Available **P**otential **E**nergy in the ocean – what is it good for?

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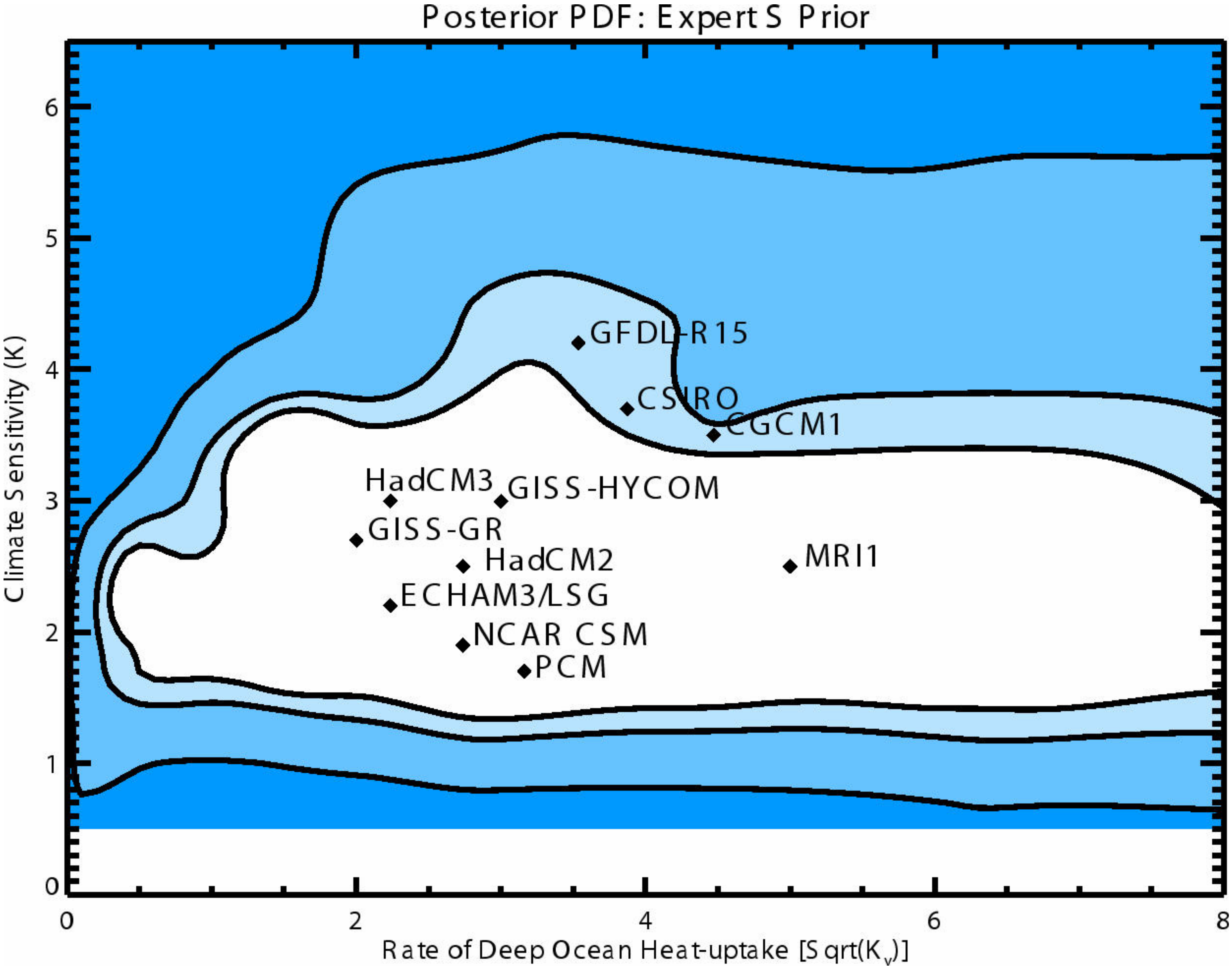


(K_v based on ratio of SSH change to SAT change)

Courtesy: Peter Stone, MIT

Applications…

- Is APE a useful indicator of model drift?
- Which processes contribute to the generation and destruction of APE?
- Do processes like vertical regridding in HYCOM distort the APE balance?

