Acidification des océans et coraux froids

Conny Maier

Last affiliation:

LOV (Laboratoire de Villefranche sur mer, CNRS/UPMC), France

MEditerranean cold-water Coral CAlcification

COraux Méditerranéens Profonds et changements climatiques

Structure / Questions

- Acidification des océans – C'est quoi ?
- Les coraux froids ou profonds: Pourquoi on pense qu'ils sont (plus) susceptible à l'acidification des océans ?
- Qu'est qu'on a apprit sur la reponse des coraux froids aux changements climatique ?
- Acidification et les coraux froids de la Mediterrannée

Acidification des océans

-> par jour: émission de ca. 80 millions des tons d'anthropogénic CO_2 dans l'atmosphère

-> ca. 1/3 est absorbé par des océans dépuis 1800

-> ralentissement des rechauffement climatique

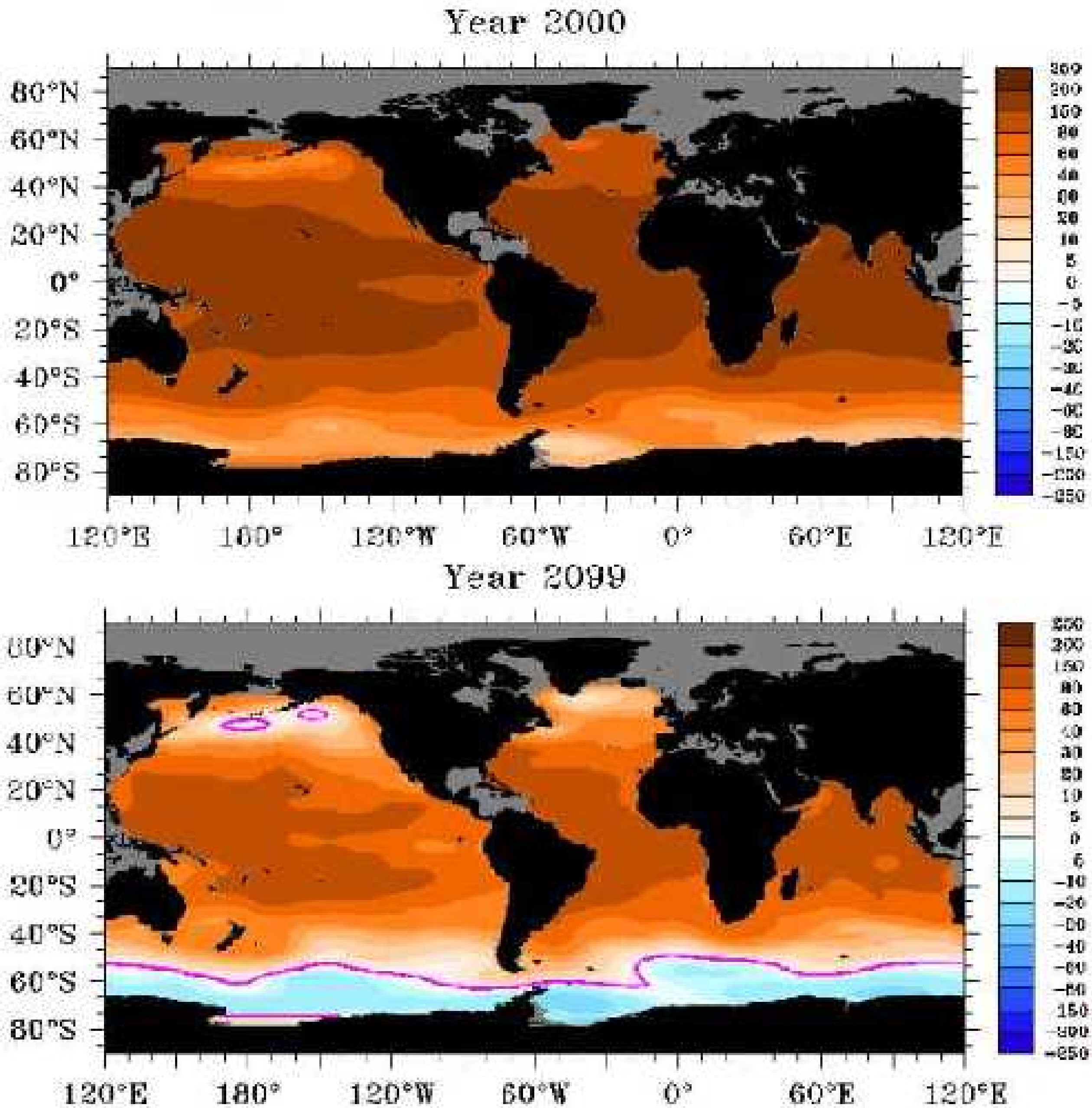
-> augmentation du carbone inorganique dissous dans l'océan et du pCO_2 de 280 (préindustriel) à 380-400 ppm aujourd'hui

-> augmentation du pCO_2 à. 700-750 ppm jusqu'à la fin du ciècle

⇒ l'acide carbonique diminue le pH de l'océan par 0.3-0.5 unités jusqu'à la fin du ciècle

OA ⇒ ***http://oceanacidification.wordpress.com+ many links herein…***

Aragonite saturation state Ω_a



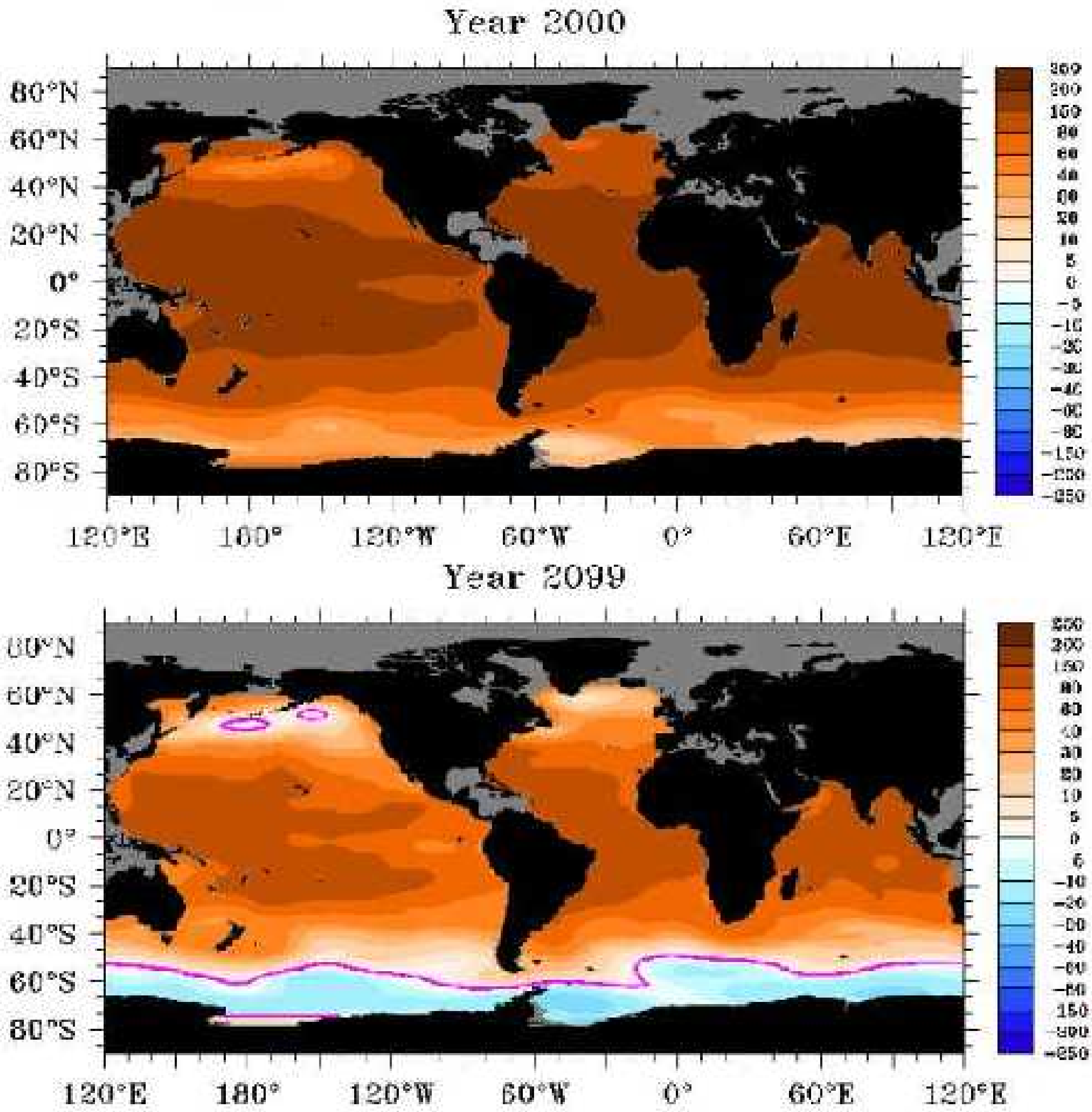
$\Omega_a < 1 \Rightarrow$ *dissolution of aragonite*

