Heat transport variation of the North Pacific subtropical gyre interior flow change during 1993-2012

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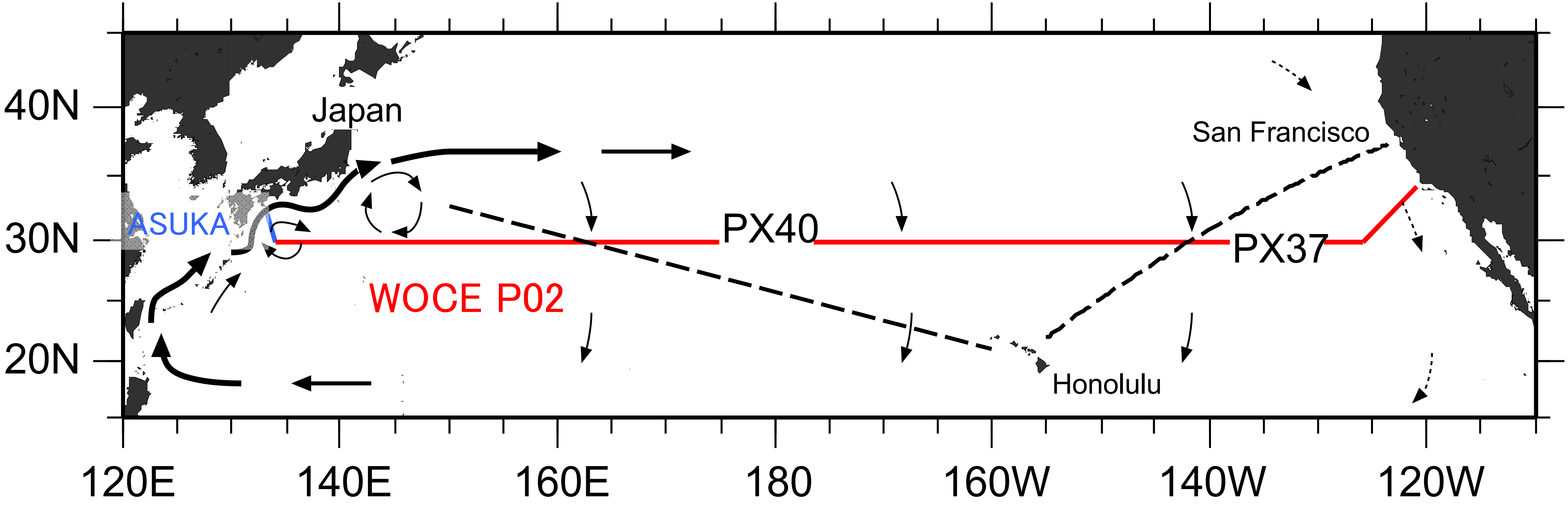
Introduction



Net heat transport

$$Q_{\mathrm{net}} = \rho C_p (T_{\mathrm{K}} - T_{\mathrm{I}}) V_{\mathrm{K}}$$

Kuroshio volume transport-weighted temp (VTWT)

Bryden & Imawaki (2001), Nagano et al. (2010)

Interior flow VTWT

Bryden & Imawaki (2001), Nagano et al. (2009, 2012)

Gyre volume transport

Imawaki et al. (2001)
Sugimoto et al. (2010)
Nagano et al. (2013)

