

The Southern Ocean and its Climate in CCSM4

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The CCSM4 Southern Ocean paper

- **Surface climatology and interannual variability**
 - Talk by Nicole Jeffery, polar climate working group
- **Water masses and water mass formation**
- **Circulation and interbasin exchanges**

The Southern Ocean: Water Masses

- **Three major water masses**
 - Antarctic Bottom Water (AABW)
 - Antarctic Intermediate Water (AAIW)
 - Subantarctic Mode Water (SAMW)
- **Global stratification, overturning circulation**
- **Sequestration**
 - heat
 - freshwater
 - carbon
 - CFCs
 - etc.

CARS 2009

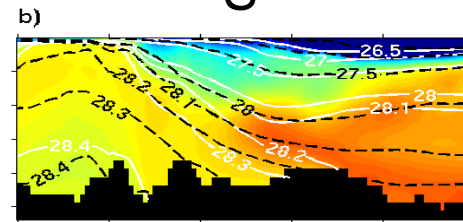
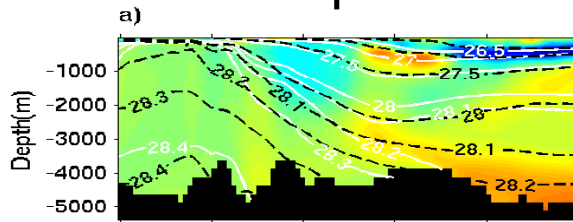
- **CSIRO Atlas of Regional Seas (2009)**
 - Gridded climatology of ocean water properties
 - Mean seasonal cycle
 - Ridgway et al. (2002)
 - <http://www.marine.csiro.au/~dunn/cars2009>

Basic T/S

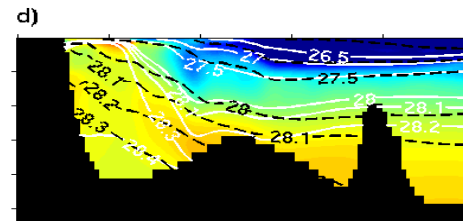
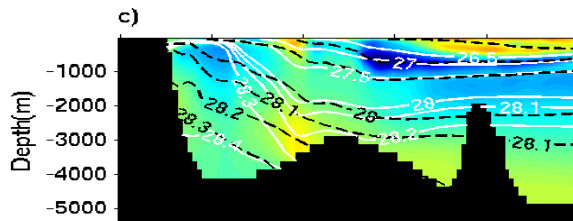
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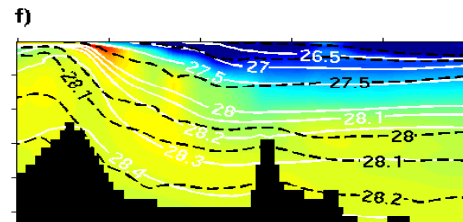
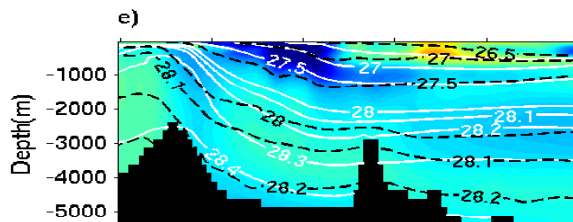
Atlantic



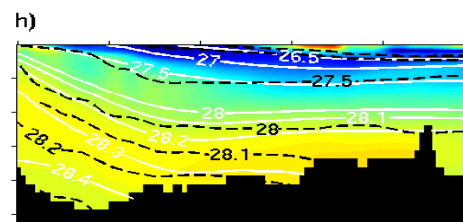
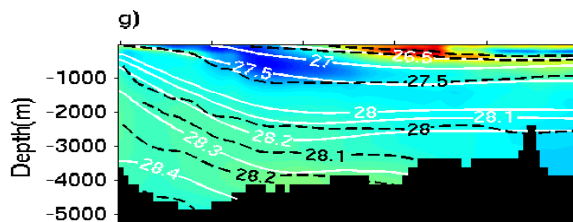
Indian



W. Pacific



E. Pacific

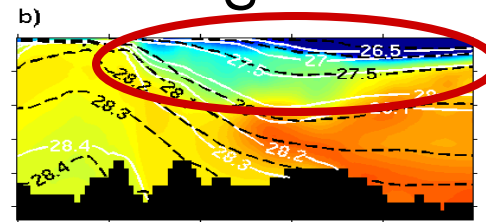
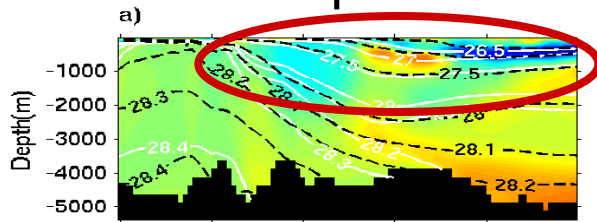


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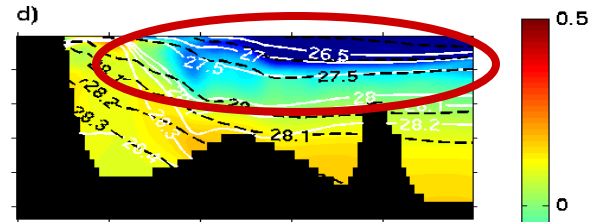
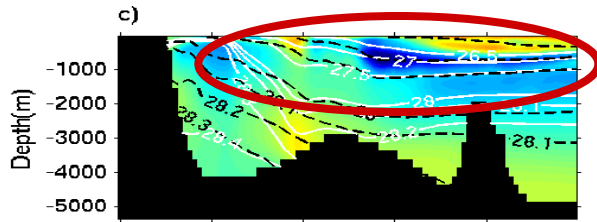
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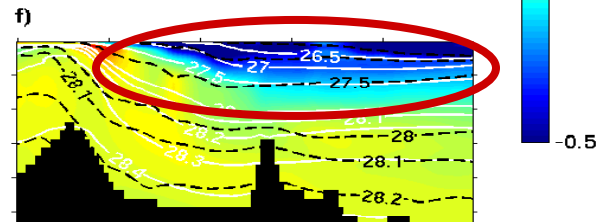
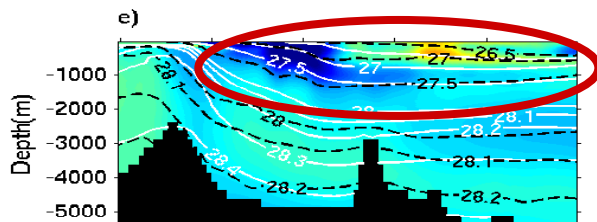
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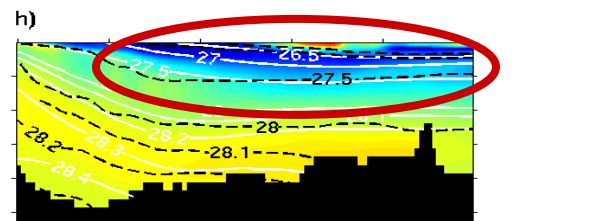
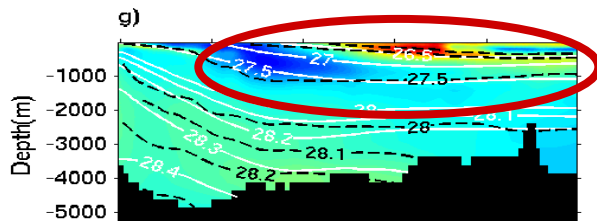
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W. Pacific



E. Pacific

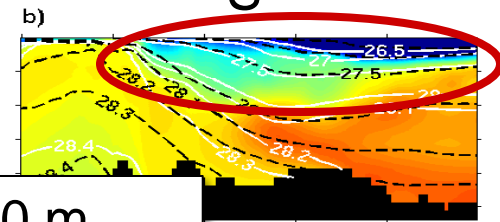
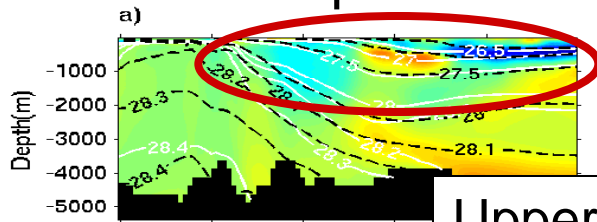


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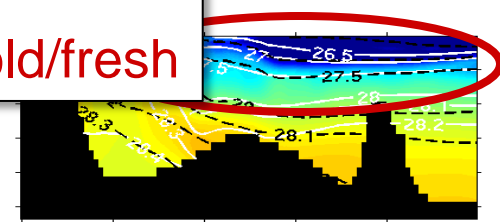
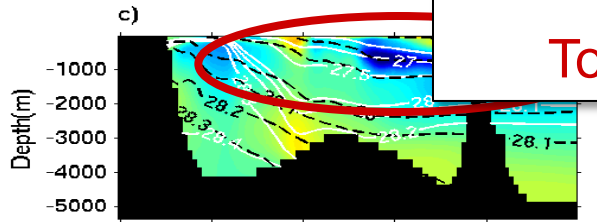
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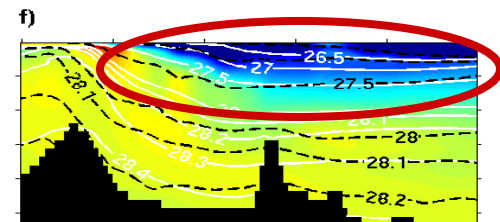
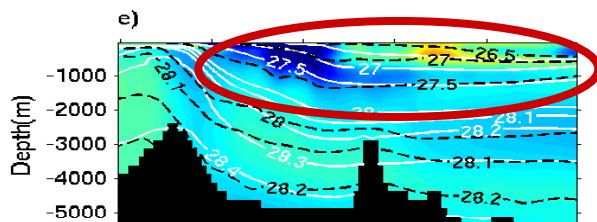
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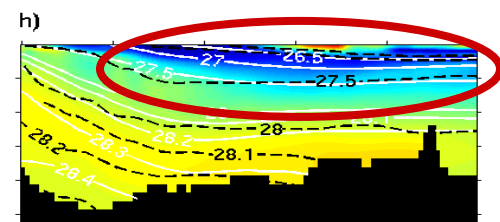
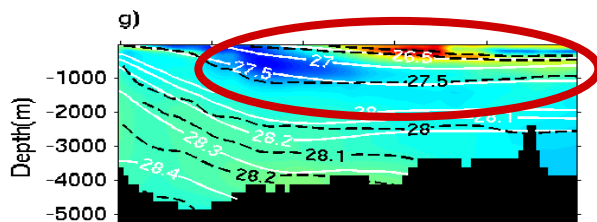
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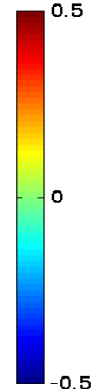
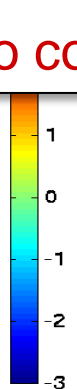
W. Pacific



E. Pacific



Upper 1500 m
Too cold/fresh

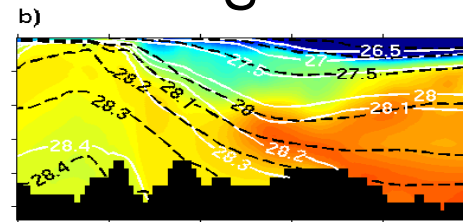
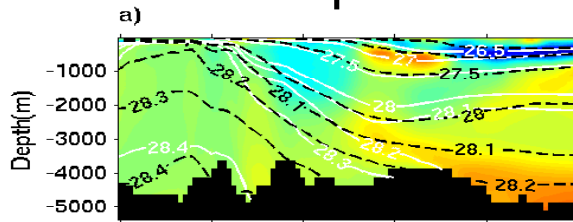


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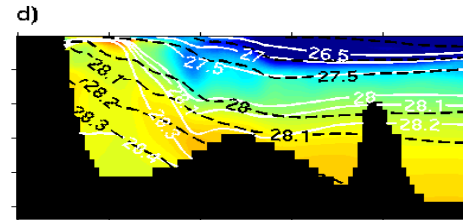
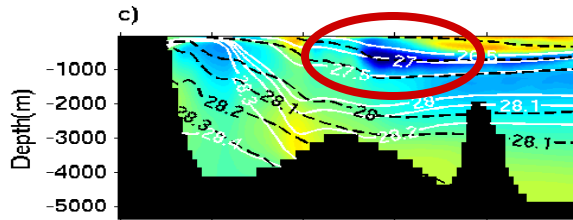
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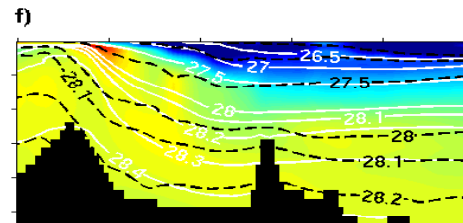
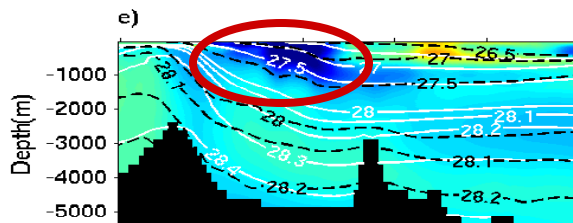
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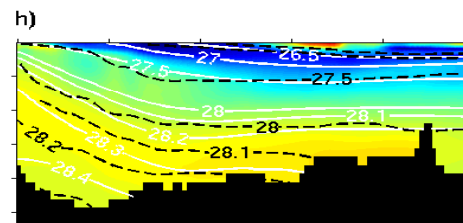
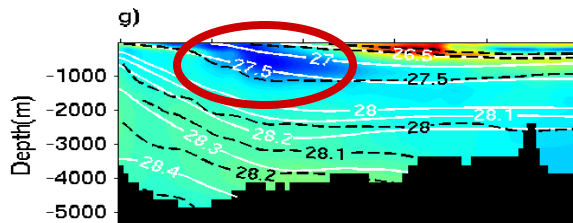
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W. Pacific



