Strengthening trade winds and an enhanced Equatorial Pacific carbon source

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Air-Sea Gas Flux Workshop

September 6, 2016

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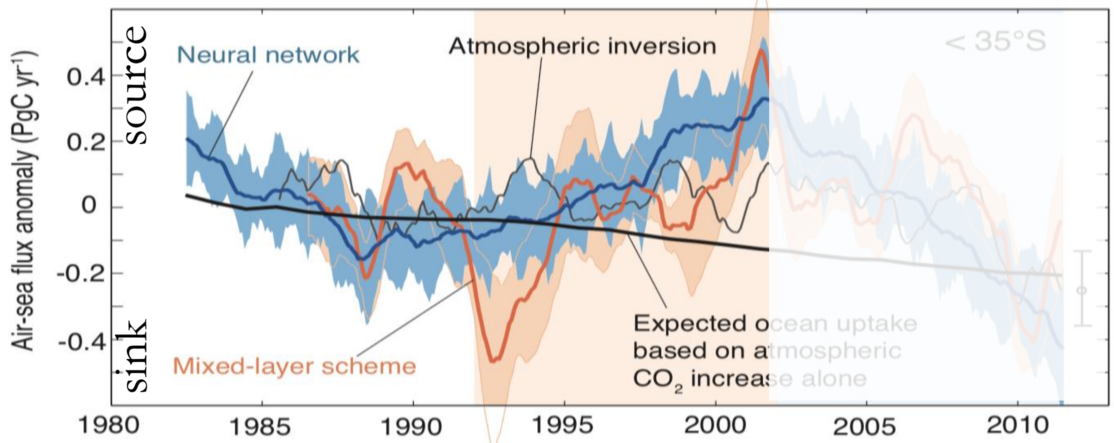
1. Question

"Dangerous" length of observational records, mixture of anthropogenic and natural forcings.

