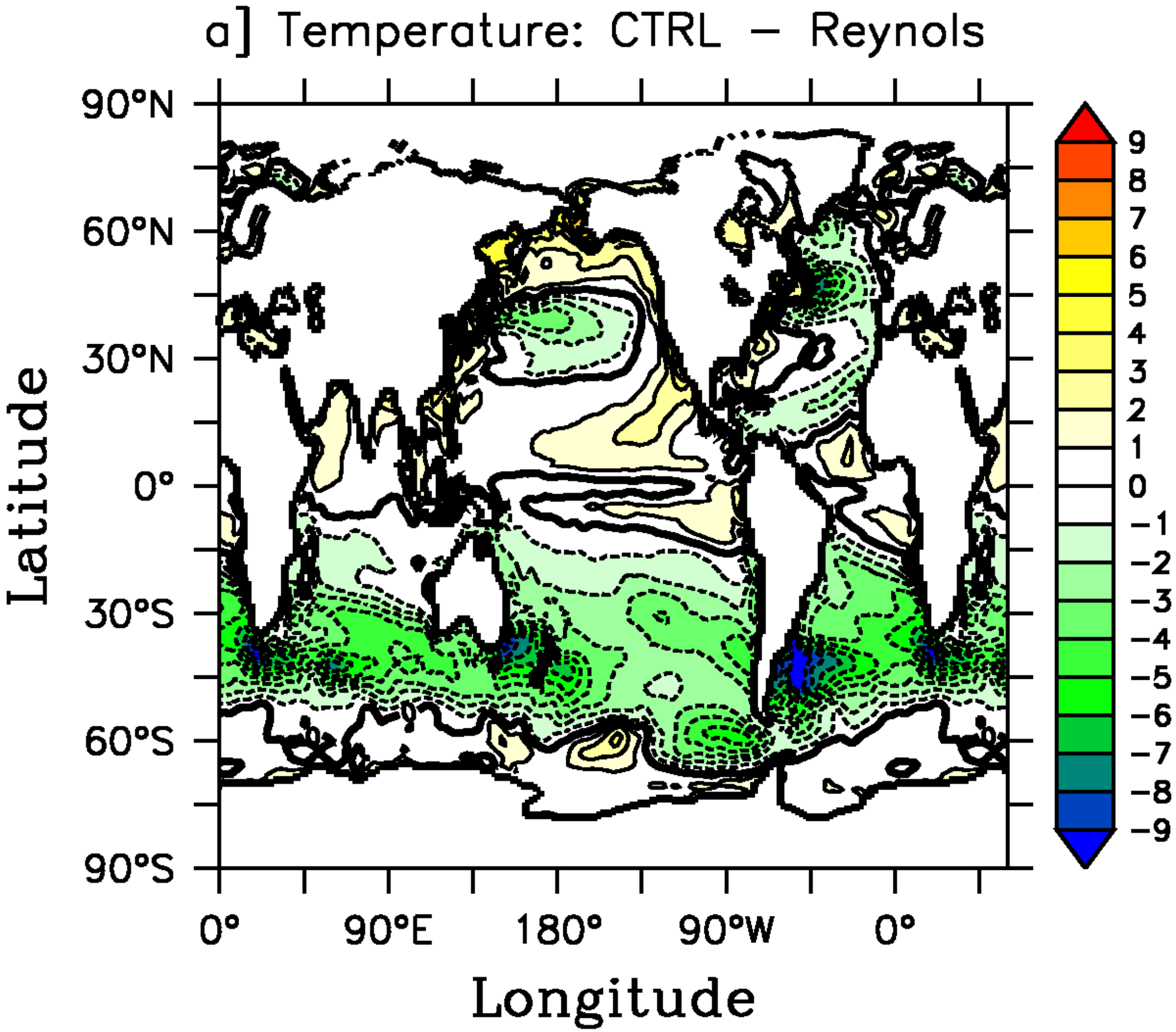
De IPSL CM4 à IPSL CM5 : couplage et océan de surface

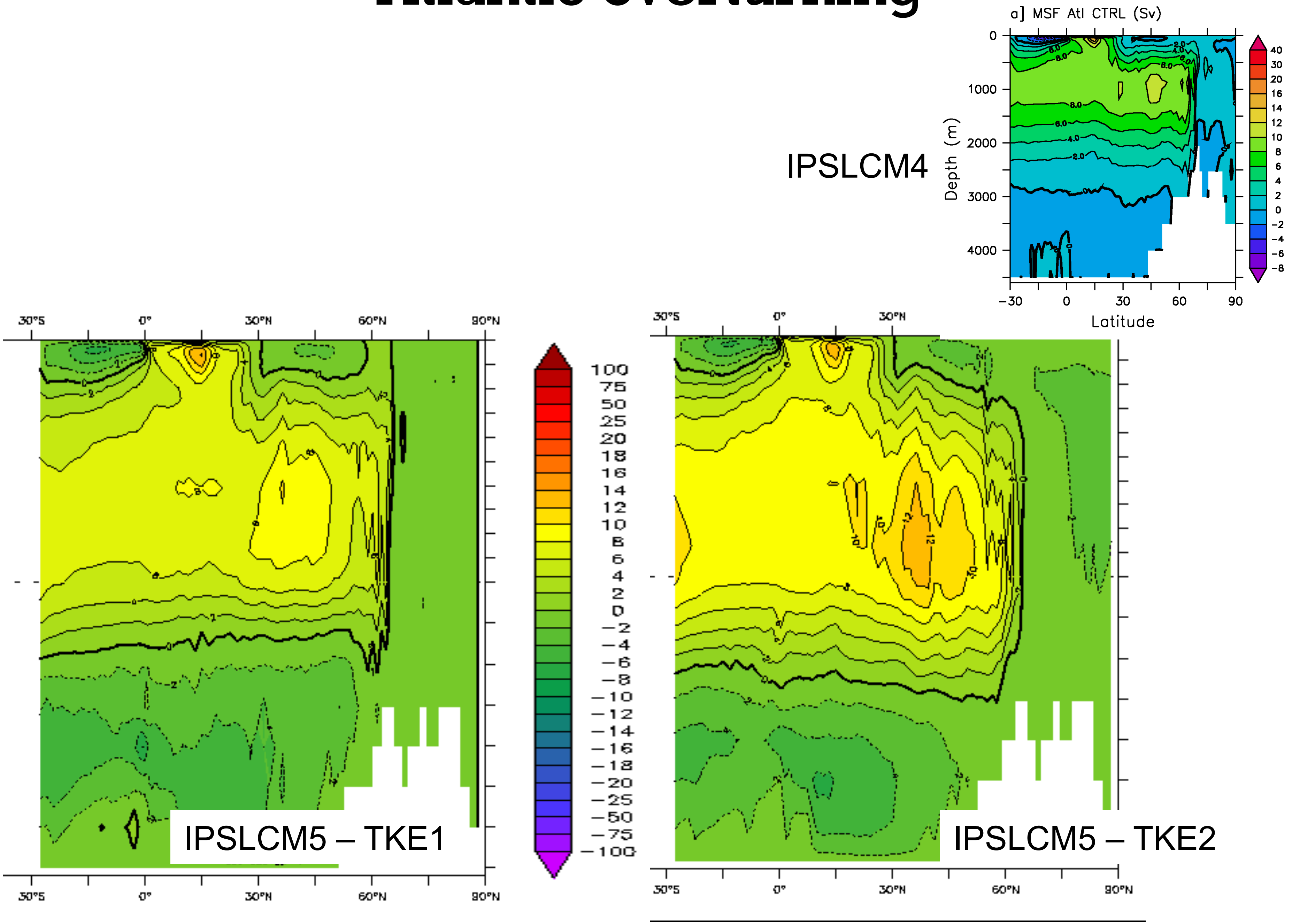
- Les nouveautés de l’océan dans IPSLCM5
- Le mélange vertical dans l’océan
- Quelques caractéristiques de IPSLCM5

IPSLCM4, biais de température



Marti O. et al., 2010: Key features of the IPSL ocean atmosphere model and its sensitivity to atmospheric resolution. Clim. Dyn. 34, 1-26.

Atlantic overturning



IPSLCM4 vers IPSLCM5

- LMDZ 96x72x19
  - > LMDZ 96x95x39
  - > LMDZ 144x142x39
- ORCHIDEE
- OPA8-LIM2 -> NEMO (OPA9-LIM2)

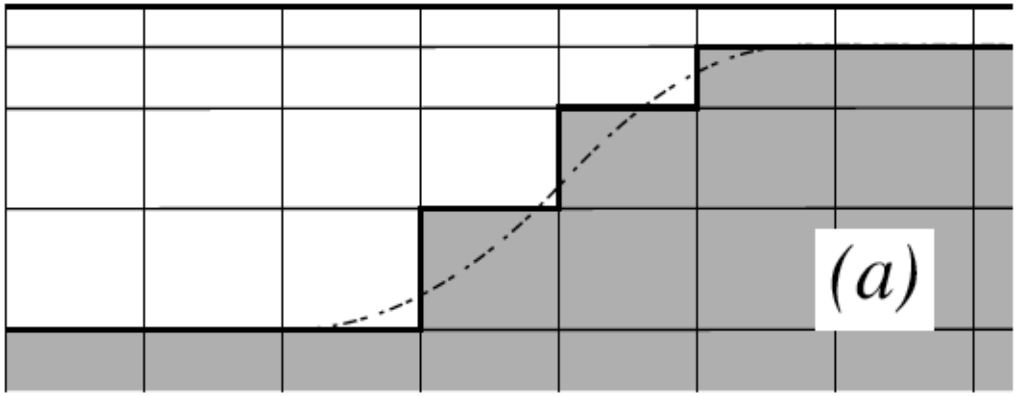
De OPA8-LIM2 (IPSLCM4) à NEMO (IPSLCM5)

- Couplage
  - Meilleure conservation (eau)
  - Quantité de mouvement :
    - $\rho C_d\, \mathbf{V}_{atm} * |\mathbf{V}_{atm}|$
      -> $\rho C_d\, (\mathbf{V}_{atm} - \mathbf{V}_{oce}) * |\mathbf{V}_{atm} - \mathbf{V}_{oce}|$
  - Interface générique dans NEMO
- NEMO
  - OPA9 : dynamique (océan « bleu »)
  - LIM2 : glace de mer (océan « blanc »)
  - PISCES : biogéochimie (océan « vert »)

