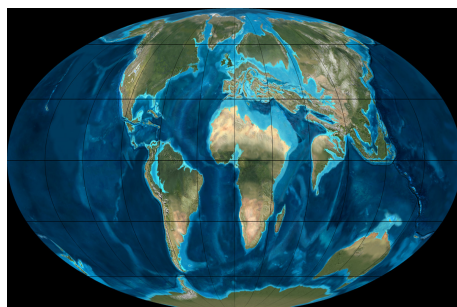
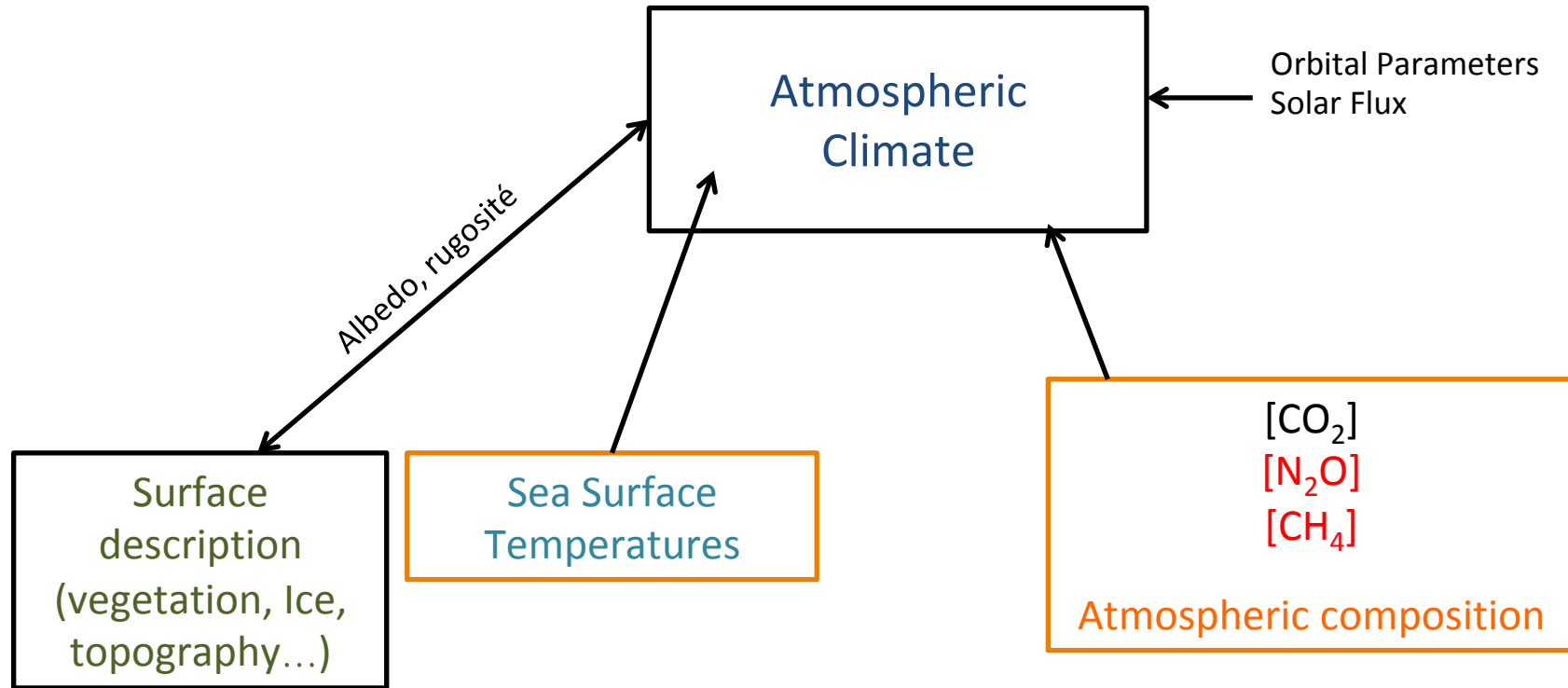
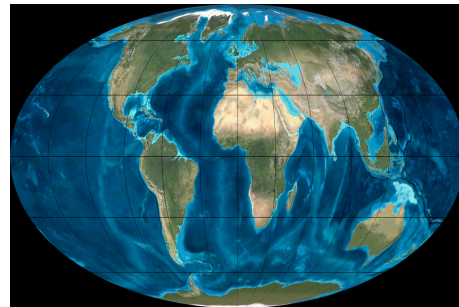


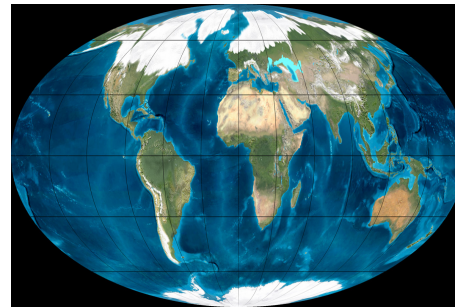
Simuler des climats (du passé)



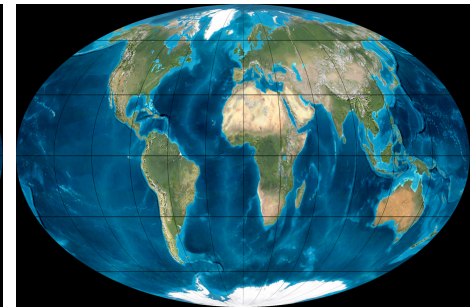
Eocene (50Ma)



Miocene (20Ma)

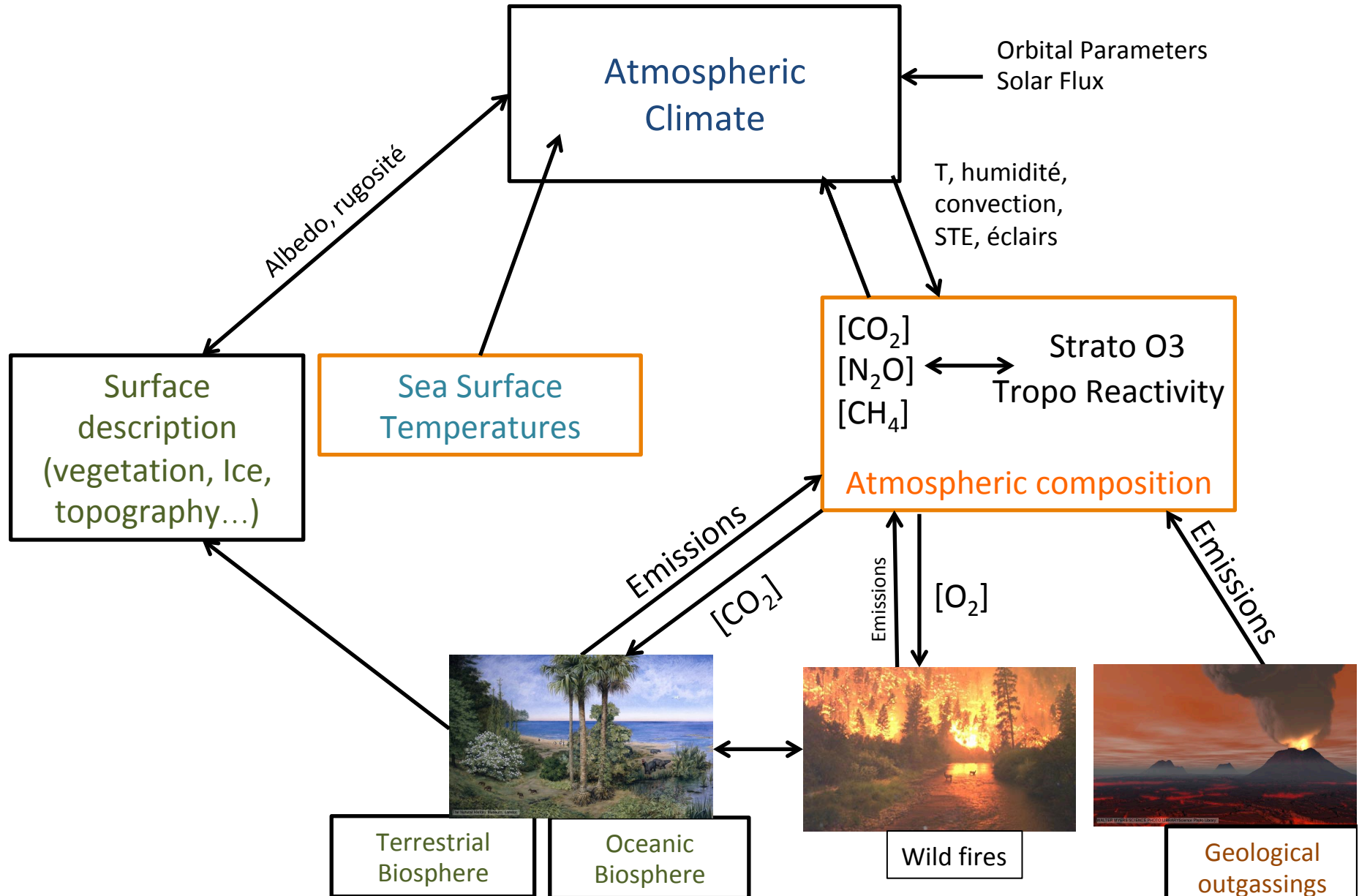


Pleistocene (50Ka)

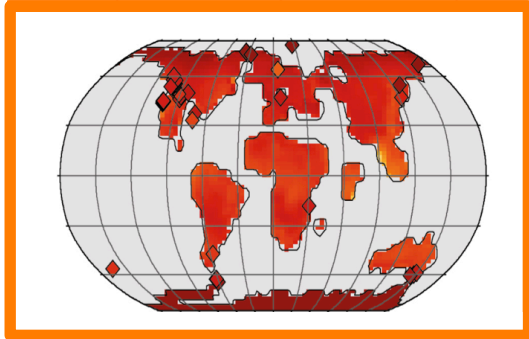


Present

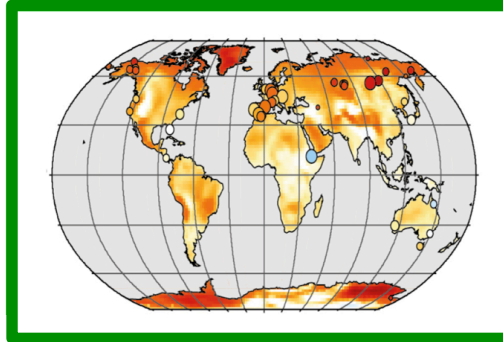
Simuler la chimie dans le contexte (des climats) du passé



