Simulated anthropogenic CO_2 storage and acidification of the Mediterranean Sea

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LSCE

Santos, March 25th 2015

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Mediterranean Sea ?

Foreword : Why study the Mediterranean Sea ?

- **Hotspot of climate change**
- **Under strong anthrop. Pressure – amplify CC effects**
- **Presents unique dynamic and geochemical properties...**

Foreword : Mediterranean Sea dynamics.

Residence time of water masses is short :

~ 70 years vs **~1000** in Global Ocean.

Anthrop. perturbation visible within **~10 years** on the water column.

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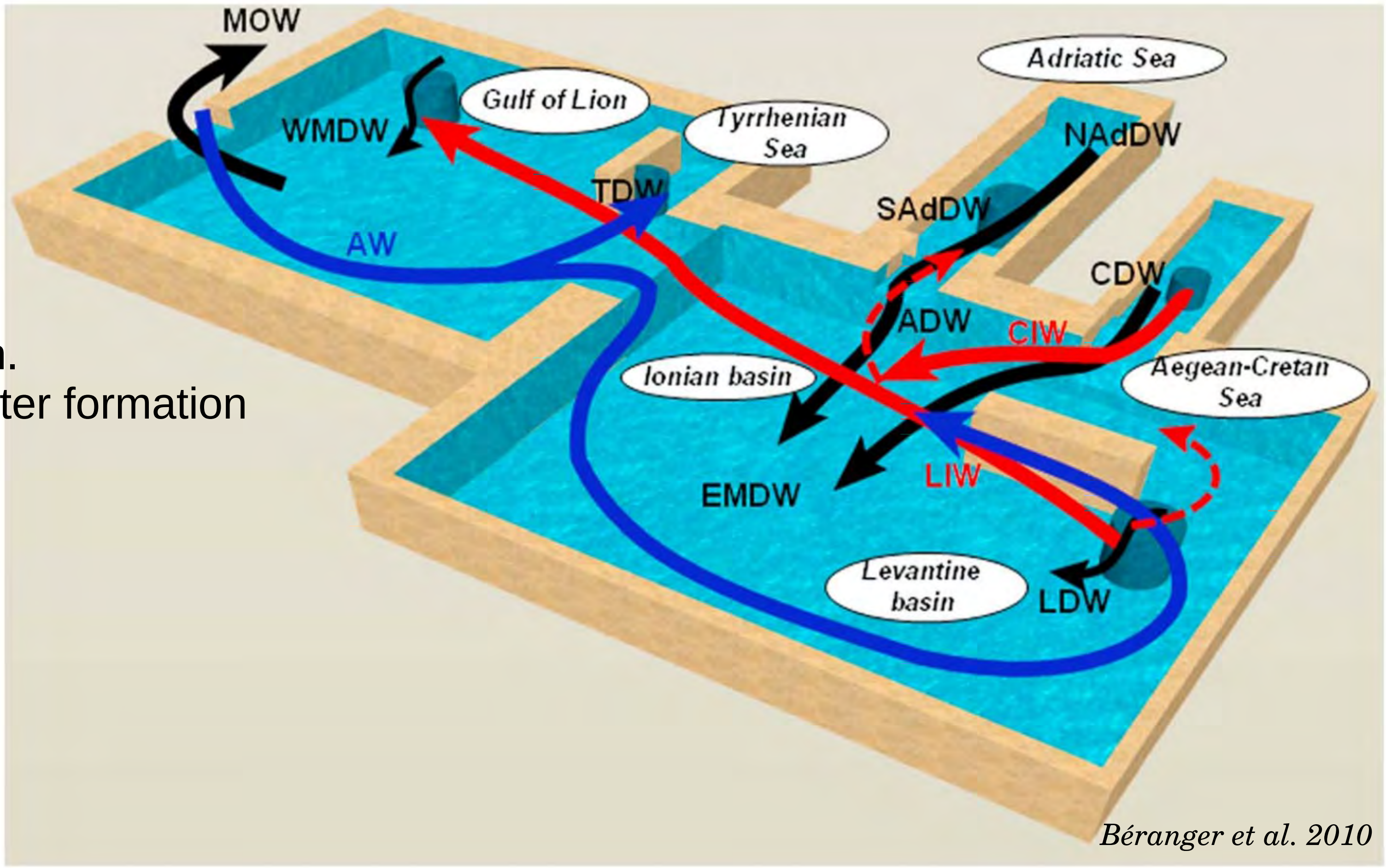

Béranger et al. 2010

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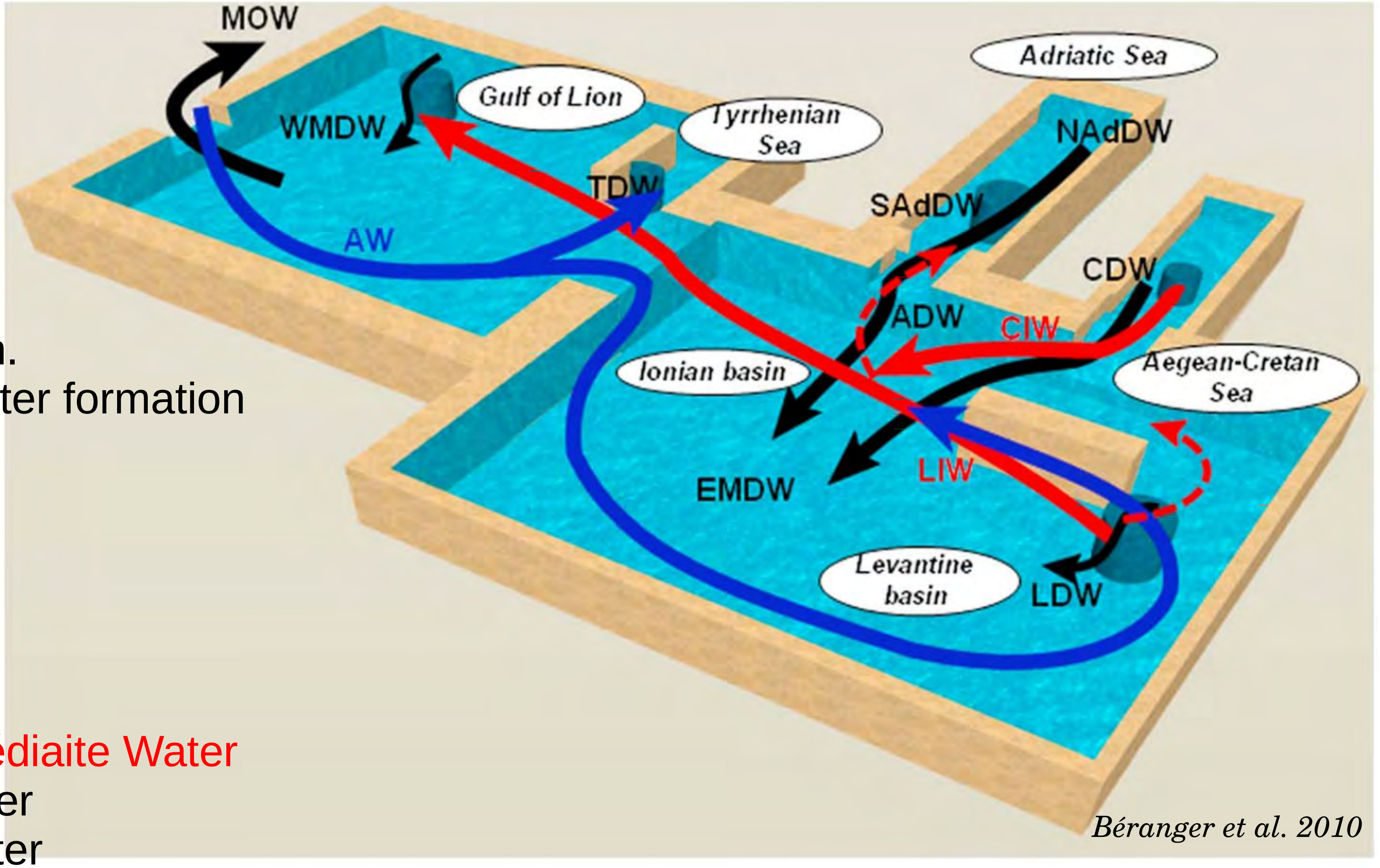
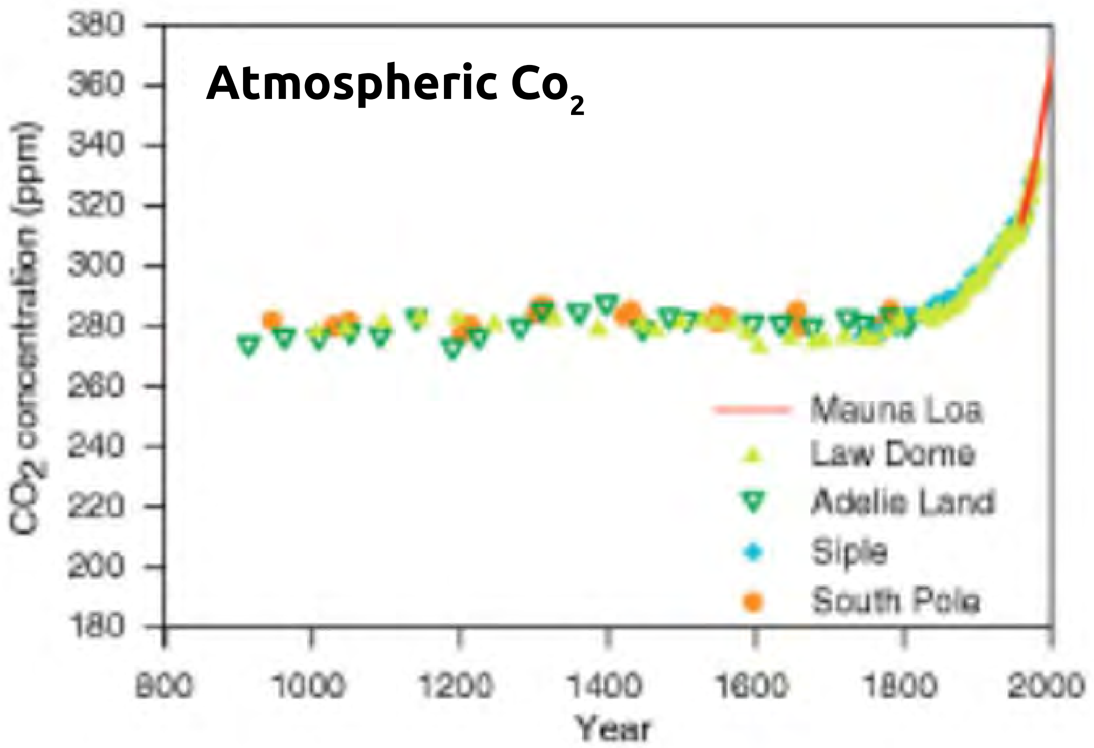