Estimated T_I at WOCE P02 (30˚N) line

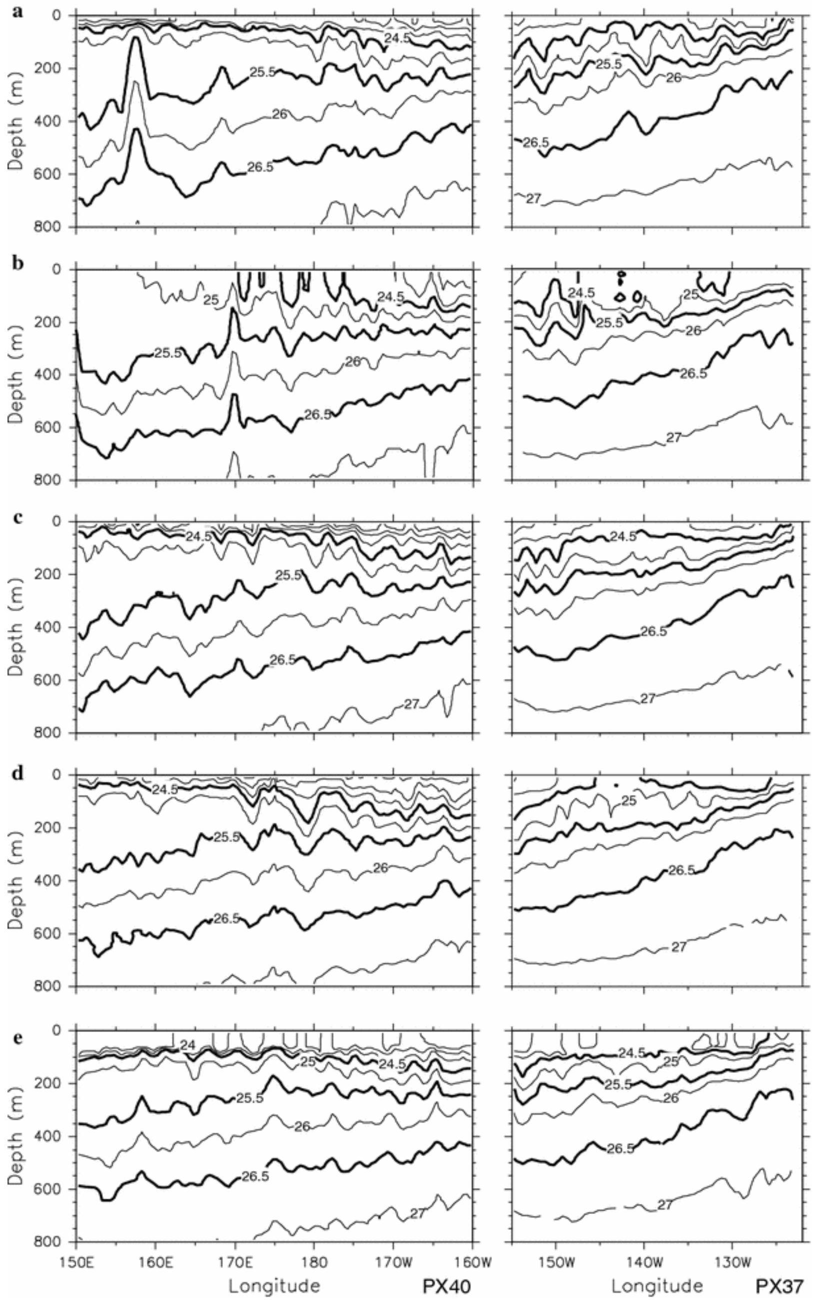
Bryden and Imawaki (2001)
October 1993—January 1994 15.8˚C

Nagano et al . (2009, 2010)
June—August 2004 15.4˚C

Difference = 0.4˚C

Is this difference related to climate variations such as Pacific Decadal Oscillation (PDO)？

PX37(San Francisco-Hawaii) / PX40(Hawaii-Japan) XBT Obs.



Jun 2004 — 14.1˚C

Mar 2005 — 13.9˚C (min)

Jun 2005 — 14.1˚C

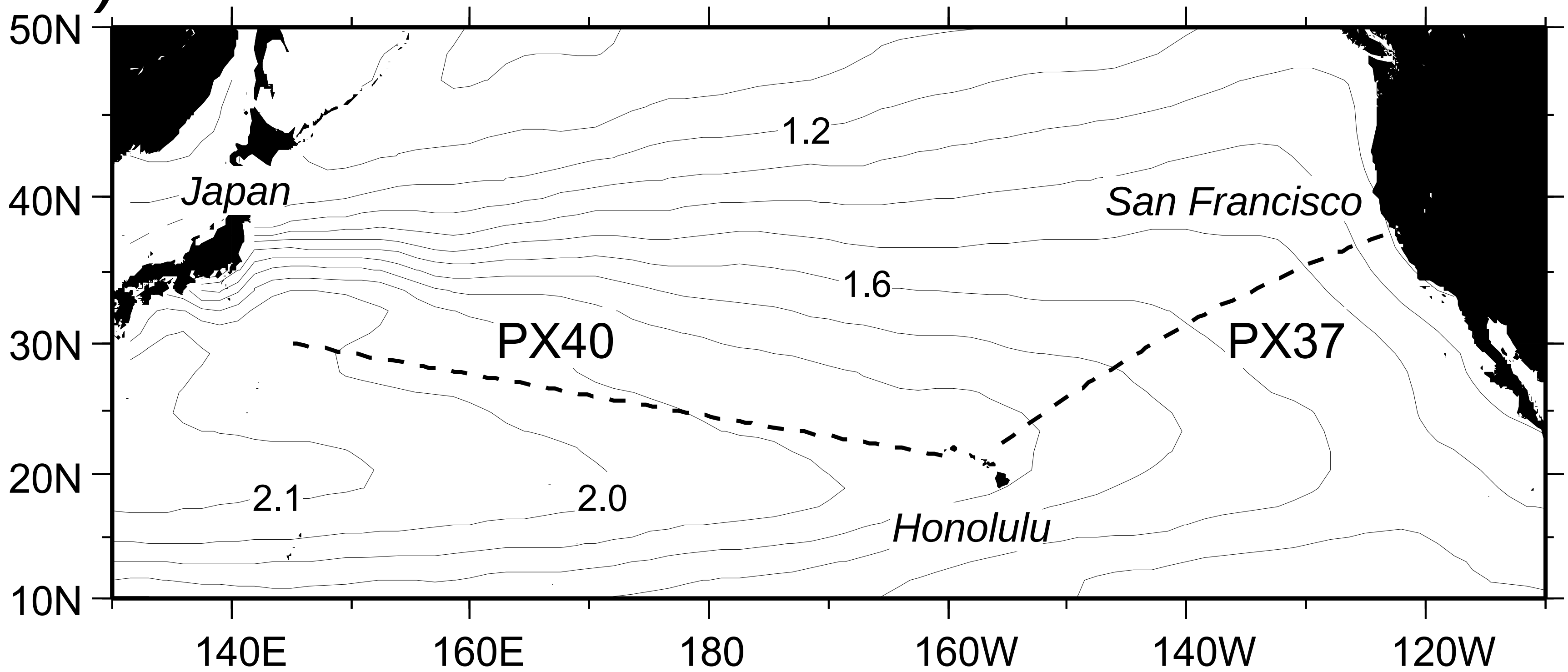
Jun 2006 — 14.4˚C

Nov 2006 — 14.7˚C (max)

ΔT_I maximizes to 0.8˚C. This may be seasonal variation?

