Testing ocean biogeochemical models using combined measurements of atmospheric potential oxygen (APO) and Ar/N_2

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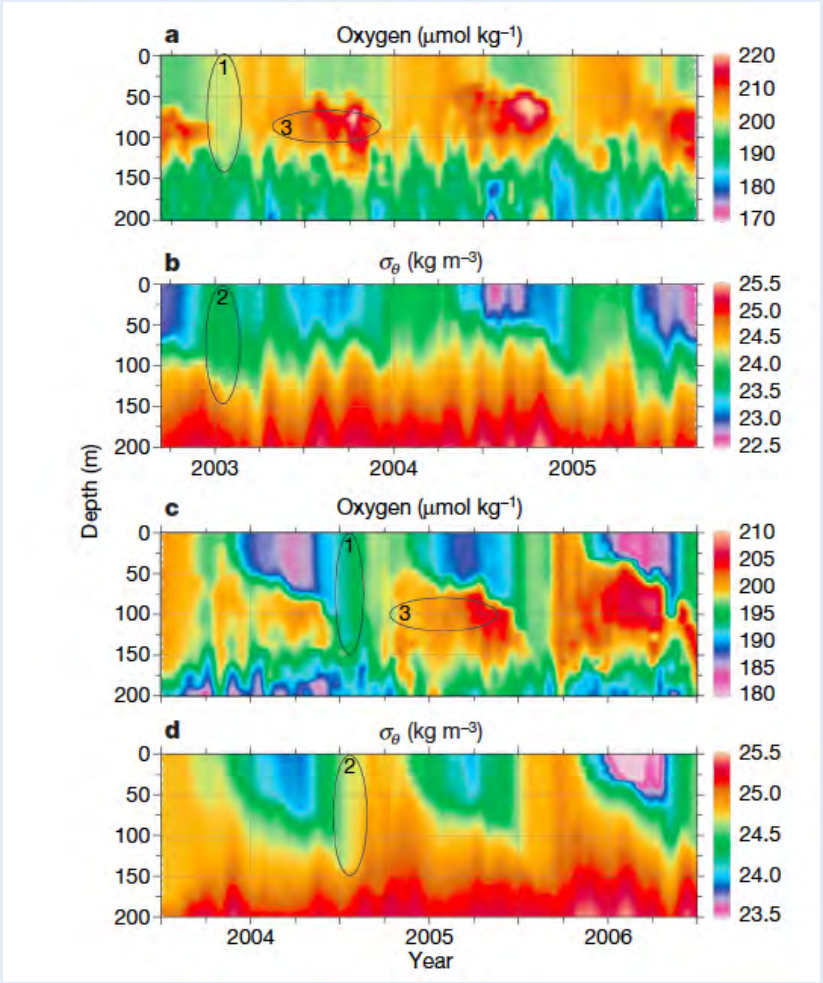
and
The Ocean Modelers

