Land cover coupling to the climate system;
implementing an interactive carbon cycle in ACCESS

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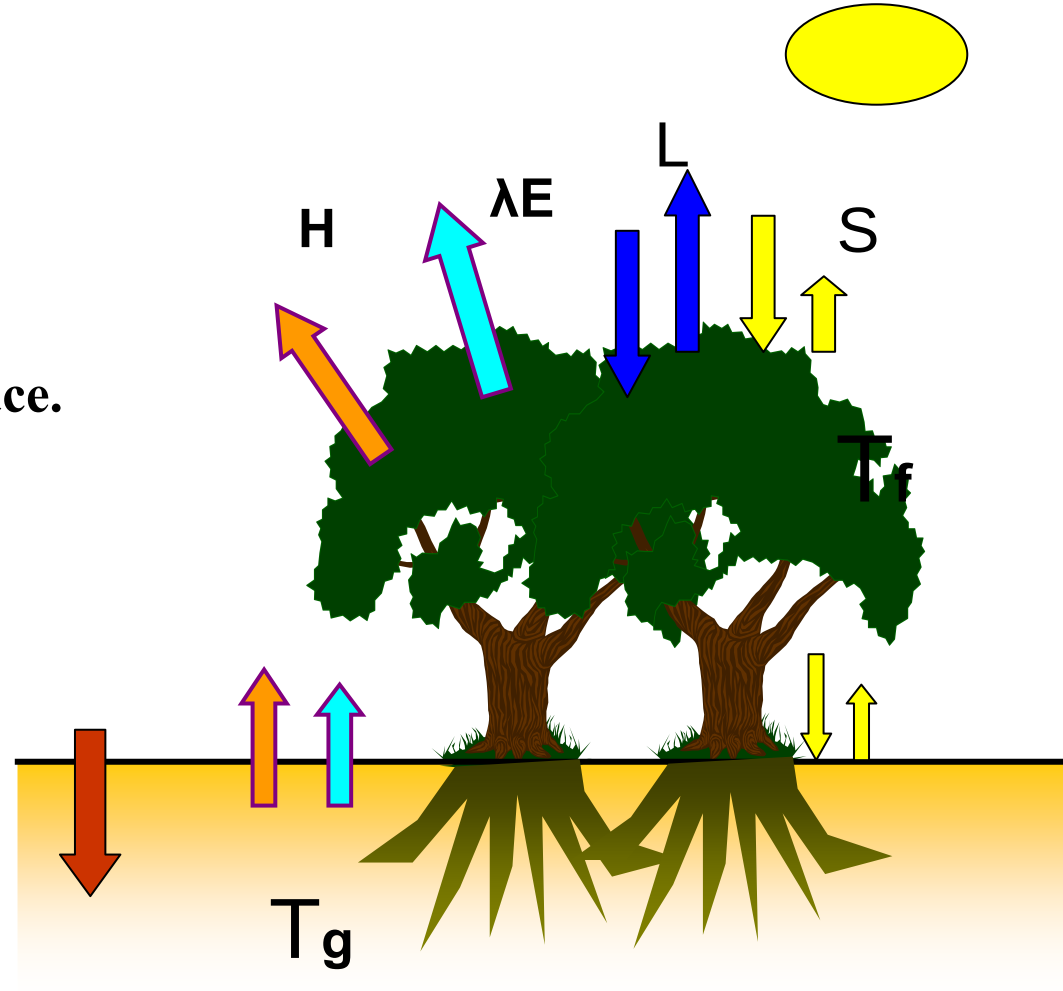
CSIRO Marine and Atmospheric Research

Law et al., Tellus, 58B, 427-437, 2006.
Kowalczyk et al., CMAR Research Paper 013, 2006

Role of the Land Surface Scheme (LSS) in GCM

LSS calculates exchanges of moisture, energy, momentum and trace gasses at the land-atmosphere interface.



Land surface important characteristics for calculation of SEB:
albedo,
leaf area index, canopy height,
surface moisture.

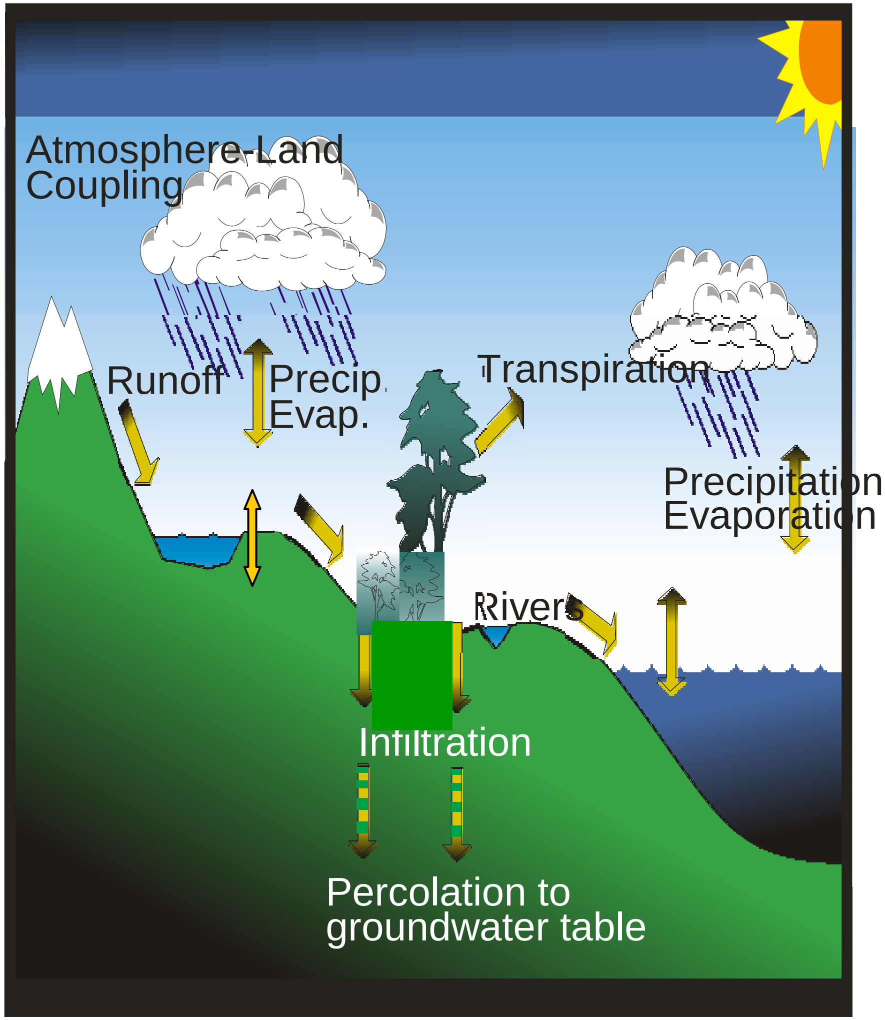
Key task is to calculate
Surface Energy Balance:

$$S_{net}\downarrow + L_{net}\uparrow - G\downarrow = H\uparrow + \lambda E\uparrow + C_g\, \delta T_g/\delta t$$

Role of the Land Surface Scheme in GCM

Surface Water Balance

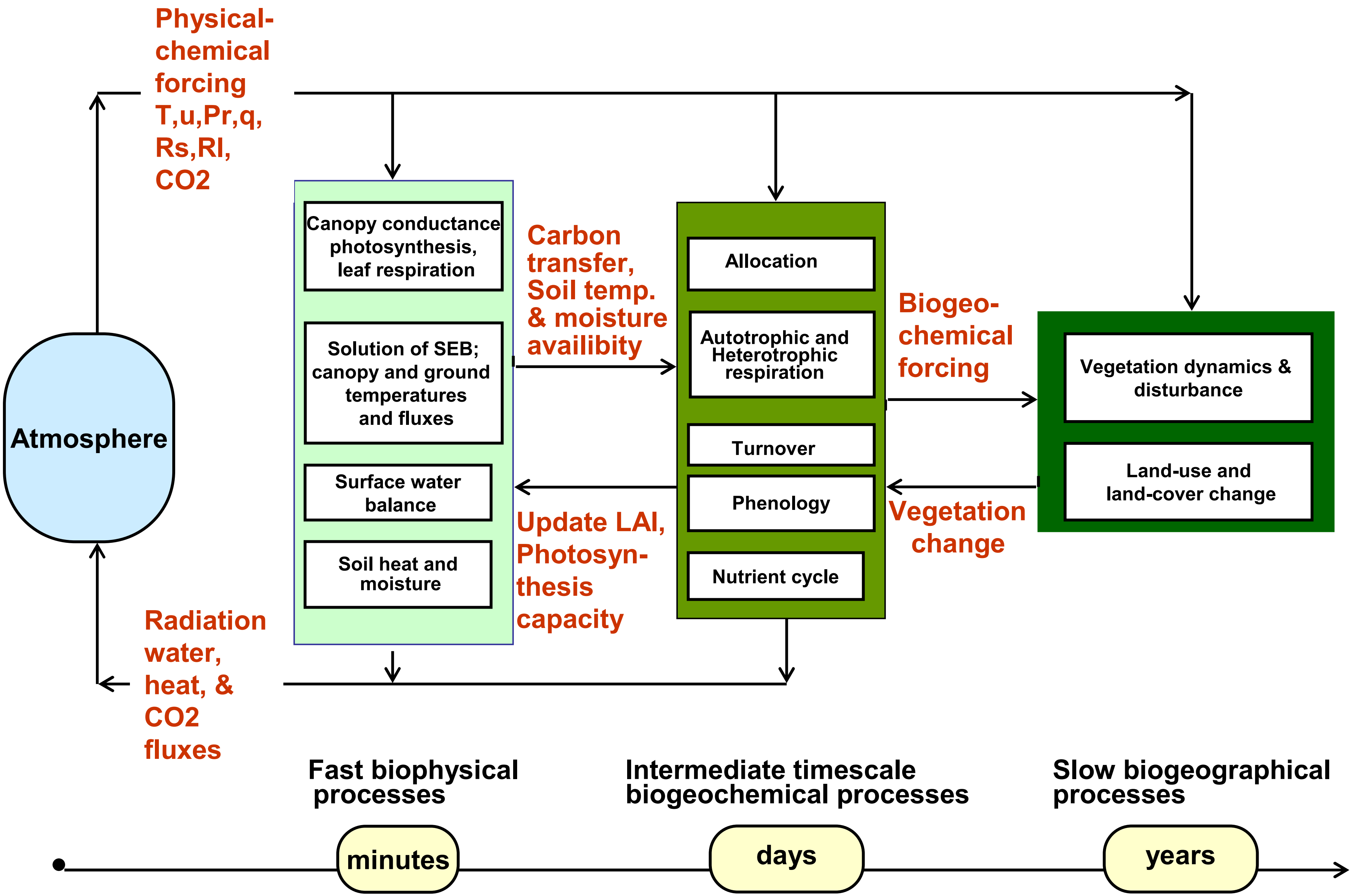
$$P_{rec} - E_{vap} - R_{unoff} = \Delta S_{now} + \Delta S_{oilMoist}$$



Land surface important characteristics:

soil hydraulic properties,
soil depth,
vegetation properties;
rooting depth
leaf area index,
max carboxylation rate

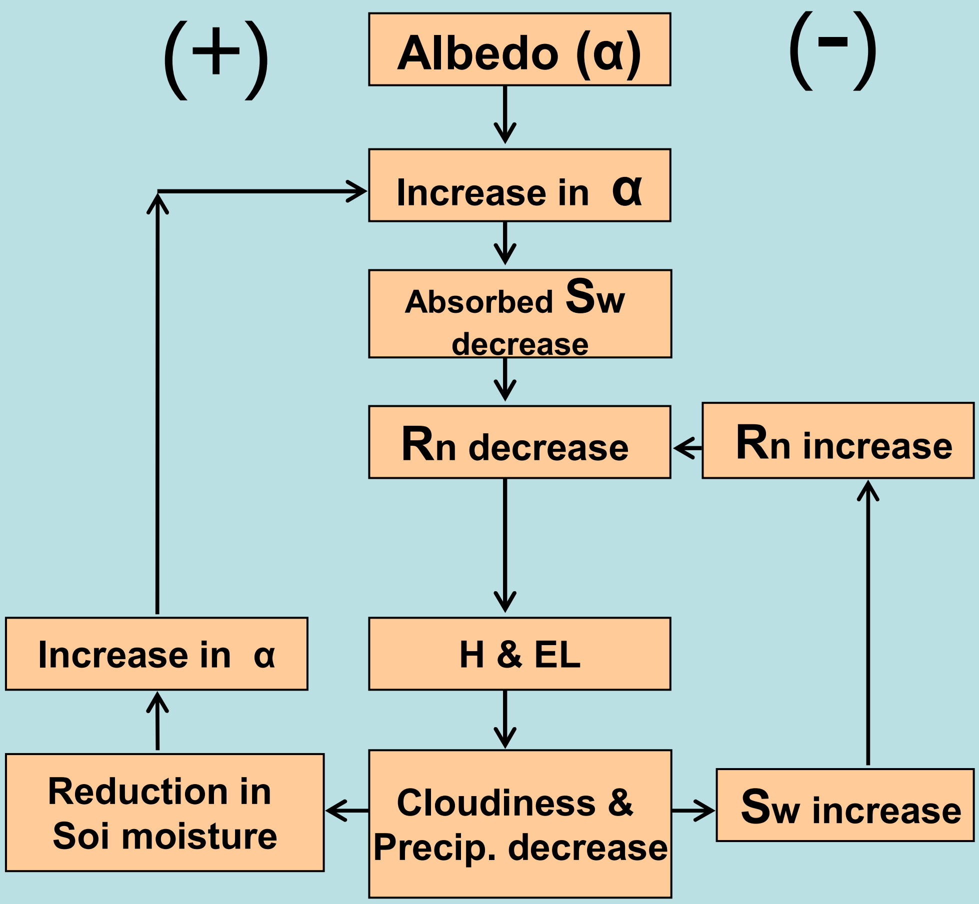
Time scale of biosphere-atmosphere interactions



Potentially important feedbacks in coupled climate-carbon cycle system.