Data-based Southern Ocean Carbon Fluxes



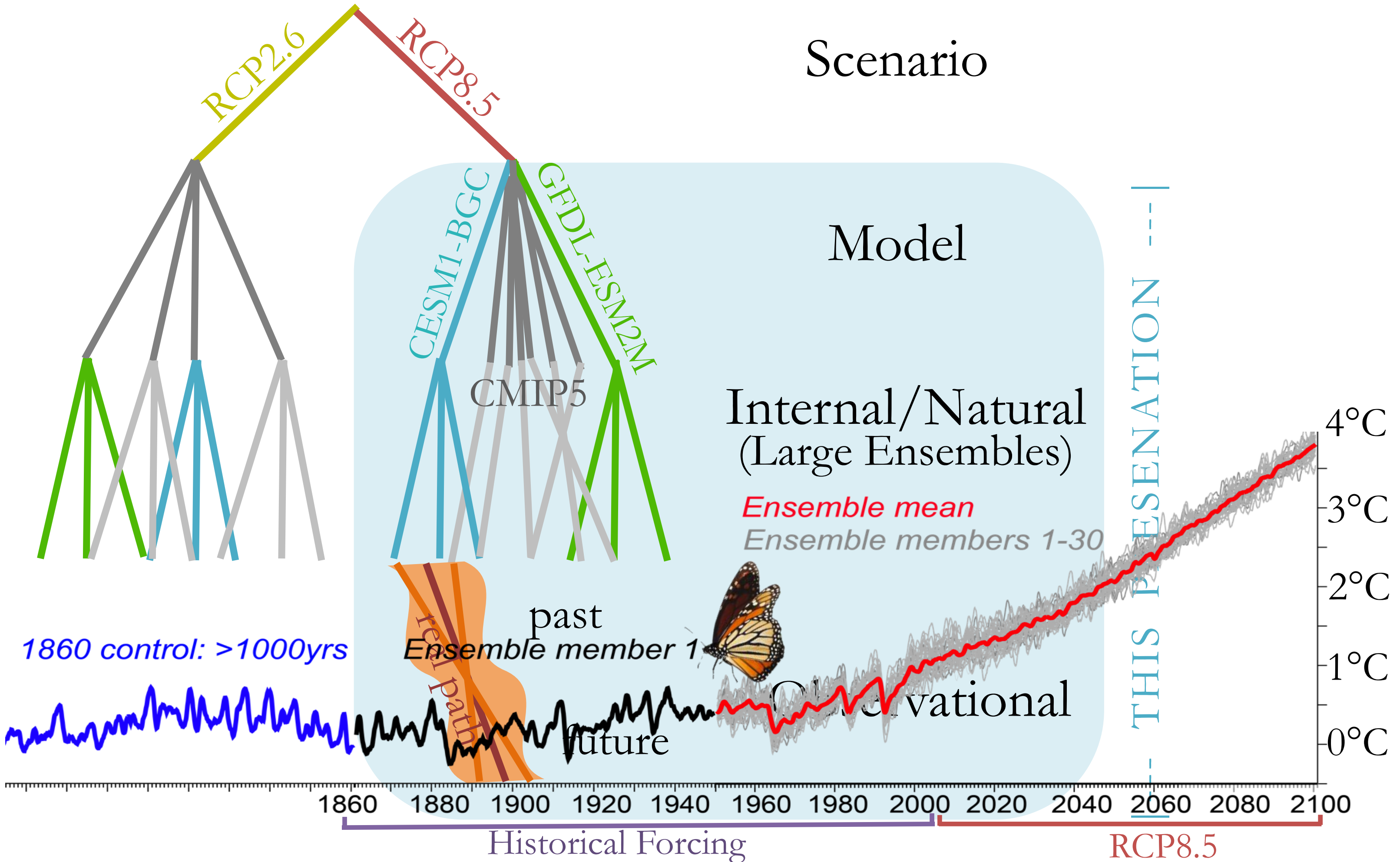
Landshutzer et al 2015

How can the newly available Earth System Model Initial Condition Large Ensemble experiments and data-based carbon flux products inform each other about natural variability in the strength of the ocean carbon sink?

Outline

1. Question
2. Tools
3. Findings
    a. Global Picture
    b. Equatorial Pacific

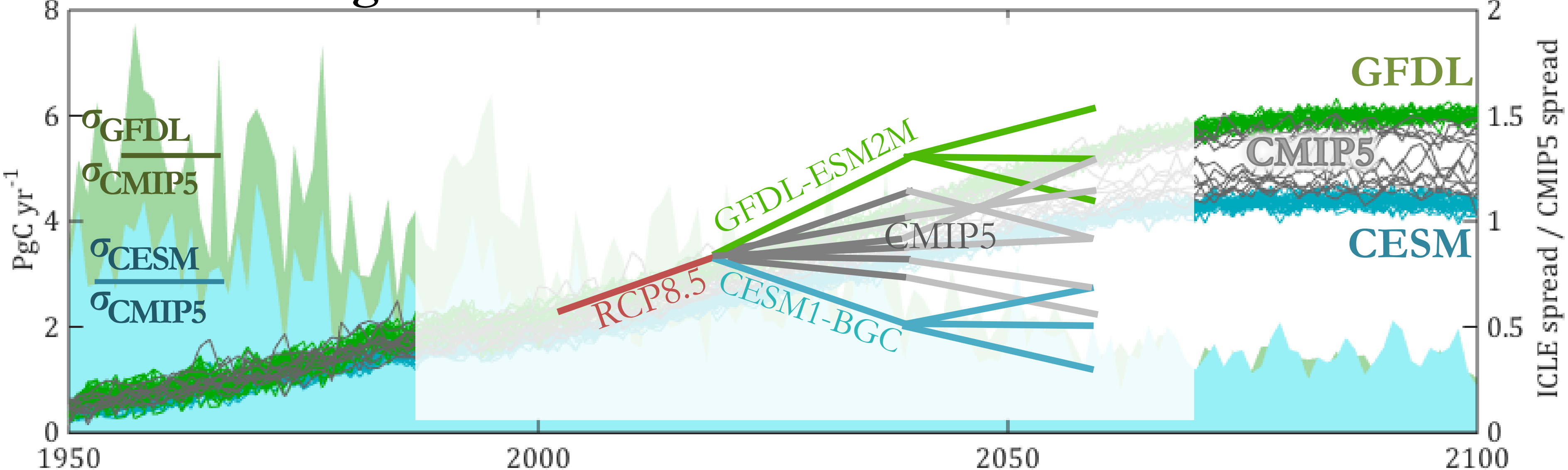
Schematic: Sources of Uncertainty



2. Tools

1. Two initial condition large ensemble experiments (GFDL-ESM2M, CESM1-BGC)
2. CMIP5 Earth System Models, multi-model ensemble

