eScience Tools for Investigating Climate Change

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NILU - Norwegian Institute for Air Research

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Introduction

Norwegian Institute for Air Research (NILU)

"Research for a clean atmosphere"

- composition of the atmosphere
- climate change
- air quality
- hazardous substances

Nordforsk, NeGI and NeIC

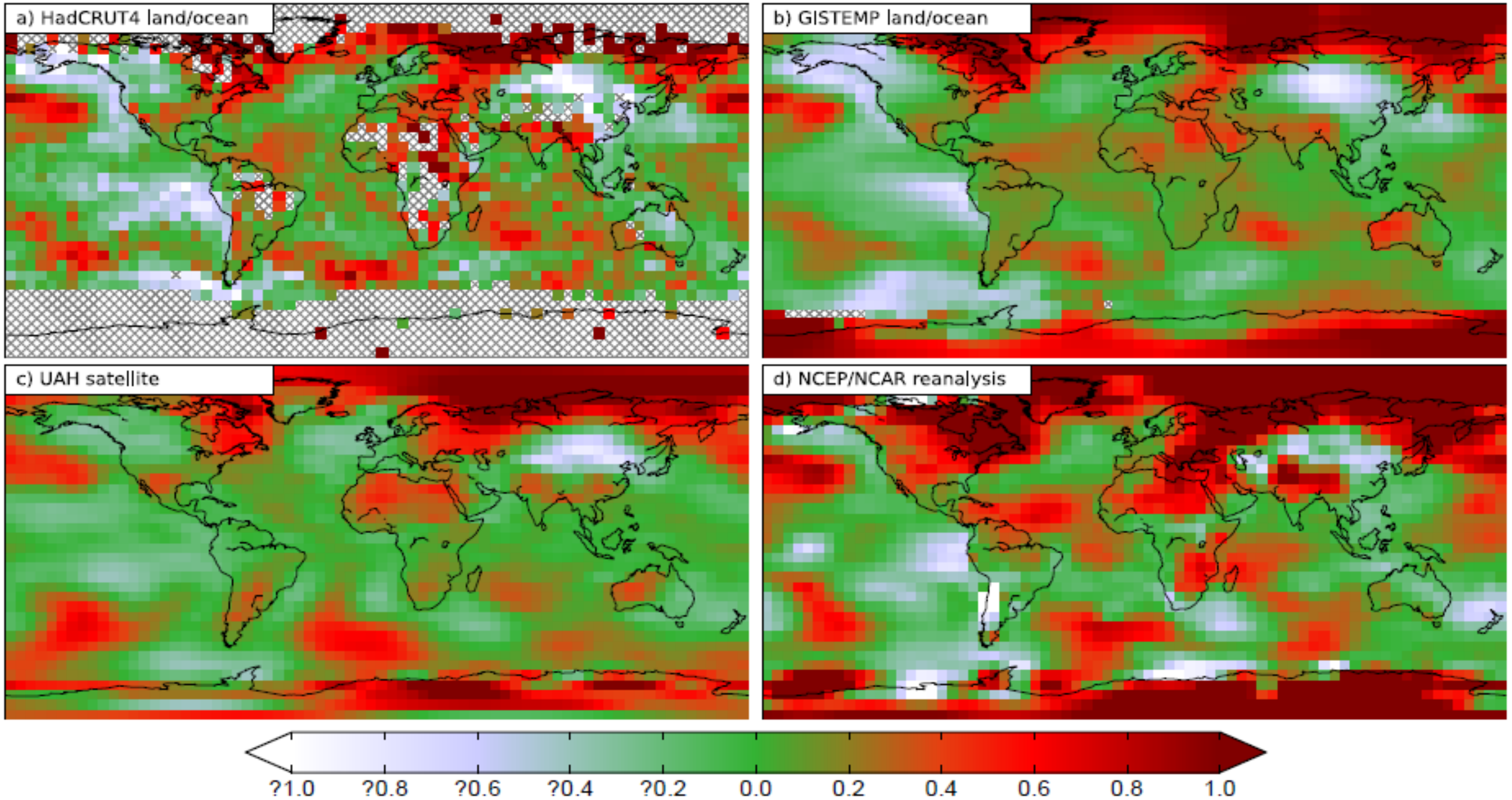
The NCoE eSTICC

eScience Tools for Investigating Climate Change at High Northern Latitudes

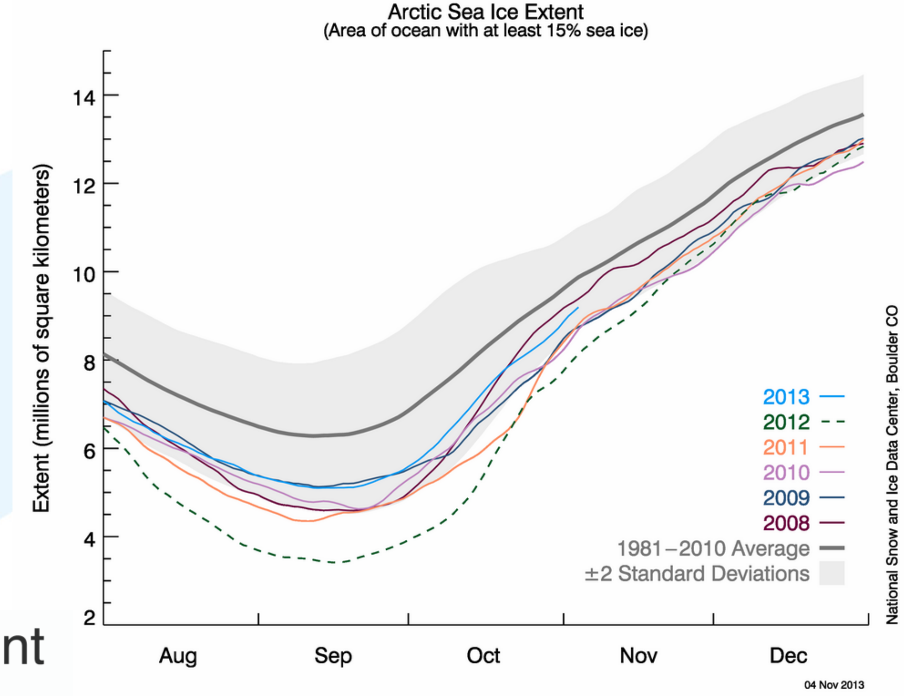
Motivation (1): The Arctic is warming faster than any other place

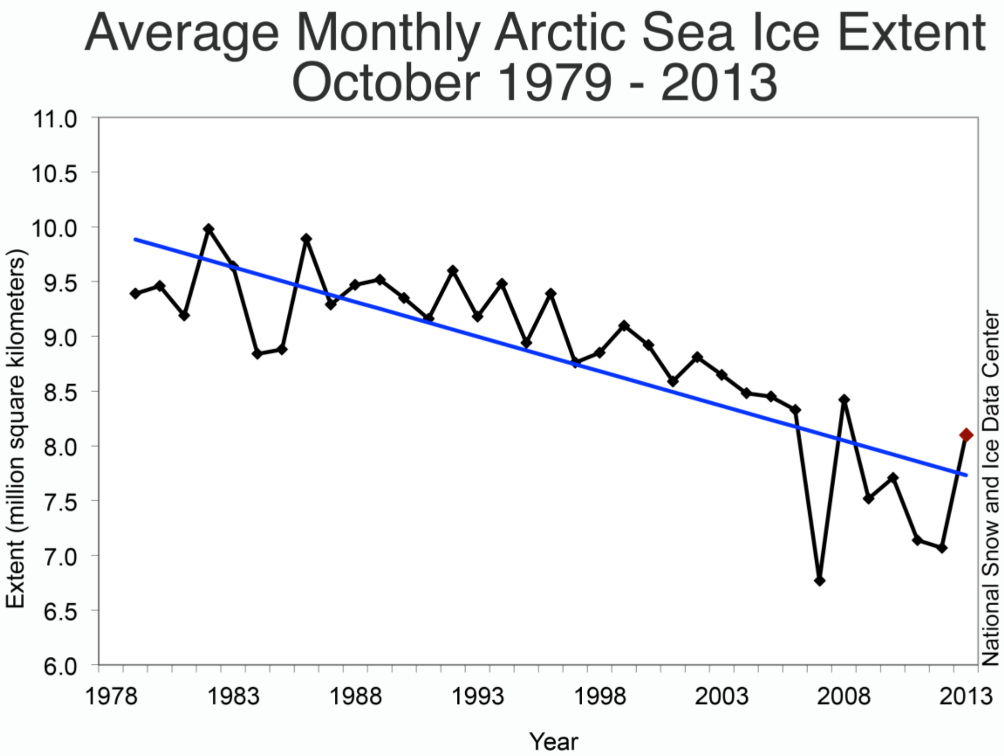
Underestimate of Arctic warming can probably explain artificial ”pause” of global warming (Cowtan and Way, 2013)