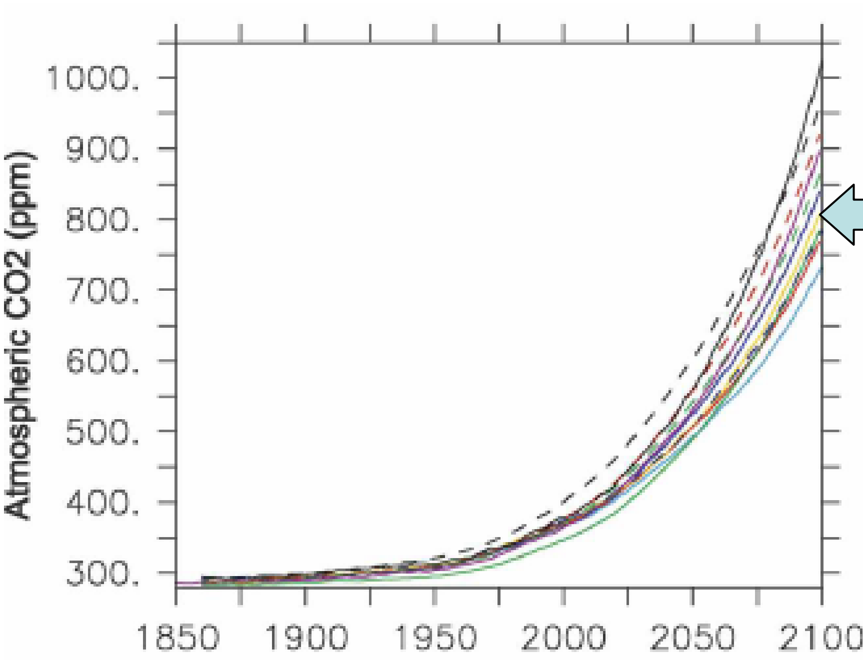
Response of the terrestrial biosphere to:

- increasing CO2
- climate change
- climate variability

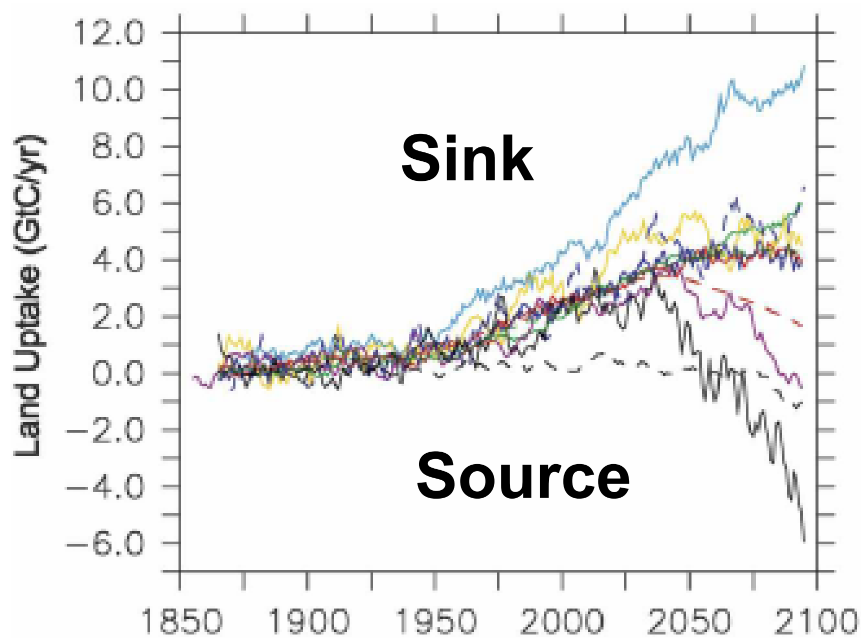


Example of a simple albedo feedbacks

C4MIP Phase II results



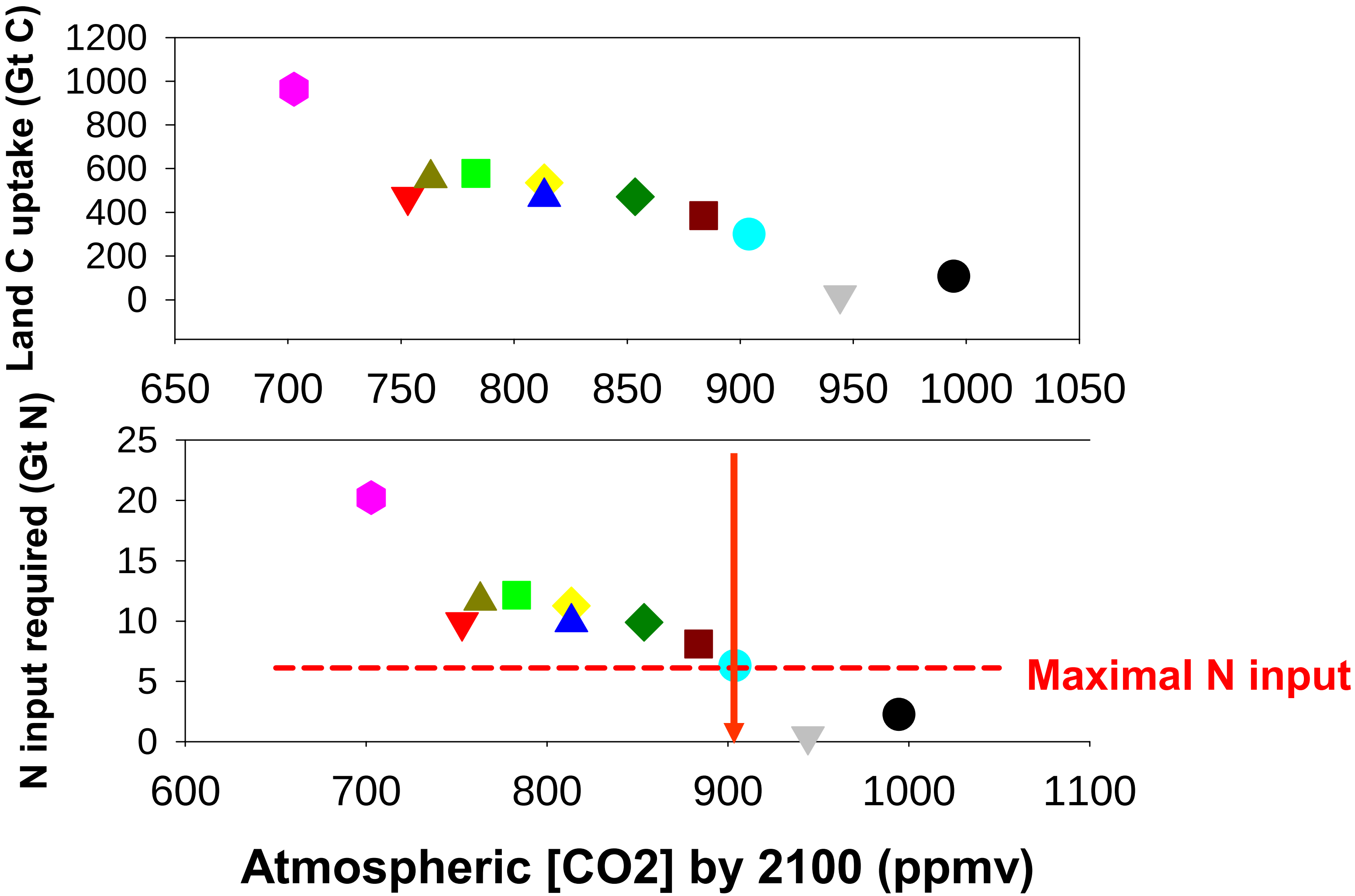
Differ by 292 ppm



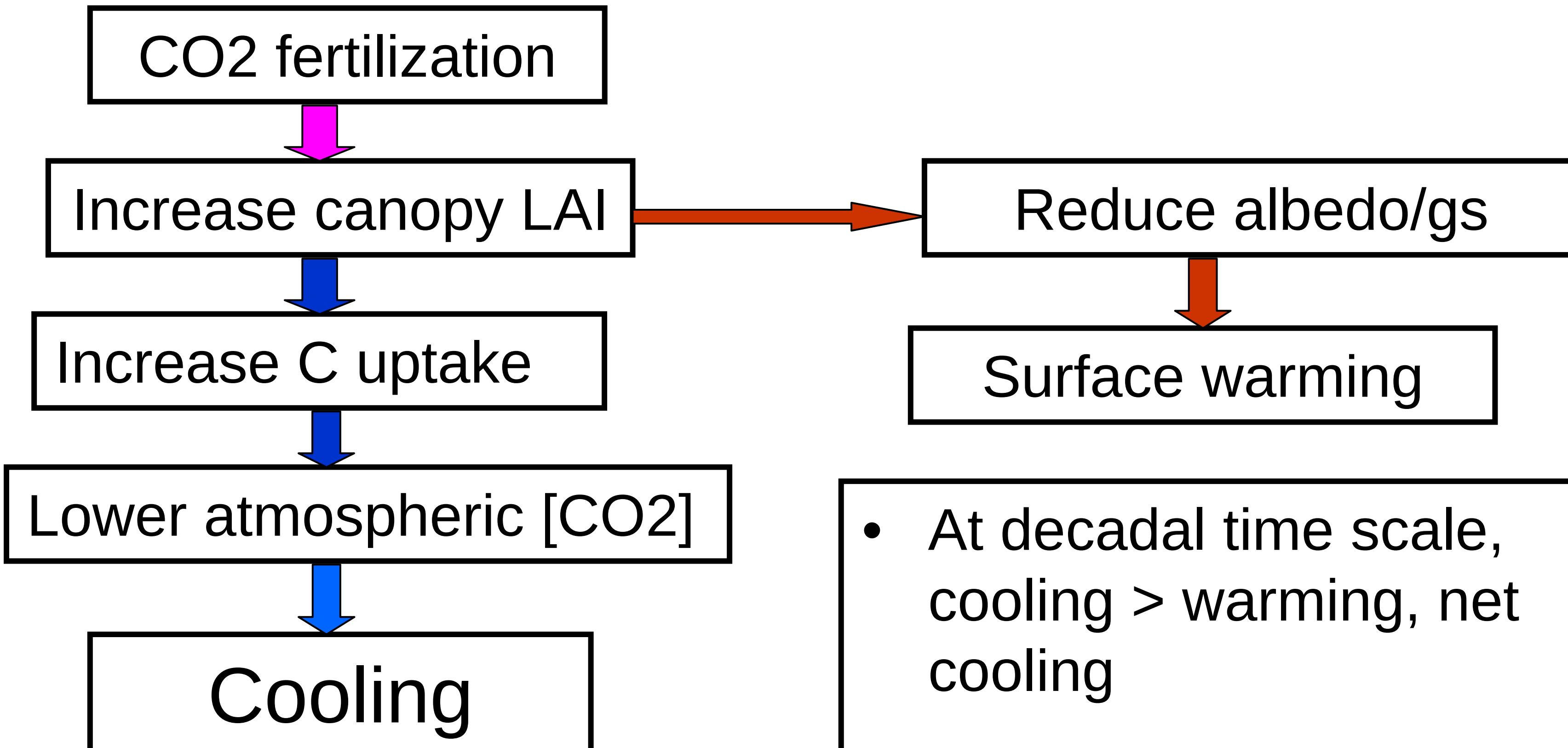
Friedlingstein et al, J. Climate, 19, 3337-3353, 2006.

Extra CO_2 results in extra warming – a positive feedback

Are those predictions realistic?

