, Daniel Landau, Baozhang Chen, Huifang Zhang, Jing Chen, Fei Jiang, Guido van der Werf, Thijs van Leeuwen, Sara Mikaloff-Fletcher, Bjorn Brooks, Weile Wang, Yanli Cheng

Past 6 months

- Developed new CT framework
- Trained 5 more TM5-ers
- Updated the TM5 tutorial to release 3.0

New

- Developed a new framework for CarbonTracker/ TM5
- currently in testing
- compatible with release/3.0
  - and with any other TM5 release!
- any TM5 executable can be plugged into a data assimilation framework

Advantages

- With TM5 and CT untangled, we can
  - Separate tasks by strength
  - maintain and upgrade them independently
  - Plug various TM5 flavors into CT
  - Plug other models into CT
  - Develop CT beyond TM5 capacities

Design

- The new CT system is python based
  - uses minimal external libraries (numpy, Nio)
- Different components of a data assimilation are designed as independent units
- Units are combined in a pipeline that performs all steps
- TM5 is one such unit, and called+controlled from the pipeline

Example (1)

```
from da.platform.maunaloa import MaunaloaPlatForm
from da.ct.dasystem import CtDaSystem
from da.ct.statevector import CtStateVector
from da.ct.obs import CtObservations
from da.tm5.observationoperator import TM5ObservationOperator
from da.ct.optimizer import CtOptimizer

PlatForm    = MaunaloaPlatForm()
DaSystem    = CtDaSystem('carbontracker.rc')
ObsOperator = TM5ObservationOperator('/Users/peters/Modeling/TM5/ct_new.rc')
Samples     = CtObservations()
StateVector = CtStateVector()
Optimizer   = CtOptimizer()
```

"Platform" is an object (unit) that controls all settings and processes needed for a computing platform, for example:

- creating job templates
- submitting jobs
- obtaining process ID's
- etc

Example (2)

```
from da.platform.maunaloa import MaunaloaPlatForm
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from da.ct.obs import CtObservations
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```

"ObsOperator" is an object (unit) that controls the TM5 model, for example by:

- Modifying rc-files
- Moving save files
- Running the model and monitor success
- ...

Design

- Your TM5 project is written, compiled, and tested independently with your favorite release/branch, and using runtm5.py and other 'standard' tools
- The CT TM5 object then takes over the created executable (tm5.x) and controls it
- N versions of serial TM5 are run in parallel (N= number of ensemble members) from within CT
- Output is gathered and used downstream
- TM5 only gets a list of observations, and returns a list of equivalent model samples

Design

- For each ‘unit’ (object in python) there exists a “baseclass” which defines the functions and variables minimally needed for the object to be passed into the pipeline

- Special instances of these units inherit all the base functionality, and extend it depending on their own needs.
- This makes it very easy to modify the new CT to your own needs

Example

baseclass StateVector

```
def Propagate(self):
    """

    Propagate the parameter values in the StateVector to the next cycle. This means a shif
    be optimized once more, and the creation of a new ensemble for the time step that just
    In the future, this routine can incorporate a formal propagation of the statevector.

    """

    # Remove State Vector n=1 by simply "popping" it from the list and appending a new emp
    # hold the new ensemble for the new cycle

    dummy = self.EnsembleMembers.pop(0)

    dummy = self.EnsembleMembers.append([])

    # And now create a new time step of mean + members for n=nlag

    dummy = self.MakeNewEnsemble(self.nlag)


    msg   =   'The state vector has been propagated by one cycle ' ; logging.info(msg)

def MakeNewEnsemble(self,lag, covariancematrix = None):
    """ Make a new ensemble, the attribute lag refers to the position
        Note that lag=1 means an index of 0 in python, hence the notat
        The argument is thus referring to the lagged state vector as [

        The optional DaCycle object to be passed holds info on the dat
        for instance to read covariance data from file. This is not pa
```

Example

CtStateVector(statevector)

```
def MakeNewEnsemble(self,lag, covariancematrix = None):
    """ Make a new ensemble, the attribute lag refers to the position
        Note that lag=1 means an index of 0 in python, hence the notat
        The argument is thus referring to the lagged state vector as [:

        The optional DaCycle object to be passed holds info on the dat
        for instance to read covariance data from file. This is not pa
        method will almost always be overwritten in the derived class

        The code below is just an example of what could be used
    """

    if covariancematrix == None:
        covariancematrix=np.identity(self.nparams)

