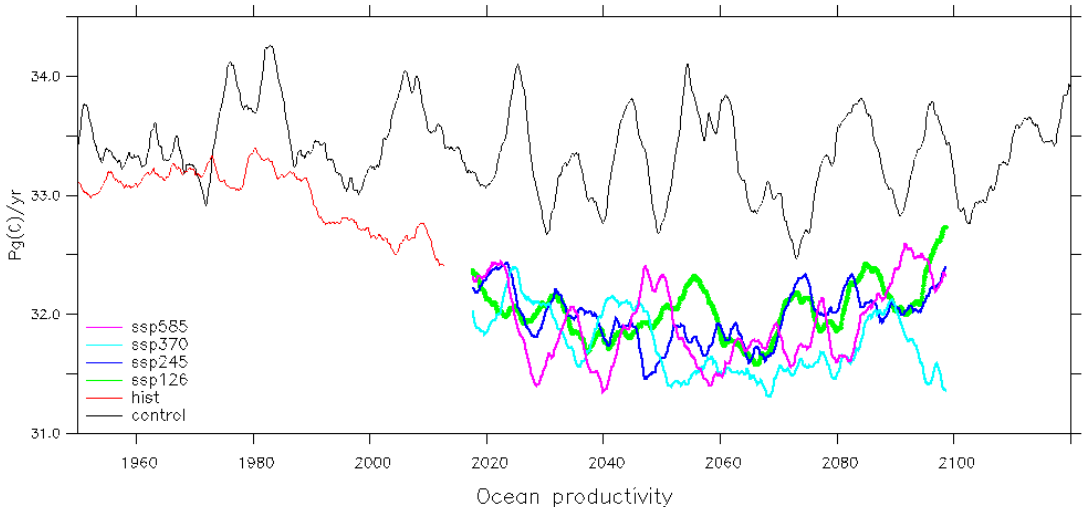
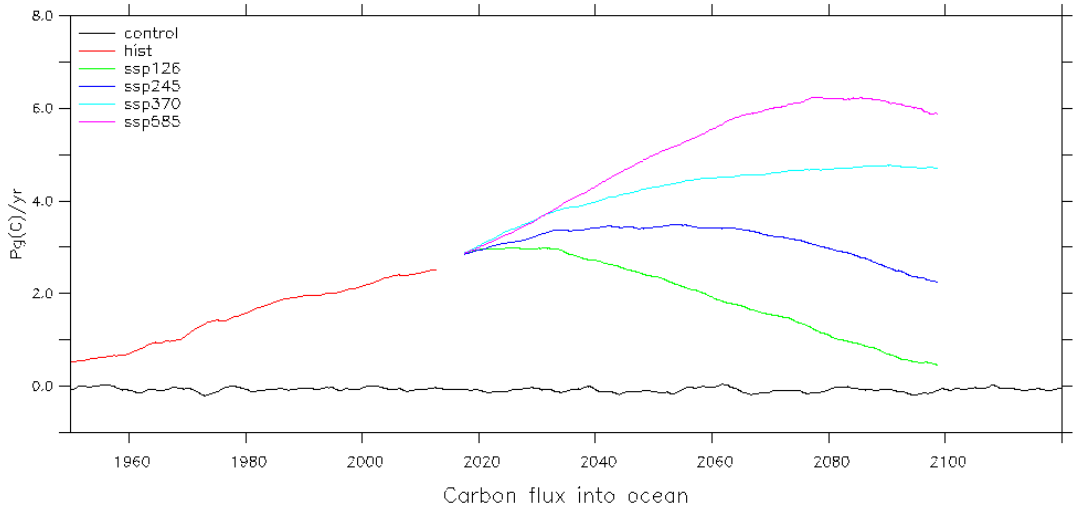
ACCESS-ESM ocean biogeochemical climate change projections