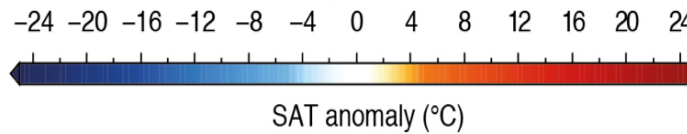
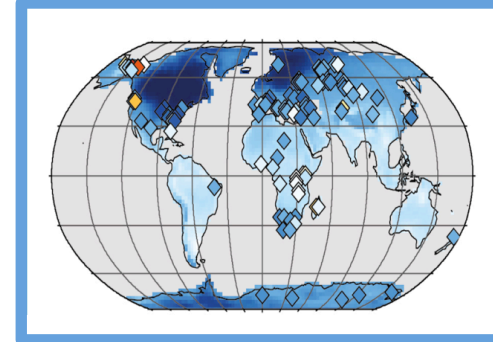
Early Eocene Climatic Optimum (54-48Ma)



mid-Pliocene warm Period (3.3-3Ma)

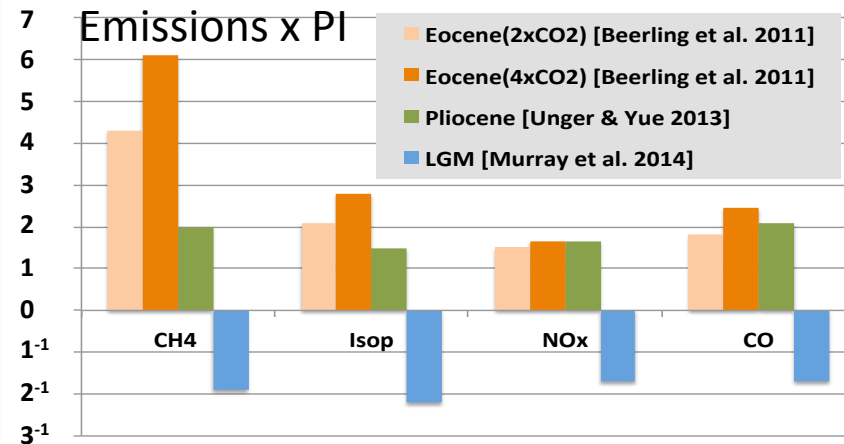


Last Glacial Maximum (21ka)

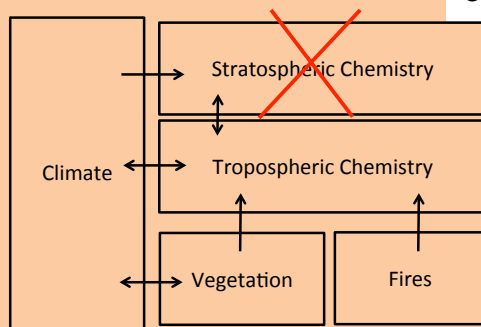


Anomalies de Surf. Air Temp. par /Preind (PI)
Données et moyennes multi-modèles
d'après Masson-Delmotte et al., IPCC 2013

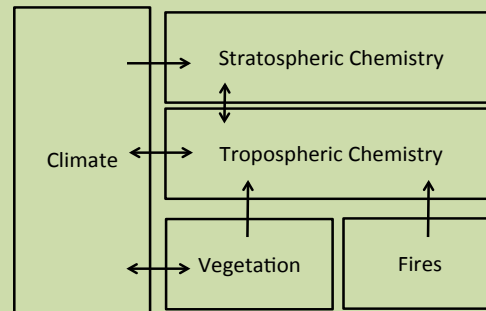
Climats chauds et humides :
+ convection => + d'éclairs
Cycles C et N plus actifs
+ de feux
+ extension végétation



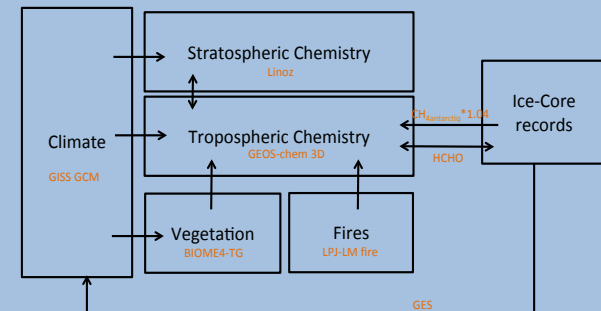
Climat froid :
- de feux,
un peu - d'éclairs
- de biogéniques?



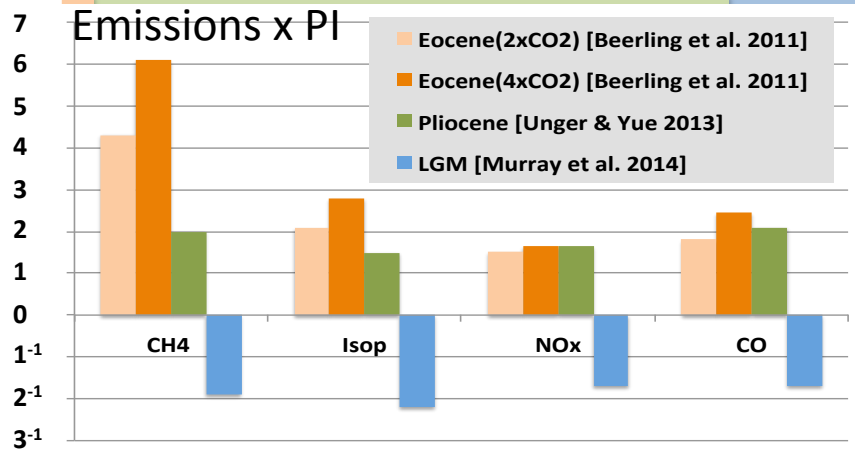
Beerling et al. 2011



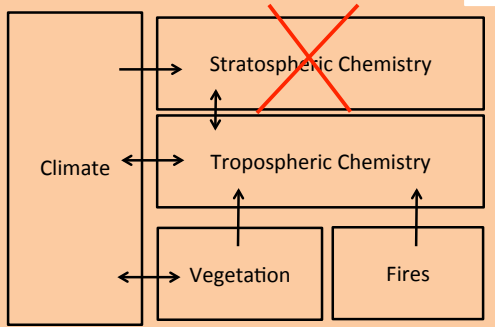
Unger & Yue 2013



Murray et al. 2014 / Achakulwisut et al. 2015



Beerling et al. 2011



Eocene

Une chimie plus rapide

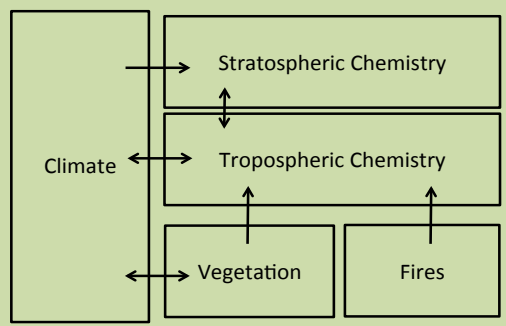
O3 et OH prod et destruction + élevée
+ de BD circulation => + de STE

Surf O3 63% + élevé qu'au PI (15-20ppb de + au dessus des forêts)
- d'OH (15 à 30%)
CH4 x4 x5

Chimie plus active mais capacité oxydante plus faible τ plus longs des composés réactifs

$\Delta T = 2.7$ K
(CH4+N2O+O3T+stratoH2O+rétroactions positives)

Unger & Yue 2013



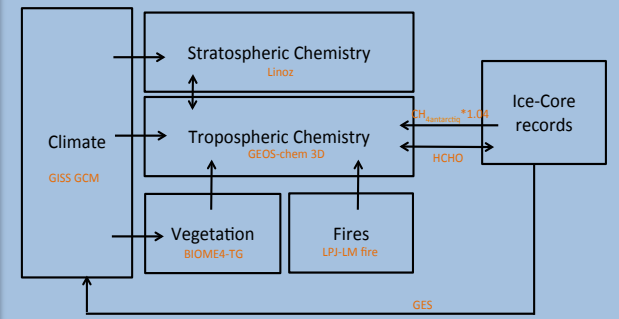
Pliocene

Masse O3 tropo 25% >PI

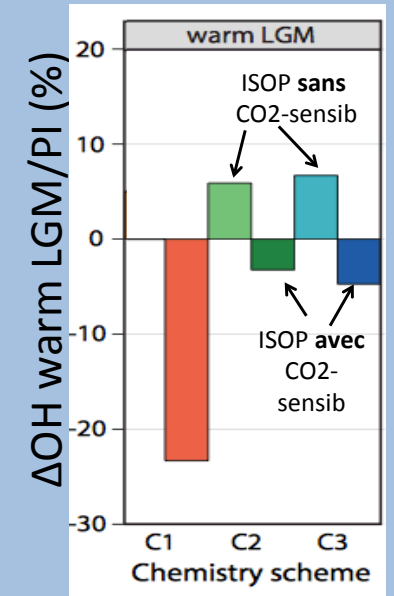
Masse O3 strato 5% >PI (car strato + froide, moins de destruction chimique) => 20% J(O3 → O1D) en moins, moins d'OH prod, moins d'OH (20%)
 τ augmentent de 20 à 30%

