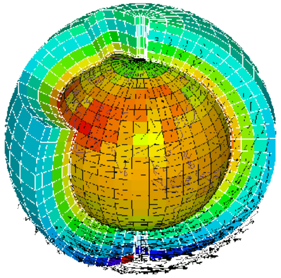
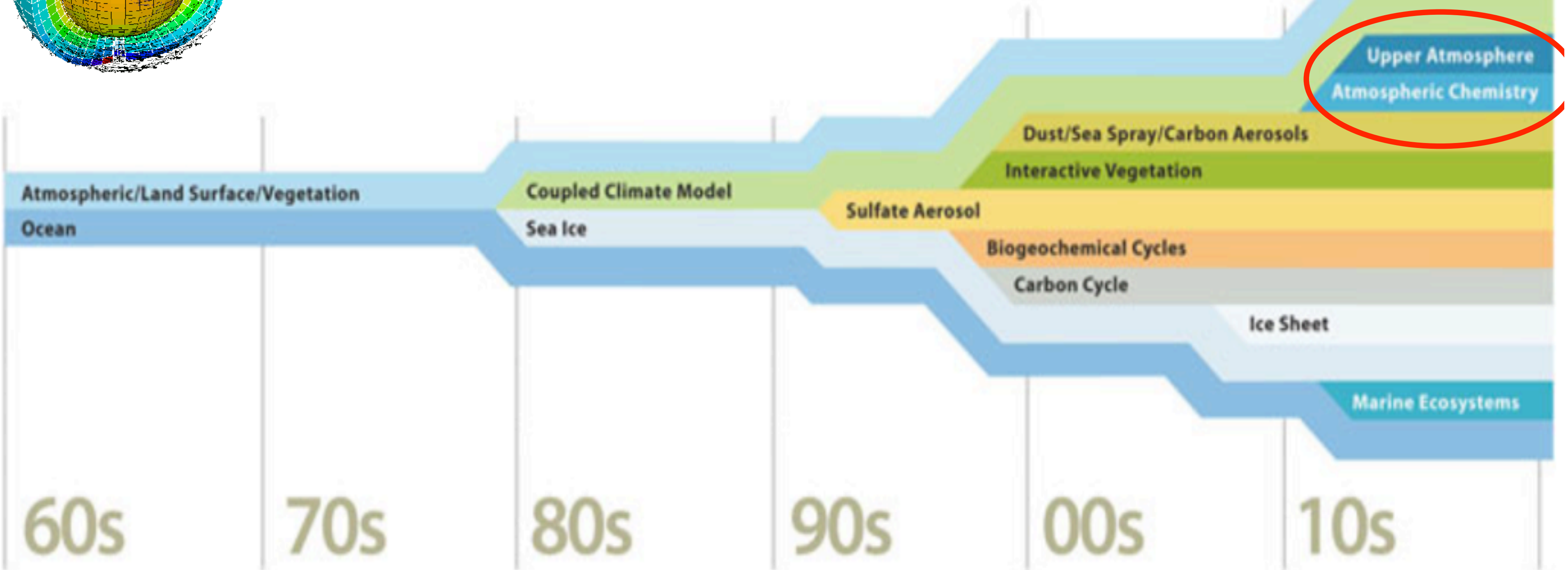
Axe 3 : Simulation of the Cenozoic atmospheric chemistry and its interactions in the Earth System