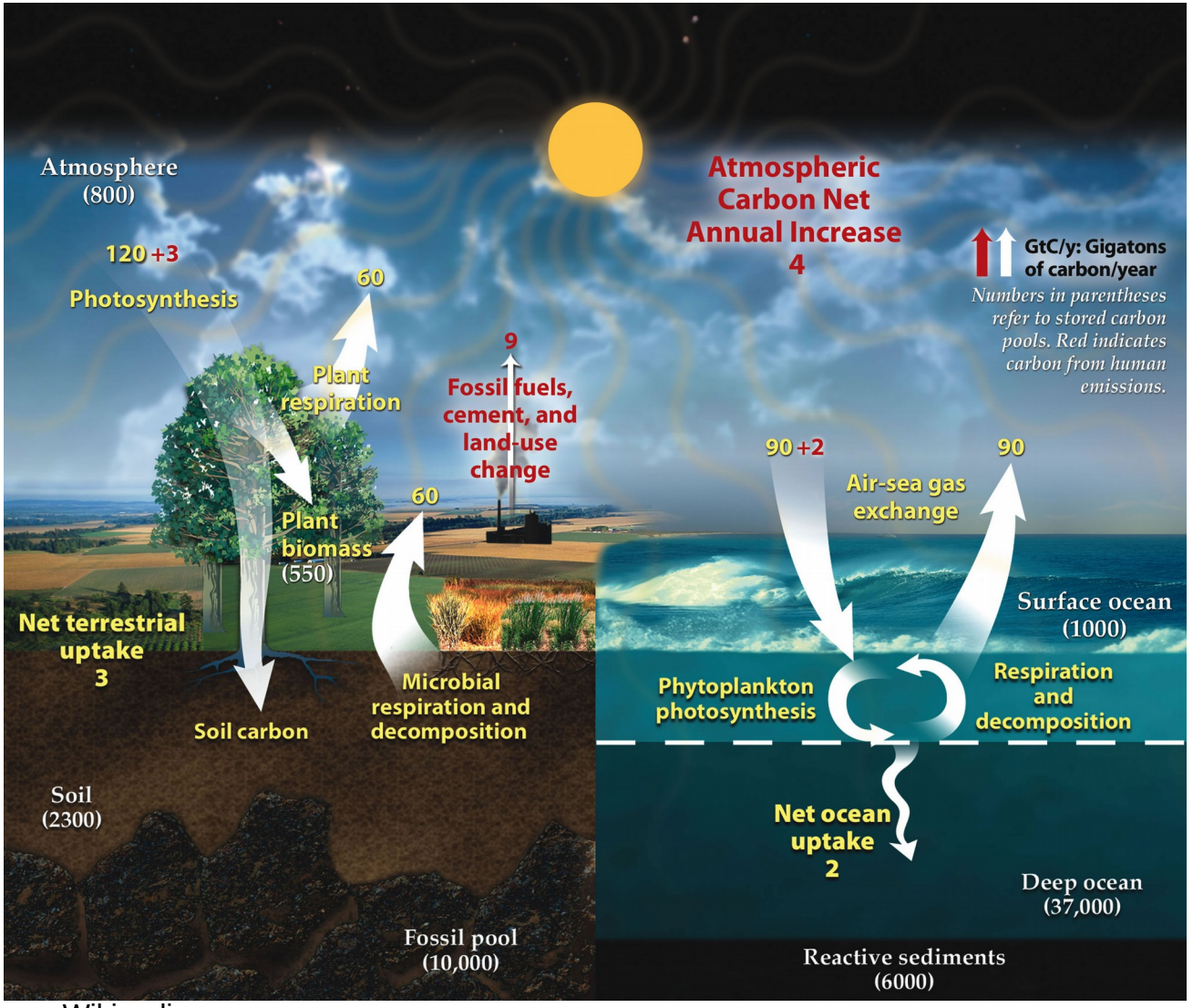




COSIMA e-workshop, May 2020

Matt Chamberlain, Andrew Lenton, Tilo Zeihn, Rachel Law.

Earth System Model



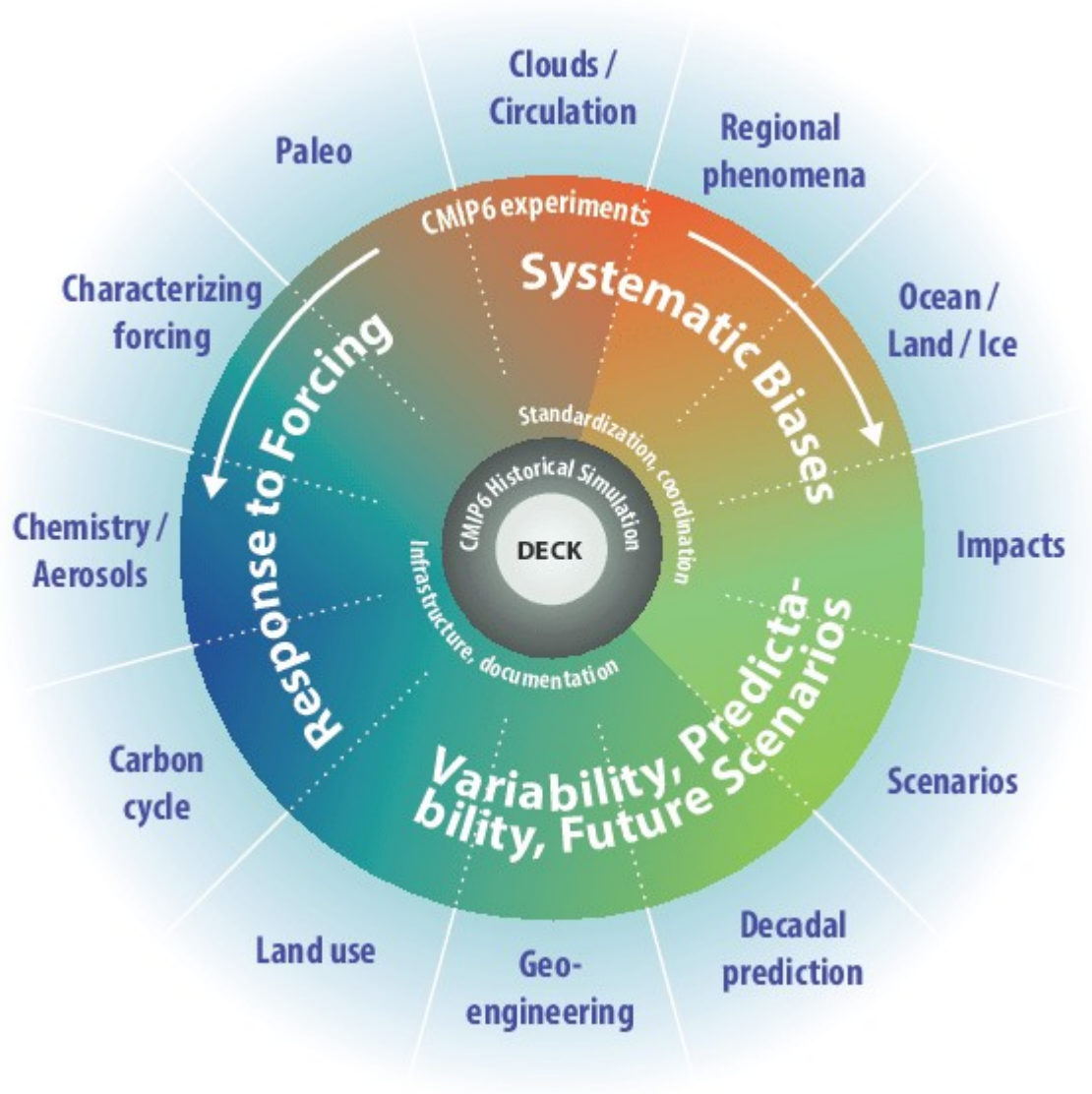
Wikipedia

ESM => global climate model with carbon cycle.
Carbon cycle shown here; nutrient and oxygen cycles also simulated.

ACCESS-ESM1.5 can run with prescribed atmospheric GHGs or emission-driven scenarios (interactive carbon).

Simulations with ESM add significant value to climate projections; demonstrate potential impacts to land and ocean BGC and ecosystems.

CMIP6 experiments



Two model ACCESS configurations were submitted to CMIP6: CM2 and ESM1.5.

Many experiments run in 2019 and results contributed to various MIPs to meet IPCC/AR6 timeline.

