The attenuation effects of eddy-induced air-sea interaction on mesoscale eddies

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Motivation

Eddy-induced spatial variability of SST generates a curl of the stress and therefore Ekman pumping. The eddies also induce Ekman pumping through the influence of eddy surface currents on the local relative winds and therefore the surface stress. It is not known how the feedback of these changes affect the oceanic mesoscale eddy field. We investigate that in this study from a set of three numerical simulations in which the effects of SST and surface current on eddy-induced Ekman pumping were imposed individually and together. The resulting eddy fields were compared with the eddy field from a control run in which the effects of SST or surface currents on eddy-induced Ekman pumping were turned off.

1 Data and Method

Configuration of ROMS model

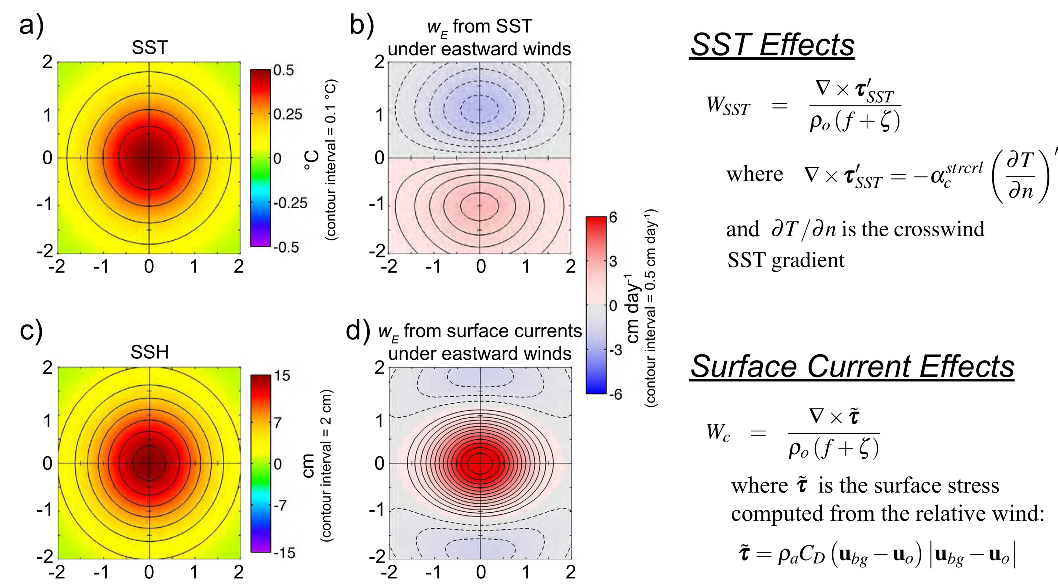
Control Run: 0.1° grid over the South Atlantic, 39 levels, initialized with OFES climatology, heat and freshwater fluxes from ERA-I, forced by OFES seasonal climatology winds.

sstFeedback: Same as Control Run, except small-scale wind perturbations are added based on crosswind SST gradients using coupling coefficients derived from OFES winds and SST. Started from the same initial condition as the spun-up Control Run and the sstFeedback Run.

uvFeedback: Same as Control Run, except surface stress was computed from the relative wind, defined to be the surface wind minus the surface ocean velocity. Started from the same initial condition as the spun-up Control Run.

sstuvFeedback: Same as Control Run, except the crosswind SST gradients induced wind perturbations are added and relative wind was used to compute surface stress. Started from the same initial condition as the spun-up Control Run.

Figure 1. Schematic Summary of SST and Surface Current Effects on Ekman Pumping for an Idealized Gaussian Anticyclone in the Southern Hemisphere (from Gaube et al., 2014, JPO)



Such Eddy-induced SST and surface current effects on Ekman pumping can also been found from satellite observations (see Gaube et al., 2014, JPO)

3D eddy identification and tracking

1) Get the pressure at each level. 2) Spatially high-pass it at each level. 3) Identify eddies in each level and connect to form 3D eddies. 4) Tracking.