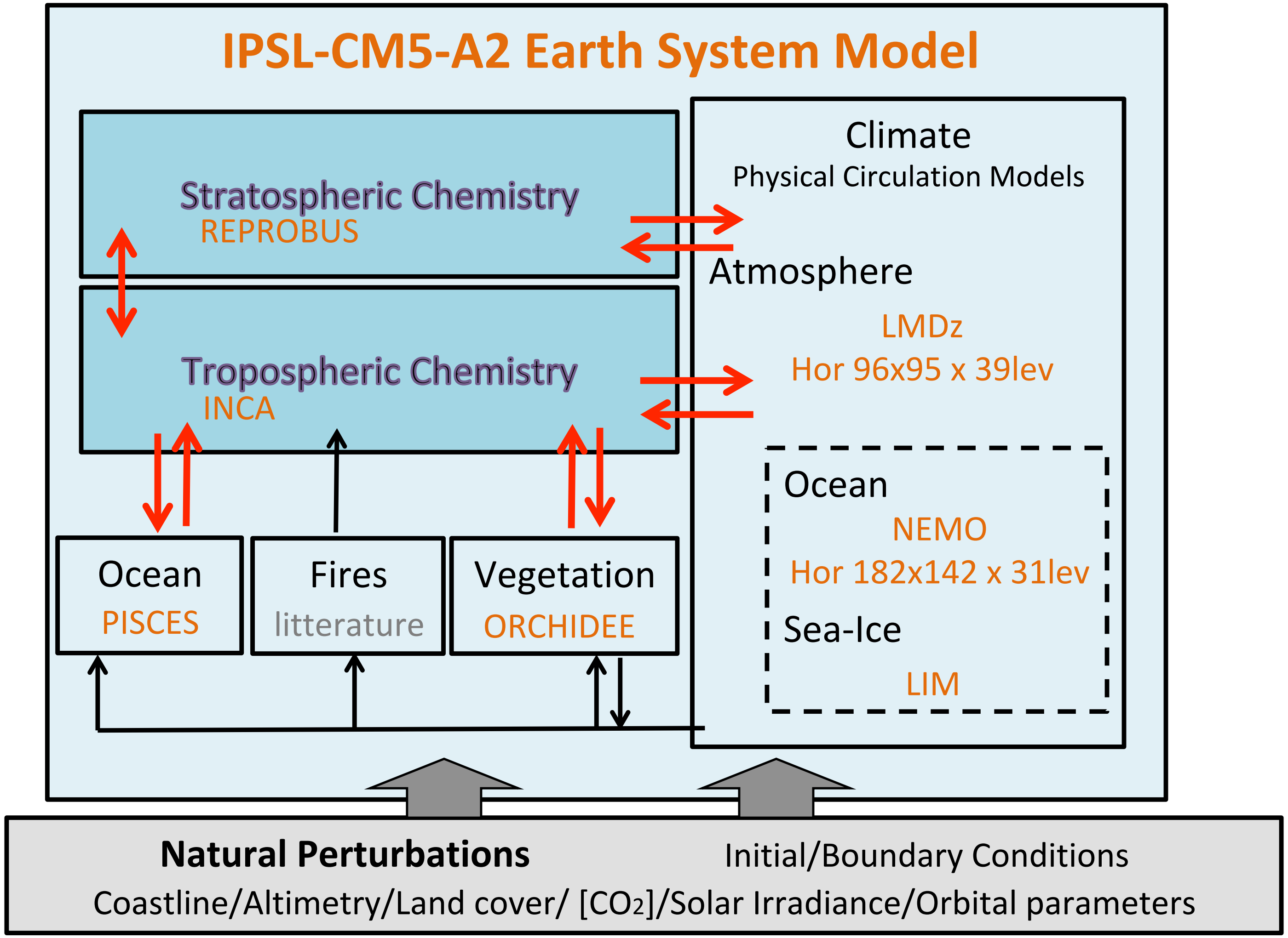
Chemistry-Climate- interactions in Earth System Models (ESM)



Schematic of components. Evolution of the parts of the Earth system treated in climate models over time. (Source UCAR)

⇒ **Implementation of atmospheric chemistry in many of them**

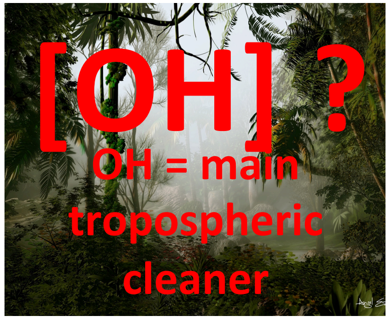
⇒ **BUT NOT CONSIDERED IN PAST CLIMATE STUDIES**

