Decadal changes in $CaCO_3$ saturation state along 179°E in the Pacific Ocean

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Motivation

Using saturation state of $CaCO_3$ (Ω) as an indicator of ocean acidification,

- Where and how much is the seawater acidified in the interior of Pacific ocean?
- How much does the acidification affect Ω?
- Does anthropogenic CO_2 really cause the ocean acidification?

Outline

1. Methods
   Calculation of Ω from observed TCO_2 and TA.
   Data from cruise MR07-06 of R/V *Mirai* (2007) and WOCE P14N (1993).
2. Results
   $\Delta\Omega_{arg}$: –0.44, $\Delta\Omega_{cal}$: –0.68 in STMW.
3. Discussion
   Anthropogenic CO_2 was main reason for decrease in Ω.
4. Conclusion

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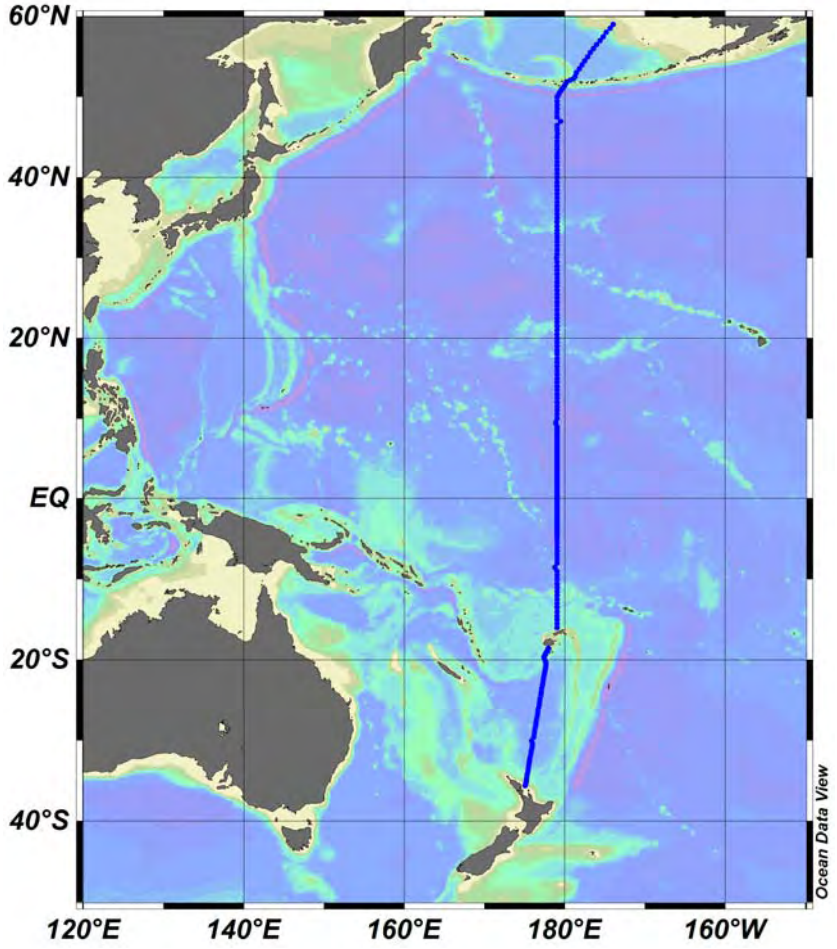
Data source