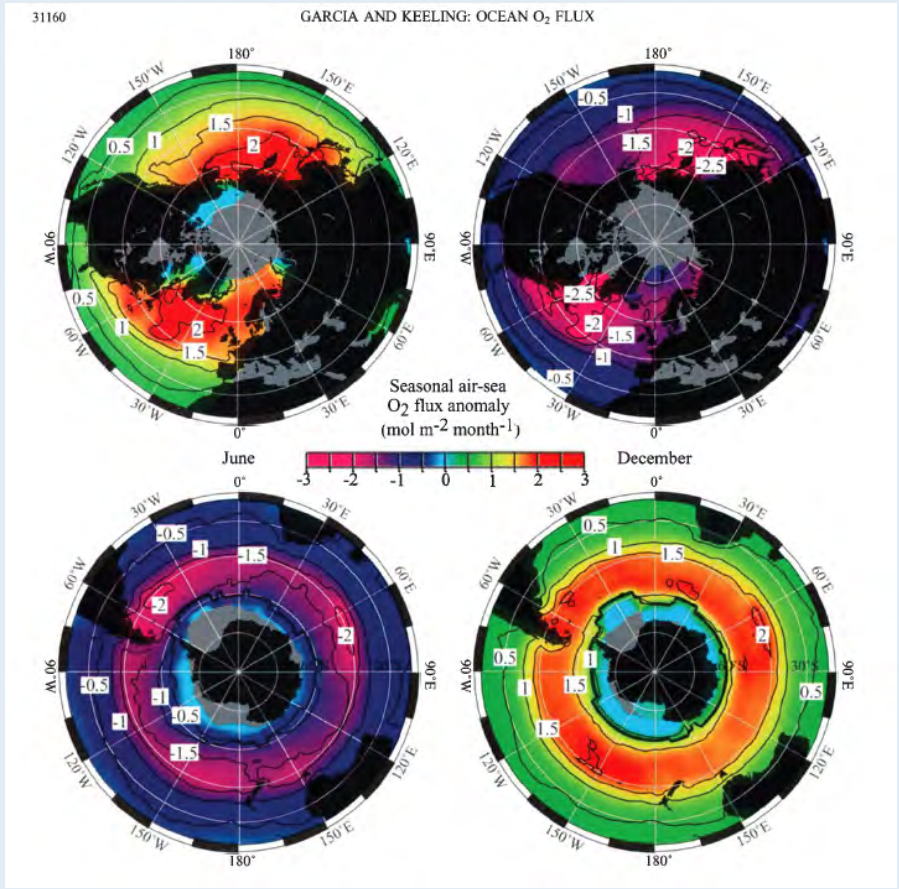
Seasonal Physical and Biogeochemical Variations – Ocean

