Using atmospheric CO_2 for Earth System Model evaluation

www.cawcr.gov.au

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Carbon cycle modelling through ACCESS-ESM1 with a focus on atmospheric transport, CABLE coordinator

CSIRO Marine and Atmospheric Research

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Australian Government

Bureau of Meteorology

The Centre for Australian Weather and Climate Research

A partnership between CSIRO and the Bureau of Meteorology

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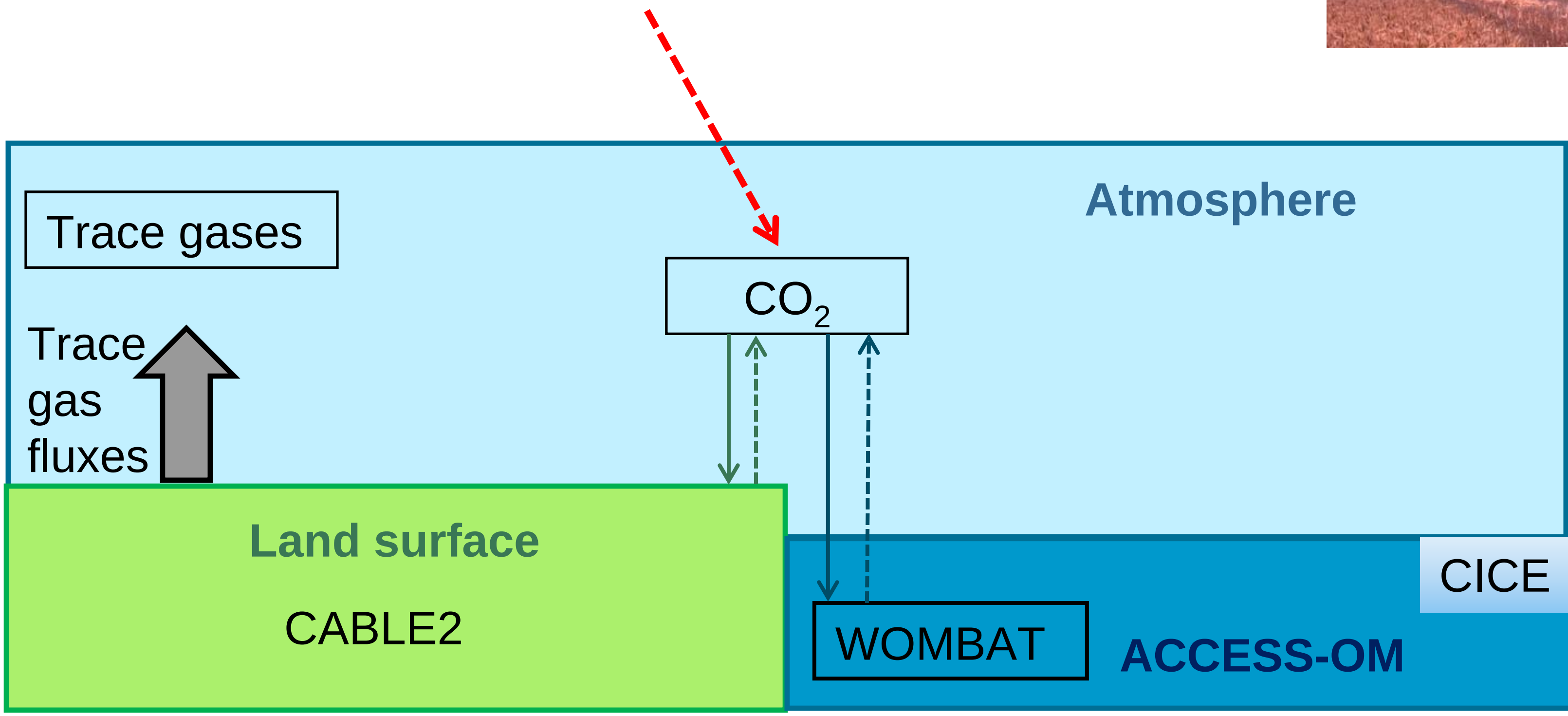
Outline

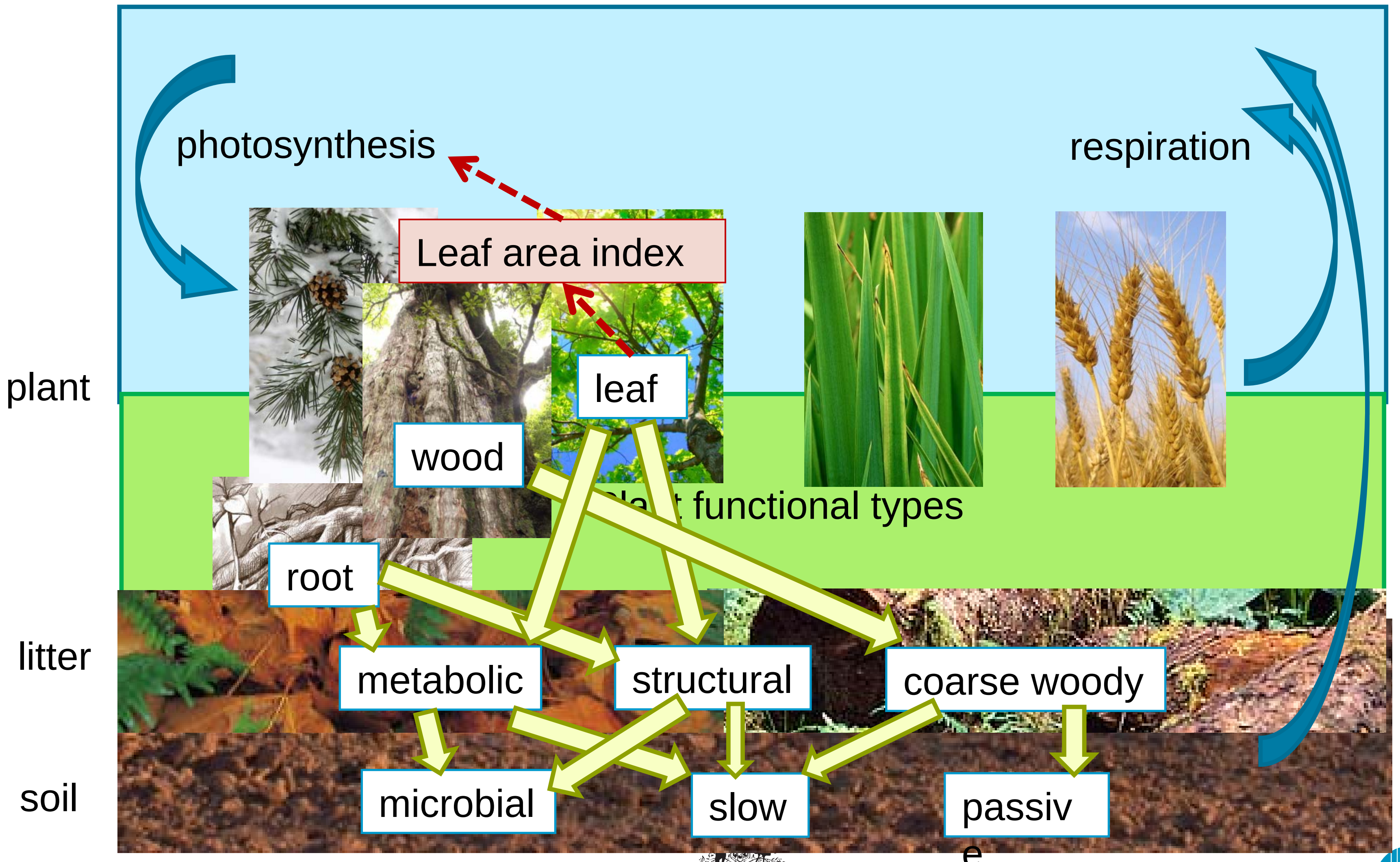
- Components of ACCESS-ESM1
- Testing and results from component models
  - Land-atmosphere only
  - Ocean only
- Initial ACCESS-ESM1 runs with prescribed atmospheric CO_2
- Why use atmospheric CO_2 to evaluate carbon fluxes
- Common diagnostics – seasonal cycle
- Much more information available ….
  - Cape Grim and SE Australian fluxes
  - Macquarie Island and southern ocean fluxes