    # Make a cholesky decomposition of the covariance matrix
```

Pipeline

- A fixed sequence of calls to functions inside each object
- Nothing inside the pipeline is object specific
- Application specific functionality is added in specific objects that derive from the baseclasses
- Example:
  - The pipeline calls:
    - observationoperator.PrepareData()
    - observationoperator.Run()
  - and not (!!!):
    - model.GetZoomedGrid()
    - model.StartTM5()

Documentation

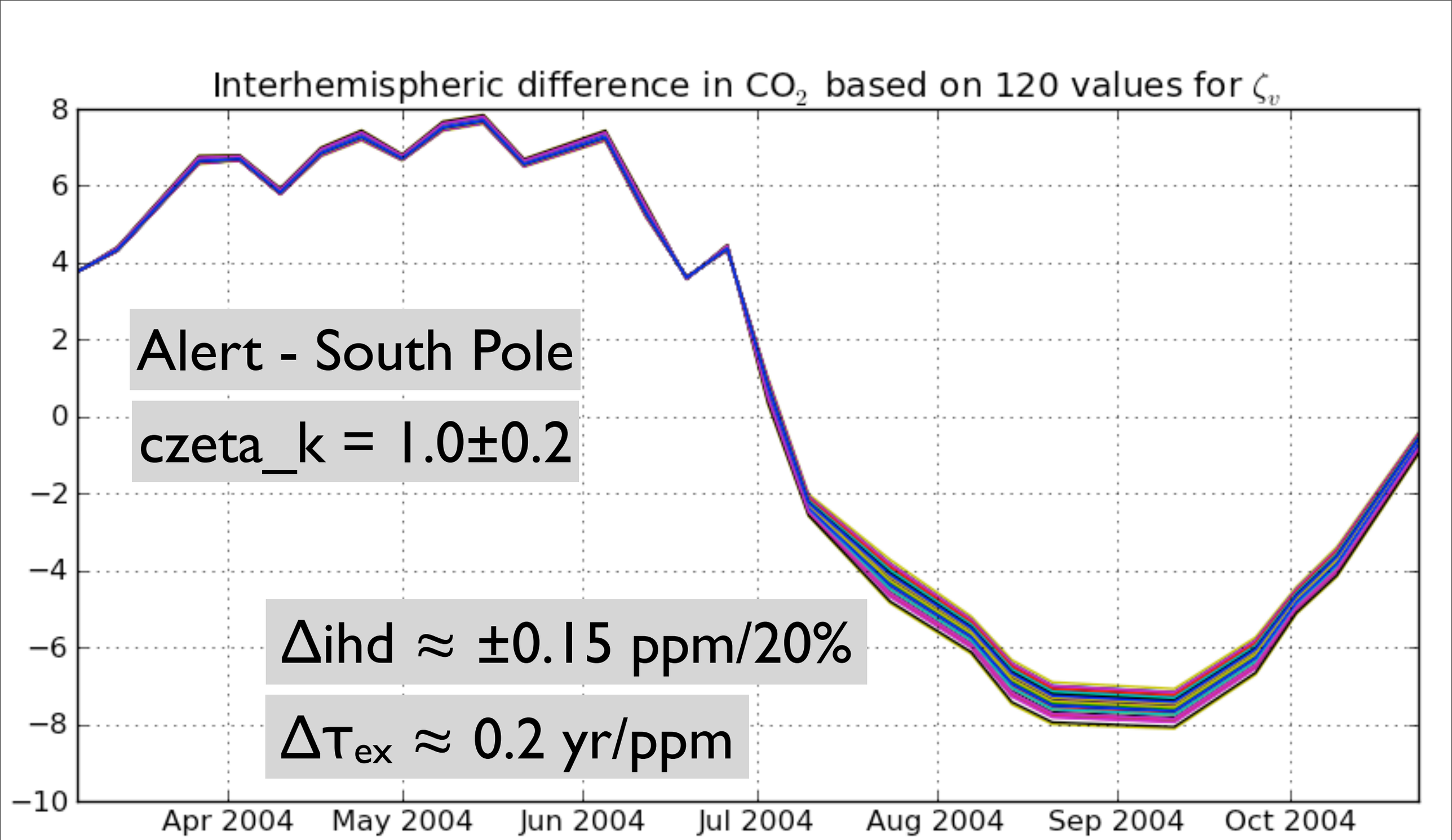
- Documentation is “inline” using Sphinx
- Combination of automated layout and structure with contents from code
- example:
  - http://www.carbontracker.eu/ctdas

Availability

- Ready for use in January 2011
- Get your TM5 code from KNMI SVN
- Get the CTDAS code from maunaloa SVN
- Contact me for a trial

Opportunities

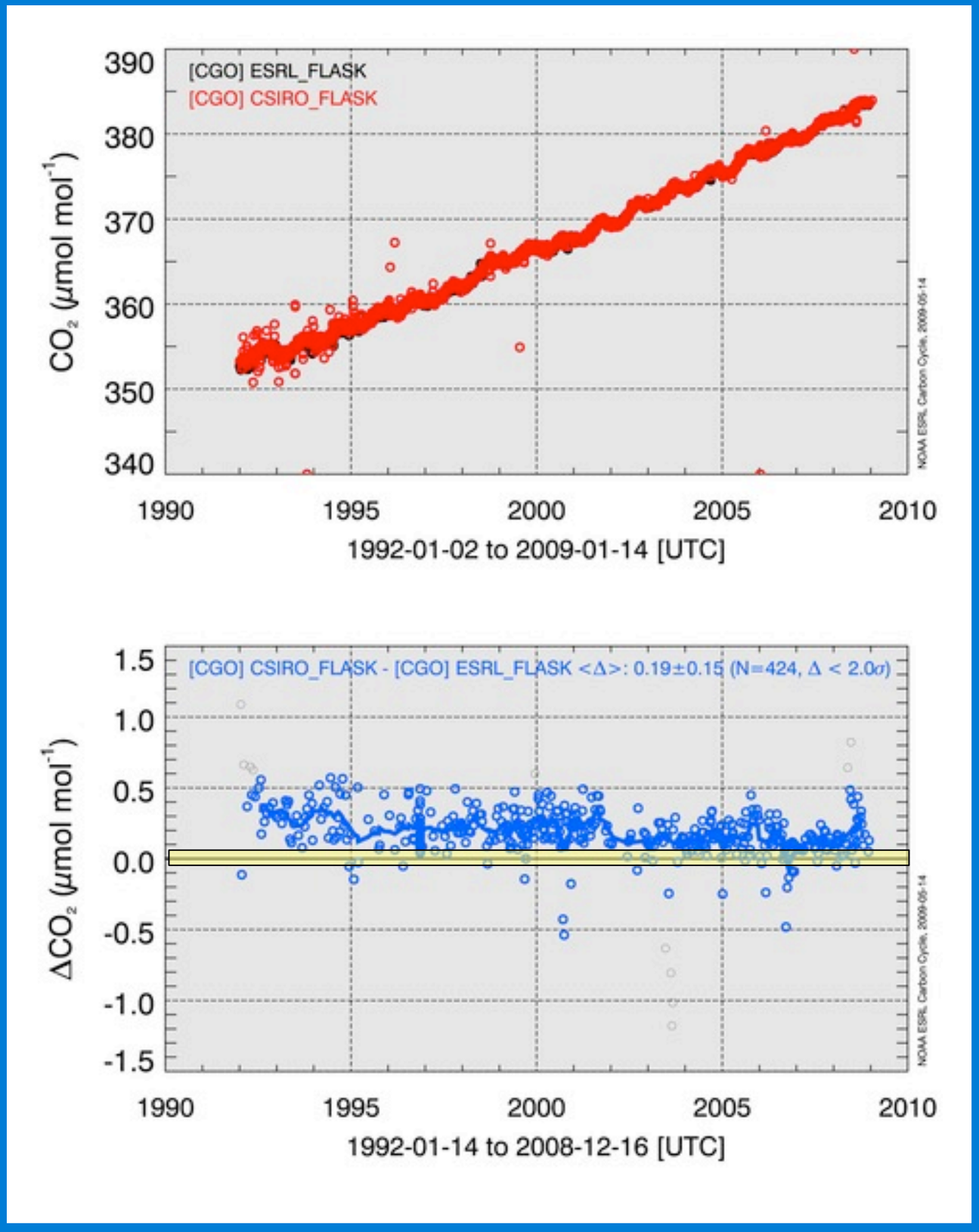
- Extend CTDAS to 4dvar system
