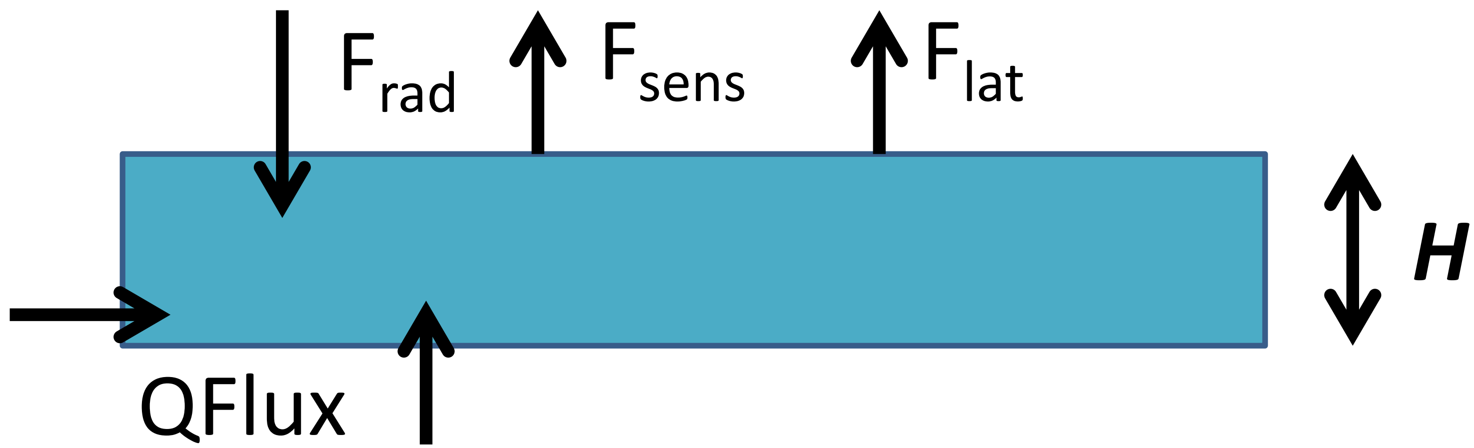
Le modèle d'océan « Slab » dans LMDZ

Francis Codron

LOCEAN/IPSL

Introduction : océan « slab »

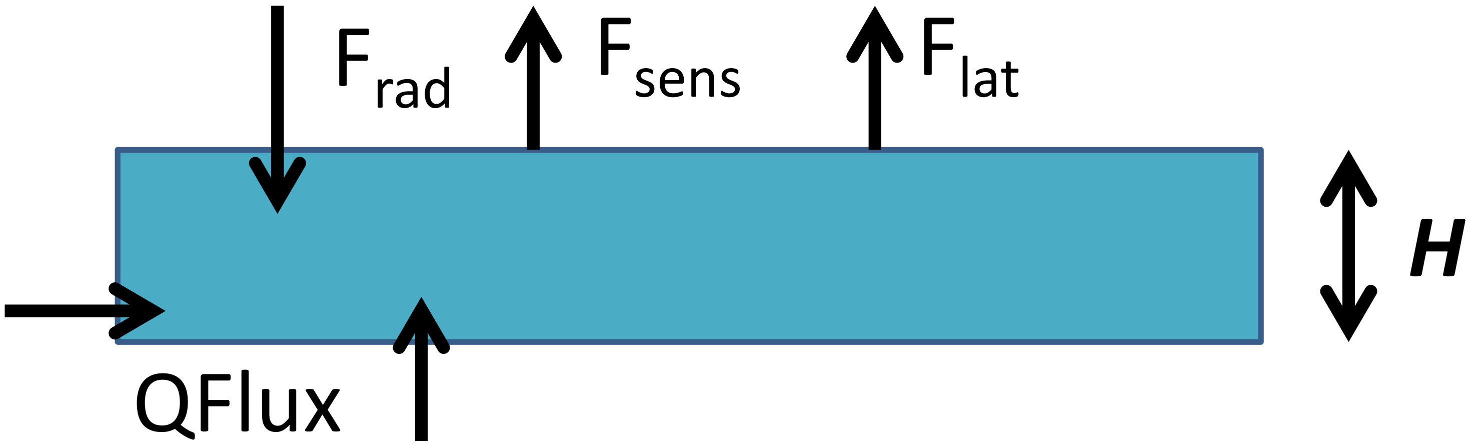


- Couche de surface mélangée de l'océan. Profondeur 50 m
- Équation d'évolution :

$$\rho c_p H \frac{\partial T}{\partial t} = F_{surf} + QFlux$$

- F_{surf} Flux en surface
- *Qflux* impact de la dynamique océanique (prescrit)
- Conserve l'énergie !

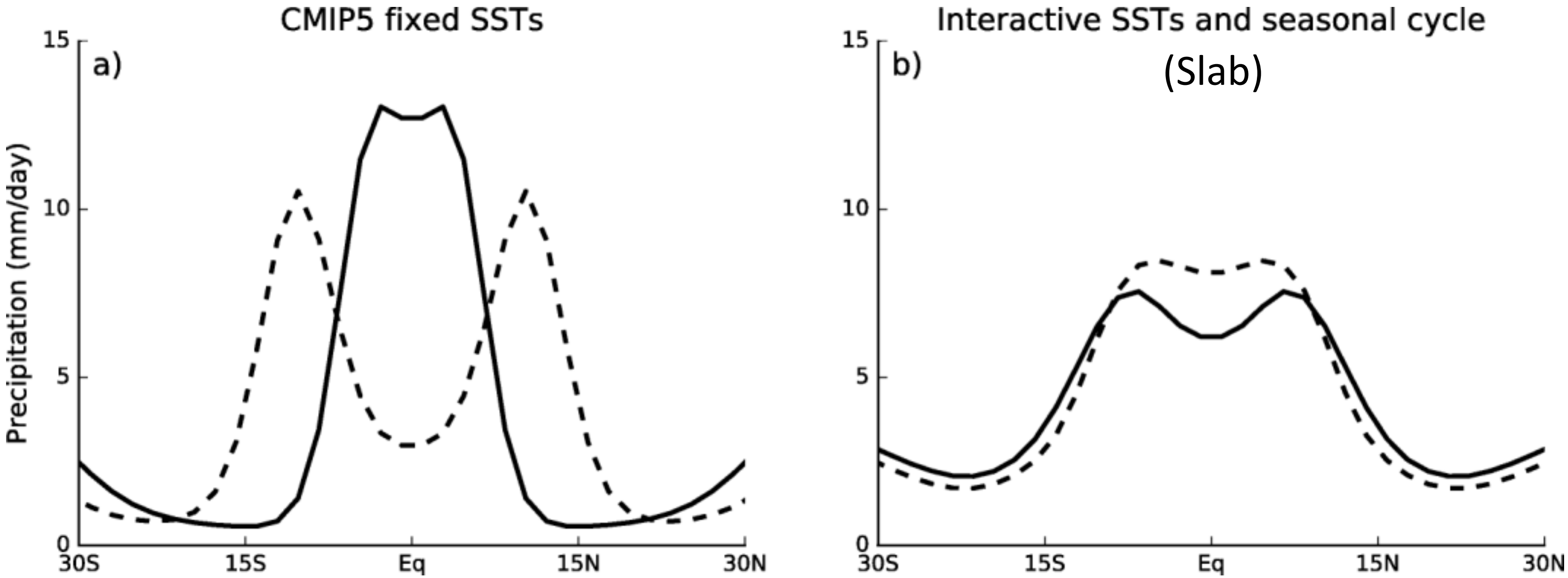
Condition aux limites type « flux »



$$\rho c_p H \frac{\partial T}{\partial t} = F_{surf} + QFlux$$

En moyenne à long terme, $\overline{F_{surf}} = \overline{QFlux}$

- Avec slab, flux imposés mais pas SST
- SST fixe : flux variables…



Précipitations en aquaplanète avec ECHAM,
2 schémas de convection profonde. *(Aiko Voigt)*

