nature International weekly journal of science

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Letter

Nature **463**, 80-83 (7 January 2010) | doi:10.1038/nature08687; Received 6 December 2008; Accepted 9 November 2009

Anthropogenic carbon dioxide transport in the Southern Ocean driven by Ekman flow

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The Southern Ocean, with its large surface area and vigorous overturning circulation, is potentially a substantial sink of anthropogenic CO_2 (refs 1–4). Despite its importance, the mechanism and pathways of anthropogenic CO_2 uptake and transport are poorly understood. Regulation of the Southern Ocean carbon sink by the wind-driven Ekman flow, mesoscale eddies and their interaction is under debate[5, 6, 7, 8]. Here we use a high-resolution ocean circulation and carbon cycle model to address the mechanisms controlling the Southern Ocean sink of anthropogenic CO_2. The focus of our study is on the intra-annual variability in anthropogenic CO_2 over a two-year time period. We show that the pattern of carbon uptake is correlated with the oceanic vertical exchange. Zonally integrated carbon uptake peaks at the Antarctic polar front. The carbon is then advected away from the uptake regions by the circulation of the Southern Ocean, which is controlled by the interplay among Ekman flow, ocean eddies and subduction of water masses. Although lateral carbon fluxes are locally dominated by the imprint of mesoscale eddies, the Ekman transport is the primary mechanism for the zonally integrated, cross-frontal transport of anthropogenic CO_2. Intra-annual variability of the cross-frontal transport is dominated by the Ekman flow with little compensation from eddies. A budget analysis in the density coordinate highlights the importance of wind-driven transport across the polar front and subduction at the subtropical front. Our results suggest intimate connections between oceanic carbon uptake and climate variability through the temporal variability of Ekman transport.

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Nature ISSN 0028-0836
EISSN 1476-4687

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