Nagano et al. (2012)

Data used for altimetry-based gravest empirical mode (AGEM) method



Temperature and salinity data 2001-2012

Temp. PX40: XBT T-7 (Tsurumi-seiki) PX37: XBT Deep Blue (Sippican)

Salinity PX40/PX37: MOAA GPV Hosoda et al., (2009)

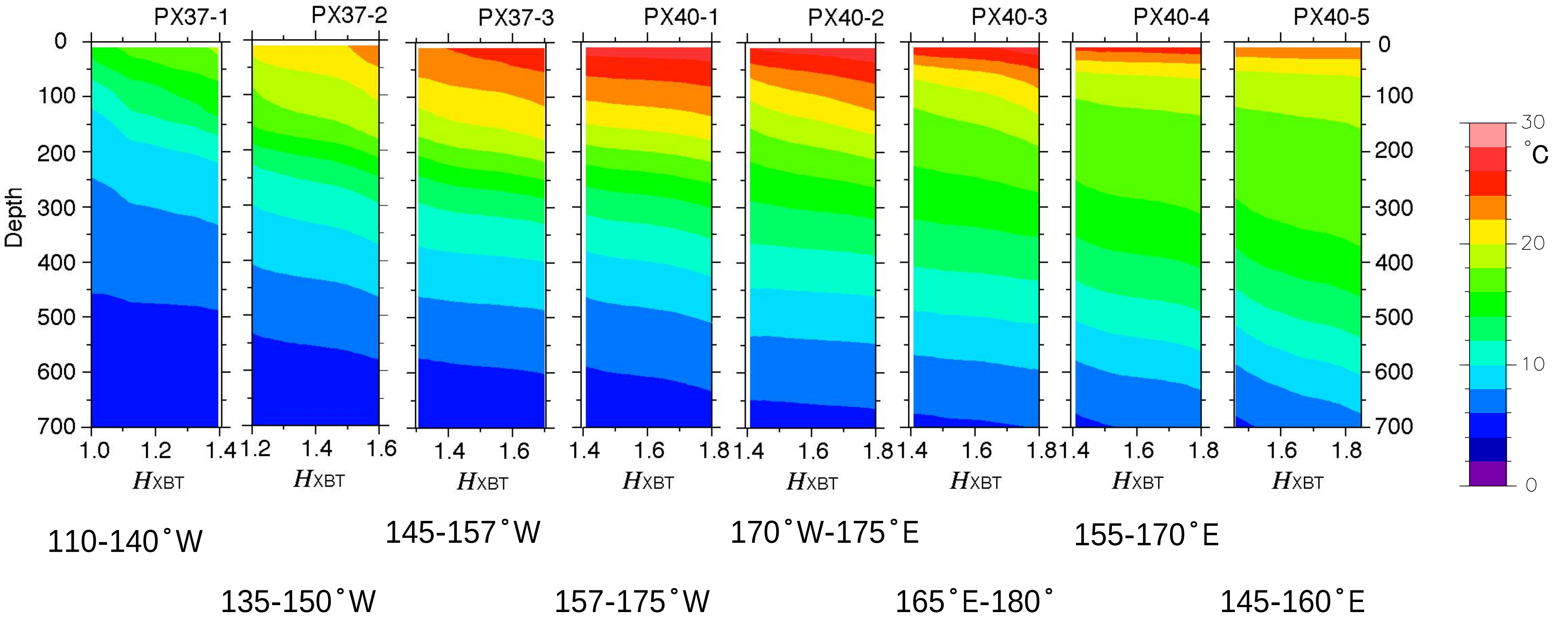
Altimetric sea surface height (SSH)1993-2012