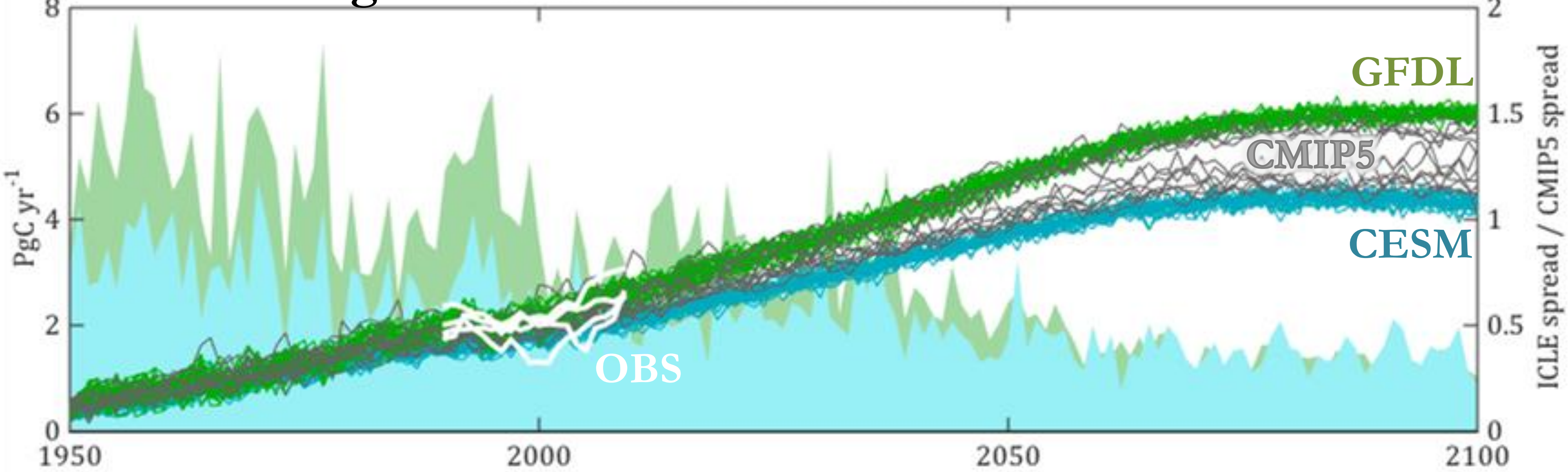
Fig. 1. Global Annual Air-to-Sea Carbon Flux



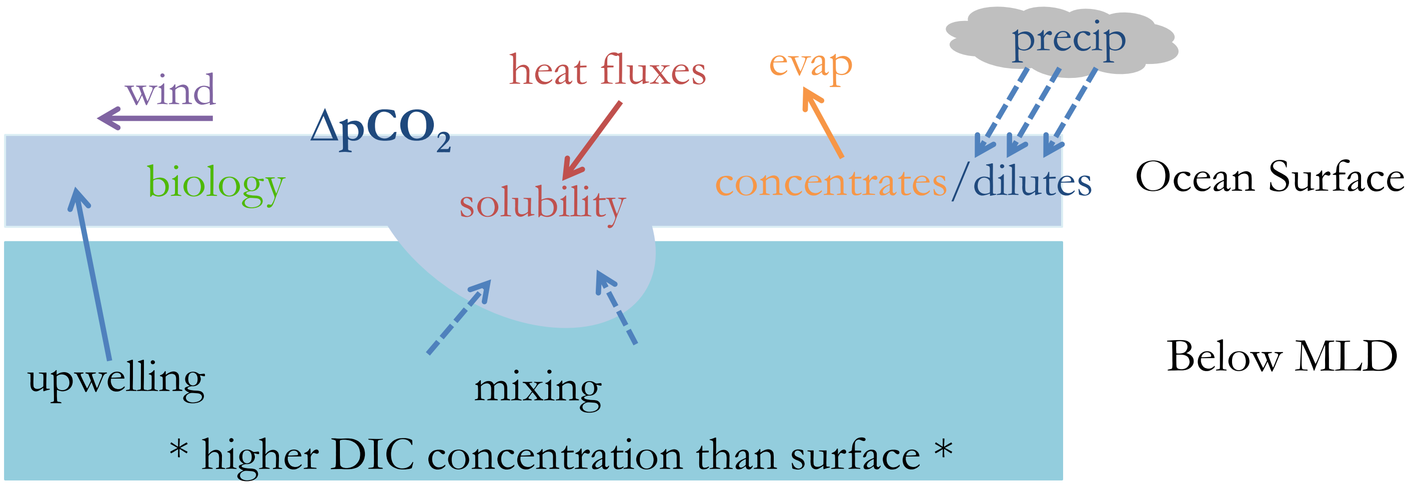
2. Tools

1. Two ICLE's (GFDL-ESM2M, CESM1-BGC)
2. CMIP5 multi-model ensemble
3. Observational data-based products of Air-Sea carbon fluxes over the period 1990-2009

Fig. 1. Global Annual Air-to-Sea Carbon Flux



Sidebar: Why is ocean carbon uptake sensitive to atmospheric initial conditions?



- Winds and climate modes change upwelling strength/patterns
- Freshwater fluxes change carbon concentrations
- Winds change gas exchange rate between ocean and atmosphere
- Temperatures changes solubility
- Buoyancy fluxes change mixing
- Biology – Nutrients, temperature, light, etc.

