



# WP1: Land carbon reanalysis ORCHIDEE driven by CERA-20C

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& the ORCHIDEE project team*

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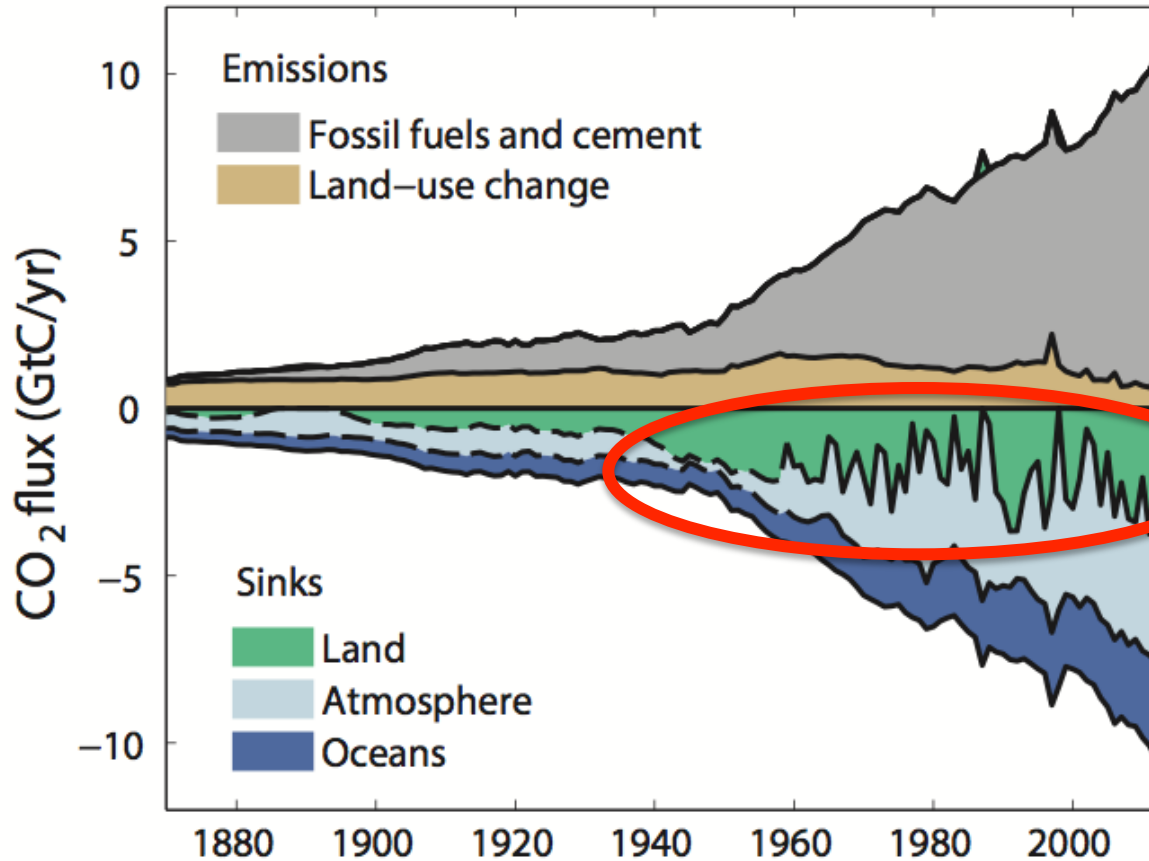
# Overall proposed contribution

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- ➔ Adding the C-cycle to the reanalysis
  - 100-year reanalysis with CERA-20C Done
  - 30-year reanalysis with CERA-SAT 2017
  
- Surface C fluxes & uncertainties:
  - land (Net and Gross) fluxes
  - anthropogenic (fossil + LUC)
  
- Land C stocks & uncertainties:
  - Aboveground & Belowground C pools
  - separated for Forests, Grass, Crops



# Global Carbon Budget



LAND  
focuss  
with  
ORCHIDEE  
(& CTESSEL)

Since 1750, human activities have emitted  $555 \pm 85$  PgC (Fossil fuel + Luse)

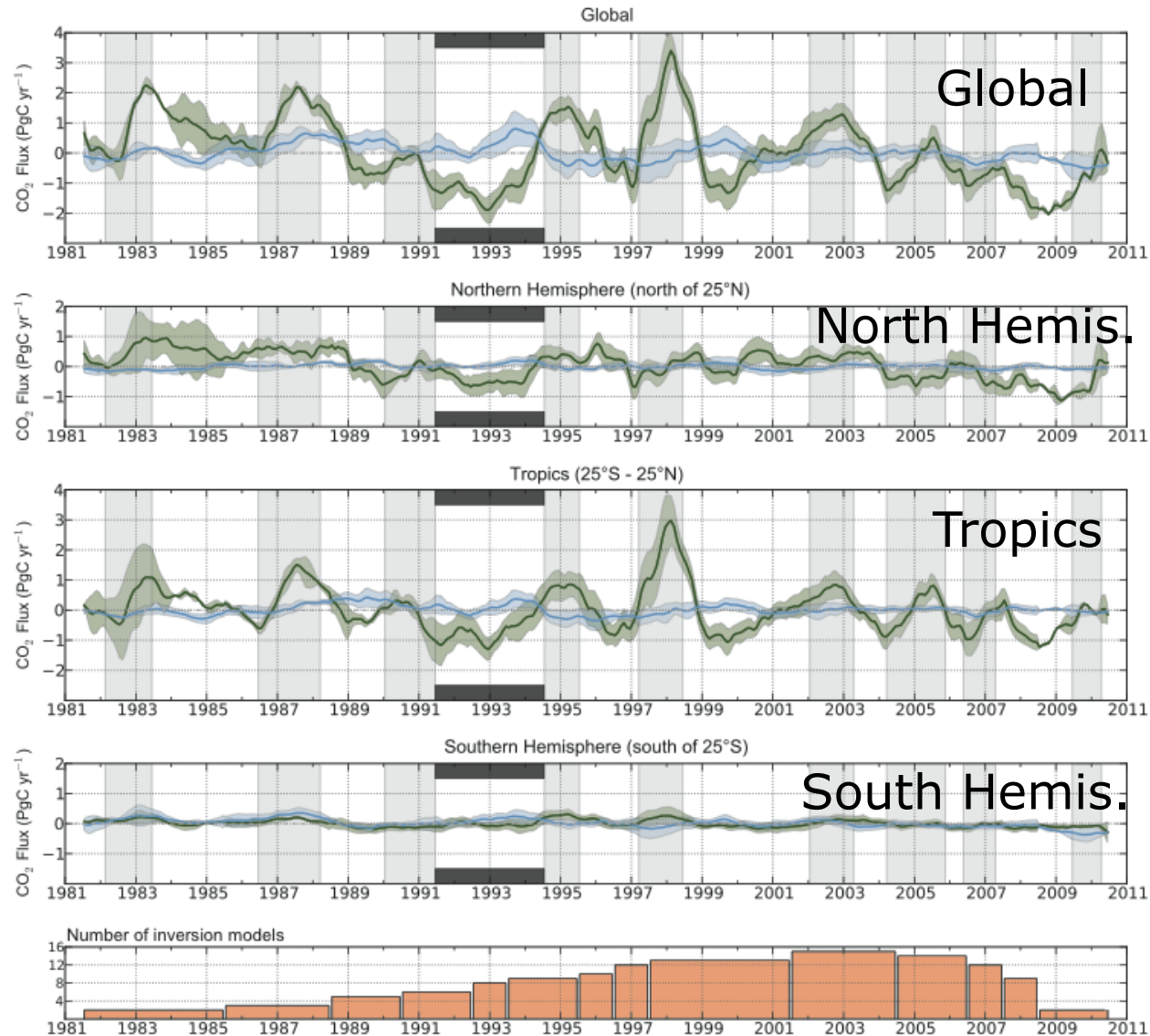
Fossil fuel CO<sub>2</sub> emissions are  $\approx 10$  PgC yr<sup>-1</sup> in 2015 (55% > 1990 level)

Over the past 50 years,  $44 \pm 6$  % of emissions remains in the atmosphere

# Current land / ocean carbon flux anomalies (from atmospheric CO<sub>2</sub> inversion)

Our objectives  
for ERA-CLIM2

1900

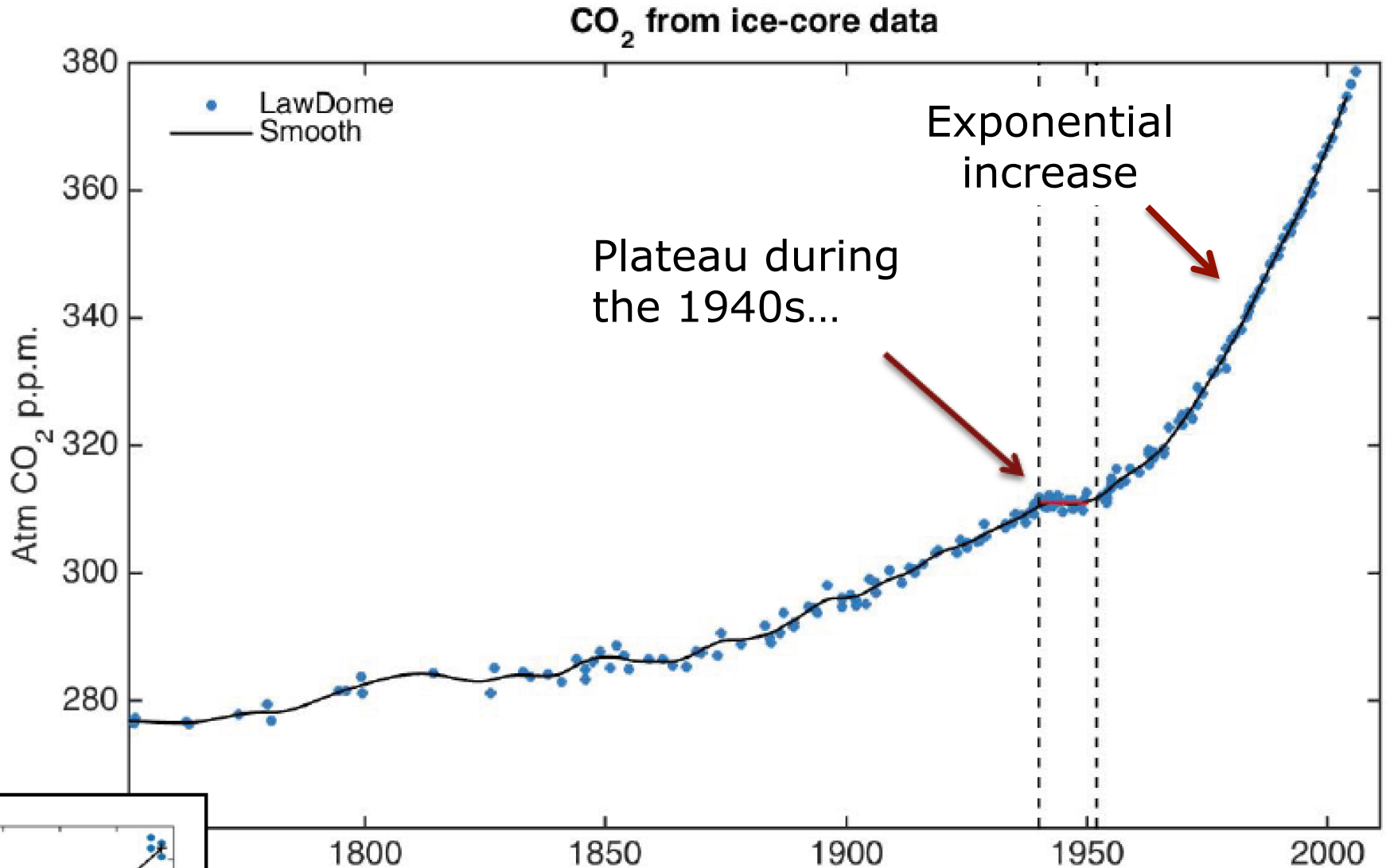


1980

2010

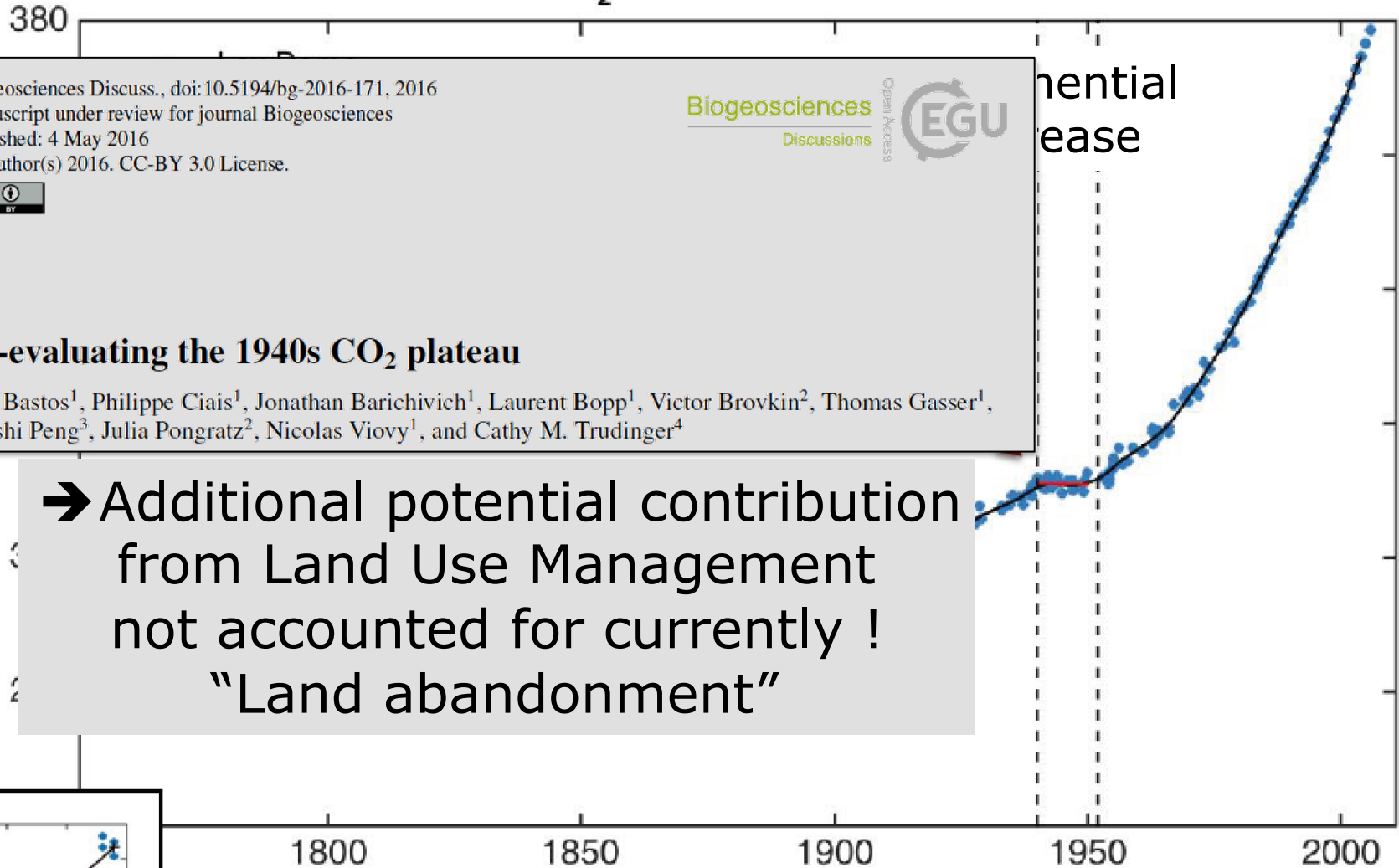


# Key features of the global C cycle over the 20<sup>th</sup> Century



# Key features of the global C cycle over the 20<sup>th</sup> Century

CO<sub>2</sub> from ice-core data



Biogeosciences Discuss., doi:10.5194/bg-2016-171, 2016  
 Manuscript under review for journal Biogeosciences  
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Biogeosciences  
 Discussions