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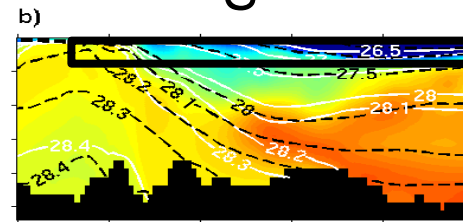
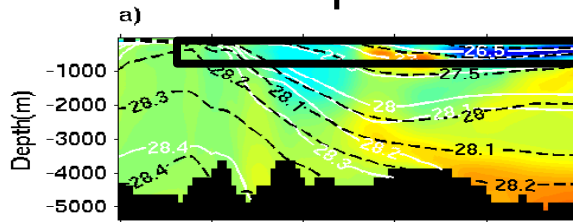


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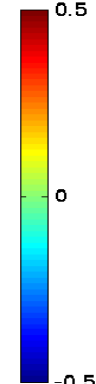
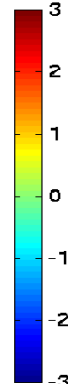
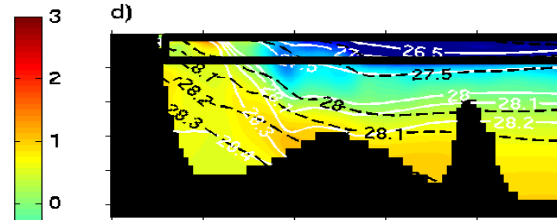
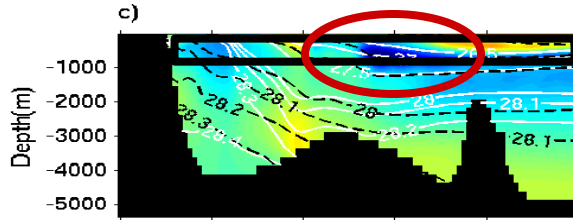
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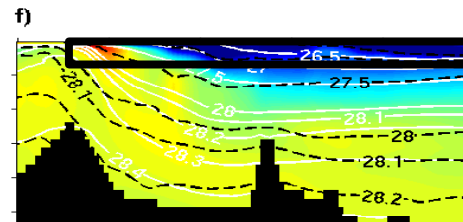
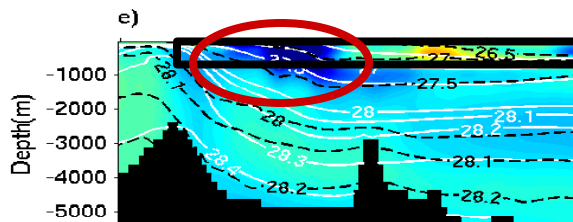
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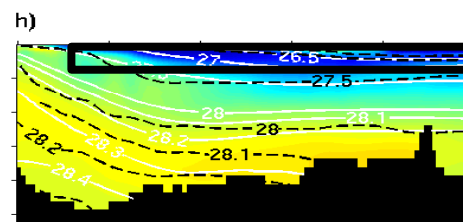
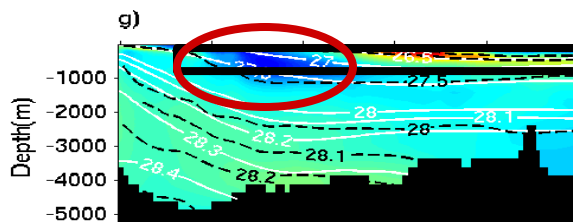
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W. Pacific



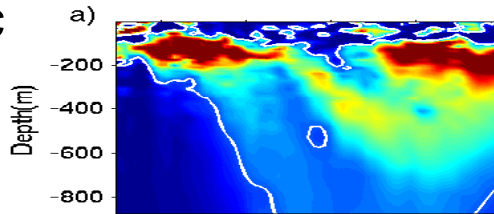
E. Pacific



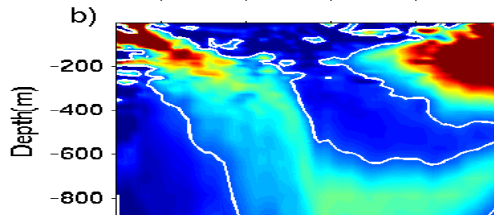
Potential Vorticity: SAMW

CARS 2009

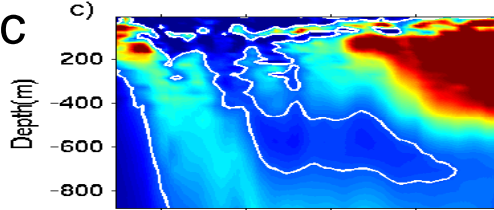
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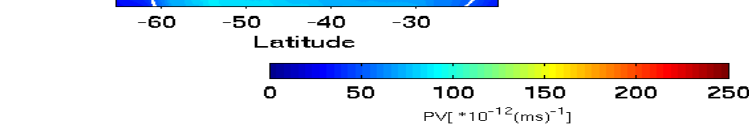
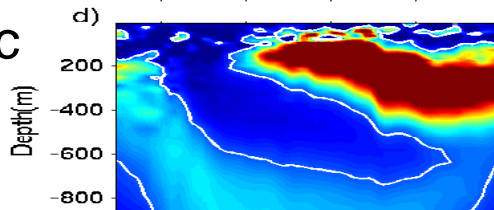
Indian



W. Pacific



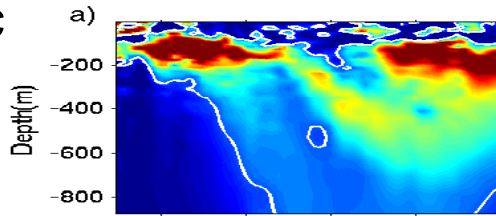
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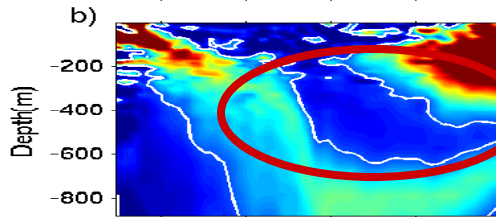
Potential Vorticity: SAMW

CARS 2009

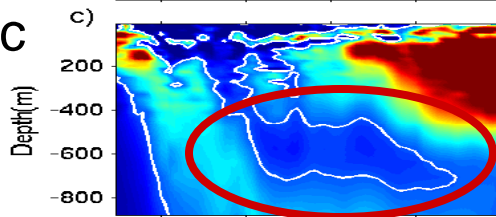
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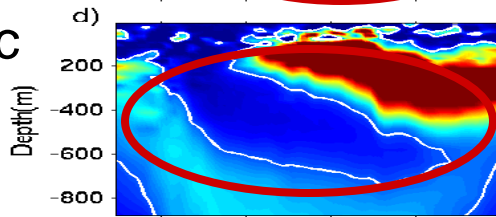
Indian



