MECHANISMS CONTROLLING SEASONAL MIXED LAYER TEMPERATURE AND SALINITY OF THE INDONESIAN SEAS IN AN ECCO ASSIMILATION PRODUCT

D.J. Halkides[1], Tong Lee[1] and Shinichiro Kida[2]

[1]Earth Sciences, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

[2]International Pacific Research Center, University of Hawaii

1. Introduction

- Indonesian Seas important to global climate & local weather/ecology:
  - Mixed Layer (ML) Temperature (MLT) drives convection associated w/ Pacific & Indian Ocean Walker Cells.
  - Interacts w/ monsoon, ENSO & Indian Ocean Zonal/Dipole Mode (IOZDM).
- Knowledge of ML processes can be used to evaluate coupled climate models & help interpret sparse data.
- We examine MLT & ML Salinity (MLS) budgets in Indonesian Seas to identify dominant processes controlling each.
- We use JPL data assimilation product (http://ecco.jpl.nasa.gov/external) [Fukumori 2002], part of Estimating the Circulation & Climate of the Ocean (ECCO) project (http://www.ecco-group.org).
  - Why use ECCO ODA?: Budget closure.

2. Validation

- Seasonal MLT & MLS from ECCO compare well to observations (Figures 1, 2, 3b,c).

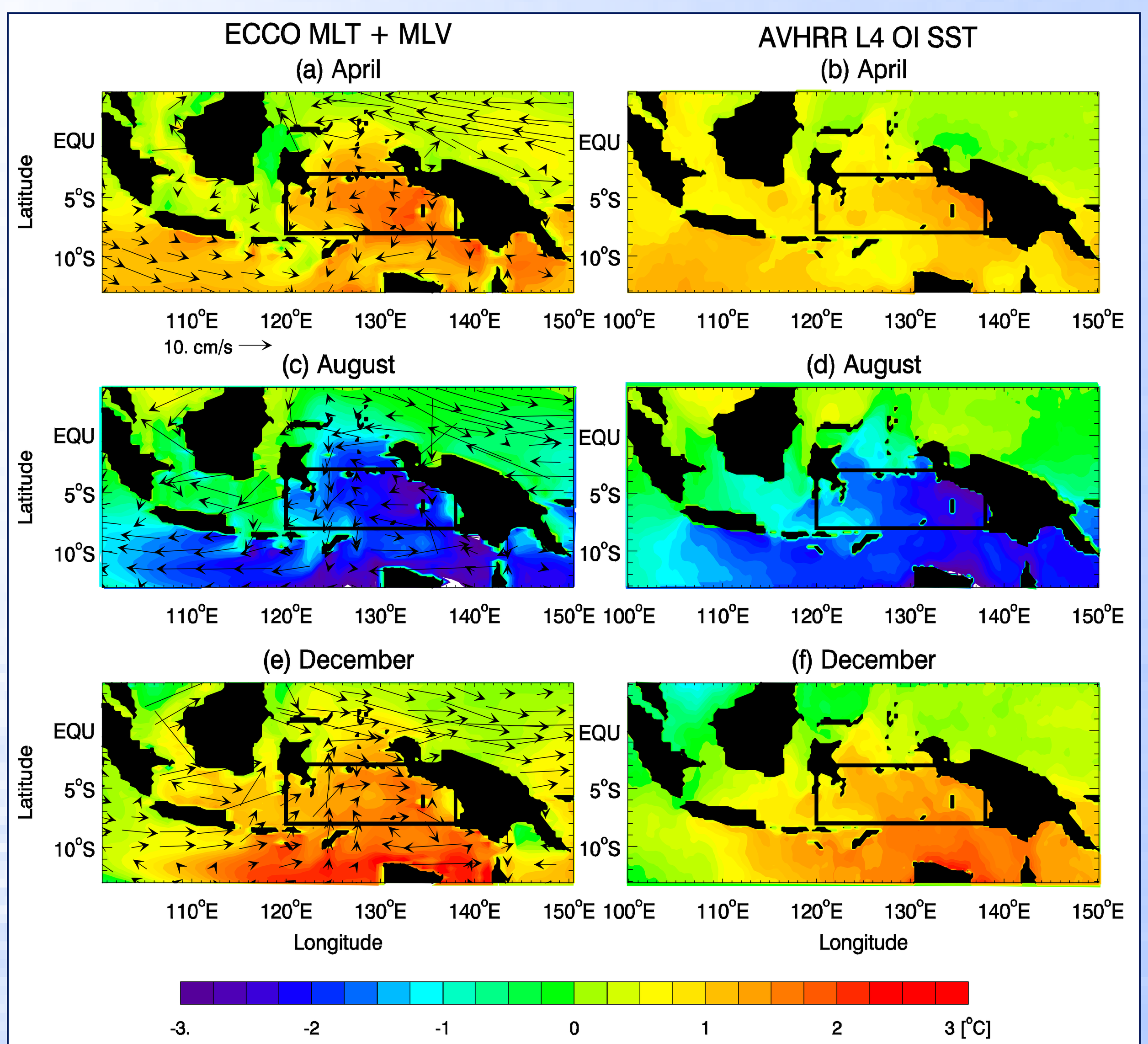

Figure 1: Seasonal anomaly of ECCO MLT with seasonal ML current velocity vectors superimposed (left), and observed SST (right) from the from the 0.25° resolution GHRSST Level 4 AVHRR Optimal Interpolation (OI) of SST (http://ghrsst.jpl.nasa.gov).

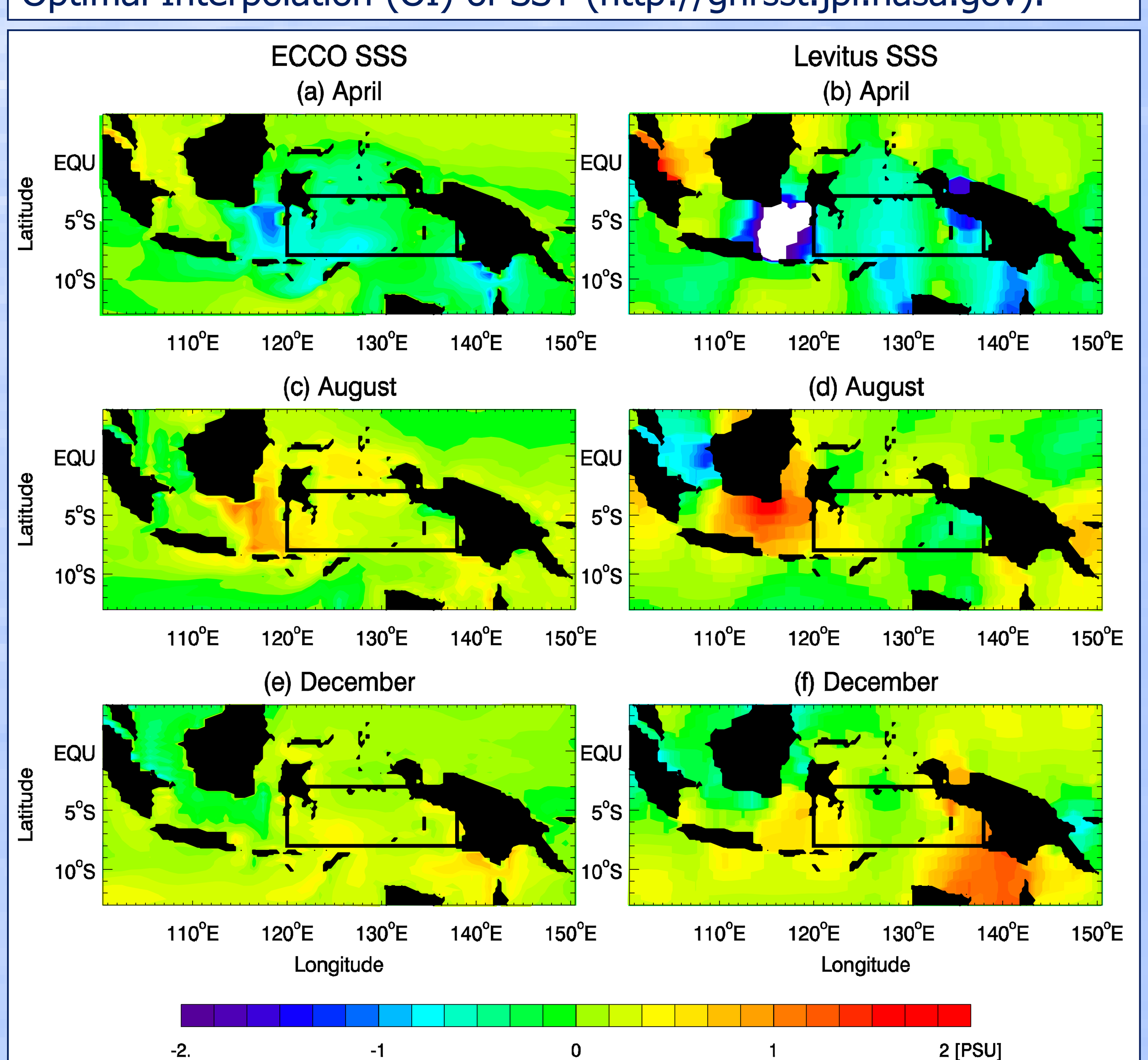

Figure 2: Seasonal anomaly of ECCO (left) & observed SSS (right; from Boyer & Levitus, 1998).