potential  
 release

## Re-evaluating the 1940s CO<sub>2</sub> plateau

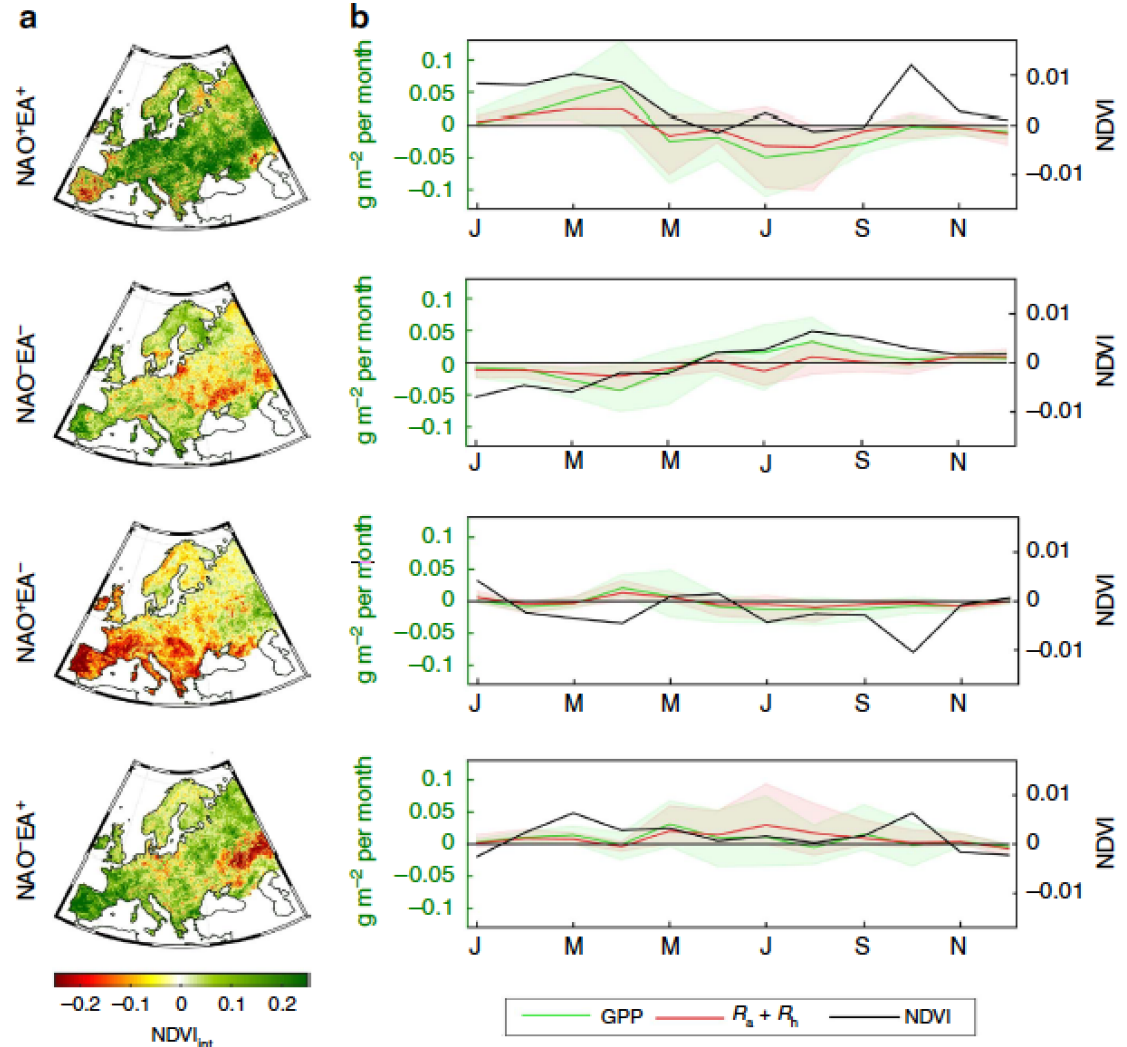
Ana Bastos<sup>1</sup>, Philippe Ciais<sup>1</sup>, Jonathan Barichivich<sup>1</sup>, Laurent Bopp<sup>1</sup>, Victor Brovkin<sup>2</sup>, Thomas Gasser<sup>1</sup>,  
 Shushi Peng<sup>3</sup>, Julia Pongratz<sup>2</sup>, Nicolas Viovy<sup>1</sup>, and Cathy M. Trudinger<sup>4</sup>

→ Additional potential contribution  
 from Land Use Management  
 not accounted for currently !  
 "Land abandonment"

# European land CO<sub>2</sub> sink influenced by NAO and East-Atlantic Pattern coupling

Ana Bastos<sup>1,2</sup>, Ivan A. Janssens<sup>3</sup>, Célia M. Gouveia<sup>2</sup>, Ricardo M. Trigo<sup>2</sup>, Philippe Ciais<sup>1</sup>, Frédéric Chevallier<sup>1</sup>, Josep Peñuelas<sup>4,5</sup>, Christian Rödenbeck<sup>6</sup>, Shilong Piao<sup>7</sup>, Pierre Friedlingstein<sup>8</sup> & Steven W. Running<sup>9</sup>

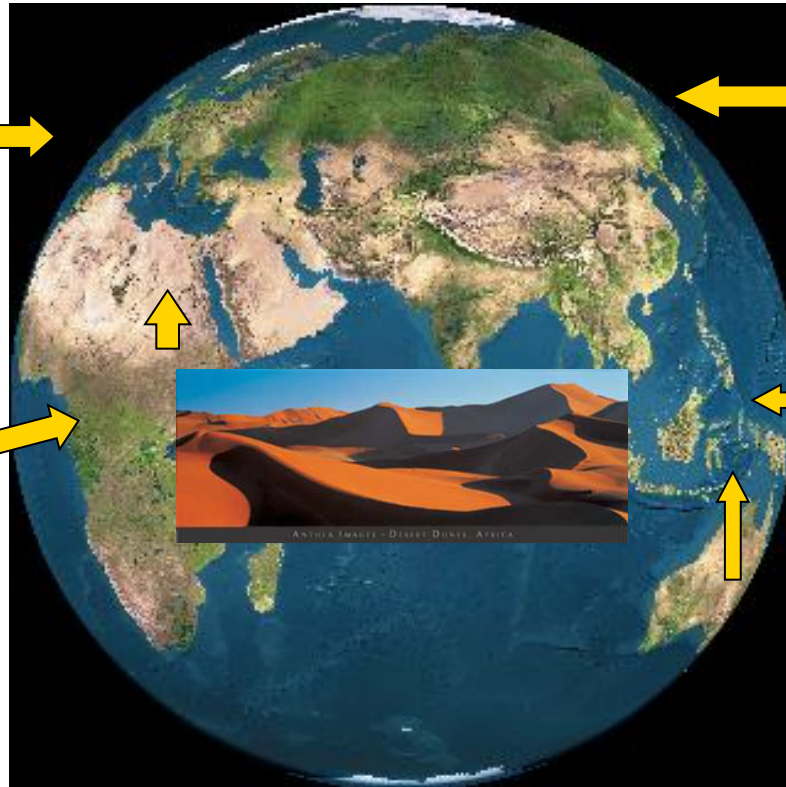
Exemple:  
climate  
C-cycle  
links  
for Europe

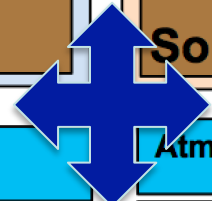
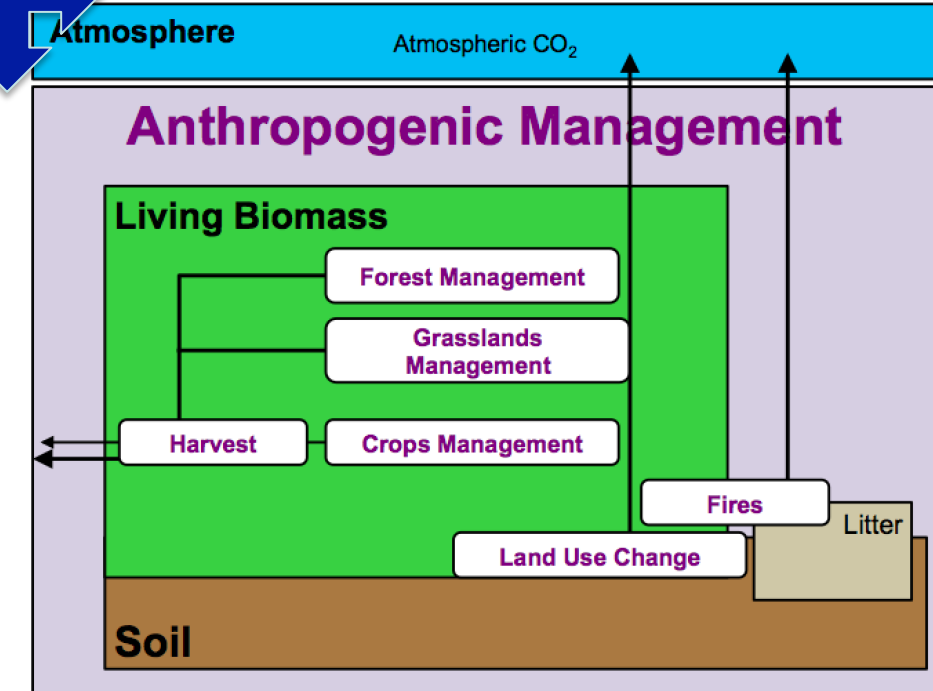
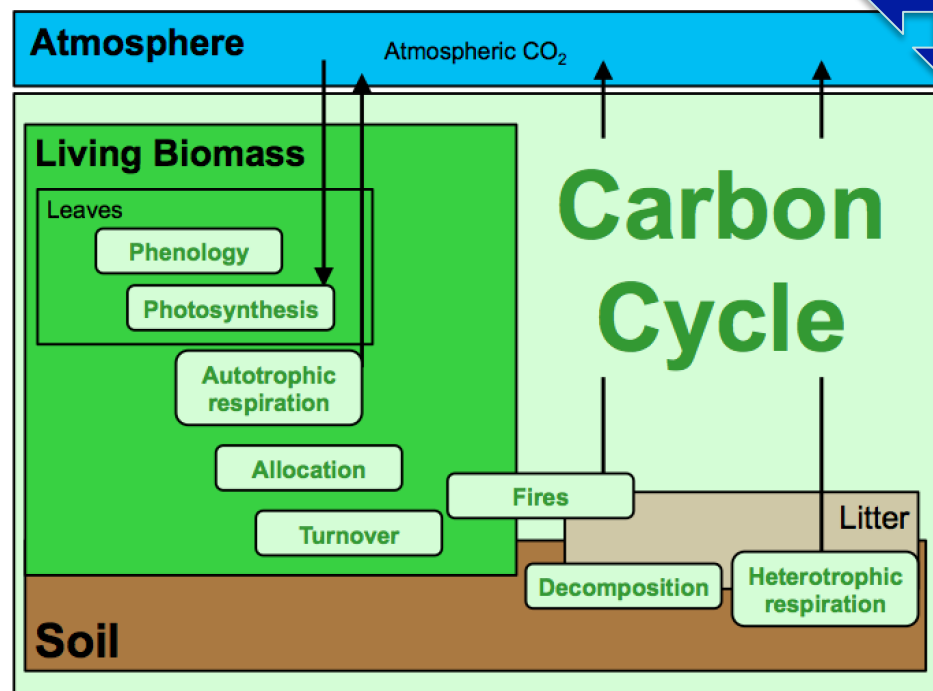
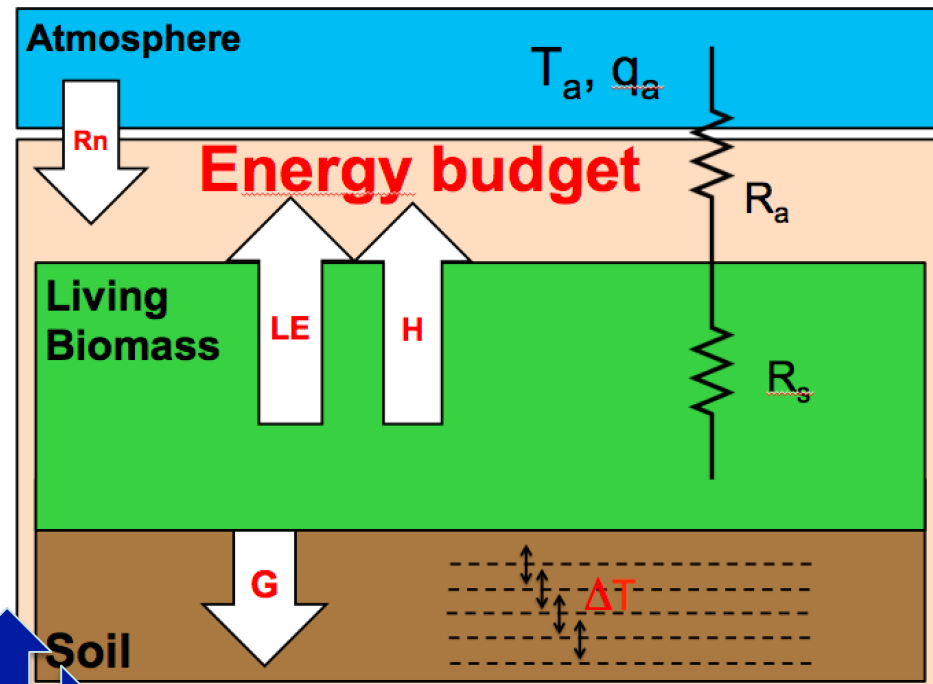
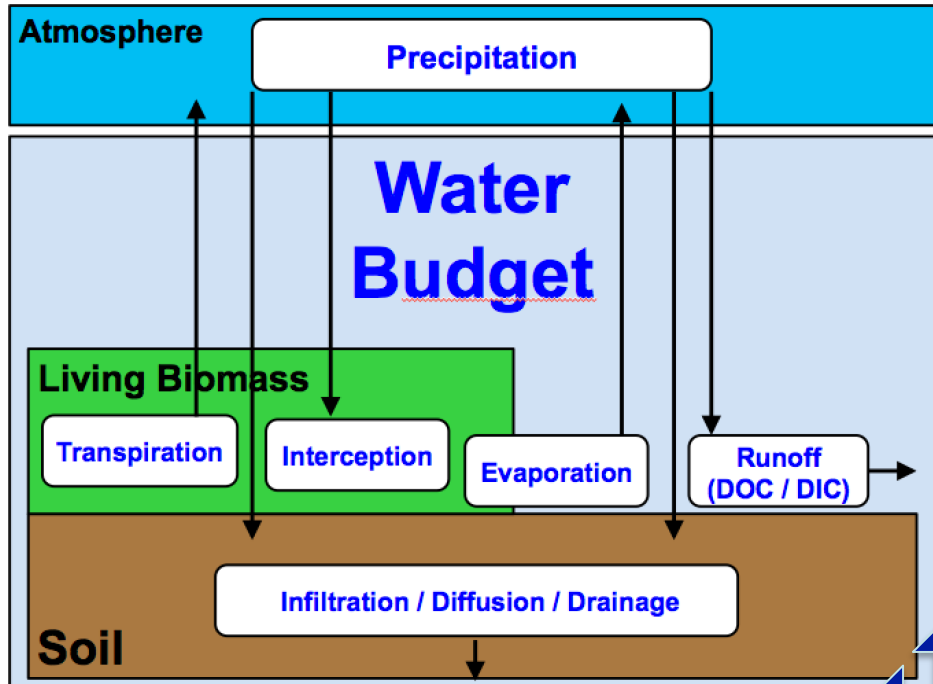




