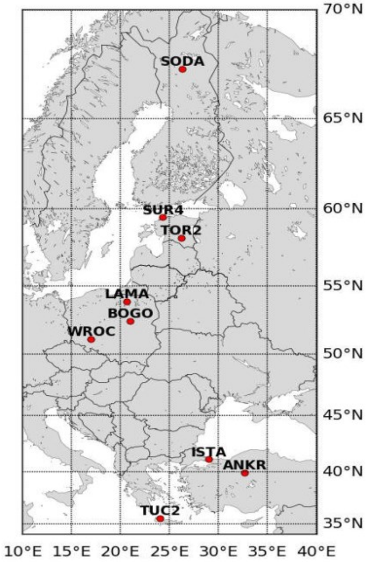
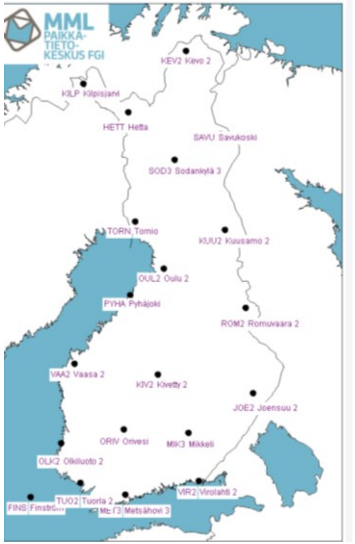
Characterizing atmospheric humidity in Eastern Europe during the last two decades by using GNSS-derived integrated water vapour

Piia Post[a], Kalev Rannat[b], Hannes Keernik[b]
[a] University of Tartu, Estonia
[b] Tallinn University of Technology, Estonia

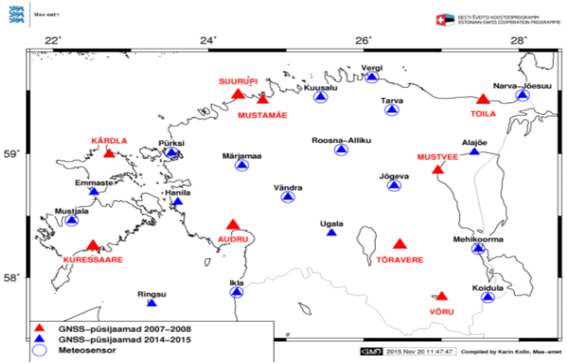
Positions of stations used in the studies

(supporting studies of local small-scale meteorological processes)





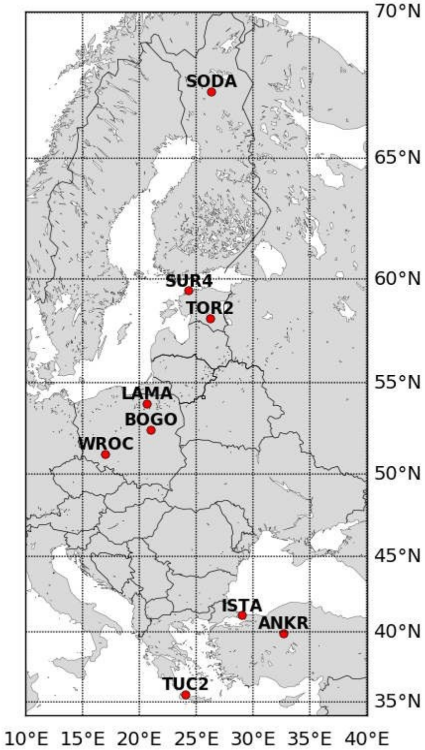
ESTPOS



A selection of nine European Reference Frame Permanent Network (EPN) stations

The RINEX-files for the GNSS data processing were provided by Maanmittauslaitos, Estonian Land Board, Latvian Geospatial Information Agency and EUREF

Experiments using data from European Reference Frame Permanent Network (EPN)