Forcages radiatifs N2O+CH4+trop O3 ≈ 3/4 de celui du CO2

Murray et al. 2014
Achakulwisut et al. 2015

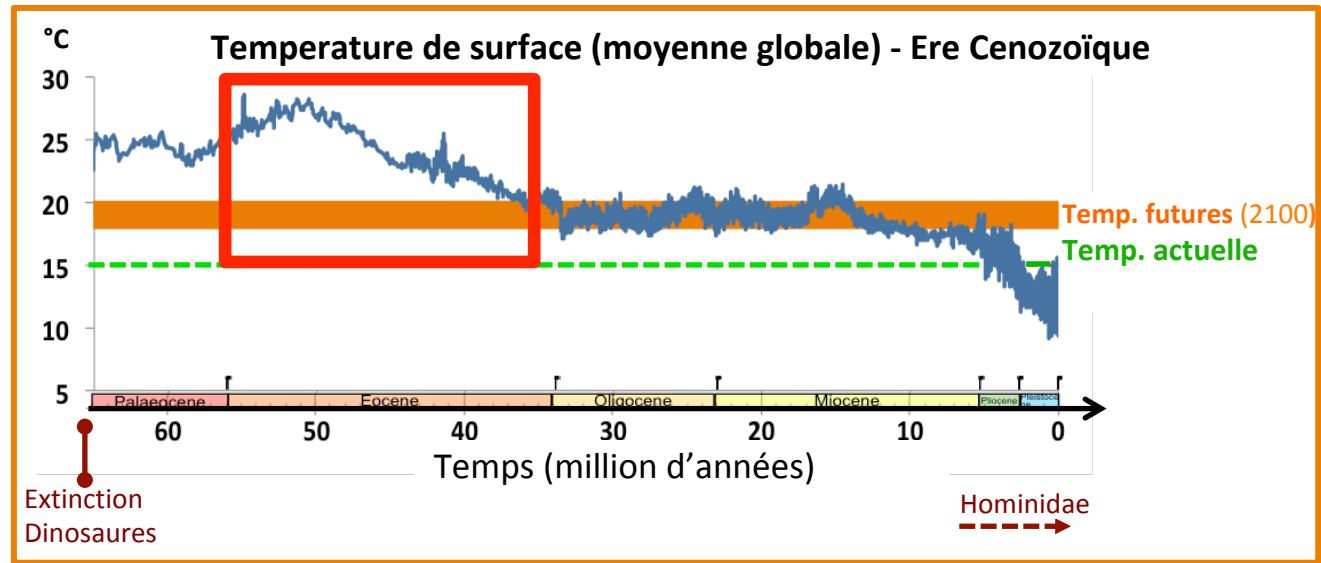


LGM

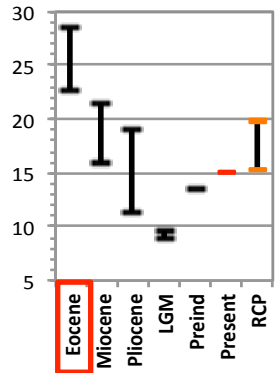


Achakulwisut et al. 2015

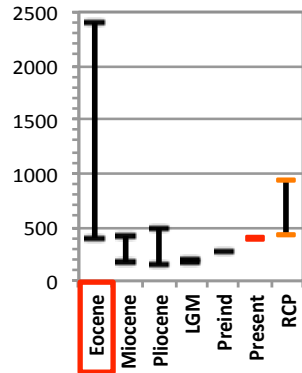
Chimie tropo à l'EOCENE



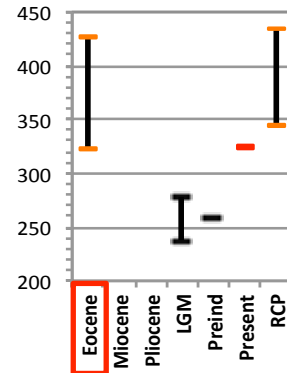
Surface Air Temperature (°C)