# Global Vegetation Model: ORCHIDEE

**Simulates the Energy, Water and Carbon balance  
Land component of the IPSL Earth System Model**





# Reanalysis with ERA-20C Analysis & comparison to other products

## A specific web site to view C results

<http://transcom.globalcarbonatlas.org/>

User/Passwd: transcom / transcom2014

Clear selections ?

CREATE PLOT

1 REGIONS

Filter... x

- Global
- Land
- Ocean
- TransCom

2 AVERAGING PERIOD

Yearly mean

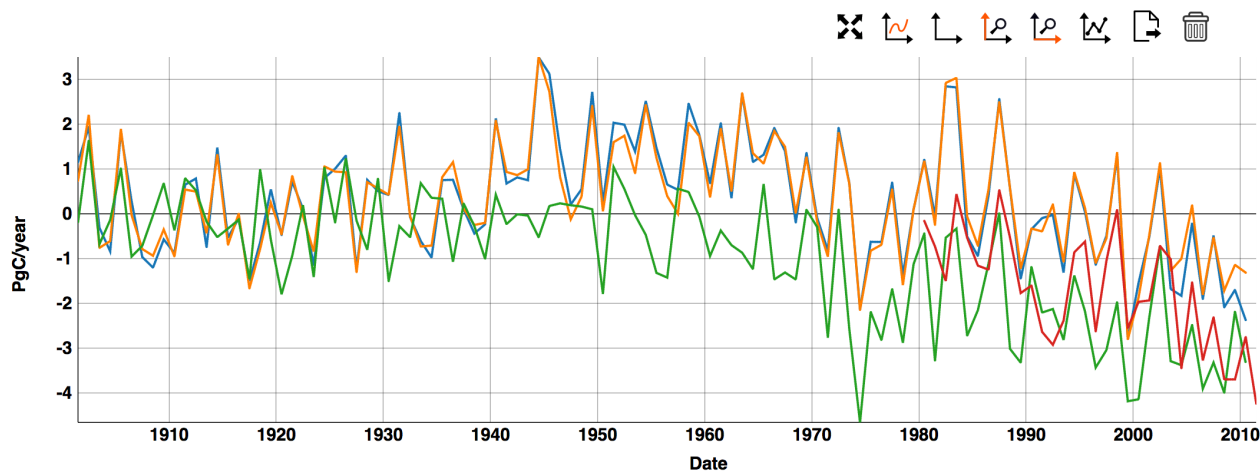
3 RESOURCES

Filter... x

- CCDAS
- CMIP5
- Data-driven
- ERACLIM2**
- FOSSIL
- Inversions
- Land (TRENDY)
- Ocean models
- ORCHIDEE
- TEST

4 VARIABLE

- Ocean\_flux
- Terrestrial\_flux**
- Terrestrial\_flux\_crop
- Terrestrial\_flux\_grass
- Terrestrial\_flux\_lu



- ORC CERA LU5 / Terrestrial\_flux / 05 Global Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux / 05 Global Land / Yearly mean
- ORC CRUNCEP LU6 / Terrestrial\_flux / 05 Global Land / Yearly mean
- LSCE var MACC V12 3 / Terrestrial\_flux / 05 Global Land / Yearly mean

- Mapping facility
- Regional total time series



→ Preparation of the forcing  
for the ORCHIDEE land surface model



## CERA-20C product

U and V wind at 10 meters  
Dewpoint temperature at 2 meters  
Surface Pressure  
Temperature at 2 meters  
Total precipitation  
Snowfall  
Surface solar radiation downward  
Surface thermal radiation downwards.

## CERA-20C ORC forcing

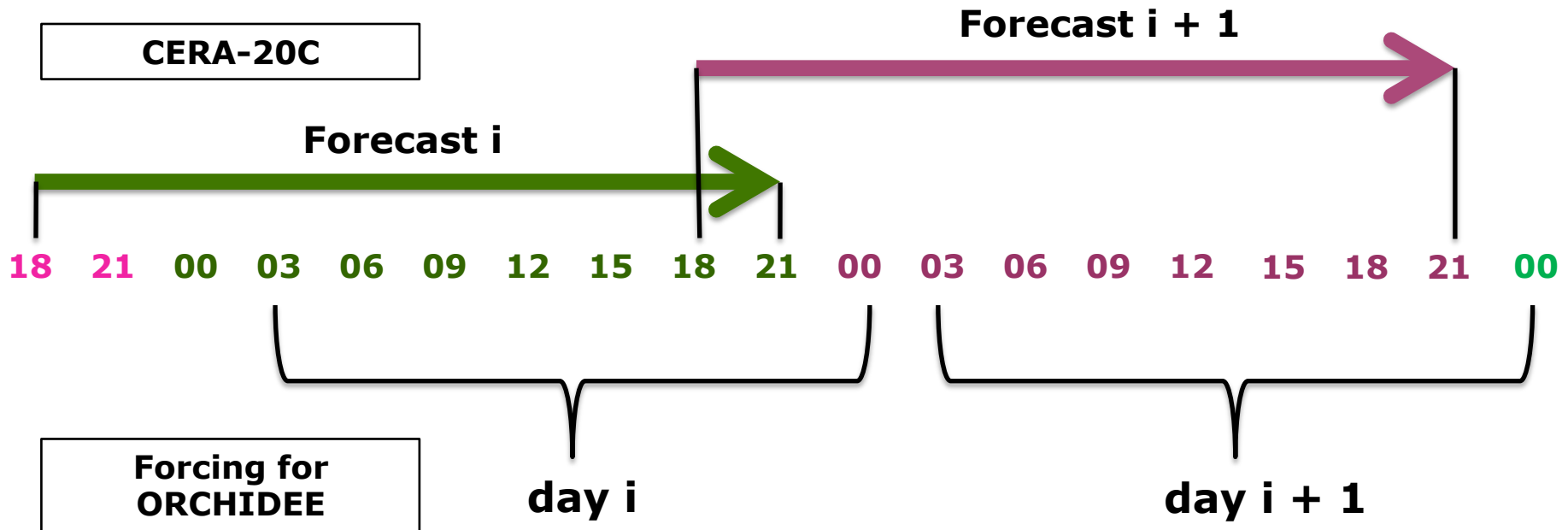
U and V wind at 10 meters  
Specific humidity  
Temperature at 2 meters  
Rainfall  
Snowfall  
Surface solar radiation downward  
Surface thermal radiation downwards.



LSCE

# Meteorological forcing – CERA-20C

**CERA-20C:** the 27-hour forecasts starting at 18:00, time resolution 3 hours, period length 1901–2010

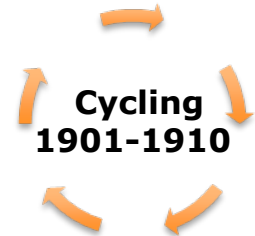


The files are arranged to obtain the good temporal and spatial format for ORCHIDEE

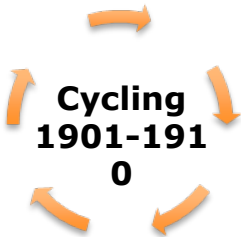


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# Simulation setup

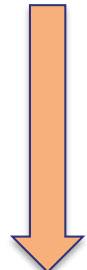


**Spin-up simulation:** 340 years, same land use 1860 (pre-industrial), CO<sub>2</sub> fixed



**Transient simulation:** 40 years, land use and CO<sub>2</sub> from 1860 to 1900

1901



2010

**Historical simulation:** varying CO<sub>2</sub> and land use every year

**CERA20C** : ESA-LUH2 13PFT vegetation map 1901-2010, most recent version of ORCHIDEE; CERA-20C meteo forcing.

**CERA20C\_01** : AR5 LUHa.rc2 13PFT vegetation map. CERA-20C meteo forcing.

**CERA20C\_02** : as **CERA20C** but not changing vegetation map, keeping it to the preindustrial period (1860).

**CRUNCEP** : as **CERA20C** but using the CRU-NCEP meteo forcing (Kalnay et al., 1996 and CRU TS 2.1 Mitchell and Jones, 2005).

Output resolution: 1 month  
Spatial resolution: 1°x 1°

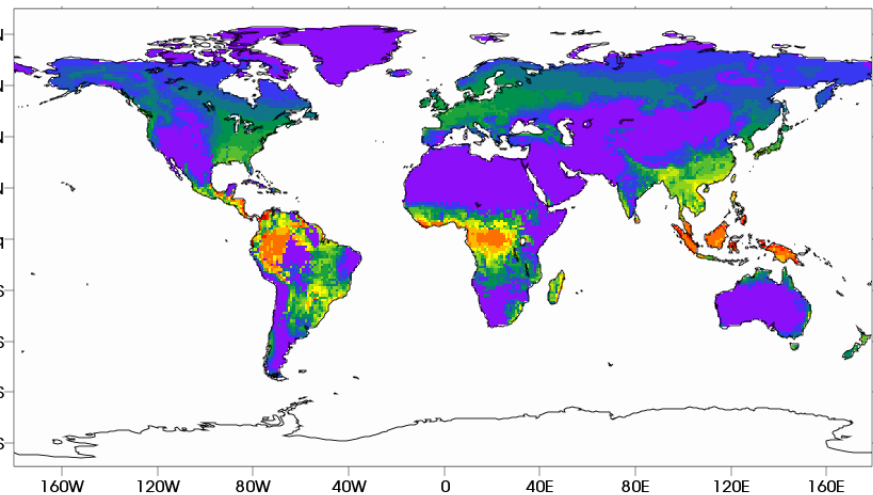




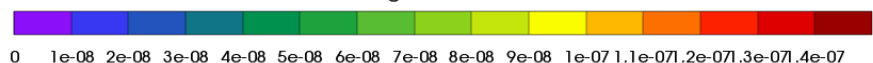
# Geographical distribution: 1990-2010

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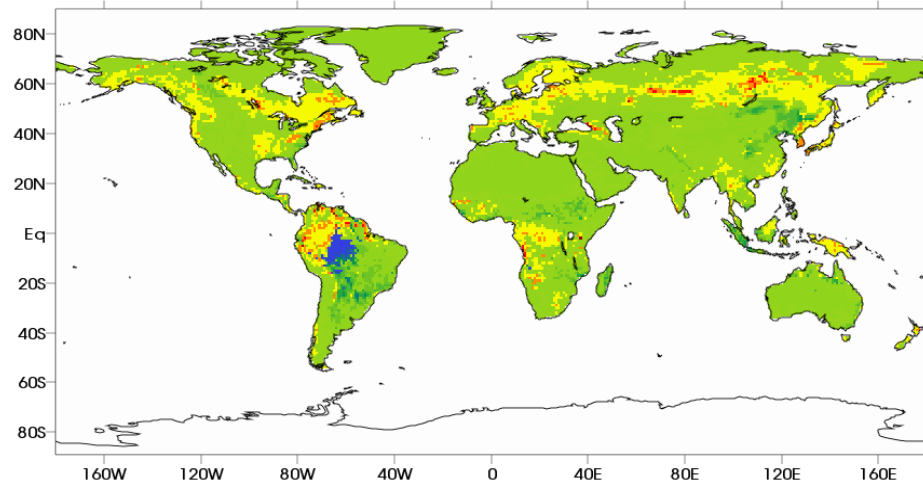
## Gross Primary Production