  - share many objects
  - different pipeline
- Extend object+baseclass design to TM5 run scripts
  - Platform object
  - Meteo object
  -


Interhemispheric difference in CO_2 based on 120 values for ζ_v
Alert - South Pole
czeta_k = 1.0±0.2
Δihd ≈ ±0.15 ppm/20%
$\Delta\tau_{ex}$ ≈ 0.2 yr/ppm
8
6
4
2
0
−2
−4
−6
−8
−10
Apr 2004
May 2004
Jun 2004
Jul 2004
Aug 2004
Sep 2004
Oct 2004

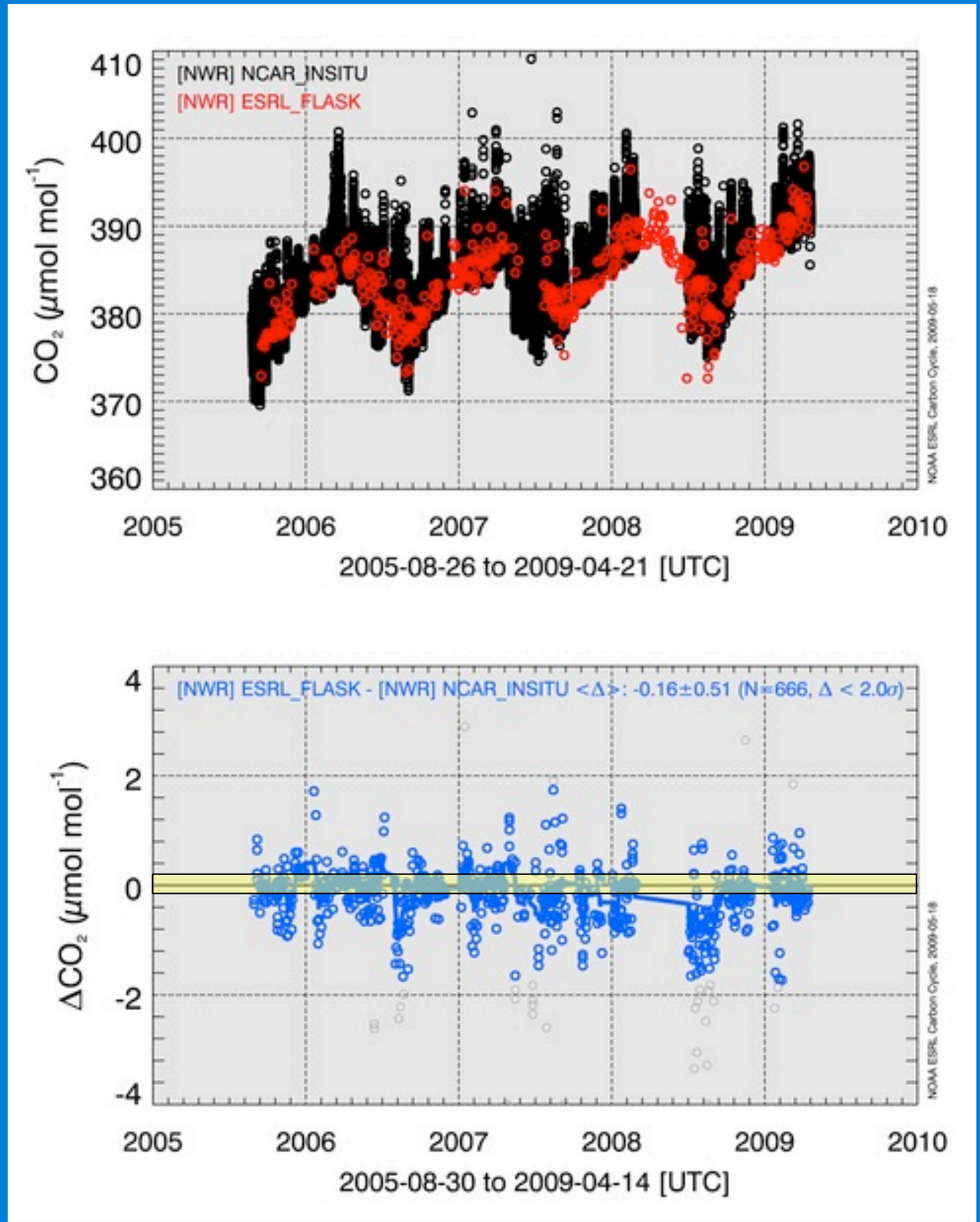
Interhemispheric exchange (IHE)

- Scaling the vertical exchange coefficients has relatively little impact on IHE
- IHE time unlikely to change much unless scaling of 100+% is used
- Seen before with diffusion scaling: making existing processes stronger does not help much (IFS is already quite binary?)
- New vertical exchange needs to be introduced
- Time for a new convection scheme??
  - entrainment explicit
  - mass-flux-diffusion formulation as in current IFS