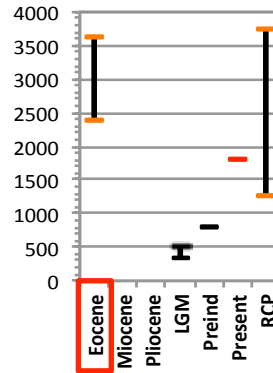
[CO₂] ppm



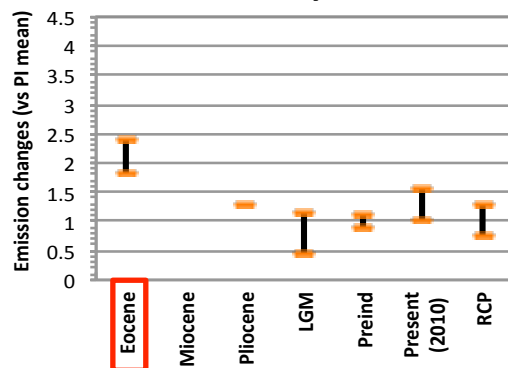
[N₂O] ppb



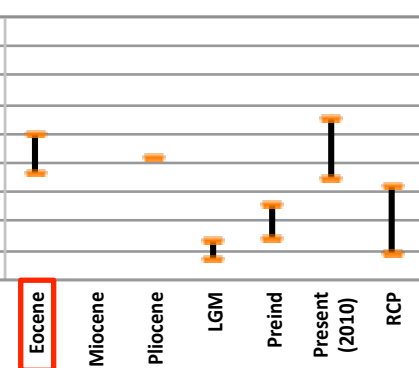
[CH₄] ppb



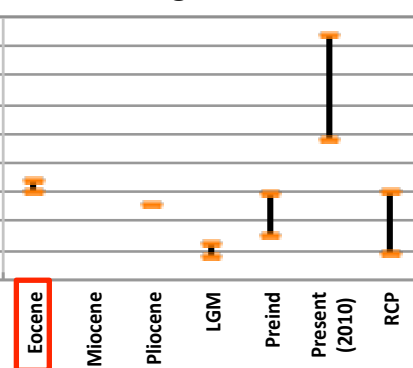
Non Methane Hydrocarbons



Carbon Monoxide

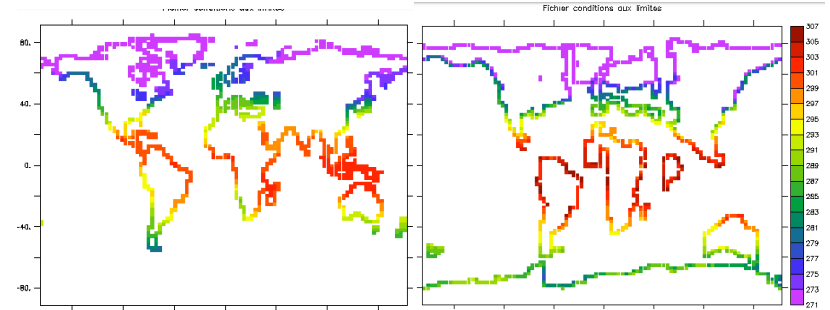


Nitrogen Oxides



En entrée du modèle de climat

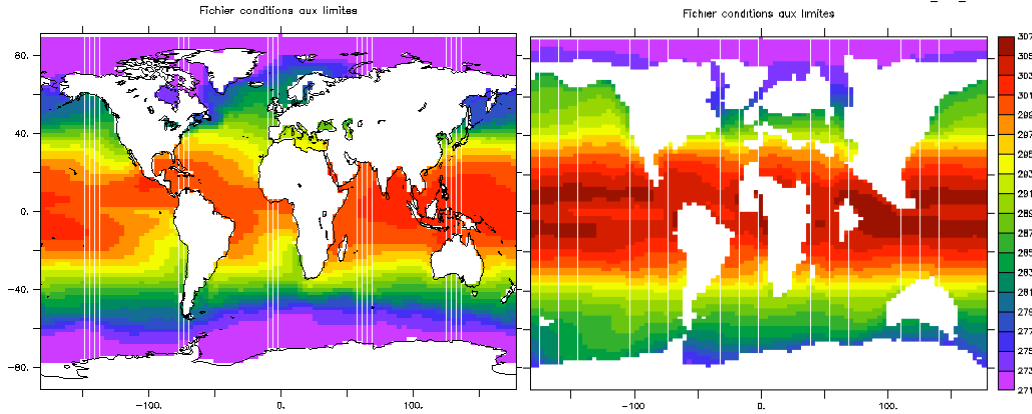
Paleogeography →



Preind

Eocene

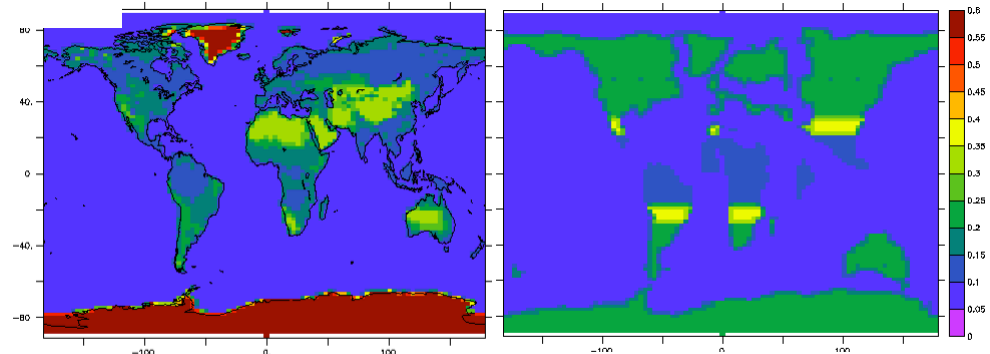
← Sea Surface Temperature



Preind

Eocene

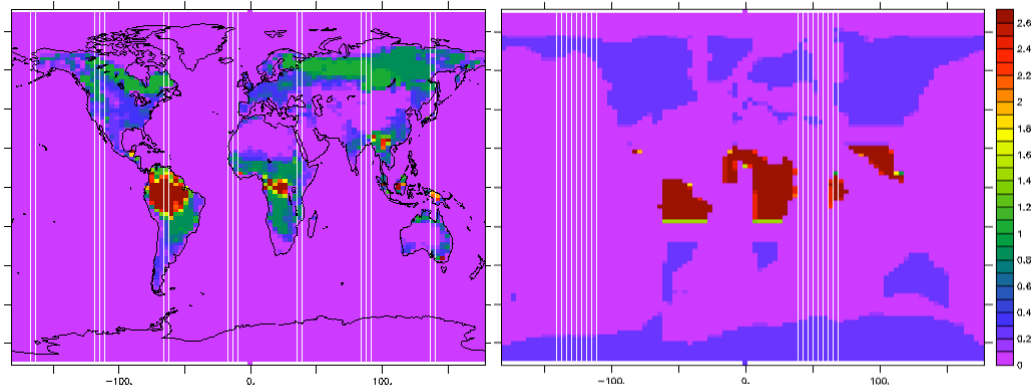
Albedo →



Preind

Eocene

← Rugosity



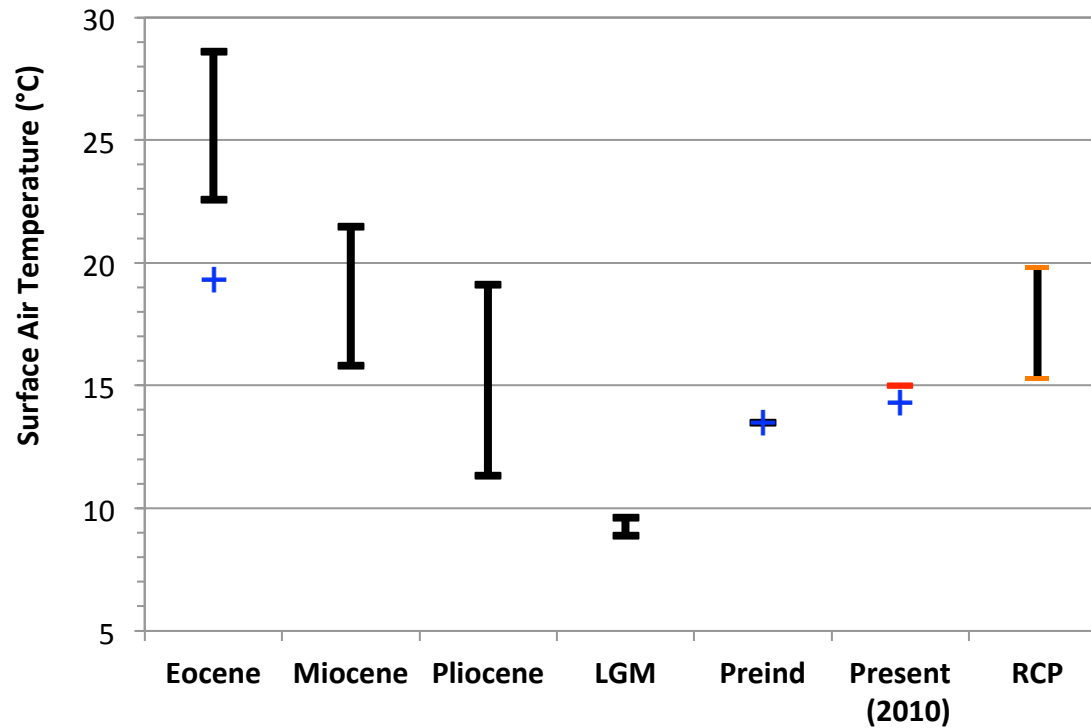
Preind

Eocene

[CO₂] = 285ppm preind pour lmdz
 [CO₂] = 1120ppm = 4x CO₂ (pas de modif N₂O et CH₄ car tout le delta GHG est mis sur CO₂)

+ changements des paramètres solaires et orbitaux (peu important ds ce cas)

En sortie du modèle de climat



Simulation	PREIND	+ 42%	EOCN sans chimie	PRESENT
H2O (mmr moy surf)	0.0093	➔	0.0132	0.0098
H2O (mmr moy tropo)	0.0023	+ 51%	0.0035	0.0024

+ simulés LMDzINCA (12 ans) pour la tropo

CH₄ INCA = 3614ppb

BVOC eocen

Autres flux= émissions préindustrielles

Souci report émissions sols/ocean sur le bon masque terre mer

Pas d'effet de la chimie sur climat

+ simulés LMDzREPROBUS (30 ans) pour la strato

Effet de la chimie sur climat

CH₄=3.614ppm

N₂O=323ppb

CH₃Br=7.006e-09

CH₃Cl=4.81642e-07

Autres CFC=0

General description		LMDz INCA	LMDz REPROBUS
Control run	preindus	x	x
	Low O ₂	x	x
	High O ₂	x	x
	Eocene clim	x	x
	Eocene clim chim	x	x

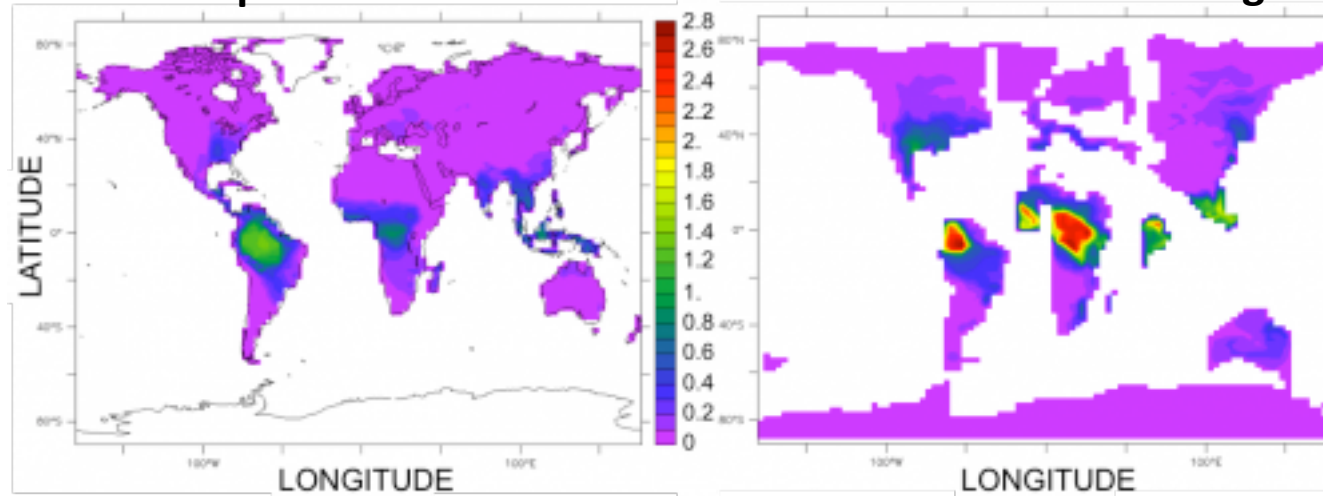
Climat eocene => TROPOSPHERE

Emissions globales d'isoprène biogénique (TgC/an) calculées par ORCHIDEE

Eocene (-55Ma)

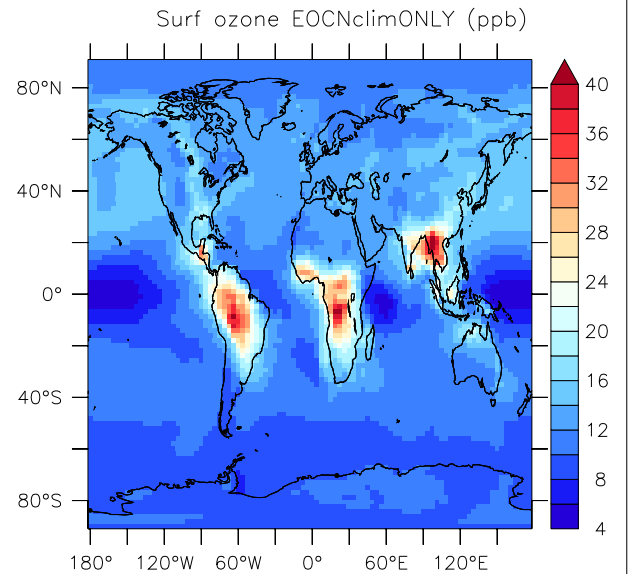
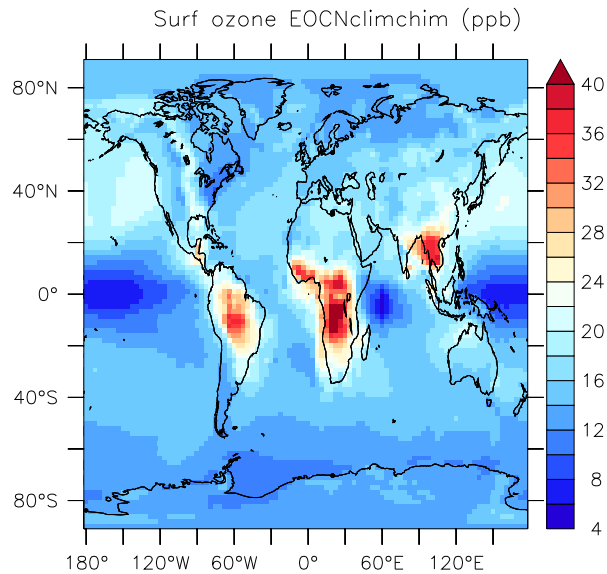
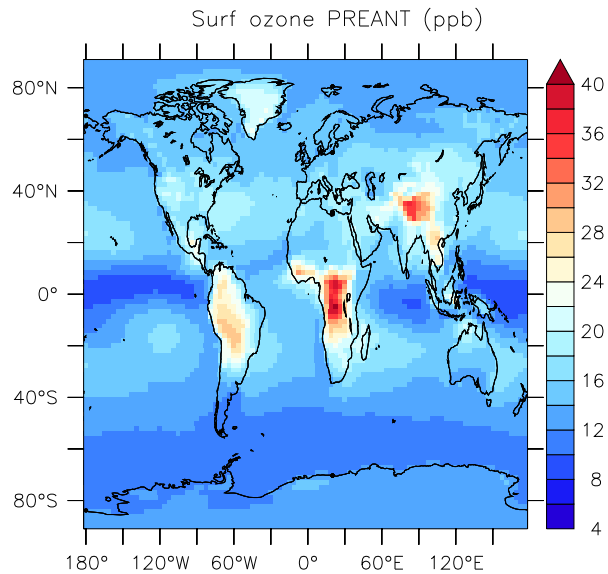
préindustriel

climat et couverture végétale



1^{er} essai : sensibilité du module d'émissions de composés organiques volatils (COV) biogéniques du modèle de végétation ORCHIDEE dans conditions Eocene (+6.7°C en surface par rapport au préindustriel)

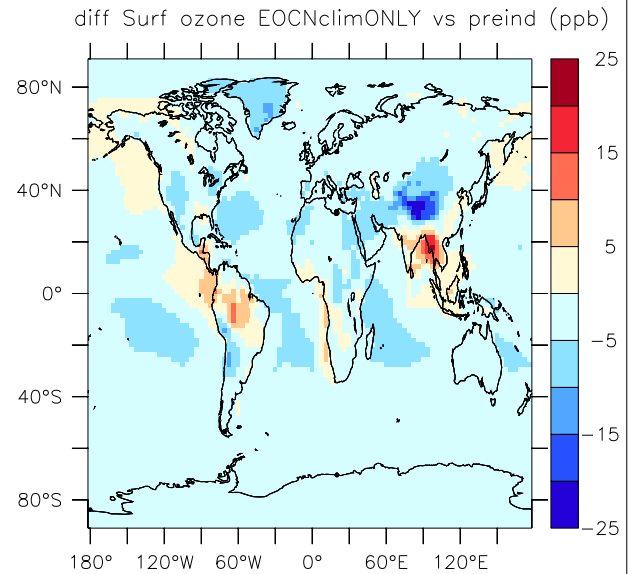
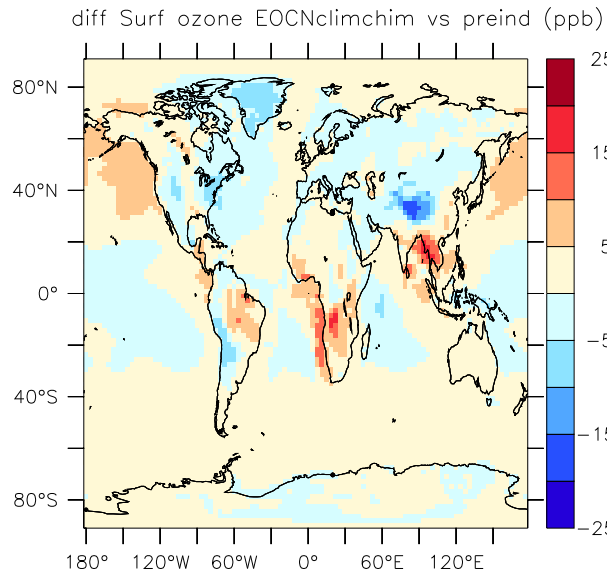
Résultats consistants avec Beerling et al. PNAS 2011 : **doublment des émissions d'isoprène** (614 TgC/an contre 281 TgC/an pour le préindustriel)



Rq : Souci report emissions
sols/ocean sur le bon
masque terre mer

Baisse sur massif Himalayen
lié à changements de
topographie

Des changements de 5 à
20ppb (cohérent avec
Beerling et al.)

