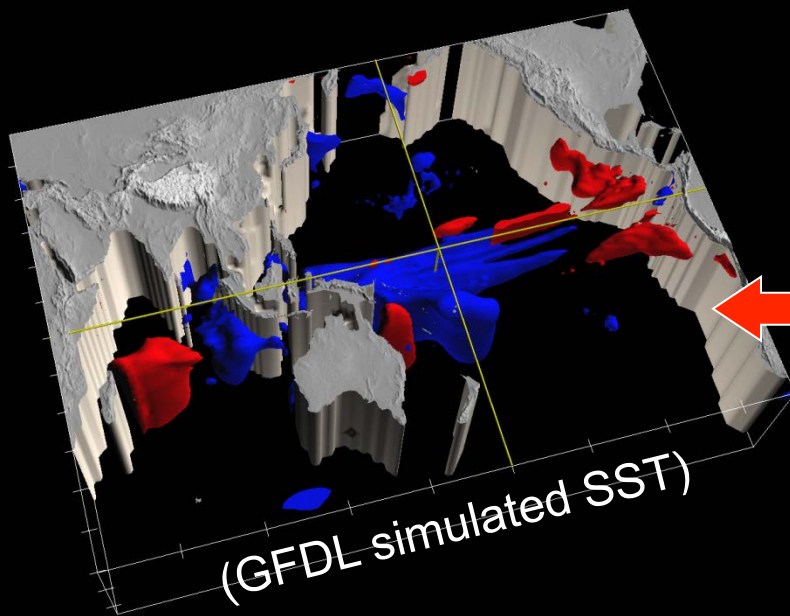


Towards improved coral proxy system models (PSMs)

Diane Thompson

Assistant Professor, Boston University

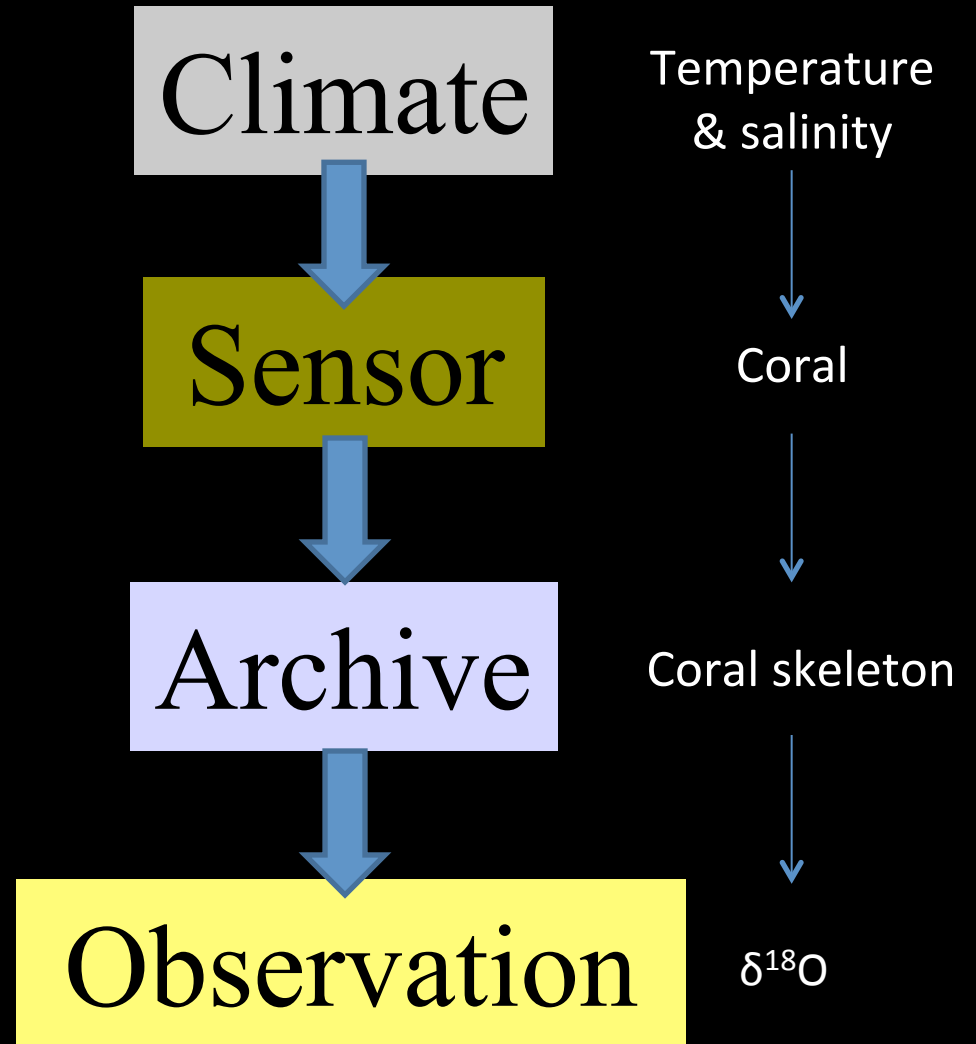
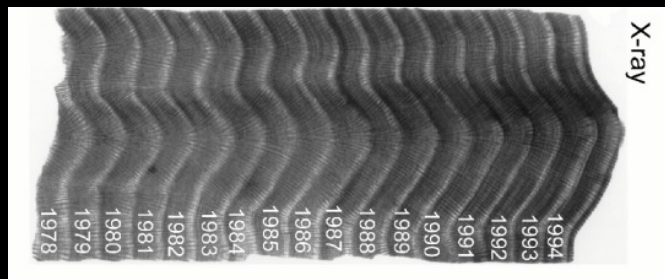
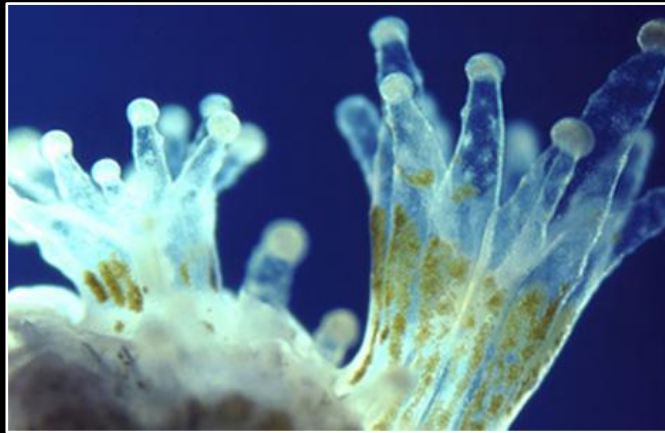


BOSTON
UNIVERSITY

Mike Evans, Sylvia Dee, Julien Emile-Geay,
Maud Comboul, Emma Reed, others

@dianethompso
thompso@bu.edu

Coral proxy system modeling



Coral proxy system modeling

Sensor model:

$$\delta^{18}\text{O}_{\text{coral}} = a_1 \text{SST} + \delta^{18}\text{O} + \varepsilon$$
$$\delta^{18}\text{O}_{\text{coral}} = a_1 \text{SST} + a_2 \text{SSS} + \varepsilon$$

(Thompson et al. 2011, 2013)

Observation model:

$$t_i = t_{i-1} - \Delta_i$$

$$\Delta_i = 1 + P_i^\theta$$

(Comboul et al. 2014)

Climate

Sensor

Archive

Observation

Temperature
& salinity

Coral

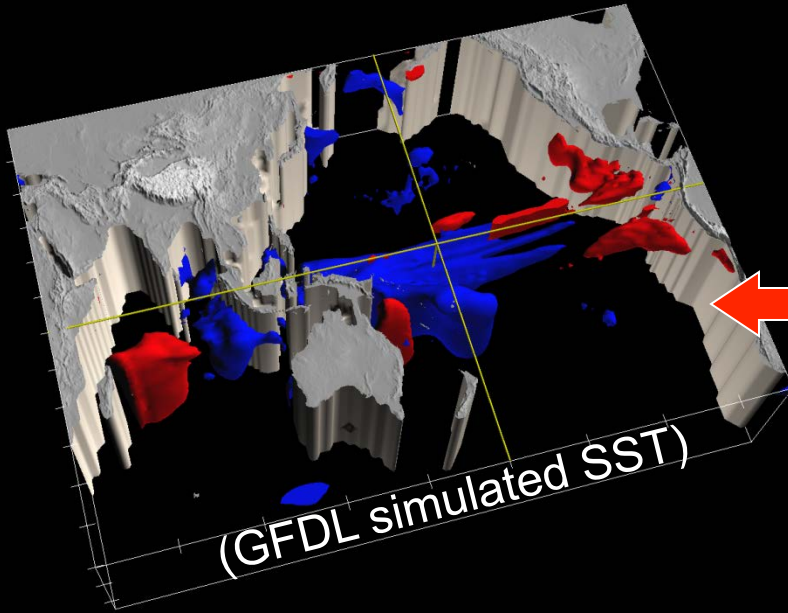
Coral skeleton

$\delta^{18}\text{O}$

PRYSM Dee et al. (2015)

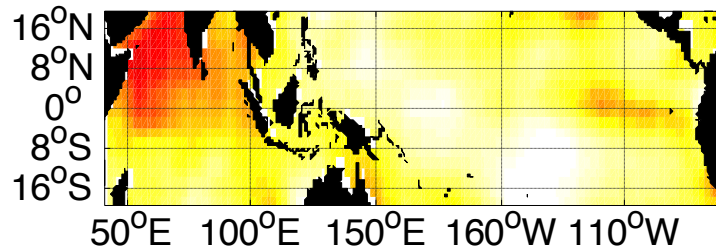
(Evans et al. 2013)

Proxy – Climate comparisons

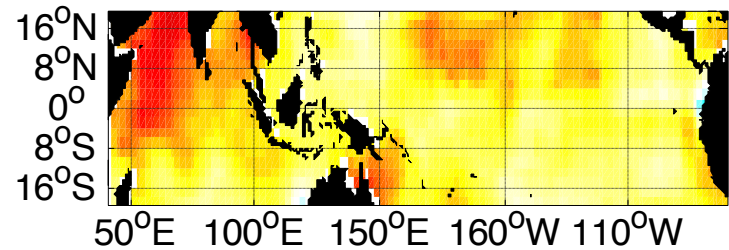


Historical SST trends (1890-1990)