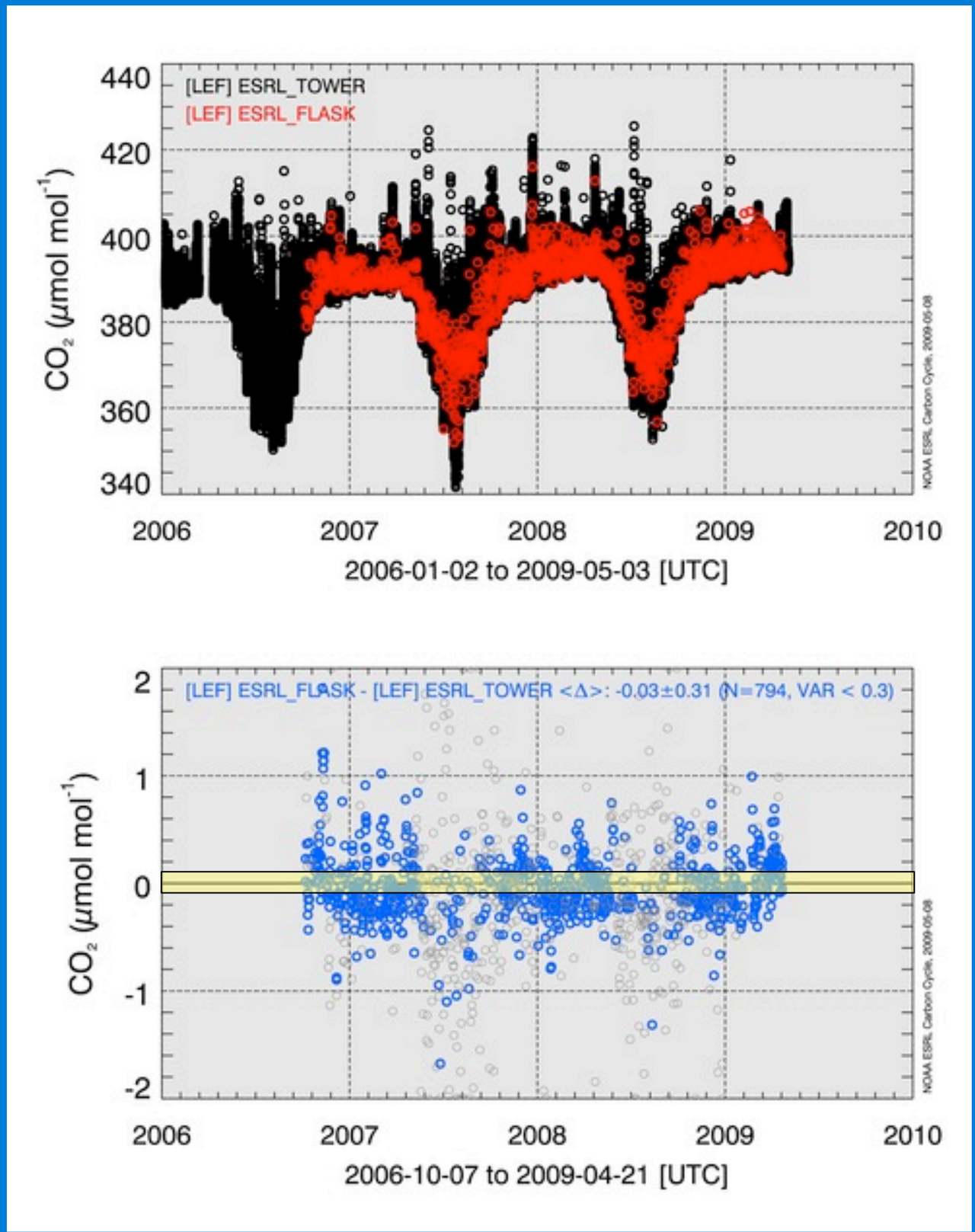
Measurement bias does exist (CSIRO/ESRL)



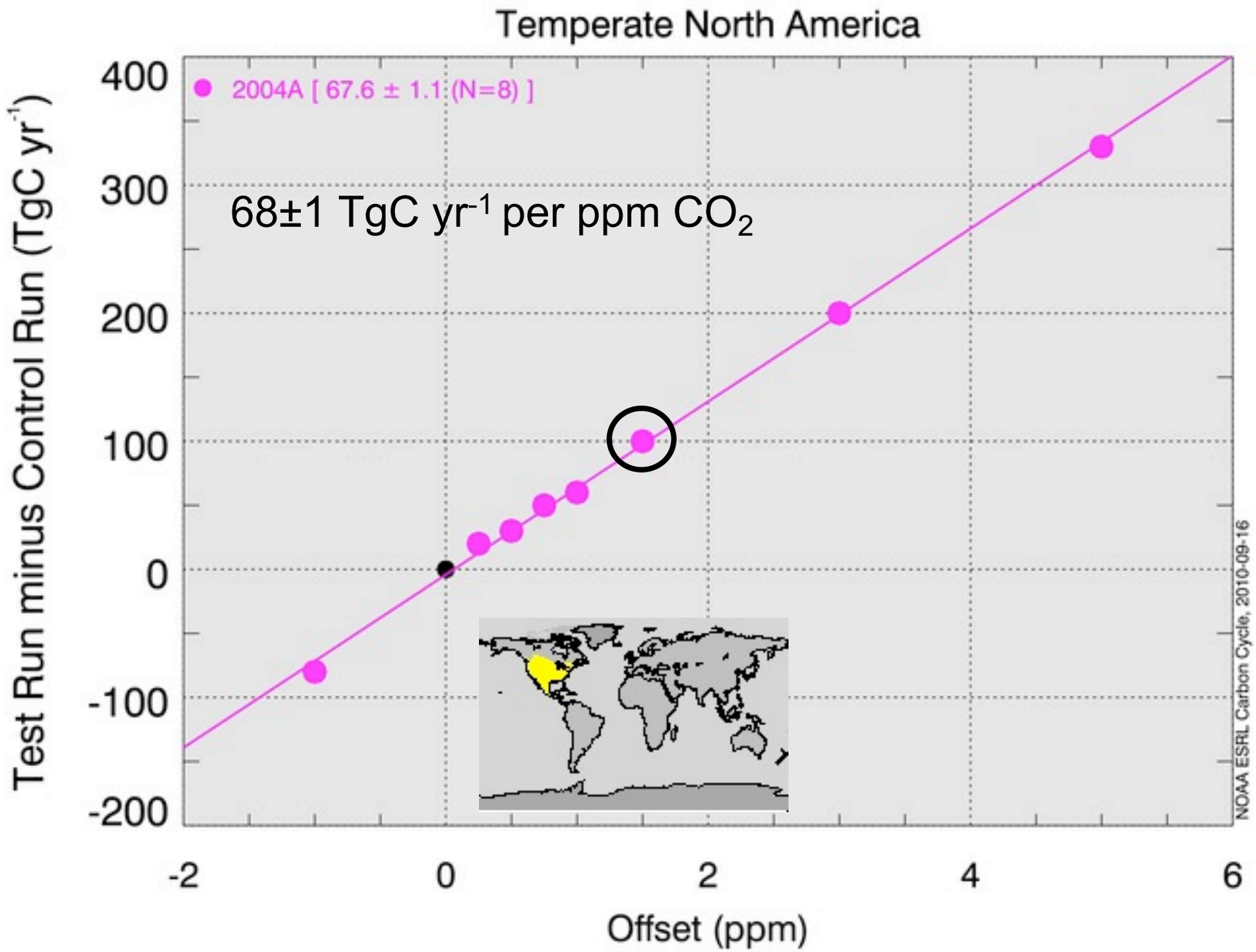
Measurement bias does exist (NCAR/ESRL)



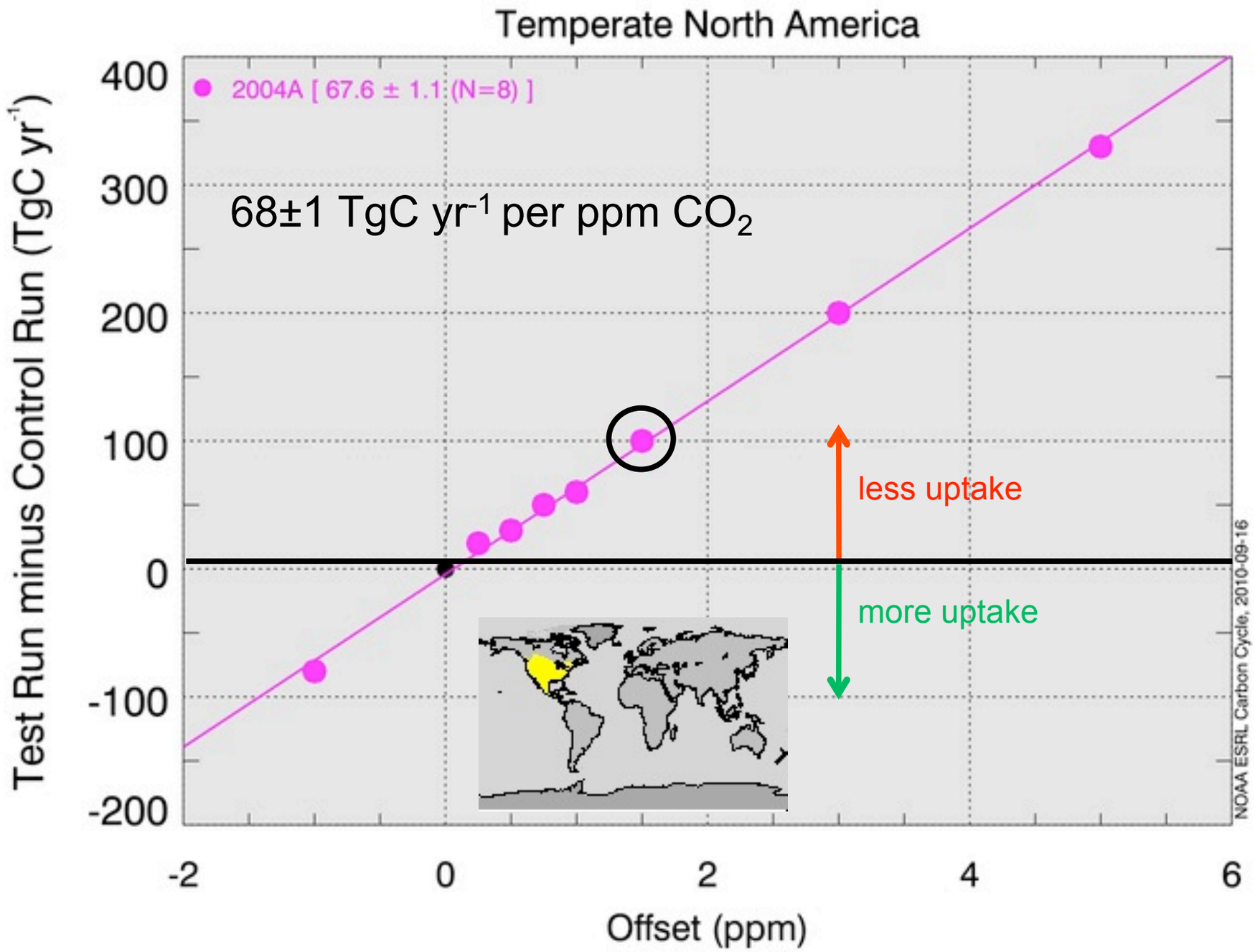
Measurement bias does exist (ESRL)



Constant offset applied to entire year (2004)



Constant offset applied to entire year (2004)



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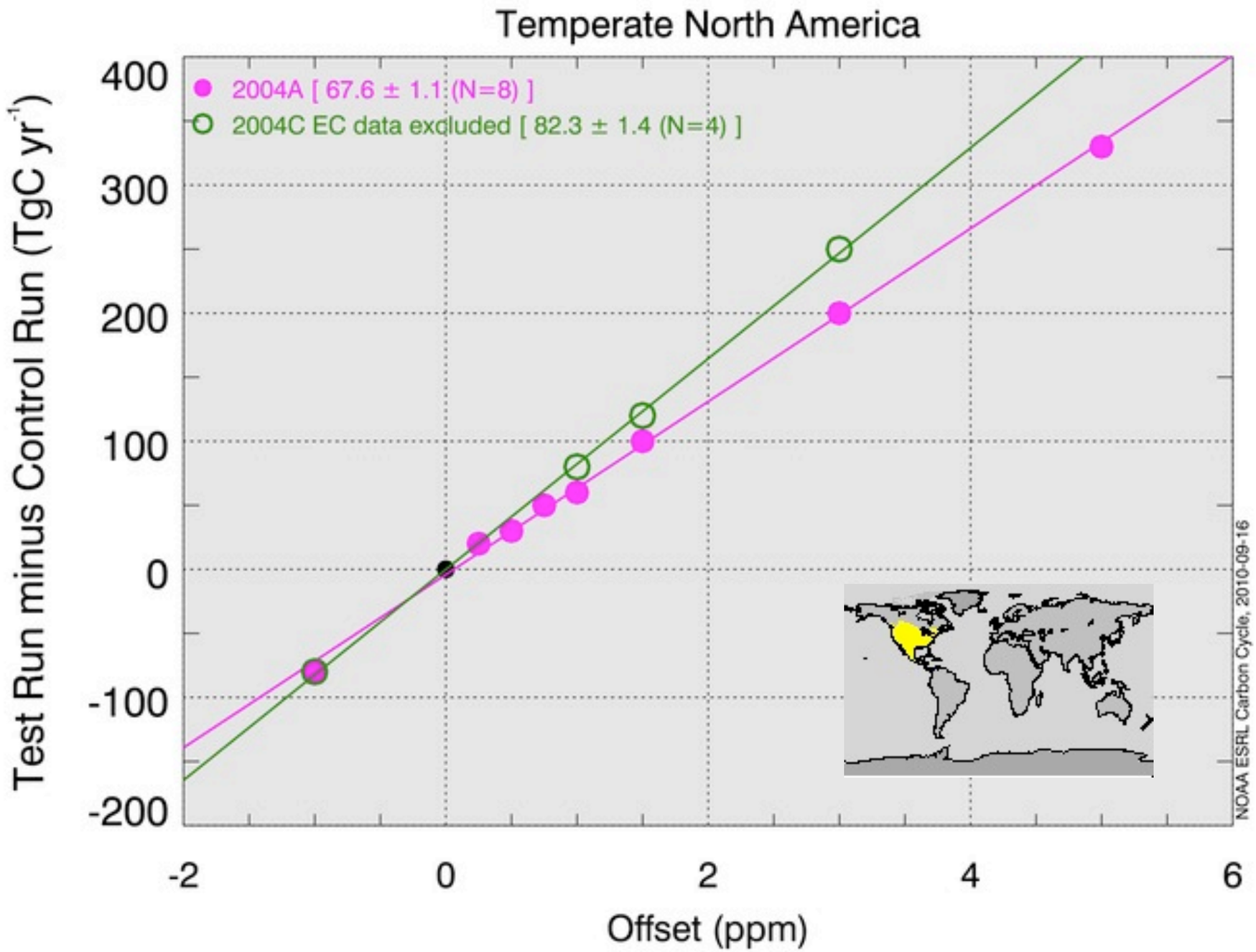
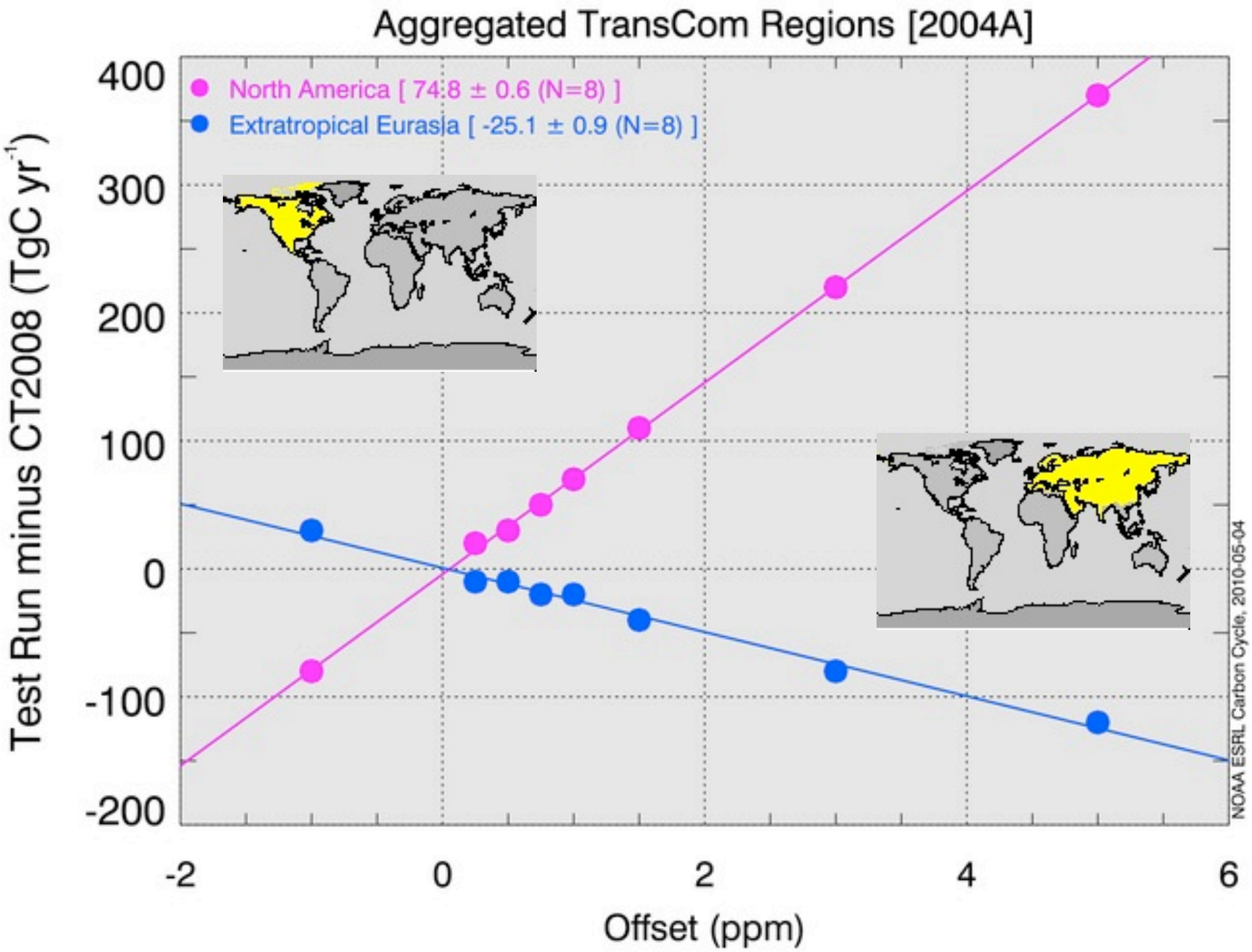
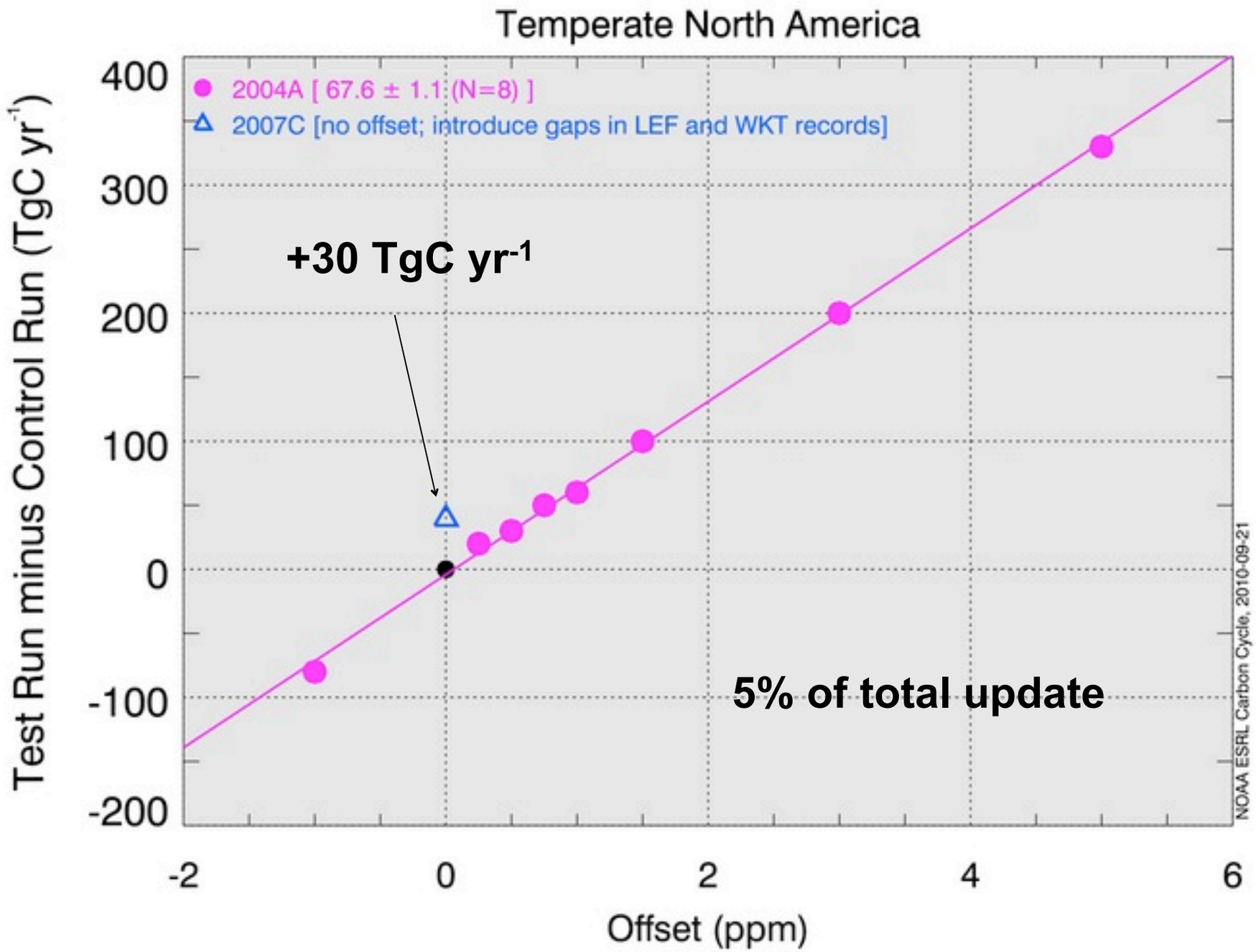


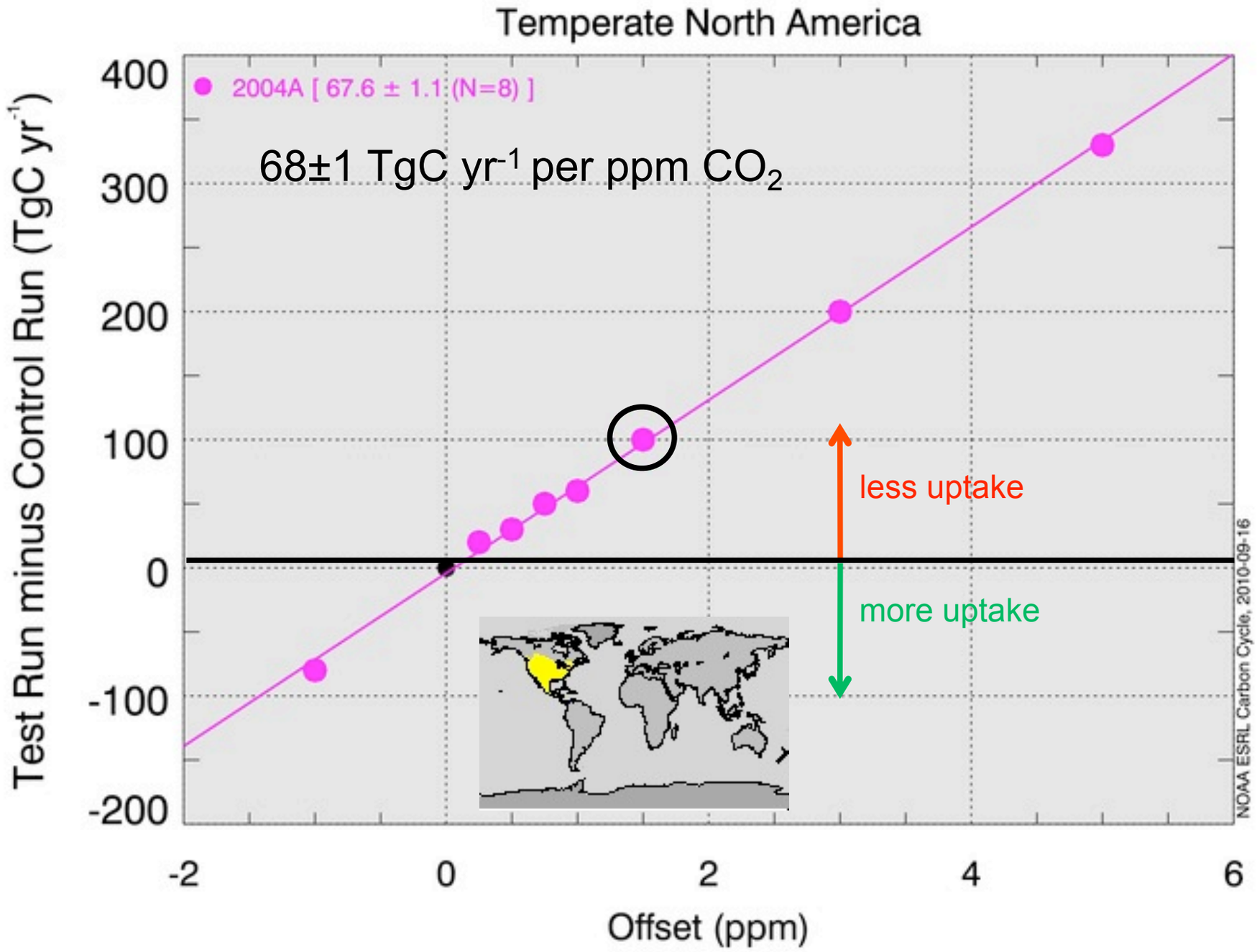
N.A. bias impacts fluxes globally



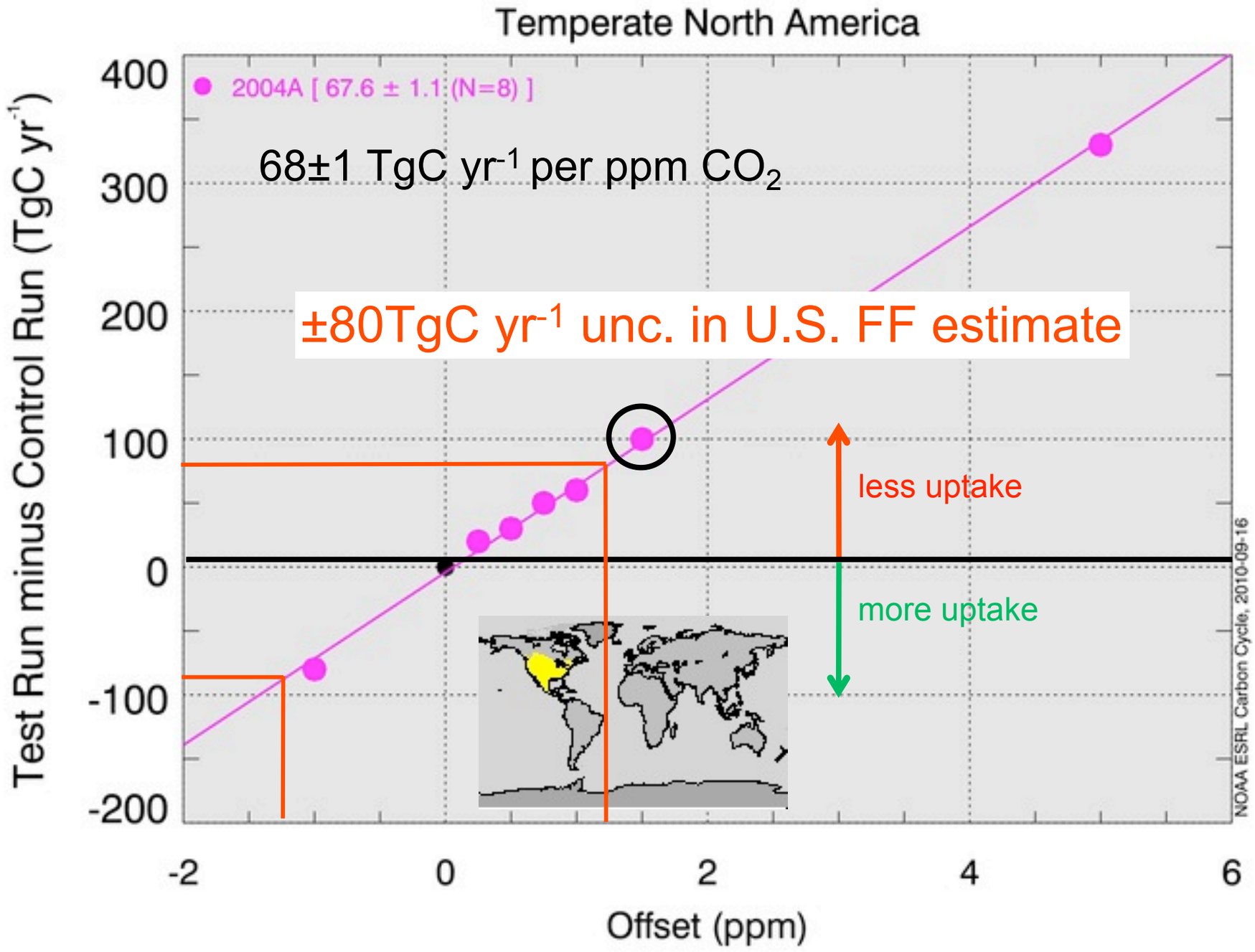
Introduce data gaps in 2007 (no offset)



Measurement bias and CarbonTracker?



Measurement bias and CarbonTracker?



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FMI – Climate change research unit

- **Head: Prof. Ari Laaksonen**