Ω depends on pressure and temperature

$\Rightarrow$ Deeper depths and higher latitudes : lower Ω

J. Orr et al (Nature, 437, 2005)

Aragonite saturation state Ω_a



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Papers on OA and CWC

Not based on coral data:

(1) Guinotte et al. (2006) -> Model of ASH for CWC (*Front. Ecol. Environ, v. 4*)

(2) Turley et al. (2007) -> Perspective paper (*Coral Reefs, v. 26*)

Experimental evidence:

(3) Maier et al. (2009) –> *Lophelia pertusa,* short-term response (*Biogeosci. v. 6*)

(4) Form, A & Riebesell, U (2012) "*L. pertusa* – N-Atlantik, short & long term response ("acclimation"?) (*Global Change Biol., v. 18*)

(5) Maier et al. (2012) Mediterranean *M. oculata*, short term (*Proc. R. Soc. L., 279*)

(6) Maier et al. (2013) Mediterranean *M. oculata* & *L. pertusa,* short & long term response (*PLOSone, v. 8*)

(7) Maier et al. (2013) Respiration of Mediterranean *M. oculata & L. pertusa* (*BGD, v. 10*)

Proxy studies:

(8) McCulloch et al. (2012) Boron isotope studies - pH upregulation (*GCA, v. 87*)

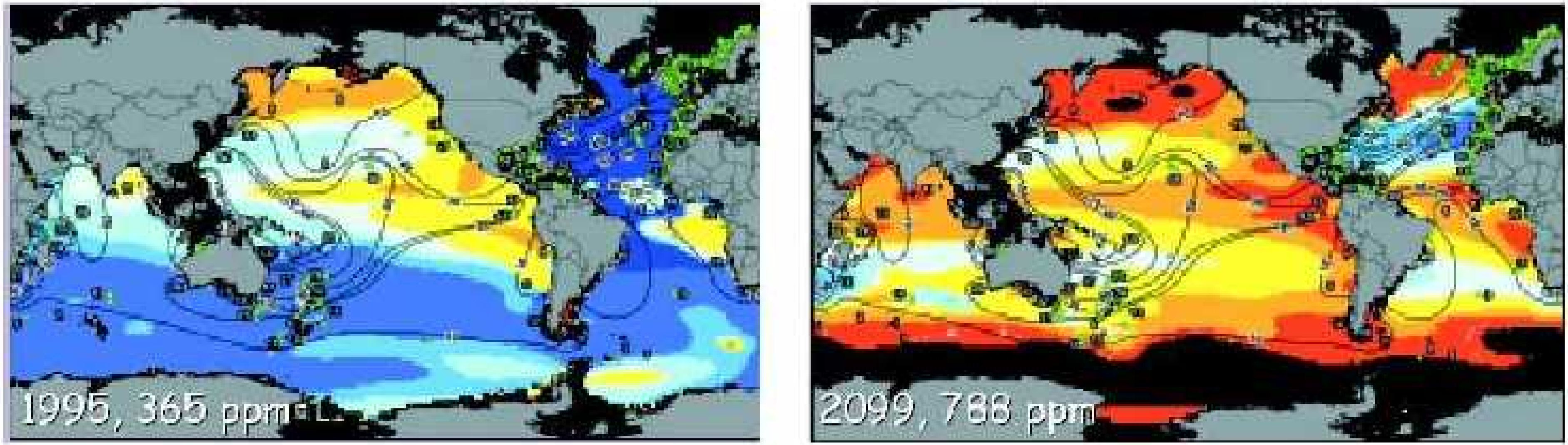
Field observations:

(9) Thresher et al. (2011) -> CWC coral sampling / observations below ASH (*MEPS, v. 442*)

(10) Jantzen et al. (in press) In situ pH gradient f. *Desmophyllum* sp.

(5-7 -> MedSeaCan)

➢Aragonite saturation horizon (ASH)



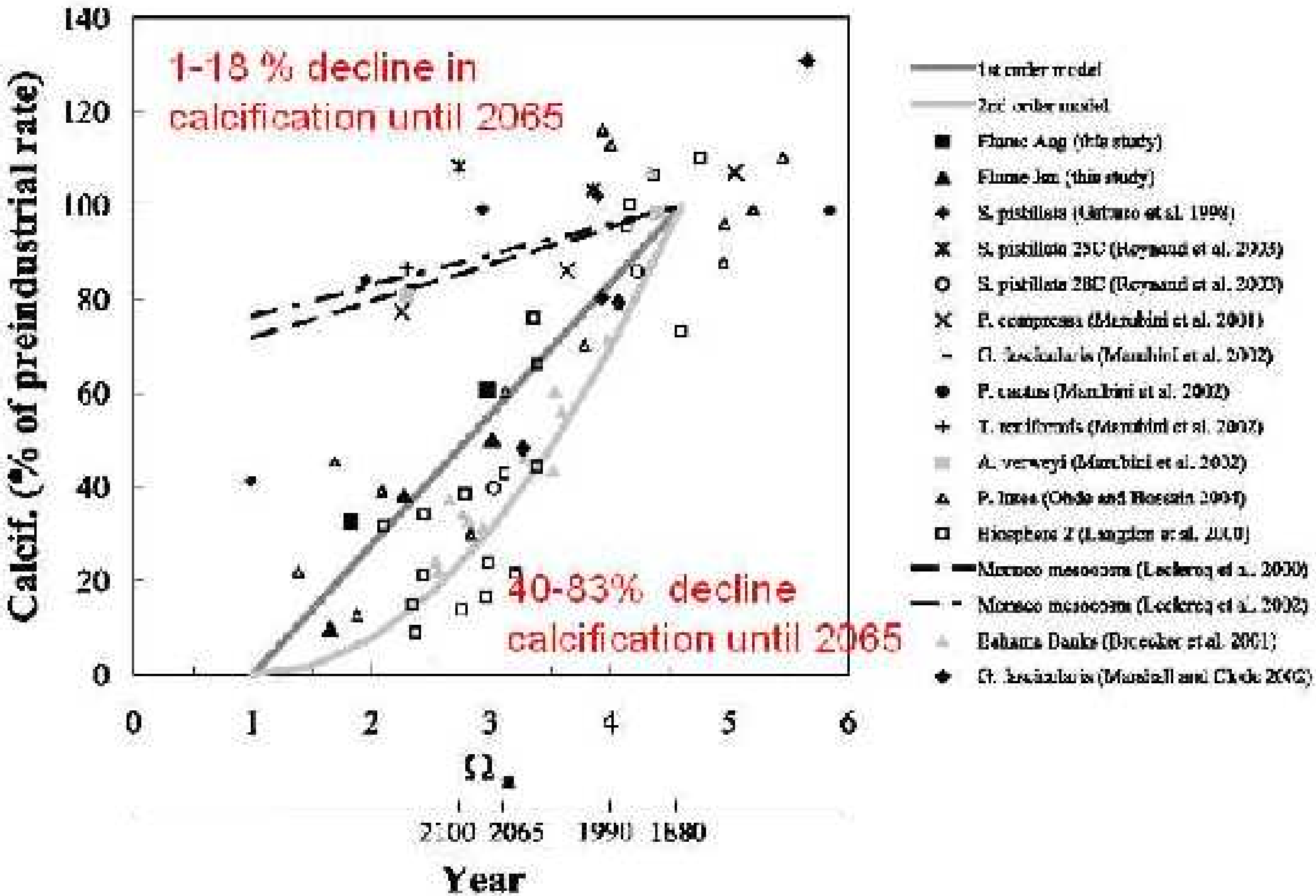
- Deep sea corals likely to be affected "sooner" by rise of the aragonite saturation horizon (ASH)