Trend in deg/decade over the last 16 years

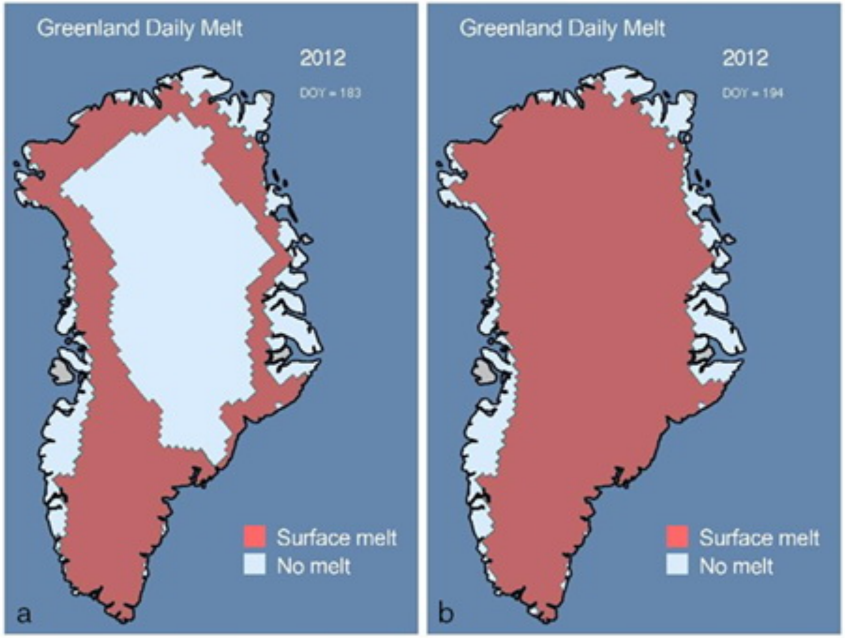


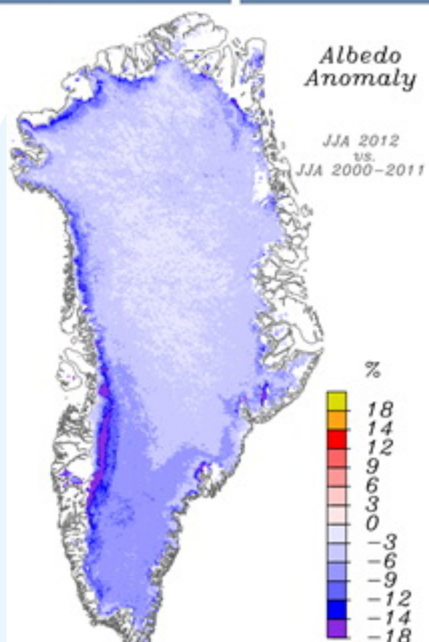
Motivation (2): Sea ice loss



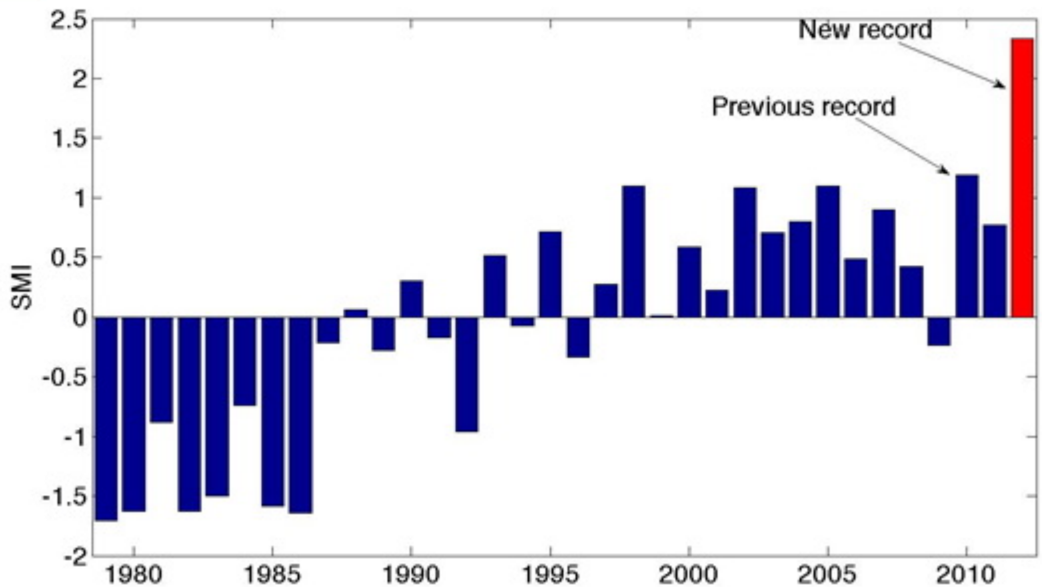


Motivation (3): Ice sheet stability





Greenland melt index:
area-weighted number of days with meltin



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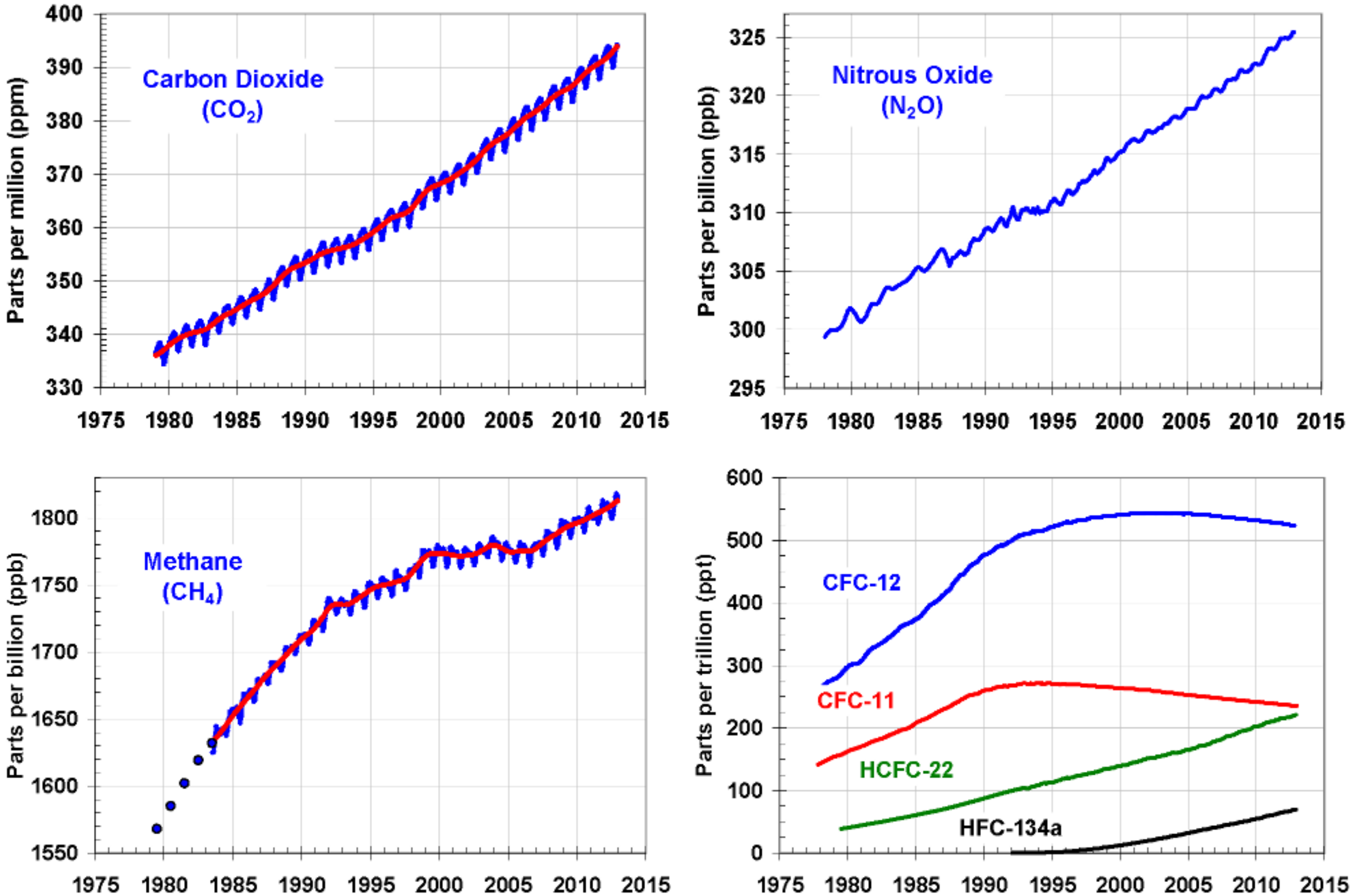
Motivation (4): Increasing Greenhouse Gas Concentrations



Boreal forests and woodlands store 30% of world's terrestrial carbon; possibly highly sensitive to warming, leading to feedback

Feedback processes

Many are driven by interactions between land, ocean, cryosphere, biosphere and atmosphere

Need to be quantified in Earth system models – but notoriously difficult

Requires interdisciplinary approach

Role of eScience

Data access: Nordic countries host globally important data bases (e.g., World Data Center for Aerosols; AEROCOM; ENSEMBLES), which shall be enhanced

Pre- and Postprocessing of model data becoming a bottleneck

Inverse modeling (greenhouse emission determination): algorithms reach computational limits

