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Contents

Contributions are sorted alphabetically within topics.

Keynotes and special talks

Baltic Earth in context with other European and national Earth system programmes
Ulrich Bathmann 1

International science collaboration for ocean climate
Anne Christine Brusendorff 3

Update on GEWEX in its 30th anniversary
Joan Cuxart 4

Natural hazards and socio-technical vulnerabilities in the Baltic Sea region
Guliano Di Baldassarre 5

Regional and Global Earth System Modelling Activities in MERGE
Paul Miller 6

The development of climate science of the Baltic Sea region
Anders Omstedt 8

Baltic Sea Operational Oceanographic System (BOOS) – a stimulator to Baltic earth system research
Jun She, P. Andersson, T Kõuts, D. Mirawslov, JH Reißmann and L. Tuomi 10

Baltic Earth, Outreach and Communication
Hans von Storch........ 12

Topic A: Salinity dynamics

Analysis of factors influencing the salinity of Baltic inflows and how these may change with sea level rise.
Lars Arneborg 13

The impact of the Atlantic Multidecadal Oscillation on the salinity variability of the Baltic Sea
Florian Börgel, C. Frauen, S. Schimanke, H.E.M. Meier 14

Water exchange through the Danish Straits with global mean sea level rise
Sandra-Esther Brunnabend, U. Gräwe, X. Lange, H.E.M. Meier 16

Using model-based sub-regional EOF patterns to reconstruct temperature and salinity fields from observations
Jüri Elken, M. Zujev.. 18

Atmospheric Forcing of Major Baltic Inflows in a 750 Years Simulation
Claudia Frauen, F. Börgel, H.E.M. Meier 20

Haline convection due to sea ice brine rejection in the Northern Baltic Sea
Celine Gieße, H.E.M. Meier 22

Hydrophysical conditions in the southern part of the Baltic Sea in summer and autumn seasons of 2016-2017
Maria Golenko, V. Paka, A. Kondrashov, A. Korzh, V. Zhurbas 24

Decadal variations in barotropic inflow characteristics and their relationship with Baltic Sea salinity variability
Katharina Höflich, A. Lehmann.. 25

Long-term changes in stratification in the Baltic Sea
Taavi Liblik, U. Lips 27

The Słupsk Sill overflow – mixing hot spot of eastward spreading saline water
Volker Mohrholz, T. Heene 28

Major Baltic Inflow statistics – revisited
Volker Mohrholz... 30

Benthic foraminifera distribution in the South-Eastern Baltic Sea in relation to the North Sea Water Inflow
Ekaterina Ponomarenko, E. Dorokhova, V. Krechik 31

Salinity dynamics and inter-sub-basin transport in the Baltic Sea
Jun She, J. Murawski 32

Topic B:
Land-sea-atmosphere biogeochemical feedbacks

The Impact of Water Constituents on Radiative Heat Transfer in the Open Ocean and Shelf Seas
Bronwyn Cahill, J. Fischer, U. Graewe, H. Burchard, J. Wilkin, J. Warner, N. Ganju 35

Nutrient retention along the Swedish coastline
Moa Edman, K. Eilola, E. Almroth-Rosell, HEM. Meier, I. Wåhlström, L. Arneborg................. 37

High resolution nutrient data to unravel the post-spring bloom elemental cycling in the central Baltic Sea
Anja Eggert, B. Schneider, J. Müller, N. Wasmund, M. Nausch, G. Nausch, G. Rehder........... 38

Spatial and seasonal phosphorus changes in the water column of an estuary of the southern Baltic Sea
Lisa Felgentreu, G. Nausch, F. Bitschofky, M. Nausch, D. Schulz-Bull..................................... 40

Air-sea Methane fluxes in the Baltic Sea using eddy covariance
Lucia Gutiérrez-Loza, A. Rutgersson, M. B. Wallin, E. Sahlée 42

The structure of the CO2 system in the mouths of the continental rivers: Odra, Vistula, Leba and Slupia
Karoline Hammer, K. Kuliński , B. Szymczycha, K. Koiorowska, M. Stokowski, B. Schneider . 44

