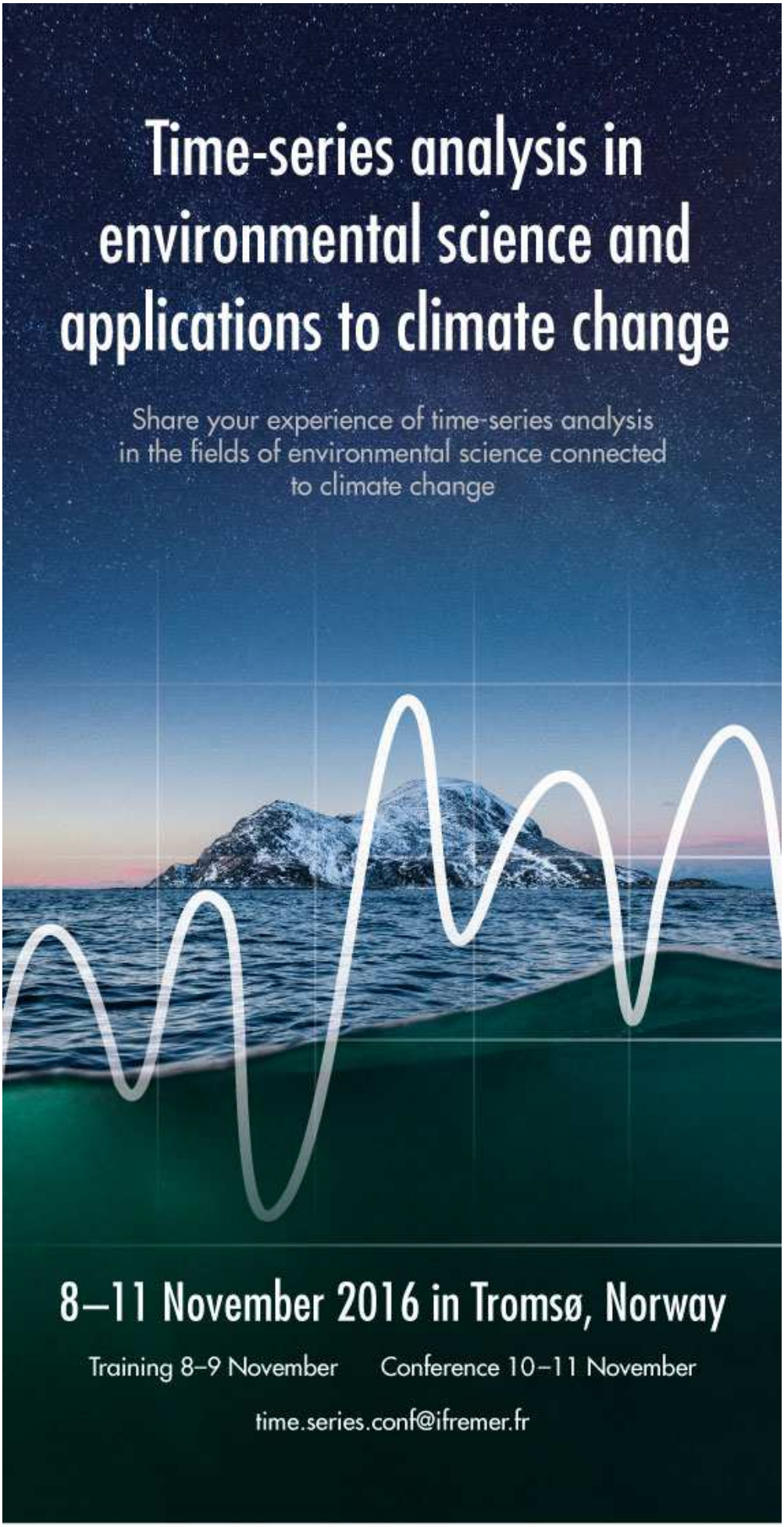
Time-series analysis in environmental science and applications to climate change

Share your experience of time-series analysis in the fields of environmental science connected to climate change



8–11 November 2016 in Tromsø, Norway

Training 8–9 November Conference 10–11 November

time.series.conf@ifremer.fr

UNIVERSITY OF TROMSØ · CAGE · Arctic Marine Geology & Geophysics · Ifremer · FixO3 · ENVRI

Content

PRESENTATION AND ORGANISATION OF THE EVENT 3

CONFERENCE THEMES 3
PROGRAMME AND WEBSITE 3
REGISTRATION / FEES 4
TRAINING AND CONFERENCE LOCATIONS 4
ORGANIZING COMMITTEE 4
SCIENTIFIC COMMITTEE 4
FUNDING 4

TRAINING PROGRAM 5

TRAINING CONTENT 6

COURSE 1: "TIME SERIES ANALYSIS IN A CHANGING CLIMATE" 6
COURSE 2: "TIME SERIES IN METHANE MEASUREMENTS AND ANALYSIS" 7
COURSE 3: "FROM DEPTH TO AGE IN SEDIMENTS: METHODS AND PITFALLS**"** 8
COURSE 4: "COMPONENTS AND VARIABILITY OF SEA LEVEL CHANGE IN A WARMING CLIMATE" 9

CONFERENCE PROGRAM 10

CONFERENCE ABSTRACTS 12

SESSION 1: "TIME-SERIES ANALYSIS FOR GLOBAL WARMING IN MARINE ENVIRONMENT AND CONNECTIONS WITH LAND AND ATMOSPHERE" 13
SESSION 2: "TIME SERIES ANALYSIS FOR GREENHOUSE GASES AND CARBON CYCLE" 21
SESSION 3: CONCLUDING SESSION 30

POSTER ABSTRACTS 35

Presentation and organisation of the event

The second conference for "Time series analysis" will be held in Tromsø, Norway, on 8-11 November 2016. While the first conference held in Brest (2012) dealt with marine science and applications for industry (http://wwz.ifremer.fr/rd_technologiques/Projets/Time-series-analysis/Conference-2012), this present conference will be focusing on the implication of climate change on the environment, including land, sea and atmosphere.

The **purpose of this event** is to gather scientists from a large range of disciplines in Earth Sciences based on regular and constant in-situ measurements, and provide a discussion forum in the field of time series analysis and forecasting.

The presentations will show how observations can help detecting climate change and its impacts focusing on both the mathematical modelling, statistics, signal processing (non-stationarity, gaps in series, extremes, etc.), and the environmental scientific results. This conference is part of a series of conferences gathering a wide community to be integrated in the ESONET-Vi (-the vision) consortium that builds upon ESONET, EuroSITES, EMSO, FixO3 and ENVRI^{PLUS} partners, extending worldwide.

Targeted audience: Based on in-situ and remote data analysis and modelling, this conference will gather senior and young researchers (post-doctoral, doctoral and master students) to share their experience in time series interpretation across several scientific fields. Starting by a 2-day training session and followed by a conference part during the two following days, this event will promote the transfer of knowledge to younger or less experienced scientists and between researchers from several research fields. Both training courses and scientific talks will be mainly based on application examples and case studies.

Conference themes

- Marine environment and connections with land and atmosphere (sea ice, atmospheric measurement, foraminifera, biogeochemistry)
- Sea level
- Methane measurements and analysis
- Ocean carbon cycle
- Mathematical tools to understand climate change

Programme and website

The program will be periodically updated on the website: http://www.fixo3.eu/events/time-series-analysis-in-environmental-science-and-applications-to-climate-change/

Registration / Fees

Participation fees are including registration, ice breaker, lunches, coffee breaks, one dinner and conference services.

Duration	**Training part only (08-09 Nov.)**		**Scientific part only (10-11 Nov.)**		**Four days (both parts)**	
Prices categories (€)	early birds (1)	full price	early birds (1)	full price	early birds (1)	full price
Regular participants	70	80	250	300	270	350
Student with grant (2)	0	0	0	0	0	0
Student without grant and post docs	50	60	150	200	230	280

(1) Registration received before 15 August
(2) granted after call for fellowships, see special conditions

Registration by sending an email to Time.Series.Conf@ifremer.fr with one of the enclosed forms by September 25th 2016. Students can apply for registration grant, see "Application-form Students 2016". Fees include access to all lectures, lunches, coffee breaks and one dinner.

Training and conference locations

The training will be held on 8-9 November at the University of Tromsø at the Naturfagbygget building (#22).
The conference will take place on 10-11 November at the Scandic Ishavshotel (Fredrik Langes gate 2, 9008 Tromsø) in the city center.

Organizing Committee

Bénédicte Ferré, UiT, Norway
Ingrid Puillat, IFREMER, France
Jérôme Blandin, IFREMER, France
Jean-François Rolin, IFREMER, France
Jacco Konijn, UVA, The Nederland
Shared email for the conference organization: time.series.conf@ifremer.fr

Scientific Committee

Jurgen Mienert, UiT, Norway
Paolo Laj, LGGE, France
Truls Johannessen, Univ of Bergen, Norway
Laura Beranzoli, INGV, Italy

Funding

The training is partly funded by the Arctic Marine Geology and Geophysics (AMGG) Research School.

The training and conference are funded by the European Commission through
- the FP7 Integrated Infrastructure Initiative **FixO3** (grant agreement N° 312463)
- the Horizon 2020 project **ENVRIplus** (grant agreement N° 654182)

Training program

8 & 9 Nov 2016: 8:30-17:00

University of Tromsø, Naturfagbygget building (#22).

