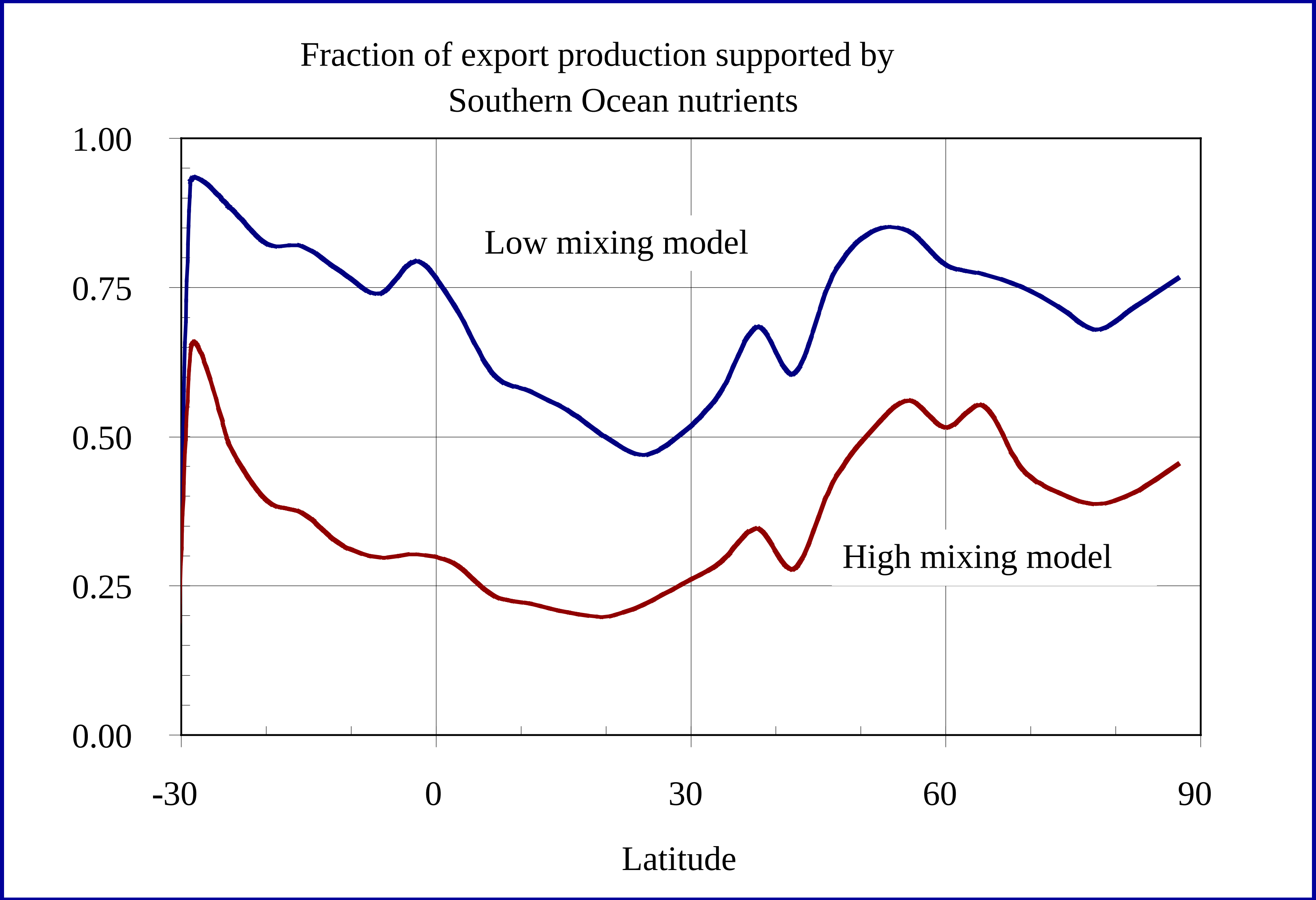
Climate modeling: where are we headed?

- → Interactive biogeochemistry
- Large ensemble simulations (multi-century)
- Seasonal-interannual forecasts
- High resolution simulations
- Regional climate change
- Assimilation of observations (esp. satellite)
- Very long simulations (e.g., ice age)
- Carbon sequestration simulations

Are we ready to do interactive biogeochemistry well?