(Turn page for derivation of APE….)

Potential energy per unit column of a fluid column in hydrostatic balance:

$$PE = \int_{zbot}^{ztop} g\rho z\, dz = \int_{ptop}^{pbot} z\, dp$$

where *bot,top* denote bottom and top of fluid column. Integration by parts yields

$$PE = (zp)_{bot} + \int_{zbot}^{ztop} p\, dz = (zp)_{bot} + \frac{1}{g}\int_{ptop}^{pbot} \alpha\, d\frac{p^2}{2}$$

where $\alpha = \rho^{-1}$

Conversion to s coordinates, global integration:

$$PE = \overline{(zp)_{bot}} + \frac{1}{g}\int_{stop}^{sbot} \overline{\alpha \frac{\partial}{\partial s}\frac{p^2}{2}}\, ds$$

where

$$\bar{q} = \frac{\int_{globe} q\, dx\, dy}{\int_{globe} dx\, dy}$$

Define mass-weighted average:

$$\tilde{q} = \overline{q\frac{\partial p}{\partial s}} \Big/ \overline{\frac{\partial p}{\partial s}}$$

With $q = \bar{q} + q^*$ $\qquad q = \tilde{q} + q'$

the integrand can be split 3 ways:

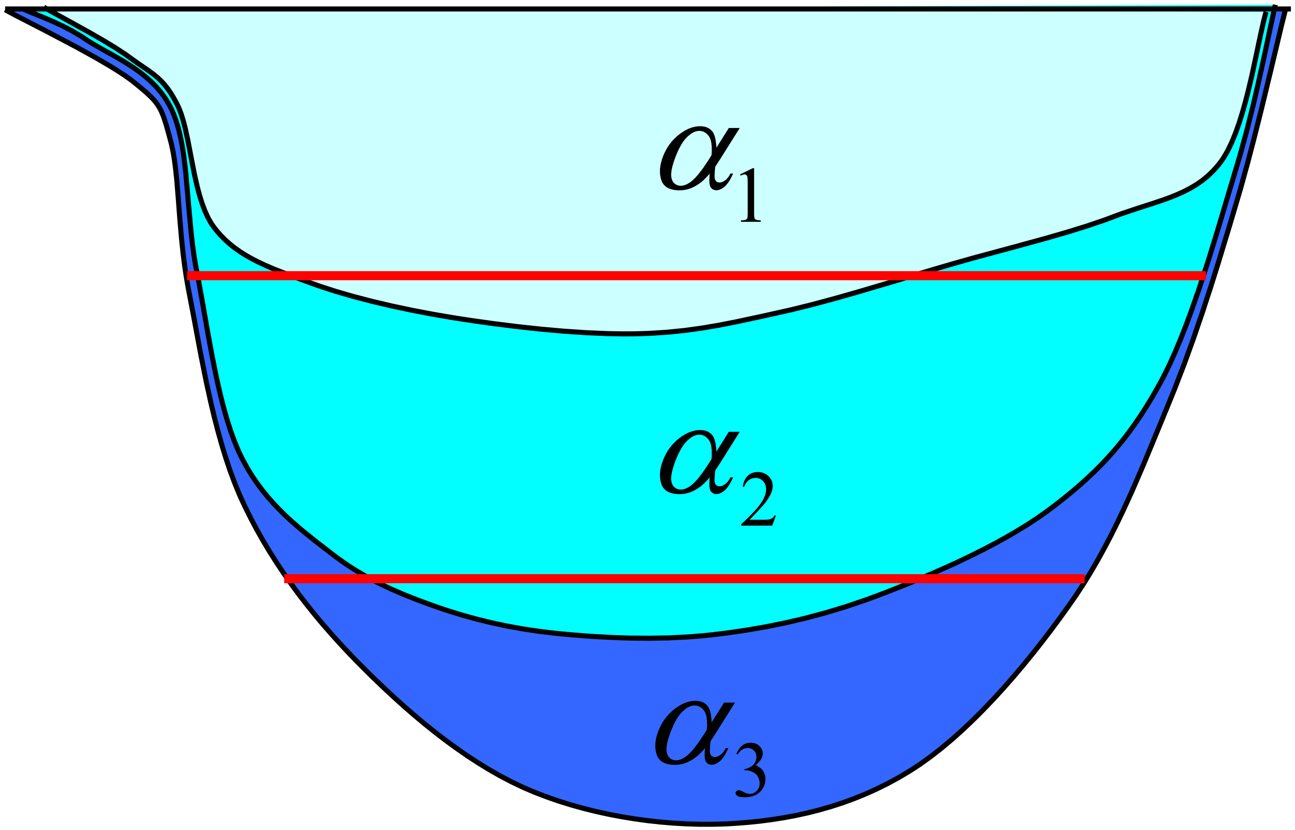
$$\overline{\alpha \frac{\partial}{\partial s}\frac{p^2}{2}} = \tilde{\alpha}\frac{\partial}{\partial s}\frac{\bar{p}^2}{2} + \tilde{\alpha}\frac{\partial}{\partial s}\frac{\overline{p^{*2}}}{2} + \overline{\alpha'\frac{\partial}{\partial s}\frac{p^2}{2}}$$