AVISO SSH anomaly

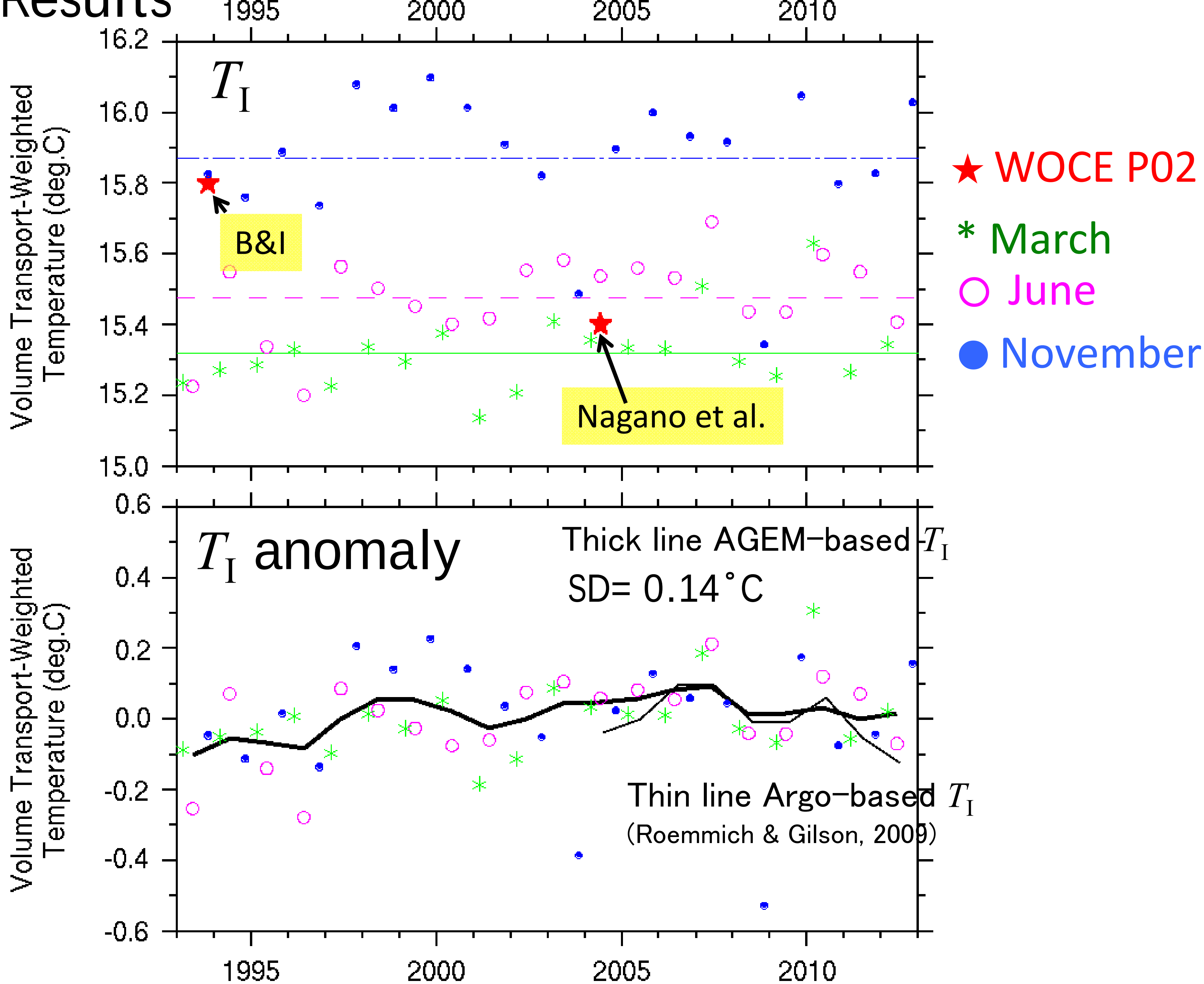
Dynamic height based on World Ocean Atlas 2005
(referred to1000dbar)

AGEM fields

Segment-wise AGEM fields down to 700 dbar in March, June, and November.
For example, pot. temp. AGEM fields in June are shown below.



Results



T_I
★ WOCE P02
* March
○ June
● November
B&I
Nagano et al.
Volume Transport-Weighted Temperature (deg.C)
16.2
16.0
15.8
15.6
15.4
15.2
15.0
1995
2000
2005
2010
T_I anomaly
Thick line AGEM−based T_I
SD= 0.14˚C
Thin line Argo−based T_I
(Roemmich & Gilson, 2009)
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6

Contributing factor to year-to-year T_{I} variation

Decomposition into pot. temp. θ and velocity v variation components $\theta = \overline{\theta} + \theta'$ $\quad v = \overline{v} + v'$

$$T_{\mathrm{I}}'(\sigma_\theta) = \int_{D(\sigma_\theta+\Delta\sigma_\theta/2)}^{D(\sigma_\theta-\Delta\sigma_\theta/2)} \int_{\mathrm{PX37/40}} (\theta'\,\overline{v} + \overline{\theta}\,v' + \theta' v')\,\mathrm{d}x\mathrm{d}z \Big/ V$$

$$= T_1'(\sigma_\theta) + T_2'(\sigma_\theta) + T_3'(\sigma_\theta)$$

$$T_1'(\sigma_\theta) = \int_{D(\sigma_\theta+\Delta\sigma_\theta/2)}^{D(\sigma_\theta-\Delta\sigma_\theta/2)} \int_{\mathrm{PX37/40}} \theta'\,\overline{v}\,\mathrm{d}x\mathrm{d}z \Big/ V$$