2 The evolution of an eddy from the same initial condition

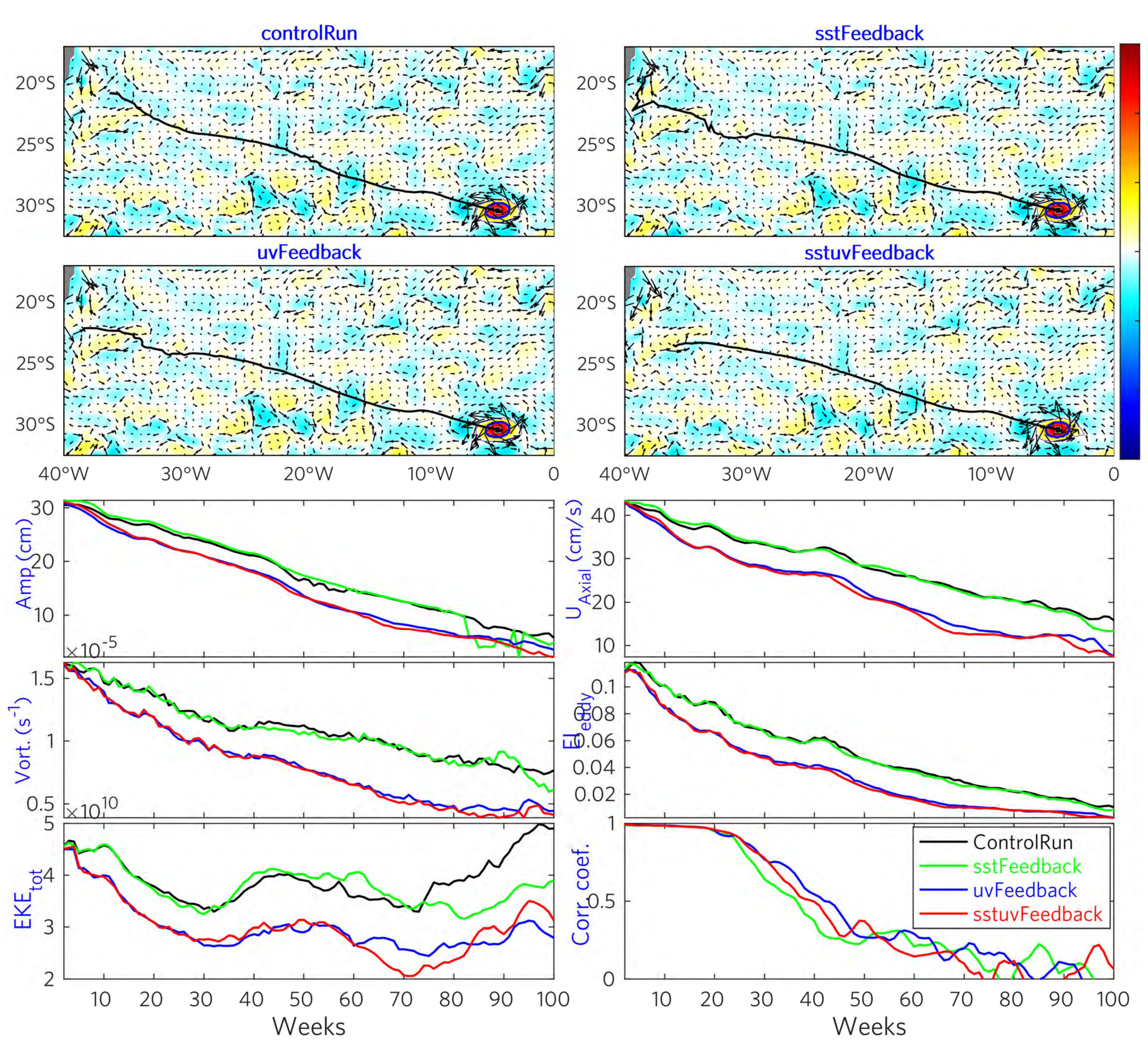


Figure 2. Trajectories of the anticyclonic eddy from the same initial condition for (a) control run (b) sstFeedback (c) uvFeedback (d) sstuvFeedback. The boundary of the eddy at the first week are marked as blue close lines. Variation of (e) eddy amplitude (f) eddy rotational speed (g) vorticity (h) eddy kinetic energy (EKE) density are compared from 4 models. (i) The kinetic energy over the domain (40W-0E, 32S-16S). (j) The spatial correlation between different models with the control run.

- The correlation with the eddy field of the control run decreases rapidly after 4-5 months.

