Polish-Norwegian Research Programme

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Atmosphere and climate change WP 6

- **T6.1. To study climate changes in the early instrumental period, NCU**
- **T6.2. To establish a homogenized West Spitsbergen (Hornsund and Isfjord Radio) air temperature time series 1934-present, met.no, NCU**
- T6.3. To study the north-south air temperature gradient on the Western Svalbard, met.no
- T6.4. Study the recent temperature anomalies on western Spitsbergen and its relation to circulation (e.g. strong mild southerlies, frequency of lows, periods of sustained along-shelf winds etc), sea ice, sea temperatures and ocean heat transport, met.no
- **T6.5. To recognize radiation and heat budget changes, NCU**
- **T6.6. To describe topoclimate data from different Hornsund regions based on historical sources and collected data, NCU**

Sea water surface energy balance in the Arctic fjord (Hornsund, SW Spitsbergen) in May-November 2014

Krzysztof Fortuniak[1], Rajmund Przybylak[2], Andrzej Araźny[2], Włodzimierz Pawlak[1] & Przemysław Wyszyński[2]

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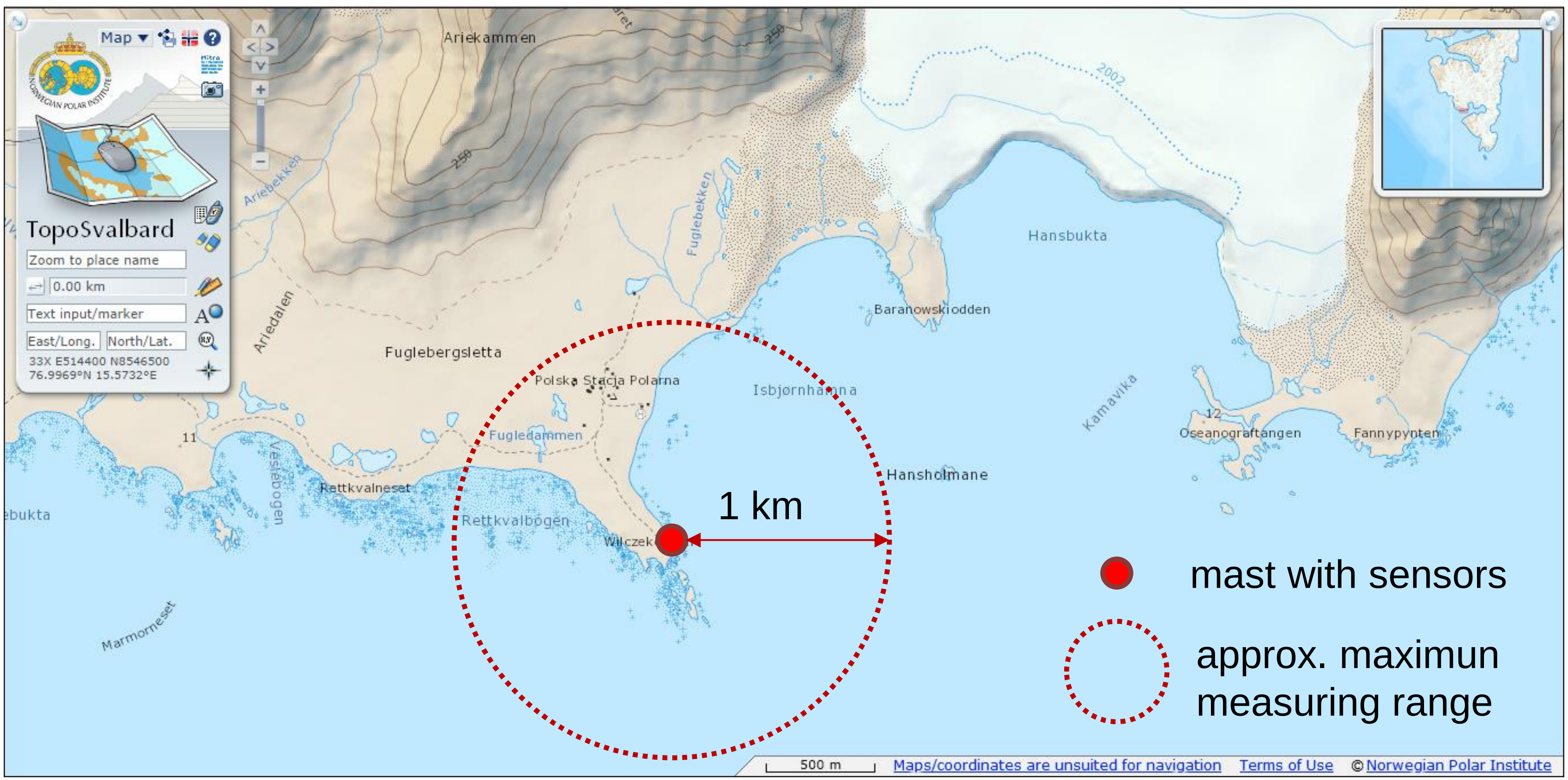
Universitas Nicolai Copernici Toruń

Veritas et Libertas Universitas Lodziensis

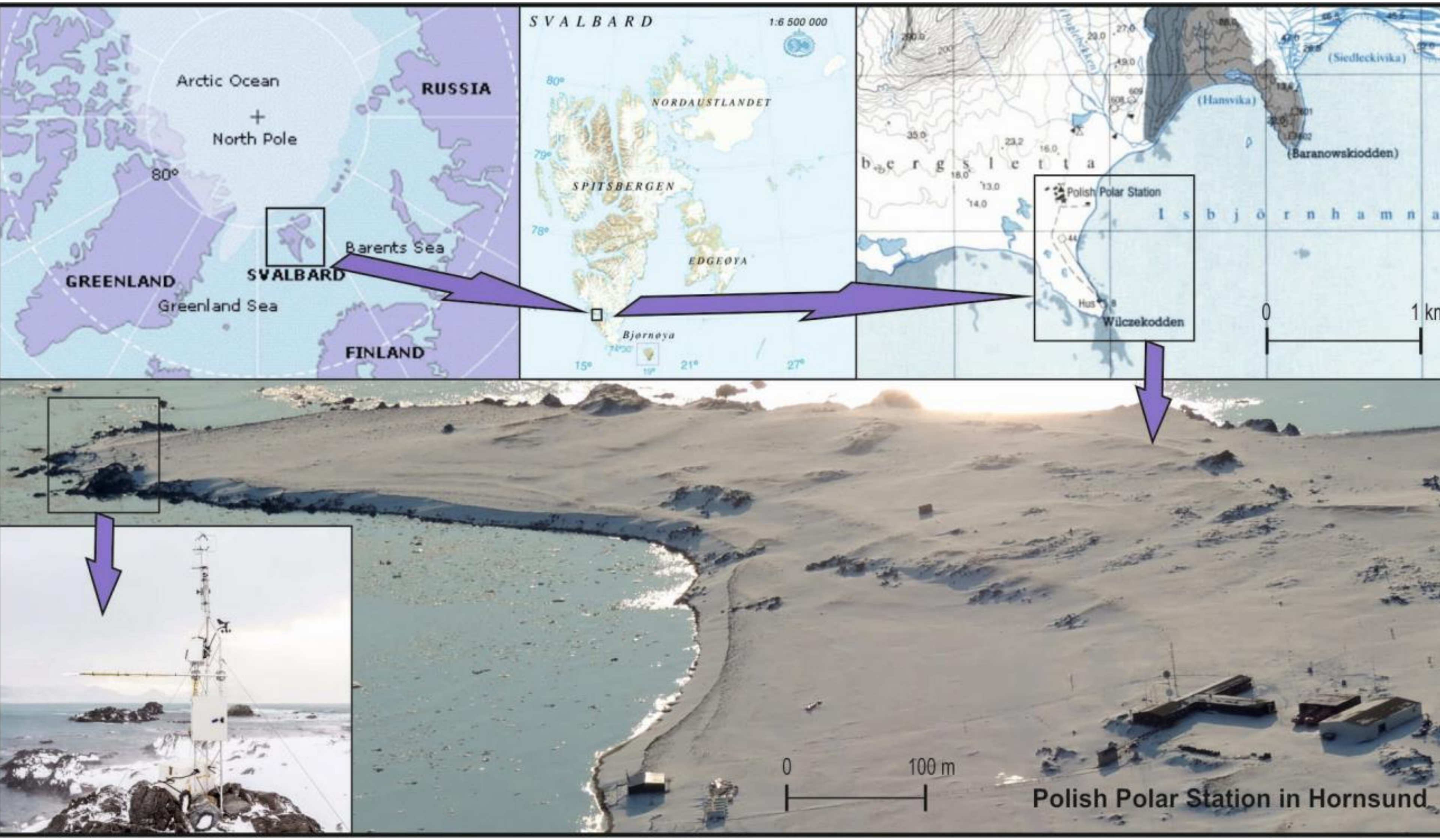
Aim of the work:

- Continuous, long-term measurements of turbulent exchange of sensible and latent heat in polar conditions
- Exchange of heat between sea and atmosphere

Area:



Location of measuring site in the Wilczek Peninsula (Hornsund, SW Spitsbergen)



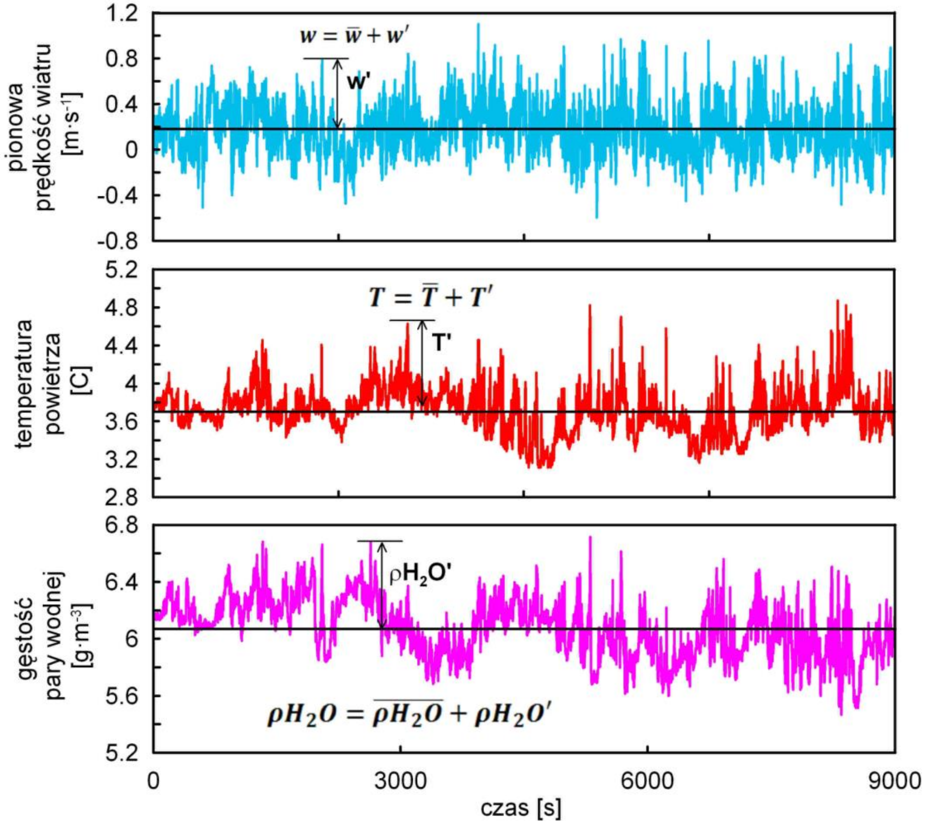

Wilczekodden (WIL)
(AWS Davis, radiation and
heat budget)
Hornsund (HOR)
(AWS Vaisala)
without ice
21.09.2014 photo A.Araźny

May 5, 2014, photo PW

Methodology

Sensible and latent heat fluxes measurement site in Hornsund, Spitsbergen

Examples of vertical wind speed and water vapor density measurements results (frequency of readings 10Hz).



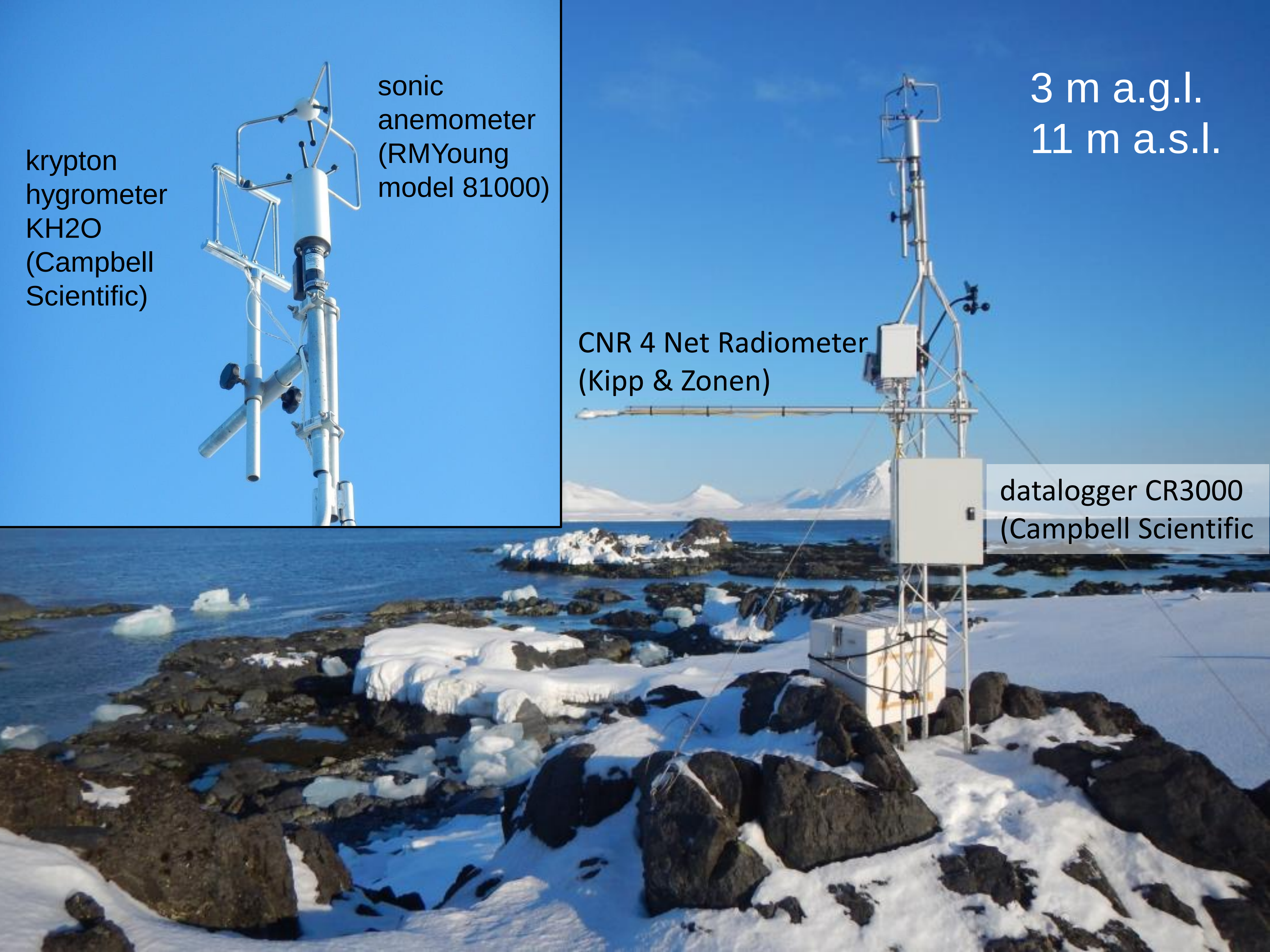
$$Q_H = \rho \cdot c_p \cdot \overline{w'T'} [W \cdot m^{-2}]$$
$$Q_E = \rho \cdot l \cdot \overline{w'\rho H_2O'} [W \cdot m^{-2}]$$