- Thermohaline circulation.
- Deep & Intermediate water formation

AW : Atlantique Water
LIW : Levantine Intermédiaite Water
CDW : Cretan Deep Water
AdDW : Adriatic Deep Water
EMDW : Earstern Med. Deep Water
WMDW : Werstern Med. Deep Water

Foreword : Mediterranean Sea geochemical properties



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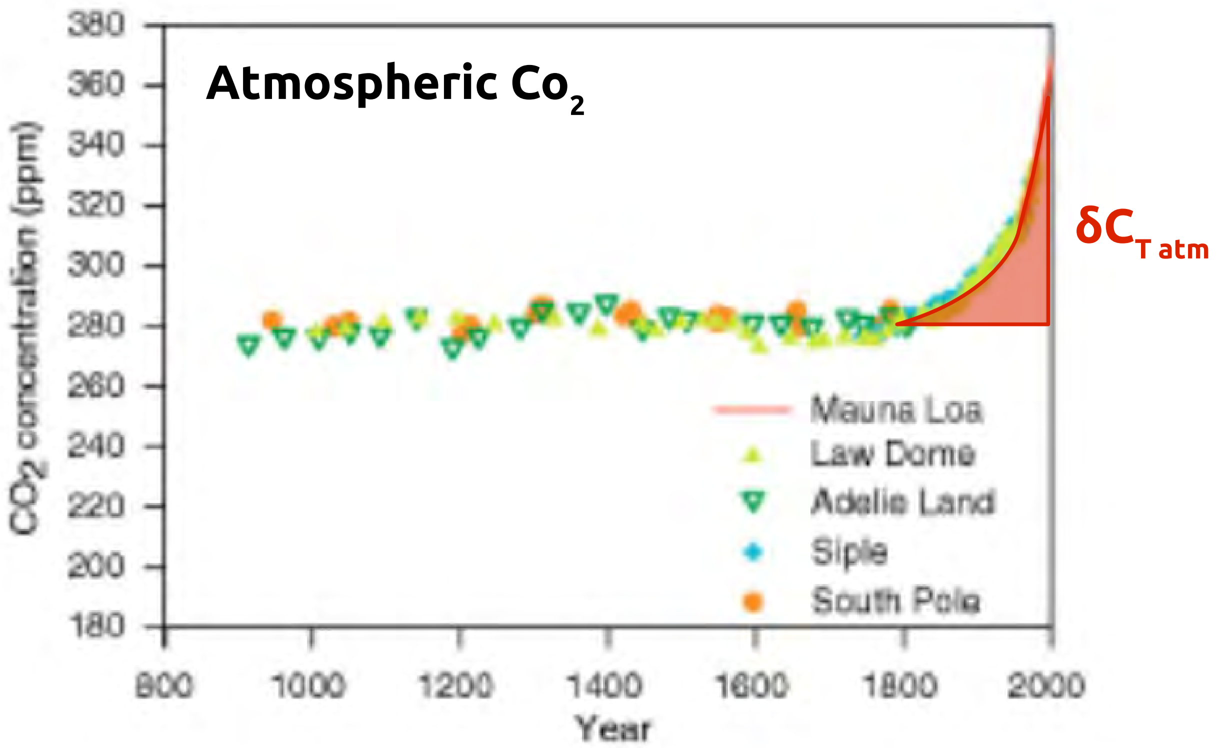
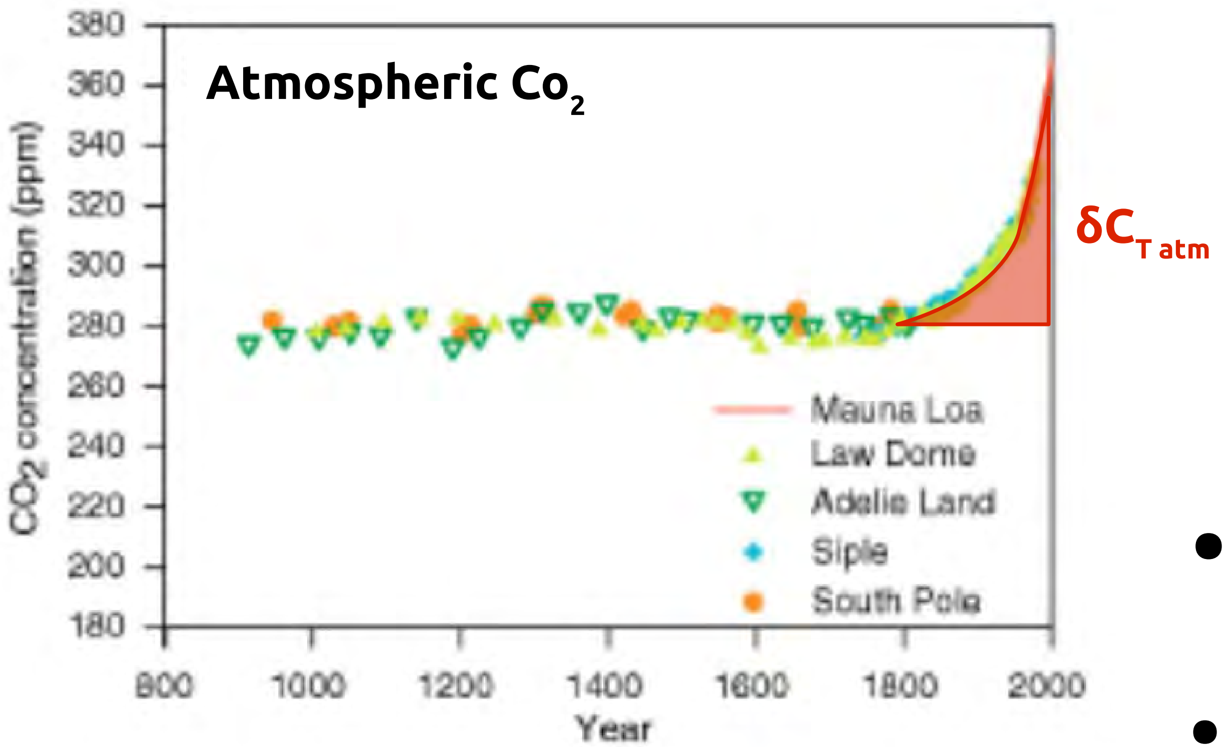


At global scale,
~25 % of anthrop. CO_2 (**δC_T**)
Taken-up by the Ocean.

Foreword : Mediterranean Sea geochemical properties



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- Mediterranean property :
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- **Alkalinity :**
  Capacity to neutralize acids.

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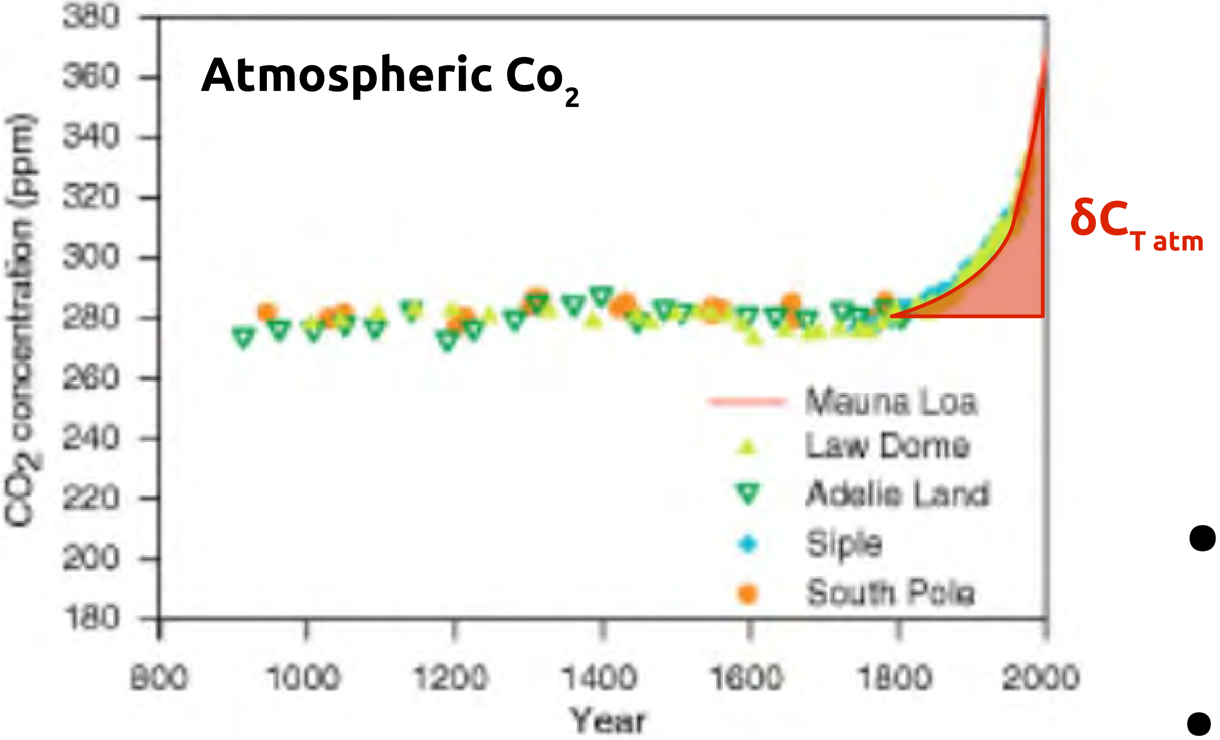