ACCESS-ESM1

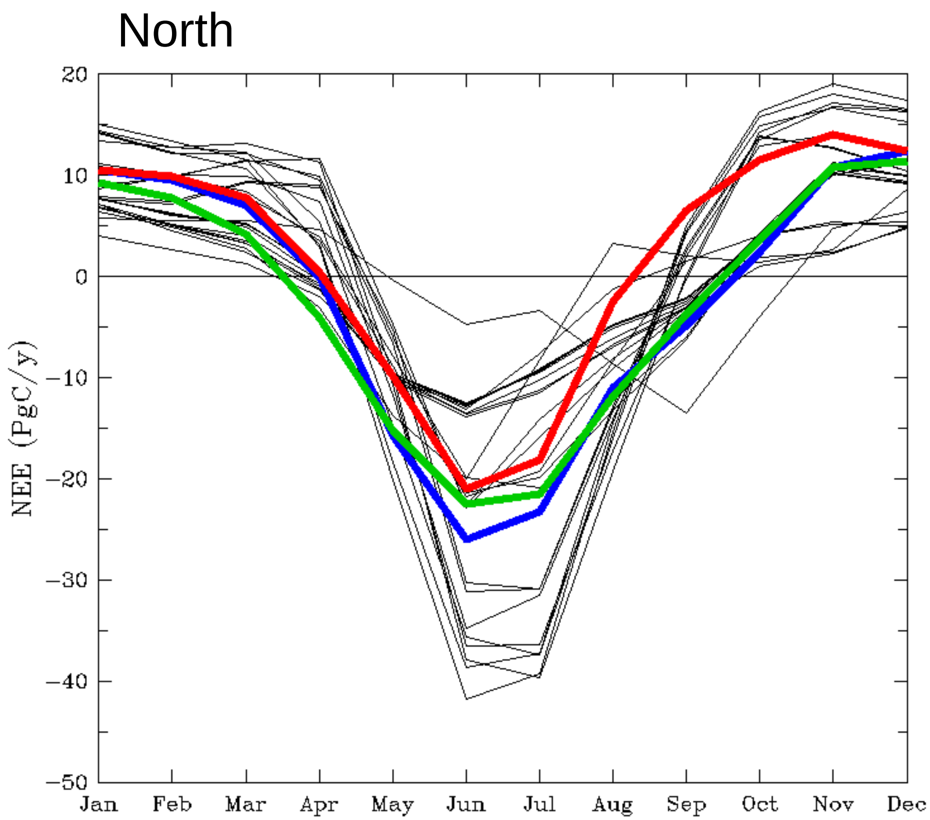


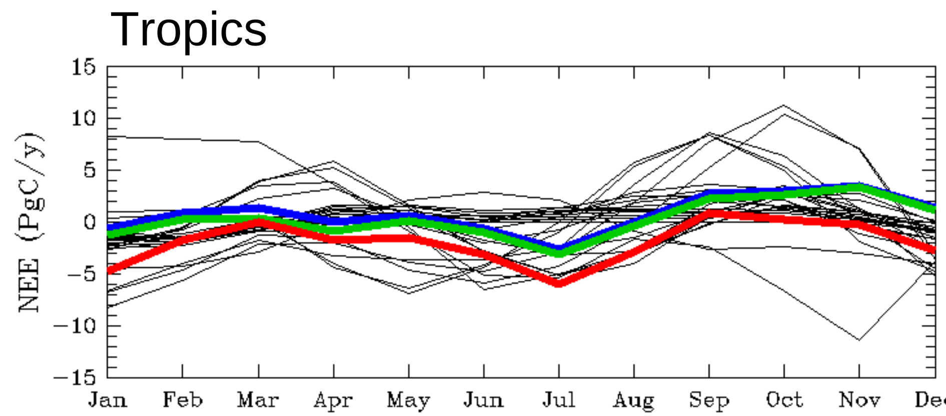
- Land carbon fluxes from CABLE2 with biogeochemistry
- Ocean carbon fluxes from WOMBAT (World Ocean Model of Biogeochemistry And Trophic-dynamics), includes a two-component plankton model (phytoplankton and zooplankton)