Calcul du « Qflux »

$$\rho c_p H \frac{\partial T}{\partial t} = F_{surf} + QFlux$$

En moyenne saisonnière,

$$\rho c_p H \frac{\partial \bar{T}}{\partial t} - \overline{F_{surf}} = \overline{QFlux}$$

- $\bar{T}$ et $\overline{F_{surf}}$ lus dans fichier limit_slab.nc

- Pour une SST réaliste, calcul à partir de sorties d'une simulation type AMIP

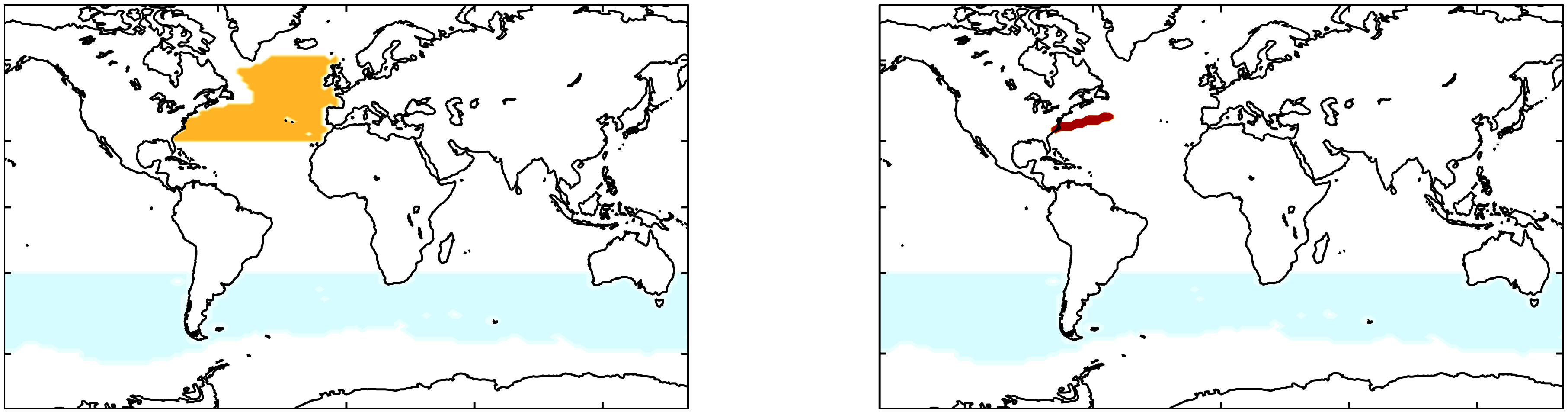
Example utilisation du Qflux (L'Héveder et al 2012)

LMDZ (144x142x39) + « Slab » Ocean : $\rho C H \frac{\partial T}{\partial t} = F_{\mathrm{surf}} + Q$

Prescribed Q-flux anomaly reproduces increased AMOC:

- Global mean = 0
- Implied meridional transport = 0,08 PW
- 2 extreme distributions on North Atlantic heating.

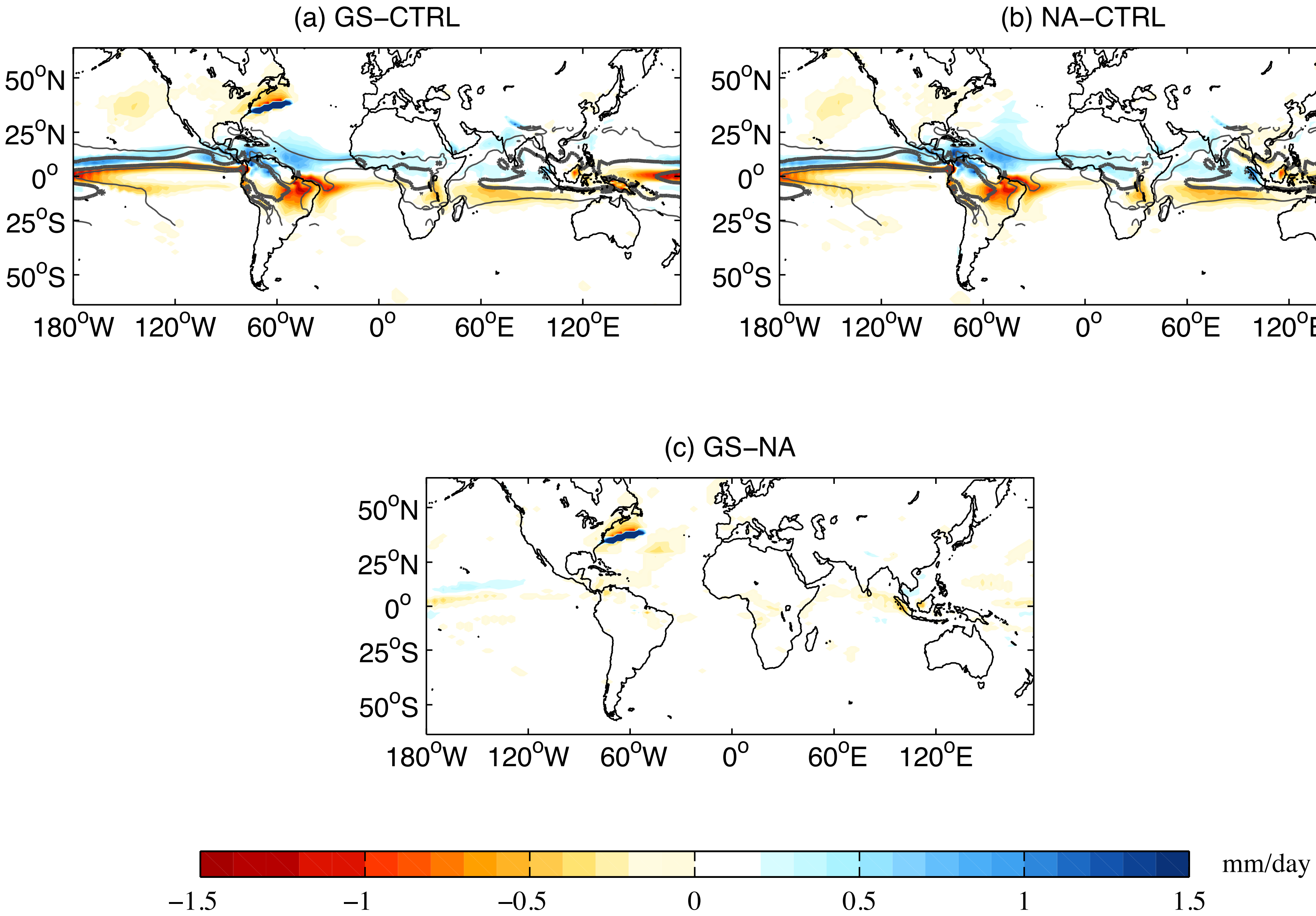
(a) NA (b) GS



North Atlantic (NA) Gulf Stream (GS)