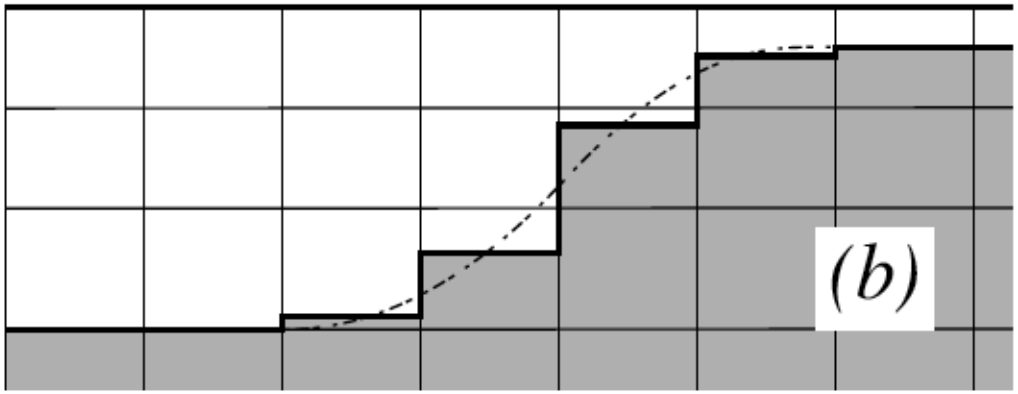
NEMO/OPA9 : nouvelle physique 1/3

- Partial steps
  - The ocean bottom as seen by the model :

a) z-coordinate with full step,



b) z-coordinate with partial step



NEMO/OPA9 : nouvelle physique 2/3

- Friction de fond (linéaire)
- Schéma advection TVD sur les traceurs
  (Total Variance Dissipation scheme, Zalesak [1979])
- Terme de vorticité conservant l'enstrophie ET l'énergie

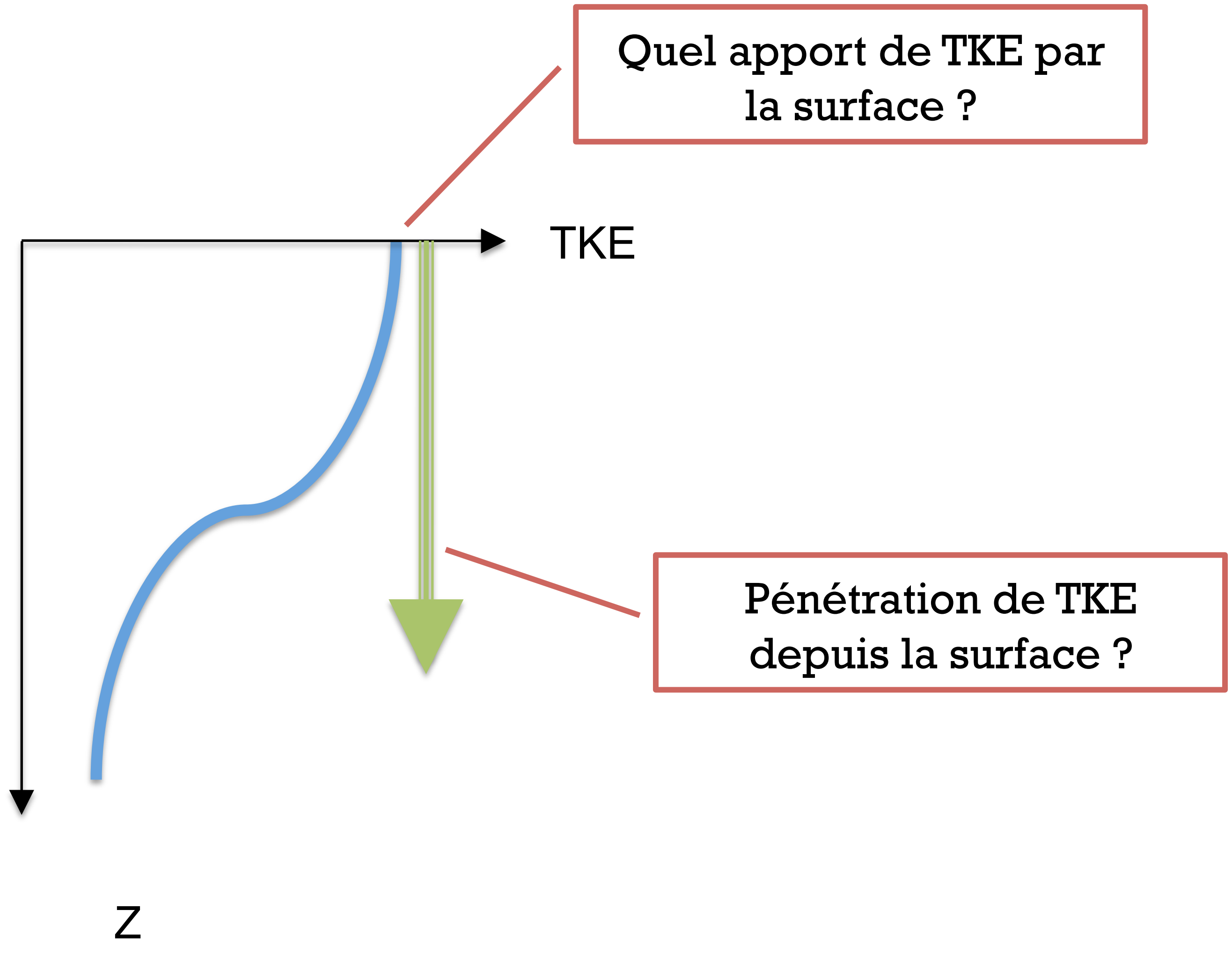
$$\frac{\partial \mathbf{U}_h}{\partial t} = \ldots - f\mathbf{k} \times \mathbf{U}_h - \mathbf{U}_h . \nabla_h \mathbf{U}_h - \frac{1}{\rho} \nabla_h p + ..$$

$$= \ldots - (f\mathbf{k} + \nabla_h \times \mathbf{U}_h) \times \mathbf{U}_h - \nabla_h (p - \frac{1}{2} \mathbf{U}_h^2) + \ldots$$

NEMO/OPA9 : nouvelle physique 2/3

- Rayonnement pénétrant en 3 longueurs d'ondes
- Couleurs de l'eau (chlorophylle observée ou couplage avec PISCES)
- Nouveau schéma de turbulence verticale

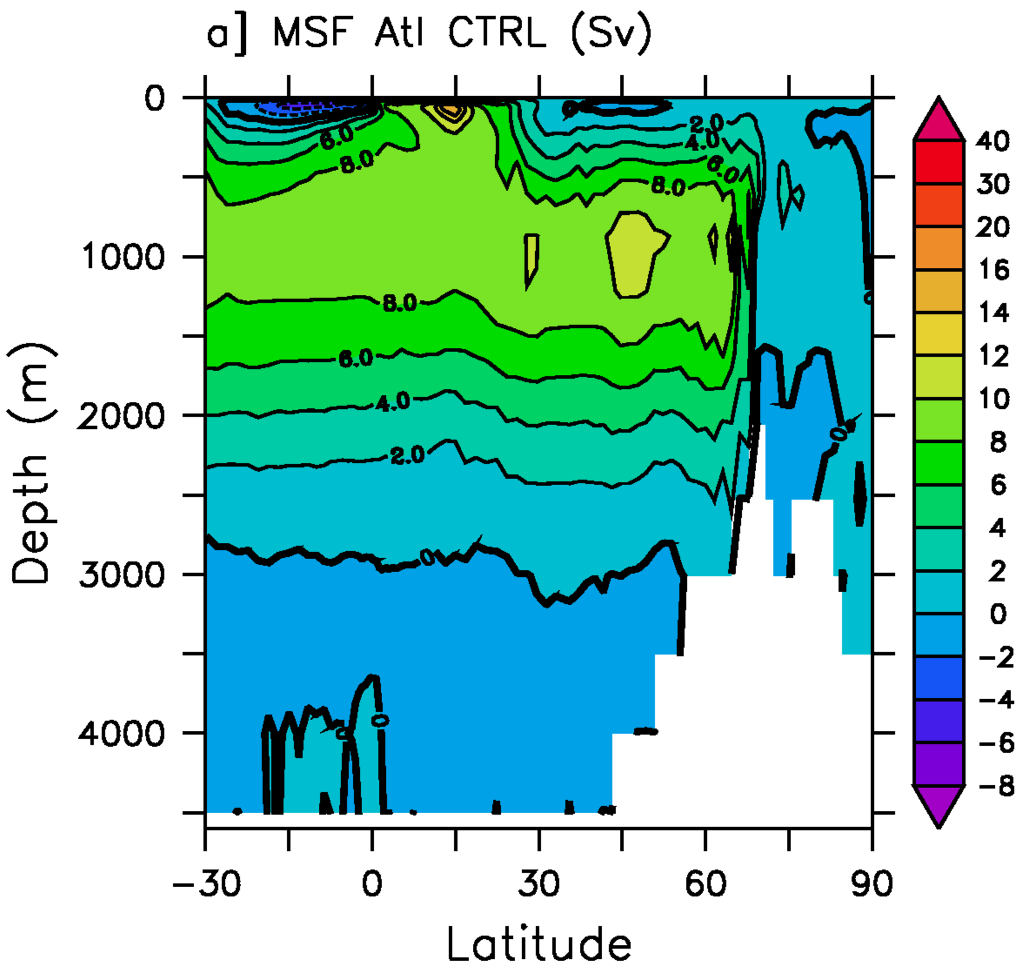
TKE : condition limite de surface et pénétration