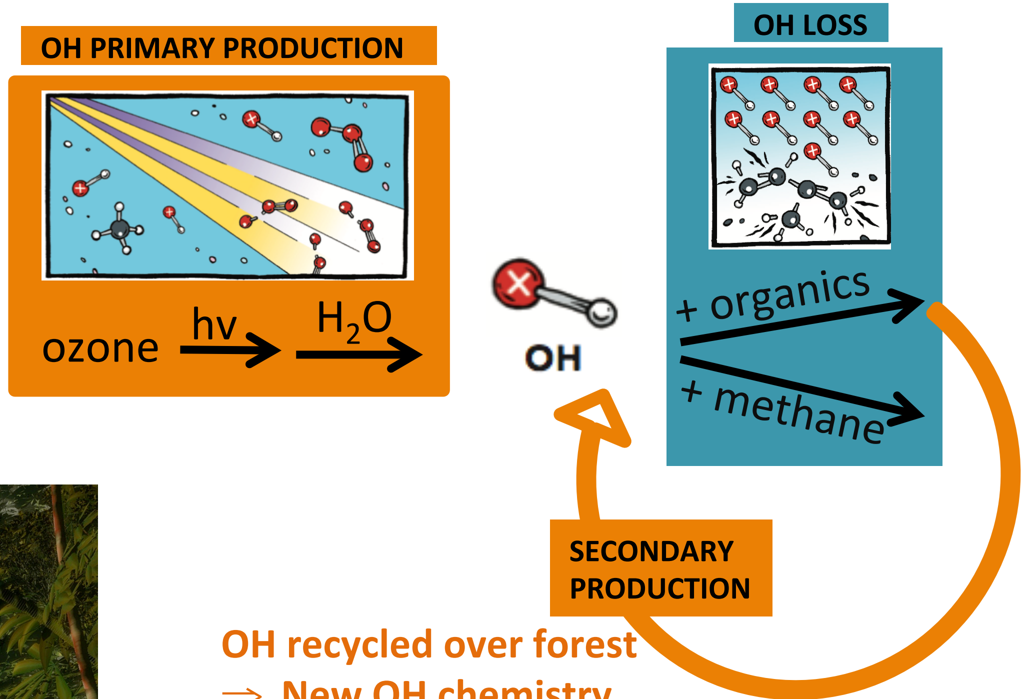


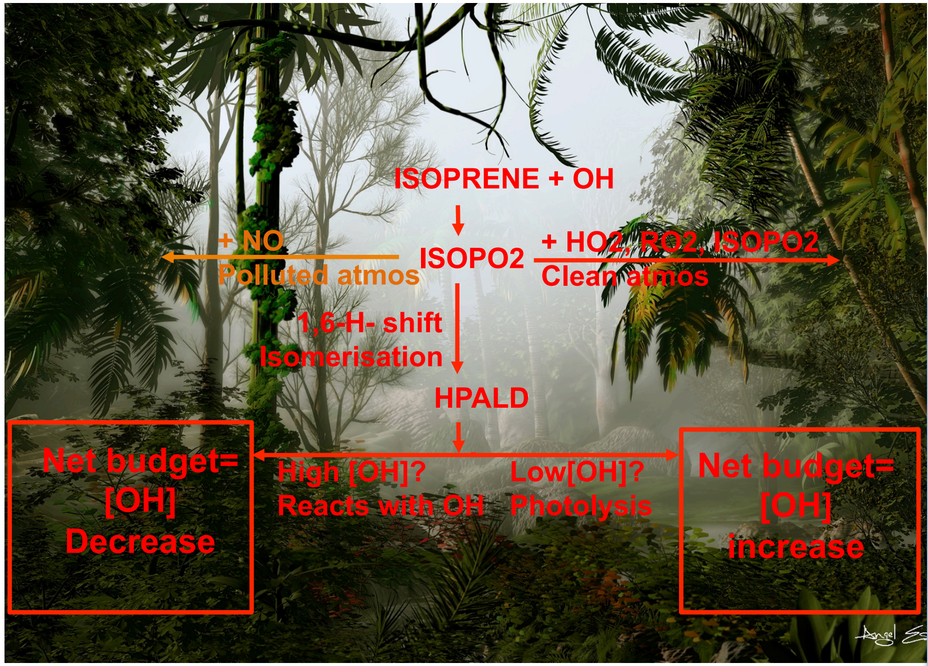
- Couplage entre chimie (strato et tropo) Xuezhou LU et Anne COZIC
- Mise en place d'une config avec ocean et autres composantes du système Terre au sein de IPSL-CM5-A2, Xuezhou LU et Anne COZIC
- Emissions océaniques dynamiques Ludivine CONTE, Laurent BOPP, SSz
- Chimie dédiée aux atmosphères faiblement polluées Cyril KARAM, SSz

