IPSL-CCM2 Coupled Model

Climate - Carbon coupled simulations

[Overview][Publications][Runs Description][Feedback Analysis][Figures][Data][Model Description][Coupling strategy][Contact]

Overview

Atmospheric CO_2 is expected to increase in the coming decades due to emissions of CO_2 by fossil fuel burning and land use changes. The rate of increase depends on anthropogenic emissions and on the capacity of the oceans and the land biosphere to take up CO_2. Current climate models predict a mean temperature increase of 1 to 4.5° C compared to the present for a doubling of atmospheric CO_2. Recent carbon cycle studies suggest that such climate change may reduce the uptake of CO_2 by the ocean or the land biosphere. It is thus necessary to account for the climate impact on the carbon cycle when translating anthropogenic emissions into CO_2 concentrations, which has not been done yet.

In order to address the climate-carbon cycle feedback, we coupled the AOGCM climate model from IPSL with a land and an ocean carbon cycle model. The carbon cycle and climate model (COAGCM) is forced by emissions, as in the real world, and the atmospheric CO_2 growth rate is calculated as the difference between prescribed anthropogenic emissions and calculated land and ocean uptakes. Therefore, CO_2 and climate are both predicted by the COAGCM.

Two climate-carbon coupled runs are performed, the control run with no anthropogenic emissions, and the scenario run where emissions are taken from IPCC (observed for 1850-1995 and IPCC SRES98 A2 scenario onward) for the 1850-2100 period. Additional runs are perfromed for feedback studies.

Our model reproduces the observed global mean temperature changes and the growth rate of atmospheric CO_2 for the period 1860-2000. For the future, we simulate that the climate change due to CO_2 increase will reduce the land carbon uptake, leaving a larger fraction of anthropogenic CO_2 in the atmosphere. By 2100, we estimate that atmospheric CO_2 will be 18% higher due to the climate change impact on the carbon cycle. When analysing the climate-carbon cycle feedback and the respective role of land and ocean, we show that the overall effect results from two antagonistic mechanisms. Climate change reduces land carbon uptake. However, this accelerates the atmospheric CO_2 increase which, in turn, enhances ocean and land uptake of CO_2 .

More (Models, Spin up, Forcing, Control run)

A review of Sinks for Anthropogenic Carbon in Physics Today with some of ours results

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Publications

- IPSL-Hadley comparison paper
  Tellus, april 2003, 55B (2), pp. 692-700
  How positive is the feedback between climate change and the carbon cycle.
  Friedlingstein, P., J.-L. Dufresne, P.M. Cox, and P. Rayner (pdf) ,

- On-line simulation paper
  Effects of climate change due to CO2 increase on land and ocean carbon uptake.
  Dufresne JL, Friedlingstein P, Berthelot M, Bopp L, Ciais P, L. Fairhead, H. LeTreut, P. Monfray
  Geophys. Res. Lett., **29**(10), 10.1029/2001GL013777, 23 May 2002
  Text and figures: (pdf) , (ps)
  " *© 2002 American Geophysical Union. Further reproduction or electronic distribution is not permitted.*"

- Off-line simulation paper
  Positive feedback between future climate change and the carbon cycle.
  Friedlingstein P, Bopp L, Ciais P, Dufresne JL, Fairhead L, LeTreut H, Monfray P, Orr J,
  Geophys. Res. Lett., Vol.28, No.8, pp. 1543-1546, Apr 2001
  texte in pdf or in ps file.
  "*© 2001 American Geophysical Union. Further reproduction or electronic distribution is not permitted.*"

- **Potential impact of climate change on marine export production.**
  Bopp L, Monfray P, Aumont O, Dufresne JL, Le Treut H, Madec G, Terray L, Orr JC,
  Global Biogeochemical Cycles, Vol. 15, No. 1, pp. 81-99, Mar 2001
  pdf file of texte and figures

- **Atmosphere-Biosphere feedbacks paper** (for Bonn meeting)