Global impact on precipitation: Northward increase

No remote impact of North Atlantic distribution



Traitement de la banquise

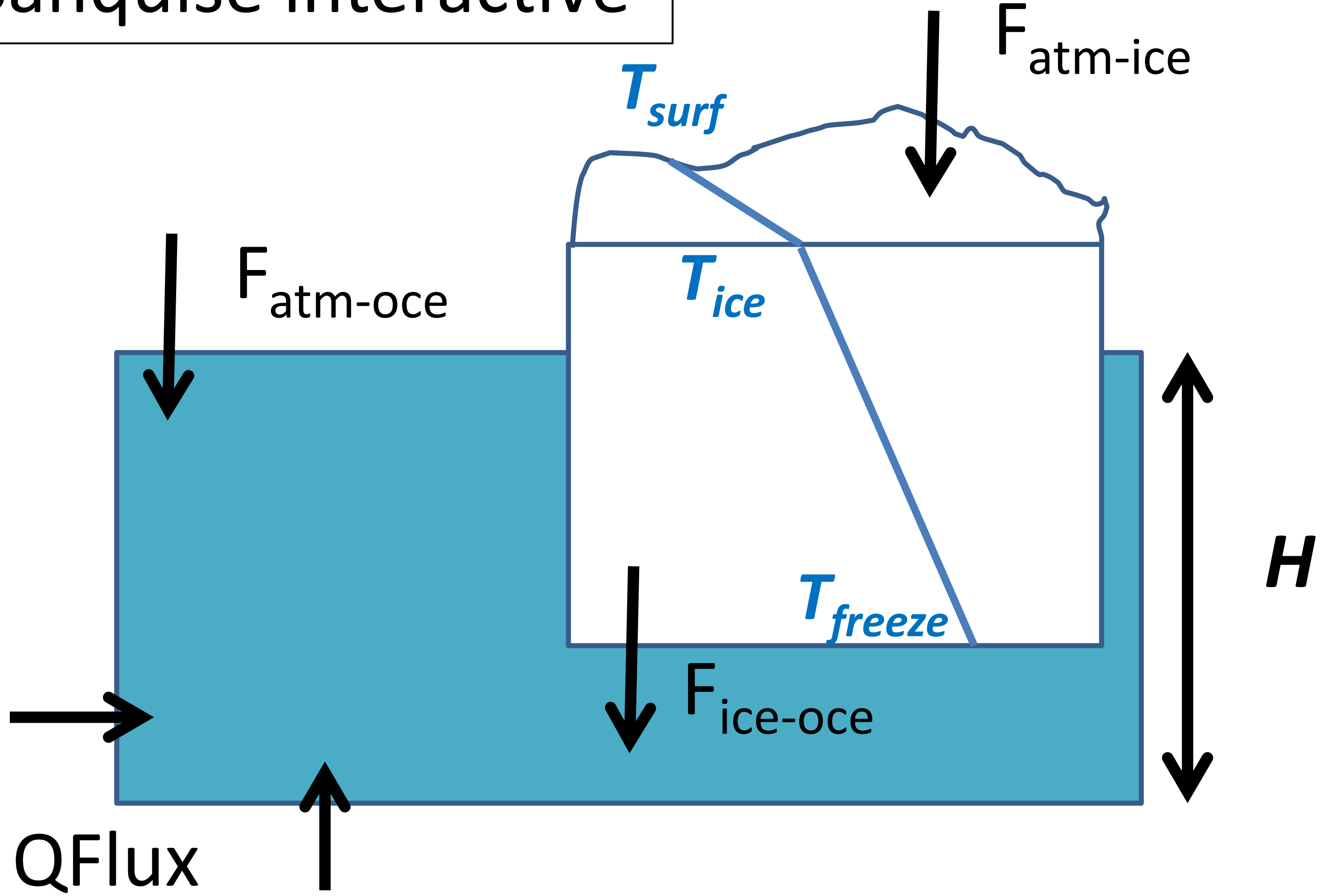
options (version_ocean) :

1. sicOBS : banquise prescrite. T_{slab}= -1,8° en présence de glace

2. sicNO : banquise ignorée (mais peut être prescrite !). T_{slab} peut devenir négative, ou positive en présence de glace.

3. sicINT : banquise interactive (thermodynamique)

Banquise interactive



En présence de glace, T_{slab} = -1,8°C

Les flux servent à créer / fondre la glace

Applications :

- Aquaplanètes
- Planètes extra-solaires (F. Selsis…)
- Terre primitive (B. Charnay)

En cours de mise au point: estimation de Qflux pour banquise interactive « réaliste »

- Variabilité banquise arctique (Camille Risi)

Paramétrisation des transports d'Ekman

(Codron 2012, Clim. Dyn)

- Transport de masse intégré dans la couche de surface :

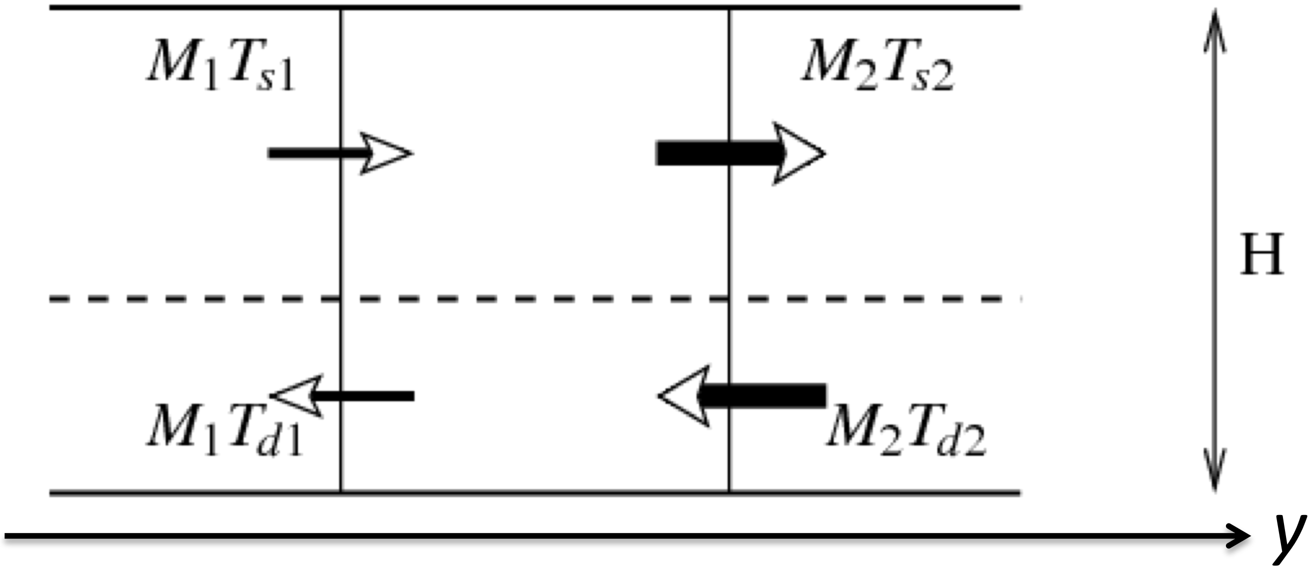
$$\overrightarrow{V_E} = -\frac{1}{f}\vec{k}\times\vec{\tau}$$

Utilisé pour advection horizontale de température T_{slab}.

- Courant de retour profond opposé, à température « profonde »
- Importance : upwellings (équateur), transports méridiens d'énergie