kg C m<sup>-2</sup> s<sup>-1</sup>



## Net Carbon Fluxes



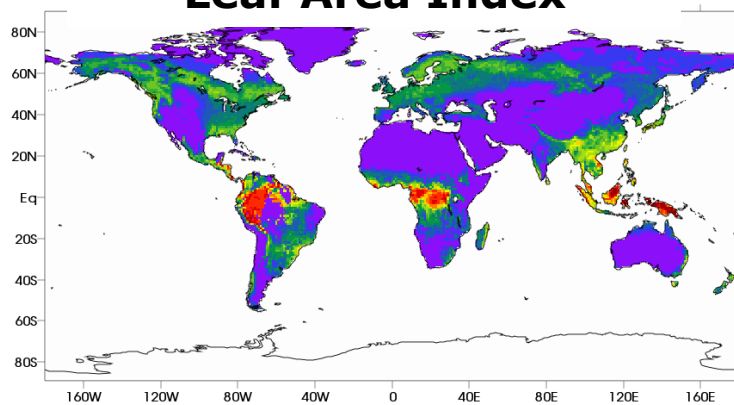
kg C m<sup>-2</sup> s<sup>-1</sup>



*C Source*

*C Sink*

## Leaf Area Index



m<sup>2</sup>/m<sup>2</sup>





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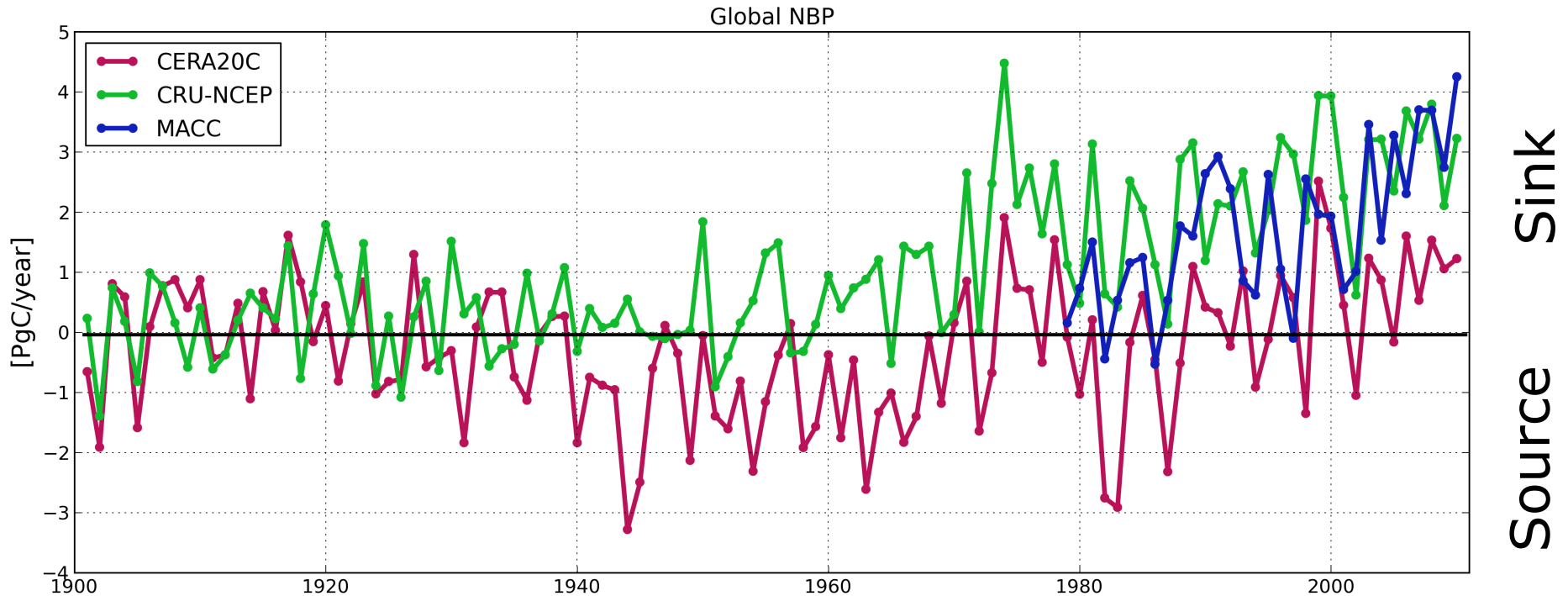
# Net Carbon fluxes

## Global land flux (PgC/yr)

**CERA20C**

**CRUNCEP**

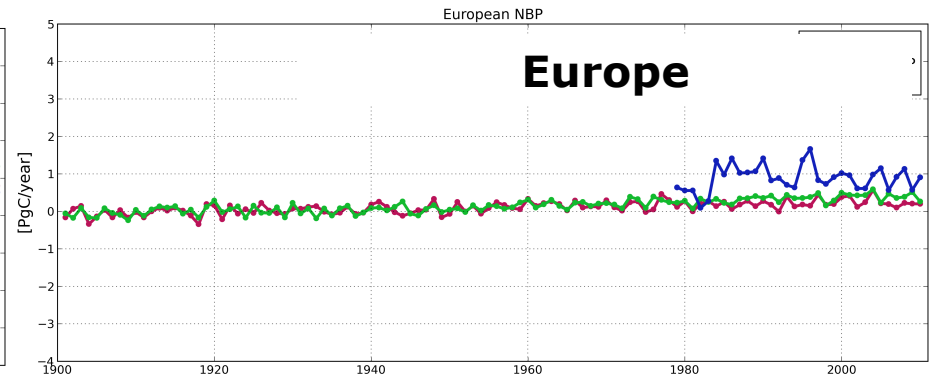
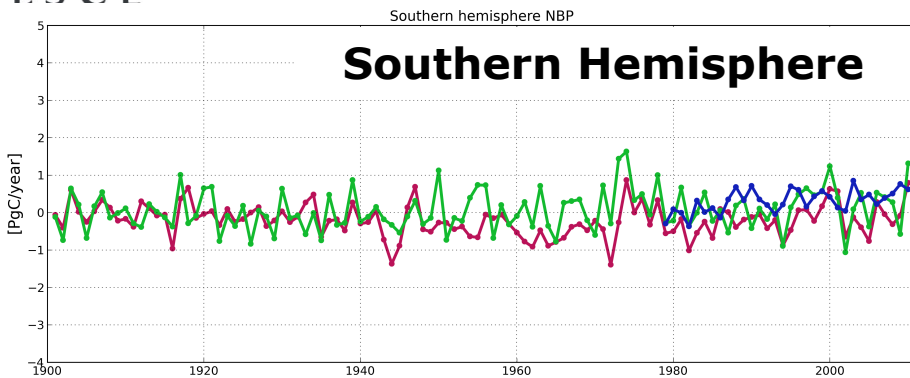
**MACC CO2  
inversion**





I.S.C.E

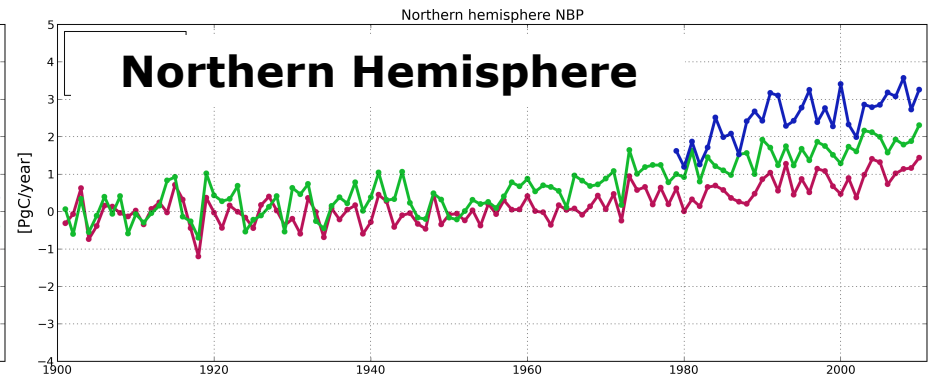
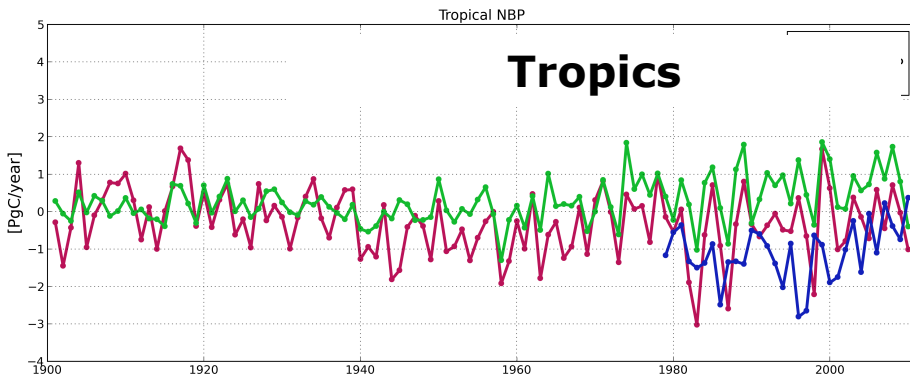
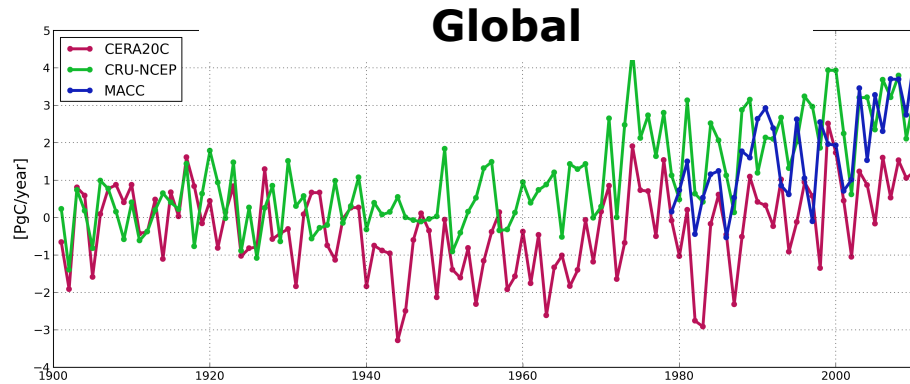
# Net Carbon fluxes



**CERA20C**

**CRUNCEP**

**MACC**

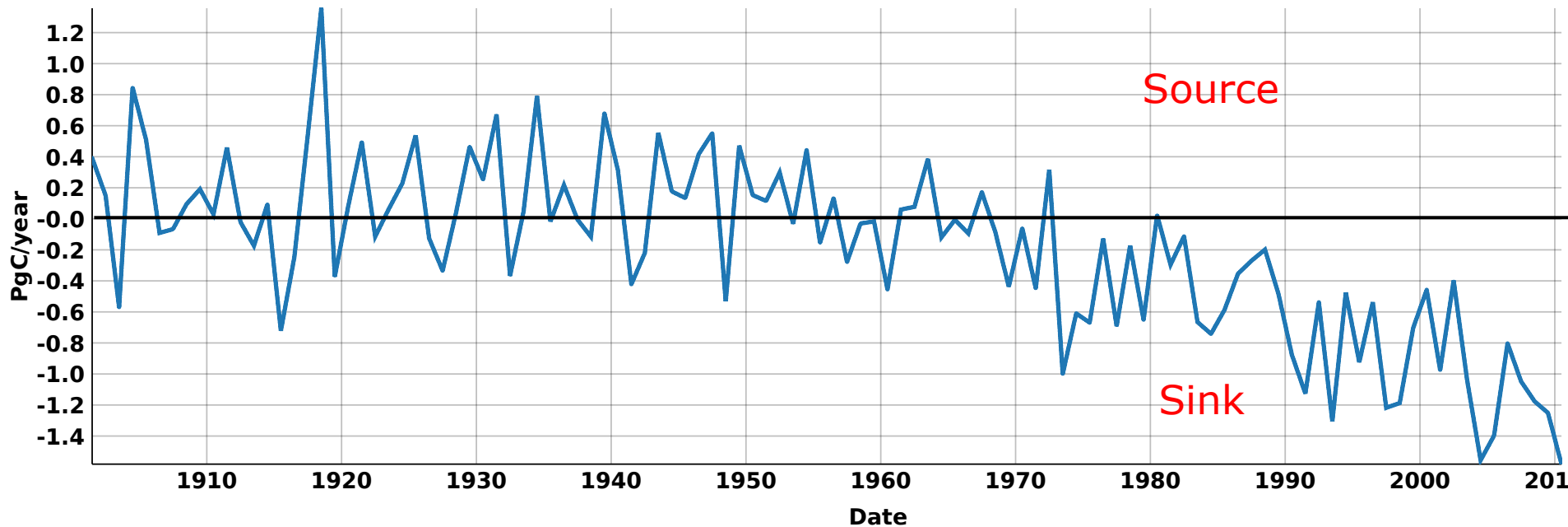




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# Net Carbon fluxes

## Northern hemisphere



● ORC CERA LU6 / Terrestrial\_flux / 06 Northern Land / Yearly mean

**All ecosystems**

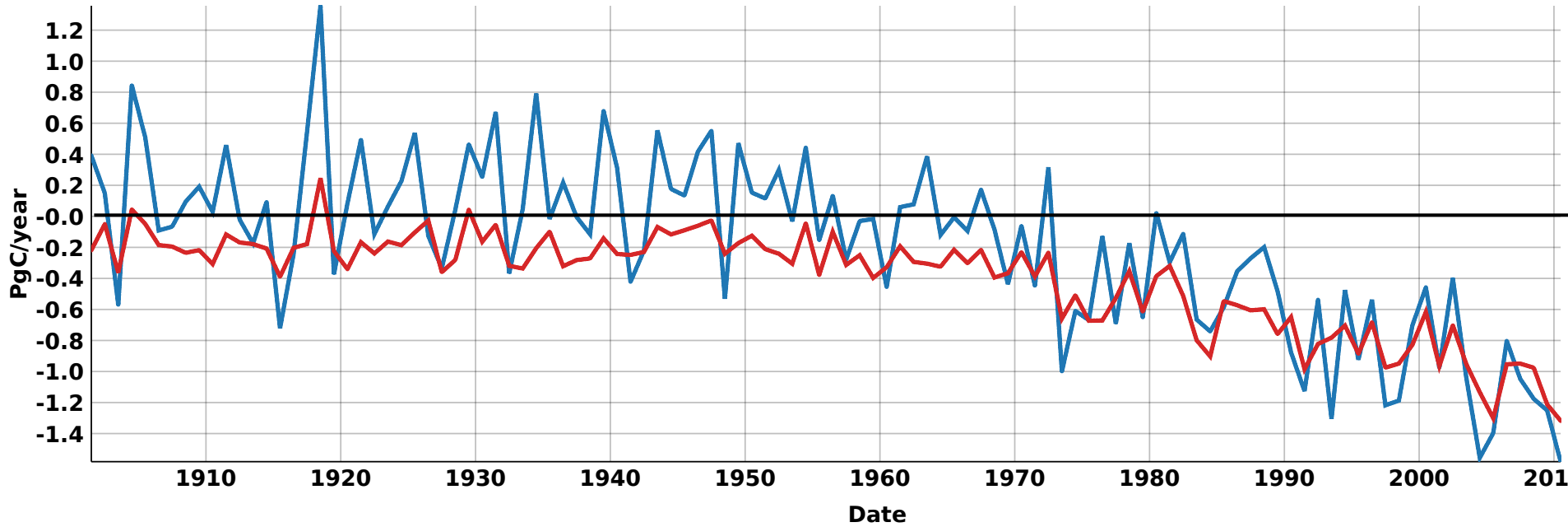
Obtain from: <http://transcom.globalcarbonatlas.org/>



