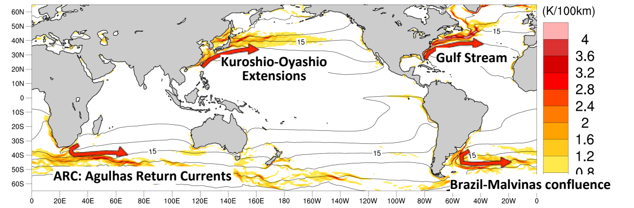
Impacts of the warm western boundary currents on the mean-state and variability of the overlying atmosphere

Hisashi Nakamura[1], Ryusuke Masunaga[2], Ayumu Miyamoto[1]
[1]RCAST, The University of Tokyo, [2]IPRC, University of Hawaii

1. Introduction

Satellite-based (1985-2012)
climatological-mean SST (°C, contour) & dSST/dy (°C/100km, shade)



- The warm western boundary currents (WBCs) carry an enormous amount of heat from the Tropics and release it intensively along the associated midlatitude SST fronts through sensible and latent heat fluxes (SHF, LHF).
- The SST fronts act to anchor stormtracks and the moisture supply from the warm WBCs energizes storms.

✓ *We identify imprints of those SST fronts on the overlying atmosphere.*

2. Data

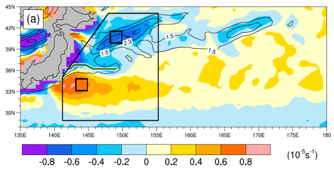
☐ JRA-55 CHS (Masunaga et al. 2018; SOLA)
- Available for 1982 – 2012
- Horizontal res. : TL319 (approximately 55 km)
- SST prescribed for assimilation has 0.25° resolution, able to resolve SST frontal structures in the vicinity of WBCs

☐ ERA-Interim
- Horizontal res. : 0.75°X0.75°; interpolated data onto MODIS grid
- SST prescribed for assimilation can resolve its frontal gradient after 2001

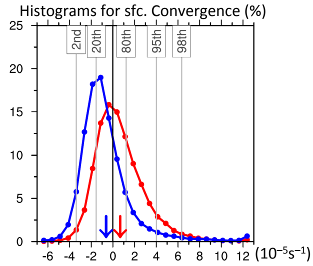
☐ MODIS on Terra
- Horizontal resolution : 1.0°X1.0°
- Only daytime observations (at 10:30LT) used
- Low-level clouds : cloud top pressure ≥ 680 hPa
- Errors likely in cloud retrieval under large solar zenith angle (>~65°)
- Low-cloud fraction (LCF) is derived under "random overlap assumption"

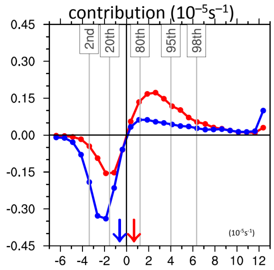
3. Histograms and contributions (KOE)

January climatology based on JRA-55CHS (1985 – 2012)
Sfc. Wind conv. (Col.), SST grad. (> 1.5K/100km)



- JRA-55CHS represents climatological-mean wind conv./div. maxima
- Conv./div. contrast across KE front forms mostly with contributions from conv. (div.) events of 1.2 ~ 4 x$10^{-5}s^{-1}$ (−1.54 ~ −2.71 x$10^{-5}s^{-1}$) in magnitudes



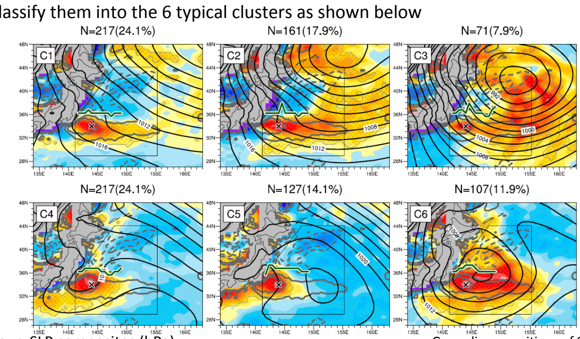


$$\frac{N_{\mathrm{bin}(i)}}{N_{\mathrm{all}}} \times \frac{1}{N_{\mathrm{bin}(i)}} \sum_{\mathrm{bin}(i)} \mathrm{CONV}_{\mathrm{bin}(i)} = \frac{1}{N_{\mathrm{all}}} \sum_{\mathrm{bin}(i)} \mathrm{CONV}_{\mathrm{bin}(i)}$$