- **Personnel: 75**
- **5 Professors, 25 PhD's, 30 PhD students**
- **6 Research groups +1:**

Aerosols and climate

Climate modelling

Greenhouse gases

Climate and society

Atmospheric radiation

Climate research

Climate centre

- **FMI – Kuopio research unit**
- **In-house High Performance Computing Facilities**
  - Cray XT5m, ~4000 cores, 35 Tflops

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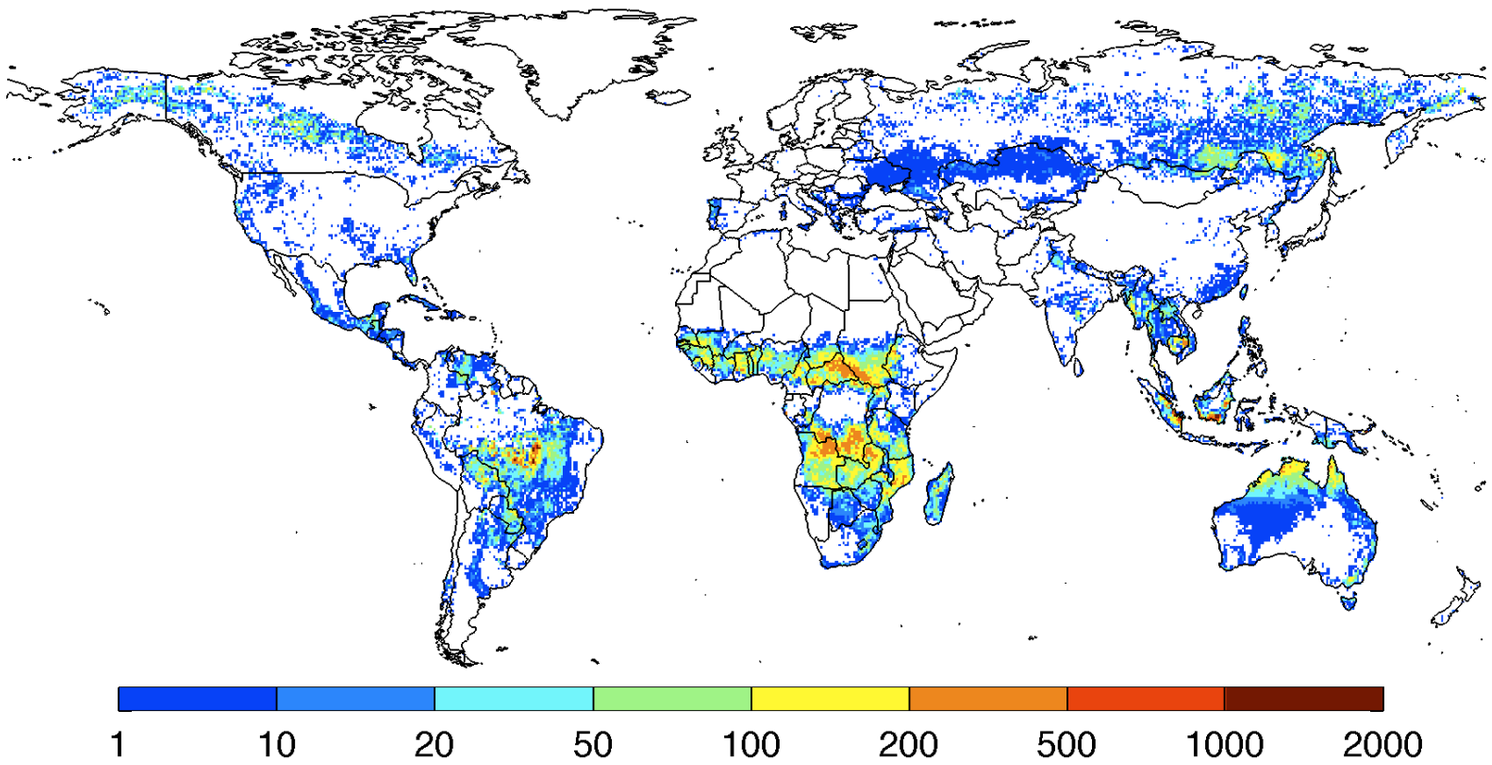
Work and plans at FMI

- **Start-up (almost completed)**
  - Visit to Wageningen, August
  - Compiles and ~runs at FMI HPC facilities
- **Funding applications (ongoing)**
  - Nordic Centre of Excellence (Nordic Ministry Council)
    - Partial resource?
    - 5-year projects (cryosphere)
    - CO_2 (+ CH_4)
  - Academy of Finland (general call, application submitted in October)
    - Develop CH_4 capability
  - Tekes (Finnish technology development centre) “climate economy” call ?