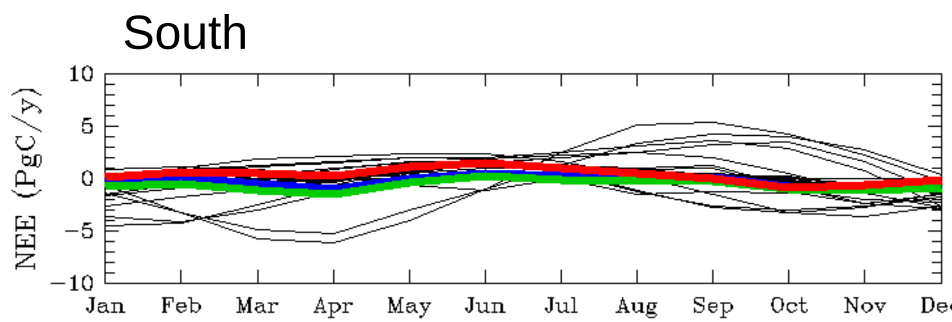
CABLE2 with biogeochemistry



Present-day land carbon flux:
Seasonal cycle: 20 year average



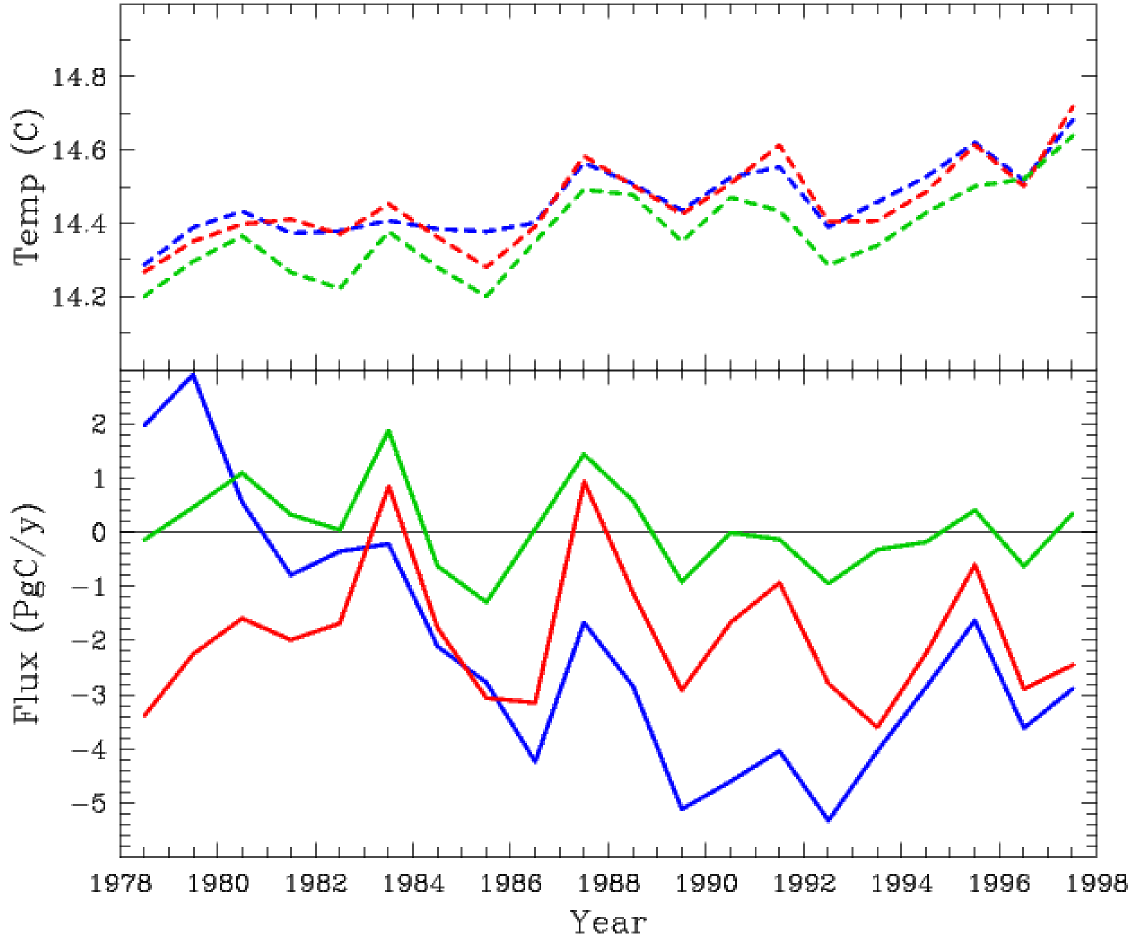




Red: prescribed LAI (1978-1987)
Blue: prognostic LAI (1978-1987)
Green: nutrient limitation (1986-2005)

Black: CMIP5 models (1986-2005 from historical run, Anav et al., J. Clim, 2013)

Global Land Carbon Fluxes



Temperature (top) and NEE (bottom) for three atmosphere only ACCESS simulations.

- Prescribed LAI (green) less variable than prognostic LAI (red). Nutrient limitation (blue)
- Correlation between interannual variations in mean temperature (top) and land carbon flux (bottom)

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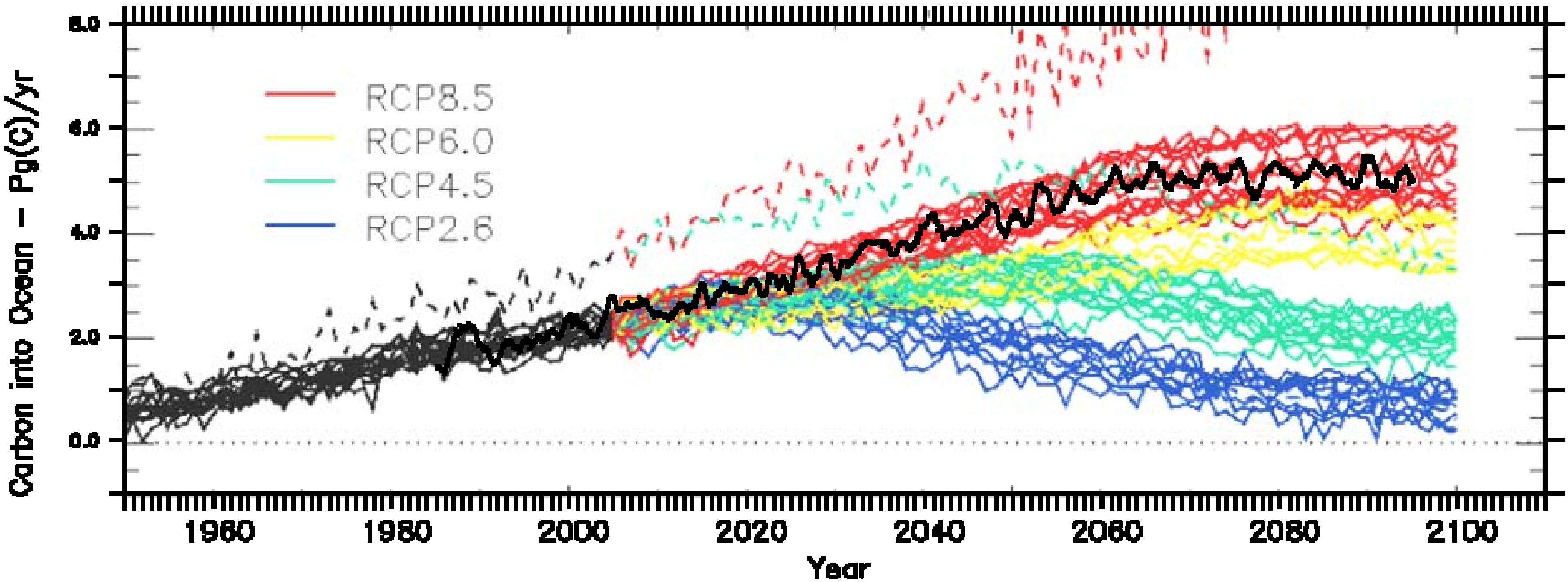
Ocean carbon flux to 2100