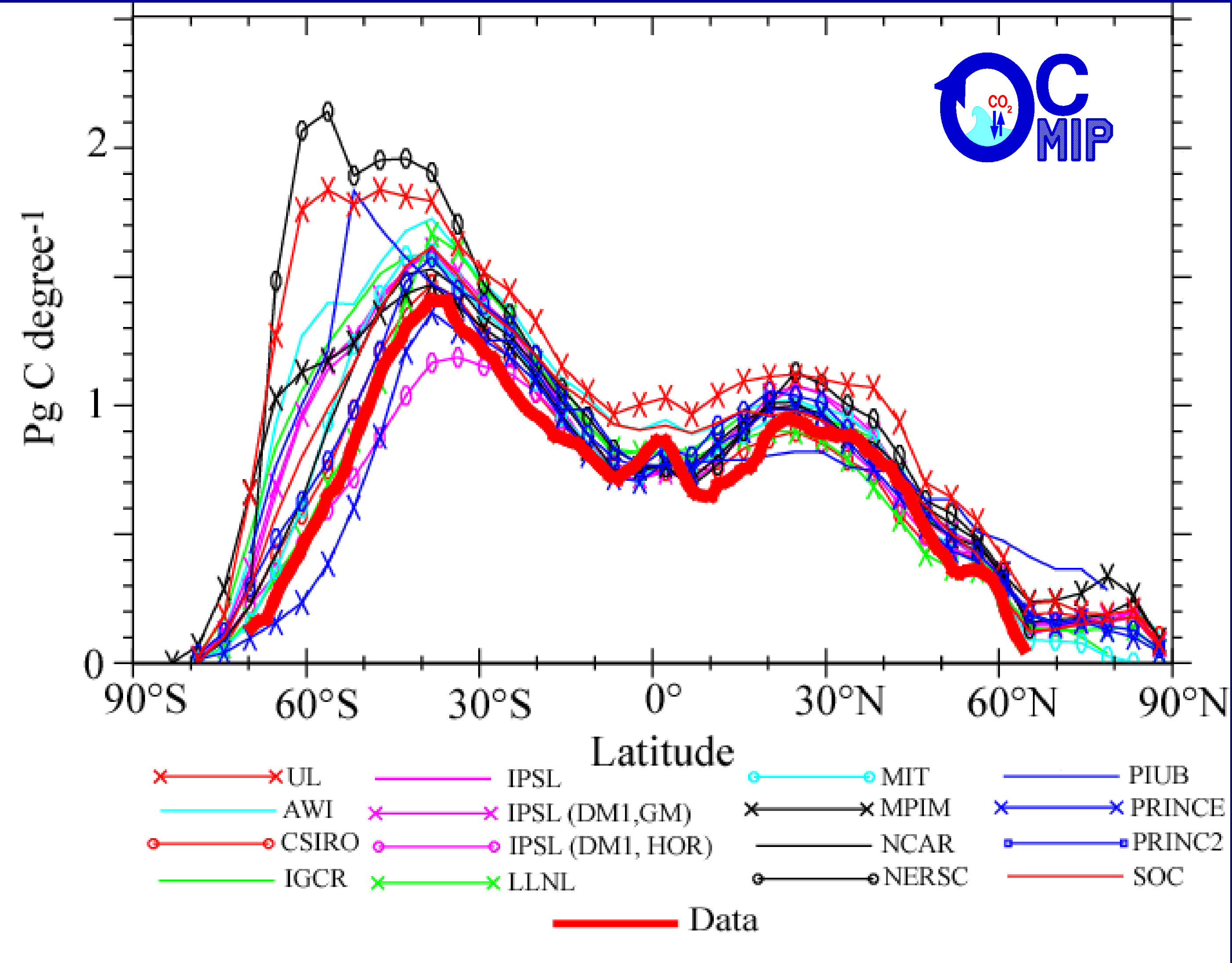
- We are already doing biogeochemistry. We have models, we have vastly more data than before, and we have made huge strides in our understanding. On the other hand:
  - Tendency has been towards increasingly complex models. Is this good/necessary? (Laws comments)
  - Process studies are limited in space and time. (Michaels talk) We need new ways of exploring the ocean that can give us more in situ data - autonomous samplers, more advanced use of satellite observations, etc.
  - We have much to learn about functional group controls, twilight zone, etc. (Michaels, de Baar, Lampitt talks). Manipulation experiments are a powerful tool.
  - We do not yet have global coverage of critical properties such as DOC and Fe (de Baar talk).
  - We are only beginning to incorporate other feedbacks to climate such as impact of phytoplankton on radiation, DMS, etc.