w' – vertical wind speed fluctuations
T' – air temperature fluctuations
$\rho H_2O'$ – fluctuations of water vapour density
ρ – air density
c_p – specific heat of air
l – heat of evaporation
$\overline{w'T'}$ – covariance of vertical wind speed and air temperature fluctuations
$\overline{w'\rho H_2O'}$ – covariance of vertical wind speed and density of water vapour fluctuations

Post-processing and evaluation of data quality:

- **10 Hz frequency**
- **„bad” data rejection (rain, snow, deposition on sensors, etc.)**
- **1 hour block averaging**
- **spike detection**
- **maximization of covariance due to sensors separation**
- **double rotation of wind coordinates**
- **correction of sonic temperature for humidity**
- **corrections for spectral losses**
- **WPL correction- evaluation of stationary data (three different tests)**
- **assessment of data quality (3 tests)**

~ 15% lack of data or rejection as a „bad data”
~ 21% of data rejected due to failed stationary tests



krypton hygrometer KH2O (Campbell Scientific)
sonic anemometer (RMYoung model 81000)
3 m a.g.l.
11 m a.s.l.
CNR 4 Net Radiometer (Kipp & Zonen)
datalogger CR3000 (Campbell Scientific

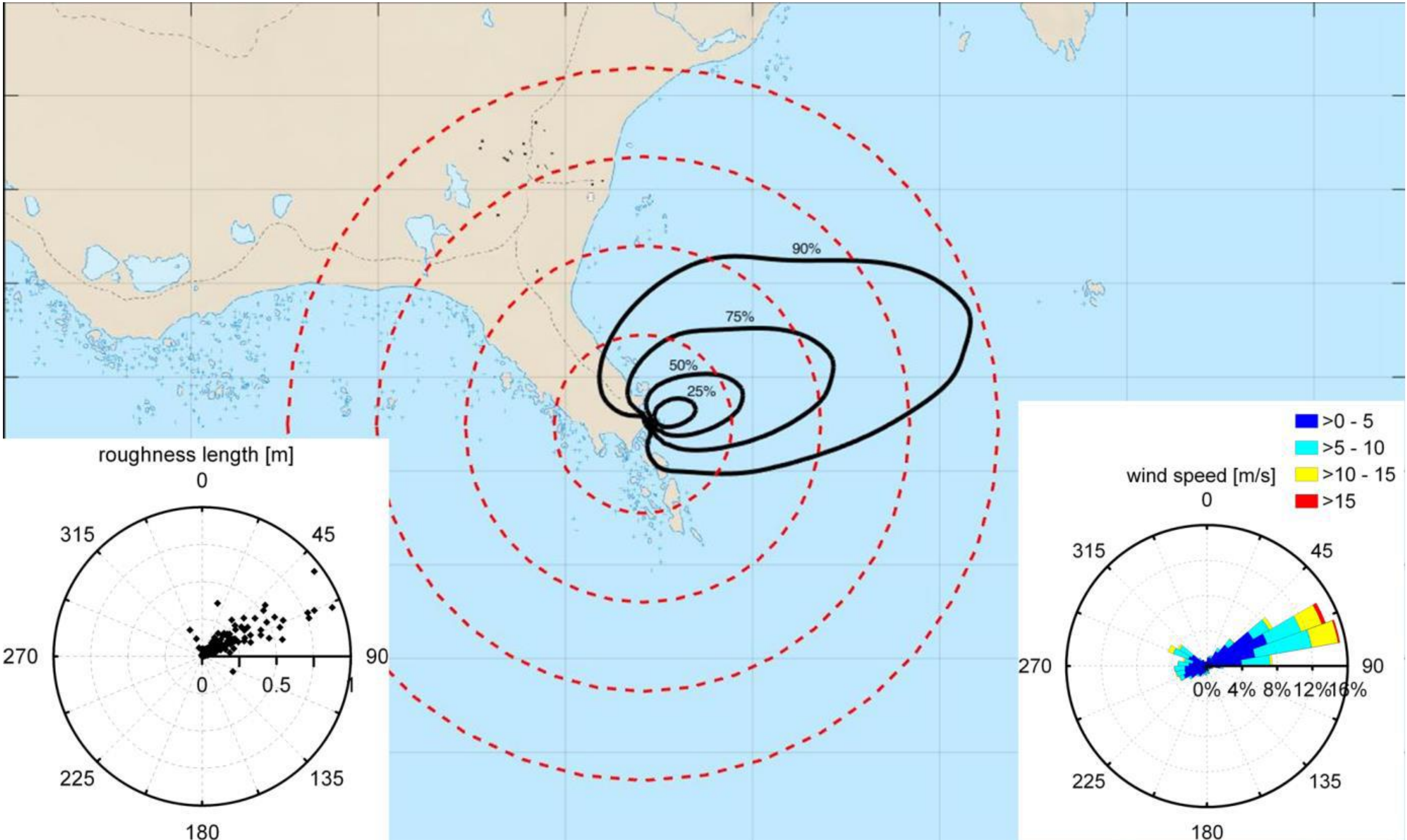

cleaning sensors
everyday


downloading data
once a week

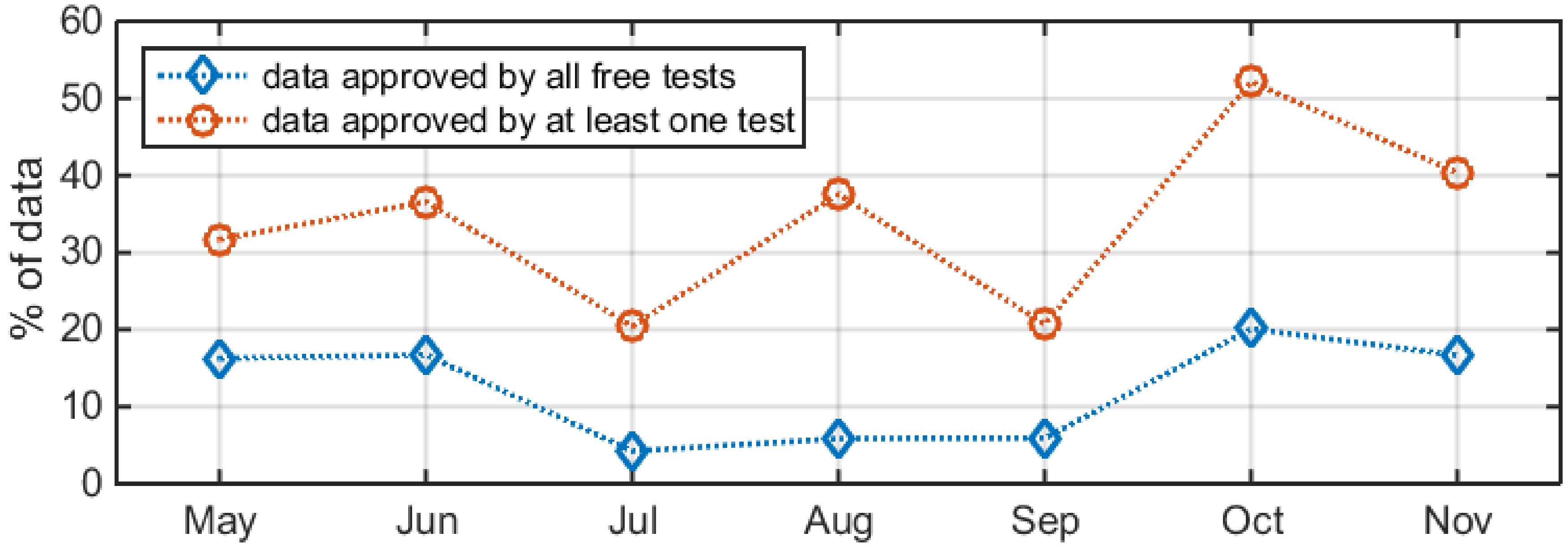

19.09.2014 photo W. Kaszkin


7.09.2014 photo W. Kaszkin

Source area of turbulent fluxes (with probability P = 25, 50, 75 and 90%) calculated for unstable conditions with use of Schmid method (main figure). Additional figures shows relations between wind direction and roughness length (left) and wind speed (right). Map source: TopoSvalbard.



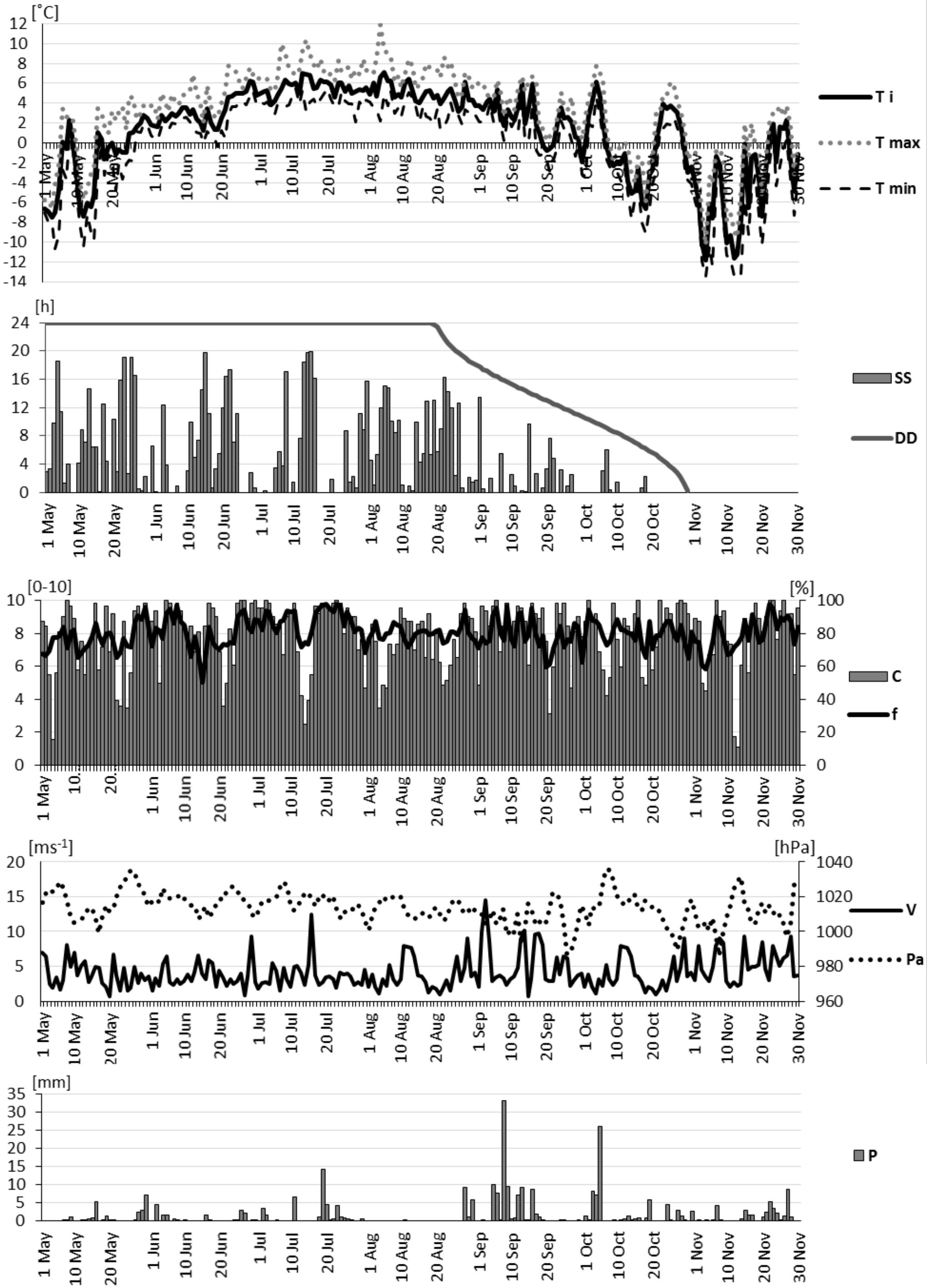
The percentage of the data approved by all three stationarity tests and by at least one of the tests



Monthly mean and sum anomalies of main meteorological variables in Hornsund (period from May to November 2014 in relation to reference period 1978–2012)