- > 70% deep water coral habitats below ASH by 2099

→ **Big trouble ahead !**

-> Guinotte et al, 2006: Front Ecol Environ 4(3): 141-146

Effect of OA on tropical corals



⇒ Small changes in the Ωa results in drastic decline of (tropical) coral growth !

Source: Langdon et al 2005

Expectation at start of OA studies

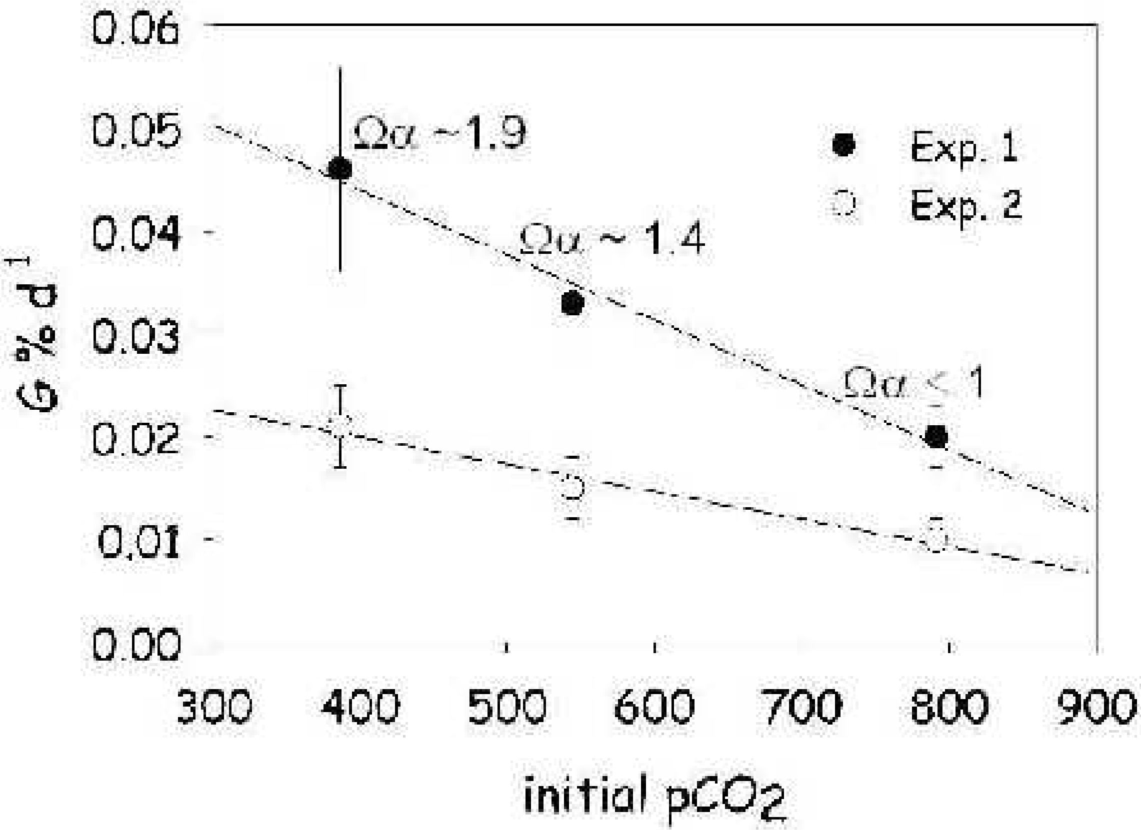
"Corals in deep-water: will the unseen hand of ocean acidification destroy cold-water ecosystems?"

Turley et al. Coral Reefs, 26: 445-448, ***2007****:*

"...It would seem unlikely, that scleractinian cold-water corals would be able to calcificy under these (undersaturated) *conditions..."*

"... if cold-water corals respond in the same way as warm-water coral species ... their calcification rates may decrease well before aragonite under-saturation occurs."

Bulk calcification of coral branches

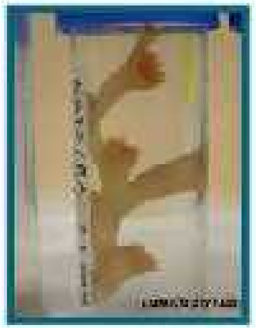


Short-term:
→ strong negative effect of elevated pCO_2 on calcification

- 50% decrease until end of century ?

Maier et al. Biogeosciences, 6, 2009

Reconsideration of data interpretation

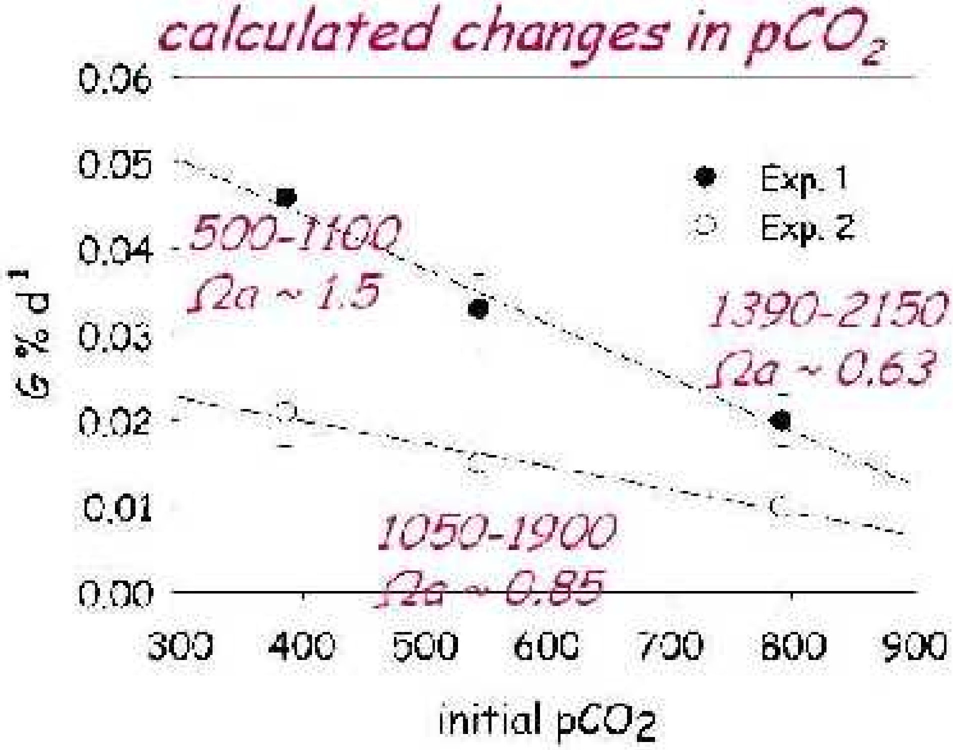


Closed system, small volume

CO_2 release by coral respiration and calcification

$$\uparrow DIC(t_{end}) = DIC(t_0) + R - G$$
$$\downarrow TA(t_{end}) = TA(T_0) - 2 * G + 1 NH_4$$