Earth System Models: full utilization of computer hardware a challenge (e.g., scalable algorithms)

Partnership: 13 partners from 7 Nordic countries, integration across three existing NCoEs (CRAICC, SVALI and DEFROST)

Country	Acronym	Institute	**Team leader**, *WP leaders*, some others
NO	NILU	Norwegian Institute for Air Research	***A. Stohl***, *I. Pisso, R. Thompson*, M. Cassiani, S. Eckhardt
DK	DMI	Danish Meteorological Institute	**Jens H. Christensen**, *S. Yang*, M. S. Madsen
DK	AU	Arctic Research Center, Aarhus University	**Mikkel P. Tamstorf**, M. Lund
FI	UHEL	University of Helsinki	**M. Kulmala**, *H. Järvinen*, *A. Lauri*, T. Vesala
FI	FMI	Finnish Meteorological Institute	***Hannele Korhonen***, *Tuula Aalto*, L. Backman
FI	CSC	CSC- IT Center for Science Ltd	**Antti Pursula**, *Thomas Zwinger*, P. Manninen
IS	UICE	University of Iceland	***Helmut Neukirchen***, Ebba Hvannberg
NO	UoO	University of Oslo	**Jon Ove Hagen**, *Anna Sinisalo*, T.V. Schuler
NO	MetNo	Norwegian Meteorological Institute	***Michael Schulz***, *Trond Iversen*, Ø. Seland
NO	BCCR	Uni Bjerknes Centre, Uni Research AS	**Helge Drange**, Mats Bentsen, Ingo Bethke
SE	SU	Stockholm University	***Ilona Riipinen***, *Peter Tunved*, R. Krejci
SE	LU	Lund University	***Torben R. Christensen***, L. Ström, M. Mastepanov
GL	GCRC	Greenland Climate Research Centre	**Søren Rysgaard**, John Mortensen

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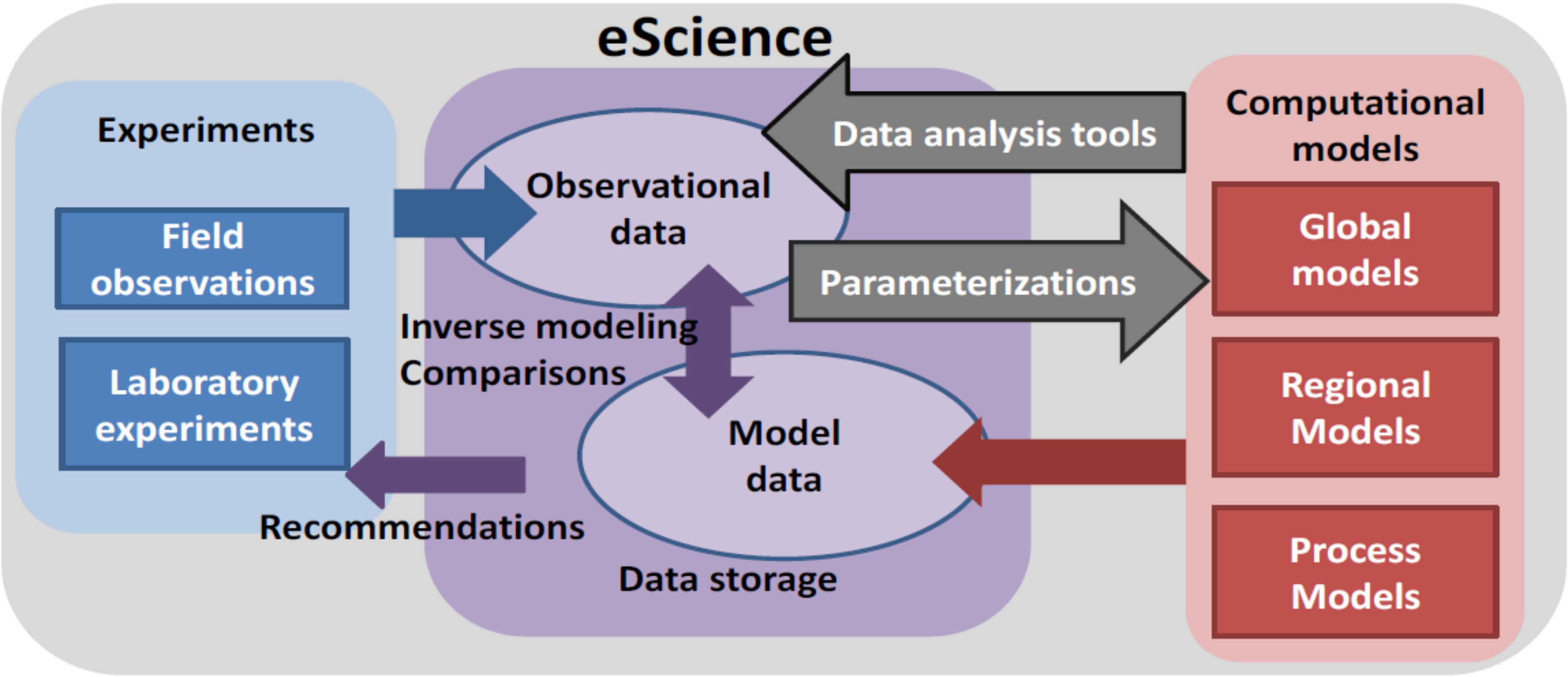
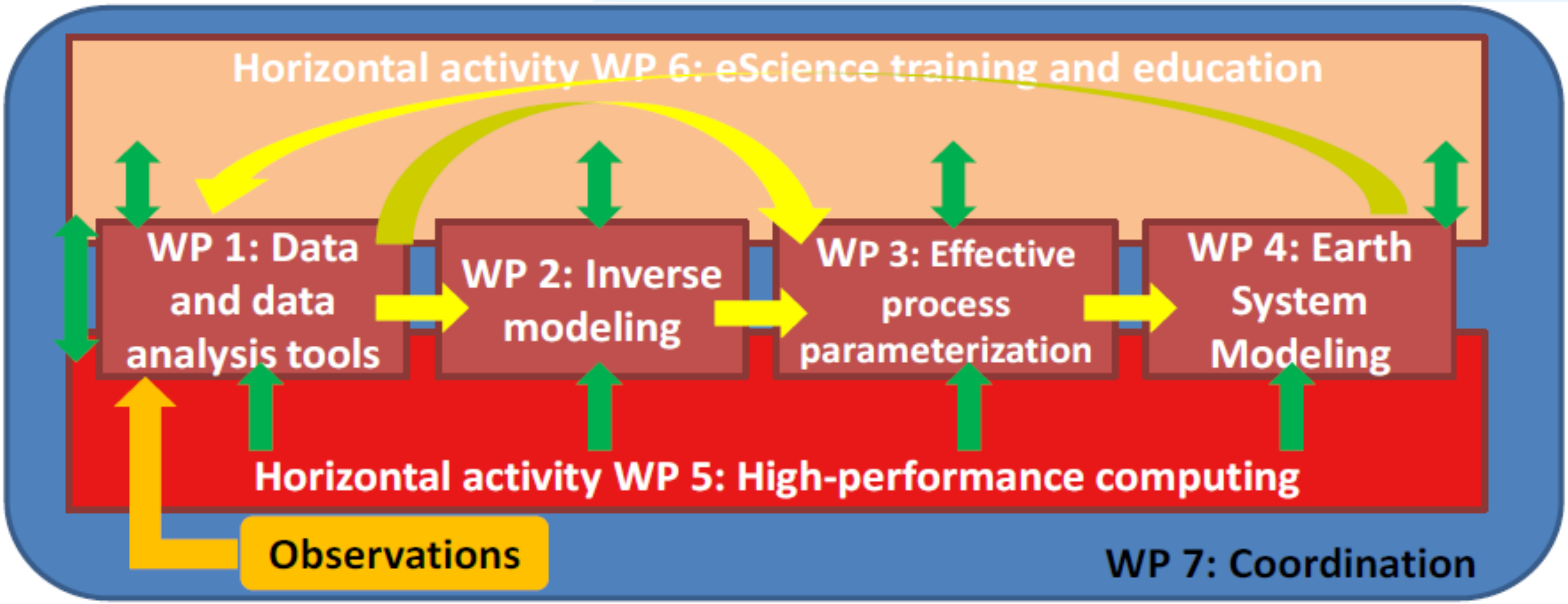
eSTICC

Overall eSTICC concept



eSTICC work packages and information flow



Databases

NILU as data centre for observations using different international protocols: databases of atmospheric composition (pH, GHGs, pollutants, aerosols)

EBAS (European Monitoring and Evaluation Programme – EMEP) more than 60 000 datasets (71 different countries, 1060 stations, 608 component types, 23 matrix types, 94 instrument types).