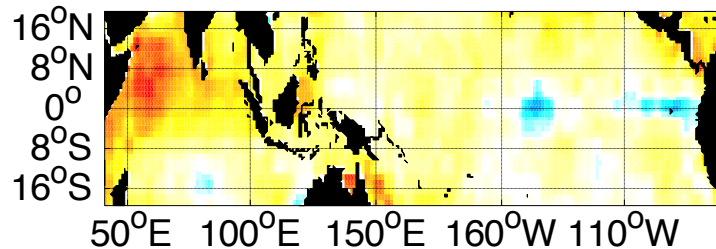
ERSSTv2



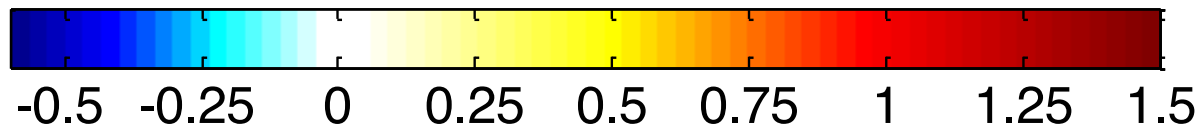
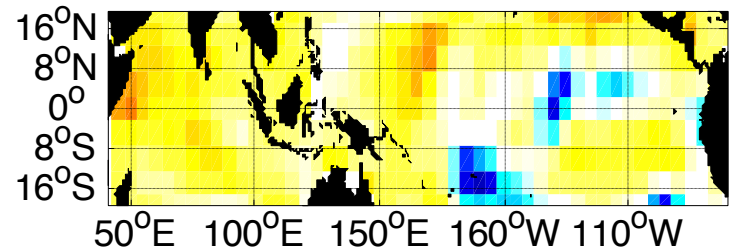
ERSSTv3



HadISST1



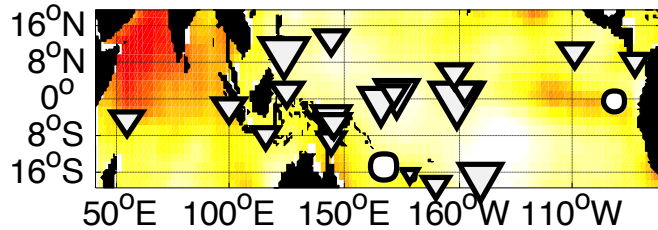
Kaplan extended v2



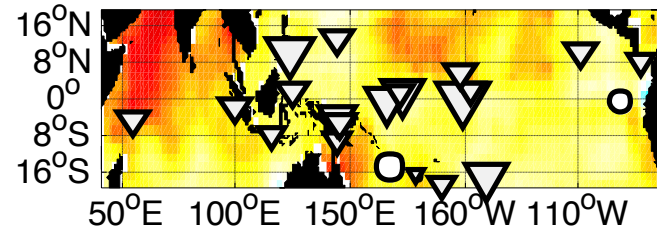
SST trend (°C/100 years)

SST and $\delta^{18}\text{O}_{\text{coral}}$ trends (1890-1990)

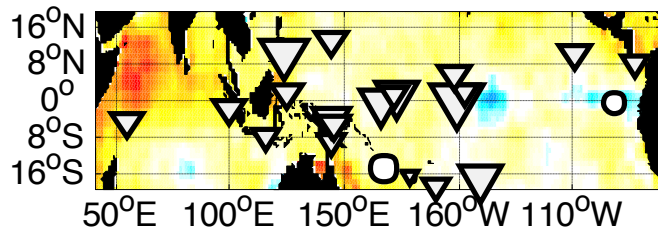
ERSSTv2



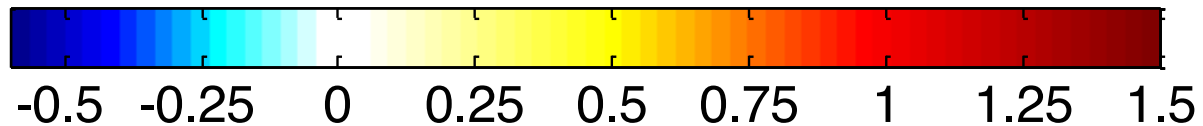
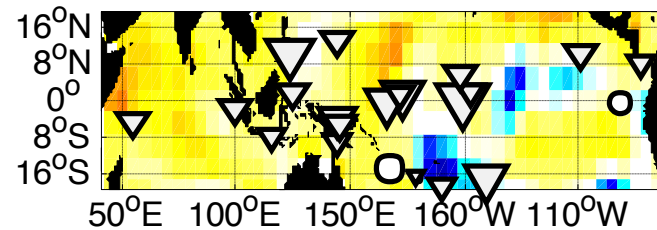
ERSSTv3



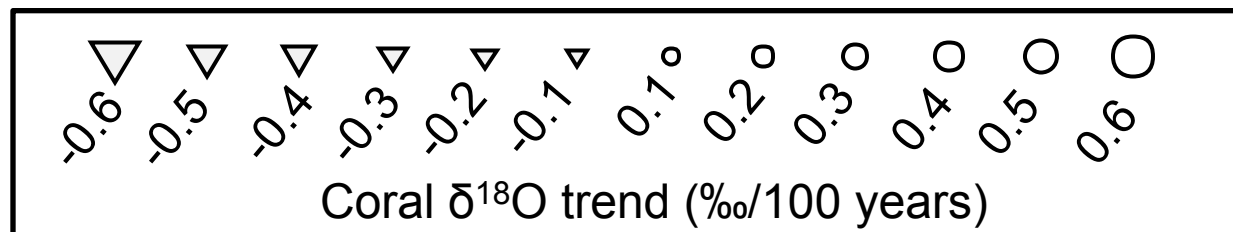
HadISST1



Kaplan extended v2



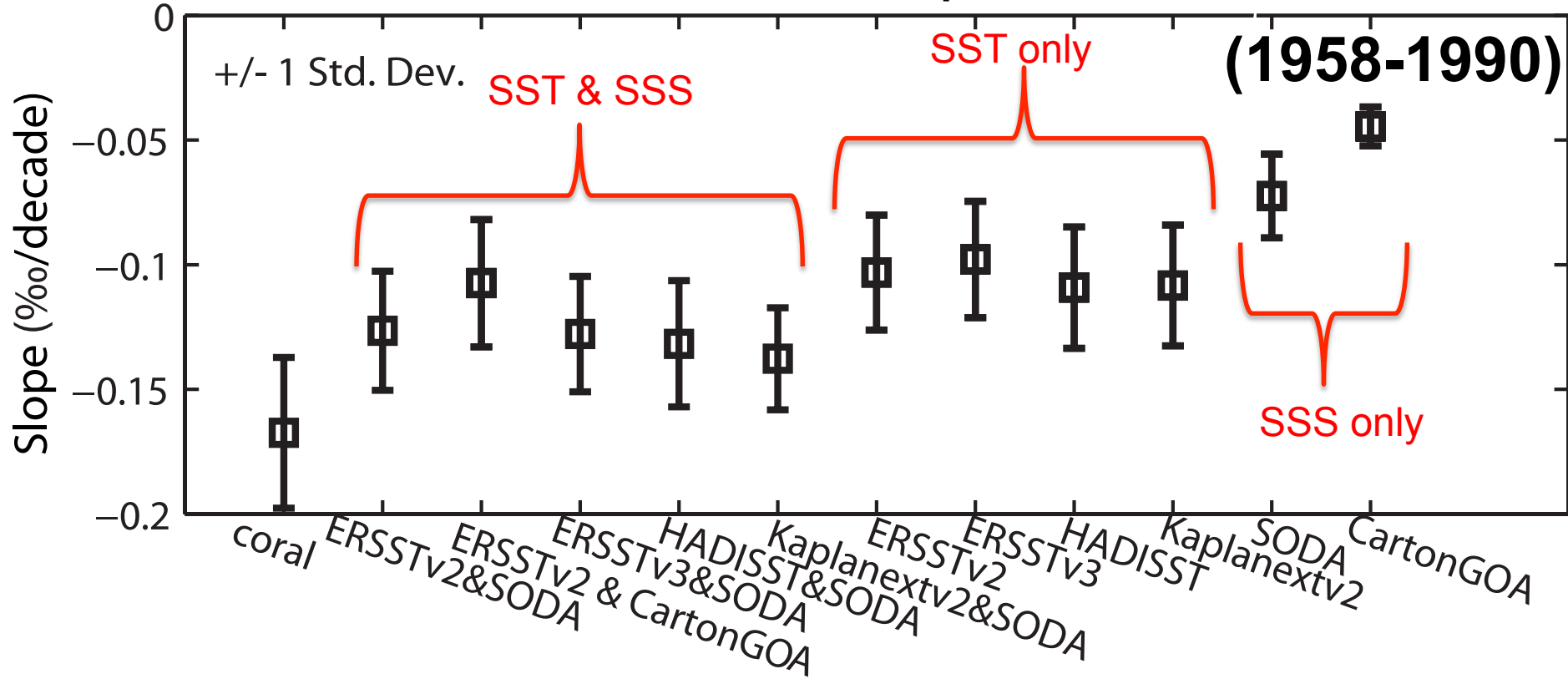
SST trend (°C/100 years)



