Sea level and bottom pressure changes around Antarctica, in relation to wind-driven meridional flows*

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*work in press at GRL (rponte@aer.com for preprints)

Outline

Problem: In situ sea level and bottom pressure (p_b) data around Antarctica are anticorrelated with various measures of zonal wind stress in the Southern Ocean. Better understanding of the observed anticorrelations requires large-scale estimates of the Southern Ocean mass fields, in the presence of sea-ice, and consistent estimates of forcing and mass transports to address the underlying dynamics.

Approach:

- Examine monthly mass fields using GRACE data
- Compare to ECCO solution produced at MIT-AER by constraining MITgcm to all altimeter data, as well as other observations
- Analyze physically-consistent ECCO solution to determine the dynamics and forcing of mass anomalies in the Southern Ocean

Summary of Results:

- Area-averaged p_b anomalies near Antarctica (south of 60S) are anticorrelated with zonal wind stress
- Near-surface meridional Ekman transport, driven by the wind, is nearly balanced by return flows at depth at slight time lags relative to the Ekman transport
- Such time lags, which can result from geostrophic adjustment at depth, cause the small associated net transport across 60S to be nearly in quadrature with the wind, and ultimately lead to the anticorrelation between p_b anomalies and zonal wind

Mass and Wind Anomalies

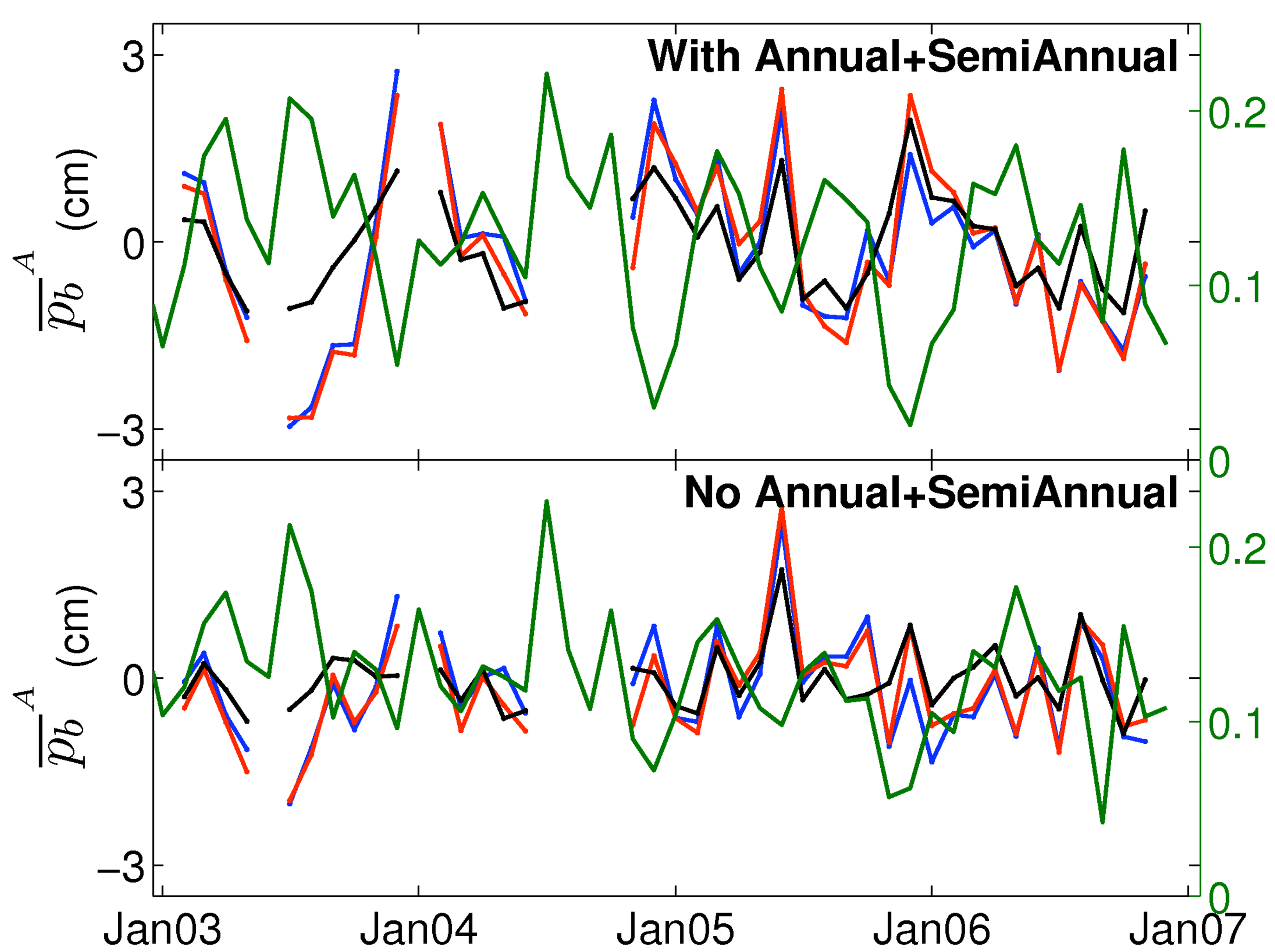

Fig. 1. Monthly time series of p_b, in equivalent centimeters of water, spatially averaged for the region south of 60S and derived from two different GRACE series (GFZ, red; CSR, blue) and ECCO estimate (black). Average zonal wind stress at 60S is shown in green.

