Mixing and Trapping in Australian Tropical Coastal Waters

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ABSTRACT

Evidence is presented indicating the existence in tropical Australia of a coastal boundary layer, often visible as a nearshore band of turbid water. The coastal boundary layer inhibits mixing between the nearshore and offshore water by two effects, firstly by trapping in mangrove swamps, and secondly due to frictional effects which inhibit inertial jets. Contrast was found between coastal boundary layer dynamics in the Gulf of Carpentaria, which has shallow inshore water and a smooth coastline, and the continental shelf of the Great Barrier Reef which has deeper inshore water and a more rugged coastline. In the Gulf, the coastal boundary layer maintains its integrity for much longer time scales than in the Great Barrier Reef continental shelf.

I. Introduction

The coastal boundary layer (hereafter CBL) is a zone of water with a particular physical, chemical or biological property that is different from the offshore water. A CBL may trap freshwater runoff, nutrients, suspended sediments, water of temperature different from estuarine and offshore waters, etc... When the CBL is well defined, it acts as a barrier to direct mixing between the estuarine and the offshore water, mixing occurring instead between estuarine and CBL water, and between CBL and offshore water. An obvious example is when steady river plumes that extend to the sea floor prevail in coastal waters (Csanady, 1984). Some well documented attention has been given to CBL dynamics in European and American temperate estuaries, principally as river plumes (e.g. Bowman, 1988). The CBL may not be important if the coastal waters are deep enough, and the freshwater discharge important all year round, that the tidal currents and (or) the wind are generally unable to break down the vertical salinity stratification in coastal waters. In this case, sea water moves up-river and controls the hydrographic properties up-river, (e.g. the analytical model of Zhang et al. 1987) and mixing between estuarine and offshore water occurs in the estuary (e.g. the pioneer field and model studies of Fritchard, 1952; Rattray and Hansen, 1966, and others).

Mixing between estuarine and offshore water also occurs at tidal frequency at the river mouth. A tidal jet may exist at ebb flood tide, and radial flow at flood tide (e.g. Fischer et al., 1979; Joshi and Taylor, 1983; Ozsoy and Unluata, 1982; Ozsoy, 1986). This asymmetry helps determine the value of the return coefficient, $R$, of an estuary, i.e. the fraction of the volume of water leaving an estuary at ebb tide that returns at flood tide. Pioneer studies of the return coefficient were undertaken by Fritchard (1960). However, the value of $R$ has been measured for few estuaries. This value was found to range typically from 0.24 to 0.6 (van de Kreeke, 1988). The value of $R$ is difficult to predict. Simple tidal jets or steady river plume dynamics do not always prevail, and the value of $R$ may be more controlled in some cases by the dynamics of unsteady river plumes (e.g. a review in Bowman, 1988). Numerical models, as opposed to simpler analytical models available for steady river plumes, are needed to estimate the fate of unsteady river plumes (e.g. Chao, 1988; Chao and Boicourt, 1986; Royer and Emery, 1985; Wolanski and Banner, 1978). These
models are not always able to predict the value of R because the assumptions behind these models are too simplistic, and to remove them requires further detailed field studies.

Nearshore dynamics are even more complex, and predictions of the value of R are even less amendable to modelling in systems comprising many estuaries closely spaced along a smooth coastline. In that case, water leaving an estuary may simply be carried to the next estuary at tidal frequency, estuarine water leaving an estuary at ebb tide and entering the same or nearby estuaries at flood tide. In that case, a CBL may exist though the water may be located in the estuaries at high tide and nearshore along the shoreline at low tide. Recirculation from one estuary to the other may prevail also at low-frequencies, when atmospheric-driven sea level fluctuations in coastal waters alternatively withdraw estuarine water from estuaries, or inject coastal water into estuaries (e.g. Wong, 1986; Smith, 1988). Presumably, estuarine water may be circulated from estuary to estuary, though presumably it may be somewhat diluted with offshore water.

Mixing rates between CBL and offshore waters can be expected to decrease with increasing uncoupling of coastal and offshore dynamics. Bottom friction would lead to such uncoupling if coastal waters are shallow even in the absence of buoyancy effects, provided the sea bottom has a slope (Csanady, 1982; Hopkins and Swoboda, 1986).

In this study, it is demonstrated that CBL processes inhibit the mixing between estuarine and offshore waters in tropical Australia. We begin by describing the situation in the Gulf of Carpentaria where we present evidence of long-term (several months) trapping of brackish water in the nearshore zone. This trapping is