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Suggestion :

Higher alkalinity induce
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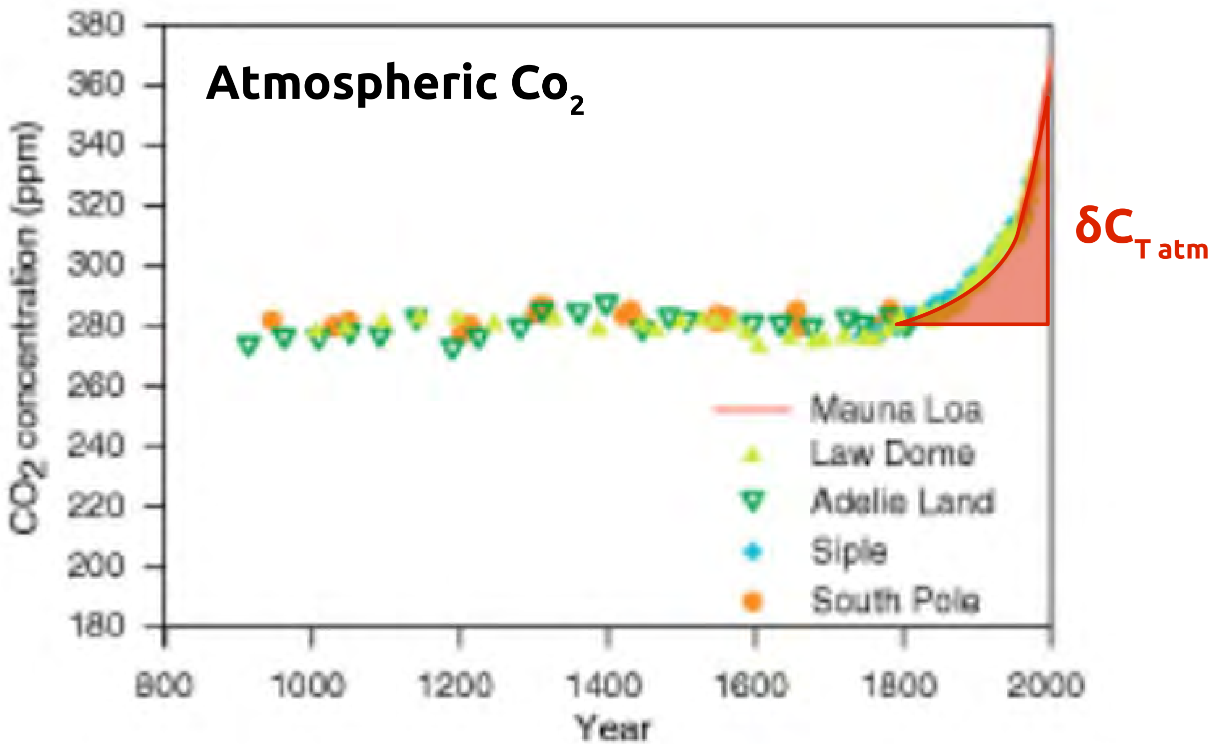

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Problem : No direct measurement of anthrop. carbon

<u>Suggestion :</u>

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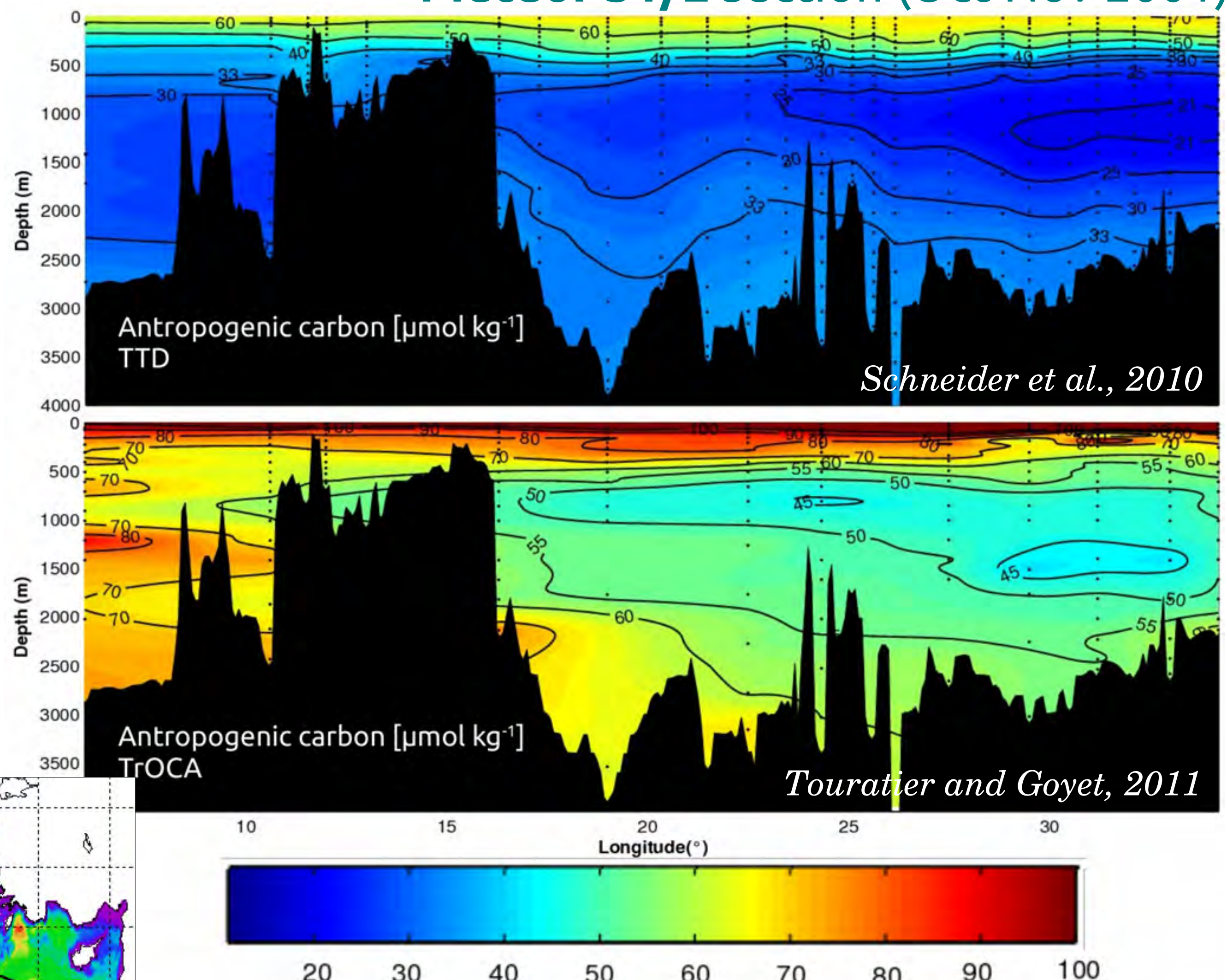
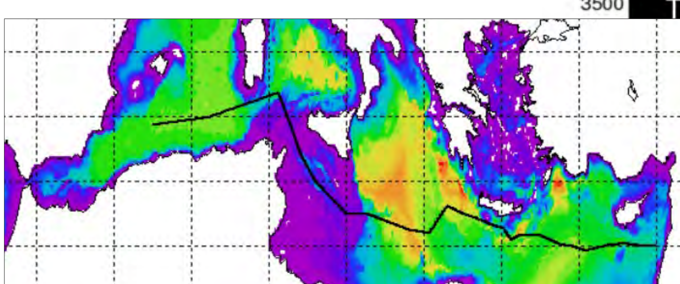
Great differences of data-based estimates of anthrop. carbon in the Mediterranean Sea.