3. Methodology

- Eq (1) describes temperature tendency (change rate w/ time) at each grid cell.

$$\frac{\partial T}{\partial t}=-\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}\right)+\left\{\frac{\partial}{\partial x}\left(\kappa_x\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(\kappa_y\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(\kappa_z\frac{\partial T}{\partial z}\right)\right\}+\frac{1}{\rho C_p}\frac{\partial(Q_{SW}+Q_{LW}+Q_{SH}+Q_{LH}+Q_R)}{\partial z}$$

- RHS contributions by advection, mixing & surface flux saved monthly.
- MLH base defined by $\sigma(z)=\sigma_0+0.125\ kgm^{-3}$
- T vertically integrated (square brackets) over ML to find MLT, described by Eq (2):

$$\frac{\partial[T]}{\partial t}=\left[\frac{1}{\rho C_p}\frac{\partial(Q_{SW}+Q_{LW}+Q_{SH}+Q_{LH}+Q_R)}{\partial z}\right]-\left[u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right]+\left[\frac{\partial}{\partial x}\left(\kappa_x\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(\kappa_y\frac{\partial T}{\partial y}\right)\right]+\left[\frac{1}{h}\Delta T\frac{\partial h}{\partial t}\right]-\left[w\frac{\partial T}{\partial z}\right]-\frac{1}{h}\kappa\frac{\partial T}{\partial z}\Big|_{z=-h}$$

- RHS brackets denote MLT change by…
  - Surface heat flux
  - Horizontal advection
  - Horizontal mixing (usually small)
  - Subsurface processes (entrainment-detrainment, vertical advection, & vertical mixing)