LSCE

# Net Carbon fluxes

## Northern hemisphere



- ORC CERA LU6 / Terrestrial\_flux / 06 Northern Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_tree / 06 Northern Land / Yearly mean

**All ecosystems**  
**Trees**

Obtain from: <http://transcom.globalcarbonatlas.org/>

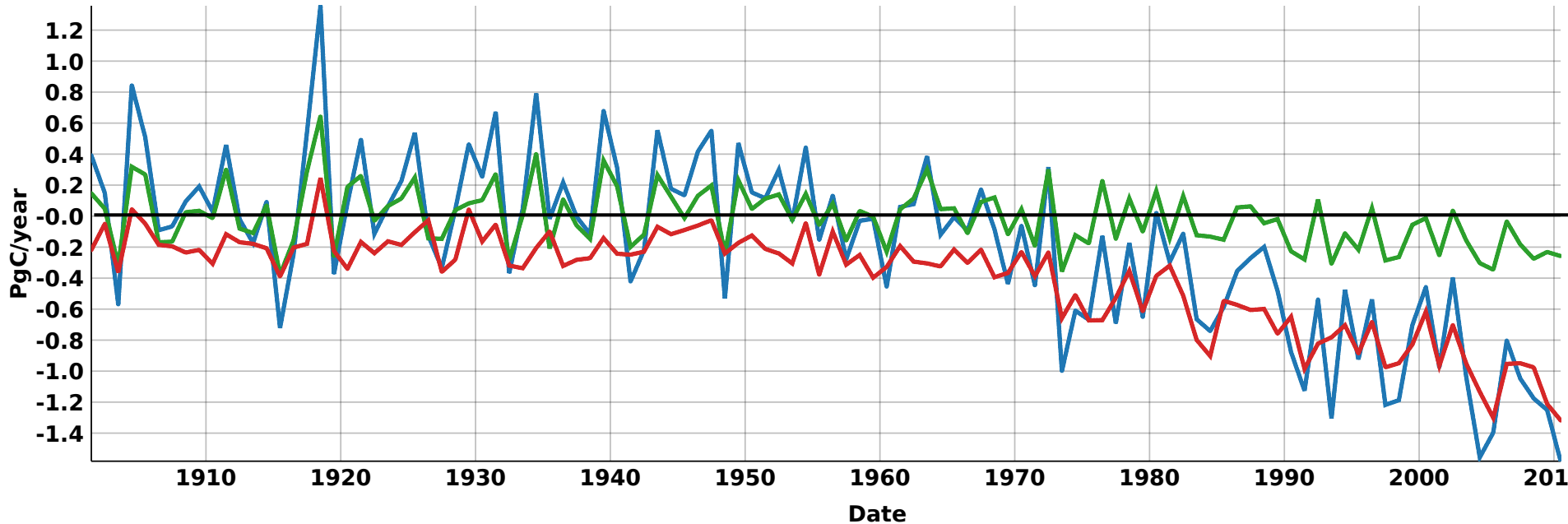




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# Net Carbon fluxes

## Northern hemisphere



- ORC CERA LU6 / Terrestrial\_flux / 06 Northern Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_grass / 06 Northern Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_tree / 06 Northern Land / Yearly mean

**All ecosystems**  
**Trees**  
**Grass**

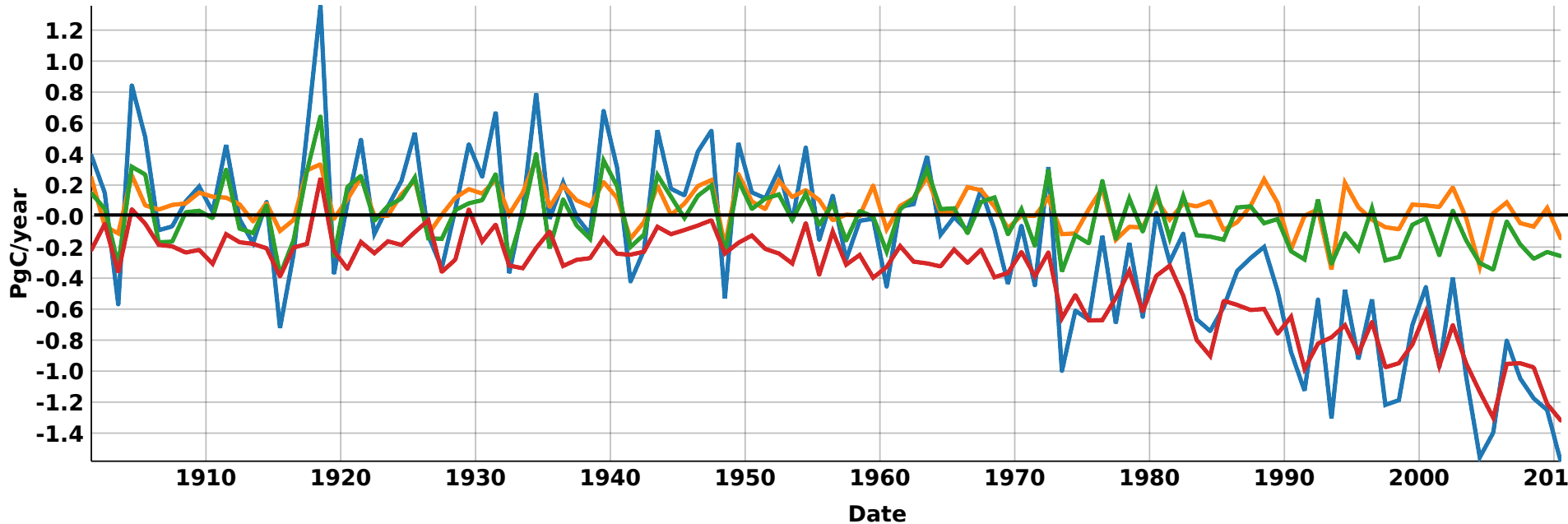
Obtain from: <http://transcom.globalcarbonatlas.org/>



LSCE

# Net Carbon fluxes

## Northern hemisphere



- ORC CERA LU6 / Terrestrial\_flux / 06 Northern Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_crop / 06 Northern Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_grass / 06 Northern Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_tree / 06 Northern Land / Yearly mean

**All ecosystems**

**Trees**

**Grass**

**Crop**

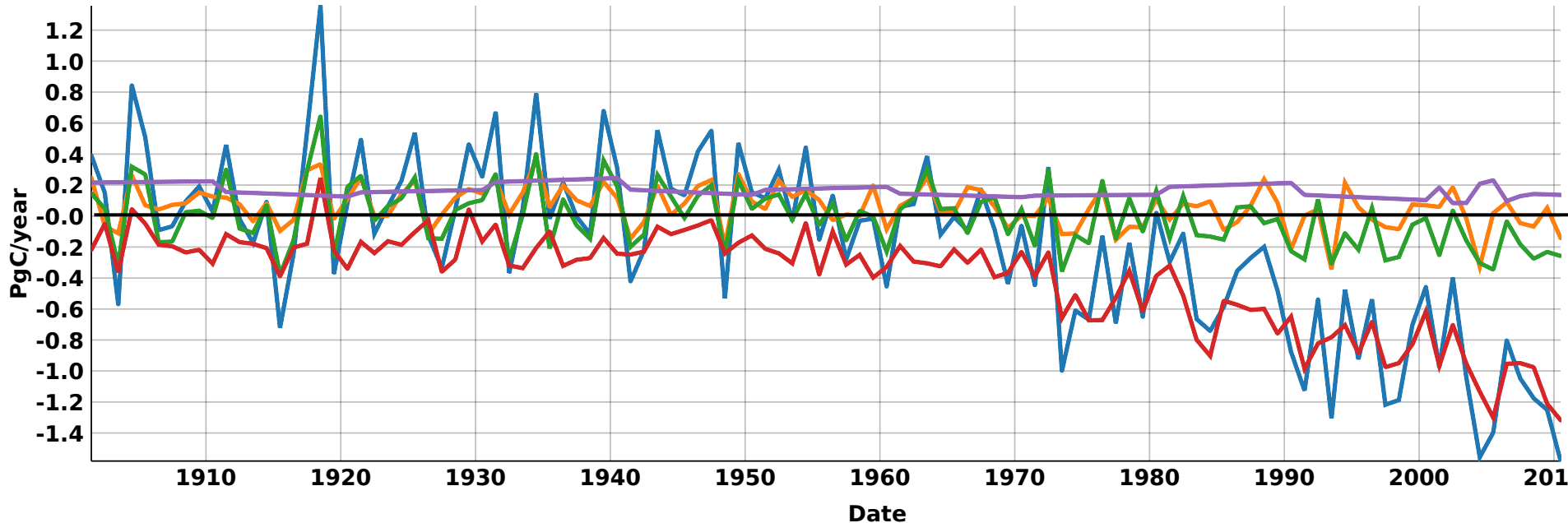
Obtain from: <http://transcom.globalcarbonatlas.org/>



LSCE

# Net Carbon fluxes

## Northern hemisphere



- ORC CERA LU6 / Terrestrial\_flux / 06 Northern Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_crop / 06 Northern Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_grass / 06 Northern Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_tree / 06 Northern Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_lu / 06 Northern Land / Yearly mean

**All ecosystems**

**Trees**

**Grass**

**Crop**

**Land use**

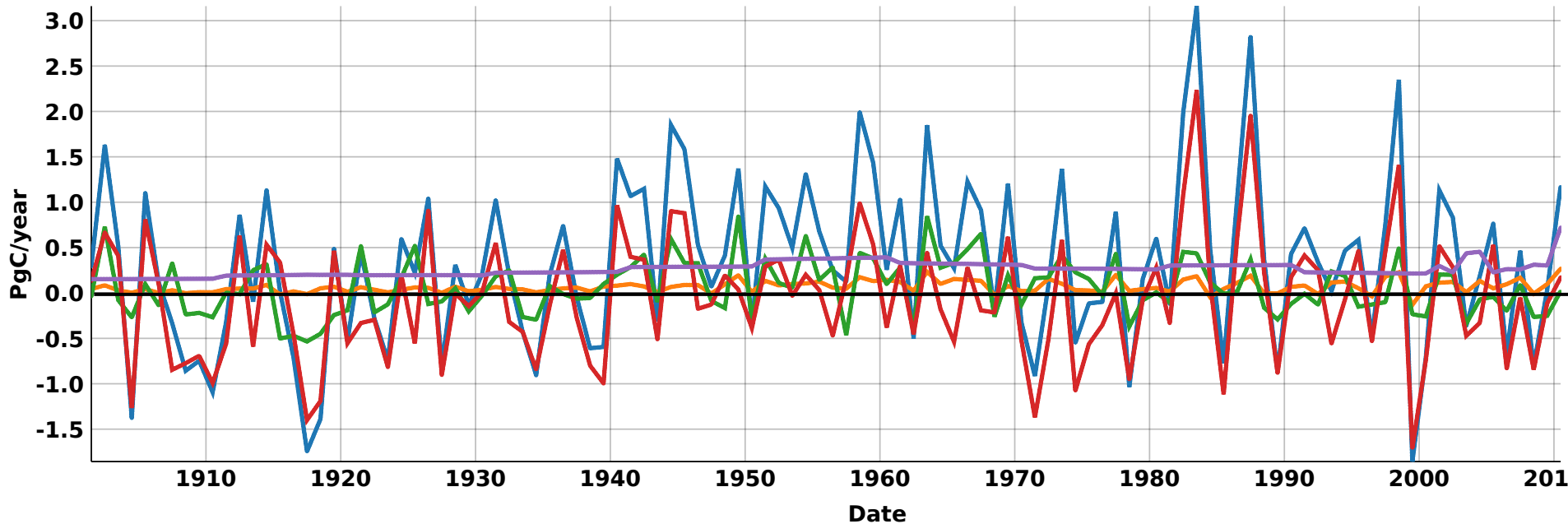
Obtain from: <http://transcom.globalcarbonatlas.org/>



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# Net Carbon fluxes

## Tropical ecosystems



- ORC CERA LU6 / Terrestrial\_flux / 07 Tropical Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_crop / 07 Tropical Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_grass / 07 Tropical Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_tree / 07 Tropical Land / Yearly mean
- ORC CERA LU6 / Terrestrial\_flux\_lu / 07 Tropical Land / Yearly mean