North Pacific Ocean - Subtropics



Riser *et al.*, 2008

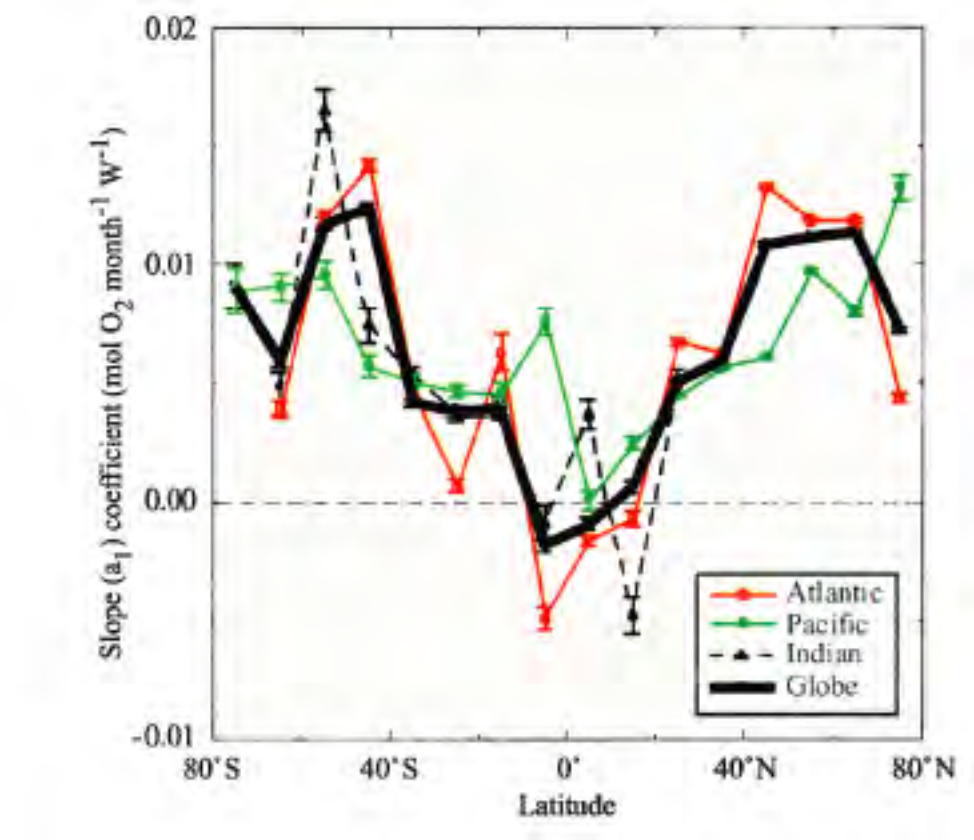
Flux > 0 : O_2 Outgassing



Garcia & Keeling, 2001

Test 1 for BGC models : Ocean Processes

Latitudinal
$fO_2/\Delta Q$ Flux Relationship



Garcia & Keeling, 2001

$$fO_2(lat) = a_1 * \Delta Q\,(lat) + a_2$$

O_2 Flux

Heat Flux
Seasonal Anomaly

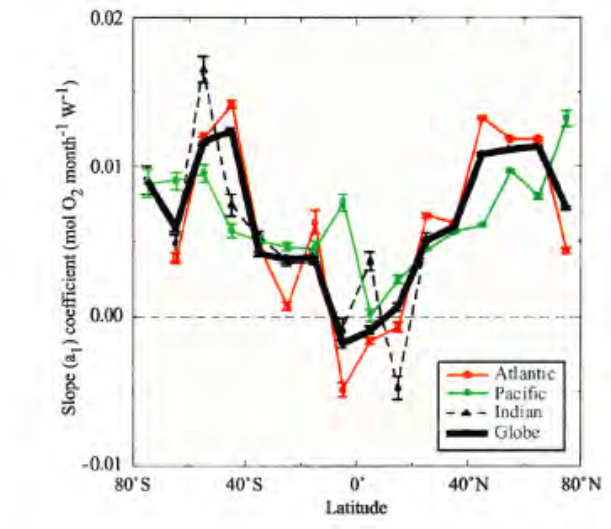
Wind speed from ECMWF

Heat flux from ECMWF

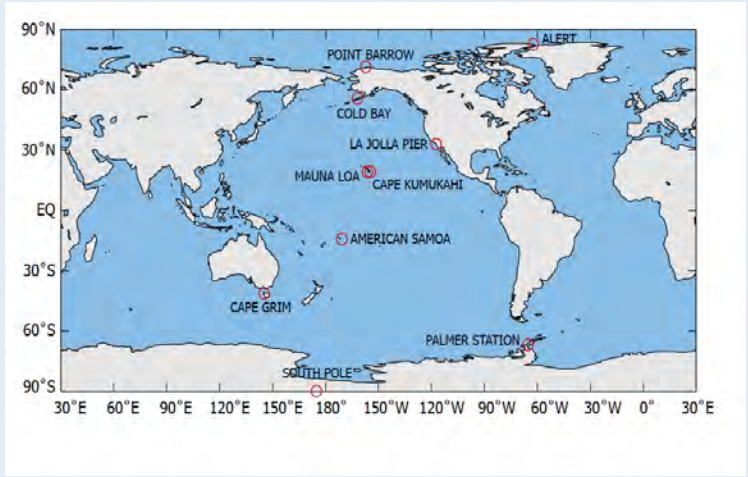
How do current bgc models compared to this ?

What can the atmosphere "see" ?

Latitudinal FO_2/Heat Flux Relationship

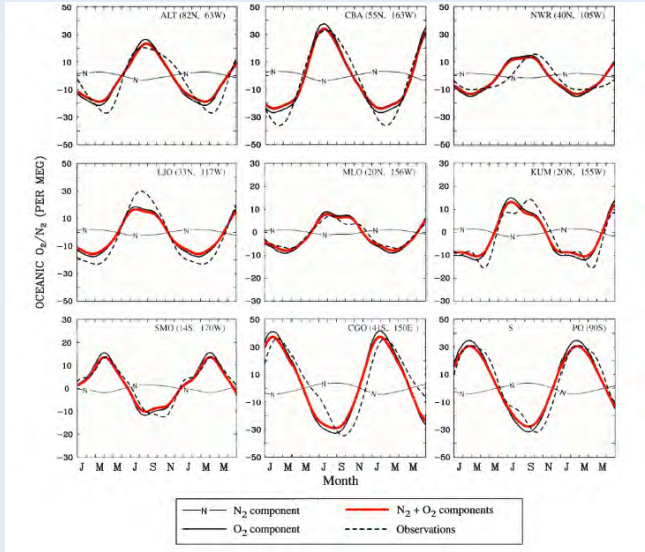


Scripps Network of Stations



Ocean fluxes of heat and gases can be ALSO constrained by atmospheric obs.

