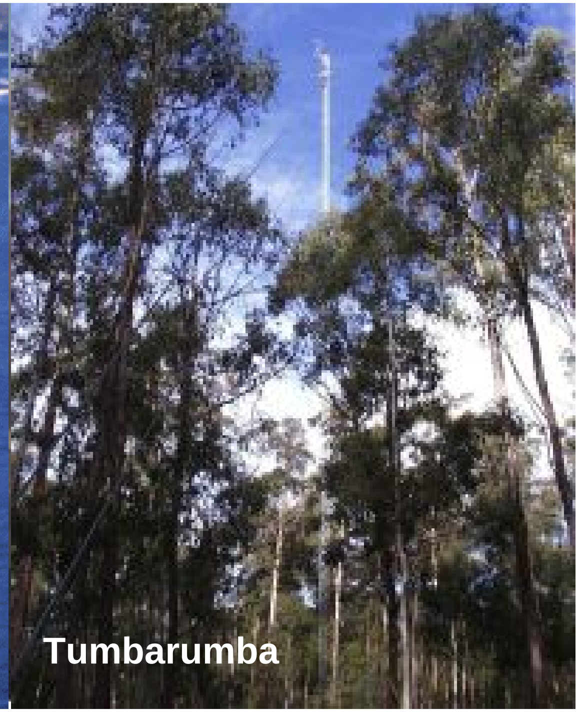


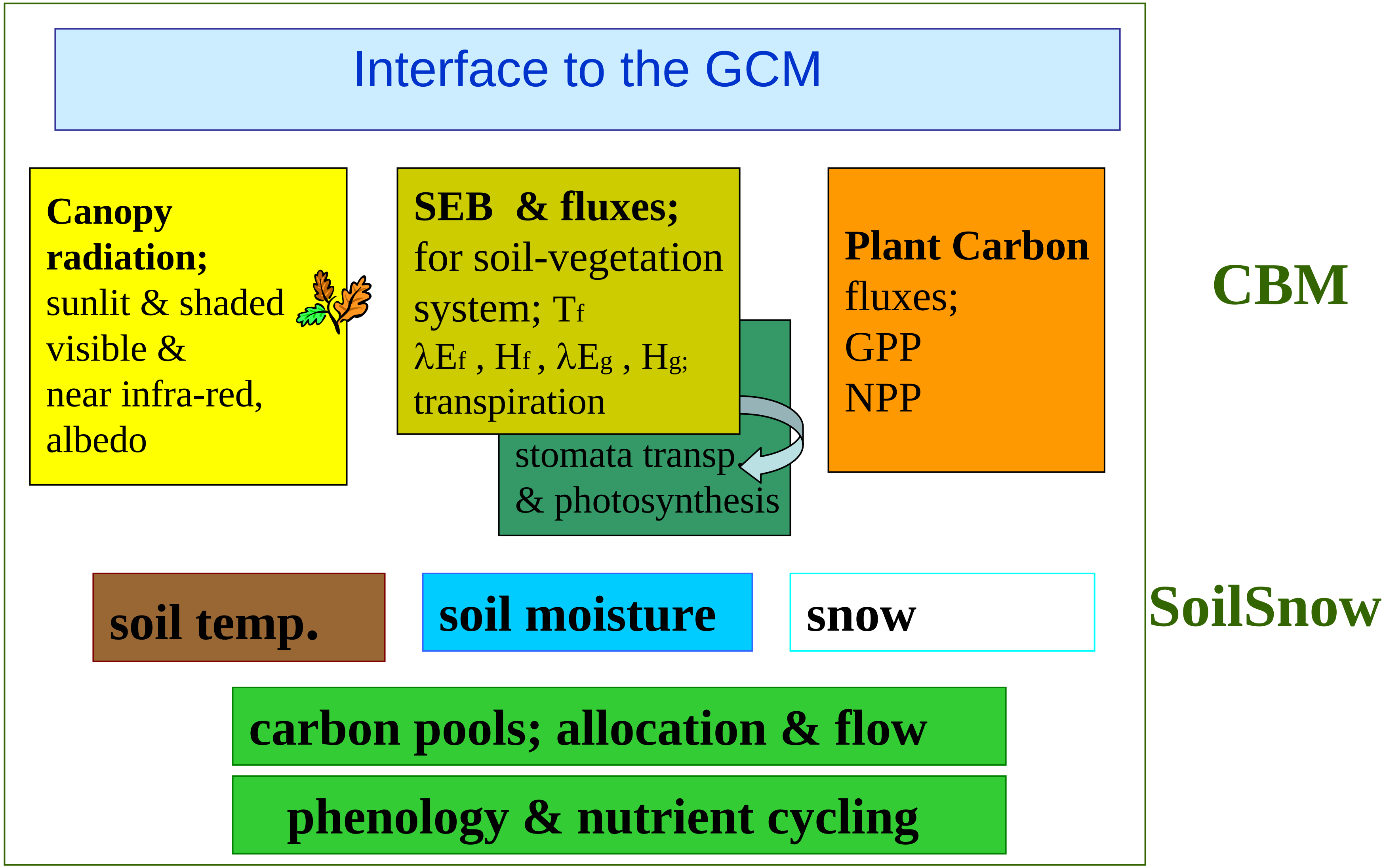
The CSIRO Atmosphere Biosphere Land Exchange model (CABLE) - Preliminary JULES results using CABLE's submodels.

Eva Kowalczyk, Yingping Wang and Rachel Law

CSIRO Marine and Atmospheric Research

Kowalczyk et al., CMAR Research Paper 013, 2006.

The general structure of CABLE



Cable's main features

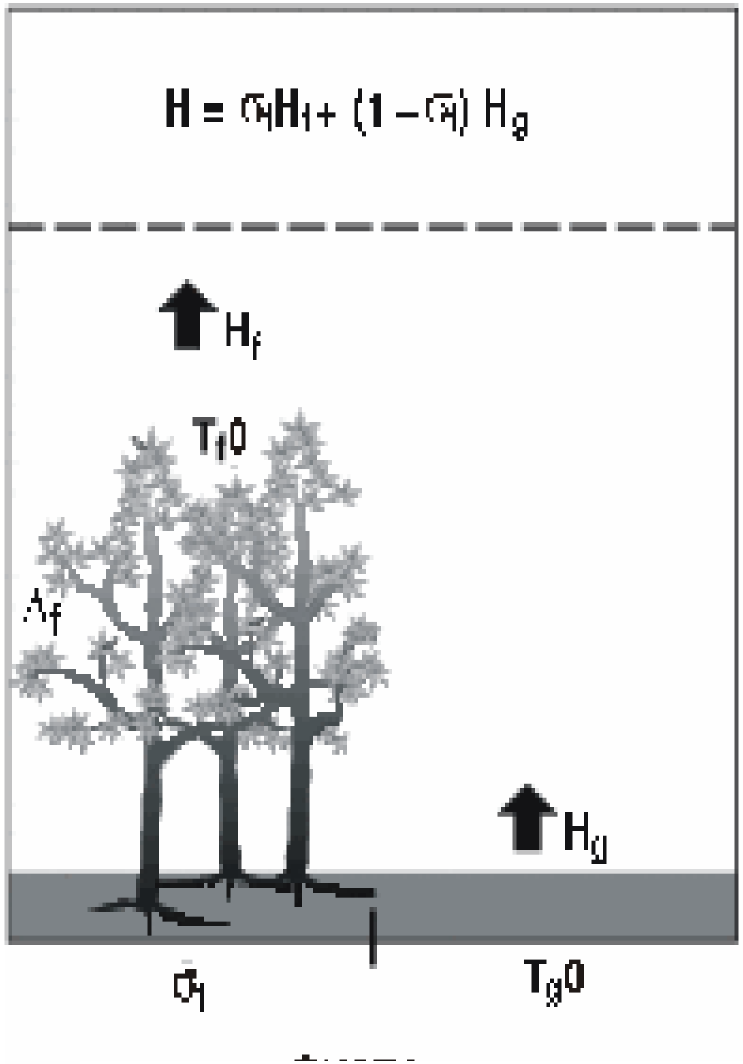
- Vegetation placed above the ground allowing for full aerodynamic and radiative interaction
- The plant turbulence model model by Raupach et al. [1997]

- A coupled model of stomatal conductance, photosynthesis and partitioning of available energy into latent and sensible heat fluxes
- Radiation model calculates the amount of radiation absorbed for three wavebands.
- The model differentiates between sunlit and shaded leaves i.e. two-big-leaf submodel for calculation of photosynthesis, stomatal conductance and leaf temperature.

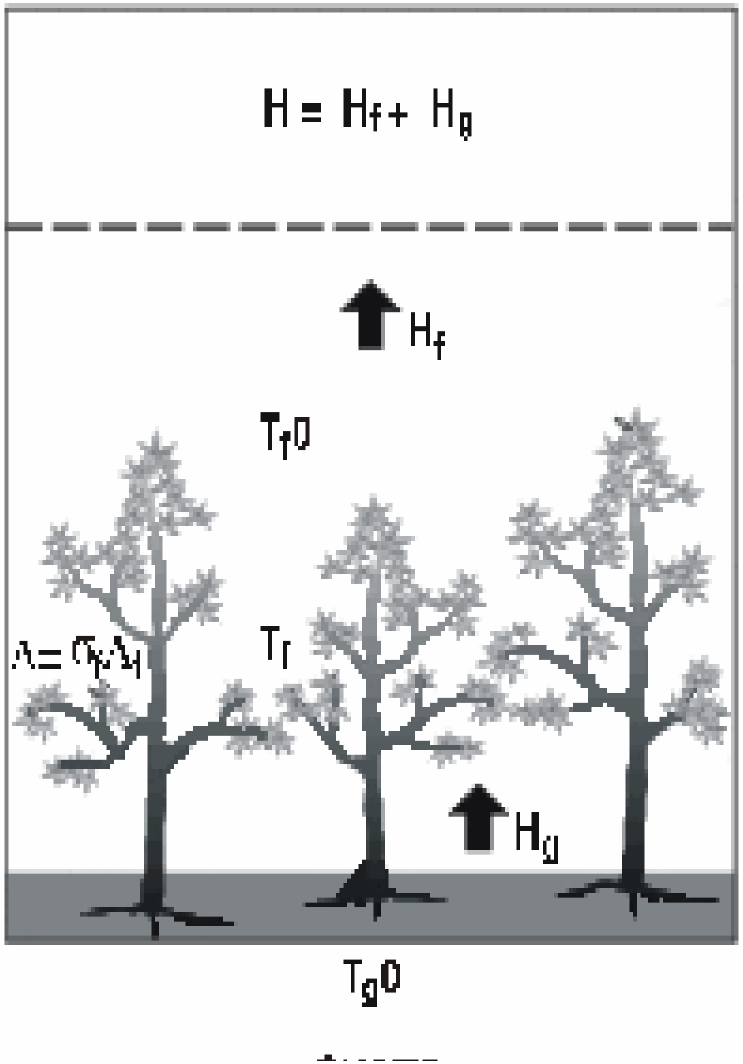
- A multilayer soil model solves the Richard's equation for soil moisture and heat diffusion for soil temperature.
- A three layer snow model used.

- A simple carbon pool model allowing for partitioning of the assimilation product between leaves, roots and wood.

Canopy representation



CABLE



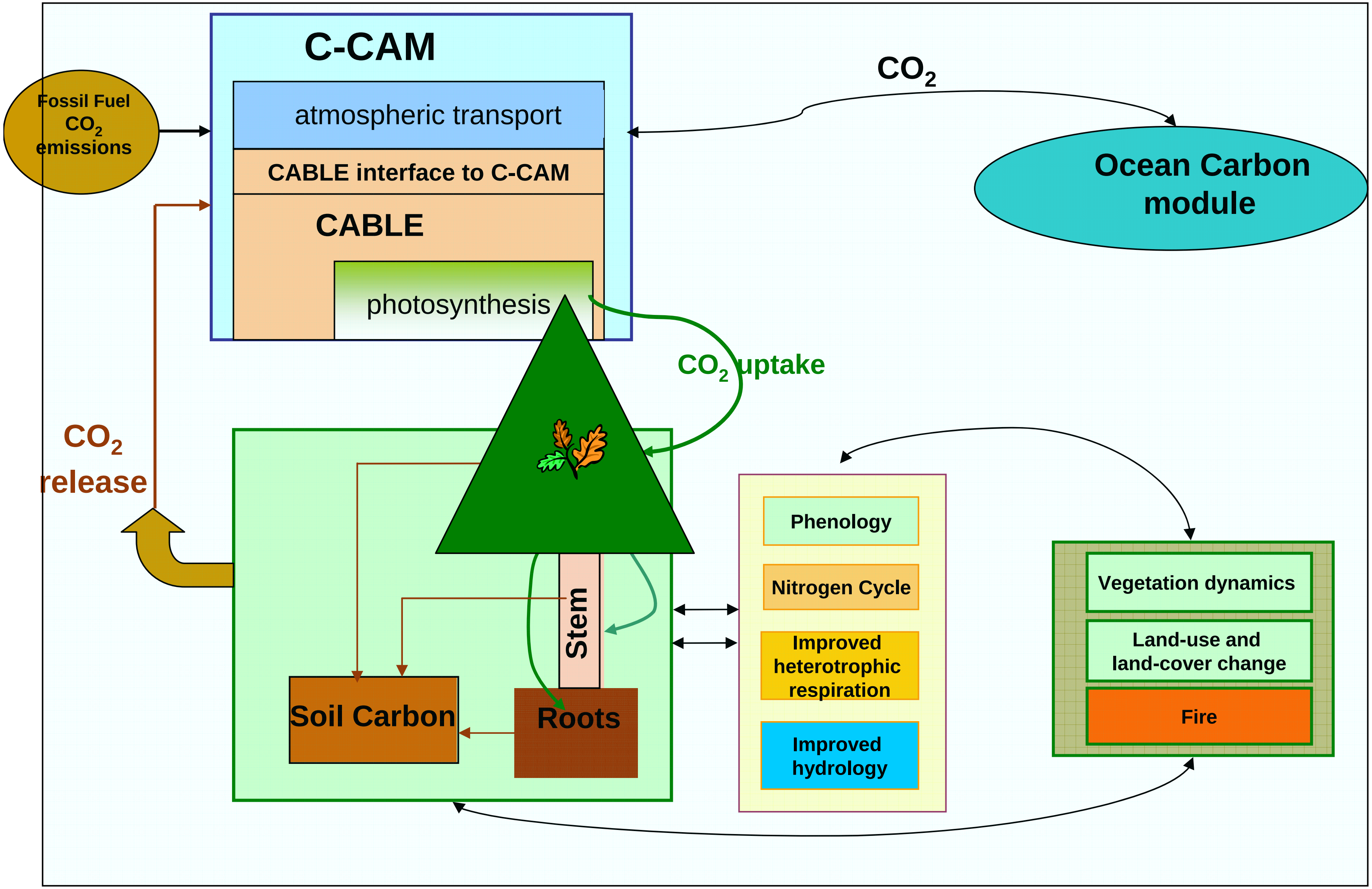
Coupled model of stomatal conductance and photosynthesis

The two-leaf model (sunlit & shaded) of Wang & Leuning [1998] is used to calculate 6 variables:

- Tf - leaf temperature
- Ds - vapour pressure deficit
- Cs - CO_2 concentration at the leaf surface
- Ci - intercellular CO_2 concentration of the leaf
- Gs - stomatal conducatnce
- An - net photosynthesis

The set of six equations is used to solve simultaneously for photosynthesis, transpiration, leaf temperature and sensible heat fluxes

Carbon cycle in C-CAM coupled carbon-climate model



Present | Near future | Future

Preliminary JULES' results using CABLE's submodels:

- snow (with JULES' grid soil under)
- soil moisture (tiles)
- soil temperature (tiles)

SOIL MODEL

Soil type is described by:

saturation content η_{sat},

wilting content η_w,

field capacity η_{fc},

non-dimensional constant b,

hydraulic conductivity K_s,

matrix potential ψ_s.

Richard's equation is solved for soil moisture,

$$\frac{\partial \eta}{\partial t} = -\frac{\partial}{\partial z}(K - K\frac{\partial \psi}{\partial z}) + \sum_i R_i(z), \qquad (1)$$

R_i terms include: runoff, drainage, root extraction.

The relationships between K, ψ and η follow Clapp and Hornberger, (1978).

Conservation of heat:

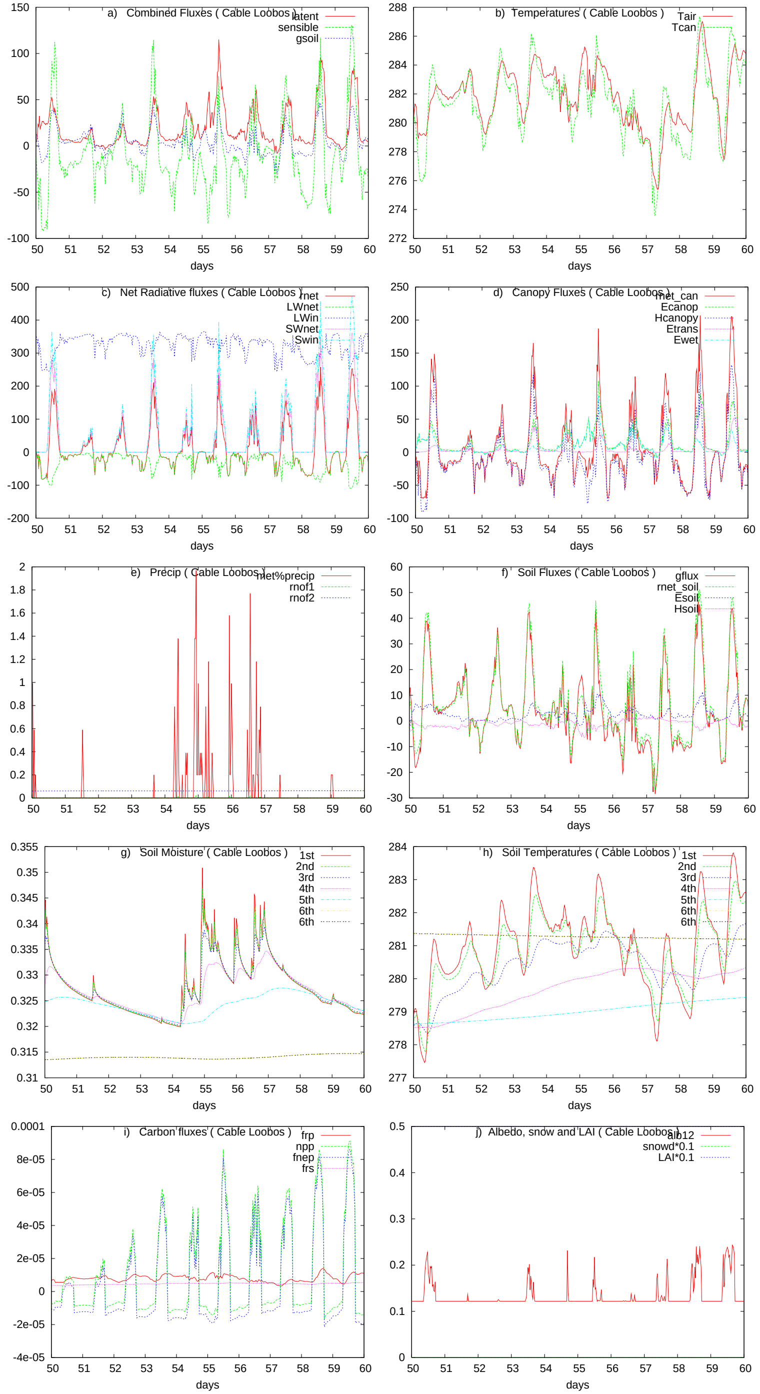
$$\rho_s c_s \frac{\partial T_g}{\partial t} = \frac{\partial}{\partial z}(\kappa_s \frac{\partial T_g}{\partial z}), \qquad (2)$$

where ρ_s is the density, c_s is the specific heat, κ_s is the thermal conductivity.