ACTRIS http://actris.nilu.no (Aerosols, Clouds, and Trace gases Research InfraStructure Network) more than 500 000 datasets

EVDC - ESA validation data centre (for satellites e.g. Sentinel)

Citi-sense

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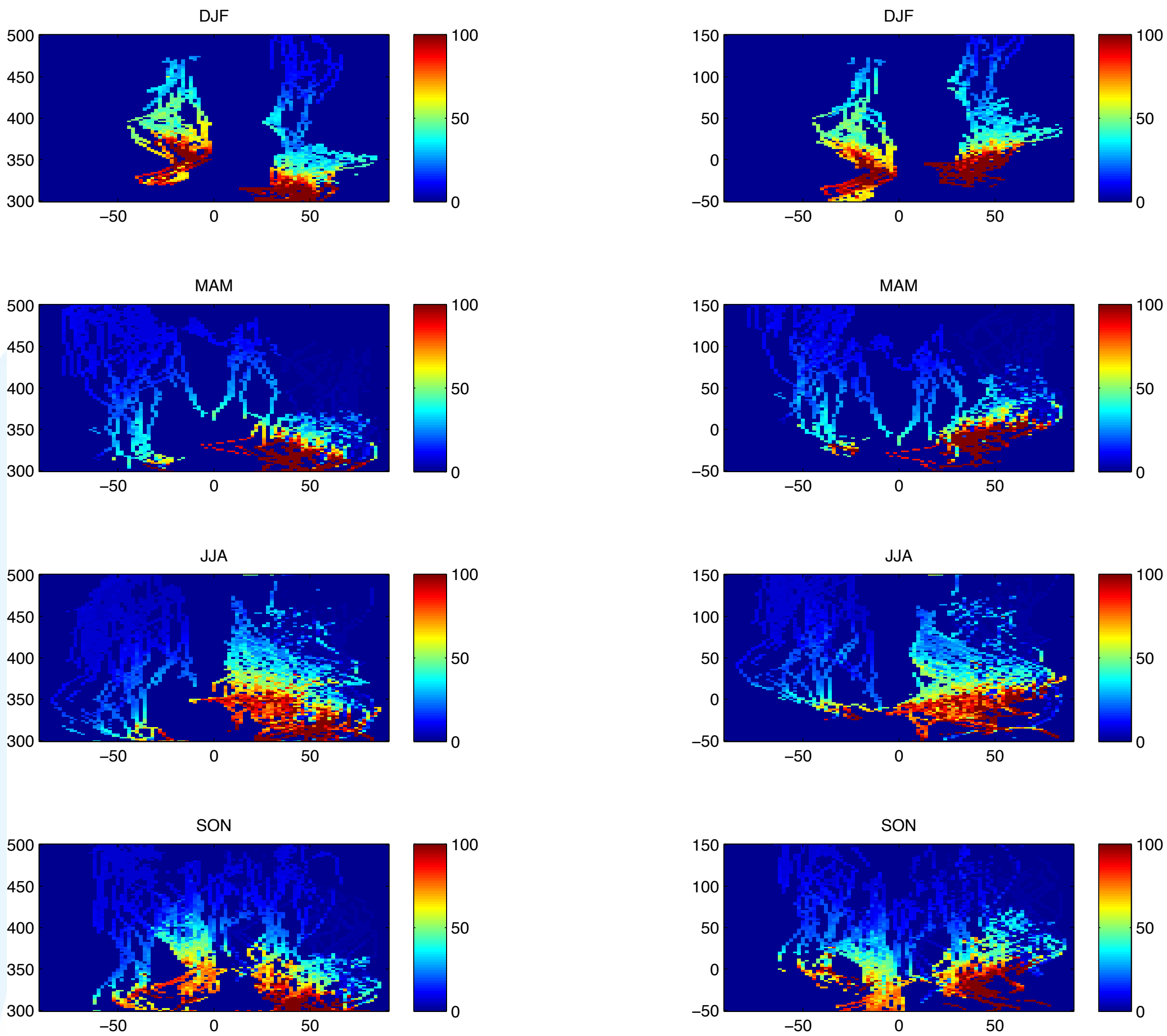
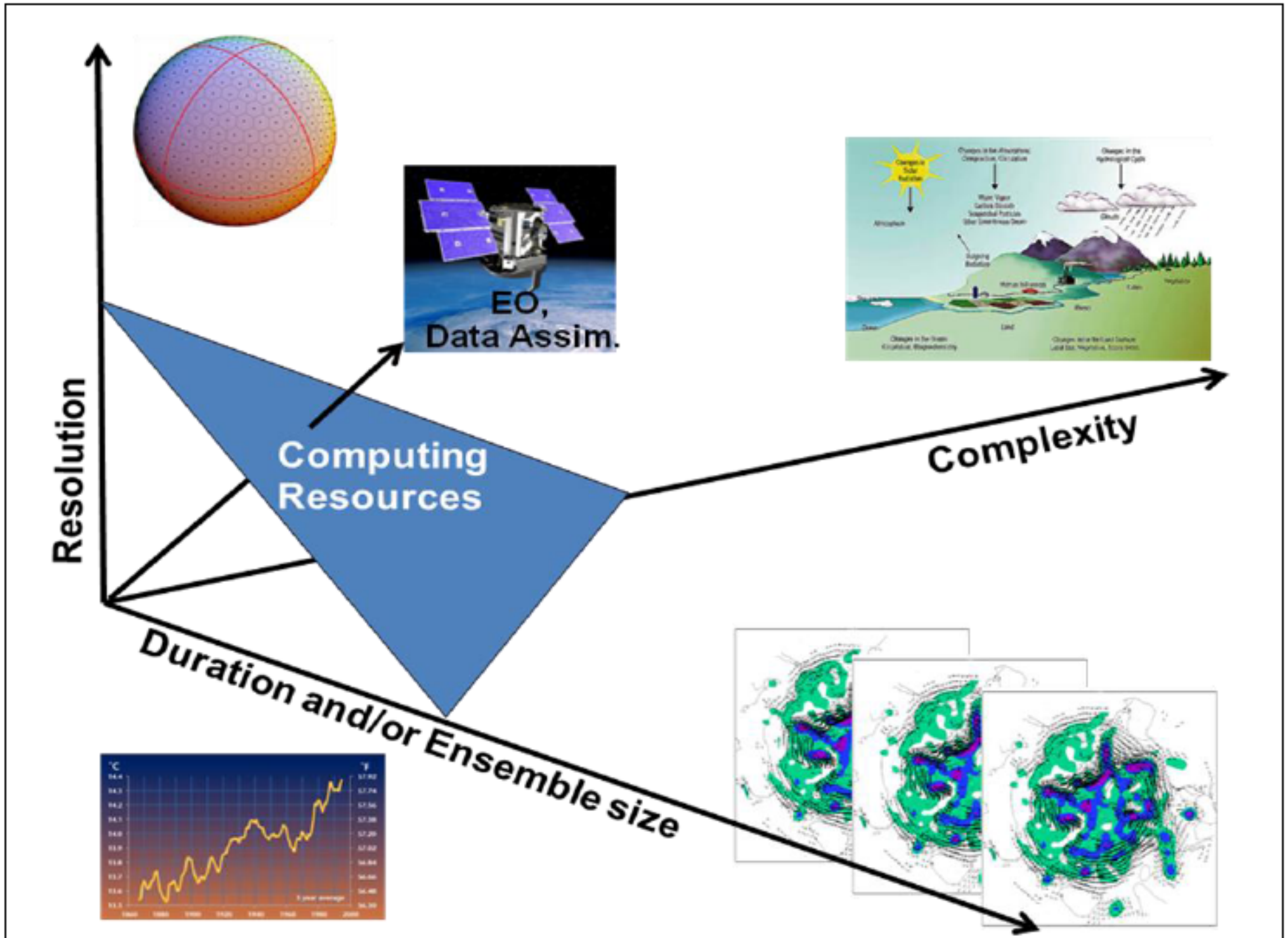
Example of data composite: UTLS CO