If evaluated in **density** space ($\alpha'=0$), the r.h.s. reduces to

$$\alpha \frac{\partial}{\partial s}\frac{\bar{p}^2}{2} + \alpha \frac{\partial}{\partial s}\frac{\overline{p^{*2}}}{2}$$

Unavailable pot. energy

Available pot. energy



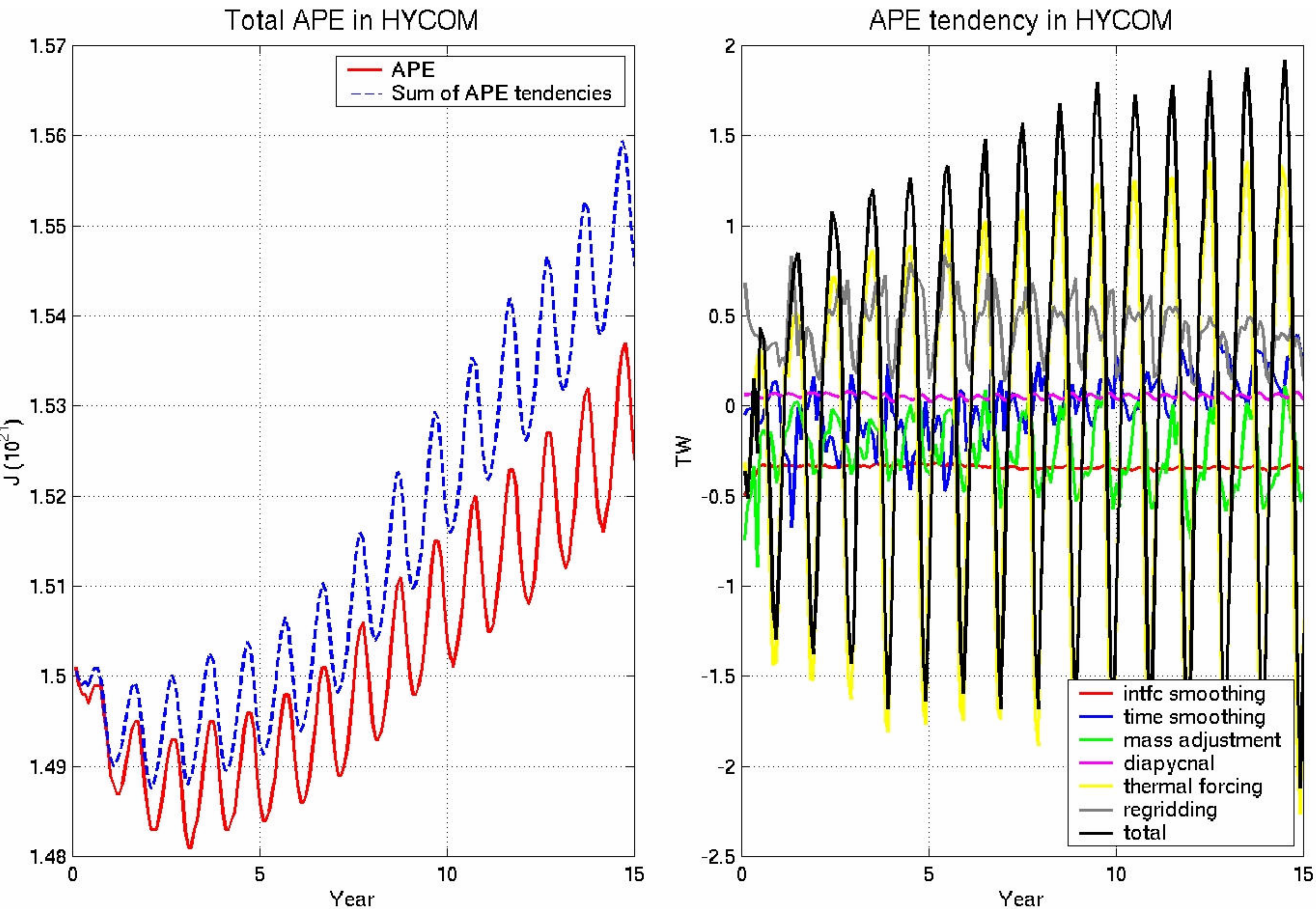
A 3-layer ocean. $\overline{p}$ shown in red

Procedure for determining $\bar{p}$:

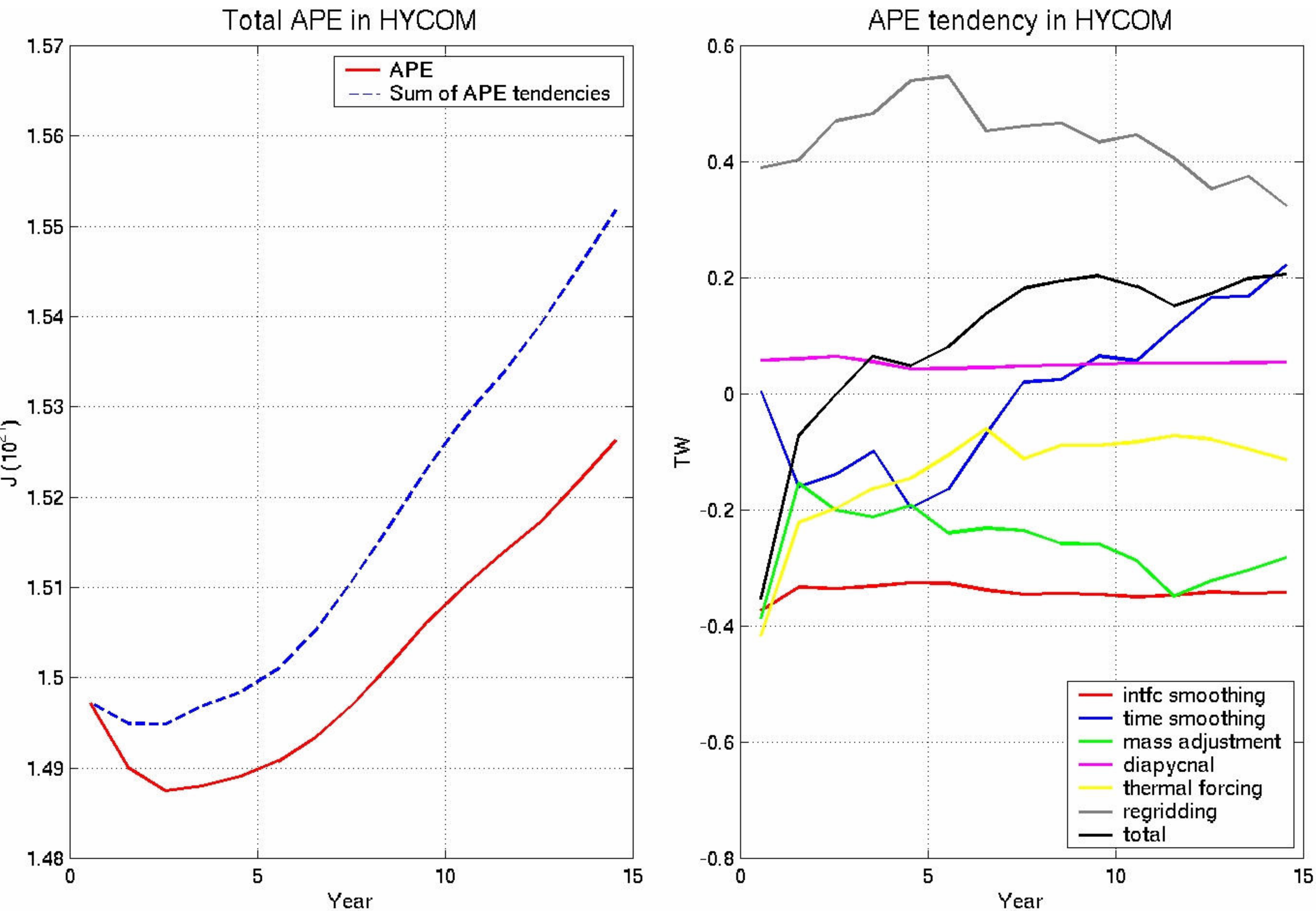
1. Compute the mass M above a given s surface.
2. Divide ocean into **large** number of **thin** isobaric slabs; determine mass m_k in each slab from bathymetric data base.
3. Counting from the top down, find the index n satisfying

