# Using process-based assimilation in support of emissions monitoring: Can we? Should we?

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# Conclusion

- Choices range from no mechanistic process modelling to complete coupled model
- The choice depends on careful understanding of user requirements
- The question is amenable to analysis by Decision Theory
- Without such analysis I think current FFDAS is a good risk but current CCDAS not yet.

# Outline

- Our problem
- What is process-based assimilation?
- The carbon budget, inversions and nuisance variables;
- Verification vs decision support;
- Risks, Benefits and how to decide;
- Conclusions.

# The Carbon Budget

$$F_{CO_2} = F_{fos} + F_{luc} + F_{ocn} + F_{lnd}$$

- Want to learn about $F_{fos}$
- Budget holds at point or over region
- Some fluxes almost disjoint
- Double-counting a problem for another day.

# Flux Inversions and Process Assimilation

## Flux Inversions

- Project unknown fluxes to concentrations via atmospheric transport model
- Optimize source magnitudes to match observed concentrations
- Use Prior source estimates
- Increment structure shaped by prior uncertainty

## Process Assimilation

- Compute fluxes from flux model
- Project onto concentrations as with inversions
- Optimize flux model parameters and state
- Compute uncertainty of parameters and state
- Project parameters and state into optimal fluxes and uncertainties.

## Advantages

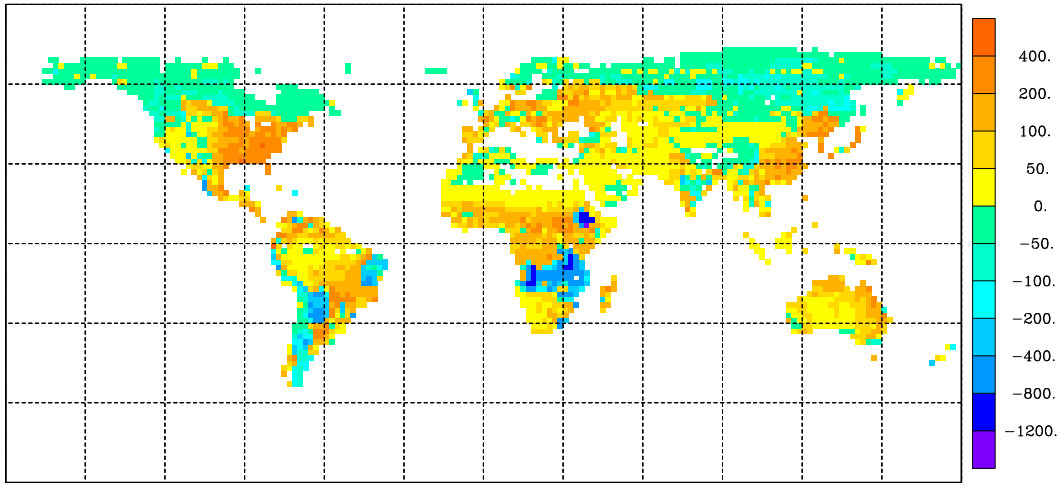
- More compact description
- Process understanding
- Include other observations
- Combine prognostic and diagnostic modelling

## Disadvantages

- Technically harder
- Live and die by model
- Uncertainty complex and hard to describe