Meteor 51/2 section (Oct-Nov 2001)

TTD method
Based on :
Water mass age (CFC)

TrOCA method
Based on :
O_2 ; **DIC** ; **Alk**

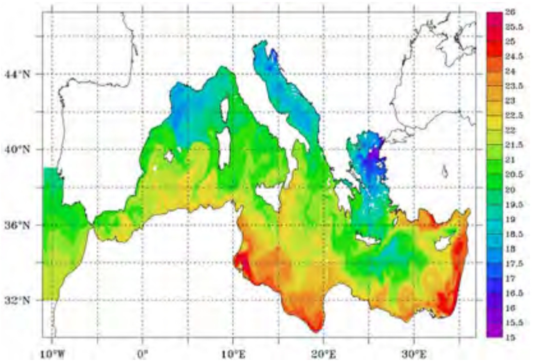




Three needed ingredients for anthr. CO_2 modelling:

1) **Model:**

   NEMO-MED12 (*Beuvier et al., 2012*)



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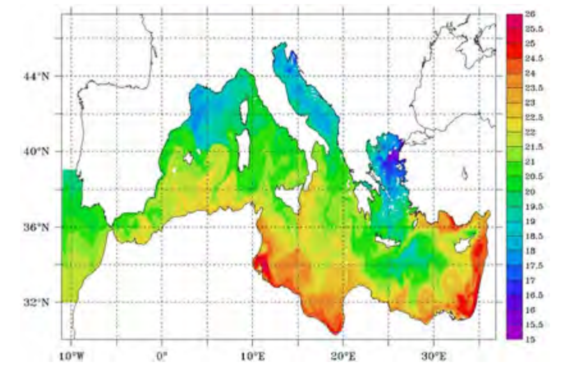
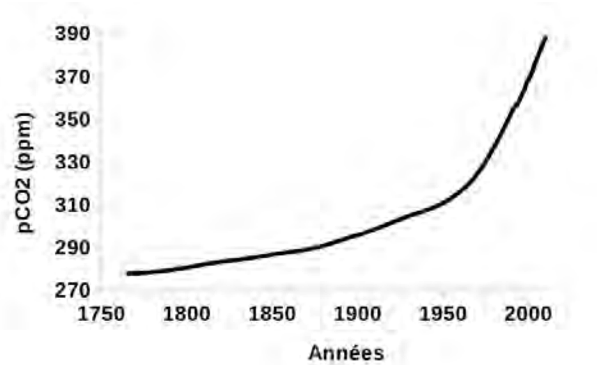


2) **Atmospheric CO_2 evolution.**

– Standard OCMIP2 approach

(force model w/ ice core + Mauna Loa observations)



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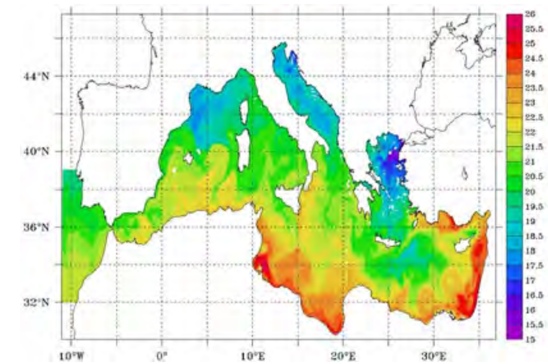

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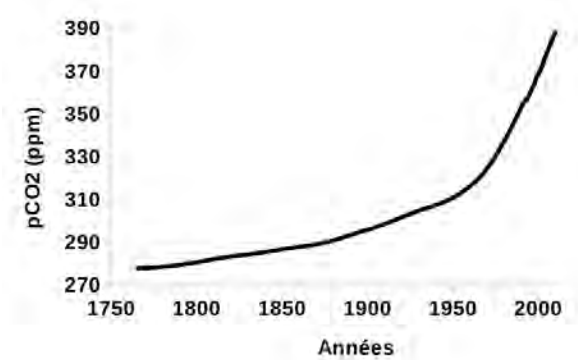

3) Perturbation method rely δC_T to pCO_2 (at surface):

– Only 1 tracer

– Abiotic method.

Sarmiento et al. (1992, JGR)

Experiences description:

1)

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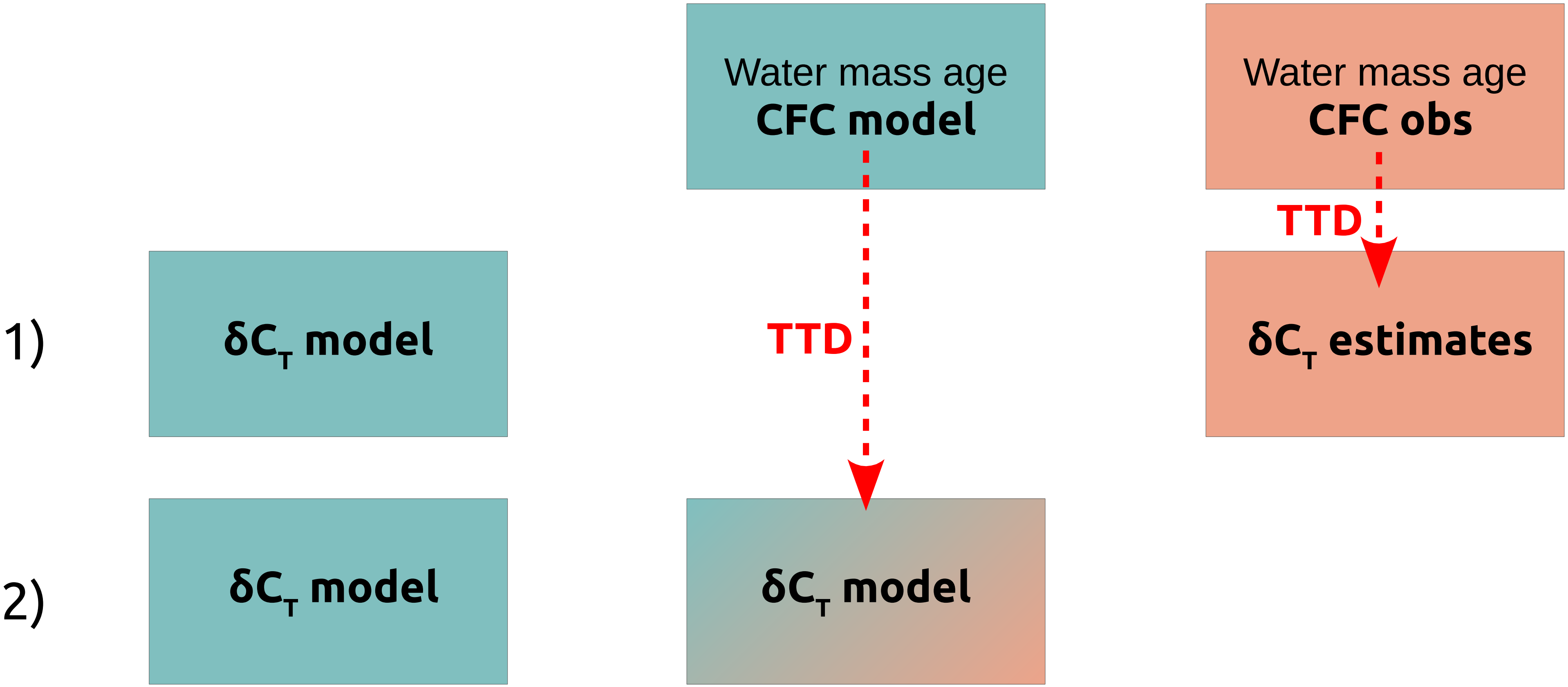