What about the Southern Ocean?



(Sarmiento et al, in prep.)

What about the Southern Ocean?

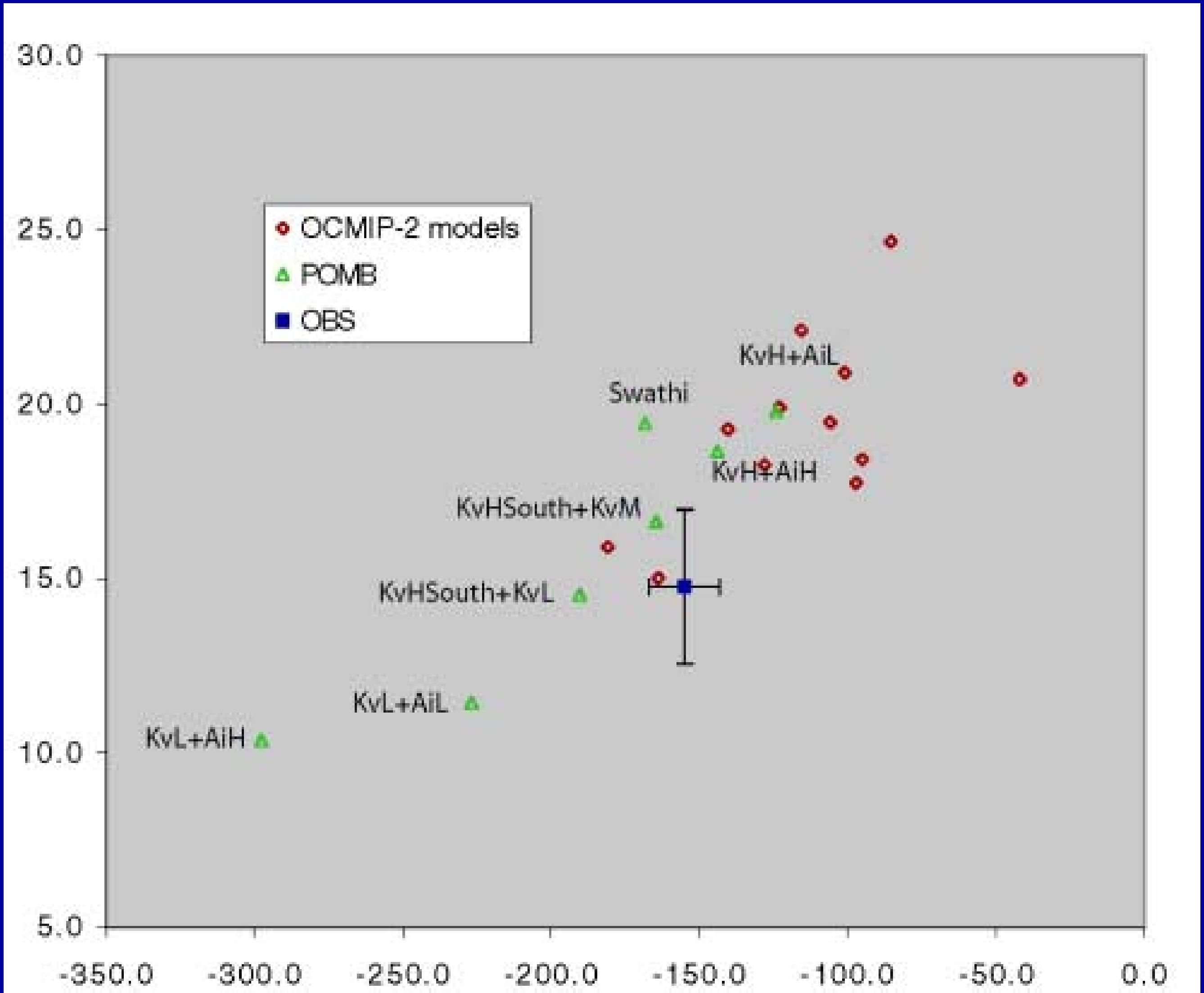


Ocean anthropogenic carbon inventory

Data (thick red line) from Sabine et al.

Models from OCMIP (Orr, pers. comm.)