Nouveautés NEMO

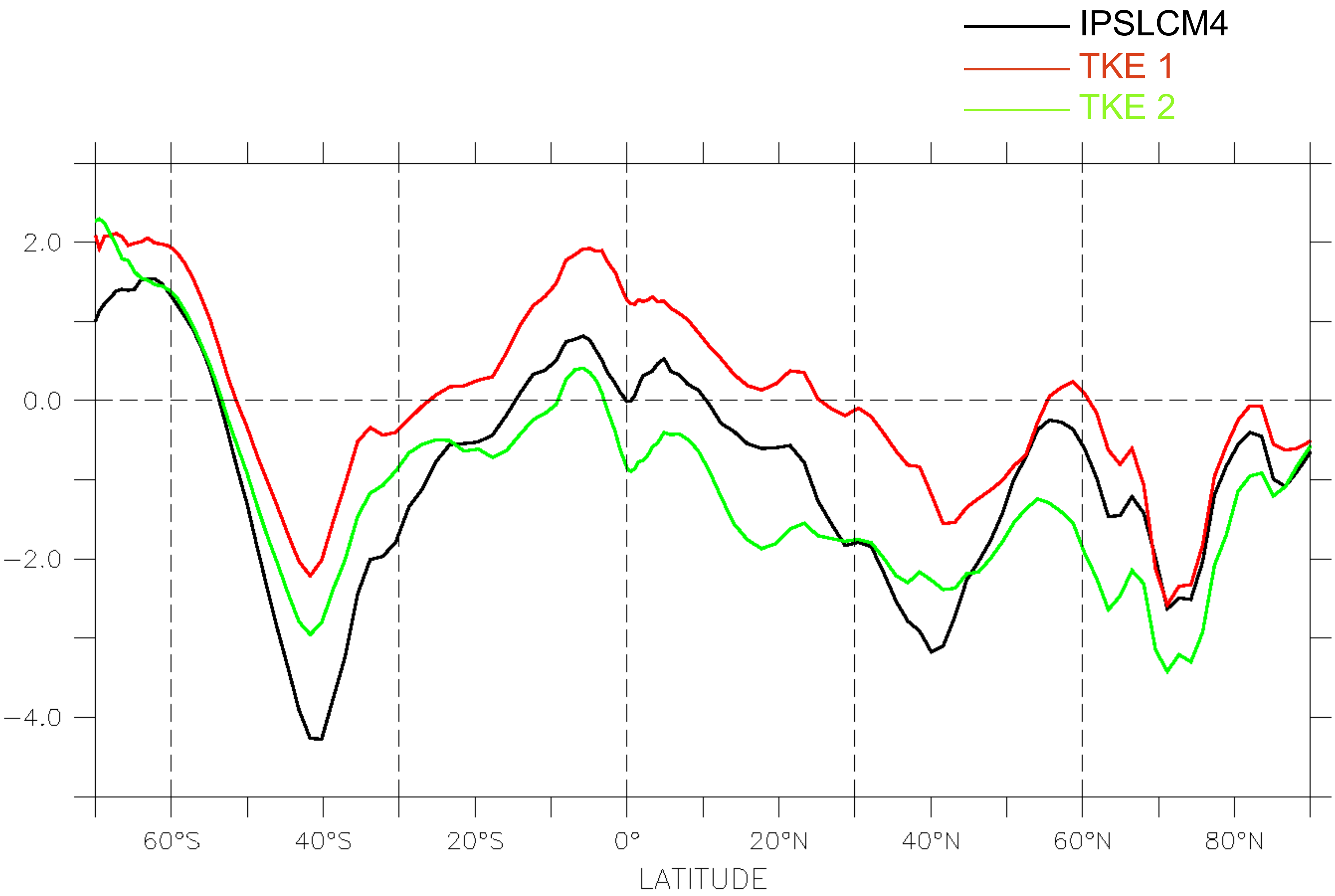
- TKE « 2 » :
  - Double diffusion ($A_T^v \neq A_S^v$) ;
  - Cellules de Langmuir ;
  - Mélange par les marées ;
  - Nouveau terme de surface lié au vent / à la tension de vent ;
  - Pénétration « forcée » dans la couche de mélange ;
- TKE « 3 »
  - Prise en compte de la variabilité rapide du vent sur le terme de surface

IPSLCM4, circulation thermohaline Atlantique

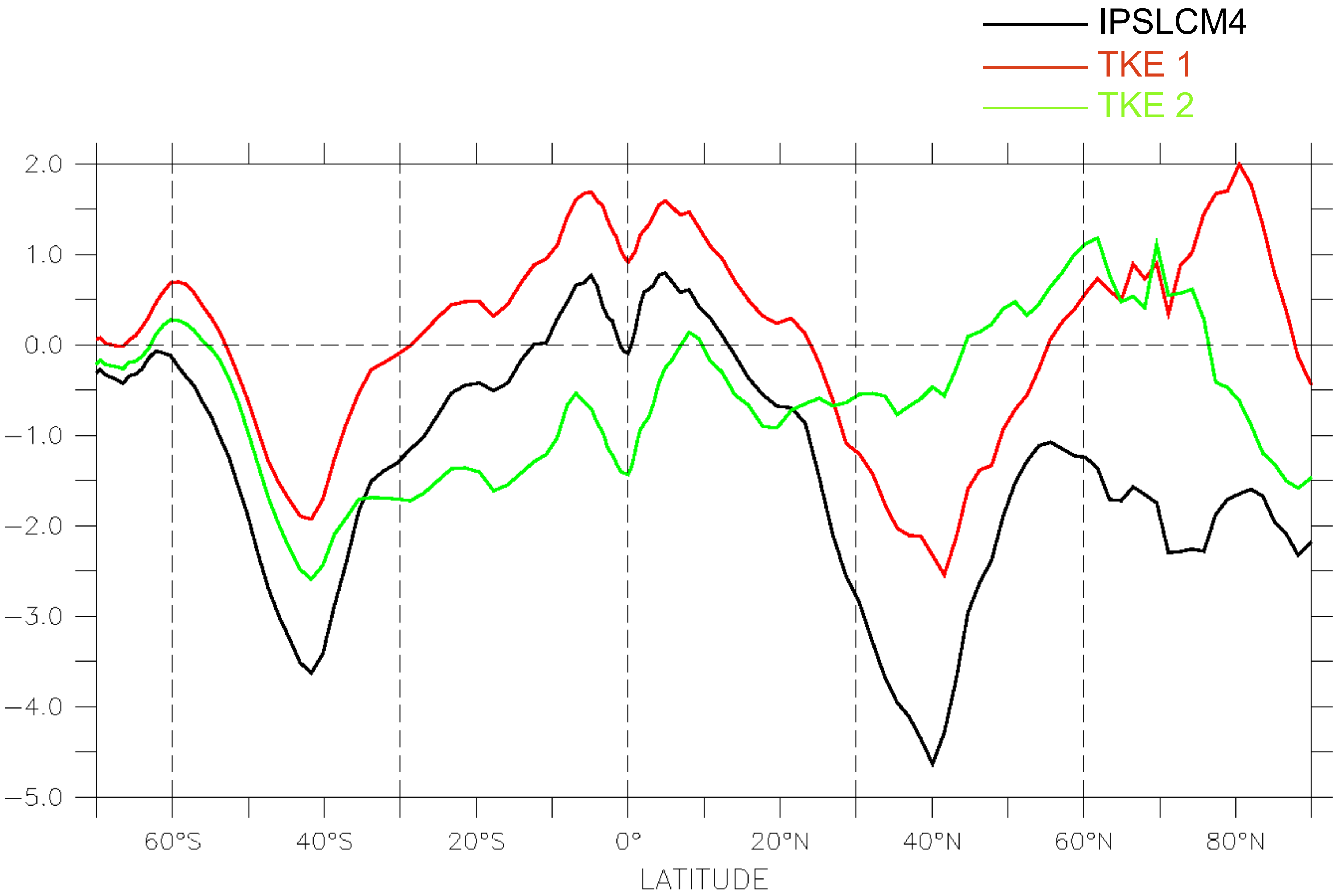


Marti O. et al., 2010: Key features of the IPSL ocean atmosphere model and its sensitivity to atmospheric resolution. Clim. Dyn. 34, 1-26.