BGC Models can be also tested Transporting the fluxes in the atmosphere by an Atmospheric Transport Model

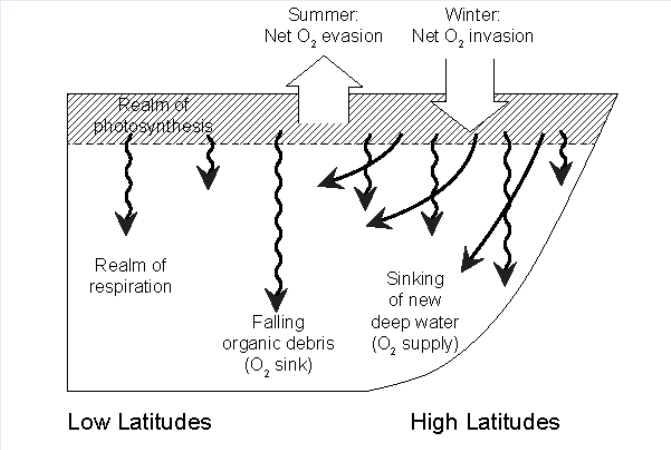


Garcia & Keeling, 2001

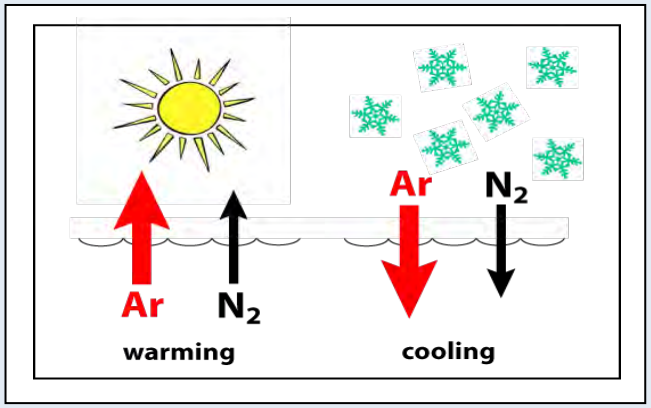
New Test for BGC models : APO & Ar/N_2

Oceanic Processes

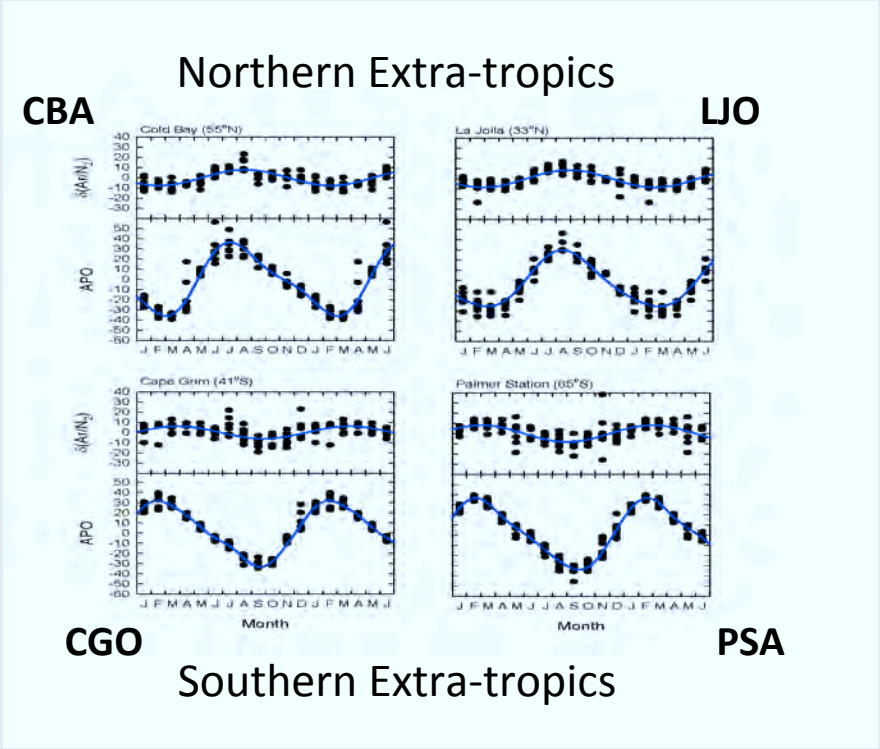
O_2 tracks both Physics and Biology



Ar and N_2 track heat (only)