Recent progress in natural photooxidative atmospheric chemistry

Oxidizing Capacity (=self-cleaning) …







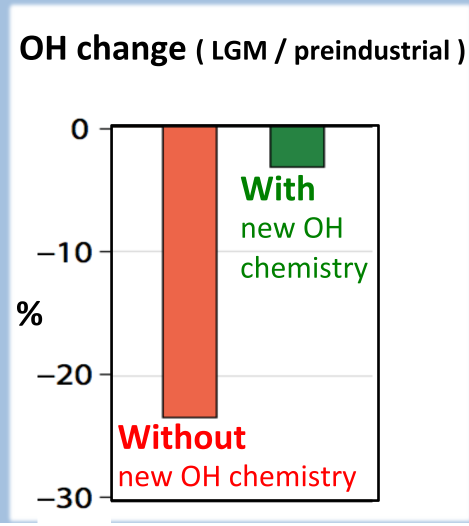
TRAVAIL DE Cyril KARAM (doctorant)

Past COLD climates

Last Glacial Maximum

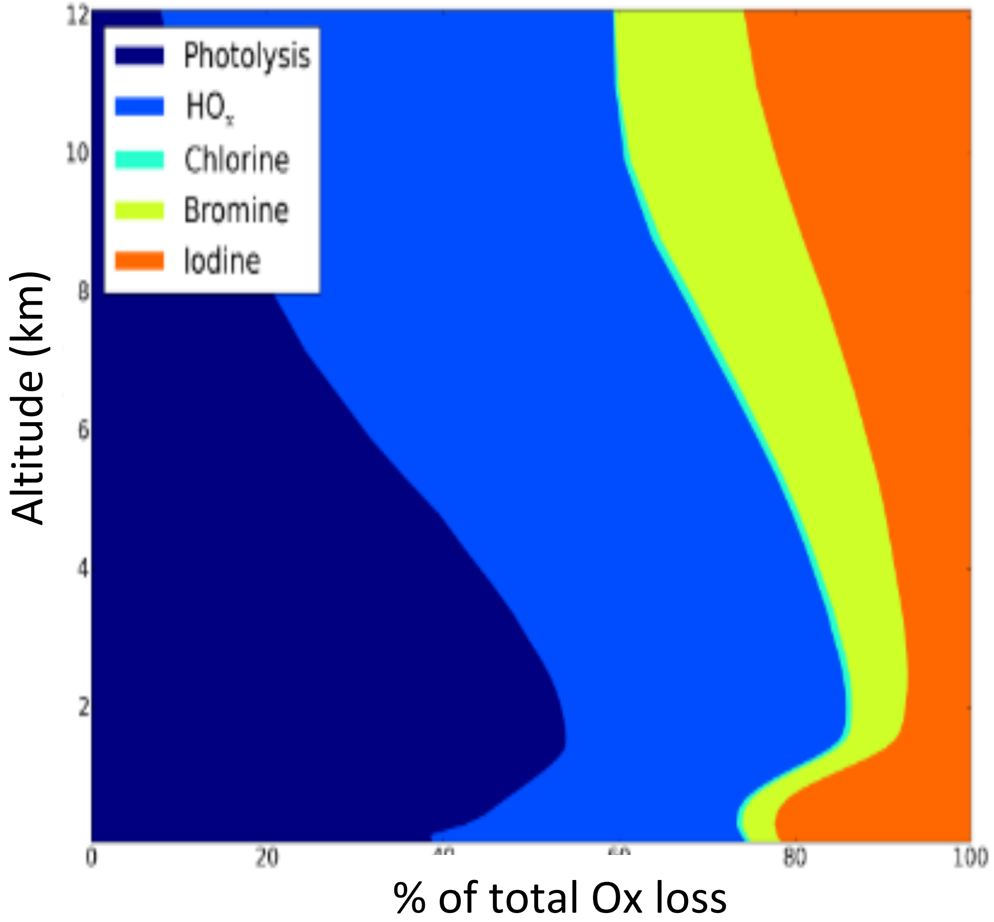
New OH chemistry dramatically alters the sensitivity of oxidizing capacity to global changes