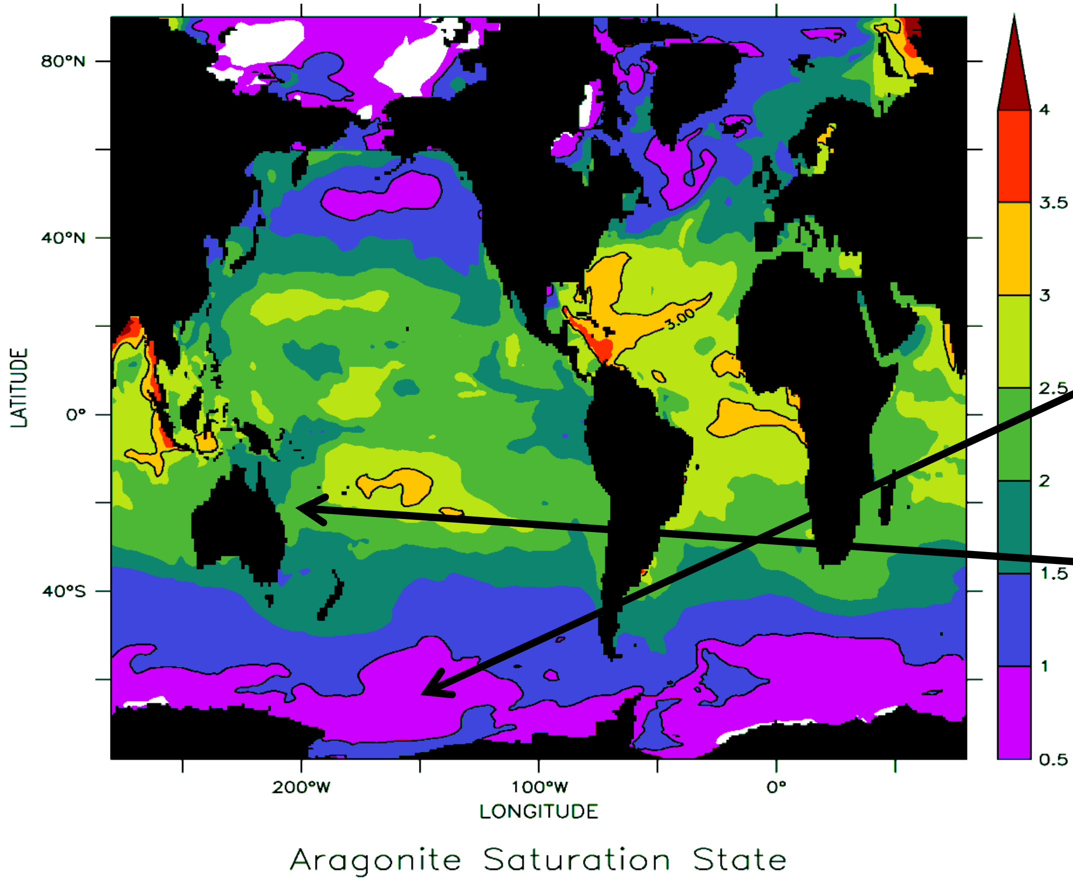
Carbon flux into the ocean



Black: ACCESS-OM with RCP8.5 forcing (data from M. Chamberlain)
Other lines: CMIP5 models (Jones et al., 2013)

Ocean acidification

Impact on surface Aragonite Saturation State



- ACCESS RCP 8.5 scenario (2072 shown)
- Under-saturated water (< 1: purple) in the Southern Ocean (aragonite shells of pteropods liable to dissolve)
- Loss of Coral Reef habitat around Australia (requires saturation state > 3: orange/red)