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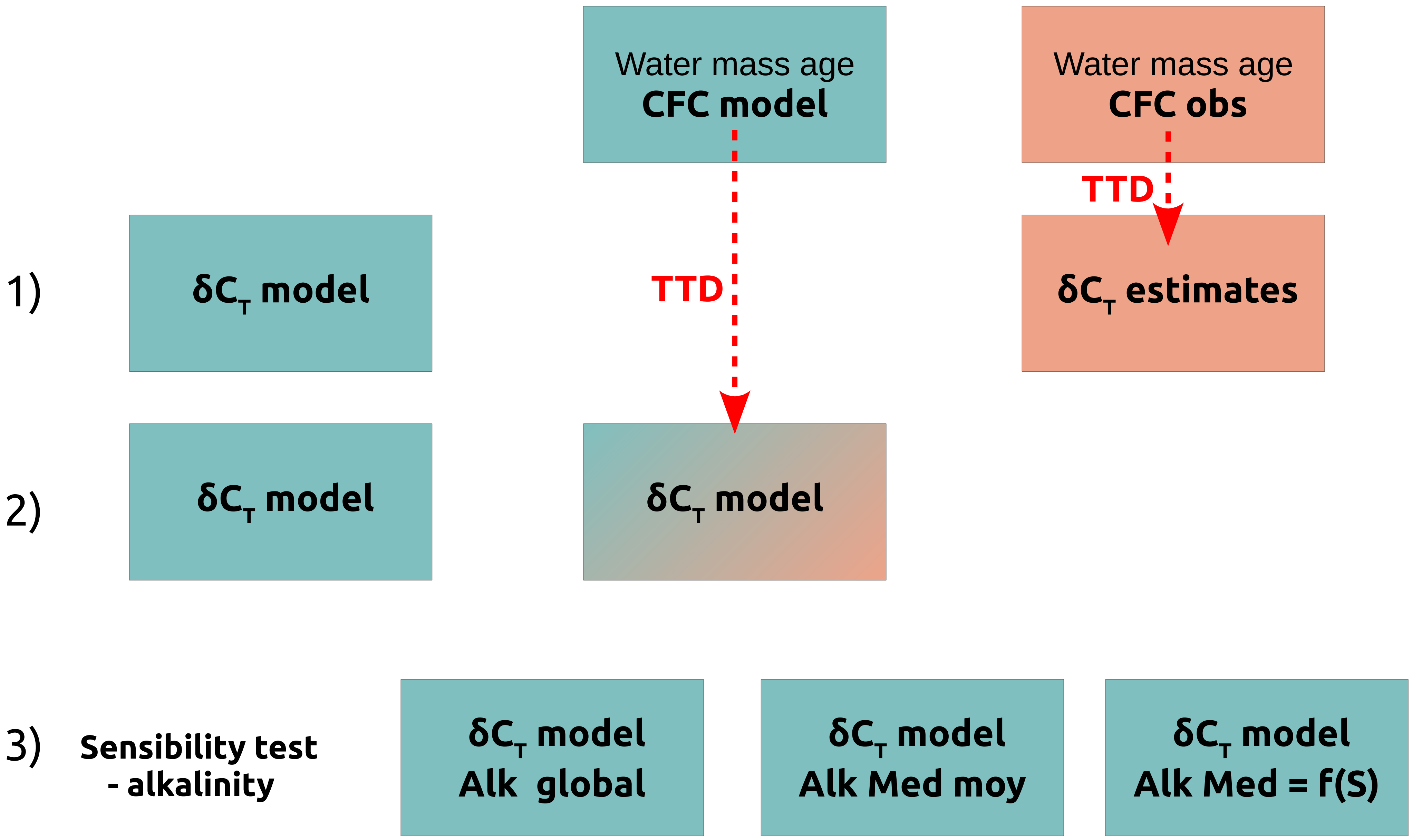
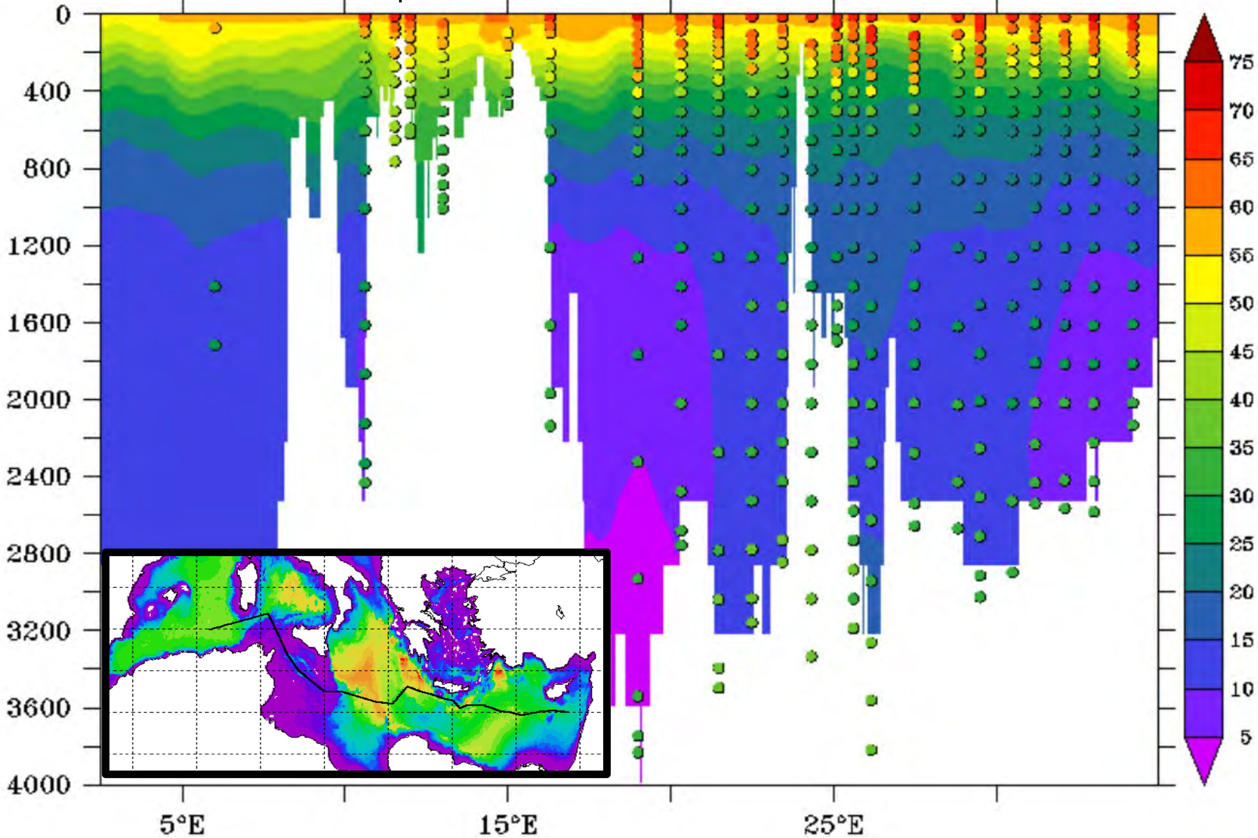
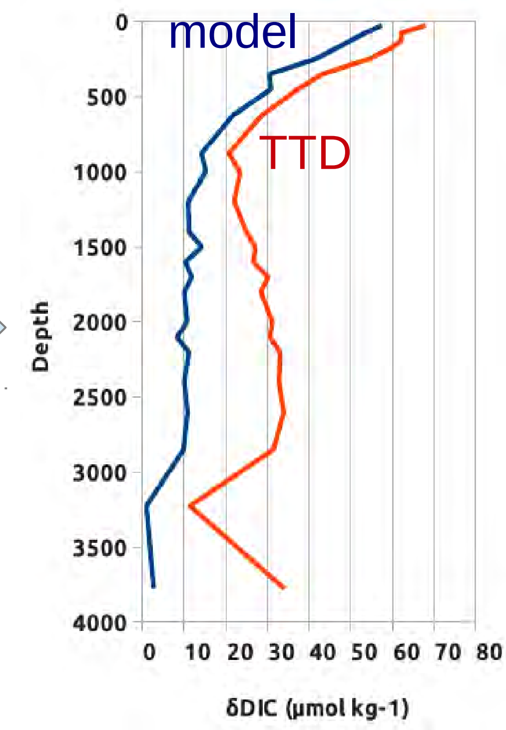


Model δC_T Everywhere lower than TTD data-based estimates.

Comparison δC_T model – TTD ($\mu mol\ kg^{-1}$)