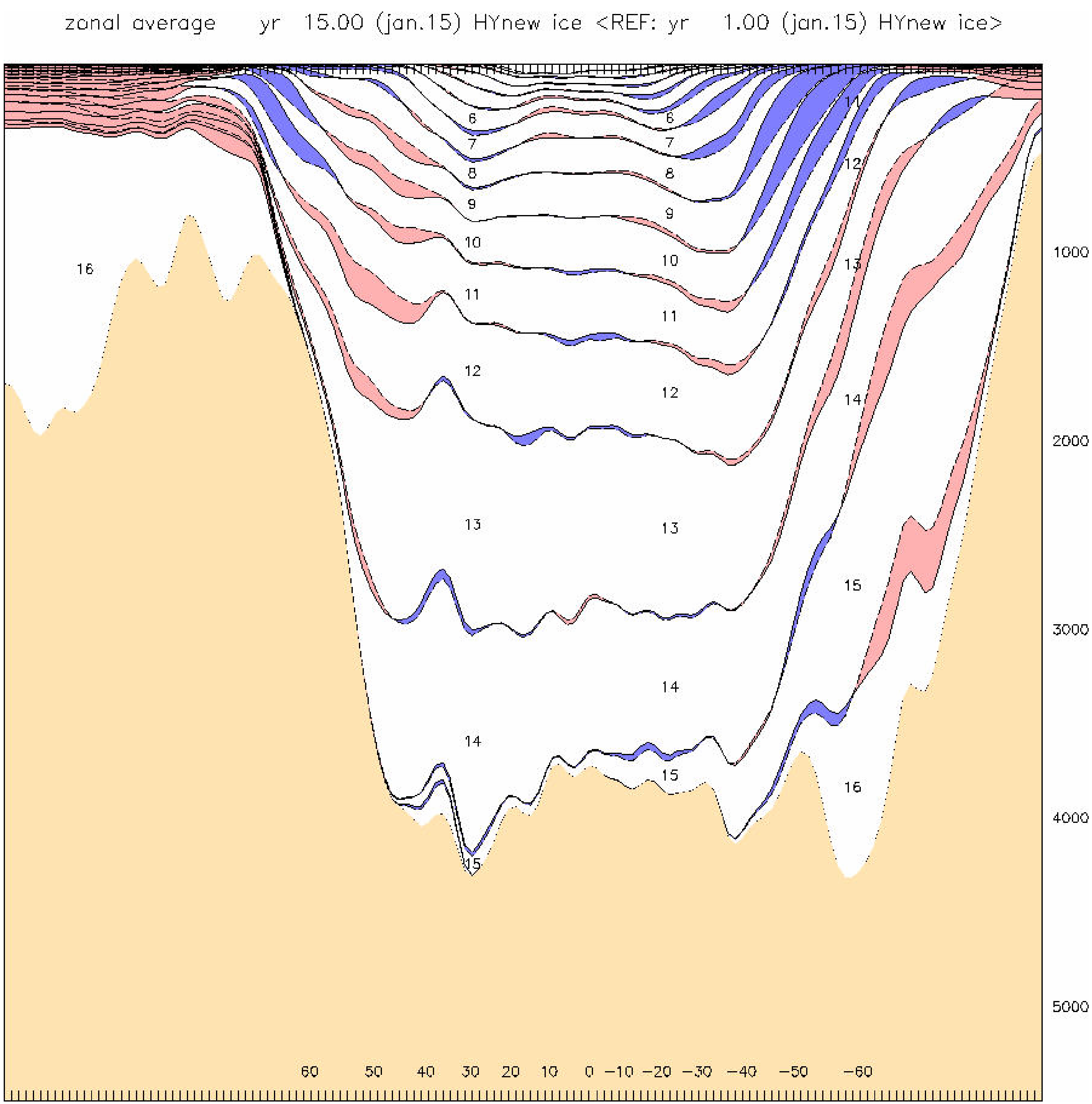
$$\sum_{k=1}^{n-1} m_k \leq M \leq \sum_{k=1}^{n} m_k$$

4. $\bar{p}$ is now known to lie between top and bottom of slab n. Interpolate to get final value.