- good agreement between GRACE and ECCO estimates (correlations between 0.65 and 0.85)
- zonal wind out-of-phase with mass anomalies around Antarctica (see also Fig. 3)
- sea level (volume) anomalies (not shown) nearly equal to p_b as expected for barotropic variability

Spatial Patterns

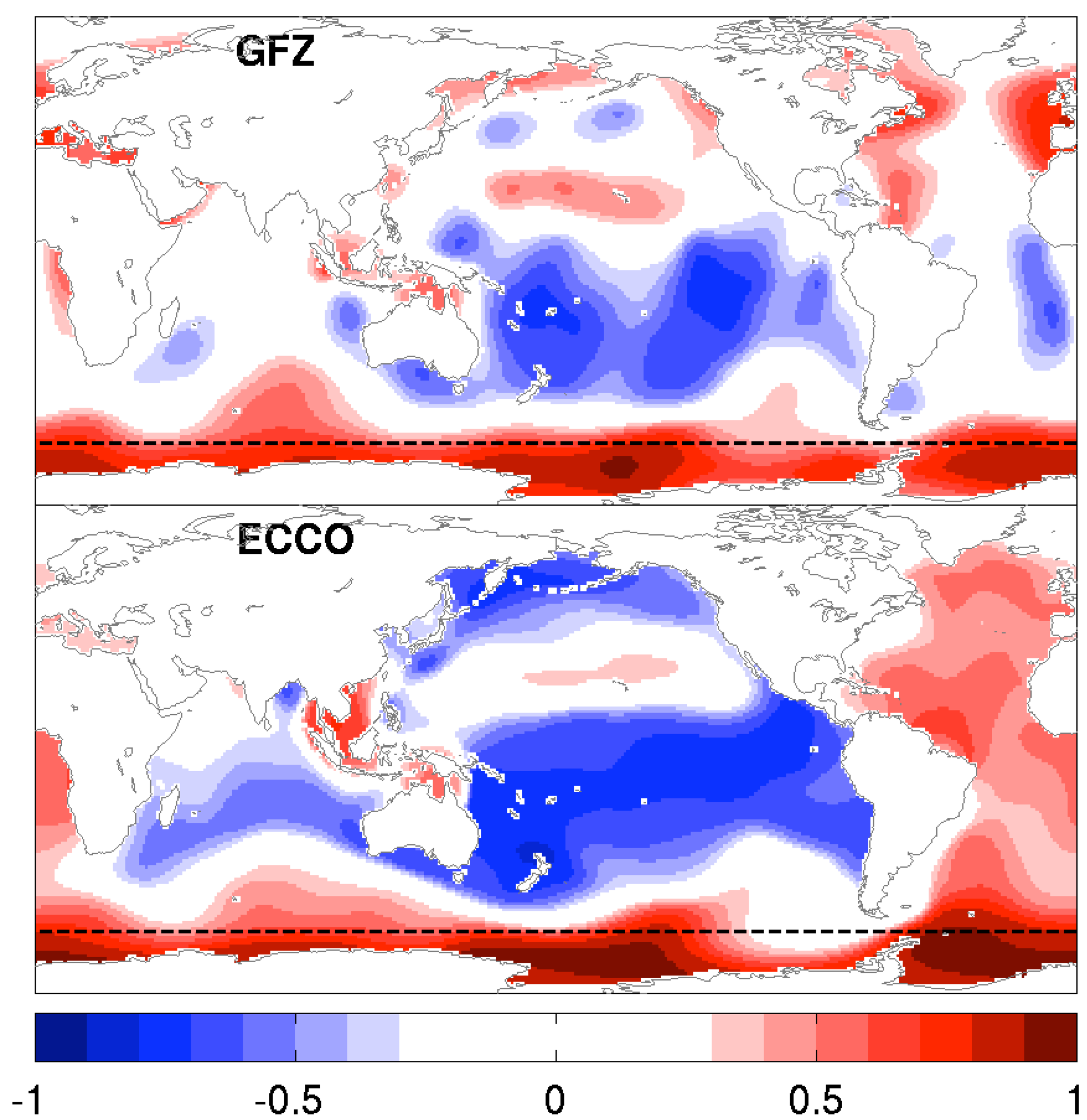

Fig. 2. Correlation between averaged p_b for the region south of the dashed line and the local p_b anomalies. Values below 95% significance level (±0.31) are not colored.