Results standardised and publicly available via the Earth System Grid (esgf.nci.org.au)

ESM1.5 Experiments

- **PreIndustrial control** – 500 years of steady state after spin up.
- **PreIndustrial control** – emission driven (interactive carbon)
- **Abrupt 4xCO2** – increase atmo. CO2 to 4x preindustrial value, run for 140 years
- **1-percent CO2** – gradual increase in atmospheric CO2, 1% per year for 140 years to 4 x PI. CO2
- **AMIP** – atmosphere only

- **Historical** – 1850 to 2014
- **Historical – emission driven**

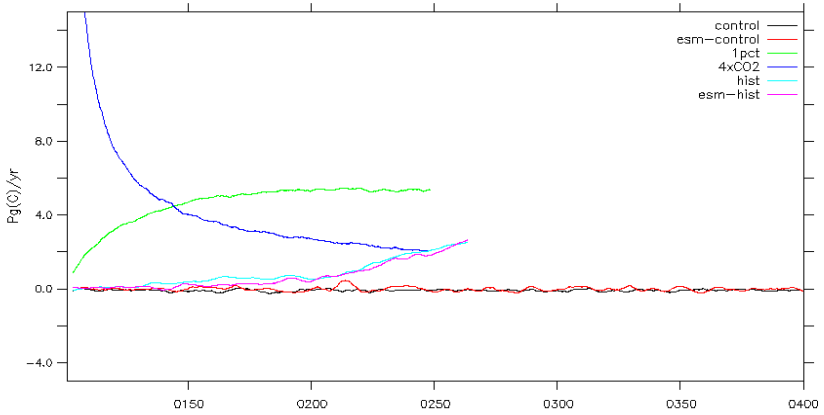
- **Scenarios – SSP 1-26, 2-45, 3-70, 5-85**, various projections of socio-economic scenarios.

- **1-percent CO2-bgc** – 'CO2 fertilisation' only
- **1-percent CO2-rad** – radiative impact only
- **1-percent CO2-rev** – reversibility and extension

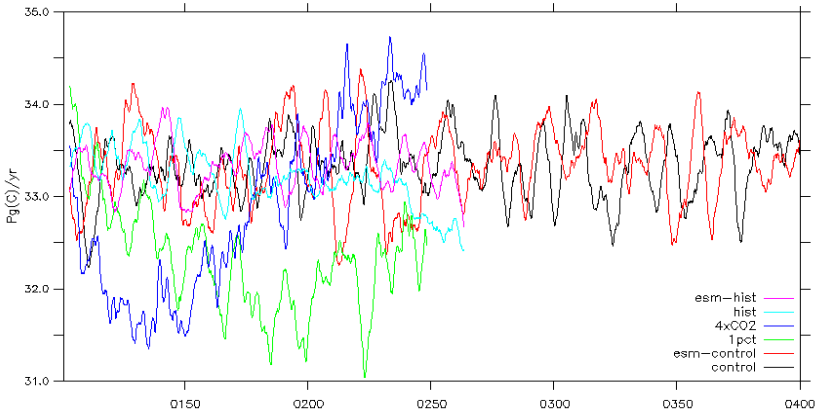
- **Pulses** – impose positive and negative CO2 changes into atmosphere.
- **Zero Emission** – branch from 1-percent CO2 run after emission of 750, 1000 and 2000 PgC, continue with zero emission.

CMIP DEC + Historical

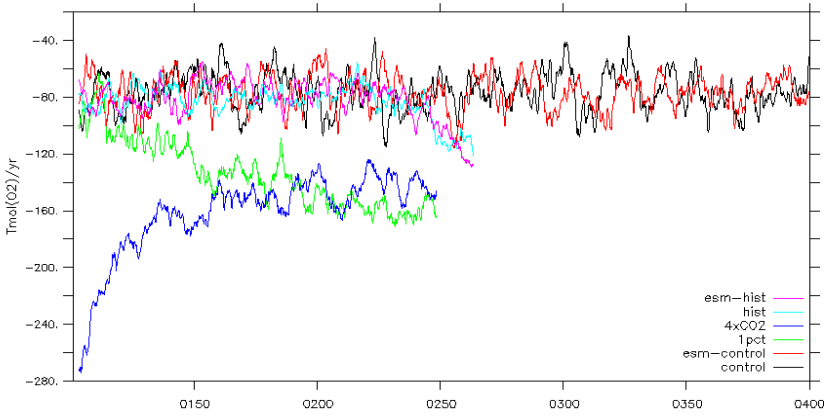
control
esm−control
1pct
4xCO2
hist
esm−hist