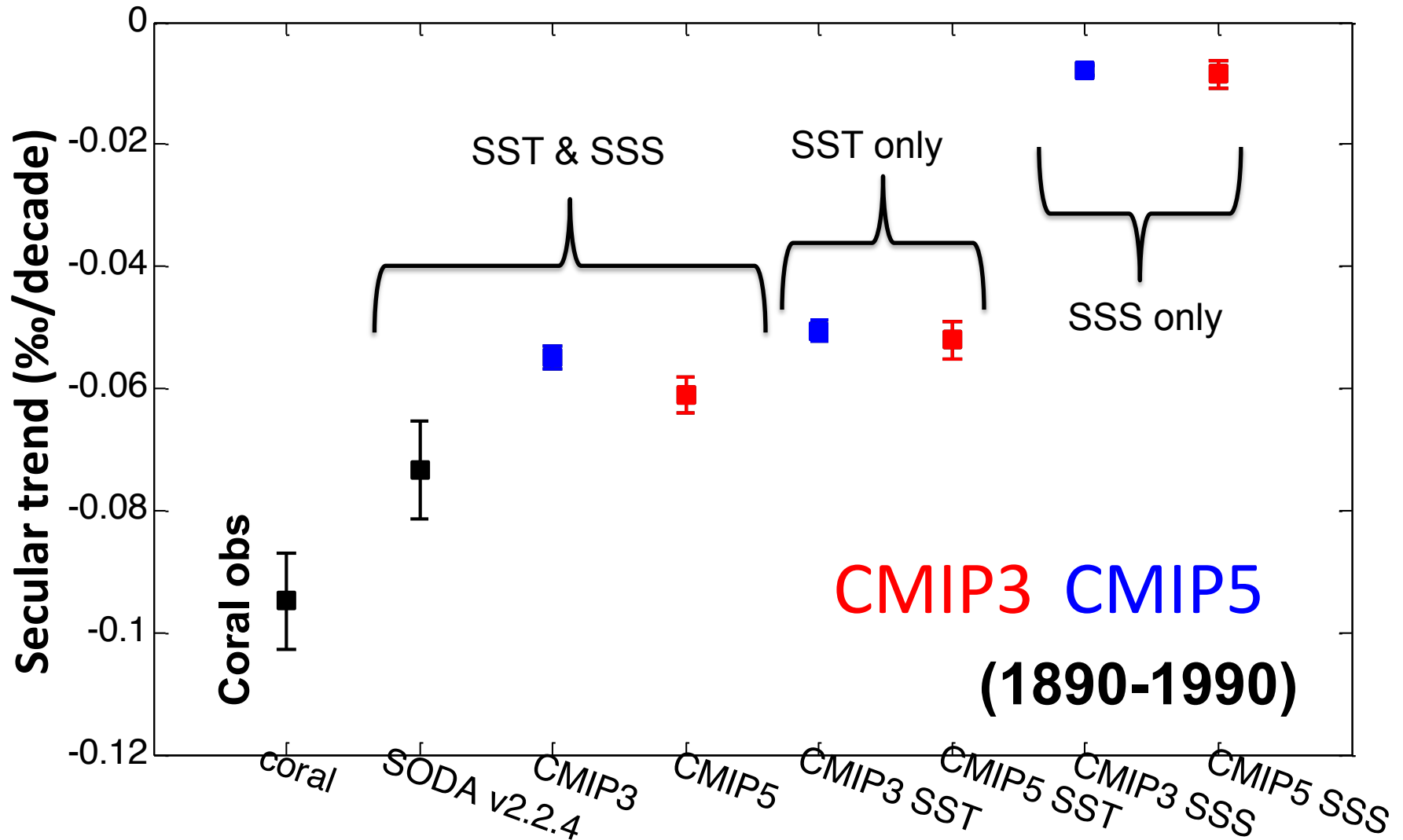
Coral $\delta^{18}\text{O}$ trend (‰/100 years)

Linear trend slope (‰/decade)

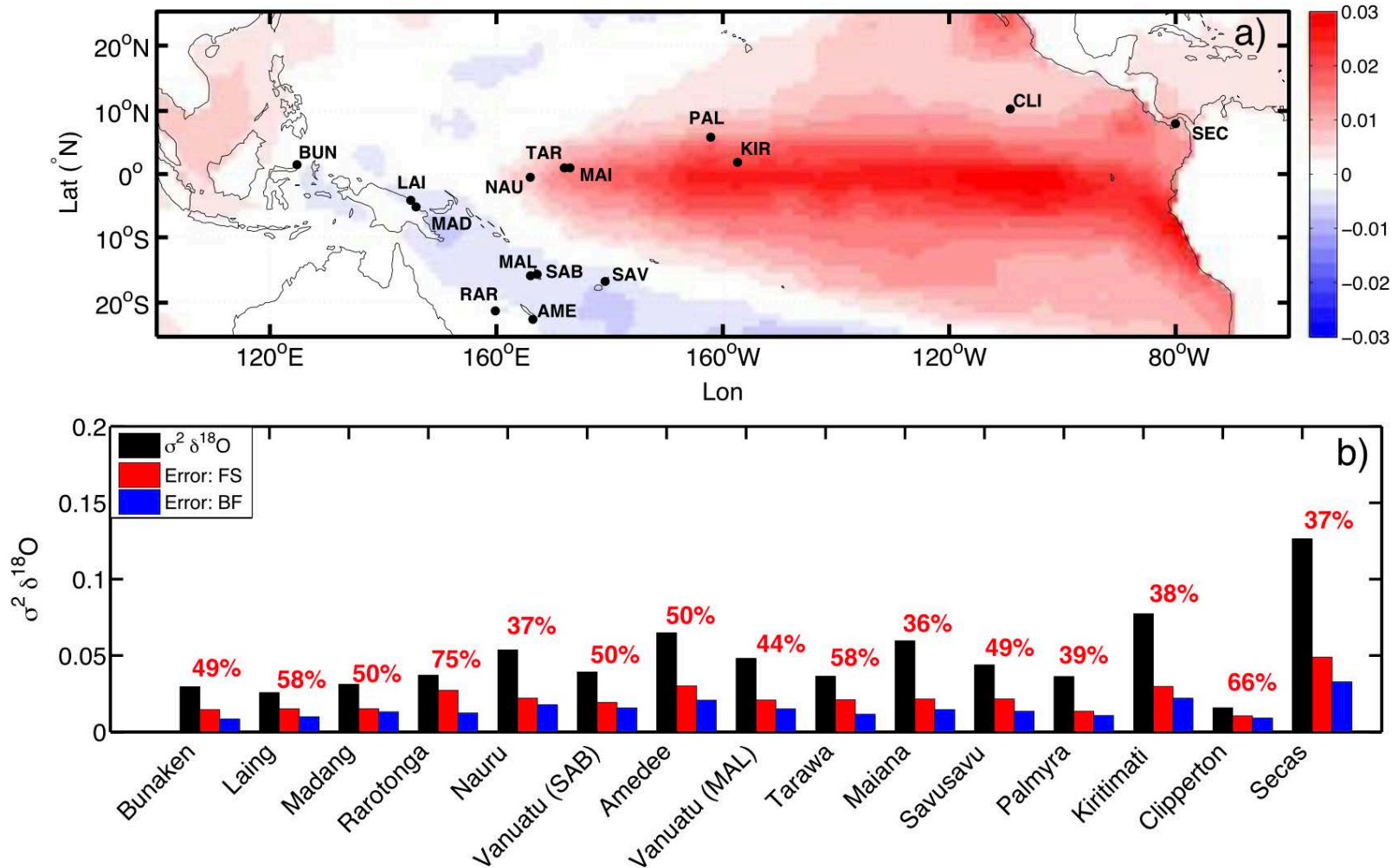
(a) Coral and instrumental pseudocoral trends



Linear trend slope (‰/decade)



ENSO variance observed vs pseudo



Uncertainties in coral PSMs

Sensor model:

$$\delta^{18}\text{O}_{\text{coral}} = a_1 \text{SST} + \delta^{18}\text{O} + \varepsilon$$
$$\delta^{18}\text{O}_{\text{coral}} = a_1 \text{SST} + a_2 \text{SSS} + \varepsilon$$

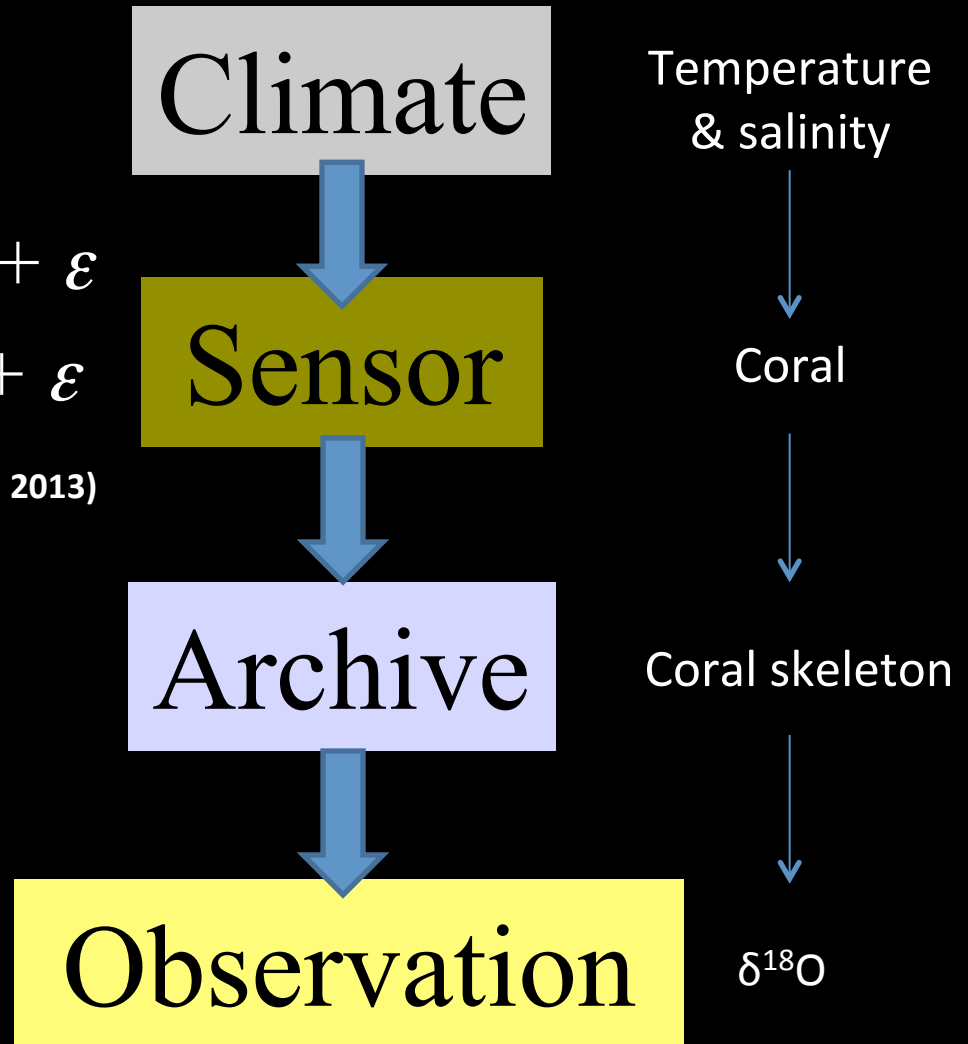
(Thompson et al. 2011, 2013)