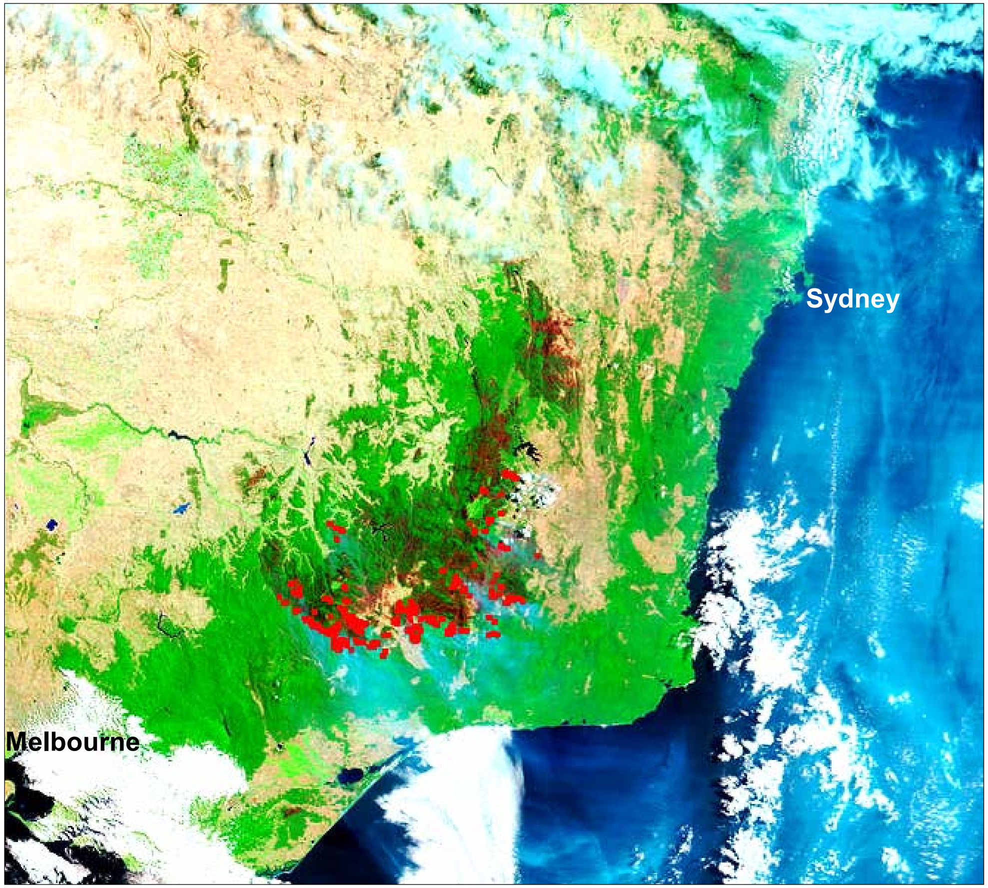


Effects of CO_2 fertilization on climate (Bala et al. 2006)



- At decadal time scale, cooling > warming, net cooling
- At century time scale, warming > cooling, net warming

Fire disturbance



Fires in southeast Australia February, 2003

Fires affected:

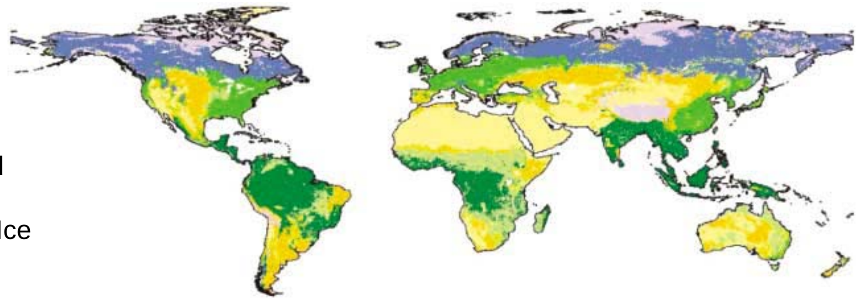
- surface albedo & vegetation properties

- released CO_2 & other trace gases and aerosols

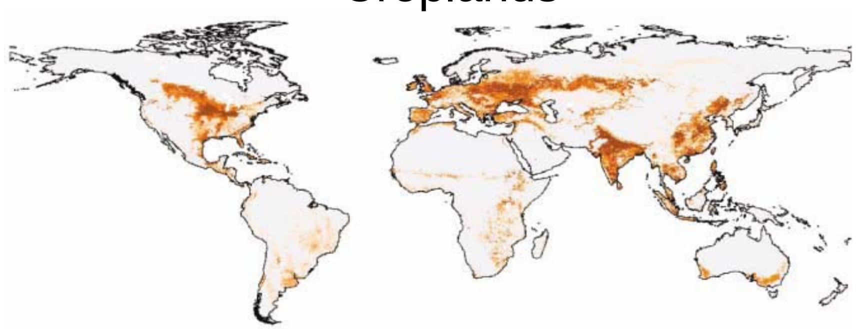
Jonathan A. Foley, *et al.* *Science* **309**, 570 (2005)

Extent of human land use & land cover change

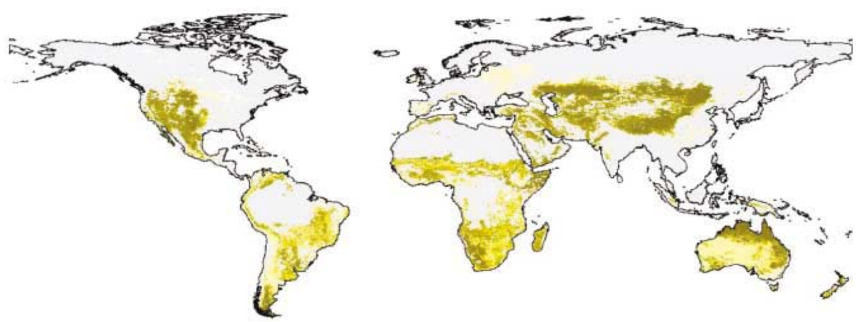
Natural Vegetation



Croplands



Pastures and Rangelands



The general structure of CABLE

Interface to the GCM

Canopy radiation;
sunlit & shaded
visible &
near infra-red,
albedo

SEB & fluxes;
for soil-vegetation system:
λE_f , H_f , λE_g , H_g;
evapotranspiration

stomata transp.
& photosynthesis

Carbon fluxes;
GPP, NPP,NEP

soil temp.

soil moisture

soil respiration

snow

carbon pools; allocation & flow

CASA-CNP

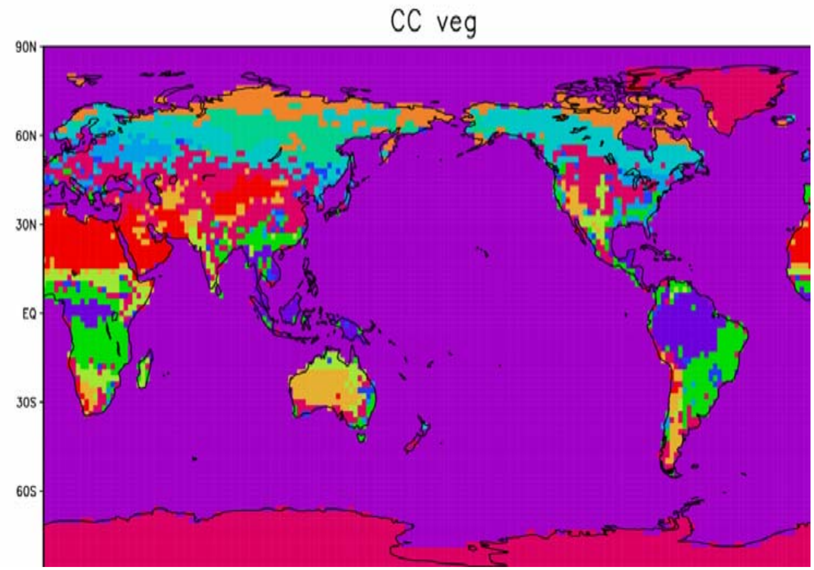
vegetation dynamics/disturbance

Kowalczyk et al., CMAR Research Paper 013, 2006

Vegetation parameters required for CABLE

VEGETATION TYPE

1 broad-leaf evergreeen trees
2 broad-leaf deciduous trees
3 broad-leaf and needle-leaf trees
4 needle-leaf evergreen trees
5 needle-leaf deciduous trees
6 broad-leaf trees with ground cover /short-vegetation/C4 grass (savanna)
7 perennial grasslands
8 broad-leaf shrubs with grassland
9 broad-leaf shrubs with bare soil
10 tundra
11 bare soil and desert
12 agricultural/c3 grassland
13 ice



A grouping of species that show close similarities in their response to environmental control have common properties such as:

- vegetation height
- root distribution
- max carboxylation rate
- leaf dimension and angle, sheltering factor,
- leaf interception capacity

Geographically explicit data

LAI – leaf area index

fractional cover

C3/C4 - fraction

the model calculates:

z0 – roughness length

α – canopy albedo

Soil parameters required for CABLE

Soil types:

Coarse sand/Loamy sand

Medium clay loam/silty clay loam/silt loam

Fine clay

Coarse-medium sandy loam/loam

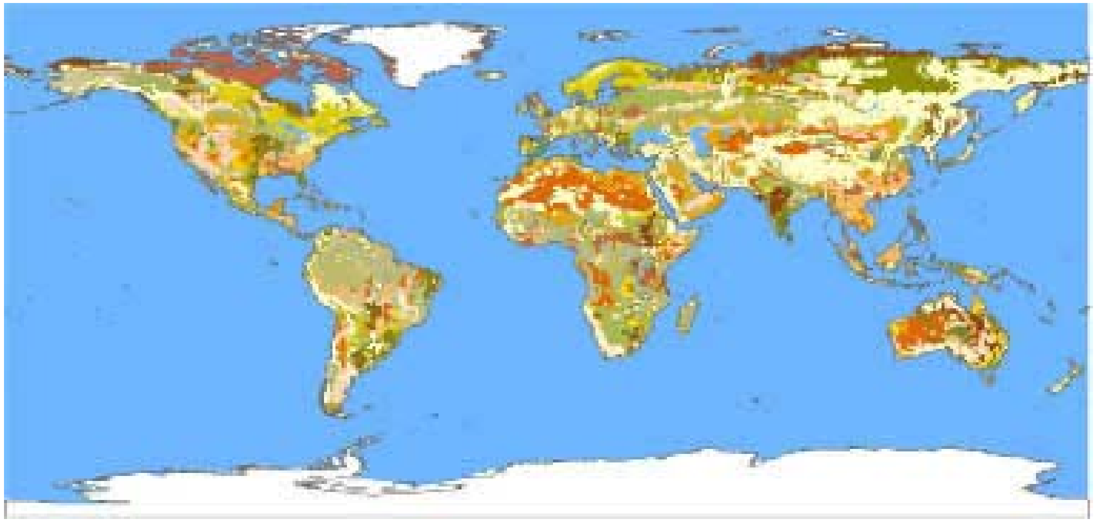
Coarse-fine sandy clay

Medium-fine silty clay

Coarse-medium-fine sandy clay loam

Organic peat

Permanent ice



Soil Properties:

- water balance:

wilting point

field capacity

saturation point

hydraulic conductivity at saturation

matric potential at saturation

- heat storage:

albedo,

specific heat, thermal conductivity

density

- soil depth

Post, W., and L. Zobler, 2000
Global Soil Types

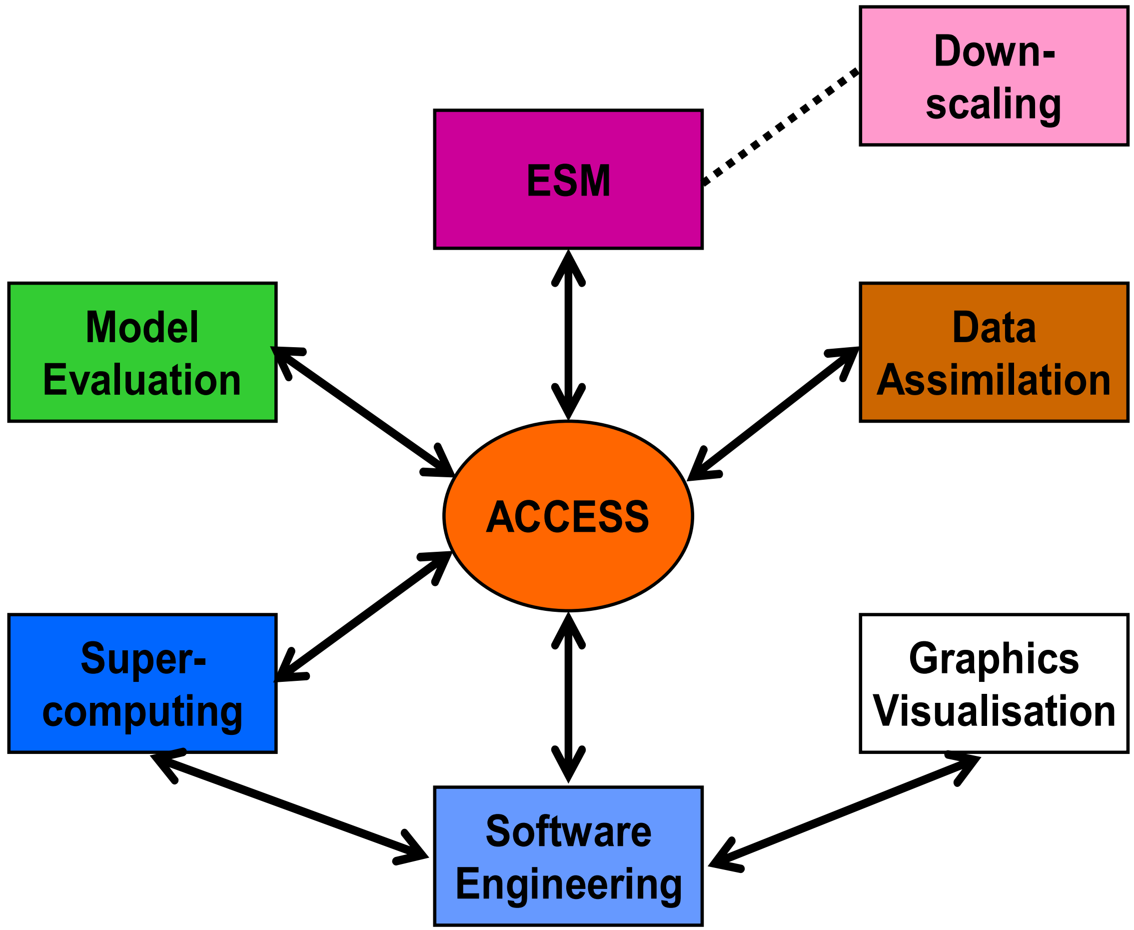
Australian Community Climate Earth System Simulator (ACCESS) modelling program