3 The attenuation effects on eddy surface properties

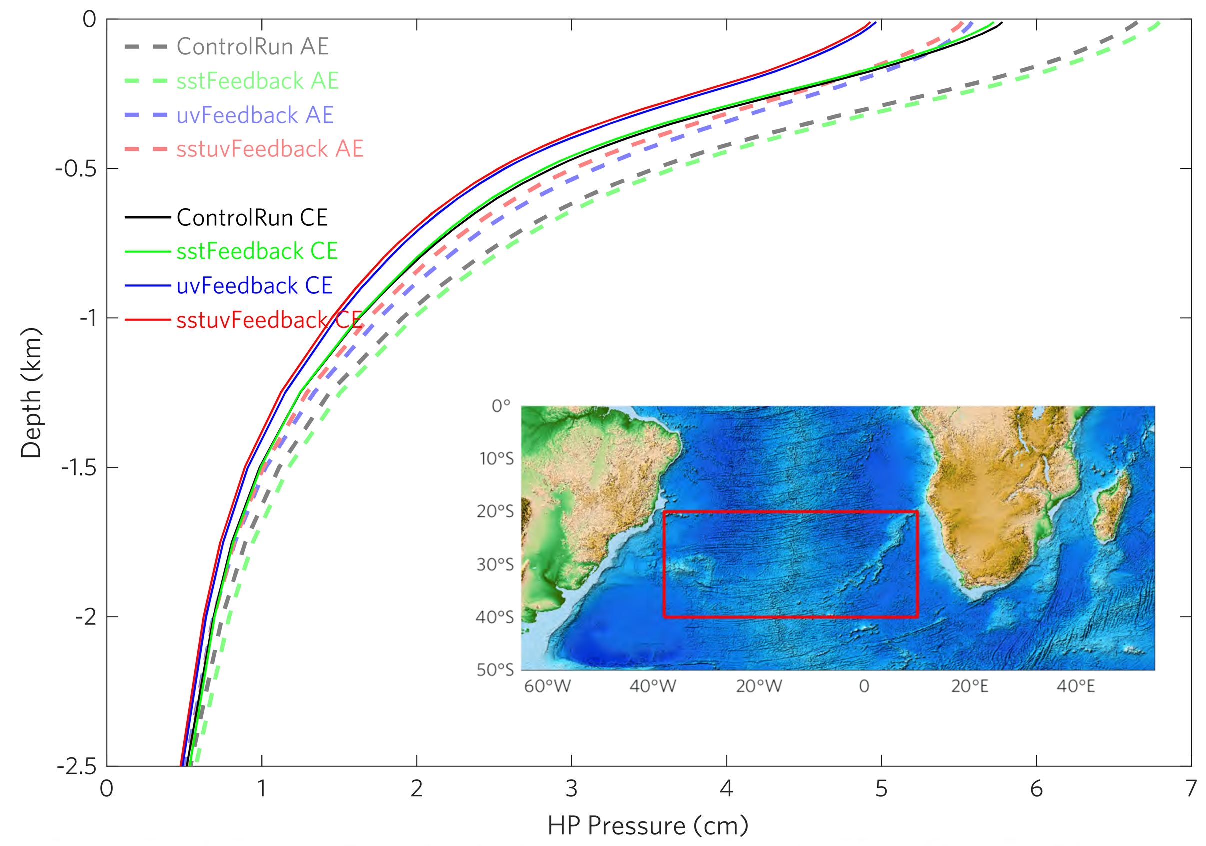


Figure 3. Composite eddy amplitude over the red box region.

- Both in the uvFeedback and sstuvFeedback, there is ~15% decreasing in eddy maximum pressure compared with the control run.
- The same attenuation effect on eddies can also be found in eddy rotational speed, eddy number, EKE, vorticity.