W. Pacific

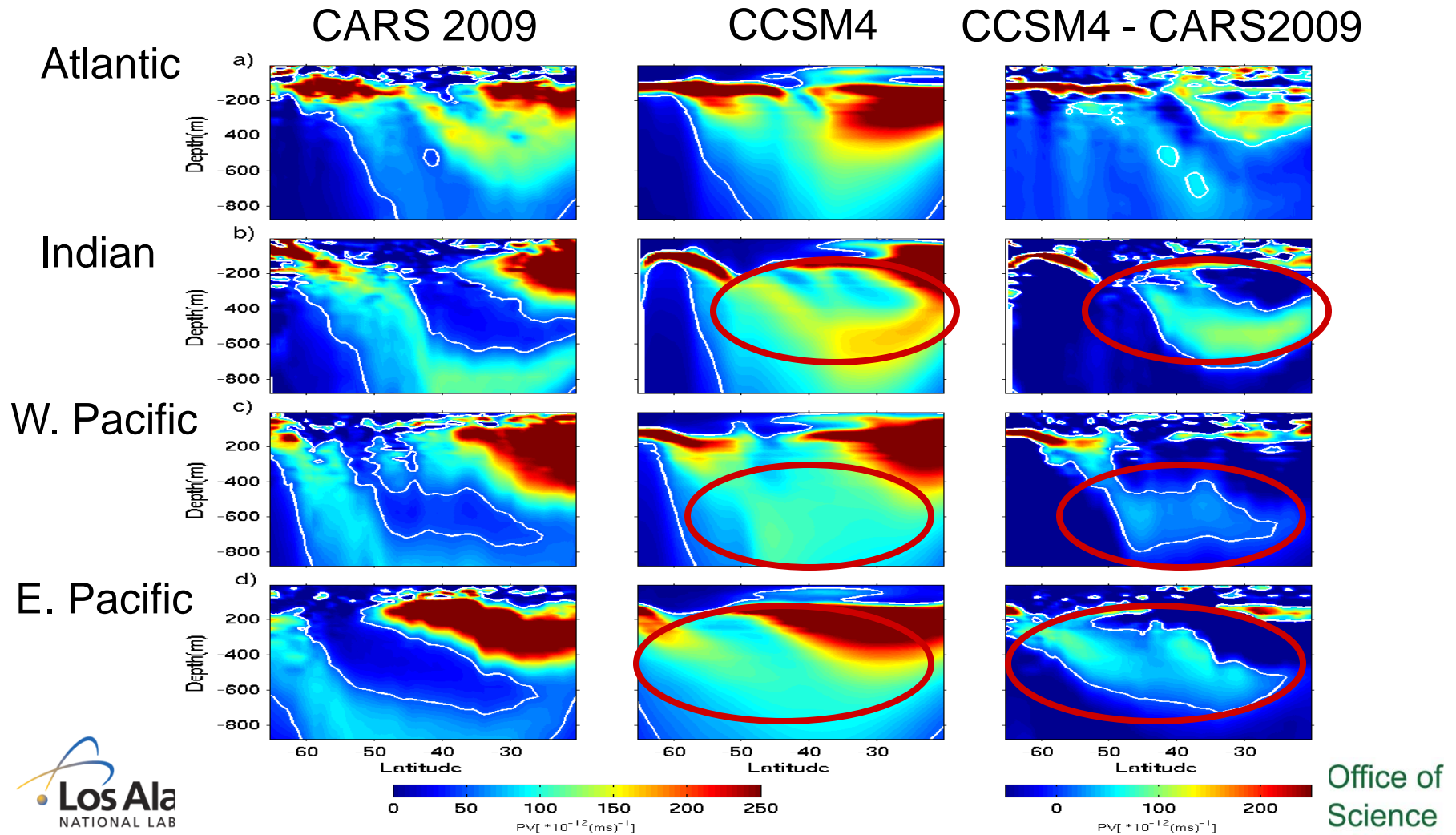


E. Pacific



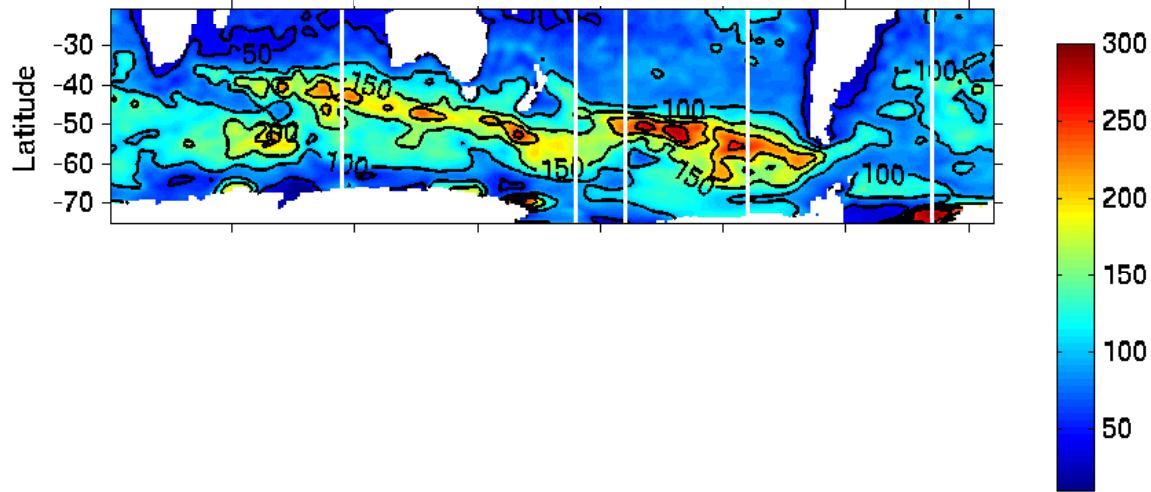
Low PV: Subantarctic Mode Water

Potential Vorticity: SAMW



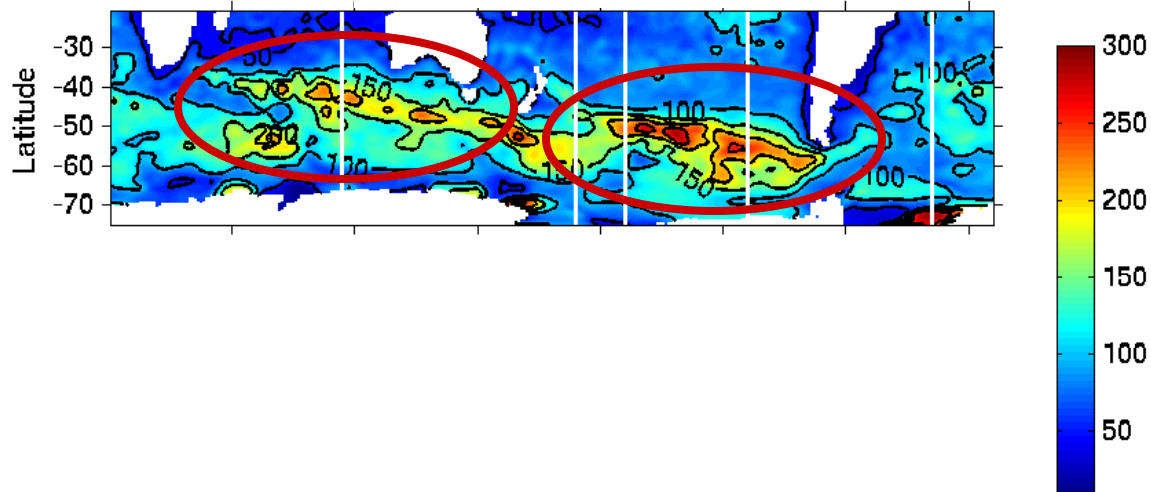
Mixed-Layer Depth: SAMW

CARS 2009



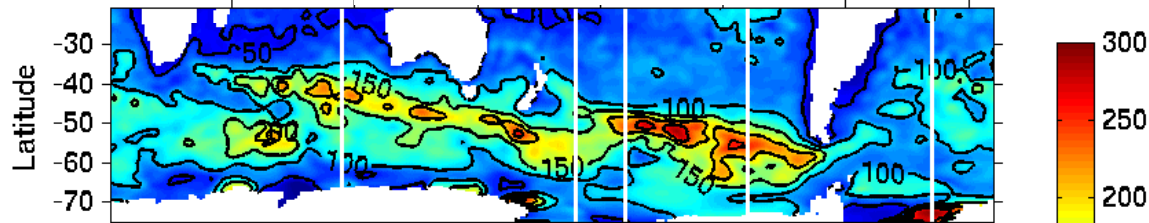
Mixed-Layer Depth: SAMW

CARS 2009

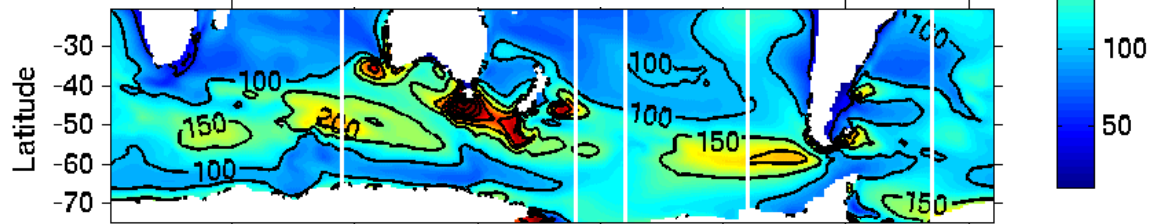


Mixed-Layer Depth: SAMW

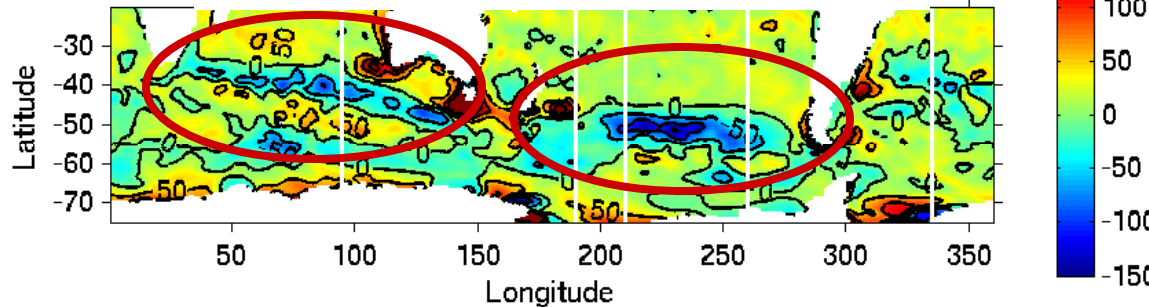
CARS 2009



CCSM4



CCSM4 - CARS2009

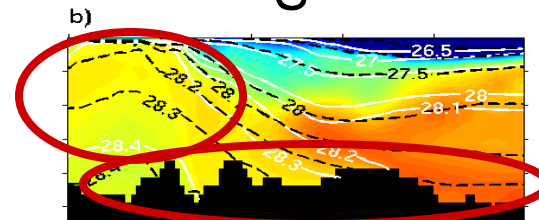
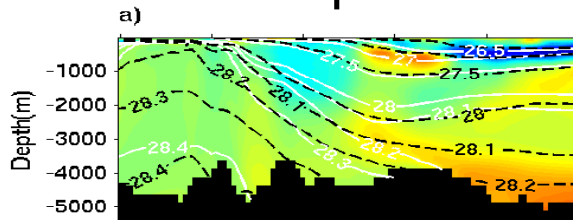


Basic T/S: AABW

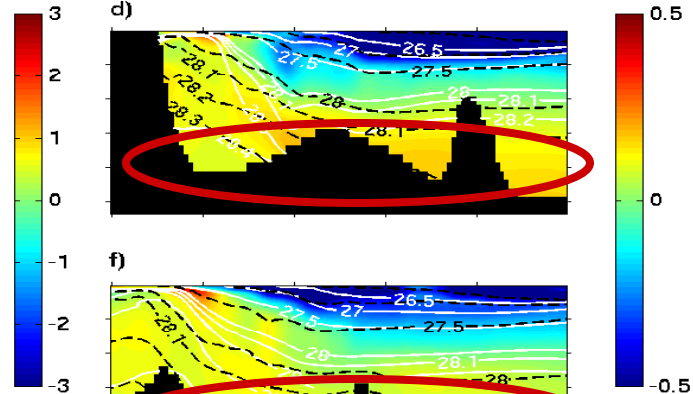
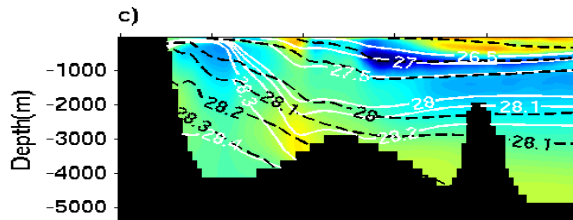
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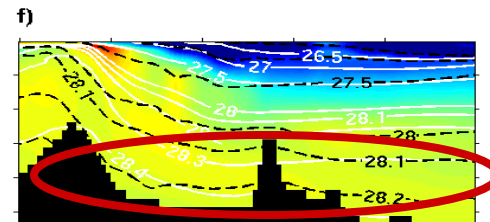
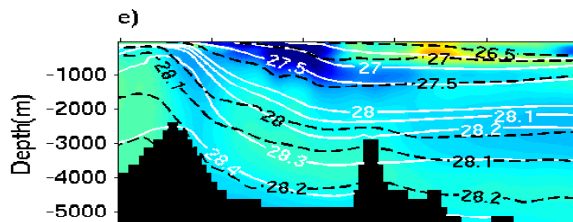
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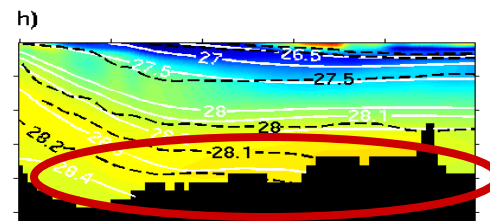
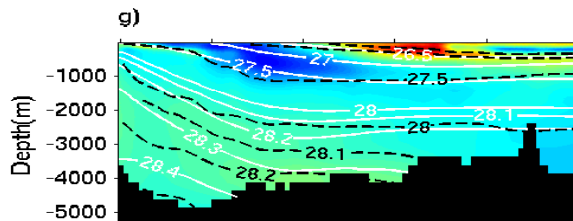
Indian



W. Pacific



E. Pacific

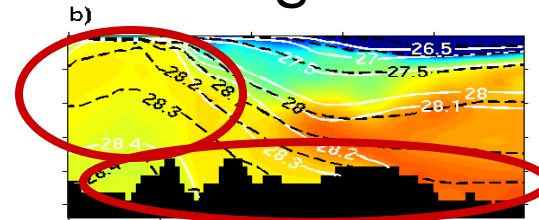
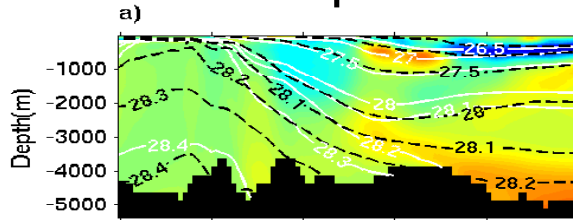


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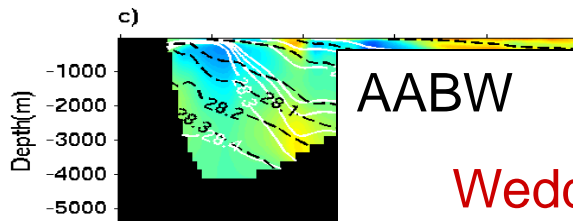
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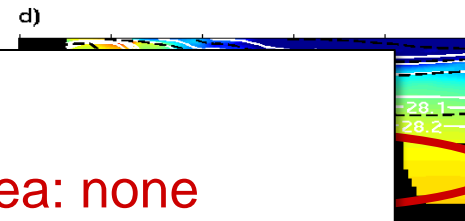
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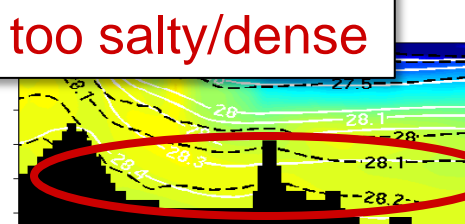
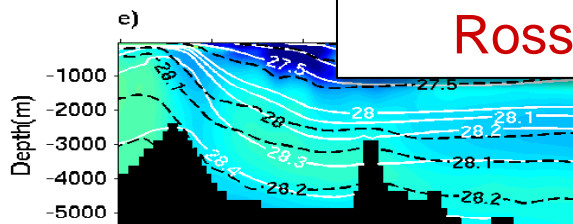
AABW

Weddell Sea: none

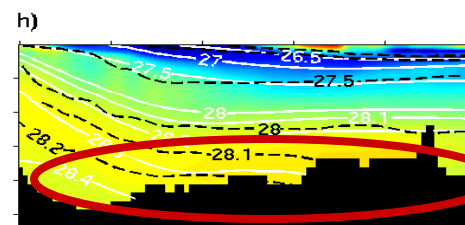
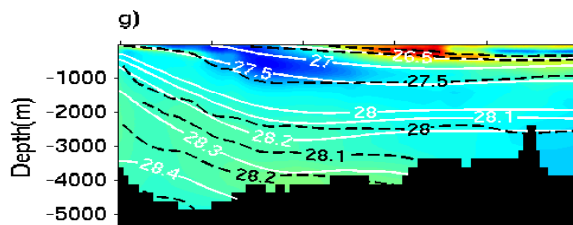
Ross Sea: too salty/dense