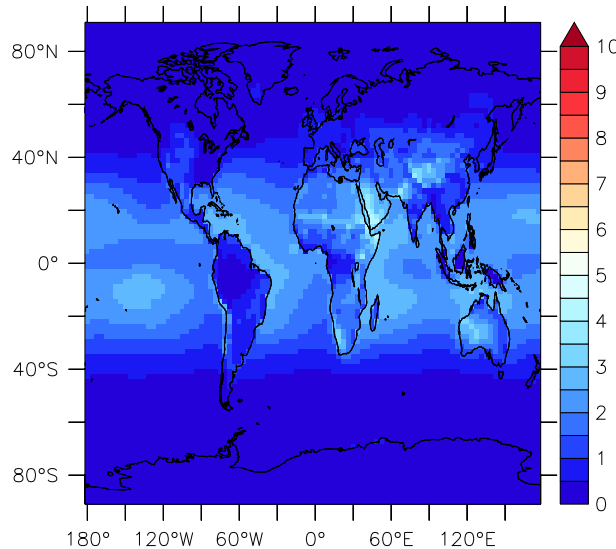


Plus de destruction liée à
plus forte humidité

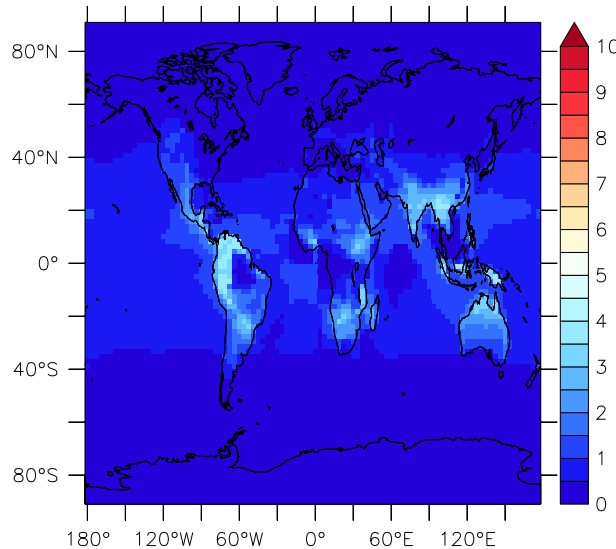
Bilan de l'ozone troposphérique		PREIND	EOCENE	(PRESENT)
Production Chimique d'ozone (Tmoles/an)	$\text{NO} + \text{HO}_2 \rightarrow \text{NO}_2 + \text{OH}$	31.4	55.5	68.5
	$\text{CH}_3\text{O}_2 + \text{NO} \rightarrow \text{CH}_3\text{O} + \text{NO}_2$	9.4	26.5	24.9
	Sum $\text{RO}_2 + \text{NO} \rightarrow \text{RO} + \text{NO}_2$	3.5	11.0	13.5
Pertes chimiques d'ozone (Tmoles/an)	$\text{OH} + \text{O}_3 \rightarrow \text{HO}_2 + \text{O}_2$	7.2	7.3	10.7
	$\text{HO}_2 + \text{O}_3 \rightarrow \text{OH} + 2.0 * \text{O}_2$	9.5	27.7	28.0
	Sum alkenes/alkynes + O_3	0.32	4.1	1.8
	$\text{O}^1\text{D} + \text{H}_2\text{O} \rightarrow 2 * \text{OH}$	26.6	57.0	52.9

Des flux chimiques deux fois plus importants qu'en preind et quasiment équivalents au present

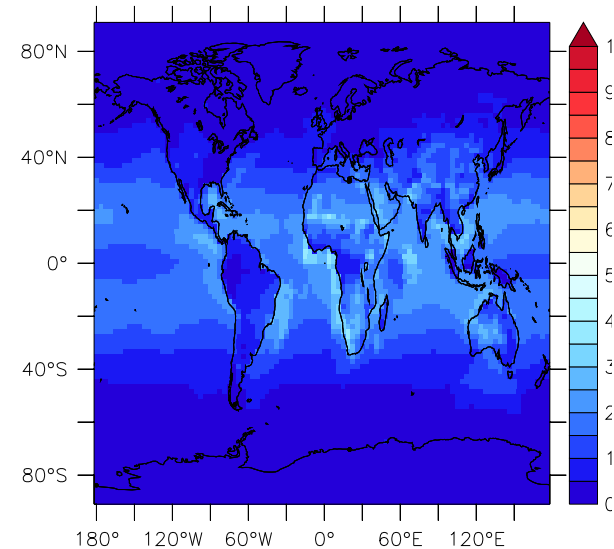
Surf OH PREANT *1e6 molec.cm⁻³



Surf OH EOCNclimchim *1e6 molec.cm⁻³

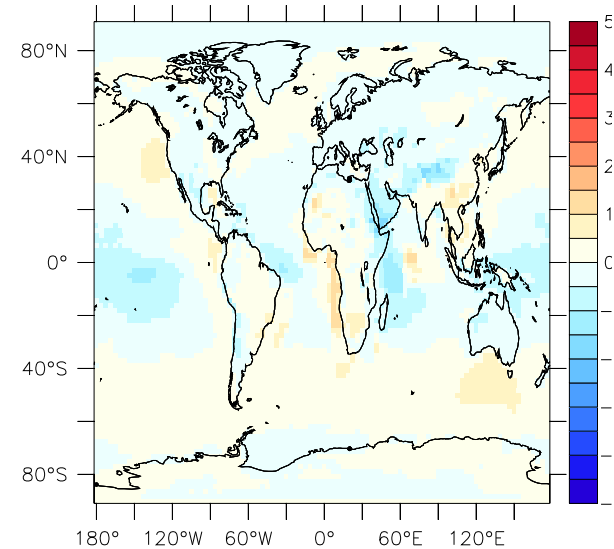
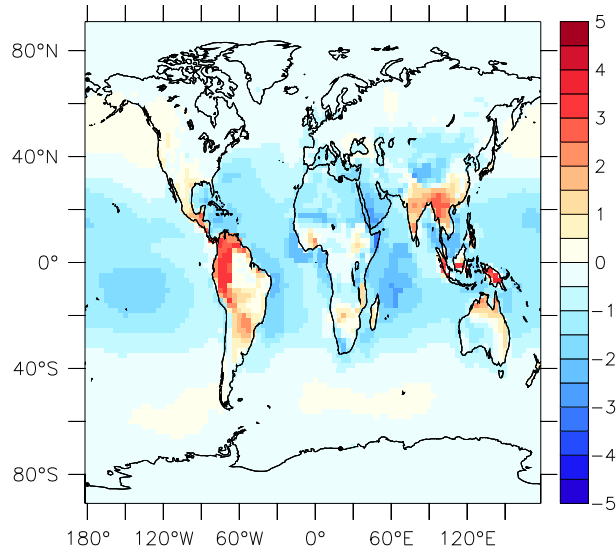