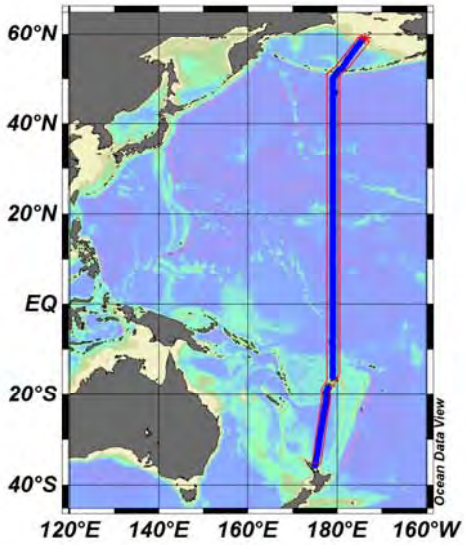


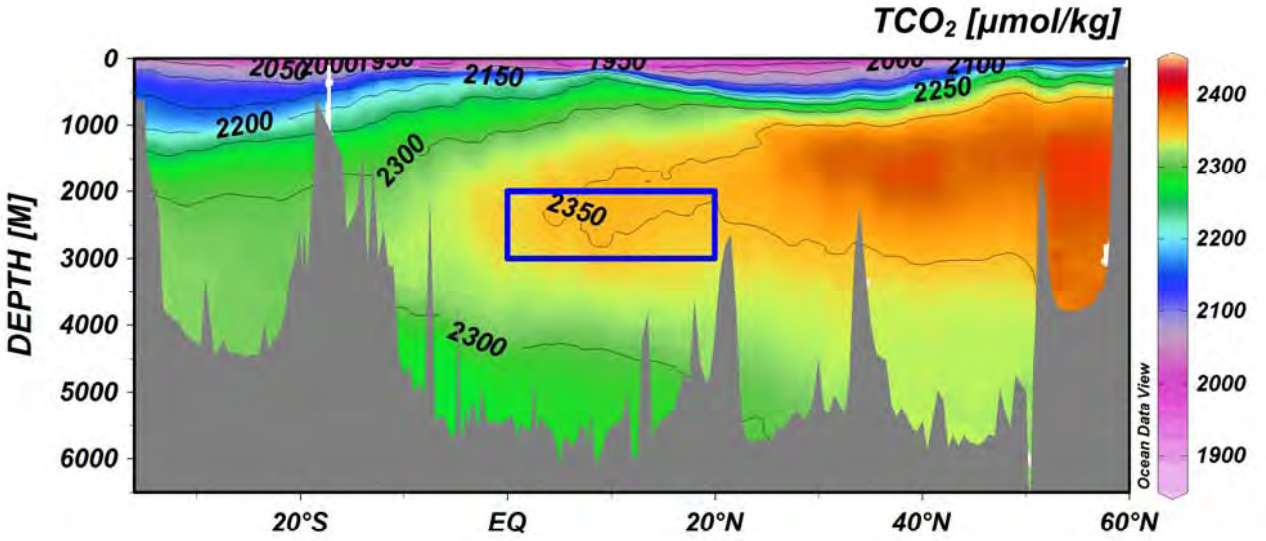
- Cruise MR07-06 of R/V *Mirai*: October – December in 2007
- Total inorganic carbon (TCO_2): coulometric
- Total alkalinity (TA): spectrophotometric, one point titration of acid
- Calibration with CRM
- WOCE P14N data in 1993: CDIAC web site

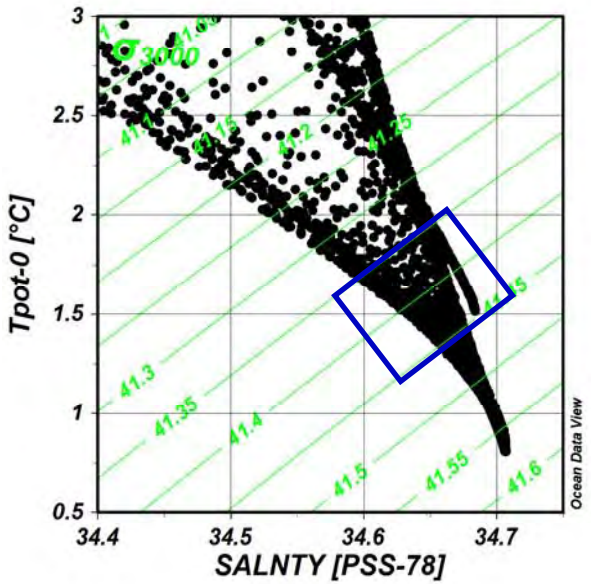
1. Methods

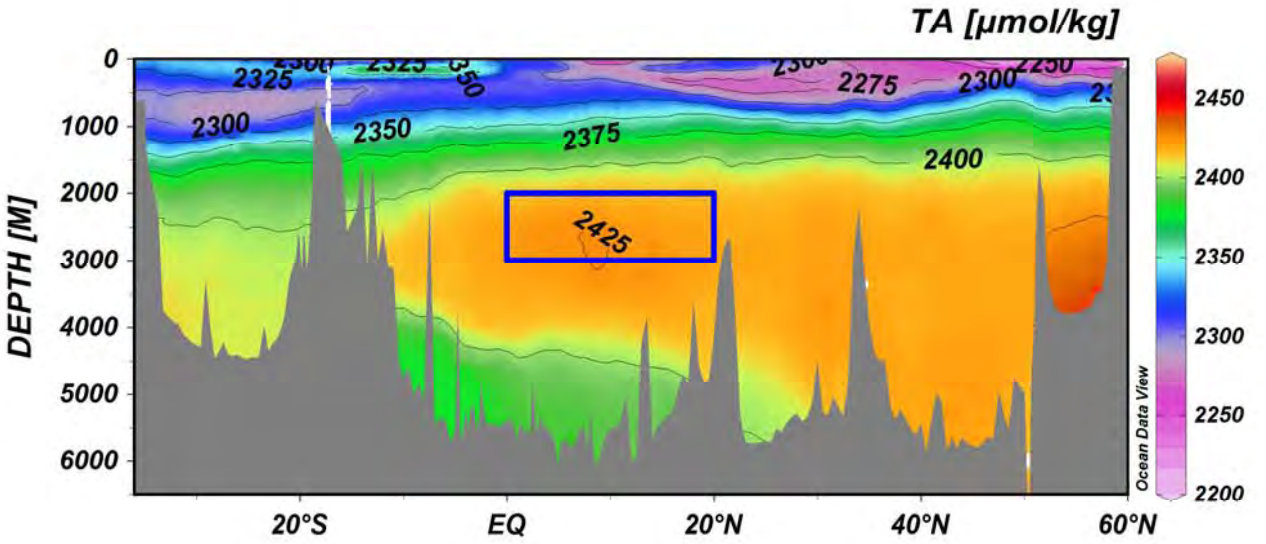
Pacific Deep Water

Samples to check data offsets









Data offsets of TCO_2 and TA

Cruise	TCO_2	TA	AOU
WOCE P14 (1993)	2347.8±4.5 (68)	2425.3±3.8 (58)	223.8±5.9 (242)
MR07-06 (2007)	2347.5±4.4 (112)	2422.4±2.3 (114)	223.5±6.1 (233)
2007 - 1993	–0.3	–2.9	–0.3
t-test (95%)	Not significant	Significant	Not significant