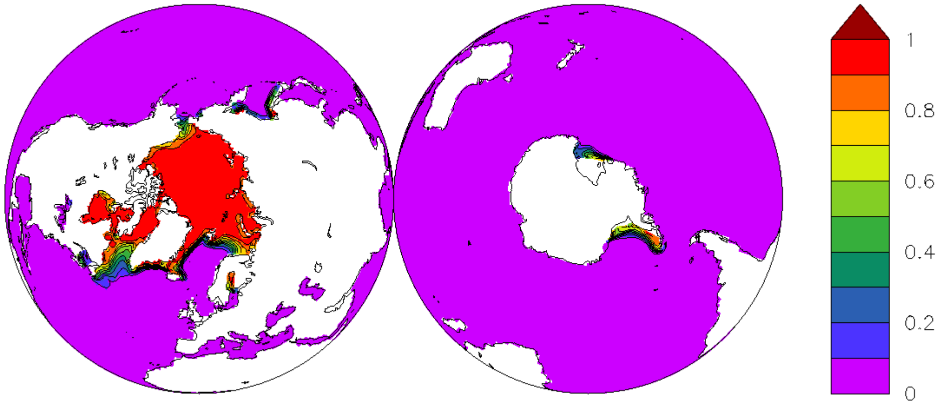
SST Janvier - Différence à Levitus



SST Juillet - Différence à Levitus



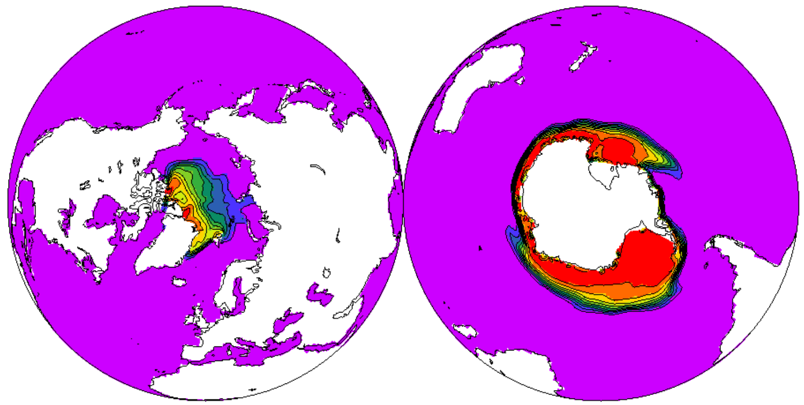
Glace de mer TKE 1 vs. TKE 2



Mars

CM5BCKUP, Soicecov_L=3

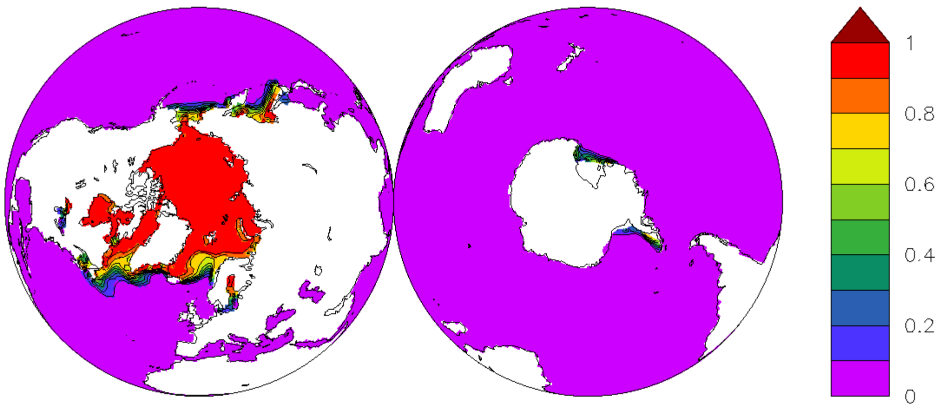
TIME : 16-SEP-2414 00:00 360_DAY



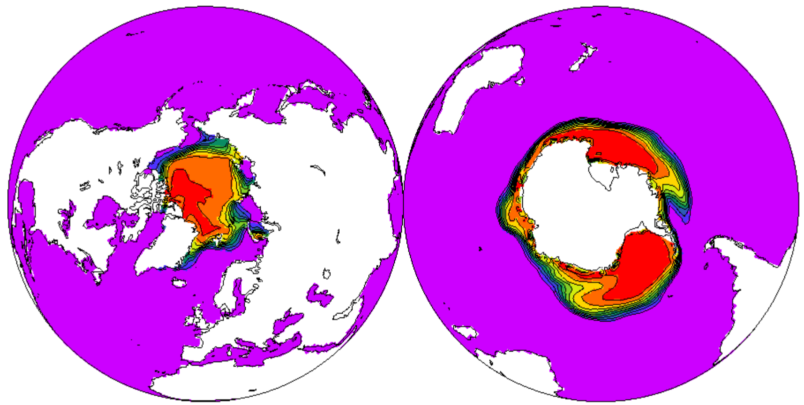
Septembre

CM5BCKUP, Soicecov_L=9

TIME : 16-MAR-2415 00:00 360_DAY

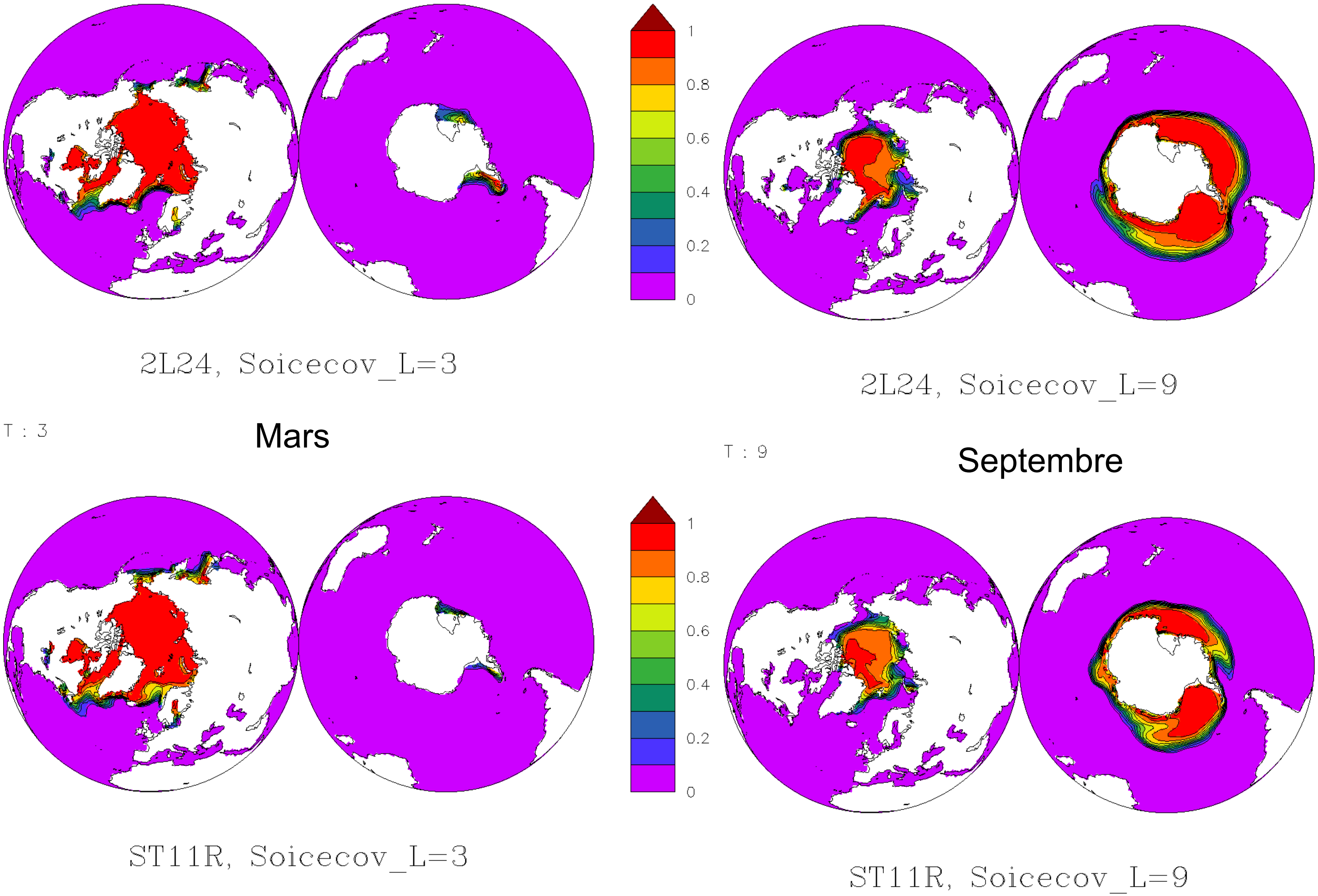


ST11R, Soicecov_L=3

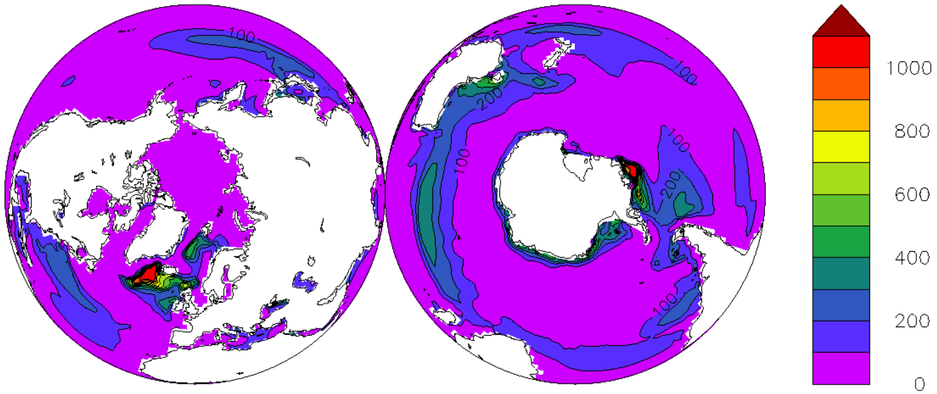


ST11R, Soicecov_L=9

Glace de mer IPSLCM4 vs. IPSLCM5

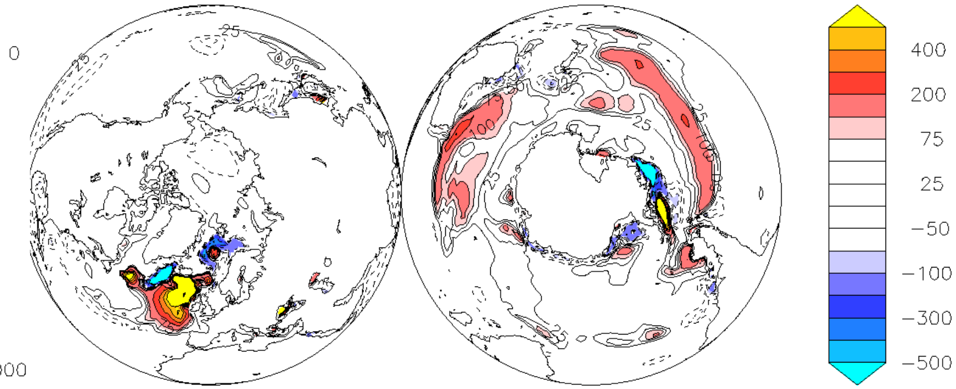


Couche de mélange TKE 1 vs. TKE 2