Achakulwisut et al. 2015



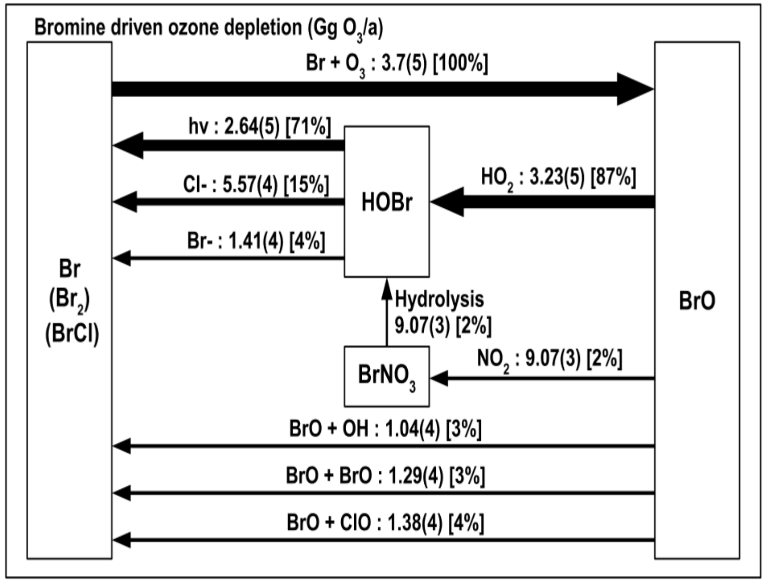
Recent progress in natural photooxidative atmospheric chemistry

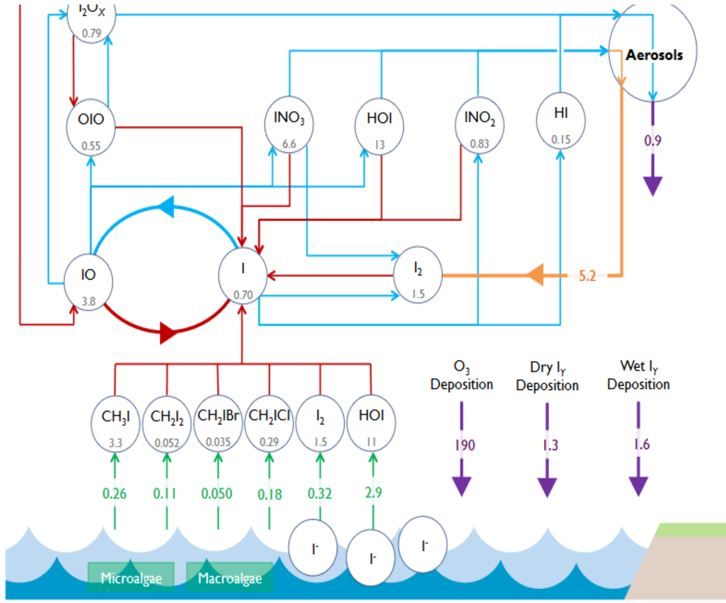
⇒ **Importance of marine halogenated compounds in the troposphere**



Global Annual-average tropospheric vertical odd oxygen loss (Ox) hrough different reaction routes (Photolysis, Hox, Iox, BrOx and ClOx) from Sherwen et al. 2016

Implementationde la chimie de l'Iode et du Brome
TRAVAIL DE Cyril KARAM (doctorant)





+ Other progress in chemistry of oxidants (Criegee, peroxy radicals, etc.)