Measuring turbulent sea-air CO2 fluxes with a closed-path gas analyzer
Martti Honkanen, J-P. Tuovinen, T. Laurila, T. Mäkelä, J. Hatakka, S. Kielosto, L. Laakso....... 46

Understanding the ecocline at shallow coasts of the Baltic Sea
Gerald Jurasinski, M. Voss, M. Janssen, B. Lennartz, the Baltic TRANSCOAST Team 48

Hydrochemical characterization of SGD in the Bay of Puck, Southern Baltic Sea
Żaneta Kłostowska, B. Szymczycha, K. Kuliński, M. Lengier, L. Łęczyński 50

The acid-base system of the Baltic Sea
Karol Kuliński, M. Stokowski, B. Szymczycha, K. Hammer, K. Koziorowska, A. Winogradow, M. Lengier, Ż. Kłostowska, B. Schneider 52

Sediments of the Baltic Sea as a source of C, N and P
Monika Lengier, B. Szymczycha, K. Kuliński, A. Brodecka-Goluch, Ż. Kłostowska 54

A Baltic Sea Ecosystem Model with non-Redfield Stoichiometry for Carbon Fixation
Thomas Neumann, A. Eggert.. 56

The chemical composition of Mytilus trossulus carbonate shells from the southern Baltic Sea: implications for environmental monitoring
Anna Piwoni-Piórewicz, P. Kukliński, S. Strekopytov, E. Humphreys-Williams, J. Najorka, A. Iglikowska 57

BONUS INTEGRAL: Improved Biogeochemical Monitoring and Greenhouse Gas Flux assessment for the Baltic Sea through high resolution trace gas data acquisition
Gregor Rehder, A. Rutgersson, L. Laakso, K. Kuliński, U. Lips, H. W. Bange, K. Andreasson, J. Shutler, and the BONUS INTEGRAL science party.. 59

Using land-based sites for air-sea interaction studies
Anna Rutgersson, H. Pettersson, E. Nilsson, H. Bergström, M. B. Wallin, E. D. Nilsson, E. Sahlée, L. Wu, E. M. Mårtensson 61

Organic matter mineralization in Baltic Sea deep waters: Rates and stoichiometry
Bernd Schneider 63

Transformations of the carbonate system in the Odra estuary
Marcin Stokowski, K. Kuliński, B. Schneider, G. Rehder, J. Müller 65

Deep submarine groundwater discharge indicated by pore water chloride anomalies in the Gulf of Gdańsk, southern Baltic Sea
Beata Szymczycha, Ż. Kłostowska, K. Kuliński, A: Winogradow, J. Jakacki, Z. Klusek, A. Brodecka-Goluch, B. Graca, M. Stokowski, K. Koziorowska, D. Rak 66

Eddies' impact on biological processes – A case study in the Western Baltic Sea for the algal blooming season 2010
Rahel Vortmeyer-Kley, M. Berthold, U. Gräwe, U. Feudel 68

Variation of organic carbon cycling modulated by benthic animals in the Baltic Sea in the past six decades
Wenyan Zhang, U. Daewel, K. Wirtz, C. Schrum 70

Topic C: Natural hazards and high impact events

Reliability of HIPOCAS wind wave hindcast data for the southern Baltic Sea
Witold Cieślikiewicz, A. Cupiał... 71

Reproduction of 10m-wind and sea level pressure fields during extreme storms with regional and global atmospheric reanalyses in the North Sea and the Baltic
Natacha Fery, B. Tinz, A. Ganske, L. Gates 73

Variability of wind storms during cold season in Northern Europe over the past 70 years
Indre Gecaite 75

Baltic storm surge event Axel along the German Baltic Sea coast in a climate perspective
Nicolaus Groll, R. Weisse, L. Gaslikova 77