1.5-Layer scheme

Slab temperature T_s, return flow at T_d

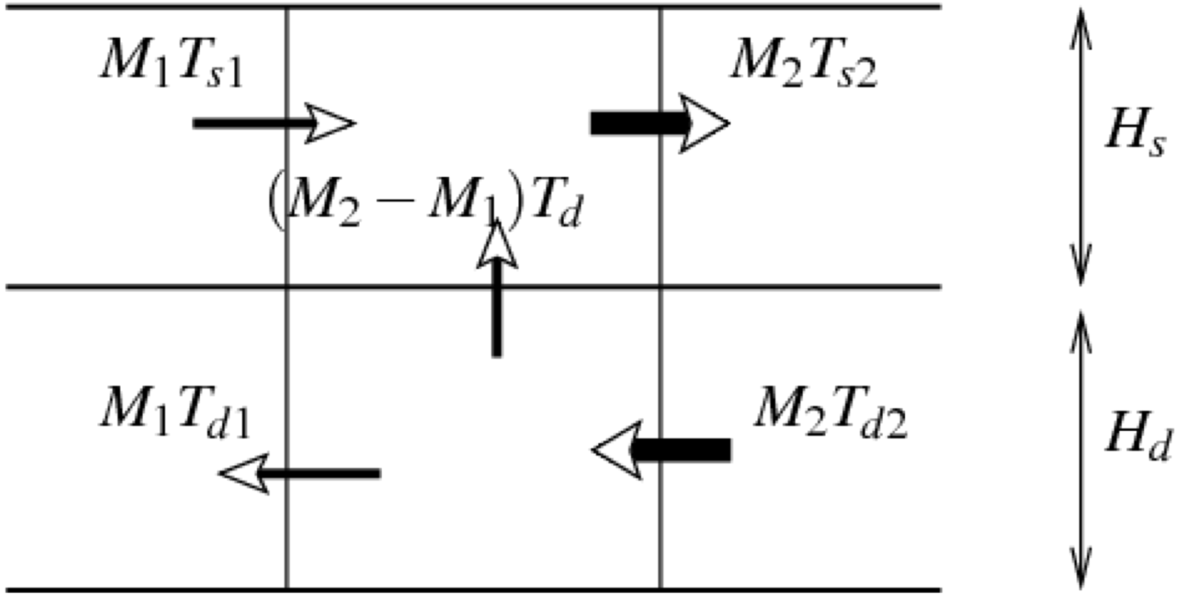


Deep temperature: $T_d = \alpha T_s + (1-\alpha) T_0$

$$\rho H S \frac{\partial T_s}{\partial t} = M_1 (T_{s1} - T_{d1}) - M_2 (T_{s2} - T_{d2})$$

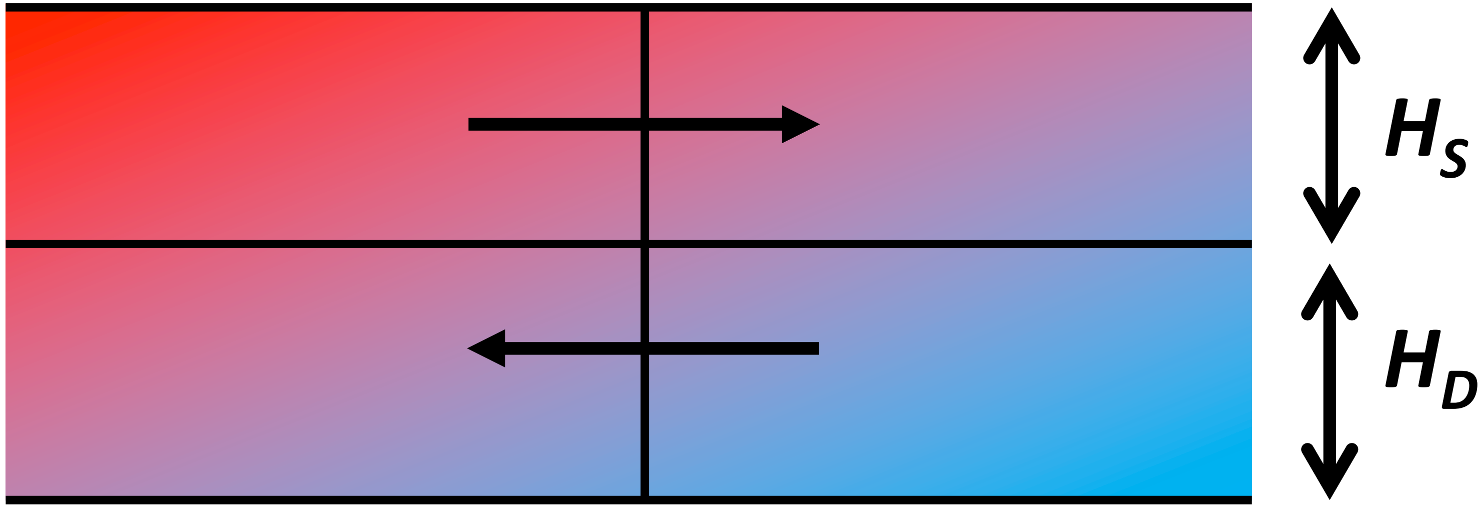
2-layer scheme

2 slab layers, prognostic temperatures T_s and T_d



- Surface heat fluxes go in the surface layer
- Convective adjustment

Gent-McWilliams scheme (eddy diffusivity)



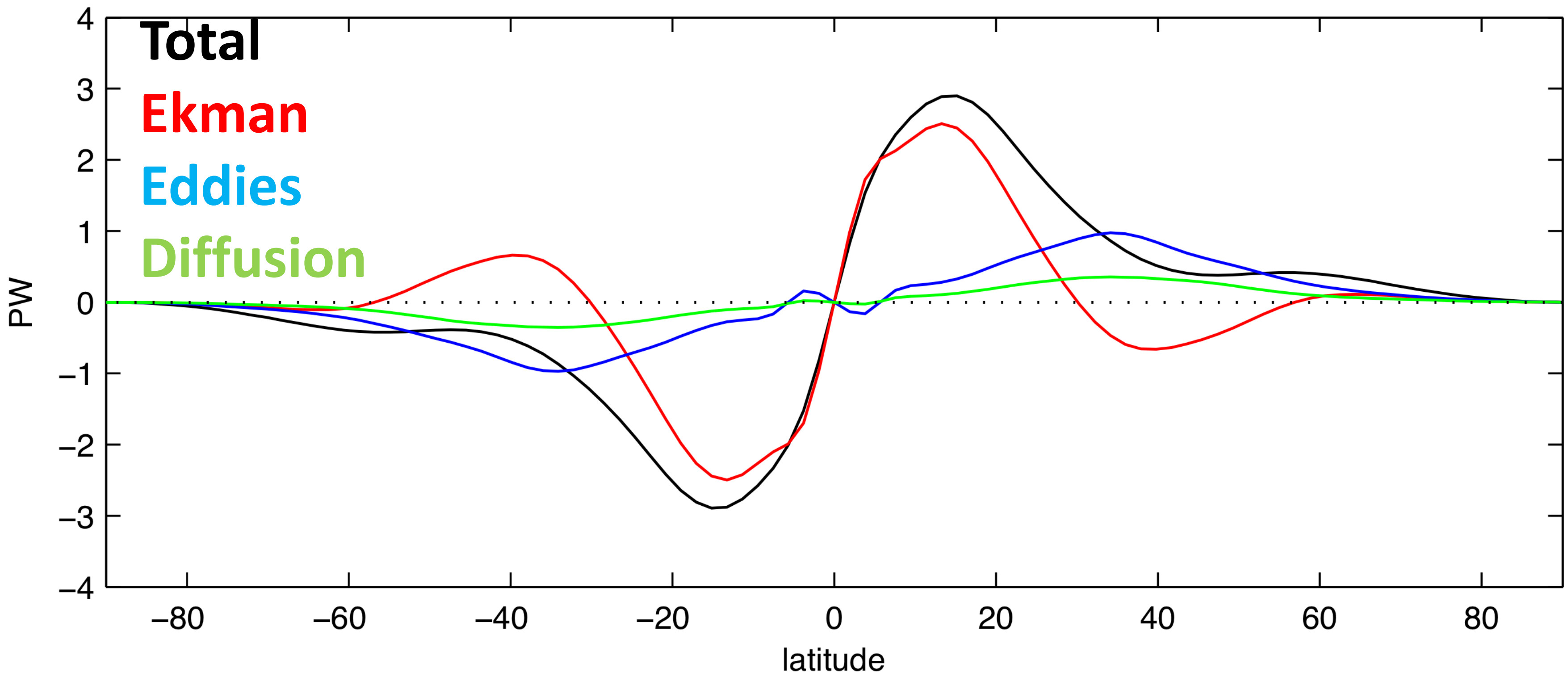
Effet des tourbillons : réduire la pente des isothermes.