# Biosphere Example (CCDAS)

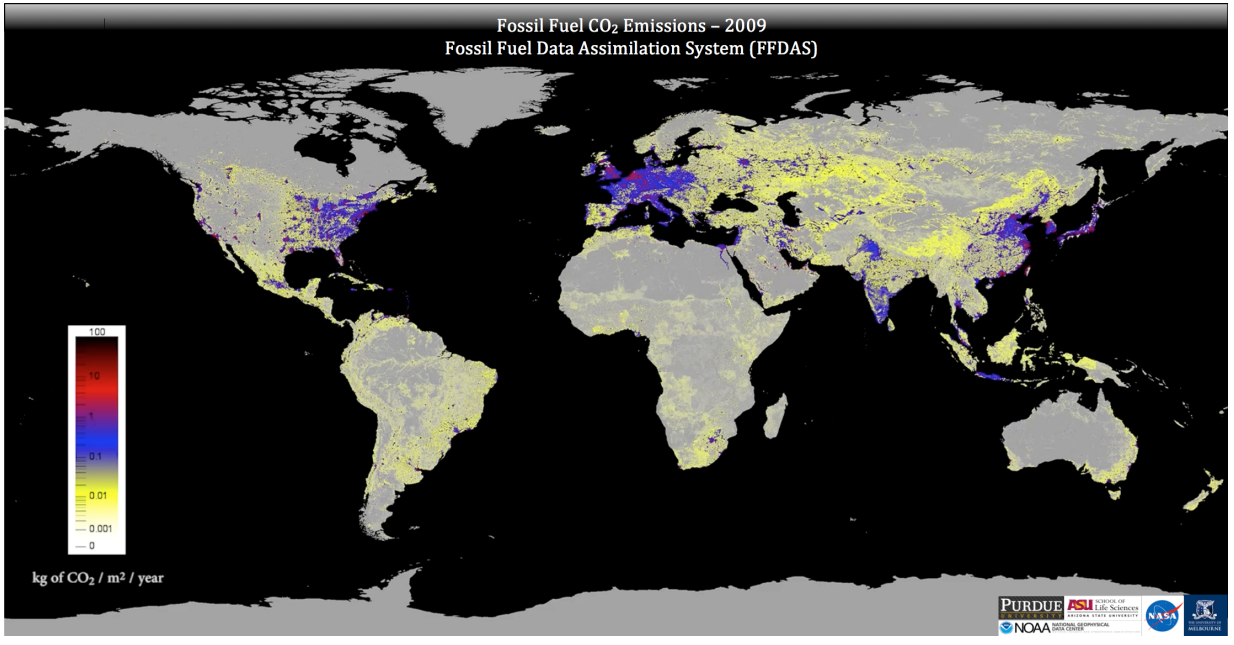
- Rayner et al. (2005)
- BETHY biosphere model coupled to TM2 atmospheric transport model
- 41 atmospheric $CO_2$ timeseries




Mean net flux to the atmosphere for the period 1980–2000 (gC $m^{-2}$ $y^{-1}$).

# Fossil Fuel Example (FFDAS)

- Asefi et al. (2014)
- sectoral description of emissions
- Constrained by nightlights, national emissions etc




Fossil fuel flux to the atmosphere for 2009

# Similarities and Differences

- Both arbitrarily detailed output
- CCDAS dozens of unknowns, FFDAS millions
- CCDAS far more mechanistic understanding.

# Back to our Problem

$$F_{CO_2} = F_{fos} + F_{luc} + F_{ocn} + F_{Ind}$$

- Want to learn about $F_{fos}$
- Atmospheric $CO_2$ measurements see $F_{CO_2}$ so everything else a nuisance
- Assimilation and background covariances are prior knowledge which reduce uncertainties, even those for nuisance variables
- Which is superior and how much should we allow?

# Uncertainty and Risk

- Choosing whether and what process assimilation like choosing prior and uncertainty
- There are statistics like the Bayes Factor $\log \left|\mathbf{HBH}^T + \mathbf{R}\right| + \chi^2$
- Does not detect bias
- Inversions one-shot deal so bias and uncertainty less separable than for, say, NWP
- *Balance between smaller confidence intervals and increased risk of bias depends on application*

# Two Scenarios

## Decision Support

- Near real time monitoring of emissions
- Private feedback to managers
- Possible signals to a credits or offsets market
- Would encourage more informative if riskier estimates

## Verification/Compliance Monitoring

- Delayed monitoring
- Verification of commitments or obligations
- Attached to enforcement
- Would encourage conservative strategy

# Putting it Together

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