Data processing

t, S, TCO_2, TA

↓ Acid base equilibrium calculation

Ω_{arg}, Ω_{cal}

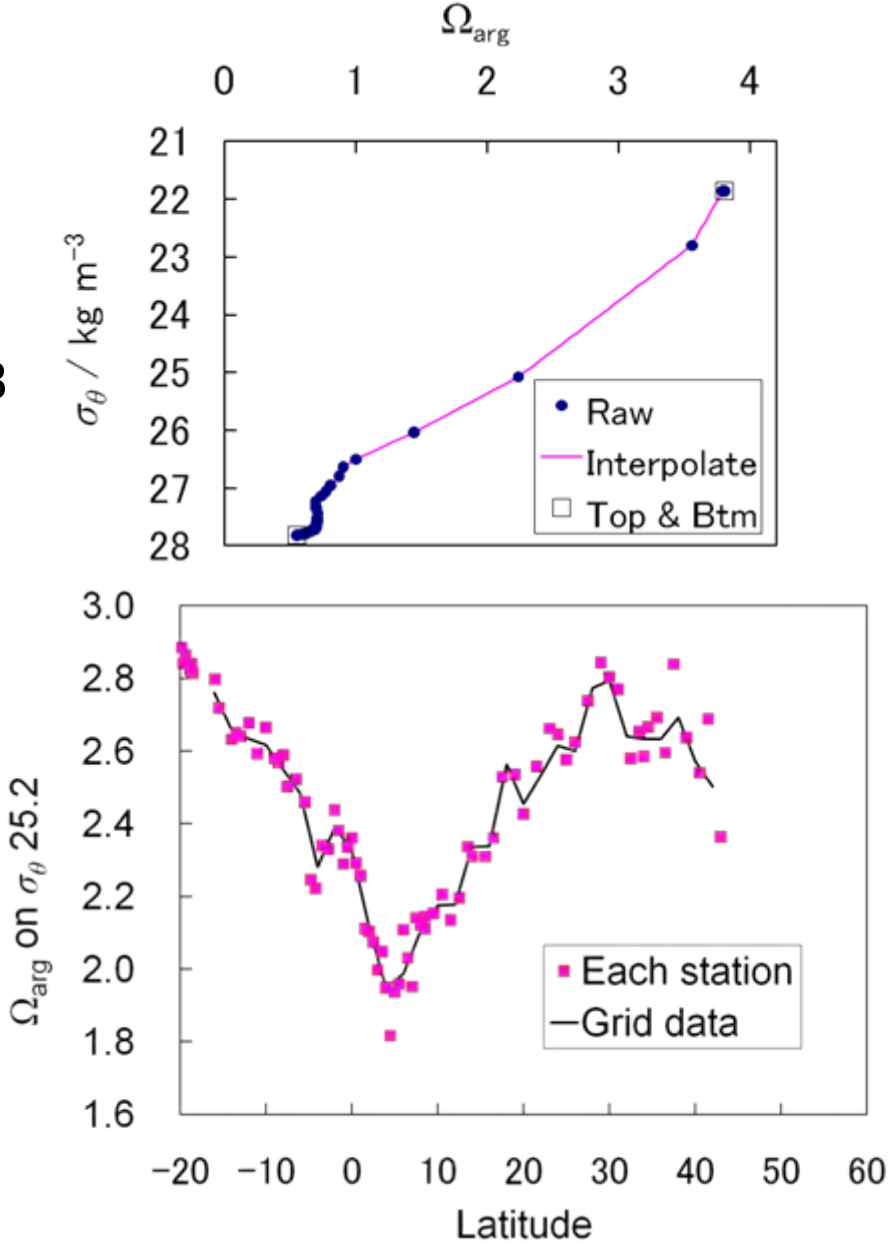
↓ Linear interpolation on σ_θ 21.0 – 27.8 (interval 0.1)

Interpolated data at a station
yrparam.ipl

↓ Linear regression at latitude 58°N – 16°S (interval 2°, range ±1° each)

Grid data
yrparam.isl

$yr : 2007 or 1993
$param : Ω_{arg}, Ω_{cal} etc.