Diagram to right shows 'scope'

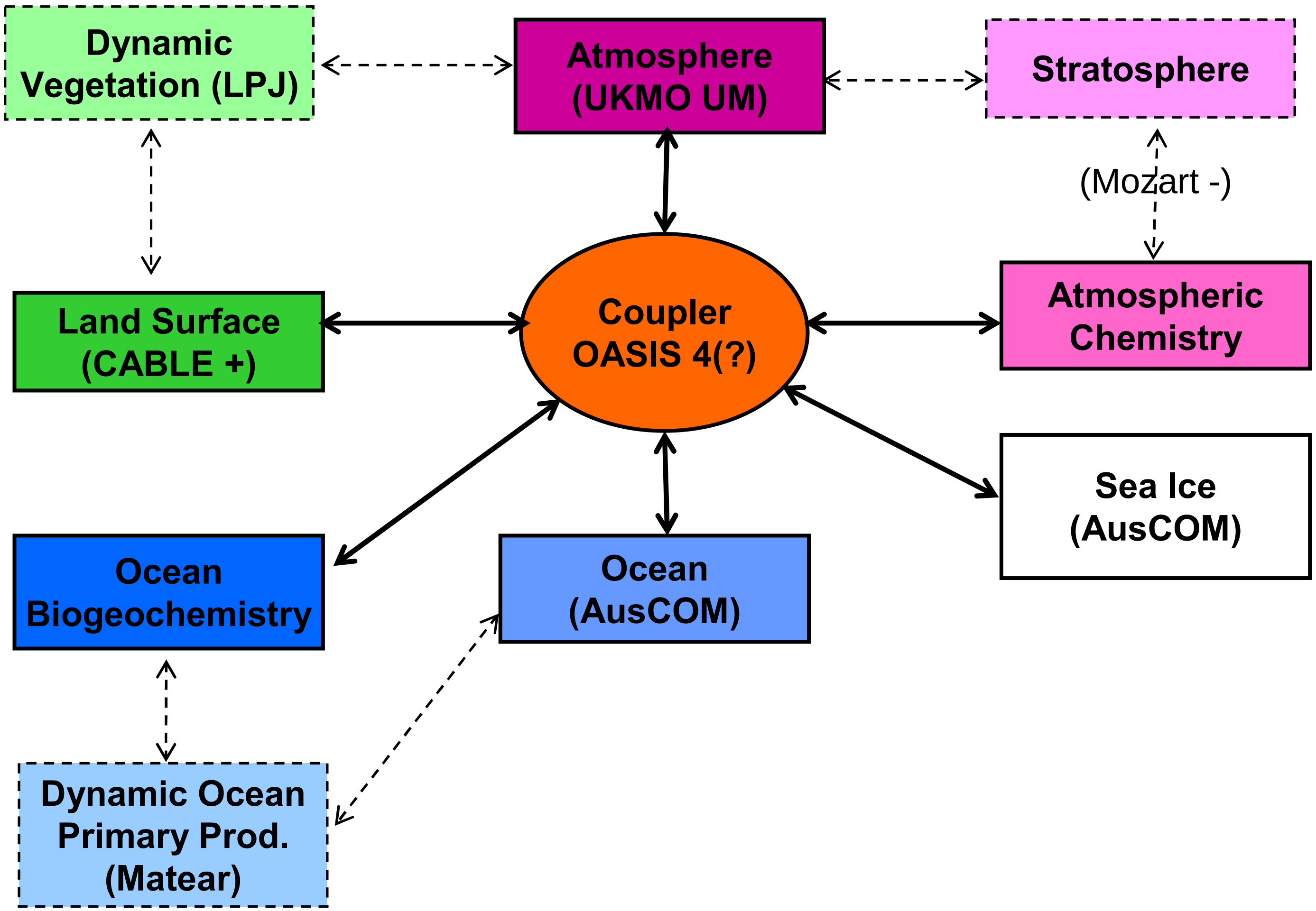
Fundamentally conceived as a modelling 'system' that meets a variety of needs. Priority needs are:

- Numerical weather prediction
- Climate change simulation capability

Collaboration between key institutions (Bureau, CSIRO, Australian Universities,….)



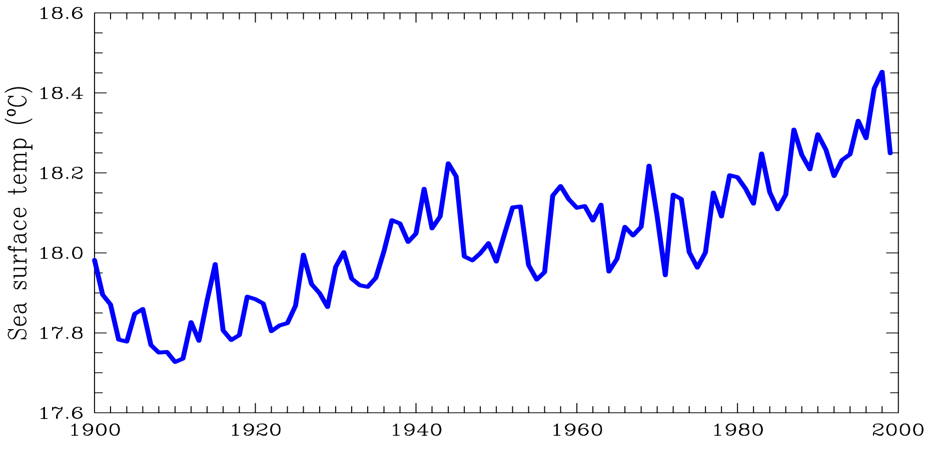
ACCESS Climate change



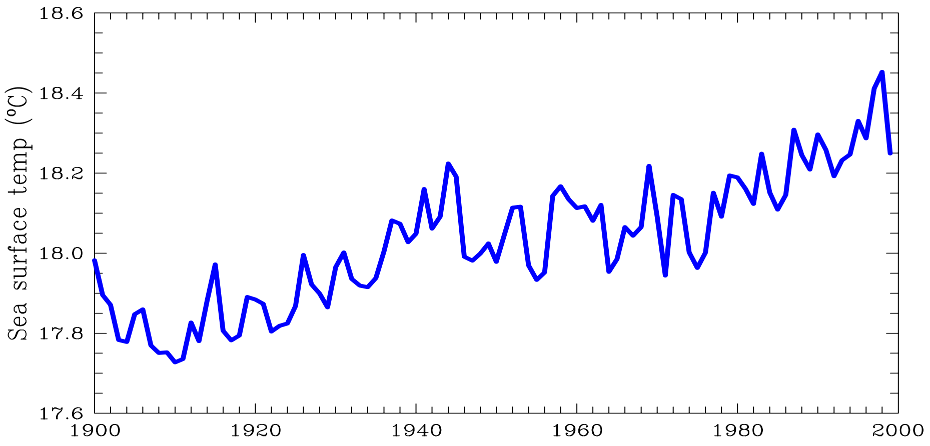
ACCESS

Key Timelines Coupled Modelling

2006	**Port component models to common computing environment and test**
2007	**Construct coupled system**
2008	**Test new physics options in coupled system**
2009	**Tune coupled system**
2010	**Perform and submit IPCC AR5 runs**



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


18.6
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17.6
Sea surface temp (ºC)
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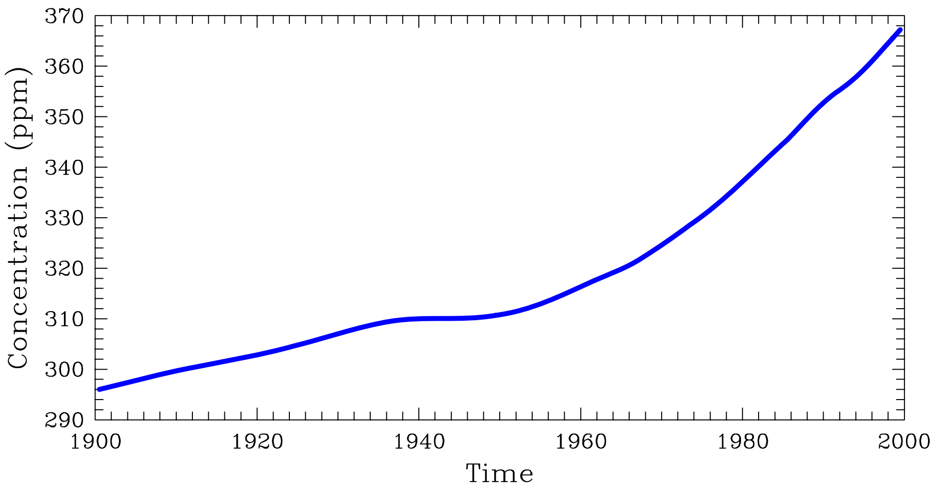
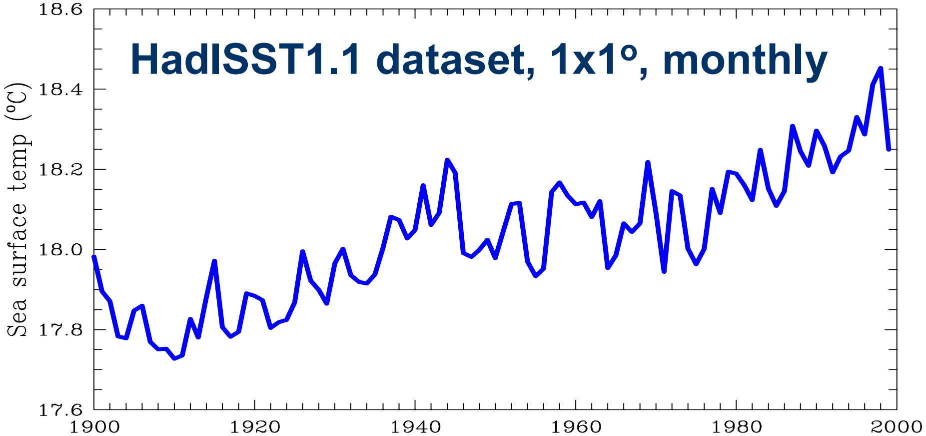

370
360
350
340
330
320
310
300
290
Concentration (ppm)
1900
1920
1940
1960
1980
2000
Time

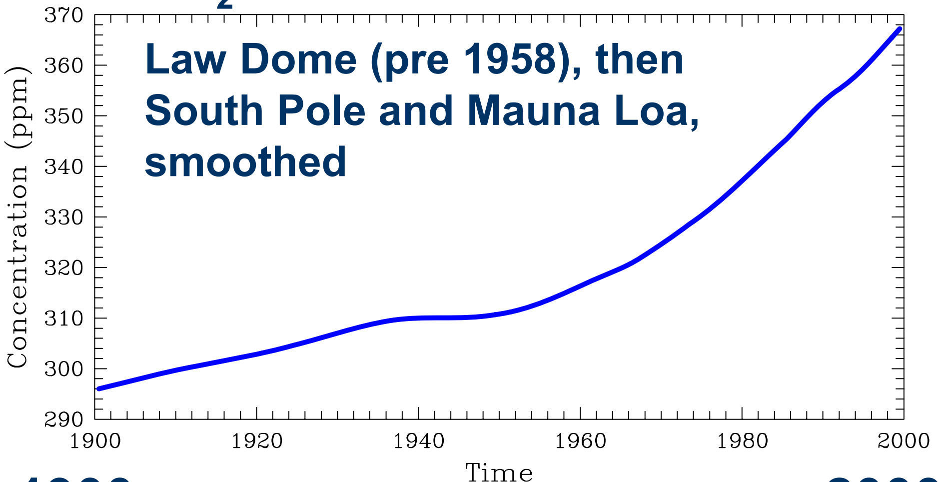
Model forcing and modelled climate in C4MIP phase I simulation

Sea Surface Temperature:

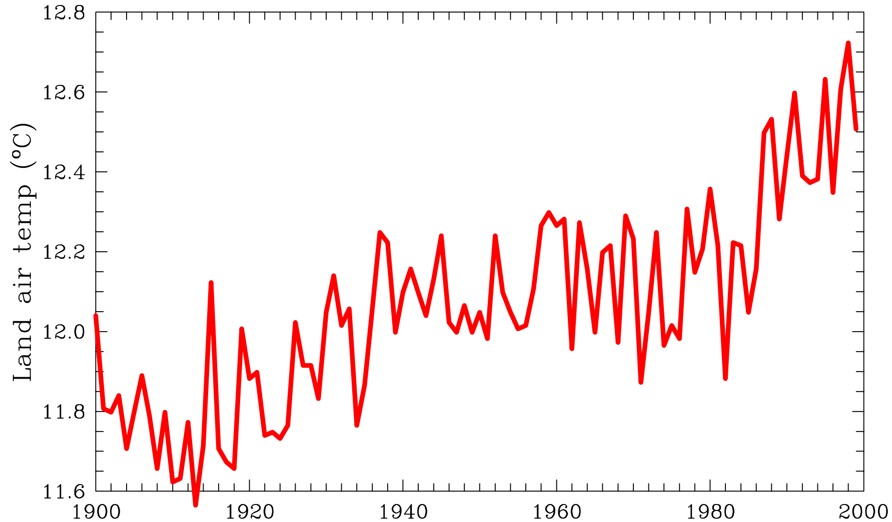


1900 **2000**

CO_2 concentration



1900 **2000**



Model forcing and modelled climate in C4MIP phase I simulation

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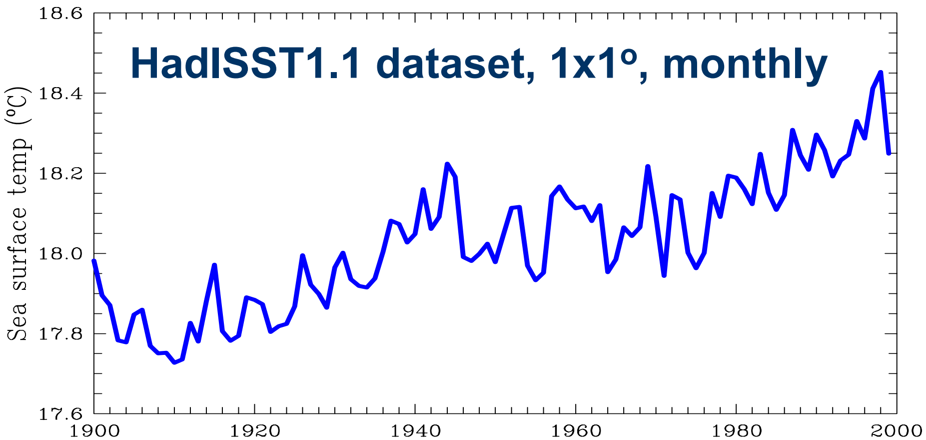
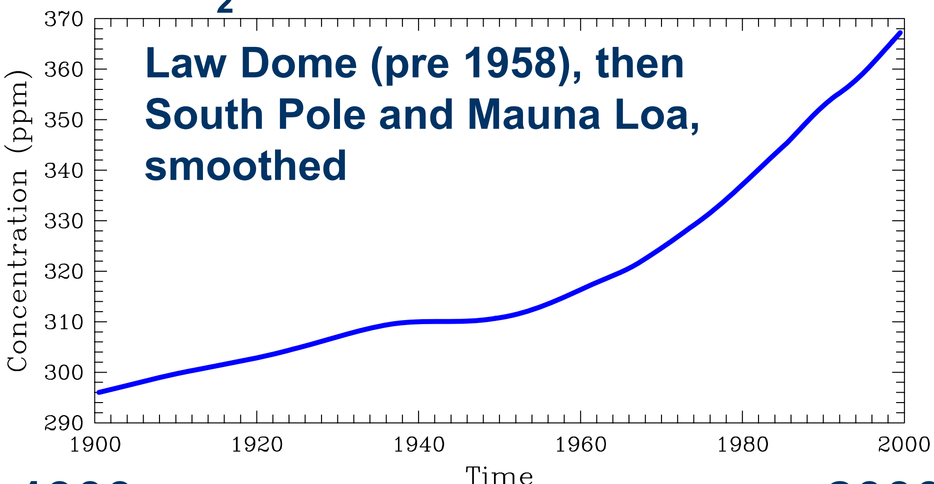