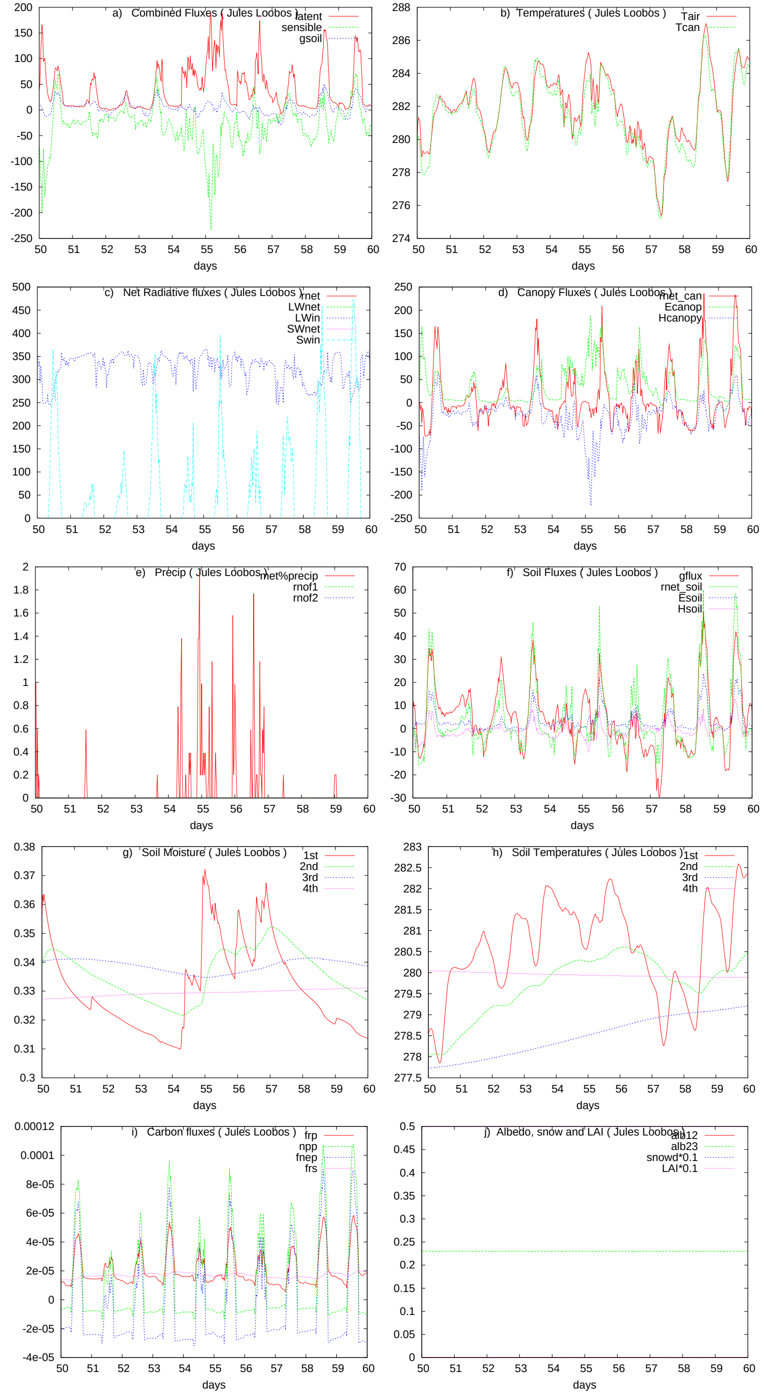
The volumetric heat capacity ($\rho_s\, c_s$):

$$\rho_s\, c_s = (1 - \eta_{sat})\, \rho_{soil}\, c_{soil} + \eta_l\, \rho_w\, c_w + \eta_i\, \rho_{ice}\, c_{ice} \qquad (3)$$

CABLE

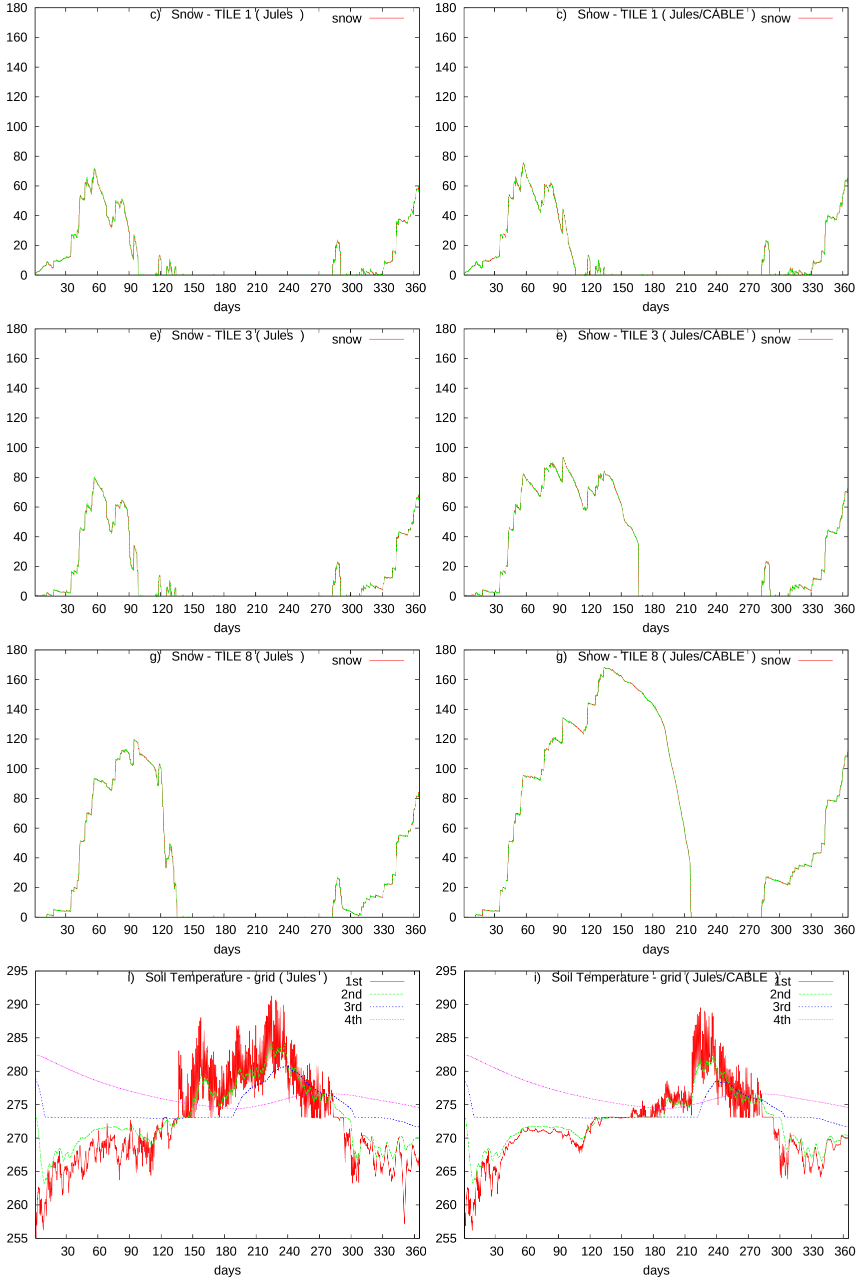

a) Combined Fluxes (Cable Loobos)
latent
sensible
gsoil
b) Temperatures (Cable Loobos)
Tair
Tcan
c) Net Radiative fluxes (Cable Loobos)
rnet
LWnet
LWin
SWnet
Swin
d) Canopy Fluxes (Cable Loobos)
rnet_can
Ecanop
Hcanopy
Etrans
Ewet
e) Precip (Cable Loobos)
met%precip
rnof1
rnof2
f) Soil Fluxes (Cable Loobos)
gflux
rnet_soil
Esoil
Hsoil
g) Soil Moisture (Cable Loobos)
1st
2nd
3rd
4th
5th
6th
6th
h) Soil Temperatures (Cable Loobos)
1st
2nd
3rd
4th
5th
6th
6th
i) Carbon fluxes (Cable Loobos)
frp
npp
fnep
frs
j) Albedo, snow and LAI (Cable Loobos)
alb12
snowd*0.1
LAI*0.1
days

JULES

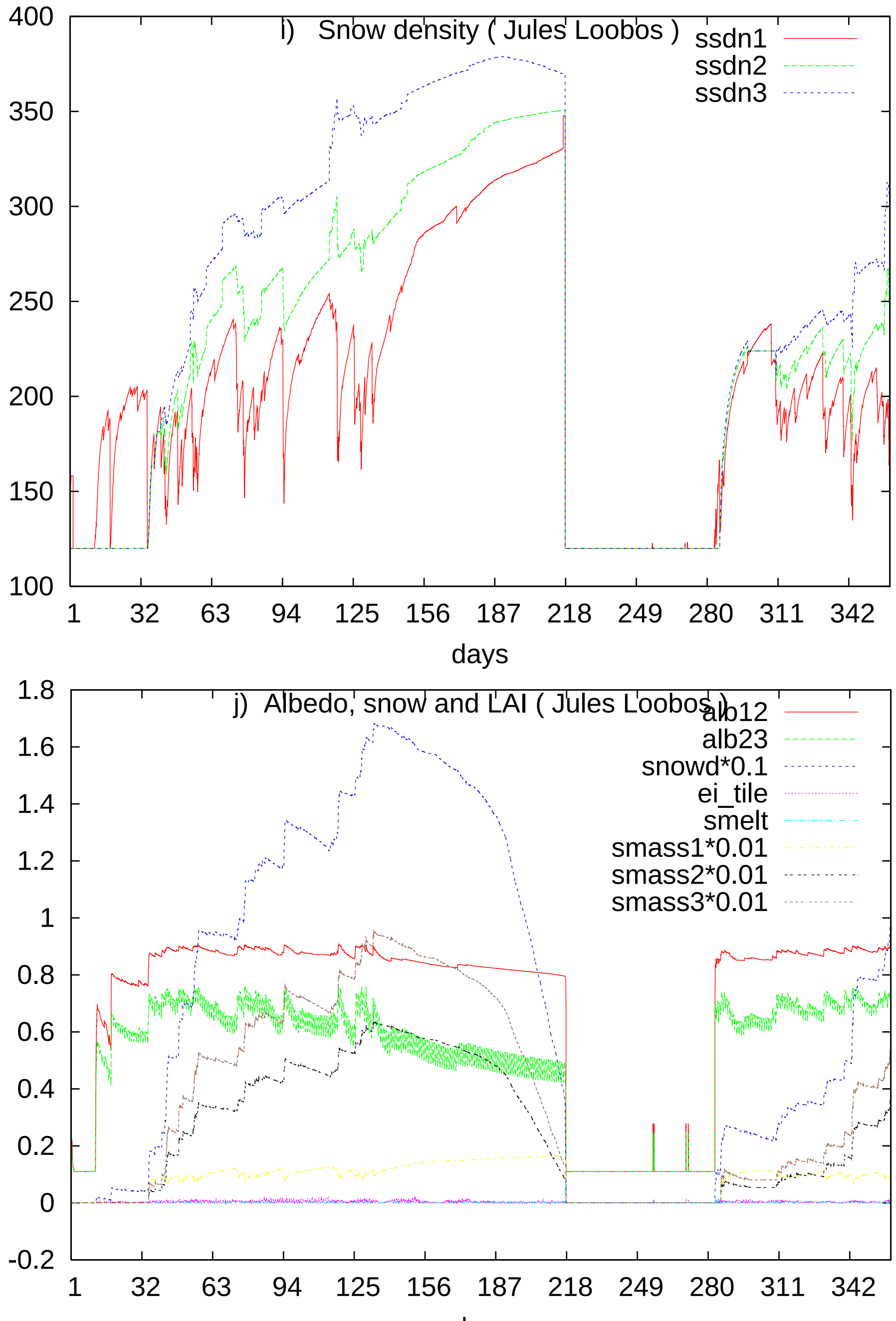

a) Combined Fluxes (Jules Loobos)
latent
sensible
gsoil
b) Temperatures (Jules Loobos)
Tair
Tcan
c) Net Radiative fluxes (Jules Loobos)
rnet
LWnet
LWin
SWnet
Swin
d) Canopy Fluxes (Jules Loobos)
rnet_can
Ecanop
Hcanopy
e) Precip (Jules Loobos)
met%precip
rnof1
rnof2
f) Soil Fluxes (Jules Loobos)
gflux
rnet_soil
Esoil
Hsoil
g) Soil Moisture (Jules Loobos)
1st
2nd
3rd
4th
h) Soil Temperatures (Jules Loobos)
1st
2nd
3rd
4th
i) Carbon fluxes (Jules Loobos)
frp
npp
fnep
frs
j) Albedo, snow and LAI (Jules Loobos)
alb12
alb23
snowd*0.1
LAI*0.1
days

Snow simulations for tiles;