Plenary session (8:30-12:00 including 30' of break)		
Course 1: Time series analysis for global warming in marine environment and connections with land and atmosphere	8 Nov. (1h30) morning	Shane Elipot and Jonathan Lilly (Univ. of Miami)
Course 2: Time series in methane measurements and analysis	8 Nov. (1h30) morning	Giuditta Marinaro (INGV)
Course 3: From depth to age in sediments: Methods and pitfalls	9 Nov. (1h30) morning	Karl Fabian (NGU)
Course 4: Components and variability of sea level change in a warming climate	9 Nov. (1h30) morning	Mark Carson (Univ of Hamburg)
Practical session (13:00-17:00 including 30' of break)		
Course 1: Time series analysis for global warming in marine environment and connections with land and atmosphere	8 Nov. afternoon 13:00-14:45: group 1 15:15-17:00: group 2	Shane Elipot and Jonathan Lilly (University of Miami)
Course 2: Time series in methane measurements and analysis	8 Nov. afternoon 13:00-14:45: group 2 15:15-17:00: group 1	Mariagrazia De Caro (INGV)
Course 3: From depth to age in sediments: Methods and pitfalls	9 Nov. afternoon 13:00-14:45: group 1 15:15-17:00: group 2	Karl Fabian (NGU)
Course 4: Components and variability of sea level change in a warming climate	9 Nov. afternoon 13:00-14:45: group 2 15:15-17:00: group 1	Mark Carson, university of Hamburg

Training content

Course 1: "TIME SERIES ANALYSIS IN A CHANGING CLIMATE"

Given by: Shane Elipot
University of Miami's Rosenstiel School of Marine and Atmospheric Science, Miami, FL, USA
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And: Jonathan Lilly
NorthWest Research Associates
Redmond, WA, USA

Content:

1) Descriptive statistics and classification of time series
2) Stationarity vs non-stationarity and trends
3) Spectral analysis and periodicity
4) Bivariate time series

Keywords:

Time series, stationarity, trend, bivariate, spectral analysis, periodicity

Course 2: "TIME SERIES IN METHANE MEASUREMENTS AND ANALYSIS"

Given by: Giuditta Marinaro
INGV, Italy

And: Mariagrazia De Caro
Istituto Nazionale di Geofisica e Vulcanologia,
Roma, Italy
mariagrazia.decaro@ingv.it

Content:

1) Introduction to underwater methane sensors.

2) The SN4 seafloor observatory experiment in the Sea of Marmara.

3) Calibration, post-calibration and data quality check

4) Software tools and tricks to handle multiparameter data files.

5) Time series analysis of methane concentration with a multidisciplinary approach.

Keywords:

methane time series, seafloor observatory, multidisciplinary analysis

Course 3: "FROM DEPTH TO AGE IN SEDIMENTS: METHODS AND PITFALLS"

Given by: Karl Fabian
Geological Survey of Norway, Trondheim, Norway
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Content:

The determination of sediment ages depends on many implicit assumptions which are rarely listed explicitly. Especially because each dating method relies on different combinations of these assumptions, it is worthwhile to obtain a systematic overview.

The course will start with a discussion of fundamental sedimentation models and tries to provide an overview the conditions for their validity.

Also an overview of different dating techniques will be given, and it will be discussed which additional assumptions and sources of uncertainty arise from their fundamental assumptions and measurement techniques.

Basic mathematical models of sedimentary mixing and diffusion will be presented.

In the practical part we will study problems of pattern matching between sedimentary sequences and the related mathematical problems.

Keywords:

Sedimentation processes, sediment dating, mathematical sediment models, pattern matching

Course 4: "COMPONENTS AND VARIABILITY OF SEA LEVEL CHANGE IN A WARMING CLIMATE"

Given by: Mark Carson
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Content:

Global sea level will rise in the future setting of climate change, and has already been rising for over 100 years. However, sea level will not rise equally everywhere. Sea level changes will vary based on the location in question and what the largest local drivers of sea level change are. We will explore which components of future sea level change are important in which locations, and also discuss the impact of natural variability on estimates of future changes. Datasets of sea level data in NetCDF format will be analysed using such methods as density calculations, and combing data from different components to form net sea level change. Various software can be used for the analysis, but the focus will be on Matlab and Python / Matplotlib.

Keywords:

Sea level, variability, model, time series, error analysis

Conference program

10 & 11 Nov. 2016: 8:45-17:00

Scandic Ishavshotel, Fredrik Langes gate 2, 9008 Tromsø

Get together		20:00 - November 9th at the Scandic Ishavshotel
November 10th		
Time	Session/talk	Chair / Speaker and Title
8:45	Introductory talk	
9:00 - 14:30	***Session 1**: Time-series analysis for global warming in marine environment and connections with land and atmosphere* *Chair: Paolo Laj (LGGE)*	
9:00	Solicited talk: Stein Sandven (NERSC)	SEASONAL AND INTERANNUAL VARIABILITY OF ARCTIC SEA ICE
9:30	Camilla Brattland (UiT)	SOCIO-ECOLOGICAL TIMELINES AND CLIMATE CHANGE NARRATIVES IN FINNMARK FJORD FISHERIES
10:00	Karl Fabian (NGU)	AMPLITUDE CALIBRATION OF A SEDIMENTARY NAO PROXY RECORD FROM THE TRONDHEIM FJORD
10:30	Break	
11:00	Chiara Borrelli (University of Rochester)	OCEAN CIRCULATION CHANGES FROM THE MIDDLE EOCENE TO THE EARLY OLIGOCENE: A BENTHIC FORAMINIFERAL PERSPECTIVE
11:30	Gilles Reverdin (LOCEAN)	ATLANTIC SURFACE SALINITY AND TEMPERATURE VARIABILITY 1896-2015
12:00	Stephanie HENSON (NOCS)	OBSERVING CLIMATE CHANGE TRENDS IN OCEAN BIOGEOCHEMISTRY: WHEN AND WHERE
12:30	Lunch	
14:00	Ingvar Eide (STATOIL)	ONLINE MULTIVARIATE ANALYSIS OF MULTISENSOR DATA FROM THE LOVE OCEAN OBSERVATORY
14:30 - 17:00	***Session 2:** Time series analysis for greenhouse gases and carbon cycle* *Chair: Jürgen Mienert (UiT/CAGE)*	
14:30	Solicited talk: Melchor Gonzales Davila (Canarias Univ.)	THE PH EVOLUTION IN TWO TIME SERIES OF DATA: THE OPEN OCEAN ESTOC SITE AND THE MAURITANIAN UPWELLING AREA

15:00	Jack Triest (LGGE)	A NEW FAST-RESPONSE, REAL-TIME AND CONTINUOUS METHANE SENSOR: MILLIONS OF DATA TO SCREEN MARINE PROCESSES
15:30	Break	
16:00	Tuomas Laurila (FMI)	TIME-SERIES ANALYSIS OF ATMOSPHERIC GREENHOUSE GAS CONCENTRATION DATA
16:30	Cathrine Lund Myhre (NILU)	TIME SERIES AND INTERPRETATION OF ATMOSPHERIC MEASUREMENTS WITH FOCUS ON THE ARCTIC REGION
Evening	Dinner at the conference hotel	
November 11th		
Time	Session/talk	Chair / Speaker and Title
9:00 - 12:00	***Session 2 (cont)**: Time series analysis for greenhouse gases and carbon cycle* *Chair: Truls Johannessen (Univ. of Bergen)*	
9:00	Jerry Tjiputra (UniResearch)	IRREPLACEABILITY ROLES OF TIME-SERIES OBSERVATION FOR OCEAN CARBON CYCLE MODELING
9:30	Ingunn Skjelvan (UiB)	TIME SERIES OF CARBON IN A CHANGING CLIMATE - EXAMPLES FROM STATION M IN THE NORWEGIAN SEA
10:00	Break	
10:30	Leif Anderson (U. Göteborg)	CHANGES IN THE ARCTIC OCEAN CARBON CYCLE DURING THE LAST DECADES
11:00	Peter Franek (CAGE)	IS MICROSEISMIC ACTIVITY ON THE WESTERN SVALBARD CONTINENTAL MARGIN RELATED TO NATURAL GAS LEAKAGE?
12:00	Lunch	
13:30 - 15:30	***Session 3**: Concluding session* *Chair: Gilles Reverdin (LOCEAN)*	
13:30	Solicited talk: Davide Faranda (LSCE/ CNRS)	HOW TO USE STATISTICAL - PHYSICS TO STUDY CLIMATE CHANGE
14:00	Fred Godtliebsen (UiT)	CHANGE POINT DETECTION FROM TIME SERIES DATA
14:30	Paul Wilkinson (LSHTM)	WHAT DO TIME SERIES OF WEATHER-HEALTH RELATIONSHIPS TELL US ABOUT FUTURE VULNERABILITY TO CLIMATE CHANGE
15:00	Nigel Yoccoz (UiT)	NON-STATIONARITY IN TIME SERIES: SOME STATISTICAL NOTES ON THE INTERACTIONS BETWEEN CLIMATE AND ECOLOGICAL SYSTEMS
15:30	*End of the conference*	

Conference abstracts

Abstracts are listed in order of appearance according to the program.

When multiple authors, the presenting author is underlined and only his/her affiliation and email address are indicated.

Session 1: "Time-series analysis for global warming in marine environment and connections with land and atmosphere"

Chaired by: Paolo Laj
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SEASONAL AND INTERANNUAL VARABILITY OF ARCTIC SEA ICE

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It is a major challenge to obtain long-term data on Arctic sea ice that is required to understand and predict the climate changes in the Arctic. Satellite earth observation (EO) data plays an increasingly important role, because satellites can provide seasonal and interannual time series of homogeneous measurements. Time series of ice concentration and ice extent data are more than 35 years long, constituting one of the longest and most important data sets for the Arctic. These data sets as well as other climate variables grow continuously, extending the times series year by year. In situ observing systems are much more limited due to logistical constraints and cost limitations. Nevertheless, there are ongoing efforts to build up time series of ice thickness, ice drift, snow cover and other sea ice variables derived from moorings and drifting ice buoys. To build long time series of sea ice data sets, it is necessary to have sustainable observing systems for the whole Arctic region. The Sentinel satellites under the Copernicus programme will provide a sustainable observing system, but for in situ data such system is not yet implemented. An integrated Arctic Observation System (in-situ and EO-based data) will enable improved monitoring and forecasting of sea ice. This is required for better-informed decisions and documentation of sea ice conditions for local communities, shipping, tourism, fishing, ecosystem research and climate research. Improved information of sea ice is important for economic development of the Arctic region, supporting national and European strategies and related maritime and environmental policies.

