Data assimilation for terrestrial biogeochemistry, why is it different?

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References

- Special Issue on Biogeochemical Data Assimilation, Copernicus journals, 2016.
Outline

- A carbon atom’s tour of the terrestrial biosphere;
- Simple dynamics, terrible physics;
- Like a model? Take two, I’ve got plenty.
- What do we observe?
- Putting it together.
A Carbon Atom’s Tour of the Terrestrial Biosphere

- Enters from the atmosphere via photosynthesis;
- Respired by the plant or incorporated into plant material;
- Falls and either incorporated into soil or respired to atmosphere;
Rough Annual Global Budget

- 100 pgC photosynthesis;
- 50pgC plant growth
- 2-3pgC stored in soil
Simple Dynamics

\[ \frac{\partial c}{\partial t} = f(t) - \kappa(t)c \]

where \( c \) is quantity of carbon in soil, \( t \), time and \( f \) and \( \kappa \) functions of time, often indirectly.

- First-order D.E.
- Dynamics force-restore;
- Sensitivity to state perturbation evanescent function of time;
- Beware of climate feedbacks.
The Problem is ...

\[ \text{NPP} = \epsilon \text{APAR} \]

\[ \text{GPP} = \min[J_C; J_E] - R_d \quad (1) \]

\[ J_C = V_{\text{max}} \frac{C_i - \Gamma_*}{C_i + K_C(1 + O_x/K_O)} \quad (2) \]

\[ J_E = J \frac{C_i - \Gamma_*}{4(C_i + 2\Gamma_*)} \quad (3) \]

\[ r(T_v) = r_{25} \exp \left\{ \frac{(T_v - 25^\circ C)E}{298KR(T_v + 273^\circ C)} \right\} \quad (4) \]
What do we Observe?

- Net fluxes, balance of arrows, very local;
- Atmospheric concentration (integrated net flux advected and diffused);
- Changes in stocks;
- Processes associated with an arrow (fluorescence, reflectance etc);
- Rarely direct measure of process.
What we do in Practice

- Solve for parameters of model and use improved parameters for analysis/prediction;
- Either solve initial condition as nuisance variable or assume preindustrial equilibrium;
- Try to combine measurements at various scales.
Does it Work?

- Critically model dependent;
- Parameters learned from one site often don’t work at another;
- Parameters learned from one dataset often degrade fit to another;
- Parameters learned from local data often don’t work globally.
Some Practical Differences

- Very long assimilation windows (perhaps decades);
- Often low-order (maybe dozens of target variables);
- Few replicate experiments so testing statistics hard.
What to do?

- The long grind of improving models of messy systems;
- Potential use of optimality criteria;
- Moving from parameters to traits which are themselves distributions.