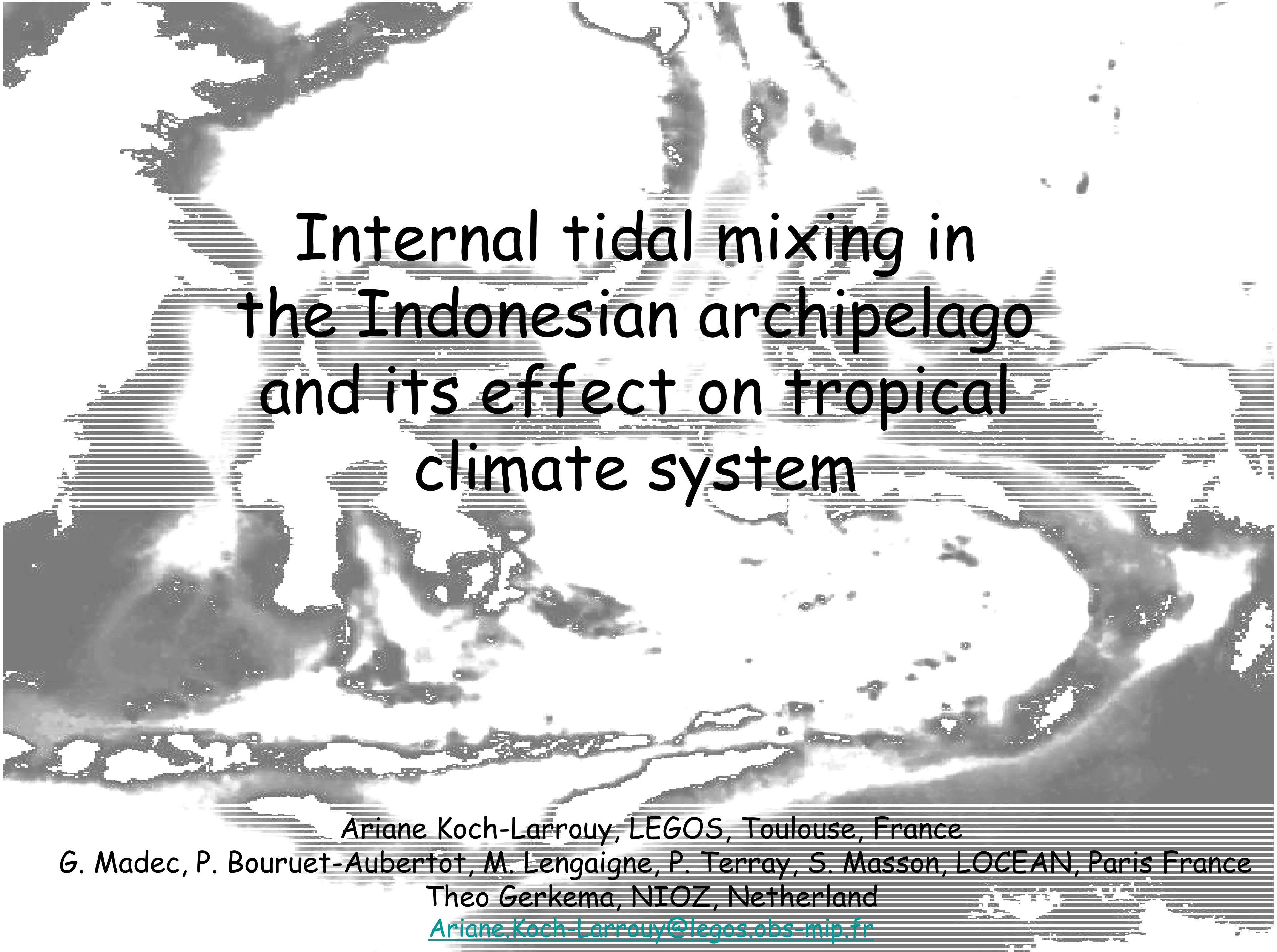

Internal tidal mixing in the Indonesian archipelago and its effect on tropical climate system

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G. Madec, P. Bouruet-Aubertot, M. Lengaigne, P. Terray, S. Masson, LOCEAN, Paris France
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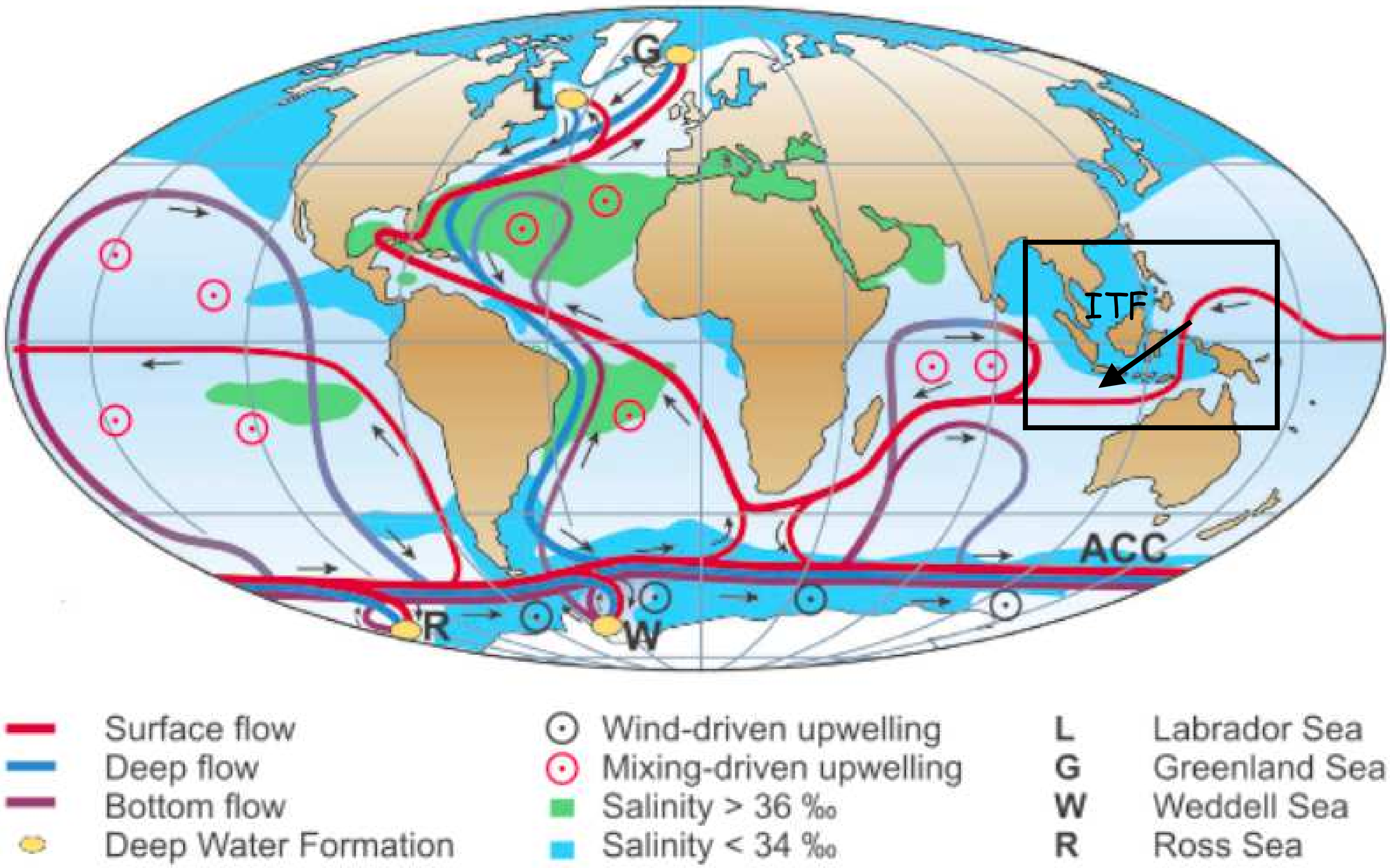
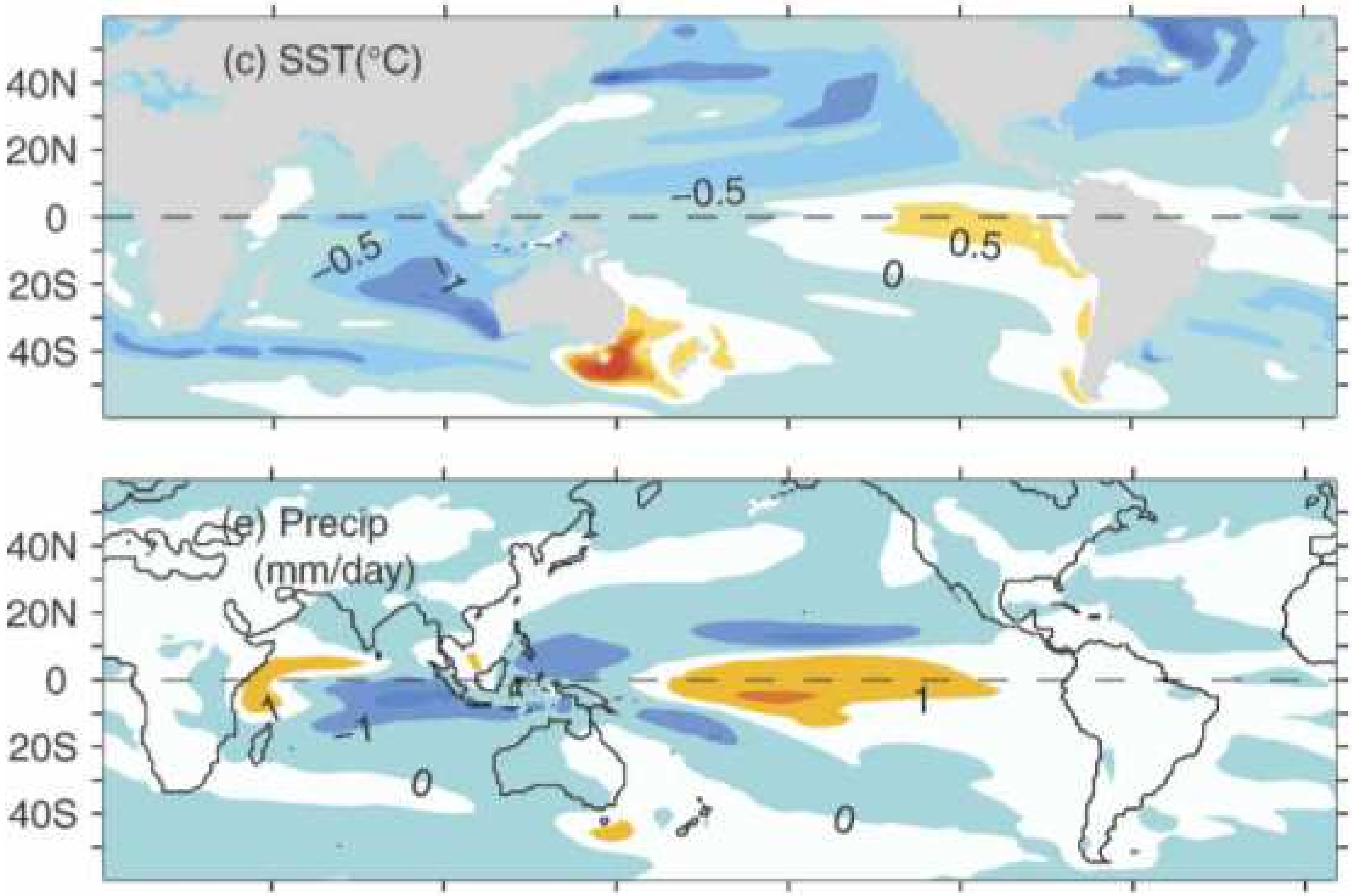
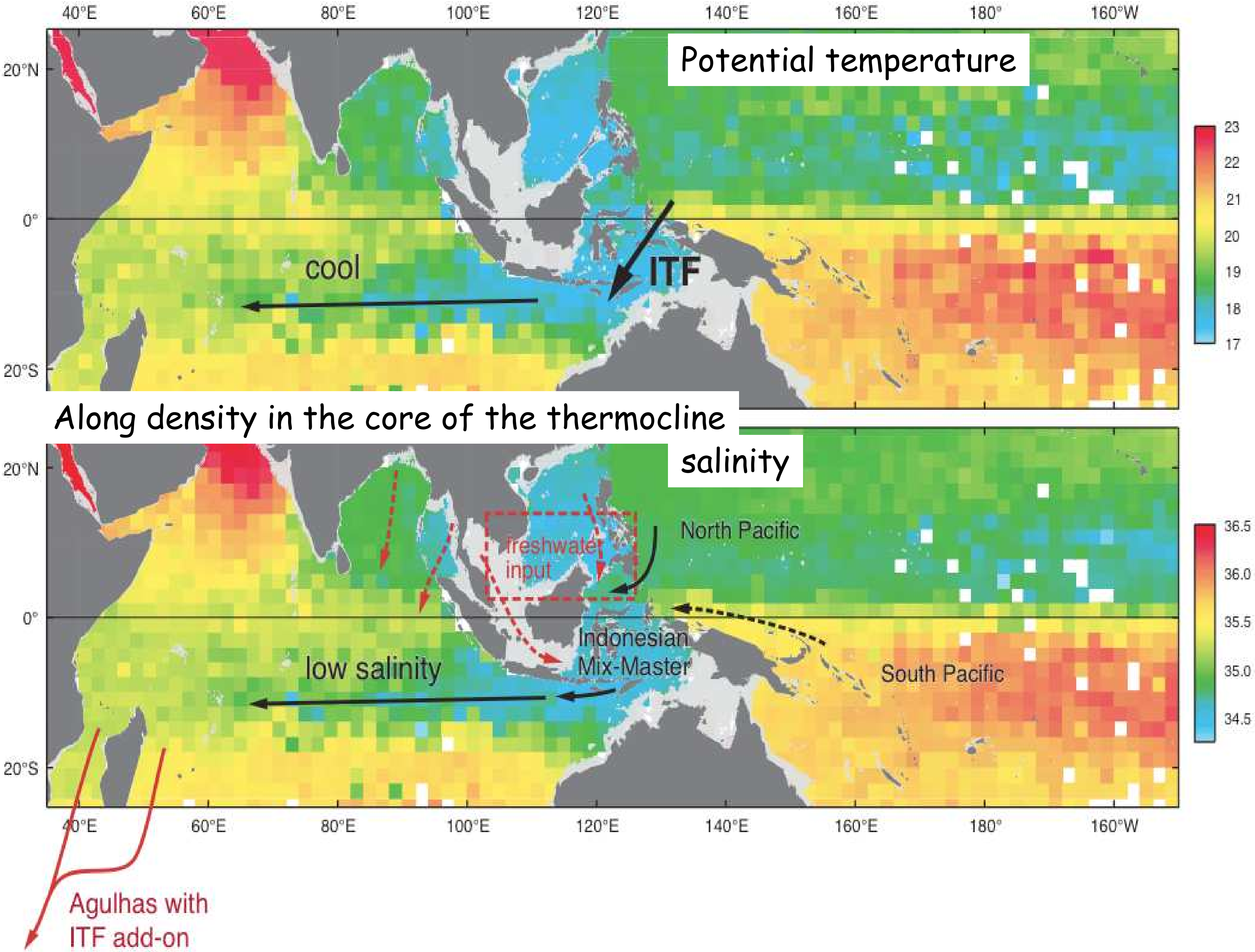
- Indonesian arhipelago only low latitude passage between two ocean basins
- Part of the upper branch of the thermohaline circulation
- Key role for ocean circulation and climate