Perspectives: Interactions biosphère /chimie atmosphérique

avec **biosphère terrestre**
J. Lathière

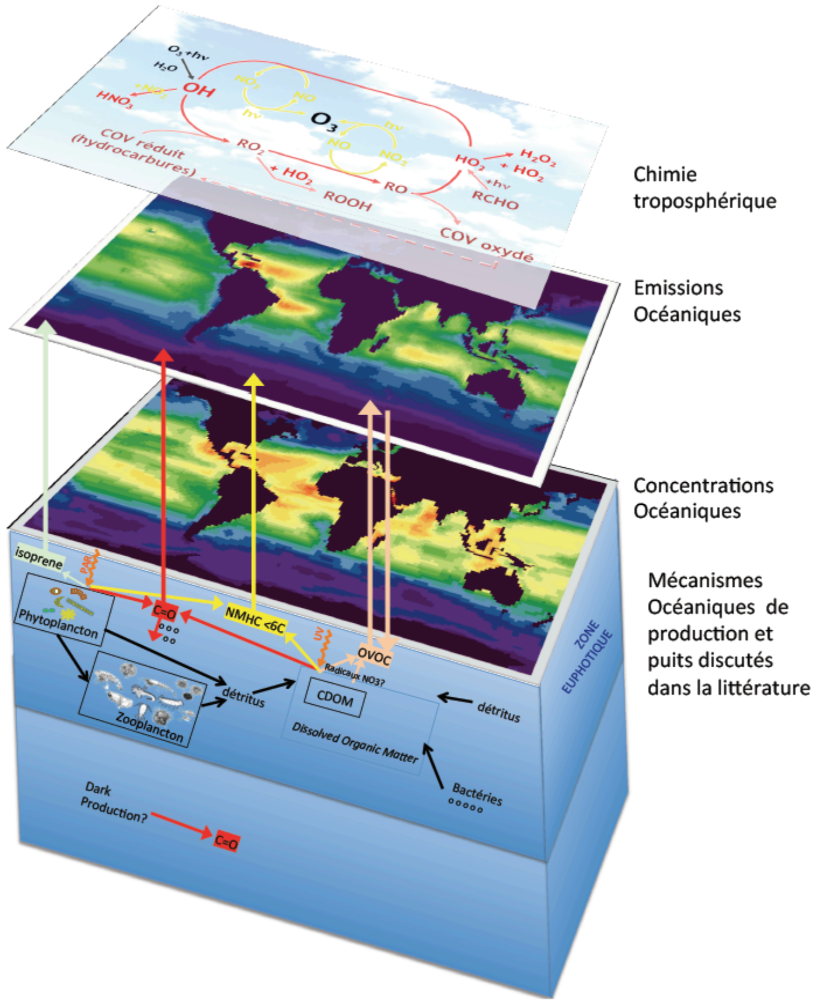
Tropospheric Chemistry

Émissions
- Facteur d'émissions à jour (Messina et al. 2016)
- Inhibition des émissions par CO_2

Impact O_3 végétation

Végétation
Modèle de végétation dynamique ORCHIDEE

avec **biosphère marine**
L Conte/ L Bopp



Methods

NEMO-PISCES model :

- A global circulation model (NEMO) and a Biogeochemical model (PISCES)[17]
- 2 phytoplankton groups / 3 non-living organic matter pools / 5 nutrients
- Run for 3000 years to reach equilibrium using a mean climatology
- Resolution : 2° x 2°cos(lat) with 31 vertical levels

Dynamical oceanic emissions of tropospheric chemistry reactants

TRAVAIL DE Ludivine CONTE (doctorante)

Processes Affecting oceanic CO concentration :

Photo-dissociation of Colored Dissolved Organic Matter | Biological-production By Diatoms and Nanophytoplankton | Bacterial Sink | Ocean-Atmosphere flux

$$\frac{\partial CO}{\partial t} = [E_{co} \times A_{CDOM} \times AQY] + [\tau_{Diat}[Diat] + \tau_{Nano}[Nano]] - [k_{Bact}[CO]] - [k_{flx}(CO_w - H.pCO_a)]$$

- E_{co}: Irradiance (290-490 nm)
- A_{CDOM}: Absorption coefficient of CDOM (Depends on chla[7])
- AQY: Efficiency of CDOM to produce CO[8,9]
- τ_{Diat}, τ_{Nano}: with Constant Rates[6] (CO might be a by-product of phytoplanktonic activities)
- k_{Bact}: Constant Rate = 0,8 d-1 OR depending on temperature and chla[10]
- k_{flx}: Transfert velocity (Depends on Temperature and Wind Speed[11])
- H: Solubility = f(Temperature, Salinity)[12]
- pCO_a: Partial pressure in Atmosphere (Mixing ratio = 90ppbv)

We used in situ measurements of surface CO concentration to evaluate simulated concentrations

