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SHORT COMMUNICATION

Annual variation of air-water temperature difference at three Estonian coastal stations

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Abstract. Water and air temperatures during 1980–2010 were compared at three coastal stations of Estonia with the aim to estimate the stability conditions of the lower layers of the atmosphere. It is shown that the difference between the air and water temperatures varies during the year and the annual cycle of this variation is different at different measurement sites and also during different wind directions. Measurements at Sõrve demonstrate an unusual situation when the air-sea temperature difference is affected by the wind systems of the Gulf of Riga and Baltic Proper.

Key words: coastal zone, air–water temperature difference, seasonal dependence.

1. INTRODUCTION

Land-sea warming contrast is a well-known physical phenomenon that reflects the different heat capacity of these two objects. The temperature difference between air and water affects fluxes of mass and energy through the air-sea interface and is an important input for calculations of sensible heat [1].

Numerical circulation models of the ocean and atmosphere solve the momentum and heat fluxes at the air-sea interface as the principal coupling agents between the sea and the atmosphere [2]. The contrast between the water and air temperatures together with the radiation regime permits one to evaluate whether or not the lower layers of the atmosphere are stably stratified [3]. As a rule, the properties of stratification are estimated by means of observations of vertical profiles of air masses [4], relying on other types of measurements and modelling efforts [5] or using automatic weather stations on ships [6]. It is natural to presume that the measured water temperature to some extent characterizes temperature over some larger region of the sea surface and that the observed air temperature similarly reflects the properties of lower atmosphere over some region. The sign of the temperature difference usually serves as a rough criterion for the stability of the lower atmosphere in the first approximation. Knowledge on the stability permits one to choose the proper method for handling the variations of the air flow properties at different levels, for example, to choose the coefficient to derive the wind speed at the height of 10 m from the measurements in higher levels [7].

In this research note we analyse the temporal behaviour of the water and air temperature measured simultaneously at three Estonian coastal meteorological stations. Not surprisingly, the difference between these temperatures varies during the year. This variation is to some extent site-specific and considerably depends on the wind direction. At one of the sites (Sõrve, at the south-western end of the island of Saaremaa) this temperature difference reveals a counter-intuitive feature.

2. MATERIAL AND METHODS

The measurements used in this research note were carried out according to the WMO (World Meteorological Organisation) prescriptions [8] at the meteorological stations of Pakri, Sõrve and Ruhnu (Fig. 1). Air temperature was measured at the altitude of 2 m above the observation field and water temperature at the depth of 30 cm on the coast, at a location where harbour buildings and islets did not shelter the site. Principal information about the meteorological stations and time series is shown in Table 1.

Fig. 1. Measurement sites.

Table 1. Characteristics of the meteorological stations and the data series

Station	Coordinates	Elevation, m	Time period
Pakri	59°23′22″N, 24°02′24″E	23	1980–2008
Sõrve	57°54′49″N, 22°03′29″E	3	1980–2009
Ruhnu	57°47′00″N, 23°15′32″E	2	1980–1987, 2003–2010

The three air temperature time series do not have any gaps or substantial inhomogeneities, but the routine of the measurements of water temperature was changed rather often. Therefore the longest possible time series was chosen from the measurements at 06:00 UTC (08:00 East-European Time) and the second longest from the data filed at 18:00 UTC (20:00 East-European Time).

3. LONG-TERM PROPERTIES OF AIR AND WATER TEMPERATURE

Due to differences in the heat capacity of water and air it is natural that the water temperature generally follows the variations in the air temperature with a certain delay throughout the year. The air warms up quickly in the spring when the water is still cold. The temperature of the water and the air become slowly equal in summer and the water is warmer than the air in the autumn. In winter, the coastal zone of Estonia is temporarily covered with ice. In such conditions the water temperature is measured in samples that are taken from under the ice with buckets. The resulting water temperature does not represent the sea surface temperature.

The air temperature has a large annual cycle at all three measurement sites. The highest monthly average (in July) is around 17 °C at all stations. The lowest monthly average is –4 °C at Pakri and Ruhnu and –2 °C at Sõrve. The water temperature is around zero in winter and at its maximum in July – approximately 17 °C at Pakri and Ruhnu and 18 °C at Sõrve. In climatological conditions of Estonia in summer the air is commonly warmer than water (Fig. 2). The situation at Sõrve differs greatly from that at the other stations: during a substantial part of the summer the water is warmer than air (Fig. 2). This feature persists for the time series containing only evening records (18:00 UTC). In May the water is even by 2.5° warmer than the air at Sõrve (Fig. 3).