Keywords:

SOCIO-ECOLOGICAL TIMELINES AND CLIMATE CHANGE NARRATIVES IN FINNMARK FJORD FISHERIES

Camilla Brattland, Einar Eythórsson and Jørn Weines
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Based on research conducted through the Fávllis network for Sami fisheries research, this paper presents examples of socio-ecological timelines (SET). The concept was developed as a tool for analysing social-ecological change at a small spatial scale. Experiences from attempting to compare and integrate science and local knowledge on fjord ecosystems is that there is little overlap between the two, because the data represent different spatial and temporal scales and very different methods. Until recently, marine scientists have concentrated on large-scale ecological systems such as the Barents Sea, and the research on fjord ecology that started in the 1990s is limited in scope and cannot produce long time series. The experience-based knowledge of local fishers on the other hand, is limited to their harvesting space. Fishers can recollect long-term trends and events of ecological change throughout their fishing career, which brings a much longer time perspective on ecological change in the area. To represent such timelines is challenging, however, and to integrate it with marine science and climate change research even more so. This presentation provides some examples of SET from climate change narratives developed from interviews with fjord fishers in Finnmark, and discusses some of the challenges and advantages to including SET in ecological and climate change research.

Keywords:

Socio-ecological systems, climate change, narratives, Sami, fisheries, Finnmark

AMPLITUDE CALIBRATION OF A SEDIMENTARY NAO PROXY RECORD FROM THE TRONDHEIM FJORD

Karl Fabian, Johan Faust, Jochen Knies
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Fjord deposits offer unique opportunities for the investigation of climatically induced processes through sedimentological and geochemical time series. Primary-productivity proxies, like CaCO3, of Trondheim-Fjord near- surface sediments show strong correlation with instrumental winter temperature, precipitation and river discharge in central Norway over the past 50 years. Because the latter are directly influenced by NAO, the first high resolution NAO proxy record (NAO-TFJ) from marine sediments covering the past 2,800 years has been established, conditional on a stationary relation between the productivity proxy and the NAO. A mathematical filter describes the transition from an annually varying NAO signal to a sediment measurement, described as a convolution of the NAO time-series with a smoothing-kernel including sedimentary mixing and the effect of the measurement footprint, averaging over a finite sediment interval. A second mathematical approach calibrates the amplitude variation that is systematically distorted by dating errors. An automated pattern-matching algorithm from speech recognition, based on dynamic time-warping, first aligns the smoothed NAO with the measured proxy record within the known age uncertainty, before performing the calibration. Numerical modeling of realistically distorted autoregressive time series shows that this approach indeed improves the determination of the calibration factor.

Keywords:

Sediment proxy records, North Atlantic Oscillation, Filtering, pattern matching, numerical models

OCEAN CIRCULATION CHANGES FROM THE MIDDLE EOCENE TO THE EARLY OLIGOCENE: A BENTHIC FORAMINIFERAL PERSPECTIVE

Chiara Borrelli
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In paleoceanography, converting climatic and/or oceanographic measurements from a sediment depth scale to a time framework and estimating the long term relationship (trend) between the measured signal and time represent fundamental steps of time series analysis. In this context, age models and statistical inference are important tools used to reconstruct ocean circulation and climate changes through time.

To illustrate these concepts, two case studies exploring changes in ocean circulation during the Eocene-Oligocene transition are presented. The late middle Eocene-early Oligocene (~40-33 Ma) represents one of the most important climatic transition of the last 50 million years (greenhouse-to-icehouse transition), when temperatures started to cool and permanent ice-sheets began to appear on Antarctica. Two hypotheses were formulated to explain this transition: 1) decline in atmospheric greenhouse gas concentrations; and 2) opening of key-oceanic gateways that impacted ocean circulation. Long-term records of benthic foraminiferal stable isotopes ($\delta^{18}O$ and $\delta^{13}C$) from the North Atlantic and the North Pacific revealed changes in ocean circulation in these two regions as consequence of the opening of the Drake Passage and Tasman Rise, supporting the hypothesis that a reorganization of ocean circulation indeed happened from the middle Eocene to the early Oligocene.

Keywords:

Benthic foraminifera, Stable isotope, Eocene-Oligocene, Ocean circulation, Age models, Statistical inference

ATLANTIC SURFACE SALINITY AND TEMPERATURE VARIABILITY 1896-2015

Gilles Reverdin[1], Andrew Friedmann[1], Aurélien Ribes[2]
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Ocean observations of near-surface salinity have been collected since the mid-1890s in the North and tropical Atlantic. We present how time series of salinity, temperature, and density are constructed from these heterogeneous data. Limitations due to sampling and data errors are illustrated based on independent time series of T and S, other fields of SST, and recent time series along dedicated ship routes, such as between Greenland and Denmark or Iceland and Newfoundland. These comparisons suggest some skill in the reconstructions, but also serious limitations due to somewhat insufficient sampling and possible systematic errors.

Statistic properties of these fields will be discussed from EOF analyses and comparisons with different known modes of climate variability. Trends are notable in all regions, contrasting the northern areas north of 45°N with the areas south of it, robust features which have developed in the last 50 years.

These gridded data can then be used to ascertain to which extent the trends can be attributed either to natural variability (including solar or volcanic forcing), or to anthropogenic forcing (either as a response to greenhouse gases emissions or anthropogenic aerosols). This step is usually referred to as Detection and Attribution (D&A). Issues on how observed time series and model simulations of the climate can be combined in these studies will be illustrated with the analysis of observed surface temperature, with contributions of model errors, insufficient data (both spatially, duration and errors), and natural variability.

Keywords:

OBSERVING CLIMATE CHANGE TRENDS IN OCEAN BIOGEOCHEMISTRY: WHEN AND WHERE

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Understanding the influence of anthropogenic forcing on the marine biosphere is a high priority. Climate change-driven trends need to be assessed and detected in a timely manner. As part of the effort towards detection of long-term trends, a network of ocean time series stations provide high quality data for f key parameters, such as pH, oxygen concentration or primary production (PP). Here, we use an ensemble of global coupled climate models to assess the temporal and spatial scales over which observations of eight biogeochemically relevant variables must be made to robustly detect a long-term trend. We find that, as a global average, continuous time series are required for between 14 (pH) and 32 (PP) years to distinguish a climate change trend from natural variability. In addition, we quantify the 'footprint' of existing and planned time series stations (the area over which a station is representative of a broader region). Footprints are largest for pH and sea surface temperature; nevertheless the existing network of observatories only represents 9–15% of the global ocean. Our results present a quantitative framework for assessing the adequacy of current and future ocean observing networks for detection and monitoring of climate change-driven responses in marine biogeochemistry.

Keywords:

Attribution, fixed point observatories, monitoring, sustained observations, climate change, biogeochemistry

ONLINE MULTIVARIATE ANALYSIS OF MULTISENSOR DATA FROM THE LOVE OCEAN OBSERVATORY

Ingvar Eide and Frank Westad
Statoil Research Centre and Camo Software, NO-7005 Trondheim and NO-0349 Oslo
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The cabled LoVe Ocean Observatory is located at 258 m depth 20 km off the coast of Lofoten-Vesterålen. Multiple sensors are used for real-time environmental monitoring with online submission of data for chlorophyll (two sensors), cDOM, TSM, turbidity, conductivity, temperature (three sensors), salinity, depth, biomass at three different depths, and current speed measured in two directions using two sensors covering different depths with overlap. Automated monitoring of all sensors is performed with Principal Component Analysis (PCA) for early detection of changes and time-trends in the overall response pattern (~100 parameters) before changes are evident in individual parameters. The site for Multivariate Data Analysis at the LoVe portal (http://LoVe.Statoil.com) shows as a first overview a score plot obtained after PCA of data from all sensors submitted online more or less continuously, analyzed consecutively and projected on a calibration model. Methods for statistical validation, and warning and alarm limits are established. Redundant sensors enable sensor diagnostics and quality assurance. In a future perspective the purpose is integrated environmental monitoring and early preventive measures in areas with discharges. Also data from spectra, images and biosensors may be incorporated. The software used are the Unscrambler X and Process Pulse from Camo Software.

Keywords:

Principal Component Analysis, PCA, Multi-block, Real-time, Environmental monitoring, Time trends

Session 2: "Time series analysis for greenhouse gases and carbon cycle"

Chaired by: Jürgen Mienert and Truls Johannessen
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A NEW FAST-RESPONSE, REAL-TIME AND CONTINUOUS METHANE SENSOR: MILLIONS OF DATA TO SCREEN MARINE PROCESSES

Jack Triest, R. Grilli, J. Chappellaz, J. Mienert, A. Silyakova, P. Jansson, B. Ferré, C. Lund Myhre and S. Platt
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Continuous high resolution profiling of dissolved methane down to ocean depths is made possible as a result of technological innovations achieved in the search for the oldest ice in Antarctica. Testing for the SUBGLACIOR probe, which is being developed at LGGE in response to the IPICS >1Ma old ice challenge, showed that much of the technology to extract the trapped gases from ice can also significantly improve the extraction and analysis of dissolved methane from the sea compared to current available sensors.

To develop this potential, an oceanographic instrument 'SubOcean' was built and deployed over a gas-hydrate zone of western Svalbard, in collaboration with CAGE, in October 2015. Continuous measurements to depths of 400 m were made over three days resulting in high-resolution 3D profiles. The very fast response time of the sensor allows to display the in-situ measurements in real-time and compare them directly to data from other instrumentation aboard the ship whilst underway. The sensor contains a membrane based gas extraction system coupled to a laser spectrometer to provide accurate measurements over a wide concentration range.

We will present the overall design of the instrument and highlight how it can help provide new insights into the spatial distribution and flux of methane in the marine environment. With millions of data acquired in a relatively short deployment time, the instrument brings as well new challenges in data treatment, that we will shortly discuss in the presentation.

Keywords:

Methane, hydrates, dissolved gases, laser instrumentation

IS MICROSEISMIC ACTIVITY ON THE WESTERN SVALBARD CONTINENTAL MARGIN RELATED TO NATURAL GAS LEAKAGE?