Observations & model predictions south of 40°S

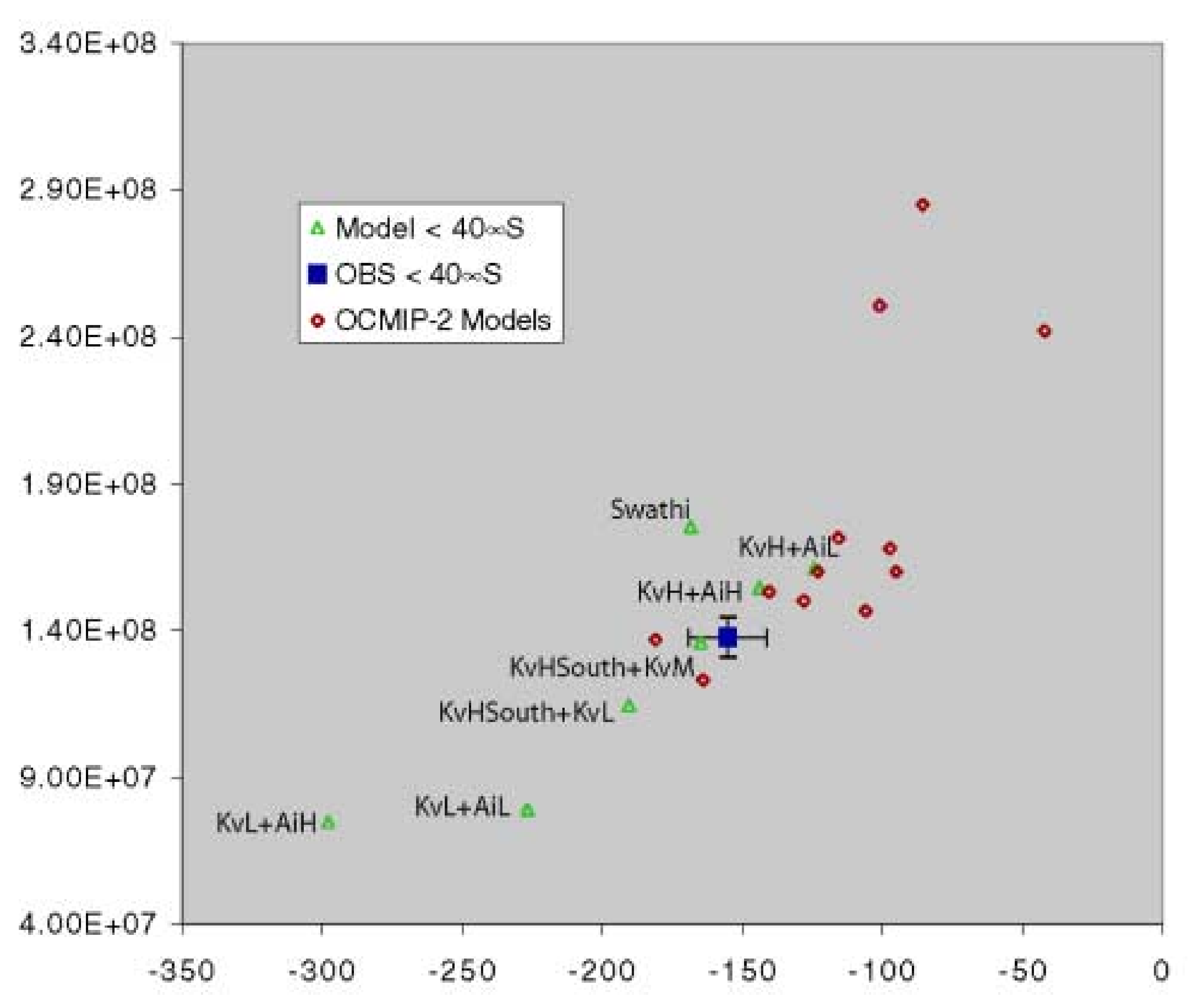


Anthropogenic CO_2 Inventory (<1600 m) Pg C

Mean Natural ^{14}C (>1500 m) ‰

Matsumoto et al, in prep.

Observations & model predictions south of 40°S



CFC-11 Inventory

Mean Natural ^{14}C (>1500 m) ‰

Matsumoto et al, in prep.