⇒ strong pCO_2 increase during incubation



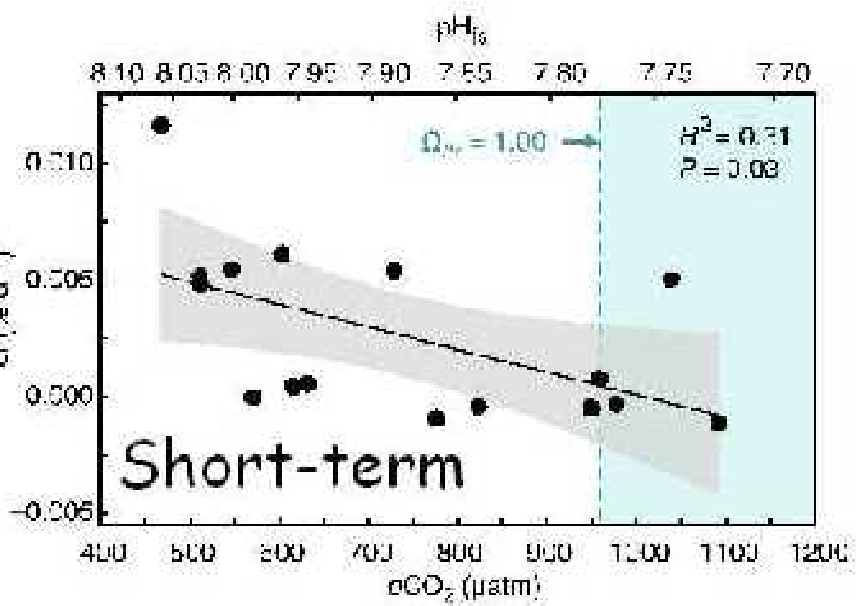
⇒ shift to much higher mean pCO_2 levels during incubations

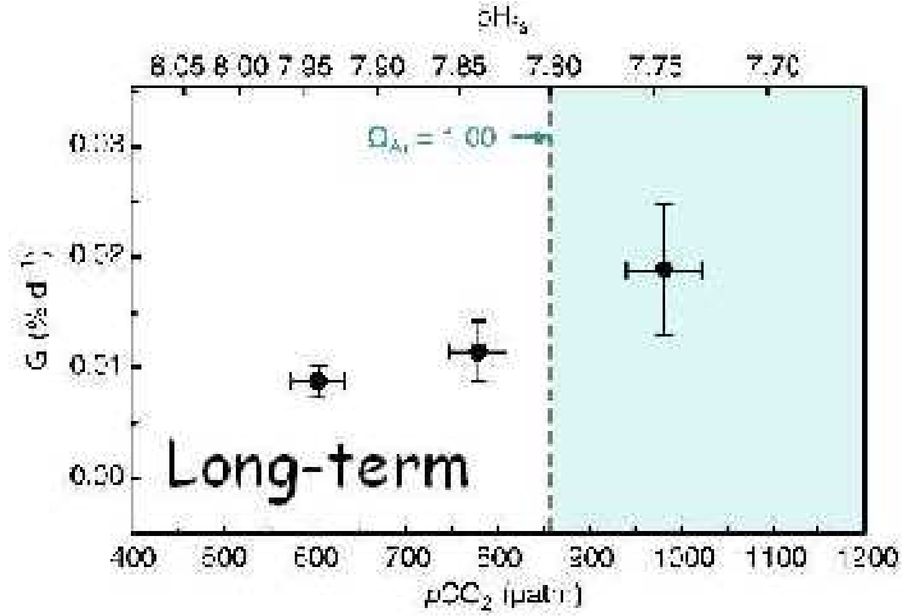
⇒ decrease in calcification due to shift to higher pCO2 levels > 1000 µatm due to R and G

⇒ positive calcification at $\Omega a \leq 1$

Maier et al 2009

Calcification of *L. pertusa* -> short and long-term: acclimation?





Short vs Long-term:
Negative for short-term vs. no effect long-term: -> "Acclimation" to high pCO_2

Form & Riebesell: Acclimation to ocean acidification during long-term CO_2 exposure in the cold-water coral *Lophelia pertusa, Global Change Biol. 18: 843-853, 2012*

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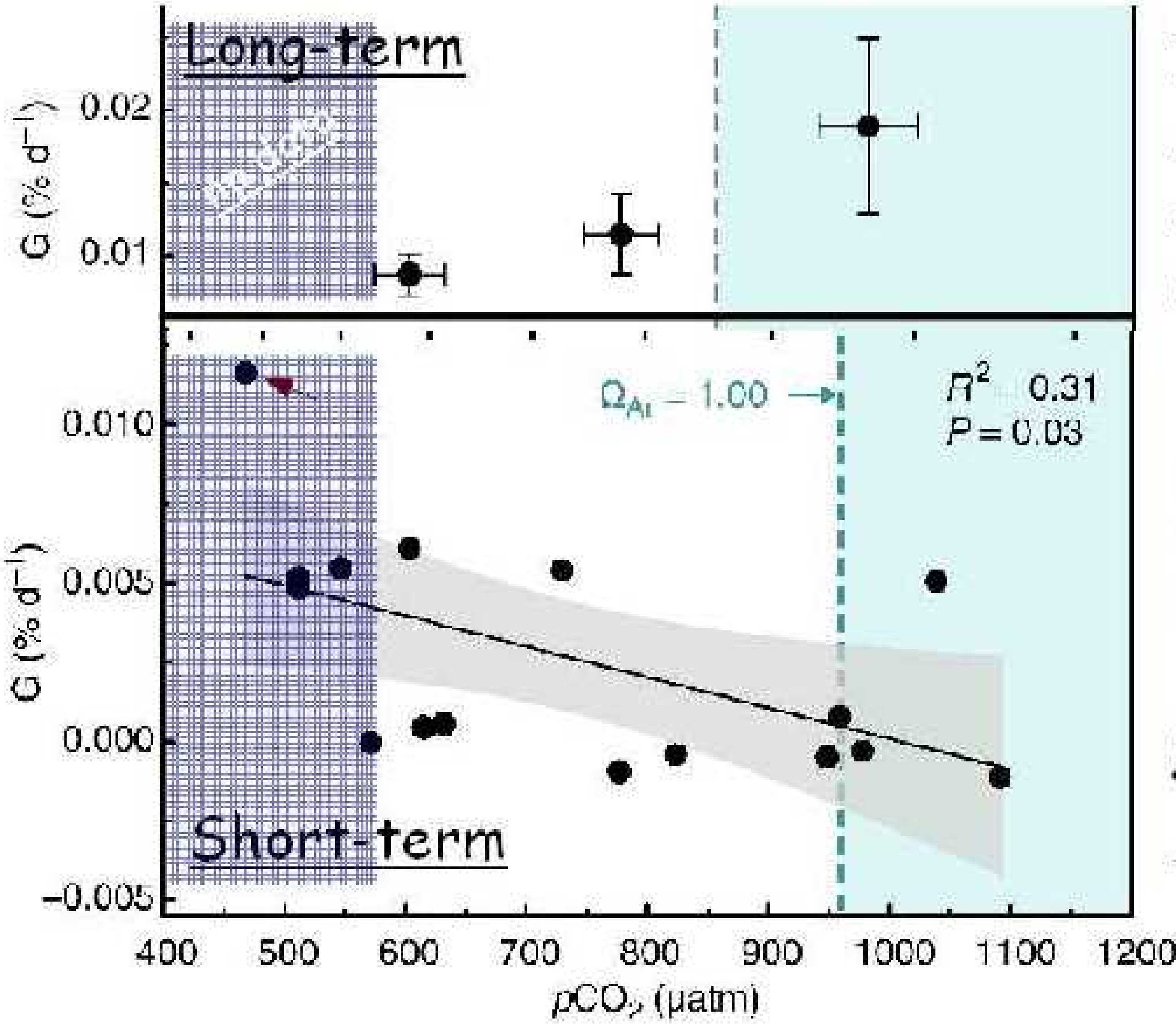