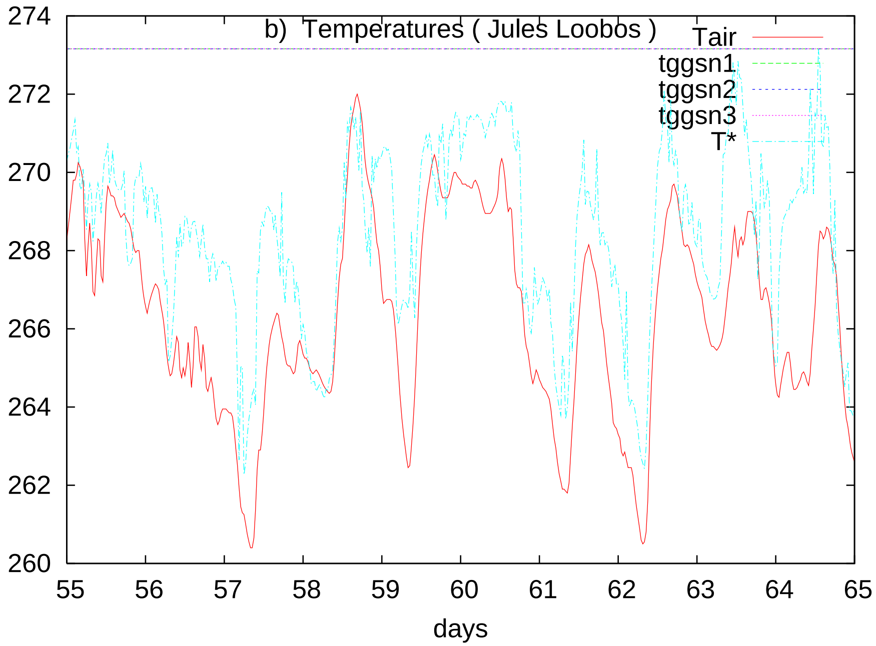
JULES JULES/CABLE

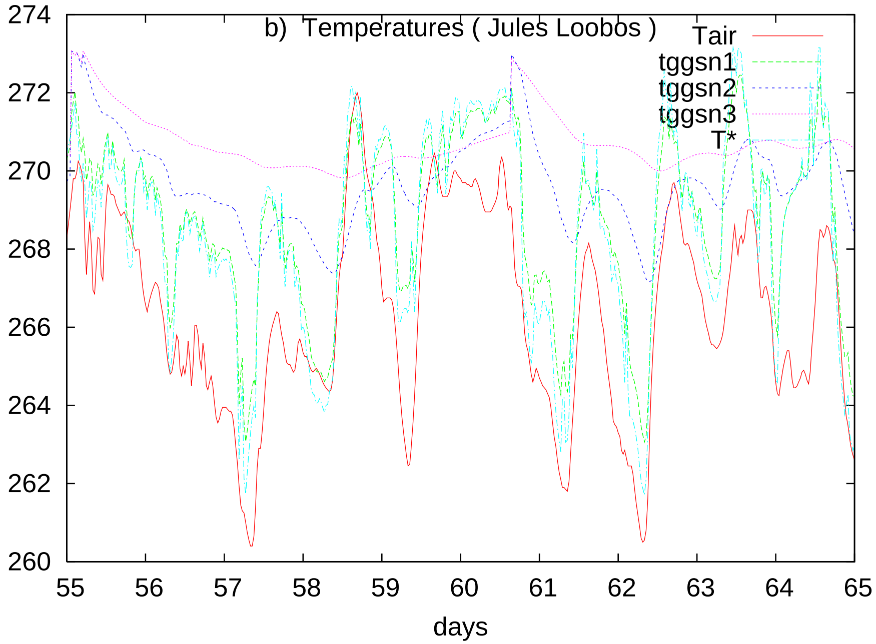


Snow simulations - JULES/CABLE

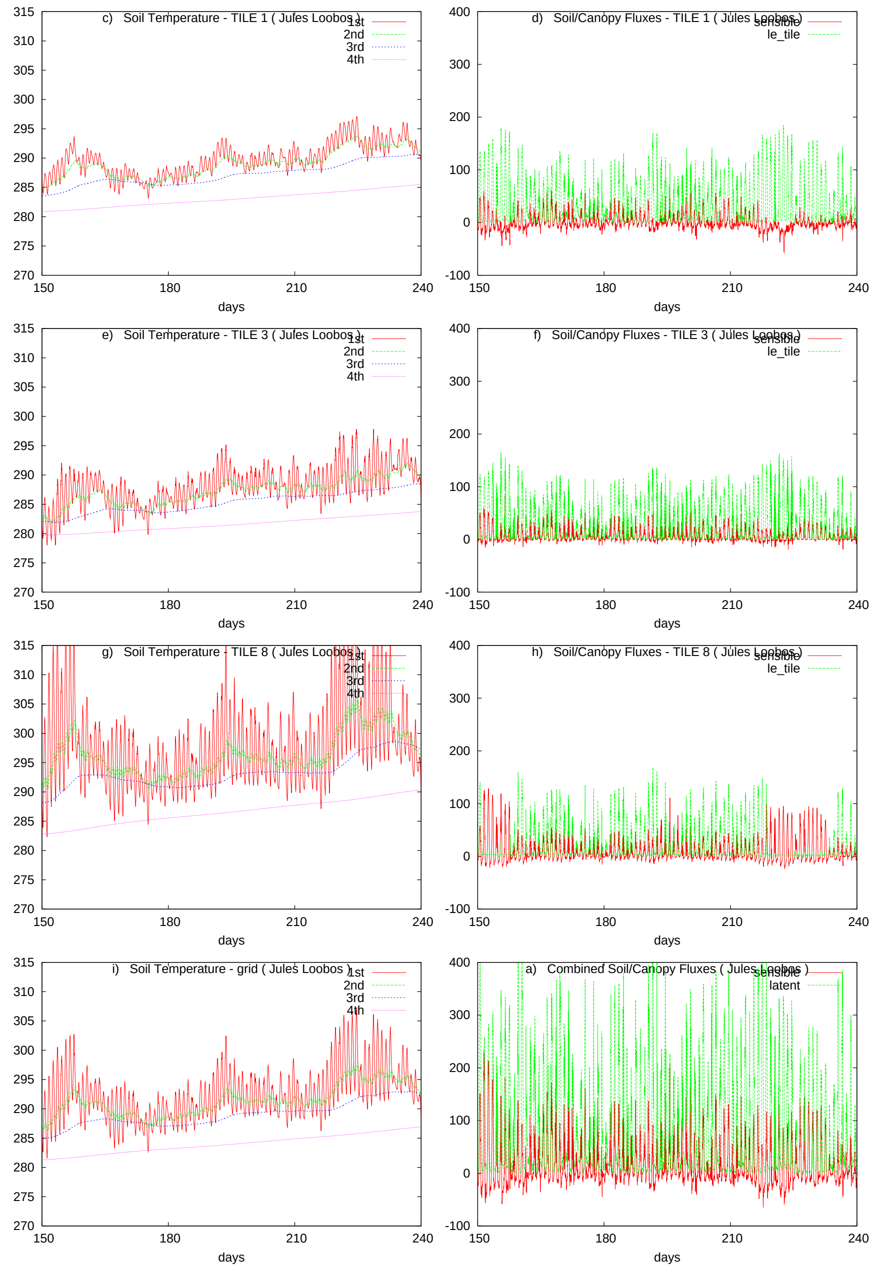


Skin temperature

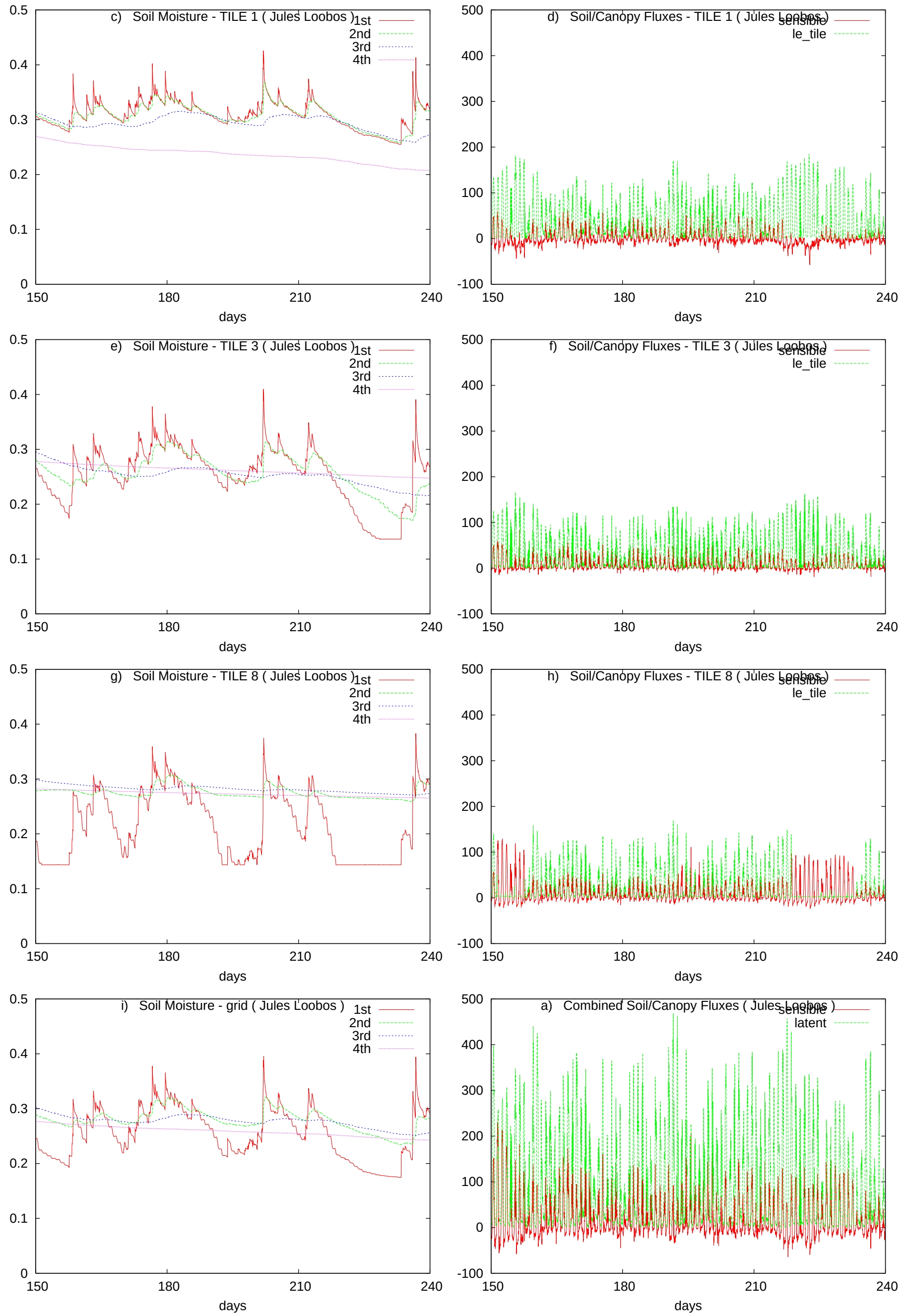




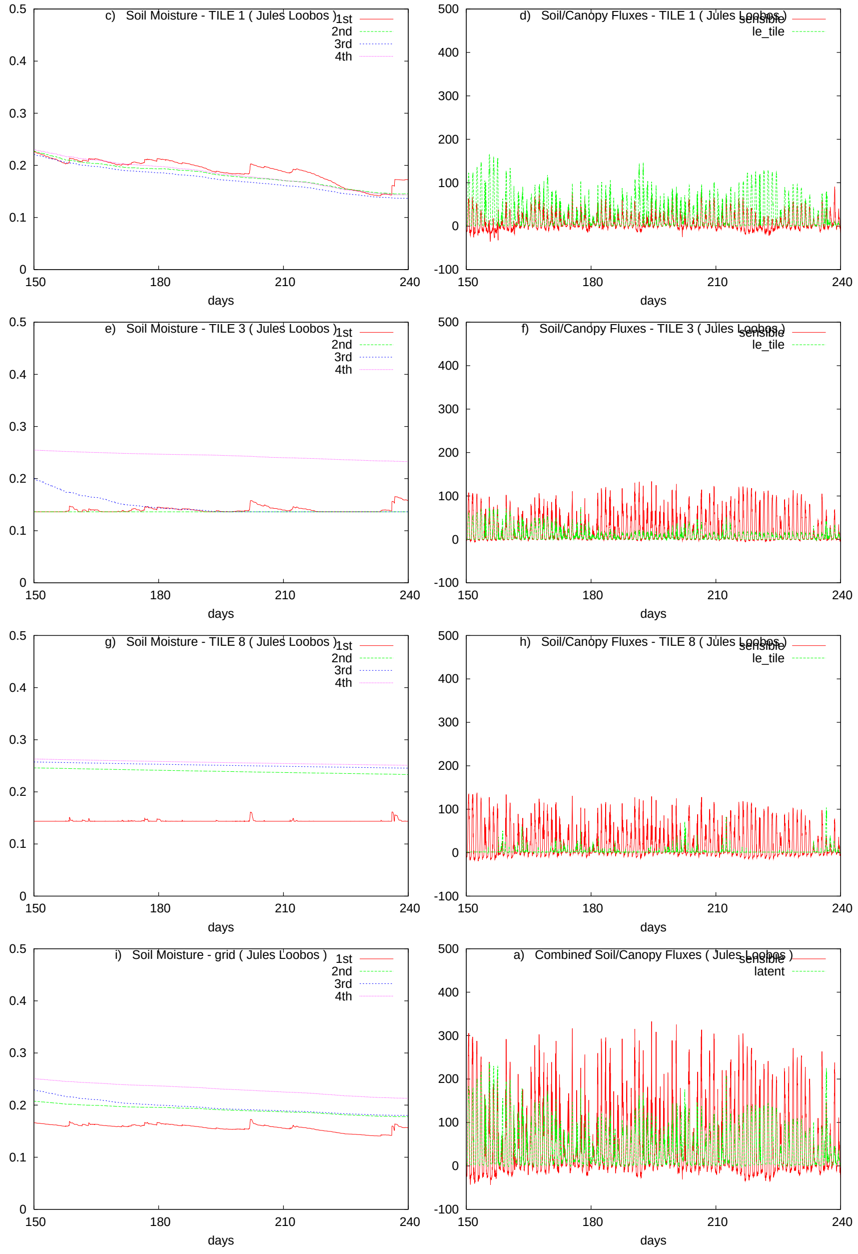
Tiled subsurface – soil temperature

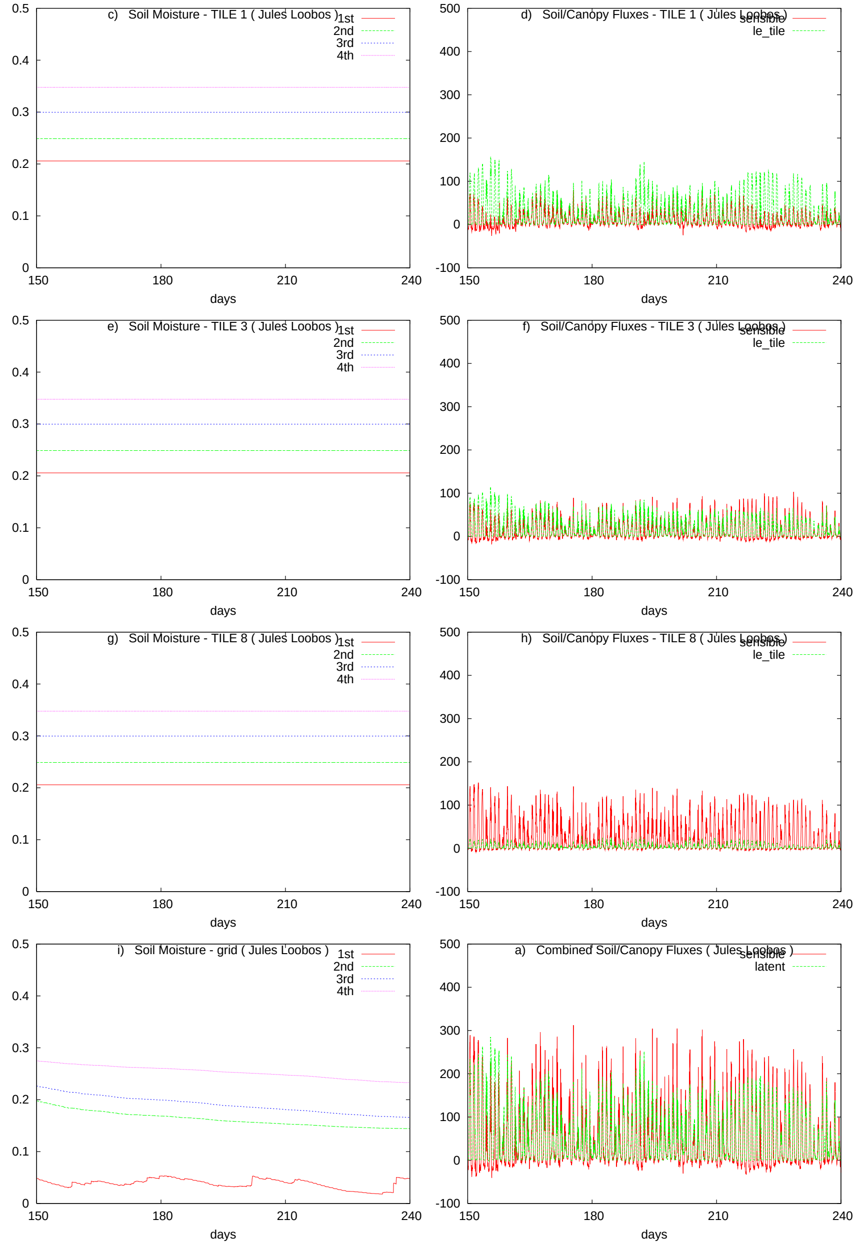


Tiled subsurface – soil moisture



Tiled versus Grid simulation

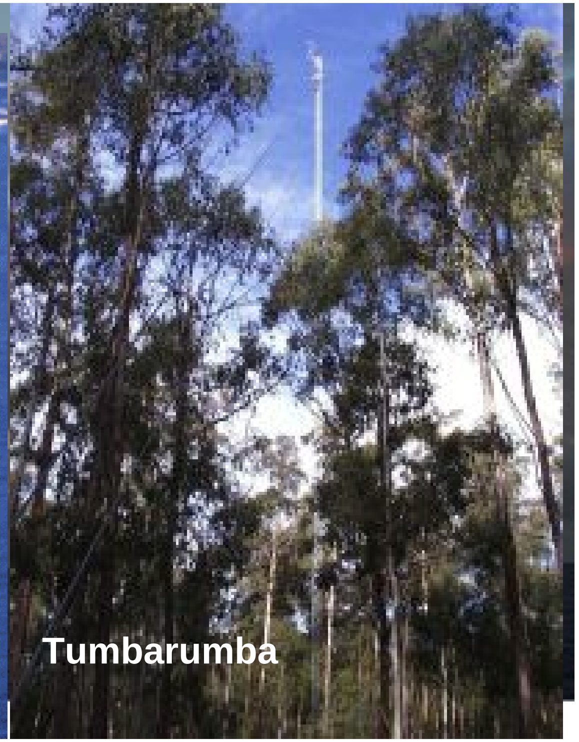




Next steps

- Couple CABLE to UM model
- Include some of CABLE's submodels into JULES

- Model development
- New carbon pools and soil respiration. Inclusion of nitrogen and phosphorus cycle
- Include more elaborate phenology – timing of onset and cessation of photosynthesis
- Water and carbon isotopes
- Include interactive leaf area index (LAI)
- Systematic method for determining model parameters



Thank you

Contact

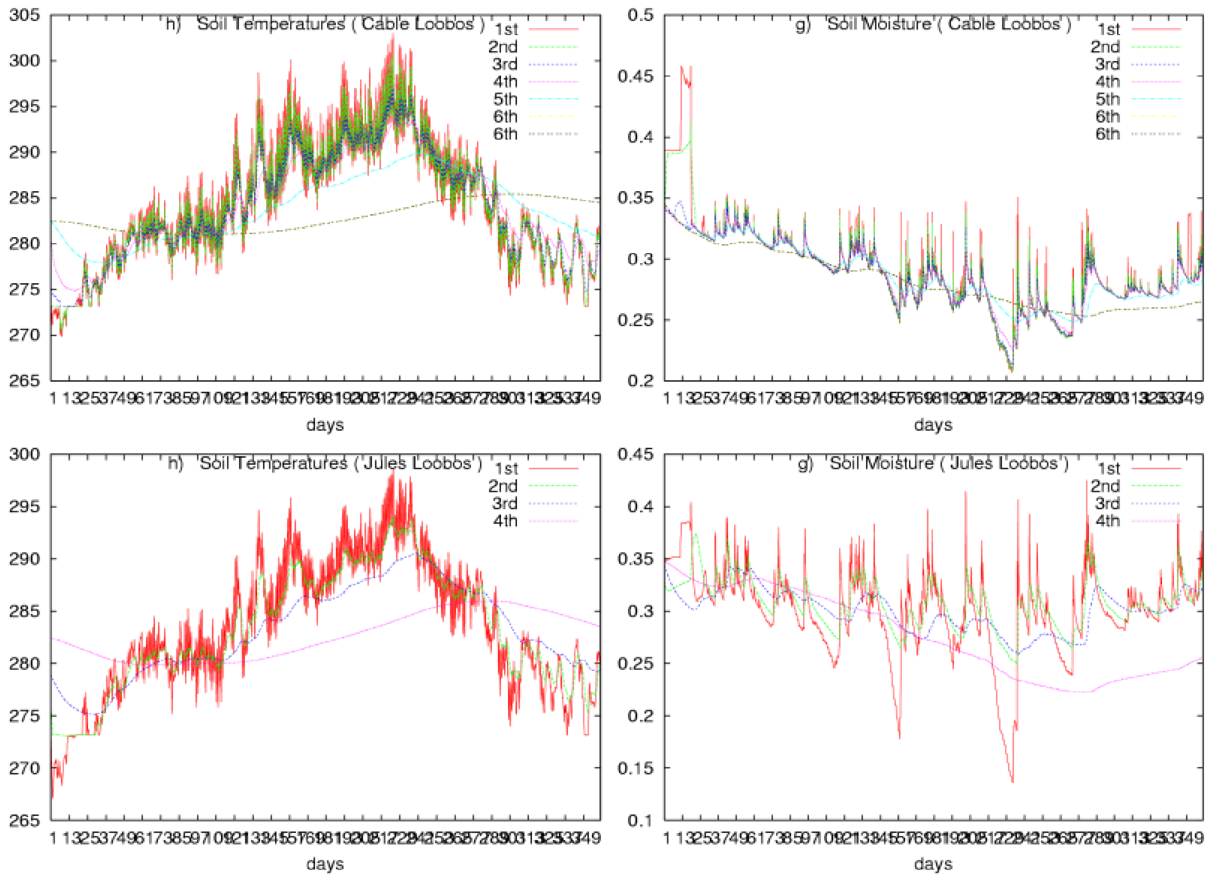
Name: Eva Kowalczyk

Phone: (61 3 9239 4524)

