Research Networking Programmes

Science Meeting – Scientific Report

The scientific report (WORD or PDF file - maximum of seven A4 pages) should be submitted online within two months of the event. It will be published on the ESF website.

***Proposal Title**: TransCom 2014*

Application Reference N°: 5476

1) Summary (up to one page)

The TransCom 2014 meeting brought together a wide range of researchers from the greenhouse gas inverse modeling community in Groningen, The Netherlands. This workshop marked the 13th of its kind since its conception in 1995, with previous assemblies held in Nanjing, Tsukuba, Melbourne, Fort Collins, Purdue, Paris, Berkeley, Utrecht, San Francisco, and Jena. The participants represented the continents we visited previously well, and also saw the usual good mix between PhD students, early career scientists, and more established researchers in the field. Communication was abundant, open, and in the general spirit of education and exchange that has been characteristic for the TransCom community.

The program consisted of three days of scientific presentations, interspersed with plenary discussions. Also, an ecological excursion to the nearby Wadden Sea, one of the largest intertidal wetlands of Europe, was organized. Presentations were divided over six themes: (1) the budget of methane, (2) new methods in inverse modeling, (3) use of satellite products, (4) urban GHG studies, (5) Transcom joint experiments, and (6) updates on global carbon budgets. In total, 30 talks of 15-20 minutes each were given.

Scientific highlights included novel views on the influence of satellite bias corrections on the CH4 budget, the first results from a global Lagrangian inverse modeling system, a new Bayesian approach to combine different information streams from GHG observations, new constraints on water-use efficiency of vegetation derived from $\delta^{13}C$, and high resolution (1km) modeling of urban and regional GHG balances.

In addition, the community received reports on a nearly finished joint activity that assesses boundary layer heights in inverse transport models, and on an inter comparison of CO_2 inversions with GoSAT remote sensing data. Finally, three new community projects were launched, one that focuses on the age of air in the troposphere, one that focuses on very reactive species, and one that aims to

combine many model results under a common umbrella including a web-based comparison tool.
Overall, the TransCom 2014 meeting was an overwhelming success and drew very positive responses from the participants.

2) Description of the scientific content of and discussions at the event (up to four pages)

We will discuss the scientific content following five of the six themes that were distinguished. The sixth, dealing with the TransCom community experiments, will be discussed under the next section on impacts and future directions.

Theme 1: The global budget of methane

Two talks in this session dealt with possible constraints from columns of CH4 measured by GoSAT. A comparison with SCIAMACHY suggests the products to be much better and have less bias. Nevertheless, treatment of bias remains a difficult challenge and multiple approaches are possible, each with an impact on the CH4 budget estimated. Two interesting regions are the USA and China. Over the US, the top-down atmospheric approach consistently changes CH4 emissions to be higher than the inventories, and to concentrate on areas with gas and oil exploration. In contrast, Chinese CH4 emissions appear overestimated due to too high emission factors for coal usage in the inventories. The latter has a substantial impact also on $\delta^{13}C$ measured in CH4, which by itself seems to support an increase of wetland emissions (an isotopically light source) over the latter half of the past decade. The atmospheric OH distribution and variations remain a large uncertain factor here.
A new Lagrangian CH4 model that runs on 1x1 degrees (FLEXPART v8), coupled to a Kalman smoother for inverse modeling, is undergoing system tests and is likely to contribute soon to the field of CH4 inverse modeling.

Theme 2: New methods and constraints in inverse modeling

A first innovation concerned the introduction of a better and faster variational optimization scheme in the NICAM model, suited for inversions using GoSAT CO_2 columns. Twin-experiments looked very promising in a near-perfect transport setup, suggesting that the Japanese group is getting close to having a full satellite inverse model system with high resolution globally. The Canadian met-office in the meantime is perfecting their ensemble Kalman smoother based setup, that aims to combine meteorological and GHG data assimilation. Mass-conservation, and the variations in air mass introduced through surface pressure analyses could be an issue they have to deal with though.
A comparison between 4dVAR and the ensemble Kalman filter setup was done through the CarbonTracker/TM5 setup used in the Netherlands. Main outcome of an experiment with two harmonized setups for CO_2 points to a large role for the choice of prior error correlation, and the transport window length. Tropical fluxes, least constrained by observations, appear the 'dumping ground' for fluxes needed to close the global balance in several approaches. The tropical fluxes are thus sensitive to transport errors, which were reduced in the LMDZ model based on plume rise modeling, with Large Eddy Simulations from Meso-NH as reference. Especially the variability and representation of extreme values of 222Rn improved, while known biases in north-south exchange were reduced, but not solved.
How to include such model errors in inverse problems was touched upon in a presentation focusing on a Bayesian approach that did not rely on Gaussian assumptions common to least-squares algorithms. With Markov-Chain methods, a

hierarchical system that includes fluxes as unknowns but also the shape of the flux uncertainty, or the model transport errors, can be minimized. This approach was shown to work well for a real tracer application. This relied on a very fast implementation of the transport model operator though, something that many applications do not have. Nevertheless, the approach opens a window of opportunity for specific situations where many instances of a flux/parameter/error model can be quickly and successively evaluated.