Variable	Period	May	Jun	Jul	Aug	Sep	Oct	Nov
Ti (˚C)	a	-2.7	1.9	4.4	4.1	1.5	-3.2	-6.3
	b	0.8	1.4	1.2	0.9	0.9	2.9	1.9
SS (hr)	a	205.4	171.0	155.4	124.9	73.7	22.8	-
	b	6.6	-6.1	8.5	87.8	-13.3	-9.1	-
SS (%)	a	27.6	23.8	20.9	17.9	17.4	11.6	-
	b	0.9	-0.9	1.1	12.6	-3.1	-4.6	-
C (0-8)	a	6.0	6.4	6.5	6.5	6.5	5.9	5.6
	b	1.4	1.9	1.8	0.9	1.8	2.2	2.2
Pa (hPa)	a	1016.3	1013.4	1012.2	1011.9	1008.6	1007.5	1005.6
	b	1.8	3.8	4.6	1.0	-2.2	6.2	4.5
V (ms^{-1})	a	4.9	3.9	4.0	4.1	4.5	5.3	6.1
	b	-1.0	-0.3	-0.3	-0.4	0.7	-1.6	-0.8
f (%)	a	79	83	86	86	82	77	76
	b	-2	-3	1	-5	-3	4	4
P (mm)	a	20.1	27.7	41.2	53.6	68.3	47.3	38.1
	b	2.9	-11.0	-1.8	-37.0	23.7	18.1	-0.3

Explanations: Ti - air temperature; SS - sunshine duration; C - cloudiness; Pa - air pressure at 0 m a.s.l.; V - wind velocity at 10 m a.s.l.; f - relative air humidity; P - atmospheric precipitation; a - period 1978-2012 (Marsz, Styszyńska 2013); b – 2014



Course of meteorological elements in Hornsund in the period from 1st May to 30th November 2014.

Explanations:

Ti, T max, T min - mean, maximum and minimum air temperature;

SS - sunshine duration;

DD – duration of the day; C - cloudiness;

f - relative air humidity;

V - wind velocity at 10 m a.s.l.;

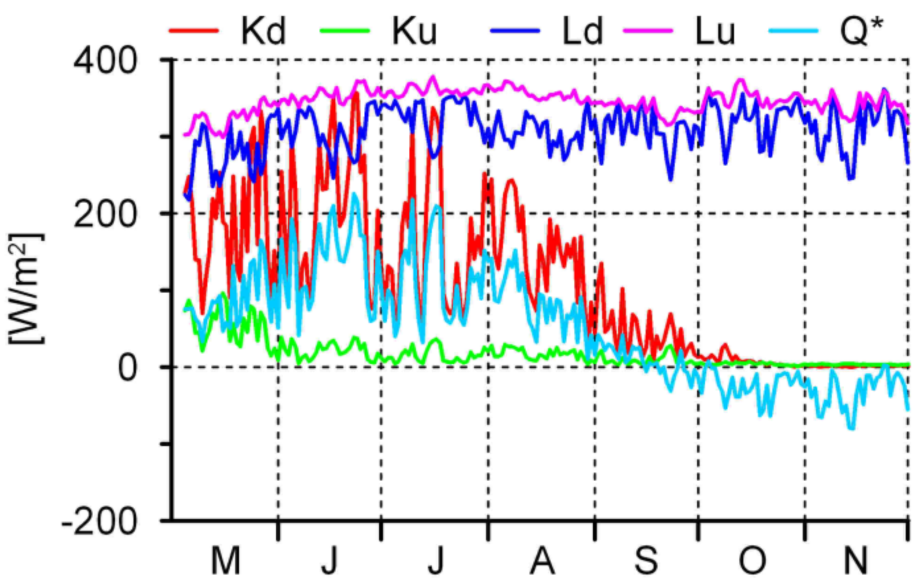
Pa - air pressure at 0 m a.s.l.;

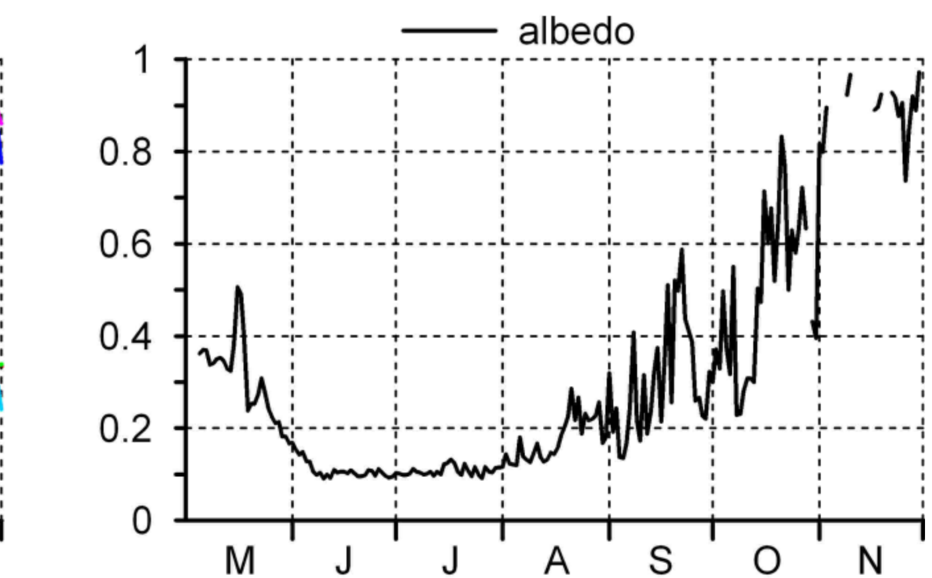
P - atmospheric precipitation.

Monthly statistics of sensible (QH) and latent (QE) heat fluxes in Hornsund in the period 1st May to 30th November 2014 (mean, standard deviation and percentiles) calculated on the base on data which passed all three stationarity tests

		May	Jun	Jul	Aug	Sep	Oct	Nov	May-Nov
Mean	QH	38.3	23.0	-13.8	-26.7	-24.4	-3.0	50.5	17.5
St. dev.		26.1	24.0	29.3	24.4	30.5	44.0	36.3	42.1
1%		0.6	-39.4	-59.1	-86.8	-114.4	-152.8	-69.2	-114.4
10%		11.6	5.5	-48.2	-67.7	-59.3	-68.9	15.4	-33.9
25%		19.7	11.2	-43.5	-33.7	-40.1	0.5	30.4	4.7
50% (Median)		32.0	19.9	-8.1	-18.2	-19.3	10.1	51.4	18.8
75%		48.9	31.9	9.1	-9.8	-3.9	19.7	65.0	39.1
90%		75.5	52.8	22.2	-6.9	10.9	31.5	92.3	61.0
99%		125.3	93.1	39.3	21.4	13.7	59.9	148.2	126.8
Mean	QE	71.8	71.3	133.3	68.6	77.1	97.2	139.9	94.9
St. dev.		73.8	63.5	67.5	43.9	115.5	92.7	133.3	96.0
1%		13.6	10.6	16.2	8.9	8.3	8.3	11.5	10.4
10%		26.1	25.4	39.9	18.0	20.2	25.5	33.9	26.3
25%		36.0	32.7	94.8	37.6	27.4	36.6	45.6	37.1
50% (Median)		53.3	46.5	141.7	60.0	39.9	58.5	83.1	59.2
75%		82.8	85.6	174.8	95.6	61.8	135.9	178.3	109.2
90%		112.5	138.0	234.3	105.5	193.0	204.5	392.0	210.5
99%		465.4	321.3	269.1	213.5	547.0	414.1	505.8	466.6