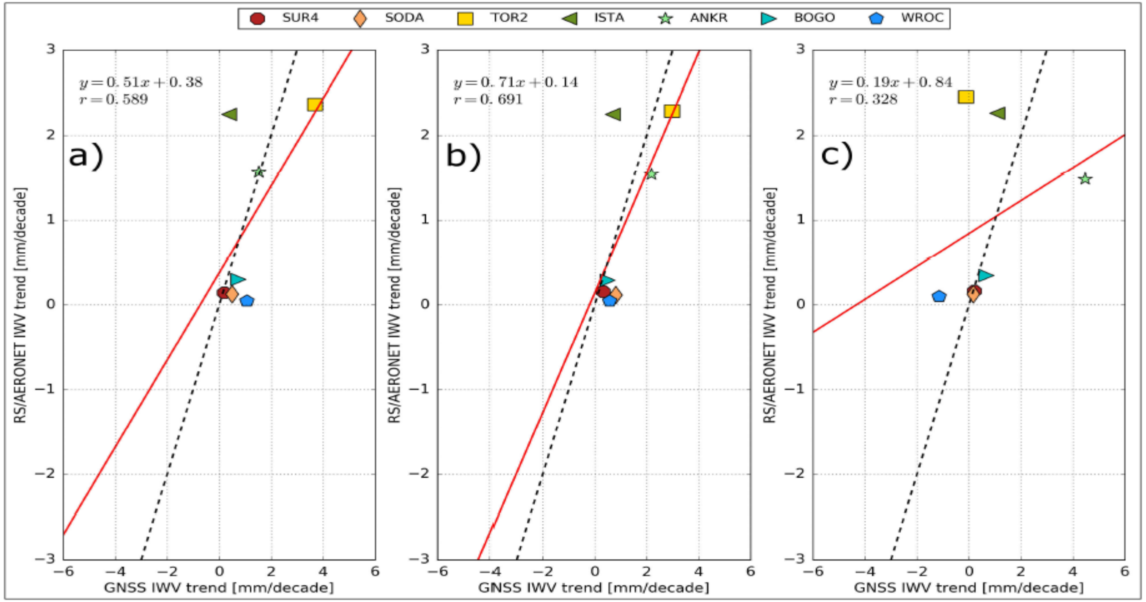


In order to estimate the Integrated Water Vapour (IWV), the data from 46 GNSS stations were processed with the GAMIT software.

Nine sites were selected based on time series length and availability of comparison techniques:

Acronym	Full name	Time period	No. of obs.	Comparison technique	Distance [km]	No. of paired obs.
SODA	Sodankylä	2000–2015	132 528	Radiosonde	12.4	9 833
SUR4	Suurupi	2000–2015	125 441	Radiosonde	14.4	5 290
TOR2	Tõravere	2008–2015	40 925	AERONET	0.6	8 871
BOGO	Borowa Gora	2000–2013	101 954	Radiosonde	10.1	7 710
WROC	Wroclaw	2000–2015	103 164	Radiosonde	12.6	7 773
ISTA	Istanbul	2002–2013	101 934	Radiosonde	15.3	7 055
ANKR	Ankara	2002–2015	102 528	Radiosonde	12.2	7 690
LAMA	Olsztyn	2001–2015	99 508	-	-	-
TUC2	Chania	2007–2015	68 598	-	-	-

Impact of antenna elevation cut-off angle on IWV trends
(preliminary results with non-homogenized time series)



Correlation of IWV trends estimated from Radiosonde or AERONET and GNSS depending on cuf-off angle
a) 10°, b) 20°and c) 30°.
The linear fits are marked with red lines, while the dashed lines show the perfect agreement.
The correlation is the strongest at 20° (r = 0.691)

Model of Nilsson and Elgered (2008) is used

$$y = y_0 + a_1 t + a_2 \sin(2\pi t) + a_3 \cos(2\pi t) + a_4 \sin(4\pi t) + a_5 \cos(4\pi t),$$

where *y* and *t* are the IWV and time in years; y_0 and a_1 denote the average and the linear trend of IWV; a_2 and a_3 are the annual components while a_4 and a_5 are the semi-annual components. These coefficients were estimated using the LSQ.

Diurnal cycle of IWV

The motivation is to check whether there exists any systematic changes in diurnal cycle within this 16-year time period.

In Suurupi (coastal site) relatively long time series (2000-2015) exists.

Tõravere (continental site, data from 2008-2015).