Long-term:
- lack of initial G control
- lack of ambient control
- weight of corals lower at high pCO_2

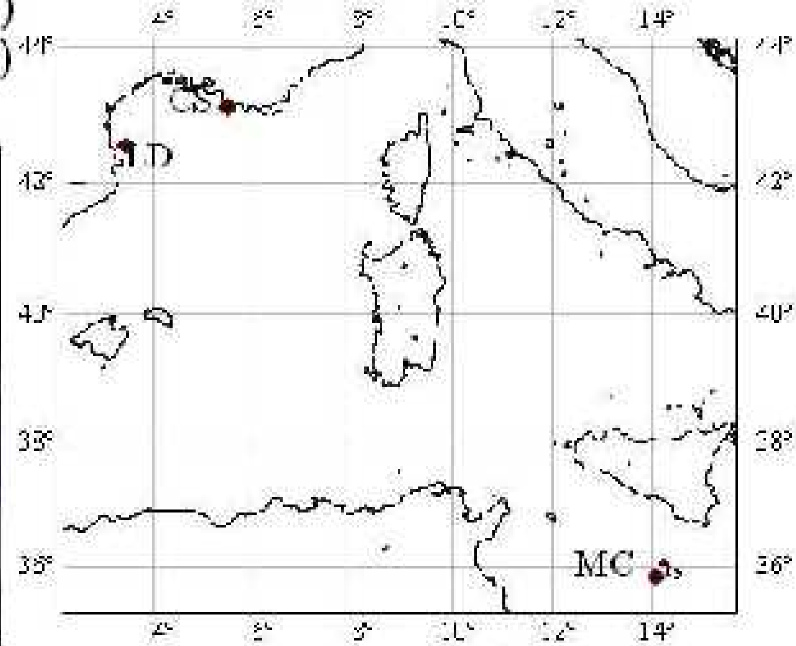
Short-term:
- slope forced by 1 high value at lowest pCO2

Short vs Long-term:
→ Acclimation ?

Form & Riebesell 2012

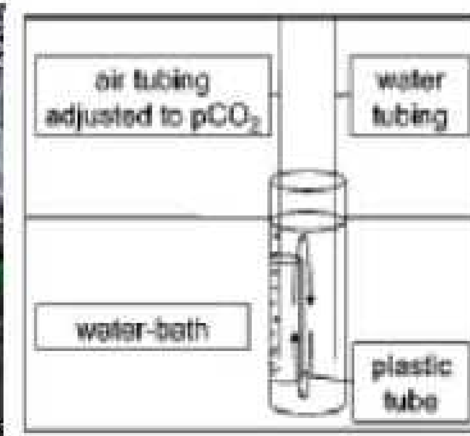
· Sampling: seawater and live corals

MedSeaCan (french Med coast)
COMP (Adriatic, Ionian Sea)



Onboard incubations to determine calcification rates using ambient seawater

Long- and short-term incubations in the lab / climate room

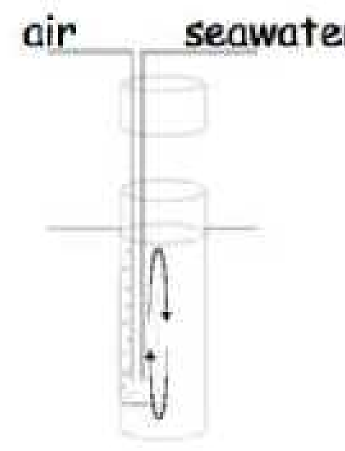


Mediterranean *L. pertusa* and *M. oculata* at increased pCO_2

Repeated measures design same corals in short- and long-term

- Calcification: alkalinity anomaly 0 - 3 months, BW 9 months

A	B	C	D
280 ppm (350 μatm) $\Omega a = 3.2$	400 ppm (468 μatm) $\Omega a = 2.6$	700 ppm (688 μatm) $\Omega a = 1.9$	1000 ppm (930 μatm) $\Omega a = 1.3$