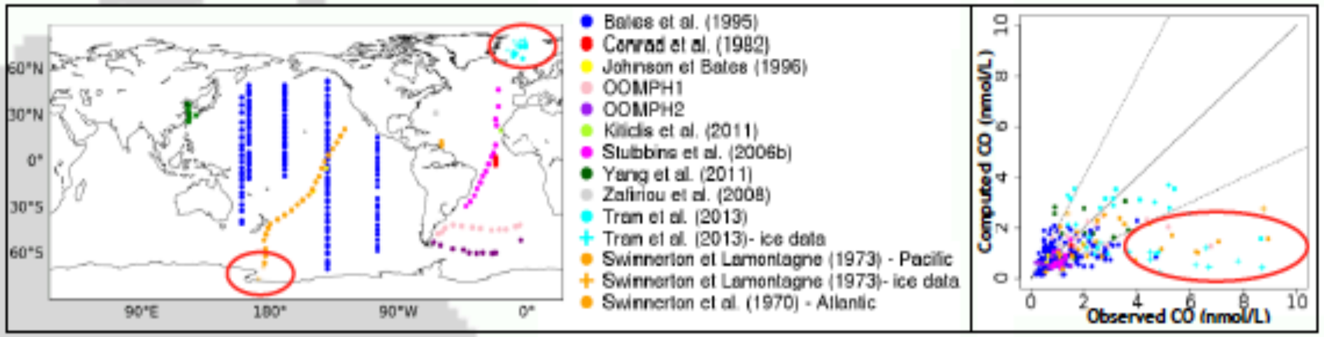


Figure 2 : Left : Position of in situ measurements of surface CO concentrations, used to evaluate computed concentrations. Right : scatter plot of computed versus observed surface CO concentrations for a run with a mean bacterial consumption rate of 0,8d-1 (RMSE = 1,38). Colors refer to the origin of the data. Red circles show polar datas.

- High in situ data (up to 9 nmol/L) in polar regions (red circles), are not accurately represente
- Those polar data present a large spatial and temporal variability and suggest specific CO prod involved in ice-covered regions

Dynamical oceanic emissions of tropospheric chemistry reactants

How Emissions respond to Climate Change ?

- We performed two long runs (from 1850 to 2100) :
  - => one with a constant pre-industrial atmospheric CO_2 concentration (285 ppm)
  - => one with an increasing CO_2 concentration corresponding to RCP 8.5 (up to 936 ppm)
- The global CO flux increases by 15,6% under an increasing atmospheric CO_2 (Figure 5)
- The global budget of biological sources and sink show little change

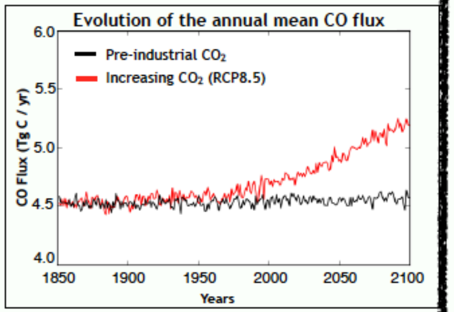


Figure 5 : Temporal evolution of the mean annual CO flux (TgC/yr). Red: with climate change under RCP8.5 scenario. Black : with constant pre-industrial CO_2 concentration. Positive flux is toward the atmosphere.

- Attribution of the rise of the global CO flux to a combination of physical processes :

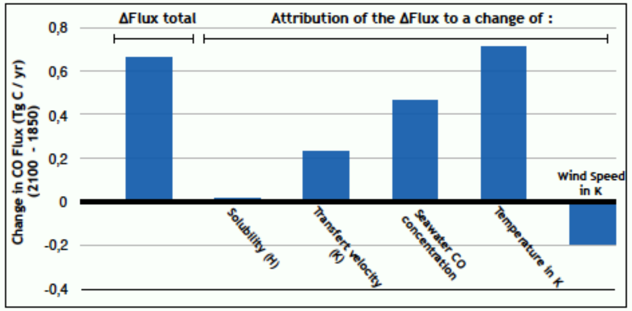


Figure 6 : Change in the ocean-atmosphere CO flux (TgC/yr) : calculated by PISCES or recalculated offline : if only H, K, or CO are changed in 2100 compared with 1850. A positive change means an increased flux in 2100 under climate change.