Observation model:

$$t_i = t_{i-1} - \Delta_i$$

$$\Delta_i = 1 + P_i^\theta$$

(Comboul et al. 2014)



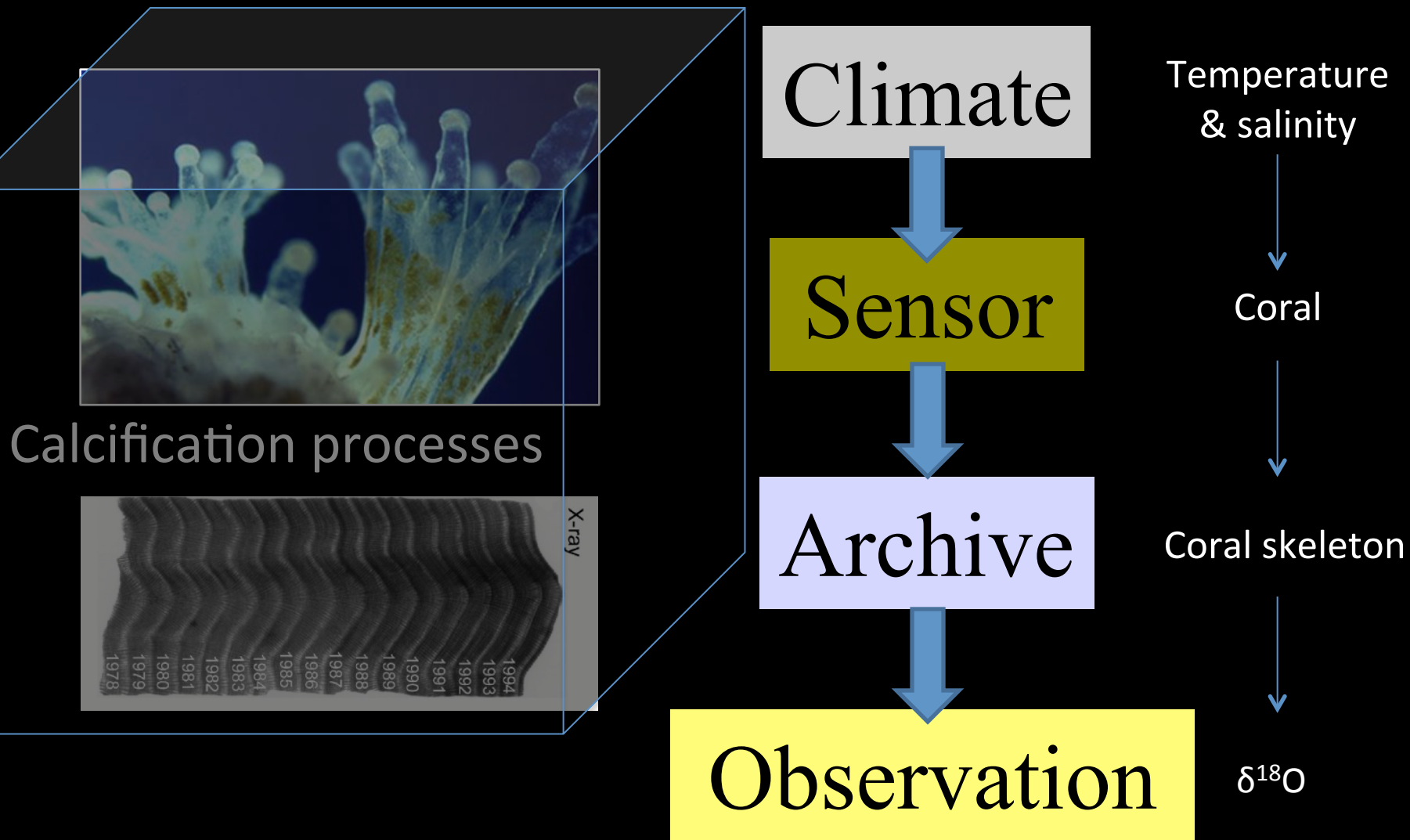
(Evans et al. 2013)

Uncertainty_{obs-synth} =

(Error_{corals}, Error_{forward model}, Error_{input})

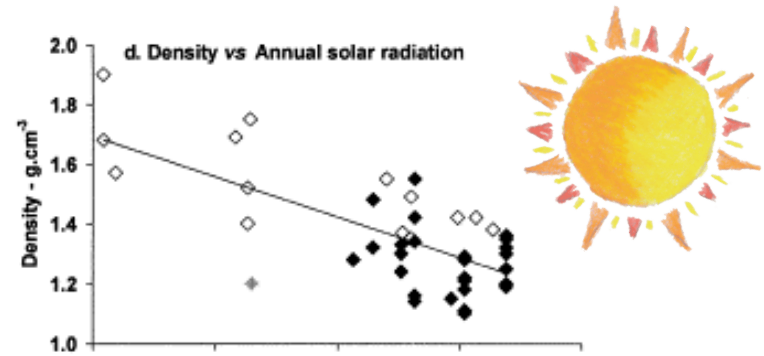
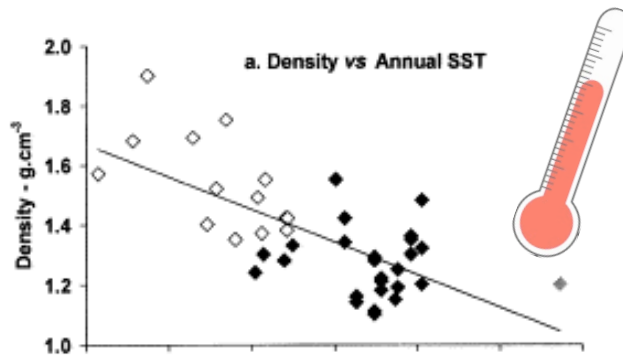
- site biases
- chronological errors
- nonlinear response
- approximation of $\delta^{18}\text{O}_{\text{sw}}$ with SSS
- other components? (e.g., biological response)
- Forcings
- SST/SSS response to forcings

Uncertainties in coral PSMs

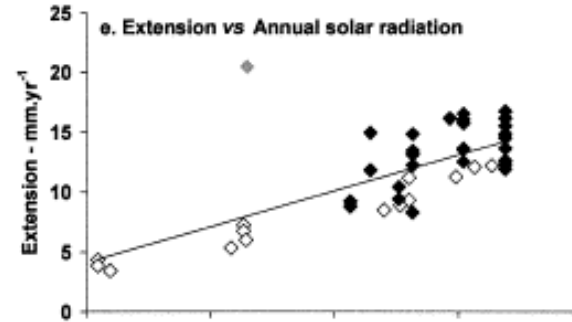
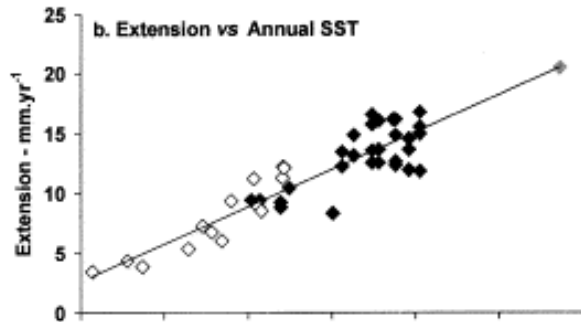


Impact of climate on coral growth

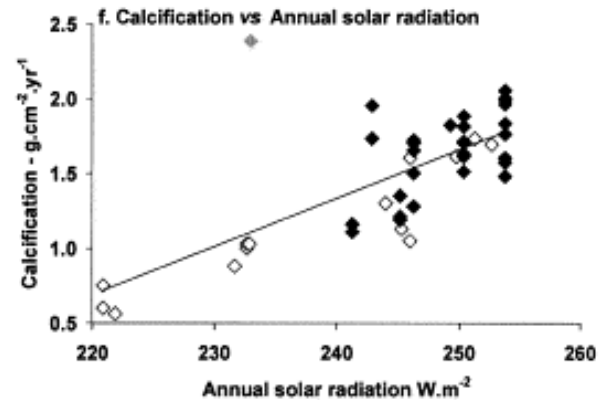
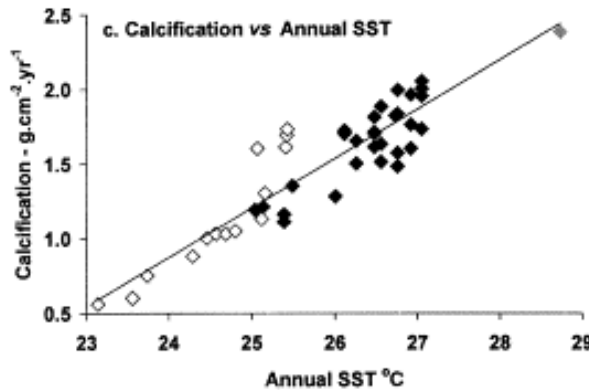
Density