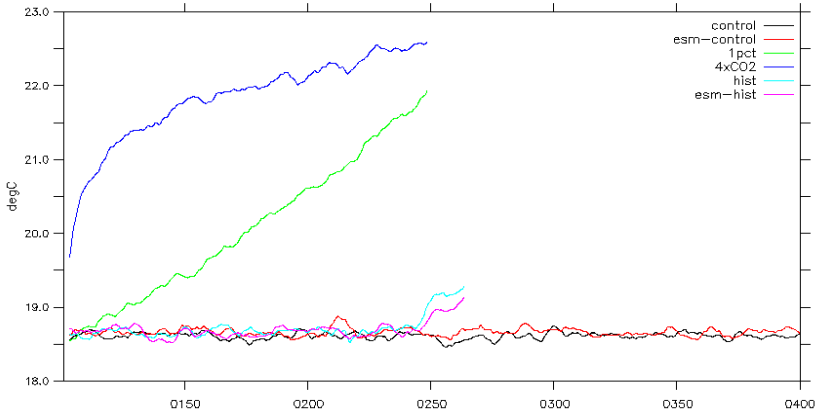
Carbon flux into ocean



Ocean productivity



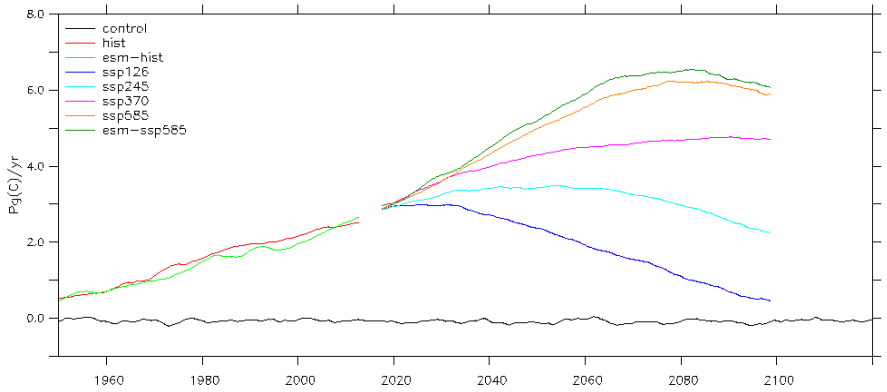
Oxygen flux into ocean



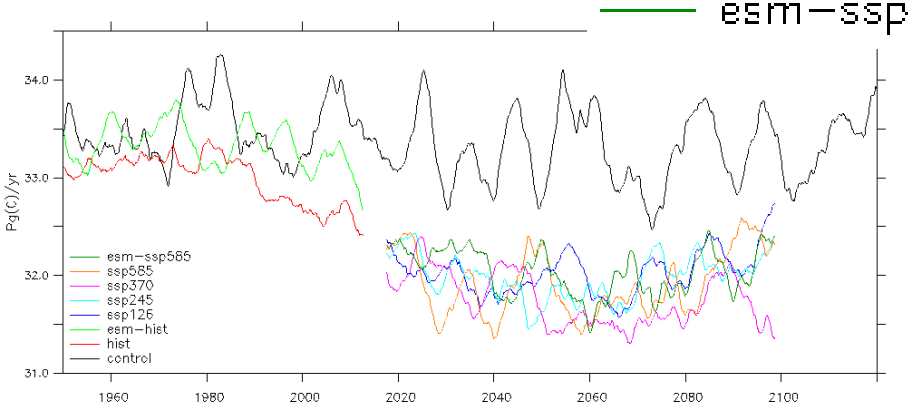
Average SST

- Control experiment fluxes are stable.
- CO2 flux in 1-percent hits 'ceiling,'
- productivity in 1-percent and 4xCO2 dip and rise.
- O2 flux largely controlled by temperature.

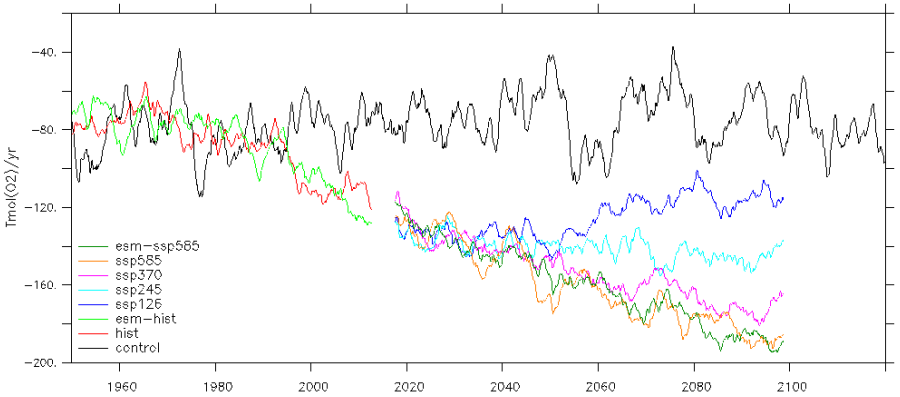
Scenarios



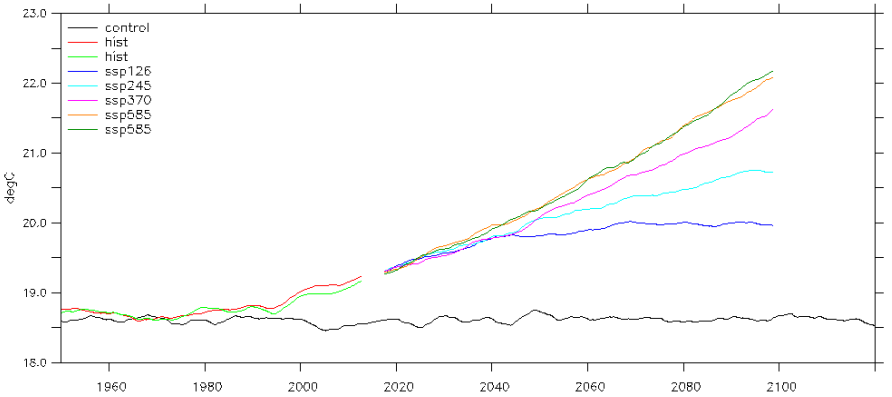
Carbon flux into ocean



Ocean productivity



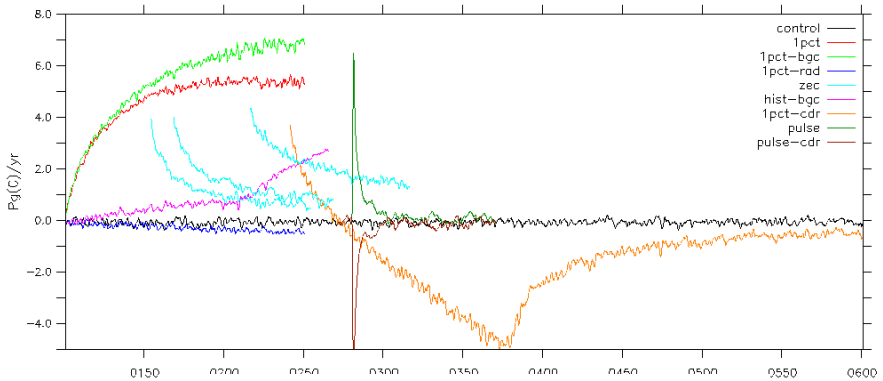
Oxygen flux into ocean



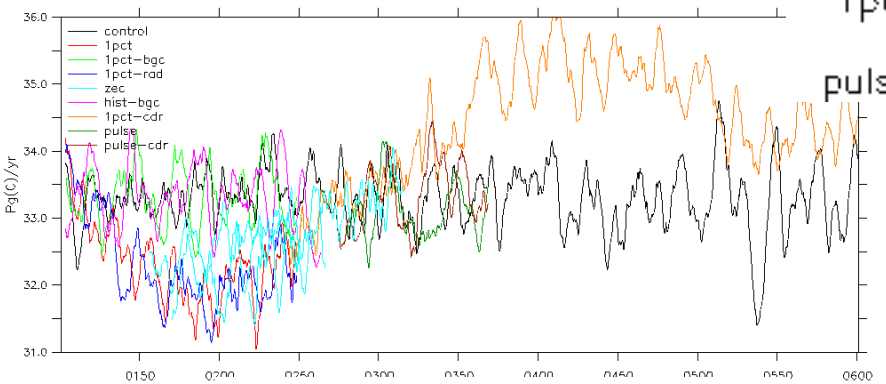
Average SST

- All scenarios show similar trends in first few decades.
- 'Business as usual'/SSP585 shows maximum in CO2 flux and dip/rise in productivity.
- Emission-driven results very close to concentration driven.