- GRACE and ECCO correlation patterns very similar
- Southern Ocean exchange of mass primarily with Pacific basin

Relating p_b, Winds, and Meridional Transports

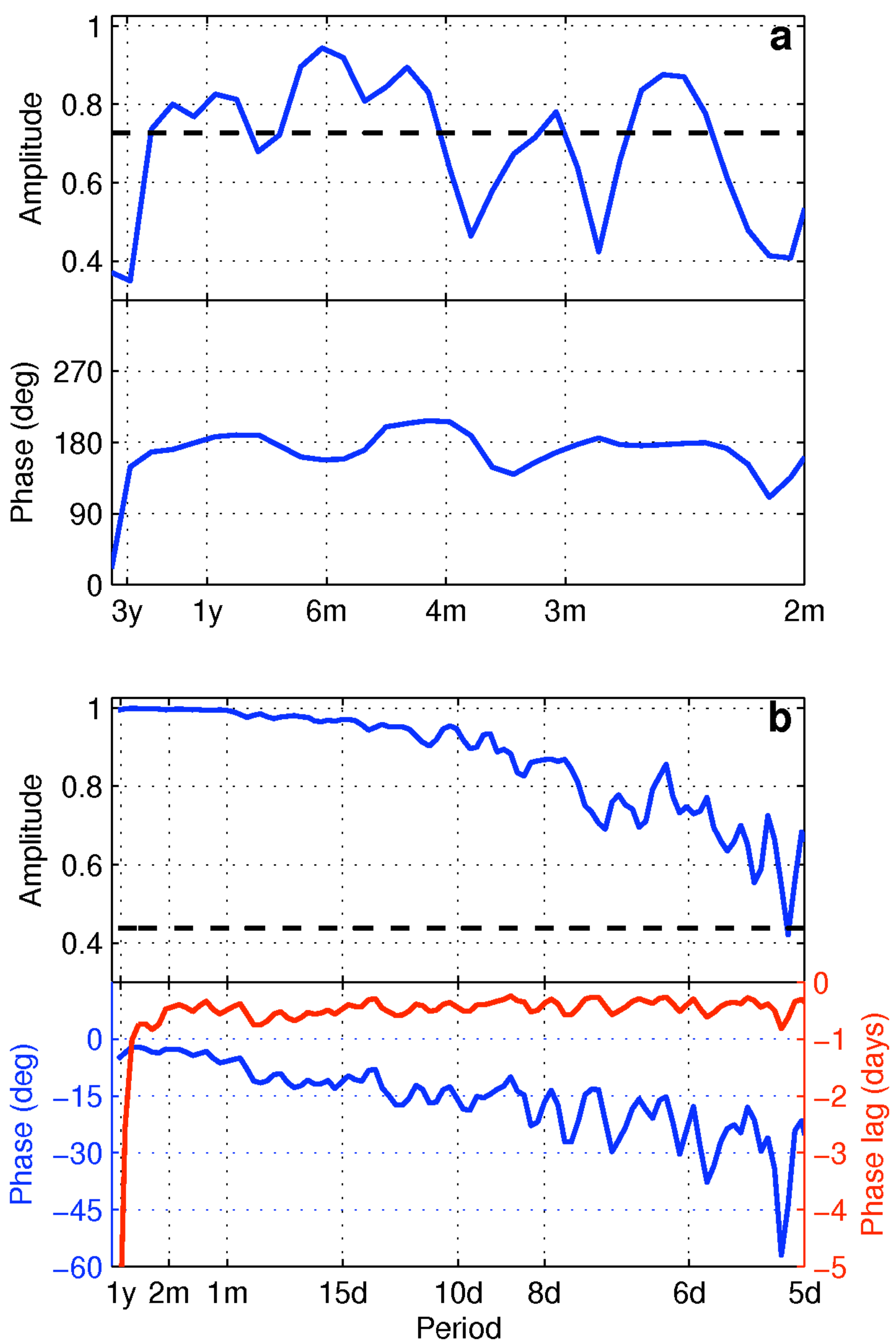

Fig. 3. Coherence amplitude and phase between **(a)** area-averaged p_b south of 60S and zonally-averaged zonal wind stress at 60S and **(b)** the latter and the negative of the zonally-integrated meridional transport across 60S occurring below shallowest topography (1300 m). Dashed line represents 95% confidence significance level. (Based on daily ECCO fields)

- Mass and wind stress anomalies are coherent and out-of-phase over several frequency bands