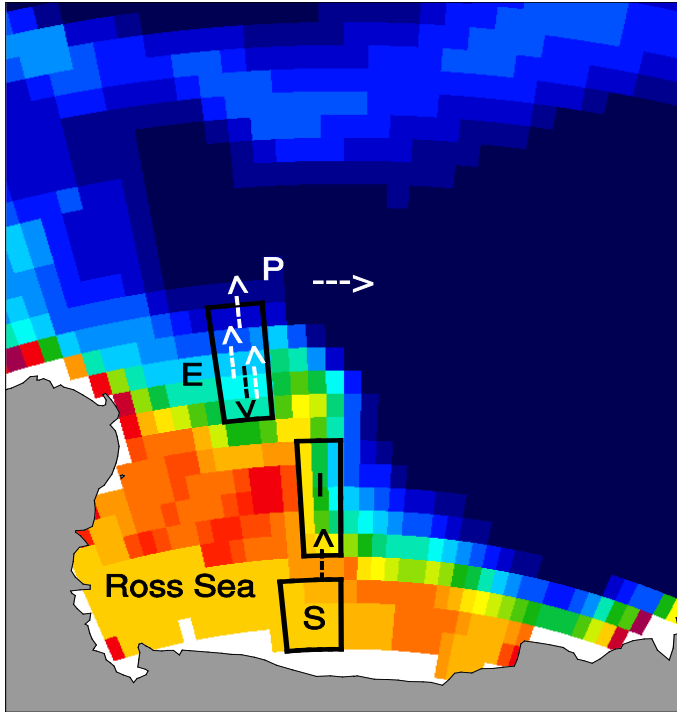
W. Pacific



E. Pacific



Basic T/S: AABW



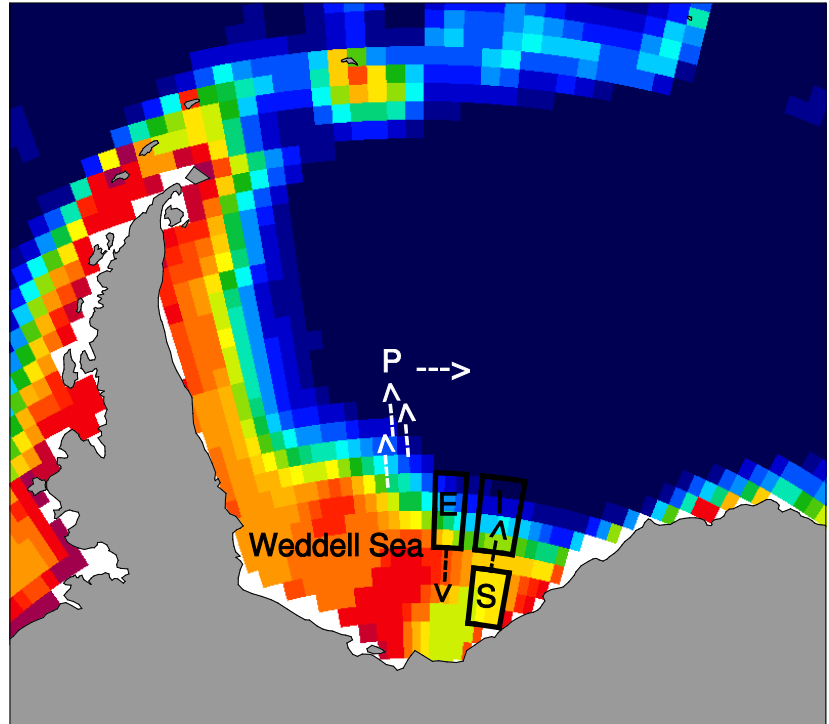
Depth in Meters

200 300 400 500 600 700 850 1000 1300 1700 2000 2500 3500



20 25 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

Vertical Level



Depth in Meters

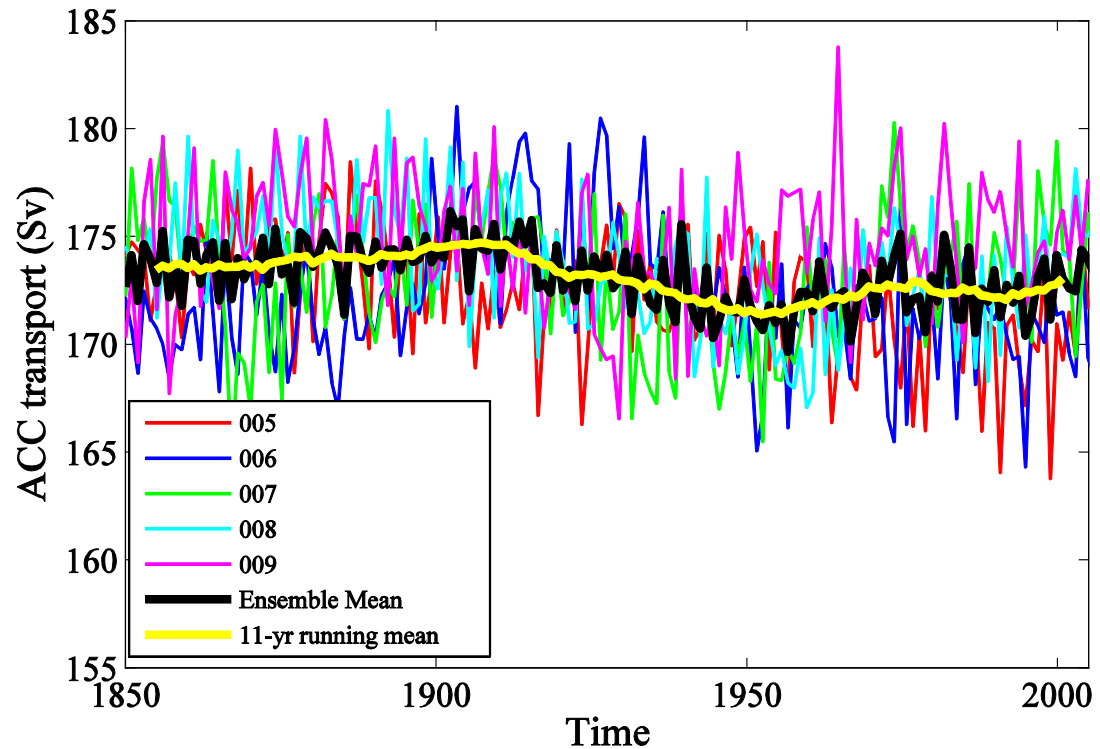
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20 25 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

Vertical Level

Antarctic Circumpolar Current Transports



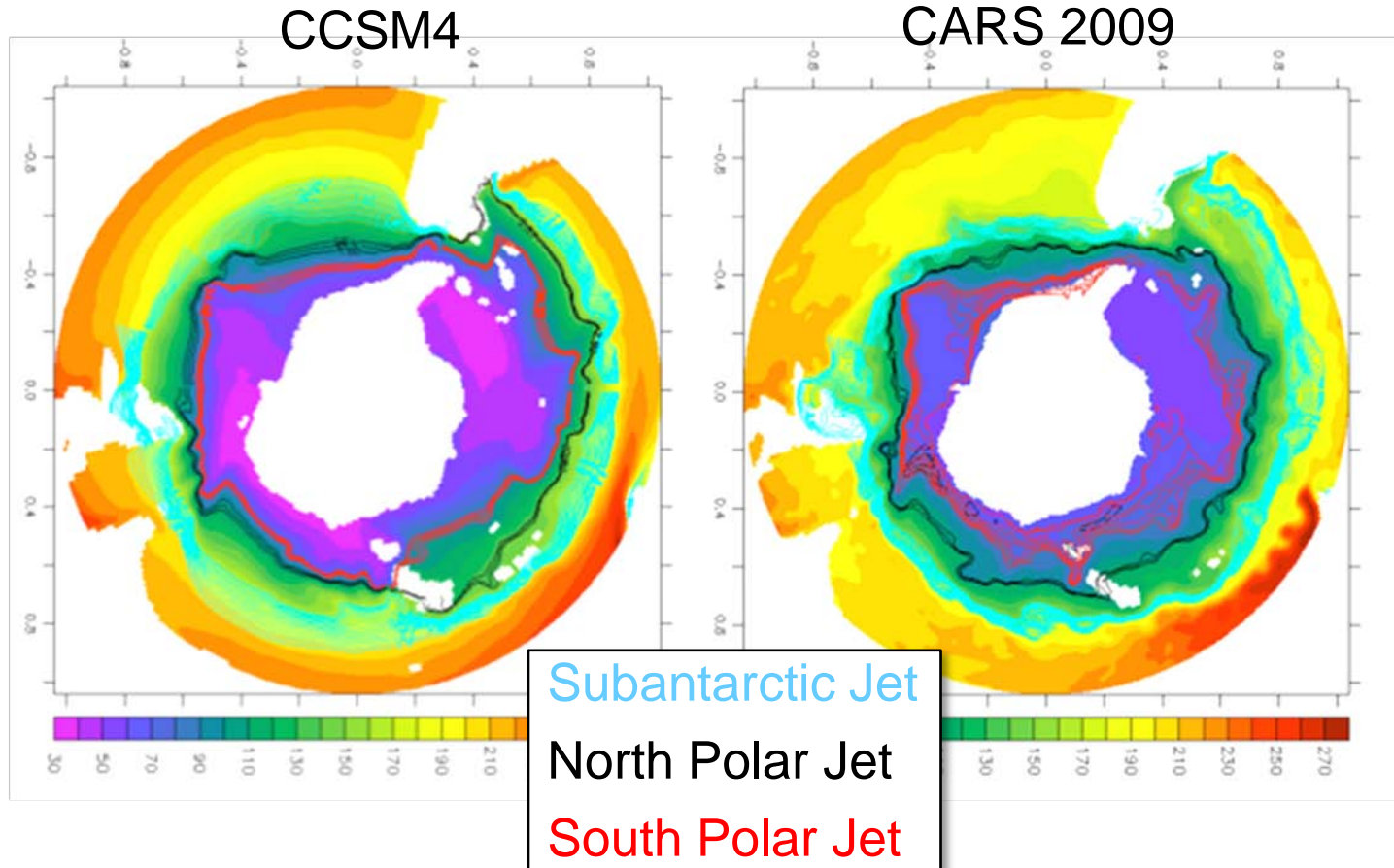
CCSM4: 173 \pm 3 Sv



Obs: 137 \pm 8 Sv



ACC Fronts

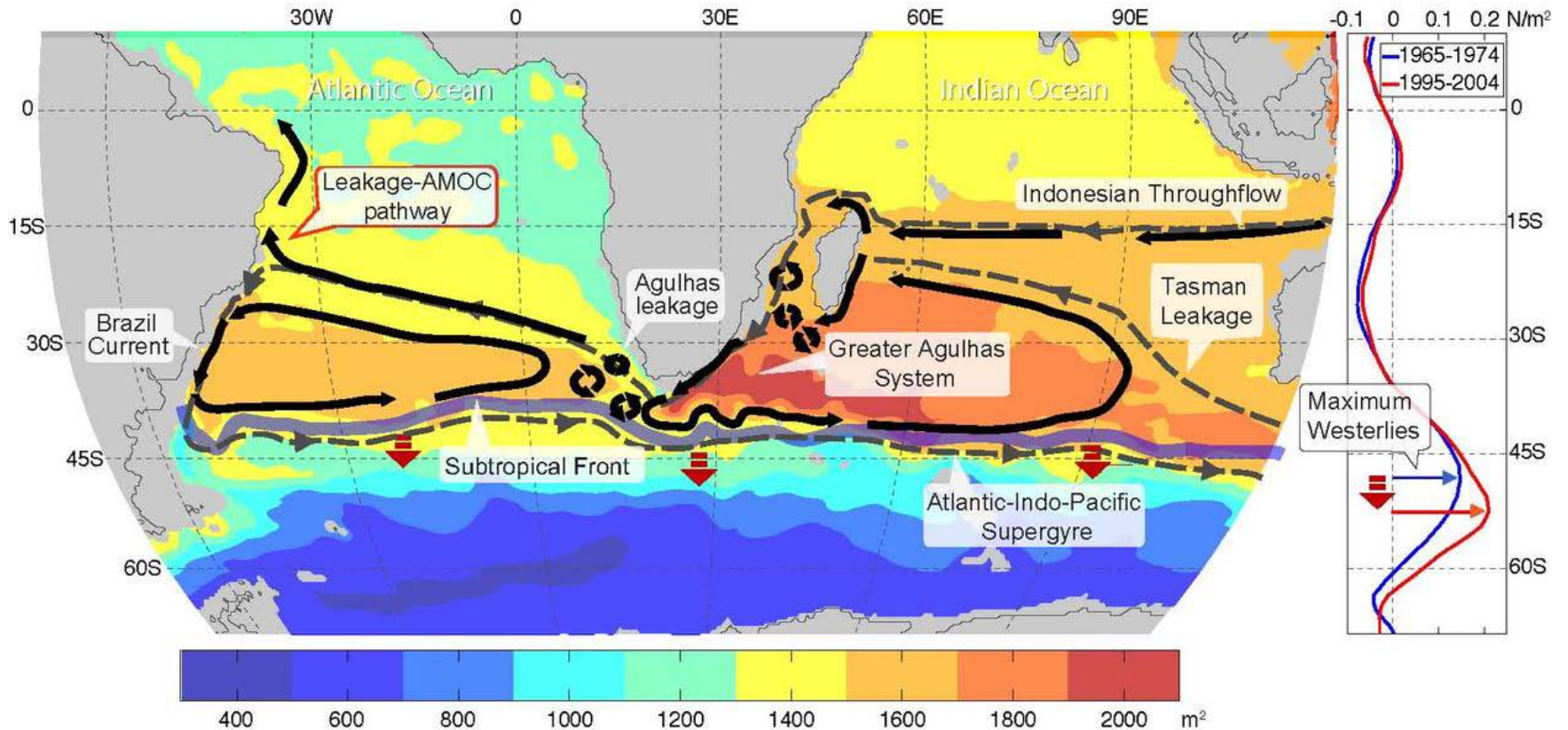


Leakages

■ Leakages

- Westward interocean transports of thermocline waters
 - Agulhas Leakage
 - Tasman Leakage
- Links
 - “Super gyre”
 - Global overturning circulation
- Potential impact on AMOC