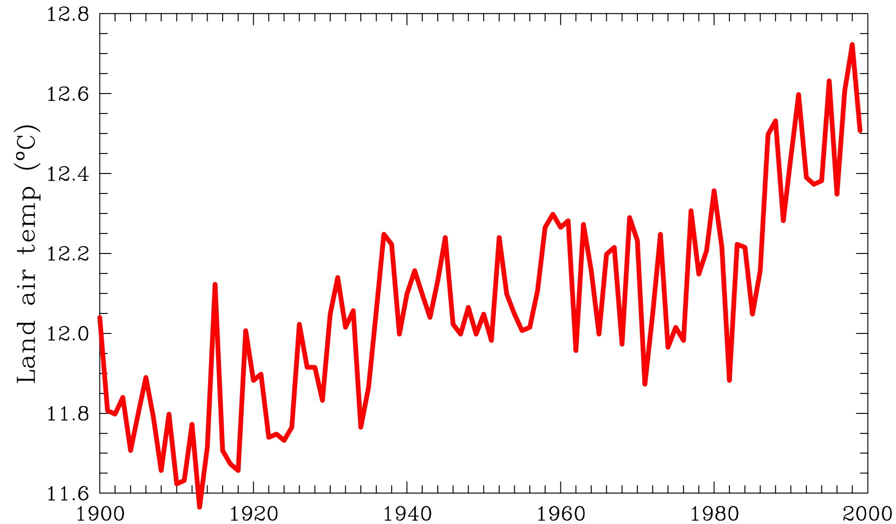
1900 **2000**

CO_2 concentration



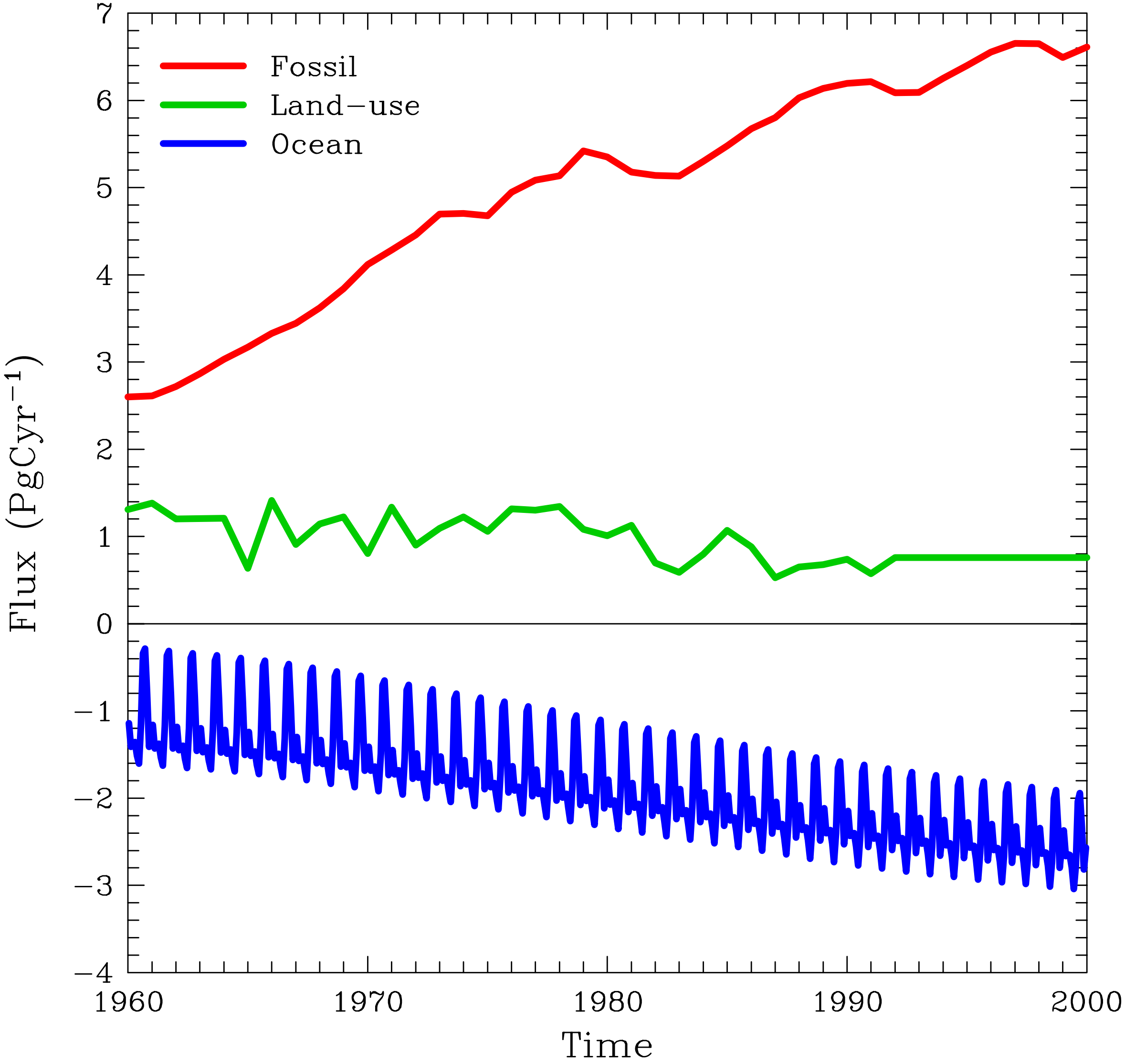
1900 **2000**

Land air temperature

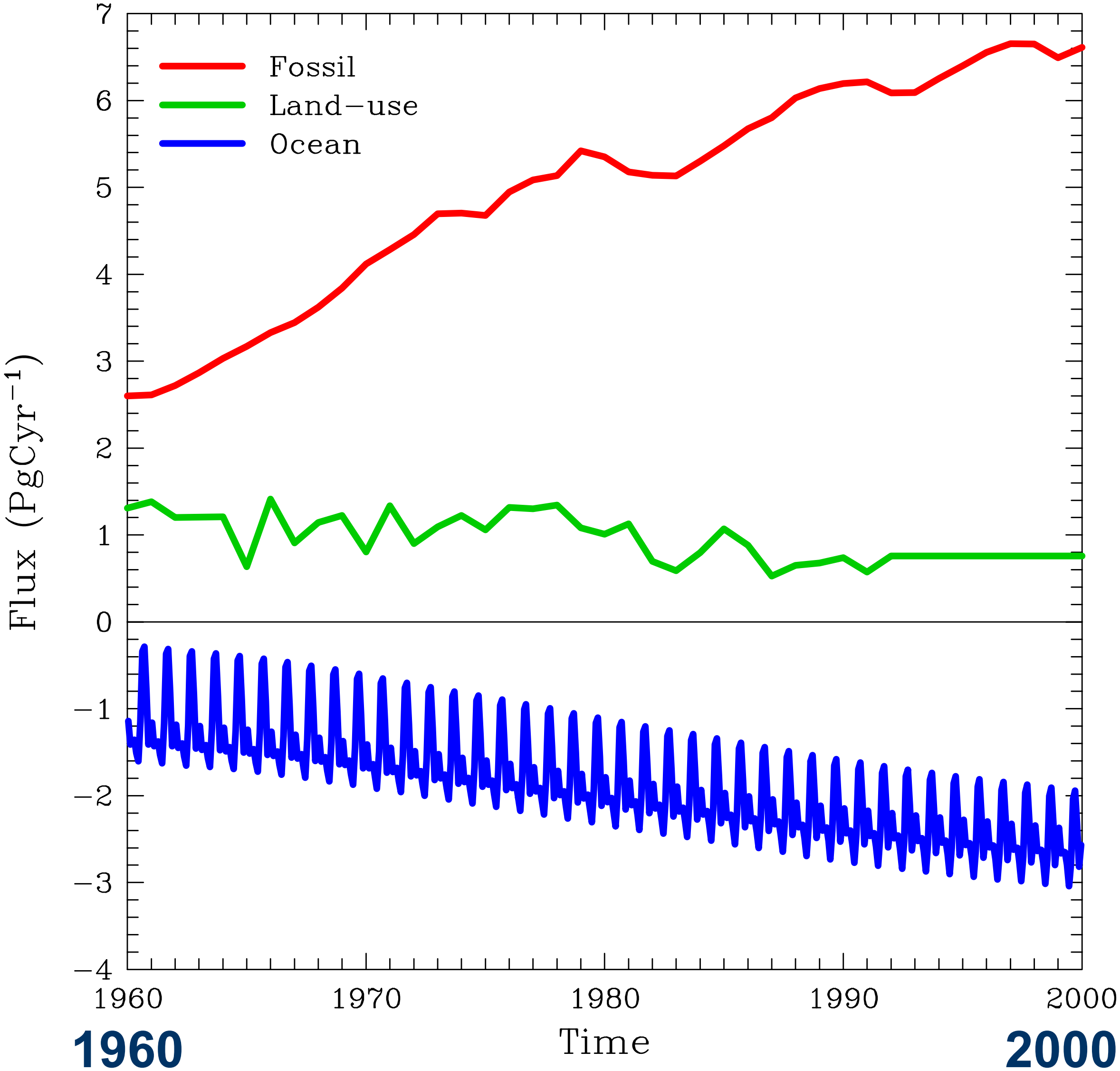


1900 **2000**

Prescribed fluxes



Prescribed fluxes



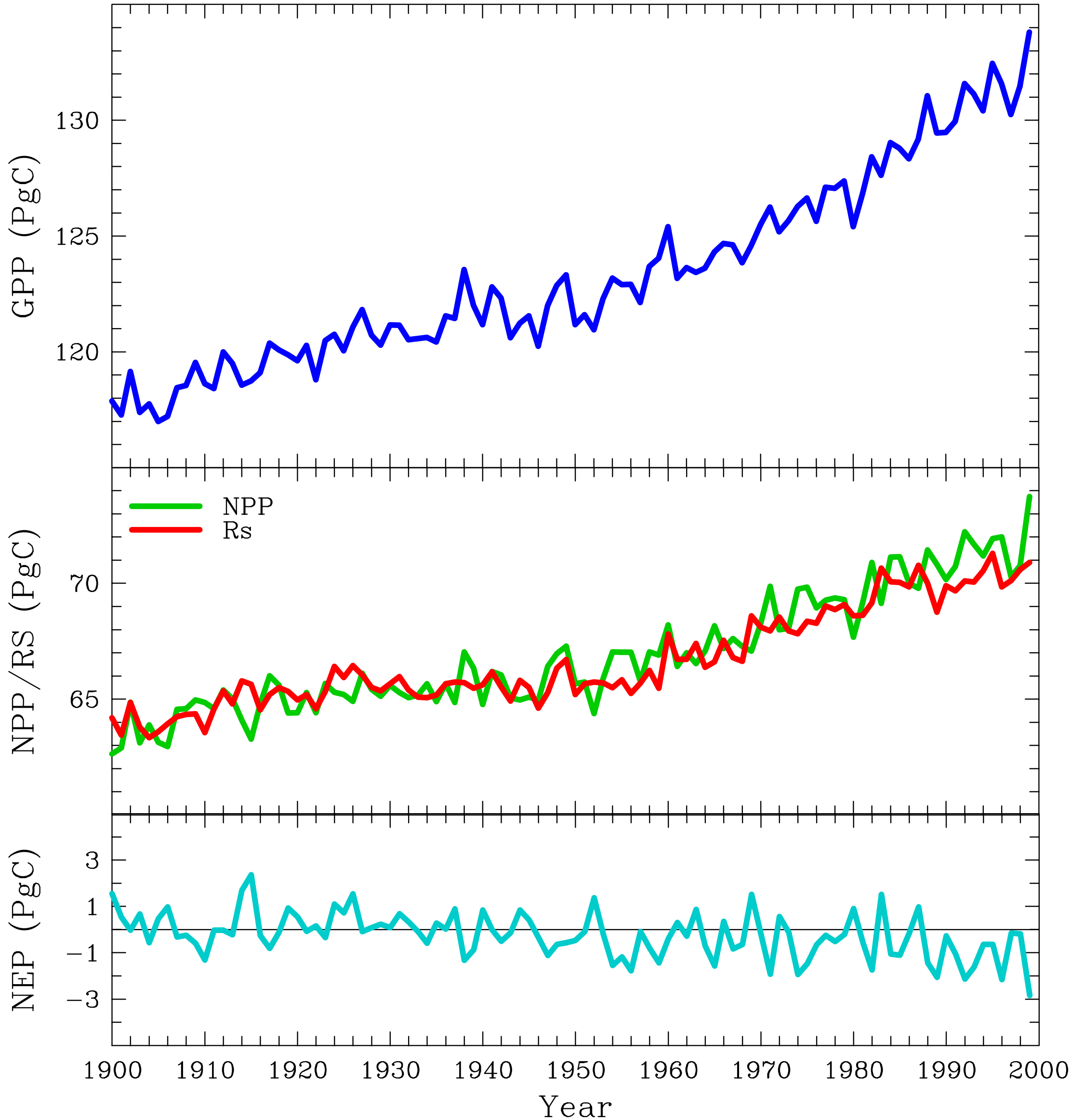
1960 **2000**

Fossil emissions, Andres et al. 1995, Marland et al., 2005, 3.75x2.5^o, annual

Land-use, McGuire et al. 2001, average 3 models, only available until 1992, only cropland establishment, abandonment

Ocean emissions, median from 11 models OCMIP2, 2x2^o, monthly, no IAV in ocean model forcing

Carbon fluxes through 20th century

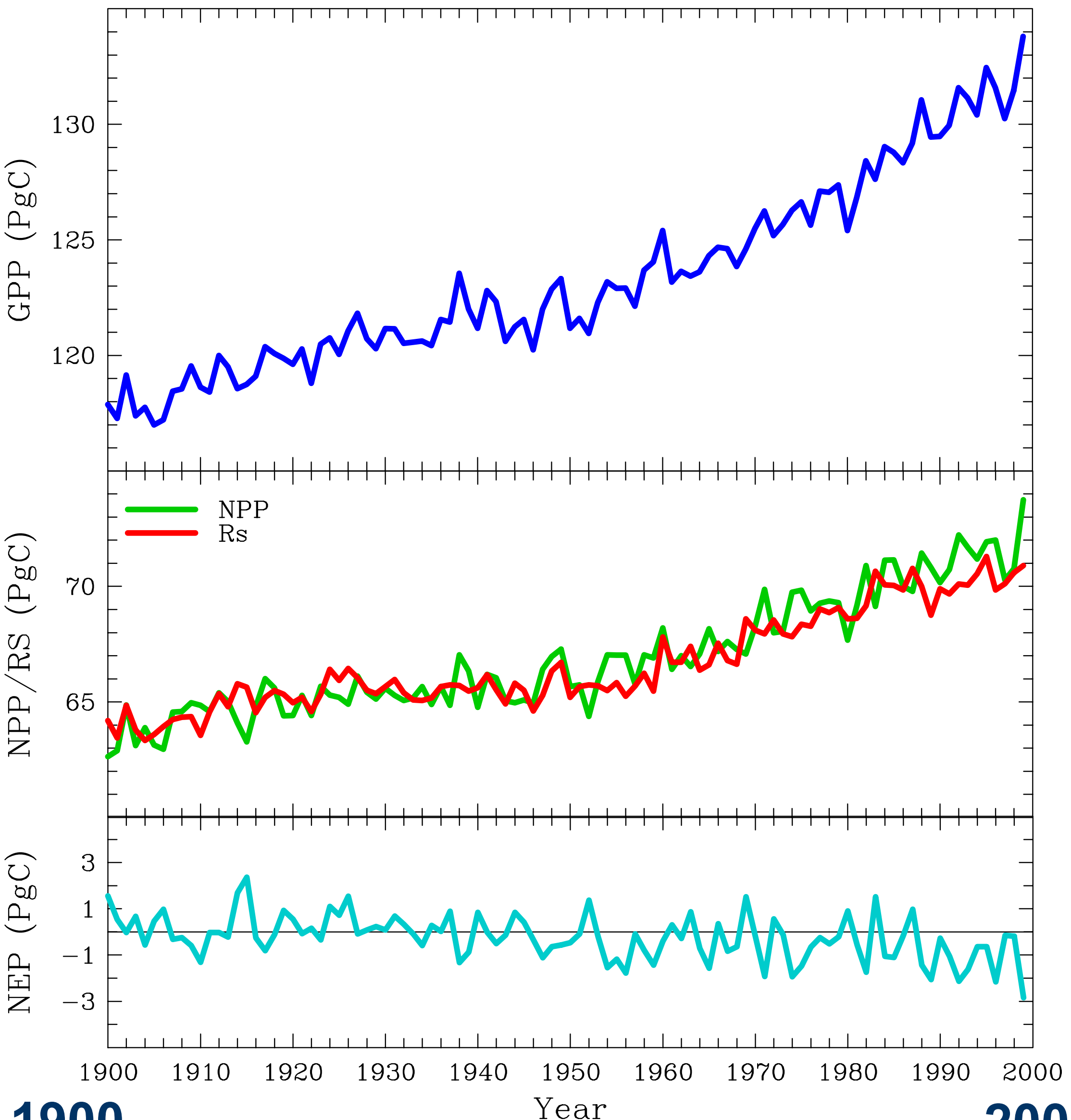


GPP – photosynthesis increases as atmospheric CO_2 increases

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



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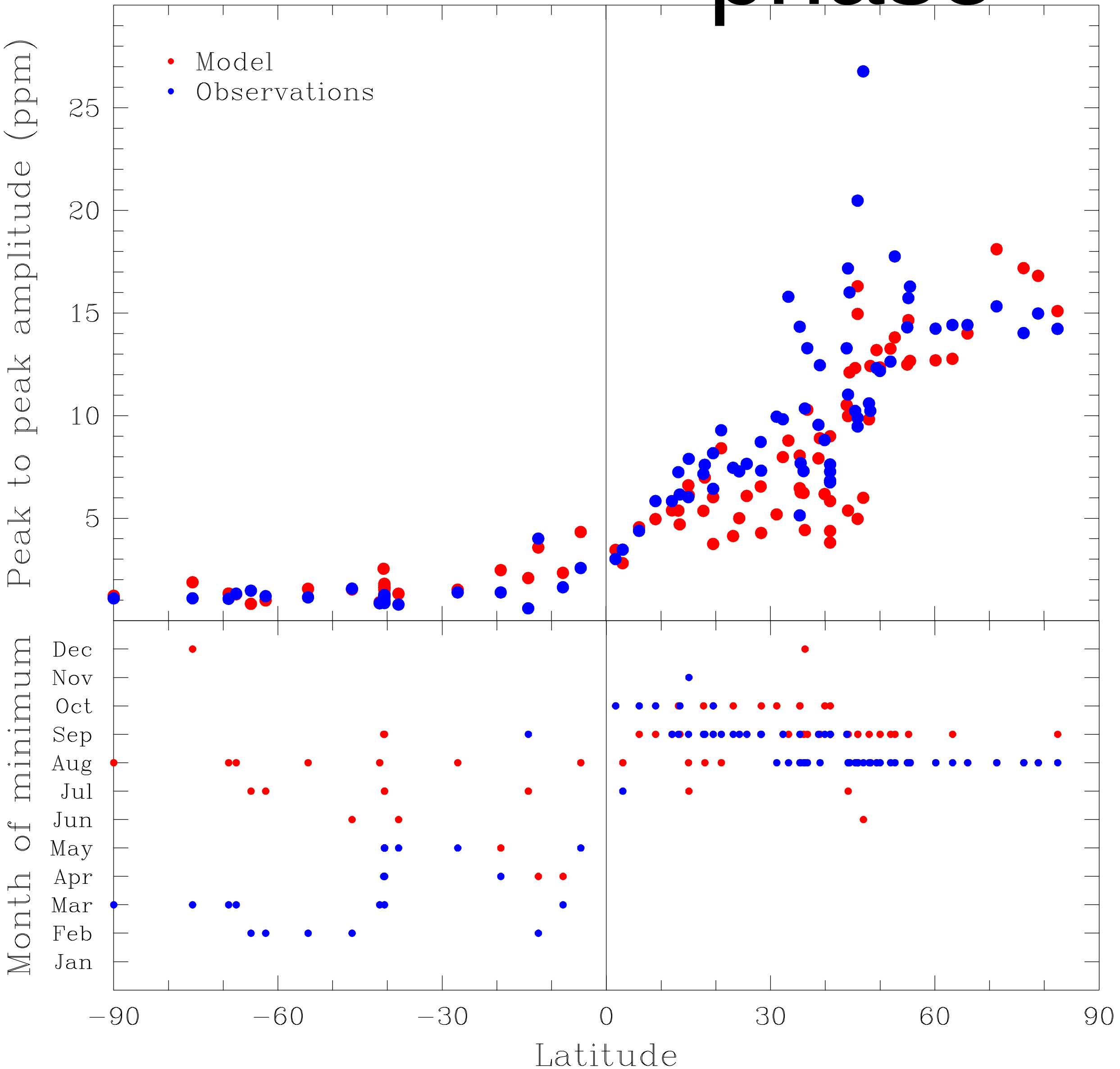
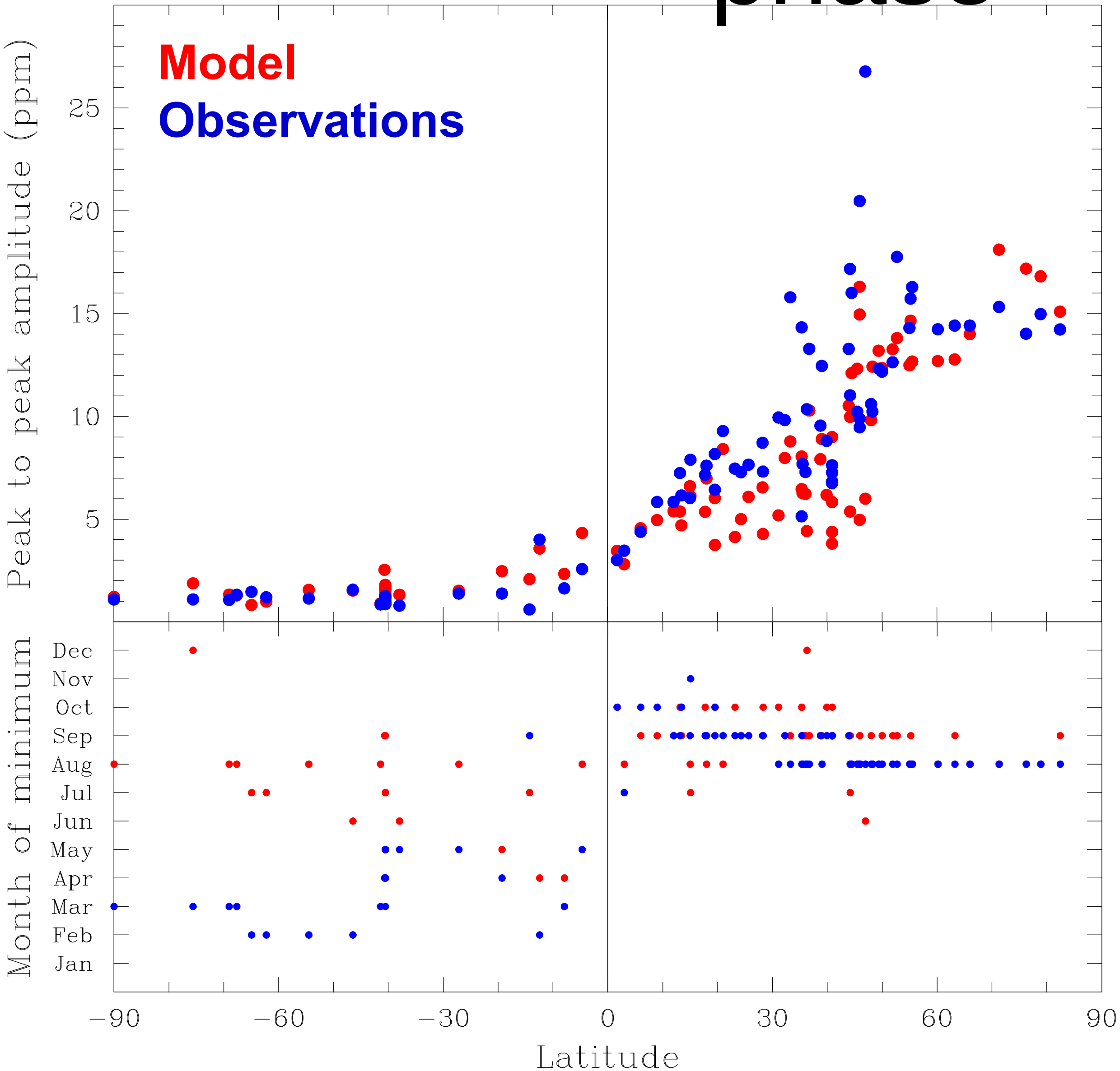
1900 **2000**