Integrated coastal hazard risk reduction and management – a closer look at the dynamical damage cost methodology used in the COHERENT project
Kirsten Halsnæs, M. A. Dahl Larsen, N. Drønen, F. Bach Kristensen, C. Sørensen, B. Brahtz Christensen.. 78

Extreme sea levels on the German Baltic Sea coast
Jürgen Holfort, B. Weidig, I. Perlet, S. Schwehmann 80

Changes in drought indices in Estonia during the period of the contemporary climate warming
Jaak Jaagus, A. Aasa 81

Spatial variability of extreme precipitation in Estonia
Jüri Kamenik, P. Post, J. Jaagus, A. Kull, A. Kaasik, S. Aņiskeviča 83

Strong currents in a cross section of two narrow straits in the Finnish Archipelago Sea
Hedi Kanarik, L. Tuomi, E. Miettunen, R. Hietala, P. Alenius 86

Causes, frequency and strength of severe high water events in the Odra River mouth area (the southern Baltic Sea)
Halina Kowalewska-Kalkowska 87

Storm surge modelling in the Baltic Sea using the high resolution PM3D model
Halina Kowalewska-Kalkowska, M. Kowalewski 88

Supercomputer-aided analysis of wave impact on coastal infrastructure
Andrey Kozelkov, R. Shagaliev, R. Dmitriev, A. Kurkin, E. Pelinovskiy 90

Non-stationary modeling of extremes in water levels along the Baltic Sea coast
Nadia Kudryavtseva, K. Pindsoo, T. Soomere 92

Three-dimensional LOGOS simulations of a Chelyabinsk-like meteorite drop into the Baltic Sea
Vadim Kurulin, A. Kozelkov, R. Shagaliev, E. Tyatushkina, A. Kurkin 94

The Connection of Storms and Significant Wave Heights in the Baltic Sea with Indices of Large-scale Atmospheric Circulation (NAO, AO, SCAND)
Alisa Medvedeva, S. Myslenkov, V. Arkhipkin, ... 95

A comparison of observed extreme water levels at the North- and Baltic Sea with extremes derived from a regionally coupled ocean-atmospheric climate model (MPI-OM) and their impact on dewatering potential at Kiel-Canal
Jens Möller, B. Tinz 97

Temporal development of residence times and the power impact to the German Baltic sea coastline induced by storm surge events
Justus Patzke, J. Kelln, D. Salecker, P. Froehle 98

Wave hindcast statistics in the Gulf of Bothnia
Jari Särkkä, L. Tuomi, R. Marjamaa, R. Hordoir, K. Eilola 100

Distribution of droughts and dry winds in the Black Sea Steppe province under current climate conditions
Inna Semenova, M. Slizhe 101

On Cyclones Causing Storm Surges in Pärnu and Narva-Jõesuu
Mait Sepp, P. Post, Ü. Suursaar 103

ERA5: High temporal and spatial resolution reanalyses as a tool to investigate high impact events and other natural hazards in the Baltic Earth region
Martin Stendel 104

The regional features of cyclonic activity and frequency of weather extremes over the territory of Belarus
Katsiaryna Sumak, I. Semenova 105

Rogue Waves in the southern North Sea
Ina Teutsch 107

Seasonal and long-term dynamics of snow cover regime in Estonia
Birgit Viru, J. Jaagus 108

Extreme rainfall analysis and estimation of intensity-duration-frequency curves using dual polarization weather radar data of Estonia and Italy
Tanel Voormansik, R. Cremonini, D. Moisseev, P. Post 110

The atmospheric circulation as a driver of dry spell in Poland
Joanna Wibig 112

Topic D:
Sea level dynamics, coastal morphology and erosion

Interannual coastal processes in Estonia, Peraküla beach monitored by laser scanning technology
Maris Eelsalu, K. Pindsoo, T. Soomere, K. Julge 115

Seasonal variability of diurnal seiches in Gulf of Riga
Vilnis Frishfelds, J. Sennikovs, U. Bethers 117

Modeling patchiness on the sea surface caused by the interplay of winds and currents in the Gulf of Finland
Andrea Giudici, J. Kalda, T. Soomere.. 119