Yet another approach that tries to take advantage of specific observational constraints on the different components we simulate in a carbon balance is the French carbon cycle data assimilation (CCDAS) approach. Successive optimizations of a biosphere model against satellite data, eddy-covariance data streams and atmospheric observations show a large degree of consistency, and a gradual decrease of errors, residuals, and uncertainties. The optimized model can at various stages be independently assessed against other data, or models such as the TRENDY ensemble, or atmospheric COS mole fractions which specifically target simulated global primary production (GPP).

Other constraints on GPP, and then specifically its efficiency under drought conditions, were derived from $\delta^{13}C$ in CO_2 observations using the CarbonTracker system. Optimizations suggest that when $\delta^{13}C$ is allowed to inform not just on changes in terrestrial net ecosystem exchange (NEE), but also on discrimination against the heavier isotope of CO_2, a consistent picture emerges of larger water-use efficiency during droughts than predicted by the common Farquhar/Ball-Berry equations included in SIBCASA. This implementation is shared by many other land-surface exchange models and improvements based on $\delta^{13}C$ could be an important new use of this tracer.

From the ocean perspective, finally, a new method to interpret pCO2 in surface water measurements was demonstrated, using inverse modeling to close the carbon budget of the ocean surface mixed-layer. In an innovative approach, seasonal cycles of ocean carbon exchange, as well as long-term mean uptake and variability was obtained that very closely agree with independent constraints. These included both ocean observations and atmospheric O2/N2 ratios.

Theme 3: Satellite data constraints

In the satellite session, we were given an overview of the current status of GoSAT, the most successful instrument to provide column CO_2 from space. Over time, biases compared to the TCCON network have decreased substantially, but gaps in the coverage due to clouds over the Amazon remain an issue. GoSAT is expected to provide a few more years of observations, alongside the new OCO-2.

The data is used intensively in inverse modeling, such as by the Japanese meteorological agency in their Bayesian synthesis inversion that also includes aircraft data. An ensemble based update of the surface fluxes, following correction of the GoSAT data with their transport model, provides surface fluxes that are forced to be consistent, and bias free. Whether such biases indeed can be reduced using models and aircraft data alone can be tested with the new AirCore measurements, such as done at the Finnish Sodankyla site. Preliminary results suggest that the TCCON columns, widely used to calibrate the satellite products, might suffer from small, but seasonal, biases themselves. The prior CO_2 profiles used in the TCCON retrieval are likely part of the problem as agreement with AirCores taken during 'special' conditions inside the polar vortex was worst. Plans for further tests are unfolding, as steadily a new XCO2 record based on true air-measurements is being built with AirCore.

Theme 4: Urban and regional inverse modeling

The first talk on regional modeling again focused on transport issues in the model. Within WRF, two schemes for vertical mixing in the planetary boundary layer were compared with two sets of surface fluxes and differences were found comparable. In an even larger ensemble study with 27 members, no clear best configuration of transport/fluxes could be identified when comparing to the data from the mid-continent intensive study in the US. Only simulated PBL depth seemed a good indicator of model performance, stressing its importance for CO_2 studies.
The dominance of fossil fuel emissions on smaller scales near populated areas was investigated for Europe, using the Swiss COSMO model at 7km resolution. In many areas, the variance of total CO_2 is highly dependent on fossil fuel derived CO_2. This is true for the diurnal time scales, but also for synoptic scales at certain sites. The use of temporal profiles for emissions was shown to improve the comparison to observations. In addition to temporal profiles, detailed spatial emissions such as derived through Hestia for Indianapolis were shown to leave detectable imprints on atmospheric CO_2, when modeled with WRF and STILT to generate footprints for measurements near this large city. The difference between various bottom-up estimates, and even different years of the same product, could even be told from an inversion. This is good news for future satellite missions such as Carbosat that aim to constrain urban GHG budgets from space. First efforts to predict the expected signals for an inverse application of Carbosat data were shown.