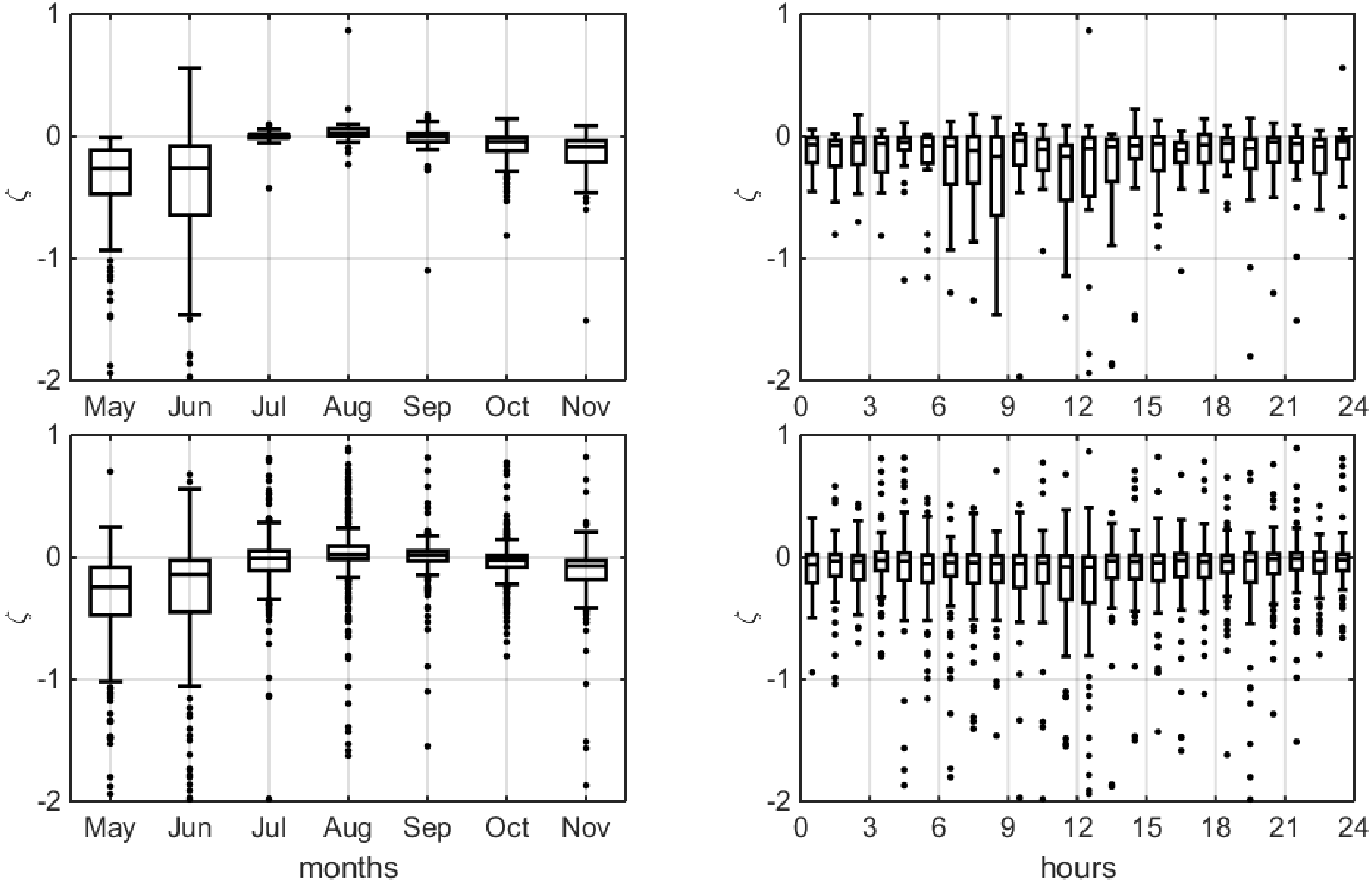
Course of daily means of albedo, radiation balance and its components in the period 1st May to 30th November 2014 in Hornsund



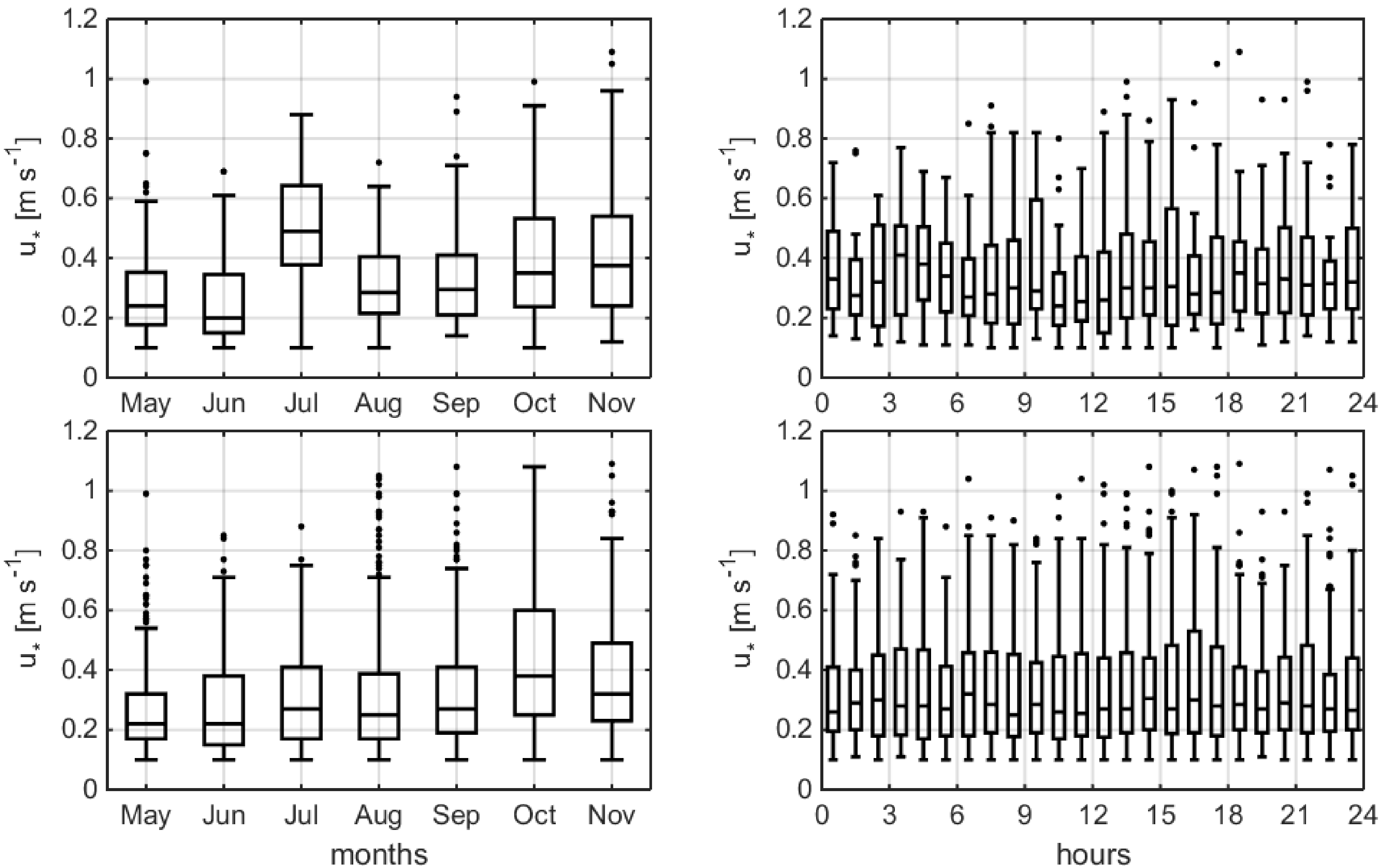


Explanations:
Q* - radiation balance,
Kd – incoming solar radiation,
Ku – reflected solar radiation,
Ld – incoming longwave radiation,
Lu – outgoing longwave radiation.