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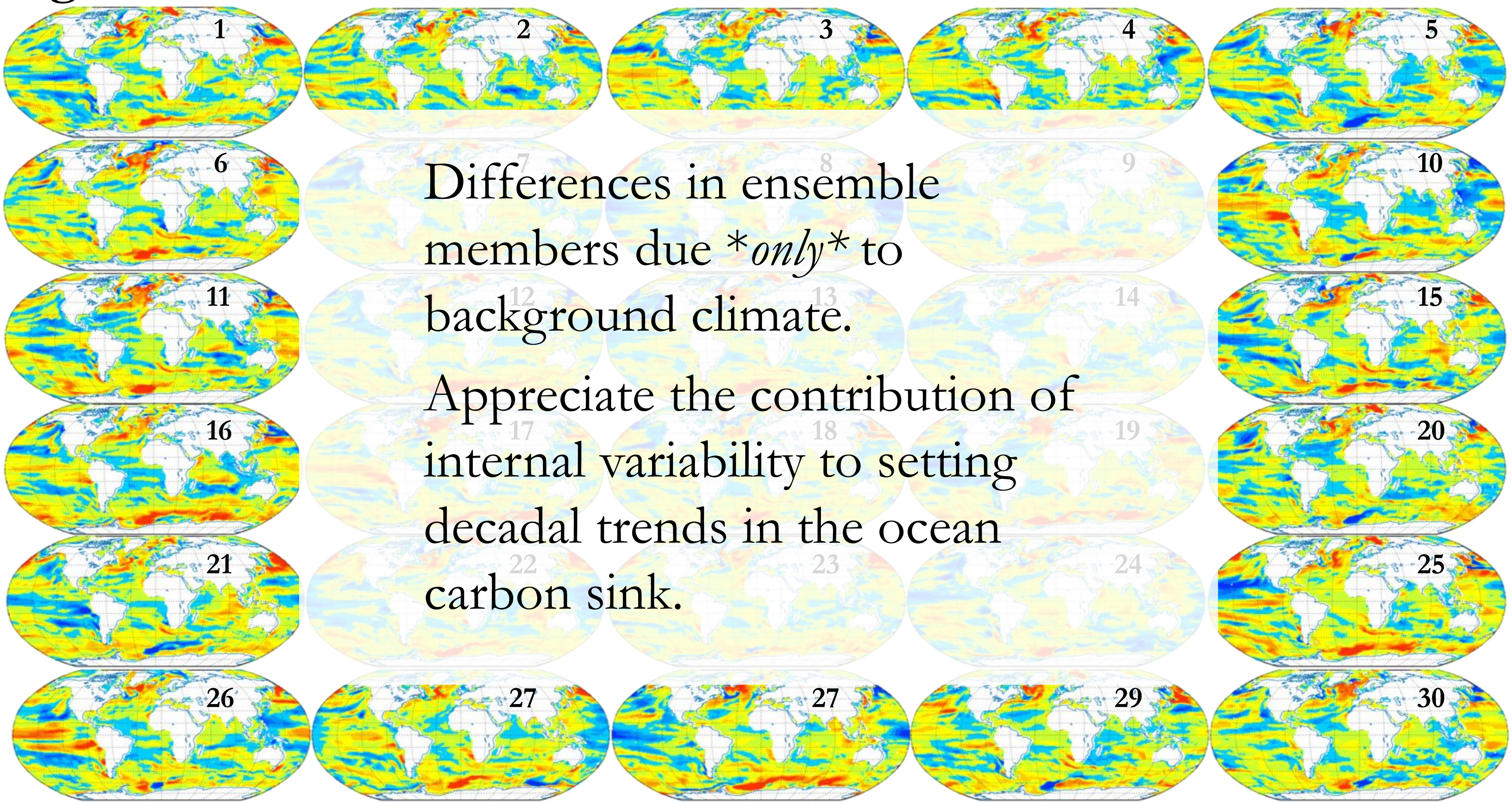
3a. Global Picture

Returning to the main question, how do the ESM ensembles and data-based ensembles compare?

(1st) Mean **&** (2nd) Natural Variability

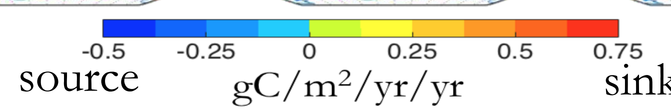
3a. Observational Period 1990-2009

Fig. 3. 20-Year Trends: Individual GFDL-ESM2M Ensemble Members



Differences in ensemble members due **only* to background climate.