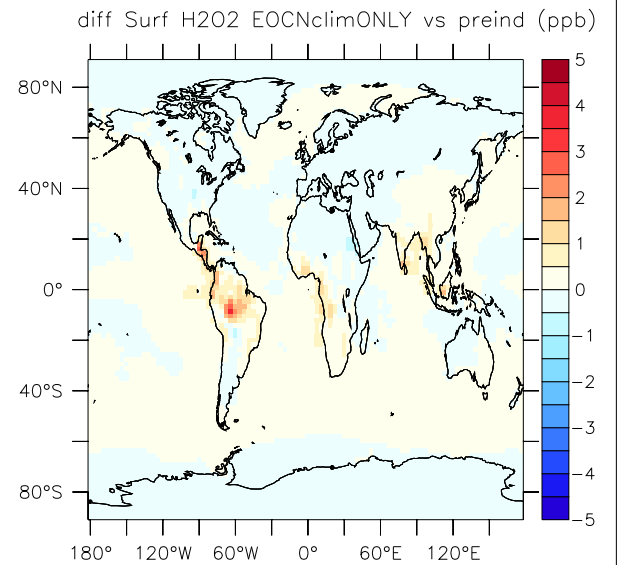
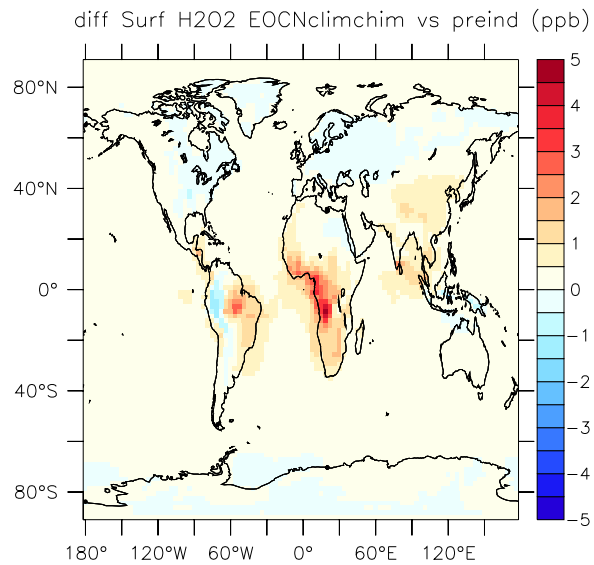
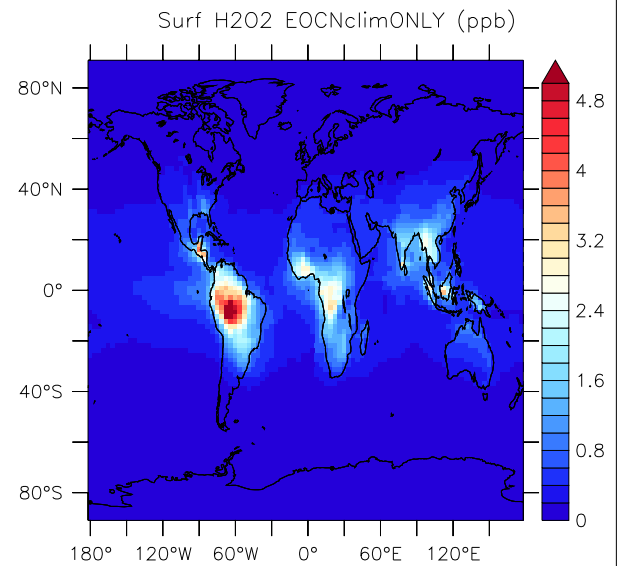
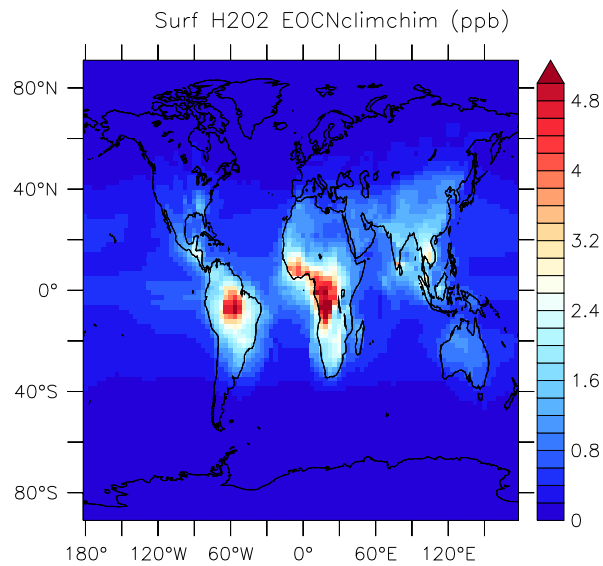
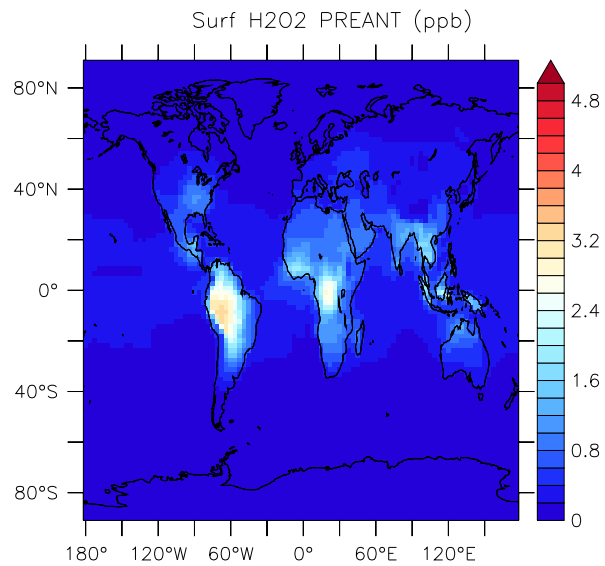
Surf OH EOCNclimONLY *1e6 molec.cm⁻³



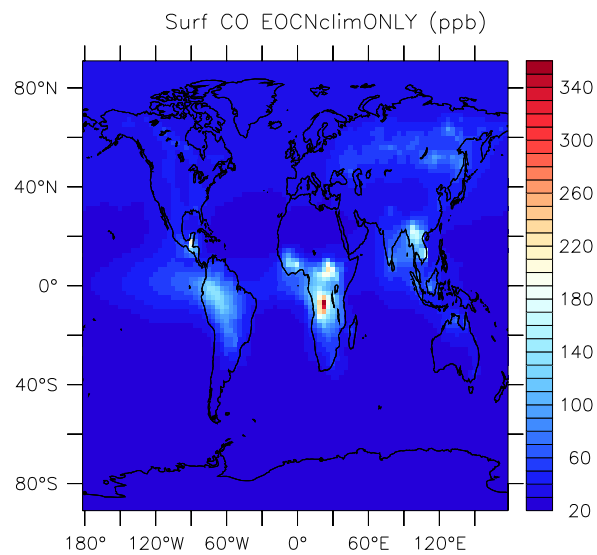
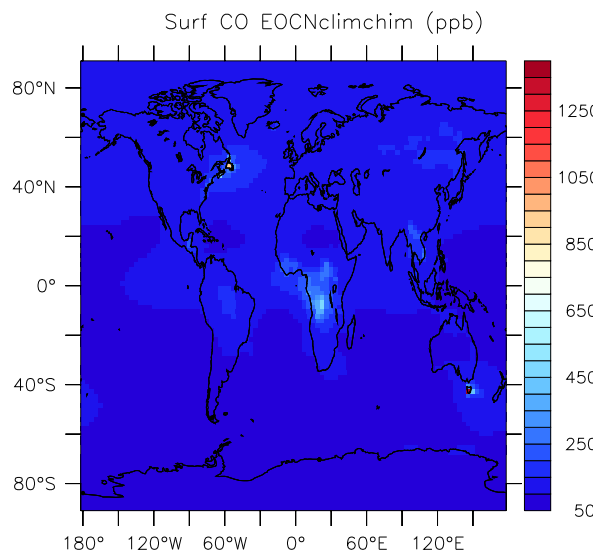
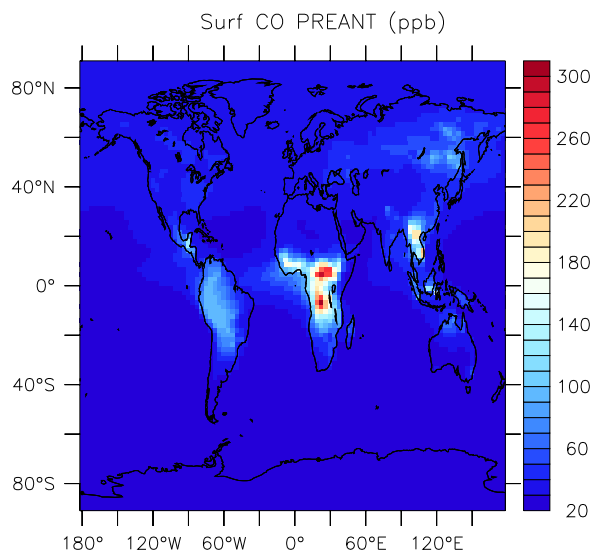
Difficile d'évaluer en surface les changements causés par changement de position des continents

diff Surf OH EOCNclimchim vs preind *1e6 molec.cm⁻³ diff Surf OH EOCNclimONLY vs preind *1e6 molec

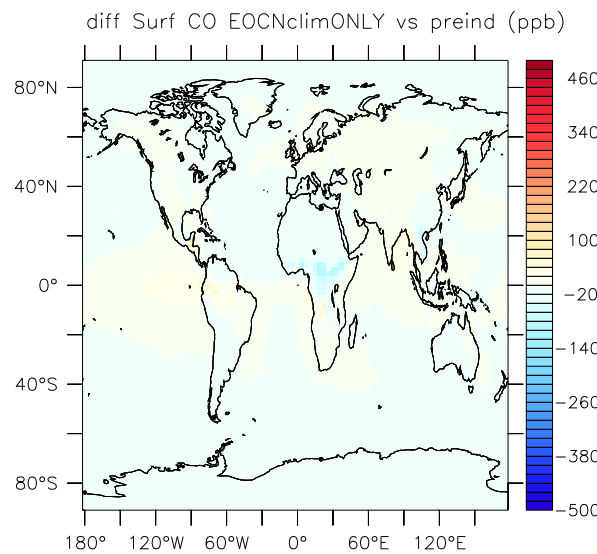
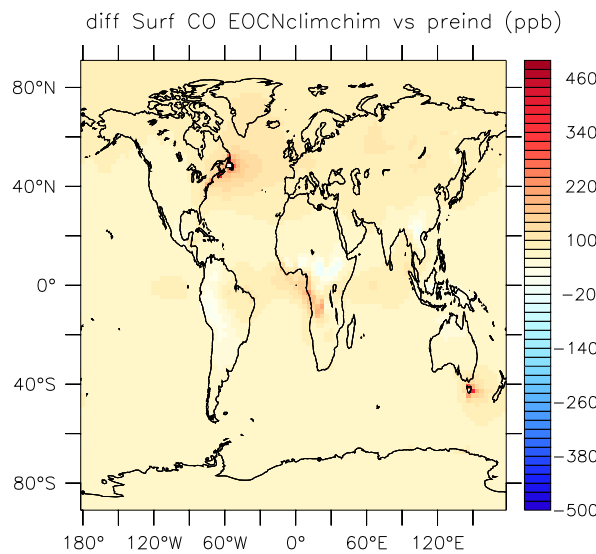