Peter Franek, Andreia-Plaza-Faverola, Jürgen Mienert, Stefan Buenz
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The western Svalbard continental margin off Prins Karls Forland is an area subjected to tectonic processes related to the spreading ridges and post-glacial flexural rebound forces. Numerous acoustic flares indicating gas seepage were observed in the water column at the upper pinch-out of the present day gas hydrate stability zone. Stability of the shallow gas hydrates may be influenced by increasing temperature of the West Spitsbergen Current. An ocean bottom seismometer was deployed here and recorded seismic motion over a period of 10 months. Earthquakes were identified in the seismic records and used for determining orientation of horizontal components of the seismometer relative to the geographic north. An automatic triggering algorithm allowed identification of numerous events with a duration shorter than 1 s. One group of the short duration events, described by mutual similarity of waveforms and relatively narrow frequency peak at 17-21 Hz, is considered to be generated by moving sources. They are most likely fin whale calls. The second group of events mainly originated east and/or west of the seismometer in a distance up to about 1 km. For these events we suggest two main source mechanisms – fracturing processes related to seafloor gas seepage and sub-seabed fluid migration.

Keywords:

West Svalbard continental margin, earthquakes, microseismic activity, gas seepage, dissociation of gas hydrates, sub-seafloor fluid migration

TIME-SERIES ANALYSIS OF ATMOSPHERIC GREENHOUSE GAS CONCENTRATION DATA

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Atmospheric concentrations of greenhouse gases, carbon dioxide and methane, have been measured using in-situ monitors already decades. Concentration variations show in addition to the long-term trend, annual variation and shorter term oscillations. Concerning carbon dioxide, annual variation is mainly produced by uptake of carbon dioxide by vegetation during the growing season, and concerning methane, photochemical destruction by solar light. Shorter term oscillations originate mainly from variations in meteorological condition, horizontal advection and vertical mixing.

In this presentation, long-term atmospheric concentrations of carbon dioxide and methane from sites in the arctic, boreal, and tropical regions and the southern hemisphere are studied to characterize variations at different scales. Annual cycle is quantified and in addition to that we look for oscillations in multiannual scale (El Nino-Southern Oscillation), seasonal scale (for example North Atlantic Oscillation) and bimonthly scale (Julian-Madden oscillation).

Keywords:

Methane, carbon dioxide, atmospheric monitoring, oscillations, meteorological analysis

TIME SERIES AND INTERPRETATION OF ATMOSPHERIC MEASUREMENTS WITH FOCUS ON THE ARCTIC REGION

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The presentation will focus on detection of atmospheric change, and in particular on the understanding of atmospheric compositional change at remote locations.

Arctic climate change is occurring and will most likely accelerate during the next decades. According to IPCC 5th Assessment report from 2013 the temperature projections for some Arctic areas show an increase of more than 10 degrees in the annual mean by the end of this century, under their "business as usual" scenario. This will have large impact on the Arctic ocean, terrestrial system and atmosphere, and on the interactions between these. It is of outermost importance to understand the background levels, detected signals of changes and reveal potential new atmospheric sources, on short, medium and long-term time scale.

Sources of atmospheric components with natural and anthropogenic origin are numerous, and various tools and methods for interpretations of atmospheric time series will be explained and illustrated with examples. In particular, new results and approaches on the understanding of Arctic methane emissions on short (weeks) and long (10-15 years) time scale will be presented. The studies are based on a combination of novel measurements, analysis of long-term observations, and various state-of-the-art modelling tools.

Keywords:

Arctic, methane, atmospheric compositional change

IRREPLACEABILITY ROLES OF TIME-SERIES OBSERVATION FOR OCEAN CARBON CYCLE MODELING

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The long record of time-series observation provides a unique data sets to (1) evaluate model projections and (2) calibrate parameterization not feasible with other observational platforms. Two of the most comprehensive biogeochemical time-series stations with long records are BATS and HOT. First, we show how the data from these stations are used to validate the rate of anthropogenic climate change, specifically the rate of ocean carbon sinks, as simulated by a suite of IPCC class Earth system models. Compare to other observational data set, the time-series data is superior in determining the contribution of physical and biogeochemical drivers to the total CO_2 uptake. This allows us to identify models that produce the observed net uptake but for the wrong mechanisms. Secondly, one of the biggest challenge of ocean carbon cycle modeling is to parameterize the non-linear ocean ecosystem dynamics. Applying a novel data assimilation scheme, we use data from three different time-series sites to optimize water-column ecosystem processes in a global marine carbon cycle model. Not only does the assimilation recover the observed seasonal variability at all stations, it also improve predictions of non-assimilated state variables from independent observations. Our studies shows that time-series observation are critical for the modeling community.

Keywords:

BATS, HOT, Data assimilation, ocean carbon cycle model, CO2 sink

TIME SERIES OF CARBON IN A CHANGING CLIMATE - EXAMPLES FROM STATION M IN THE NORWEGIAN SEA

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Long time series are invaluable, as they allow us to determine small changes in systems which are characterised by large natural variability. Station M was initiated in 1948, and the site is located at a fixed position in the Norwegian Sea. Its main focus was originally meteorological and hydrographic monitoring, and the time series of temperature and salinity from the deep water are amongst the longest in the world. Over the years also biogeochemical parameters were included at Station M. Time series for inorganic carbon has been monitored since 2001, and in this talk trends in both hydrography and biogeochemistry are presented. The trends observed at Station M are parts of a larger picture in the Nordic Seas, and a taste of this will also be presented.

Keywords:

carbon, time series, trends, acidification, CO2-uptake, Norwegian Sea

CHANGES IN THE ARCTIC OCEAN CARBON CYCLE DURING THE LAST DECADES

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The Arctic Ocean has undergone dramatic changes during the last decades, the most pronounced being the retreat of the summer sea ice coverage. This has impacted the transformation and fluxes of carbon through; increased primary production by better light regimes, and increased input of dissolved and particulate organic carbon from land by both river runoff and coastal erosion. When the terrestrial organic matter degrades it adds to a flux of CO_2 to the atmosphere as well as to ocean acidification. The changes in primary production will mainly impact the carbon budget if the produced organic matter sediments into the deep ocean. To observe such a change requires a longer time scale than what we at present have. Added to these changes in the "natural" carbon cycle is the increase in dissolved inorganic carbon by uptake of anthropogenic CO_2 from the atmosphere.

Data collected by expeditions in the central Arctic Ocean from the 1980th up to present will be evaluated to elucidate observed changes. Also data from the Siberian shelf and the fate of waters produced in this region will be presented.

Keywords:

Arctic Ocean, sea ice, terrestrial input, ocean acidification

The pH evolution in two time series of data: the open ocean ESTOC site and the Mauritanian upwelling area

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Long-term time series are the most powerful tool for investigating any change in ocean biogeochemistry and its effects on the carbon cycle. We have evaluated two different time series, the open ocean ESTOC site (European Station for Time series in the Ocean at the Canary islands) with observations of monthly measured pH (total scale) since 1995 by following all changes in response to increasing atmospheric carbon dioxide and the monthly high resolution partial pressure of carbon dioxide in the Mauritanian upwelling from 2005 to 2012. The surface waters at the ESTOC site have become more acidic, -0.0019 ± 0.0002 units yr^{-1}, whereas the carbonate ion concentrations and $CaCO_3$ saturation state have also decreased over time. C_T at constant salinity, NC_T, increased at a rate of 1.05 ± 0.02 µmol kg^{-1} yr^{-1}, linked to an fCO_2 increase of 2.0 ± 0.2 µatm yr^{-1} in both the atmosphere and the ocean. The ESTOC site is presented by way of a reference site to follow ocean acidification changes in the North Atlantic Sub-tropical gyre. On the other hand, coastal upwelling along the eastern margins of major ocean basins are large economic regions where the physical forcing of upwelling processes can be affected by global warming. The Mauritanian data set provides directly evidence of seasonal and interannual changes in the physical and biochemical processes that confirm an uwpelling intensification and an increase in the CO_2 outgassing in the 10ºN - 27ºN region, one of the four most important upwelling regions of the planet. The eight years of data also indicated that computed $pH_{T,is}$ at 21ºN decreased at a rate of -0.003 ± 0.001 pH units per year . The integrated CO_2 fluxes for the area were between 2.3 to 3.1 10^6 mol, with an increase during the studied period of $0.1 \cdot 10^6$ mol yr^{-1}. The Mauritanian upwelling has being shown as an important area sensitive to climate changes due to upwelling intensification, which strongly affects the CO_2 surface distribution, ocean acidification rates and air-sea CO_2 exchange.

Keywords:

Time series stations, carbon dioxide, open ocean trends, upwelling regions, acidification

Session 3: Concluding session

Chaired by: Gilles Reverdin
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HOW TO USE STATISTICAL-PHYSICS TO STUDY CLIMATE CHANGE

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In this talk we will present some statistical and mathematical techniques to study climate change and the modification in the occurrence and frequency of extreme events. We will discuss the limits of a pure statistical approach and explain how the information about the dynamics and the physics of the climate could be used to improve the estimates of climate change effects. In particular, we will discuss how turbulence affects the climate change signal on atmospheric circulation and how one can separate the turbulent and coherent component to get information about the physical processes which will be more affected by the greenhouse forcing.

Keywords

CHANGE POINT DETECTION FROM TIME SERIES DATA

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Frequently, features found in a time series depend on the resolution for which the data are considered. Scale-space is a powerful technique for analysing data of this type. In the talk, we introduce the idea behind scale-space methodologies and show how it can be used to draw objective conclusions for a large number of different data sets. First, we show how data in a time series with independent noise can be analysed. Then, we discuss pairwise comparison of time series. We also discuss a scale-space method that is suitable for detecting periodicities in a time series. Some methodology for dependent data is also briefly described through applications before we show how the method can be used to detect differences between a climate model and observed data sets.

Keywords:

Scale-space, periodicities, pairwise comparison, dependent data, objective evaluation, sizer

WHAT DO TIME SERIES OF WEATHER-HEALTH RELATIONSHIPS TELL US ABOUT FUTURE VULNERABILITY TO CLIMATE CHANGE?