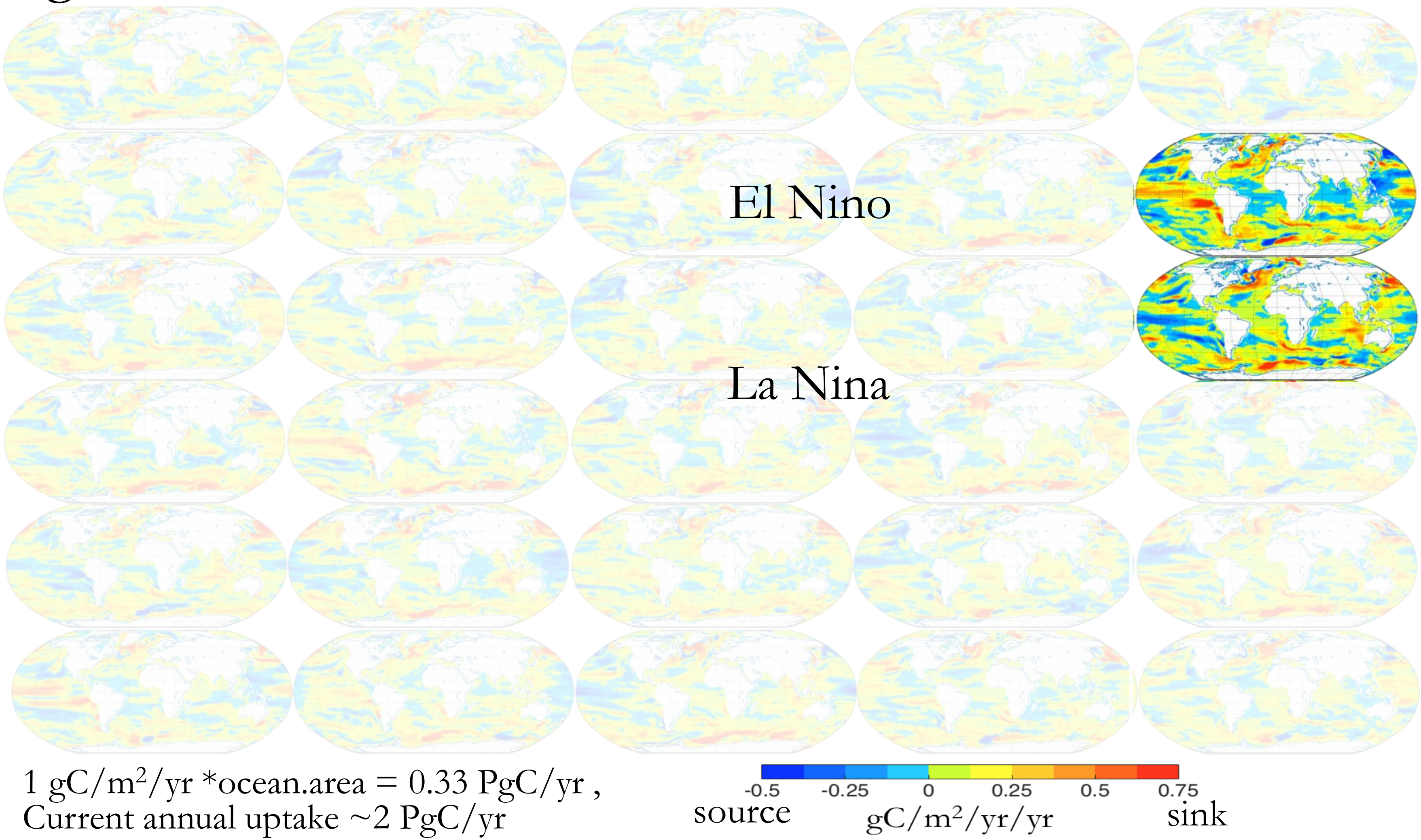
Appreciate the contribution of internal variability to setting decadal trends in the ocean carbon sink.