This unusual and interesting feature could be partially explained by different location of the measurement sites in terms of the openness with respect to the nearshore–open sea water exchange. At Pakri and Ruhnu the water temperature is measured at a location where the water exchange with the open sea is not restricted. Therefore the water temperature filed at these locations characterizes the temperature of the surface layer of the sea rather well. At Sõrve the measurements are carried out in a shallow bay that is open only to the South. From July to January the West and South winds dominate in the north-western Baltic Proper.

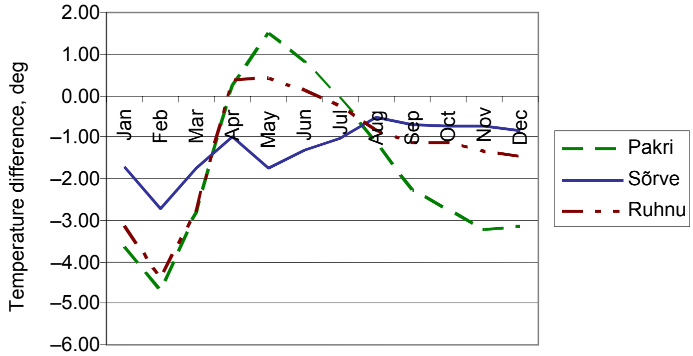

Fig. 2. Monthly mean air and water temperature difference at 06:00 UTC.

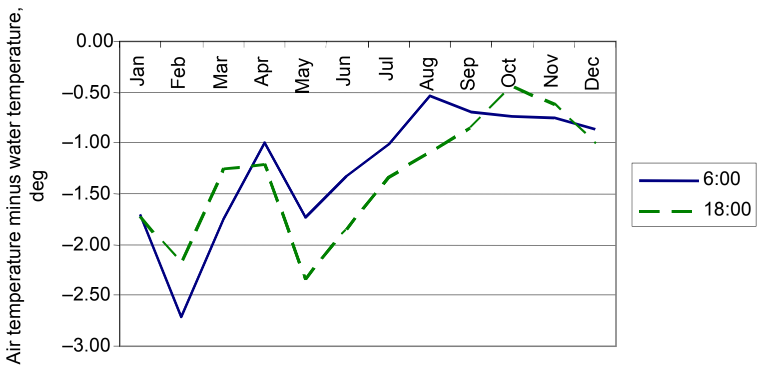

Fig. 3. Monthly mean temperature difference at Sõrve in the morning and in the evening.

These winds usually carry warm surface water to the bay. Therefore the water temperature at Sõrve not necessarily exactly represents the thermal conditions in the open sea.

4. TEMPERATURE DIFFERENCE AND THE WIND DIRECTION

It is widely known that the air–land temperature differences and atmospheric movements are tightly interrelated. In order to evaluate the impact of the latter driver to the highlighted feature, the above analysis was repeated for different wind directions. The measured wind data were divided into four rhumbs: North 360°±45°, East 90°±45°, South 180°±45°, West 270°±45°. Due to the asymmetry of the wind roses and different length of the meteorological time series, the number of recorded wind data varies for different wind directions (Table 2). Calm situations are not taken into account.

Figure 4 shows that the difference between the air and water temperatures depends notably on the wind direction. For North and East winds the annual