- Vitesse advective ~ pente
- Transport intégré type diffusif
- Re-stratification

Implementation

- LMDZ AGCM, 96x96 grid points, 39 levels
- Ocean-planet geometry, no sea ice
- Obliquity (seasons), no eccentricity
- Ekman transport and GM + horizontal diffusion
- No additional heat flux (Q-flux = 0)

Mean northward energy transport by the ocean



- Ekman : poleward transport in the Tropics, weaker equatorward in mid-latitudes
- Eddy diffusion in mid-latitudes (large temperature gradients)

Sensitivity experiments:

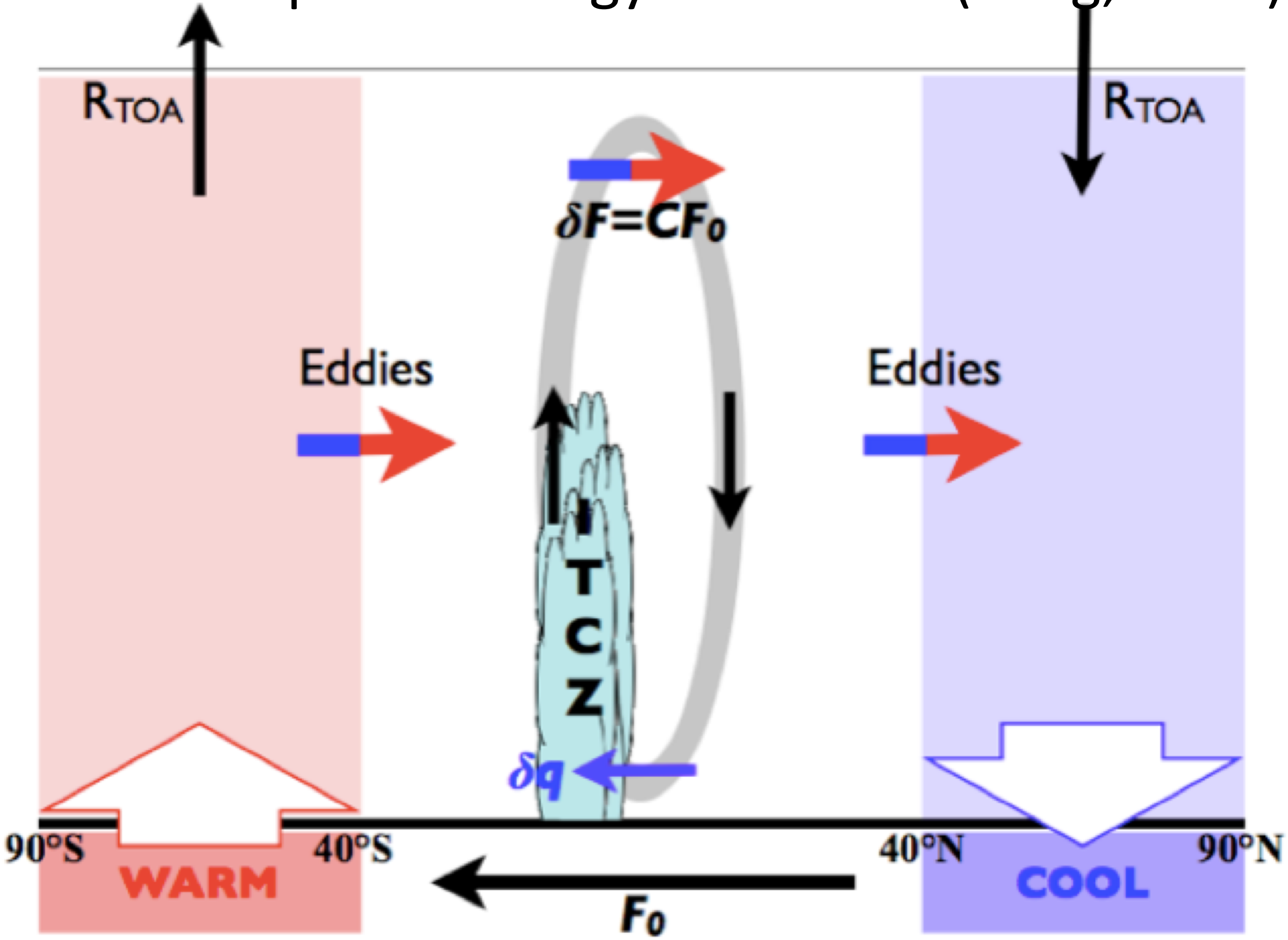
add 1 PW northward transport between 40°S and 40°S
(as additional prescribed Q-flux in the slab)

1. Interactive Ekman and diffusive transports

2. Ekman and diffusion prescribed as control seasonal cycle

Compensation transports d'énergie atmos - océan

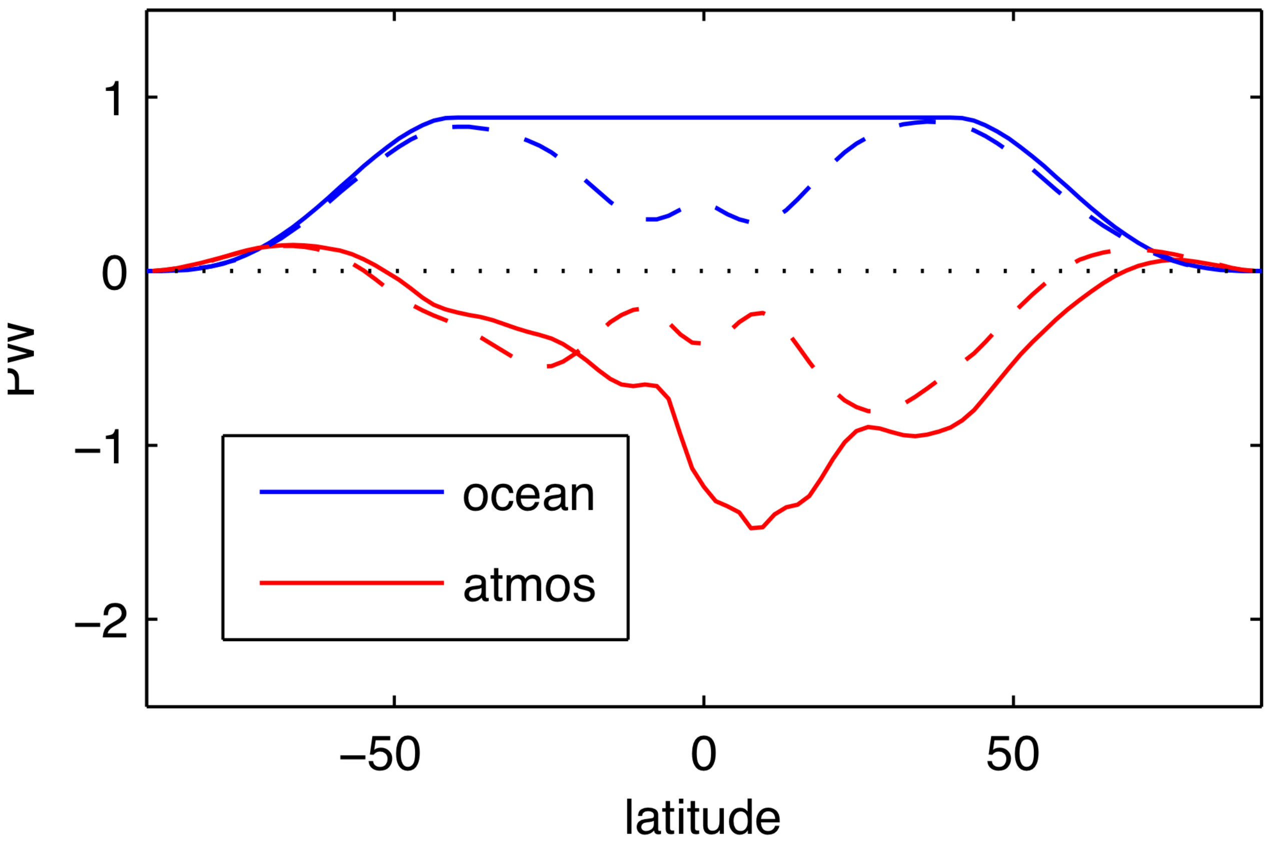
Response of atmospheric circulation and ITCZ to inter-hemispheric energy imbalance (Kang, 2009)