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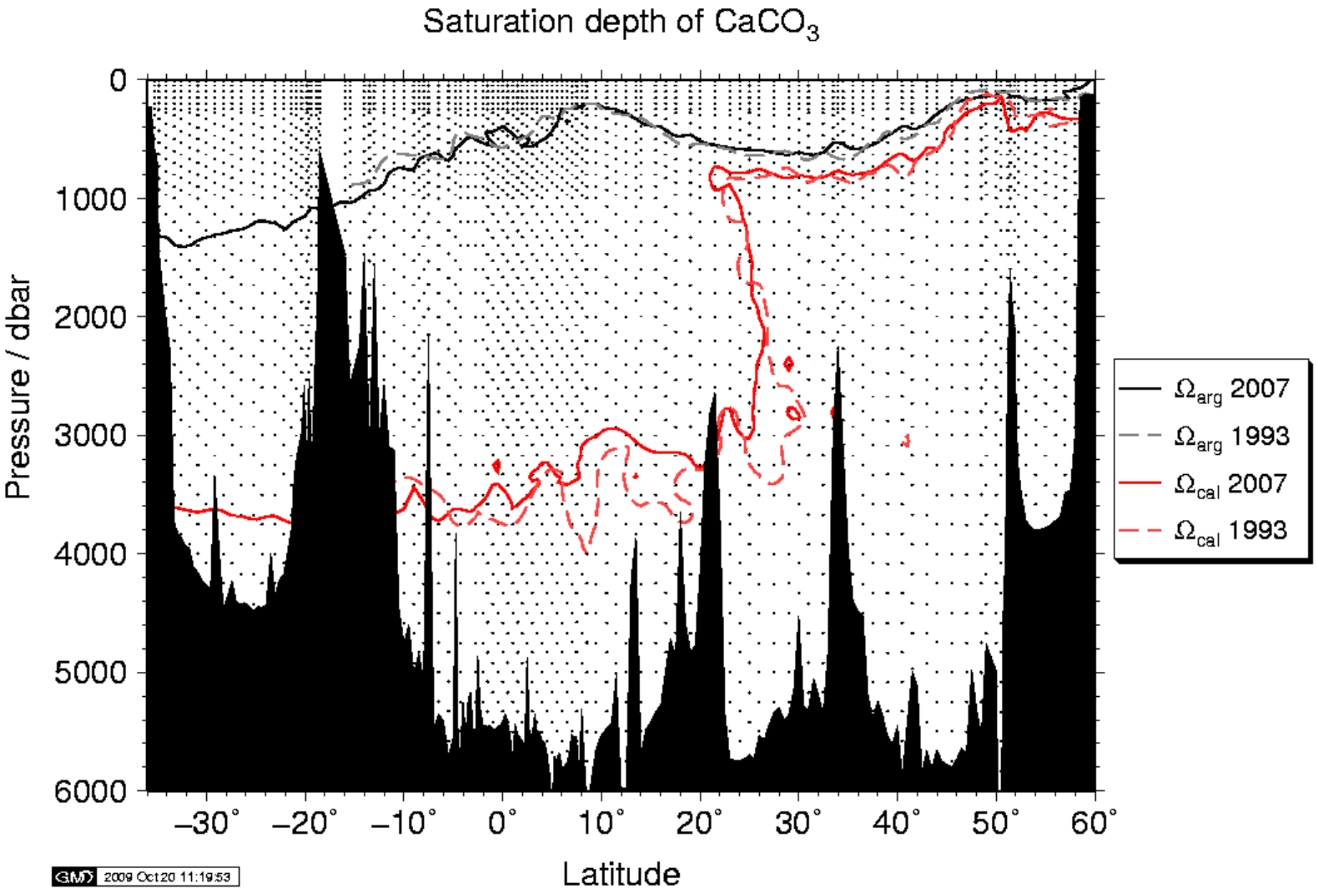