} θ variation component

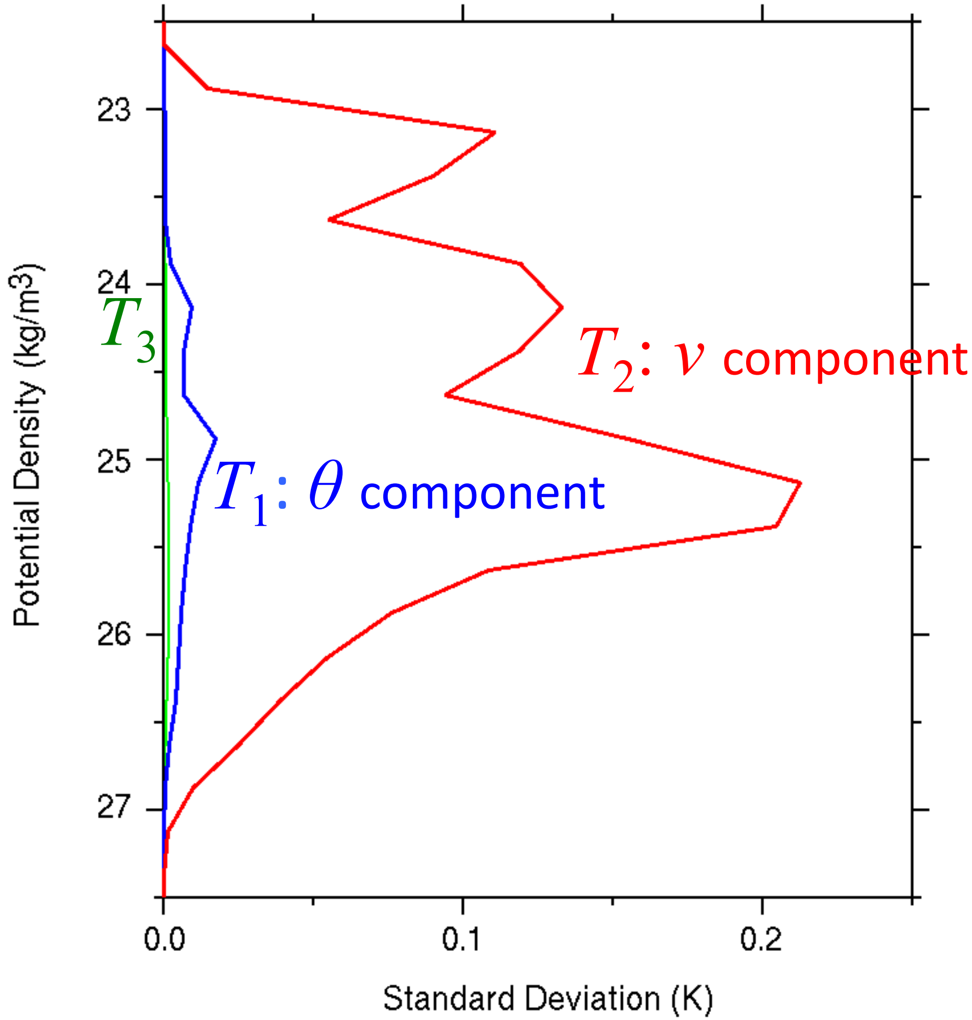
$$T_2'(\sigma_\theta) = \int_{D(\sigma_\theta+\Delta\sigma_\theta/2)}^{D(\sigma_\theta-\Delta\sigma_\theta/2)} \int_{\mathrm{PX37/40}} \overline{\theta}\,v'\,\mathrm{d}x\mathrm{d}z \Big/ V$$