Leakages

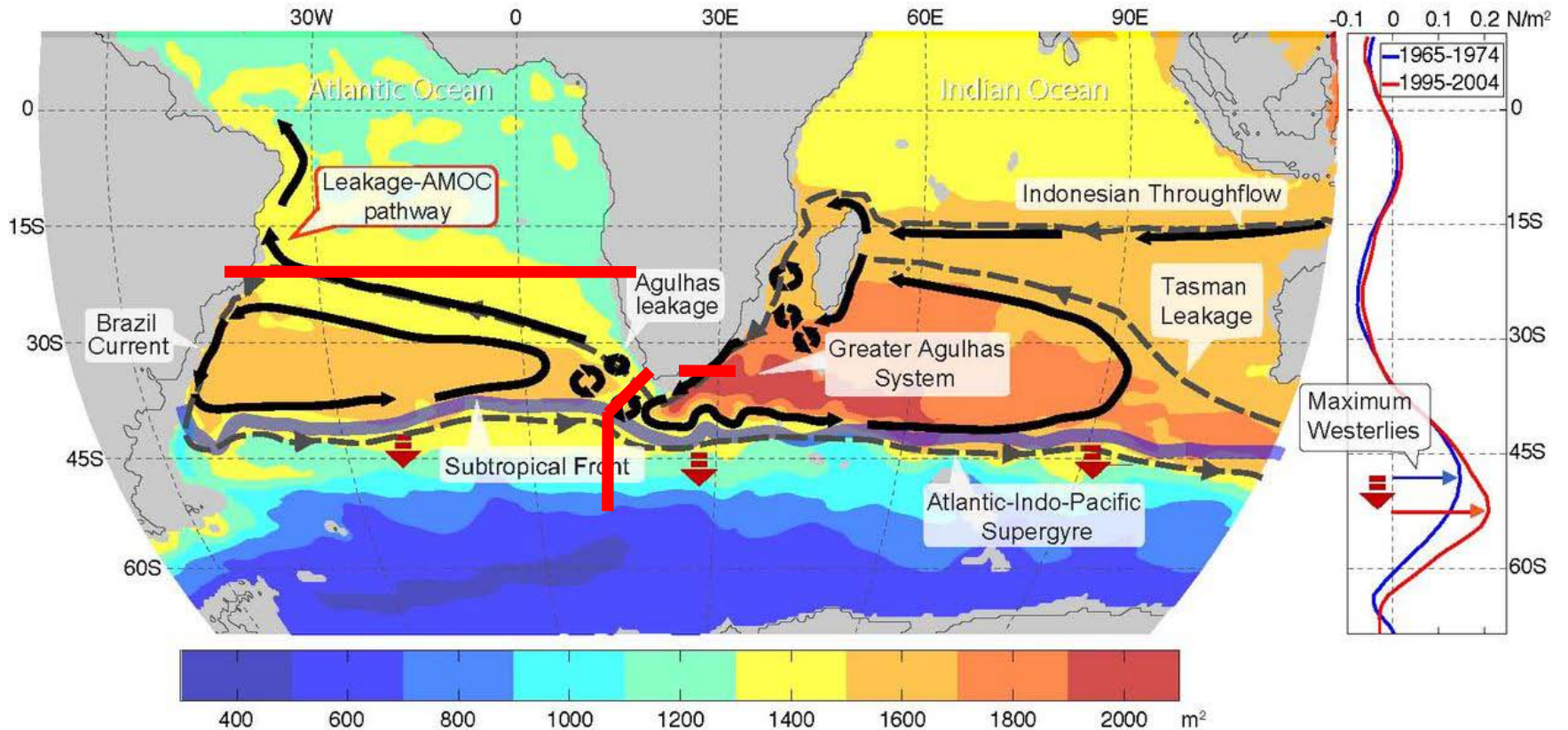


Leakages

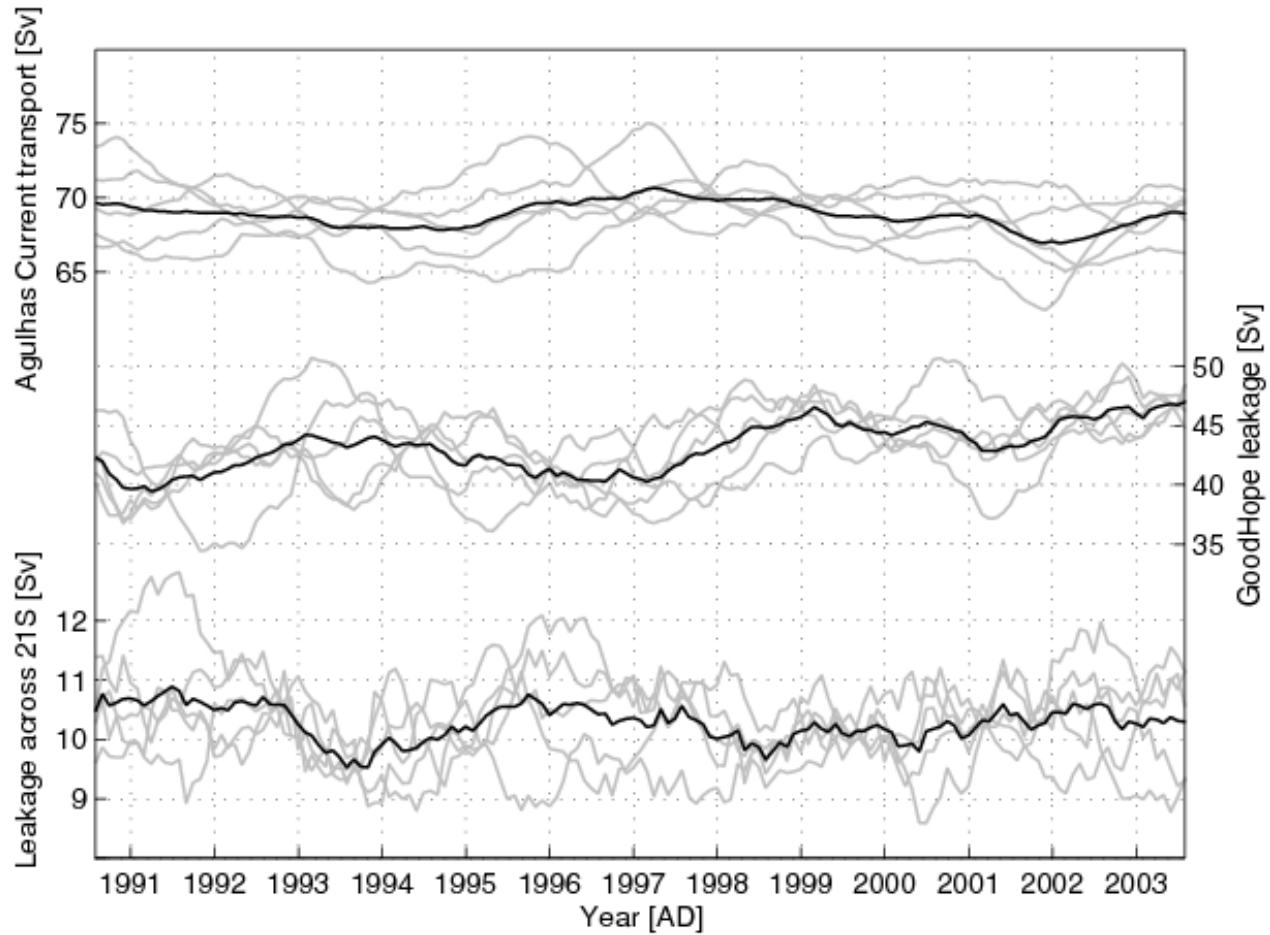
■ Lagrangian analysis

- Monthly 3D velocity fields, 1980-2005
- Release numerical floats
- Agulhas Current
 - 110,000
 - entire water column
- East Australian Current
 - 80,000
 - upper 2500 m