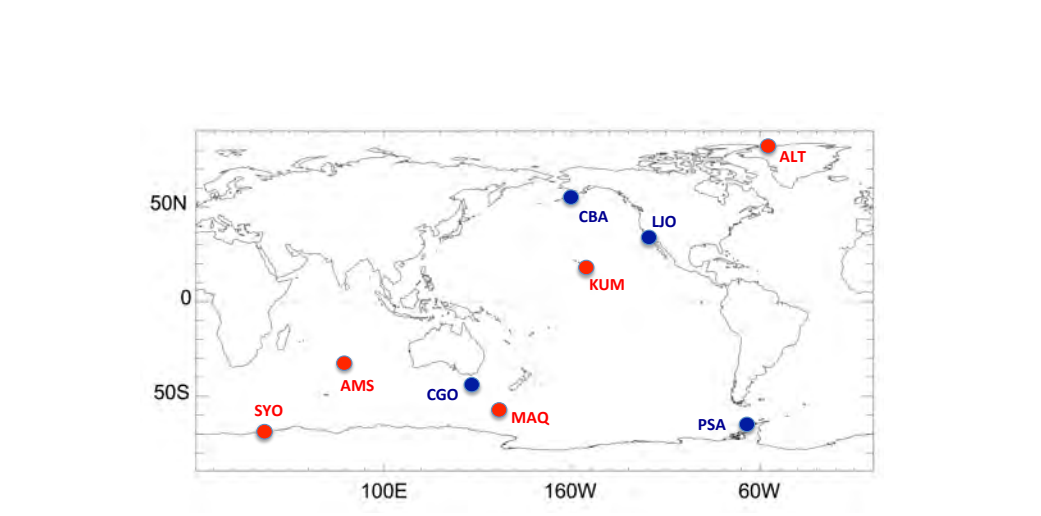
Atmospheric observations



Atmospheric Potential Oxygen
= O_2 + 1.1 * CO_2

Atmospheric Observations as Models Benchmark ?

Scripps (& more) Network of atmos. stations



Station	AMP(APO) / AMP(Ar/N_2)
Cold Bay (CBA)	4.15 ± 0.41
La Jolla (LJO)	3.20 ± 0.27
Cape Grim (CGO)	4.89 ± 0.68
Palmer Station (PSA)	3.97 ± 0.54

Seasonal Heat Fluxes

Ocean Gas Fluxes

Atmospheric Transport of ocean fluxes (TM3)

A new benchmark for ocean bgc models ??

Suite of forced Ocean Models to test

Model	Ocean Physics Res.	Ocean BGC
MOM4	~ 1 by ~1	TOPAZ (GFDL)
CCSM	~ 1 by ~1	BEC (NCAR/UCI)
NEMO - CTRL	2 by 0.5 – 2	PISCES (IPSL)
NEMO - WS	2 by 0.5 – 2	PISCES (IPSL)
CESM	2 by 0.5 – 2	BEC (NCAR)

$$\text{Flux} = \frac{\partial S}{\partial T} \frac{Q}{C_p \cdot \rho} \alpha$$

Models are forced by re-analyzed products (heat, water fluxes & wind stress)

Models compute O_2 and CO_2 fluxes
N_2 and Ar fluxes are HF fluxes derived (Keeling & Shertz, 1992)

$\delta S/\delta T$ = Gas Solubility

Q = Heat Flux

C_p = Heat Capacity

ρ = SW Density

α = 1/1.3 (Jin et la. 2007)