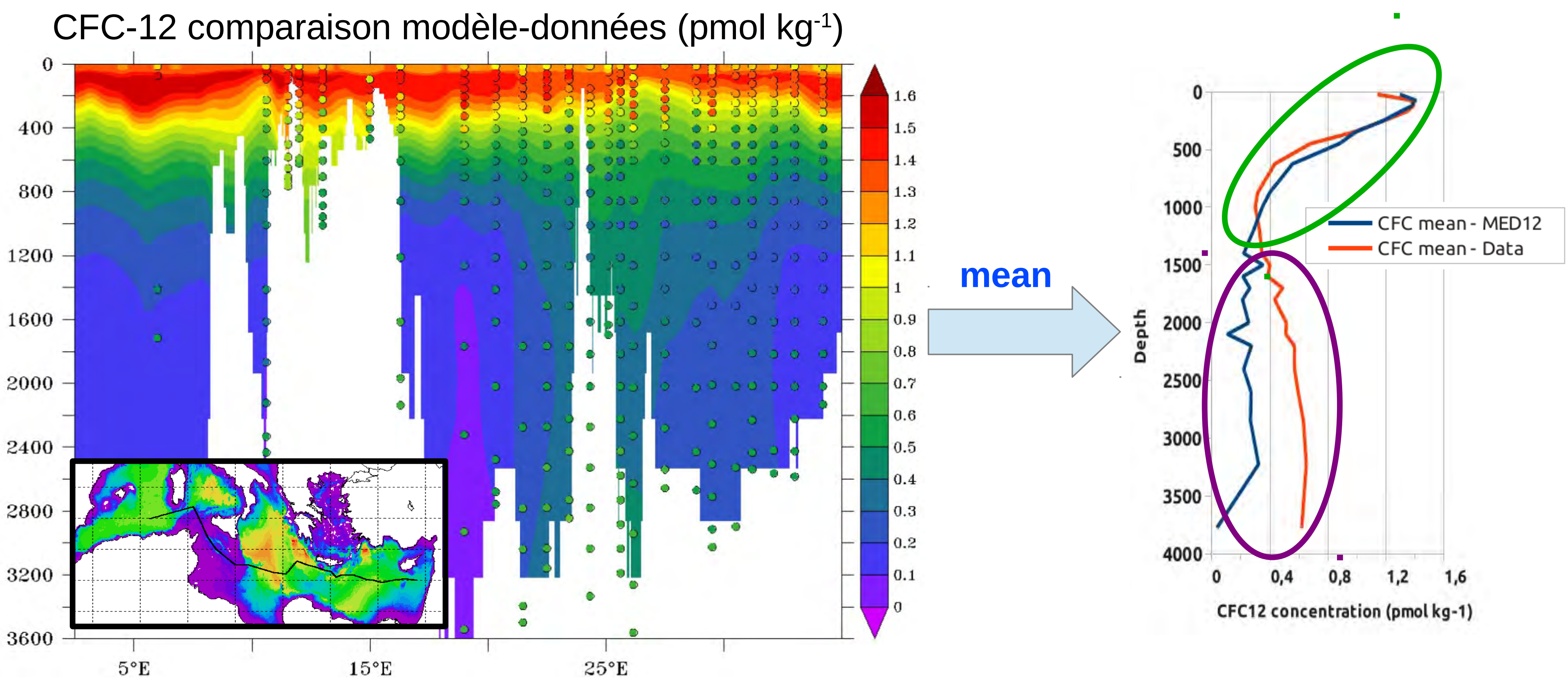


mean



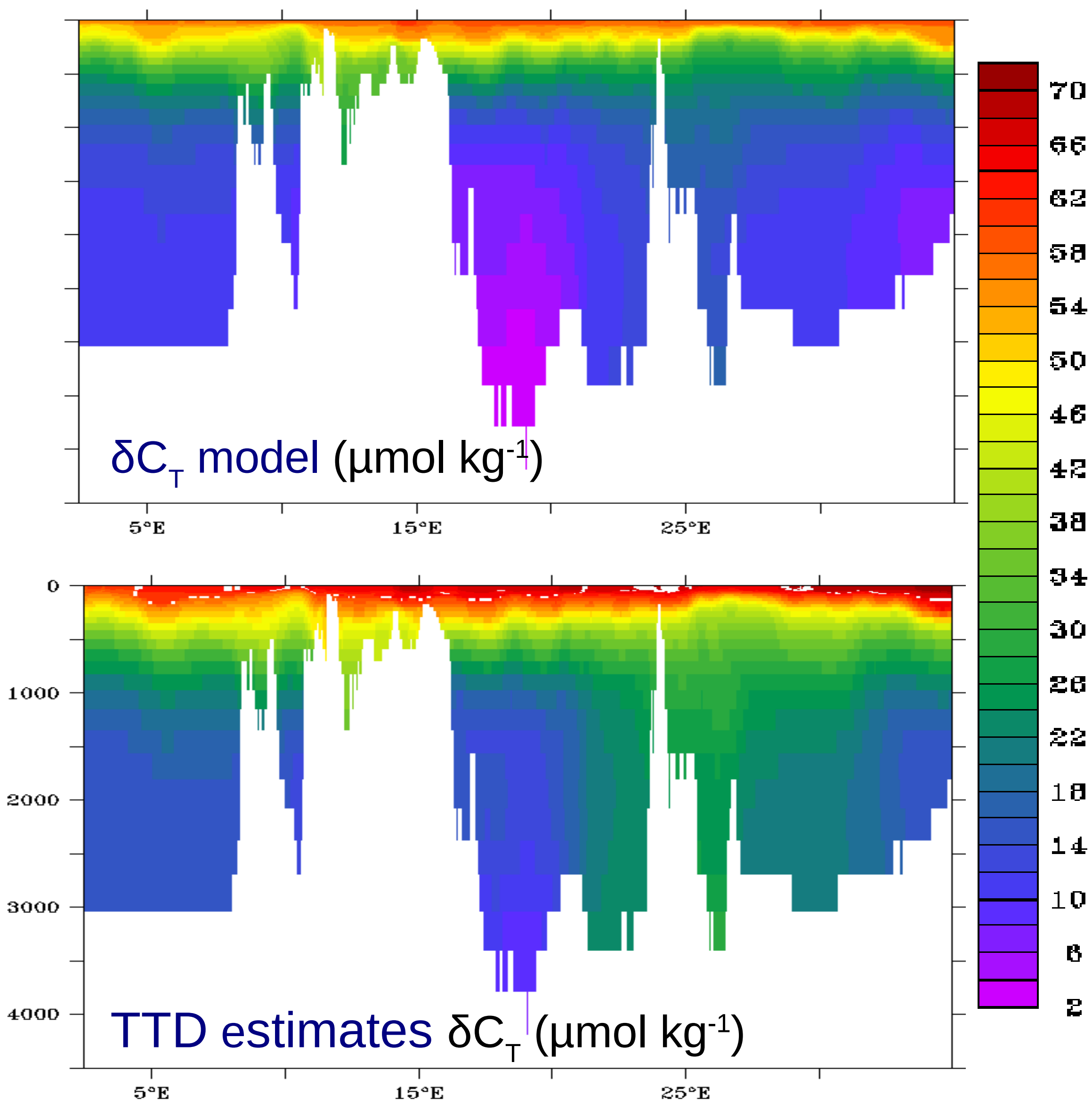
But... dynamic evaluation with CFC-12 shows Good correspondence over 1500m depth.

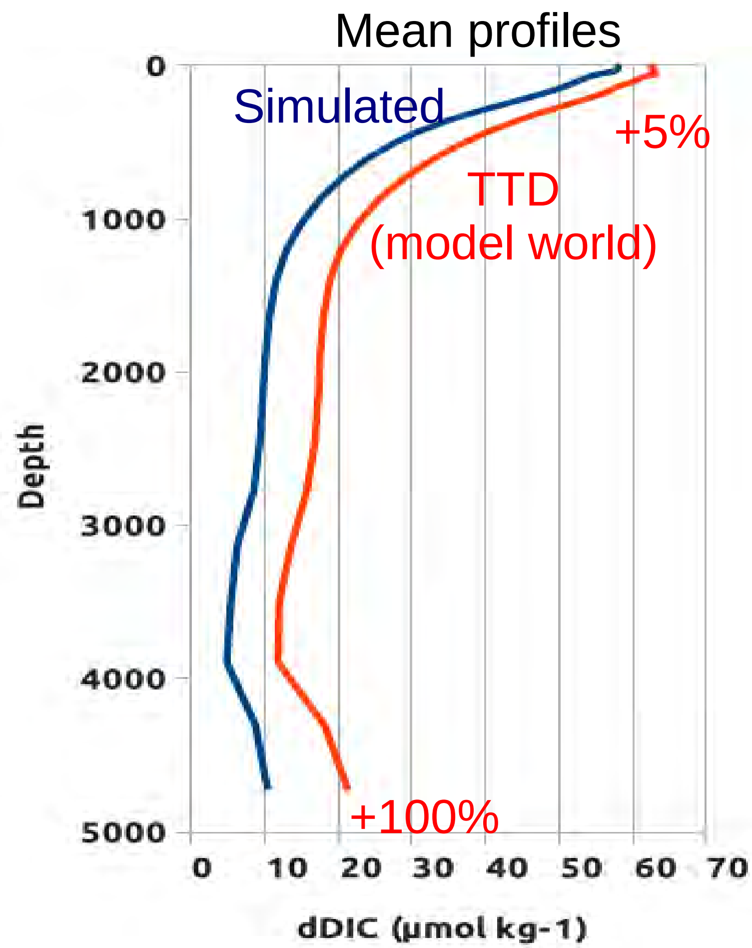
CFC-12 comparaison modèle-données (pmol kg^{-1})



TTD in "Model World" over-estimates model δC_T

TTD in "***Model World***"

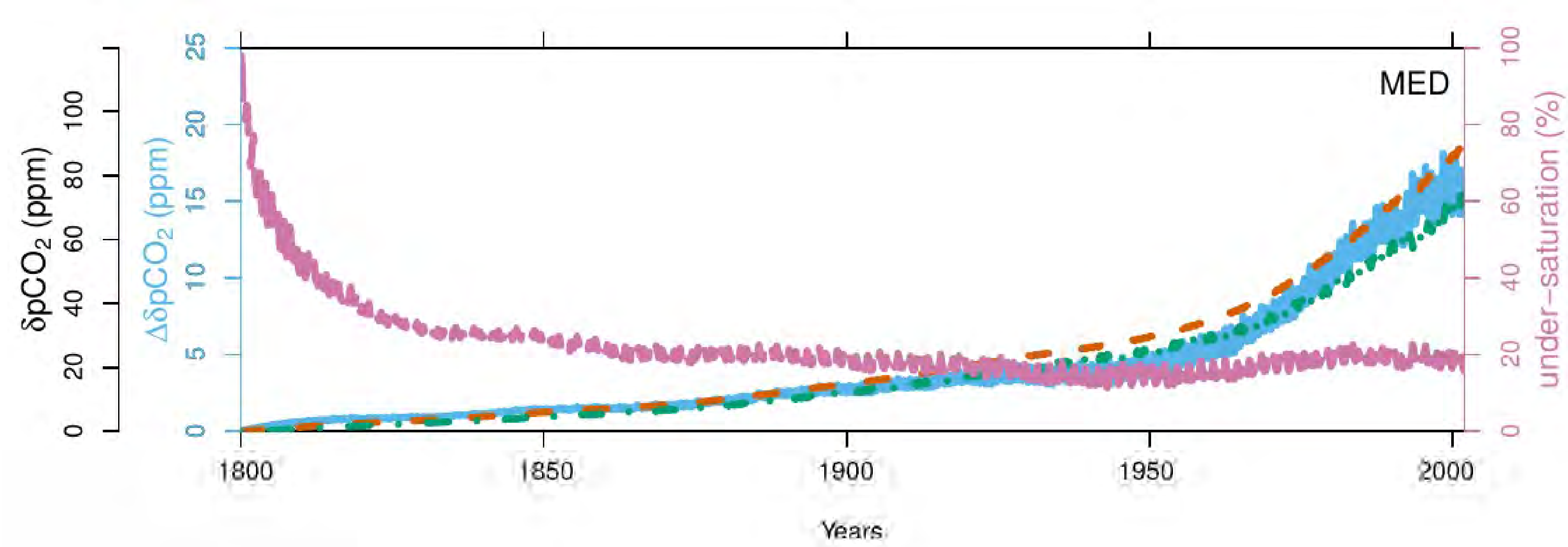




Global Inventory (Pg C en 2001)

Model	1.0
TTD (model world)	1.4

TTD over-estimates δC_T because of air-sea equilibrium assumption.



- **Data-based methods assume air-sea δC_T equilibrium**
- **But model surf. Ocean presents 15-20% under-saturation**

Positive bias in data-based estimates.

Mediterranean higher alcalinity Results in +10% δC_T uptake.

3 simulations with different surface alkalinity :

GLO : 2300 µmol kg^{-1} (mean **Global Ocean**)

MED : 2530 µmol kg^{-1} (mean **Med**)

VAR : variable Alk = f(salinity) [Schneider et al., 2007]