Figure from R. Matear

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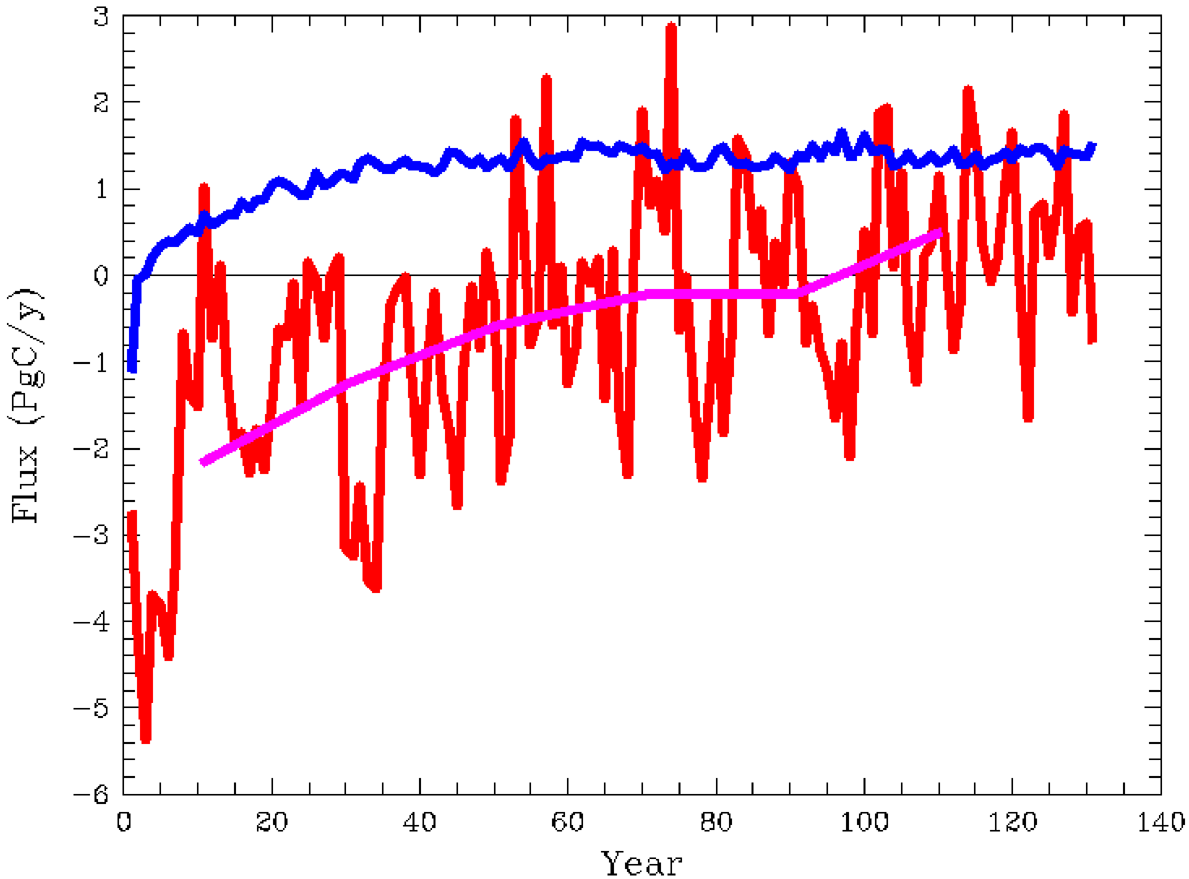
ACCESS-ESM1: pre-industrial

Carbon fluxes: run with prescribed atmospheric CO_2



Annual mean net ocean (blue) and land (red) carbon flux to atmosphere.

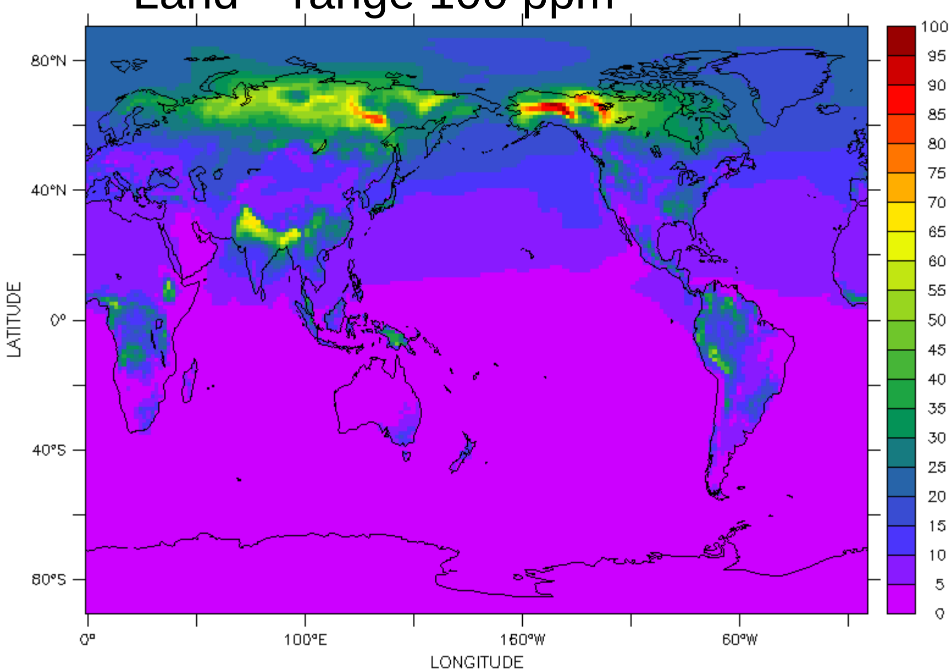
Aim is zero flux under pre-industrial conditions.

Long spin-up times for carbon pools

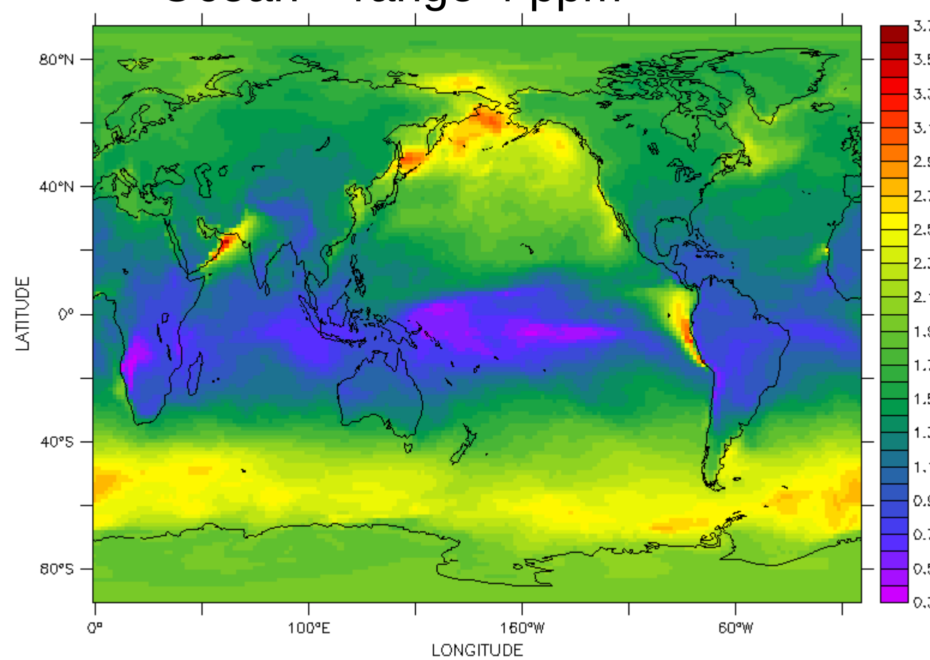
Modelled atmospheric CO_2

- Land and ocean carbon fluxes input to atmosphere as passive tracer
- Measure of seasonal amplitude at each grid-cell in lowest model level: year 120 maximum month – minimum month