Distinctive features of surface circulation in the southeastern part of the Baltic Sea by subsatellite oceanographic experiments held in 2014-2017
Evgeny Krayushkin, O. Y. Lavrova, K. R. Nazirova.. 121

Modeling of internal waves in the Baltic Sea
Andrey Kurkin, O. Kurkina, E. Pelinovsky, E. Rouvinskaya 123

Observations, modeling and analysis of internal gravity waves in Sea of Okhotsk
Oxana Kurkina, A. Kurkin, E. Rouvinskaya, A. Giniyatullin 125

Sea level change: mapping municipality needs for climate information
Kristine S. Madsen, J. Murawski, J. She, P.L.Langen 127

Validation of altimetry-derived regional sea level trends based on reconstruction of Baltic Sea 2D sea level of the last century
Kristine S. Madsen, J. L. Høyer, J. She, P. Knudsen, Ü. Suursaar.. 129

On the water level measurements in the Gulf of Riga during 1961–2016
Rain Männikus, T. Soomere, N. Kudryavtseva 130

Spatial and temporal features of synoptic and mesoscale Baltic sea level variability
Igor Medvedev, A. Medvedeva 132

Building natural morphologies for effective beach nourishment
Kevin Parnell.. 134

Modelling the Development of Large-Scale Mud Deposits in the Baltic Sea Basins driven by energetic events
Lucas Porz, W. Zhang, C. Schrum 136

Scattering and backscattering properties of Estonian coastal waters
Mirjam Randla, M. Ligi, T. Kutser, A. Ansper, K. Alikas 137

Radar remote sensing of the meteo-marine parameters in the Baltic Sea
Sander Rikka, R. Uiboupin, A. Pleskachevsky, V. Alari, S. Jacobsen, T. Kõuts 139

Coastal erosion on the Kotlin Island's coastline in the Gulf of Finland, the Baltic Sea: a model study to elaborate mitigation measures
Vladimir Ryabchenko, I. O. Leontyev, D. V. Ryabchuk, A. Y. Sergeev, A. Y. Dvornikov,
S. D. Martyanov, V. A. Zhamoida.. 141

Identification of extreme storm tides with high impact potential for the German North Sea coast
Ralf Weisse, L. Gaslikova, I. Grabemann 143

Geographical diversity in the occurrence of extreme sea levels on the coasts of the Baltic Sea
Tomasz Wolski, B. Wiśniewski.. 144

Topic E:
Regional variability of water and energy exchanges

Impact of «small» climate-forming factors in the formation of the hydrological regime of the basins of the Zapadnaya Dvina and Neman Rivers in Belarus
Maryia Asadchaya, A. Kvach, L. Zhuravovich 147

Temporal behavior of atmospheric circulation types in Marmara Region (NW Turkey)
Hakki Baltaci 149

The critical role of atmospheric forcing for simulating the dynamics of the Baltic Sea ecosystem
Ute Daewel, C. Schrum, B. Geyer 151

Model estimates of climate and streamflow changes in the Western Dvina River basin
Irina Danilovich, S. Zhuravlev, L. Kurochkina, A. Kvach 153

Analysis of bottom and wind friction velocities in inflow and non-inflow periods in the Baltic Sea
Maria Golenko, V. Zhurbas 155

Changing effect of large scale atmospheric circulation on the regional climate variability of the Baltic Sea over the period 1948-2017
Andreas Lehmann, P. Post, K. Höflich 157

Relationship between satellite measured soil moisture and meteorological parameters
Viktorija Mačiulytė 159

Evaluating mean circulation and transport in the Archipelago Sea
Elina Miettunen, L. Tuomi, H. Kanarik, P. Alenius. K. Myrberg 161

The maximum runoff of small rivers of the Mountainous Crimea flowing into the Black Sea in modern climatic conditions
Valeriya Ovcharuk, O. Todorova, E. Myrza 162