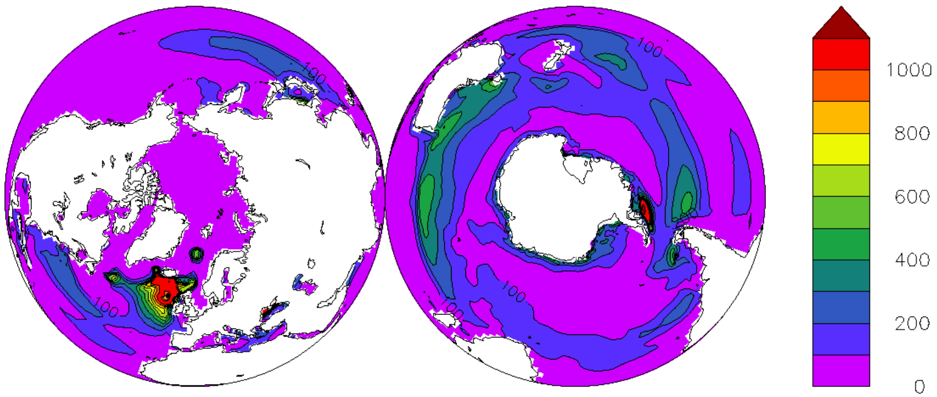


CM5BCKUP, Somxl010_L=@MAX

TIME : 01-JUL-2414 00:00 to 01-JUL-2415 00:00 360_DAY



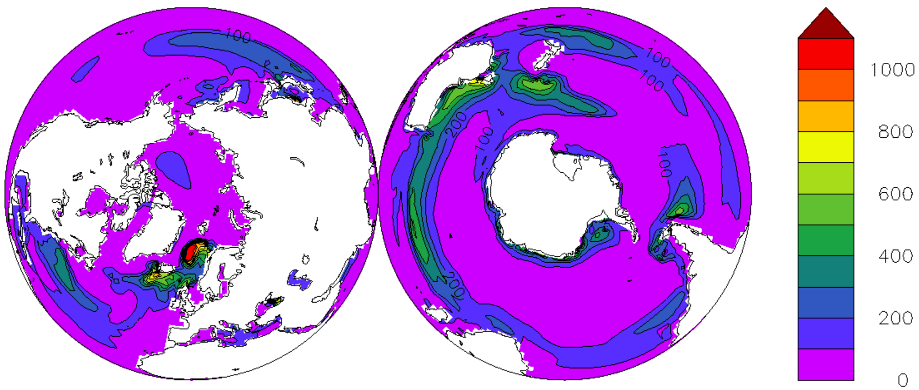
ST11R−CM5BCKUP, Somxl010_L=@MAX



ST11R, Somxl010_L=@MAX

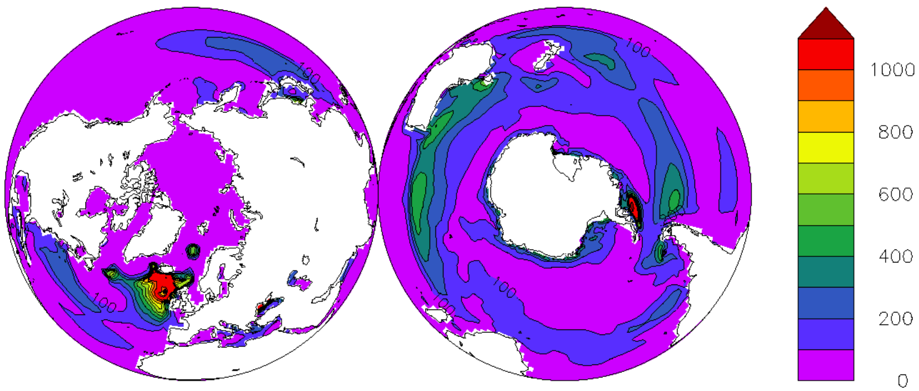
Couche de mélange IPSLCM4 vs. IPSLCM5

T : 0.5 to 12.5

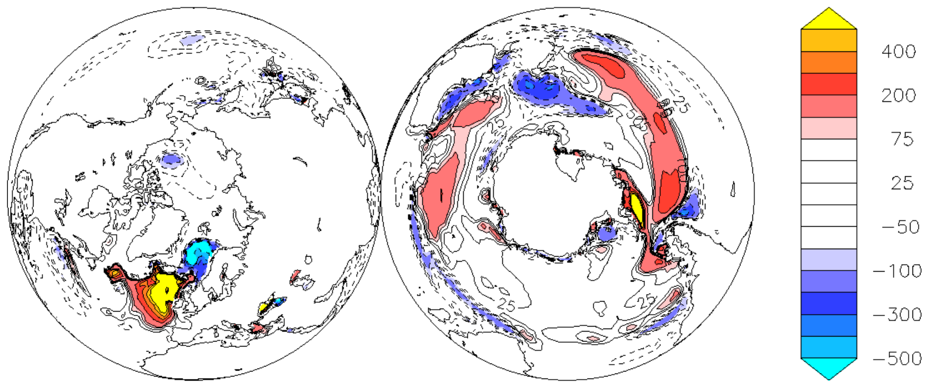


2L24, Somxl010_L=@MAX

T : 0.5 to 12.5



ST11R, Somxl010_L=@MAX



ST11R−2L24, Somxl010_L=@MAX

ENSO (1)

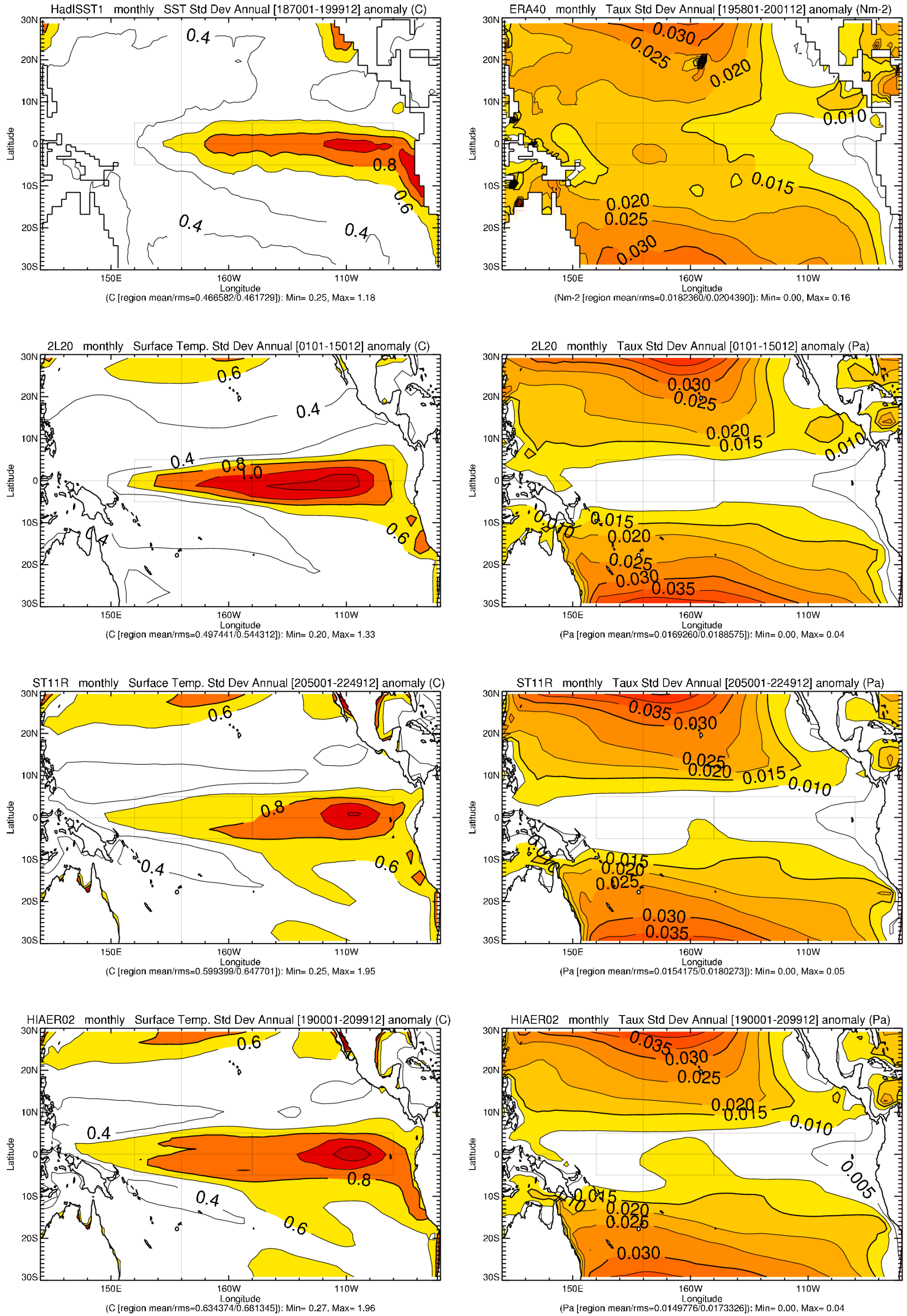
Ecart-type
SST (gauche) et
τ_x (droite)

Obs

IPSLCM4

IPSLCM5

IPSLCM5 – LMDZ144x142



ENSO (2)