**All ecosystems**

**Trees**

**Grass**

**Crop**

**Land use**

Obtain from: <http://transcom.globalcarbonatlas.org/>



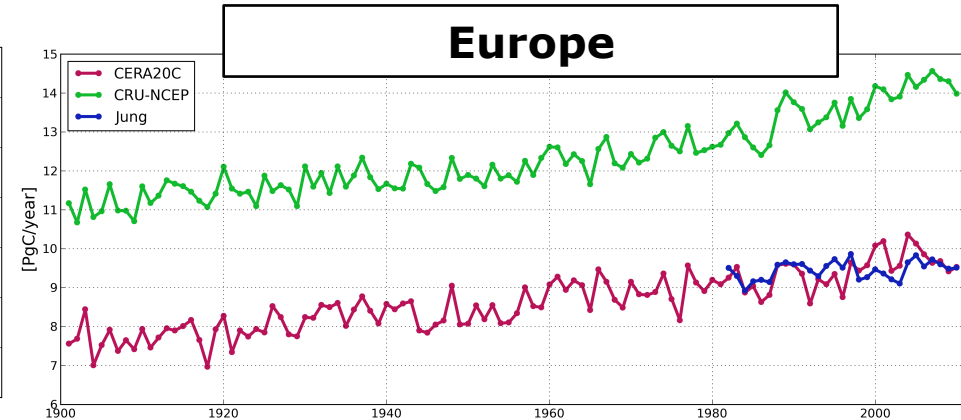
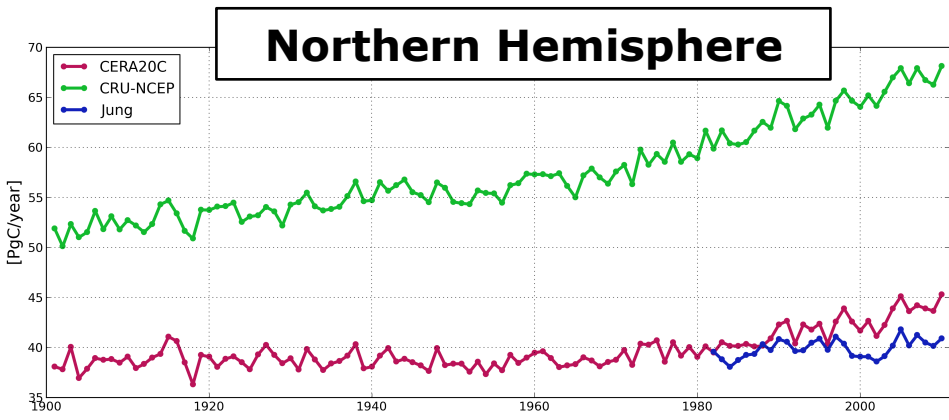
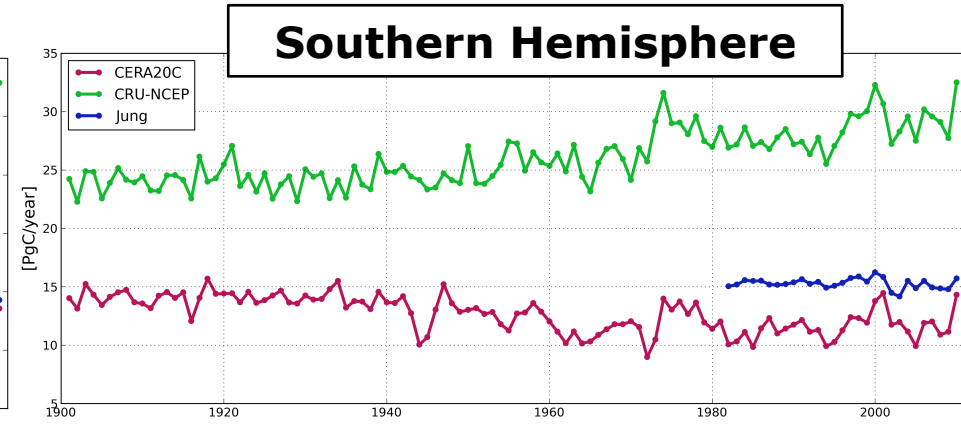
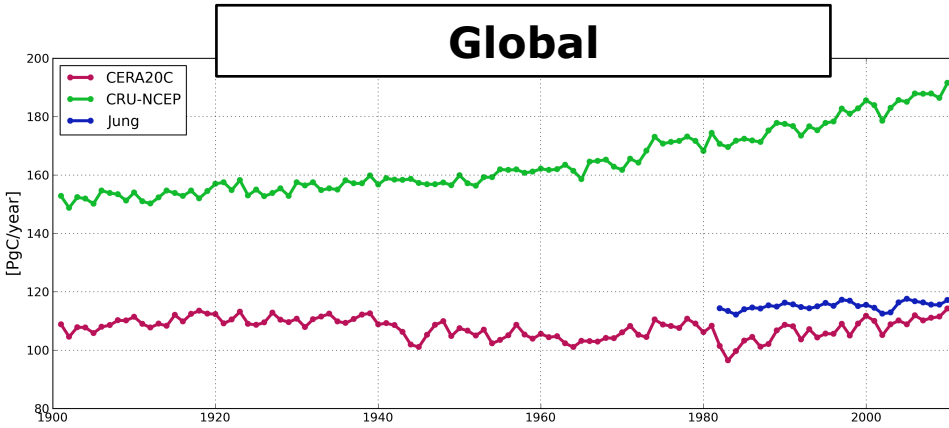
LSCE

