Model-data fusion strategy workshop: Land carbon initial overview

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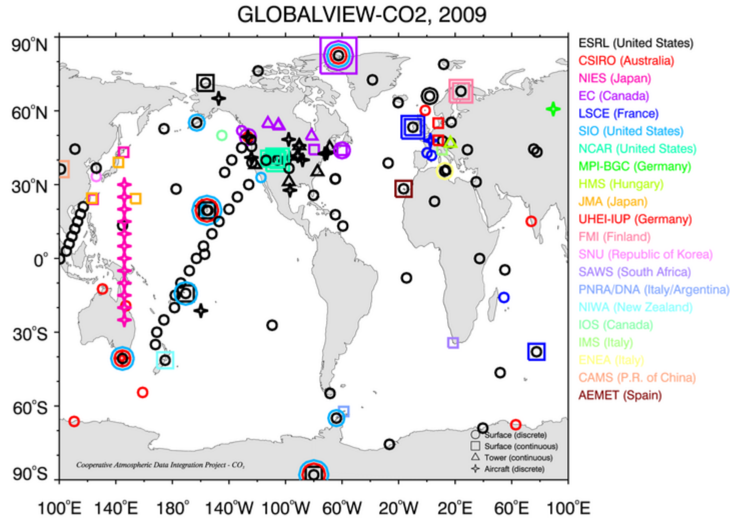
Australian Government
Bureau of Meteorology

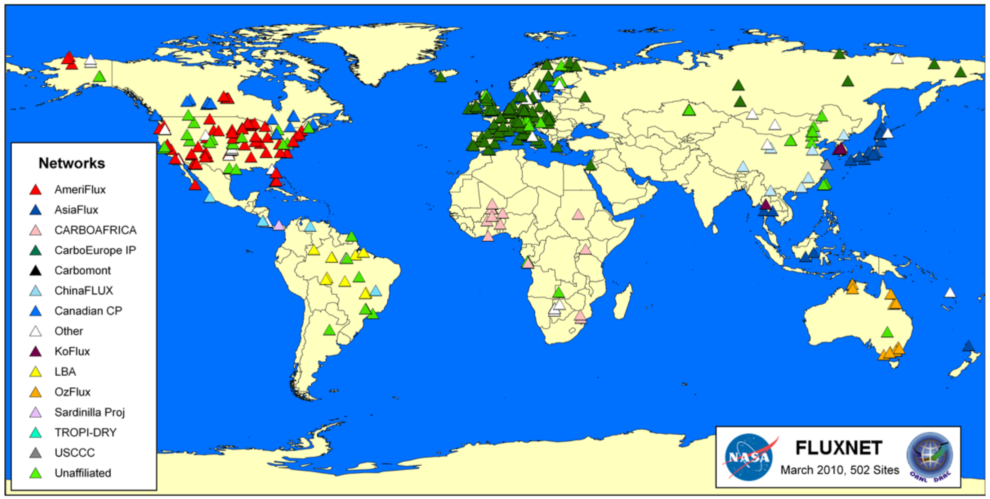
The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

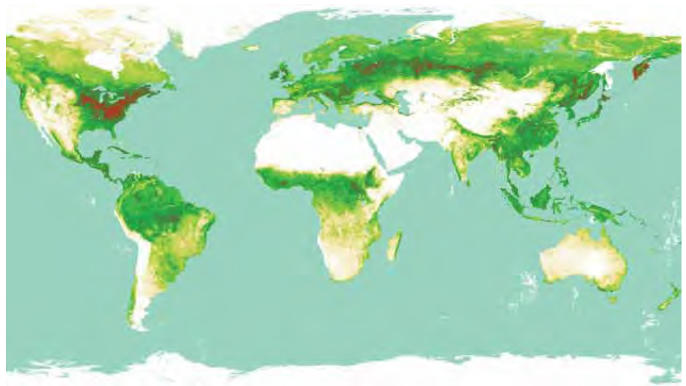
CSIRO

Data

- Atmospheric concentration at selected sites
- Flux network
- Remote sensing (LAI, fAPAR, land cover, CO_2)
- Forest inventories
- Also need meteorology, topography, soil properties, land use history