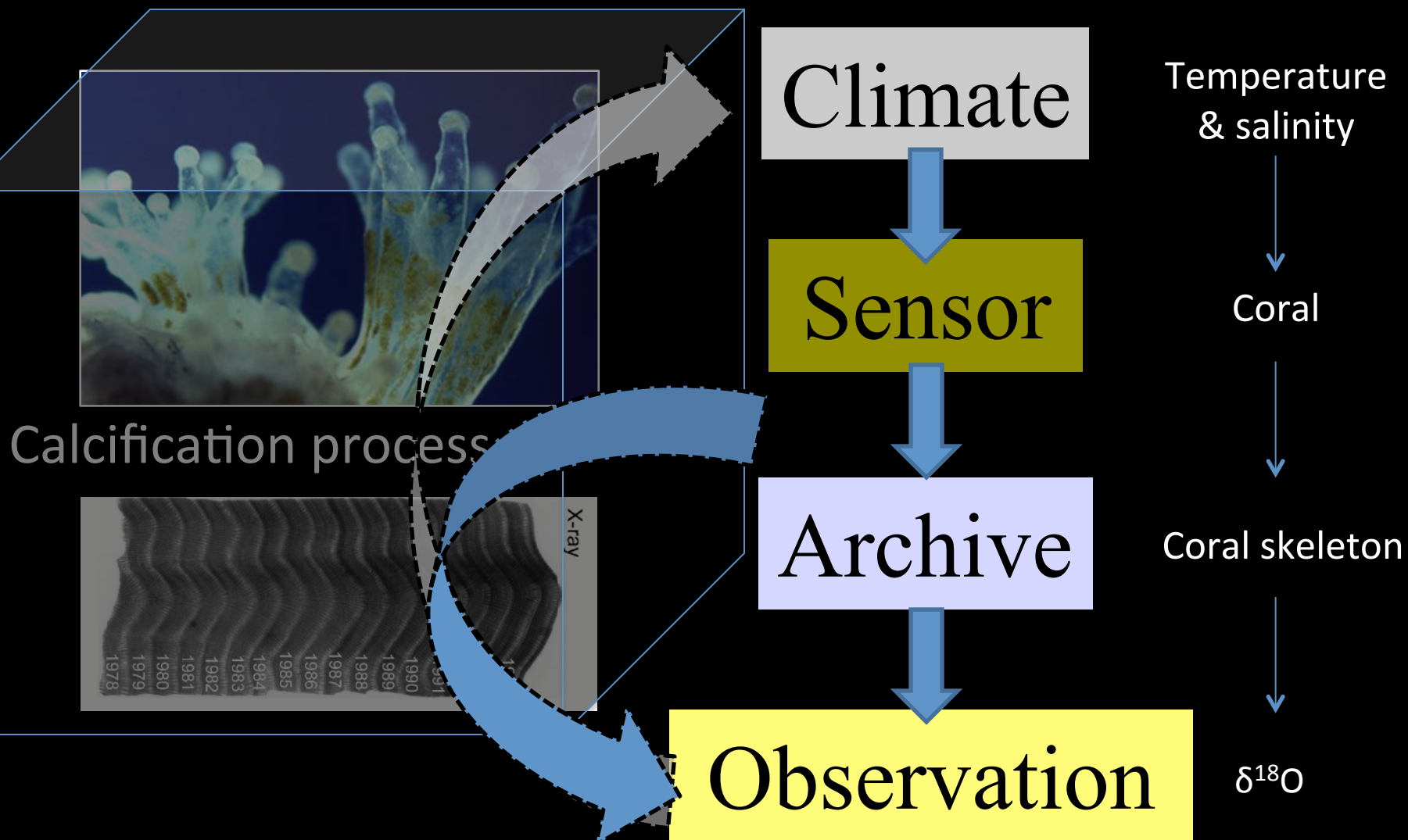
Extension



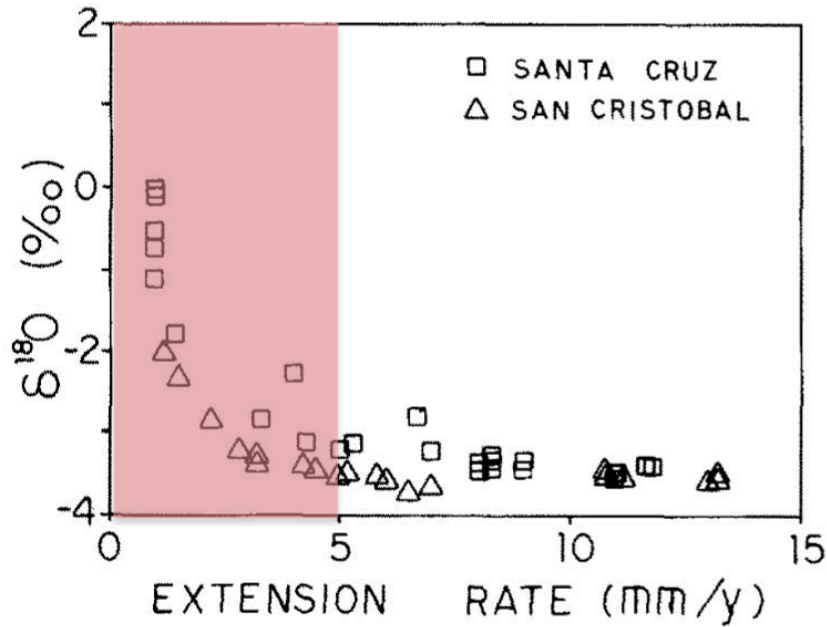
Calcification



Uncertainties in coral PSMs

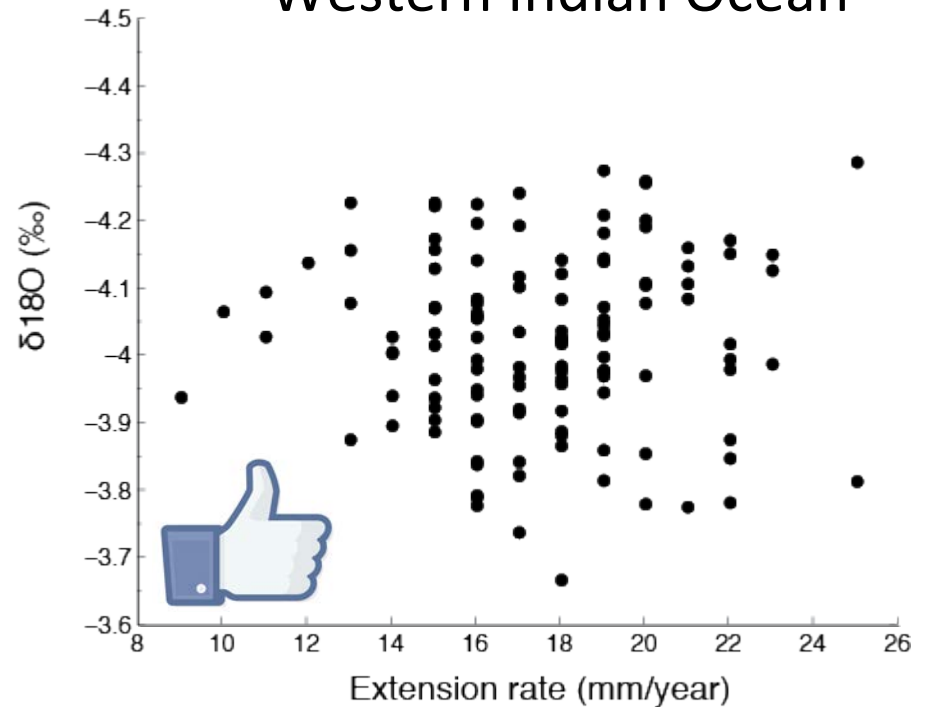


Impact of growth on skeletal chemistry?