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In environmental epidemiology, time series studies are used to characterize the relationship between short-term (often daily) fluctuations in health outcomes and weather parameters, such as maximum daily temperature. Their results are important for attribution of outcomes to the influence of weather, but because of their design they reflect only the impact of short-term exposure (acute exacerbation of illness or precipitation of acute events such as heart attacks, strokes and death) rather than the consequences for lifestyles and behaviours of living under altered climatic conditions. They therefore have an important, but somewhat indirect and incomplete, bearing on the consequences of climate change for human health. They do provide a basis for quantifying exposure-response relationships (e.g. temperature-mortality) which have been used to quantify attributable burdens of both cold and heat effects in different populations and the impact of specific weather events such as heat waves and floods. When combined with scenario projections of future climatic patterns, such relationships also provide a basis for estimating the potential health burdens of climate change under a range of assumptions. An important focus for research is to understand how those relationships are modified by population factors and specific adaptation measures (e.g. of housing design, use of heat warning systems etc) that may be used to help limit future vulnerability under climate change. Time-series studies that focus on seasonal or inter-annual variations in health outcomes can also be used to study such consequences of climate change as changes in the distribution of vector-borne disease and altered food productivity consequent to reduced precipitation, although for such forms of impact more indirect methods of analysis are typically deployed

NON-STATIONARITY IN TIME SERIES: SOME STATISTICAL NOTES ON THE INTERACTIONS BETWEEN CLIMATE AND ECOLOGICAL SYSTEMS

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Models predicting the current and future impacts of climate change on ecological systems are often based on short time series (50-100 years at best). Such short time-series make it difficult to assess the stationarity of underlying dynamics – it is difficult to distinguish systemic changes from stochastic variability. Considering also the possibility of having future climates with no present-day analogues, I suggest that we should adopt a multi-models approach, focusing on plausible scenarios rather than focusing on one or a few "statistically best" models. I will illustrate such ideas using current work on arctic ecosystems.

Keywords:

Non-linear dynamics, predictions, multi-model predictions.

Poster abstracts

CLIMATE EFFECTS ON HISTORIC BLUEFIN TUNA CAPTURES IN THE GIBRALTAR STRAIT AND WESTERN MEDITERRANEAN INFERRED BY MEANS OF TIME SERIES ANALYSIS

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Historical capture records of bluefin tuna (BFT) from the Gibraltar Strait and Western Mediterranean show pronounced short- and long-term fluctuations. Some of these fluctuations are believed to be associated with biological and ecological process, as well as distinct climate factors. For the period of study (1700–1936), we found a long-term increasing trend in the BFT captures and in the climate variables. After applying a time series analysis, it is highlighted the role played by SST on bluefin population variations. The most relevant result of this study is the strong correlation found between the total solar irradiance and bluefin captures. The solar irradiance could have affected storminess during the period under study, mainly during the time interval 1700–1810. We suggest physico-biological mechanisms that explain the BFT catch fluctuations in two consecutive time intervals. In the first period, from 1700 to 1810, this mechanism could be high storm and wind activity, which would have made the BFT fisheries activities more difficult by reducing their efficacy. In contrast, during the interval from 1810 to 1907, the effects of wind and storms could be on spawning behaviour and larval ecology, and hence on year class strength, rather than on fish or fisherman's behaviour.

Keywords:

Historical bluefin tuna captures; Total solar irradiance; Sea surface temperature

DID A NEW REGIME START IN THE NORTH PACIFIC IN 2014?

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Marine ecosystems have often undergone regime shifts, defined as abrupt changes of environmental properties. These shifts have pronounced effects on physical and biological conditions. In the North Pacific a major shift was reported in 1977, with subsequent impacts on the marine ecosystem. In addition to the 1977 event, a sudden increase of the North Pacific Sea Surface Temperature (SST) was reported during winter 2014. This does not seem to be a one-off event, as the mean SST of the area has remained elevated ever since. Here we discuss the similarities of these two events, with a possibility of describing a new regime that began in 2014. Change point analyses have been applied on SST time series with the North Pacific large scale oscillations as covariates. Furthermore, Pearson and lagged correlations have been applied in order to investigate the relationship between SST and North Pacific Oscillation, Pacific Decadal Oscillation and North Pacific Gyre Oscillation. The results present a well defined relationship between the aforementioned parameters and show similarities between the 1977 and 2014 events. Further analyses aim to investigate which processes preceded, and could have caused, the abrupt shift as well as the potential effects on the fisheries of the region.

Keywords:

Regime Shifts, Sea Surface Temperature, Large marine ecosystems

TEMPORAL VARIABILITY OF PARTICLE FLUXES IN KONGSFJORDEN, SVALBARD

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Kongsfjorden is a fjord of Svalbard at 79° N; it is located on the west coast of Spitsbergen region. All glaciers reaching Kongsfjord are rapidly retreating. To verify the temporal variability of particle fluxes and composition on long time-scales and monitoring variations of thermohaline characteristics, an instrumented mooring, equipped with an automatic sediment trap, three temperature and salinity recorders and two current meters, was deployed in September 2010 in the inner fjord at ~100 m water depth. Five years of the total mass fluxes will be presented and the mass flux, together with the organic and inorganic elements will be discussed. The highest peaks have been recorded in summer and fall months, followed by reduced fluxes during winters. During summer 2013 the TMF reached ~330 g m^{-2} day^{-1} and on this date it was observed the maximum value of %C inorg (3.78) and the minimum values of %OC (0.21). Temporal variability of mooring data will be discussed concurrently with meteorological parameters recorded by the Amundsen-Nobile CCTower of CNR in Ny-Ålesund; the rain precipitation, for example, is used as a runoff proxy. We can make a comparison of these data, to elucidate the main processes involved in the particle sedimentation in inner Kongsfjorden.

Keywords:

Arctic, Particle flux, Fjord system

Other information:

There is evidence that land-to-ocean fluxes of particulate material along the Arctic coasts are changing. Recent studies suggest that the increasing hydrologic regime observed in the last decades is the consequence of recent climate warming and related to changes in permafrost conditions. It's important to detect what is the main contribution of particle flux in the Arctic fjords and which is its origin. The terrestrial input could be due to the melting of glaciers or to the surface runoff that generates debris into the sea from the melting of permafrost. The marine input could be due to the biological pump.

ERROR PROPAGATION FROM SPARSE TIME SERIES DATA

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On timescales approaching that of the Cenozoic, it is typically necessary to deal with sparsely populated time series data, which generally requires interpolation to a full record to be of use. Interpolation is often linear, however other interpolation methods may prove more accurate and realistic, especially where oscillations are present. Using a dataset of palaeo surface ocean pH and atmospheric CO_2, I show how such a sparse dataset may lead to large uncertainties. This propagates into model calculations, possibly leading to identification of spurious trends. Sophisticated time series data analysis methods are not often used on data produced by models, as this might be expected to only reveal periodicities originally imposed on the model, however nonlinearity and lags in model equations may lead to novel time series data analysis results.

Keywords:

Carbon cycle, time series, model

TEMPORAL VARIABILITY IN THE BIOGEOCHEMISTRY OF THE SURFACE NORTH ATLANTIC: OVER A DECADE OF SHIP OF OPPORTUNITY DATA

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We present a high-resolution time series of the surface North Atlantic biogeochemistry. A voluntary observing ship has been collecting underway seawater samples every 4 hours on its monthly track between the UK and the Caribbean since 2002. The samples are analysed for macronutrients (nitrate + nitrite, phosphate, silicate). The results are coupled with open-access mixed layer depth information and satellite-derived chlorophyll concentrations. The large meridional extent of the ship's track means multiple biogeographical regions are crossed. Nutrient concentrations range from NO_3^- + NO_2^- < 1 µmol/l in the subtropical gyre to NO_3^- + NO_2^- < 10 µmol/l in the UK shelf sea. The poor correlation between the mixed layer depth and the nutrient concentrations in the subtropical gyre confirms that vertical mixing is not the main nutrient source in the western part of the gyre unlike the northern part of the ship's track. The high chlorophyll anomaly in the subtropical gyre between 2010 and 2011 matches an increase in nitrate and the big drop in the strength of the meridional circulation. The time-series will continue to grow in the future and help enhance our understanding of the Atlantic biogeochemical cycles.

Keywords:

Atlantic, Nutrients, Variability

σ_θ CHANGE IN THE COASTAL NORWAY AND ITS EFFECT ON THE COLD-WATER CORAL REEFS

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The occurrence of cold-water corals (CWCs) is related to hydrographical background. Healthy northeastern Atlantic CWC reefs are associated with specific sigma-theta range of σ_θ = 27.5 ± 0.2 kgm^{-3}-1000. At the coastal Norway, southern reefs are off this limit and they are decaying compared to those in the northern Norway and off the coast. Time-series analyses from the fixed hydrographical stations show that σ_θ has changed -0.1 - -0.2 kgm^{-3}-1000 per hundred years during the last 70 years at the depths of 200 - 300 meters. This indicates that conditions have changed unfavourable to coral reefs in south during the industrial time and that the reefs in the north will experience stress within the following decades. To study the present differences in biogeochemical and physical background of the CWCs in real time, state-of-art landers were deployed between 2012 and 2014 for several months both to north and south coral reef site. The change in density will effect on the mixing of the water column, which could effect on the growth of CWCs. Since CWC reefs provide a habitat to numerous species, the decay of CWC reefs at the Norwegian coast affects the whole benthic ecosystem.

Keywords:

Cold-water corals, in-situ measurements, hydrography

PATTERNS IN SEASONAL VARIATIONS IN CHROMOPHORIC DISSOLVED ORGANIC MATTER AS AN INDICATOR OF AUTOCHTHONOUS PRODUCTION IN THE NORTH ATLANTIC SUBTROPICAL GYRE

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In many oligotrophic regions of the ocean, such as the North Atlantic Subtropical Gyre, production and consumption processes of organic carbon are decoupled. Use of an inexpensive and easy-to-measure tracer, such as the chromophoric, or light-absorbing, fraction of dissolved organic matter (CDOM) could be invaluable to delineating newly produced, autochthonous DOC.
A time-series of CDOM measurements collected at the Bermuda Atlantic Time-series Site (BATS) suggests that seasonal production of 'new' DOC correlates with CDOM and presents opportunities for CDOM to be used as a tracer of labile carbon.