Theme 5: Update on global carbon balances

This session opened with a fresh look at the changing seasonal amplitude of CO_2 at sites in the northern hemisphere, previously described in Graven et al.. Using a different set of transport, fossil fuel, and biosphere models it was demonstrated that fossil fuel emissions cannot be responsible for the observed increase, and a large role for the biosphere is needed to explain the observations. Long time series are needed for such an analysis, because variability such as for instance due to the 2012 North American drought is large. The use of multi-model ensembles was taken to the next level at NOAA ESRL, where the new release of CarbonTracker uses 16 members that vary in ocean, biosphere, and fossil emissions as well as transport model configuration. This in an attempt to put better uncertainty ranges on the inferred surface fluxes of CO_2. A similar effort based on a comparison of different inverse models from Europe, North America, Australia, and Asia drew much interest too. These results were put into an online comparison platform along with vegetation and ocean model results. Asia, where flux estimates traditionally differ due to sparse data coverage, will become part of a separate inter comparison under TransCom. Finally, first results were shown for new flux estimates from South America using new aircraft data recently published in Gatti et al.. Their estimates of the changing carbon balance during the 2010 drought were partially confirmed by inverse modeling, but depend strongly on the fire emissions that can be derived from different sources.

3) Assessment of the results and impact of the event on the future directions of the field (up to two pages)

During two sessions, progress on various TransCom joint activities were discussed. In addition, various new initiatives were proposed and received with enthusiasm. This suggests that this meeting will lead to new activities for the next years. Specifically, we discussed:

(a) The Planetary Boundary Layer experiment is nearly finished and a draft paper will be circulated soon. Many groups participated and some even with multiple model configurations. An analysis shows that all models overestimate the nocturnal PBL height, and also each model seems biased in their representation of daytime PBL heights. Interestingly, the ensemble mean reproduced observations best.
(b) Twelve models are participating in an experiment focused on Very Short Lived Species, with the focus now on CHBr3 and CH2Br2. A paper is in preparation showing comparisons to different surface and aircraft data
(c) The Asia region is developing quickly both in terms of its GHG balance, and its monitoring capacity. A closer inspection of model-model differences in this region was proposed, and will be lead by Prabir Patra. Several groups will deliver results to compare to new and existing measurement programs in the area.
(d) The use of "age-of-air" tracers was demonstrated through a small demo-experiment with four models, and drew much interest. This metric can be used alongside traditional pieces of information such as the tropical-NH dipoles, and rectifiers, to better characterize transport differences between models. An experiment with a simple protocol will be proposed by Maarten Krol
(e) From the satellite inverse perspective, there is room for further comparison of model results, but then focusing on interannual variability instead of mean fluxes. Several longer record are now available for the groups that already contributed, and more groups have developed inverse modeling capacity since then.
(f) For both CH4 and CO_2, further integration of different model outcomes was deemed necessary. The Global Carbon Project is one effort to leverage, and in addition local repositories are setup mainly in France to facilitate comparison. Also smaller comparison activities from EU projects could be helpful by allowing other estimates on board. Typically, simple output protocols suffice.

Overall, these discussion points will lead to a number of new TransCom activities. The lack of organized funding means that these will depend on the efforts of individual PIs to organize these. Considering that this working mode has been quite successful for the past 10 years, we are confident this meeting will again mark an advance in our collaborations in GHG inverse modeling.

4) Annexes 4a) and 4b): Programme of the meeting and full list of speal and participants

Tuesday, June 24th
First day

09:30 – 10:00	Welcome with coffee & tea
10:00 – 12:00	Session: Understanding the budget of methane.
Slot 1	**Houweling** Intercomparison of CO_2-intervensions using satellite retrievals from GOSAT.
Slot 2	**Arfeuille** Lagrangian modeling of methane (MAIOLICA II project).
Slot 3	**Bergamaschi** Inverse modeling of global CH_4 emissions using different satellite retrieval products from GOSAT and SCIAMACHY.
Slot 4	**Bousquet** Global methane budget: recent trends and GCP synthesis effort.
Slot 5	**Monteil** Identifying model and observation biases in GOSAT xCH_4 inversions using the TM5 transport model.
12:00 – 13:30	**Lunch**
13:30 – 15:00	Session: New methods in inverse modeling.
Slot 1	**Niwa** A variational inversion system with an icosahedral grid atmosphere model.
Slot 2	**Rigby** Hierarchical Bayesian methods for uncertainty quantification in inverse modeling.
Slot 3	**Polavarapu** A coupled meteorology-tracer assimilation system for flux inversion.
Slot 4	**Babenhauserheide** Comparing surface flux inversion of Carbontracker and TM5-4DVar.
15:00 – 15:30	Coffee break
15:30 – 16:00	**Locatelli** Atmospheric transport and chemistry of trace gases in LMDz5B: evaluation and implications for inverse modeling.
16:00 – 17:30	Session: Transcom: ongoing and new activities.
Slot 1	**Jacobson** Report on the PBL activity.
Slot 2	**Krysztofiak** Model intercopmarison of very short-lived substances (VSLS): Overview & preliminary results from TRANSCOM-VSLS