Bonn Paper

- **Climate-carbon feedbacks associated with CO2 anthropogenic emissions using the IPSL coupled model: an amplification effect?**
  J.L. Dufresne, P. Friedlingstein
  Lettre IGBP-France, N.11, Novembre 2000
  Texte in pdf or in ps file.
  Texte en français ici ou au CNRS

Runs Description

run code	run name	CO2 emission	CO2 concentration	coupling between carbon and climate
LF7	control	fixed, no emission	computed	coupled
LF8	scenario	fixed, anthropogenic emissions	computed	coupled
LF9	prescribed climate	fixed, anthropogenic emissions	computed	uncoupled, climate from the control run
LFA	-	fixed, no emission	computed	uncoupled, climate from the scenario run
LFB	prescribed CO2	inferred from carbon balance	taken from the fixed climate run	uncoupled, climate from the scenario run

- Anthropogenic emissions follow estimation for the historical period and the IPCC SRES98-A2 scenario after year 2000.
- CO2 is the only greenhouse gaz considered.
- Model Description
- Schematic of the four simulations. Each simulation is associated to a given color. The boxes exhibit a specific variable or subpart of the earth system. Box color indicates which simulation provides the data.
  gif or postscript files

Feedback Analysis

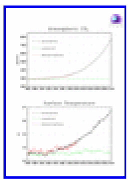
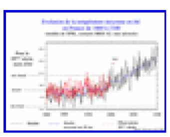
run difference	Name	CO2 emission	CO2 concentration	Climate	Feedback mechanism
LF8-LF7	**Coupled change**	-	-	-	coupled climate change and CO2 change du to CO2 emission
LF9-LF7	**CO2 change without climate feedback**	-	-	same	CO2 change du to CO2 emission without the influence of climate change du to CO2 emission
LF8-LF9	**Climate impact on CO2**	same	-	-	overall impact of climate change (du to CO2 emission) on CO2 uptake
LFB-LF9	**Direct climate impact on CO2**	-	same	-	direct impact of climate on CO2 uptake, du to CO2 emission
LF8-LFB	**Indirect climate impact on CO2**	-	-	same	indirect impact of climate on CO2 uptake, du to CO2 emission. (i.e. impact

					of CO2 increase du to climate change).

Figures

[Time Series], [Zonal Mean], [Maps], [EOF Analysis], [Others]

Time Series (1860-2100)

- 
  • **Atmospheric CO2 and global mean surface temperature** time series for the scenario run, for the control run, and comparison with observations
  • Séries temporelles de la **concentration de CO2 et de la température moyenne de la surface de la Terre**, pour la simulation de controle (pas d'émission de CO2 dues aux activités humaines), pour la simulation scenario, et observées
  gif, ps, jpeg files
- 
  • **Mean summer surface temperature over France** time series for the scenario run
  • Série temporelle de la **température éstivale moyenne, en France**
  gif, eps, ppt, pdf files
- **Carbon change time series :**
  - **Carbon budget**
    Left axis (gTC) : red: emissions, green: biosphere, dark blue: ocean
    Right axis (ppmv) : light blue : simulated atmospheric CO2, black : observed atmospheric CO2
    [gif] or [ps] files
  - **Carbon budget (IPSL compared with Hadley Center)**

Color scheme as above.
[gif] or [ps] files

- **Climate impact :**
  (a) on Atmospheric CO2. [gif] or [ps] files
  (b) on Carbon budget [gif] or [ps] files
  (c) on Carbon uptakes [gif] or [ps] files

- **Direct and indirect climate effect : Distribution of the CO2 anthropogenic emission between the three carbon reservoir (atmosphere, biosphere, ocean). On the right side of the figure are zoomed the difference between the simulations results, and illustrated in terms of the two different component of the climate change impact on the carbon cycle : direct climate impact and indirect impact through the climate driven atmospheric CO2 change.**
  [gif] or [ps] files