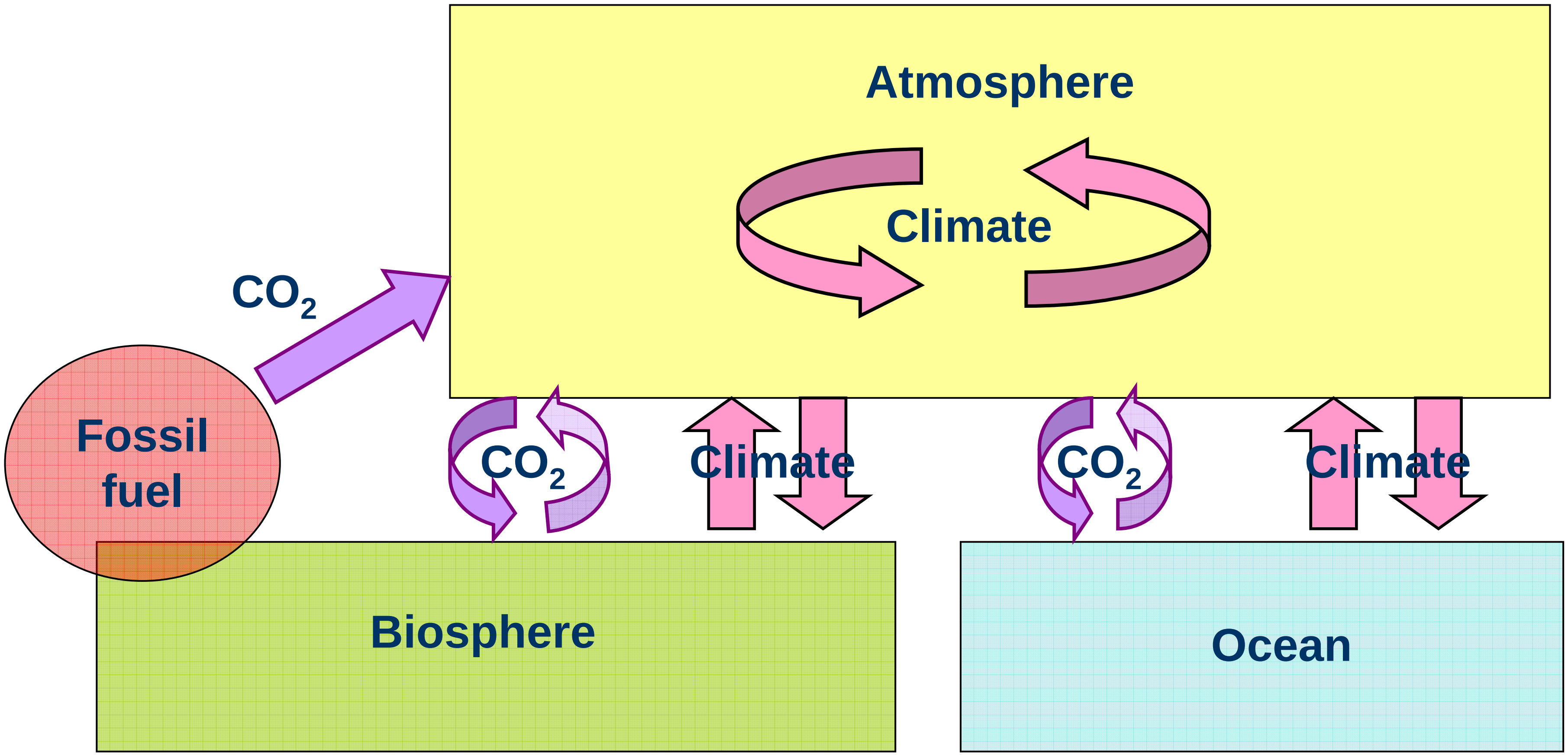
Email: eva.kowalczyk@csiro.au

Web: www.cmar.csiro.au

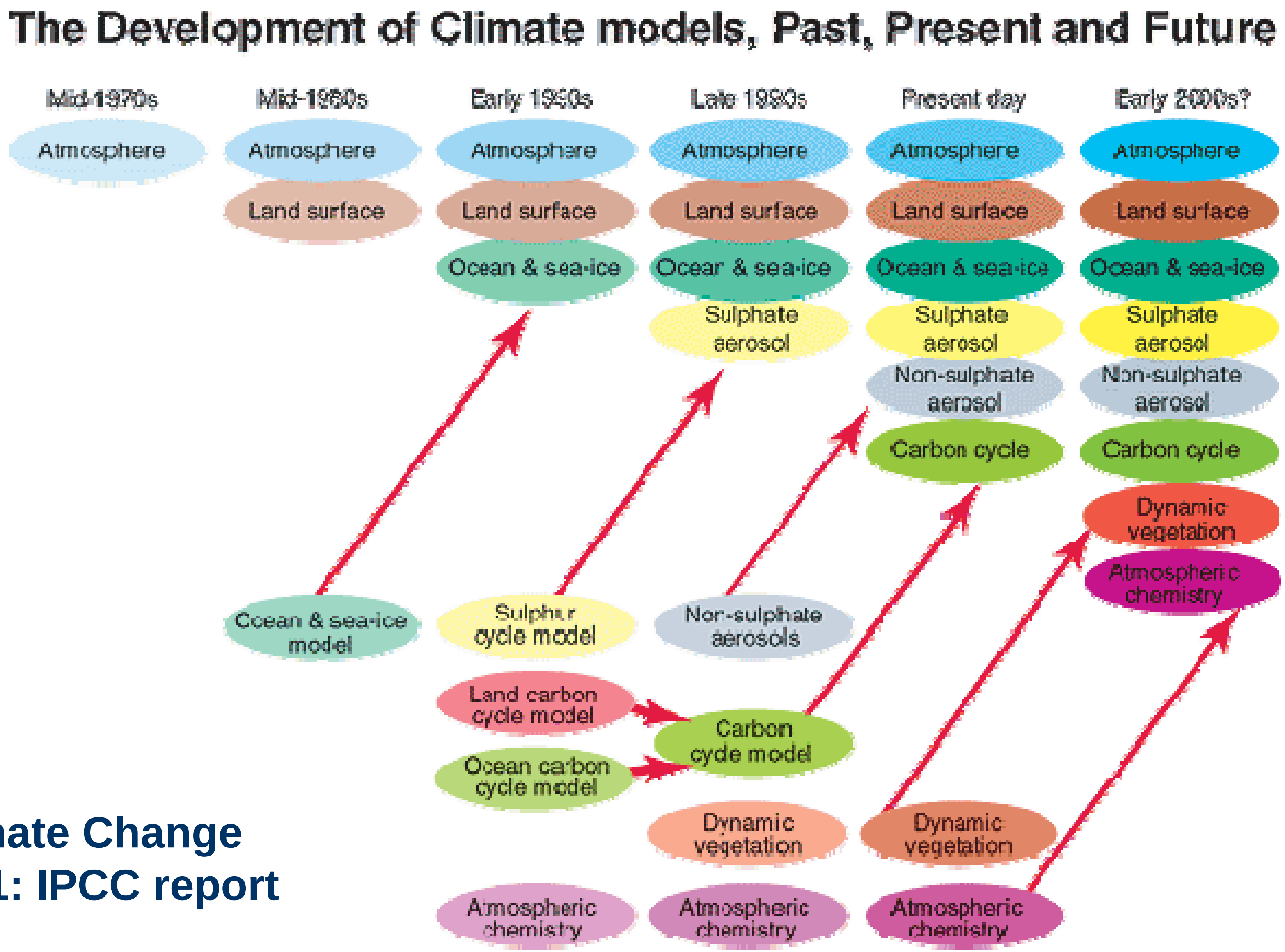
Soil temperature and moisture



Carbon and climate

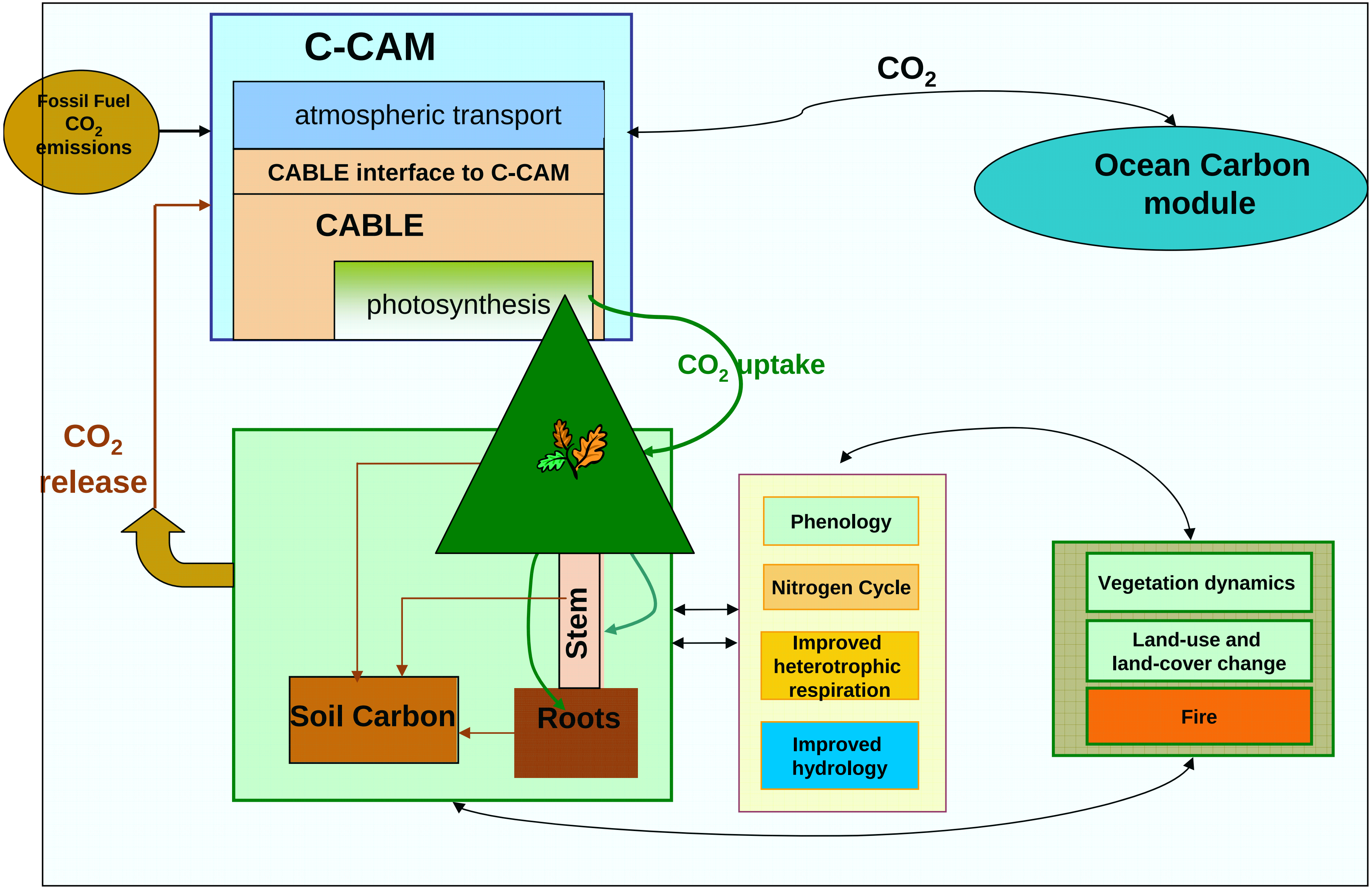


Modelling climate



Climate Change 2001: IPCC report

Carbon cycle in C-CAM coupled carbon-climate model

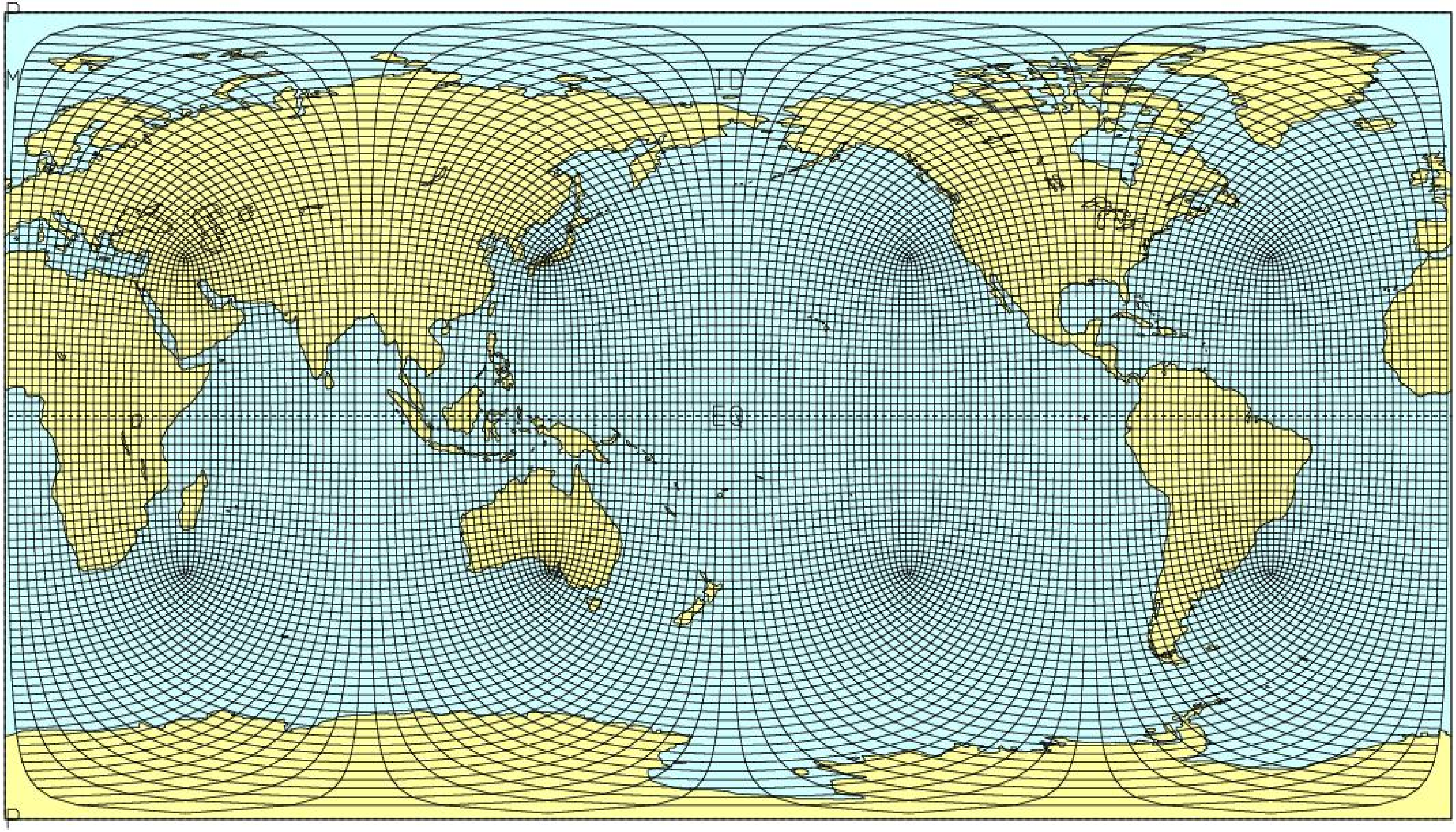


Present

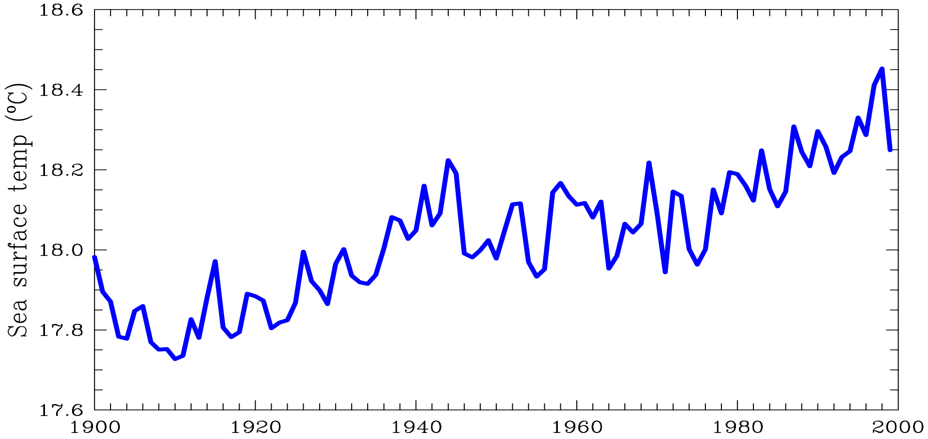
Near future

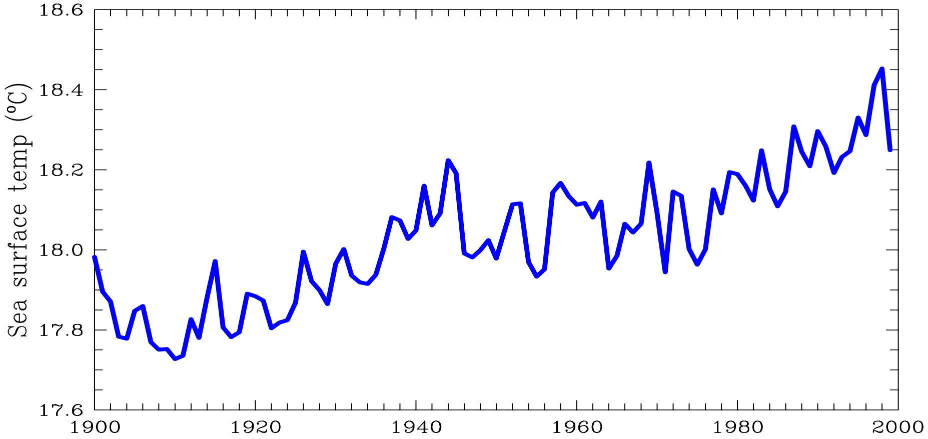
Future

Conformal-cubic C48 grid used for C4MIP simulations

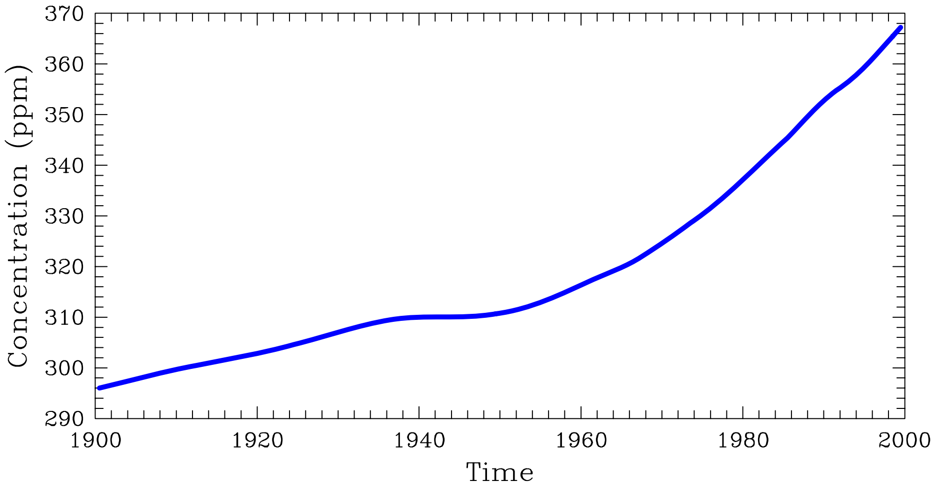


Resolution is about 220 km


Sea surface temp (ºC)
18.6
18.4
18.2
18.0
17.8
17.6
1900
1920
1940
1960
1980
2000



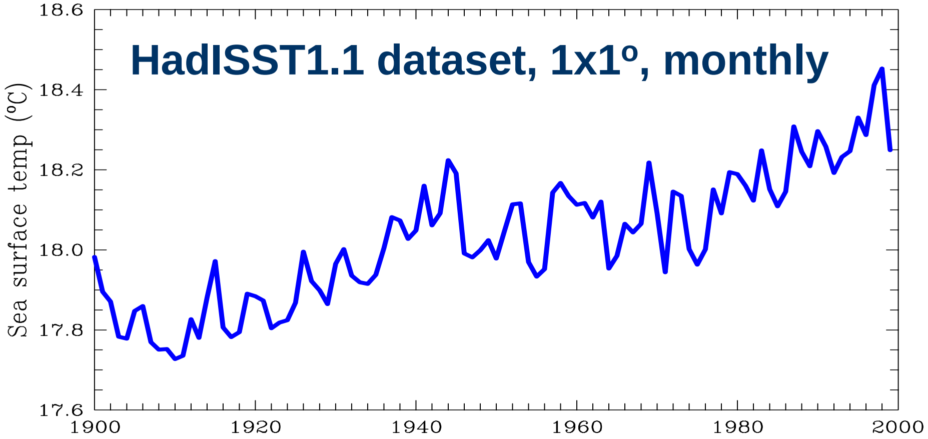
18.6
18.4
18.2
18.0
17.8
17.6
Sea surface temp (ºC)
1900
1920
1940
1960
1980
2000



370
360
350
340
330
320
310
300
290
Concentration (ppm)
1900
1920
1940
1960
1980
2000
Time

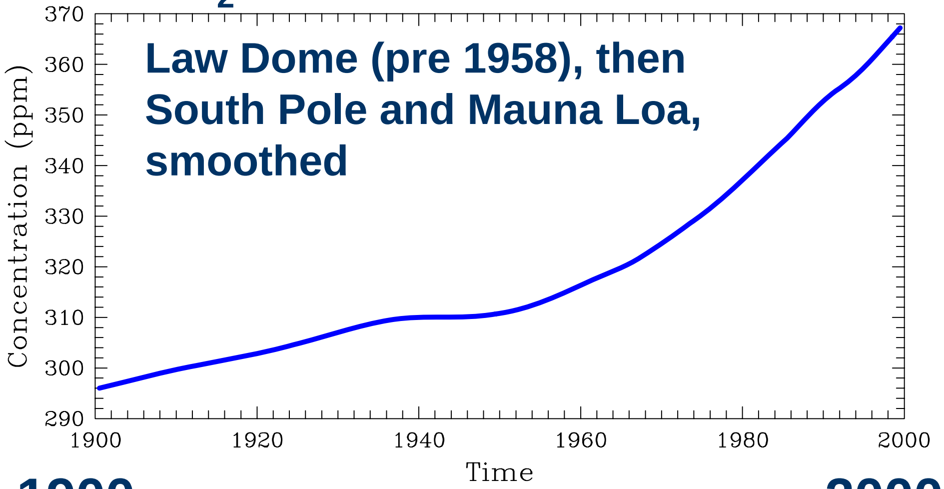
Model forcing and modelled climate

Sea Surface Temperature:

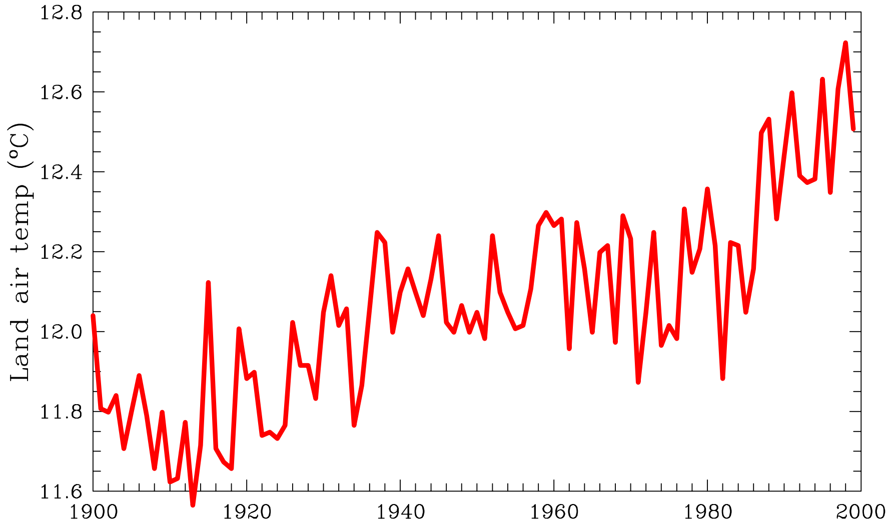


1900 **2000**

CO_2 concentration

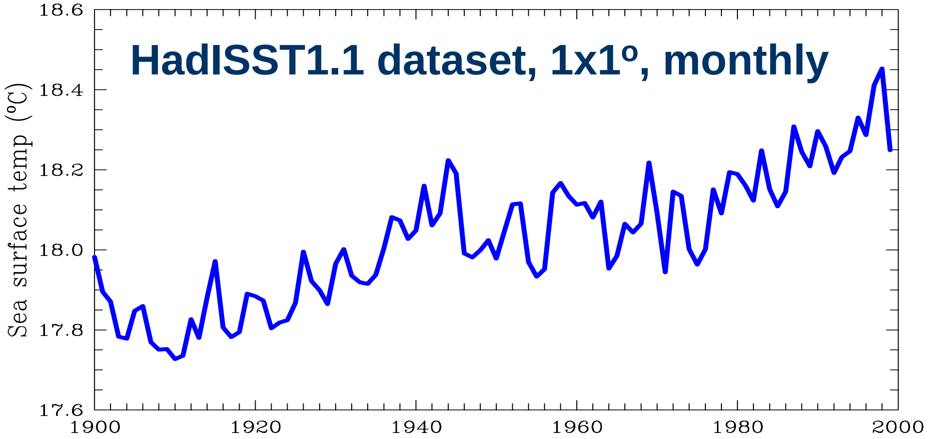


1900 **2000**



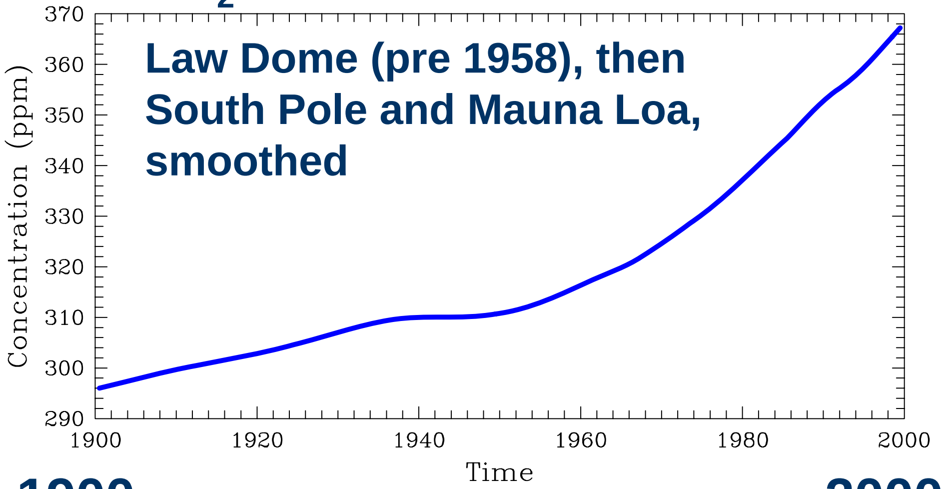
Model forcing and modelled climate

Sea Surface Temperature:



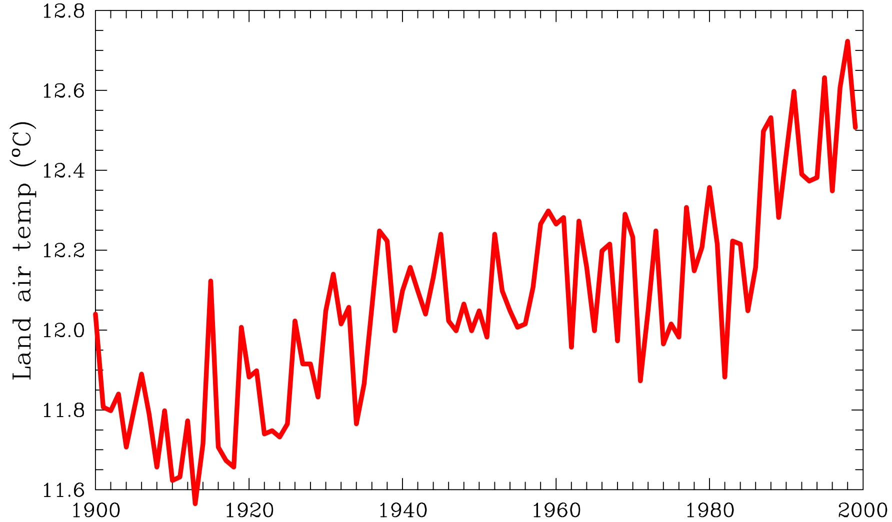
1900 **2000**

CO_2 concentration



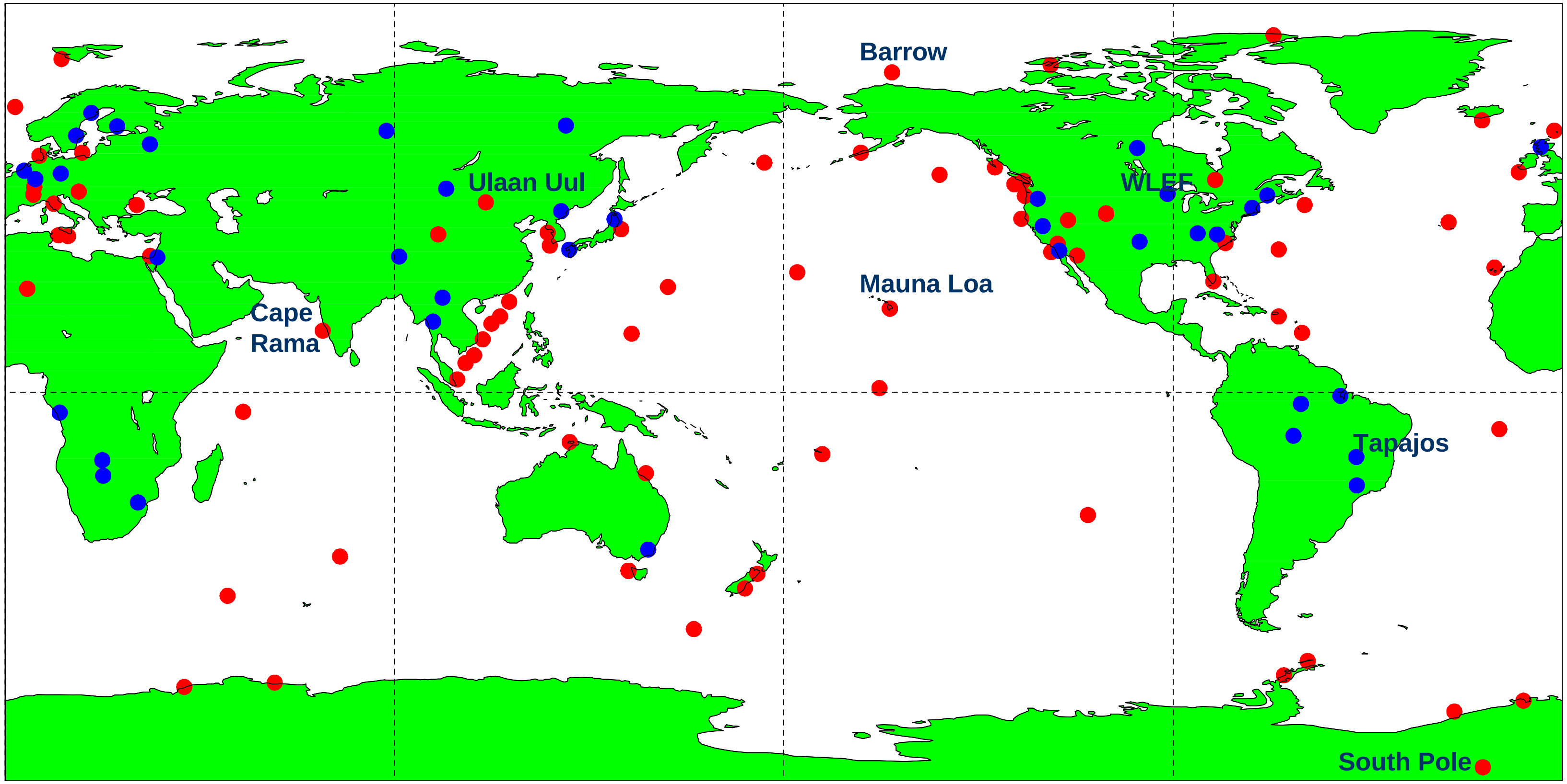
1900 **2000**

Land air temperature



1900 **2000**

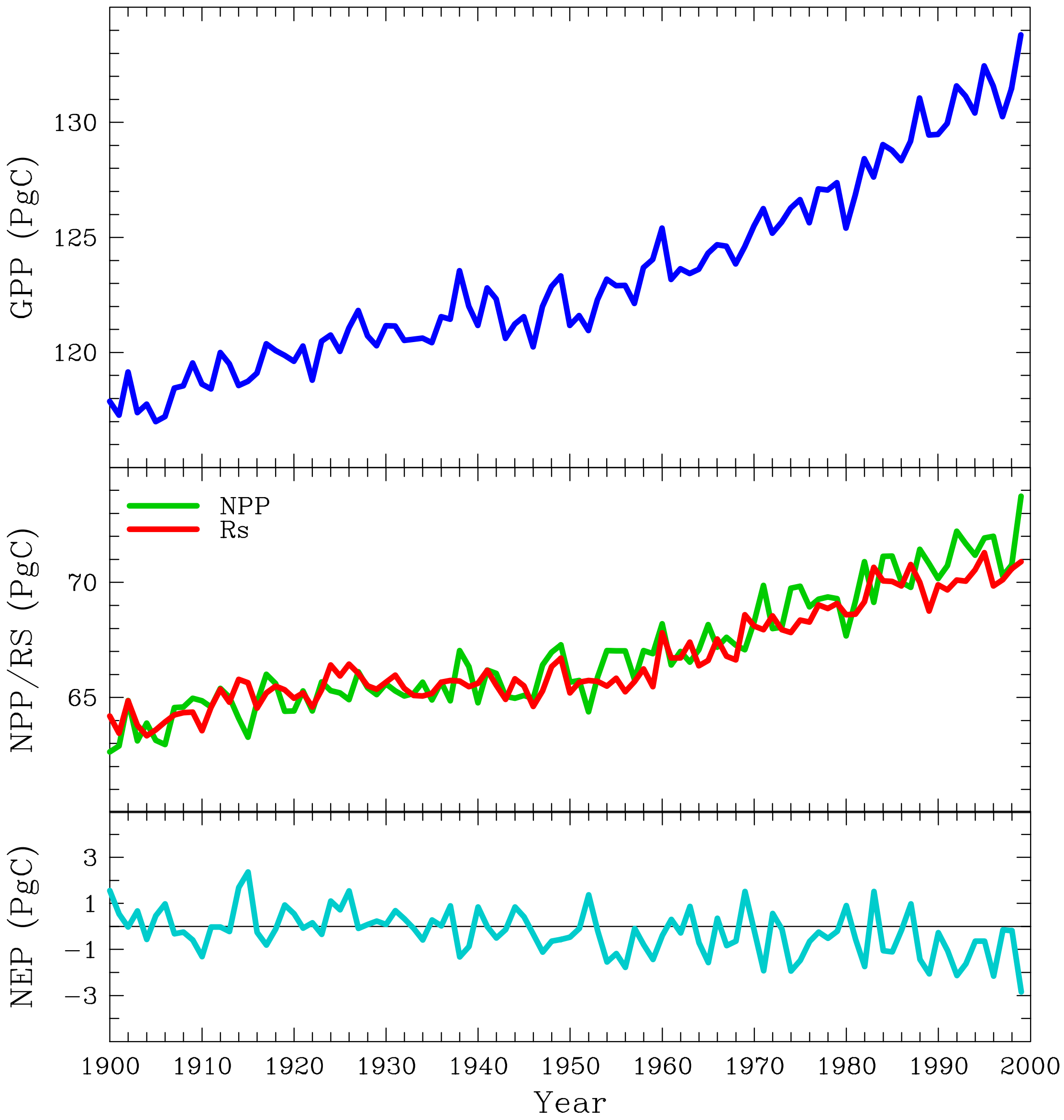
Map of output locations



Red: atmospheric sampling sites, blue: flux tower sites

Atmospheric data ‘see’ CO_2 sources/sinks from a larger region than flux towers

Carbon fluxes through 20th century

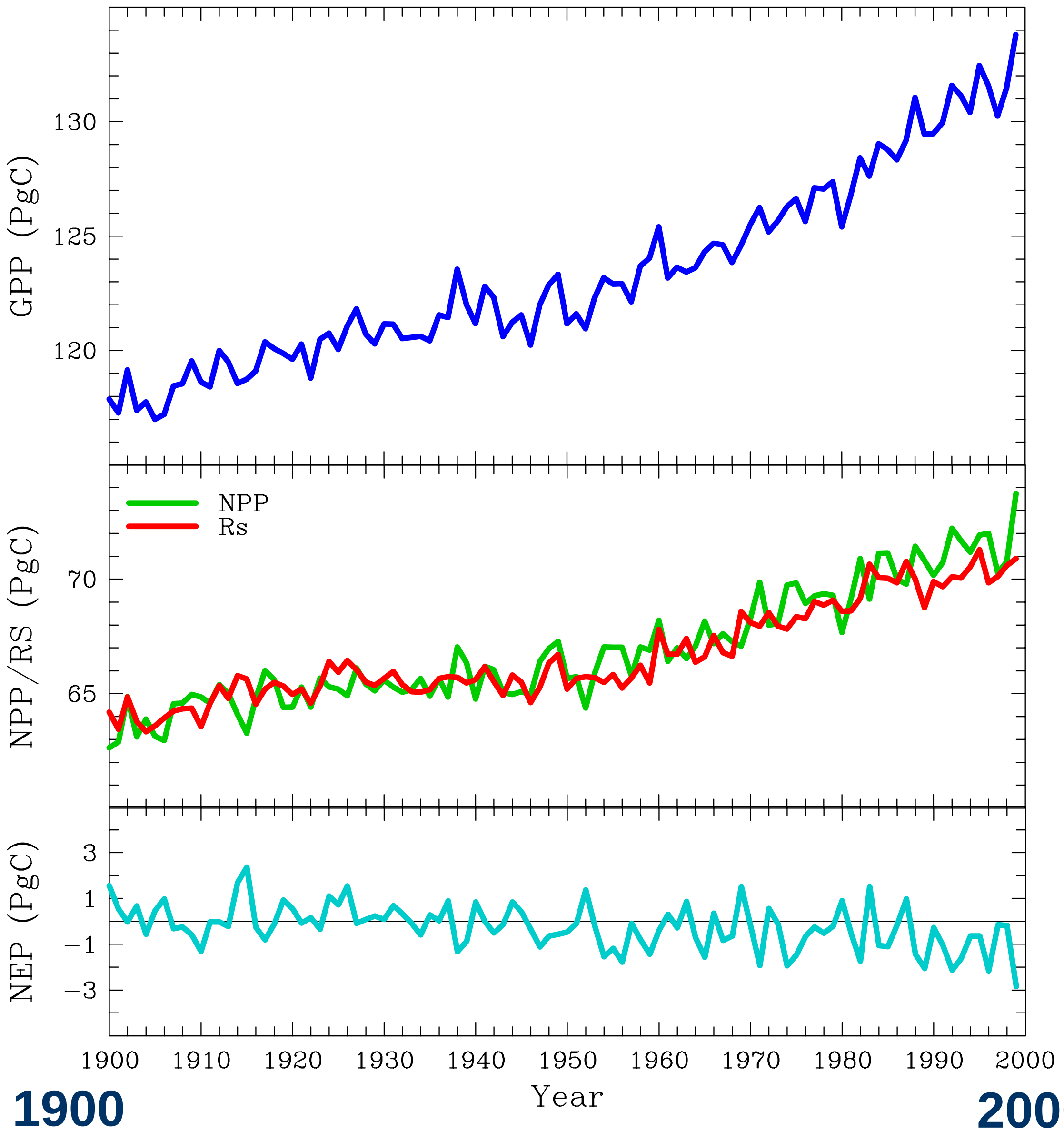


GPP – photosynthesis increases as atmospheric CO_2 increases

NPP (photosynthesis minus plant respiration) and soil respiration increase with increasing CO_2

NEE (net exchange with atmosphere) starts ~neutral (tuned) and becomes sink

Carbon fluxes through 20th century



GPP – photosynthesis increases as atmospheric CO_2 increases

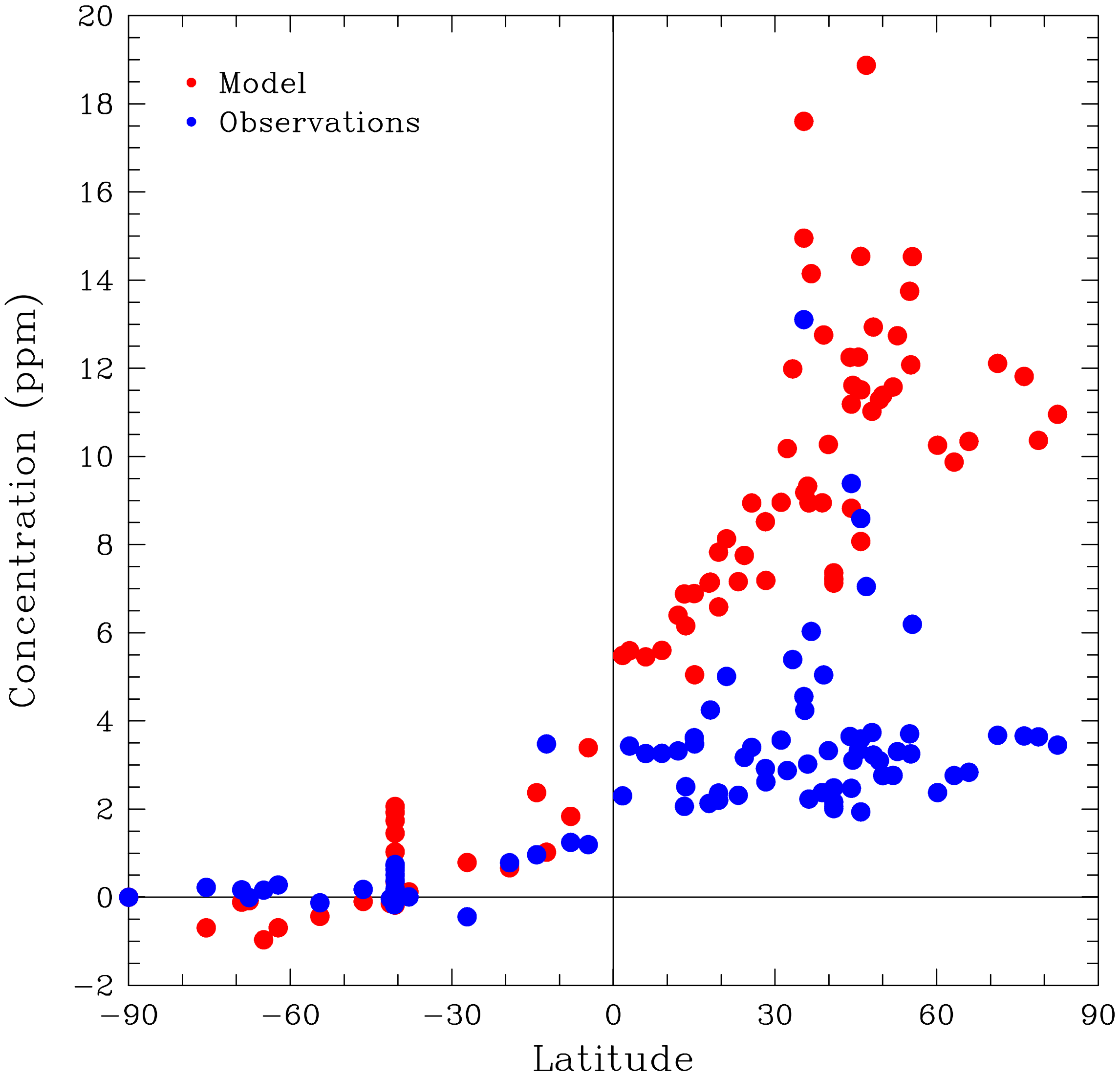
NPP (photosynthesis minus plant respiration) and soil respiration increase with increasing CO_2

NEE (net exchange with atmosphere) starts ~neutral (tuned) and becomes sink

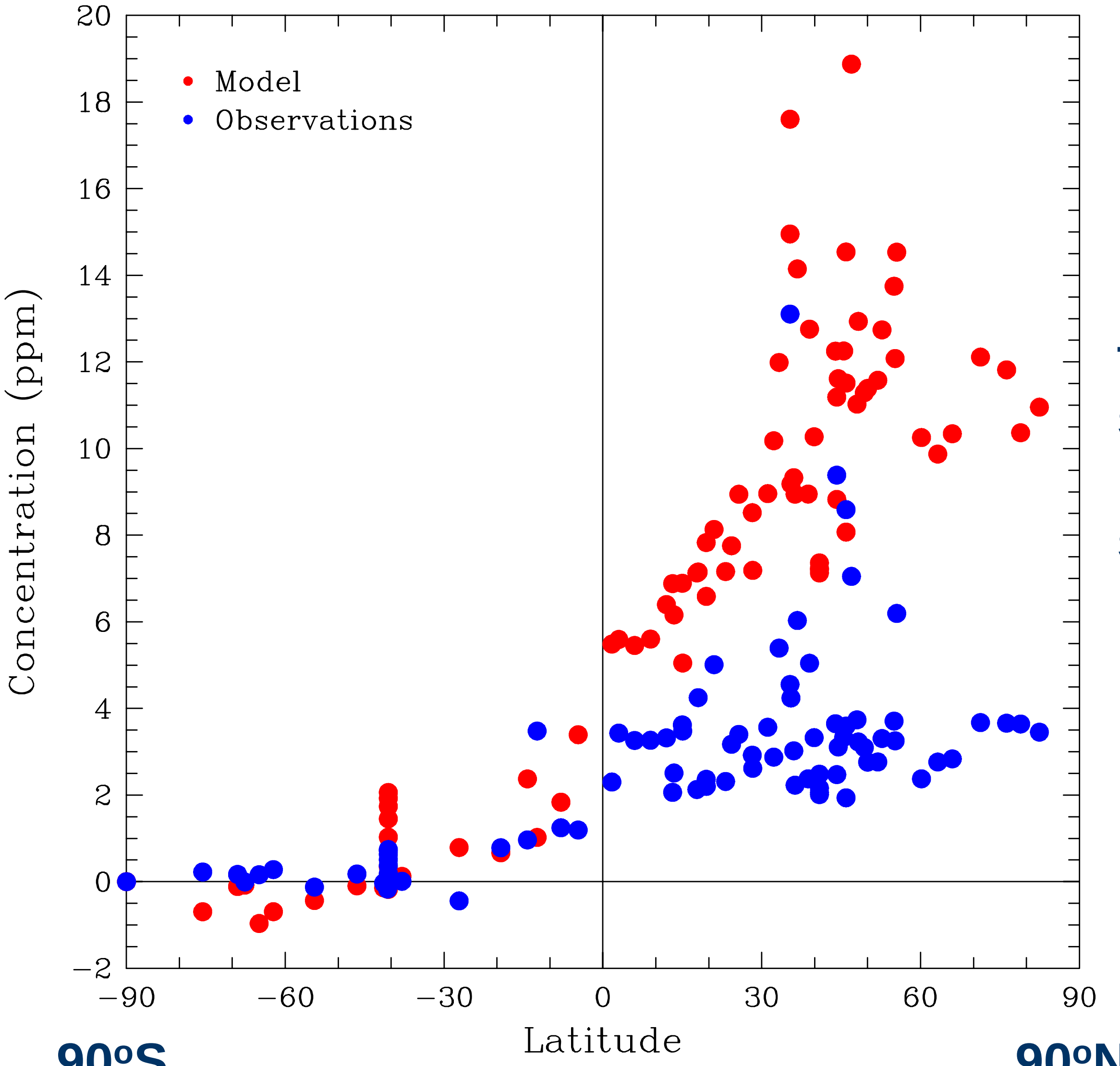
1900

2000

North-South gradient of CO_2 (1980-1999)