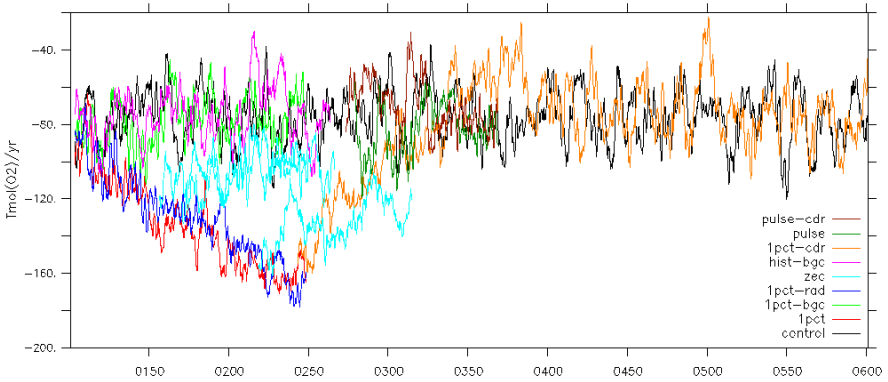
C4+CDR MIPs



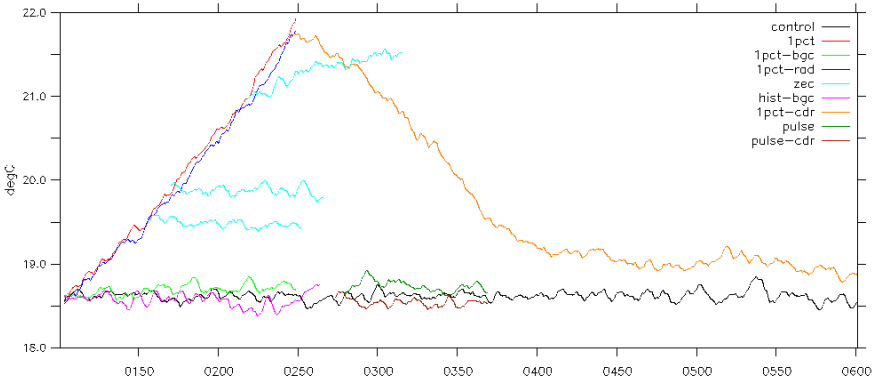
Carbon flux into ocean



Ocean productivity



Oxygen flux into ocean



Average SST

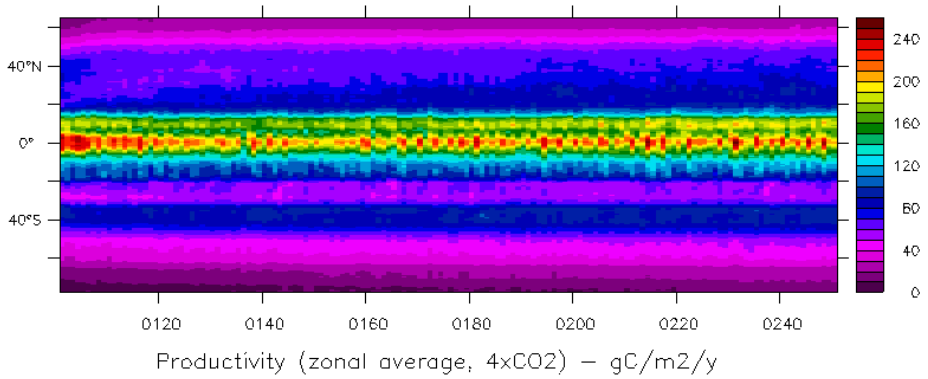
- non-linearity in components of 1-precent expriments.
- time lag in CO2 outgass in 1%-reverse.

- in 1% reverse+recover, productivity enhanced in recovery, but O2 only returns to base value.

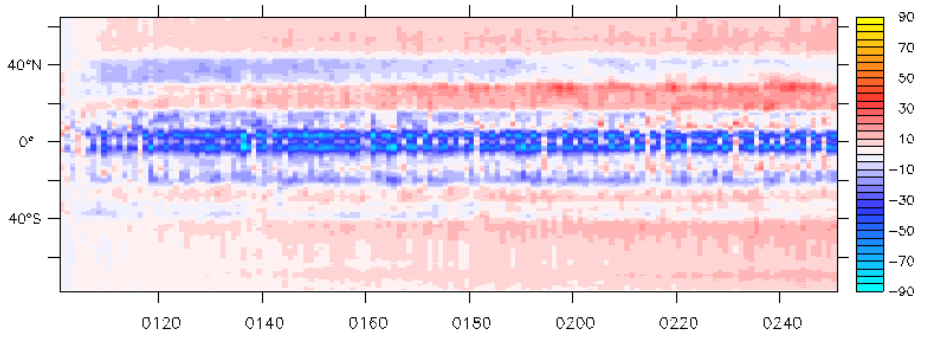
Some observations from multi-experiment comparison

- Apparent maximum to CO2 ocean uptake (will be reached ~2070 in business-as-usual scenario).
  - Due to slowdown in uptake in upper ocean reservoirs.
- Global ocean productivity drops (5-10%) in all scenarios, but increases in warm climates (details to follow)
- Oxygen flux largely driven by temperature; O2 flux returns to background in reversibility/recovery experiment leaving ocean in O2 deficit (~5%).

Regions driving productivity changes



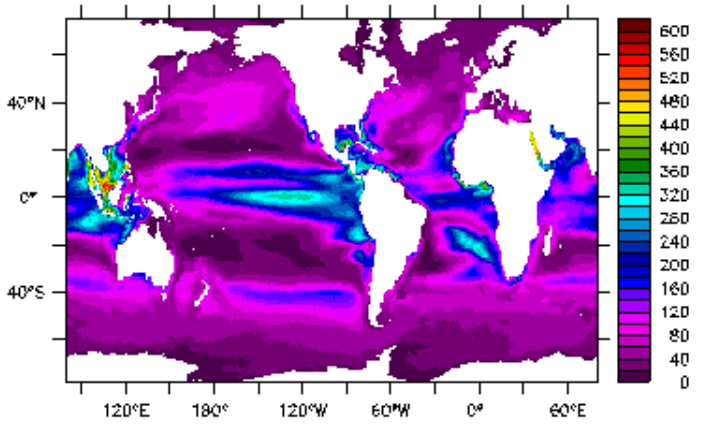
Productivity (zonal average, 4xCO2) – gC/m2/y



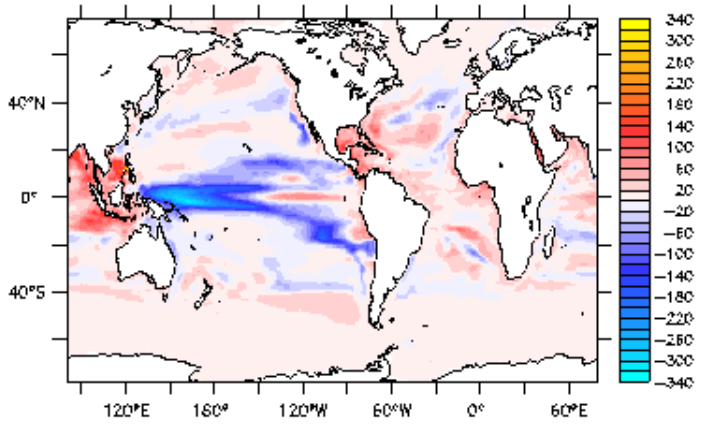
Productivity change – gC/m2/y

- "What is driving the drop and rise in global productivity in SSP585, 1% and 4xCO2 experiments?"