} v variation component

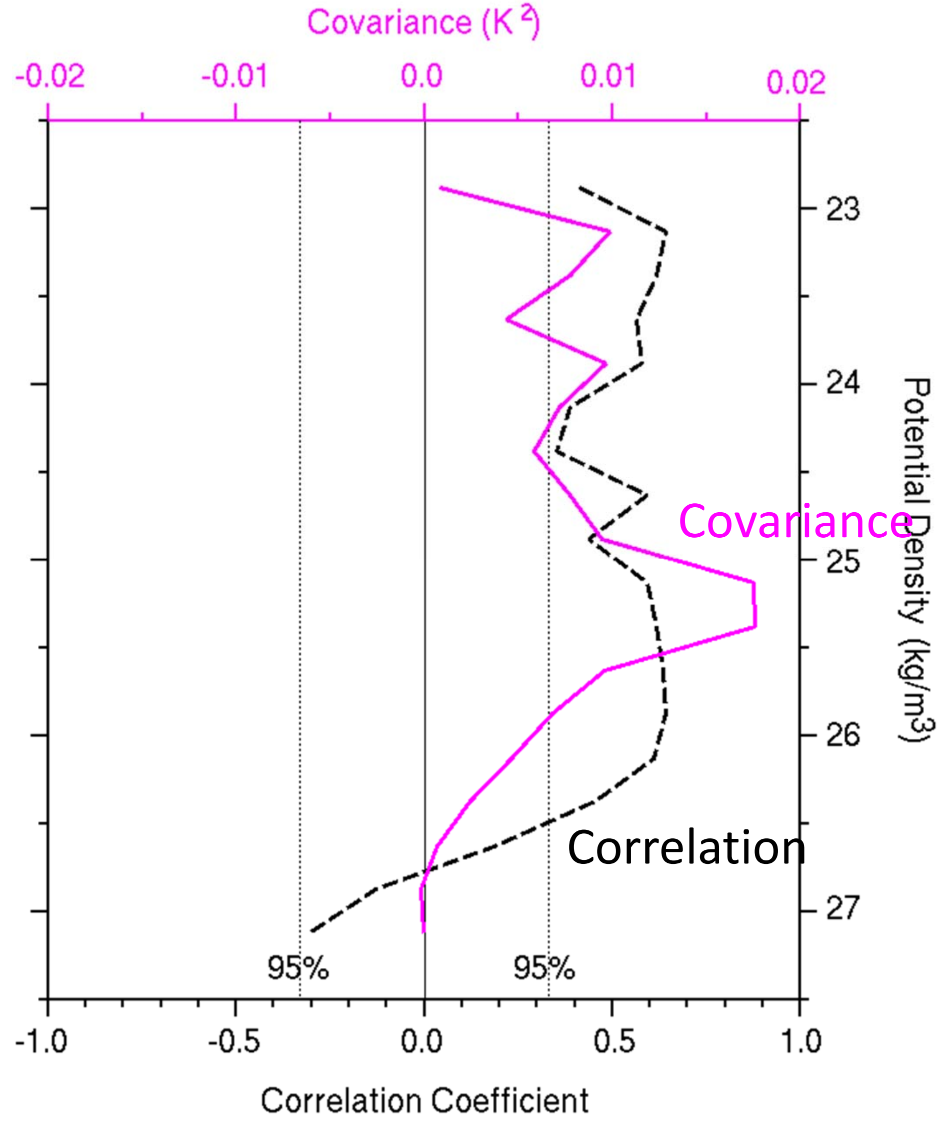
$$T_3'(\sigma_\theta) = \int_{D(\sigma_\theta+\Delta\sigma_\theta/2)}^{D(\sigma_\theta-\Delta\sigma_\theta/2)} \int_{\mathrm{PX37/40}} \theta' v'\,\mathrm{d}x\mathrm{d}z \Big/ V$$

} θ and v component

SD of T_1 , T_2 , and T_3 ($\Delta\sigma_\theta$=0.25kg/cm^3)