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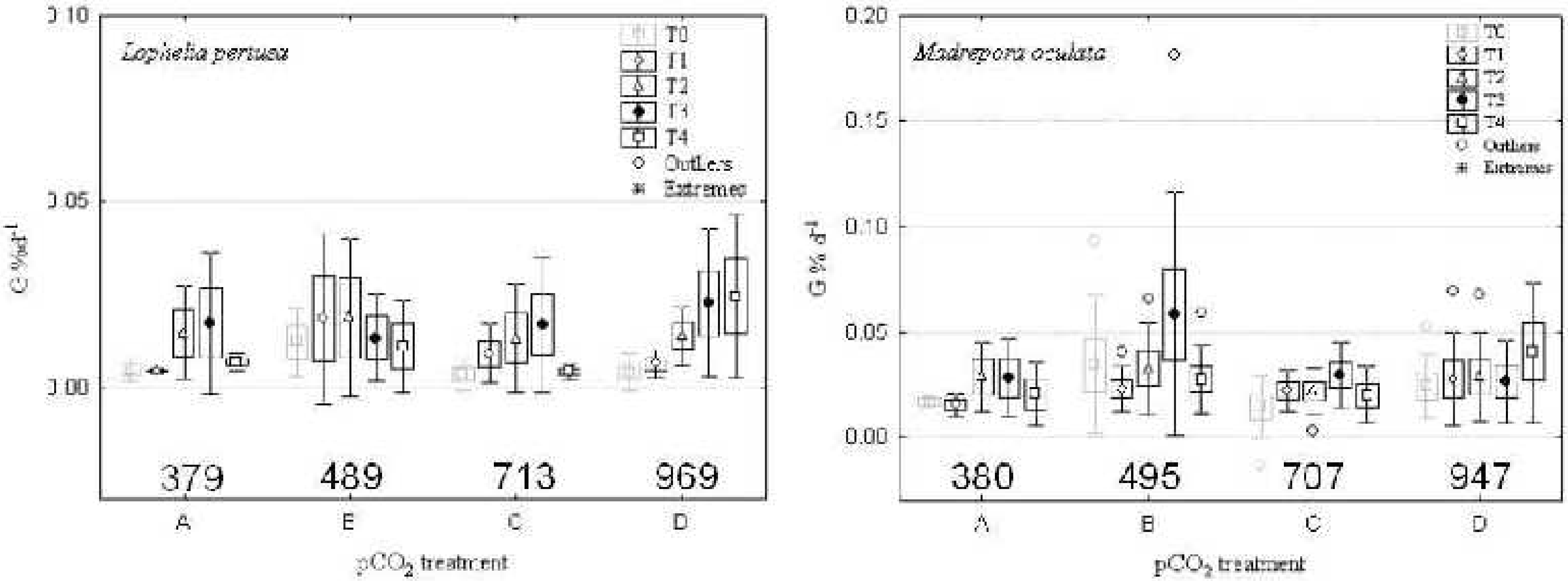
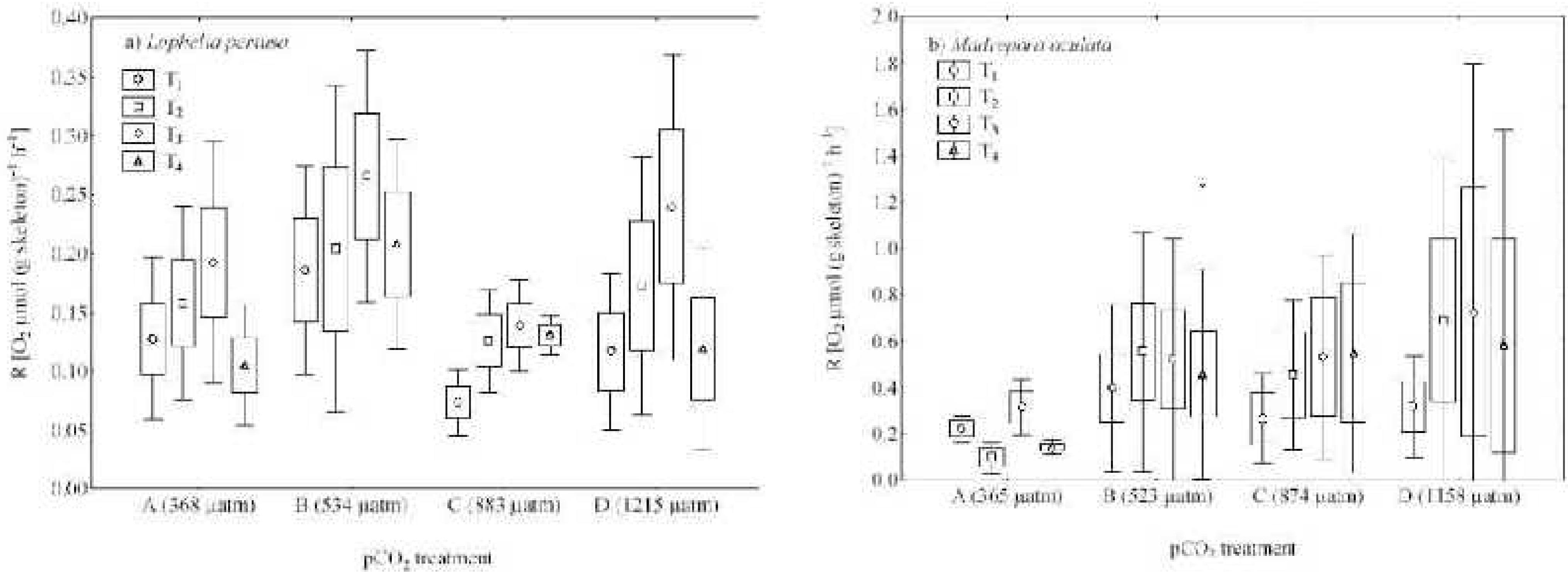


-> no pCO_2 effect, no acclimation to pCO_2

-> but <u>effect of time independent of pCO_2</u>

Maier et al. PlosOne, *2013*

If there is no shift in calcification rates is there a metabolic response (respiration) with increasing pCO_2?

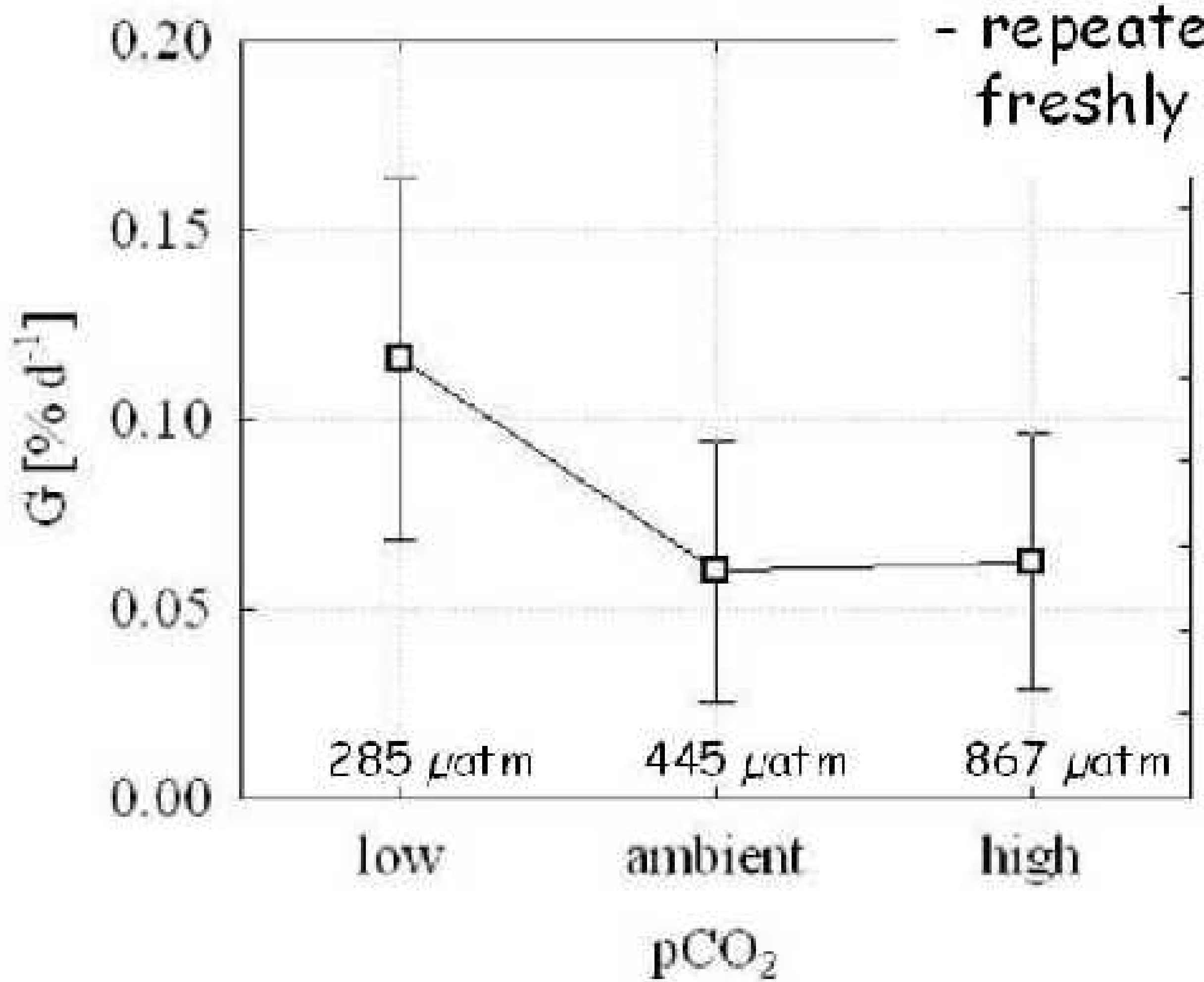


-> no pCO_2 effect, no acclimation to pCO_2

-> again: effect of time independent of pCO_2

Maier et al. BGD, *2013*

Calcification of *Madrepora oculata* at reduced and higher pCO_2



- repeated short-term (1-day) with freshly collected corals (on board)