- investigate productivity changes in abrupt 4xCO2 experiment where changes are most significant.
- time series of zonal averages indicate different regions responding at different times.



Productivity (y146–150 ave, 4xCO2) – gC/m2/y

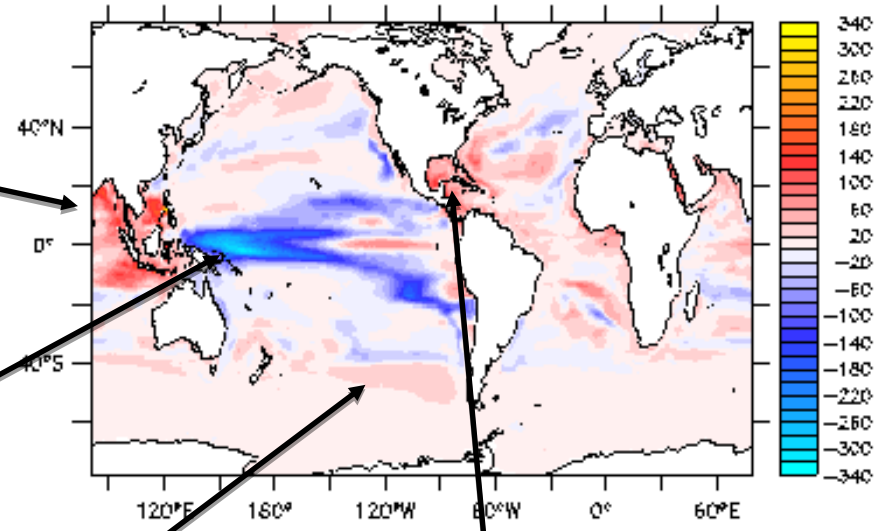


Productivity change – gC/m2/y

Regions driving productivity changes

SE Asia: increase in productivity related to increase in temperature and mixed layer depth.

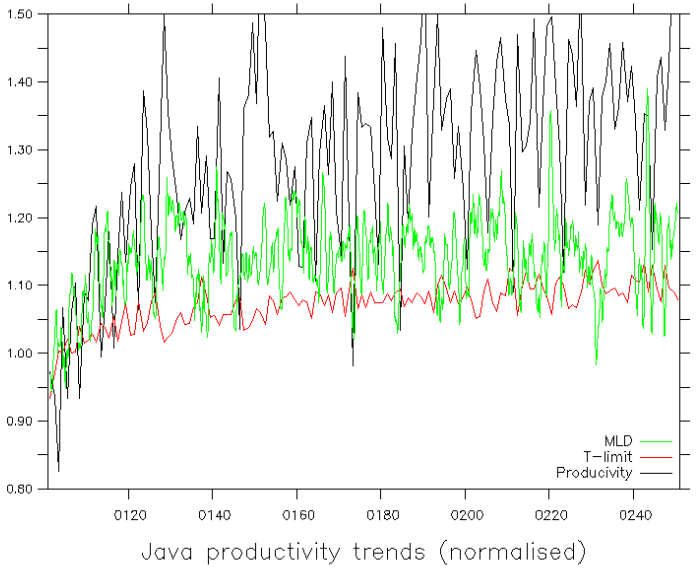
Equatorial Pacific: decrease in productivity with reduction in nutrient extent.

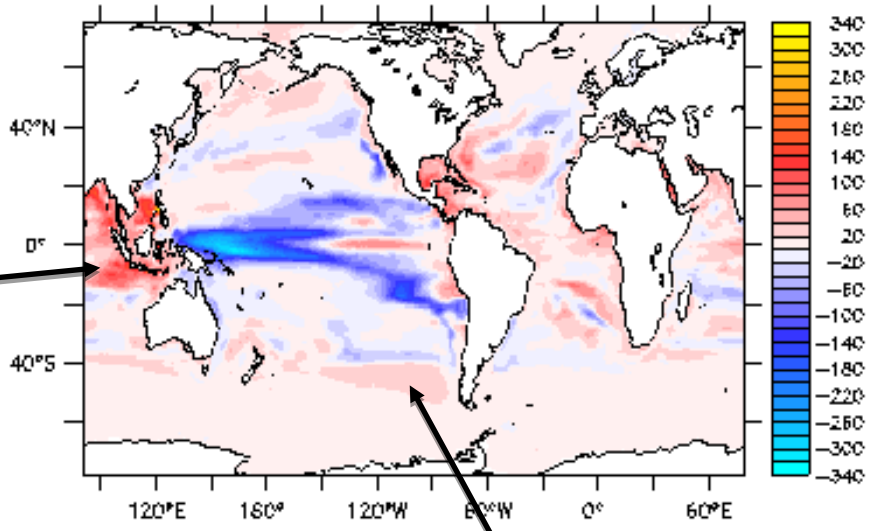


SE Pacific: increase in productivity with temperature

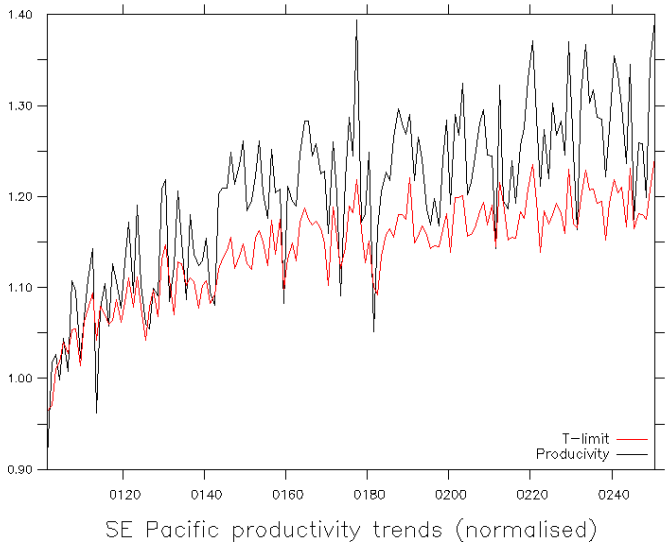
Gulf of Mexico: increase in productivity with extra nutrients.