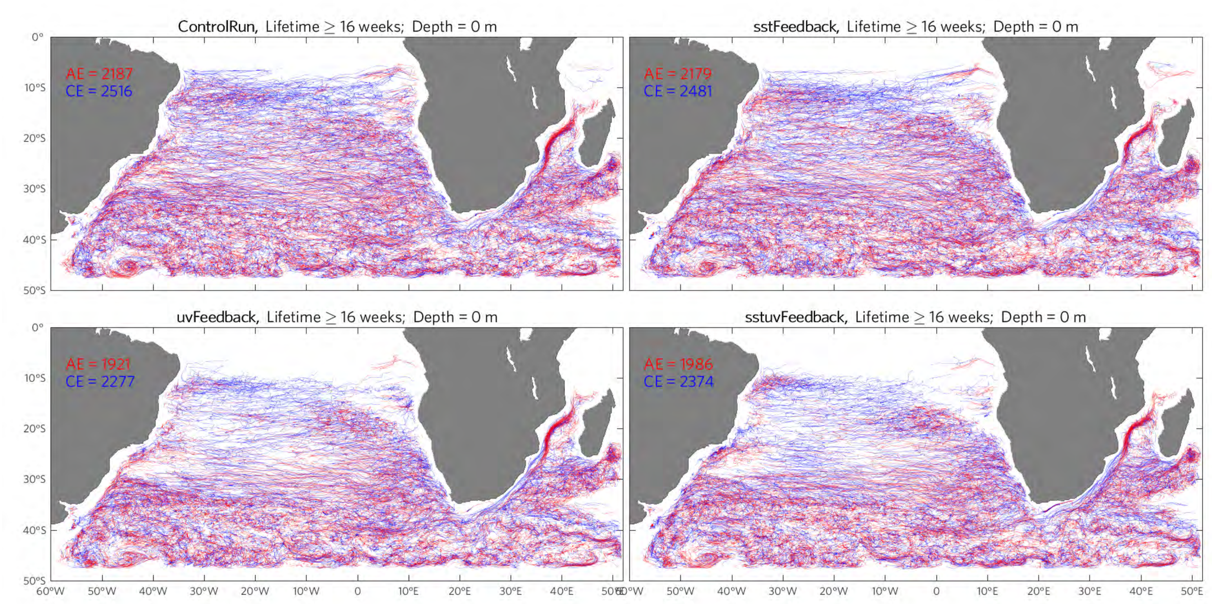
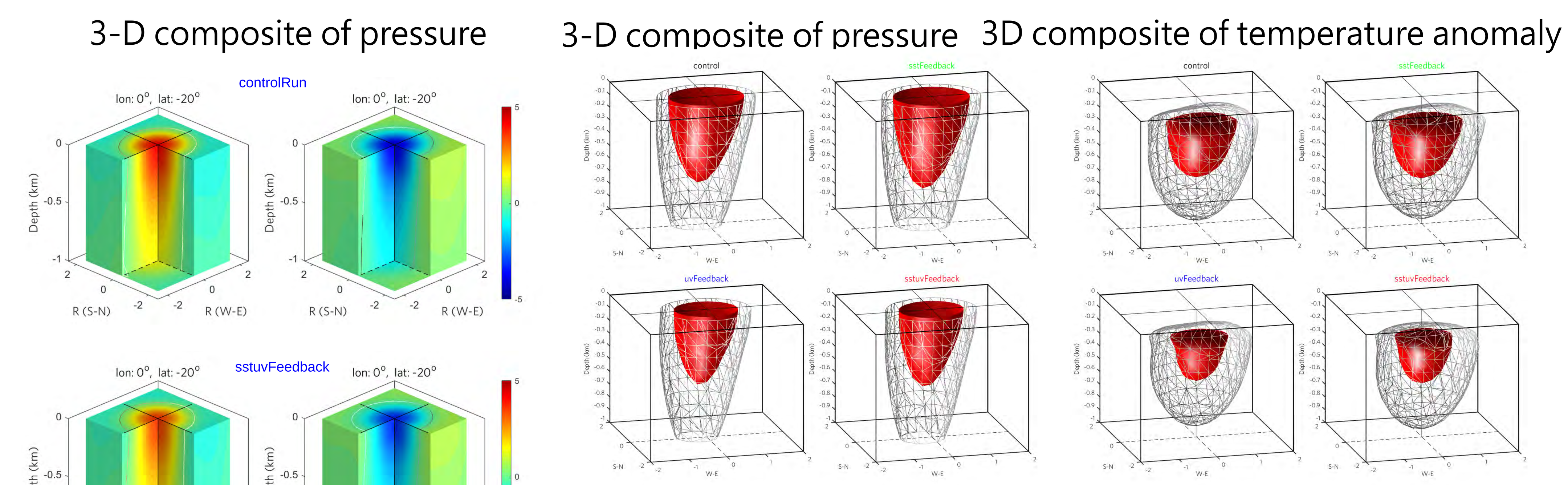


Figure 4. Trajectories of eddies with lifetimes exceeding 16 weeks at surface.

- Eddy Trajectories decreased ~10-15% with larger decreasing locate at lower latitude.

4 Composite average structures of the 3-D eddies



The outlier gray surface: P = 1 cm
The red surface: P = 2 cm

The outlier gray surface: Ta = 0.1°C
The red surface: Ta = 0.3°C

- Both the uvFeedback and sstuvFeedback have ~15% decreasing in high-pass pressure compared with the control run.
- Eddy size doesn't change much as other properties.

5 Summary

- Numerical simulations must include both surface current effects on the wind forcing in order to generate a realistic mesoscale eddy field.
- Surface current effects on the wind stress in the uvFeedback and sstuvFeedback model:
  - The EKE is reduced by ~20%.
  - Both eddy polarities are attenuated in eddy generation number, eddy amplitude, eddy rotational speed by 10~15%.
- Eddy-induced SST effects on the wind stress in the sstFeedback model:
  - The EKE is the same as in the control run, but the eddy field is very different.