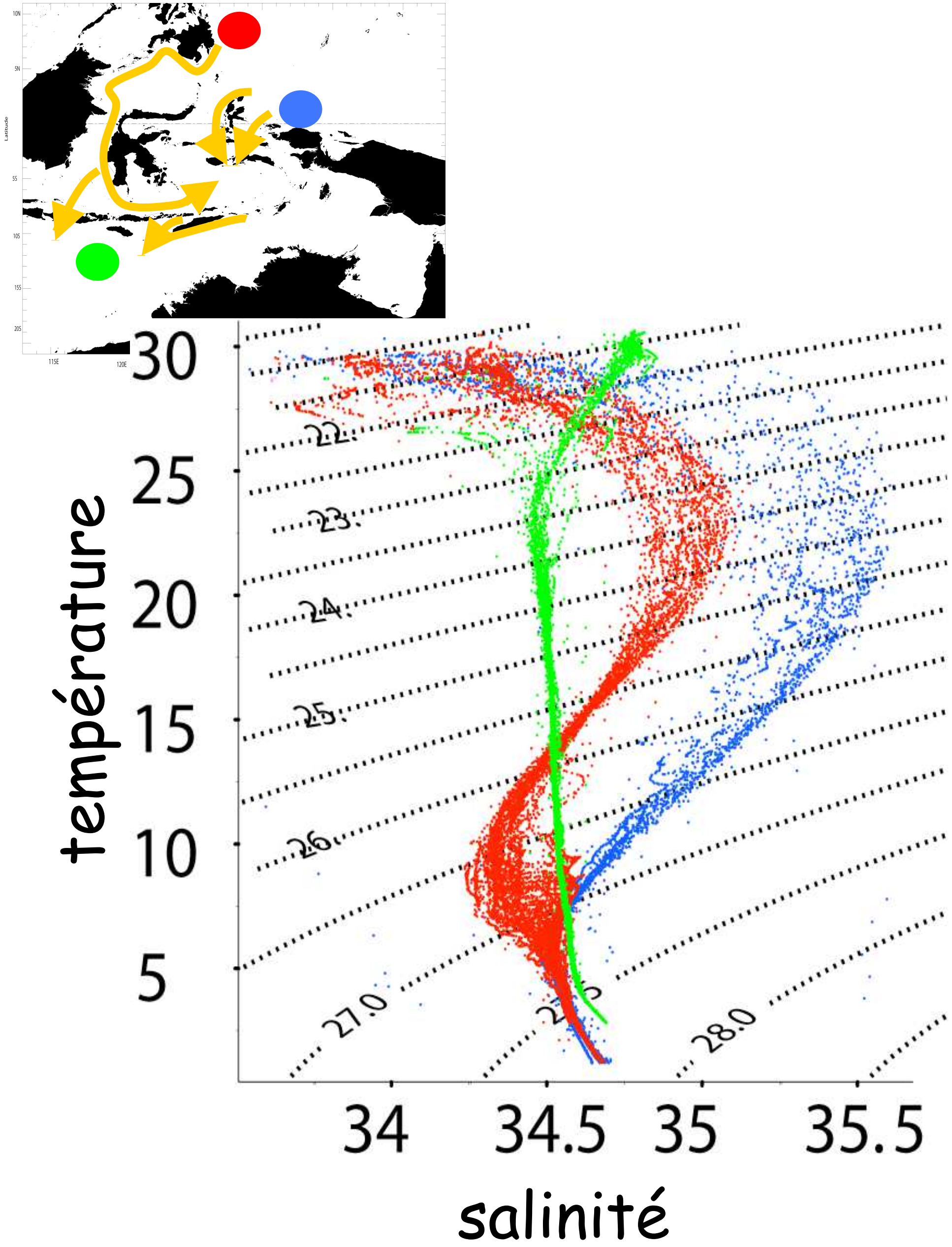


Strong Anomalies in Indo/Pac Oceans if closing the ITF

Song et al. 2007



Potential temperature
cool
ITF
Along density in the core of the thermocline
salinity
freshwater input
North Pacific
Indonesian Mix-Master
low salinity
South Pacific
Agulhas with ITF add-on
40°E
60°E
80°E
100°E
120°E
140°E
160°E
180°
160°W
20°N
0°
20°S
23
22
21
20
19
18
17
36.5
36.0
35.5
35.0
34.5



Advection diffusion model suggest hudge mixing

-> vertical diffusivity estimated

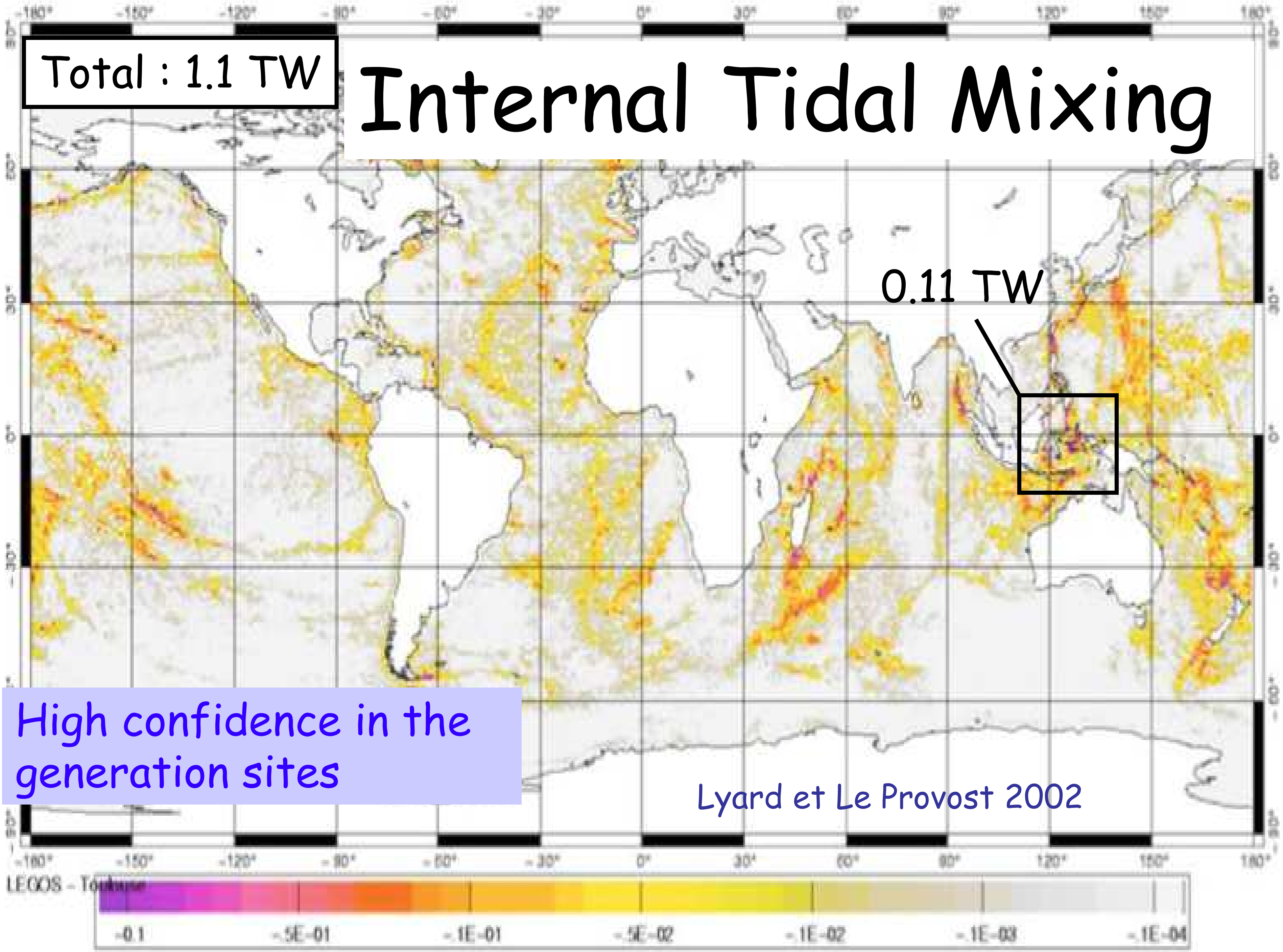
Kz ~ 1-2 cm^2/s

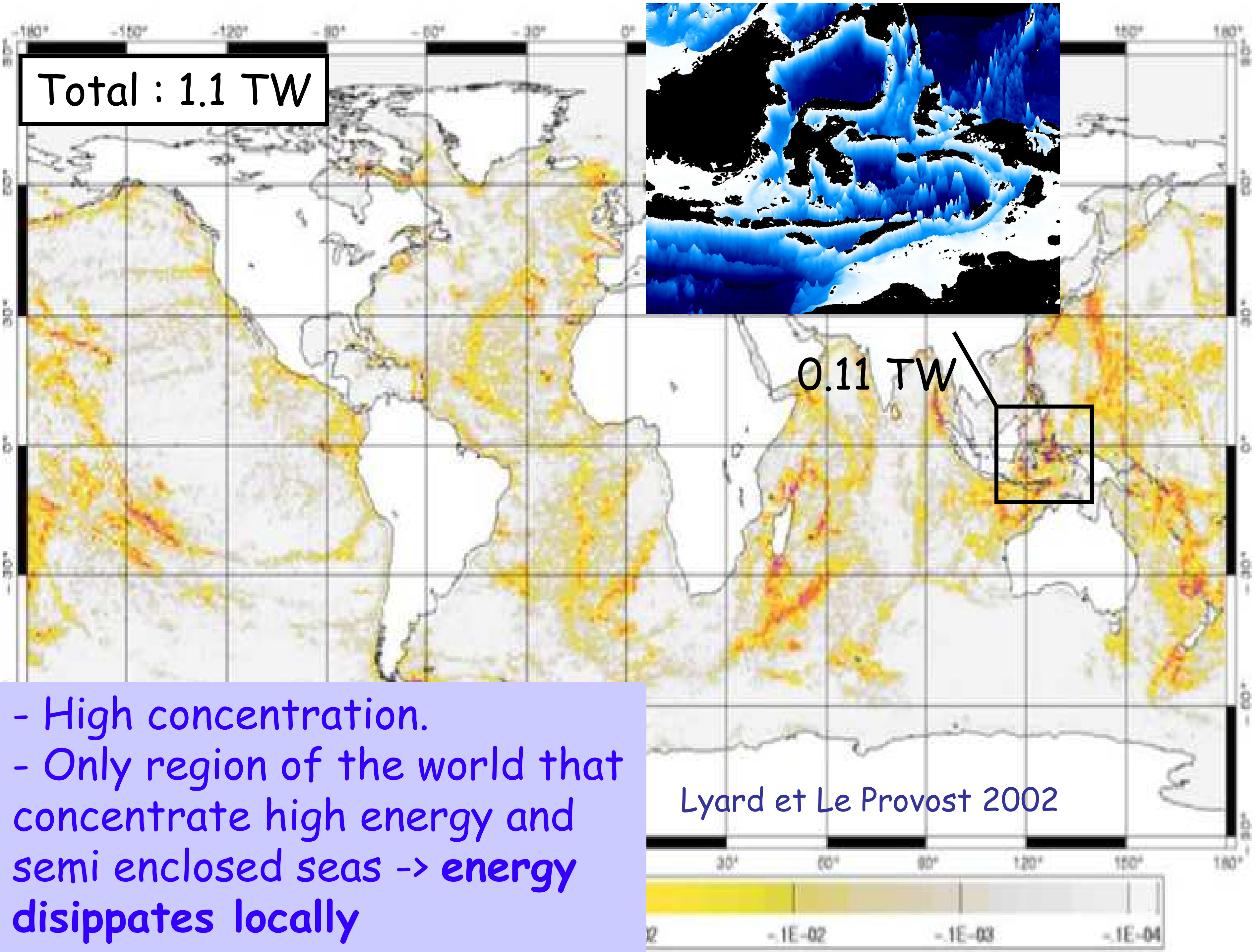
Hautala et al 1996, Ffield et Gordon 1996

= 10 times > open ocean

? What energy ?