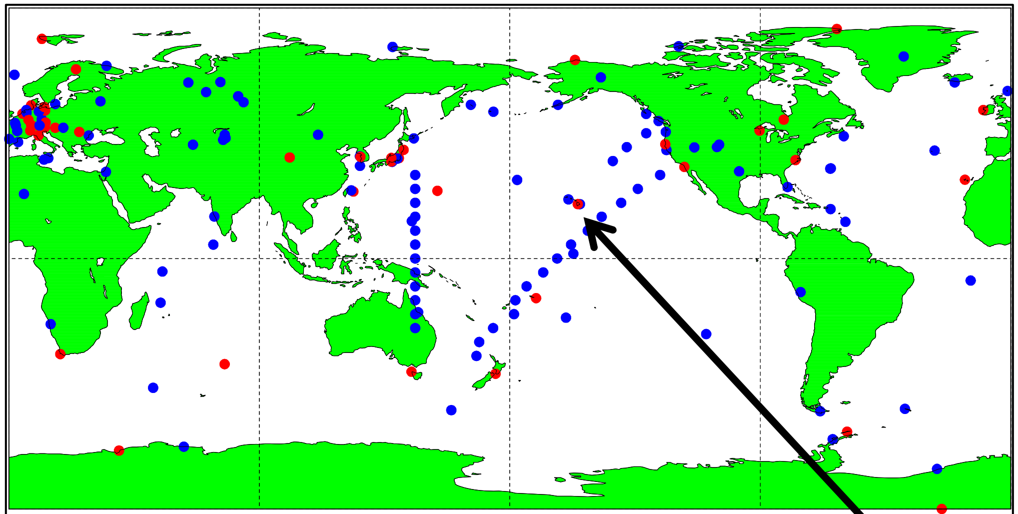
Land – range 100 ppm



Ocean – range 4 ppm



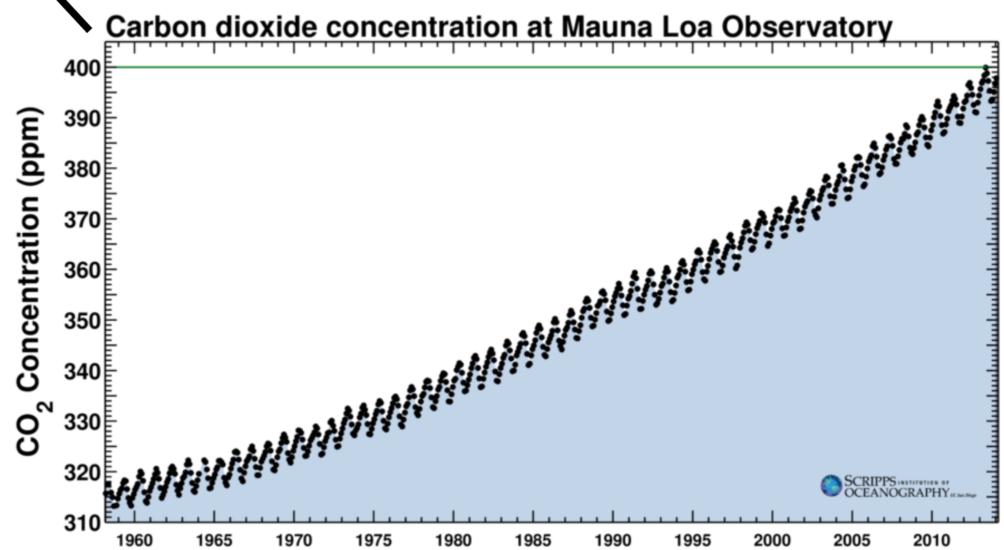
Atmospheric CO_2 for evaluating carbon flux



Flasks (blue); In-situ, hourly (red)

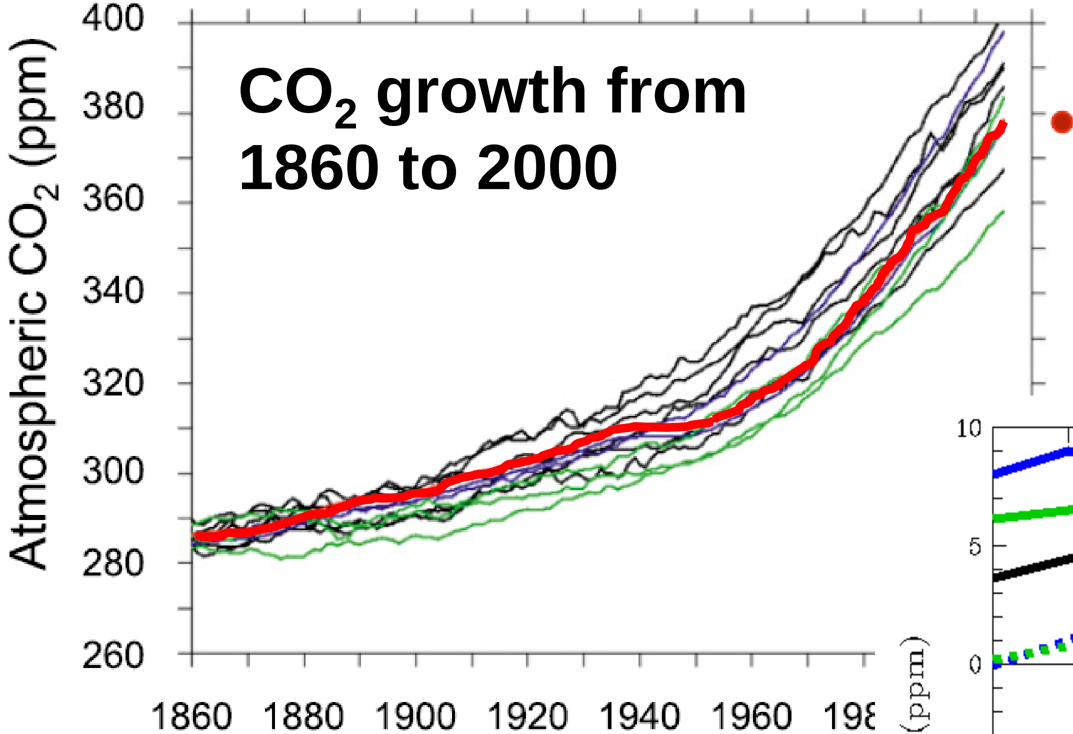
World Data Centre for Greenhouse Gases:
http://ds.data.jma.go.jp/gmd/wdcgg/
Globalview-CO2 (data product) :
http://www.esrl.noaa.gov/gmd/ccgg/globalview/