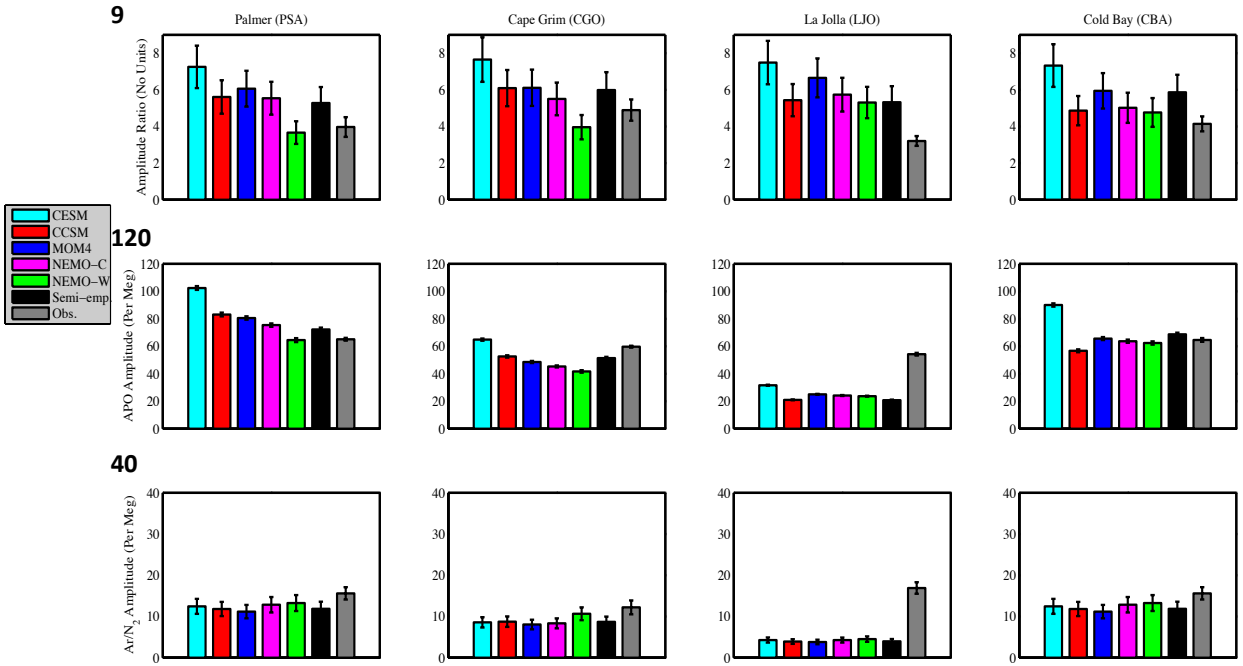
Ranking the models

PSA CGO LJO CBA

Amplitude Ratio

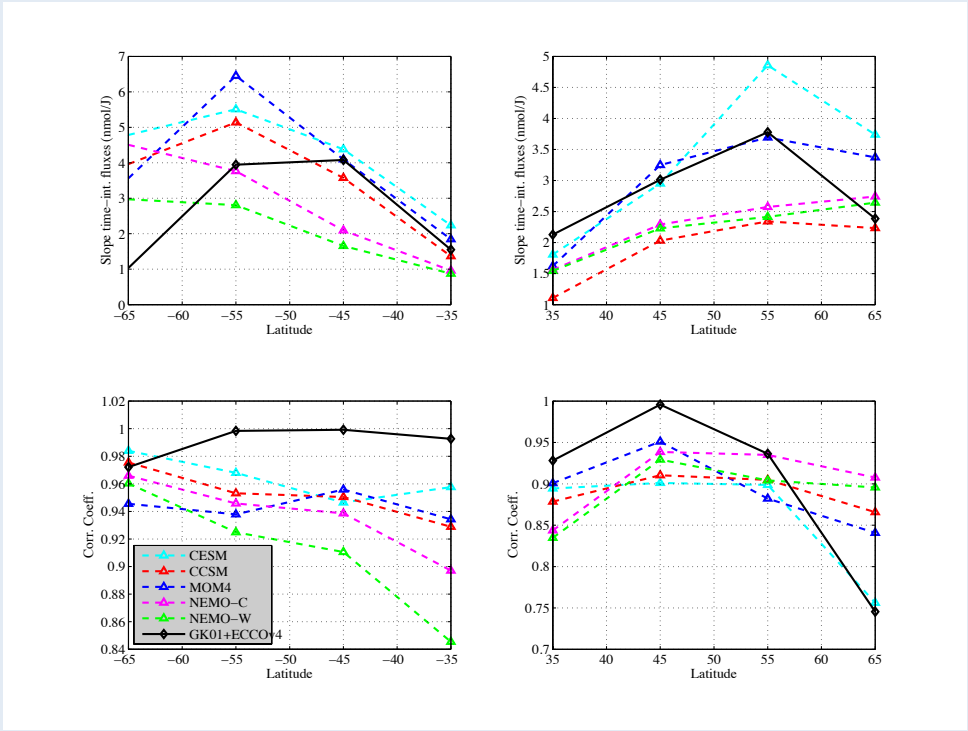
APO Amplitude (Per Meg)