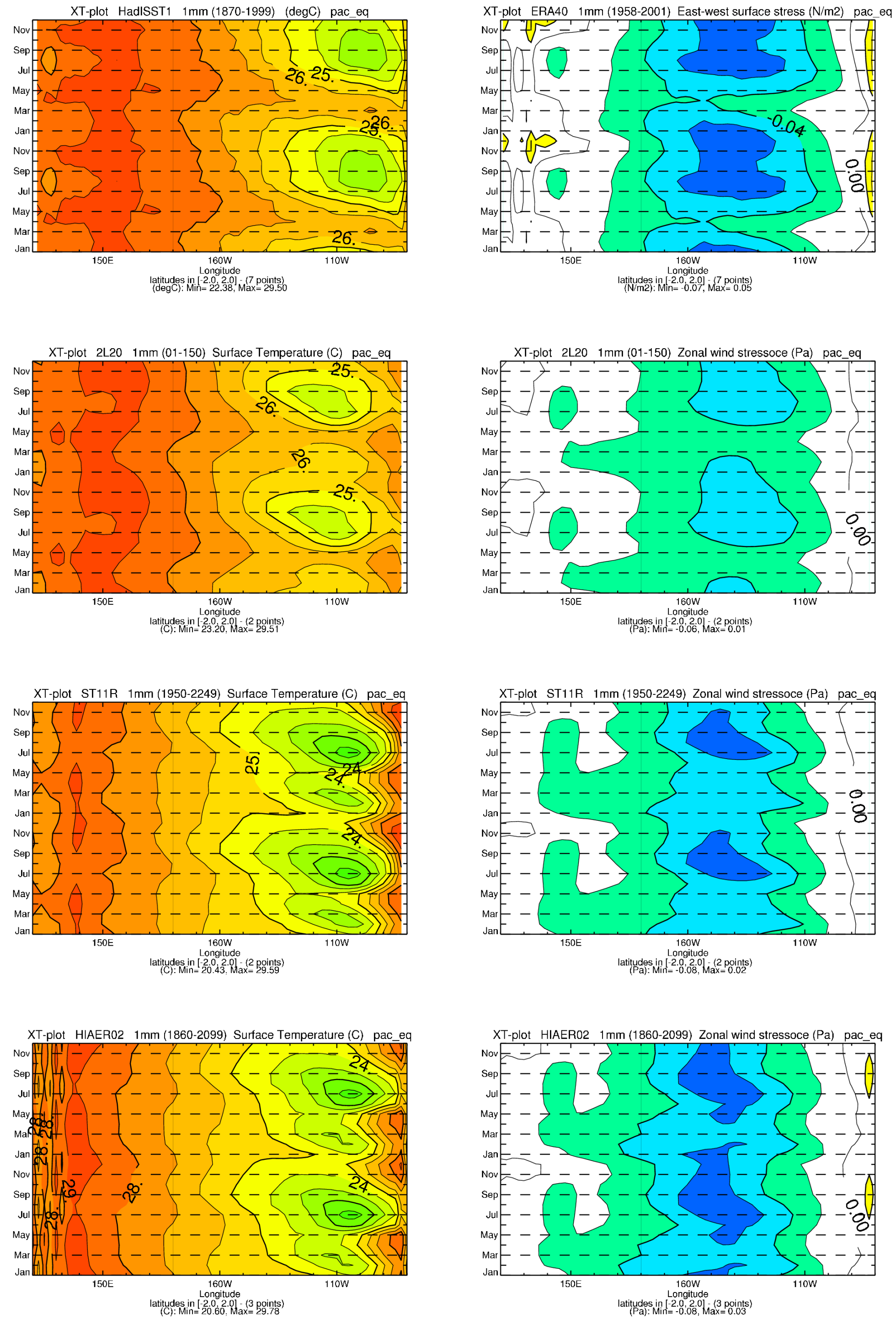
Cycle saisonnier moyen
SST (gauche) et
τ_x (droite)