- Based on 6-hourly JRA-55CHS data
- Red (blue) represents stats. at conv. (div.) max. marked in the upper panel
- Arrows for climatological means

4. Cluster analysis (KOE)

i) Identify 900 SLP snapshots associated with moderate wind conv. (1.2~4.0×$10^{-5}s^{-1}$) just south of the KE front [144°E, 34°N] in the period of 1985 – 2012
ii) Classify them into the 6 typical clusters as shown below



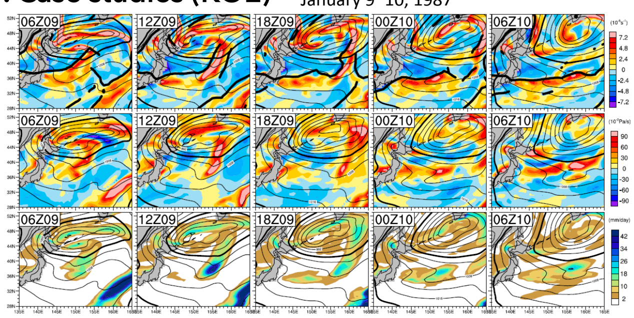
Contour: SLP composites (hPa) Green lines: positions of SST fronts
Color : sfc. wind convergence composites ($10^{-5}s^{-1}$)

- C1 ~ C3 (50%) : Moderate surface wind conv. persistent along the KE behind developed synoptic-scale cyclones
- C4 ~ C5 (38%) : Generations of meso-alpha scale cyclones over KE
- C6 (12%) : Passages of synoptic-scale cyclones in moderate strength

➔ The Gulf Stream and Agulhas Return Current (ARC) regions exhibit similar characteristics, though somewhat less clear in the sARC region

5. Case studies (KOE)

January 9~10, 1987



Contour: SLP (hPa); Thick lines: 925hPa atmospheric fronts
Color : (top) sfc. wind conv. ($10^{-5}s^{-1}$), (middle) 600hPa ascent (10^{-2}Pa), (bottom) precip. (mm/day)

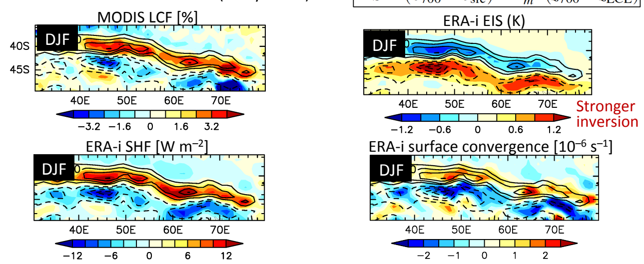
- A zonal band of surface wind convergence forms along the KE associated with a atmospheric stationary front anchored along the KE
- The wind convergence in moderate magnitude accompanies ascent and (shallow convective) precipitation

6. Summertime LCF (ARC)

✓Latitudinal 9° high-pass filtering to highlight impacts of the Agulhas Return Current
✓Analysis period (2002-2015)

Contour : SST (every 0.5 °C)

EIS: estimated inversion strength
$\mathrm{EIS} = (\theta_{700} - \theta_{\mathrm{sfc}}) - \Gamma_m^{850}(z_{700} - z_{\mathrm{LCL}})$



- Local LCF maxima forms along the warm ARC, despite local EIS minima
- Enhanced SHF, due to enhanced synoptic-scale cold advection across the SST front, and surface conv. along the ARC act to increase LCF locally

✓ Net cold advection not only sucks heat from the warm ARC but also reduces shortwave radiation into the ocean, promoting SST frontolysis

7. Conclusions

- SST fronts along the WBCs act to induce surface wind convergence in moderate intensity and shallow cloud band due to stationary atmospheric fronts, shaping cross-frontal contrasts observed as wintertime climatology
- Low-level cloud fraction is locally augmented along the ARC under the enhanced SHF associated with cold air advection across the SST front

Reference

1. Masunaga et al. (2018, SOLA)I: JRA-55CHS: An atmospheric reanalysis produced with high-resolution SST.
2. Miyamoto et al. (2018, J. Climate): Influence of the subtropical high and storm track on low-cloud fraction and its seasonality over the south Indian Ocean.
3. Masunaga et al. (2020, J. Climate): Processes shaping the frontal-scale time-mean surface wind convergence patterns around the Kuroshio Extension in winter.