Internal Tidal Mixing

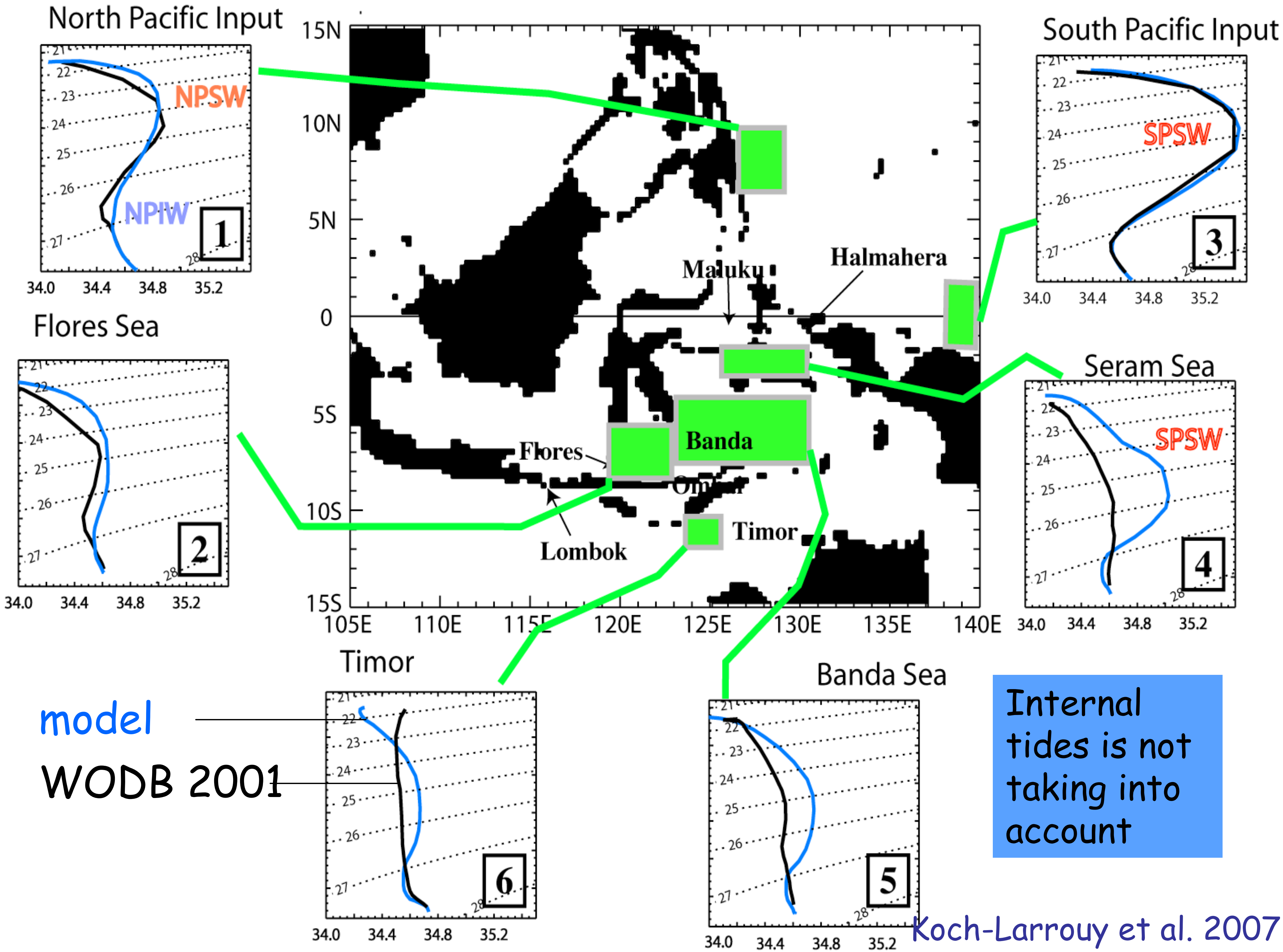




- High concentration.
- Only region of the world that concentrate high energy and semi enclosed seas -> **energy disippates locally**

This study:

Ocean only Model : NEMO $\frac{1}{4}°$ resolution



Internal tides is not taking into account

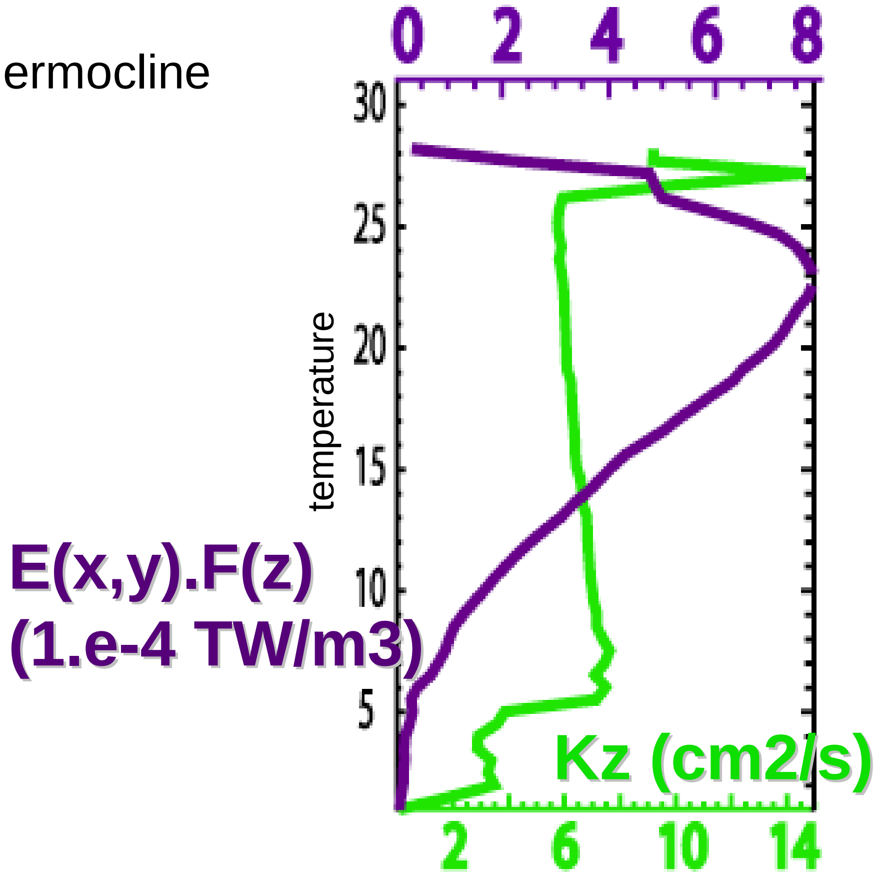
Koch-Larrouy et al. 2007

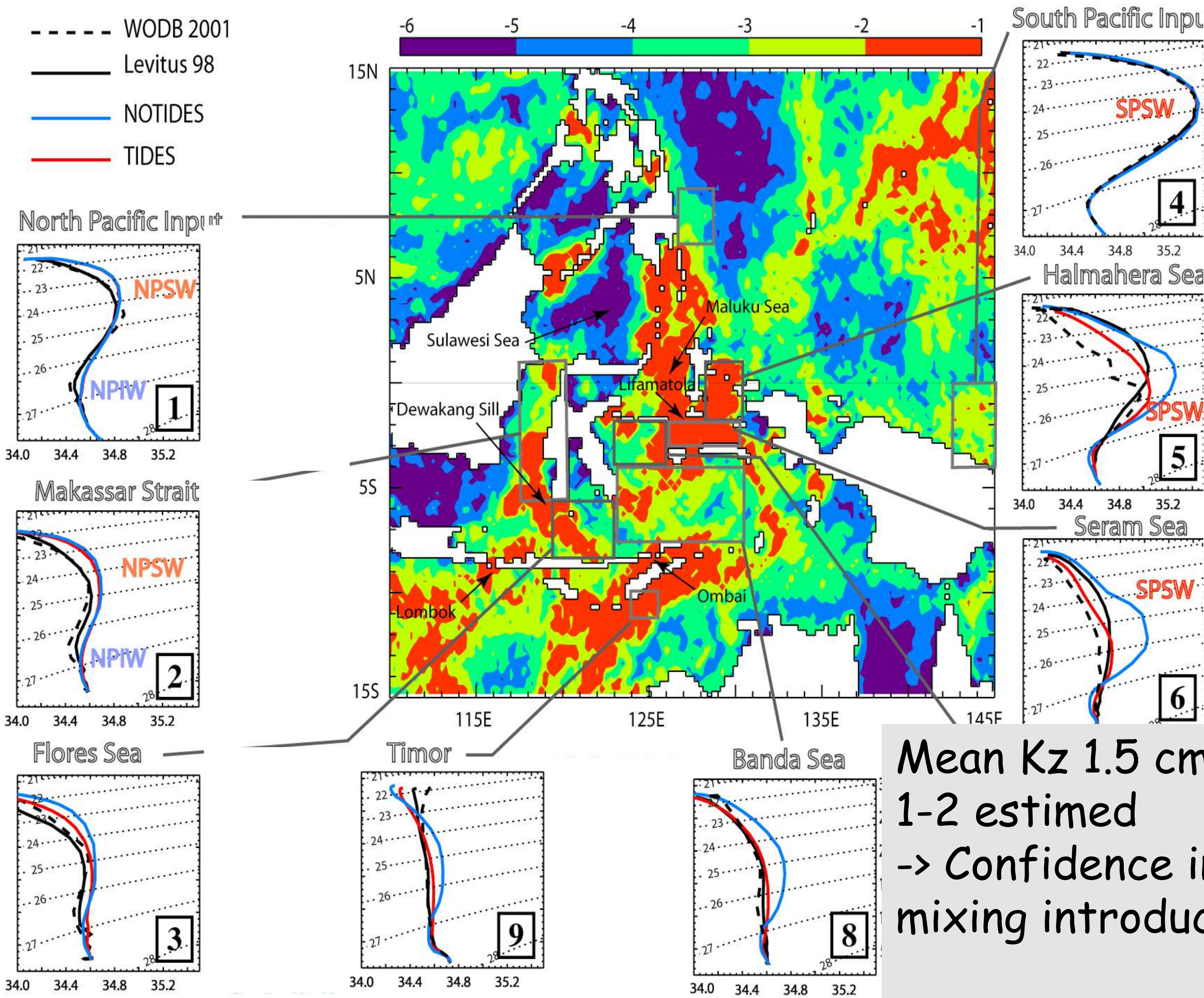
Mixing parameterization

All the energy
dissipated locally

Biggest
approximation
of param
MAX in thermocline

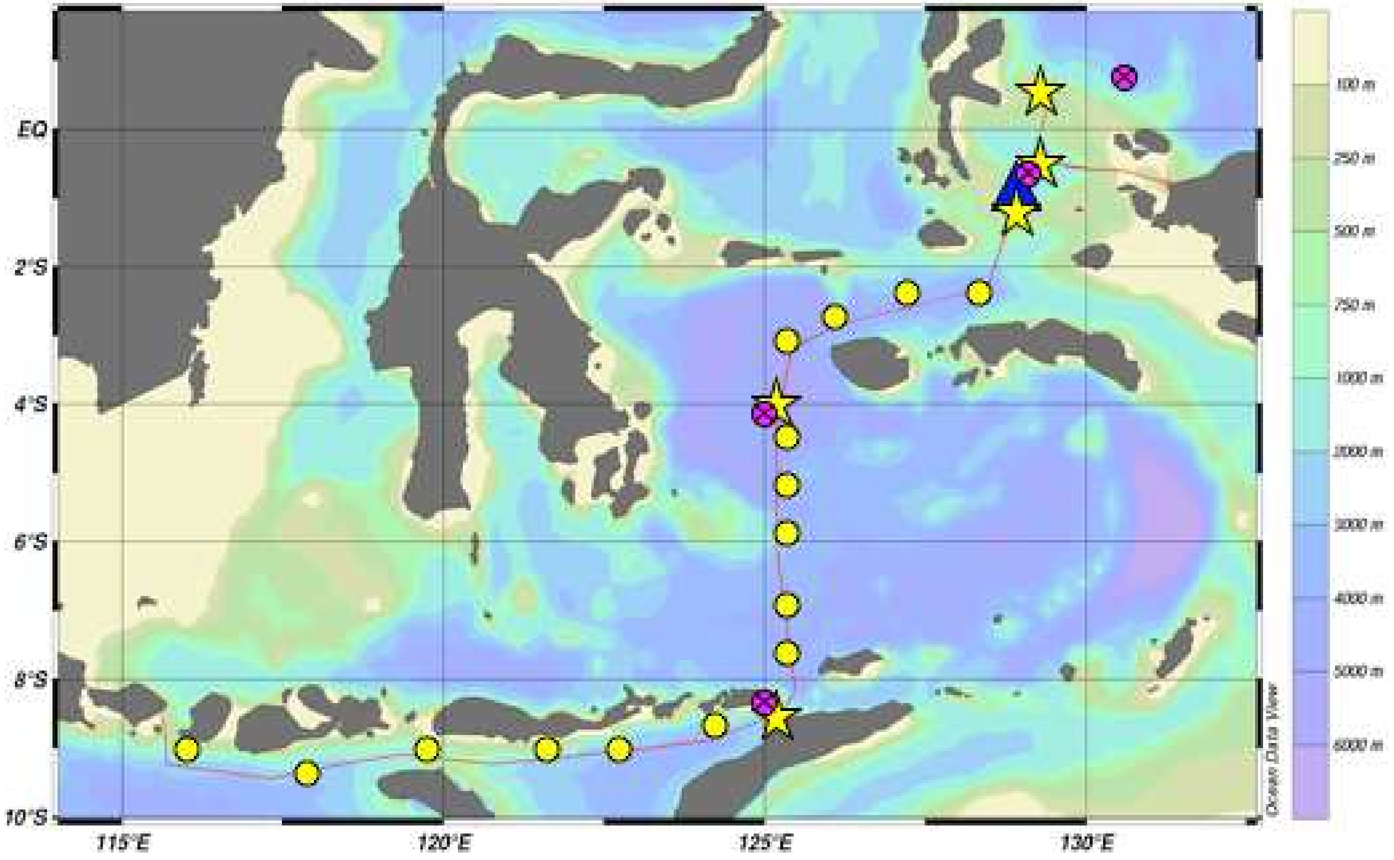
$$k_{z\ tides} = \frac{0.2\, q\, E(x,y)\, F(z)}{\rho N^2}$$





Mean Kz 1.5 cm2/s ~
1-2 estimed
-> Confidence in
mixing introduced

INDOMIX 2010 cruise
First cruise dedicated to mixing

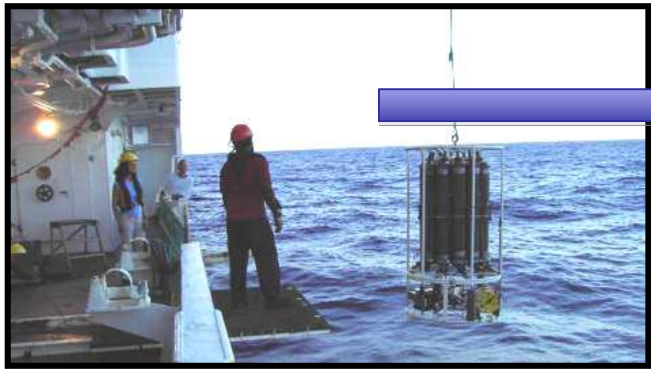


repeated profiles during 24h to catch the diurnal tidal cycle

Microstructure measurements
VMP/CTD
Turbulence + TS profiles

Direct measure of instantaneous mixing

CTD/LADCP
Currents + TS profiles

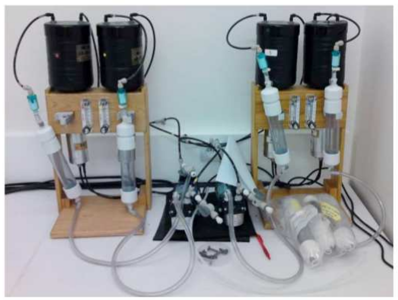


Indirect measure of instantaneous mixing

Radium + Actinium

measure of **INTEGRATED** Mixing (yrs)

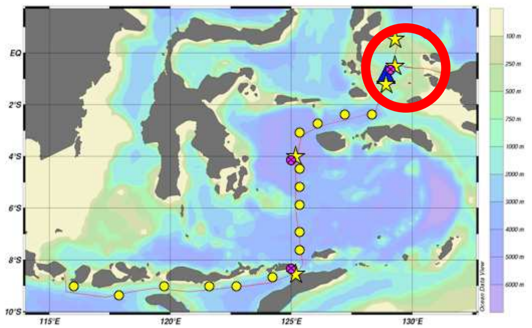
RaDeCC



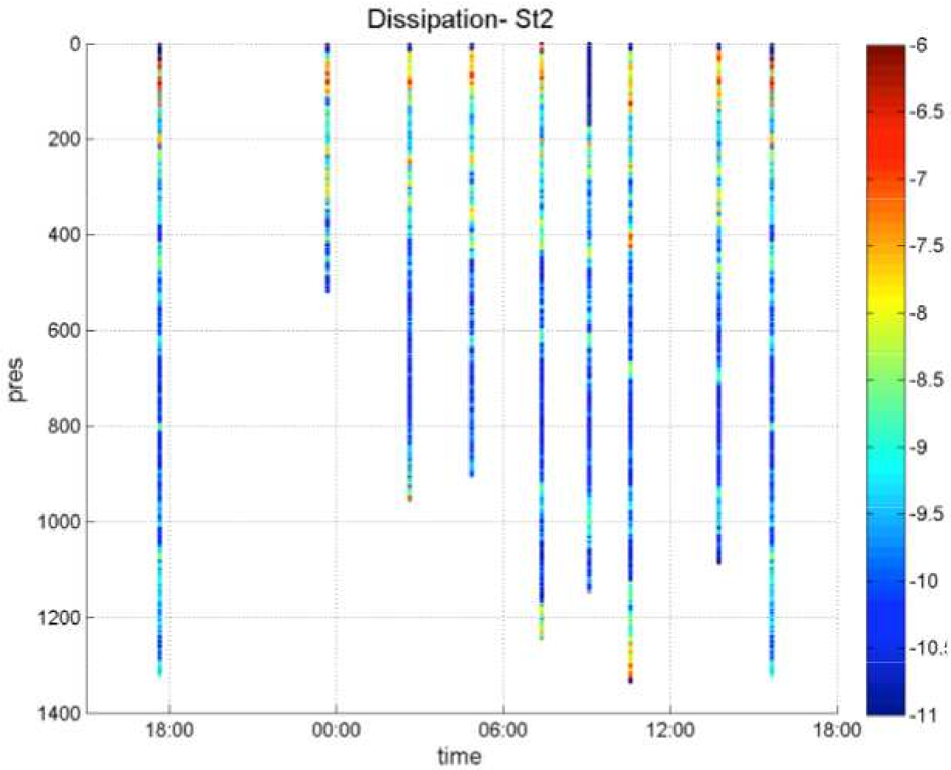
^{224}Ra, ^{223}Ra, ^{227}Ac

Gamma spectrometry : Underground laborato

^{226}Ra, ^{228}Ra



Kinetic energy dissipation at Station 2

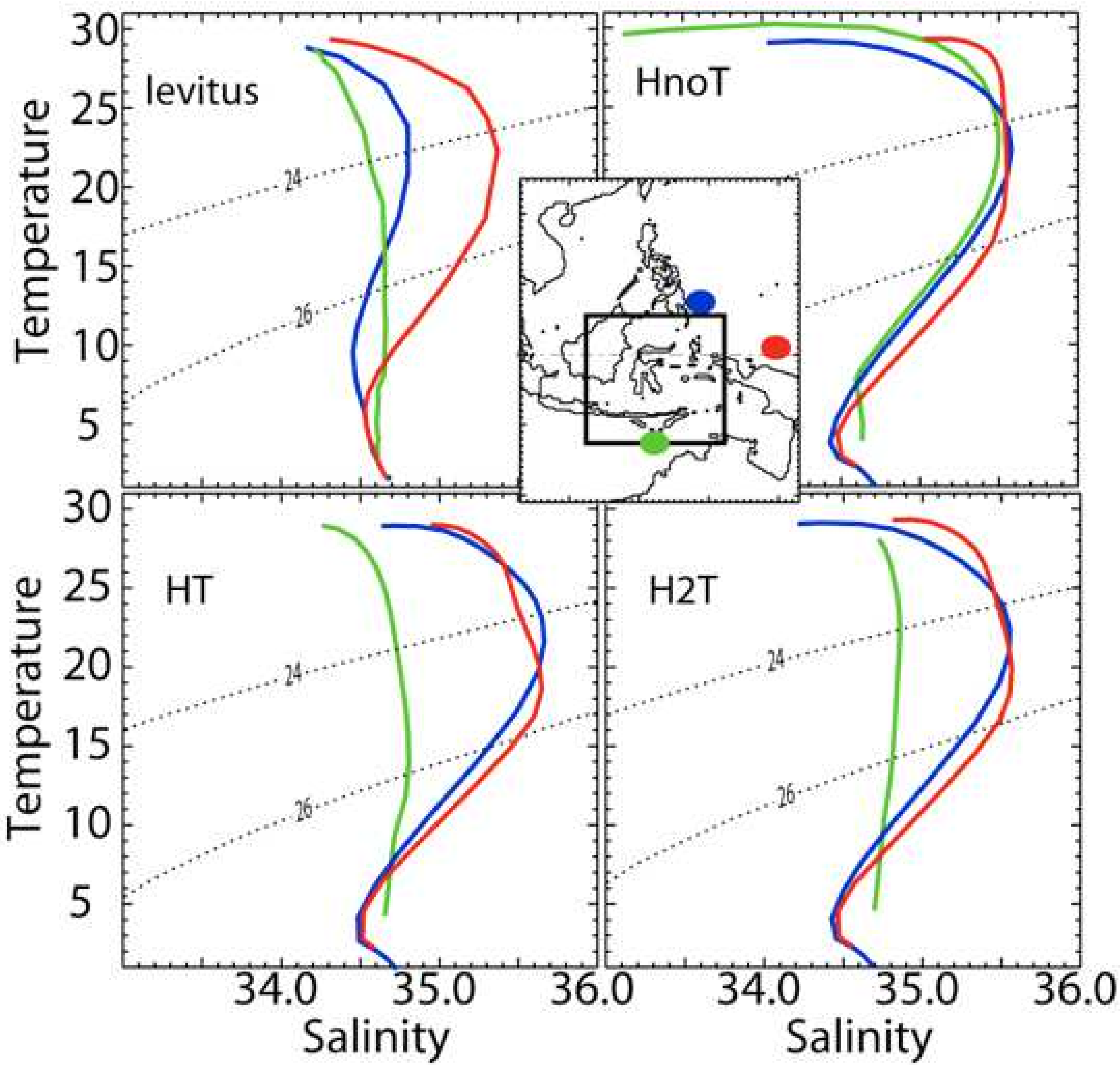


Strong Dissipation close to the surface

Mean Kz 1-10 cm2/s
-> Validation of strong mixing in the thermocline and at the surface

Implications of mixing:
Coupled Model :