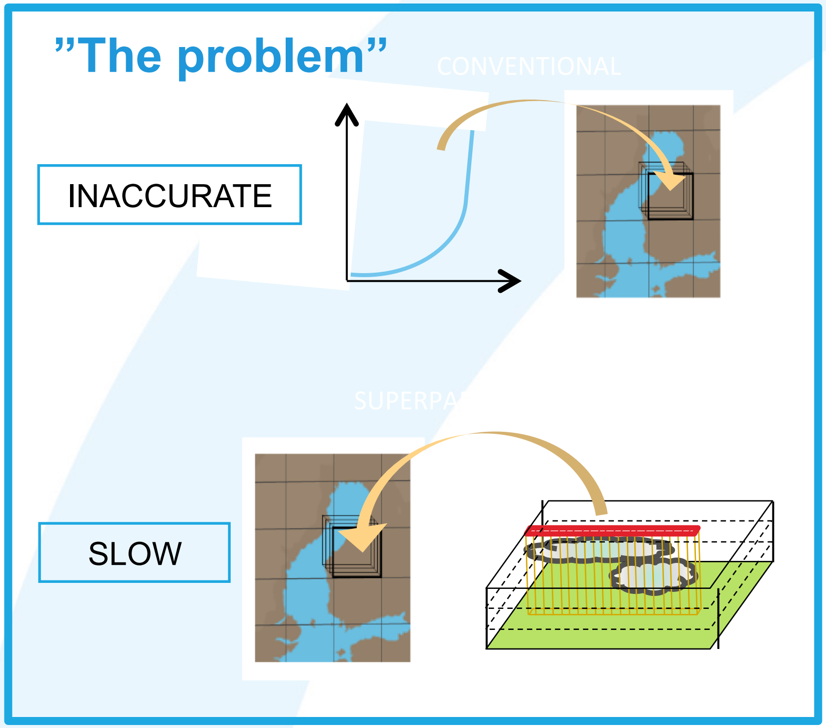


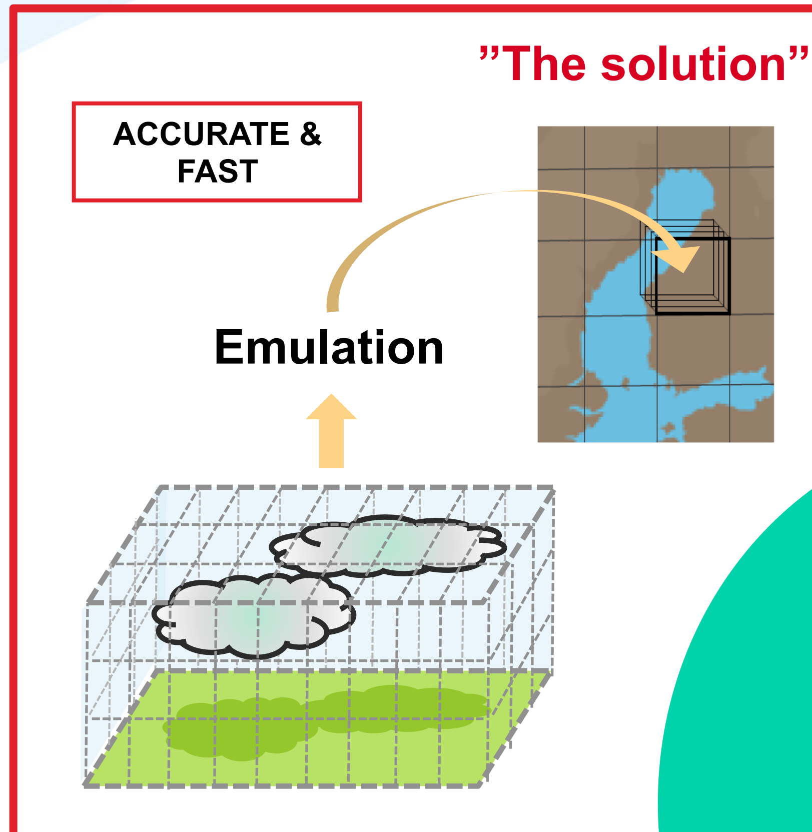
Computing resources for climate modeling are highly dependent on resolution, complexity, duration, ensemble runs and data assimilation



Jim Kinter. The world modelling summit

New parametrisations: emulation of sub-grid scale aerosol cloud interactions in climate models (H. Korhonen)





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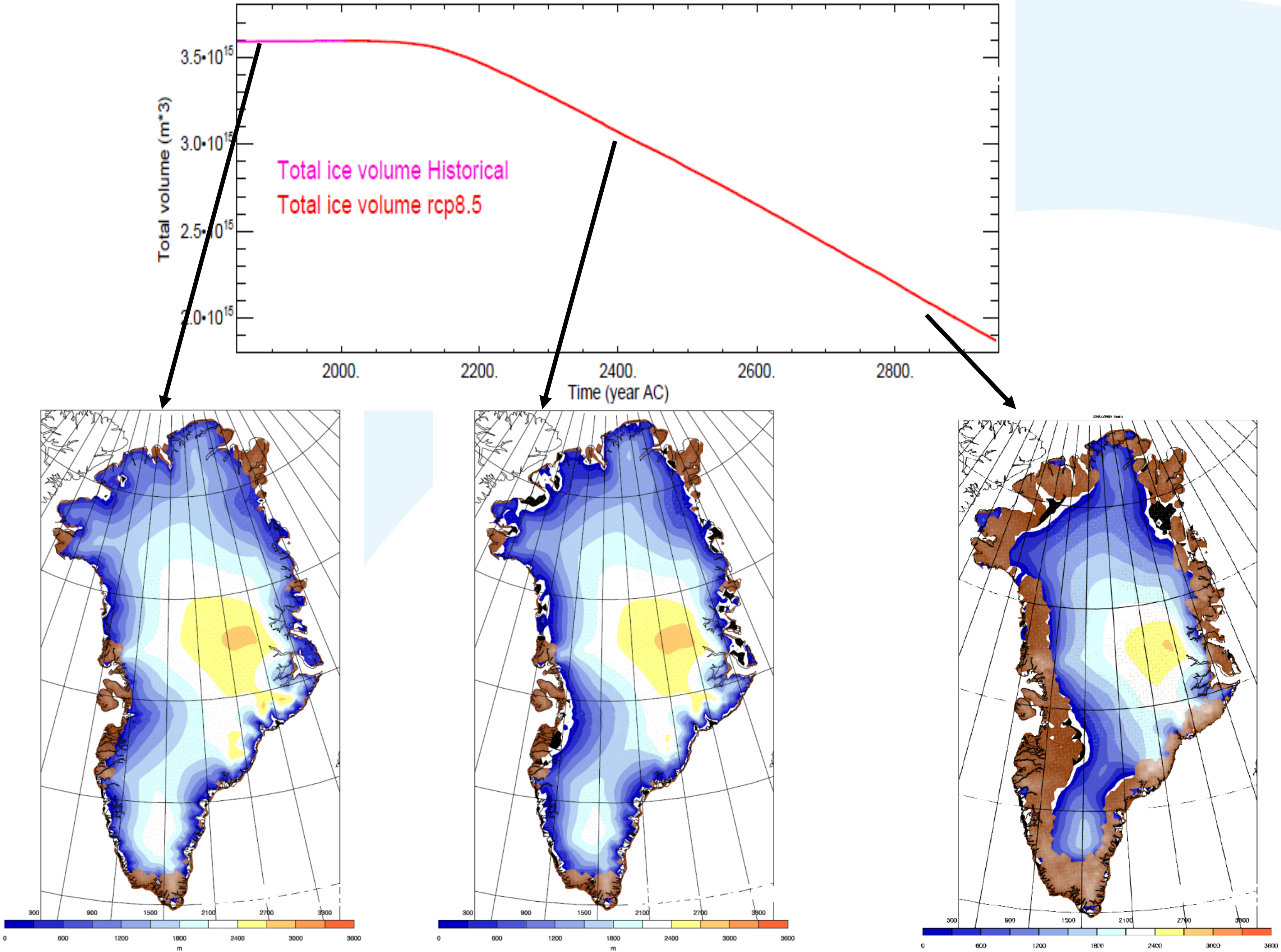
The Greenland ice sheet evolution



FLEXPART web products

http://niflheim.nilu.no/IgnacioPY/MAGIC/MAGIC.py

With Sabine Eckhardt and Andreas Stohl

Model set-up

The Lagrangian transport model FLEXPART can be run both forward (from sources) or backward (from measurement stations) in time, whatever is more efficient

e.g.: Backward in time for 20 days

Model output: 4-dimensional emission sensitivity field (3 space dimensions plus days backward in time)

Mixing ratio = emission sensitivity field x emission flux field

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Input data

Input winds from meteorological (ecmwf, ncep), climatic (NorESM) and mesoscale (WRF) models

ECMWF analyses:

Resolution 1x1 degree, but 0.1 x 0.1 degree in the area of interest

Large volume of data (1 file ~ 500 Mb, hourly resolution)

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Available products

The model output consists of a gridded 3-d response function to an emission input. The response function (emission sensitivity) gives the contribution (in ppb) a source of unit strength at a particular location would make at the measurement location

The response function is proportional to the total residence time of the particles on the 3-d grid