Keywords:

CDOM, dissolved organic carbon, oligotrophic

THE THERMAL STATE OF SVALBARD PERMAFROST: INSIGHTS GAINED FROM GROUND TEMPERATURE TIME SERIES

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Ground temperatures in central Spitsbergen, Svalbard are monitored in a series of boreholes instrumented with thermistor strings. Permafrost temperatures are presented for six of the deepest boreholes, which were drilled between 2008 and 2009. Since the onset of ground temperature measurements, permafrost has warmed at varying rates between the boreholes and the landforms that contain them. Mean annual ground temperature at 10 m depth warmed a maximum of 0.9°C in five years. Active layer thickening has also occurred, and can be observed both in the ground temperature data and in measurements made via mechanical probing. The ground temperature time series are also used to investigate active layer and permafrost response to short term events like rain-on-snow. The ground temperature time series demonstrate that the thermal state of permafrost on Svalbard, and its response to climate change, is highly dependent on site-specific factors like ground material and snow cover characteristics.

Keywords:

Permafrost, Svalbard, Ground temperature

LONG TERM OBSERVATIONS OF N2O AND CH4 AT BOKNIS ECK TIME SERIES STATION

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In coastal waters, greenhouse gases, like N_2O and CH_4, are produced by a series of biological processes, which are favoured under hypoxic conditions. Excessive nutrient inputs lead to severe eutrophication and deoxygenation, thus coastal areas are considered as hot spots for greenhouse gas emissions. Although wastewater treatment plants have been installed around the Baltic Sea and nutrients concentrations have decreased for the past several decades, dissolved oxygen concentrations are decreasing. Here we examined seasonal and annual variations of N_2O and CH_4 based on monthly sampling at the Boknis Eck (BE) Time Series Station, one of the oldest continuously sampled marine time series sites located in the southwestern Baltic Sea. Measurements of N_2O and CH_4 started in July 2005 and June 2006, respectively. We observed a pronounced seasonal pattern for N_2O with high concentrations in winter-early spring and low in autumn, and a less pronounced seasonal pattern for CH_4. There is no straightforward relationship between N_2O/CH_4 and nutrients. N_2O/CH_4 variations are presumably to be more closely associated with oxygen. We did not find a significant N_2O/CH_4 trend and continuous monitoring is essential to predict future N_2O/CH_4 variations.

Keywords:

nitrous oxide, methane, eutrophication

INTERANNUAL VARIATIONS OF FRESHWATER CONTENT IN HORNSUND

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Salinity measurements have been used to calculate the freshwater content in Hornsund for the years 2001 to 2014. In 2011 there was significantly higher freshwater content in the fjord, compared to the other years. The high freshwater content in 2011 was attributed to the inflow of sea ice and sea ice meltwater of Barents Sea origin. The lowest amount of freshwater was found in July 2014. No good relashionship between estimations of variations in terrestial runoff and freshwater content in the fjord was found. The distribution of freshwater in Hornsund seems to be governed by wind conditions and the rotational dynamics in the fjord. The fractional contributions of meteoric water, sea ice meltwater, and seawater was calculated based on δ^18O and salinity measurements in September 2013.
Significant amounts of meteoric water was found in the surface waters of the bays Burgerbukta and Brepollen. The δ^18O in Brepollen, the innermost bay of Hornsund, showed unusually high values compared to other δ^18O measurements taken in and around Svalbard. This was attributed to the possible existence of a hydrothermal vent or significant amounts of sea ice meltwater in the bay.

Keywords:

Oceanography, freshwater, sea ice

CIRCULATION STRUCTURES FROM THE GEOSTROPHIC CURRENT FIELD IN THE MALTA-SICILY CHANNEL

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The spatial and temporal variabilities and main forcing functions (wind stress, thermohaline forcing, etc) of the Malta-Sicily channel (MSC) are important for the Mediterranean sea, since it is exposed to possible oil spills associated with the heavy marine traffic and the strong fishing activities in the mid-Mediterranean.
At the same time such dynamical processes influence the biological transport and are relevant from the productive and environmental point of view.
Geostrophic current field was computed from AVISO sea surface elevation data sets, in order to identify the main circulation features, which are fundamental for the understanding of the MSC circulation dynamics. The dataset available includes sea surface height (SSH) starting from January 2012 to November 2014.

Keywords:

MSC circulation, geostrophy, SSH

MIDDLE TO LATE HOLOCENE HYDROCLIMATE VARIABILITY ON THE TIBETAN PLATEAU INFERRED FROM A MULTI-PROXY LAKE SEDIMENT RECORD, GALANG CO, SOUTHEASTERN TIBET

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The Indian summer monsoon (ISM) is the primary source of precipitation to the Nyainqêntanglha mountain range in the eastern Tibetan Plateau. Predicting variability in the ISM is limited when reliant on modern monitoring and as such paleoclimate records are needed to expand these records to assess long-term variability. This ongoing study is using sediment cores and surface sediments from a transect of eastern Tibetan lakes to assess paleo precipitation and lake levels. The previously unstudied lake, Galang Co, is at a relatively low elevation (2800 m) in a heavily-forested watershed. Two Livingstone and three surface cores along with surface sediments were collected in June 2015. Oldest dates from these cores show that the record spans over 7,400 years before present. Initial analyses of this lake has shown trends in changing lake levels from a shallow, peat-rich bog to a deeper lake that are inferred from sedimentology, grain size, and organic carbon matter. These preliminary results are compared with existing paleo records from surrounding lakes to make inferences about decadal trends in ISM variability. These climate records aim to assist with developing and constraining climate models that assess how precipitation from the ISM will be impacted by future changing climate.

Keywords:

Paleoclimate, Monsoon, Climate variability

EARLY WARNING SIGNALS FOR APPROACHING TROPICAL CYCLONES USING TIME SERIES ANALYSIS

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The PhD project intends to create a multi-purpose tool to predict a bifurcation or catastrophe in a dynamical system given time series data as input, with intended applications in weather and climate. The proposed method involves analysing auto-correlation, noise and trends in the time series. This builds upon the work of Valerie Livina and Timothy Lenton which aims to predict dramatic climate change (e.g. ice ages) from paleoclimate time series; it is hoped that this project will refine the previous method.

Initially, the case of an approaching tropical cyclone -- studying sea level pressure and wind speed time series -- has been investigated. Results are preliminary but do suggest that a deeper analysis may lead to a cyclone being visible through inspection of the correlations in the time series before it is obviously visible (i.e. pressure drops and wind speed rises).

Keywords:

Bifurcation, Meteorology, Auto-correlation.

Other information:

The poster will give a short introduction to the PhD project, including how the results will be used to predict (e.g.) ice age events, then give details of the time series analysis methods used, and a summary of the preliminary results with specific application to tropical cyclones.

RECONSTRUCTING THE PRE-RAPID AMOC FLUCTUATIONS USING MULTIPLE-DATASET REGRESSION ANALYSIS

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The Atlantic Meridional Overturning Circulation (AMOC) has a prominent role in northward heat transport from the Florida Straits, leading to Europe's climate being milder than other locations at the same latitude. Several studies project a potential decrease in atmospheric temperatures as a consequence of a slow-down in the AMOC. The RAPID array at 26° N has collected 12 years of observational data from 2004-2016. This study reconstructs a longer period to analyse the AMOC at different timescales; from decadal to interannual. A statistical method was developed to generate a hindcast series, using large-scale observational indices of longer observational period are well sustained for a longer time. The coefficients from the ridge regression analysis of deseasonalised, standardised RAPID AMOC data, North Atlantic Oscillation (NAO), Arctic Oscillation (AO), European atmospheric temperature records, Florida Straits transport, Arctic ice extent and western boundary and eastern boundary sea level, are used to produce a reconstruction of the AMOC from the 1980s. Both the general trend over three decades as well as shorter-scale interannual variability are examined from the reconstruction in order to better understand its current state.

Keywords:

Time series, AMOC, hindcast

A COMPARISON OF THE AGULHAS CURRENT TRANSPORT AND ITS VARIABILITY IN TWO REGIONAL OCEAN MODELS

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Two regional ocean models; The Hybrid Coordinate Ocean Model and The Regional Ocean Modelling System were analysed together with in-situ transport estimates from the Agulhas Current Time-series (ACT). The 30-year model time-series provides a sufficient temporal overview, thus making it easier to establish significant seasonal and inter-annual variability, as well as being able to recognise variable mesoscale features. According to the three-year ACT observations, the Agulhas Current estimates a jet transport of -84± 24Sv and a mean transport of -77± 32Sv, the negative transport always being in the southwest direction. HYCOM simulates a higher jet and net transport of -89± 40Sv and -85± 44Sv over the 30-year simulation period. ROMS simulates a narrow current, with lower jet and net transport of -59± 30Sv and -53± 21Sv. In terms of the seasonal cycle, both time series in the ROMS model and the observations display a maximum transport in the austral summer and a minimum transport in the winter. Whereas the HYCOM transport displays a maximum transport in the austral fall and minimum in the winter, lagging the observations by approximately two months. Inter-annual variability was evident in both model transport time-series with slight decadal variability evident in ROMS. The models show that jet transport remains sensitive to the mesoscale variability due to the increased spatial and temporal scales thus emphasizing the importance of model precision to accurately simulate Agulhas transports.