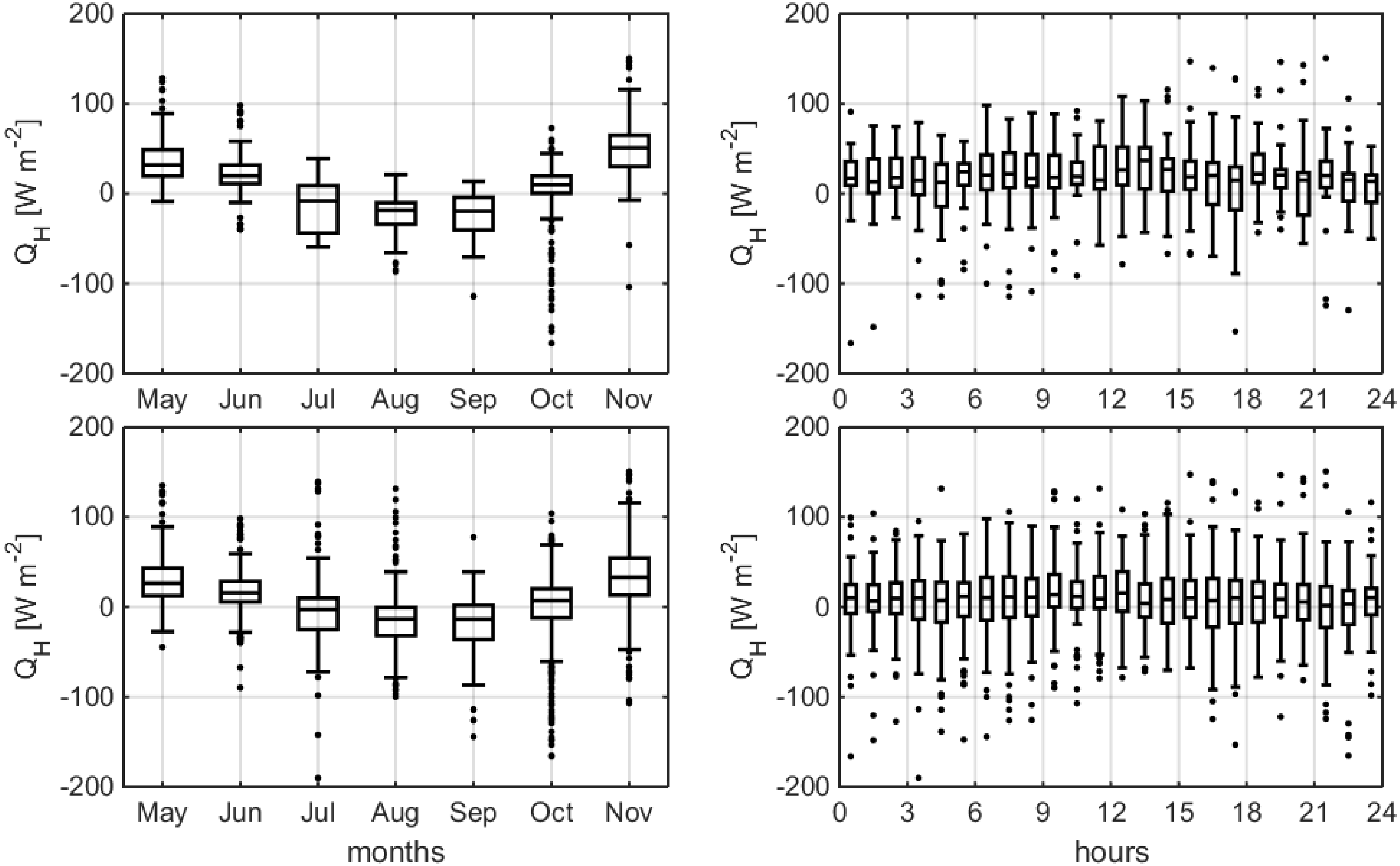
Box-whiskers plots for the stability parameter, $\zeta = z'/L$, for months (left) and hours (right) in Hornsund in the period from 1st May to 30th November 2014. The upper plots based on the data approved by all three stationarity tests (3T), the lower plots based on the data approved by only one of the stationarity tests (1T).



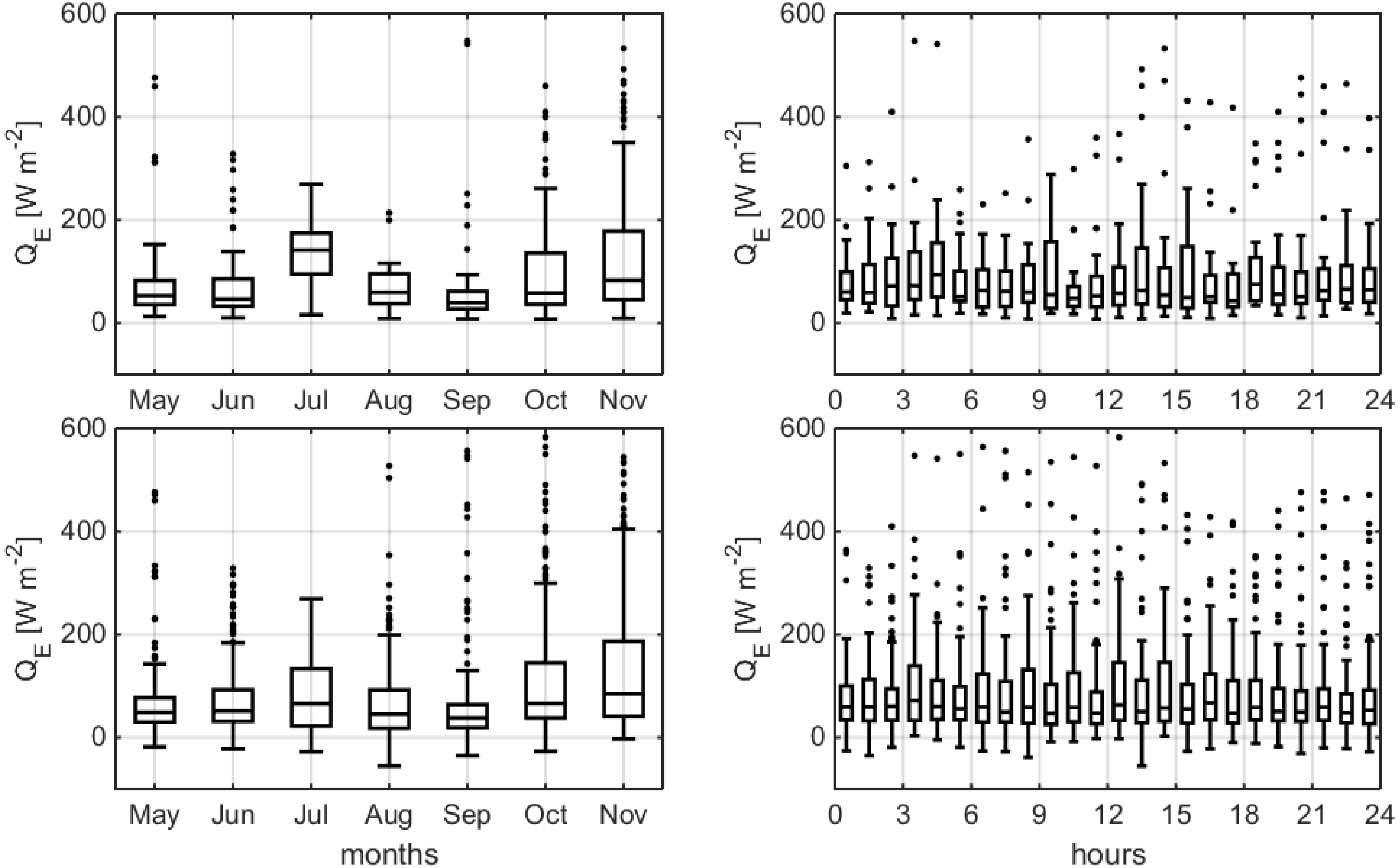
The same as on previous slide but for a friction velocity, u_*.