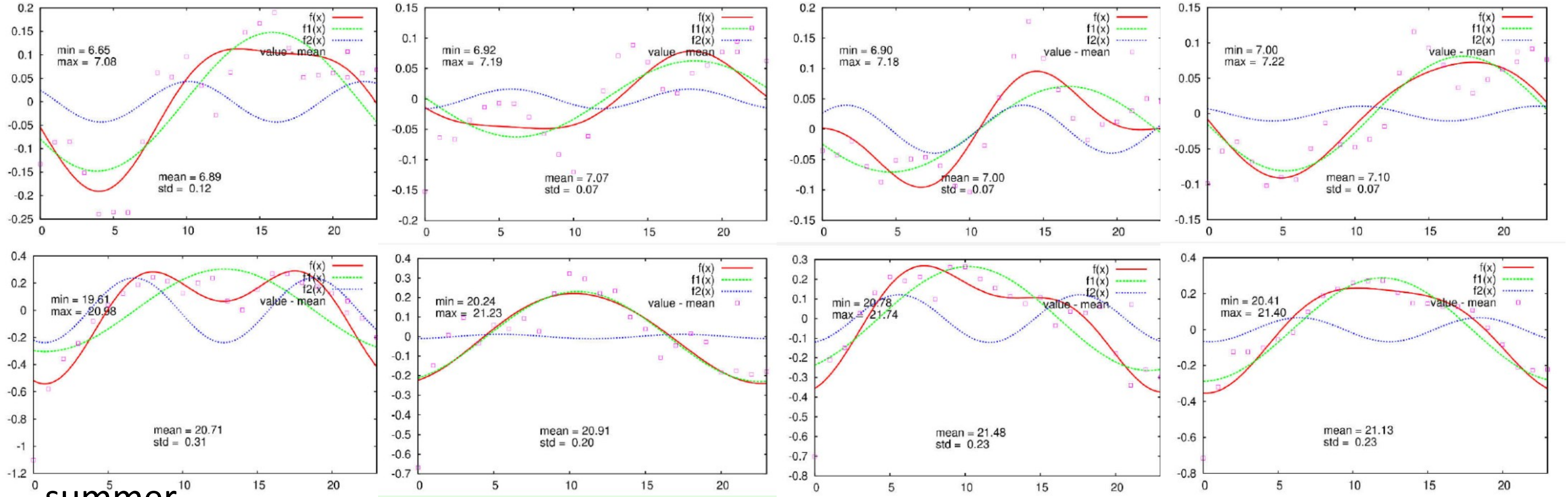
The harmonic analysis used in investigation of the diurnal cycle of IWV (with periods of 24 hrs and 12 hrs) is based on a method described by Dai *et al*. (JGR,107, D10, 10.1029/2001JD000642, 2002).

This analysis represents just preliminary results and an excerption from a broader set of sites.

It is planned to continue and to compare with reanalysis EPN Repro 2.

Diurnal cycle of IWV (anomalies)