    - CO_2 balance for Finland?
  - Possibly targeted funding opportunities in the not so far future
- **In-house and National cooperation (starting up)**
  - “Promotion” of CarbonTracker in seminars (Global modelling & Methane)
  - “Standard runs”
  - Testing with additional CO_2 data (problem with “timing”)
  - Comparison to Sodankylä FTIR CO_2 column data (problem with “timing”)
  - Common funding applications (Univ. Helsinki & others)

Emission factor modeling for global biomass burning emissions estimates

Thijs van Leeuwen, Guido van der Werf, and Wouter Peters



GFED biomass burning emissions, based on multiplying Burned area, fuel consumption, emission factors

Convert dry matter emissions to emissions of CO, CH4, aerosols, etc

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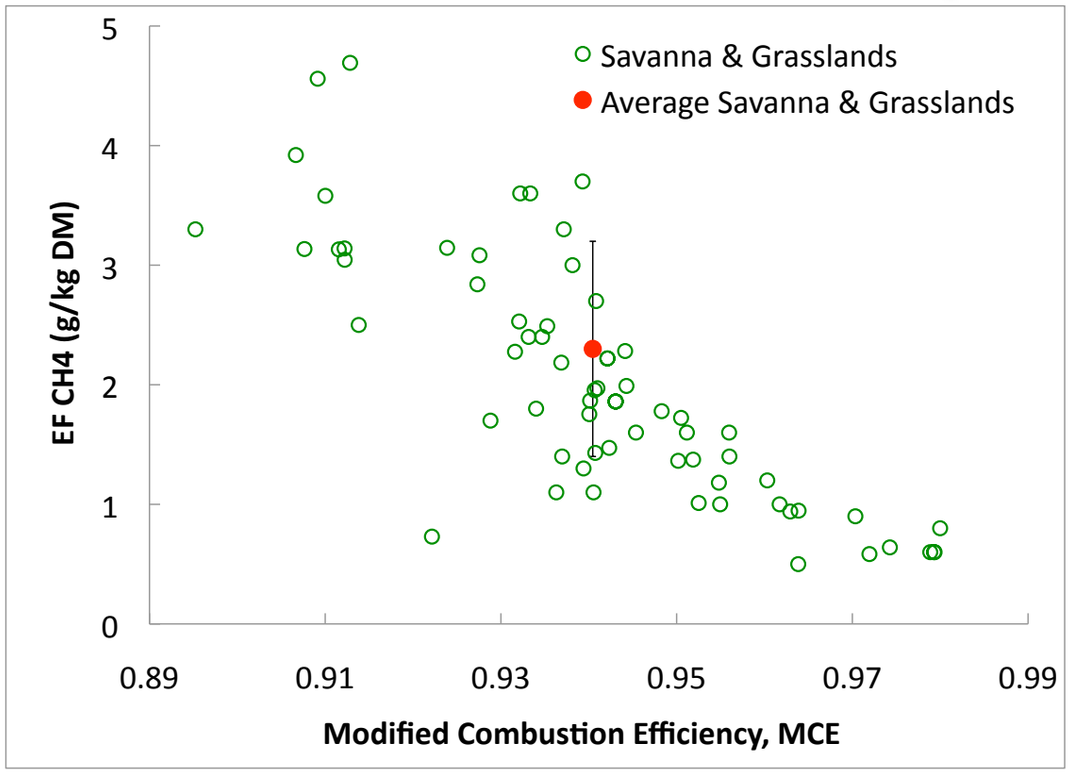
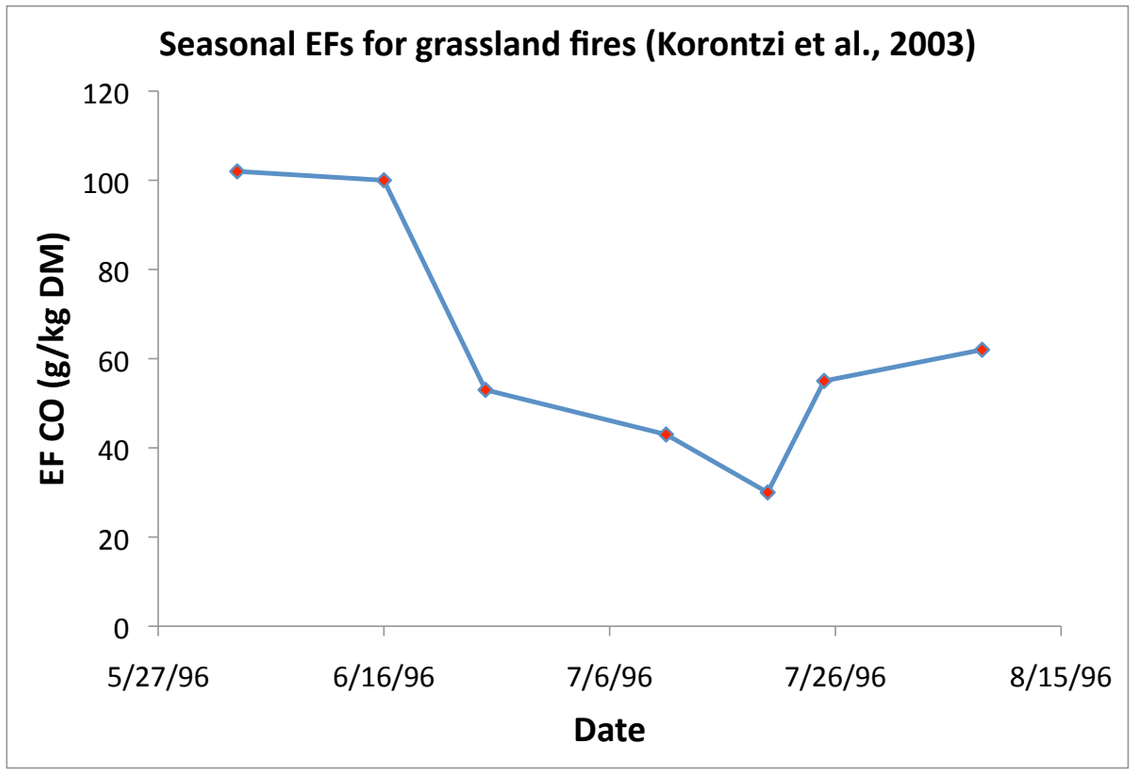