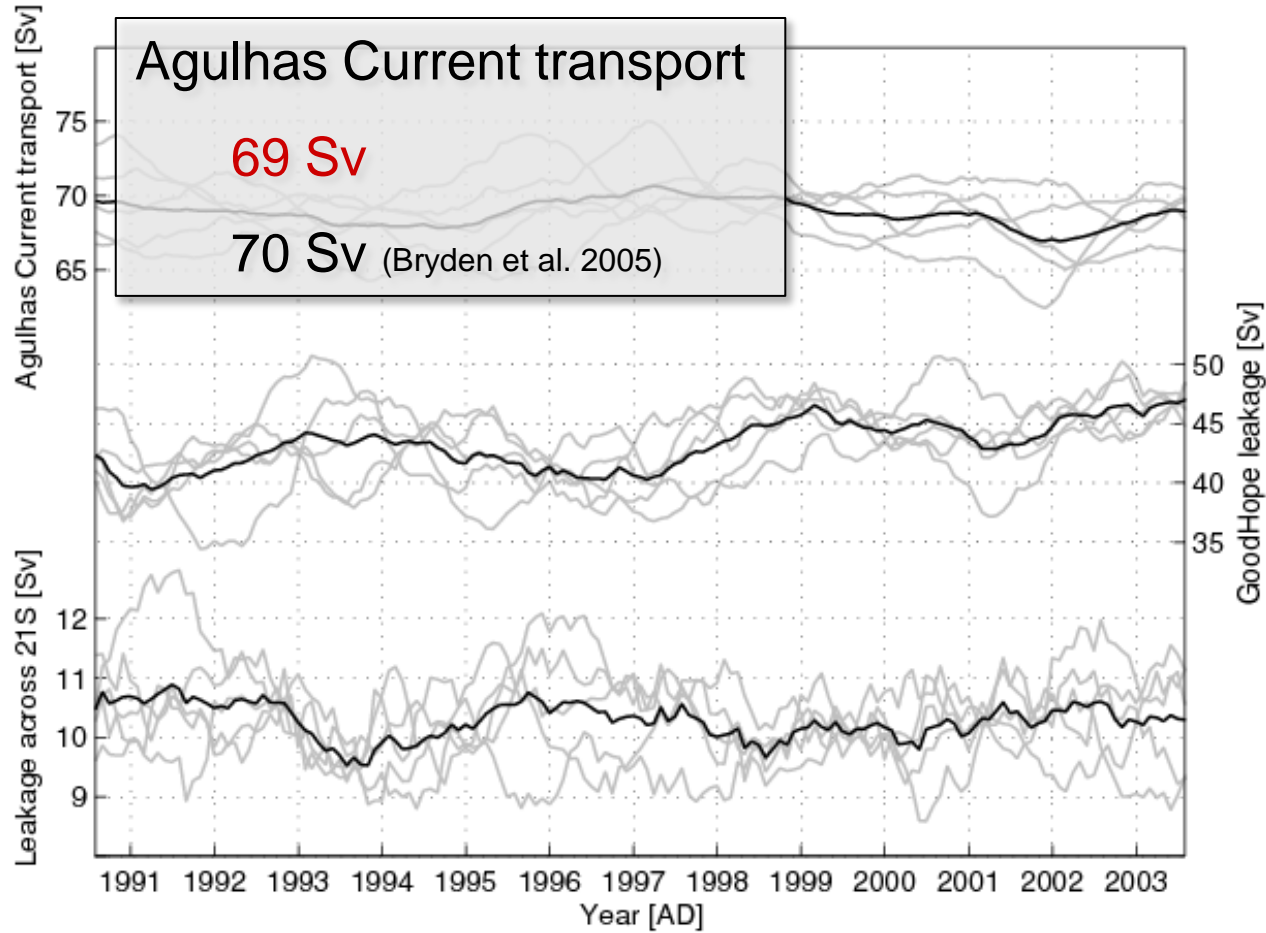
Agulhas Leakage



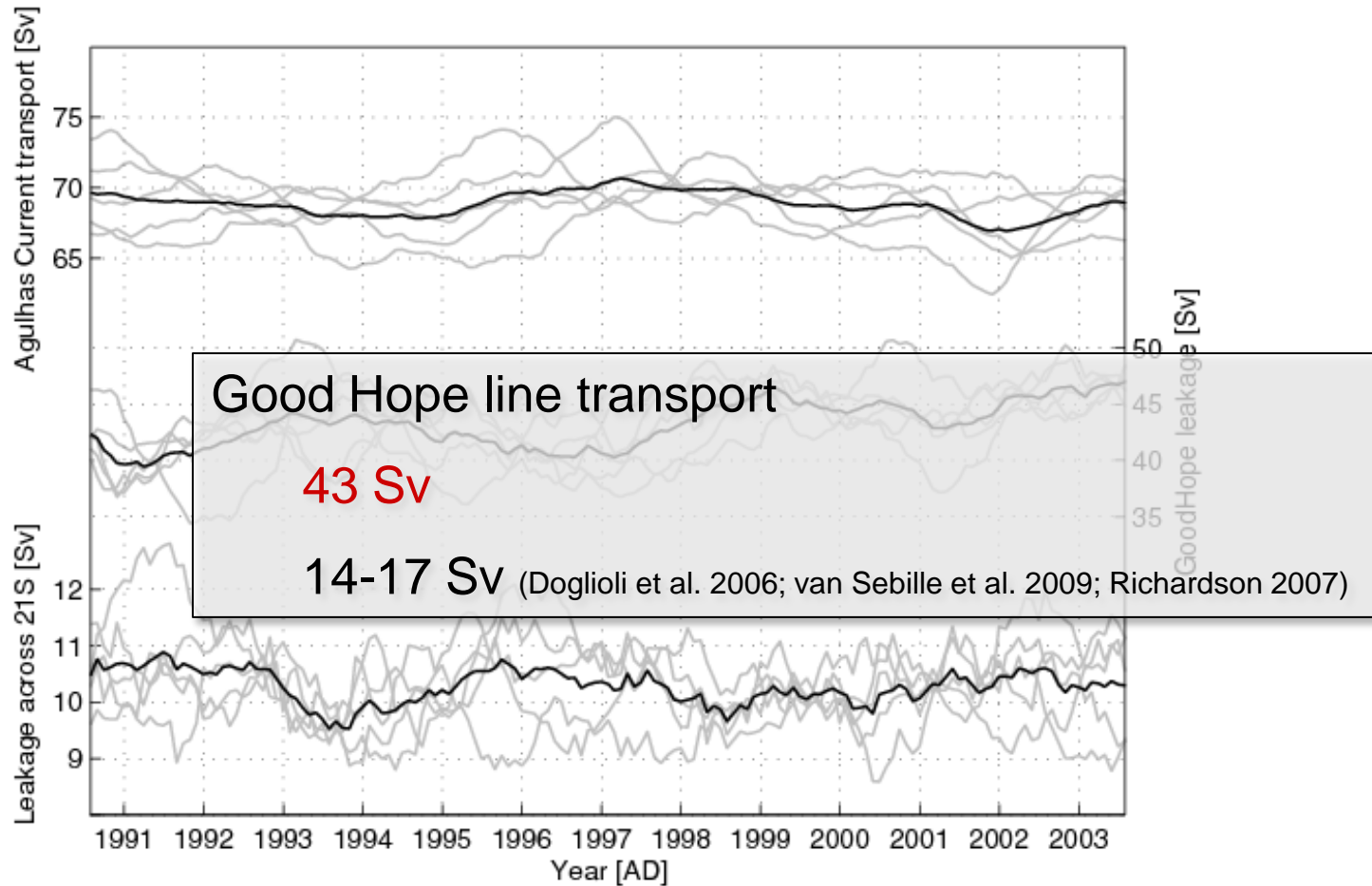
Agulhas Leakage



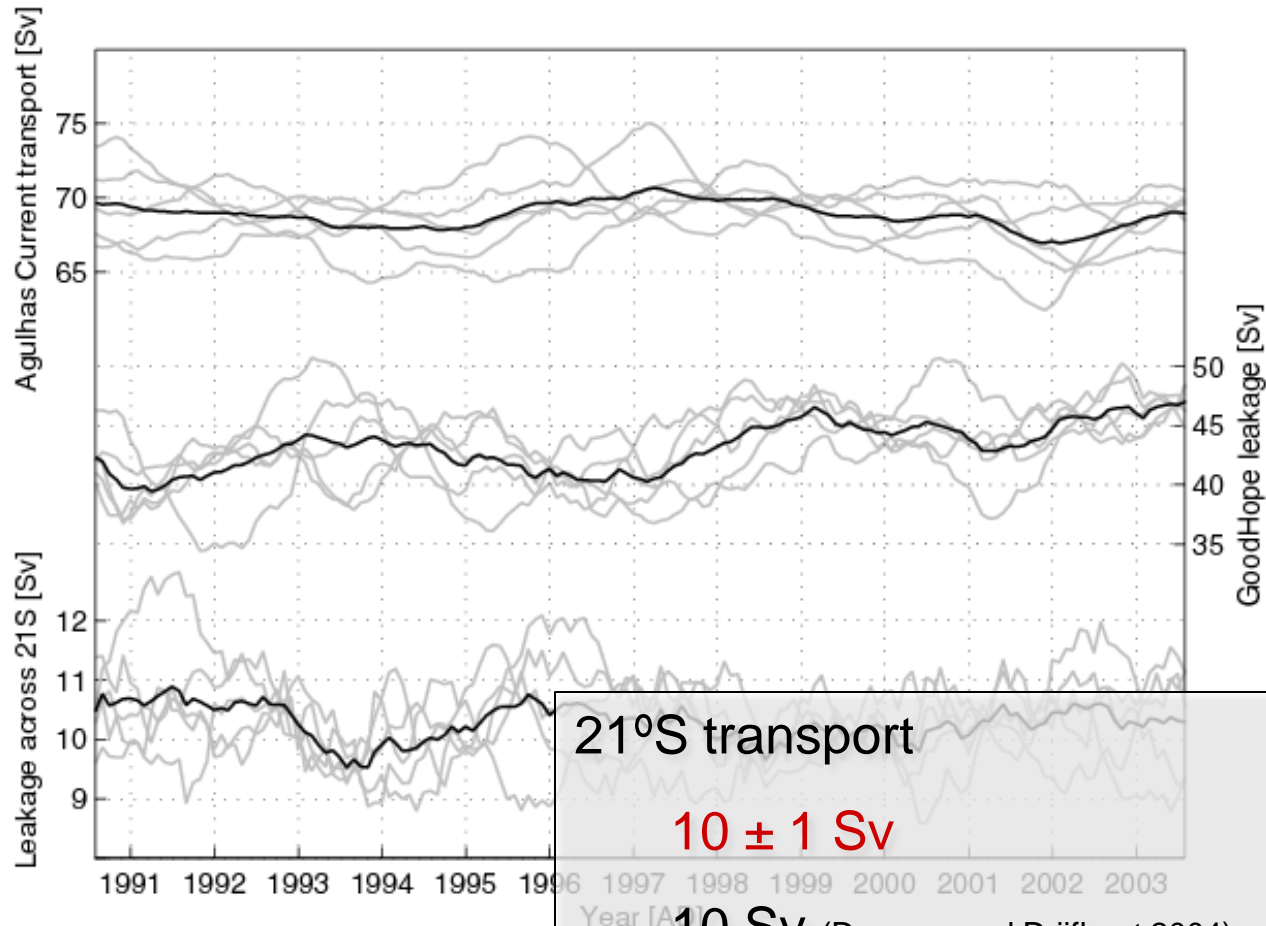
Agulhas Leakage



Agulhas Leakage



Agulhas Leakage



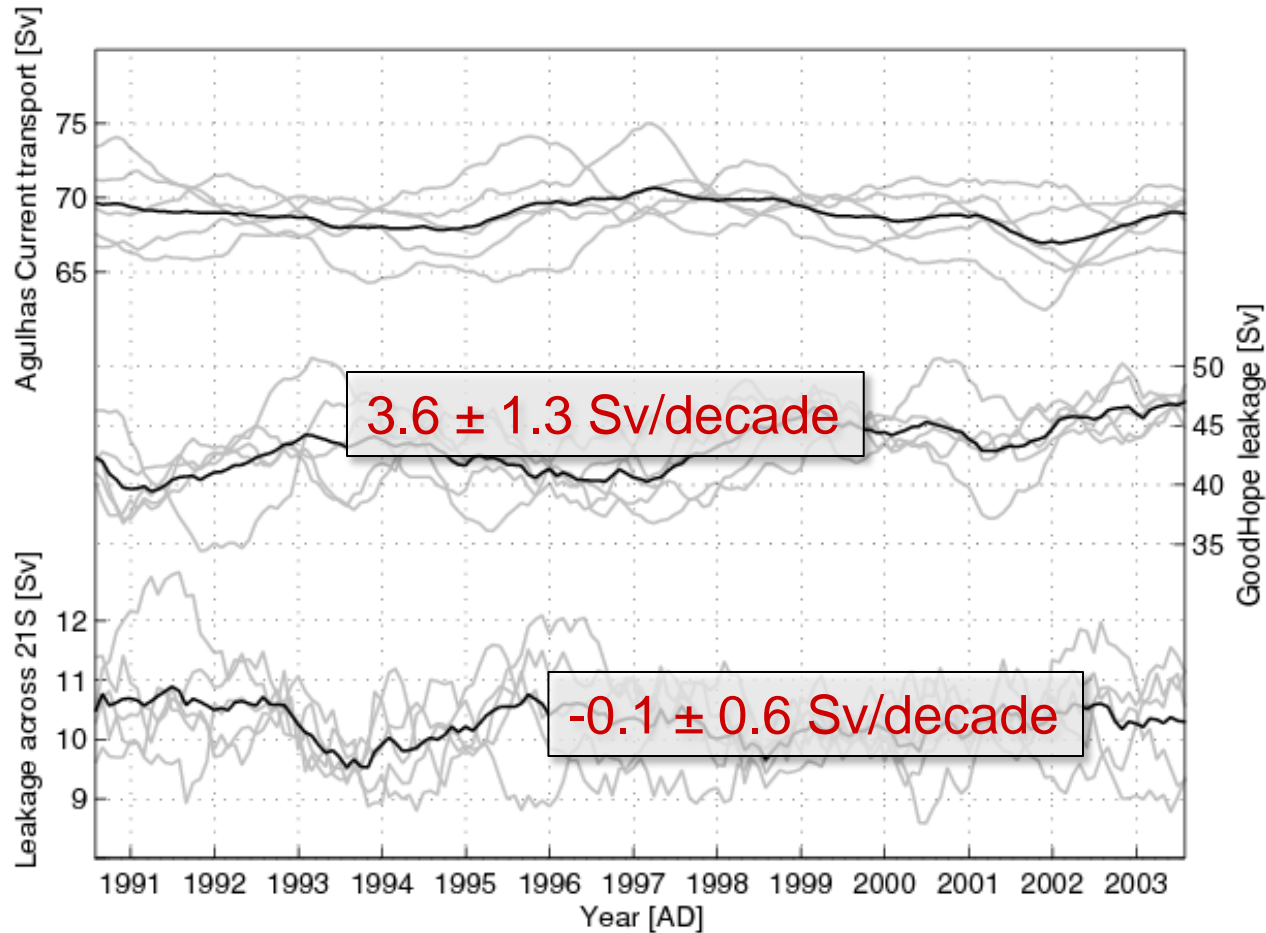
21°S transport

10 ± 1 Sv

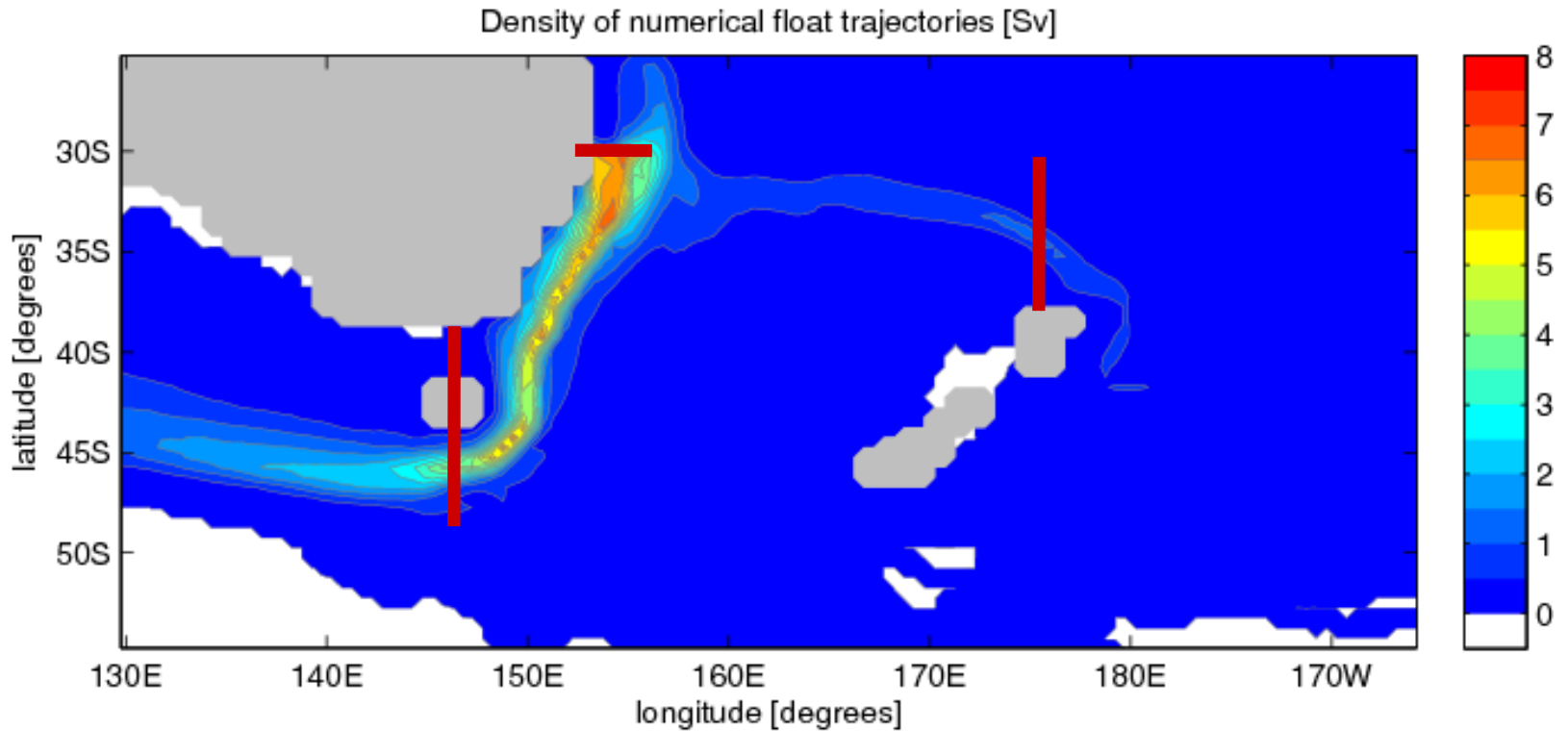
10 Sv (Donners and Drijfhout 2004)