1 $gC/m^2/yr$ *ocean.area = 0.33 PgC/yr ,
Current annual uptake ~2 PgC/yr

3a. Observational Period 1990-2009

Fig. 3. 20-Year Trends: Individual GFDL-ESM2M Ensemble Members



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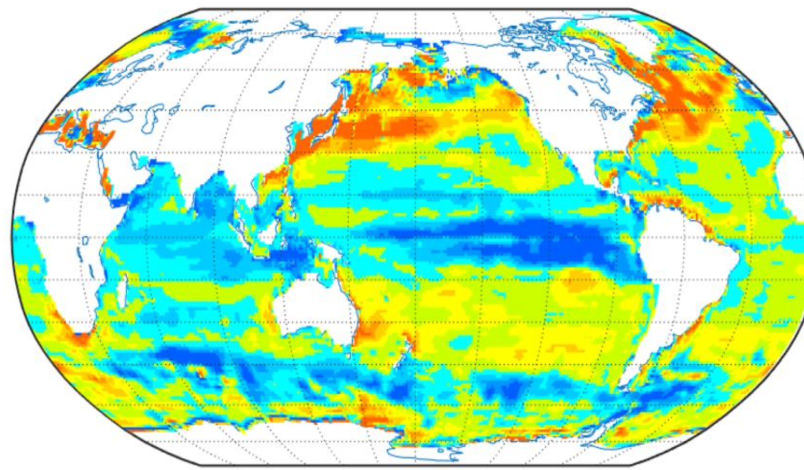
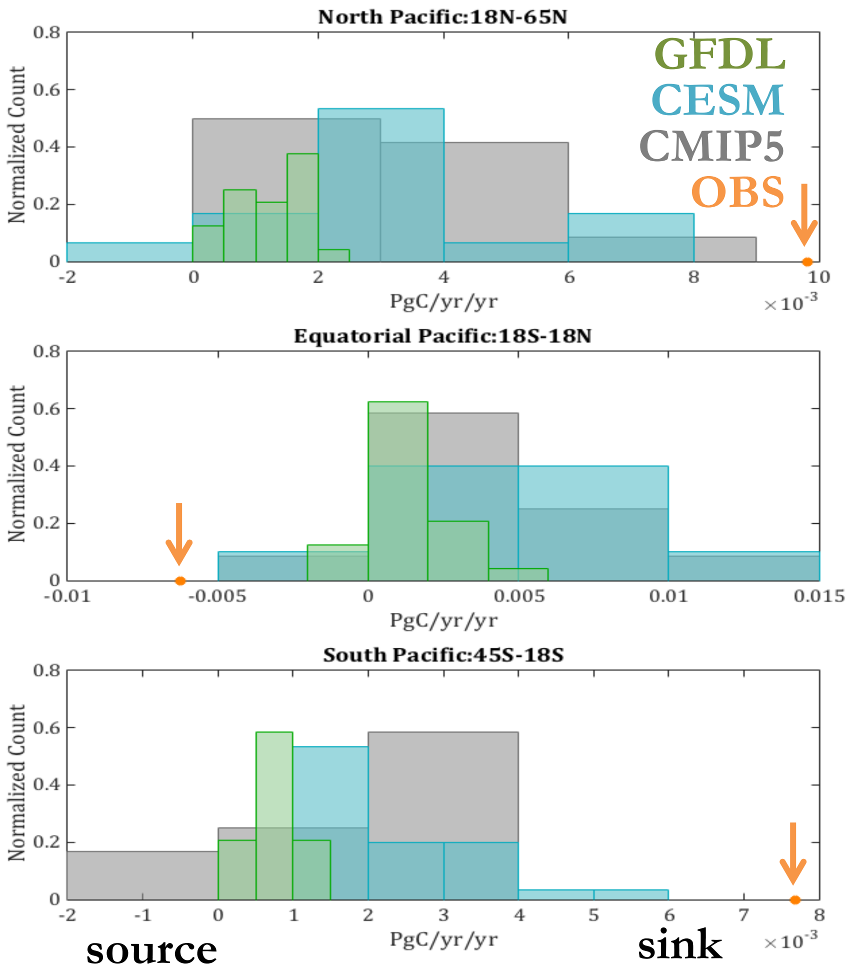


Data-Based Trends

3b. Equatorial Pacific

Fig. 5. Histograms of carbon trends in Pacific



Mean OBS trends in Pacific Air-Sea carbon flux outside the range of the ensembles.