Ar/N_2 Amplitude (Per Meg)



Global Dataset Vs BGC Models

South Hemisphere **North Hemisphere**



Focus on extra-tropical systems

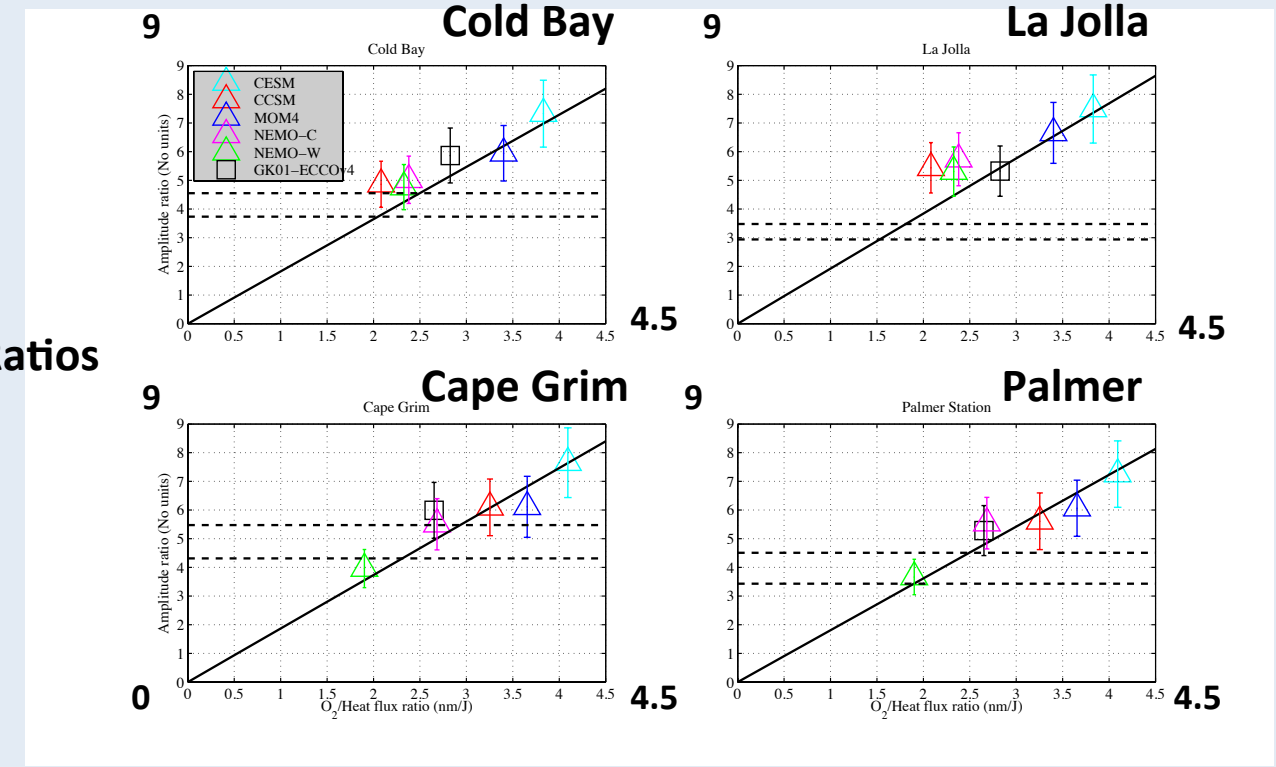
Models show Different Sensitivity on FO_2/Heat Flux

Same models also show different sensitivity in different hemispheres

WHAT IF now we combine :