Seasonal cycle: amplitude and phase



Seasonal cycle: amplitude and phase

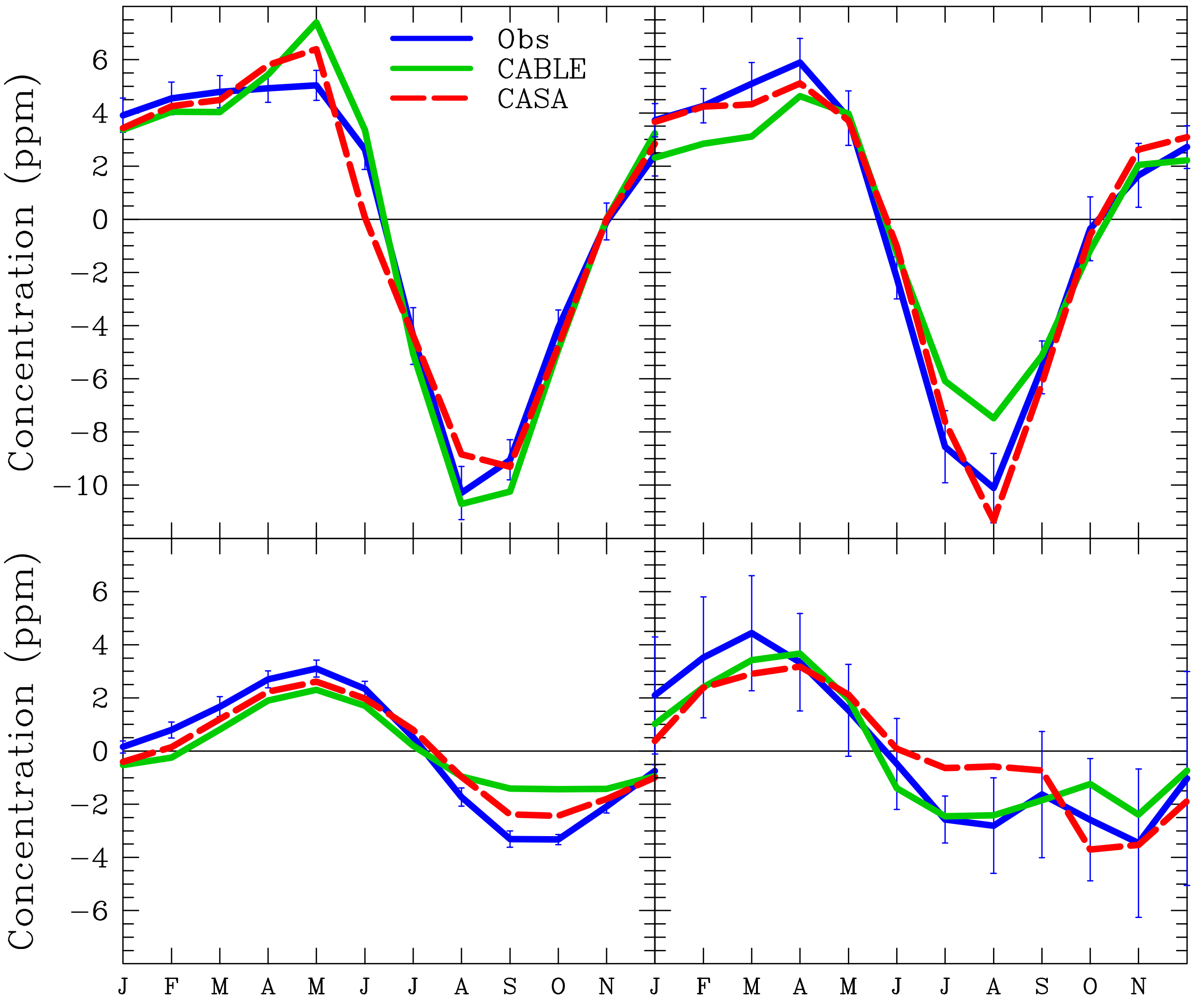


Peak to peak amplitude – too low in northern mid-latitudes

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

Data: GLOBALVIEW-CO2 (2003)

Seasonal cycle: NH sites

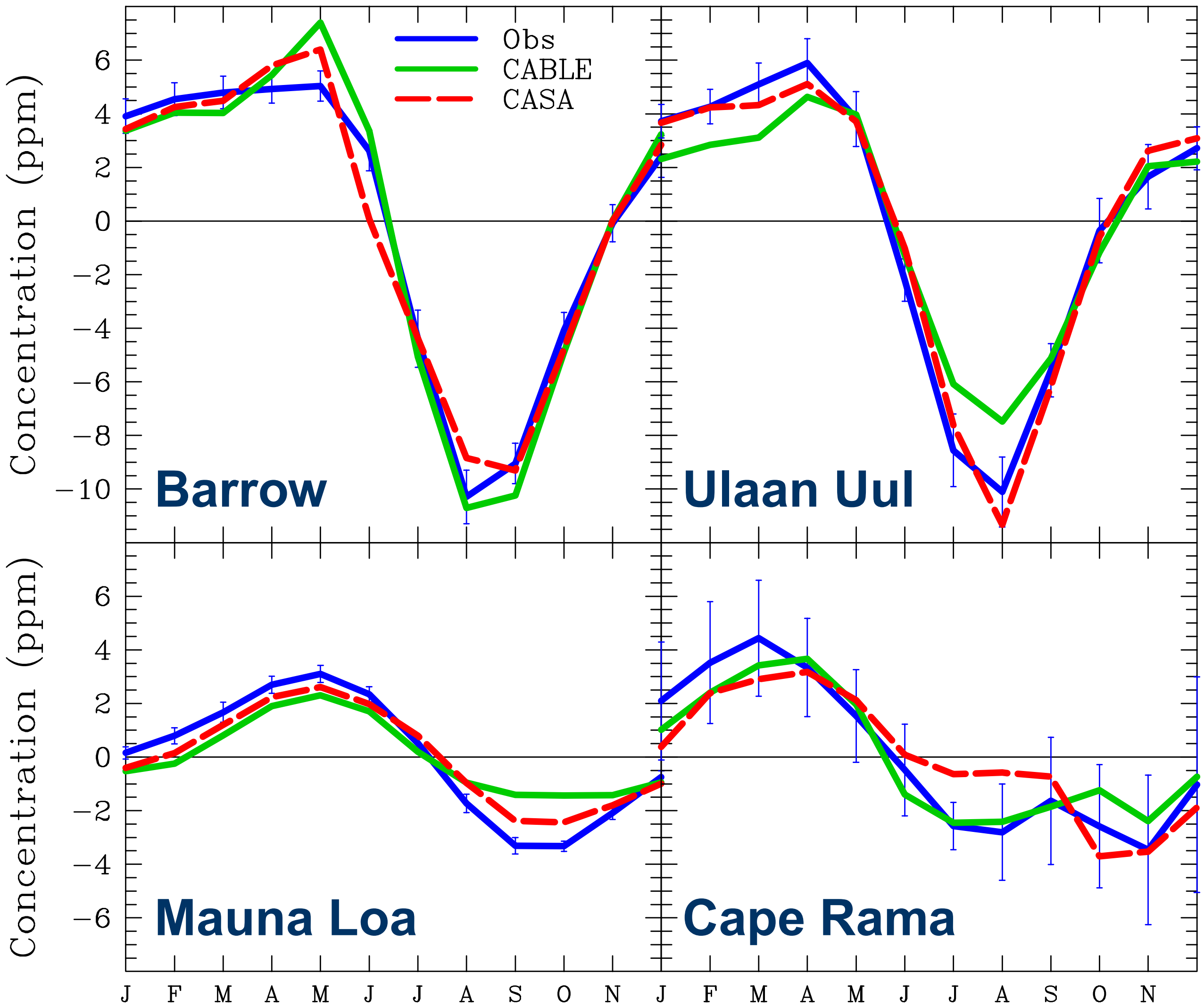


Seasonal cycle: NH sites

Blue: obs

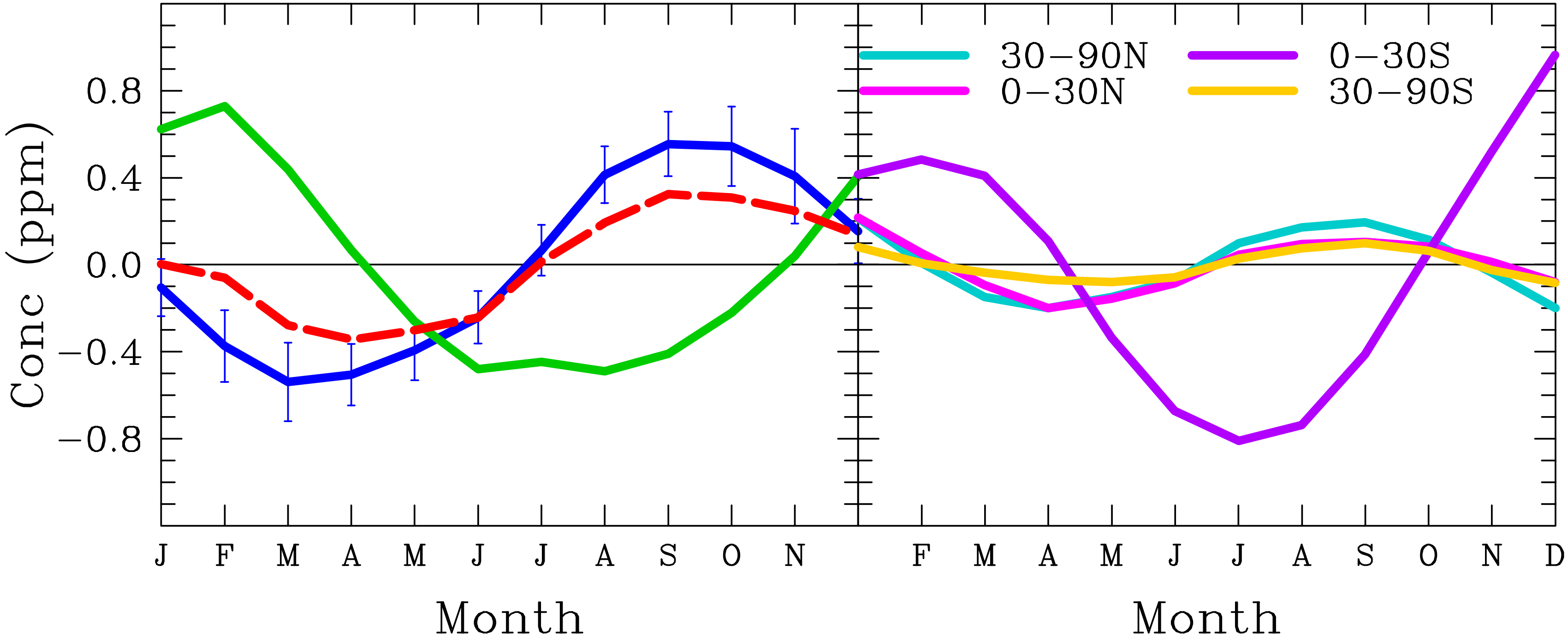
Green: CABLE

Red: CASA



Data: GLOBALVIEW-CO2 (2003)