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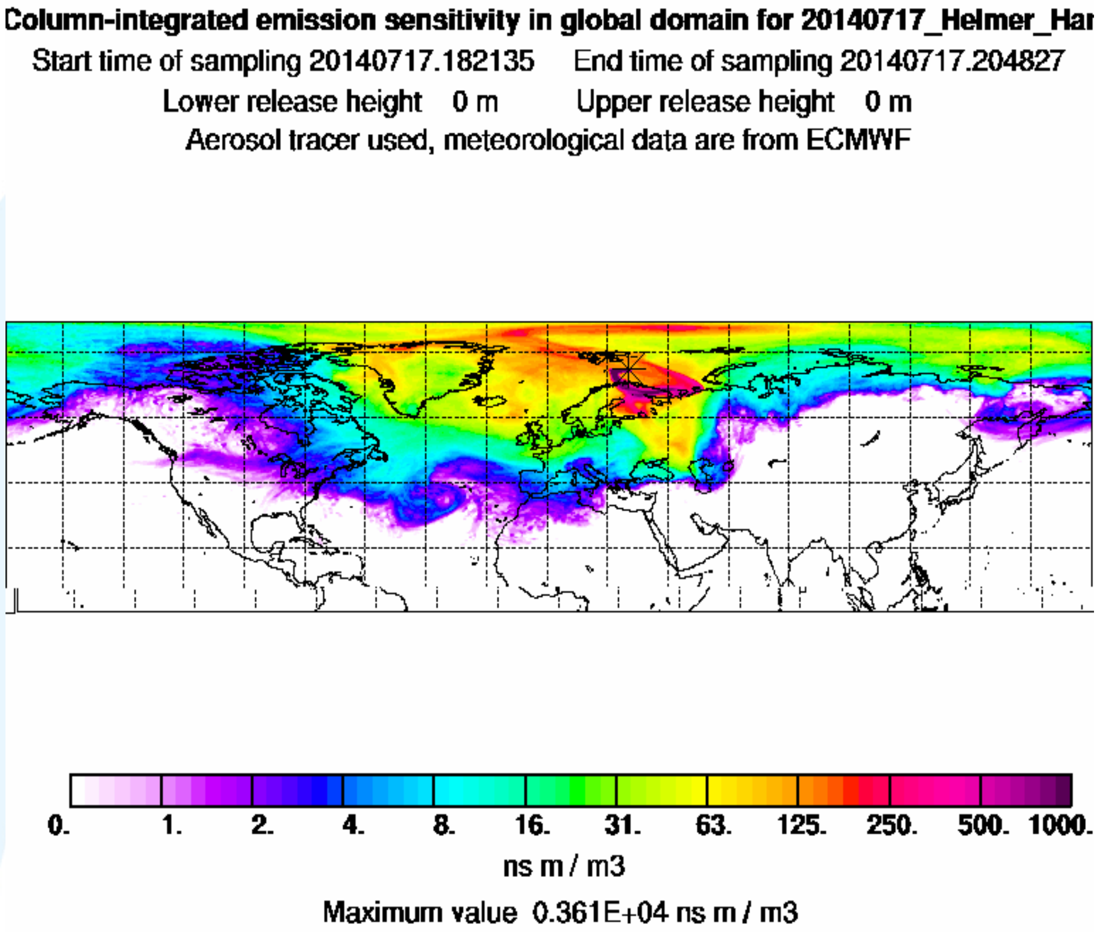
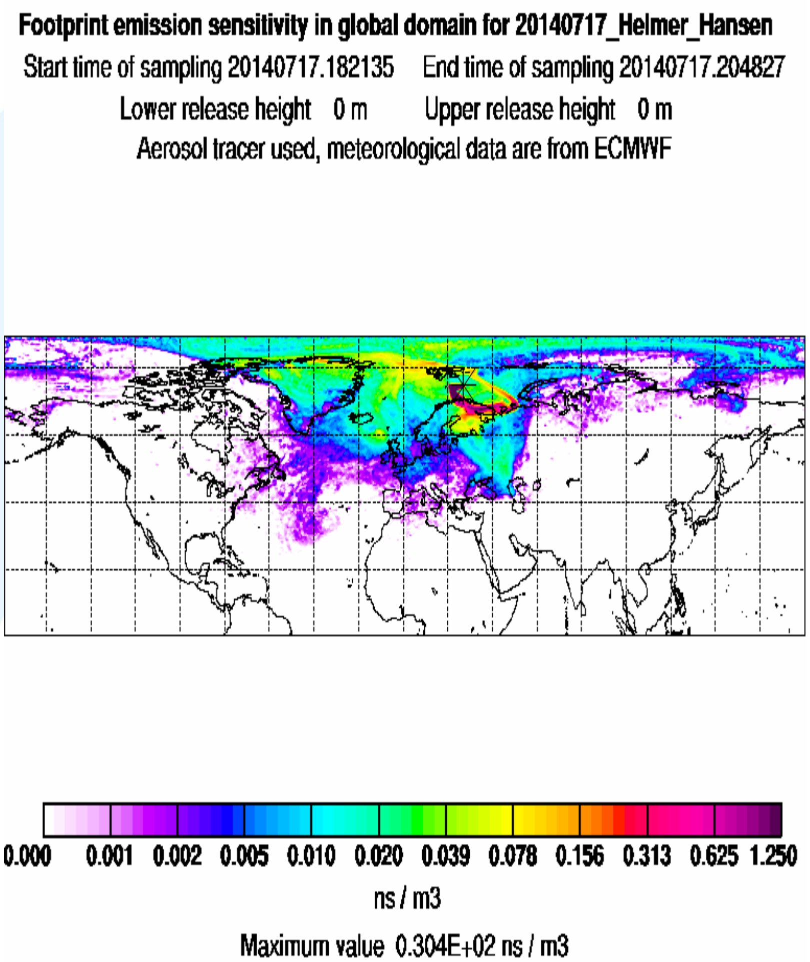
Available products

1. Column-integrated emission sensitivity: A first overview of where emissions could have influenced the air



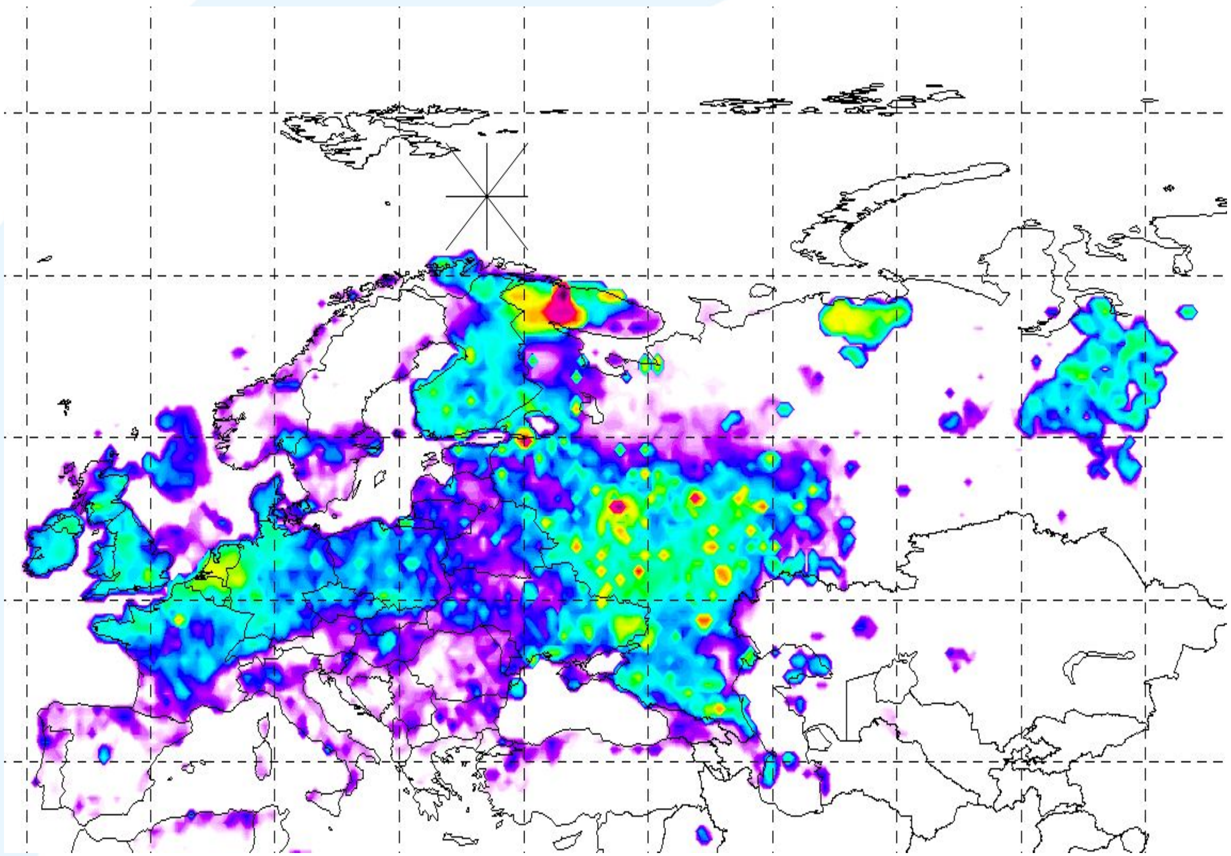
Available products

2. Footprint residence time: The residence time in the lowest 150 meters, because most anthropogenic emission sources are located there.