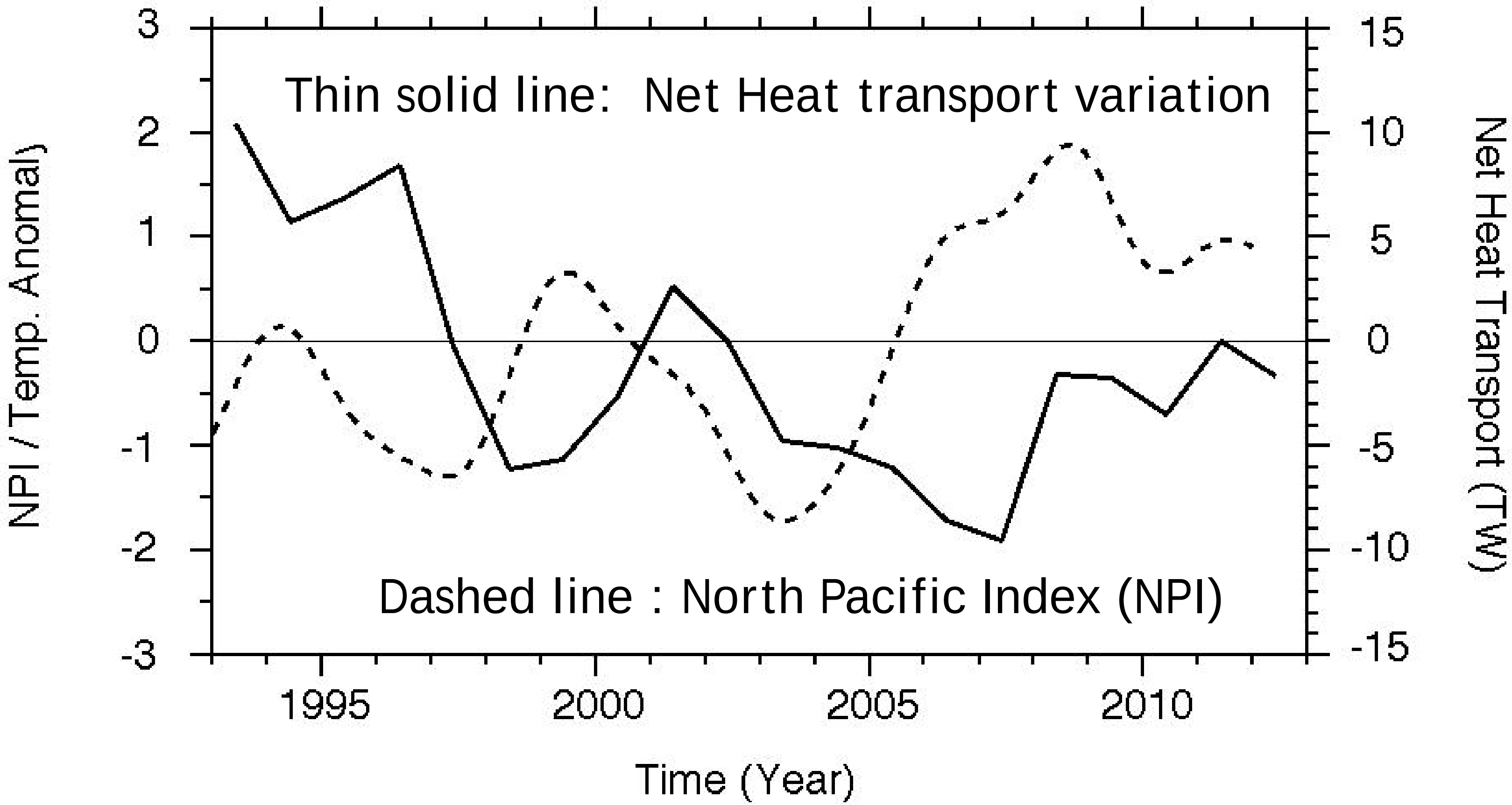


Correlation and covariance between T_{I} and T_2 ($\Delta\sigma_\theta$=0.25kg/cm^3)



Net heat transport variation due to T_{I} variation, Q_{I}

$$Q_{\mathrm{I}}^{'} = -\rho C_p \overline{V}_{\mathrm{STG}} T_{\mathrm{I}}^{'}$$



Summary

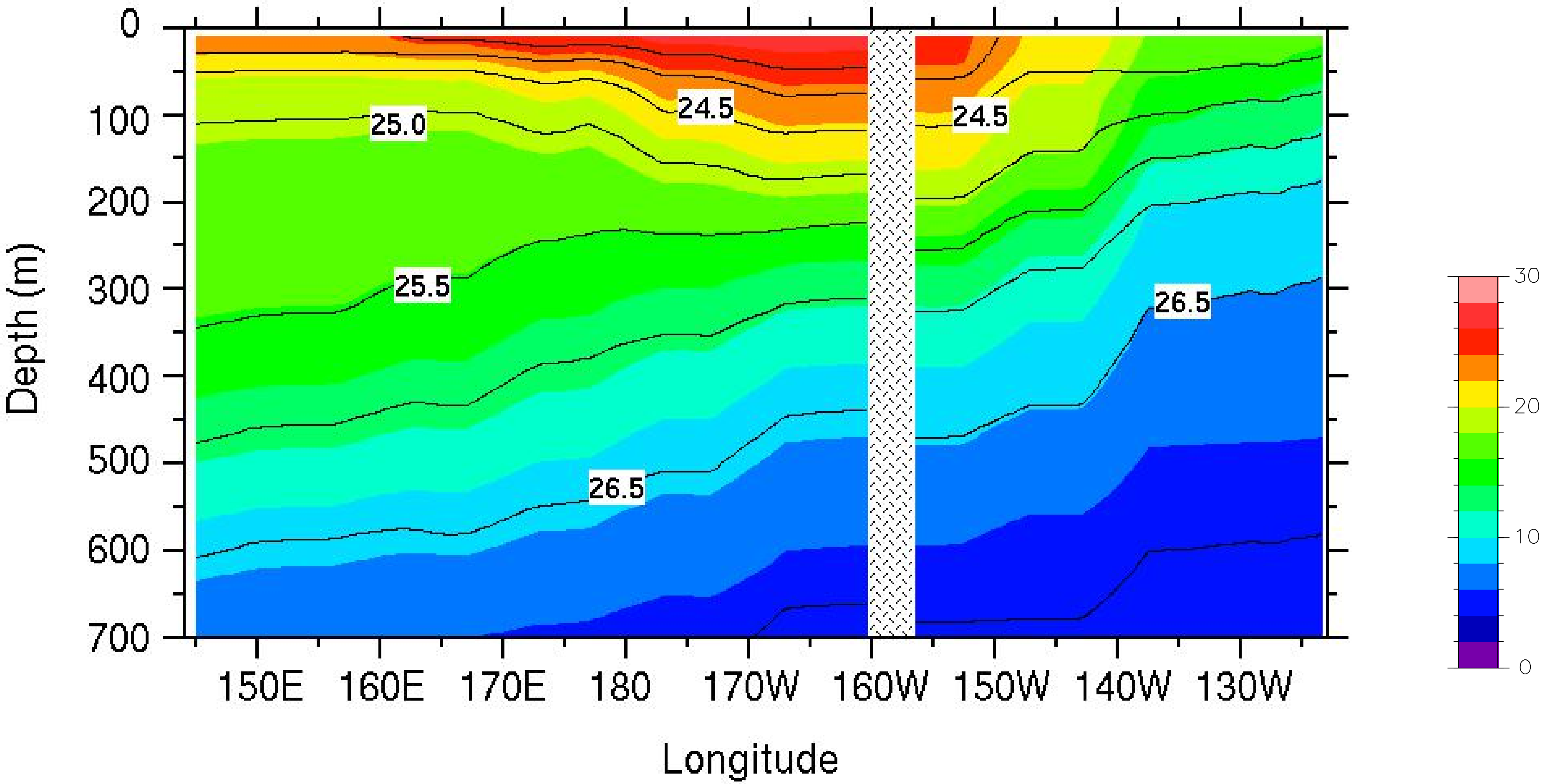
By segment-wise AGEM method, we estimated volume-transport-weighted temperature of the subtropical gyre interior flow at PX37/40 line (San Francisco-Hawaii-near Japan) and separated the year-to-year variation from the mean seasonal variation.