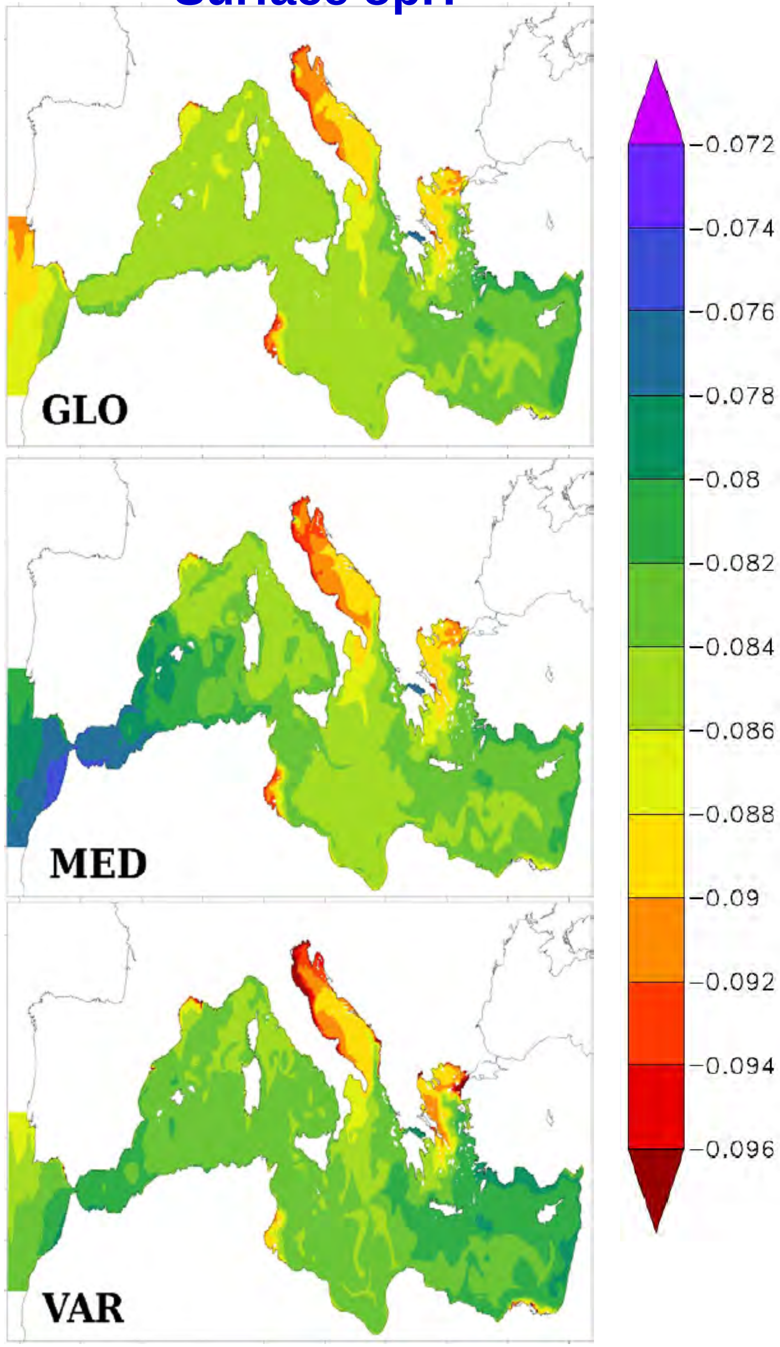
Results	Total δC_T Pg C	Inventory mol-C m^{-2}
GLO	0.927	30.22
MED	1.028	33.52
VAR	1.029	33.55

pH change appears insensible to alkalinity

GLO : 2300 µmol kg^{-1}
MED : 2530 µmol kg^{-1}
VAR : variable

Results	δpH
GLO	-0.085
MED	-0.084
VAR	-0.084

Surface δpH



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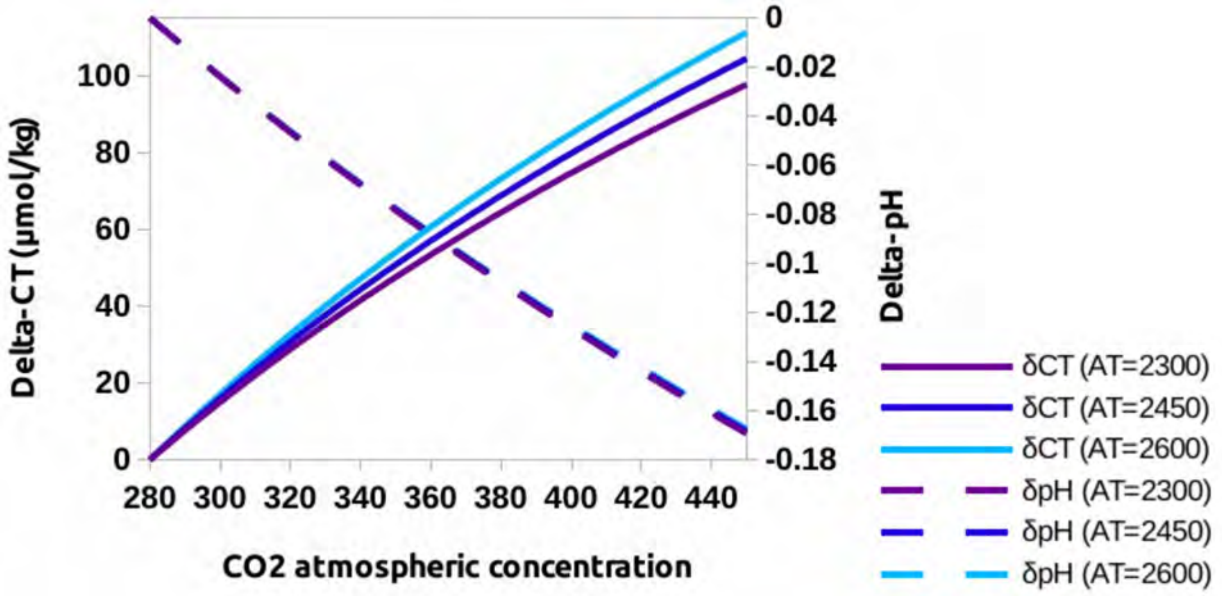

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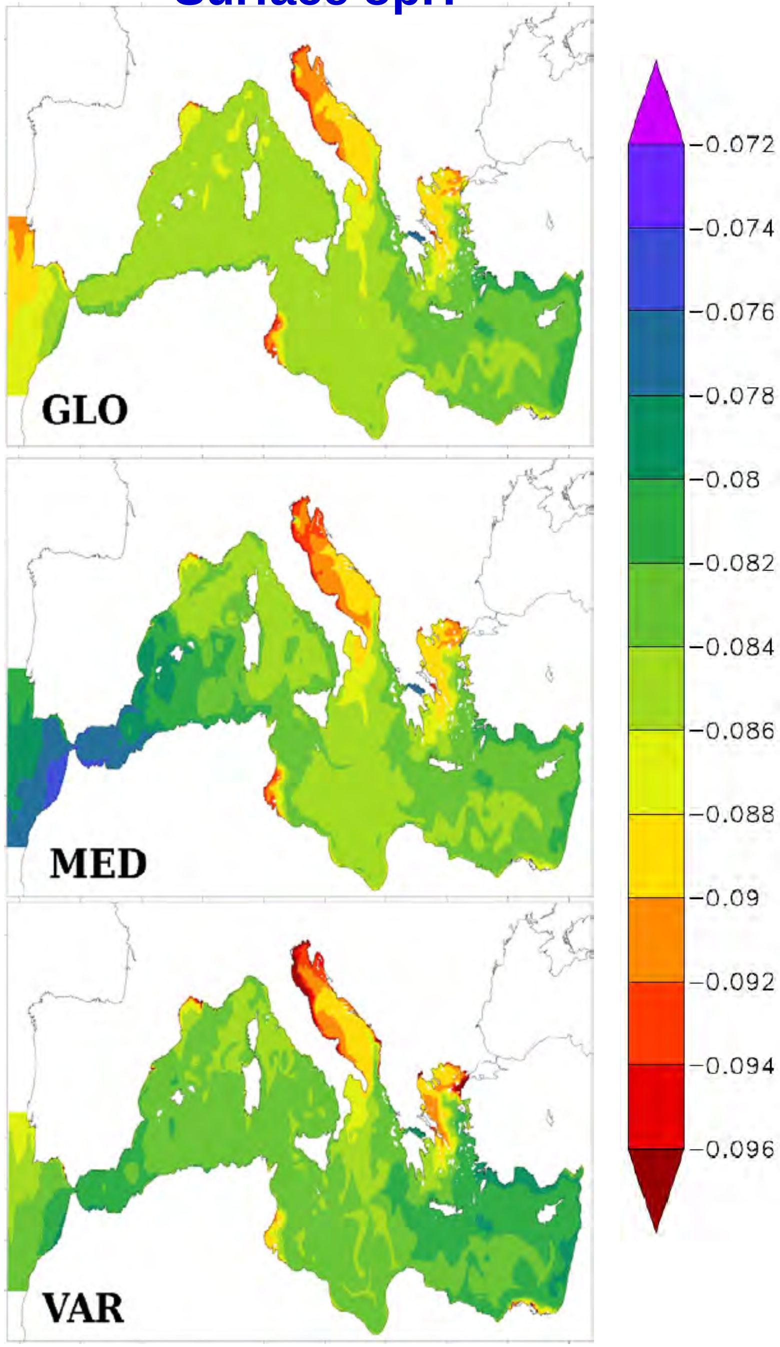
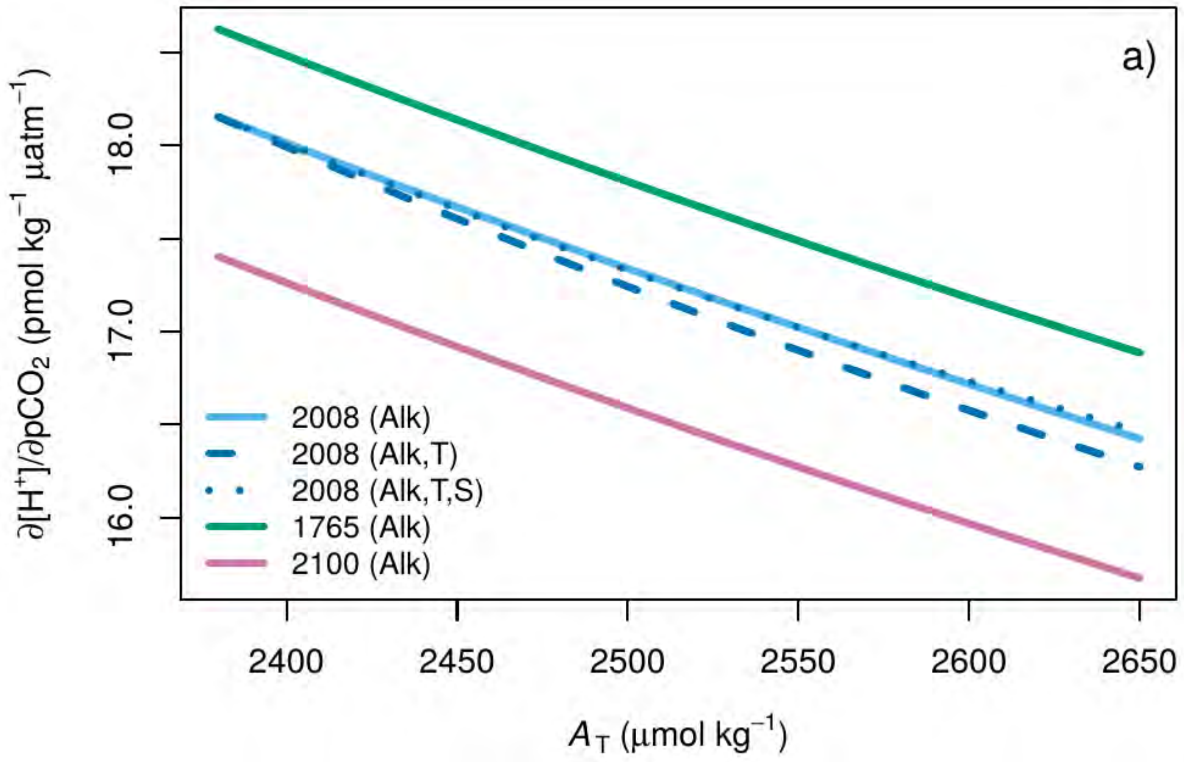
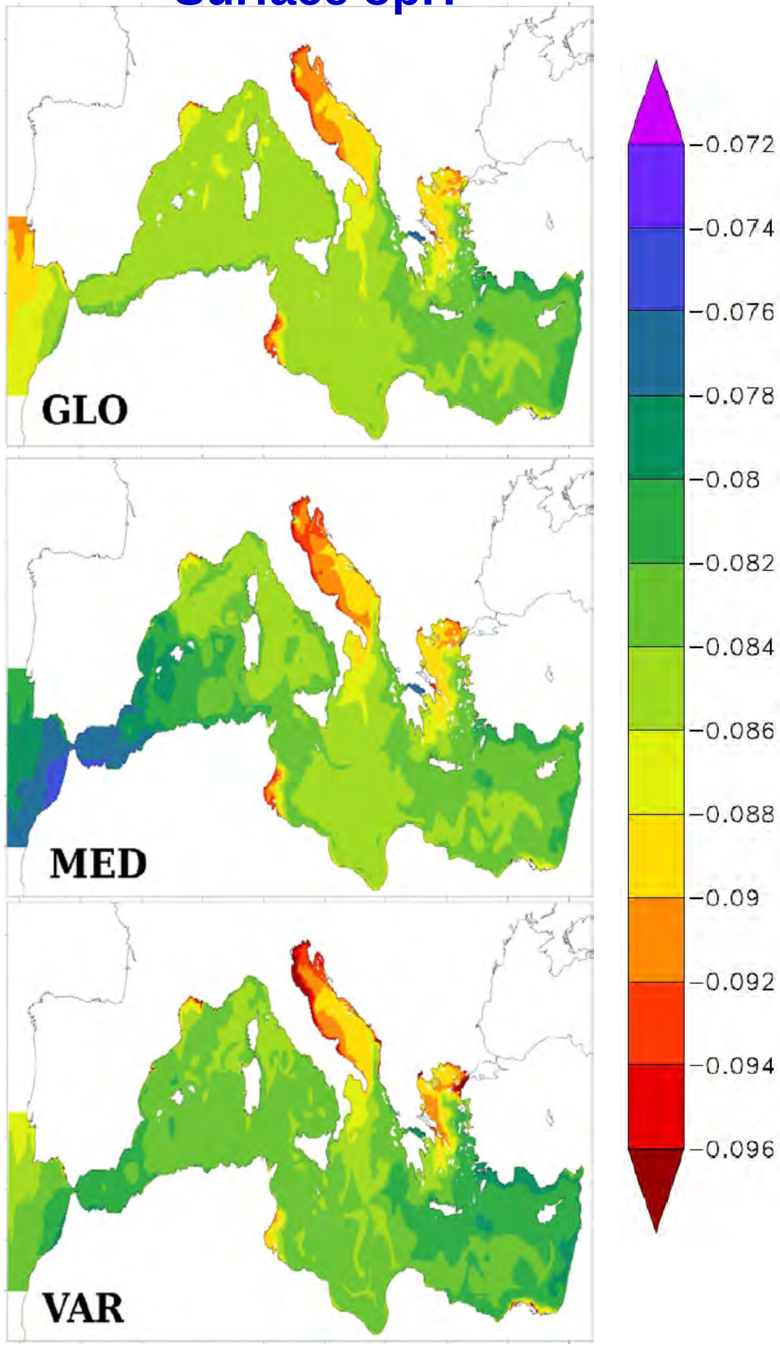