- To date, most emissions assessments (including GFED) rely on biome-averaged EF values based on ~100 field measurements to convert dry matter losses to trace gas emissions
- Substantial variability in measurements though, both in space and time





- We aimed to explain spatial and temporal variability, building an EF model driven by climatic data and information on vegetation characteristics
- This model will be combined with GFED dry matter emissions
- TM5 is used as the atmospheric transport model to compare and validate new CO emissions with space-based observations from MOPITT and SCIAMACHY

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Recent CT/TM5 activities

- Implementation of S. America zoom region for "CT-South America"
  - Also involves using new GHG measurement sites; changing covariance, etc.
  - Have results; now testing some sensitivities
- Training Brazilian colleagues to use and implement CT in Brazil.
- Currently 4 year funded project, but there is a long term interest. Also willingness to participate in future TM5 meetings.

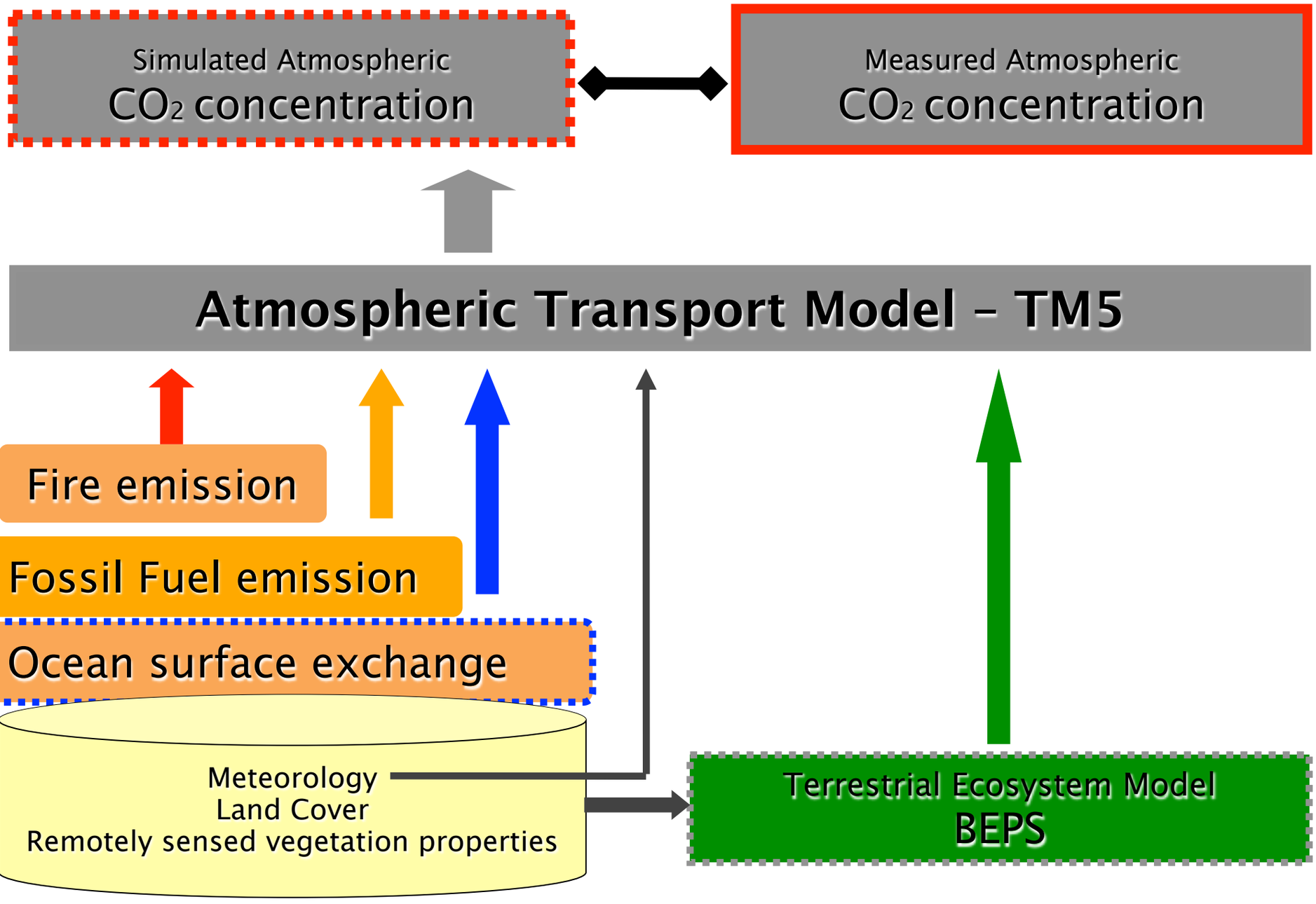
TM5 & CarbonTracker report

- **Current work:**We are now studying the TM5 & CarbonTracker.We have been trained for TM5 by Wouter Peters and will be trained for CT next week.

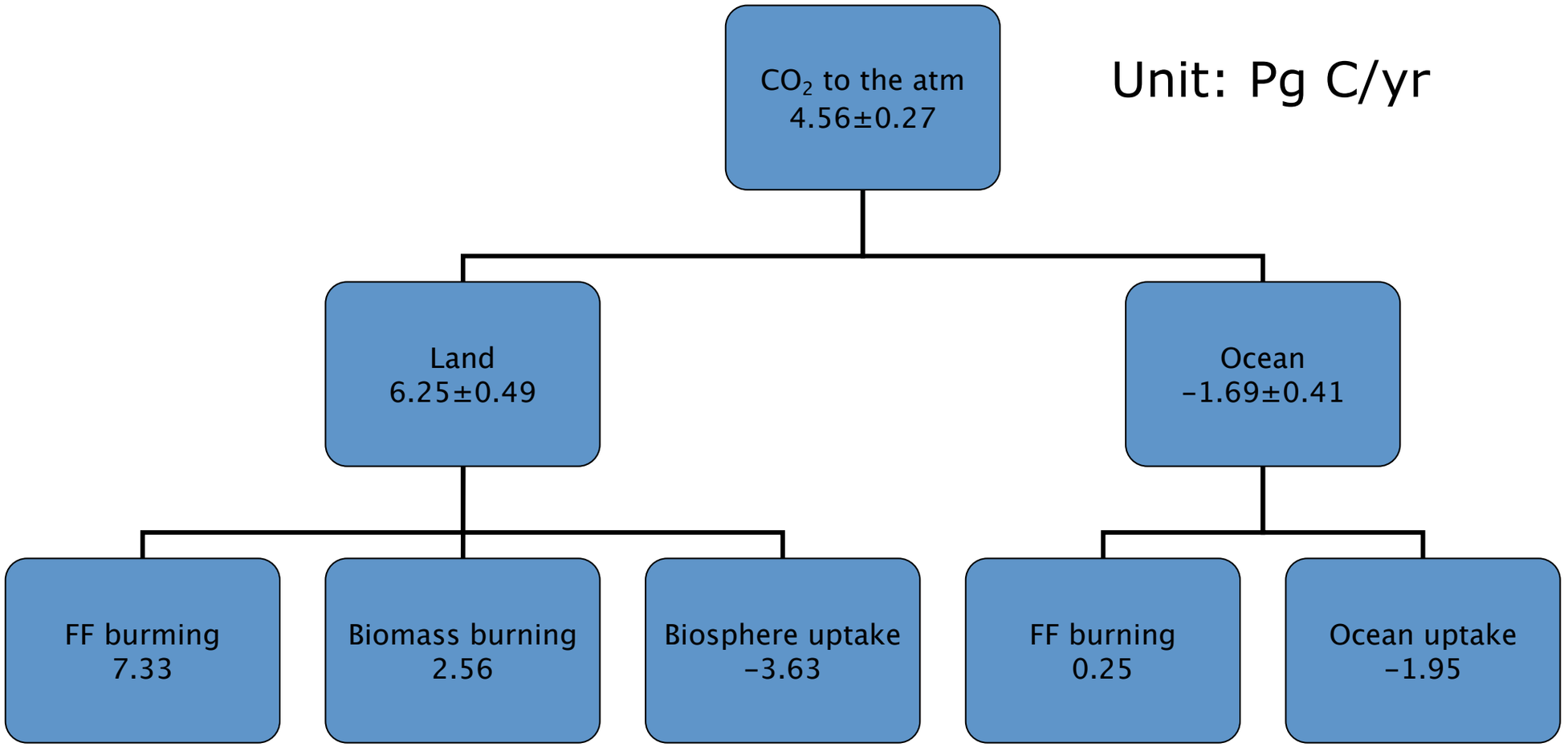
- **Future plans:**We are planning to follow your work but focus on China's landmass (nested) .We want to use the TM5 & CarbonTracker to produce quantitative estimates of atmospheric carbon uptake and release for China.

Inversion technique

Used at University of Toronto and Nanjing University (Two groups led by Prof. Jing Chen)



Global Carbon Budget (2002-2007)
Through atmospheric inversion (models: BEPS, TM5)



Deng and Chen, University of Toronto