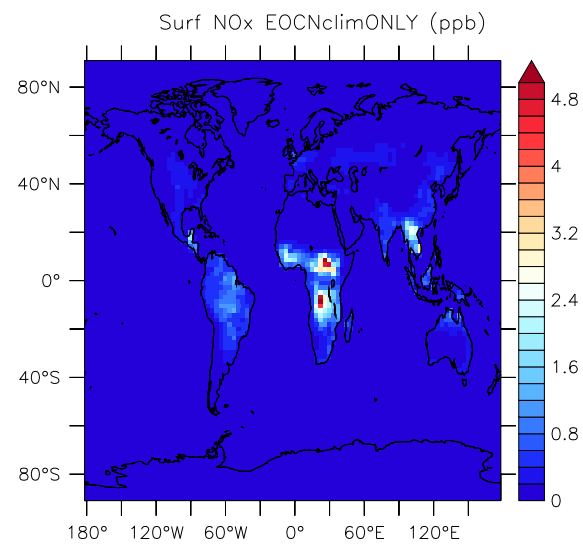
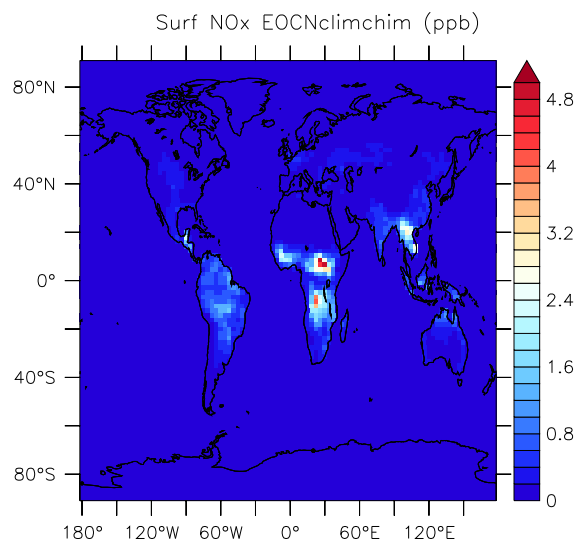
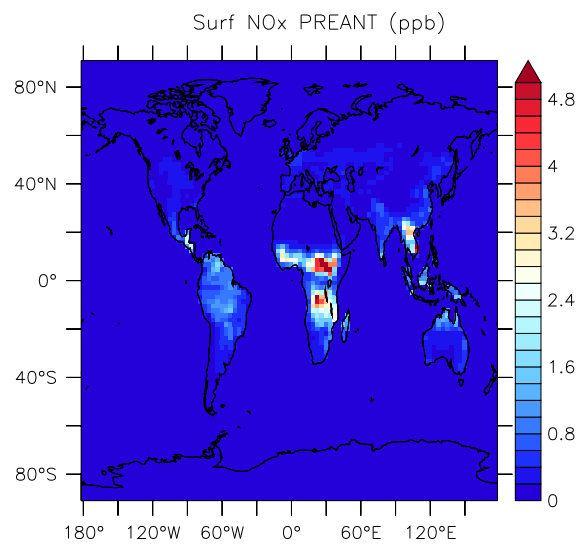


Bcp + de H2O2
car bcp plus
d'HO2

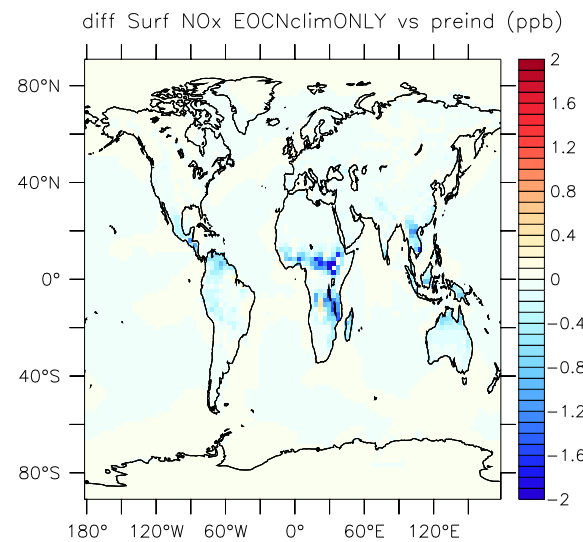
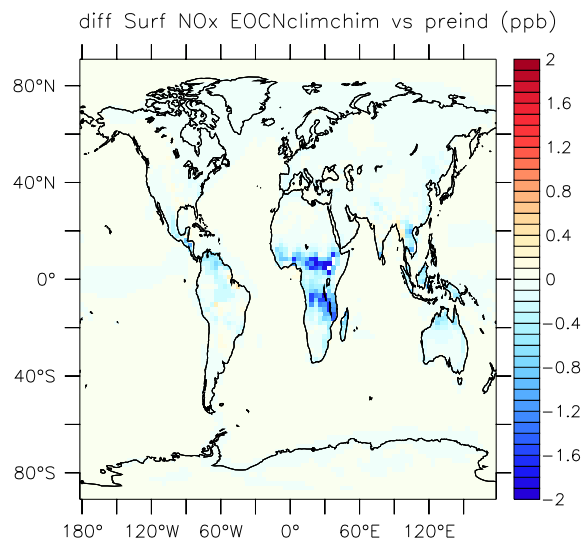


Changements de CO
directement lié aux
changements de CH4





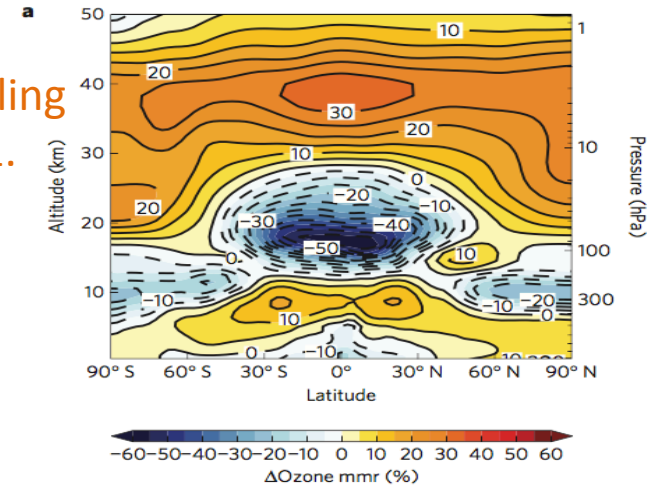
Moins de NOx en surface (émissions inchangées)



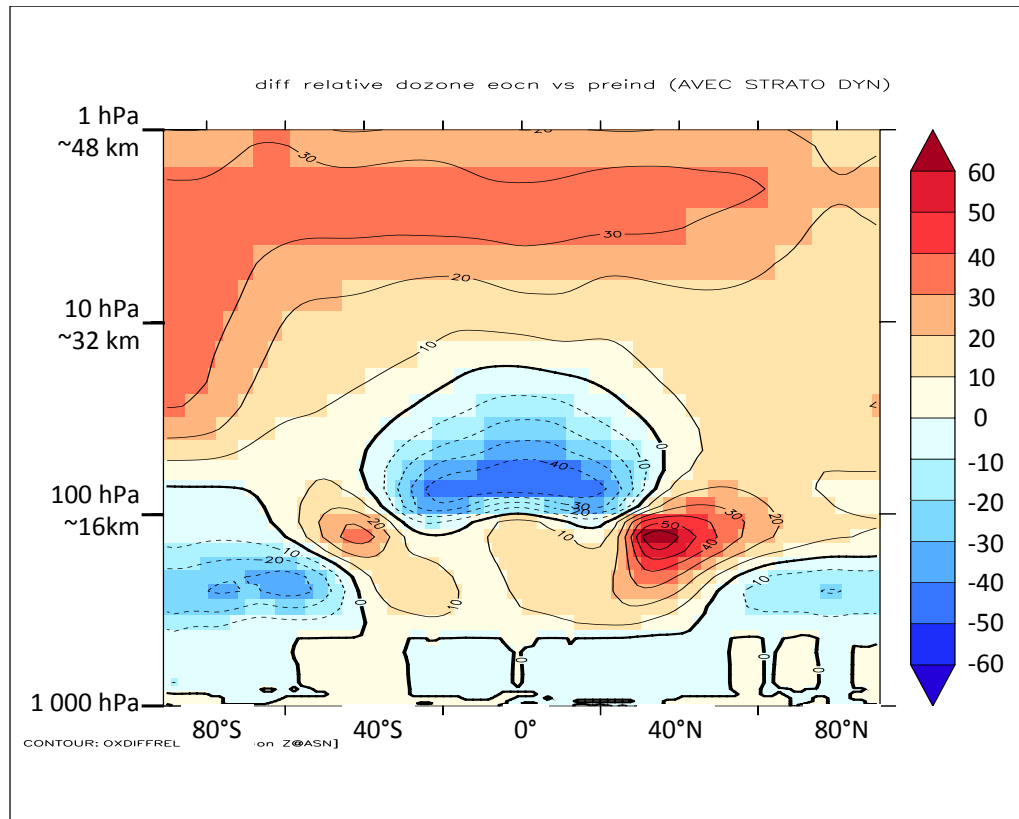
Bilan de OH troposphérique			PREIND	EOCENE	(PRESENT)
Production chimique OH Tmoles/an	PRIMAIRE	$O1D + H2O \rightarrow 2 * OH$	26.6	57.0	52.9
	SECONDAIRE	$NO + HO2 \rightarrow NO2 + OH$	31.4	55.5	68.5
		$HO2 + O3 \rightarrow OH + 2.0 * O2$	9.5	27.7	28.0
		$H2O2 + hv \rightarrow 2.0 * OH$	3.3	13.0	8.9
		ROOH+hv & MACR+hv (sans prise en compte de rdmts)	2.2	15.0	7.1
Pertes chimiques OH Tmoles/an		$CO + OH \rightarrow CO2 + CO2CO + H$	32.0	88.3	87.9
		$CH4 + OH \rightarrow CH3O2 + H2O$	15.3	49.6	36.8
		$OH + O3 \rightarrow HO2 + O2$	7.2	7.3	10.7
		$H2O2 + OH \rightarrow H2O + HO2$	3.6	7.9	7.7
		$OH + HO2 \rightarrow H2O + O2$	8.9	10.0	11.7
		$OH + OH \rightarrow H2O + O$	0.005	0.002	0.003
		$H2 + OH \rightarrow H2O + H$	12.4	12.4	14.0
		Sum other inorg + OH	3.9	2.7	5.8
		Sum other C1 compounds + OH	17.3	37.0	33.2
		Sum (ISOP & MACR & MVK) + OH	<1 ^E -10	14.0	10.3
		Sum other orga compounds + OH	3.8	10.7	11.0

STRATOSPHERE LMDzREPROBUS

(climat CO₂=1120ppm)
 CH₄=3614ppb from Beerling
 N₂O=323ppb et al. 2011.
 CH₃Br=7.006e-09
 CH₃Cl=4.81642e-07
 Autres CFC=0



Eocene vs Preindustrial stratospheric ozone change (%) in a simulation including stratospheric chemistry



upper stratosphere: O₃ increase due to a weaker loss of O₃ in the upper stratosphere (can lead to reduced UV in the troposphere)