winter



summer

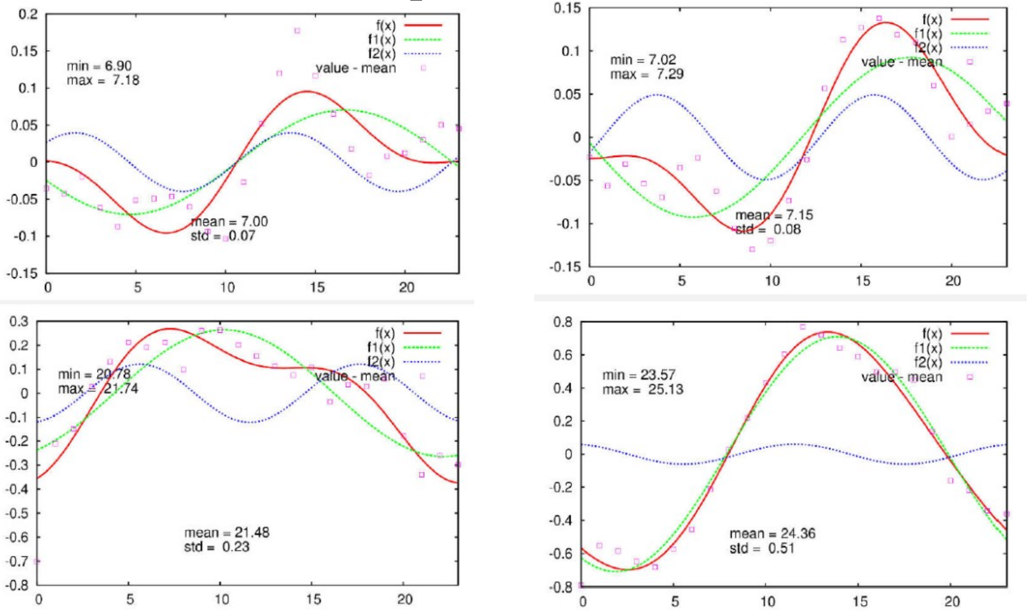
2000-2005 2005-2010 2010-2015 2000-2015

SUR4 - It can be noticed, that the characteristic pattern of 6-year excerptions (2000-2005, 2005-2010, 2010-2015) may slightly differ from the statistics calculated over the full timeline.

Diurnal cycle of IWV (anomalies)

winter

summer



SUR4 2010-2015

TOR2 2008-2015

Anomalies from seasonal mean IWV stay small in winter and reach 5-6 times higher values in summer.

GNSS for Severe Weather Events (ref. Geophysica)

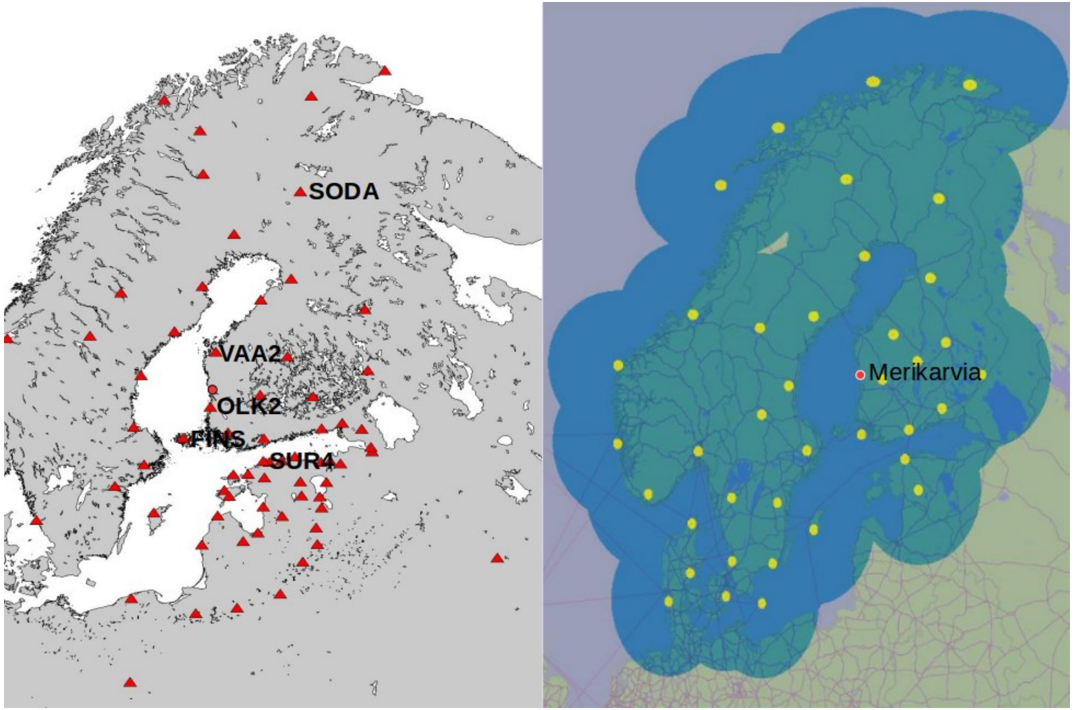
Geophysica (2018), 53(1), 65–91

Sea-Effect Snowfall Case in the Baltic Sea Region Analysed by Reanalysis, Remote Sensing Data and Convection-Permitting Mesoscale Modelling