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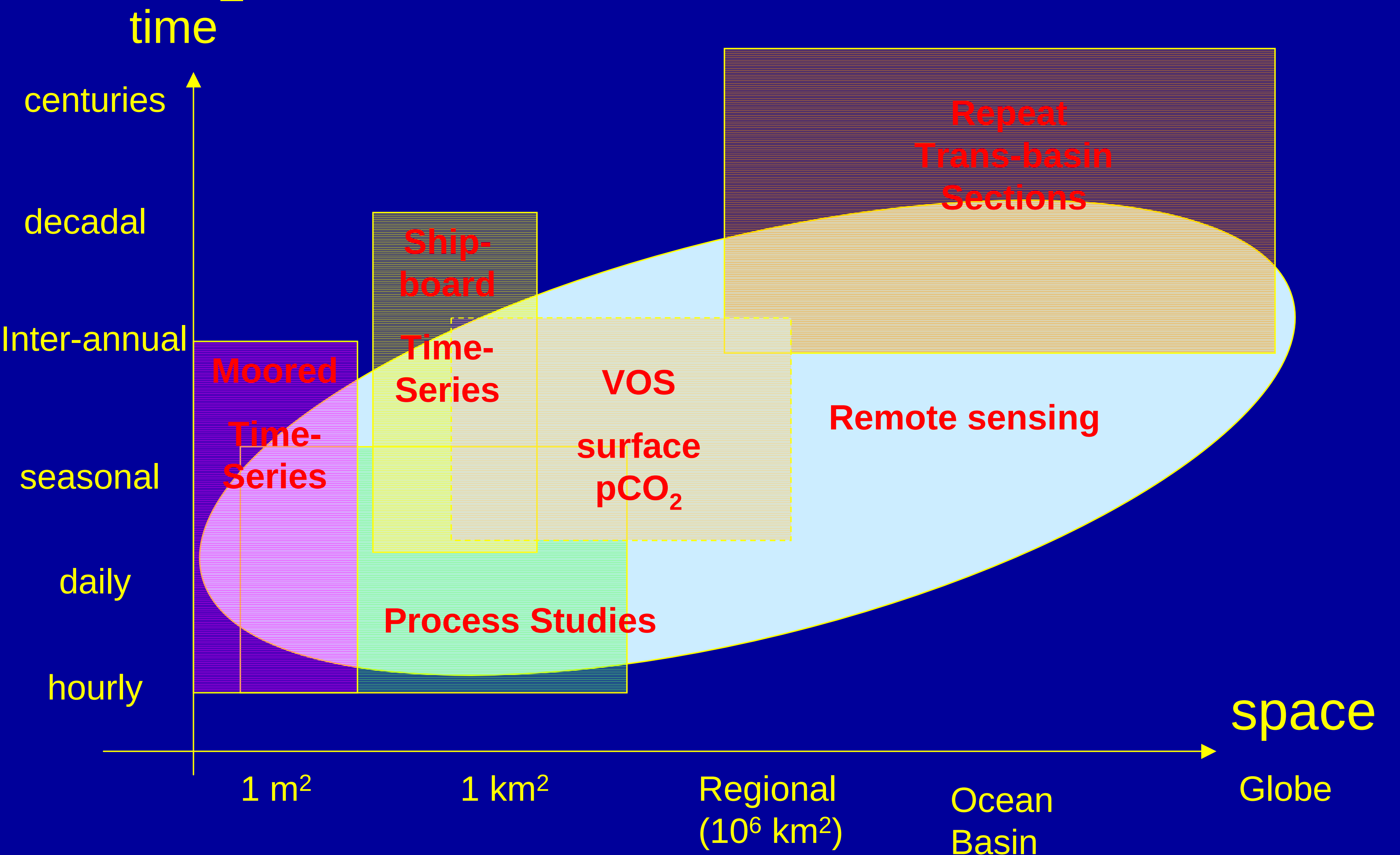
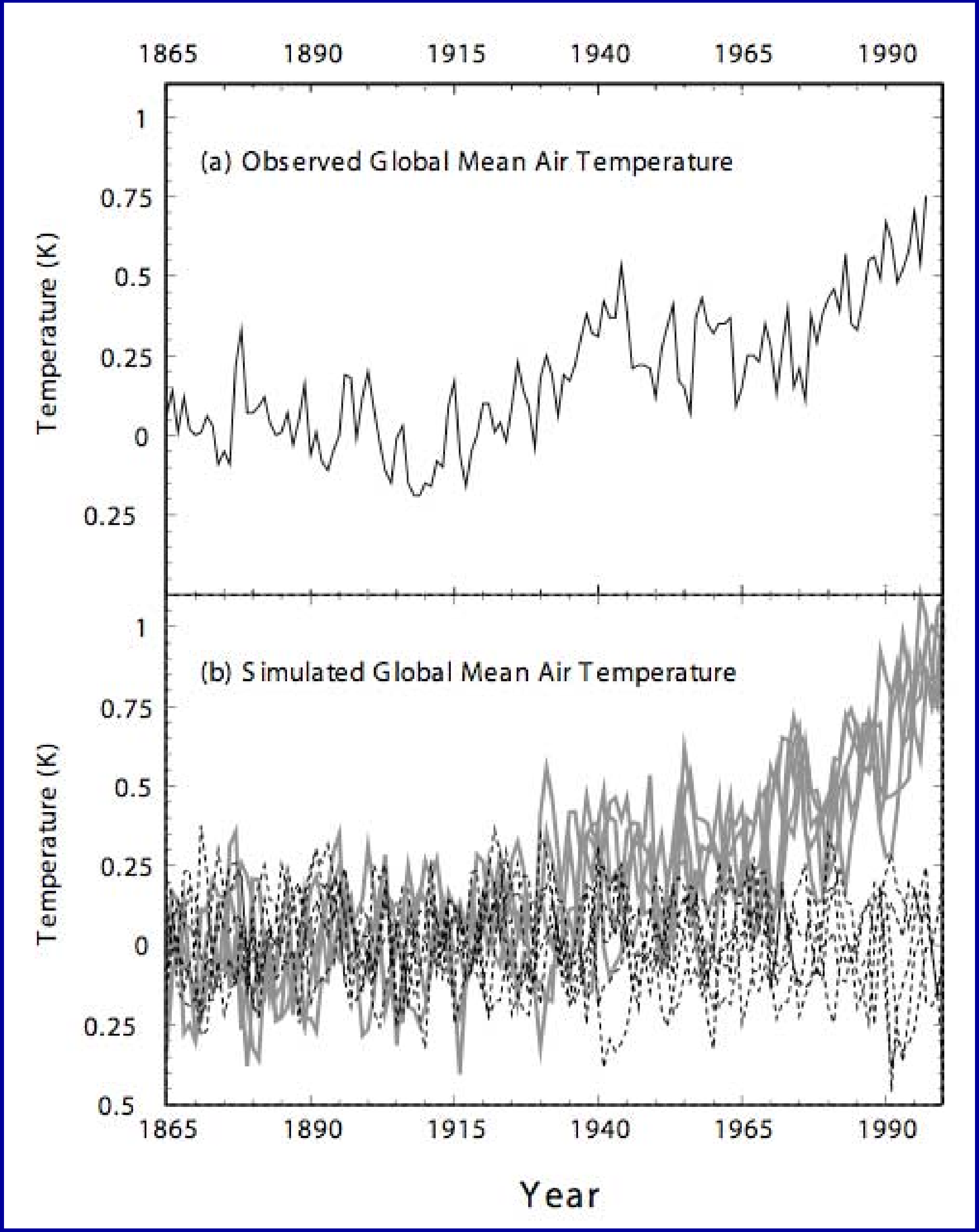
Climate sensitivity: what observations tell us about model predictions