- Ocean NEMO 2° resolution
- Atmosphere Hadam 3° resolution
- OASIS coupling



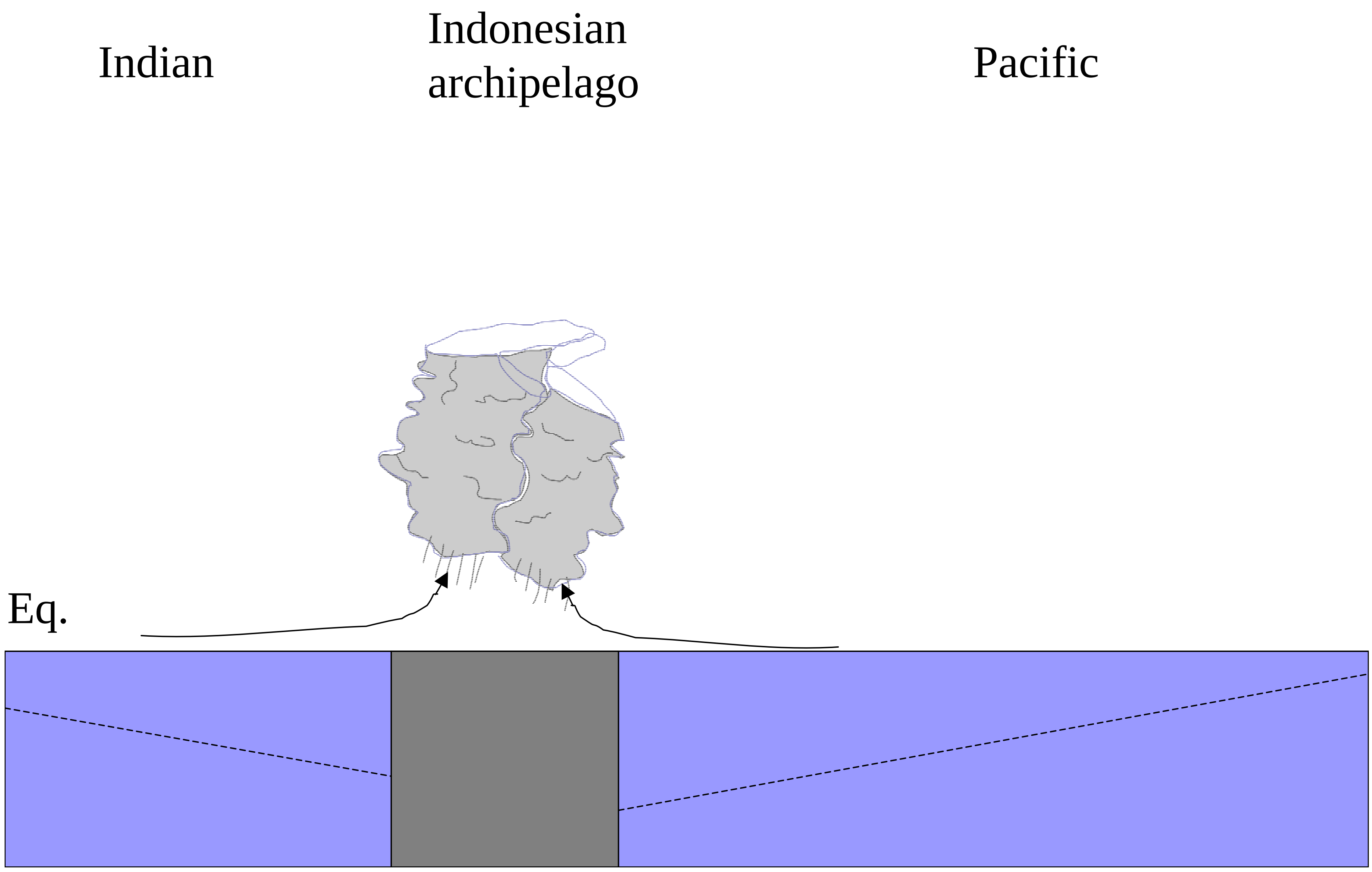
Notides

Tides

2*Tides

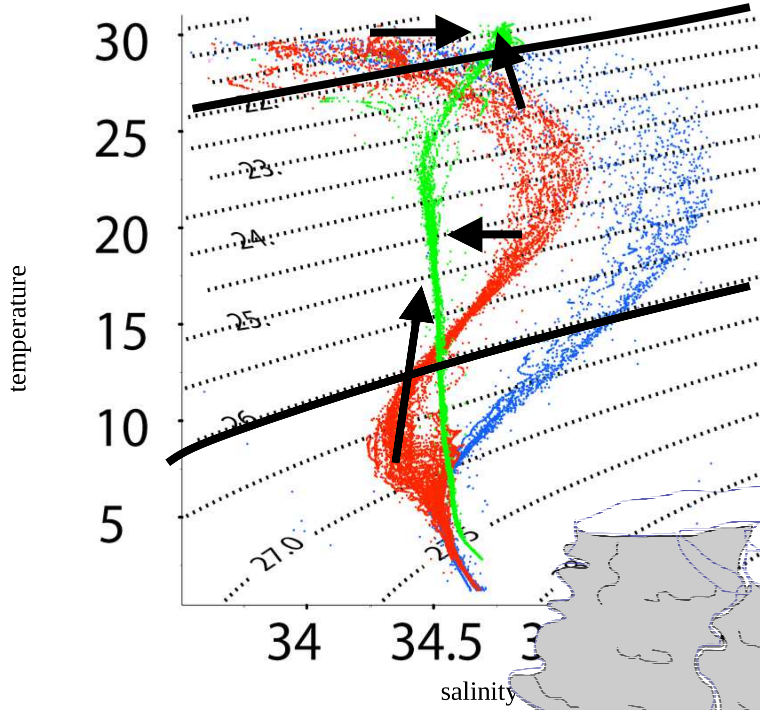
Effect on climate system

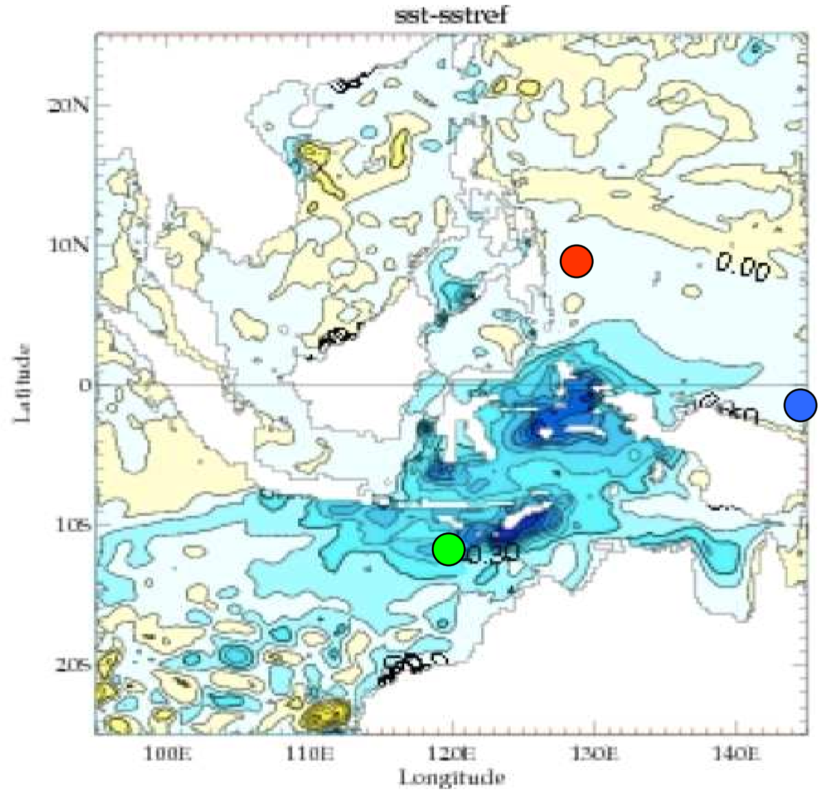
-> mean state



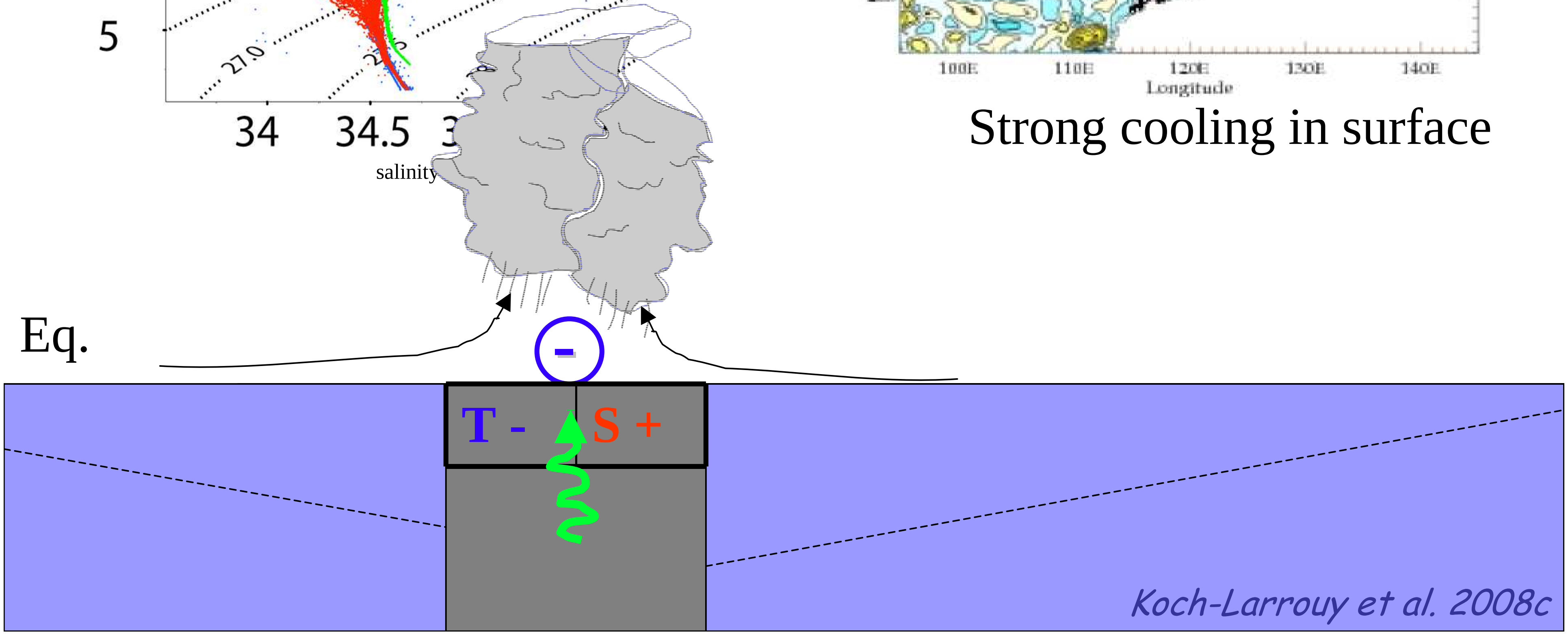
Effect on climate system

-> mean state



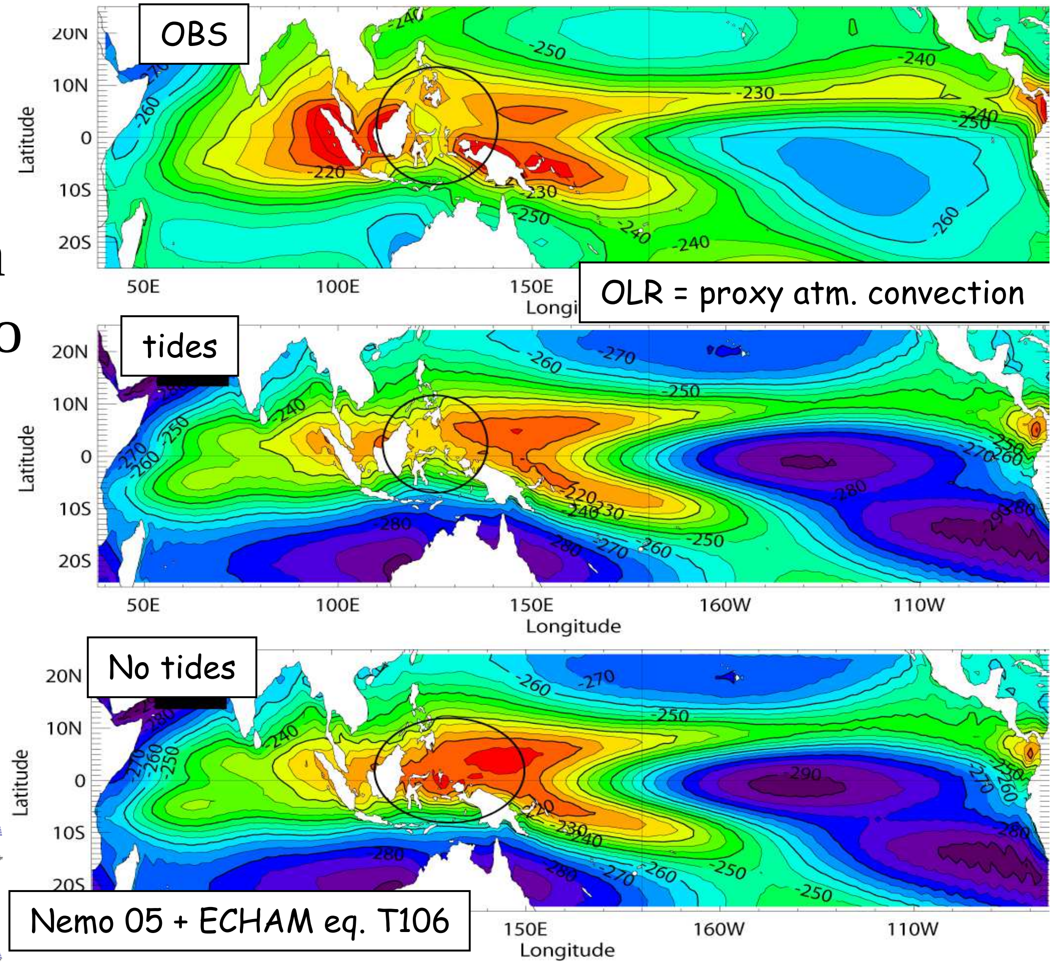