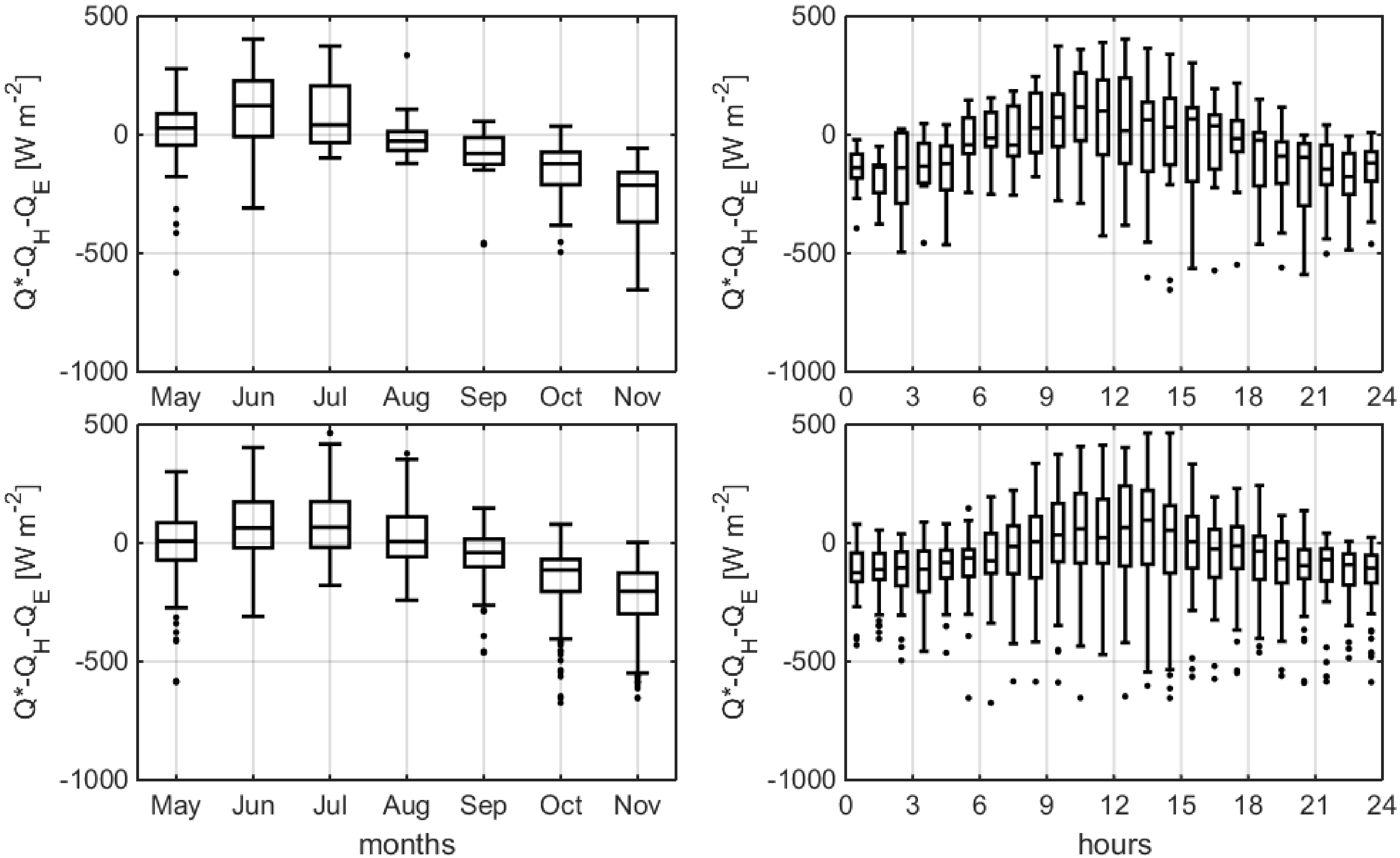
The same as on previous slide but for sensible heat flux, QH.



The same as on previous slide but for latent heat flux, QE.



The same as on previous slide but for the rest from the energy balance: $Q* - QH - QE$.



CONCLUSIONS 1:

The results show the complexity of the surface energy exchange between sea water and atmosphere in Arctic fjords. This turbulent exchange is dominated by latent heat flux, which on average is significantly higher than a sensible heat flux. The dominant latent heat flux is in general upward, which indicates a sea surface cooling by evaporation. On average, QE remained on a constant level of around 70 Wm^{-2} in the summer, increasing at the beginning of winter. The sensible heat flux was significantly lower and took negative values from July to October, which means downward turbulent transport of heat to the surface and might be related to the presence of glacial ice in the fjord, with melting ice consuming heat from the surface air layer. One remarkable feature of the turbulent energy exchange in this Arctic fjord was the sporadic appearance of very high values of latent heat, with the maxima exceeding 500 Wm^{-2}, which happened close to neutral stratification. This indicates that under favourable conditions, the sea-air energy exchange could be very intensive.

CONCLUSIONS 2:

The results also show the difficulties in estimating turbulent fluxes in the Arctic with the aid of the eddy covariance method. The extreme weather conditions result in a large number of data being excluded from analysis, either due to sensor failures or to the non-fulfilling theoretical assumptions of the method. Moreover, even if standard steps in flux calculations have been well worked out by the EC community, data quality verification is more subjective. Each stationarity test approves a slightly different set of data, while the choice of tests used and their combination remain a subjective decision. With large amounts of excluded data, this can significantly affect the results, especially when the approved data are used in gap-filling procedures. The monthly totals of energy based on such procedures can be tilted toward making a case for approved data, but which are not necessary representative of the prevailing weather conditions.

Thank You!

Krzysztof Fortuniak[1], Rajmund Przybylak[2], Andrzej Araźny[2], Włodzimierz Pawlak[1] & Przemysław Wyszyński[2]

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