3b. Observational Period 1990-2009, Pacific

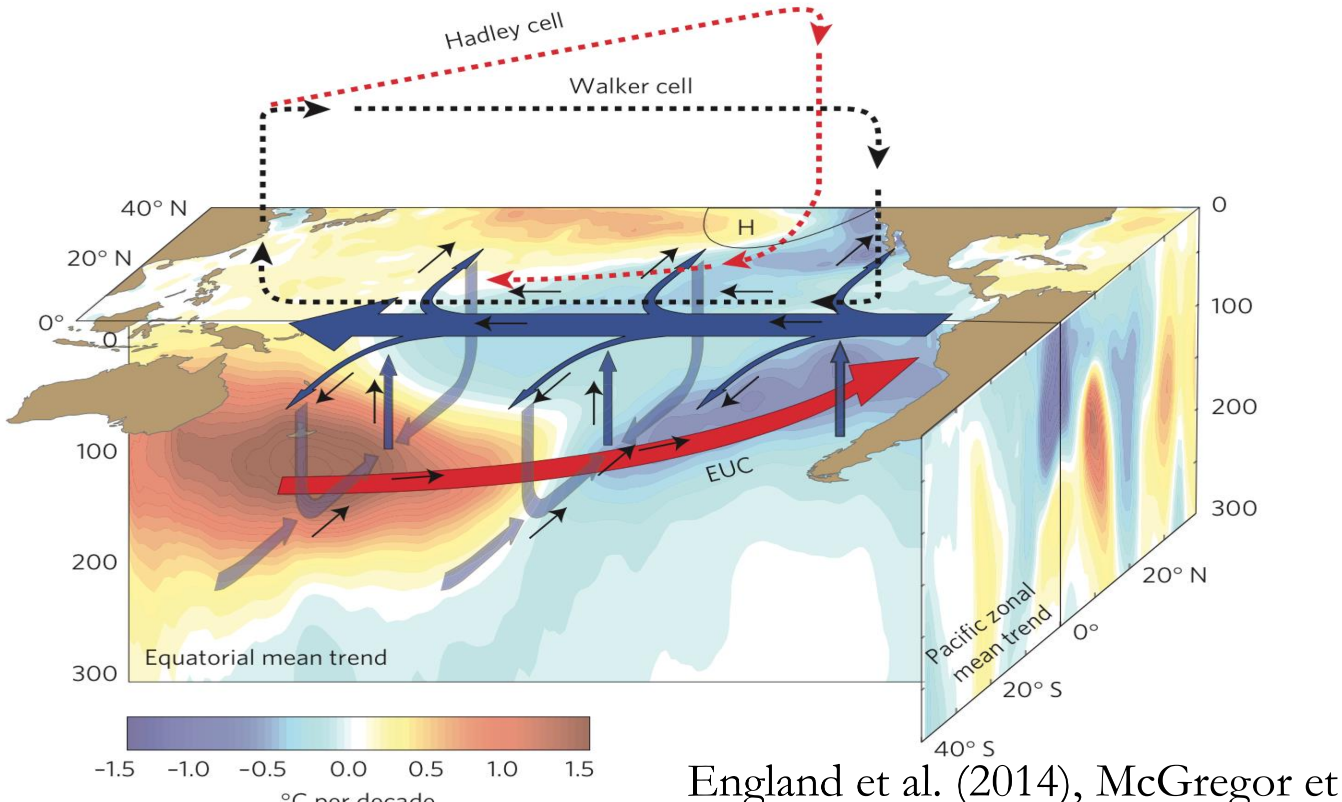
Why are the observed trends in Air-Sea carbon exchange over the Equatorial Pacific outside the range of the ensembles?

Hypothesis: Model bias in wind stress

3b. Observational Period 1990-2009, Pacific

Model bias in Eq. Pacific wind stress lead to model bias in hindcasting 1980's-2010's Pacific Basin SST's.

To what extent is this true for carbon fluxes?



England et al. (2014), McGregor et al. (2014)

Support for Wind-stress hypothesis:

Consistent model bias in

(1) Wind-stress

(2) East-West SSH gradient

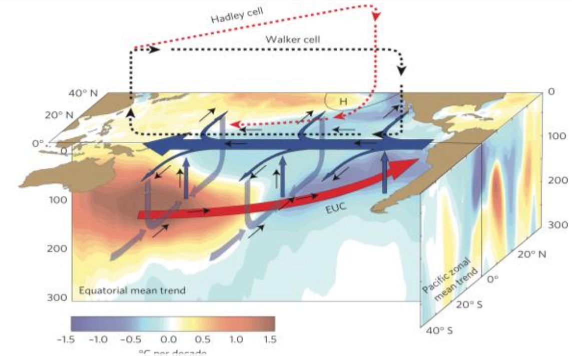
(3) Air-Sea carbon fluxes

3b. Observational Period 1990-2009, Pacific

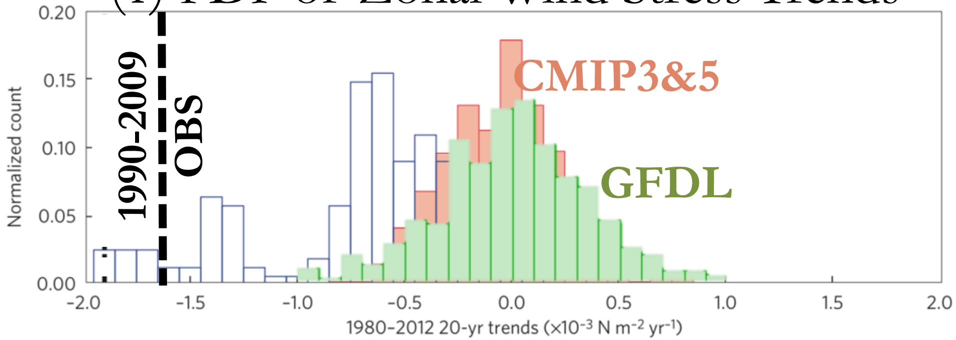
(1) Wind-stress

(2) East-West SSH gradient

(3) Air-Sea carbon fluxes



(1) PDF of Zonal Wind Stress Trends



(3) Wind vs. Carbon Trends

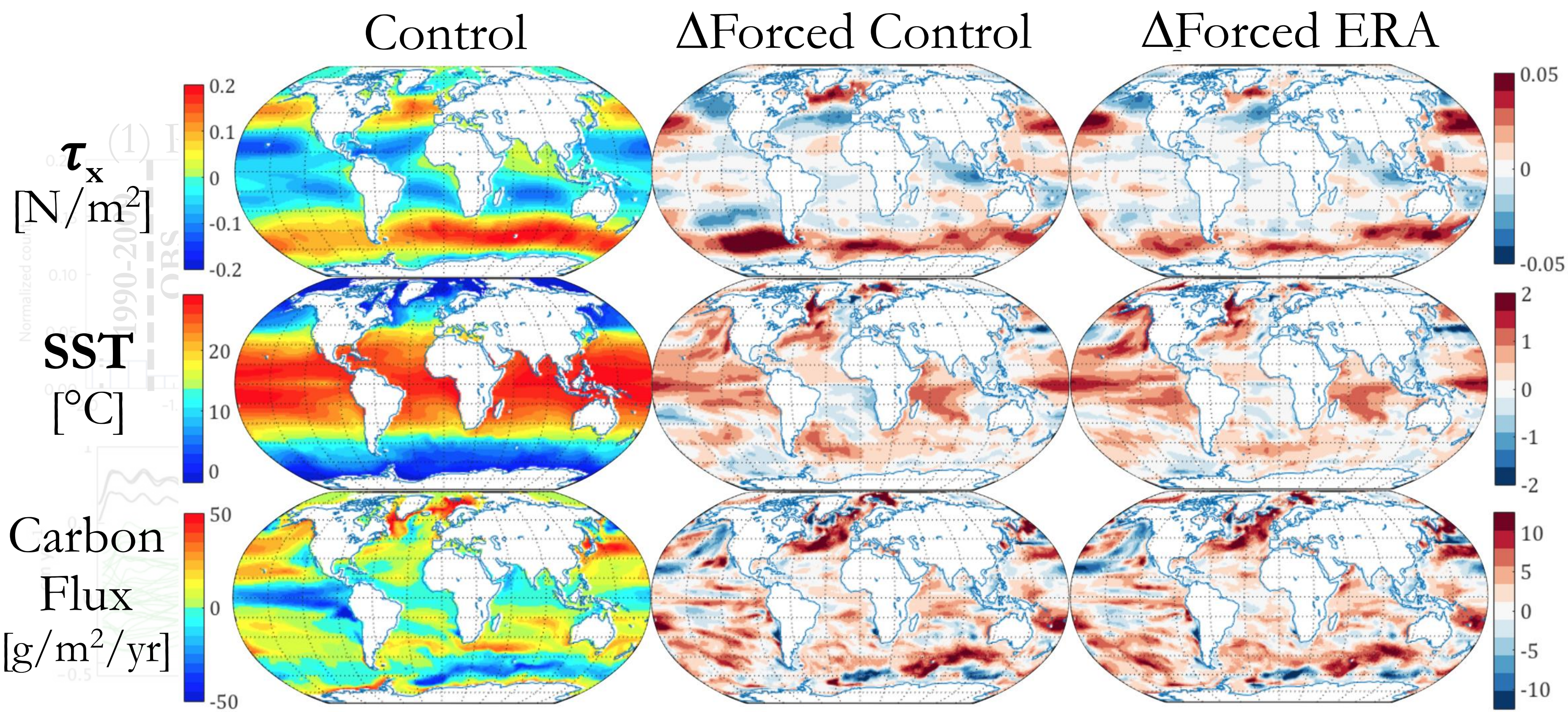
3b. Observational Period 1990-2009, Pacific

<u>Currently Underway</u>: **wind-substitution experiments**, using Delworth et. al., (2014) method, but with ESM2M, testing ocean-carbon response to observed decadal trends in Equatorial Pacific winds.

3b. Observational Period 1990-2009, Pacific

<u>Currently Underway</u>: **wind-substitution experiments**

First 2 years (1979-1980) of simulations complete:



Conclusions

1. Initial Condition Large Ensemble and Multi-model experiments with ESM's indicate natural variability produced much of data-based regional trends in the ocean carbon sink over past 2 decades.

2. Model bias in decadal variability of Equatorial Pacific wind stress is candidate cause of disagreement between data-based estimates and modeled trends in the ocean carbon sink in this region.