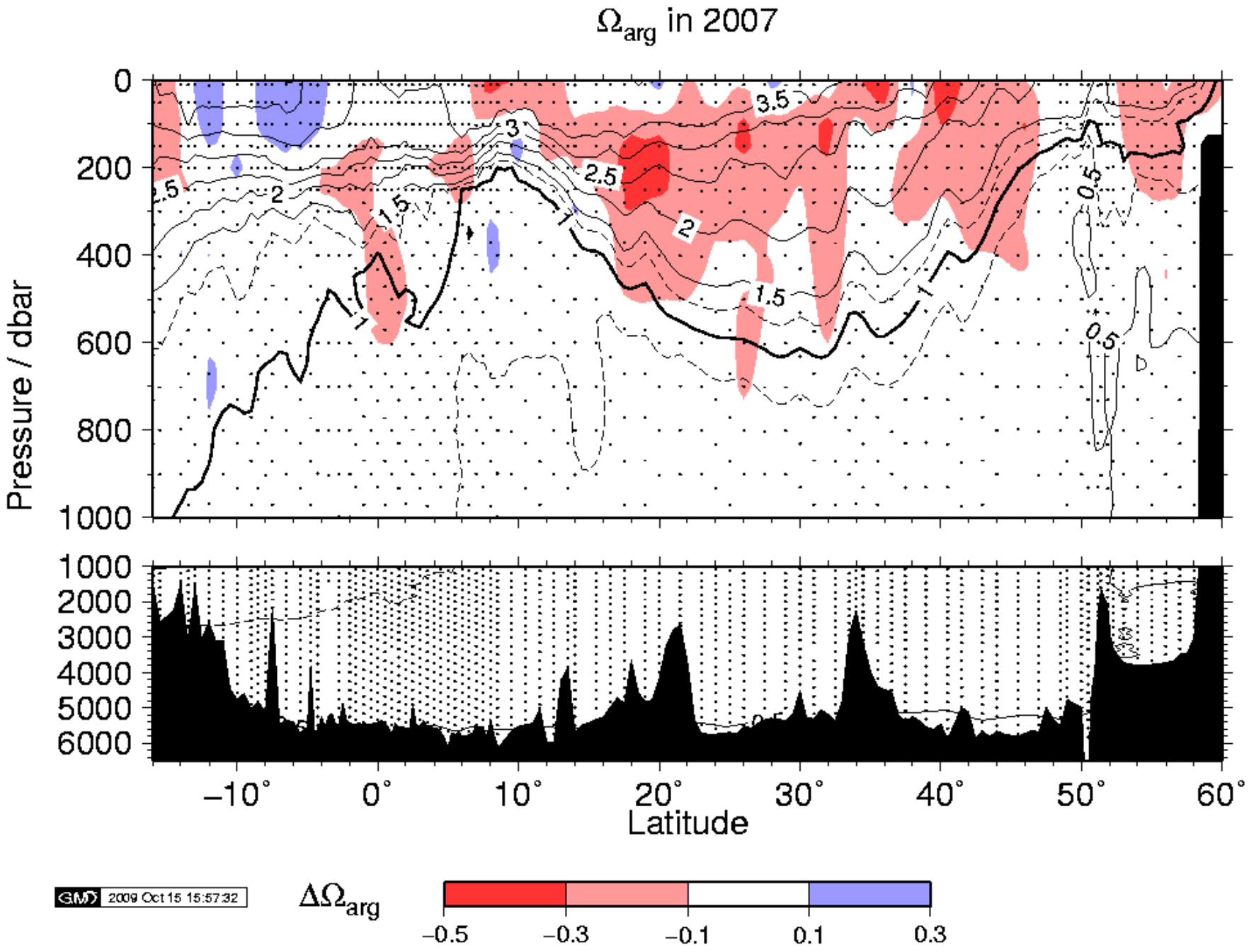
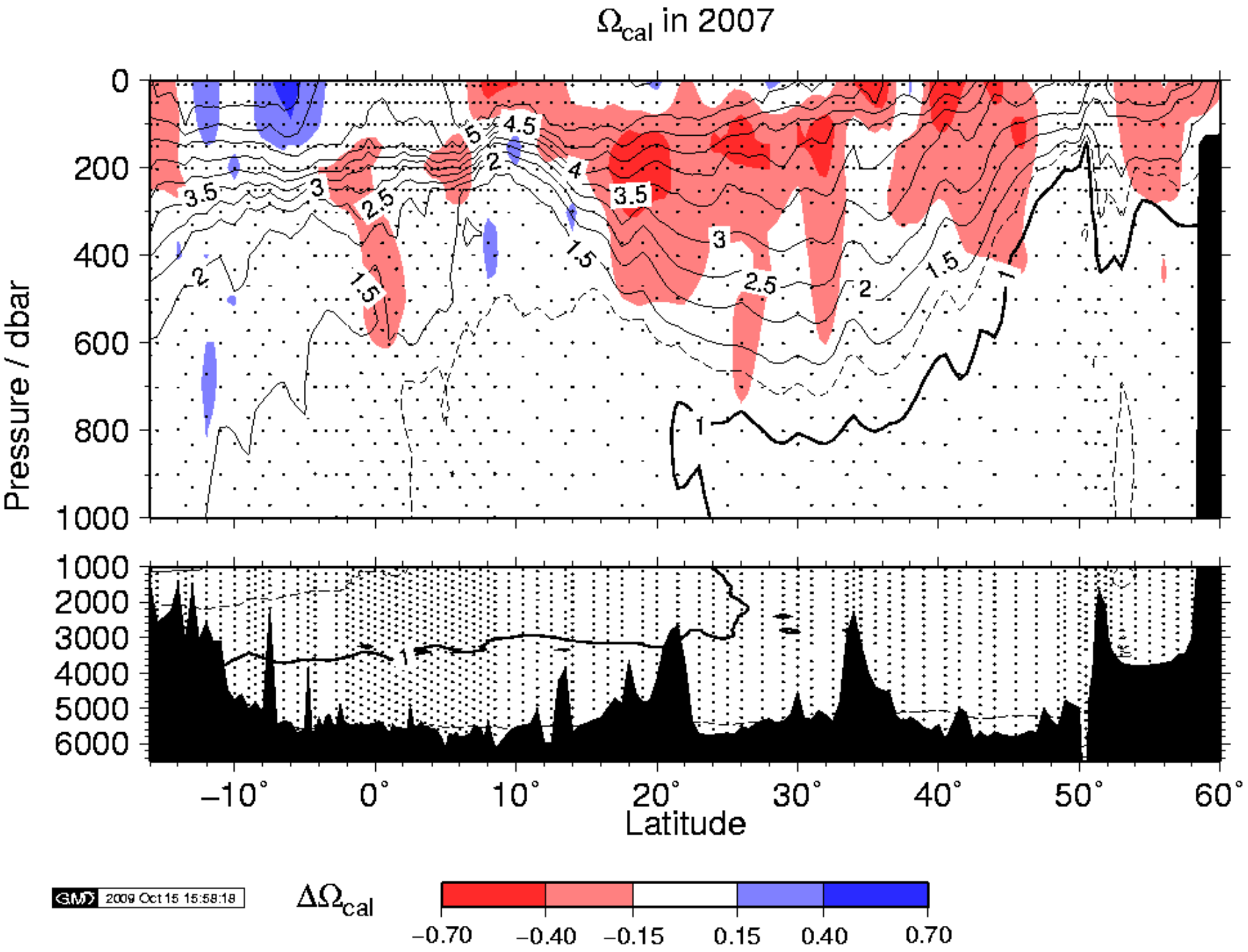