Enhancement of radar rainfall estimates for Estonian territory through optical flow temporal interpolation
Jorma Rahu, T. Voormansik, P. Post 164

Wind and Turbulence Measurements with RPA during the ISOBAR Campaign
Alexander Rautenberg, M. Schön, K. zum Berge, H. Mashni, P. Manz, S. Kral, L. Baserud, J. Reuder, R. Kouznetsov, E. O'Connor, I. Suomi, T. Vihma, J. Bange 166

On Summer Low Water Periods in Estonian Rivers in the Years 1951-2016
Mait Sepp 167

A descriptive analysis of the linkage between the vertical stratification and current oscillations in the Gulf of Finland
Irina Suhhova, T. Liblik, M.-J. Lilover, U. Lips 168

Water balance assessment using SWAT for Russian subcatchment of Zapadnaya Dvina River
Pavel Terskii, A. Kuleshov 170

Assessment of changes in river runoff for small and medium-sized rivers in the Russian part of the Baltic Sea basin under non-stationary climatic conditions
Valery Vuglinsky, D. Timchenko 172

Cloud and radiation variability and trends for the northern Baltic region as observed and modelled for present day climate and future scenarios
Ulrika Willén 174

Topic F:
Multiple drivers of regional Earth system changes

The Eckernförde Bay (SW Baltic Sea) through the ages: Time-series measurements at the Boknis Eck time-series station
Hermann Bange 175

Hydroclimatic dynamics and peatland land cover response over last centuries – A multi-proxy reconstruction from hydro-meteorological data, peat stratigraphy, testate amoebas and remotely sense approaches
Ieva Baužienė, J. Edvardsson, M. Lamentowicz, J. Taminskas, R. Šimanauskienė 177

Quantifying the land-use climate forcing in the past: a modelling approach focusing on Europe and the Holocene (LandClim II)
Esther Githumbi, A.-K. Trondman, R. Fyfe, E. Kjellström, J. Lindström, Z. Lu, F. Mazier, A. B. Nielsen, A. Poska, B. Smith, G. Strandberg, S. Sugita, Q. Zhang, M.-J. Gaillard 179

Temperature variability of the Baltic Sea since 1850 in model simulations and observations and attribution to variability in the atmosphere
Madline Kniebusch, H. E. M. Meier, T. Neumann 181

Variability of nutrient concentrations in the western Baltic Sea between 1995 and 2017
Joachim Kuss, G. Nausch, M. Naumann, D. Schulz-Bull 182

Recently accelerated oxygen consumption rates amplify deoxygenation in the Baltic Sea – observations and model results
H. E. Markus Meier, G. Väli, M. Naumann, K. Eilola, C. Frauen 184

Changes of the frames of agroclimatic areas in the XXI century on the territory of Belarus
Viktar I. Melnik 185

Physical oceanography sets the scene for the Marine Strategy Framework Directive implementation in the Baltic Sea
Kai Myrberg, S. Korpinen, L. Uusitalo 187

Hypoxic to euxinic conditions in the Baltic Sea 1969-2016 – a seasonal to decadal spatial analysis
Michael Naumann, S. Feistel, G. Nausch, T. Ruth, J. Zabel, M. Plangg, M. Hansson, L. Andersson, L. Viktorsson, E. Lysiak-Pastuszak, R. Feistel, D. Nehring, W. Matthäus, H. E. M. Meier 188

Influence of the Grodno hydroelectric power station on the hydrological regime of the Neman river (Belarus, the Baltic Sea basin)
Ala Pauros, A. Kvach, L. Zhuravovich 189

Shipping and the environment in the Baltic Sea region - results of the BONUS SHEBA project
Markus Quante, J. Moldanova, M. Eriksson, E. Fridell, J.-P. Jalkanen, V. Matthias, J. Tröltzsch, M. Karl, I. Maljutenko and the Sheba Team 191

Pinus sylvestris L. inter- and intra-annual growth response to climatic conditions
Egidijus Rimkus, R. Pukienė, A. Vitas, J. Kažys 193