North-South gradient of CO_2 (1980-1999)

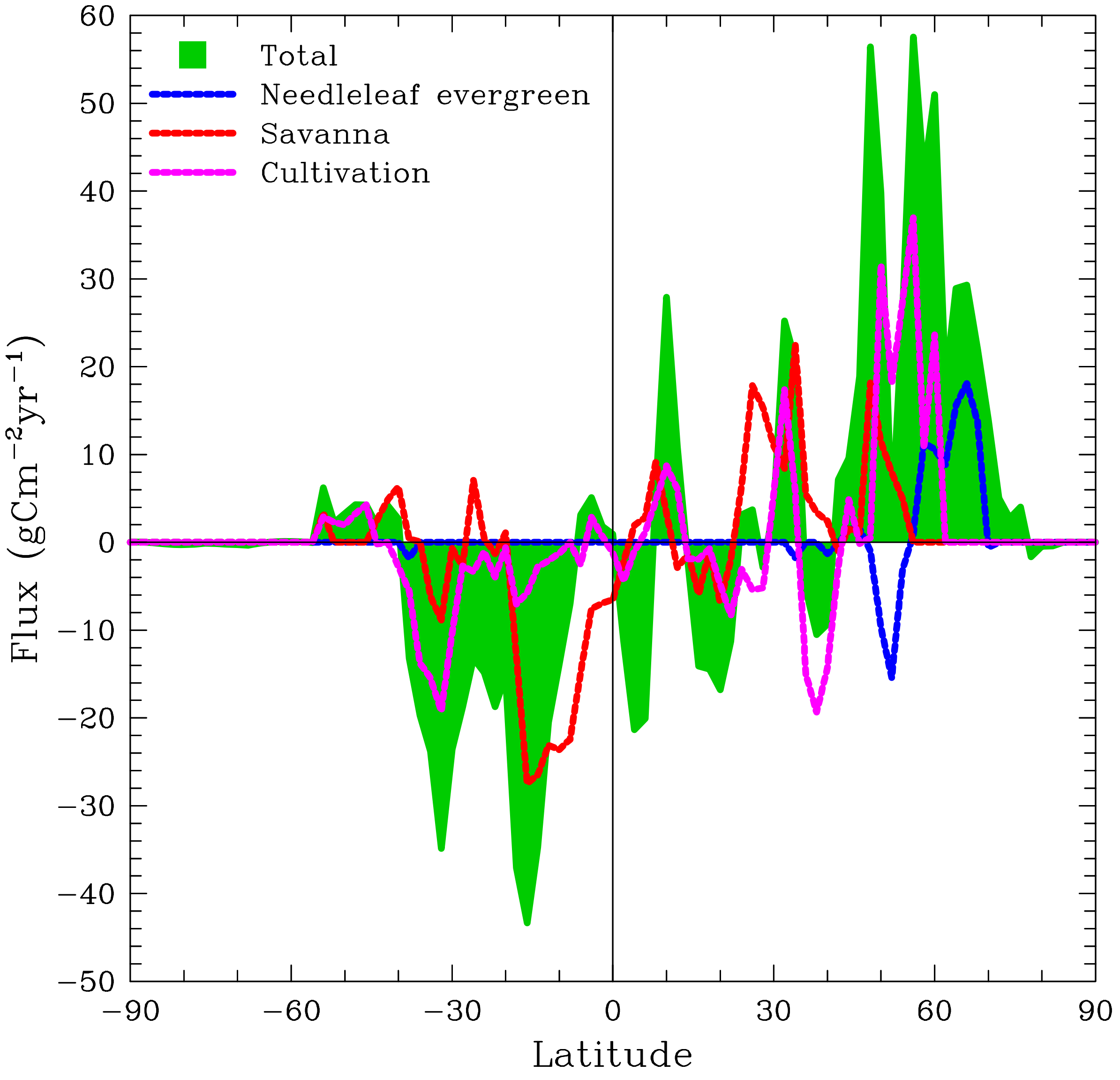


90°S **90°N**

N-S gradient too large in model. Assuming transport OK, implies source distribution incorrect – too little sink in northern hemisphere

Data: GLOBALVIEW-CO2 (2003)

Zonal mean net ecosystem exchange

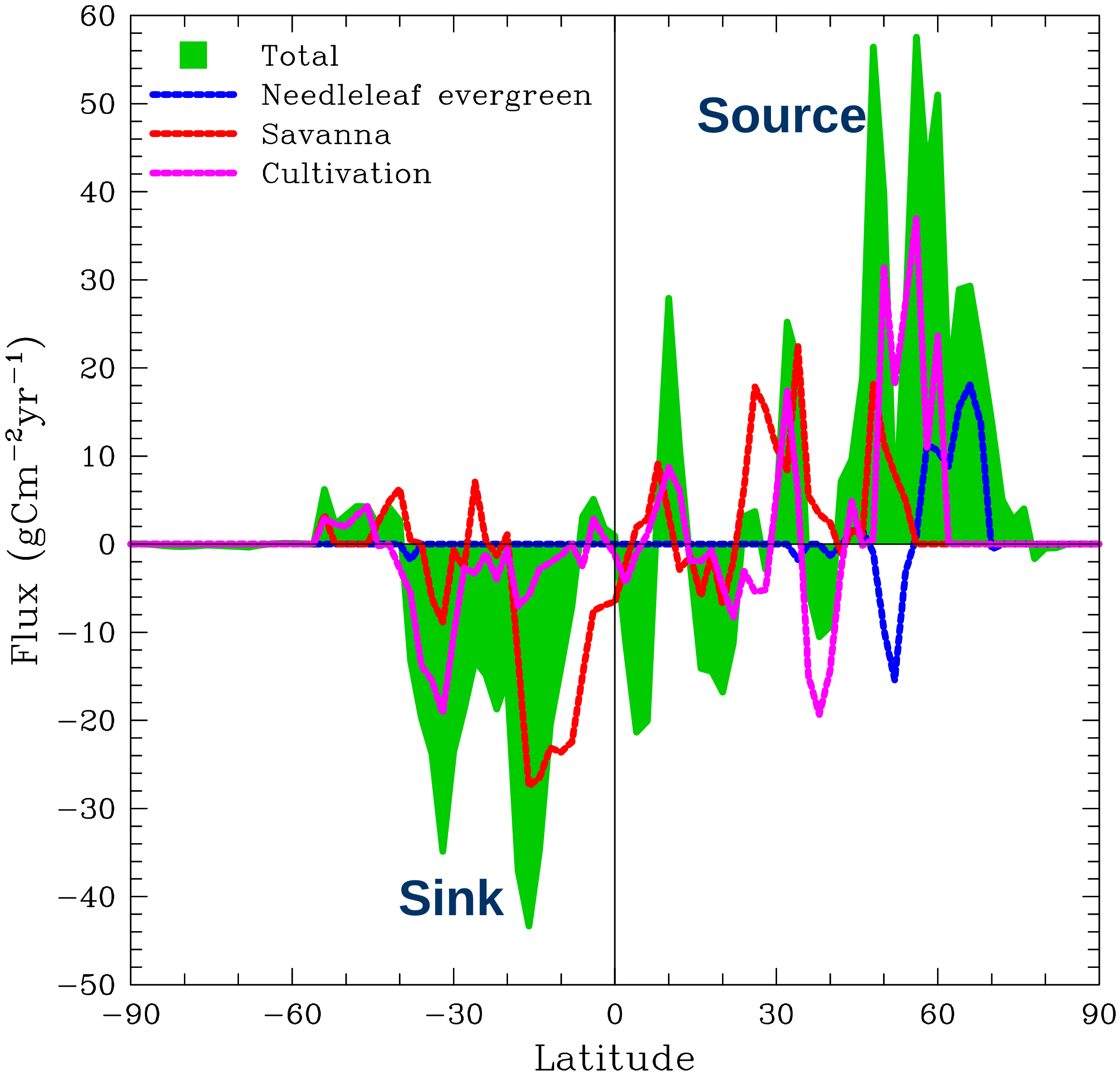


Zonal mean net ecosystem exchange

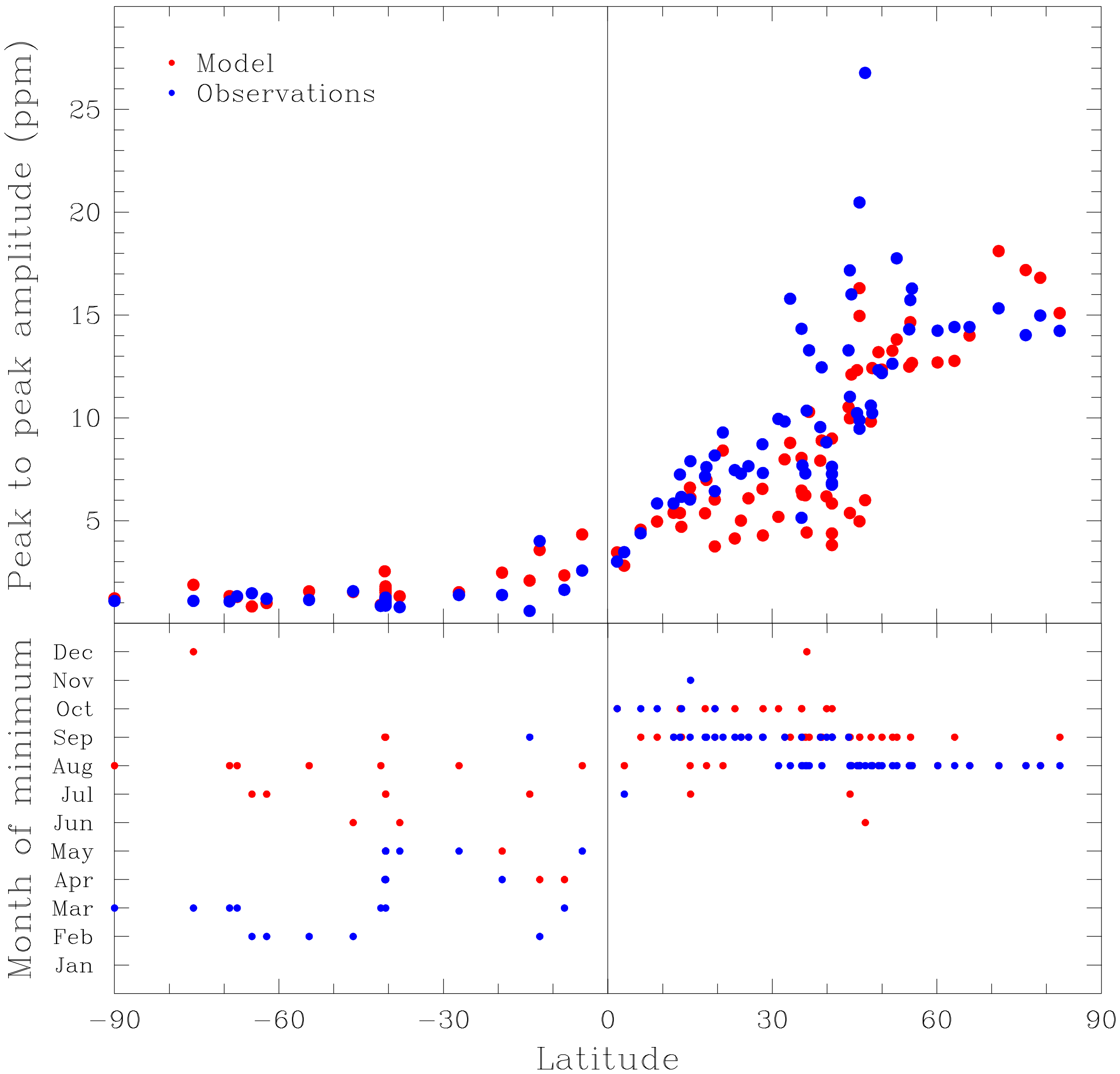
Northern mid-high latitude source, southern low-mid latitude sink indicates

- **problems with biosphere simulation e.g. expect cultivation closer to neutral**

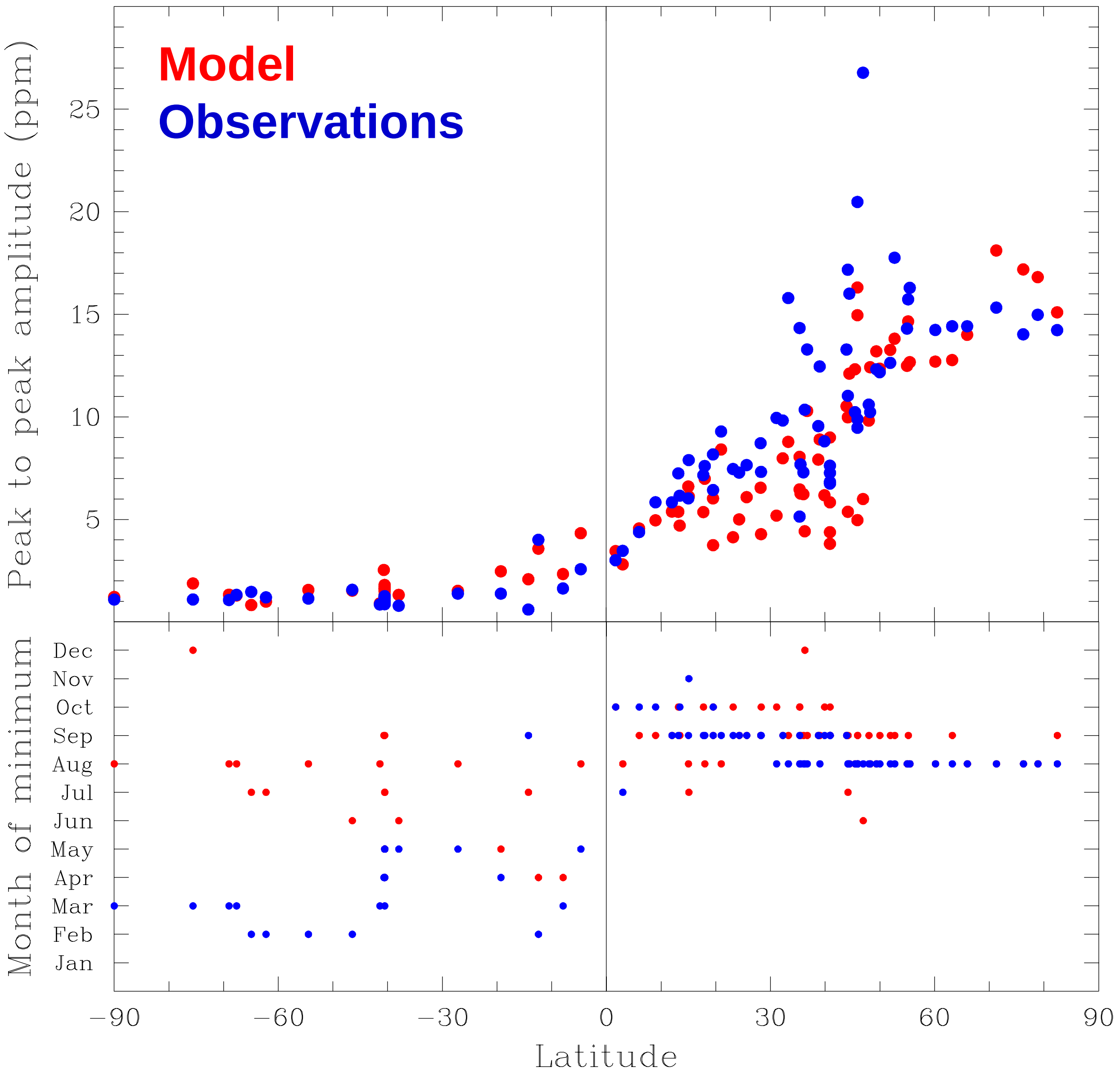
- **missing processes e.g. fire suppression, recovery from disturbance, nitrogen fertilisation, tropical deforestation**



Seasonal cycle: amplitude and phase



Seasonal cycle: amplitude and phase

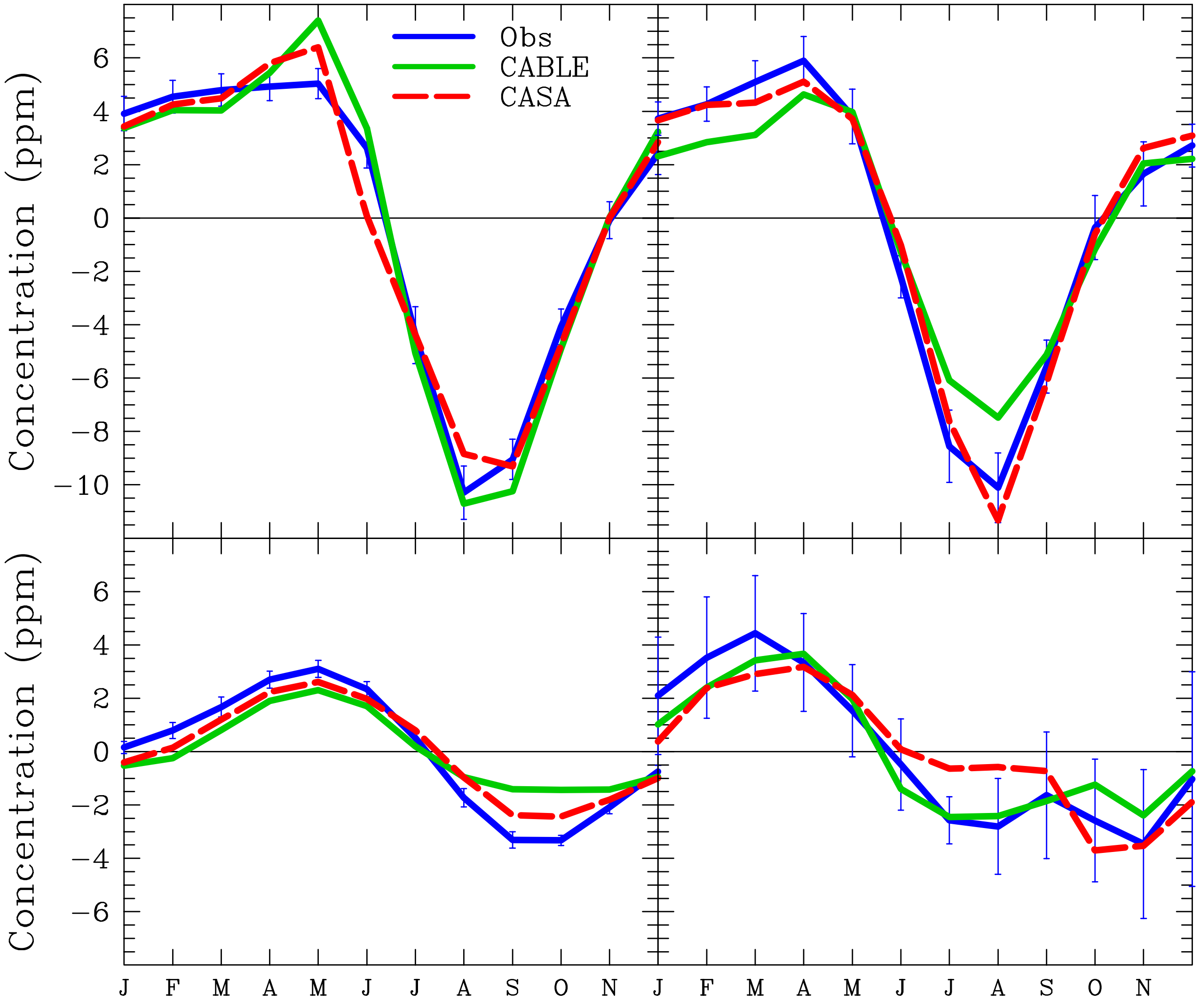


Peak to peak amplitude – too low in northern mid-latitudes

Month of minimum, out by 4-5 months in southern hemisphere

Data: GLOBALVIEW-CO2 (2003)