Kang (2008,09), Frierson (2012,13), L'Héveder (2015), Donohue (2013,14), TRACMIP project…

Difference of northward energy transport by Ocean and Atmosphere

- Fixed Ekman / diffusion
- Interactive Ekman / diffusion



- Large differences between fixed / inter cases (esp. Tropics)
- Good compensation between ocean and atmosphere

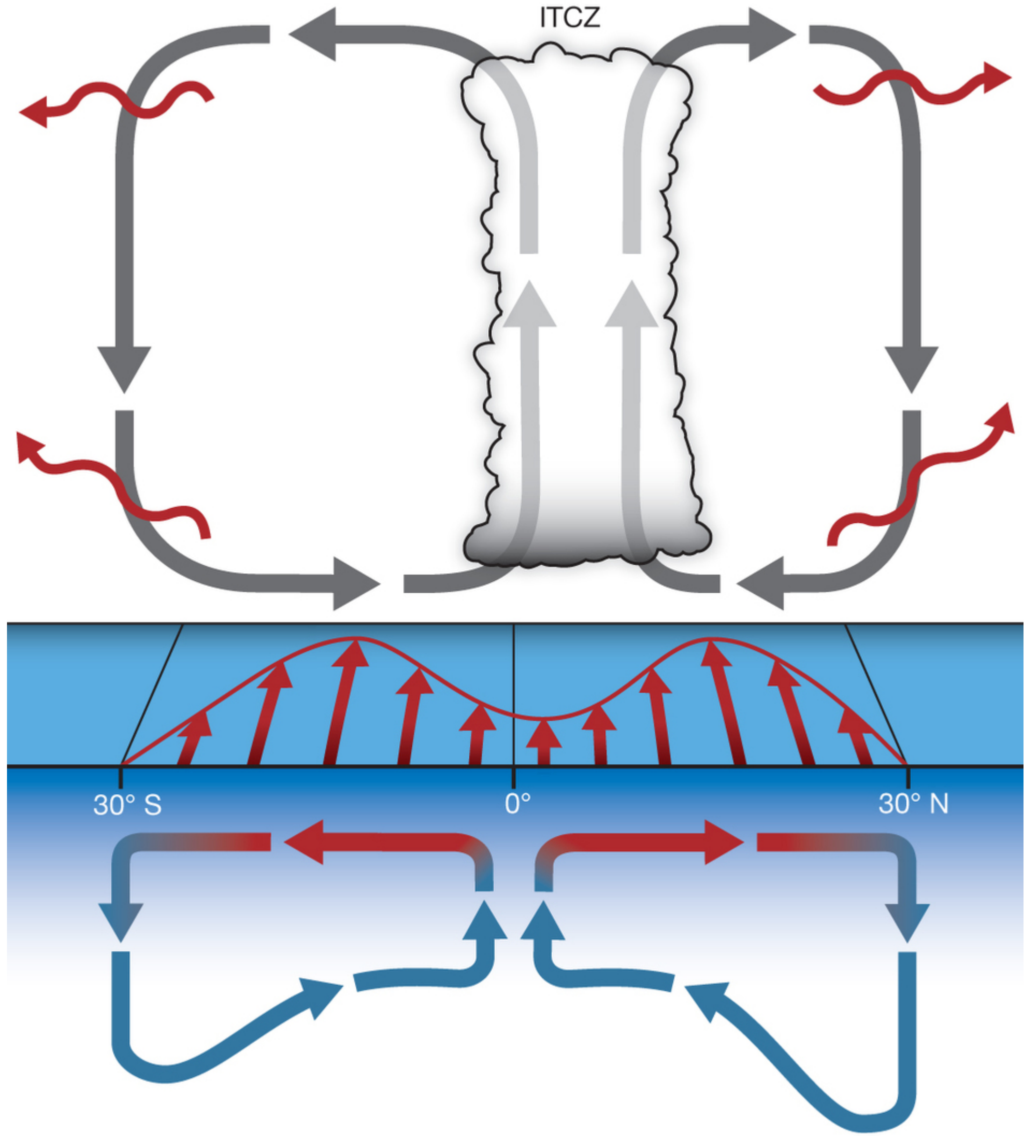
All these studies use a « slab » ocean... $\rho C H \frac{\partial T}{\partial t} = F_{\text{surf}} + Q$

But energy transports by atmosphere and ocean are not independent

Tropics:

Shallow circulation cells

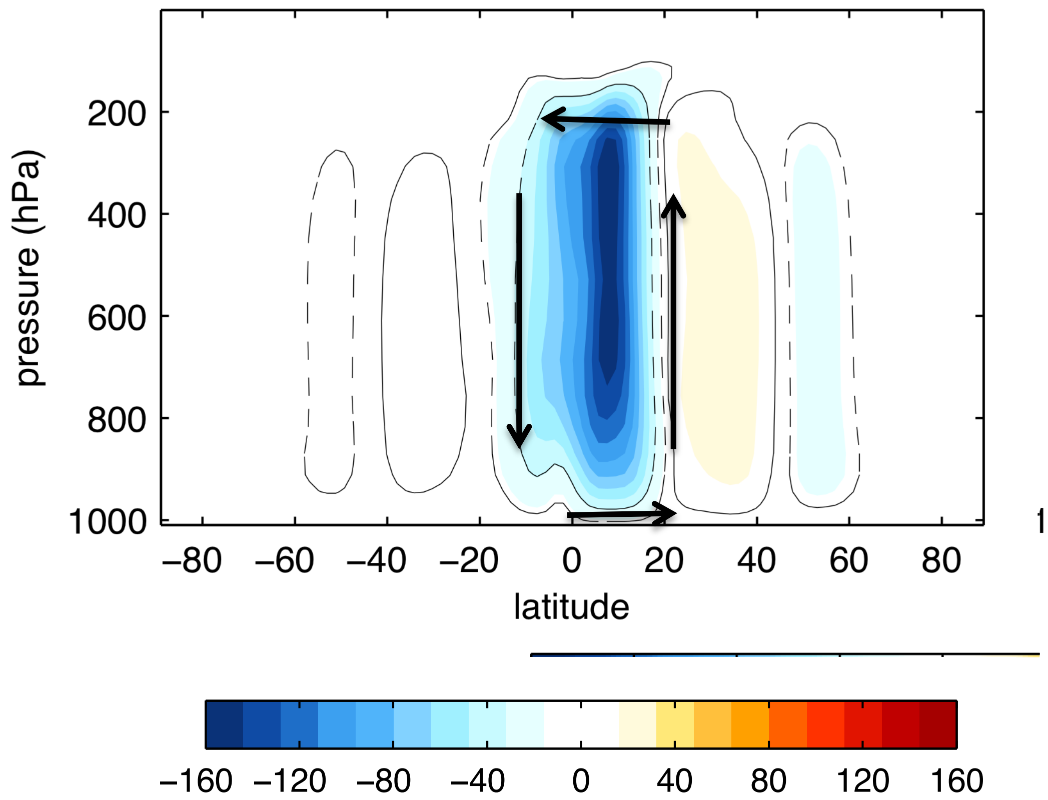
- Driven by trade winds / Ekman transport
- Mass transport = Hadley cells
- Transport energy poleward