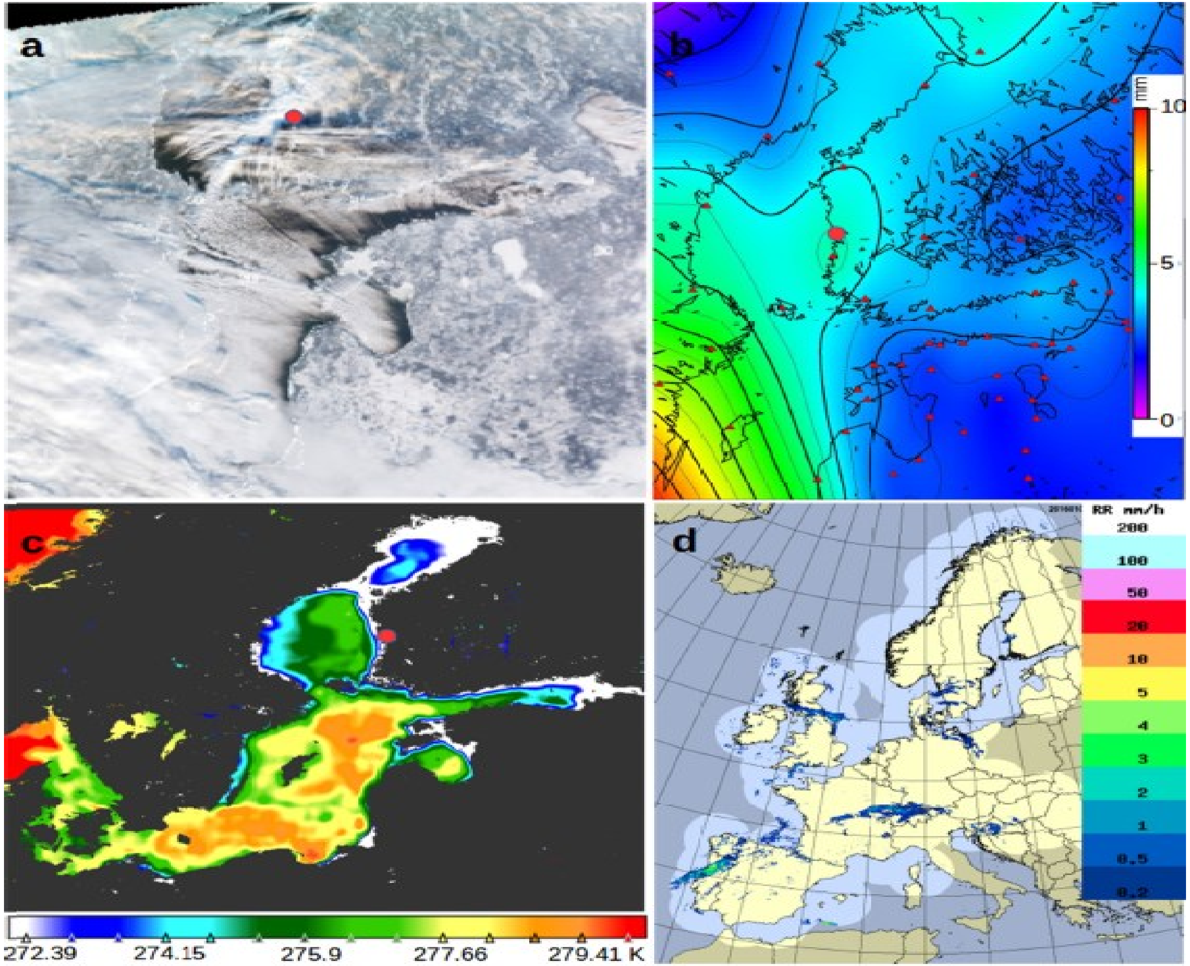
Taru Olsson[1], Piia Post[2], Kalev Rannat[3], Hannes Keernik[3,4], Tuuli Perttula[1], Anna Luomaranta[1], Kirsti Jylhä[1], Rigel Kivi[1] and Tanel Voormansik[2]

[1]Finnish Meteorological Institute, Finland
[2]University of Tartu, Institute of Physics, Estonia
[3]Tallinn University of Technology, Estonia
[4]Estonian Environmental Research Centre, Estonia

This paper is an extension of a former study of a record-breaking snowfall of 73 cm (31 mm as liquid water) that fell in less than 24h in Merikarvia, Finland, 8. January 2016 (*Olsson et al*., 2017).