Wednesday, June 25th
Excursion + dinner

09:00 – 10:30	Session: New constraints in inverse modeling.
Slot 1	**Van der Velde** New atmospheric constraints from $\delta^{13}C$ of CO_2.
Slot 2	**Peylin** The LSCE CCDAS approach.
Slot 3	**Gerbig** Joint CO_2 and APO inversions for air-sea carbon exchange.
Slot 4	**Chen** Aricore CO_2 and CH_4 profiles from Finland.
11:00 – 11:15	Coffee break

11:15 – 12:30		Session: Interpreting satellite data constraints.
	Slot 1	**Maki** The impact of satellite bias correction in CO_2 data assimilation .
	Slot 2	**Maksyutov** Recent developments in inverse modeling of CO_2 and CH_4 fluxes using G observations in NIES.
	Slot 3	**Houweling** The use of OSSEs to support the design of new satellite missions.
12:30 – 13:30		Take-away lunch
13:30 - …		Excursion + dinner

Thursday, June 26th
Final day

09:00 – 10:30		Session: Regional and urban inverse modeling.
	Slot 1	**Butler/Diaz** Diagnosing atmospheric transport model error contributions to CO_2 model-data residuals in North America.
	Slot 2	**Yu** Modeling anthropogenic CO_2 in Europe using a high resolution atmospheric model.
	Slot 3	**Janardanan** Atmospheric CO_2 using high resolution meteorology and flux maps.
	Slot 4	**Pillai** Tracking major city emissions of CO_2 from space: a high resolution inverse modeling approach.
10:30 – 11:00		Coffee break
11:00 – 12:30		Session: TransCom: ongoing and new activities
	Slot 1	**Krol** Lifetime tracers: a general diagnostic for atmospheric transport. General discussion afterwards.
12:30 – 14:00	Lunch	
14:00 – 17:00		Session: Updates on global and regional C budgets.
	Slot 1	**Peylin** Multi-model carbon budgets from GEOCARBON.
	Slot 2	**Patra** Greenhouse gases budgets of the tropical and temperate Asia.
	Slot 3	**Taguchi** Seasonal amplitude of CO_2 simulated with stationary natural flux and growing anthropogenic flux.
	Slot 4	**Peters** Inverse modeling of the Amazonian carbon balance.
	Slot 5	**Jacobson** N/A
17:00 – 17:30		Closing and goodbye

Annex 4b: Full list of speakers and participants

Title	Full Name	Gender	Affiliation
Doctor	Huilin Chen	M	University Of Groningen
Professor	Wouter Peters	M	University Of Groningen
Ad. Professor	Saroja Polavarapu	F	Environment Canada
Doctor	Heather Graven	F	Imperial College London
Mister	Yousuke Niwa	M	Meteorological Research Institute
Doctor	Prabir Patra	M	Research Institute for Global Change
Doctor	Matthew Rigby	M	University of Bristol
Mister	Takashi Maki	M	Meteorological Research Institute
Doctor	Gisele Krysztofiak	F	Karlsruhe Institute of Technology
Mister	Yu Liu	M	Swiss Federal Institute of Technology Zürich
Doctor	Dhanyalekshmi Pillai	F	Universität Bremen
Doctor	Tatsuya Yokota	M	National Institute for Environmental Studies
Professor	Martin Heimann	M	MPI for Biochemistry, Jena, Germany
Doctor	Shamil Maksyutov	M	National Institute for Environmental Studies
Doctor	Shoichi Taguchi	M	National Institute of Advanced Industrial Science and Technology
Mister	Rajesh Janardanan Achari	M	National institute for environmental studies, t
Professor	Maarten Krol	M	Wageningen UR
Miss	Marie Combe	F	Wageningen UR
Doctor	Zhen Zhang	M	Swiss Federal Institute for Forest, Snow and Landscape Research WSL
Mister	Gregoire Broquet	M	LSCE
Doctor	Martha Butler	F	Penn State University
Professor	Philippe Bousquet	M	IPSL/LSCE
Doctor	Thijs van Leeuwen	M	SRON netherlands institute for space research
Mister	Philippe Peylin	M	LSCE
Doctor	Thomas Lauvaux	M	Penn State University
Mister	Robin Locatalli	M	LSCE
Mister	Ivar van der Velde	M	Wageningen UR
Doctor	Florian Arfeuille	M	EMPA, Switzerland
Mister	Sudhanshu Pandey	M	SRON netherlands institute for space research
Mister	Guillaume Monteil	M	IMAU/SRON
Mister	Andy Jacobson	M	University of Colorado and NOAA Earth System
Miss	Liza Diaz-Isaac	F	Penn State University
Miss	Linda Kooijmans	F	University Of Groningen
Mister	Wei He	M	University Of Groningen
Doctor	Cristoph Gerbig	M	BGC Jena