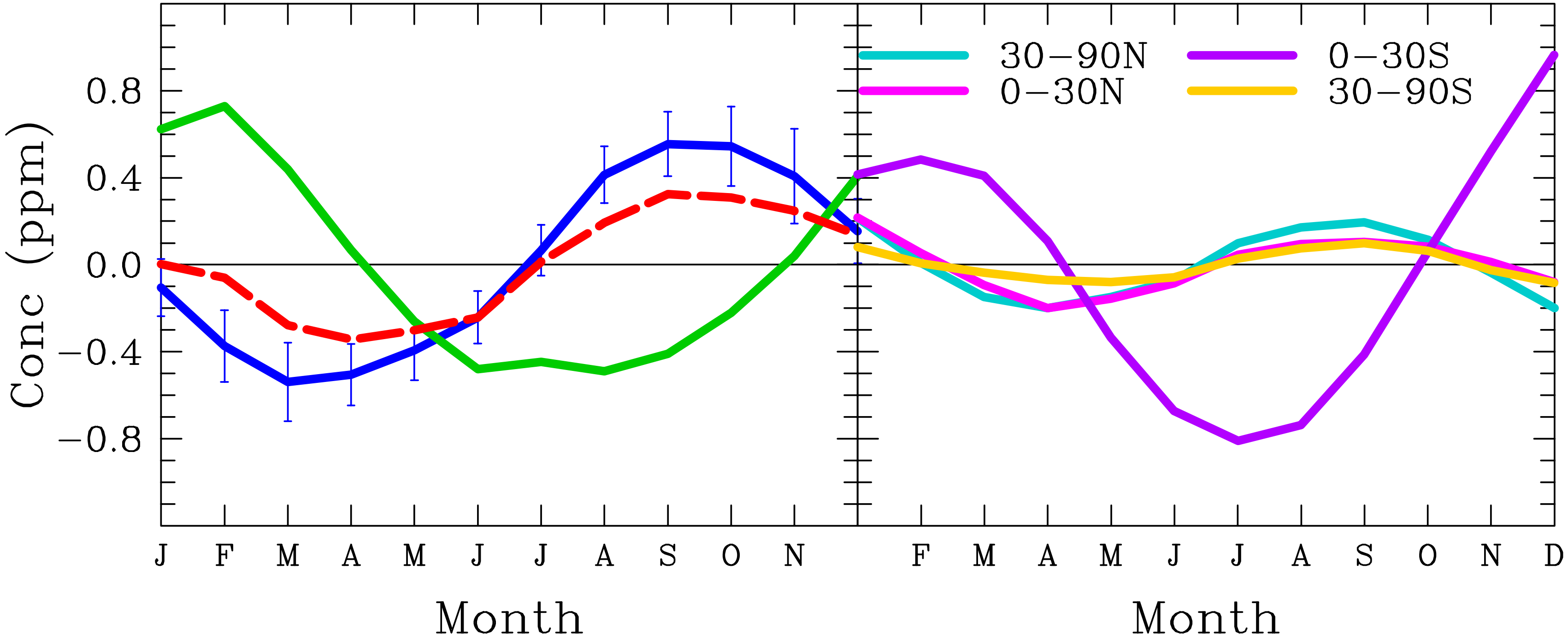
Seasonal cycle: southern hemisphere



Seasonal cycle: southern hemisphere

South Pole

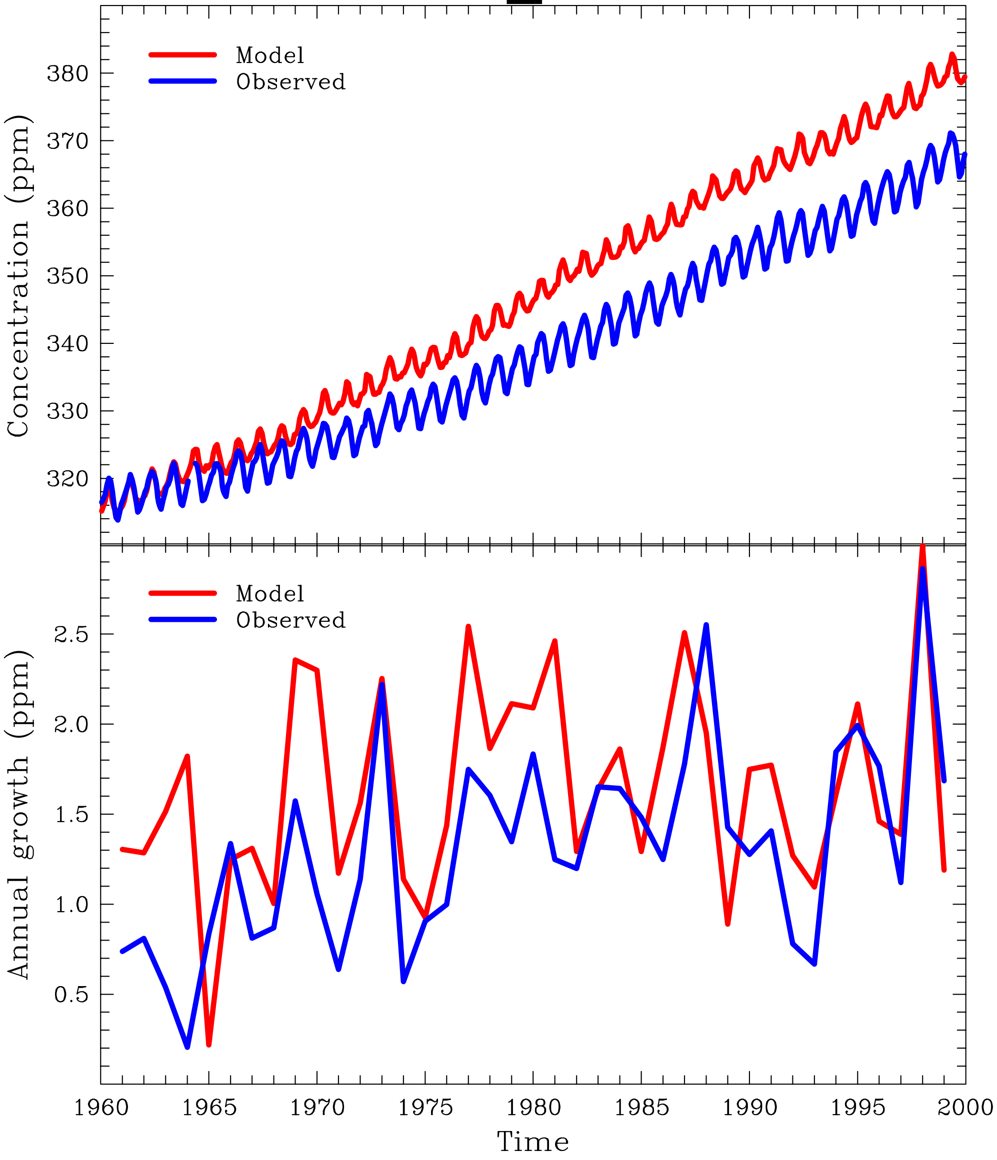
Contribution of source from each semi-hemisphere



Blue: obs, green: model, red: CASA

Data: GLOBALVIEW-CO2 (2003)

CO_2 at Mauna Loa



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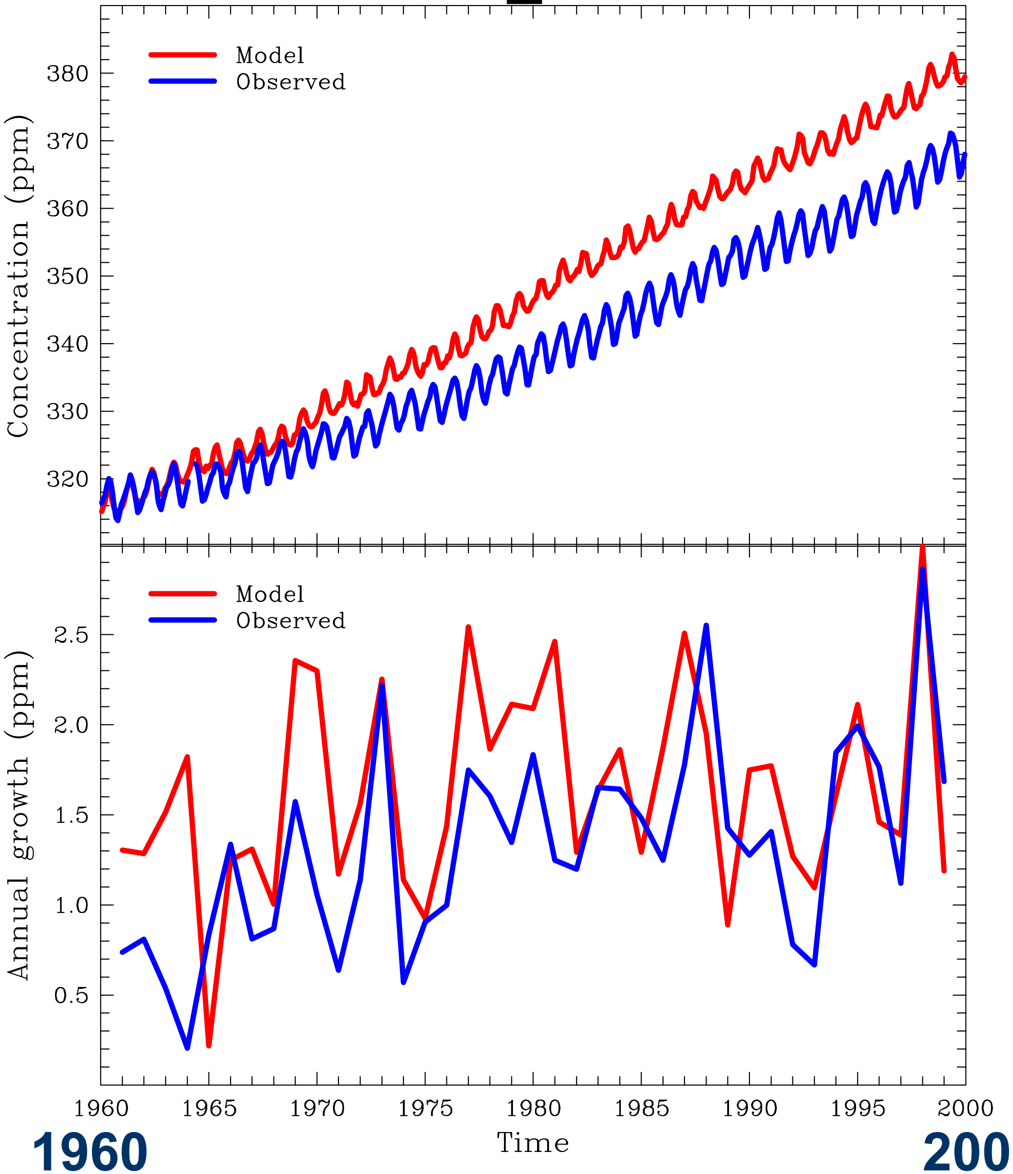

CO_2 concentration (ppm)

Model: red, Observed: blue

Annual growth of CO_2 (ppm/yr)

Data: Keeling et al (2005)

1960 **2000**

What did we learn

- Seasonal cycle in SH is incorrect;
- Soil respiration is too simple;
- Savannah biome: NPP too large, perhaps we need a better representation of C3/C4 LAI dynamics

Law R., Kowalczyk E., Wang Y.-P., Tellus, 58B, 427-437, 2006

Next steps

Model development in the CSIRO

- Couple CABLE to HadGAM;
- Couple CABLE with CASACNP and a global phenology model;
- A systematic method for estimating model parameters and model errors;
- Assist universities in coupling LPJ with CABLE+CASACNP+Phenology;
- All components must be ready by middle 2009 for further tuning for IPCC AR5.

Thank you

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