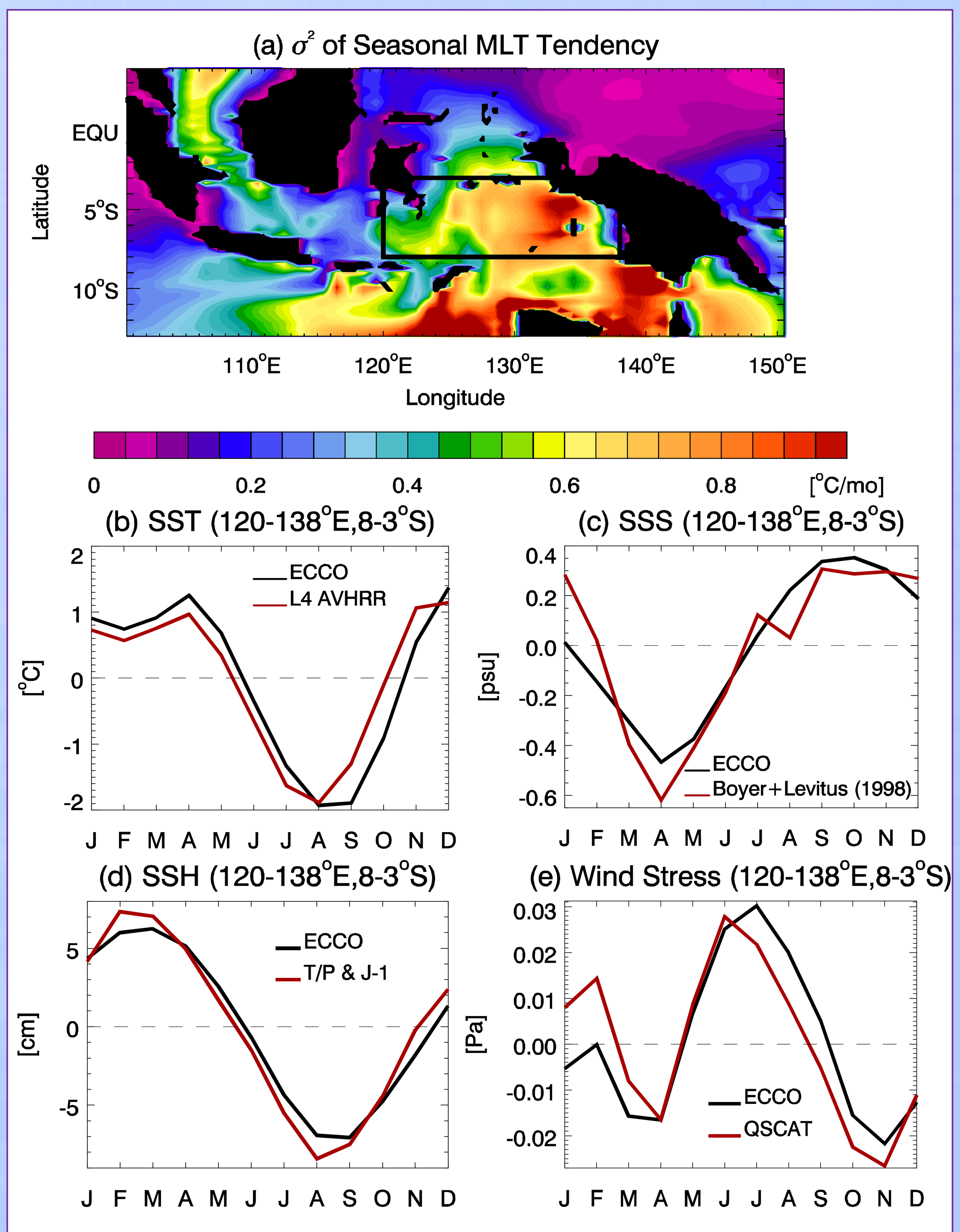

Figure 3: (a) Map of variance of seasonal ECCO MLT tendency; Seasonal cycles of ECCO & observed (b) SST, (c) SSS, (d) SSH, (e) wind stress, averaged over box in panel (a), covering Banda & Arafura Seas.

- Box chosen based on tendency variance (Figure 3a; similar to Halkides & Lee 2008).
  - Region well simulated (Figure 3b-e)

4. MLT Budget

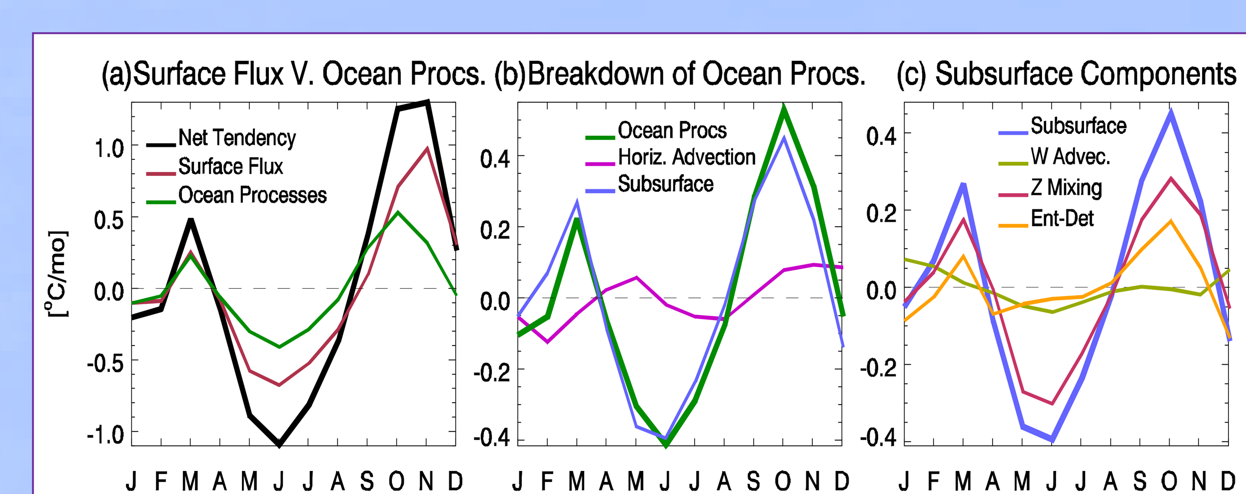

Figure 4: Seasonal MLT budget averaged over (120-138°E;8-3°S): (a) net tendency & contributions by surface flux & ocean processes; (b) ocean process breakdown into horizontal advection & subsurface processes; (c) subsurface process breakdown into vertical advection, mixing, entrainment-detrainment contributions.