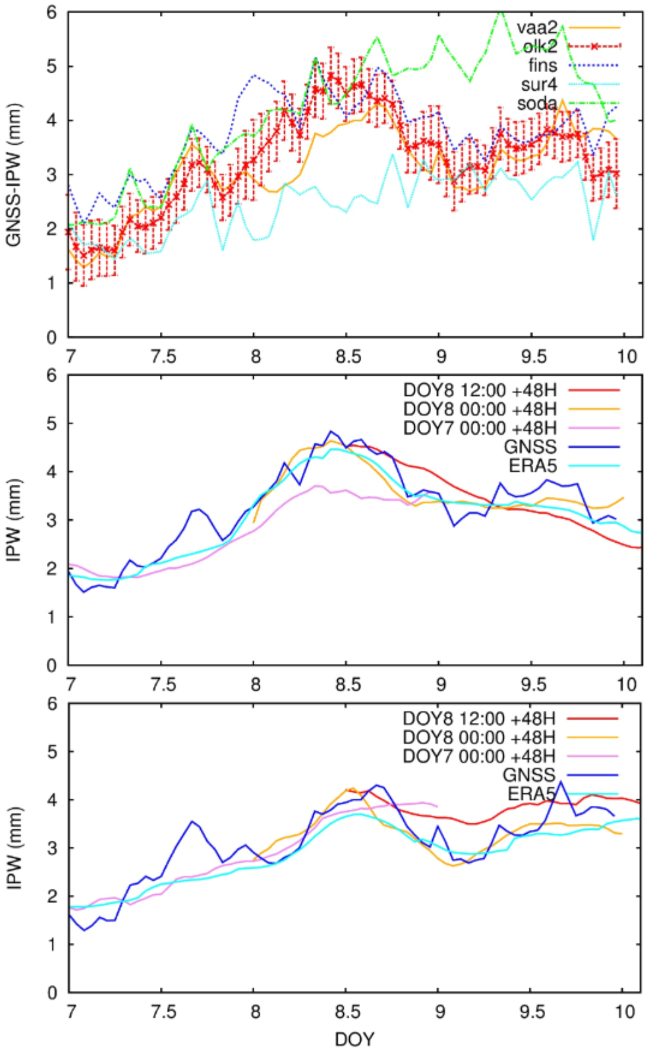


GNSS sites (left, red triangles, VAA2 - Vaasa, OLK2 - Olkiluoto, FINS - Finstrom, SUR4 - Suurupi, SODA - Sodankyla) used in this study and OPERA radar data (right, yellow spots) from Finland, Sweden, Norway, Denmark and Estonia (radar in use in 2016). Merikarvia is marked with a red spot.



(a) MODIS Terra RGB showing various types of convective snowbands over the Northern Baltic Sea on 8 January 2016 at 10:20 UTC.
(b) GNSS-IWV fields (mm) at 13 UTC.
(c) Copernicus CMEMS sea surface temperature (K) at 00 UTC.
(d) One-hour accumulated precipitation (mm/h) observed by weather radars at 13 UTC.

Merikarvia is marked with a red spot.



Top panel: Integrated water vapour (IWV) time series for 7-10 January 2016 are shown for five GNSS sites (VAA2 - Vaasa, OLK2 - Olkiluoto, FINS - Finstrom, SUR4 - Suurupi, SODA - Sodankyla) with error bars for the nearest site, Olkiluoto (red).

Comparison of GNSS-IPW with IWV extracted from ERA5 reanalysis and HARMONIE model for the Olkiluoto (**middle panel**) and Vaasa (**bottom panel**) GNSS sites. Three different forecast cycles (red, yellow and pink, 2016010812, 2016010800 and 2016010700, respectively) are shown for HARMONIE with assimilated radar reflectivities.

Conclusions and outlook

- We have used GNSS data from several sites in Eastern Europe. The exact set of stations depends on the task.
- Considering IWV trends, the optimum cut-off angle is 20°. Possible offsets (and their effect on the IWV trends) due to the changes in instrumentation will be investigated.
- IWV diurnal cycle preliminary analysis does not show any clear trends.
- In case of extreme snow case in Finland the dense GNSS stations net backs better spatial distribution of IWV, but there are no stations over the sea.
- We have developed a capability for more extended analysis from numerous sites, but also noticed a lot of problems with initial data (especially while talking about meteorological data from EUREF/IGS data repositories)

Acknowledgements

Research is done during COST action ES1206 - Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate (GNSS4SWEC)

The research at TUT and FMI was partially supported by the EU Project GAIA-CLIM. The RINEX-files for the GNSS data processing were provided by Maanmittauslaitos, Estonian Land Board, Latvian Geospatial Information Agency and EUREF.