Old Ocean metric : FO_2/Heat
New Atm. metric : Amplitude Ratio

Ocean + Atmosphere



AMP. Ratios

Northern Hemisphere

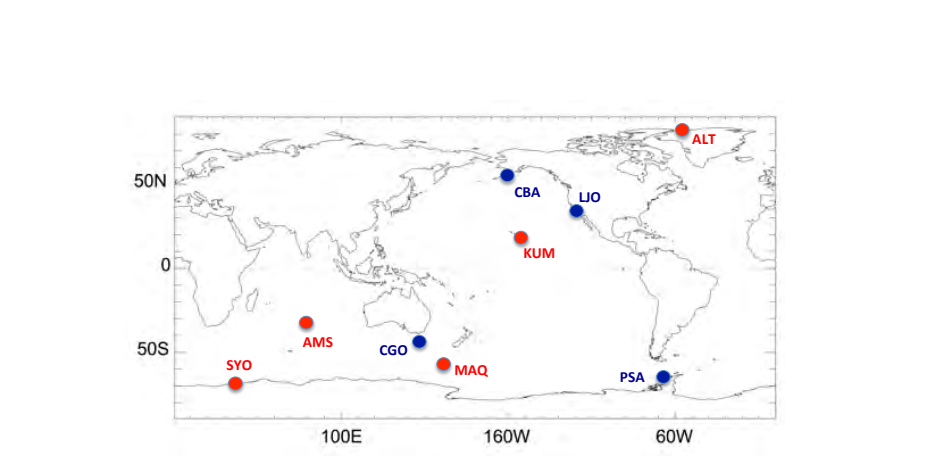
Southern Hemisphere

O_2/Heat Flux ratio (35 - 65 average)

Manizza *et al., in prep.*

Both methods seem to converge !!

What's Role for the Atmospheric Transport ?

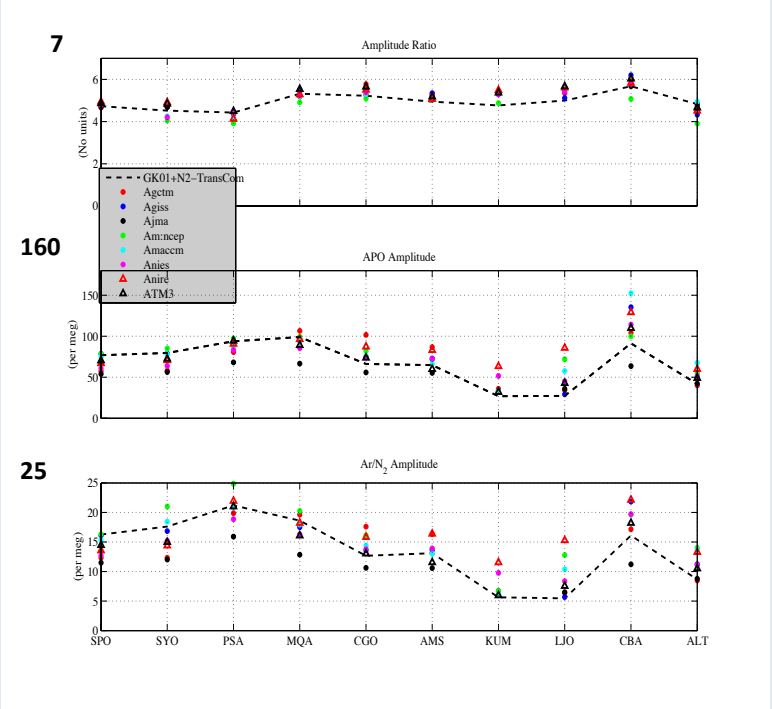


Atmospheric Stations

Amplitude Ratio

APO Amplitude (Per Meg)

Ar/N_2 Amplitude (Per Meg)



TransCom Models

O_2 fluxes (Garcia & Keeling 01)
N_2 fluxes (Blaine 2005)
Different physical transport

AMP. RATIO insensitive to transport model

Conclusions

Atmospheric obs. can be used as a new rigorous test for the performance of bgc models on air-sea gas fluxes at seasonal time scale.

The new method can help us to evaluate the performance of the ocean bgc models in the physical and biogeochemical components of O_2 fluxes via the use of Argon and then the ratio of seasonal amplitudes (Amp_{APO} / $Amp_{Ar/N2}$).

The use of APO and other atmospheric gases can be adopted as new metric to constrain , in conjunction with satellite products as (e. g. C export production) to constrain the ocean bgc components of the CMIP5 Earth System Models (Nevison *et al., 2015*) .