Mauna Loa figure:
http://keelingcurve.ucsd.edu/



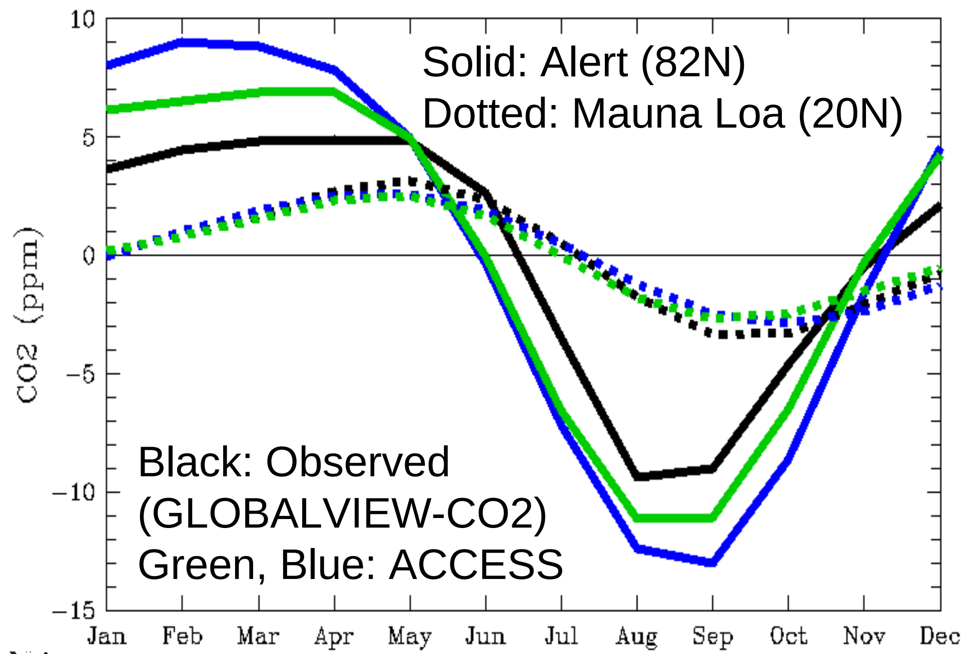
Model-obs comparisons
'Baseline' selection
Diurnal cycle
Model sampling location (coasts, mountains)
Flux error or transport error?

Common diagnostics



Red: observed. Other: CMIP5 models
Friedlingstein et al., J. Climate, 27, 511-526, 2014.

Seasonal cycle of atmospheric CO_2 concentration



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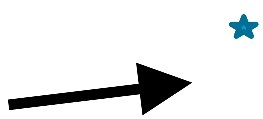


21% < 2 days

44% 2-6 days

35% > 6 days

← 1.5 day →

← 5.6 day →

← 22 day →

Law, R. M., Steele, L. P., Krummel, P. B., and Zahorowski, W. (2010) Synoptic variations in atmospheric CO_2 at Cape Grim: a model intercomparison, Tellus 62B, 810-820.

Radon
R^2=0.90

CO_2
R^2=0.77

Missing peaks due to Tasmania. Common problem for radon and CO_2. Exclude Tasmania using wind direction (70-190^o), number of events with correlation > 0.6 increases from 16% to 30%.

Radon
R^2=0.93

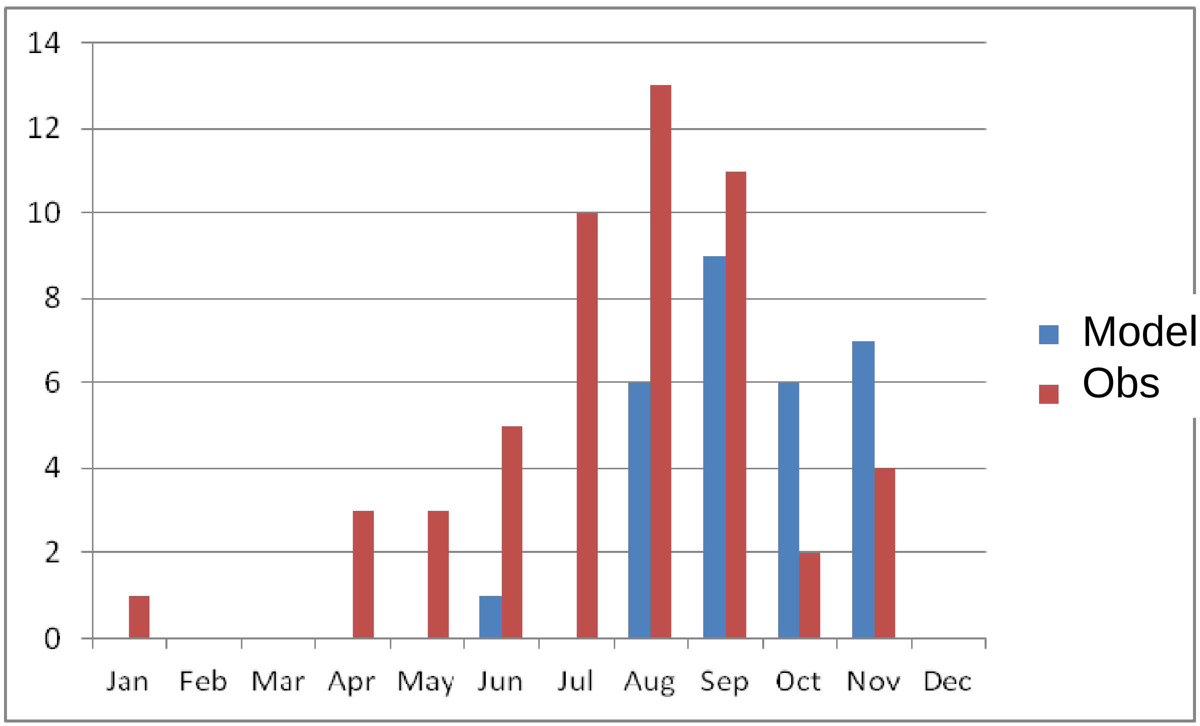
CO_2
R^2 = 0.21 (casa)
R^2 = 0.29 (SiB)