Obs

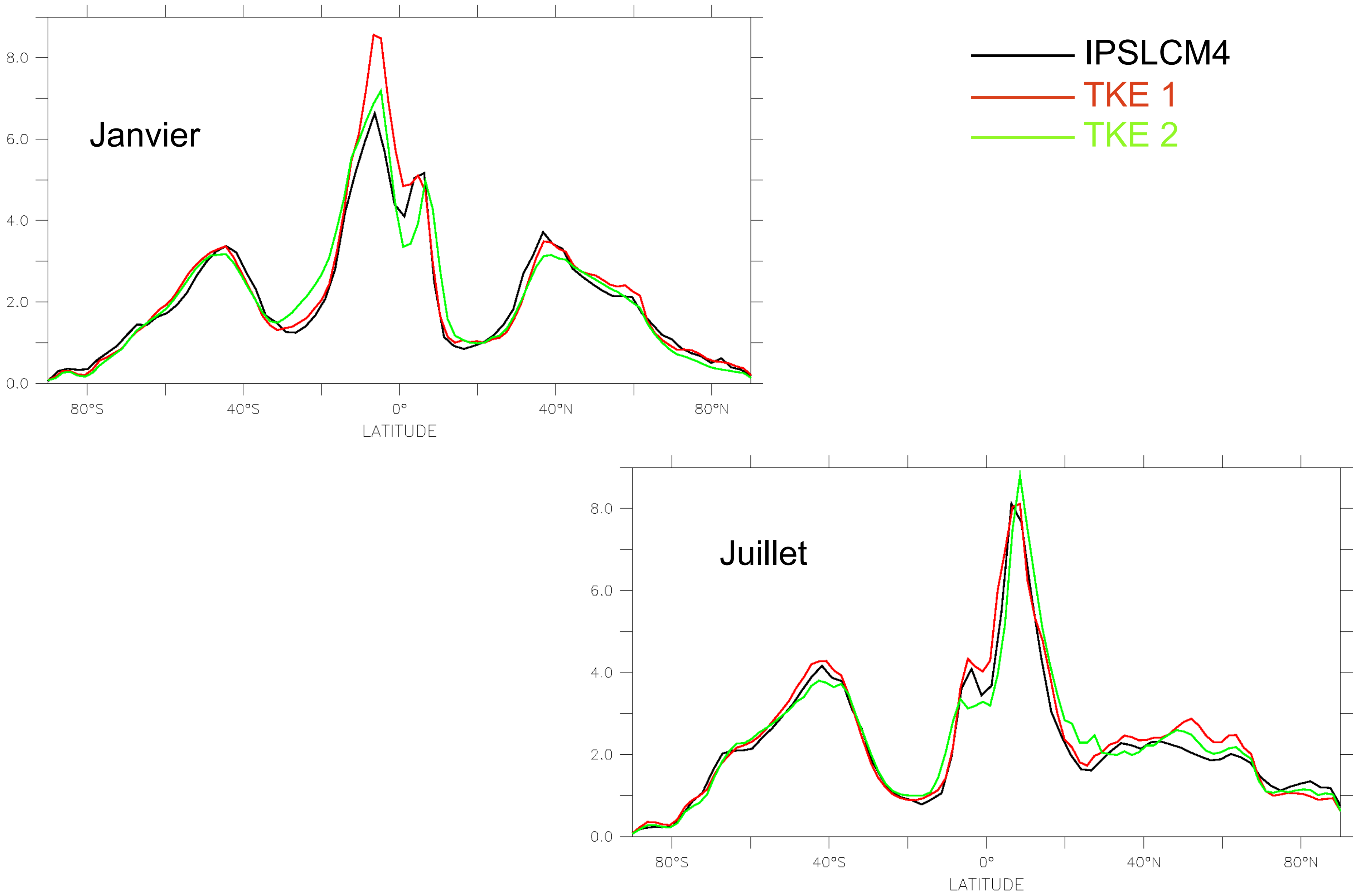
IPSLCM4

IPSLCM5

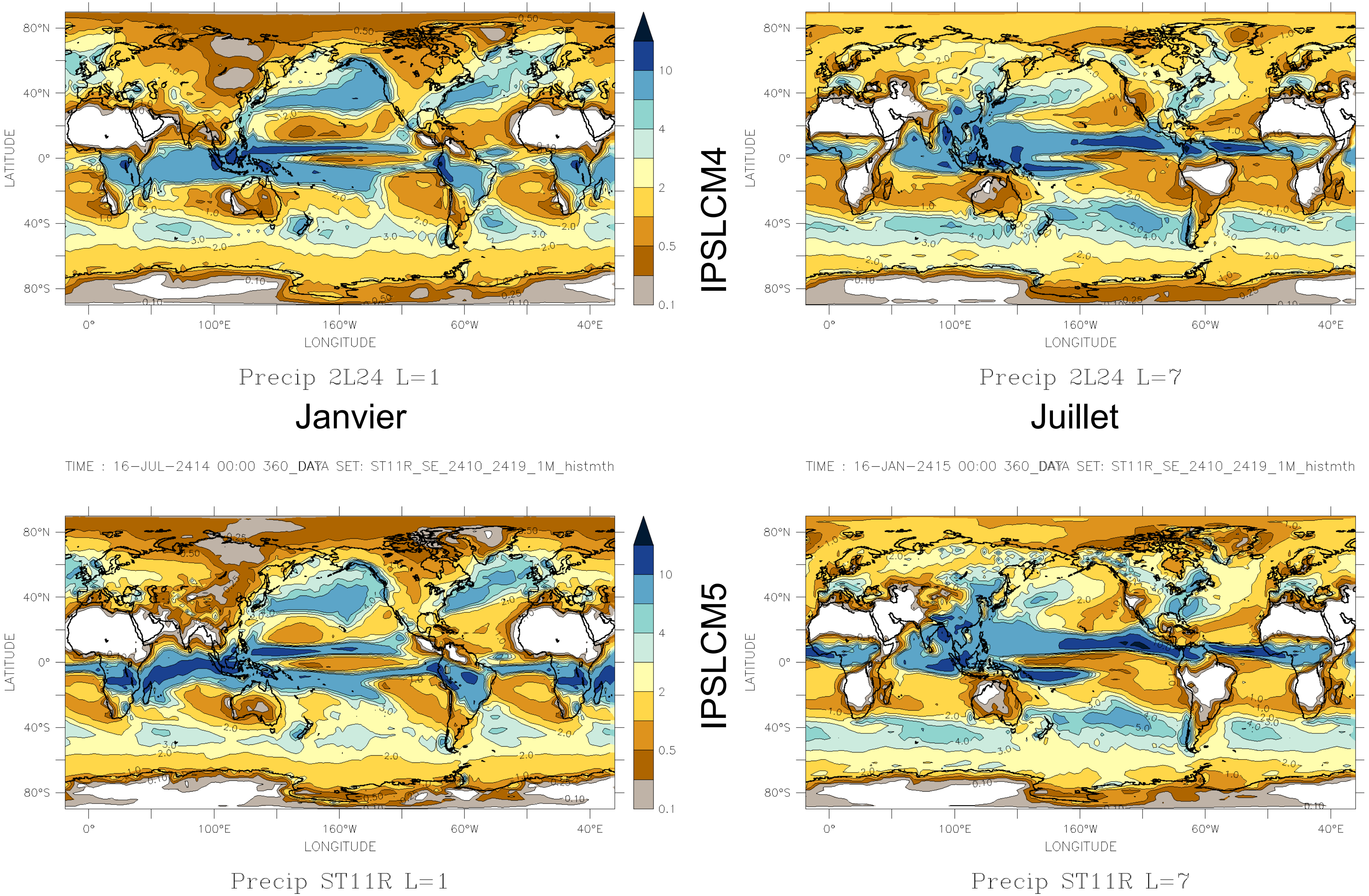
IPSLCM5 – LMDZ144x142



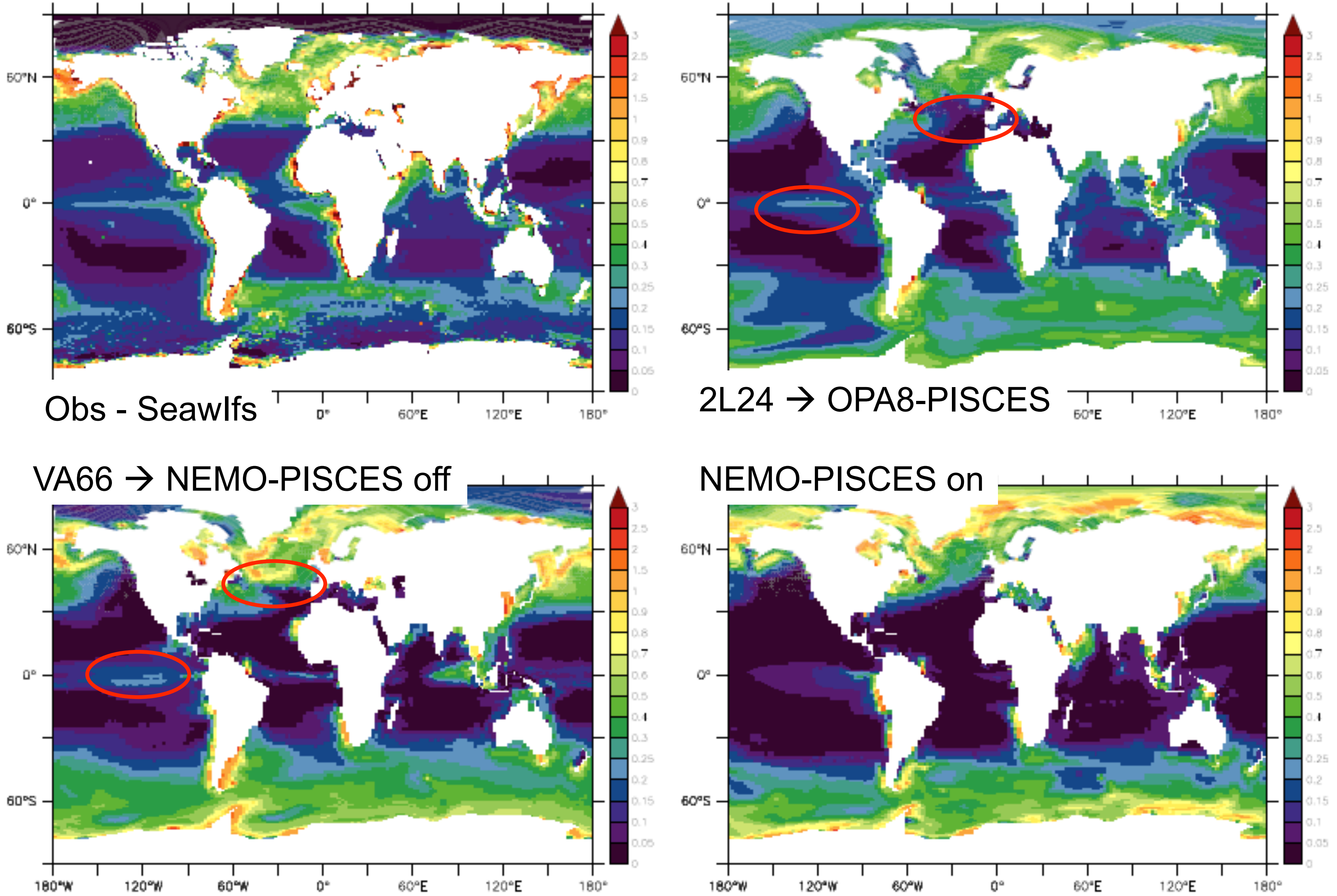
Précipitation



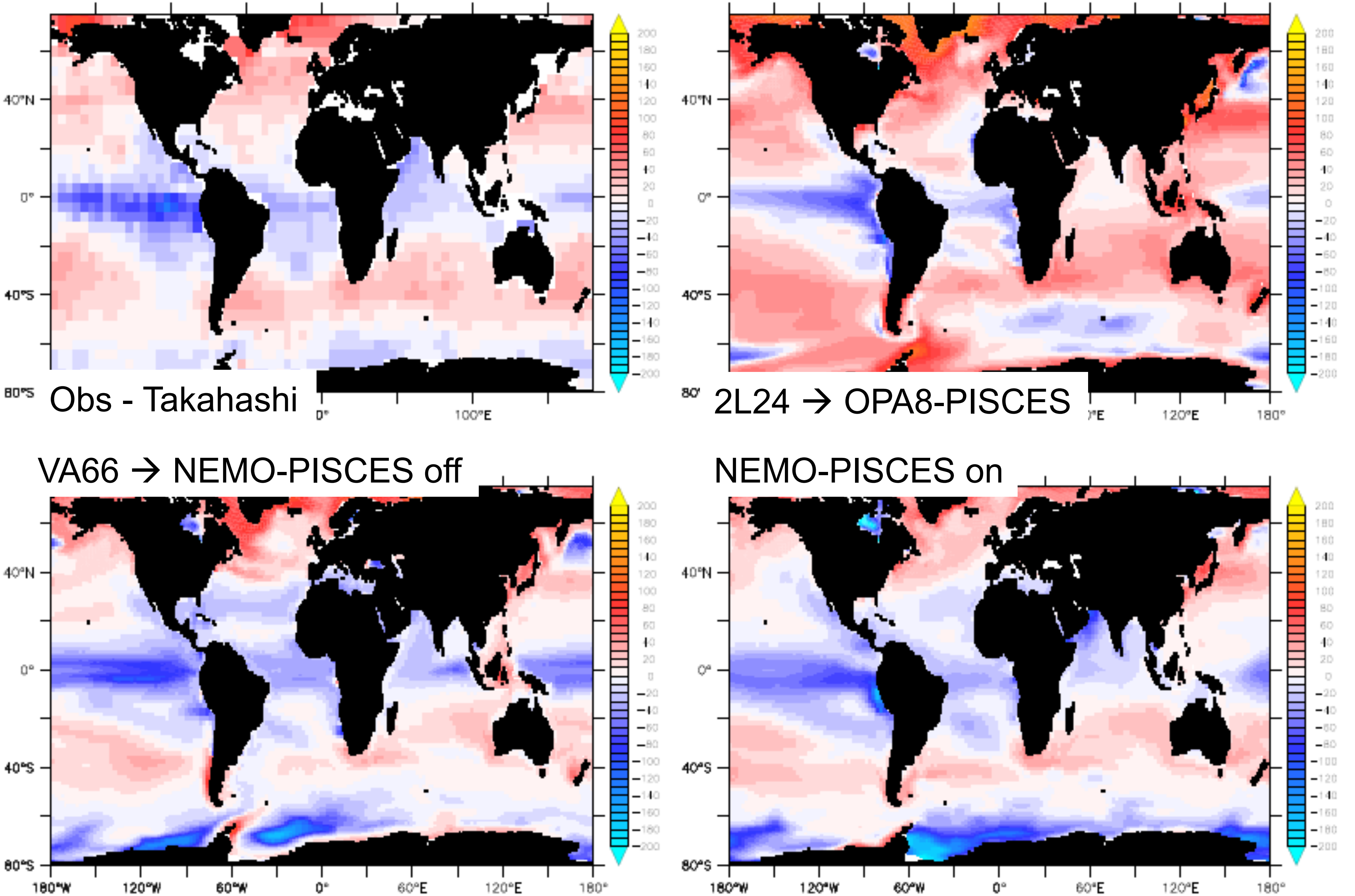
Précipitation IPSLCM4 vs. IPSLCM5



Chlorophylle de surface (moy. ann., mgC/m³)



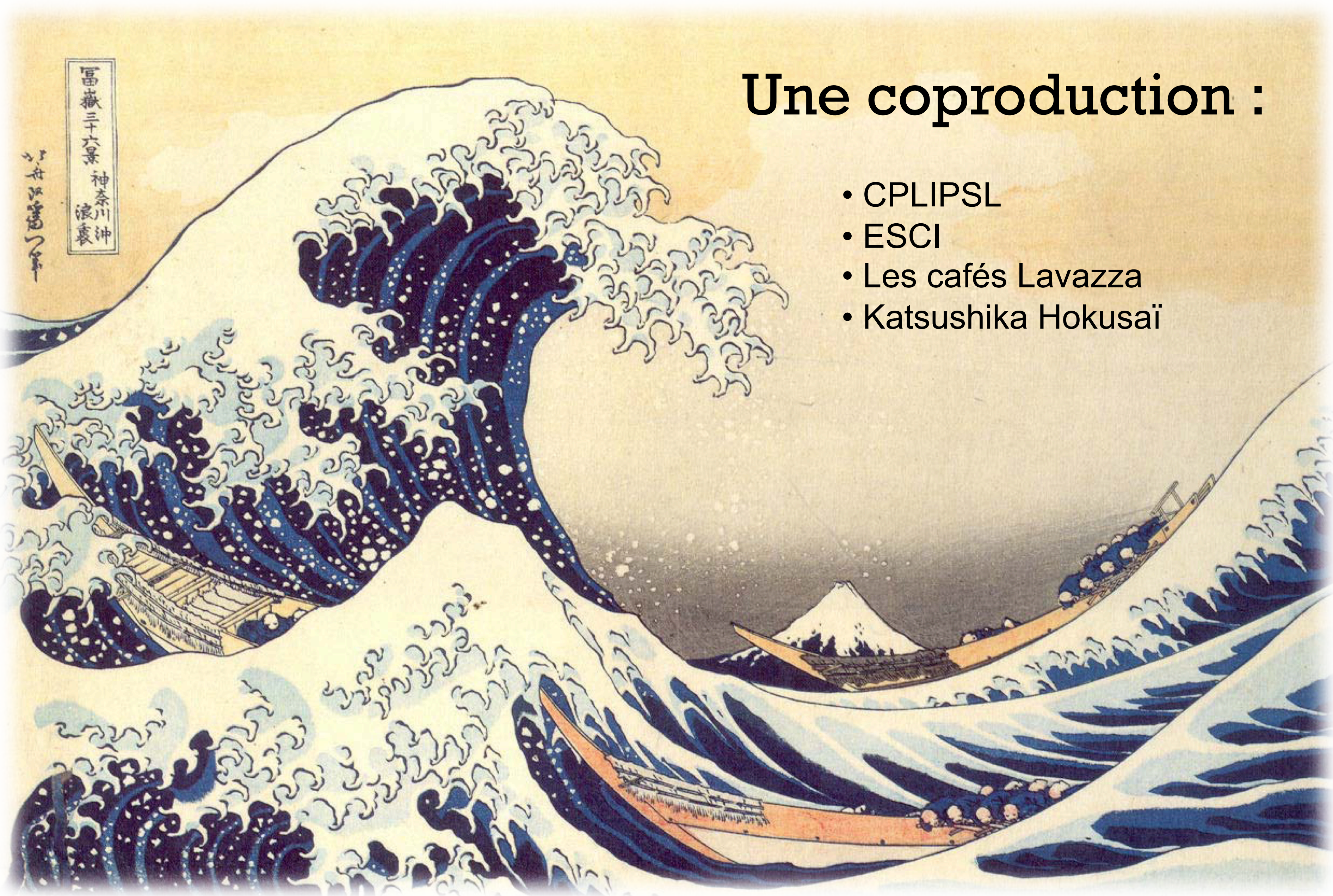
Delta pCO_2 (moyenne annuelle, ppm)