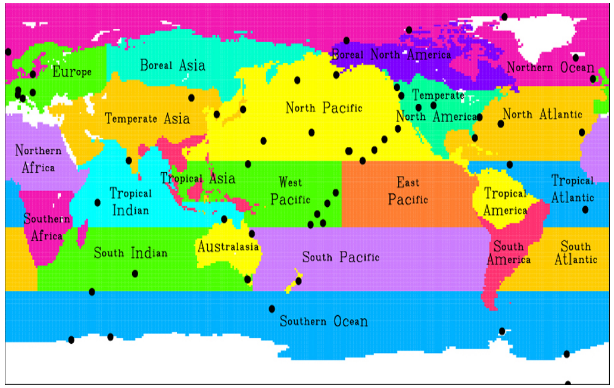


Models

- Atmospheric transport model to relate fluxes and concentrations: infer surface carbon fluxes from spatial and temporal variation of atmospheric concentration data (“top-down” inversion; no process model)

- Land surface model: calibrate parameters using flux data, forest inventories (“bottom-up”, process model allows prediction)

- Land surface model and atmospheric transport model: calibrate LSM parameters using atmospheric concentration data plus site and remotely sensed data (combines “top-down” and “bottom-up” approaches, e.g. CCDAS)



Issues

- Large spatial heterogeneity (climate forcing, soil types, vegetation, land use history)
- Limited spatial coverage of concentration data
- Atmospheric transport needed for top-down
- Representation error (point observations vs model grid)
- Aggregation error
- Hard to combine different types of data, and data providing information on different timescales
- Don’t have advantage of daily comparison of forecasts like NWP
- Incomplete process knowledge, poorly known model parameters
- Equifinality, observability of parameters - covariance between parameter estimates. Consequences for prediction outside range of calibration.
- Parameter estimation – assumes process representations are structurally correct
- Models or observations may be biased (Gaussian assumption invalid)

State of the science

- Now
  - MDF using multiple data-streams for carbon still hard (models probably not good enough)
  - Currently using toy systems for MDF
  - Disjoint in scale (time & space) between where MDF is ‘possible’, where we’d like to do it, and where real process information resides and different sources of data available.

- In 10 years?
  - Operational MDF with carbon as a by-product (GEMS+GEOLAND)
  - MDF component in all developing models (e.g. more efficient parameter estimation, models developed with better code standards to allow adjoints)
  - Use of remotely sensed CO_2
  - Consistency of carbon accounting with our modelling
  - Multi-model data fusion

Where should we aspire to be?

- Intellectual not operational leadership (limited resources)
- Operational focus should be regional
- Make as much as possible of remote-sensing
- Should be joining big collective efforts (e.g. there should be a community MDF toolbox in the same way as there's a community climate model)
- Exploit connection with other terrestrial cycles – water, nutrients, energy
- More use of information in high frequency variations (for concentration data need good transport)
- Terrestrial model error feeding into future climate predictions and stabilisation scenarios (best done in MDF framework)
- Move initiation of seasonal forecasts and decadal climate projection science away from equilibrium constructs

Current & planned activities

- ATACC – Assimilation of Trace Atmospheric Constituents for Climate, lead by Peter Rayner
  - Generate transport model consistent with ACCESS; assimilate observations including remotely sensed CO_2, build global CCDAS optimized for Australia.

- Australia-RECCAP
  - Global RECCAP = REgional Carbon Cycle Assessment and Processes, Global Carbon Project activity – comparison of bottom-up and top-down estimates on regional scale http://www.globalcarbonproject.org/activities/RECCAP.htm
  - Australia-RECCAP = Establish the mean carbon balance of the Australian continent for the period 1990-2008, including its component sink and source fluxes. It will be achieved by using a combination of bottom-up and top-down measurements and model outputs from Australian and global analyses.
  - Uncertainty analysis – Ian Enting

Current & planned activities

- AWAP - Australian Water Availability Project
  - Focus so far has been on estimating soil moisture and water fluxes over the Australian continent
    http://www.csiro.au/awap/
  - Extend by adding carbon to the model, and assimilating remotely sensed observations of vegetation greenness
  - Explore multi-model data fusion

- CarbonTracker
  - Inversion for carbon fluxes using the square root ensemble Kalman filter, with open access to results on the internet
    http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/
  - Focuses on Nth America; also being developed for other regions including Europe, Asia and Australasia (at NIWA, NZ) and for methane.

- Stakeholder needs
  - Carbon accounting community – verifying country emissions
- Key gaps
  - Computational resources and people
- Areas where rapid progress is possible
  - Expect rapid progress in ensemble methods
- Important areas where progress is likely to be limited
  - Model development (this is the major limitation for land carbon MDF at the moment)
- Relates research areas
  - Geosequestration - Funding additional Australian monitoring site with a flux tower in Queensland