Saturation depth of $CaCO_3$
Pressure / dbar
0
1000
2000
3000
4000
5000
6000
−30°
−20°
−10°
0°
10°
20°
30°
40°
50°
60°
Latitude
Ω_{arg} 2007
Ω_{arg} 1993
Ω_{cal} 2007
Ω_{cal} 1993
GMT 2009 Oct 20 11:19:53

2. Results


Ω_{arg} in 2007
Pressure / dbar
0
200
400
600
800
1000
1000
2000
3000
4000
5000
6000
3.5
3
2.5
2
1.5
1
0.5
−10°
0°
10°
20°
30°
40°
50°
60°
Latitude
GMT 2009 Oct 15 15:57:32
$\Delta\Omega_{arg}$
−0.5
−0.3
−0.1
0.1
0.3

2. Results


Ω_{cal} in 2007
Pressure / dbar
0
200
400
600
800
1000
1000
2000
3000
4000
5000
6000
−10°
0°
10°
20°
30°
40°
50°
60°
Latitude
GMT 2009 Oct 15 15:58:18
$\Delta\Omega_{cal}$
−0.70
−0.40
−0.15
0.15
0.40
0.70

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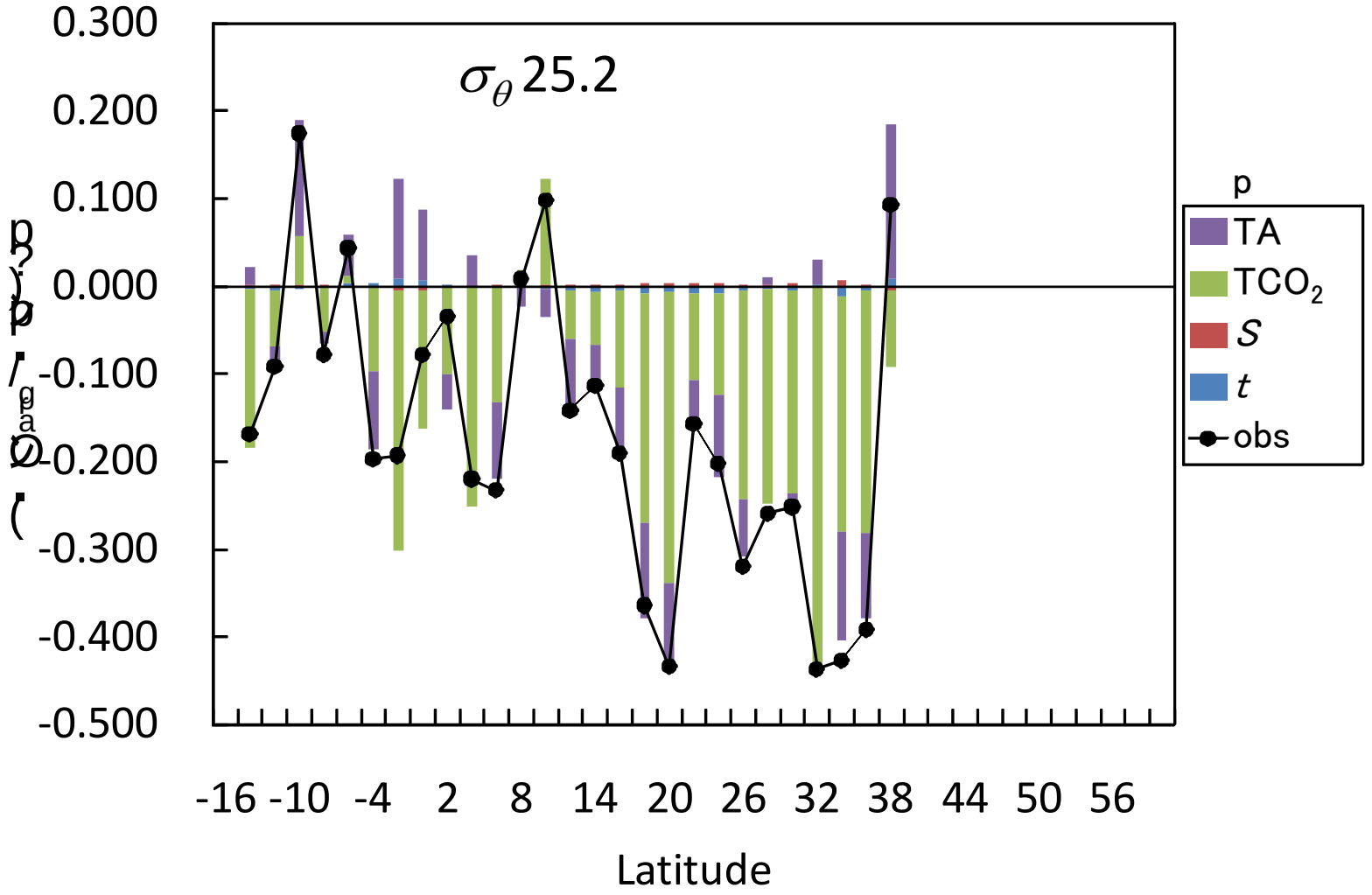
Reasons for decrease in Ω