Available products

3. Source contribution maps for CH_4: The footprint multiplied with the anthropogenic emission flux from ECLIPSE inventory (17 July)



Inverse flux modeling

Optimal fluxes given by:

$$\min_x [(\boldsymbol{x} - \boldsymbol{x_0})^T \mathbf{B}^{-1} (\boldsymbol{x} - \boldsymbol{x_0}) + (\mathbf{H}\boldsymbol{x} - \boldsymbol{y})^T \mathbf{R}^{-1} (\mathbf{H}\boldsymbol{x} - \boldsymbol{y})]$$

where:

$\boldsymbol{y}$ = observations

$\boldsymbol{x_0}$ = prior fluxes

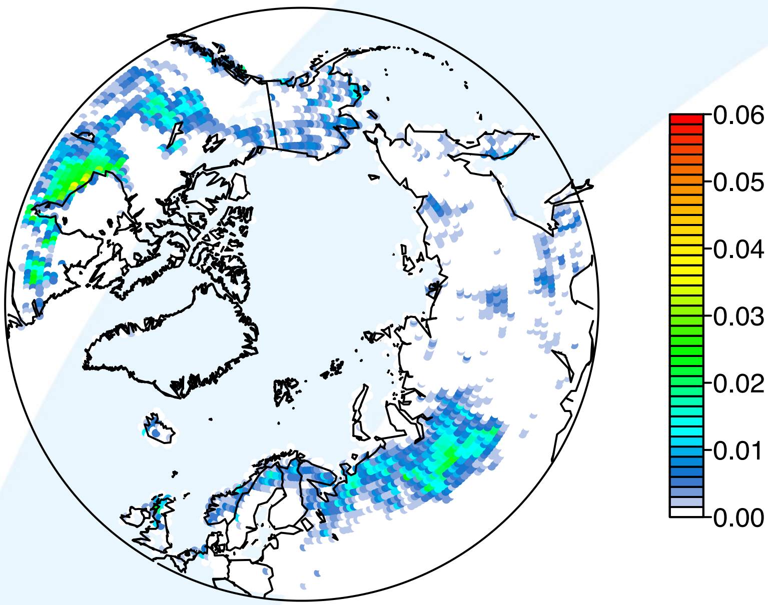
H = matrix of source-receptor relationships

B = prior flux error covariance matrix

R = observation error covariance matrix

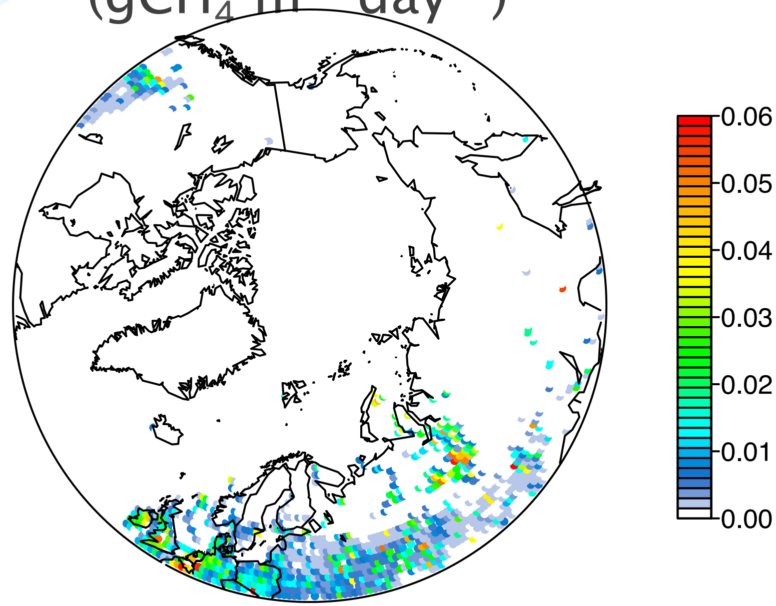
CH4 Prior flux estimates (R. Thompson)

Annual mean wetlands
($gCH_4\ m^{-2}\ day^{-1}$)



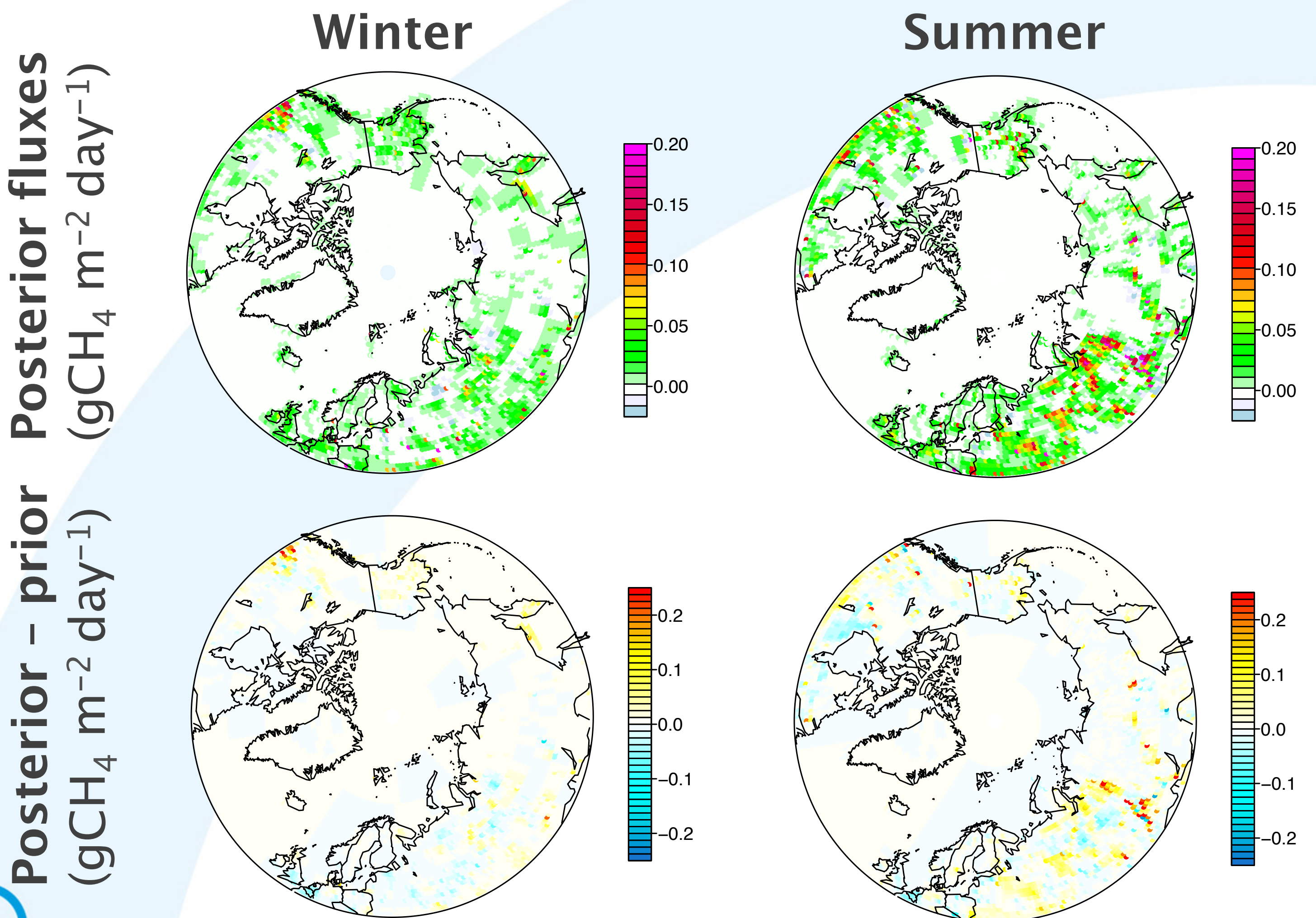
Bergamaschi et al. (2007)
Kaplan scheme implemented in the LPJ DGVM model

Annual mean anthropogenic
($gCH_4\ m^{-2}\ day^{-1}$)

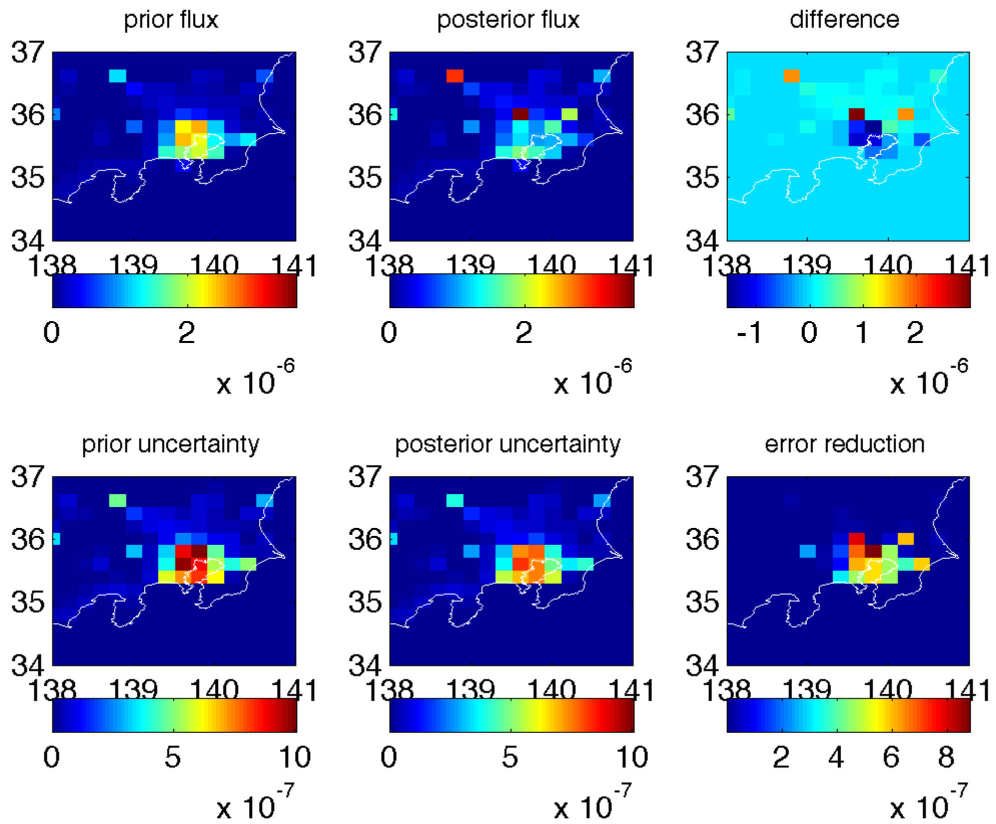


EDGAR-4.2 FT2010

CH4 Posterior fluxes (R. Thompson)