- Year-to-year variation of T_{I} is principally caused by that in volume transport in potential density layer of 25.0-25.5σ_θ.

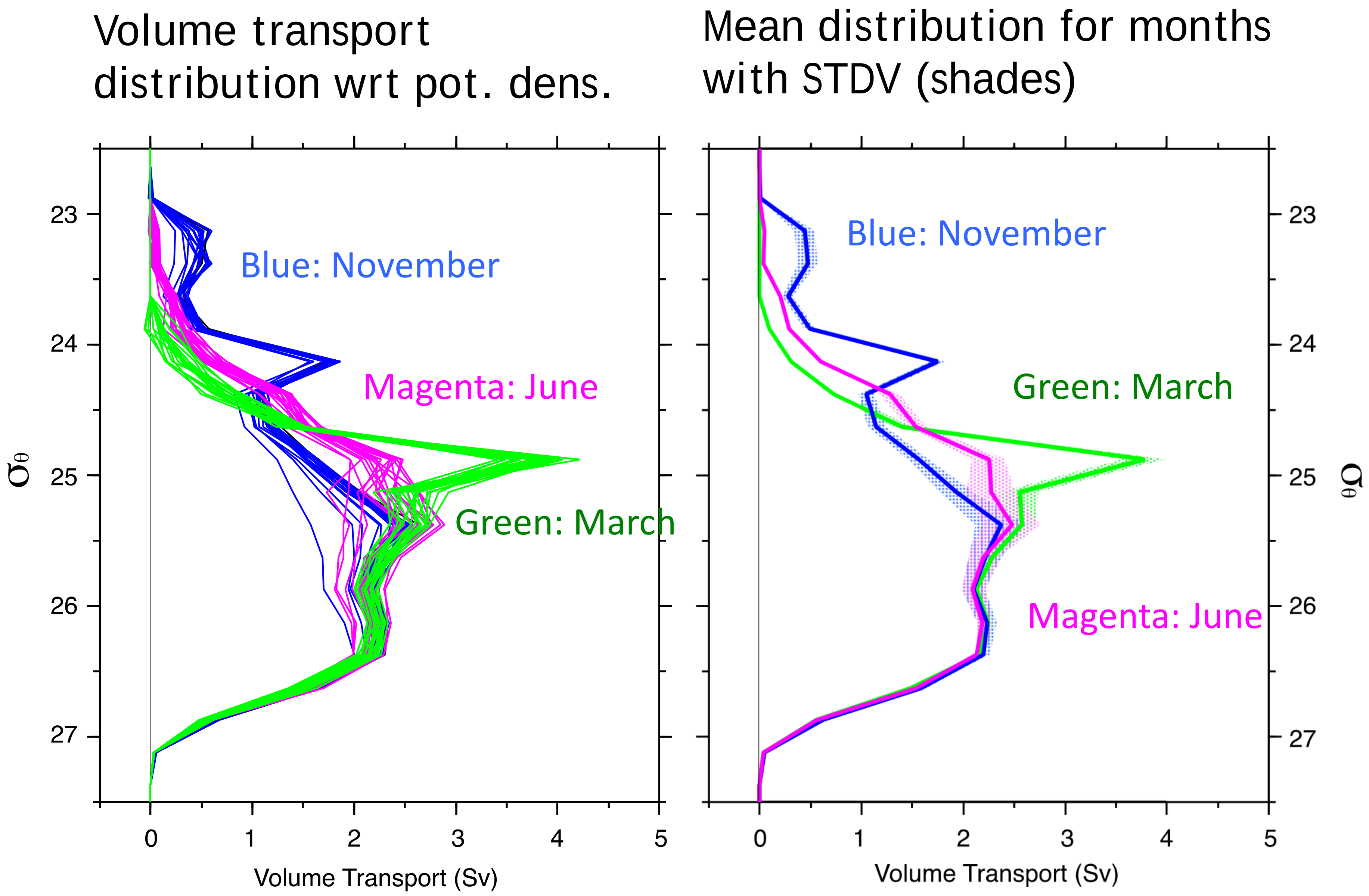
- Troughs of quasi-decadal scale variation of heat transport were found in 1998 and 2007, and lag behind positive phase of PDO by up to 4 years.

Just days ago, this study was accepted in *Ocean Dynamics*.

AGEM-based potential temperature and density in June 2007



Contour: Potential Density, CI=0.5σ_θ
Color shade: Potential temperature


Volume transport
distribution wrt pot. dens.
Mean distribution for months
with STDV (shades)
Blue: November
Magenta: June
Green: March
Volume Transport (Sv)
σθ
23
24
25
26
27
0
1
2
3
4
5

Comparison between T_{I} and climate index