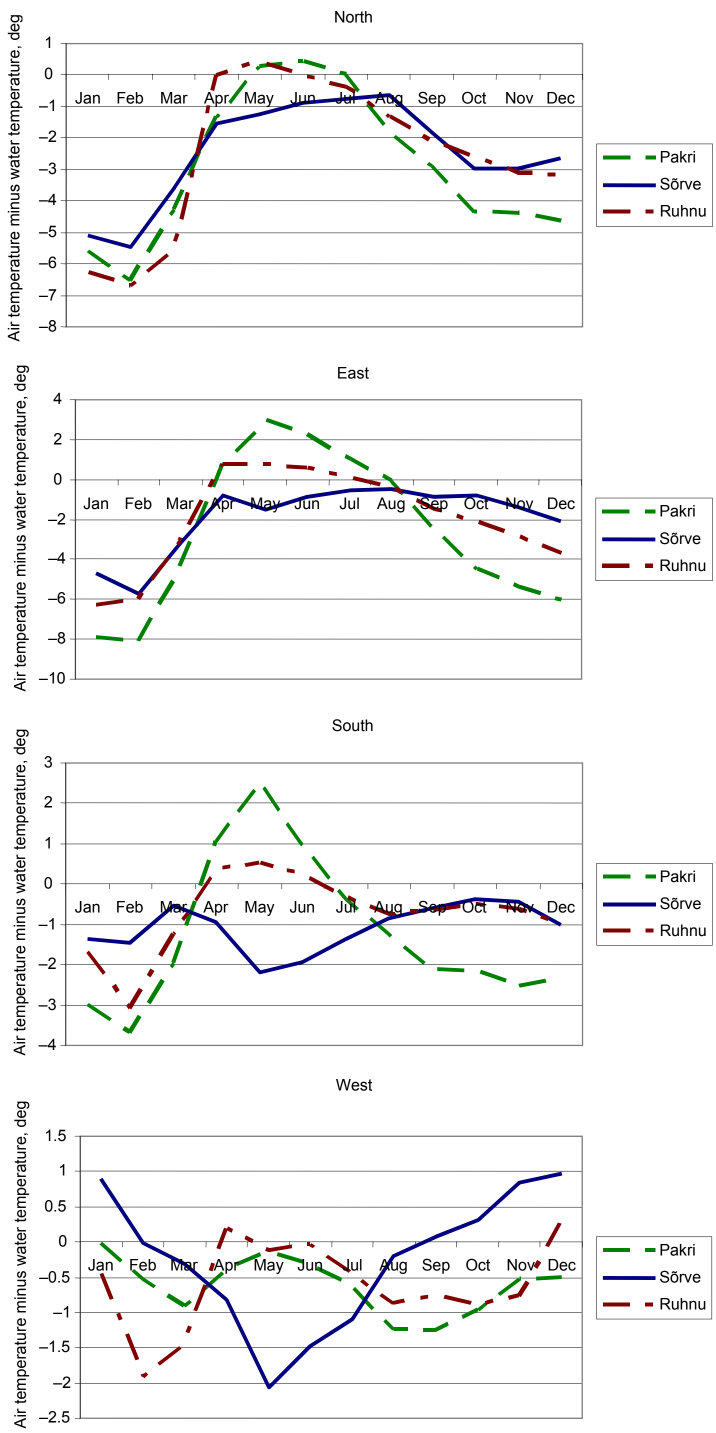

Fig. 4. Annual cycles of the temperature difference at different stations during different wind directions.

Table 2. Number of recorded winds for different rhumbs at 06:00 UTC

Wind direction	Pakri	Sõrve	Ruhnu
North	2011	1973	1012
East	2110	2123	858
South	4213	3101	1855
West	2037	3016	1326

cycle of the temperature difference is similar to the one depicted in Fig. 2. South winds approach Pakri over the Estonian mainland. This is the likely reason why the annual amplitude of the temperature difference is larger at Pakri than at other stations where South winds approach the measurement site over the sea. West winds are onshore for all stations. At Pakri they blow along the Gulf of Finland, at Ruhnu from the Gulf of Riga and at Sõrve from the Baltic Proper. This analysis signals that the above-described unusual behaviour of the temperature difference at Sõrve is caused by the location of this site at the end of the narrow peninsula. The water temperature is measured on the western coast of the peninsula. Thus, the particular location for the temperature measurements may be a partial reason for the contradiction between the local and the open sea temperature regime because the surface water is carried from the open sea to the water temperature measurement site by the West (and South) winds.

5. CONCLUSIONS

The research sheds some light to the problem of adequacy of existing estimates of the stratification conditions of the lower layers of the atmosphere in the coastal zone. It is commonly assumed that stratification of air masses is stable when the water is colder than air. The presented results show that in the conditions of selected stations at the Estonian seashore in most cases the water is warmer than the air whereas details of the temperature difference depend substantially on the season. The annual cycle is different at different sites and additionally depends on the wind direction. Most interestingly, the measurements at Sõrve demonstrate the frequent presence of an unusual situation when the air–sea temperature difference is reversed and possibly strongly affected by the wind systems of the Gulf of Riga and Baltic Proper.

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Õhu- ja veetemperatuuri vahe aastane tsükkel kolmes Eesti rannikujaamas

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On võrreldud õhu- ja veetemperatuuri kolmes Eesti rannikujaamas aastatel 1980–2010 eesmärgiga hinnata atmosfääri alumiste kihtide stratifikatsiooni stabiilsust. On näidatud, et õhu- ja veetemperatuuri vahe oleneb aastaajast, mõõtmiskohast ning tuule suunast. Mõõtmised Sõrves näitavad, et seal on tegemist erilise olukorraga, kus õhu- ja veetemperatuuride vahet mõjutavad Riia lahe ning Läänemere avaosa tuulesüsteemid.