- Surface heat flux dominates (Figure 4a)
  - Cools (warms) when insolation in north (south) & winds heighten (weaken) during summer (winter) monsoon.
- Ocean processes, dictated by subsurface processes, reinforce tendency (Figure 4b)
- Subsurface contribution mostly vertical mixing (w-advective part small; Figure 4c)
  - Reason needs further investigation
- Monsoon winds coincide spatially w/ ML heat loss, subsurface cooling & ML thickening (not shown).
- Consistent w/ bulk of summer cooling being due to ML heat loss & turbulent mixing by monsoon wind.
- New Guinea coastal shelf-upwelling, which may enhance summer cooling [Kida & Richards 2008] is not resolved, thus its role in MLT needs further investigation.

5. MLS Budget

- Salinity & MLS equations similar to Eqs (1) & (2), replacing T w/ S & surface flux w/ virtual salt flux representing effects of evaporation, precipitation & run-off.
- Ocean processes dominate seasonal MLS in Banda-Arafura Seas (Figure 5a).
- Subsurface processes, horizontal (mostly meridional) advection are both important (Figure 5b).
  - Vertical advec., mixing & entrainment-detrainment all contribute (Figure 5c).

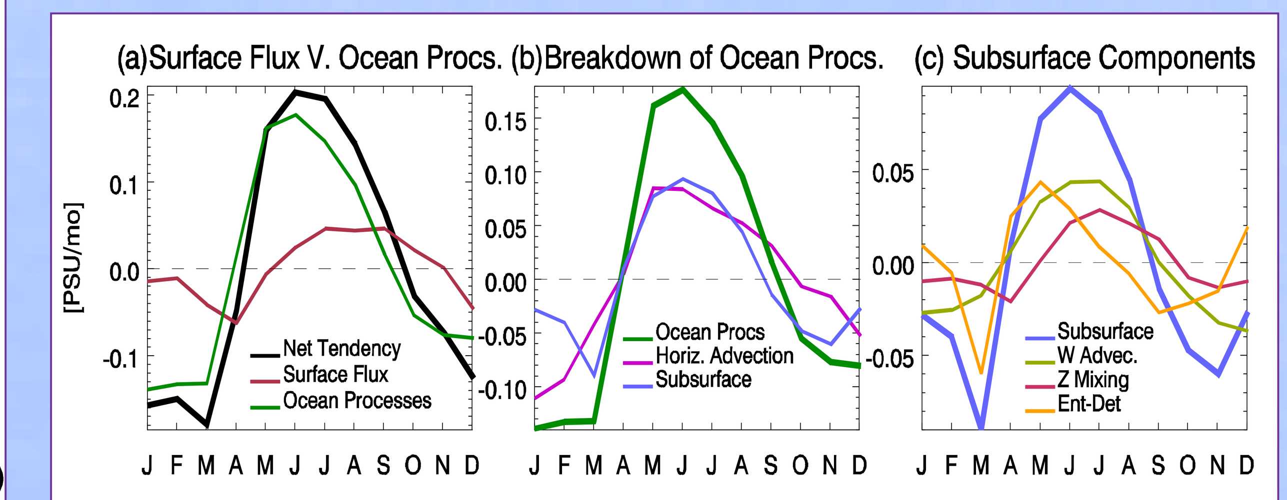

Figure 5: Seasonal MLS budget averaged over (120-138°E;8-3°S): (a) net tendency & contributions by surface flux & ocean processes; (b) ocean process breakdown into horizontal advection & subsurface processes; (c) subsurface process breakdown into vertical advection, mixing, entrainment-detrainment contributions.

- Enhanced summer MLS consistent w/:
  - Reduced rainfall (insolation in north)
  - Enhanced evaporation, vertical intrusion of salty subsurface water into ML
    - Summer monsoon winds.
- Reduced winter MLS consistent w/:
  - Seasonal rainfall south of equator
  - Reduced evaporation & subsurface processes
    - Low winter monsoon winds.

6. Summary & Conclusions

1) Seasonal MLT dominated by surface heat flux & secondary contribution by vertical mixing, both associated w/ seasonal monsoon variability.

2) Seasonal MLS dominated by variability of upwelling & vertical mixing of salty subsurface water into ML, meridional advection, regulated by monsoon wind.

References

Fukumori, I. (2002), A partitioned Kalman filter and smoother, Mon. Wea. Rev., 130, 1370-1383.

Halkides, D.J., T. Lee (2008): Mechanisms controlling seasonal-to-interannual mixed-layer temperature variability in southeastern tropical Indian Ocean (accepted JGR).

Kida S., K.J. Richards (2008), Seasonal Sea Surface Temperature Variability in the Indonesian Seas (submitted JGR).