Seasonal cycle: NH sites

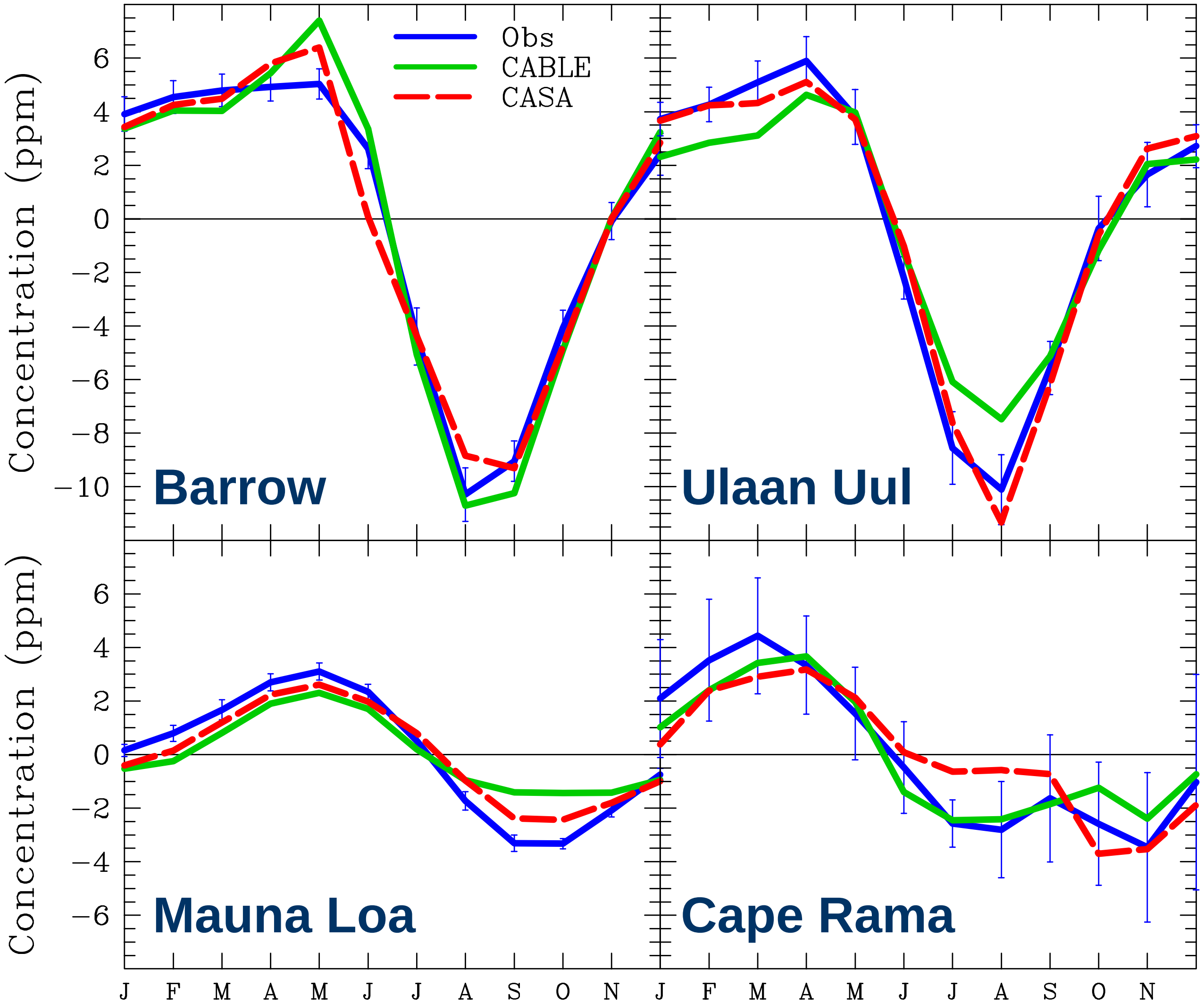


Seasonal cycle: NH sites

Blue: obs

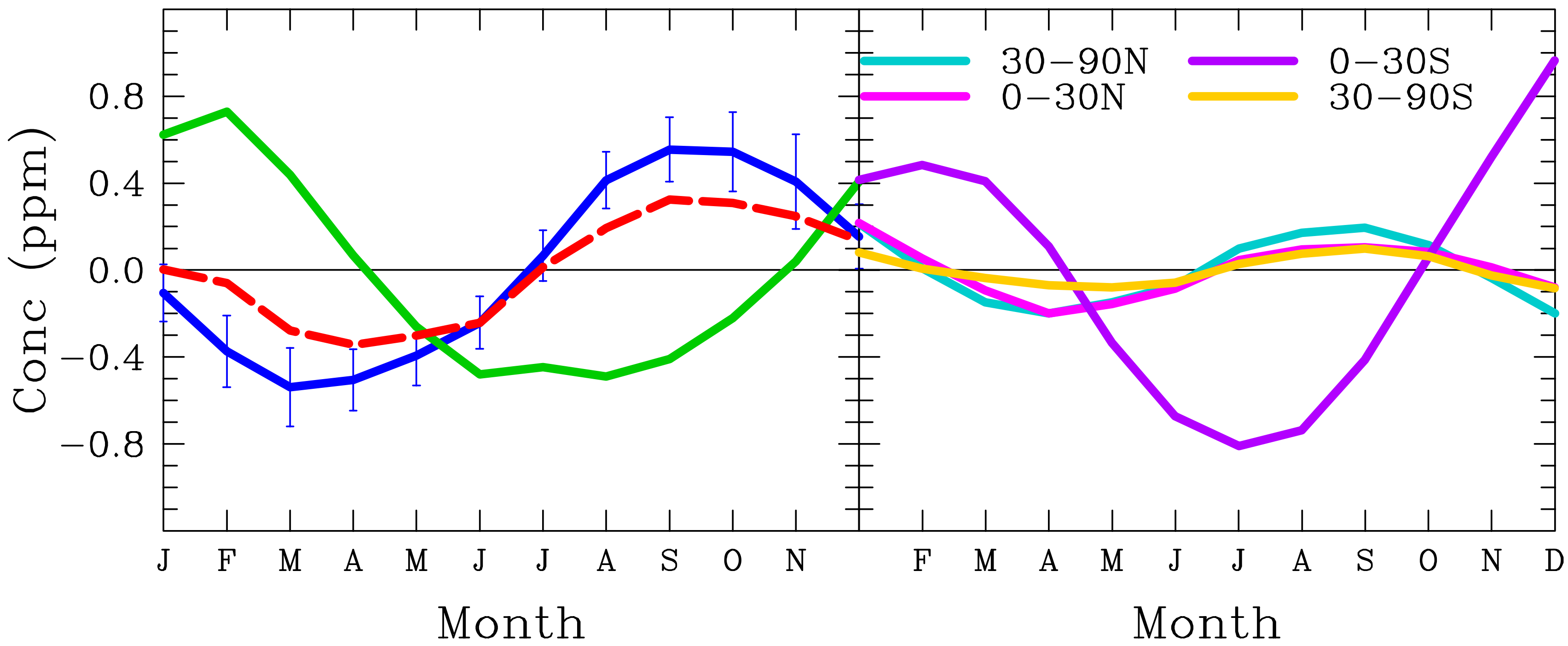
Green: CABLE

Red: CASA



Data: GLOBALVIEW-CO2 (2003)

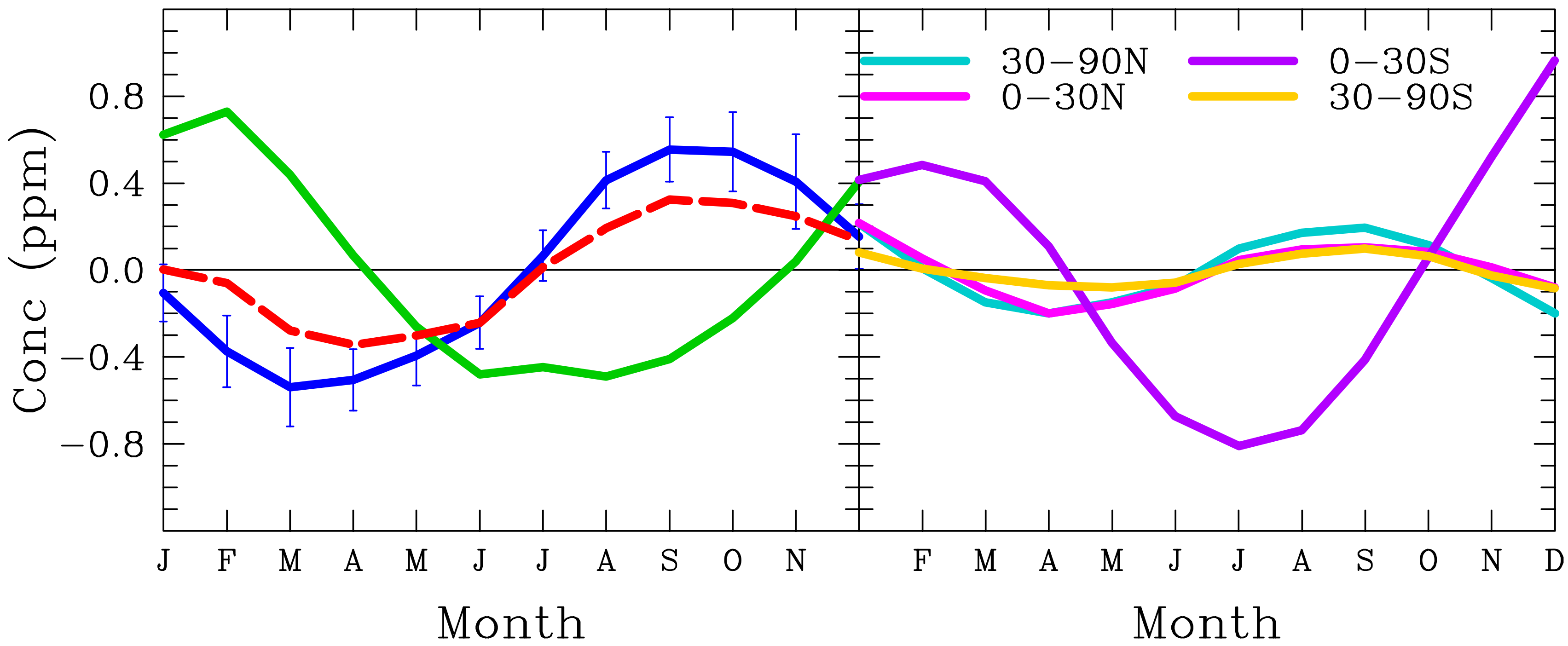
Seasonal cycle: southern hemisphere



Seasonal cycle: southern hemisphere

South Pole

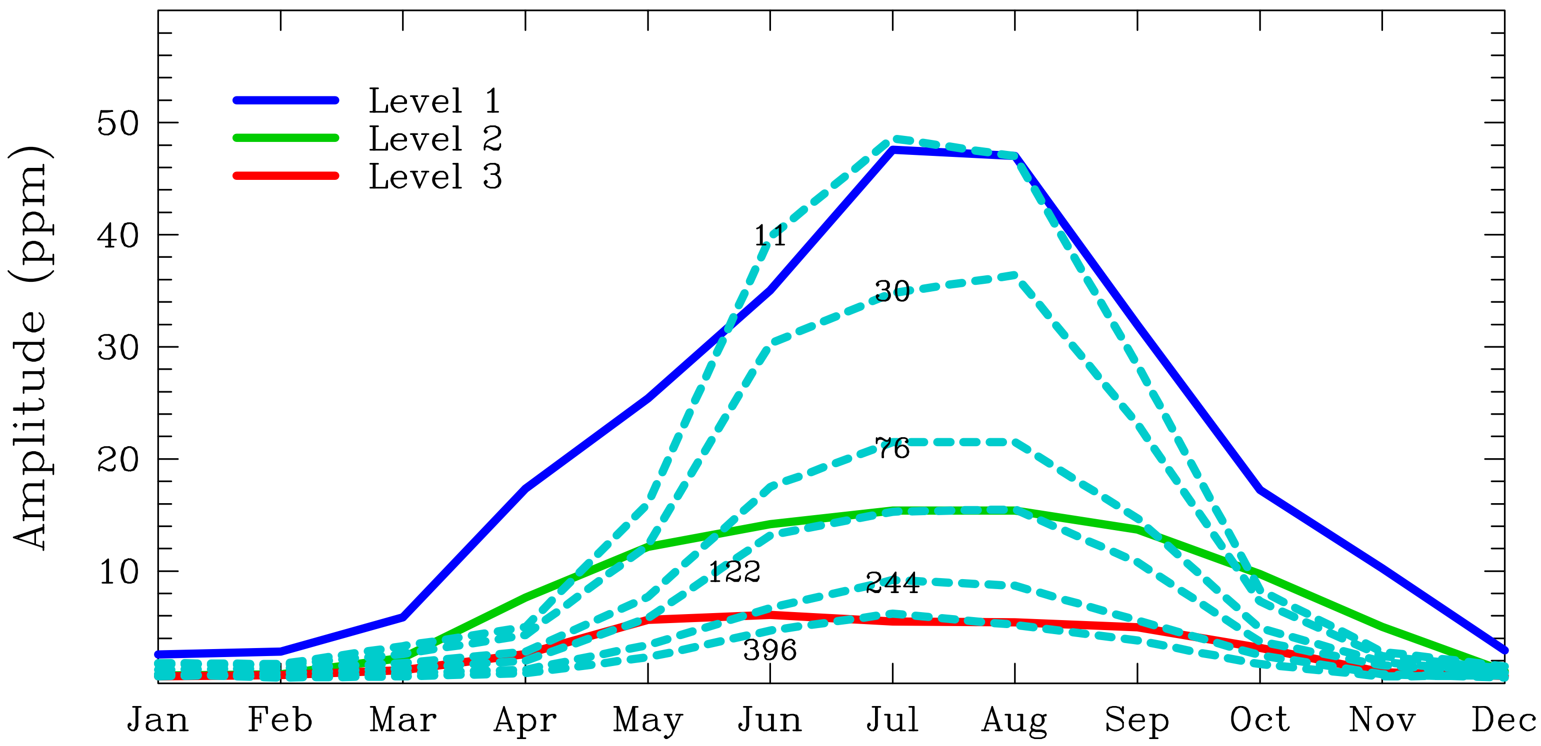
Contribution of source from each semi-hemisphere



Blue: obs, green: model, red: CASA

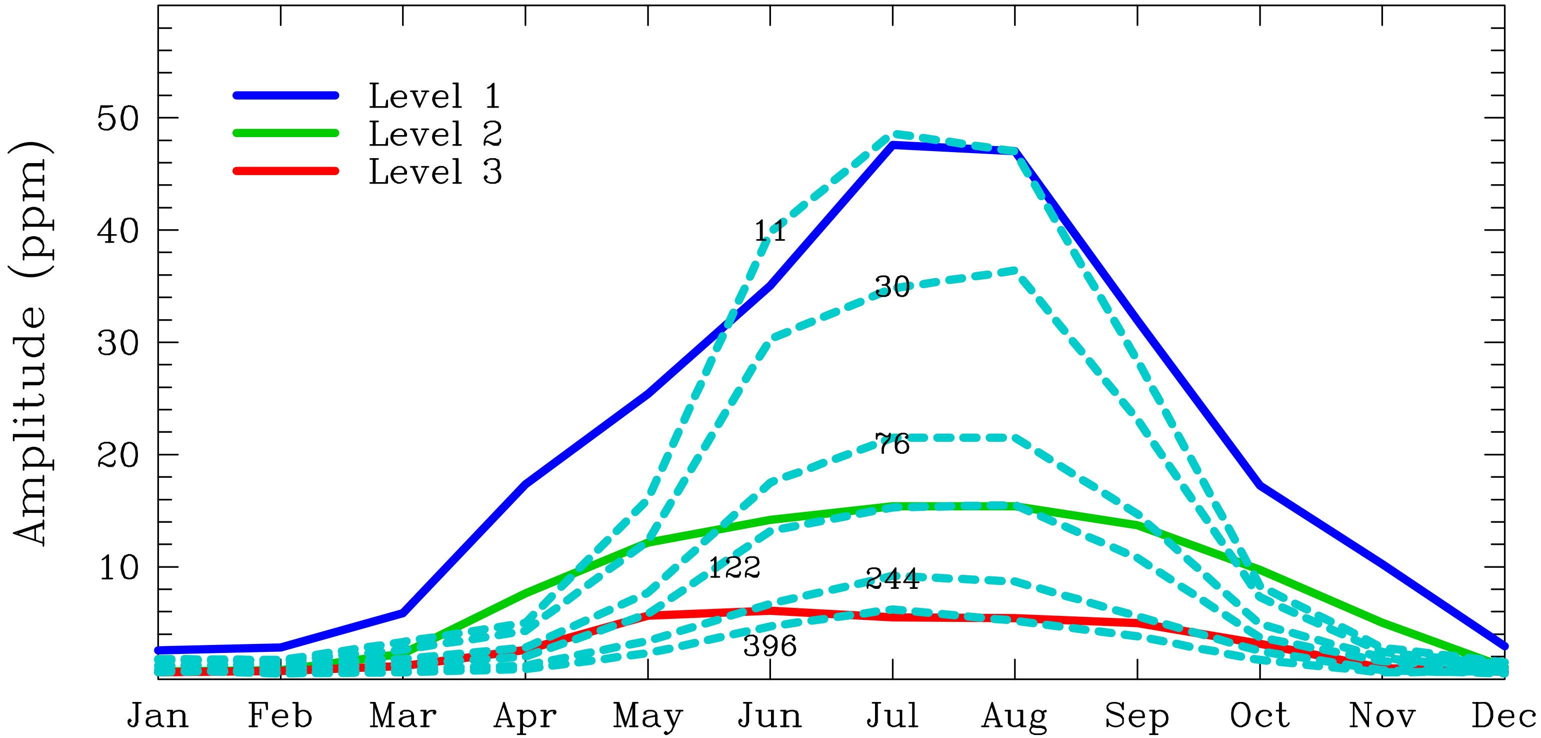
Data: GLOBALVIEW-CO2 (2003)