Keywords:

Agulhas Current, Volume Transport, Seasonal Cycle

DATA ASSIMILATION OF ARCTIC SEA ICE

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Accurate ice forecast in the Arctic is very important for ship traffic, weather prediction and climate analysis. Ice forecasts can be improved by assimilating observed sea-ice parameters in the sea-ice model, but there are many assimilation methods with many different levels of complexity. The aim of this work has been to compare two assimilation methods, one simple and one complex to see if the extra effort is needed. The Los Alamos CICE model in a standalone mode has been used for the sea-ice modelling, with forcing from ocean (ROMS) and atmosphere (ECMWF). The sea ice observations are reanalysed sea-ice concentration products in the Arctic from OSISAF. The two assimilation methods which have been compared are the combined optimal interpolation and nudging scheme (COIN) and the Ensemble Kalman Filter (EnKF). To compare the results I have foretasted the model 30 days after assimilation to see which method that provides the best initial state for the forecast. I have found that for an average of 5 forecasts distributed over a year the EnKF drifts significantly less than for the COIN assimilation.

Keywords:

Sea-ice, Assimilation, Arctic

CONTRIBUTION OF STATISTICAL MODELING TO THE UNDERSTANDING OF THE MASS BALANCE OF A SMALL ARCTIC GLACIER (AUSTRE LOVÉN, SVALBARD)

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Arctic glaciers are good indicators of the ongoing climate change because their dynamics is especially sensitive to warming temperature and changes in precipitation. The work described in this paper aims at better understanding how contrasted climatic and snow conditions in recent years do constrain, sometimes unexpectedly, mass balance dynamics. This study focuses on a small arctic glacier, the Austre Lovén in Svalbard (79°N). Objectives are (i) to identify factors and combination of factors affecting annual mass balances and (ii) to reveal trends over time and space.
The Austre Lovén (4,5 km²) is an observatory glacier equipped with a dense network of measuring devices (temperature, ice stakes…). Harsh field conditions do sometimes require time-series reconstructions prior to run any analysis. Statistical tools such as interpolation were tested and used to identify the relevant indicators (temperature, liquid precipitations, snow accumulation…). An explanatory model based on multiple linear regression was set up with a rigorous statistical validation. Multivariate analyses (PCA, classifications) were finally run to spatialize trends.
The results show that regression modelling is a good approach for small scale mass balance studies. The spatial dimension of the ongoing processes was highlighted. A significant role of site properties and snow conditions throughout years was also identified.

Keywords:

explanatory modelling, glacier mass balance, multivariate statistics

EVALUATION OF PRECIPITATION DATA FOR MODELLING RUNOFF IN ALPINE REGIONS

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This poster is based on the Master's thesis of Paribesh Pradhan. The thesis evaluates a gridded disaggregated hourly precipitation dataset, RdisaggH, for Switzerland. RdisaggH is a product derived from rain-gauge observations and weather radar data, and developed by MeteoSwiss. In this study, this RdisaggH precipitation dataset is compared with a gridded data from rain gauge stations (Meteo dataset). The evaluation is based upon the results obtained after running both these two precipitation datasets into a hydrological model called PREVAH (PREecipitation-Runoff-EVApotranspiration HRU Model) which is a semi-distributed hydrological modelling system. The model was run for five catchments in Switzerland. Out of these five catchments, three alpine catchments were chosen.

The results showed that RdisaggH simulated runoff obtained from PREVAH produced good results for catchments larger than 100 km^2 as opposed to those below 50 km^2. The larger catchments at higher elevation also simulated more realistic runoffs than the ones at lower elevation. RdisaggH dataset also managed to capture the seasonal variability of these larger catchment better than the Meteo dataset. In all catchments, RdisaggH simulated runoff overestimated the recession period to a varying degree for high precipitation events.

Keywords:

PREVAH, Hydrological Modelling, Precipitation data

QUANTIFYING GLACIAL AND NON-GLACIAL WATER AND NUTRIENT SOURCES IN THE WOLVERINE GLACIER CATCHMENT, ALASKA

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Glacial meltwaters contribute nutrient loads that are required by downstream ecosystems to thrive. How glacial hydrological systems respond to climate change is largely unknown. This project compares physio-chemical variables like pH, electrical conductivity (EC), total dissolved solids (TDS), temperature, dissolved organic carbon (DOC), dissolved organic matter (DOM) and ions of meltwater from both glacial and non-glacial streams within the same catchment. Such analysis will aid in detecting differences between the two and potentially quantifying their contributions into the outlet stream which begins at the terminus and ends at the ocean. This new project will aid in increased understanding of glacial hydrological systems in a changing climate and how such changes might impact downstream and oceanic ecosystems.

Data thus far indicate clear differences in the physio-chemical signatures of different sources such as glacial, tundra and mixed outlet stream. For example EC, a proxy for nutrient load, changes dramatically over the melt season, with tundra streams seeing an increase and terminus stream a decrease. For the sites analyzed so far, the DOC concentration seems to decrease over May-June. Fluorescence Index values calculated so far reveal that from May-June, glacial outflow has more microbial DOM, while tundra streams have more terrestrially derived DOM.

Keywords:

time series, glacier chemistry, physio-chemical variables

INDIAN OCEAN DIPOLE ACTIVITY IN 20TH CENTURY OBSERVATIONS AND SIMULATIONS

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The Indian Ocean dipole (IOD) is a coupled ocean-atmosphere system with anomalous cooling in the east, warming in the west and easterly wind anomalies, resulting in a complete reversal of the climatological zonal sea surface temperature (SST) gradient. The IOD strongly influences East African climate by causing anomalously strong October – December (OND) precipitation. Using observational data and historical CMIP5 (Coupled Model Intercomparison Project phase 5) model output, the September – November (SON) dipole mode index (DMI), OND East African precipitation and SON zonal wind index (ZWI) are calculated. We pay particular attention to detrending SSTs for calculating the DMI, which seems to have been neglected in some published research. The ZWI is defined as the area-averaged zonal wind component at 850 hPa over the central Indian Ocean. Regression analysis is used to evaluate the models' capability to represent the IOD and its impact on east African climate between 1948 and 2005. Simple correlations are calculated between SST, zonal wind and precipitation to show their interdependence. High correlation in models implies a good representation of the influence of IOD on East African climate variability and our goal is to detect the models with the highest correlation coefficients.

Keywords:

Indian Ocean dipole, multi-model study, multi century evolution

UNDERSTANDING THE CHARACTERISTICS AND DRIVERS OF DROUGHT REGIME OVER EASTERN AFRICA

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Drought remains a threat to many socio-economic activities in eastern Africa, yet the drivers of mega-droughts (i.e. drought regimes) over this region remain unknown. This study presents the characteristics of drought regimes over Eastern Africa and examines the influence of the various atmospheric teleconnections on the drought. Using a drought index that account for influence both precipitation and evaporation (i.e. Standardize Precipitation and Evapotranspiration Index, SPEI) in characterizing droughts, the study employed the Principal Component Analysis (PCA) technique to obtain the drought regimes, and apply the Wavelet Analysis and Correlation Analysis to describe the temporal variability of the drought regimes and the relationship between the variability and atmospheric teleconnections. The results show that four drought regimes account for more than half of mega-drought over eastern Africa. The core of the drought regimes are over north east Kenya, south west Somalia, south central Tanzania, north east South Sudan and north Somalia. Three of the four drought regimes are strongly linked with the El Nino Southern Oscillation Index and the India Ocean Dipole index. Results of this study have application improving the seasonal prediction of mega-droughts in eastern Africa.

Keywords:

Drought regimes, Eastern Africa, Teleconnections

REGIME SHIFT AND LONG-TERM WARMING TREND BEFORE-AND-AFTER 1900 IN CENTRAL ASIA, AUSTRALIA AND EUROPE

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The average Earth surface air temperature (SAT) anomaly is a direct indicator of climate change. This paper presents a different approach to identify regime shift and to model an unbiased linear warming trend with SAT anomaly in regions of Central Asia, Australia and Europe. The results show that SAT anomaly has mean-shifts upwards from negative (cooler) to positive (warmer) phase before-and-after 1900 in Central Asia, Australia and Europe. Their variances enlarge only in Central Asia and Australia but not in Europe. The uncertainty of climate variability becomes larger and larger in Central Asia and Australia after 1900. Chow-test shows that the three regions have regime shifts in SAT anomaly before and after 1900. Europe is warming faster than that in Central Asia and Australia.

Keywords:

Regional Regime Shifts, Non-stationary Time Series , Regional Warming

A 60 YEARS TIME-SERIES ANALYSES OF THE UPWELLING INDEX IN IBERIA PENINSULA

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Trends in upwelling index (based on offshore and inshore SST differences) in three different areas of Portuguese Iberian coast (North-western, South-western and South-Algarve) were studied and compared using two different sea surface temperature (SST) datasets: remote sensing SST from 1985 to 2009 (short-term time-series) and observed SST measures from 1950 to 2010 (long-term time-series). The comparative evaluation of common trends among areas and data sources was made with Dynamic Factorial Analyses (after seasonality removed) and was followed by a sudden shifts evaluation of the upwelling index time-series for annual and monthly data. Upwelling index trends within areas for different data sources are similar for the last 25 years while different trends were recorded among areas for the long-term data and similar trends were observed among areas for short-term. A high oscillation of intra-annual upwelling index was recorded but overall the long-term annual data reveal an intensification of the upwelling over the years in wester coasts while in the southern coast an upwelling relaxation is observed. In recently decade's annual short-term data showed for all areas an upwelling intensification. Annual and monthly shift analyses reveal a smooth decrease of the Upwelling Index until the 1970s in all western Portuguese Coast while in the southern Portuguese Coast this decrease extends until middle 1990s. Thereafter and during the last six years, upwelling index show different evolution of the UPW index time-series in the western coast: an intensification pattern in the north-western area, increased at higher rate than previously recorded; and a relaxation period of the upwelling in the south-western area immediately after an 15 years of high intensification period. The south area also appears to record an intensification of the upwelling since 1995 after an upwelling relaxation period of 10 years.

Keywords:

Time series analyses, Portuguese coast, Upwelling trends

GAS EMISSION IN THE ADRIATIC SEA

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Geophysical data with different scales of resolution reveal in the study area the occurrence of widespread acoustically anomalous zones. They are interpreted as gas chimneys, indicating focusing of gas along subvertical structures.