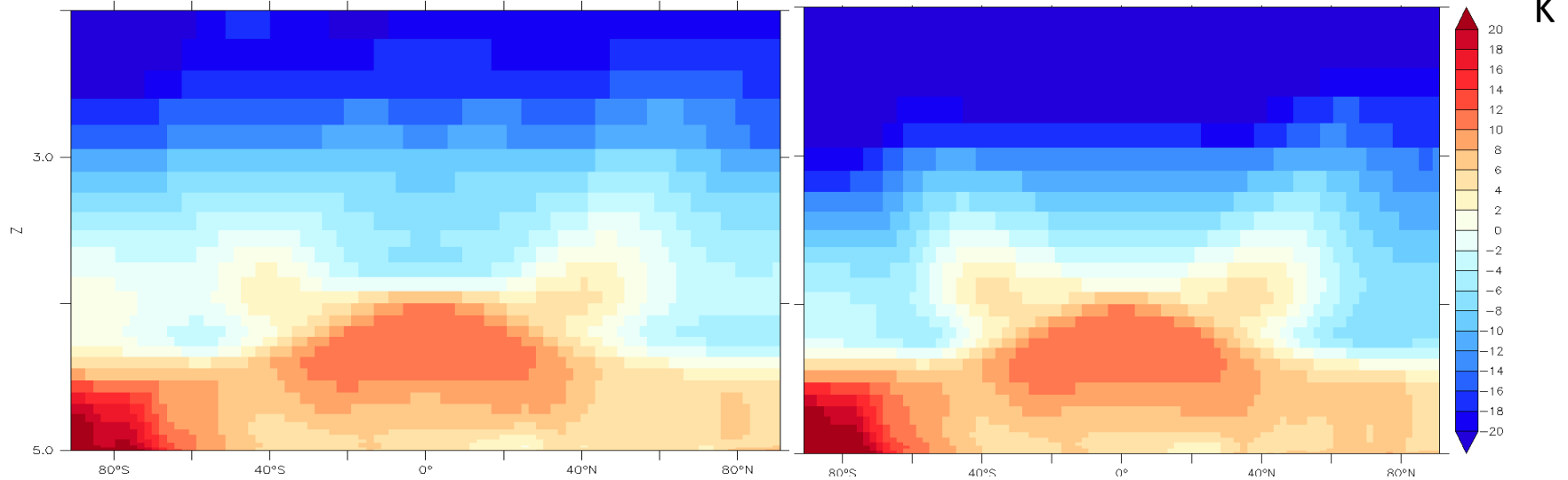
lower stratosphere: decrease of O₃ in the tropics and increase at middle latitudes due the intensification of Brewer Dobson circulation.

consistent in magnitude with the climate effect simulated by Nowak et al. 2015 for a 4xCO₂ run and the N₂O and CH₄ effects on stratospheric chemistry simulated by Revell et al. 2012.

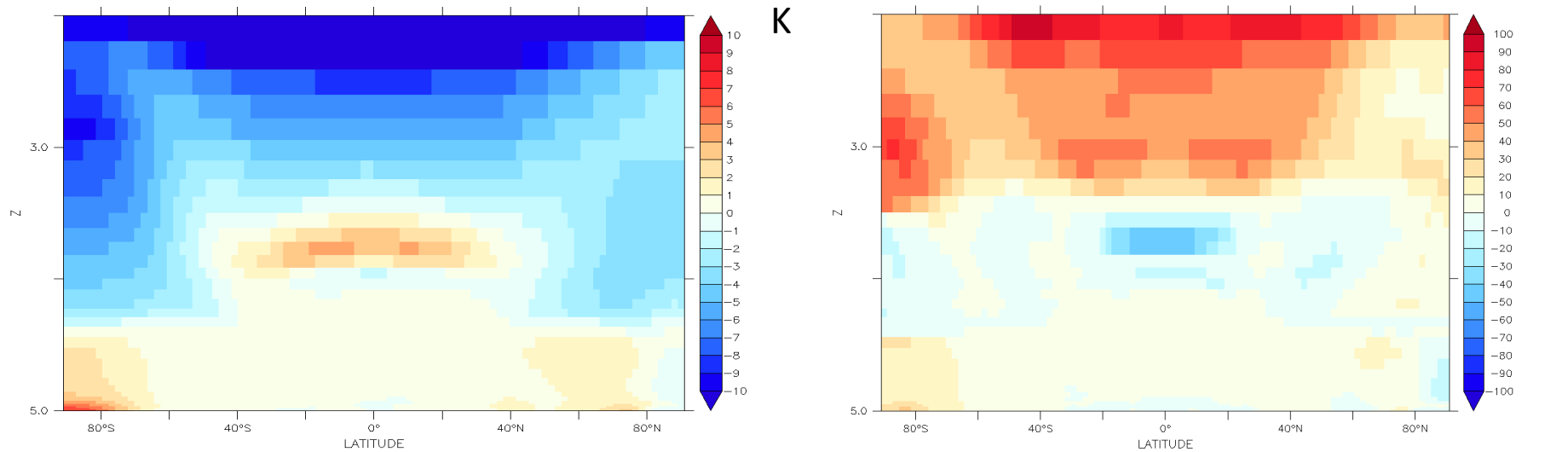
Effet sur la temperature

Difference de temperature entre eocen et preind **AVEC** STRATO DYNAMIQUE

Difference de temperature entre eocen et preind **SANS** STRATO DYNAMIQUE



Difference entre les deux (sans-avec) , effet de la strato dynamique



TEMPDIFFLMDZ - TEMPDIF (regrid: on Z@ASN) **A reprendre avec climatos sur 30 ans (ici 10 ans)** TEMPDIFF (regrid: on Z@ASN)

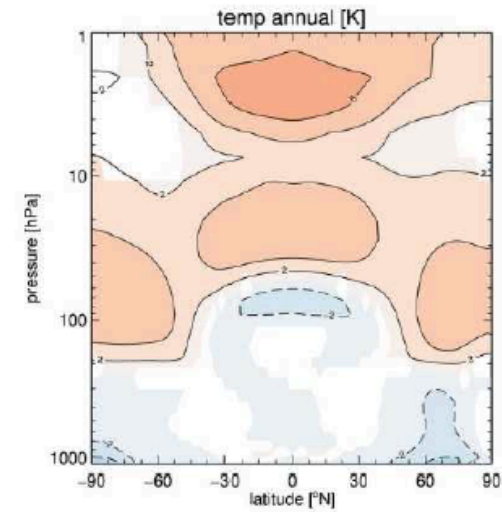
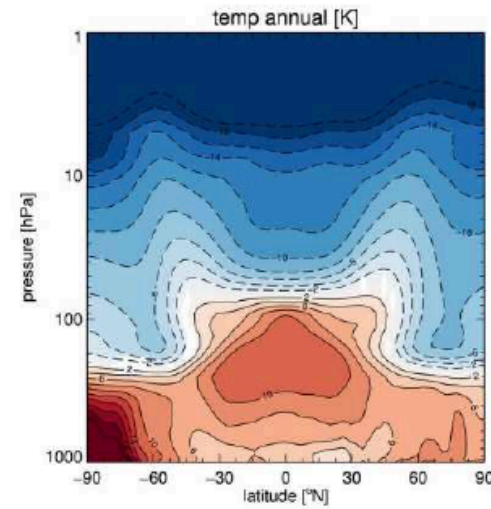
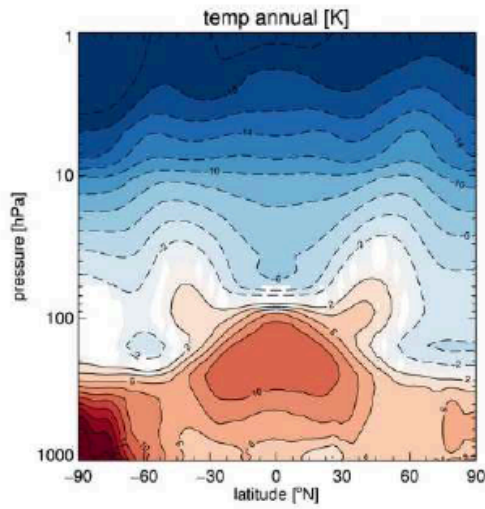
Annual

Interactive Ozone

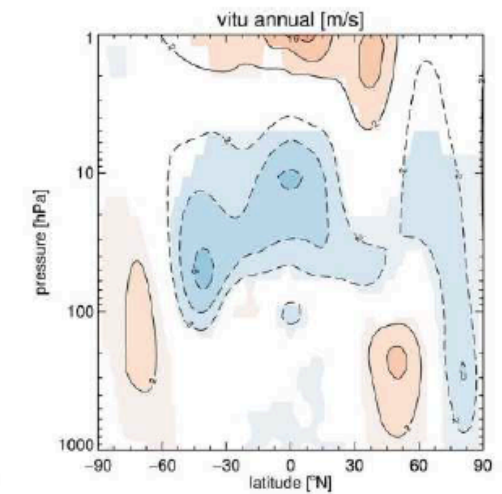
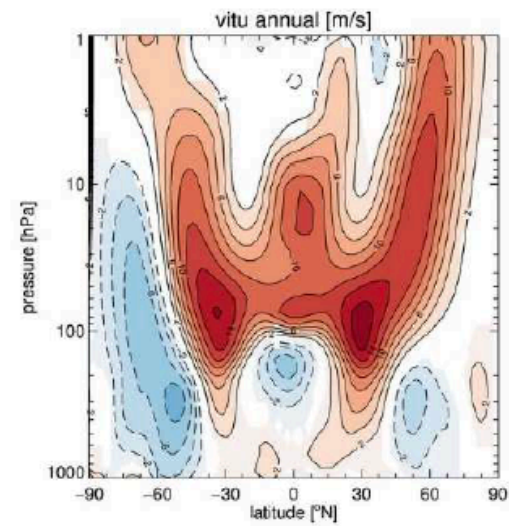
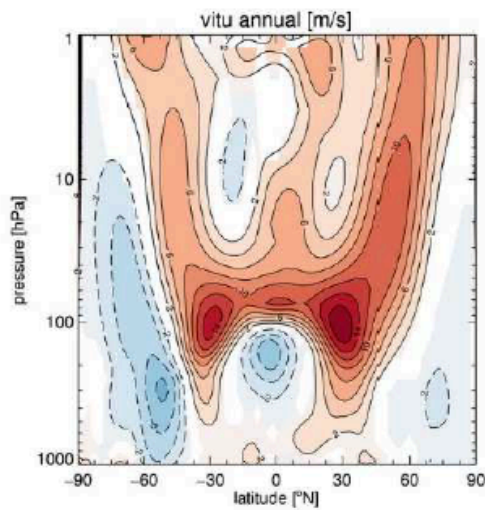
Fixed Ozone

Interactive-fixed

Temperature



Zonal wind



Travail qui débute , Rémi THIEBLEMONT

Net down radiatif flux at TOA

Difference de flux net TOA ($\text{nettop} \cdot \cos(j)$) entre eocn et prind Avec strato dyn

Difference de flux net TOA ($\text{nettop} \cdot \cos(j)$) entre eocn et prind sans strato dyn