- **Climate change time series :**
  - **Sea-ice :**
    - **Maximum (thick line) and minimum (thin line) sea-ice extent, for the control (solid line) and the scenario (dashed line) run, in Artic and Antarctic. Five year running mean.**
      gif or eps files
    - **Relative change, respective to the control run, of the sea-ice volume, sea-ice extent and the seasonal cycle of the sea-ice extent :**
      in Artic gif or eps files
      in Antarctic gif or eps files
- **Feedbacks**
  - **sensibilities (dC/dT and dT/dC), gain and amplification factor for offline (solid line) and online (dashed line) simulations**
    gif or postscript files

Zonal Mean

Control Run

- **Comparison between the simulation and the ERBE data zonal average mean TOA :a)radiation budget (Wm/2)b) net incoming SW (thin lines) and output LW (thick lines) TOA (W/m2)**
  gif or postscript files
- **Net shortwave incoming (thin lines) and longwave outgoing (thick**

lines) flux (W/m2) at the top of atmosphere as observed by ERBE (long dash), as computed by the atmospheric model in the coupled run (continous line) and in a forced control simulation (short dashe). In a) during the australe winter (JJA) and in b) during the asutrale summer (DFJ).
gif or postscript files

Maps

Scenario Run

- **Surface temperature difference between periode (1979:1998) and periode (1860:1940). IPSL model and observations (Johns et al. 1994, Parker et al. 1994).**
  gif or postscript files
- **Surface temperature (Top) and precipitaion (Bottom) difference between the scenario and the control run, around year 2100 (10 year mean, 2090-2099).**
  gif or postscript files
- **An other surface temperature (Top) and precipitation (Bottom) difference between last ten years and first ten years of simulation.**
  gif or postscript files
- **SST (left) and SST difference (right) between the scenario and the control run, around year 2100 (10 year mean, 2090-2099). Top : january to april mean. Botom : jully to october mean.**
  gif or postscript files
- **Regional fluxes (in GtC/yr) in 2030-2050 from LF8 (red), LF9 (black) (Top), and regional climatic effect (green) and additional CO2 effect (blue) (Bottom) (M. Berthelot and L. Bopp).**
  gif or postscript file

Control Run

- **Difference between control run SST and Levitus SST (black/white)**
  gif or postscript files

- **DJF and JJA precipitaion for the control run.**
  gif or postscript files

- **Interannual surface temperature variability (RMS of the detrend annual mean temperature). Model (control run, 190 years) and observations (40 years : 1860-1998) (Johns et al. 1994, Parker et al. 1994).**
  gif or postscript files

- **Antarctic sea-ice fraction and thickness, in february (minimum) and september (maximum)**
  gif or postscript files

- **Arctic sea-ice fraction, in february (maximum) and september (minimum)**
  gif or postscript files

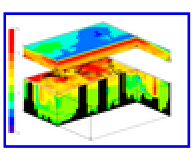
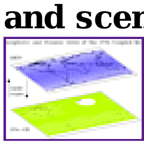
- **Arctic sea-ice thickness, in february (maximum) and september (minimum)**
  gif or postscript files

EOF Analysis

EOF (maps) and time series (PC, principal components)

- **Biopshere, annual NEP. Filtered following Lat and Lon over 5 points. Filtered following time over 5 points. Four first EOF.**
  - **LF7 , 3 first EOFs: [gif] , [ps],**
  - **LF8 , 4 first EOFs: [gif] , [ps],**
  - **Coupled climate/carbon change (LF8-LF7) , 4 first EOFs: [gif] , [ps],**
  - **NEP change without climate feedback (LF9-LF7), climate impact on NEP (LF8-LF9), direct climate impact (LFB-LF9) and indirect climate impact (LF8-LFB) [gif] , [ps],**

Other figures

-  **3D plot of the temperature difference beween control and scenario around year 2100 (By Laurent Fairhead)**
-  **The Atmospheric and Oceanic Grids (By Laurent**

Fairhead) [gif] , [png] , [ps]

-  **Time evolution of CO2, surface temperature change and climate impact on land carbon cycle**

Data access on the web

Monthly and annual means for the following variables are readily available.

- **Data access via FTP: at LMD or at IDRIS**
- **Data access via DODS at LMD or at IDRIS**

Contact

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