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Moderate Warming Guaranteed in Northern Europe and Southern Australia by Sverdrup Upwelling

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Introduction

The Flinders Current, in the Southern Hemisphere, which is the northern arm of the anticyclonic gyre, south of Australia [1], and the Gulf Stream, in the Northern Hemisphere, which is the northern arm of the anticyclonic gyre, north of Europe, are cousins. We show that both major oceanic circulations are particularly favorable to major upwellings through their interaction with the adjacent polar waters, which give rise to beneficial nutrient rich marine ecologies. How does this process occur? This is the topic of this note.

Sverdrup Upwelling

There are two upwelling mechanisms, due respectively to

a) well known Ekman dynamics which are forced by the surface wind field generated by the atmospheric general circulation [2].

b) Sverdrup dynamics which are forced by the surface current field generated by the oceanic general circulation. The negative temperature anomaly due to the cool current gives rise to a negative lateral diffusive heat flux, which causes the upwelling of cool water to occur. This process is currently under investigation in [3].

Ekman upwelling occurs for a negative coastal wind stress in the Southern Hemisphere and for a positive coastal wind stress in the Northern Hemisphere, and Sverdrup upwelling occurs for a cool coastal current in both Hemispheres. Downwelling conditions occur for a warm coastal current, and when the wind direction is reversed.

For our purposes, the key finding is that in the Flinders Current and the Gulf Stream, the two upwelling mechanisms reinforce each other to increase the total upwelling, although for different dynamical reasons. In the South Indian Ocean, the Flinders Current is an eastern boundary current, whereas in the North Atlantic Ocean, the Gulf Stream is a western boundary current. The upwelling dynamics in both cases are however the same.

In the North Atlantic Ocean, the warm waters of the Gulf Stream encounter the cool water mass occurring in the northern Atlantic Ocean, and in the South Indian Ocean the cool waters of the Flinders Current encounter the warm water mass occurring in the southern Indian Ocean. Both situations are favorable to Sverdrup upwelling, which is enhanced by Ekman upwelling due respectively to the westerly wind field in the North Atlantic Ocean and to the easterly wind field in the South Indian Ocean.

Conclusion

The Sverdrup upwelling (in particular) and the Ekman upwelling which are occurring in the northern Atlantic Ocean and in the southern Indian Ocean are of vital importance to the productivity of the marine ecology, and arguably also to the generation of only a moderate warming in the climate of northern Europe and southern Australia, in this era of climate change.

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