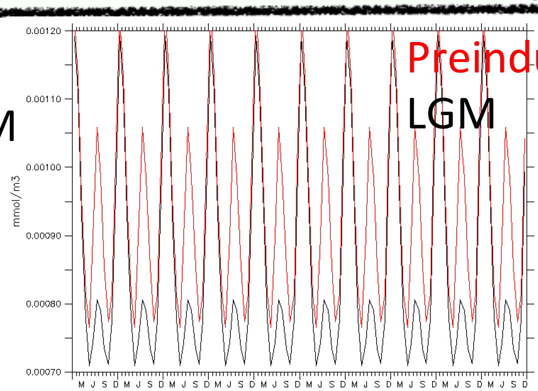
=> Solubility of CO (*H*) decreases due to a global rise of sea surface temperature

=> Transfert velocity (k_{flx}), depending on temperature and wind speed, increases

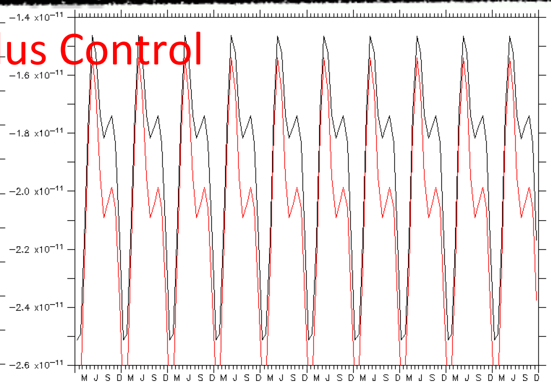
=> CO concentration in surface seawater tends to increase slightly :
Temperature ↗ => stratification ↗ => mixing ↘

=> Among those processes, the change of the gaz transfert velocity k_{flx} due to the surface temperature increase dominates to increase the CO flux towards the atmosphere (Figure 6)

Tests en conditions LGM



CO concentrations (mmol/m3)



CO flux (mol/m2/s)

Concentrations plus faibles mais export vers atmosphere plus grand

lié à augmentation des vents LGM(?)

TRAVAIL DE Ludivine CONTE (doctorante)

Réunions	dec	jan	fev	mars	avr	mai	juin	juil	aout	sept	oct	nov	dec	jan	fev	mars	avr	mai
Axis 2 - Development for past pristine atmospheres																		
WP3 Chemistry Model																		
Full tropo and strato model to test on present day conditions																		
Present day climatology to be compared with observations																		
Preindustral climatology to be compared with observations and to multimodel experiment (few data)																		
Evaluation of the model performance for present-day and preindustrial conditions																		
WP4 New natural emissions																		
Evaluation of Biogenic emission range (from ORCHIDEE) for each scenario																		
Evaluation of Oceanic emission range (from PISCES) for each scenario																		
Evaluation of Wildfires emission range (from litterature and collaboration) for each scenario																		
Sensitivity studies to Natural emissions																		

En retard car stratégie un peu modifiée (tests sur run eocene avant tout)
(+ thèses C Karam et Ludivine Conte) mais pas de problèmes majeurs
Devlpts techniques ont bien avancé

A VENIR 12 prochains mois : evaluation du modèle de chimie et sensibilité des émissions naturelles. devrait etre OK

Réunions	dec	jan	fev	mars	avr	mai	juin	juil	aout	sept	oct	nov	dec	jan	fev	mars	avr	mai	juin	juil	aout	sept	oct	nov	dec	jan	fev	mars	avr
Axis 3 - Cenozoic atmospheric chemistry simulations																													
WP5 Paleo chemistry-Climate simulations																													
Last Glacial Maximum Simulation																													
Eemian Simulation																													
Mid-Pliocene Simulation																													
Optimum Miocene Simulation																													
Paleocene-Eocene Thermal Maximum Simulation																													
Analysis of the simulations, realism of the results, comparison with previous study and ISOTOPE																													
Climatologies of 3D distribution of reactive compounds and corresponding surface UV radiation																													
WP6 Earth System Feedbacks																													
Simulation of the climate feedback due to composition change (ESM forced by WP5 concentrations) for each of the 6 past conditions																													
Quantification of chemistry effect on climate																													
IPSL-CM5 model with interactions between: Climate and 3D atmospheric N2O, CH4, O3/Chemistry and terrestrial biosphere/Atm Chemistry and marine biogeochem																													
Simulation with the IPSL-CM5 model first with all the couplings for hot climate conditions (100 yrs + 1base line 100yr)																													
Quantification of the feedbacks																													

WP5 : priorité a été mise sur tester config Eocene, pas de probleme non résolus
Les 4 autres configs passés vont etre testés en LMDz-INCA/ LMDz-reprobus ET LMDzINCA_REPR d'ici a la fin de l'été grace aux 300000h supp obtenues sur curie

WP6 : on y pensera plutot en 2019