Quantification and attribution of regional greenhouse gas sources using trace gas measurements

Breakout session description

- Trace gases are a powerful tool for both attribution of CO2 and CH4 sources and sinks, and for evaluation of CO2 and CH4 flux estimates.
- A variety of gases can be used to identify natural and anthropogenic sources and sinks.
- Planned or opportunistic trace gas releases whose magnitude is known can be used to evaluate and possibly calibrate CO2 and CH4 flux estimates.
- Barriers to widespread use of these methods include
  - uncertain source ratios,
  - limited trace gas analytic capacity,
  - expense of wide-area, long-term experimentation, and
  - lack of knowledge of existing tools.

Breakout objectives

- Barriers to widespread use of these methods include
  - uncertain source ratios,
  - limited trace gas analytic capacity,
  - expense of wide-area, long-term experimentation, and
  - lack of knowledge of existing tools.
- This breakout will provide a brief review of the state of the art in this field and then open a moderated discussion to identify the outstanding needs and opportunities in this field. The breakout will attempt to identify
  - advances in measurement technology,
  - expansion of field networks,
  - future field experiments, and
  - observational design studies

needed to improve both attribution and uncertainty assessment.

Current state of knowledge

- Biogenic CO2
  - 13CO2, O2
  - 13CO2 is difficult to interpret. Measurement density is limited.
- Fossil CO2
  - 14CO2, CO
  - 14CO2 is very expensive. CO is a very messy tracer
- Methane
  - 13CH4, ethane
  - Difficult disaggregation.
  - Difficult, expensive sensors
- Planned release tracers
  - N2O, SF6, perfluorocarbons
  - Difficult, expensive sensors
  - Expensive to create large-area, long-term releases
- Methods for integrating these gases into atmospheric inverse methods are not well developed in many cases.

What is needed? What are the most important targets and opportunities?

- Improve uncertain source ratios
- Improve limited trace gas analytic capacity / Advance measurement technology
- Reduce expense of wide-area, long-term experimentation
- Improve knowledge of existing tools.
- Expand field networks,
- Deploy and design future field experiments

Goals: improve attribution and reduce flux uncertainty.

Attendance and topics for discussion

Concept of tracer:tracer method

- Relating single species (e.g. CO2ff) atmospheric measurements to emission flux relies heavily on the quality of the atmospheric transport model
- If emission flux of one tracer is known then tracer:tracer relationship can determine emission flux of second gas (emission ratio is preserved)
  - reduces reliance on models, since the emission ratio will be preserved even if model transport is biased.
  - Model still needed to get approximate footprint area.
- Can use tracer:tracer relationships to partition source sectors.
  - E.g. CO co-emitted with CO2ff, almost exclusively from vehicle sector.
  - If know emission ratio for each sector, can determine the fraction of CO2ff from vehicles.

Jocelyn Turnbull

Current limitations and potential solutions

- Uncertain trace gas emissions and source ratios
  - E.g. CO – USEPA NEI inventory is much too high.
  - Inventories for many other species (eg halocarbons) are very simple spatial allocations of reported national totals – likely quite wrong at the urban scale
  - Measurement at source – e.g. side-of-highway measurement of CO:CO2ff ratio from traffic.
  - More effort into improved inventories for trace gases.
- Limited analytical capability
  - Especially for 14C/fossil fuel CO2!
  - Most labs can only measure a subset of the trace gases of interest
  - Most trace gases still limited to flask sampling and laboratory measurement
  - Focus on trace gases that can be measured in situ and/or are readily measured – e.g. CO, acetylene
- Spatial and temporal resolution of trace gas inventories and observations need to be recounciled
  - Urban areas are heterogeneous
  - Each sampling location/time sees a subset of the urban area
  - First attempt at modelling tracer ratios (Thomas Lauvaux)

Jocelyn Turnbull

What is needed? What are the most important targets and opportunities?

- Improve uncertain source ratios
- Improve limited trace gas analytic capacity / Advance measurement technology
- Reduce expense of wide-area, long-term experimentation
- Improve knowledge of existing tools.
- Expand field networks,
- Deploy and design future field experiments
- How can we deal with covariances in tracer ratios?
- Use the tracers to evaluate transport model errors.
- Must understand measurement biases and errors, which may differ with different tracers. And consider tracer lifetimes, thus extent of application.

Goals: improve attribution and reduce flux uncertainty.

Suggestions for progress

- Use atmospheric transport fields to predict expected spatial and temporal variability in tracers…design observational requirements. Develop objective methods for model-data comparisons.
- Urban scale – strengths and weaknesses of various approaches.
- Consider data assimilation and inversions with tracers. Evaluate transport fields with trace gases?
- Perfluorocarbons. Wish to make release/sample systems remote – enable less costly field experiments. Numerical or observational experiments. NARAC has done some of this with SF6 for accidental releases. Are these comparable? Or are new projects warranted? Scales of several 100's of km to a few 1000 km possible with PFCs.
- SF6 history of evaluation of transport modeling (global scale). Take care with transport / flux covariances.
- Issues to consider with regional scales and how to assimilate multiple data sources – what methods are needed?

more

- Other remote sensing of trace gases where we know emissions ratios? Relationship to GHGs? Atmospheric chemistry remote sensing – blend into GHG data assimilation and inversions – does that bring benefit or not? Experiment. Parallel with air quality at local scales?
- NO2, ozone and formaldehyde with 4km , hourly resolution – TEMPO + similar instruments over Asia and Europe? UV/Vis spectrometers. Maybe ammonia from IR. CO, CH4? GOSAT2 – CO, CO2.
- Break down the carbon / chemistry divide, particularly long-term satellite mission planning.
- Co benefits of reducing GHG emissions and improving air quality.
- Urban scale – open path absorption methods? Many gases, "local remote" sensing. Ground based or aircraft, sideways or vertical pointing. Try at the ground with available tech first.
- What can we add to existing experiments? E.g. influx, LA-megacities.
- Inversions with known sources and sinks? Inversions over known experimental modifications of fluxes. Policy changes altering fluxes?
- Perfluorocarbon experiment with fluxes that change over time…try to solve for this from an urban inversion. Bay area – changes in traffic emissions from vehicle fleet changes – try to detec.

more

- INFLUX – main power plant is changing from coal to natural gas…other experiments like this that might provide a test bed? Transport tracer = plume at different distances?
- Urban – within the emitting area – not a well mixed ABL… approaching the flux tower / turbulence / LES zone. New analyses needed?
- How many urban experiments do we need? (some discussion at Lucy Hutyra's urban breakout).
- What is a useful regional scale? Political domains. Ecosystem domains. E.g. EPA and state emission reductions. Discussion of "did you make it?" States will delegate to cities…relevant policy domains for "regional."

Main topics

- Lots of interest in urban scales. Many questions. Including microscale transport.
- Data assimilation methods, including transport error, with multiple observation assimilation, and details of how to do this at any scale.
- Chemistry – GHG divide – break down, experiment. E.g. schiamachy nature-geosci paper – Reuter et al.

Wish list for gases – better, cheaper, faster sensors

- Ethane sensors – many
- 14C cheaper
- Radon. Vertical transport
- Doppler lidars
- OCS (or is it COS?)