These chimneys are locally associated to deep-seated, Miocenic faults; they affect the uppermost Stratigraphic layers and the seafloor, where gas is then capable to escape in the water column as shown by numerous gas flares.

We are approaching the problem from different points of view: geological, geophysical and geochemical. My work is aimed to quantify the amount of gas present in sediments through signal analysis of seismic data and logs. Different logs (available or calculated) are used to extract density and porosity and to create synthetic seismograms bounding the seismic sections. Seismic data are then processed preserving amplitudes to perform an AVO analysis aimed to a quantification of gas present in sediments.

Keywords:

Gas, Seepage, Log

INVESTIGATING PARTICLE FLUX IN THE ICELAND BASIN USING A MESOSCALE SEDIMENT TRAP ARRAY

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The flux of organic particles to the deep ocean, known as the biological carbon pump, sequesters carbon on climatically significant timescales and is thus a control on atmospheric carbon dioxide levels. The Iceland Basin is a physically dynamic region and can transition to High Nutrient Low Chlorophyll conditions after a bloom due to iron limitation. To investigate the physical and biological controls on deep ocean carbon storage two annual cycles of particle flux were sampled using four sediment traps in a mesoscale array. The traps sampled at 2000 m depth during 2006 – 2008 providing a time series of particle flux. The surface ocean was characterised using satellite chlorophyll a, sea surface temperature and sea level anomaly. A statistical funnel was applied to the satellite data to quantify the area where particles could originate in the surface ocean. The estimated sediment trap volume flux and satellite time series data were then used to investigate relationships between surface ocean processes and deep ocean particle flux. Future work will include analysing the trap samples for particulate organic and inorganic carbon, particulate organic nitrogen, biogenic silica and trace metals to fully categorise fluxes to the deep Iceland Basin for the two year time series.

Keywords:

Particle Flux, Carbon Sequestration, Iceland Basin

FLOW FORECASTING USING THE ANALOG METHOD

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In this study the analog based forecasting technique is used in short range runoff forecasting. The procedure involves searching past precipitation and temperature time series data with closest magnitude and trend as the reference dataset. Past flow observations resulting from similar climatic and antecedent hydrologic condition are then adopted for the forecast period. Matching of antecedent and forecast dataset with past observations is done using such skills as mean absolute percentage error (MAPE) and root mean of squares error (RMSE). Preliminary results have shown that this simple analog based flow forecasting technique can provide a first-hand short range runoff estimate. However, the result highly depends on the availability of sufficient set of archive data with similar magnitude and trend as the reference dataset. As such it shows low performance under extreme climatic and hydrologic events. Combined use of the analog technique with the probability concept has shown encouraging result; and such hybrid approach is expected to contribute in overcoming some of the current limitations of this technique.

Keywords:

Runoff, forecasting, modelling

EFFECTS OF CLIMATE WARMING ON PERMAFROST, THROUGH TIME ANALYSIS OF SOIL TEMPERATURE AND WATER CONTENT AT A SITE IN SVALBARD

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Permafrost, defined as soil with continuous below-freezing temperatures for at least two years, is an important element of the Cryosphere: it comprises 23% of the northern hemisphere land area, and, via its carbon budget, can have a significant impact on global climate systems.

We analyze soil temperatures, moisture data, and meteorological data from the Bayelva permafrost site, located in NY-Alesund, Svalbard. We derive the thickness of the active layer of the permafrost (the upper layer which seasonally freezes and melts) over time. Our results show an increase in the active layer thickness (ALT) of 3-4 cm per year during the analyzed period of 15 years. This increase in thickness of the upper layer implies that the permafrost is melting, possibly as a result of warming air temperatures due to climate change.

We further examine snow accumulation and ablation rates and their affect on the permafrost using the GEOtop model, which models the mass and energy balance of the hydrological cycle including water, snow, and ice. Using the Bayelva data as constraints for the model, and employing a sensitivity analysis, we derive how the changing climate affects the snow processes, which in turn regulate the underground temperatures of the permafrost.

Keywords:

Permafrost , active layer thickness, hydrological model.

SNOW DISTRIBUTION IN TRANS-HIMALAYAN LADAKH

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Ladakh is situated on the high altitude mountain Himalayan desert in the extreme North of India. Snow cover is one of the vital natural resources in accessing the availability of water in the streams during melt periods for irrigating the fields and it is strongly affected by climate variations due to its high sensitivity to changes in temperature and precipitation.

One of the prime necessities was to have an access to weather station data in this remote and sensitive area. Therefore the installation of a low cost custom made weather station became one of the basic factors in order to get an accurate snow monitoring.

This poster focuses on the installations of: A custom made Linux based Raspberry Pi weather station on a peak at 4222 m above sea level in the Gyamtsa, western fork of the upper Leh Valley and describes a followed snow-course based on point measurement at three different plots varying in slope, elevation and aspects in South Pulu, a location high up the North-Eastern fork of the upper Leh Valley. Leh is the capital of Ladakh. This is in order to monitor the seasonal variation in snow cover distribution and its redistribution by wind over the winter months (December to February).

Keywords:

Raspberry Pi weather station , changing snow-cover, time-lapsed photograph

Other information:

Snowfalls in the Ladakh region are relatively light due to the lee of the mountains, although this region experiences long winters. It is remote from major moisture and extremely low temperatures reduce the moisture holding capacity of the air to extremely low values. Therefore, it is most difficult to find possible surveying sites accessible in winter for field observation.

SEASONAL VARIABILITY OF AIR-SEA CO2 FLUXES IN ISFJORDEN, SVALBARD

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Air-sea CO_2 fluxes in an Arctic fjord along the West Spitbergen coast (Isfjorden) were investigated over an annual cycle. This cold surface water region is affected by glacial meltwater discharges in summertime and intense convection and brine release in wintertime. The surface water was undersaturated in pCO_2 with respect to the atmosphere throughout the study period, with the strongest undersaturation occurring in late spring as a result of the spring bloom. Meltwater release in the summer months lowers the surface pCO_2, but the coinciding warming of the surface layer counteracts the effect. The annual flux was estimated to -37.6 gC m^{-2} $year^{-1}$, and the fjord system is likely to be a sink for CO_2.

Keywords:

Arctic fjord, air-sea CO_2, time-series

TRACKING THE WESTERN MEDITERRANEAN TRANSITION SINCE 2005: THE RADMED PROGRAMME AND THE ATHAPOC MOORING

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The evolution of the Western Mediterranean Deep Water (WMDW) thermohaline anomaly, the so-called Western Mediterranean Transition (WMT), was analysed since its appearance in winter 2004/2005 using θ-S data from two deep hydrographic stations seasonally sampled during the RADMED monitoring programme in the NE of Menorca and off Cape Palos since 2003 and 2007 respectively. Increasing trend in S and θ of the order of 10^{-3} $year^{-1}$ and $5{\cdot}10^{-3}$ ºC $year^{-1}$ in the WMDW were shown, one order of magnitude higher than previously reported. The ATHAPOC deep mooring, equipped with five current meters, eight CTDs, eight thermistors and two sediment traps, was installed in the NE of Menorca in 2015 and will be used to clarify the internal processes occurring in the water column in relation to the changes induced by the WMT.

Keywords:

Deep waters, Western Mediterranean, WMT

OXYGEN AND HYDROGEN STABLE ISOTOPES AS CLIMATE TRACERS IN THE LACLAVERE PLATEAU, ANTARCTIC PENINSULA

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Laclavere Plateau (63°27´15´´S /57°41'53''W /1130 m.a.s.l.) is situated in the northern tip of the Antarctic Peninsula. The climatological regime in the north of the Peninsula presents a complex interaction between the different elements that form the climatic system. Since 2008, we have studied this Plateau, where several surface firn cores (<20m depth) have been collected. Here we show that the deuterium excess (dexcess = δD - 8 δ18O), oxygen and deuterium isotopic ratios can be potentially used as seasonal markers.
We estimate that the Laclavere Plateau present appropriate conditions for the conservation of the isotopic signal recorded in the snow that accumulates on its surface (mean value of 1,700 kg m2 a-1). Therefore, we conclude that isotopic signal recovered from Laclavere's Plateau ice show that ice is a strong indicator of actual meteorological parameters, which make them capable of being proxy of local variability in atmospheric circulation, snow accumulation and temperatures above surface. The well preserved isotope signal, along with the thick ice cover over the Laclavere Plateau (surveyed by geophysical methods), project this place as a favorable spot to recorver a medium depth ice core (>250m), from which it could be developed a high temporal resolution paleoclimatic reconstruction.

Keywords:

Antarctic Peninsula, Firn cores, Stable Isotopes

INTRA-SEASONAL VARIABILITY OF SEA-SURFACE TEMPERATURE FROM LAGRANGIAN AND EULERIAN DATA ENTANGLED IN DRIFTER TRAJECTORIES

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The global array of Lagrangian and quasi-Lagrangian instruments (surface drifters, subsurface and profiling floats) supplies a constantly growing data base of position and temperature observations that are irregularly distributed in time and space. The questions remain how to disentangle from these data information about the underlying ocean circulation, and whether the derived variability is consistent between the Lagrangian and other data products.

In this study we address these questions in the context of intra-seasonal variability encoded in surface drifter trajectories and the corresponding temperature time series: 1) measured by the drifters themselves, 2) the daily ERA-Interim reanalysis, and 3) mixed-layer (MIMOC) monthly climatology temperatures sub-sampled on drifter trajectories. Our study region is the Nordic Seas where ample drifter data is available including a large set of drifter pairs. First, using correlation- and spectral analysis, we report on close correspondence of drifter temperatures to the daily ERA temperatures on all scales, and to the monthly MIMOC temperatures on monthly-to-seasonal time scales. The slopes of SST frequency spectra over the sub-seasonal frequencies range exhibit a power law. Second, we further investigate the drifter pair dispersion and drifter pair temperature statistics. These show that the interplay of the spatiotemporal variability on sub-monthly scales seen in drifter temperatures is not reproduced by either the daily ERA- or MIMOC temperatures.