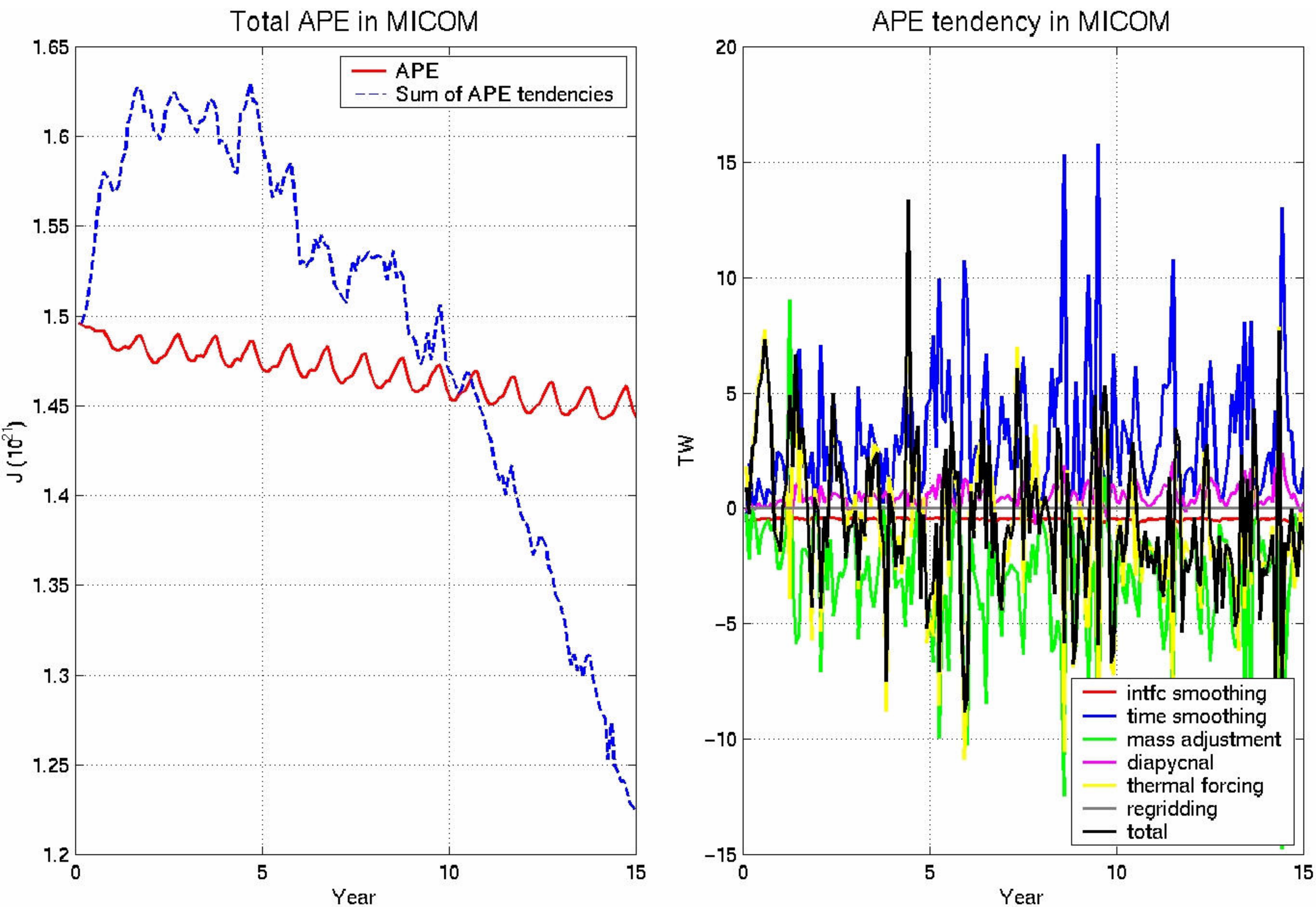


Total APE in HYCOM
APE
Sum of APE tendencies
J (10^{21})
Year
APE tendency in HYCOM
TW
Year
intfc smoothing
time smoothing
mass adjustment
diapycnal
thermal forcing
regridding
total