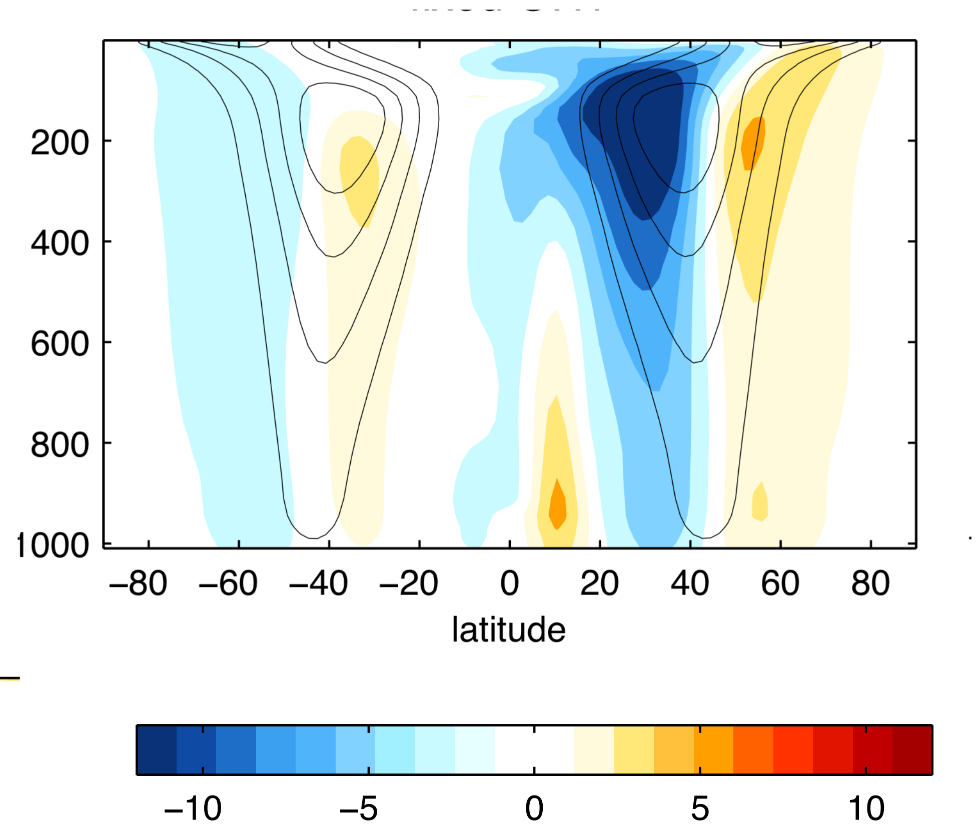
(Schneider et al, 2014)

Atmospheric circulation response, fixed OHT

Meridional Streamfunction (10^9 kg/s)



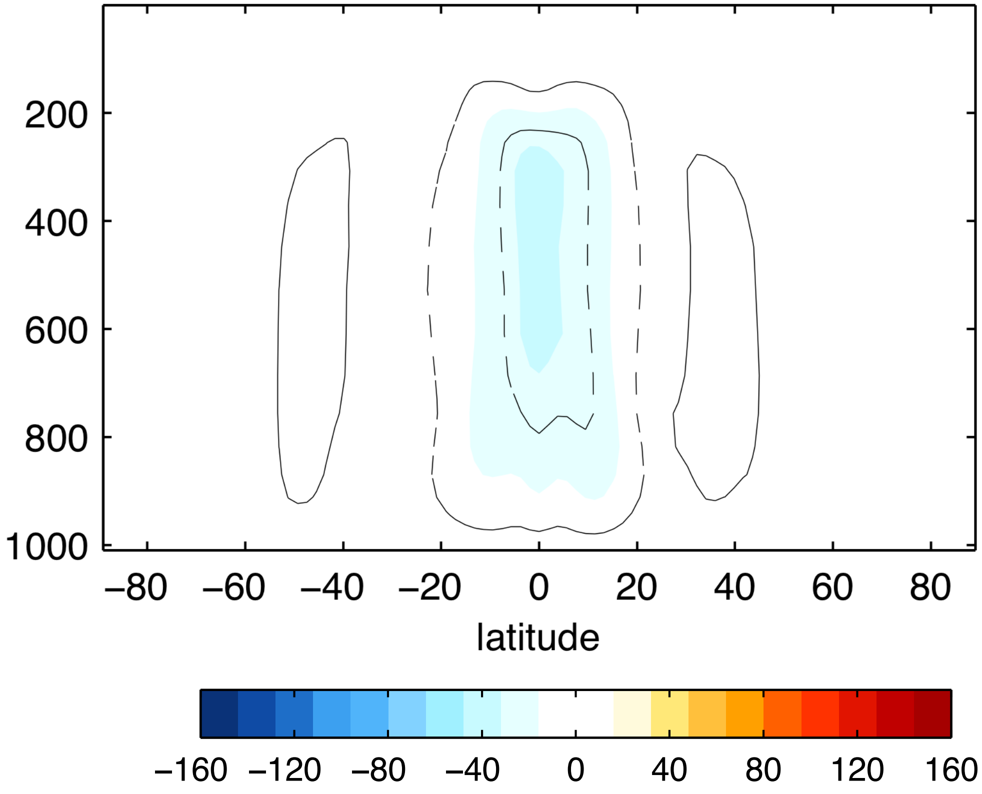
Zonal wind



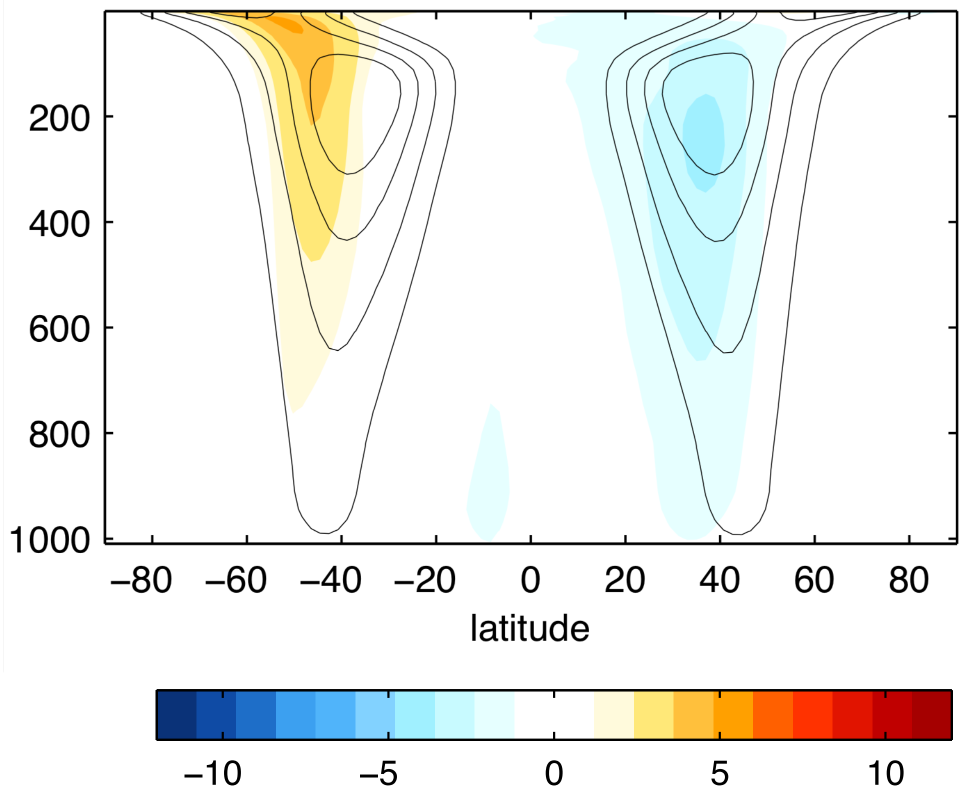
- Northward jet shifts
- Cross-equatorial Hadley cell & opposite trade wind changes

Atmospheric circulation response, fixed OHT

Meridional Streamfunction (10^9 kg/s)