Regions driving productivity changes



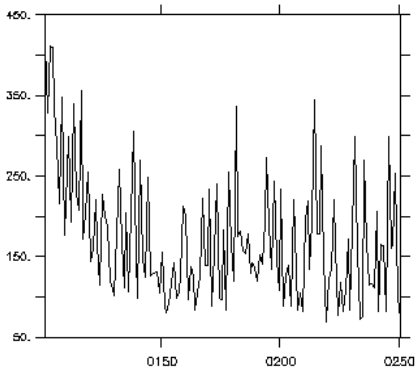


SE Asia.: increase in productivity related to increase in temperature and mixed layer depth.

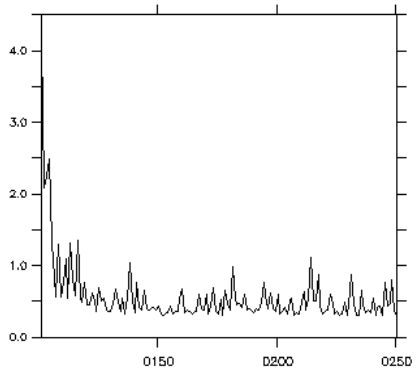


SE Pacific: increase in productivity with temperature

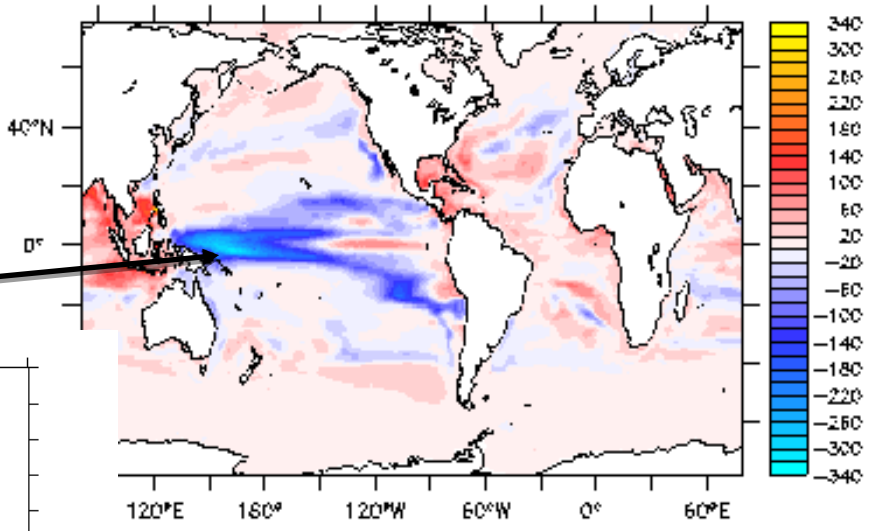
Regions driving productivity changes



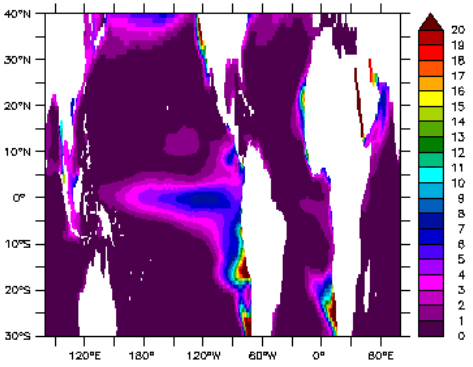
Producitvity ave – gC/m2/y



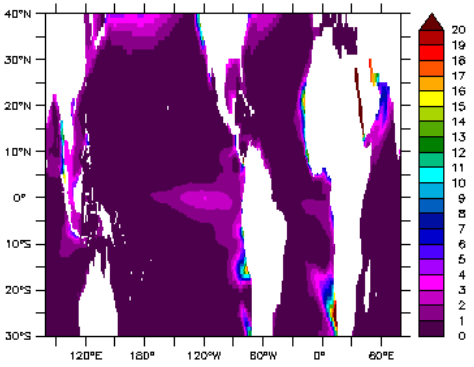
Nit. ave – mmol/m3



Productivity change – gC/m2/y



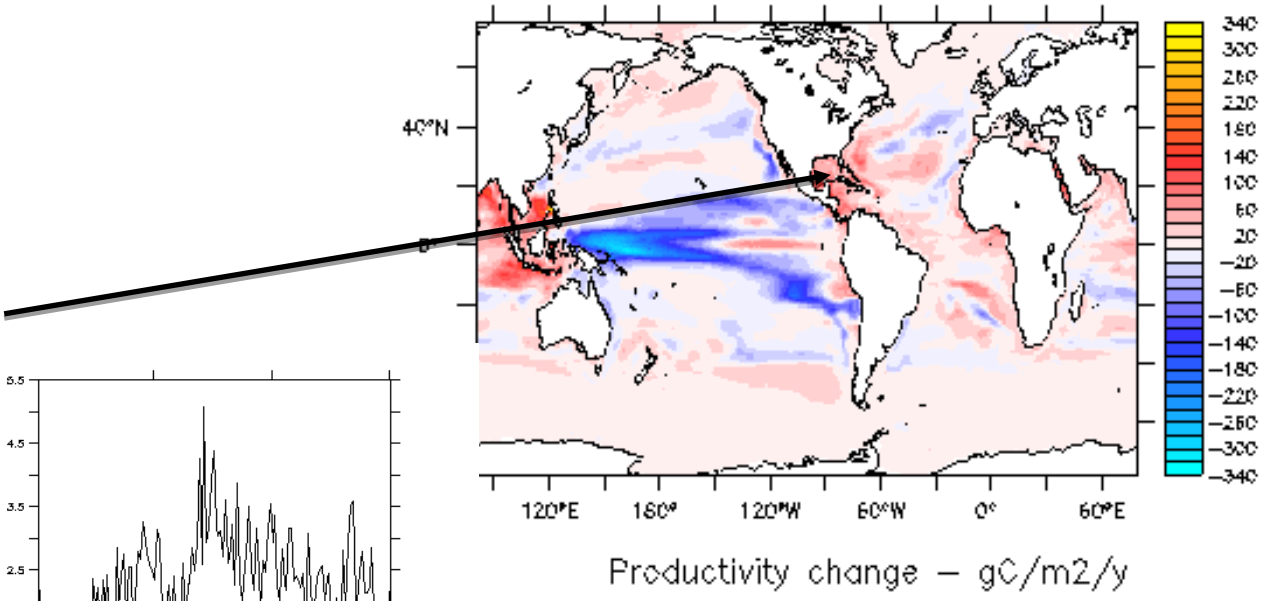
Nit. ave – mmol/m3

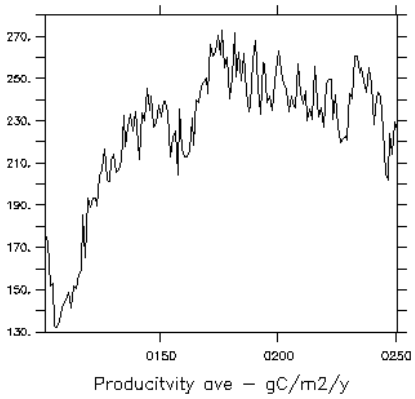


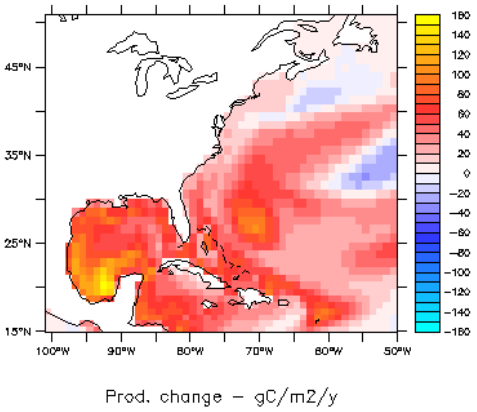
Nit. ave – mmol/m3

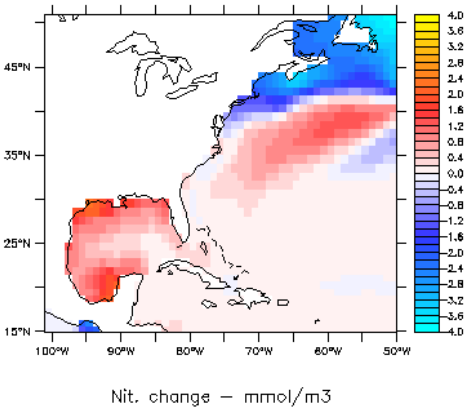
Equatorial Pacific: decrease in productivity with reduction in nutrient extent.

Regions driving productivity changes