Red: Casa 3 hr
Green: SiB 1 hr

CASA August flux

Drawdown periods – carbon uptake

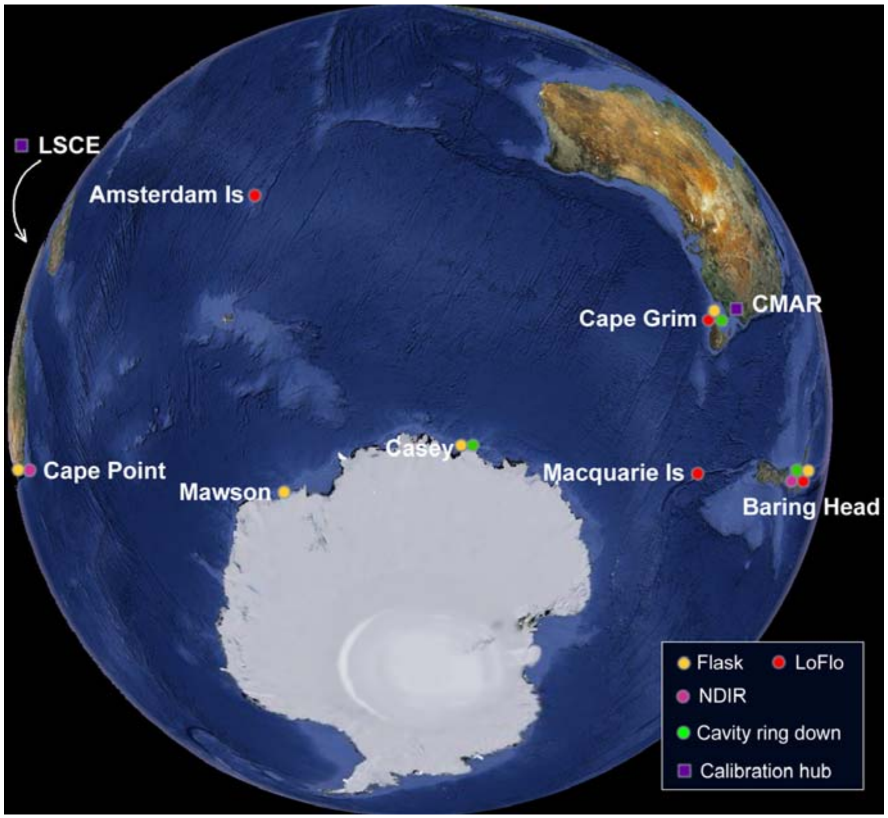
- Identify all periods when CO_2 drops more than 2 ppm below baseline
- 2002-2003 observations: 52 cases. Ensemble mean model CASA 29, SiB 4



Difference in seasonality of below baseline CO_2 suggests difference in seasonality of carbon uptake

Winter crops in Western Victoria??

Macquarie Island CO_2 and Southern Ocean carbon flux



Opportunities

- Continuous year round measurements
- Atmosphere provides integrated signal from large region
- Sampling region varies on synoptic timescales

Challenges

- Logistics
- Long storage times for flasks
- Limited access to service instruments
- Harsh conditions

- Low CO_2 gradients – need high precision data for detectable signals

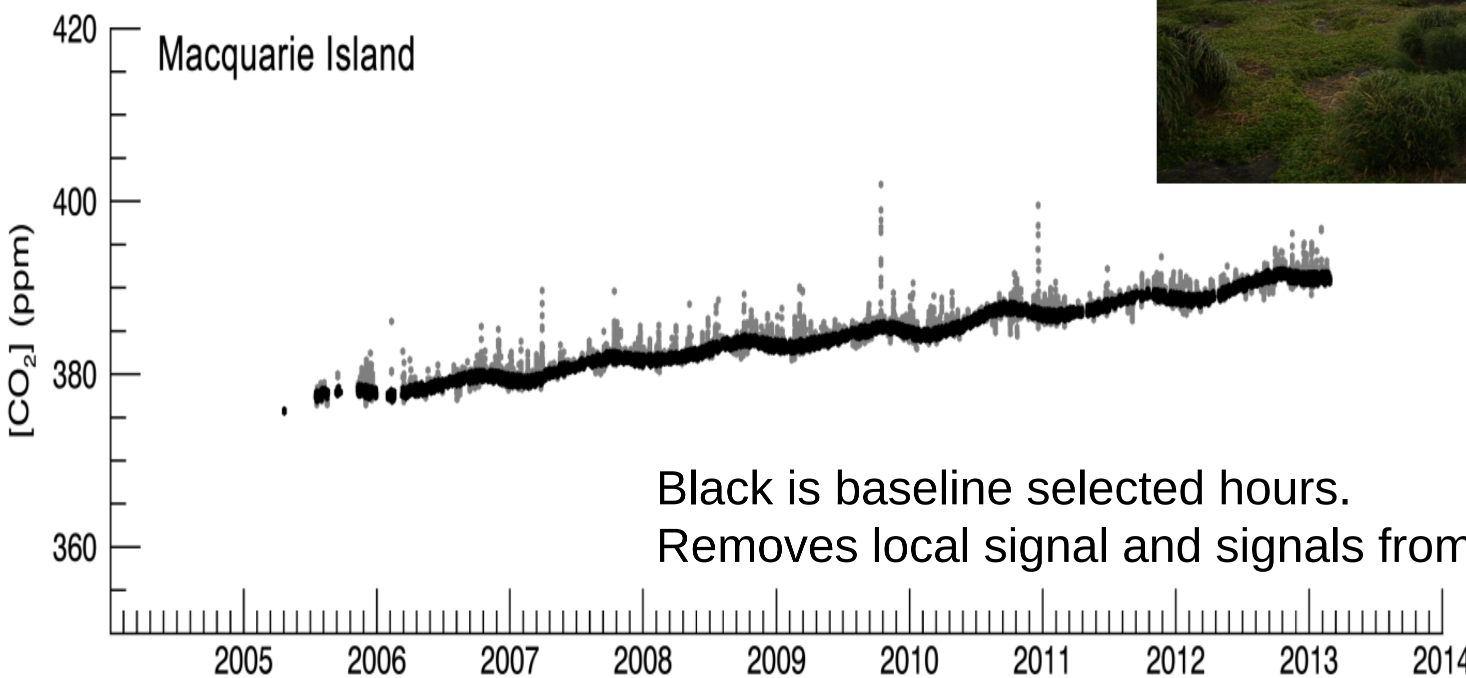
Macquarie Island atmospheric CO_2

First in-situ measurements: 17 April 1979

- Technology of the time not up to the task

Contemporary record

- CSIRO LoFlo Mark 2 analyser from April 2005
- Minute measurements averaged to hourly,
- High precision



Black is baseline selected hours.
Removes local signal and signals from SH continents.

How best to extract information?