→ **50 % reduction since pre-industrial**

→ **no effect for future pCO_2 level**

Maier et al. *Proc. R. Soc. L 279: 1716-1723, 2012*

Summary -> work so far published

- Constant calcification rates over a large pCO_2 range: ambient - 1000 µatm]
- No effect of OA on respiration rates
- Likely positive effect on calcification when lowering pCO_2 to pre-industrial
- Positive calcification at Ω_a < 1 from experiments AND in situ data

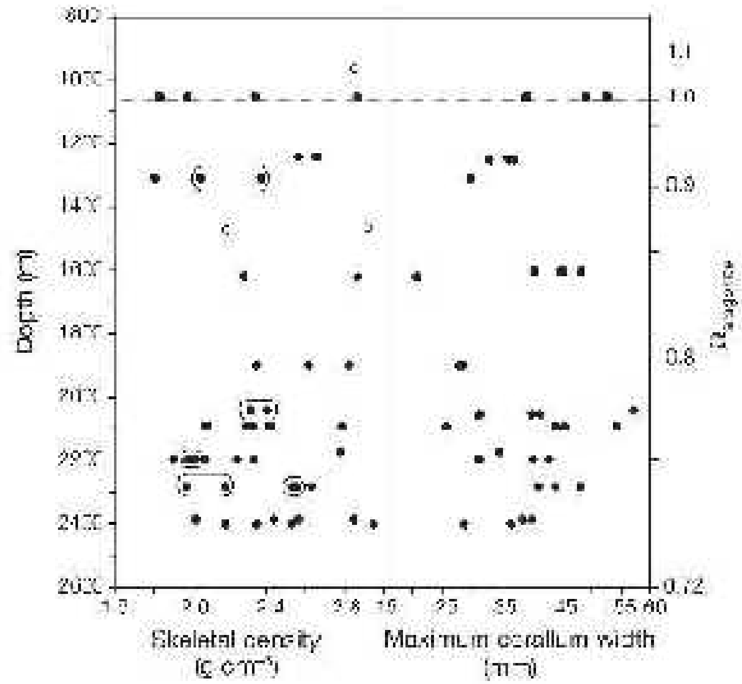


Fig. 4 from Thresher et al. 2011

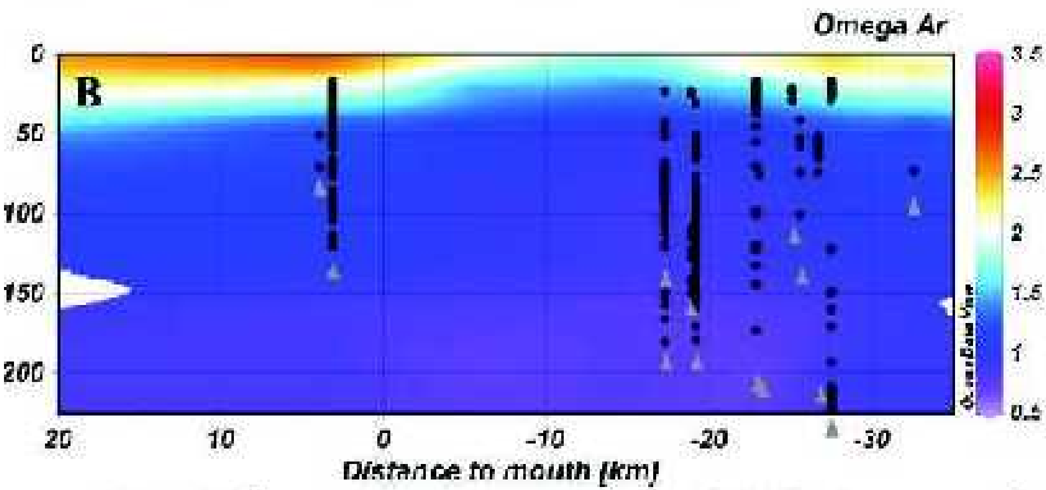
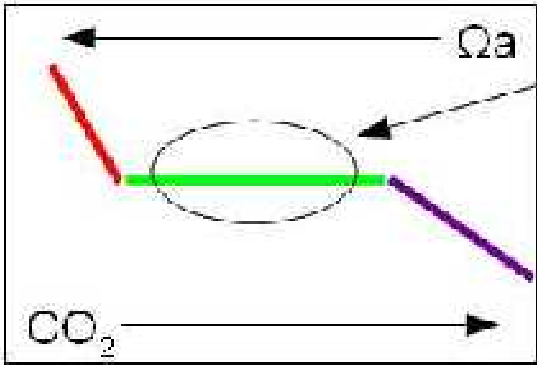


Fig. 2 from Jantzen et al., 2013: Desmophyllum at Chilean Fjord

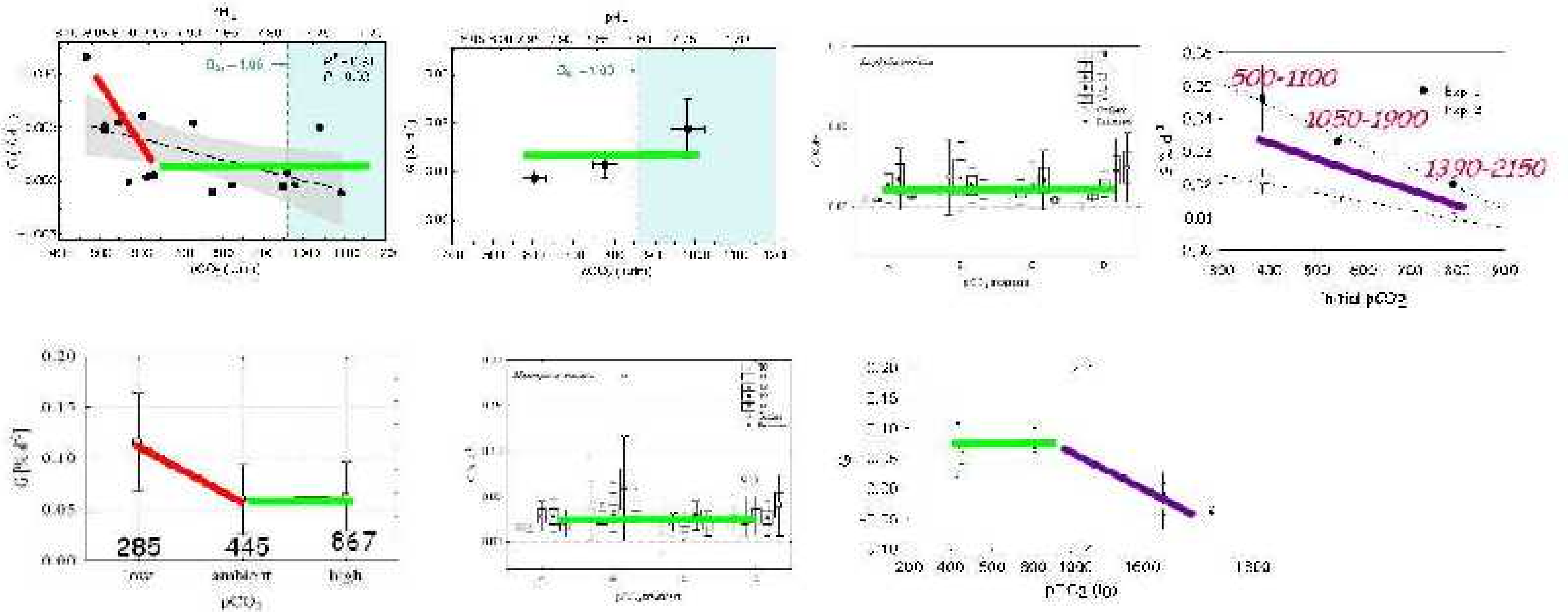
Acclimation to changes in pCO_2 ?