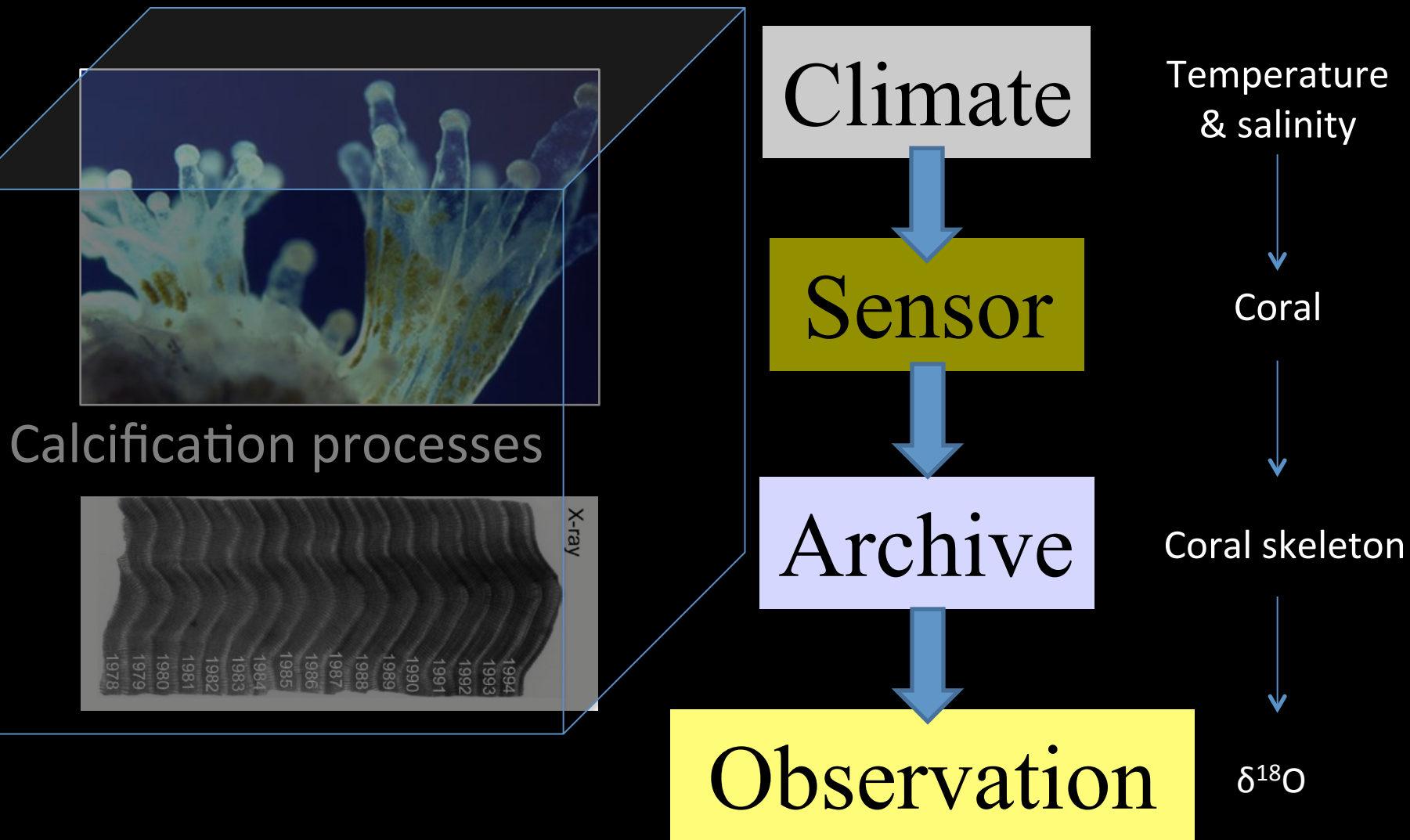


McConnaughey 1989

Example: Pemba Reef,
Western Indian Ocean



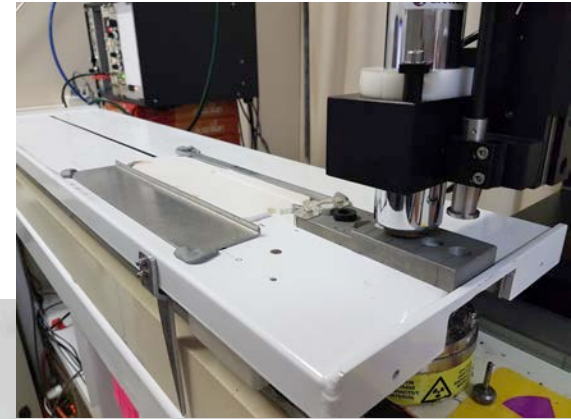
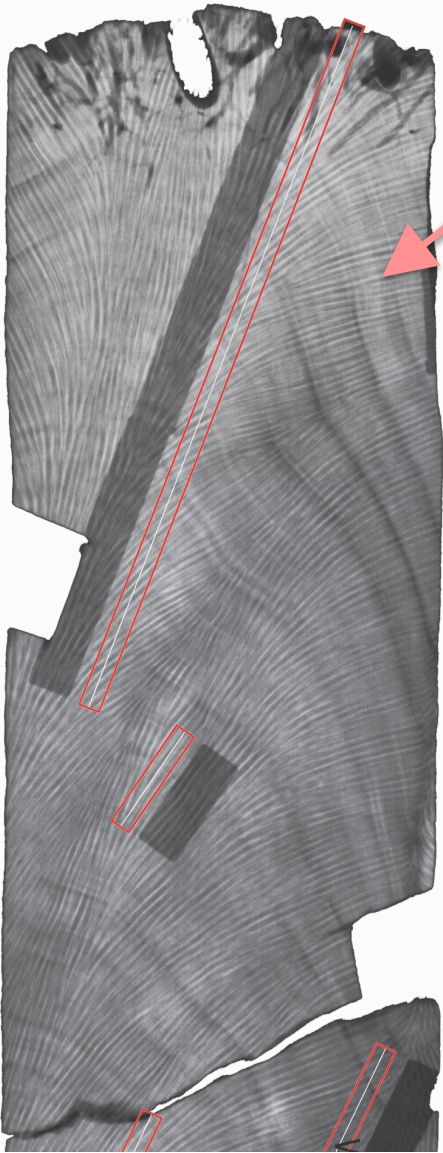
Uncertainties in coral PSMs



Impact of growth on skeletal chemistry?

Coral Density:

1. X-ray densitometry
2. Gamma densitometry

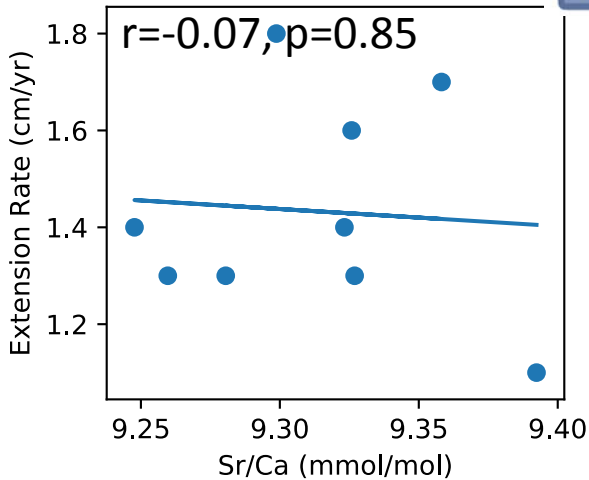


Impact of growth on skeletal chemistry?

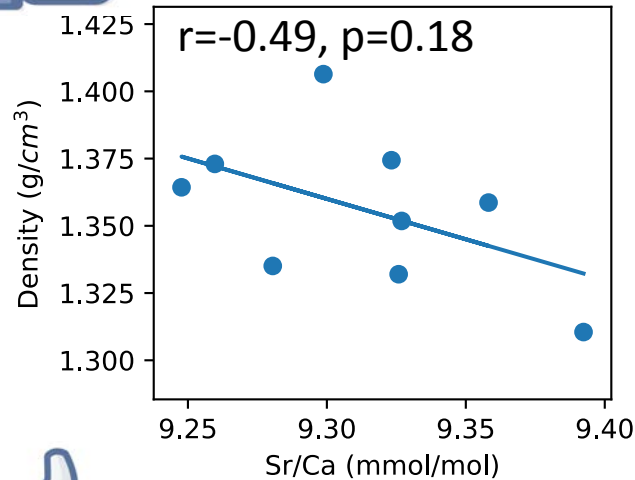
Galapagos:



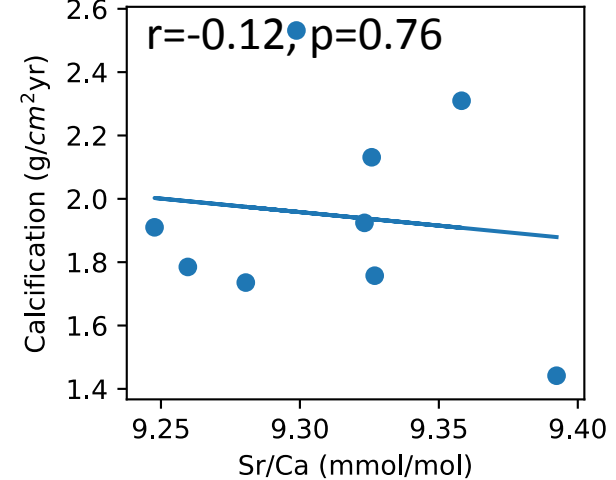
Sr/Ca vs. Extension



Sr/Ca vs. Density



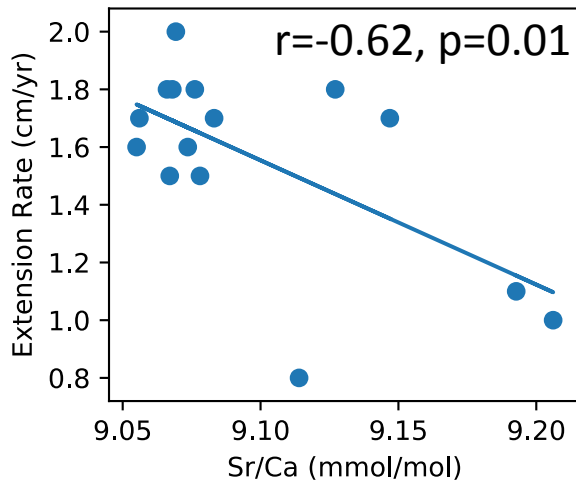
Sr/Ca vs. Calcification



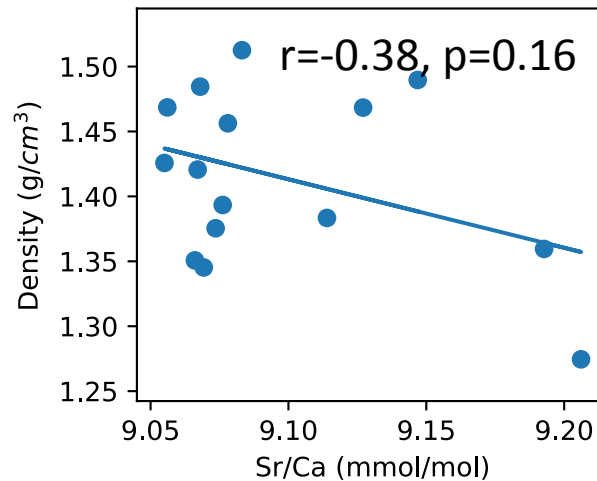
Great Barrier Reef:



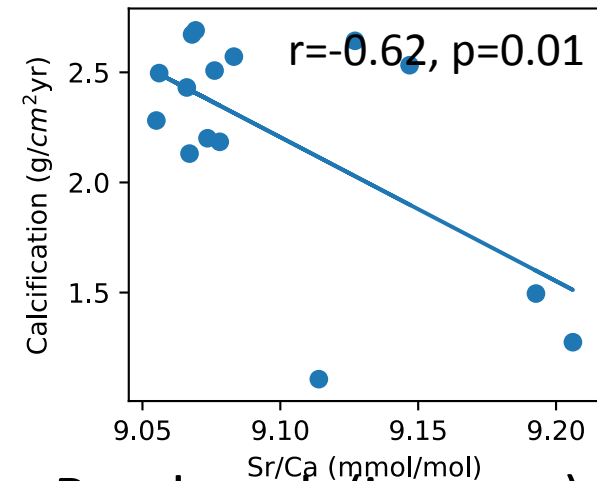
Sr/Ca vs. Extension



Sr/Ca vs. Density

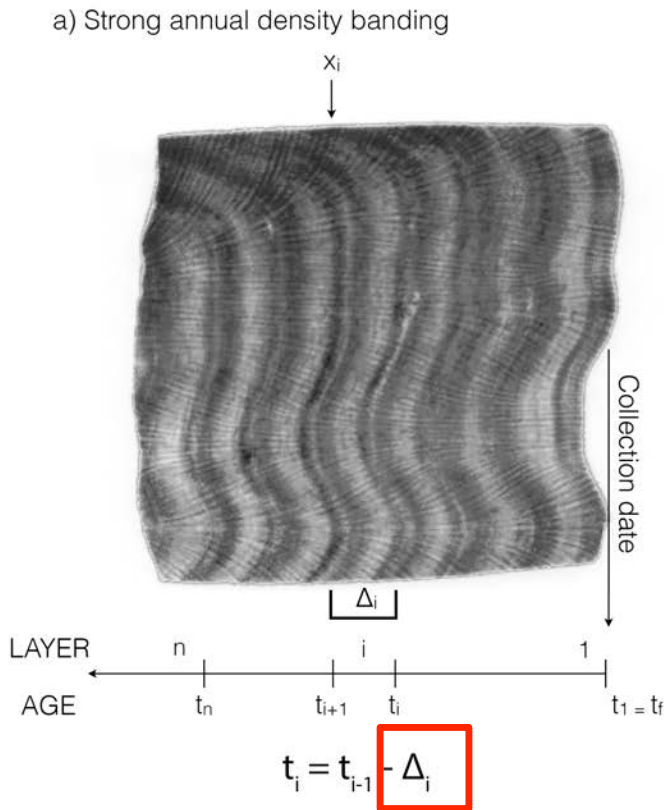


Sr/Ca vs. Calcification



Reed et al. (in prep.)