Strong cooling in surface

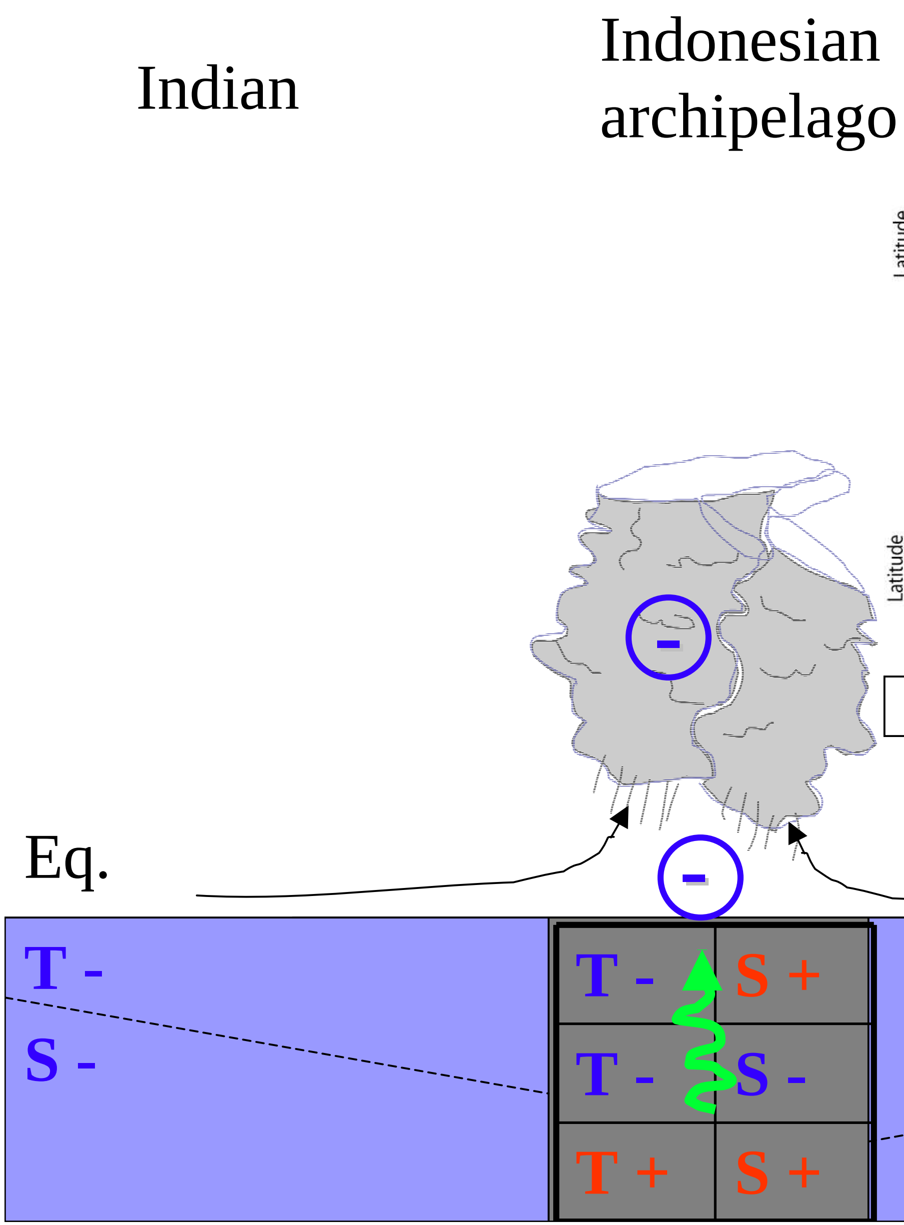


Effect on climate system

-> mean state



Reduces local convection in good agreement with observations



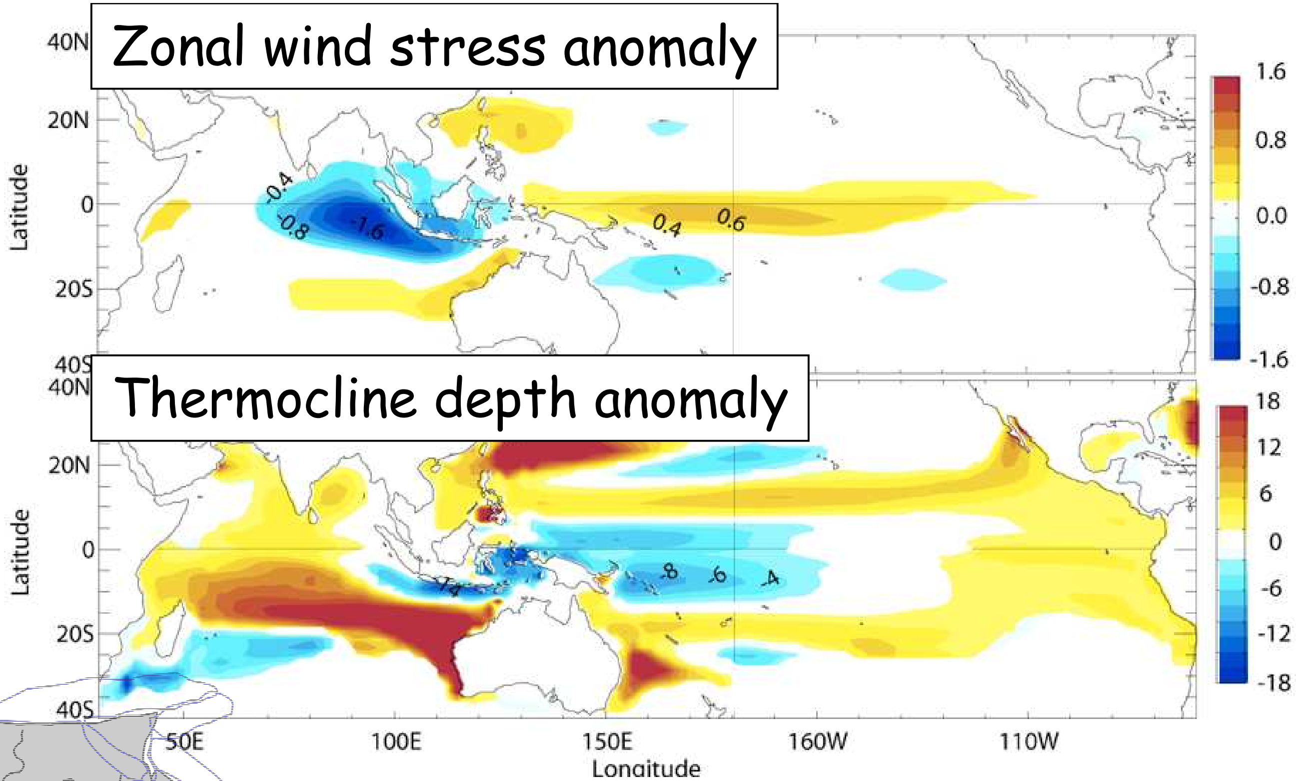
Effect on climate sys

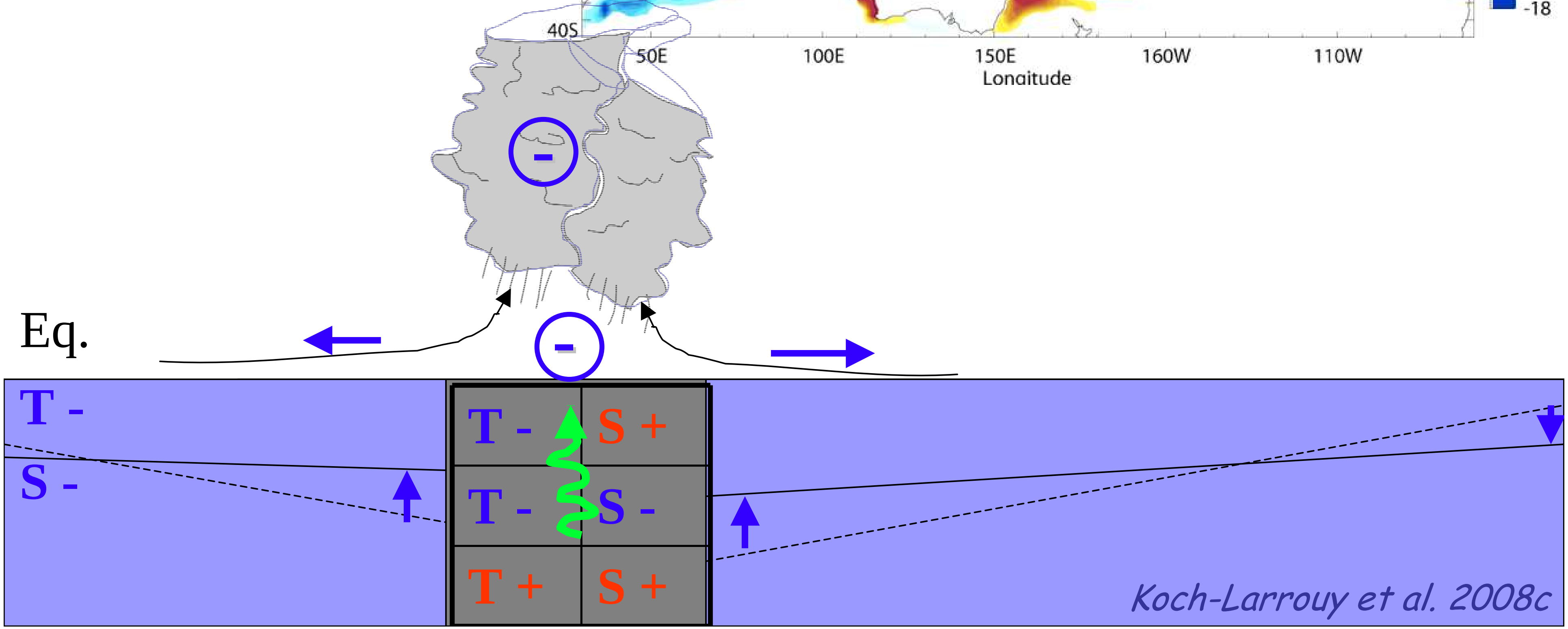
-> mean state

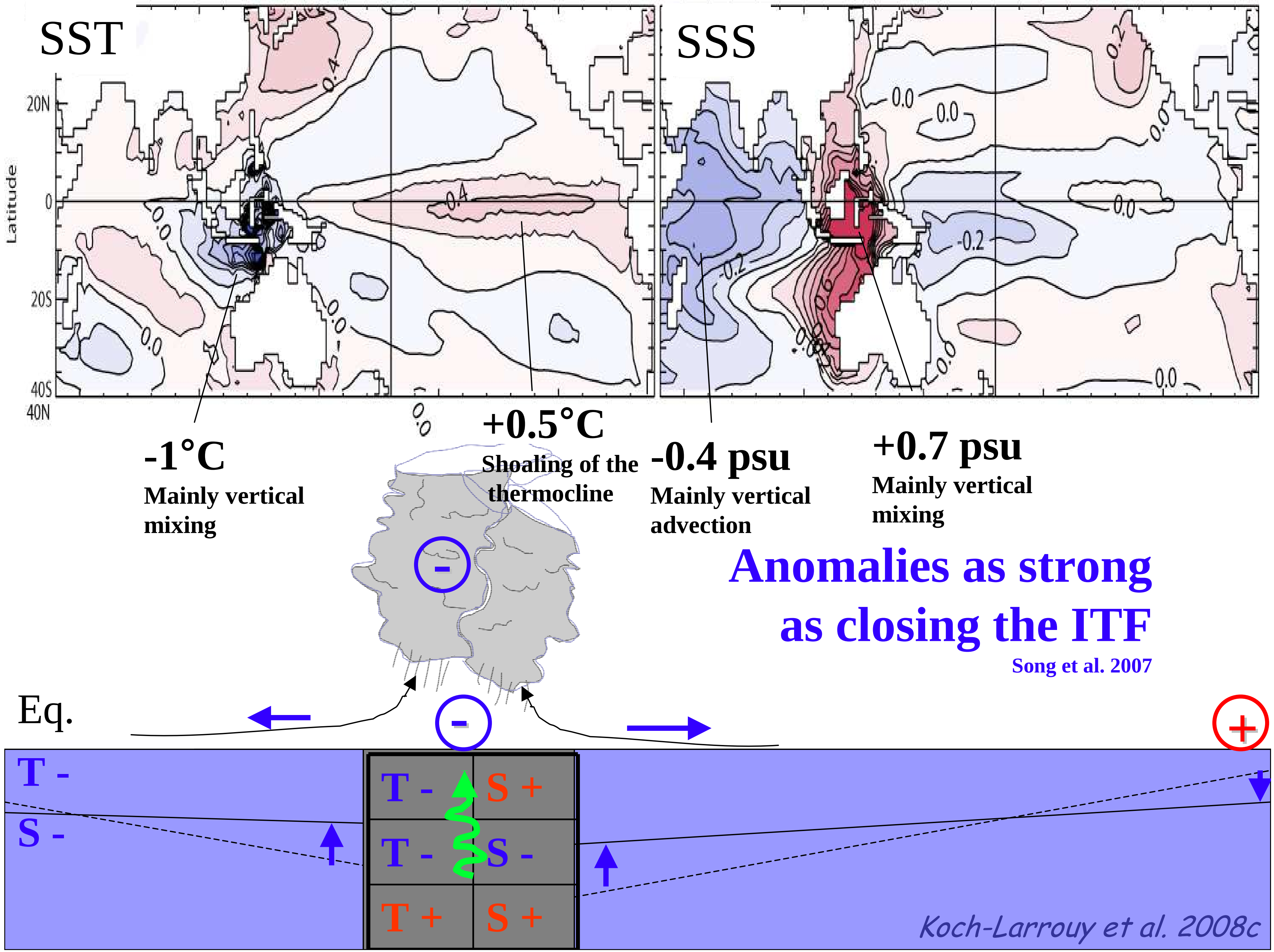
Reduce local convection

↓

reduce wind convergence



