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The temperature minimum at tidal fronts

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Abstract. This paper presents a mechanism to explain the observed formation of a surface temperature minimum at tidal fronts in shelf seas. Tidal fronts mark the boundary between water which is kept vertically mixed by fast tidal currents and water which stratifies in summer. The fronts are associated with strong horizontal surface gradients of several water properties, including temperature. In the early studies of tidal fronts, a minimum in surface temperature was occasionally observed between the cool surface waters on the mixed side of the front and the warm surface waters on the stratified side. It was suggested that this was caused by upwelling of deep water at the front. In this paper we describe an alternative and simpler explanation based on the local balance of heating and stirring. The net heat flux into the sea in spring and early summer is greater on the mixed side of the front than on the stratified side. This happens because the heat loss mechanism is dependent on sea surface temperature and stratified waters, having a higher surface temperature, lose more heat. The stratified water near the front therefore has lower heat content (and lower depth-mean temperature) than the mixed water. If some of the stratified water becomes mixed, for example with increased tidal stirring at spring tides, a zone of minimum surface temperature will be formed at the front. A numerical model for the study of this mechanism shows that the temperature minimum at tidal fronts can be explained by the process described above. The minimum appears most clearly at spring tides, but can still be present in a weaker form at neap tides. A further prediction of the model is an increase of the horizontal temperature gradient at spring tides, which is in agreement with observations. An unexpected outcome of the modelling is the prediction of the formation of a marked sea surface temperature minimum, not yet observed, occurring in the autumn and located at the summer position of the tidal front.

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