	Oceanic Contribution to atmospheric CO_2	Biological Pump
100 yr time scale	Not much	Not much
100,000 yr variations	Some	Some
Interannual variations	Some	Some

CO_2 Observational Platforms and Sensors



(Sabine, pers. comm)



Observed (top) and simulated (bottom) global mean temperature

Natural variability makes it difficult to detect the signal

(GFDL Model)

Optimal Detection

- Observations at location $\mathbf{x}$ and time t define an observational vector consisting of a natural climate component and a signal component with amplitude α_s

$$\Psi_{obs}(\mathbf{x}, t) = \Psi_{nat}(\mathbf{x}, t) + \alpha_s \Psi_s(\mathbf{x}, t)$$

- Models are used to determine the fingerprints $\Psi(\mathbf{x}, t)$ of the natural climate and warming signal components.
- The amplitude of the warming signal α_s is obtained by fitting the observations to the fingerprints.

(Hasselmann, 1979, 1997; Hegerl and North, 1997; Santer et al., 1995)

Attribution

- Attribution requires decomposing the total warming fingerprint into components corresponding to each of the processes being considered:

$$\alpha_s \Psi_s(\mathbf{x}, t) = \sum_{1}^{m} \alpha_i \Psi_i(\mathbf{x}, t)$$

- This is very difficult to do.

(Hasselmann, 1979, 1997; Hegerl and North, 1997; Santer et al., 1995)

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