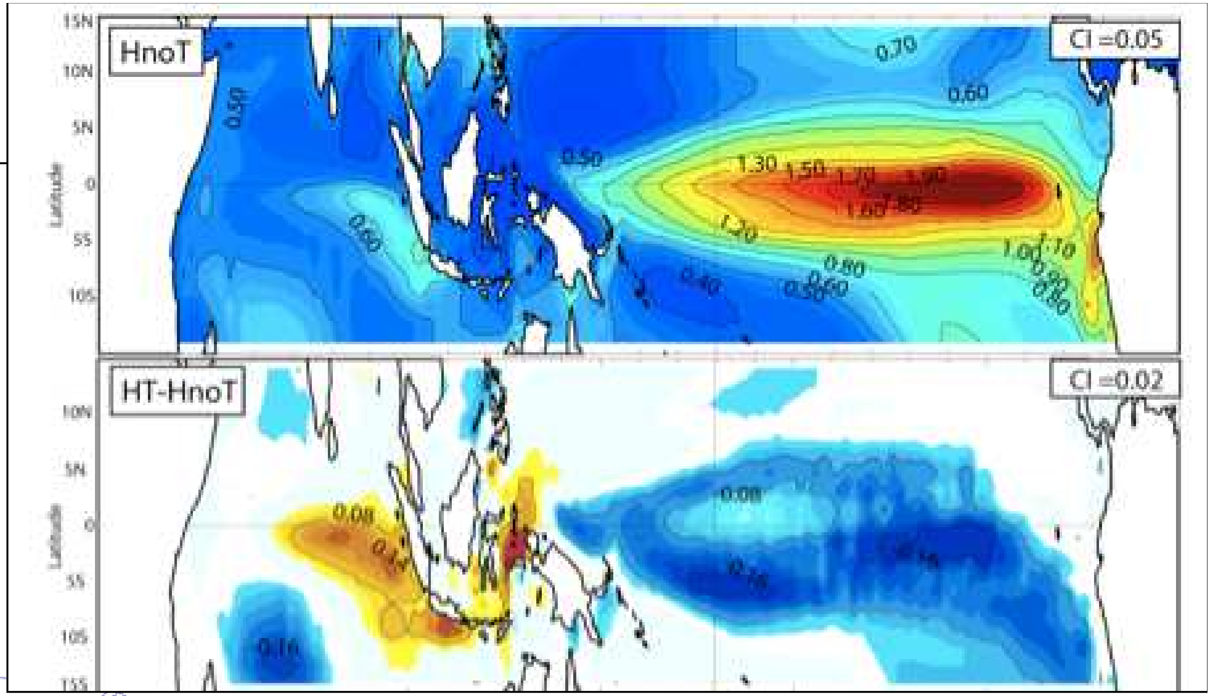


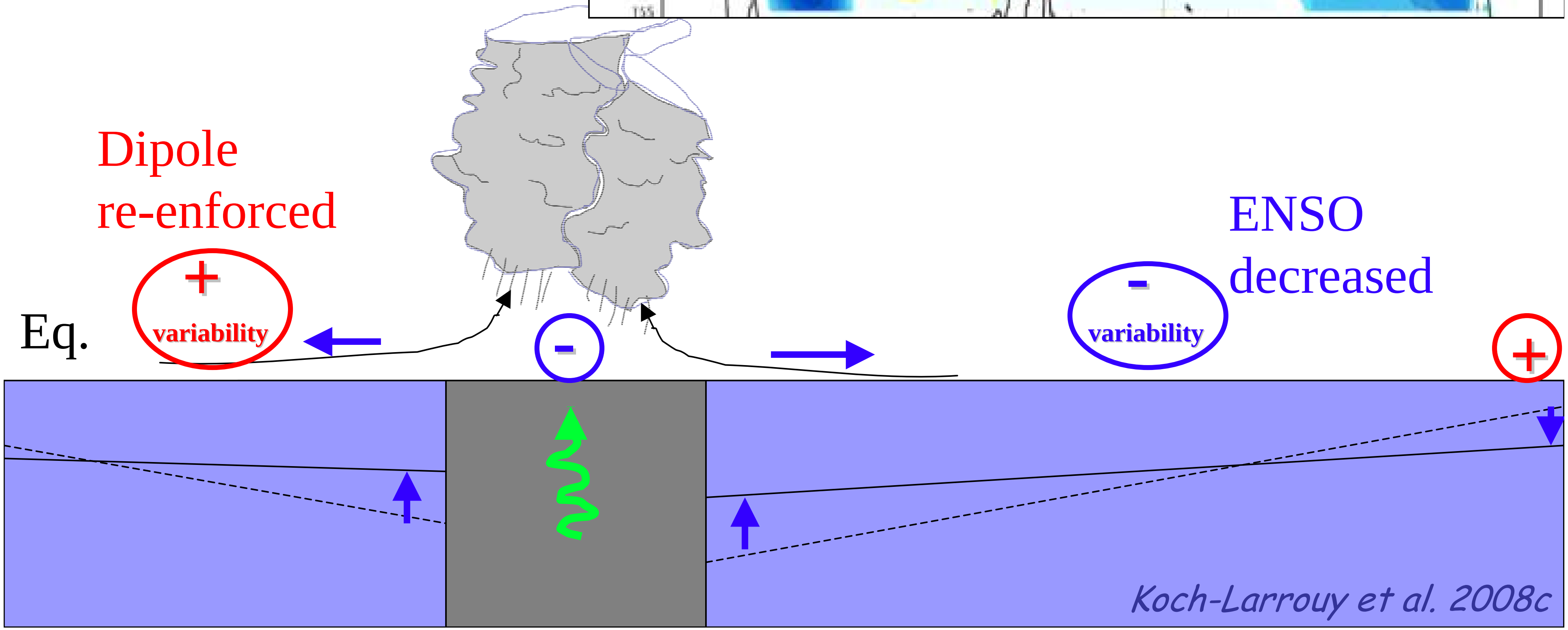


SST
SSS
Latitude
20N
0
20S
40S
40N
0.4
0.0
0.2
-0.2
0.6
-1°C
Mainly vertical mixing
+0.5°C
Shoaling of the thermocline
-0.4 psu
Mainly vertical advection
+0.7 psu
Mainly vertical mixing
Anomalies as strong as closing the ITF
Song et al. 2007
Eq.
-
+
T -
S -
T -
S +
T -
S -
T +
S +
Koch-Larrouy et al. 2008c