$$\left(\frac{\partial \Omega}{\partial \mathrm{TCO}_2}\right)\Delta \mathrm{TCO}_2 = \Omega(t_{2007}, S_{2007}, \mathrm{C2007}, \mathrm{A}_{2007}) - \Omega(t_{2007}, S_{2007}, \mathrm{C1993}, \mathrm{A}_{2007})$$

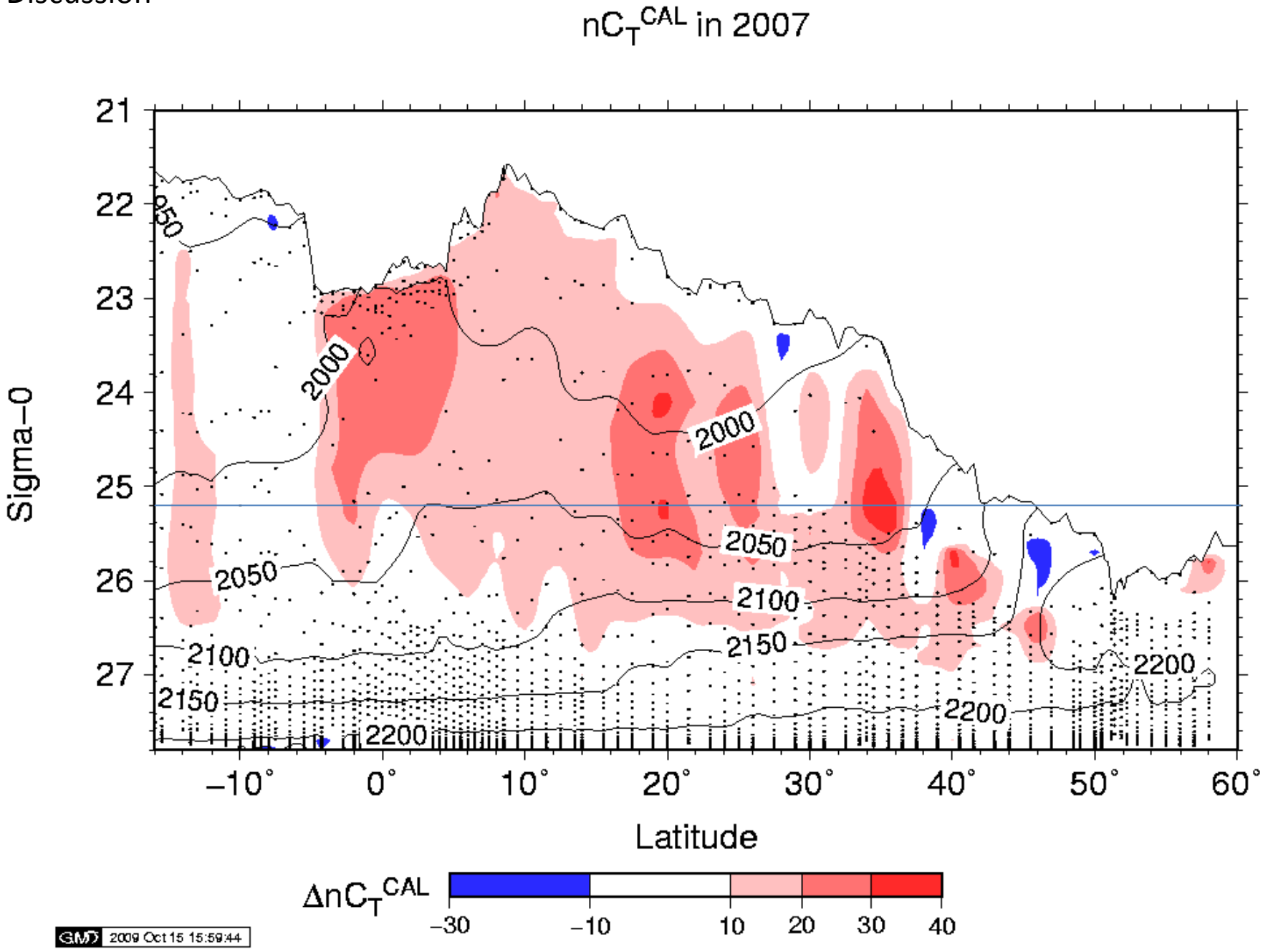


Estimation of anthropogenic CO_2

- Preformed TCO_2
  $nC_T^{CAL} = (TCO_2 - AOU \times 0.69) \times 35 / S$

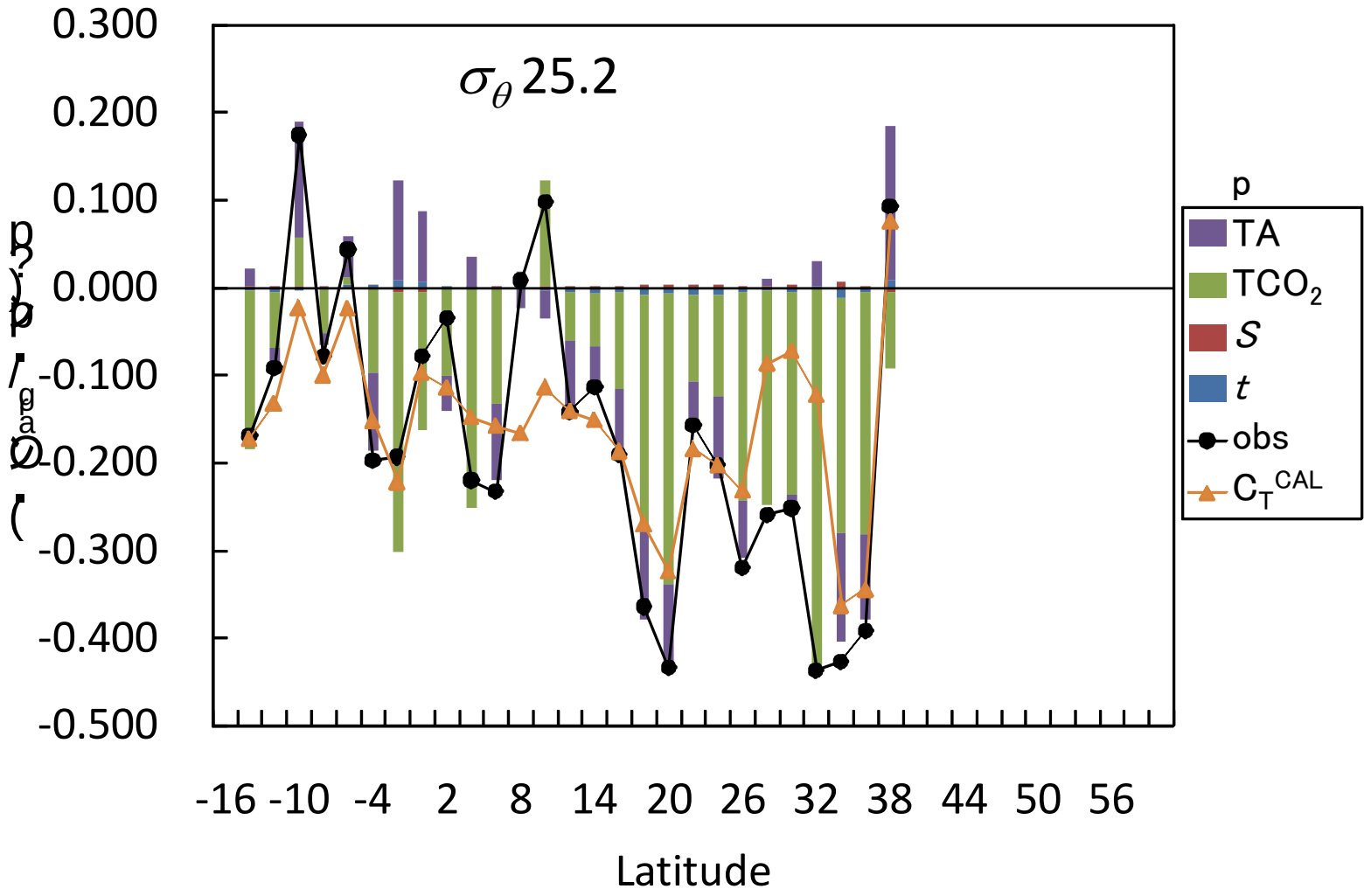
Murata et al., 2008

- $TCO_2 = C_T^{CAL} + C^{org} + C^{CaCO3}$
- $C^{org} = AOU \times 0.69$
- $\Delta C^{CaCO3} \approx 0$
- $\Delta C^{anth} = \Delta nC_T^{CAL}$


nC$_T$^{CAL} in 2007
Sigma−0
21
22
23
24
25
26
27
2000
2050
2100
2150
2200
−10°
0°
10°
20°
30°
40°
50°
60°
Latitude
ΔnC$_T$^{CAL}
−30
−10
10
20
30
40
GMT 2009 Oct 15 15:59:44

Effects of anthropogenic CO_2 on Ω_{arg}

$\Omega_{arg}(t_{1993}, S_{1993}, \mathbf{C_{1993} + \Delta C_T^{CAL}}, A_{1993}) - \Omega_{arg}(t_{1993}, S_{1993}, \mathbf{C_{1993}}, A_{1993})$



Conclusion

- Observed changes in Ω_{arg} between 2007 and 1993 ranged from –0.44 to +0.29.
  (For Ω_{cal}, from –0.68 to +0.43)
- The maximum decreases of the saturation states were found at 300±100 dbar, where mode waters exist.
- Increase in TCO_2 (mainly by anthropogenic CO_2 input) was the dominant cause of the decreases in Ω_{arg} and Ω_{cal}.

Questions -->> ssaito@jamstec.go.jp

Acknowledgement

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