Long term impacts of societal and climatic changes on nutrient loading to the Baltic Sea
Marianne Zandersen, S. Pihlainen, K. Hyytiäinen, H. Estrup Andersen, M. Jabloun, E. Smedberg, B. Gustafsson, A. Bartosova, H. Thodsen, H. E. M. Meier, S. Saraiva, J. E. Olesen, D. Swaney, M. McCrackin 195

Topic G: Regional climate system modeling

Evaluation of the ERA-20C data using surface observations in the Hardanger Glacier, Norway
Bhuwan Chandra Bhatt, A. Sorteberg 197

Evaluation of a regional climate system model for the Baltic Sea region
Sandra-Esther Brunnabend, M. Placke, C. Frauen, F. Börgel, M. Schmidt, T. Neumann, H. E. M. Meier 198

Do we know more about climate change than during PRUDENCE?
Ole Bøssing Christensen, M. A. D. Larsen, M. Drews, M. Stendel, J. H. Christensen 200

Projected Changes in Baltic Sea Upwelling in Climate Change Scenarios
Christian Dieterich, M. Gröger, S. Schimanke, L. Arneborg, H. E. M. Meier 202

Assessment of Different Wind Products as Forcing for Baltic Sea Ocean Models
Claudia Frauen, U. Gräwe, H. E. M. Meier 204

High resolution discharge simulations over Europe and the Baltic Sea catchment
Stefan Hagemann, T. Stacke, H. T. M. Ho-Hagemann.. 206

The BALTIC and NORTH SEAS CLIMATOLOGY (BNSC) - a comprehensive, observation-based data product of atmospheric and hydrographic parameters
Iris Hinrichs, A. Jahnke-Bornemann, V. Gouretski, A. Andersson, B. Klein, R. Saddikni, N. Schade, D. Stammer, B. Tinz... 208

Implementing surface wave effects into an ocean general circulation model of the Baltic Sea: A semi-empirical type wave model approach
Katharina Höflich, A. Lehmann.. 210

Different methods to handle seasonal ice cover in wave modeling
Riikka Marjamaa, L. Tuomi, J.-V. Björkqvist, H. Kanarik, J. Vainio, R. Hordoir 212

Assessment of ocean circulation models for their applicability in the Baltic Sea
Manja Placke, H. E. M: Meier, U. Gräwe, T. Neumann, Ye Liu.. 213

Copernicus regional reanalysis for Europe
Semjon Schimanke, P. Lundén, M. Ridal, L. Isaksson, L. Edvinson.. 215

Climate Change in Estonia – warmer weather patterns or more warm weather patterns?
Mait Sepp, P. Post, M. Lakson 216

Pinus sylvestris L. inter- and intra-annual growth response to climatic conditions

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1. Introduction

The *Pinus sylvestris L.* is widely distributed in boreal and temperate climatic zones and, therefore, predominantly serves as an object to investigate various environmental effects and influences of climatic conditions on different ecosystems (Bogino et al. 2009, Seo et al. 2011).

T. Bitvinkas started dendrochronological investigations in 1961, in Lithuania. The 38-year sequence (1976-2013) of *Scots* pine tree diameter measurements using band dendrometers in Aukštaitija National Park study site make this series unique of its kind.

The main objective of this paper is to assess the impact of temperature and precipitation to inter- and intra-annual *Pinus sylvestis L.* growth fluctuations.

2. Description of study site

The study site is located in the North-East part of Lithuania in the Aukštaitija National Park (Figure 1). The landscape consists of moraines formed by the last glacier. About 70% of the area are covered by forests with dominating pine stands that make 80 % of the forested land. In 1976, a permanent study site with an area of 0.98 ha was established (Vitas, 2011). Geographical coordinates of the site are 55°26' N 26°02'E with elevation around 160 m a.s.l. The soil is podzolic, parent material is sand with gravel and pebble intrusions. Ground water is deeper than 5 m.