Amplitude of diurnal cycle



Amplitude of diurnal cycle

WLEF tower, Wisconsin, USA **Data: GLOBALVIEW-CO2 (2003)**

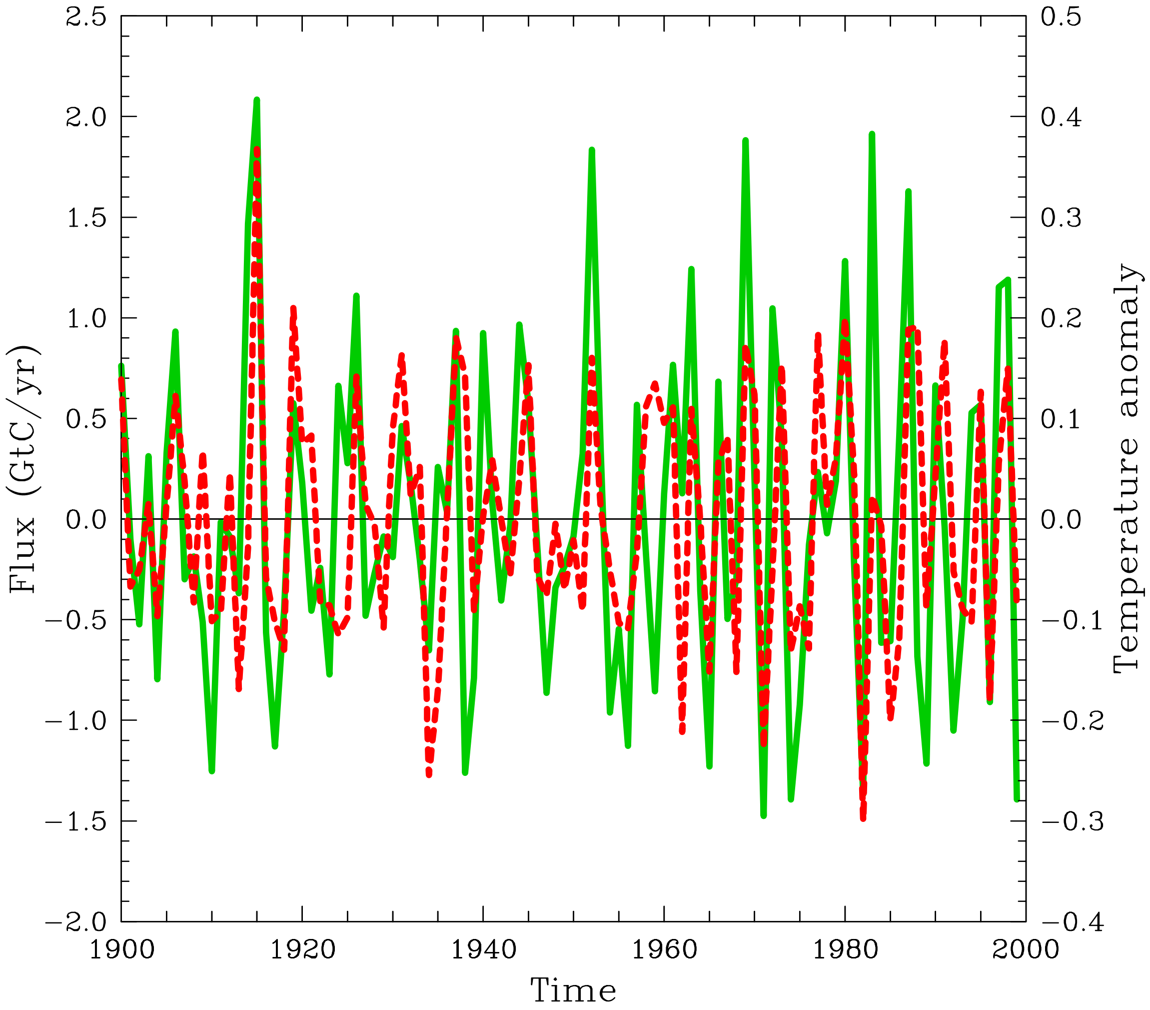


Model levels approximately 37, 179, 456 m above surface

Dotted lines – observed median amplitude

Interannual variability

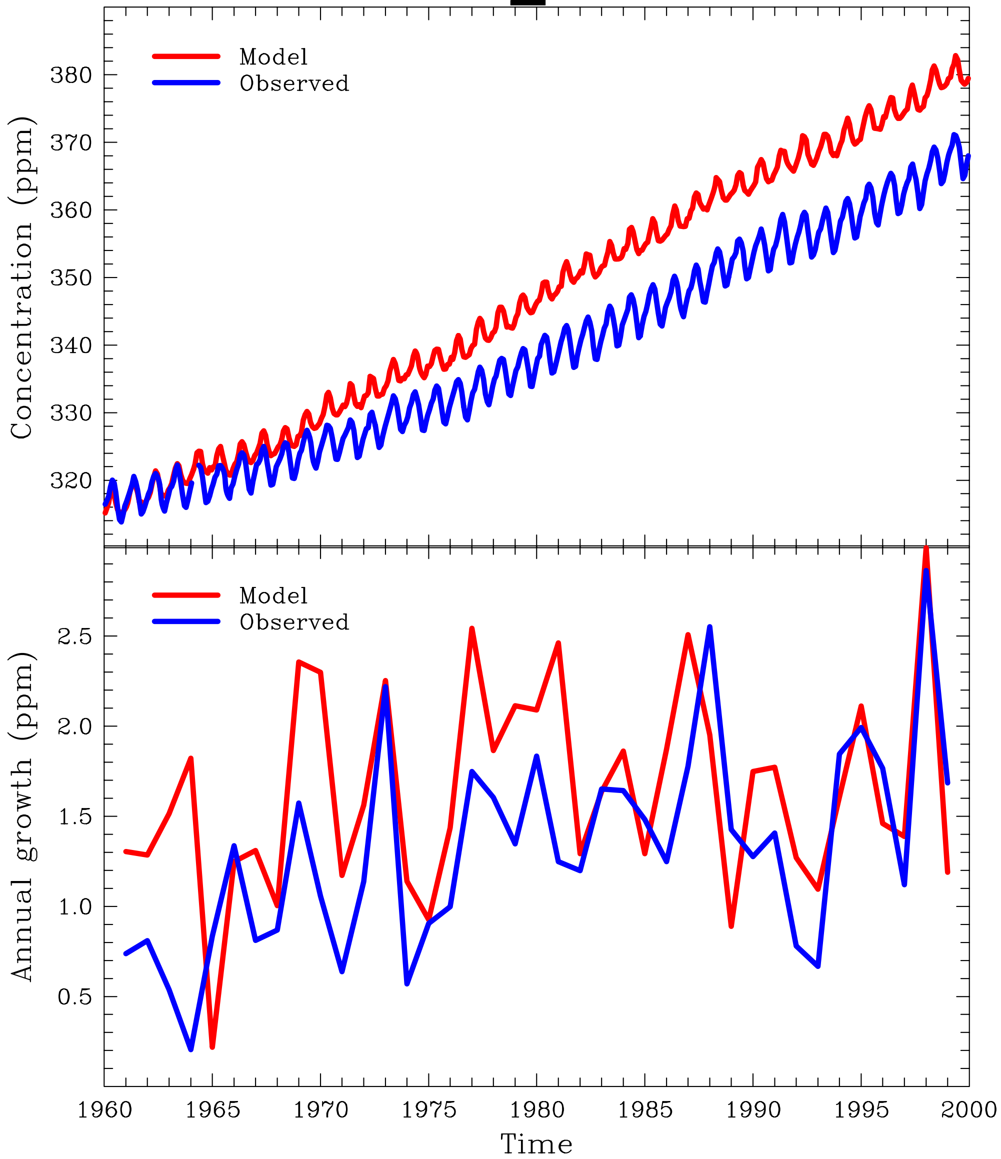
IAV NEE (green) and IAV temperature (red)



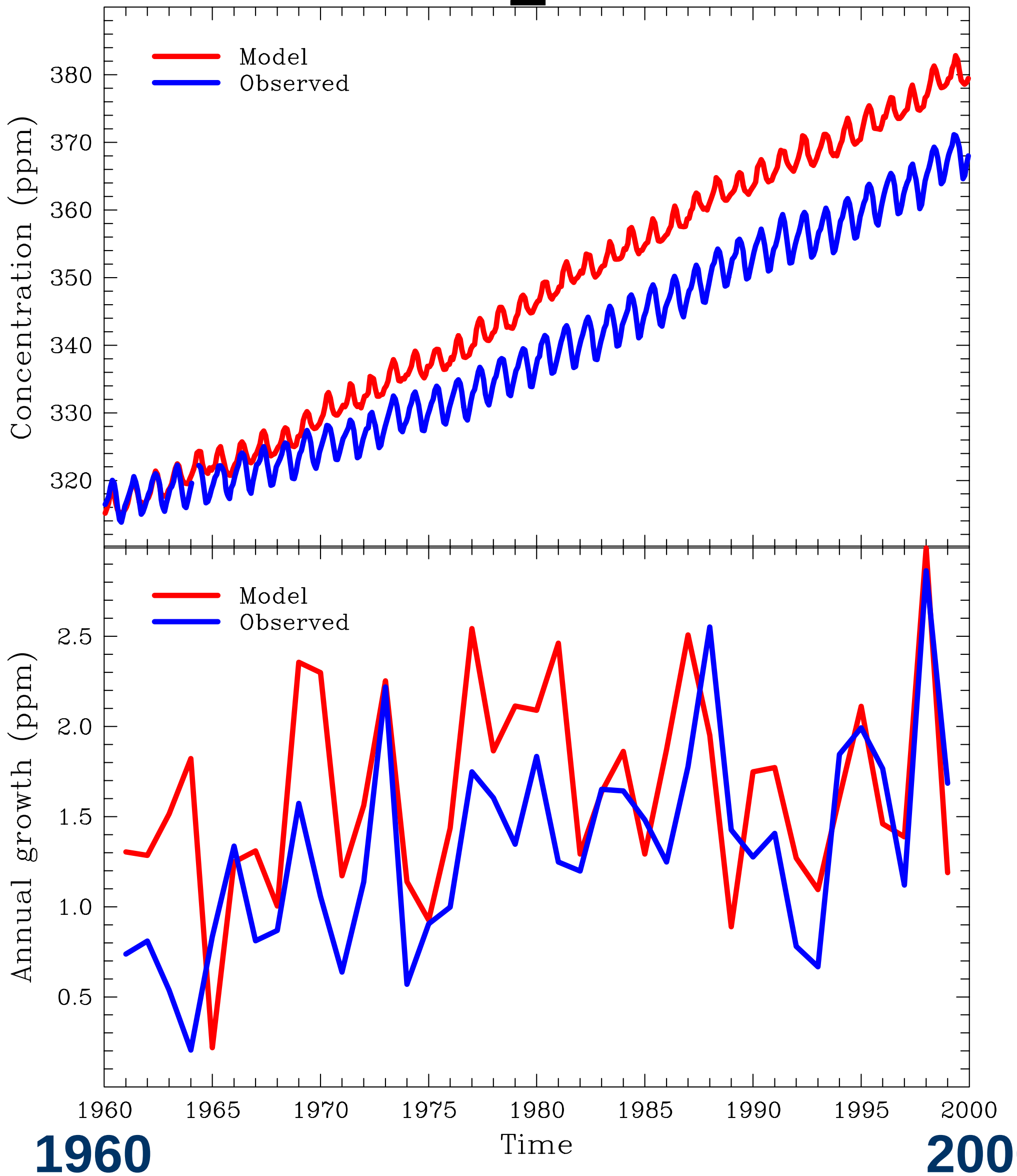
Fit to long-term trend removed

Correlation 0.59, weaker with precip

CO_2 at Mauna Loa



CO_2 at Mauna Loa



1960 **2000**

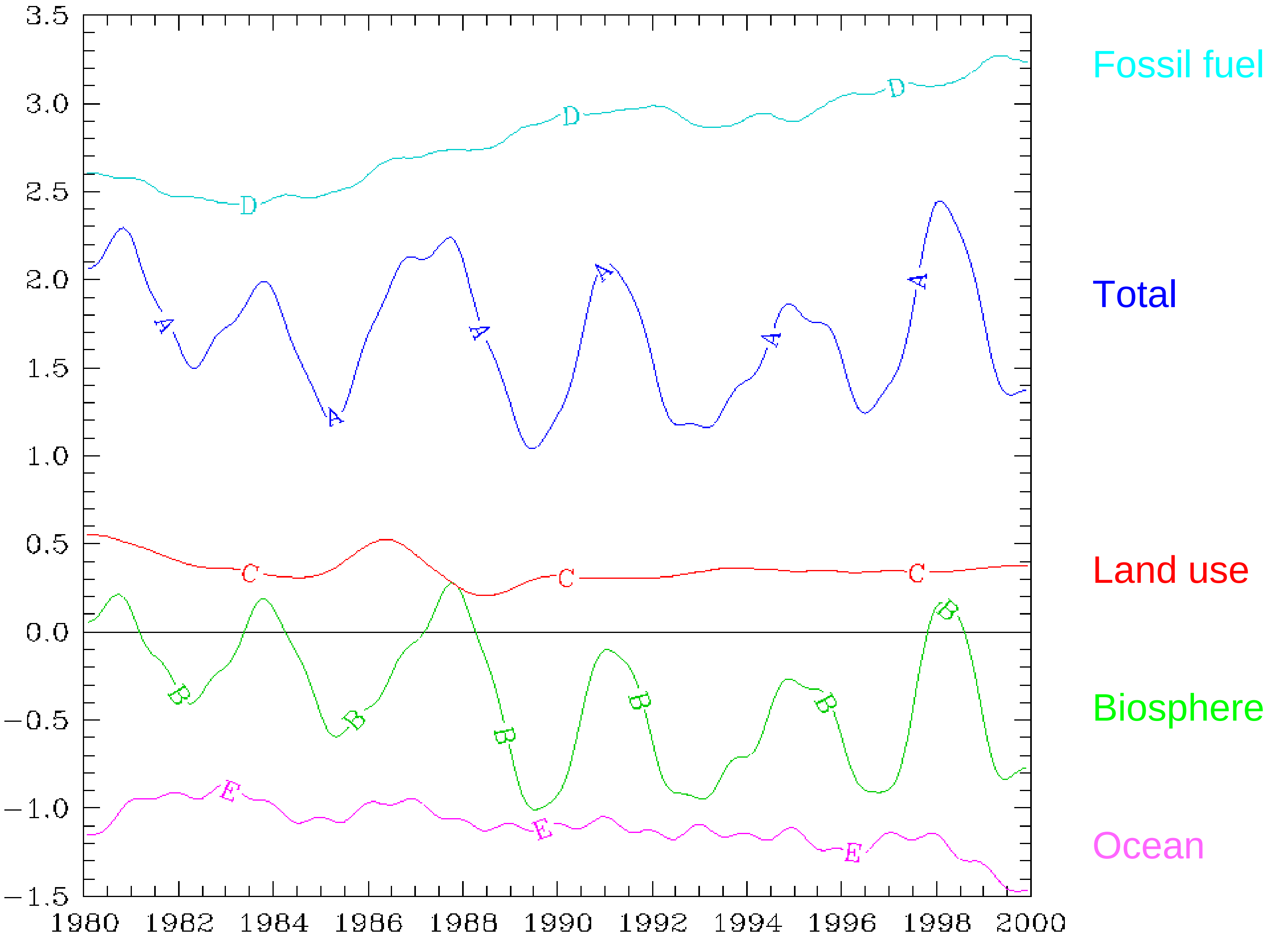
CO_2 concentration (ppm)

Model: red,
Observed: blue

Annual growth of CO_2 (ppm/yr)

Data: Keeling et al (2005)

CO_2 Growth Rate Components at South Pole Station (ppm/yr)

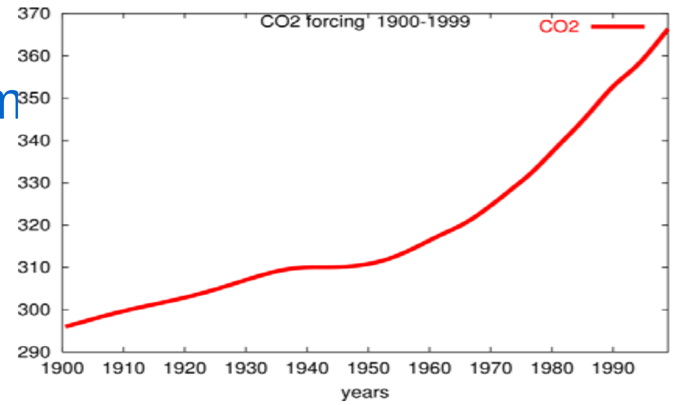


What did we learn

- Respiration overestimated – too sensitive to temperature?
- Savanna biome, NPP too large, perhaps need more plant respiration
- Cultivation biome, expect to be closer to neutral over annual cycle
- Global GPP and NPP larger than expected -suggests too much photosynthesis

CSIRO Carbon-climate simulation

- **C4MIP phase I simulation:**
  - Coupled CABLE (CSIRO Atmosphere Biosphere Land Exchange LSS) with CCAM (Cubic Conformal Atmospheric Model).
  - Used prescribed SST, carbon fluxes from ocean, fossil fuel and land use change from 1900 to 2000.
  - Two atmospheric CO_2 concentrations used:
    1) prescribed historical CO2 globally uniform
    2) a result of atmospheric transport of all carbon fluxes including biospheric fluxes.

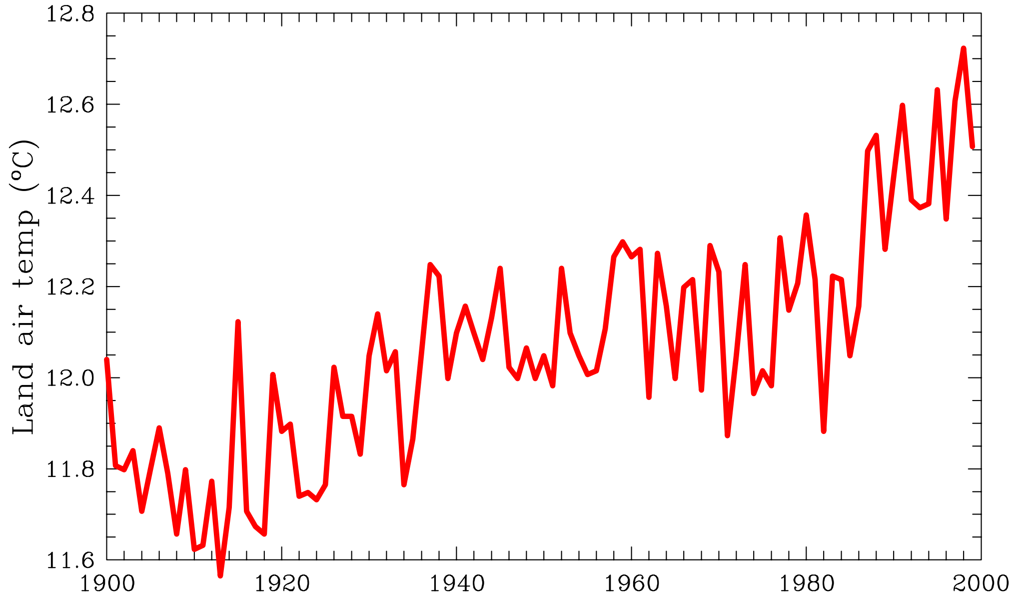


  - **Two simulations**:

    RUN1: biosphere sees prescribed historical CO2 from 1900 to 2000
    RUN2: biosphere sees prescribed historical CO2 from 1900 to 1970, then CO2 is kept constant at 1970 level from 1971 to 2000.

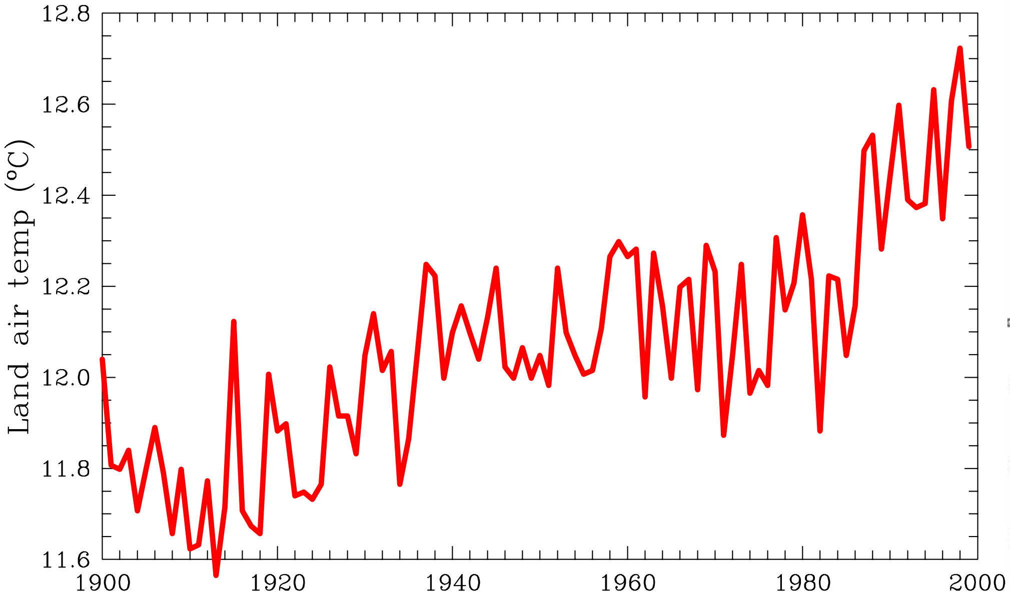
Law et al., Tellus, 58B, 427-437, 2006.

Modelled climate

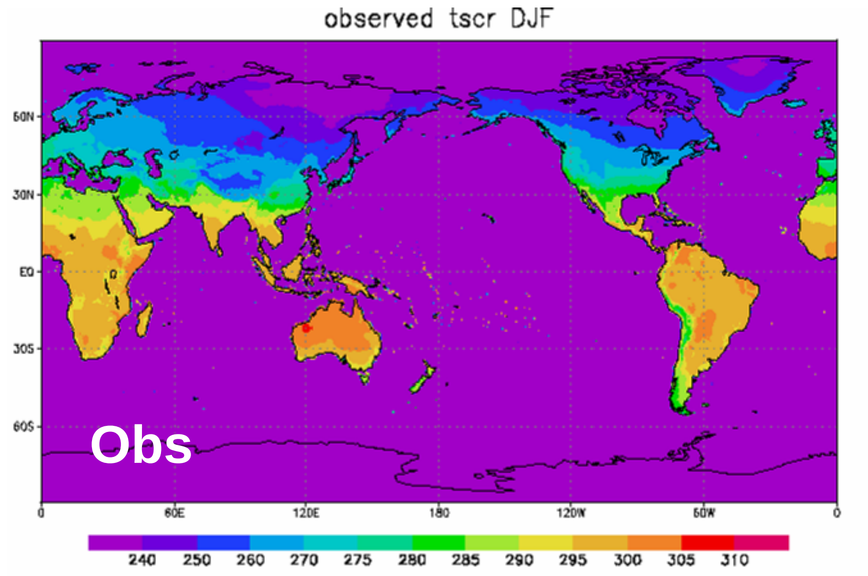


Modelled climate

Land air temperature



1900 **2000**



Screen temperature: DJF 80-99