Higher alkalinity induces a slightly lower pH change

Acidification rate = $\dfrac{\partial [H^+]}{\partial\, pCO_2}$

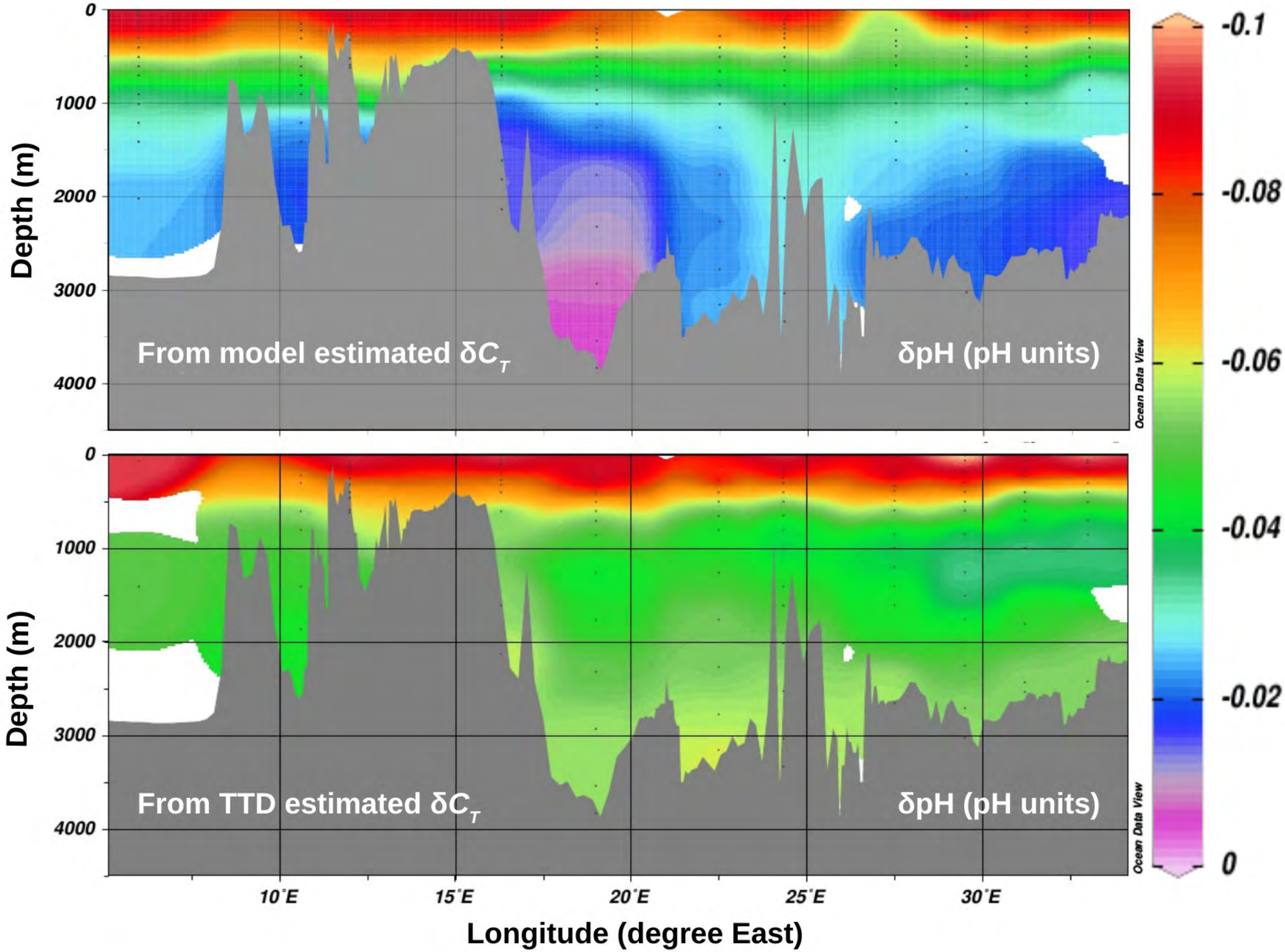


Surface δpH



Alkalinity alone reduces acidification rate of 8 %

But unlike Global Ocean,
pH change already impacts Mediterranean bottom water



Conclusions:

- Model : lower limit (1 Pg-C)
  TTD evaluation : upper limit (1.7 Pg-C).

  → 1 < Mediterranean δC_T < 1.7 Pg-C

- Surface :
  Med. alkalinity induces higher δC_T uptake
  but acidification is equivalent to Global Ocean

- Bottom water pH already reduced : $\delta pH < -0.06$

Conclusions:

- Mediterranean Sea δC_T storage and acidification

  Published (see Palmiéri et al., 2015 - Biogeosciences)

- Supplementary constrains to δC_T and acidification

  ==>> Study of Mediterranean δC_T and acidification under climate change
  with biogeochemical feedbacks - Le Vu et al., in prep
  (MedSeA ; MerMex)

¡¡¡ Obrigado !!!

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