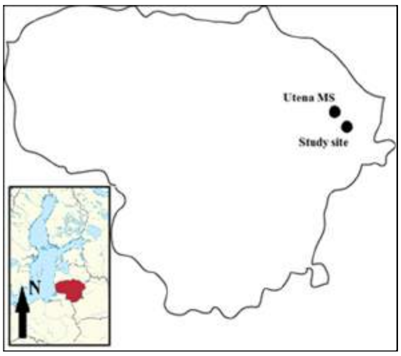

Figure 1. Location of study area and nearby meteorological station.

3. Data and methods

Dendrometrical measurements of tree diameter in Aukštaitija National Park area have been carried out in 1976-2017. Data set includes the warm periods of 36 years (measurements were not carried out in 1987 and 1992). The average start date of measurements is 30 April and the end date – 5 September. Measurements were carried out on a regular basis every three days. We analyzed changes of tree diameter data from 1 May to 31 August.

For measurement of tree seasonal growth manual band dendrometers were installed on 24 pine trees in 1976: 19 mature pine trees and 5 young pine trees (Vitas, 2011). Initial analysis of data quality revealed the 8 cases (<1%), when the individual tree growth dynamics in some years very strongly stood out from others. Such cases were excluded from further analysis. Several cases of failure of dendrometer were also recorded. In such cases the gaps in the data sets were not filled in and the average values of tree growth during warm season were calculated from the trees without gaps in data series.

We used median value calculated from all measured trees as main parameter of annual tree growth in our study because in most cases data distribution is asymmetric. Annual tree growth was calculated by summing up median values of each three-day period. The daily values of tree diameter growth were calculated after interpolation between known measured values.

The Mann-Kendal test was used for evaluation of statistical significance of tree diameter growth tendencies. The changes were considered as statistically significant when the p-value was lower than 0,05.

Meteorological data from the closest to study area Utena meteorological station was used (Figure 1). We analyzed daily and monthly mean, maximum and minimum air temperature as well as daily and monthly precipitation sums. The relationships between tree diameter growth and weather conditions in study area were established.

4. Results

On average, in the study area the tree diameter increased by 0.75 mm annually. This value varies from 0.17 mm in 1979 to 1.16 in 2011 (Fig. 2). The analysis shows a statistically significant ($\alpha<0.05$) positive tree growth trend in May-August during the period from 1976 to 2013. Statistically significant positive changes were recorded in May, June and August. The changes in July are also positive, but statistically insignificant. This corresponds well with the air temperature trends in Utena MS. The air temperature rise was determined during the whole year in Utena. But the most significant changes were recorded in April and July. Temperature increase in April led to earlier start of tree growth while significant temperature rise in July prolonged the period of intensive growth of trees. Increasing precipitation amount on August also favored tree growing conditions.

The largest tree diameter growth was determined in June (35 % of annual increase). Meanwhile in August this value falls to 15 %. Analysis of daily values showed the strongest growth during the period from 14 May to 24 June (maximum - 15 June) (Fig. 3). It was found that during the period from 14 May until 24 June 58 % of the total annual tree diameter increase was recorded on an average. Keeping in mind the day length influence on a plant photosynthetic activity, we can suggest that strong growth period up to 24 June produces early wood with thin cell walls and wide lumina, while denser late wood start to be formed after summer solstice. However, due to a large variability of the intra-seasonal tree growth dynamics it is very difficult to estimate the precise position of such regime change on an annual scale.

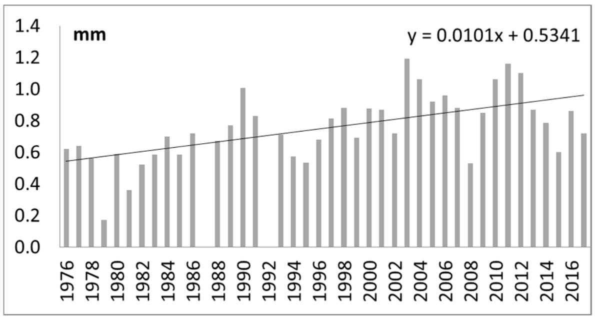

Figure 2. Median of tree diameter growth (mm) in May - August in study area.