- Deep return flows and zonal stress are highly coherent, up to submonthly periods

- Winds lead southward bottom transport at very short lags (from 0.5 to a few days)

- Lag of ~0.5 days is approximately consistent with geostrophic adjustment at depth occurring over the inertial timescale

- Full flow adjustment to the winds likely involve other mechanisms and may take a few days, as the result for annual period suggests

Phase Relationships

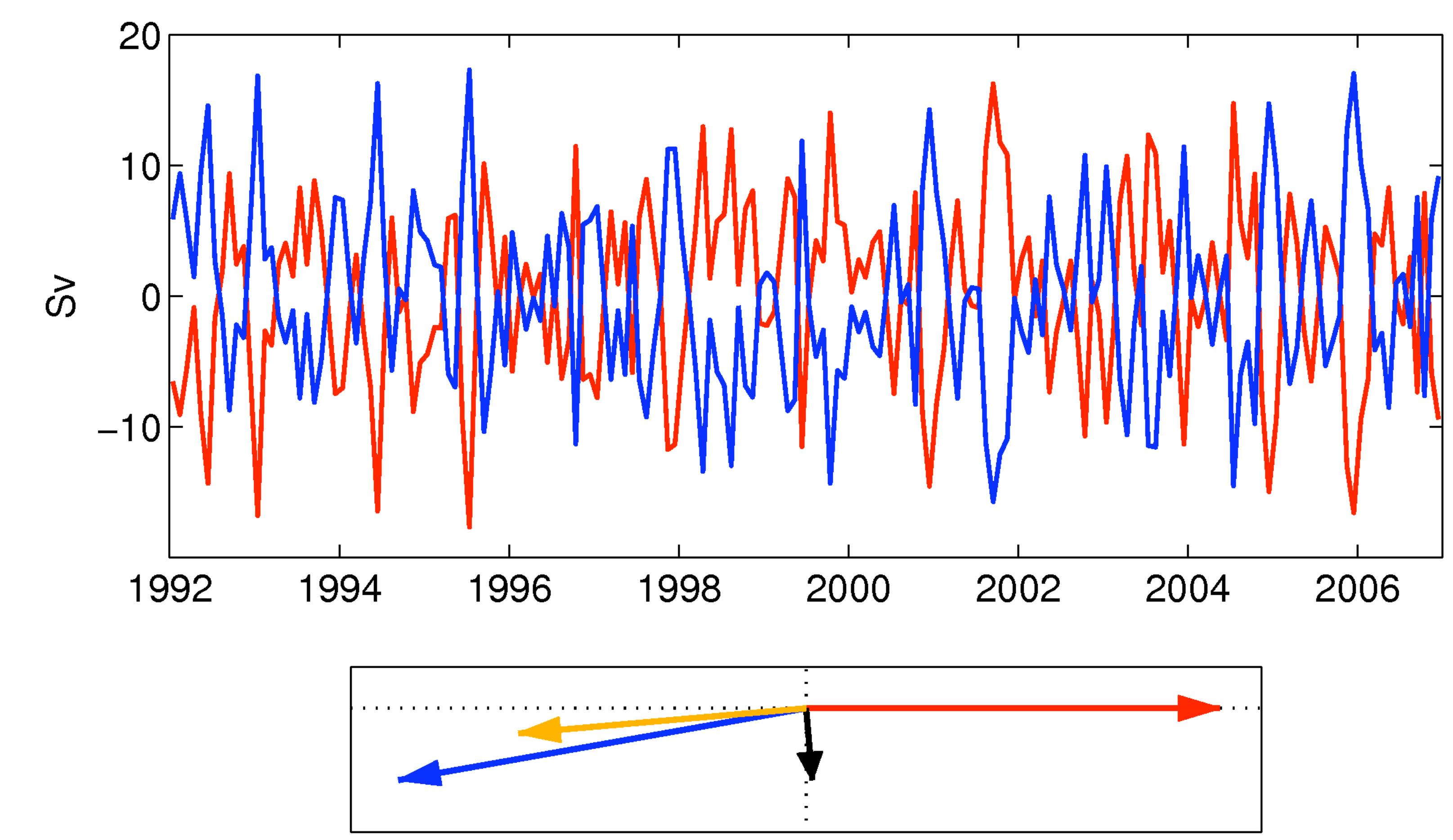

Fig. 4. Monthly time series of integrated meridional transports across 60S in Sverdrup (1 Sv $=10^6$ m^3/s), with time means removed: (top) wind-driven Ekman transport (red) and transport below 1300 m (blue).

- Vector schematic shows bottom return transport slightly delayed relative to Ekman transport, yielding a small net transport (black) that leads the Ekman transport by ~90°. Resulting bottom pressure change south of 60S (yellow) leads peak northward transport by 90°, from conservation of volume.