A faire …

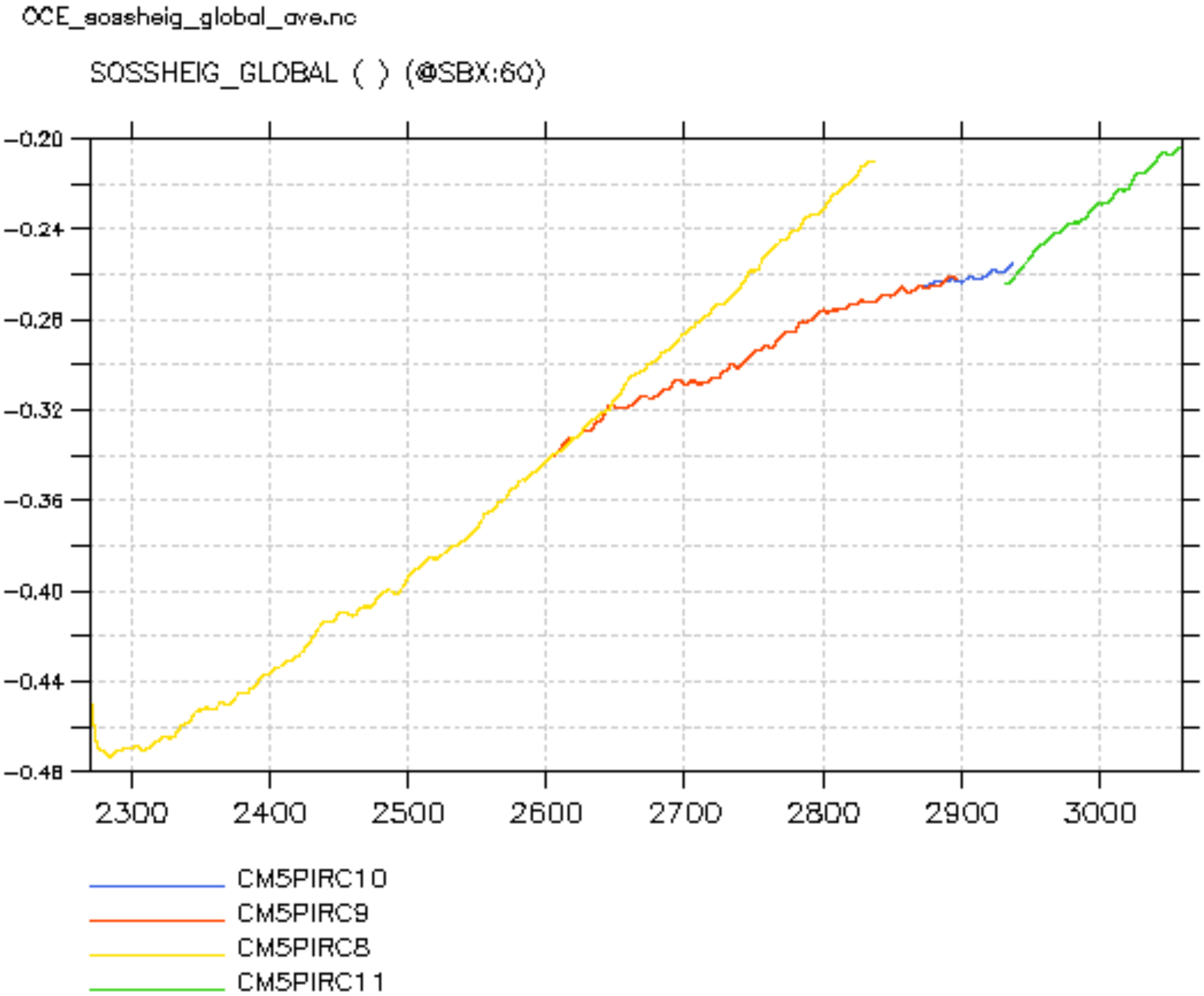
- Nouvelle physique LMDZ, et réglages ad hoc de TKE ;
- Couplage avec LIM3 : plusieurs types de glace ;
- Evolution vers OASIS 4.

神奈川沖浪裏 (1831), 葛飾 北斎 (*1760-1849*)



Une coproduction :

- CPLIPSL
- ESCI
- Les cafés Lavazza
- Katsushika Hokusaï


OCE_sosheig_global_ave.nc
SOSSHEIG_GLOBAL ( ) (@SBX:60)
-0.20
-0.24
-0.28
-0.32
-0.36
-0.40
-0.44
-0.48
2300
2400
2500
2600
2700
2800
2900
3000
CM5PIRC10
CM5PIRC9
CM5PIRC8
CM5PIRC11

Mélange vertical

$$\frac{dX}{dt} = \ldots + \frac{\partial}{\partial z}\left(A_T^v \frac{\partial X}{\partial z} \right)$$

$$A_m^v = C_k l_k \sqrt{e}$$

$$A_T^v = A_m^v / P_{rt}$$

Coefficients de mélange vertical

Longueur de mélange

Energie cinétique turbulente verticale (TKE)

Nombre de Prandtl

Madec G., 1002, NEMO ocean engine, Note du Pôle de Modélisation de l'IPSL No 27, ISSN1288-1619

TKE (e) : variable pronostique

Production par cisaillement vertical de courant

Mélange vertical

$$\frac{\partial \bar{e}}{\partial t} = A_m^v \left(\frac{\partial \mathbf{U}_h}{\partial z} \right)^2 - A_T^v N^2 + \frac{\partial}{\partial z} \left(A_m^v \frac{\partial \bar{e}}{\partial z} \right) - C_\varepsilon \frac{\bar{e}^{3/2}}{l_\varepsilon}$$

Terme de flottabilité :
- Profil stable : destruction

Dissipation Kolmogorov

$$l_k = l_\varepsilon = \sqrt{2\bar{e}} / N$$

Fréquence de Brünt-Vaïsala

$$P_{rt} = \begin{cases} 1 \text{ if } R_i \le 0.2 \\ 5R_i \text{ if } 0.2 \le R_i \le 2 \\ 10 \text{ if } 2 \le R_i \end{cases} \qquad R_i = N^2 / \left(\partial_z \mathbf{U}_h \right)^2$$

Madec G., 1002, NEMO ocean engine, Note du Pôle de Modélisation de l'IPSL No 27, ISSN1288-1619

Circulation de Langmuir

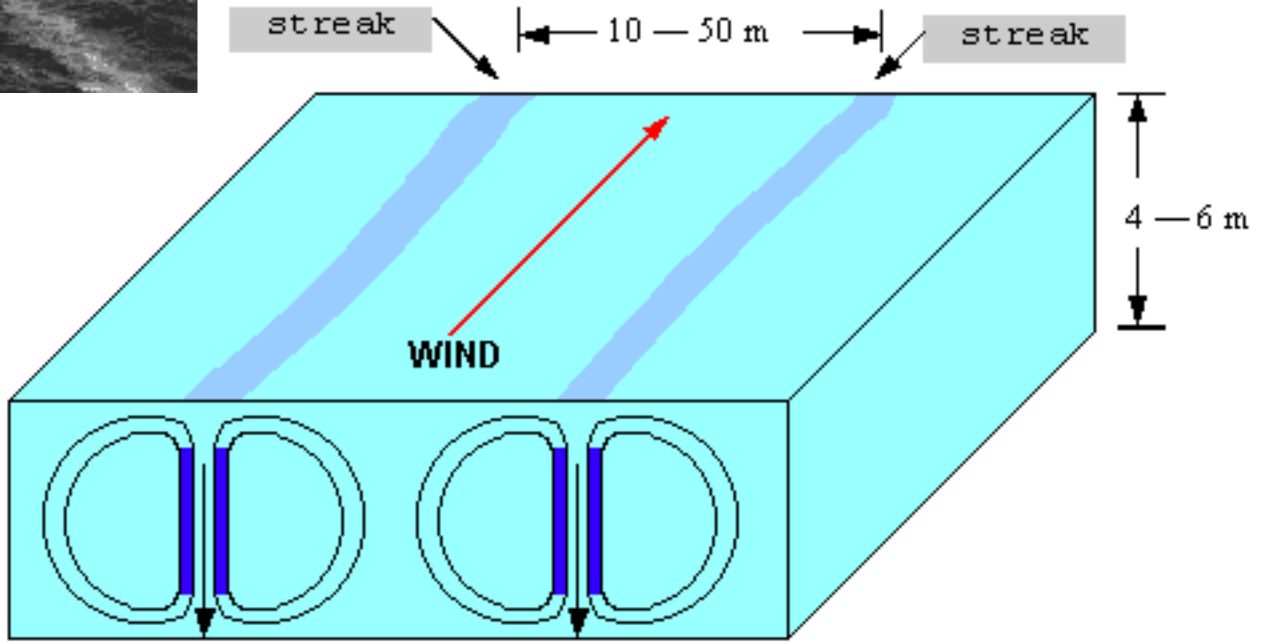


Figure 1 Diagram tracing water through Langmuir circulation cells.