We also analyzed the thirty-day periods when the growth of the trees was the most intense. During these thirty-day periods the tree diameter increased between 32% (in 1991) up to 65% (1979 and 1999). The middle dates of these periods mostly fall on 6-10 June. The earliest intense growth (3 May - 2 June) was recorded in 1984, when warmer than normal April and May were followed by abnormally cold summer. The latest period of the most intense growth was recorded in 2005 (16 July – 15 August). This year was marked by a relatively cold spring (especially March) and extremely rainy May. Cool June was followed by a warmer than normal July, and this led to an intensification of tree diameter growth which was further accelerated with the heavy rainfalls in early August.

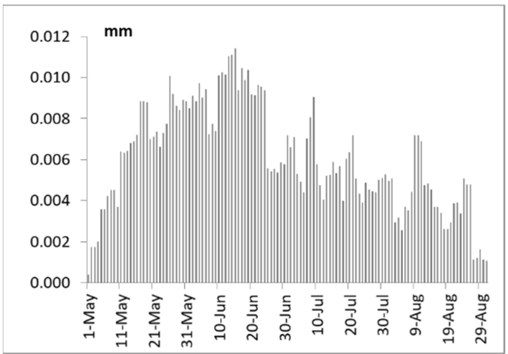

Figure 3. The average (mm) daily increase in tree diameter during the period from May to August in 1976-2013.

Weak statistically significant relationship (r = 0.35) links the tree growth in May with maximal air temperature of the same month. Meanwhile, correlation between precipitation amount and tree ring growth is statistically insignificant. At the beginning of warm season precipitation amount is less important for tree growth because the ground is usually saturated with water after snow melt and despite the lack of precipitation weather conditions can be favorable for vegetation if the air temperature is higher than the average. A close correlation between the air temperature in April and the tree growth in May was determined. The warmer first part of spring (which is largely predetermined by the temperature of April) leads to earlier start of tree growth. Therefore, for May growth rate the temperature of April has greater impact than the temperature of May. It was found that the last frost date also statistically significantly correlates with tree growth rate in May (r=-0.40).

According to our investigation results, the main factor which determines June-August tree growth fluctuations is precipitation amount. Since the amount of heat during these months is usually sufficient, a limiting factor becomes moisture availability for the wood formation. Another explanation of the precipitation impact on tree diameter changes is associated with tree swelling. In rainy periods trees swell and after that they shrink during following dry period. During the investigation period 7 cases were recorded (all in July and August) when the monthly changes in the median diameter of the trees was equal to 0 or even negative. During all of them a strong negative rainfall anomalies were observed.

We analyzed the short term changes of tree growth according to the measurements carried out every three days. The cases with median tree diameter increase of 0.1 mm or more within three days period were investigated. Total number of such cases was equal to 48. It was determined that such rapid growth is exclusively associated with heavy precipitation events. Precipitation amount during the five-day period prior to the measurement varied from 2 to 113 mm. Average value (35,1 mm) significantly exceeded the mean five-days precipitation sum in May-August (12 mm). Smaller than 12 mm precipitation amount was observed only five times and in all such cases it was recorded after a prolonged period without rain or with a very small amount of it. Thus, the rapid growth events can be explained by the recovery which follows the tree shrinkage in dry period.

We also investigated the cases when the decrease in tree diameters was observed during three-day periods. Total number of such cases was equal to 111. In 81 cases there weren't any precipitation during three days period prior to the measurements and in 101 cases precipitation amount was smaller than 3 mm.

5. Conclusions

The analysis shows a statistically significant positive tree growth trend in May-August. For tree diameter growth in May the thermal conditions of the entire spring season gain the largest impact, while in summer the precipitation amount is of decisive importance. During a warm spring tree vegetation starts earlier. Lack of precipitation in summer months can lead to soil moisture deficit and tree growth rate can decrease or even shrinkage of trees can start.

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