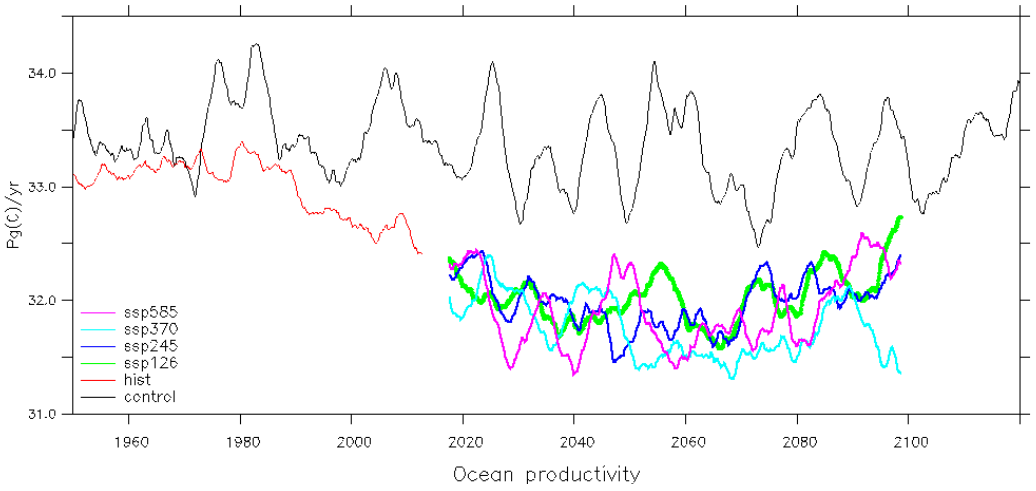
Gulf of Mexico: producivity increase matches nutrient changes spatially and temporally.

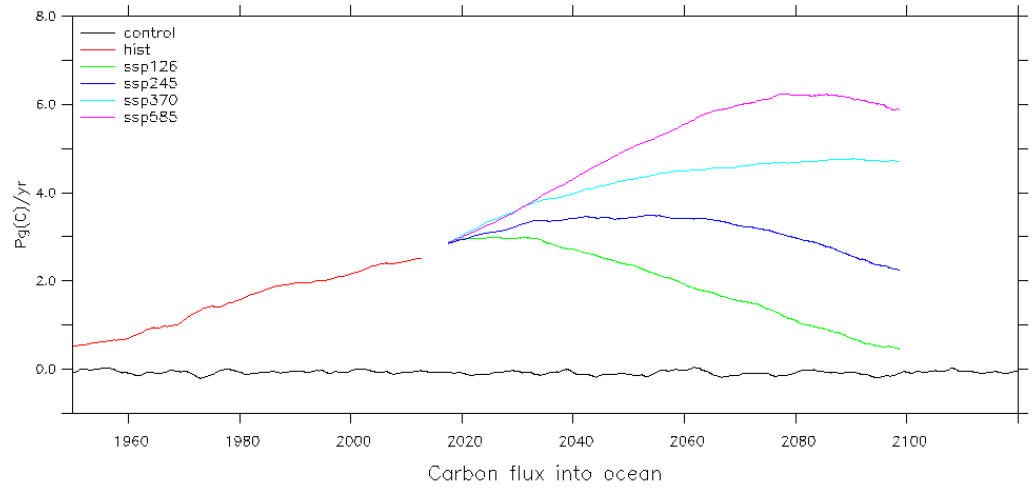
Looking forwards...

2019 busy with production experiments for CMIP6.
2020 transition to gadi (substantial speed up, ~30%), continue some CMIP6 contributions, analysis.

Options and work to do (depending on support)…
- ocean BGC developments: nitrification/denitrification processes, biophysical coupling.
- land BGC developments: dynamic vegetation.
- non-CO2 greenhouse gases.
- incorporate into CM2.
- test resolution dependence of results (downscaling).

Thanks.





- Now have ESM projections of climate change showing consistent and significant impacts to global and regional ecosystems.

- Demonstrate that the ESM is a valuable tool to start to understand processes behind these changes.