Anthropogenic CO2



Summary

- big storage volume
  - ESM modeling -> Lagrangian model input
  - Lagrangian model output
    - Analysis
    - Visualisation
- large speed of transfer/processing required
  - Inverse (and direct) modeling
  - Transfer and sharing of large datasets
- complexity of data
  - Different sources of measurements
  - Database harmonisation including model data (e.g. fluxes, footprints, sourece contributions)

Outlook

We need to upgrade our coding panoply

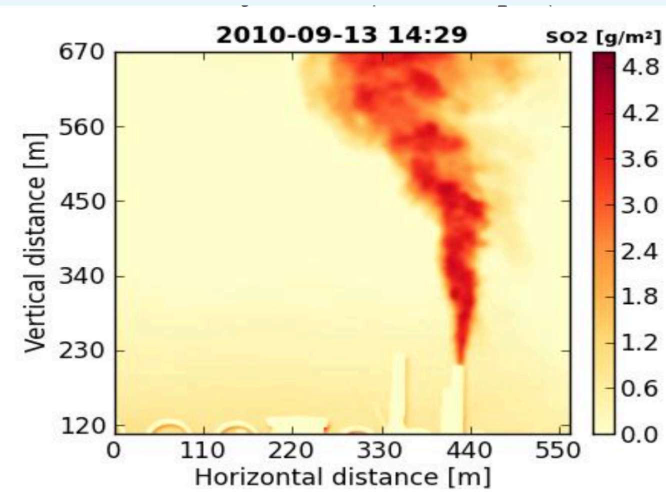
Better management of the databases of model output and measurement

Not always best practices. Other disciplines (e.g. machine learning) could provide some insights on good practices

COMTESSA

(Camera Observation and Modelling of 4D Tracer Dispersion in the Atmosphere)

Figure 2: Envicam-2 UV (blue) and NicAir-2 IR camera (on tripod), monitoring emissions from Bardarbunga volcano, Iceland.



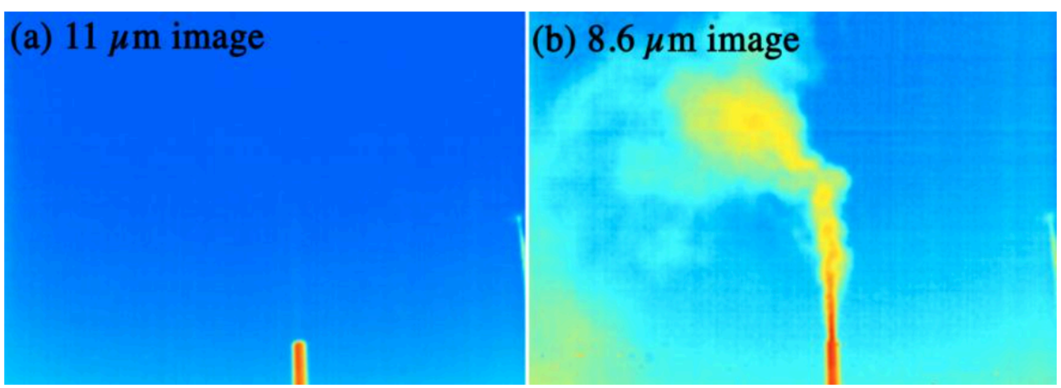


Figure 3. (a) IR camera image obtained at 11 μm of an SO_2 plume from a stack at an industrial smelter (aluminium). (b) Exactly the same plume but imaged at 8.6 μm, where SO_2 has a strong absorption. Combing these images allows the temperature and concentration effects to be separated.

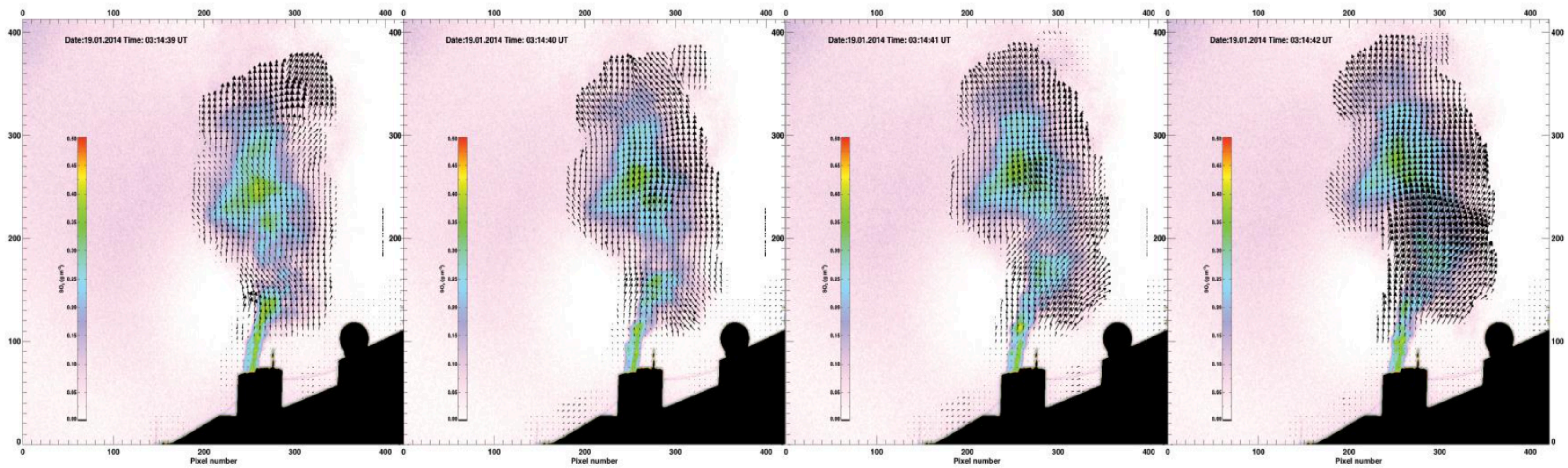


Figure 1. Sequence (~1 s time interval) of UV camera retrievals of SO_2 and velocity vectors for a ship plume.

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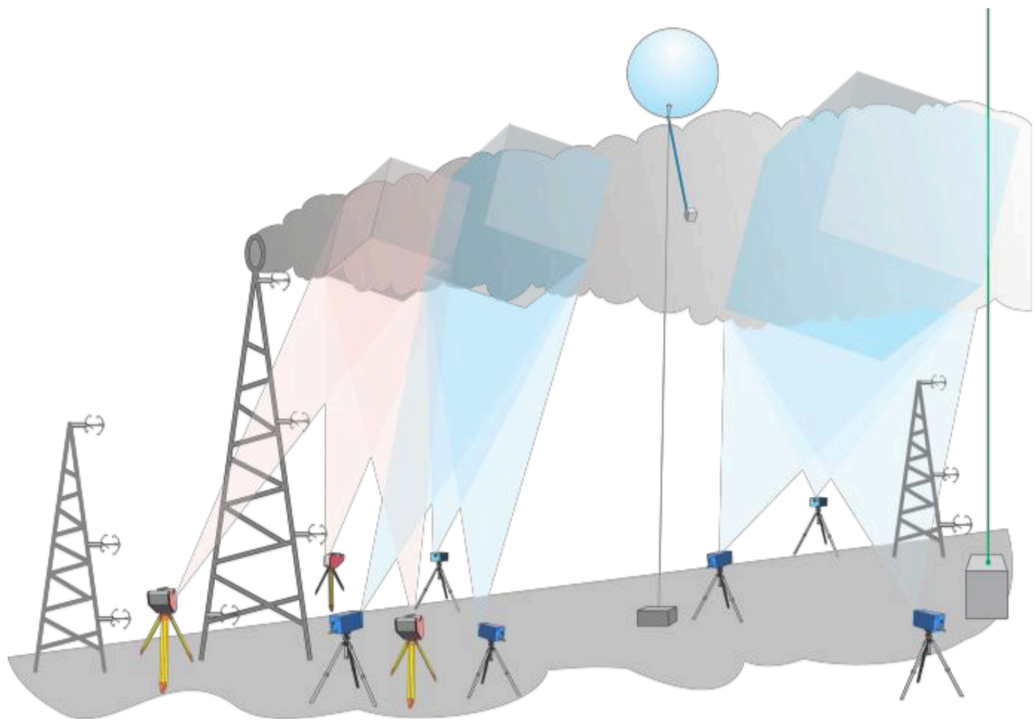

Fig. 3: Sketch of a plume measurement campaign with both UV cameras (blue) and IR cameras (red), as well as a ceilometer, instrumented masts and a tethered balloon.

Aim: time series of
3D tomographical
reconstruction
To validate
1024^3 LES simulations

Thank you!