4 Sv (Biastoch et al. 2009)

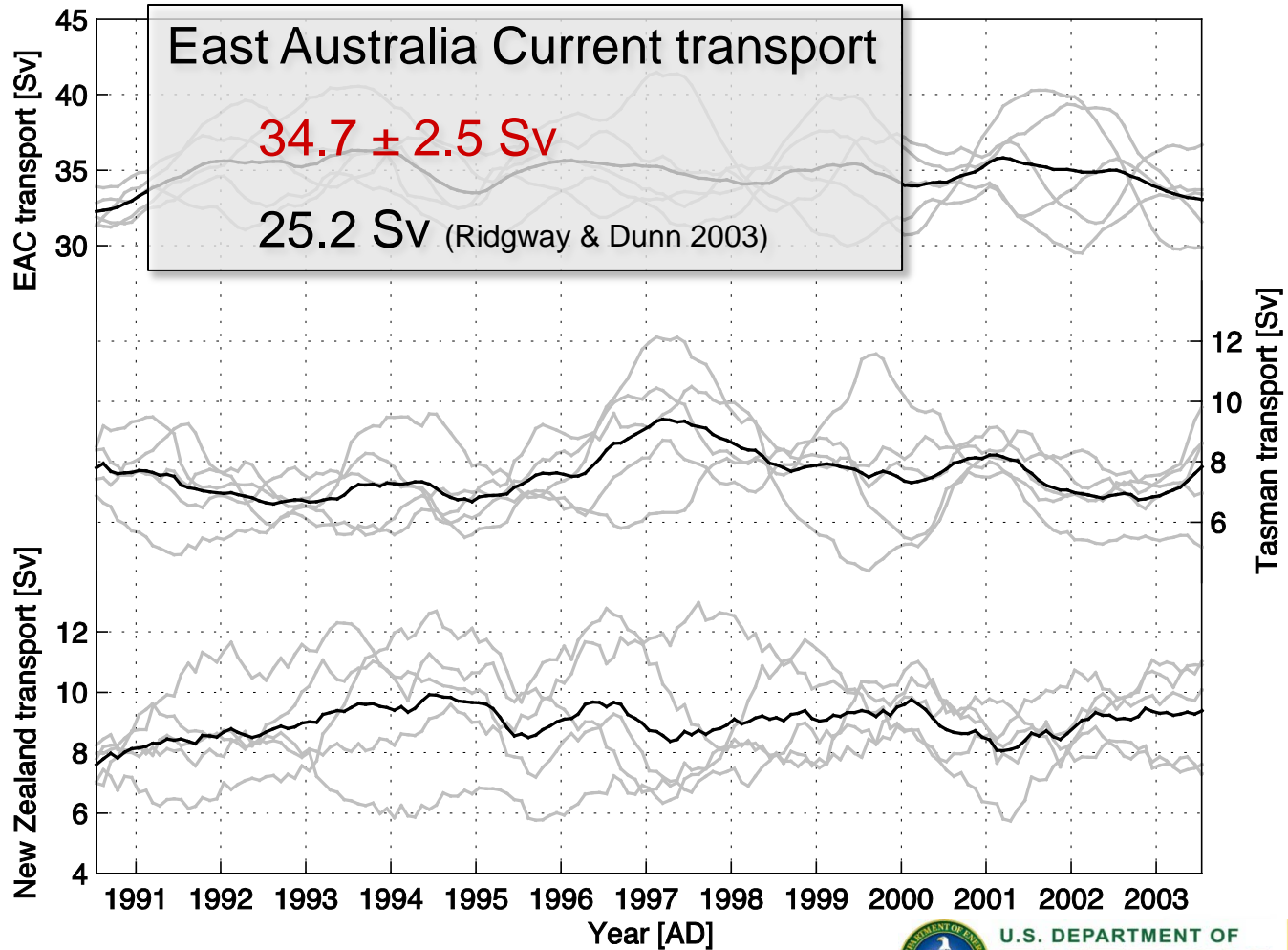
Agulhas Leakage



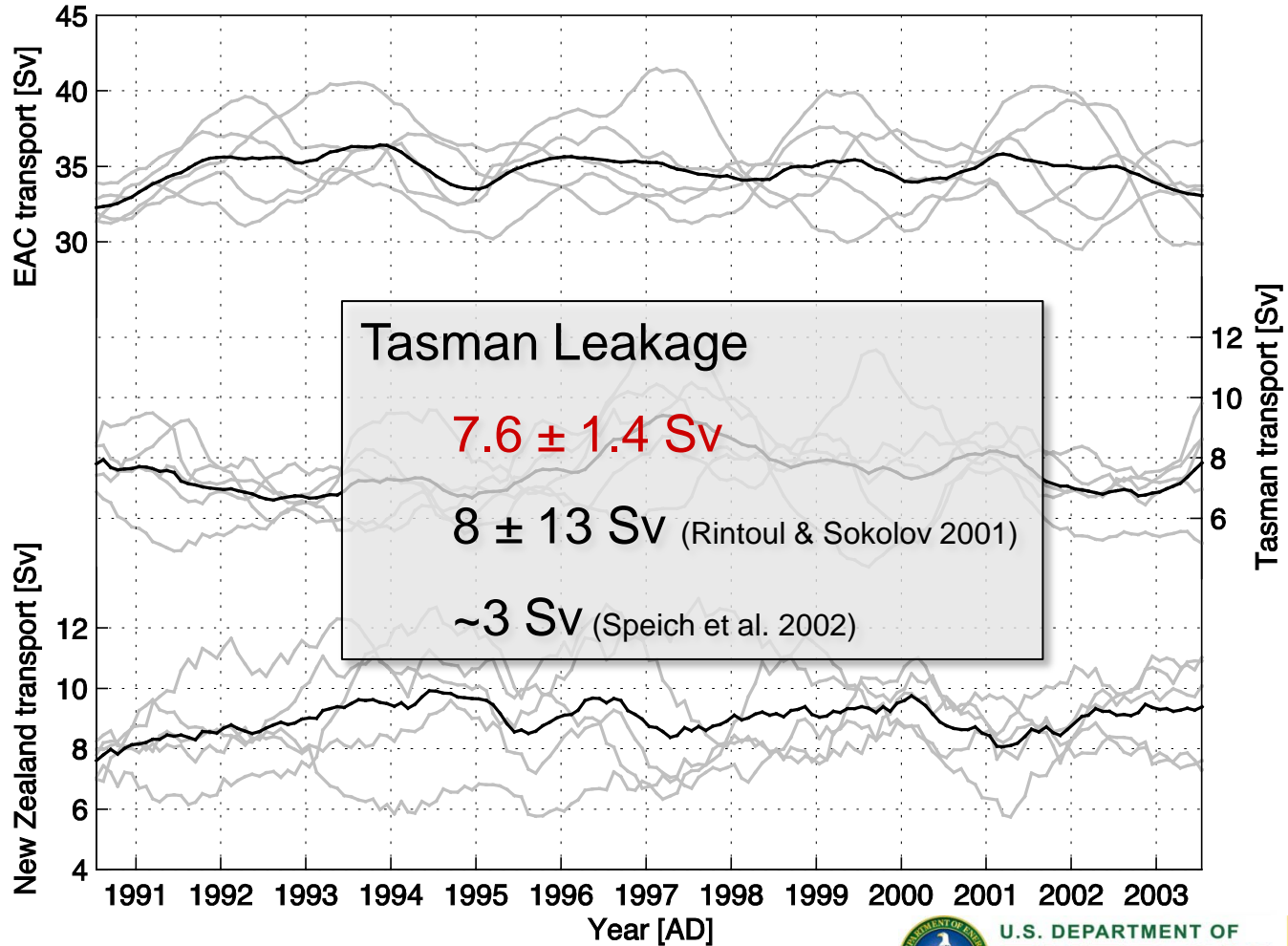
Tasman Leakage



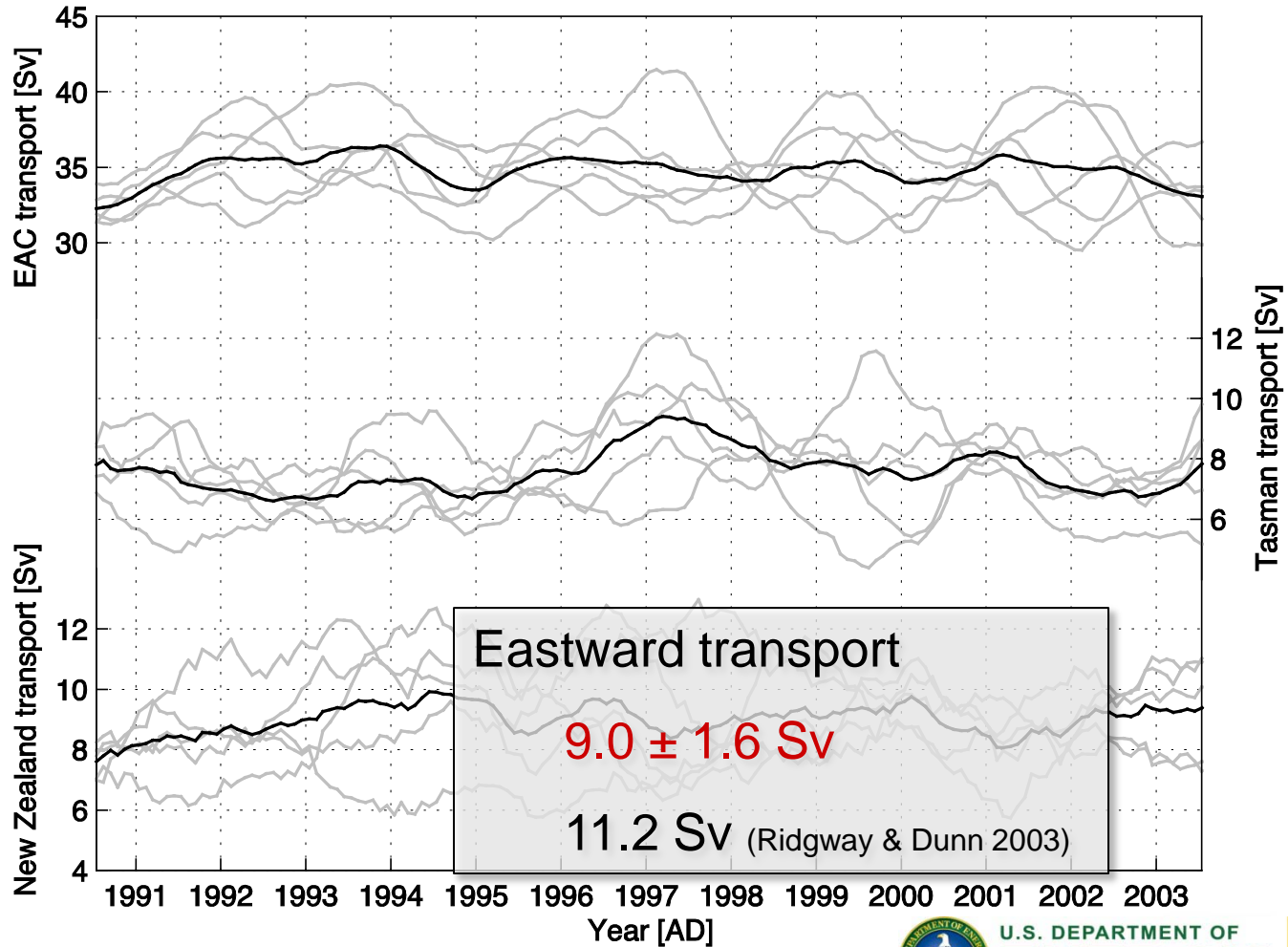
Tasman Leakage



Tasman Leakage



Tasman Leakage



Conclusions: Water Masses

- **Inadequate ventilation of SAMW and AAIW**
 - Too shallow mixed layers
 - Cause
 - Changes in mixed-layer physics?
 - Consequences
 - Underestimates sequestration

Conclusions: Water Masses

■ Inadequate ventilation of SAMW and AAIW

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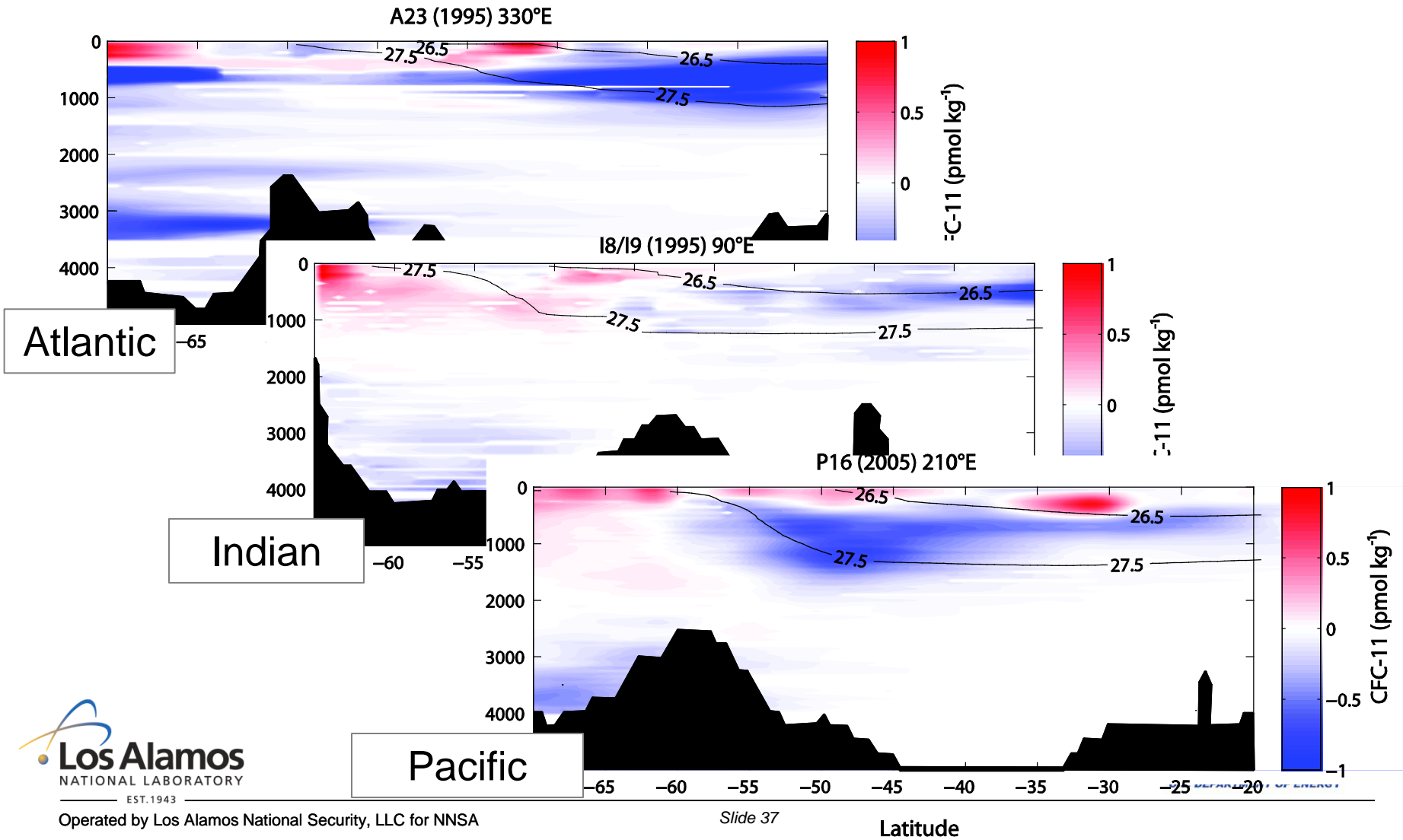
■ Inadequate production and outflow of AABW

- No production in Weddell sea
- Too salty in Ross Sea
- Causes
 - Systematic errors in coupled air-sea-ice system?
 - Overflow parameterization?
- Consequences
 - Too stably stratified ocean
 - Underestimates sequestration