Archive model for chronological uncertainty

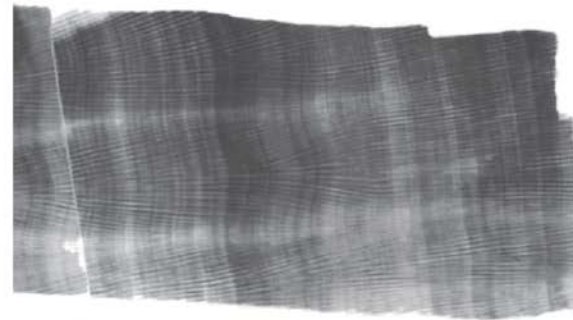


BAMS (Comboul et . 2014)

b) Growth discontinuities & bioerosion



c) Weak seasonality



d) Growth variations



Uncertainty_{obs-synth} =

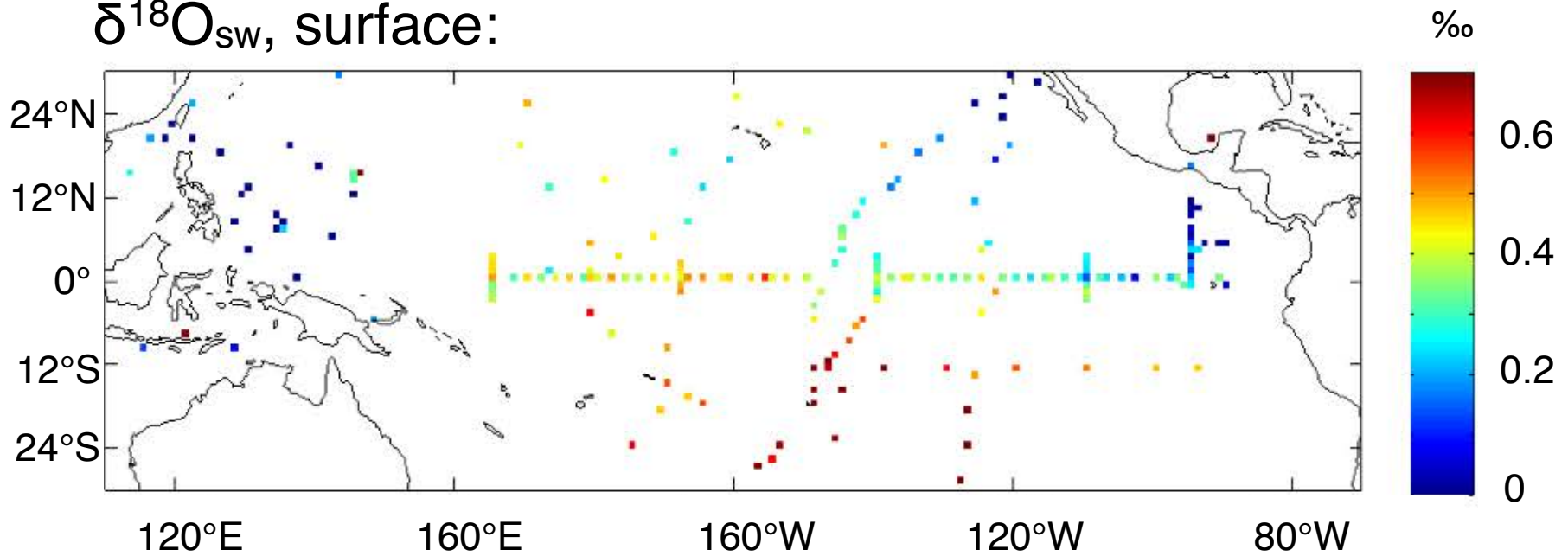
(Error_{corals}, Error_{forward model}, Error_{input})

- site biases
- chronological errors
- nonlinear response
- approximation of $\delta^{18}\text{O}_{\text{sw}}$ with SSS
- other components (e.g., biological response)
- Forcings
- SST/SSS response to forcings

LeGrande and Schmidt 2006

Tropical Pacific Basin $\sim 0.27\text{‰}/\text{psu}$

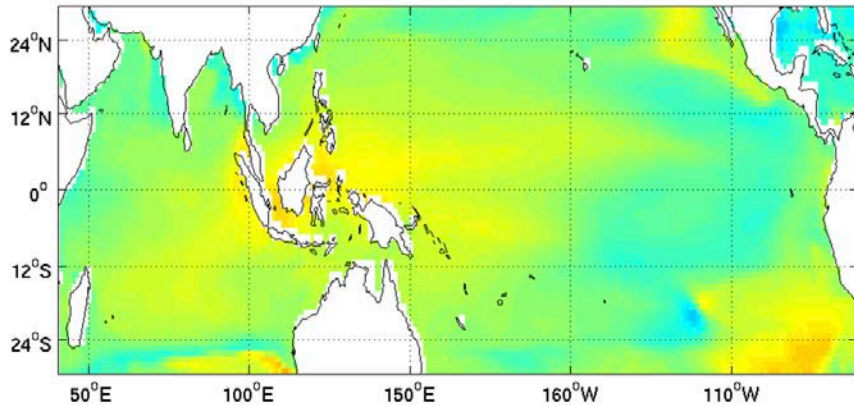
$\delta^{18}\text{O}_{\text{sw}}$, surface:



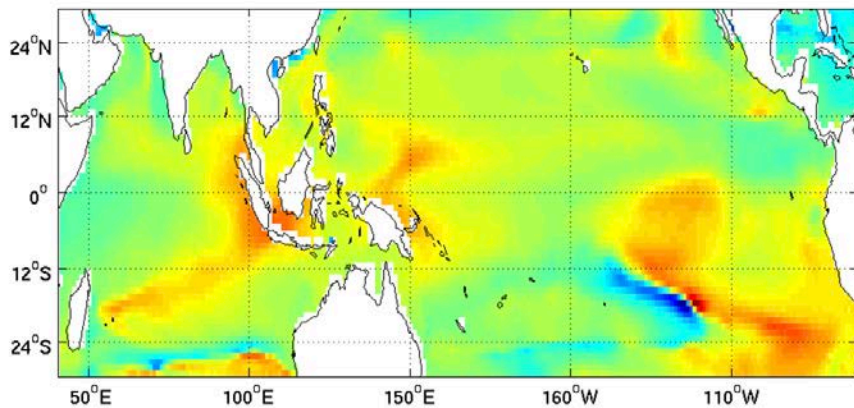
$\delta^{18}\text{O}$ - SSS slope

GISS ModelE2 Monthly Preindustrial control

(a) Monthly

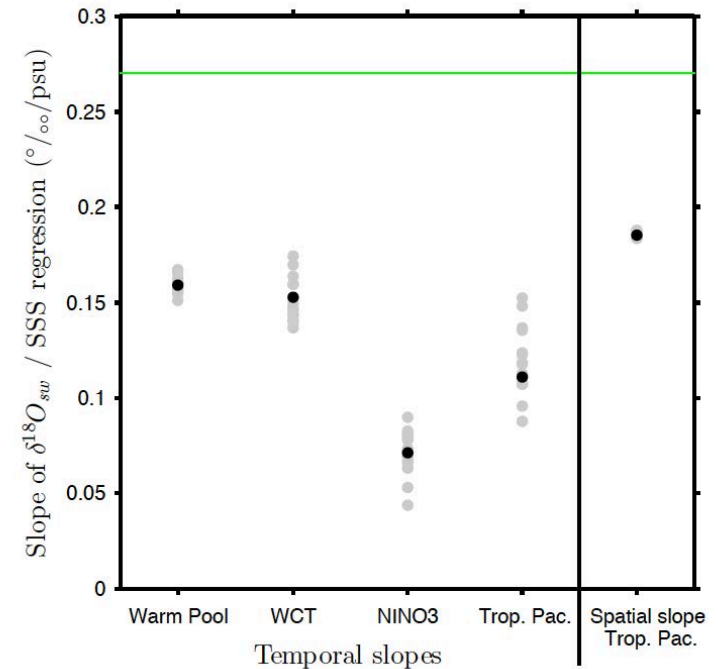


(b) Decadal



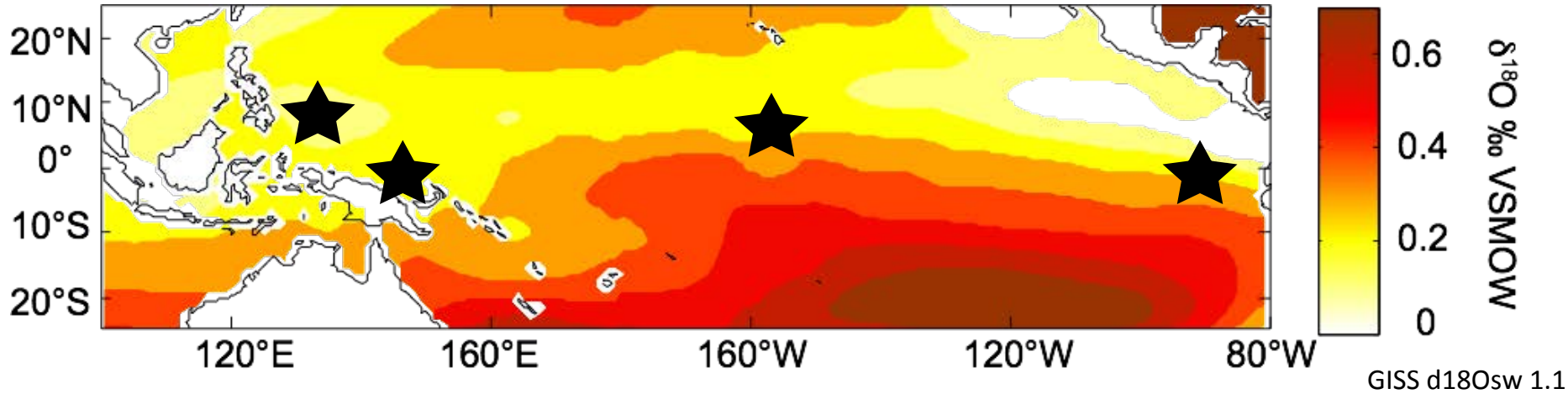
Thompson et al. (2013)