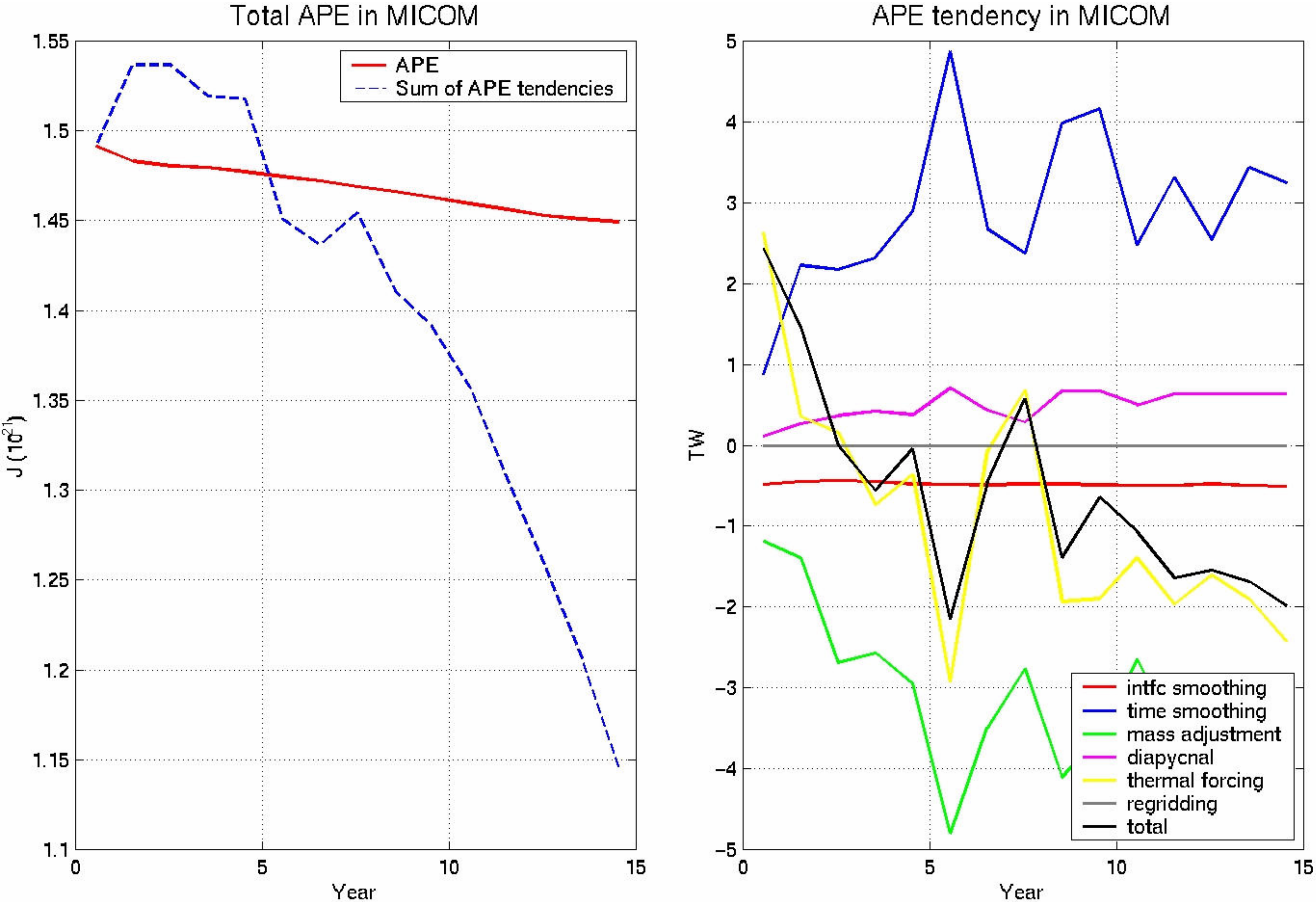

Total APE in HYCOM
APE
Sum of APE tendencies
J (10^{21})
Year
1.57
1.56
1.55
1.54
1.53
1.52
1.51
1.5
1.49
1.48
0
5
10
15
APE tendency in HYCOM
TW
Year
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
intfc smoothing
time smoothing
mass adjustment
diapycnal
thermal forcing
regridding
total



zonal average yr 15.00 (jan.15) HYnew ice <REF: yr 1.00 (jan.15) HYnew ice>
1000
2000
3000
4000
5000
60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60



Total APE in MICOM
APE
Sum of APE tendencies
J (10^{21})
Year
APE tendency in MICOM
TW
Year
intfc smoothing
time smoothing
mass adjustment
diapycnal
thermal forcing
regridding
total


Total APE in MICOM
APE
Sum of APE tendencies
J (10^21)
Year
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
0
5
10
15
APE tendency in MICOM
TW
Year
5
4
3
2
1
0
−1
−2
−3
−4
−5
intfc smoothing
time smoothing
mass adjustment
diapycnal
thermal forcing
regridding
total

zonal average yr 15.00 (jan.15) MInew ice <REF: yr 1.00 (jan.15) MInew ice>