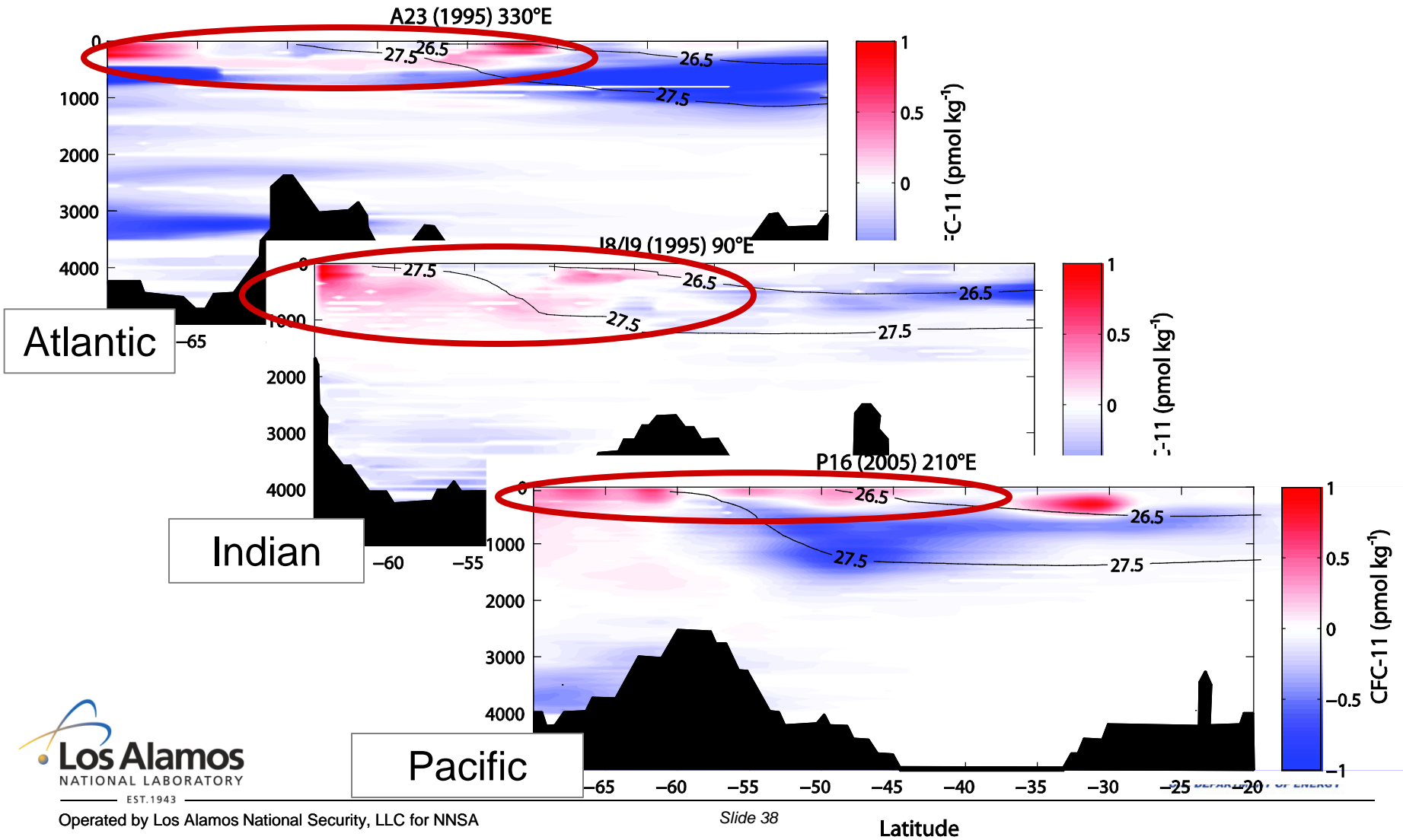
Conclusions: Transport

- **ACC still too strong**
 - Positive wind stress bias?
- **Agulhas Leakage too strong**
 - May be okay, since most recirculates
- **Tasman Leakage okay**

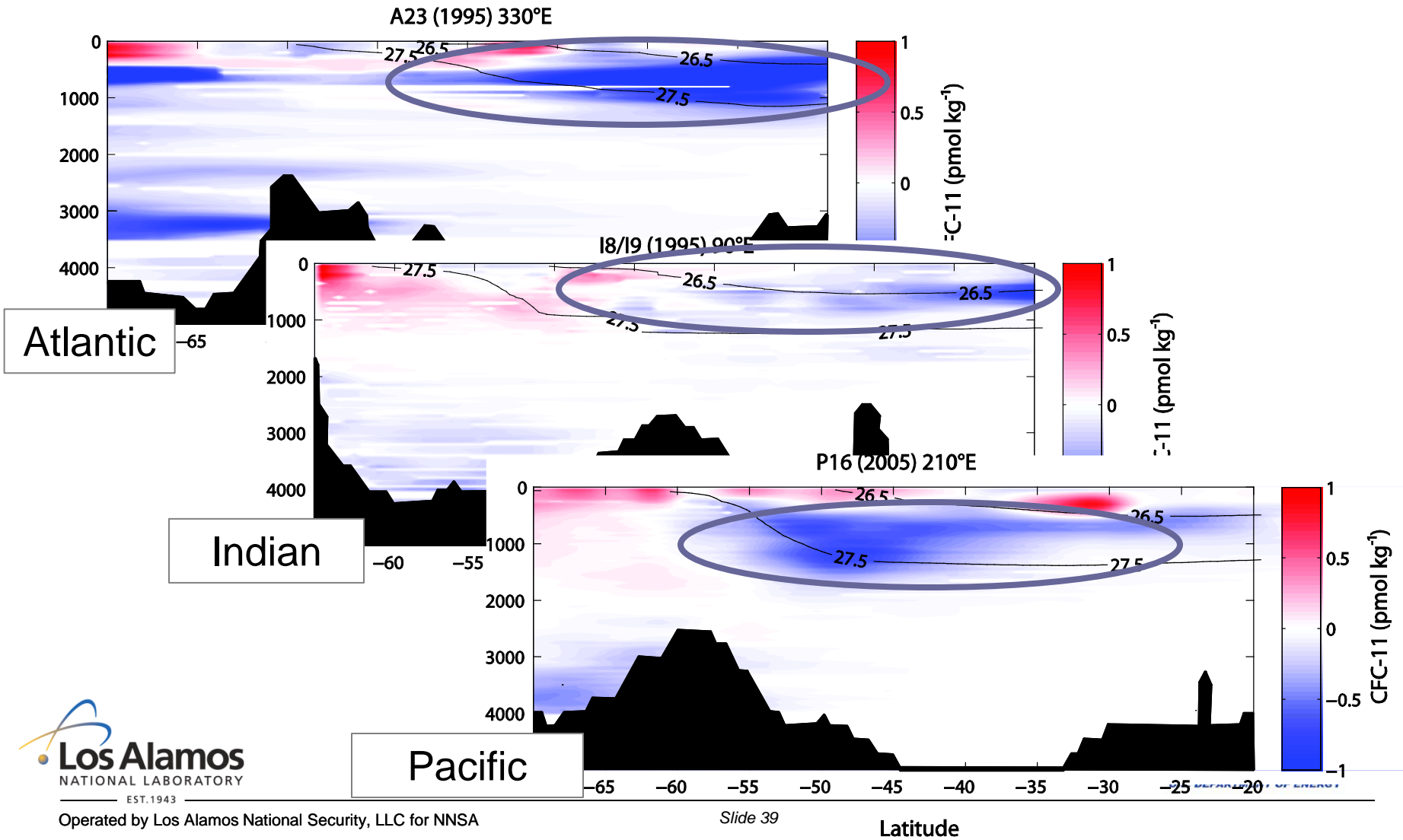
CFC-11



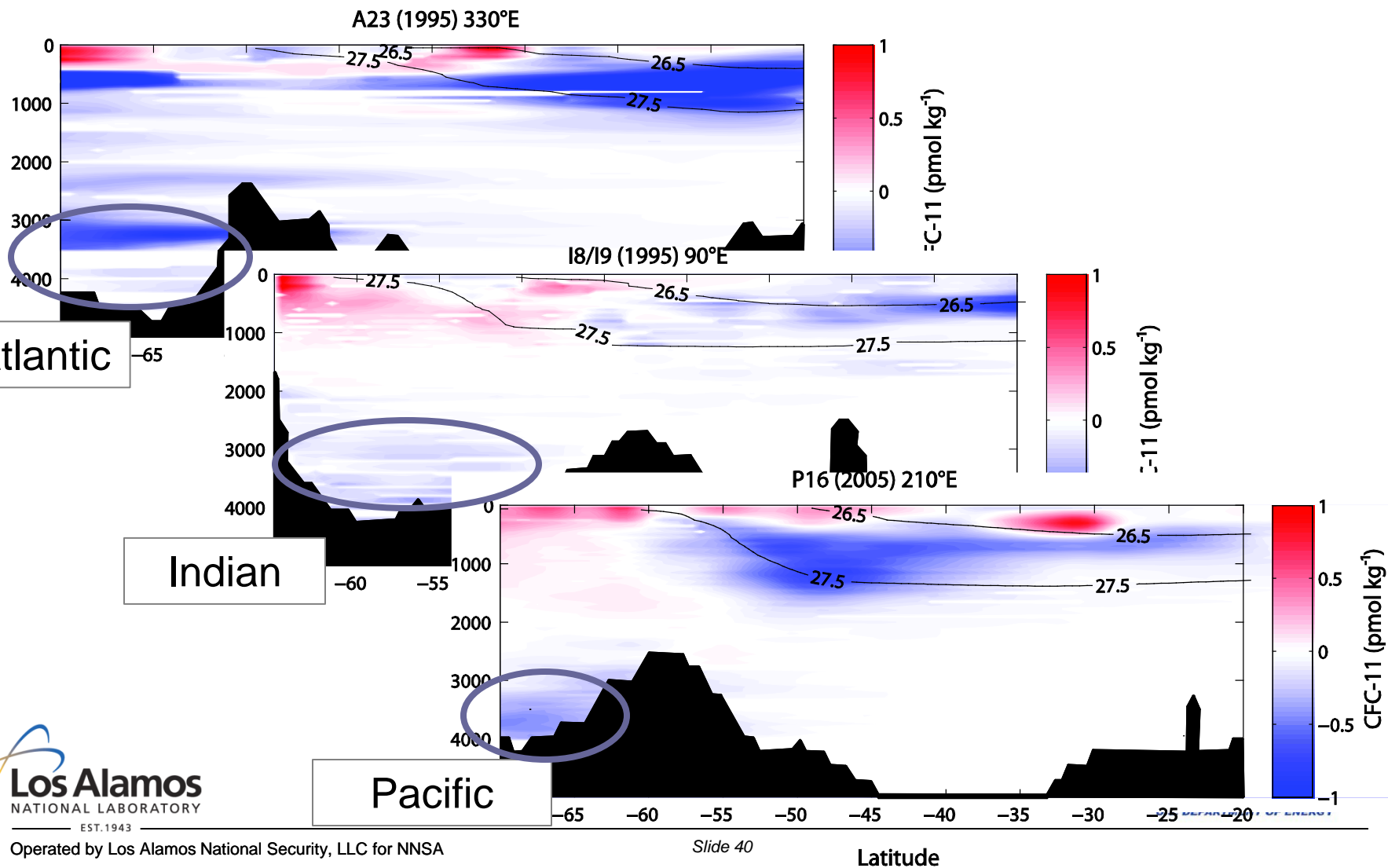
CFC-11



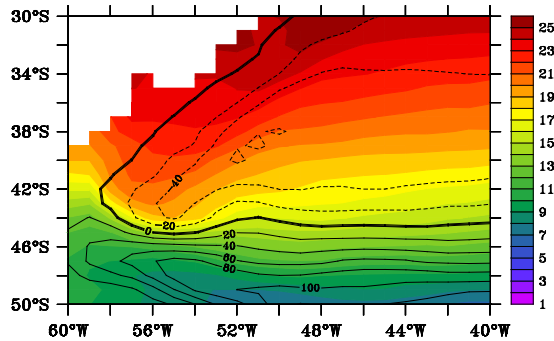
CFC-11



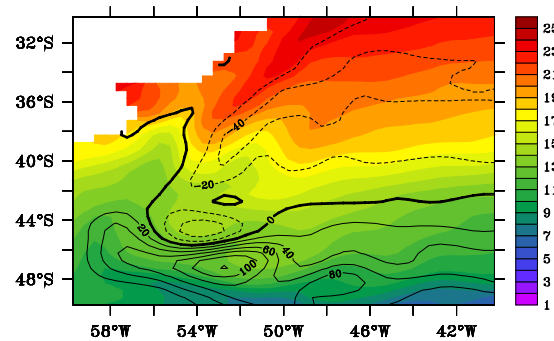
CFC-11



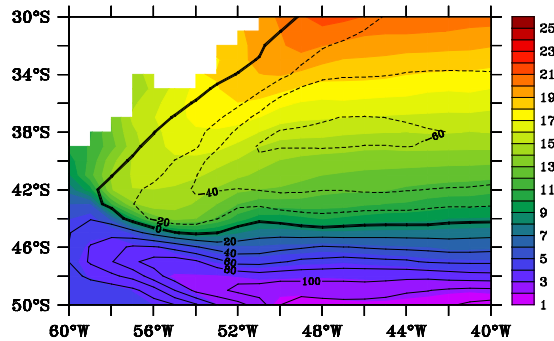
Interocean Exchange: Brazil-Malvinas Confluence



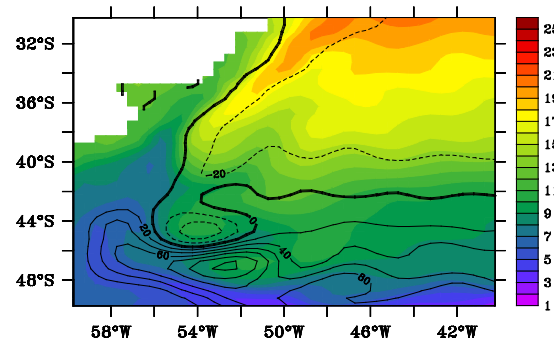
CCSM4 (SST and BSF) JAN



SODA (SST and BSF) JAN



CCSM4 (SST and BSF) JULY



SODA (SST and BSF) JULY