Calcification response curve



pCO_2 range for which short- and long term studies are available that allow to address acclimation

- threshold for G at low pCO_2 range
- large range with no sensitivity of G to pCO_2 changes
- threshold of G at very high pCO_2 ($\Omega a < 1$)



Other methods / approaches in OA studies

- **pH upregulation in calicoblast** layer is an energy requiring process
  - -> Boron isotopes (CWC: McCulloch et al., 2012)
  - -> micoelectrode studies (tropical corals, Al-Horani et al., 2003)
  - -> live tissue imaging (tropical corals, Venn et al., 2011)

- **Changes in gene expression**
  - -> changes in pCO2 show suppression of metabolism and enhancement of organic maxrix synthesis – tropical *Acropora*, (Kaniewska et al., 2012; Moya et al. 2012).
  - -> CWC – two presentations at CWC in Amsterdam 2012: Carreiro-Silva et al., subm. to GCB, Desmophyllum; Dahl et al., Lophelia, unpubl.)

- - **Role of prokaryotes?**
  - **->** reduction in prokaryote diversity under high pCO2 (Weinbauer, pers. comm.)

Other methods / approaches in OA studies

... to be further explored:

- **Reproduction** (maturation of gametocytes) might be enhanced once surplus energy is available

? role of coral-associated prokaryotes?

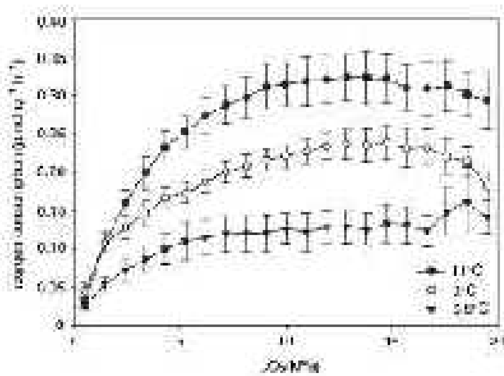
-> Radioisotope labelling: H-Leu and C-HCO_3 labelled revealed significant activity in coral associated chemo- and heterotroph microbes (Maier et al., unpubl.)

-> High abundance of viruses and bacteria in mucus and coelenteron – shifts may mitigate some of pCO_2 induced changes in coral functioning (cannot account for energy balance)

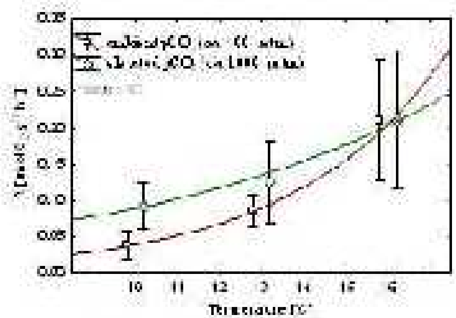
-> **Tissue δ C/δ N and skeletal δ C/δ O over large pCO_2 gradients** may provide further insight into "resourse partitioning between calcification and tissue metabolism" (Maier et al., 2010 - tropical corals)

-> ***in situ***

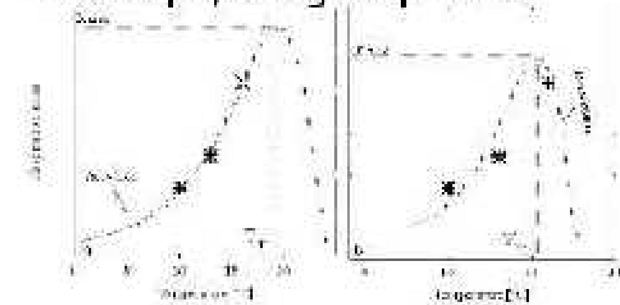
Are Med CWC at T tolerance limit?



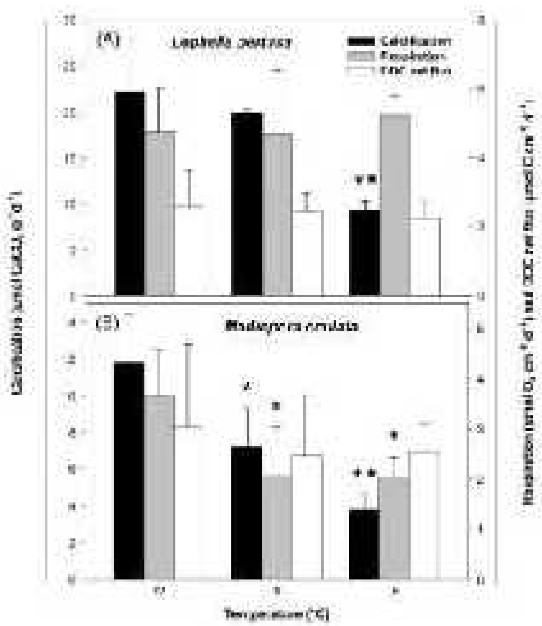
Lophelia, non-acclimatized, North Atlantik (Dodds et al. 2007)



Thermophysiological profile:



Lophelia, non acclimatized, Mediterranean; (Maier et al. BGD, 2013 Suppl.)



Naumann et al., in press DSR II
-> 1 month acclimation from 12°C -> 9°C -> 6°C

Lophelia:
- Calcification increases with T
- Respiration constant betw. 6-12°
- DOC net flux constant

Madrepora:
- Calcification increases with T
- Respiration higher at 12°C
- Doc net flux rel. constant

http://dx.doi.org/10.1016/j.dsr2.2013.05.025

Summary and Conclusions

- No effect of pCO_2 as projected until end of the century
- No effect of OA on respiration rates even for very high pCO_2
- No indication for accclimation for a pCO_2 range between 400 to ca. 1200 μatm and a time range up to 9 months
- No compensatory effect of negative pCO_2 effect by increasing food supply (*M. oculata*)
- CWC exhibit non-linear response to OA with at least 2 thresholds around pCO_2 of pre-industrial-ambient and above 1000 μatm
- Clear indication, that *L. pertusa* AND *M. oculata* can maintain calcification at $\Omega_{arag} < 1$

Implications and Outlook

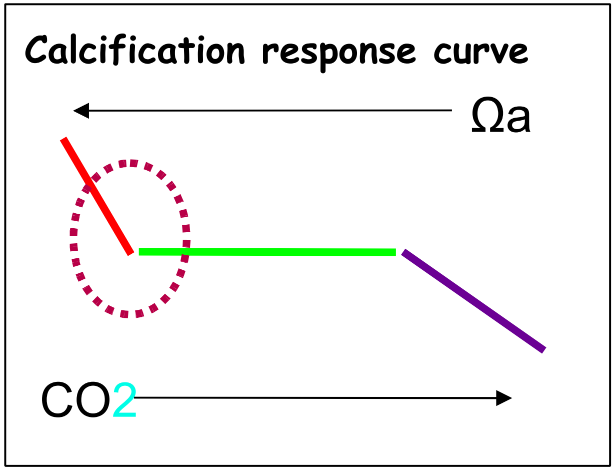
CWCs can maintain a positive calcification at $\Omega_a < 1$

-> so ocean acidification does not matter to CWCs ? !

For Mediterranean corals: high A_T and T -> probably on the safe side with respect to OA for end of century projections

- what about Temperature ?
- what about sensitivity at low pCO_2?

This is where we are now!



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