HadCM3 preindustrial control



Russon et al. (2013)

New paired $\delta^{18}\text{O}$ and salinity observations

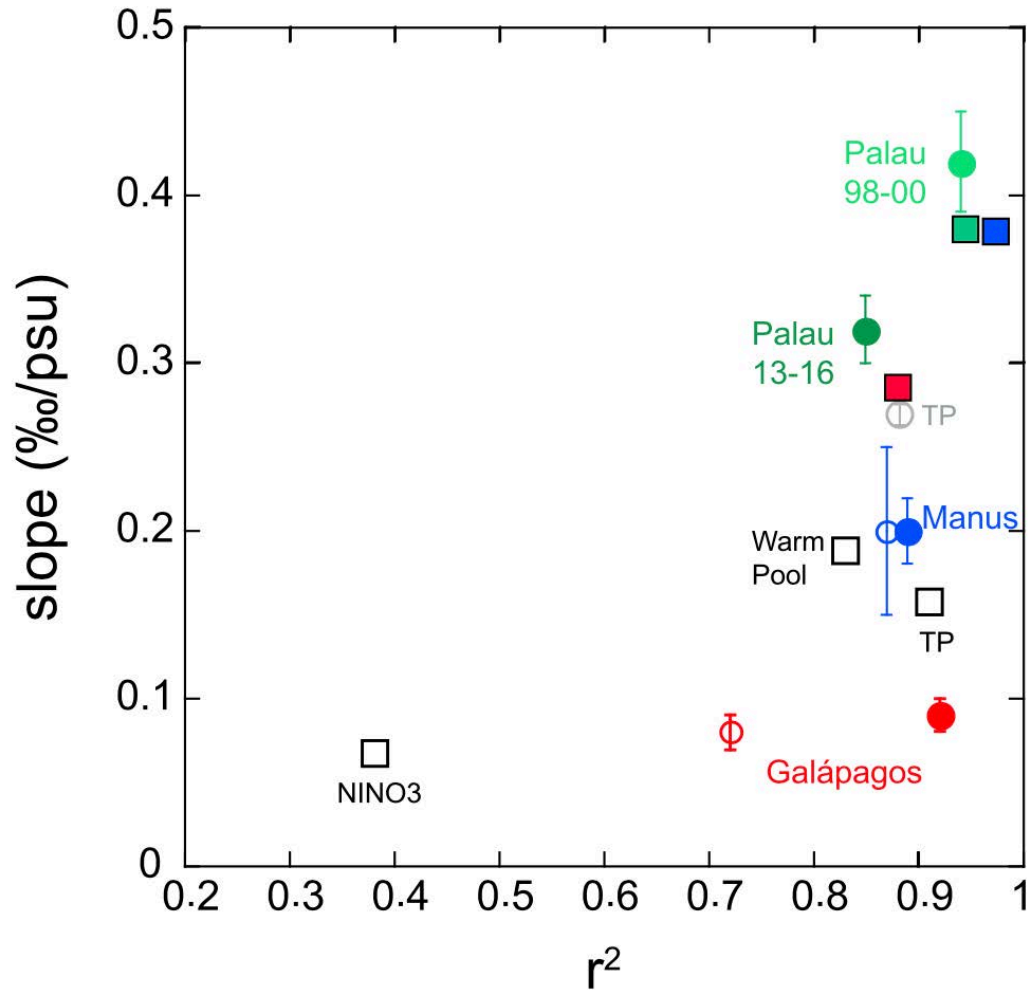


weekly seawater samples, 2012-2015

Spatial & temporal $\delta^{18}\text{O}$ and salinity relationships

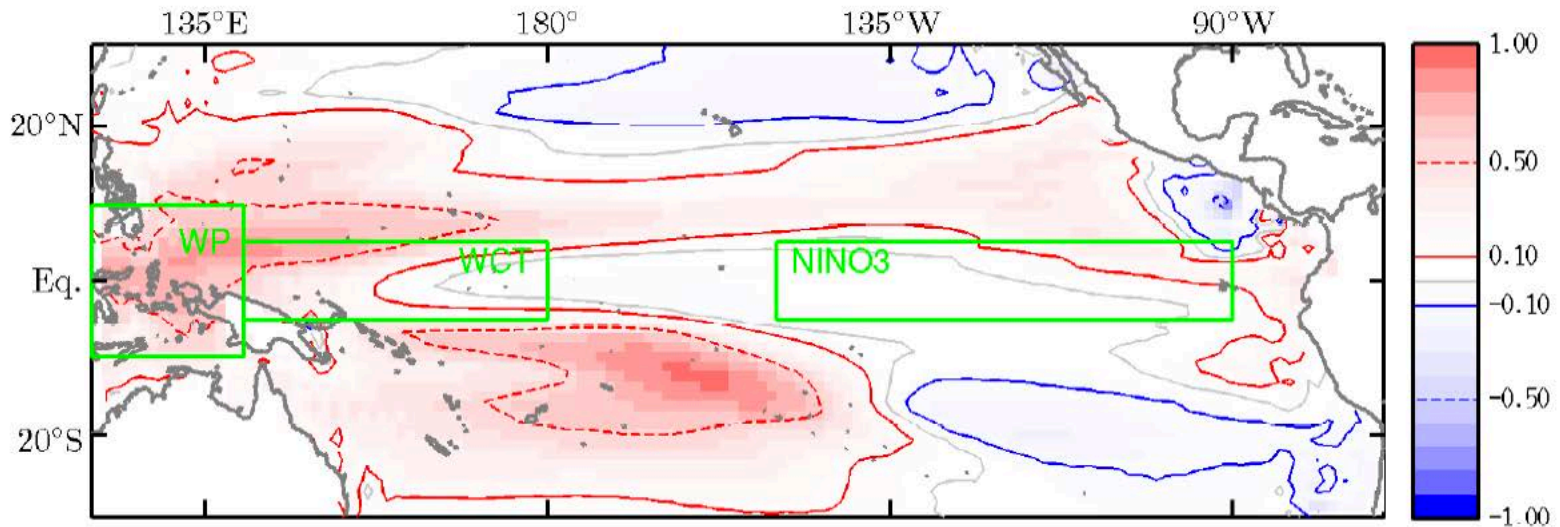
- 1. Does the $\delta^{18}\text{O}$ -salinity relationship vary across the tropical Pacific?**
- 2. Does the spatial $\delta^{18}\text{O}$ -salinity relationship approximate the temporal $\delta^{18}\text{O}$ -salinity relationship at different sites?**

$\delta^{18}\text{O}$ - SSS slope



Impact coral forward modeling?

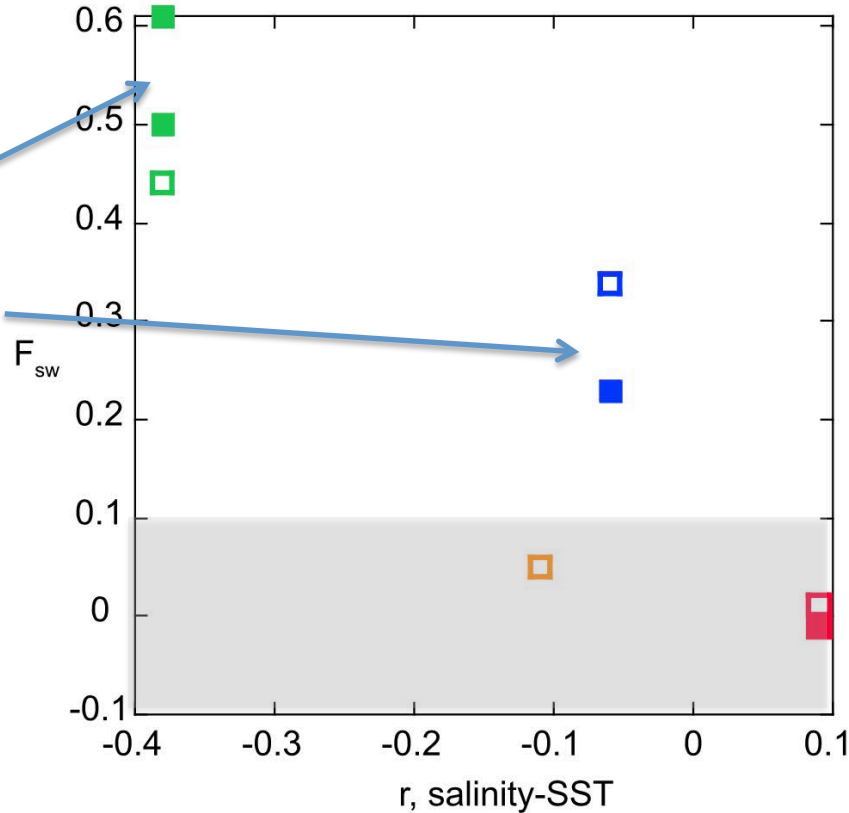
A) F_{sw} , fraction of $\delta^{18}O_{coral}$ variance from $\delta^{18}O_{sw}$



Russon et al. (2013)

Impact coral forward modeling?

■ local (temporal) slope
□ L&S06 TP slope



$\delta^{18}O_{sw}$ contributes constructively to $\delta^{18}O_{coral}$ (likely due to covariance)
LOCAL CALIBRATION NEEDED

$\delta^{18}O_{sw}$ does not contribute significantly to $\delta^{18}O_{coral}$

Conclusions

- Pseudocoral-coral discrepancies in magnitude of trend and variability
- Simulated $\delta^{18}\text{O}_{\text{sw}}/\text{SSS}$ biases and uncertainty in the $\delta^{18}\text{O}_{\text{sw}}$ -SSS relationship likely contribute significantly to these discrepancies in the Western Pacific
- Impact of non-linear, growth-related effects likely minimal for $\delta^{18}\text{O}$ (but may impact Sr/Ca)

Questions?