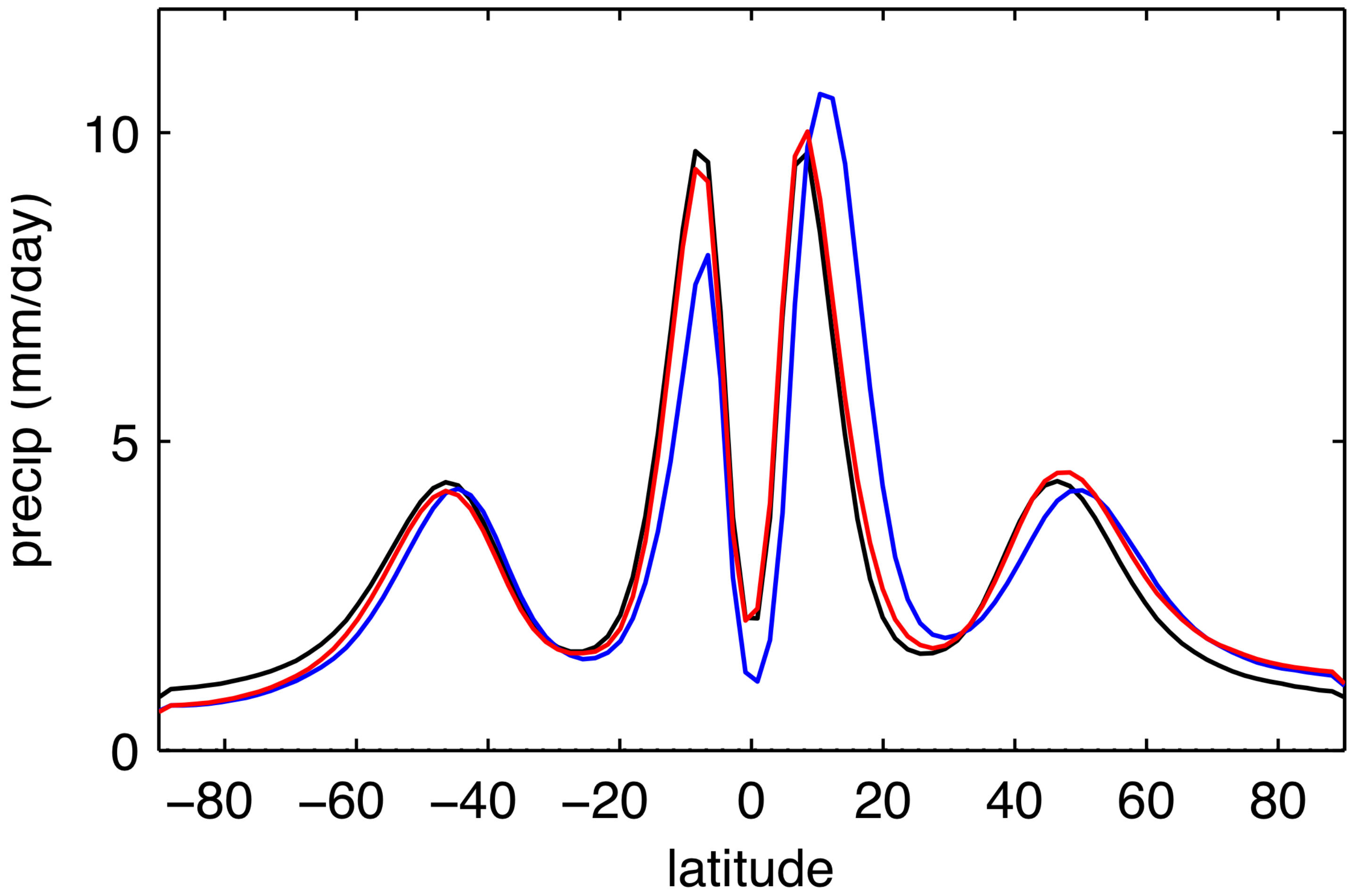


Zonal wind



➢ Réponse beaucoup plus faible

Précipitations



Contrôle **1PW interactif** **1PW fixe**

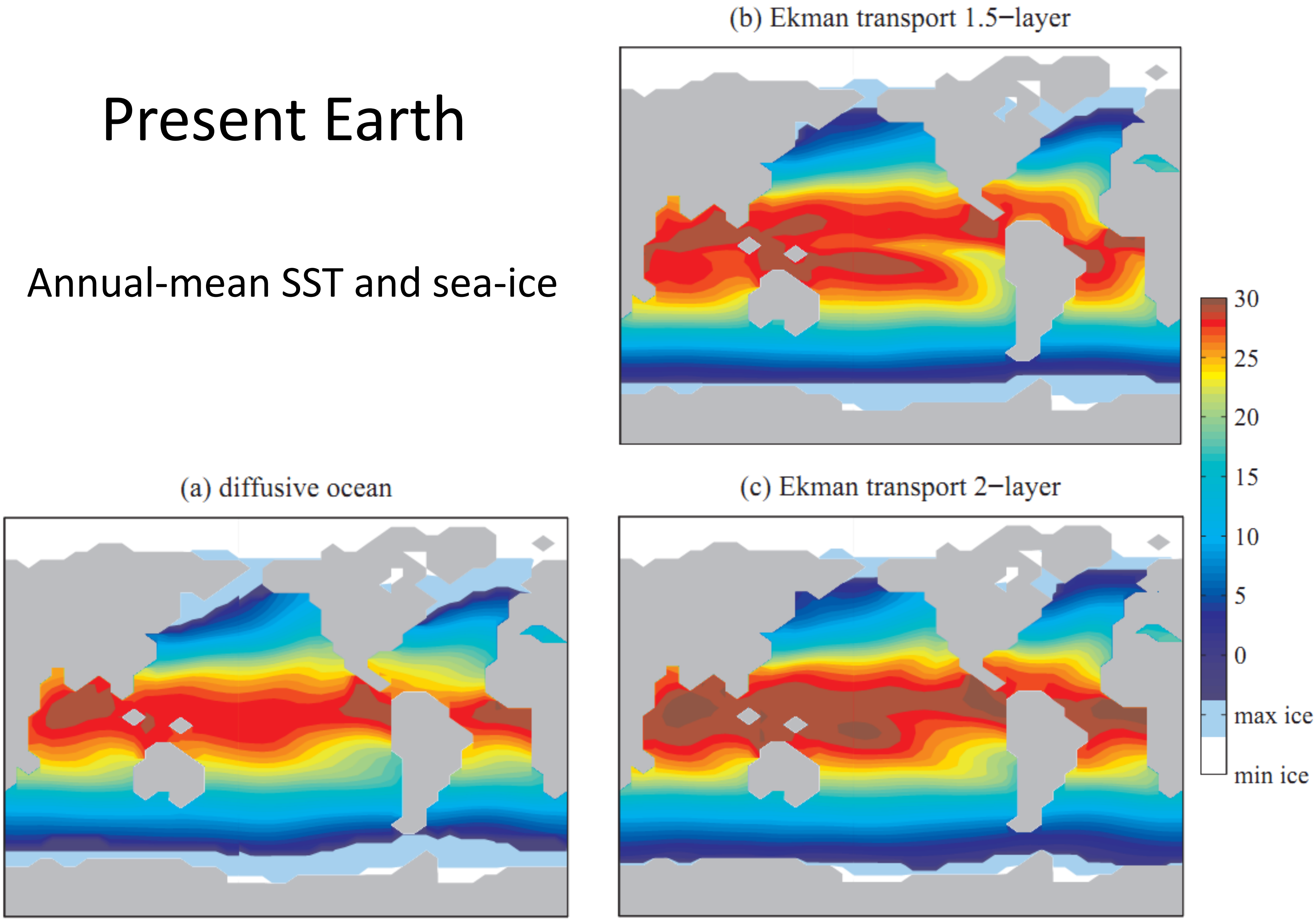
Conclusions

- Tout ça est en standard dans la physique de LMDZ : type_ocean = slab
- 2 routines : ocean_slab_mod et slab_heat_transp_mod
- Un peu de mise en place (fichiers limit et qflux, variables sortie, choix de paramètres…)

➢ Venir me voir !

Present Earth

Annual-mean SST and sea-ice



Mean seasonal cycle:

Precipitation and northward energy transport by the atmosphere

Energy flux equator
In red