Effect on climate system
-> variability

Std of SSTs





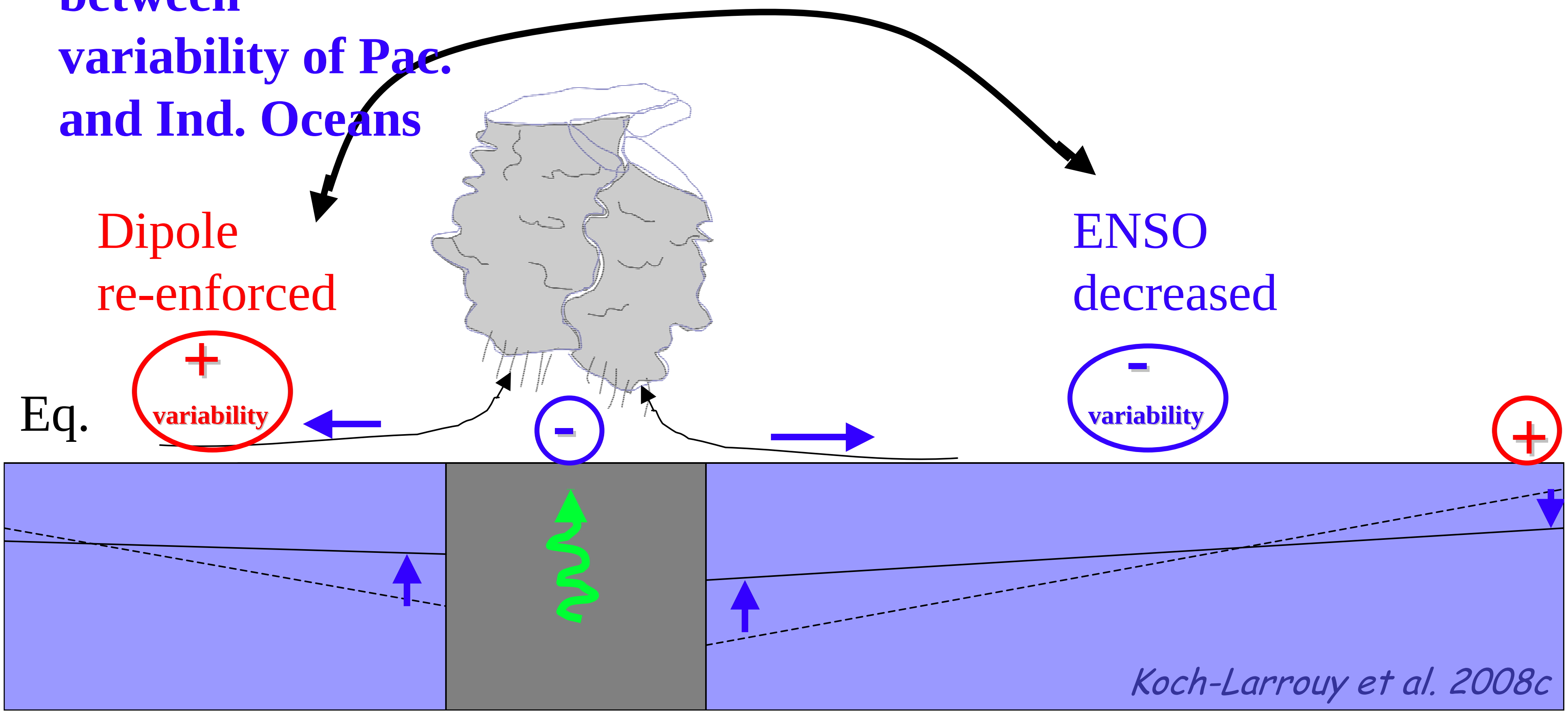
Effect on climate system

-> variability

Indian

Indonesian archipelago

Modify link between variability of Pac. and Ind. Oceans



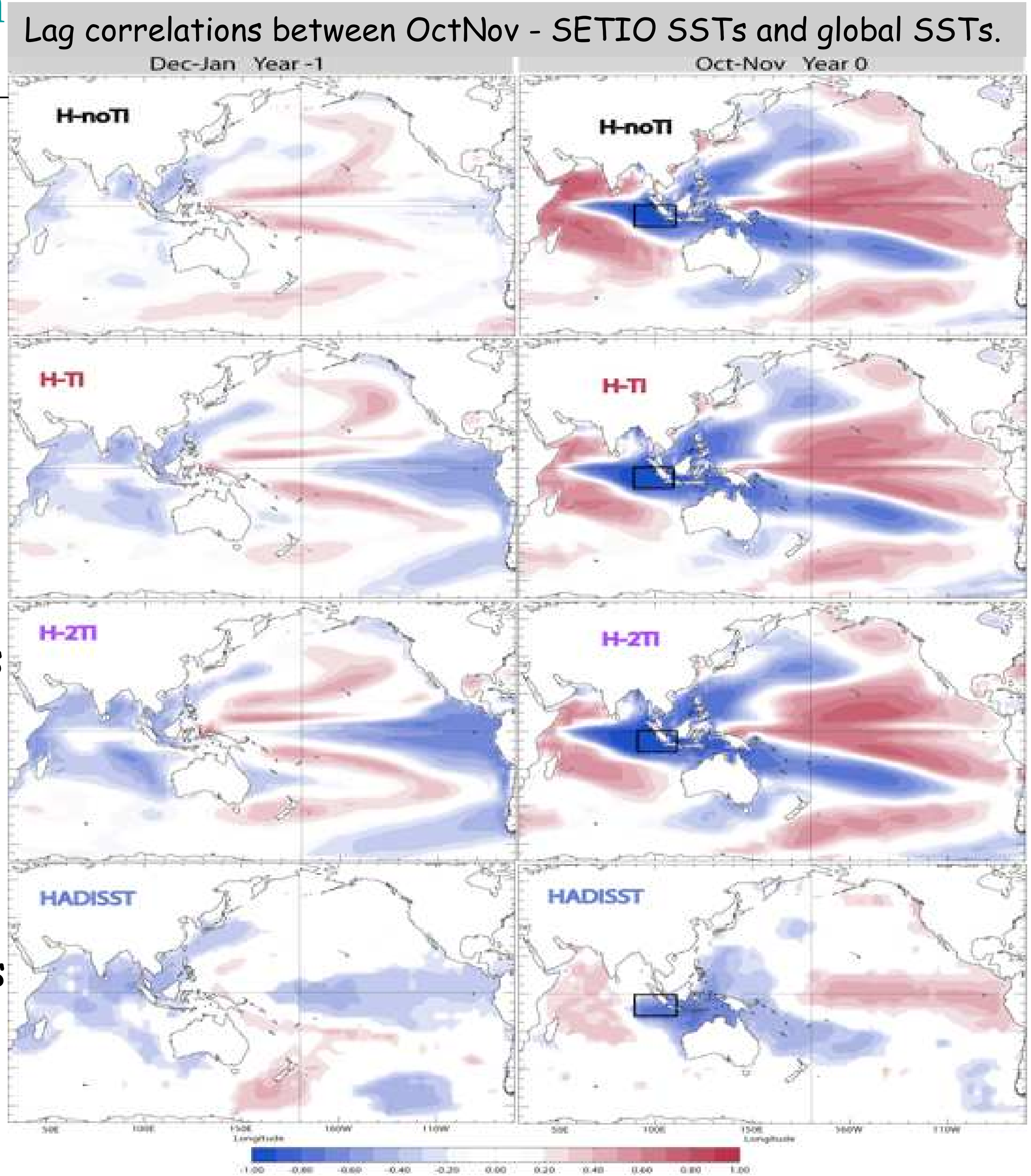
Effect on climate system
-> variability

No tides

1 x tides

2 x tides

Obs



Tidal mixing increases IODZM predictability

In good agreement with Observation

Conclusions

- Unique region of the world = strong internal tides generation
  + semi enclosed seas.
- Specific parameterization energy constrained
  mean Kz in good agreement with observation independantly
  + water masses in good agreement with observations.

  ➢ *Koch-Larrouy, et al. 2007 GRL*

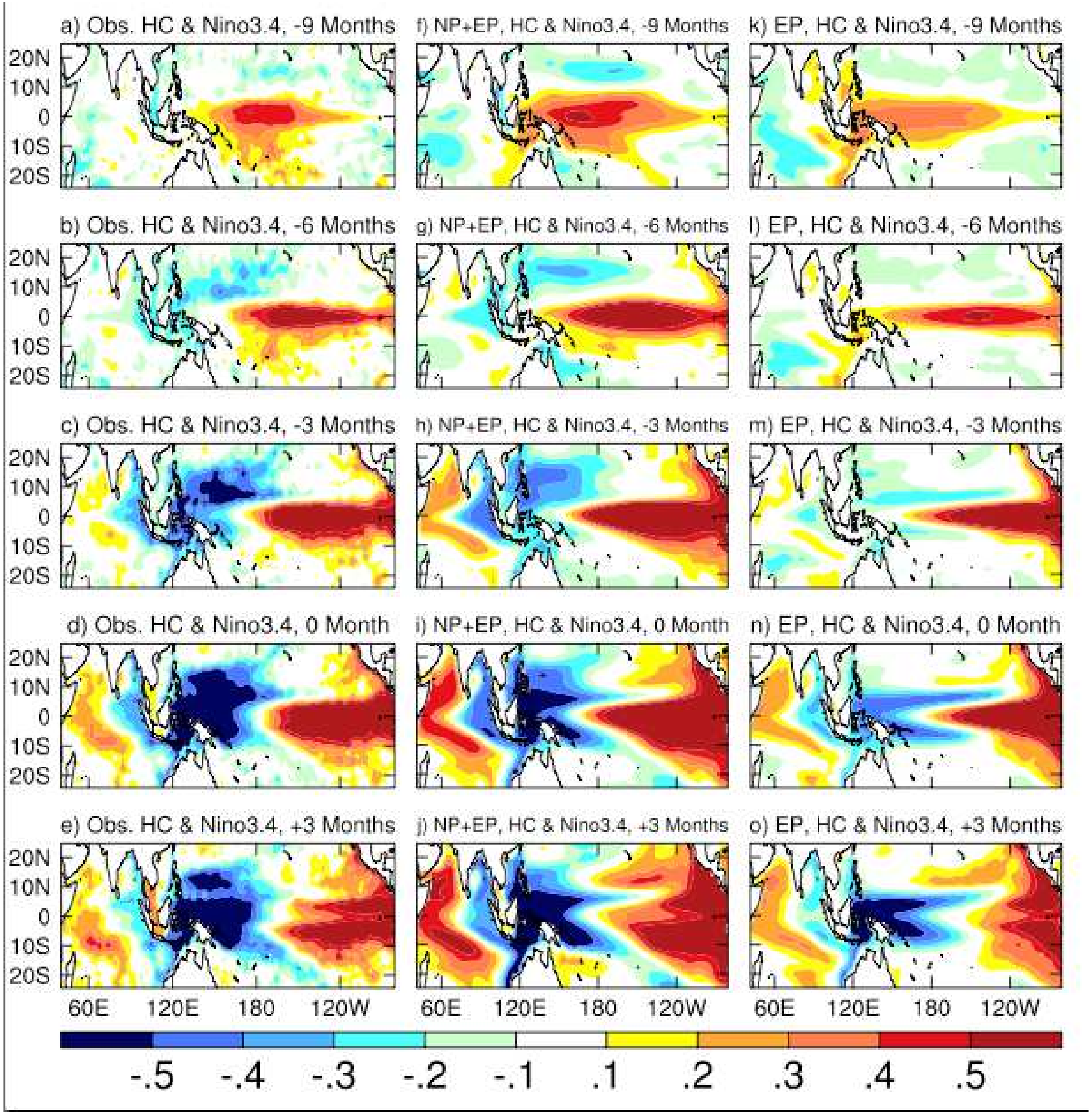
- **Confirmation of strong** mixing in the thermocline and at the surface thanks to INDOMIX measures

  ➢ *Koch-Larrouy et al. In prep*
  ➢ *Bouruet-Aubertot et al. In prep*
  ➢ *Van Beek et al. In prep*

- Tidal mixing in the indonesian seas **reduces SST, local rain**
  In good agreement with observations
- **Anomalies as strong as closing the ITF !!!**
- Effect on variability between ENSO and IOD in good agreement observation

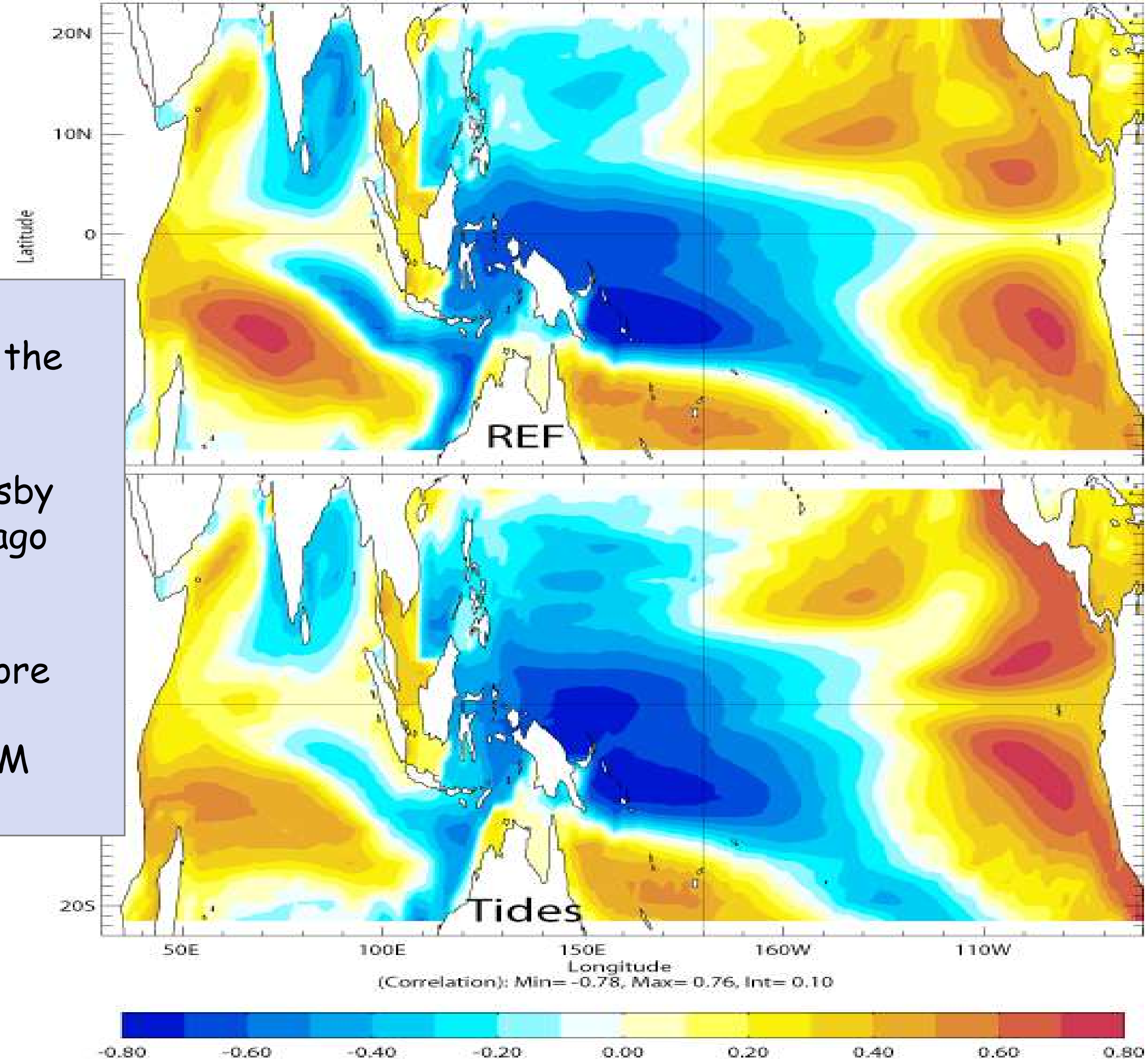
  ➢ *Koch-Larrouy, et al. 2009 Climate Dynamics*


Thanks !
INDOMIX 2010



a) Obs. HC & Nino3.4, -9 Months
f) NP+EP, HC & Nino3.4, -9 Months
k) EP, HC & Nino3.4, -9 Months
b) Obs. HC & Nino3.4, -6 Months
g) NP+EP, HC & Nino3.4, -6 Months
l) EP, HC & Nino3.4, -6 Months
c) Obs. HC & Nino3.4, -3 Months
h) NP+EP, HC & Nino3.4, -3 Months
m) EP, HC & Nino3.4, -3 Months
d) Obs. HC & Nino3.4, 0 Month
i) NP+EP, HC & Nino3.4, 0 Month
n) EP, HC & Nino3.4, 0 Month
e) Obs. HC & Nino3.4, +3 Months
j) NP+EP, HC & Nino3.4, +3 Months
o) EP, HC & Nino3.4, +3 Months
20N
10N
0
10S
20S
60E
120E
180
120W
-.5
-.4
-.3
-.2
-.1
.1
.2
.3
.4
.5

Lag correlations between Nino34 SSTs and upper Heat content anomalies (surface - neutral density 26). Nino 34 leads by 6 months the Heat content anomalies



TIDES simulation shows less corelation between Nino and the Indian Ocean Rosby waves.

1) Tidal mixing damps the Rosby propagation via the Archipelago

2) Indian Rosby waves are more correlated to the Indian Variability (Increased IODZM variability)