# Photosynthesis: Gross Primary Production

**CERA20C**

**CRUNCEP**

**Jung: MPI product**



Jung et al. 2011: up-scaled FLUXNET observations to the global scale

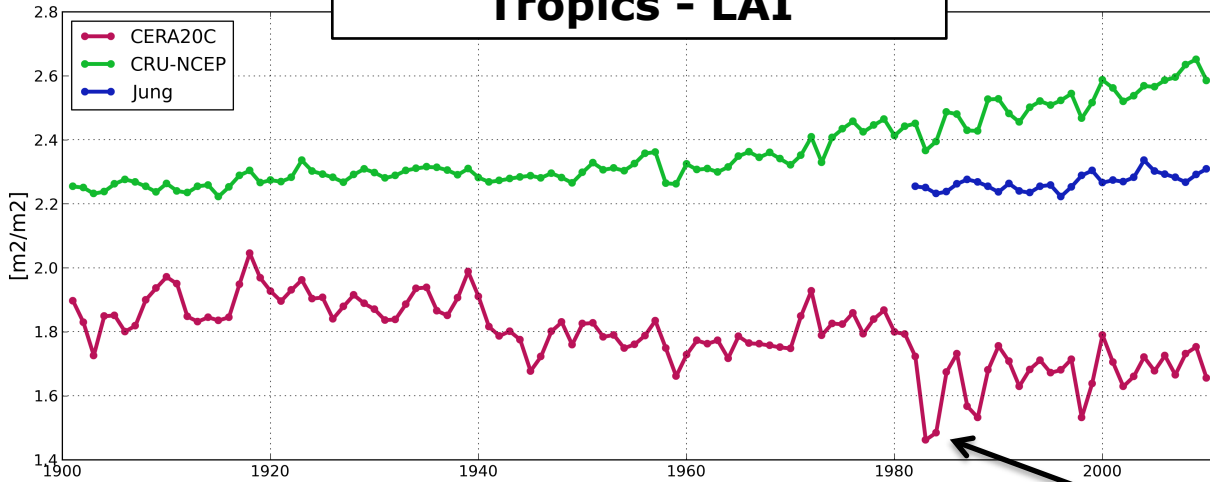




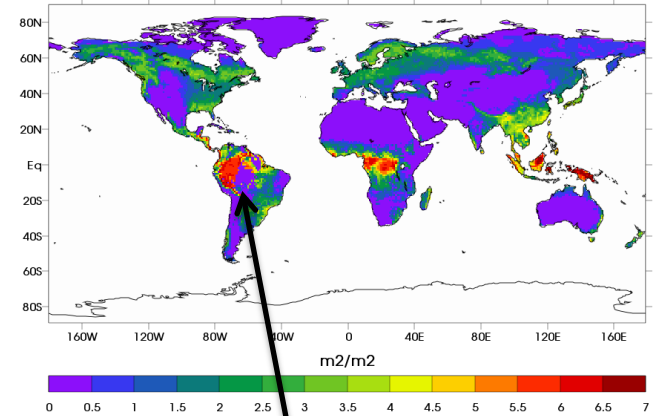
LSCE

# Tropics

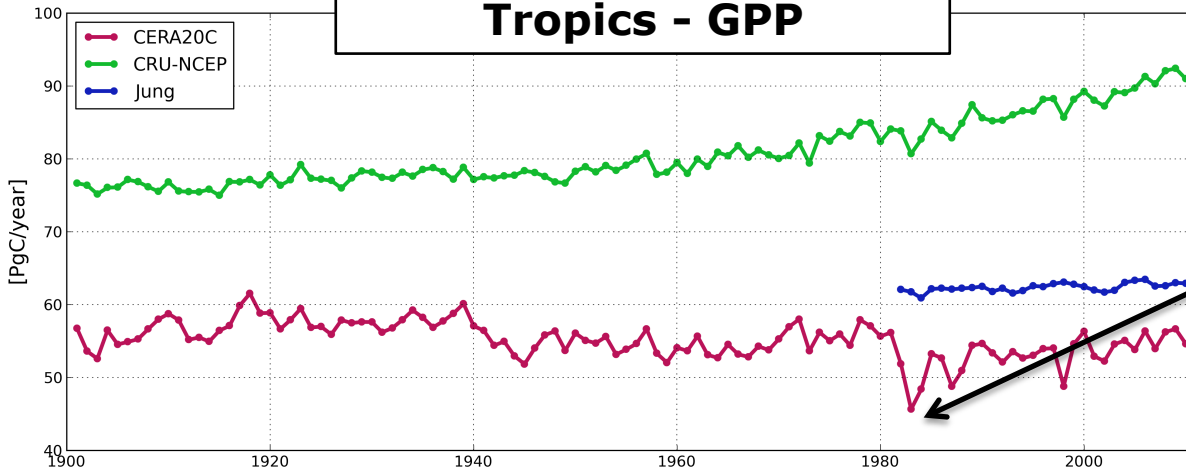
### Tropics - LAI



### LAI 1990-2010



### Tropics - GPP



Strong drop of LAI and GPP

**CERA20C**

**CRUNCEP**

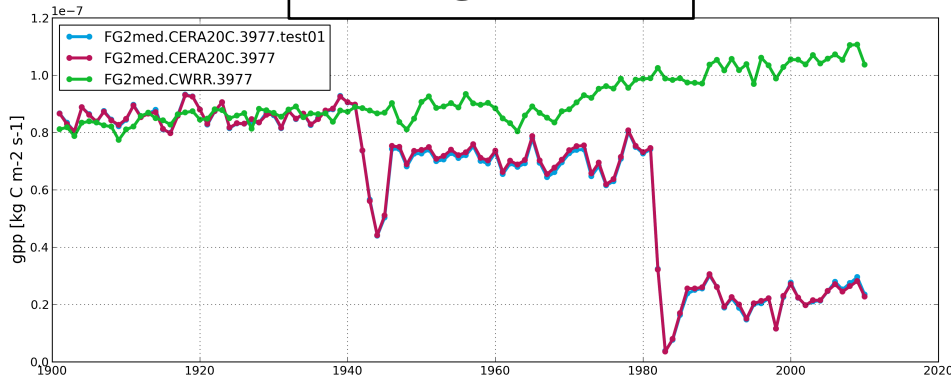
**MACC**



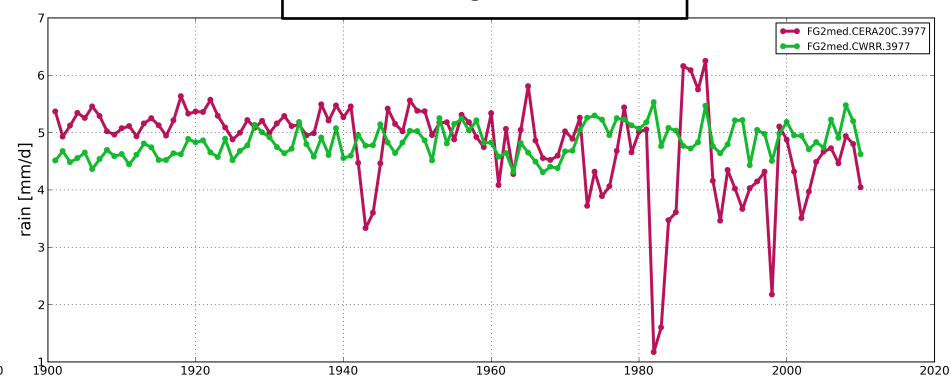
LSCE

# Amazonian region

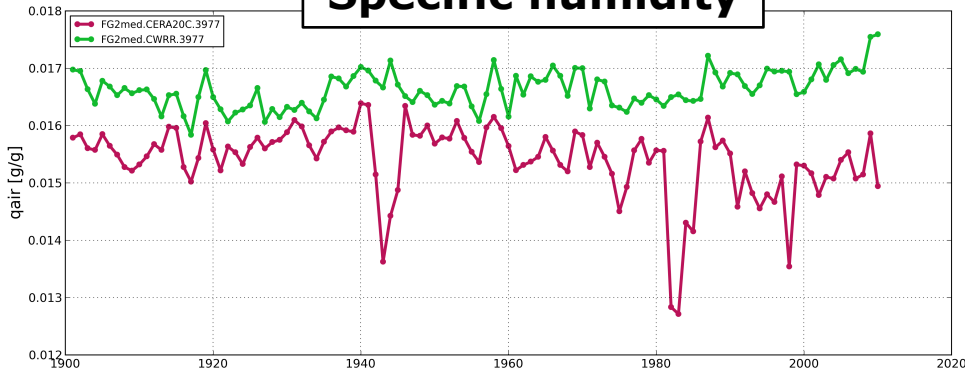
## GPP



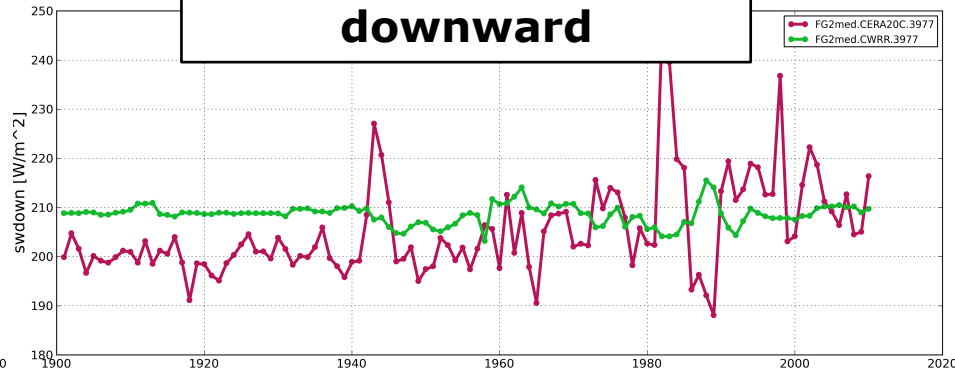
## Rain



## Specific humidity



## Solar radiation downward



**CERA20C**

**CRUNCEP**

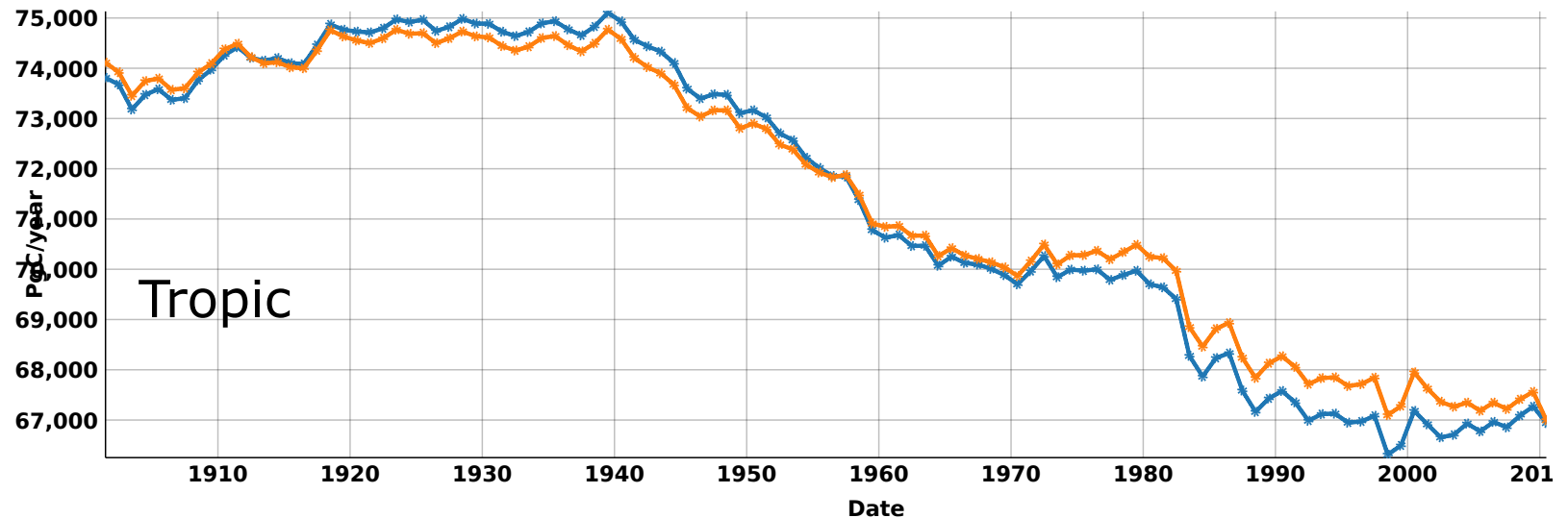
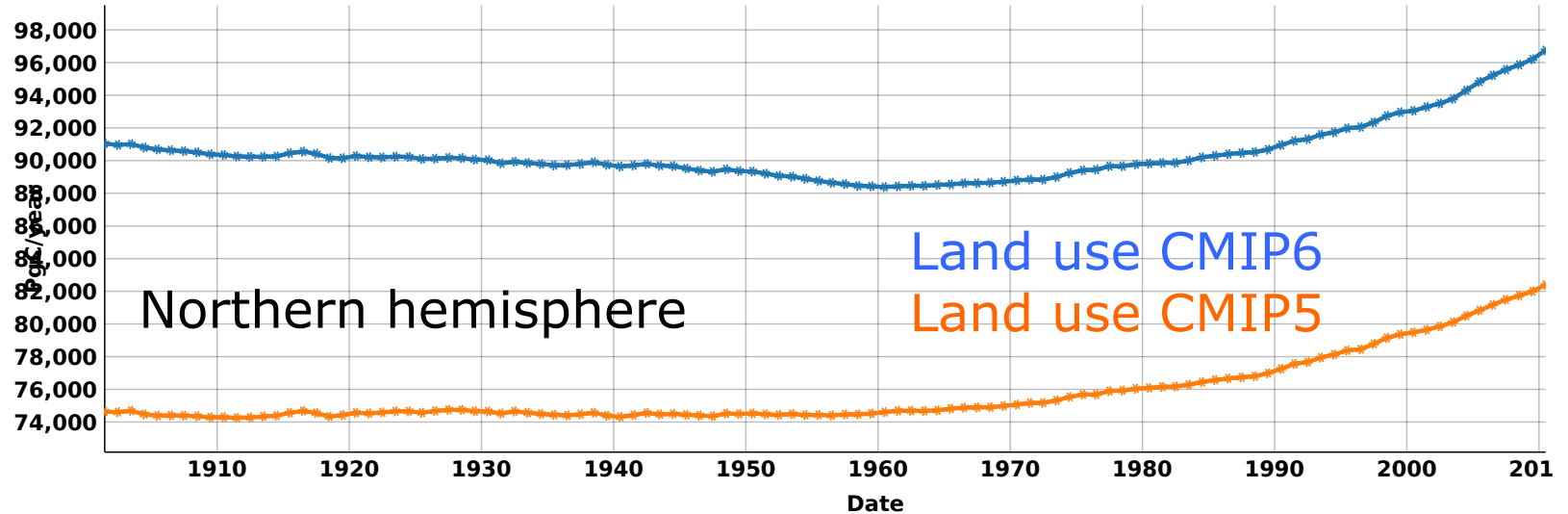
The strong drop of LAI and GPP is linked to a sever decrease of rainfall



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# Vegetation carbon stocks

## Total C stocks (PgC)





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# Conclusion and Perspectives

1. Validation phase is ongoing; promising results
2. CERA-20C simulation compares well to other products
3. The Amazonian drop has to be figured out
  - Biases in precipitation are crucial
  - Need for bias corrected forcing !
4. Consolidate the ORCHIDEE model version
  - Process integration (Add N cycle)
  - Parameter optimization (WP2)
5. Consolidate the web-site to display all results





→ Including the C cycle in a global reanalysis may help for future downstream services..

Thank you...

→ <http://transcom.globalcarbonatlas.org/>





LSCE

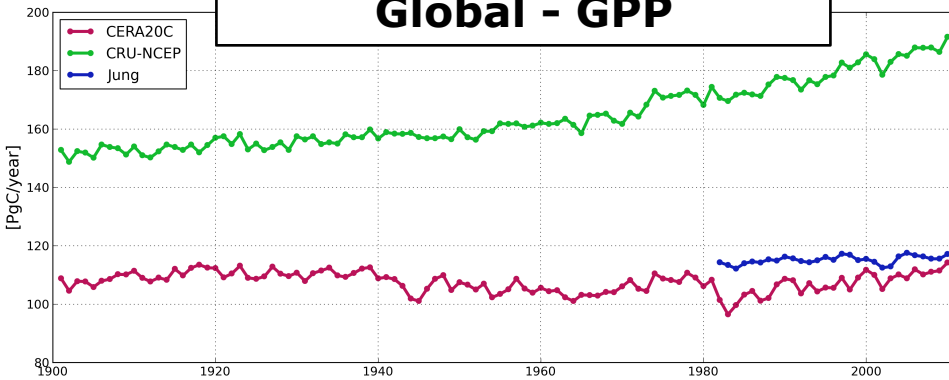
# Photosynthesis: Gross Primary Production

**CERA20C**

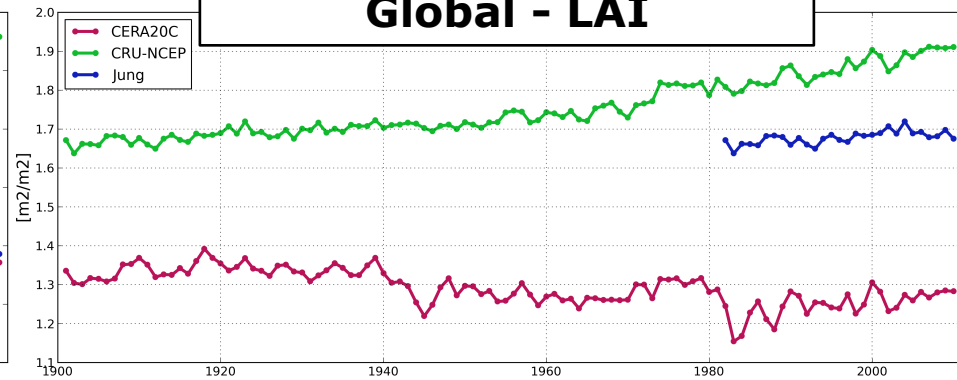
**CRUNCEP**

**Jung MPI product**

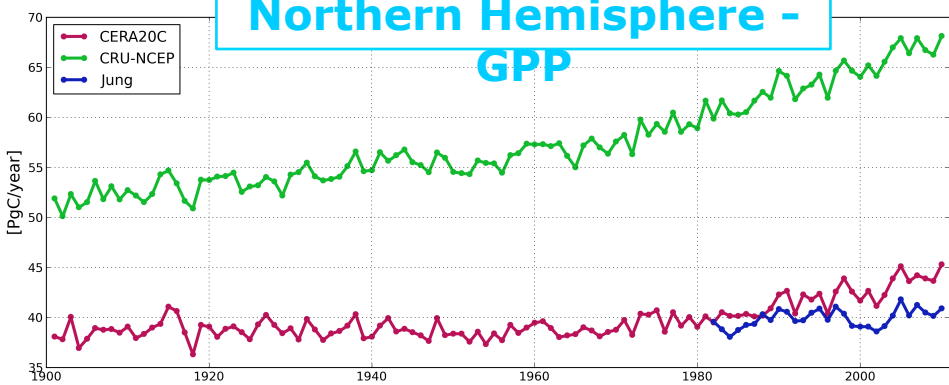
## Global - GPP



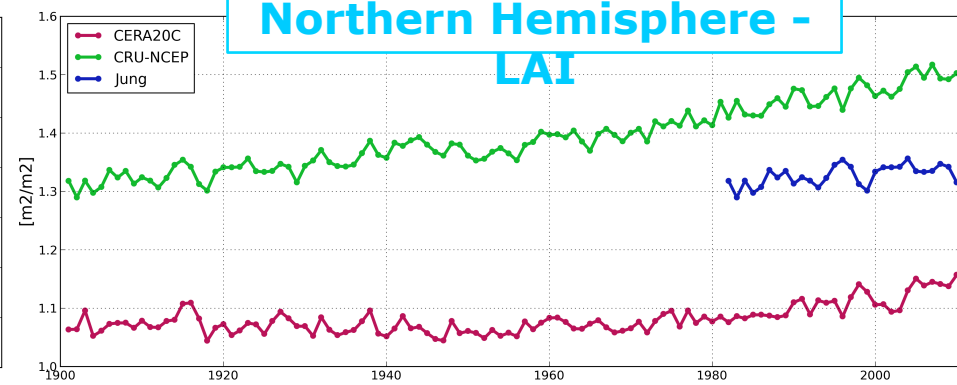
## Global - LAI



## Northern Hemisphere - GPP



## Northern Hemisphere - LAI



Jung et al. 2011: up-scaled FLUXNET observations to the global scale using the machine learning technique



# Leaf area Index and Gross Primary Production

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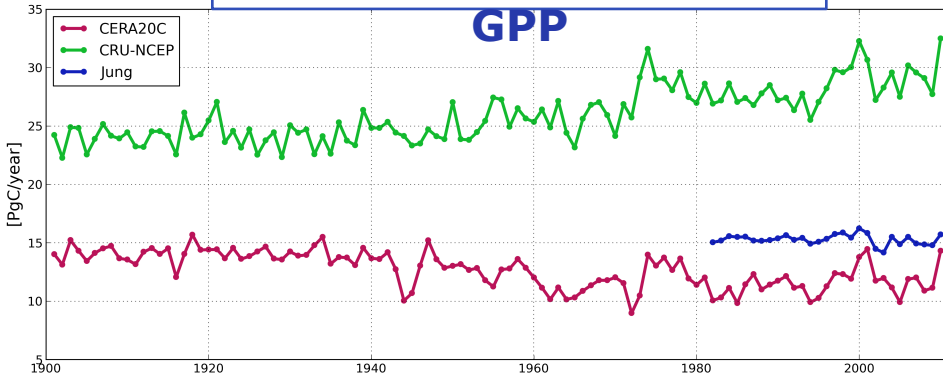
**CERA20C**

**CRUNCEP**

**Jung MPI product**

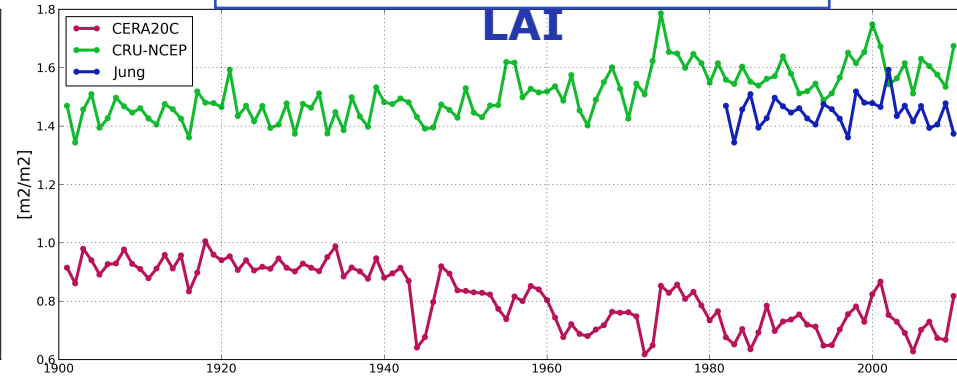
**Southern Hemisphere -**

**GPP**

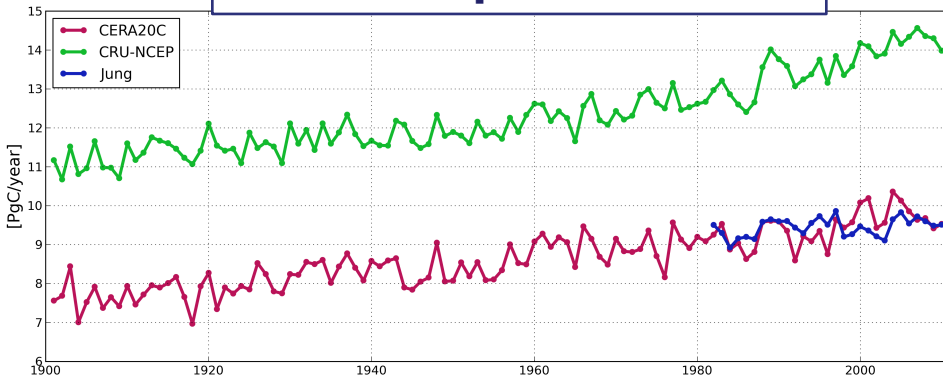


**Southern Hemisphere -**

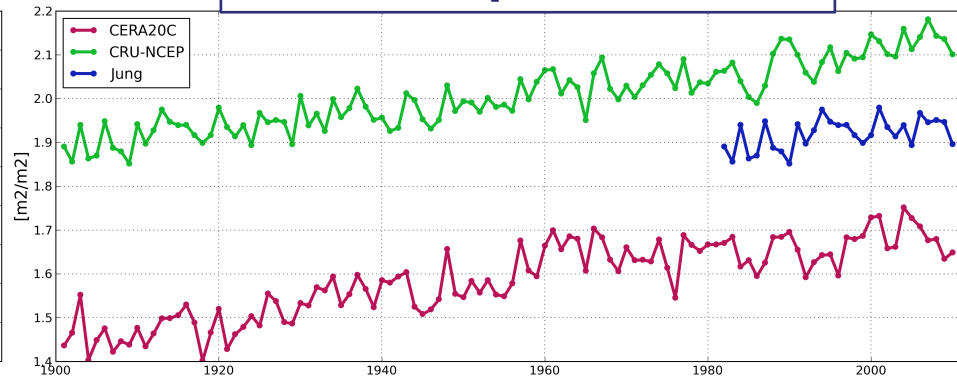
**LAI**



**Europe - GPP**

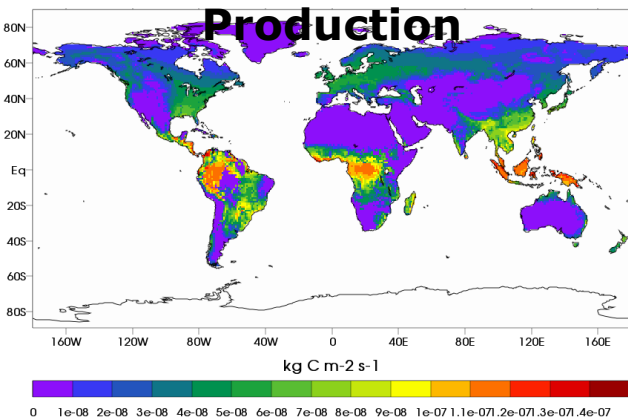


**Europe - LAI**

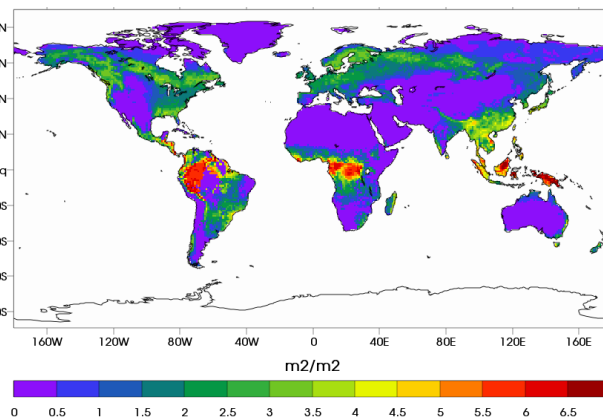


## CERA20C

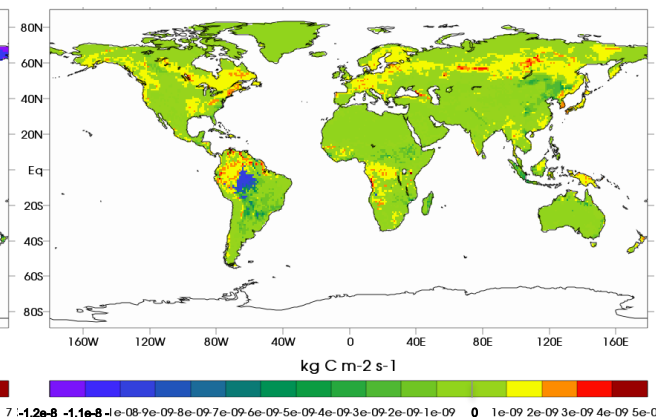
### Gross Primary Production



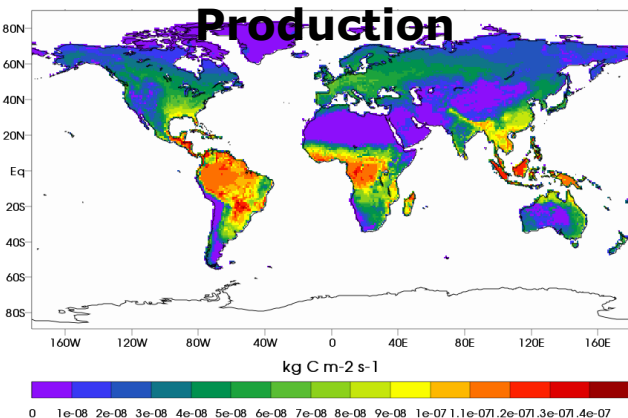
### Leaf Area Index



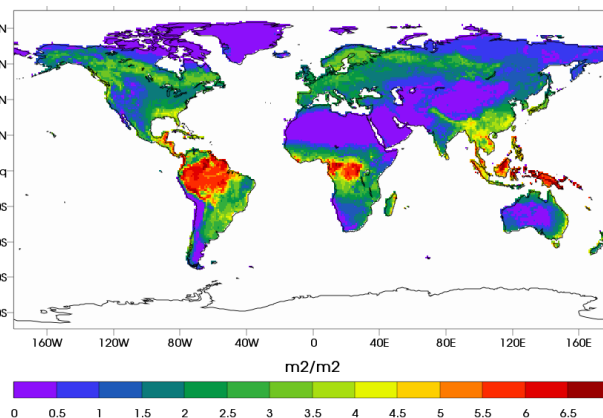
### Net Carbon Fluxes



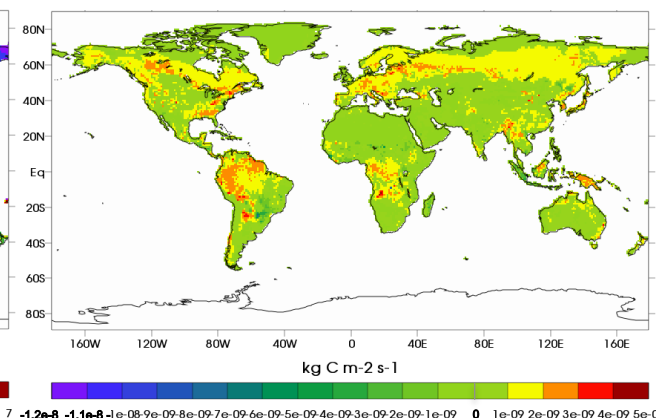
### Gross Primary Production



### Leaf Area Index



### Net Carbon Fluxes



## CRUNCEP



# ORCHIDEE recent developments for CMIP6

## Implemented

## Ongoing:

New Aerodynamic resistance

Nitrogen – carbon Coupled cycles

Optimized albedo (using MODIS)

Permafrost carbon

Land cover based on ESA-CCI

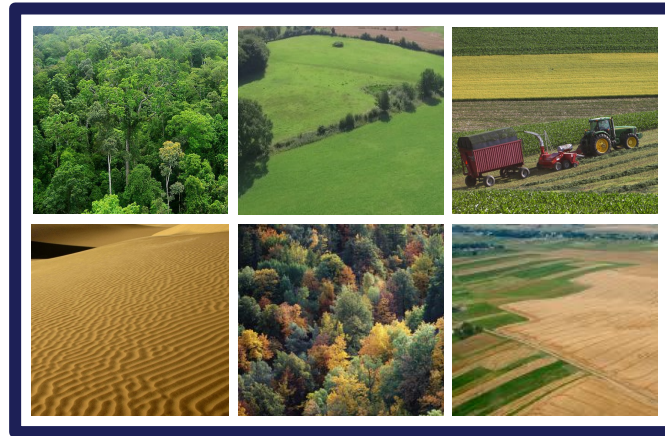
Forest management & forest structure

New 3 layers snow model

11-layer soil hydrology With soil freezing

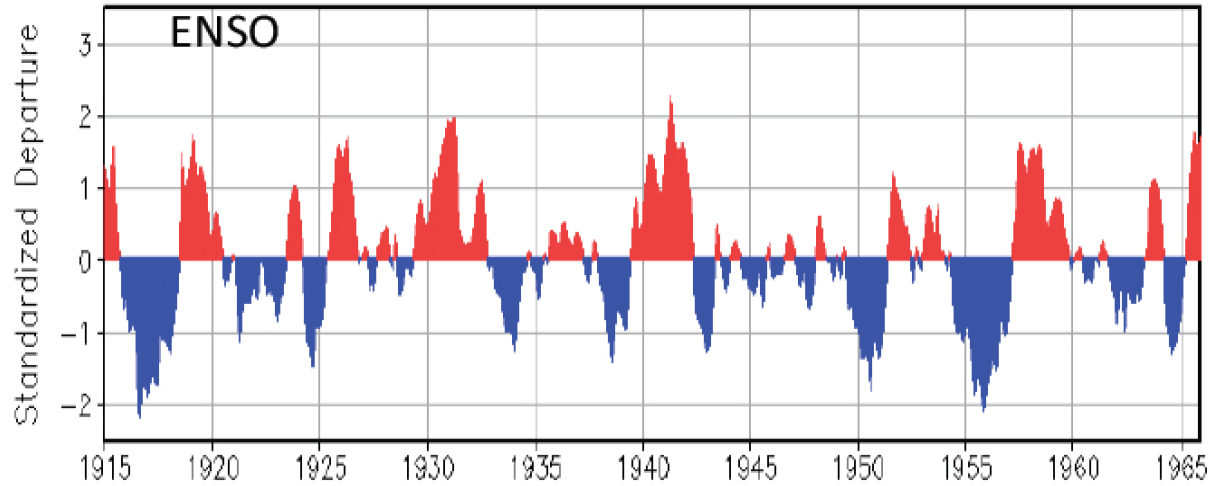
SPITFIRE and Land use gross transitions

Improved Dynamic vegetation

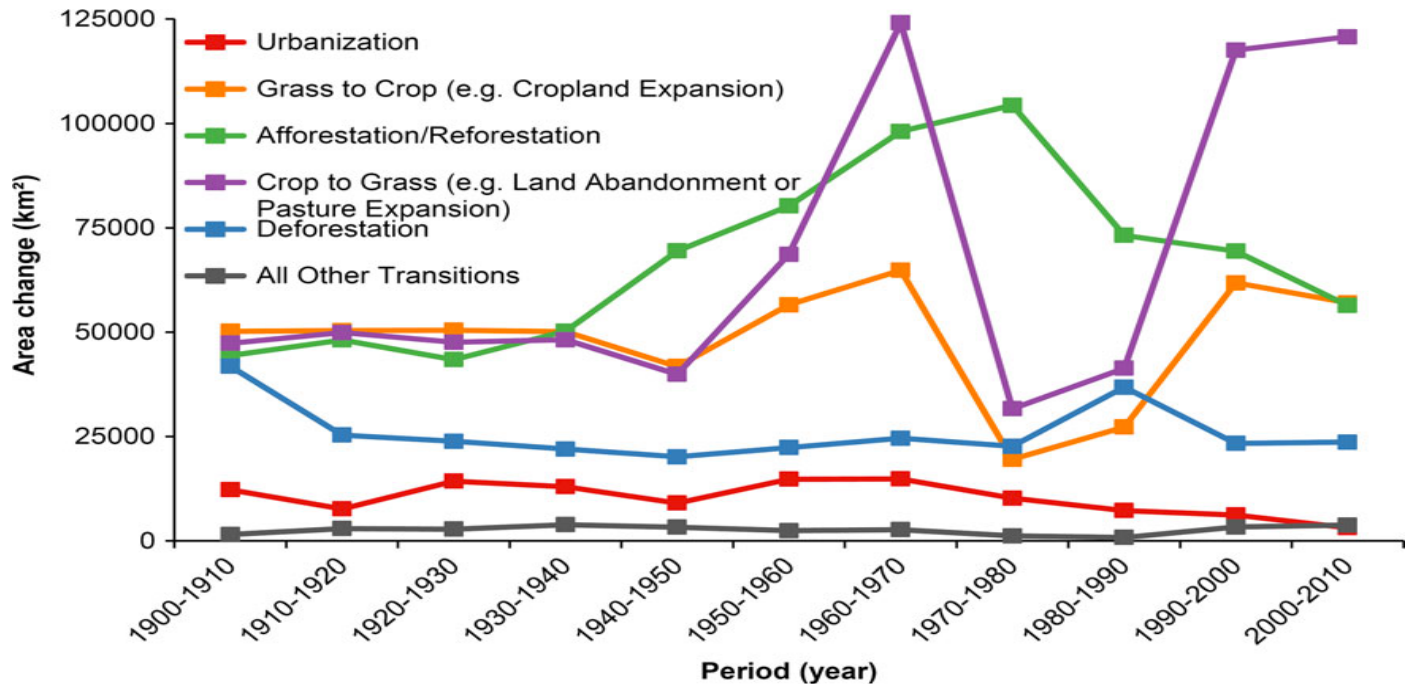


# Few major drivers of the C-cycle

Climate



Land use change



Ex: data from Fuchs et al. 2015 (HILDA)