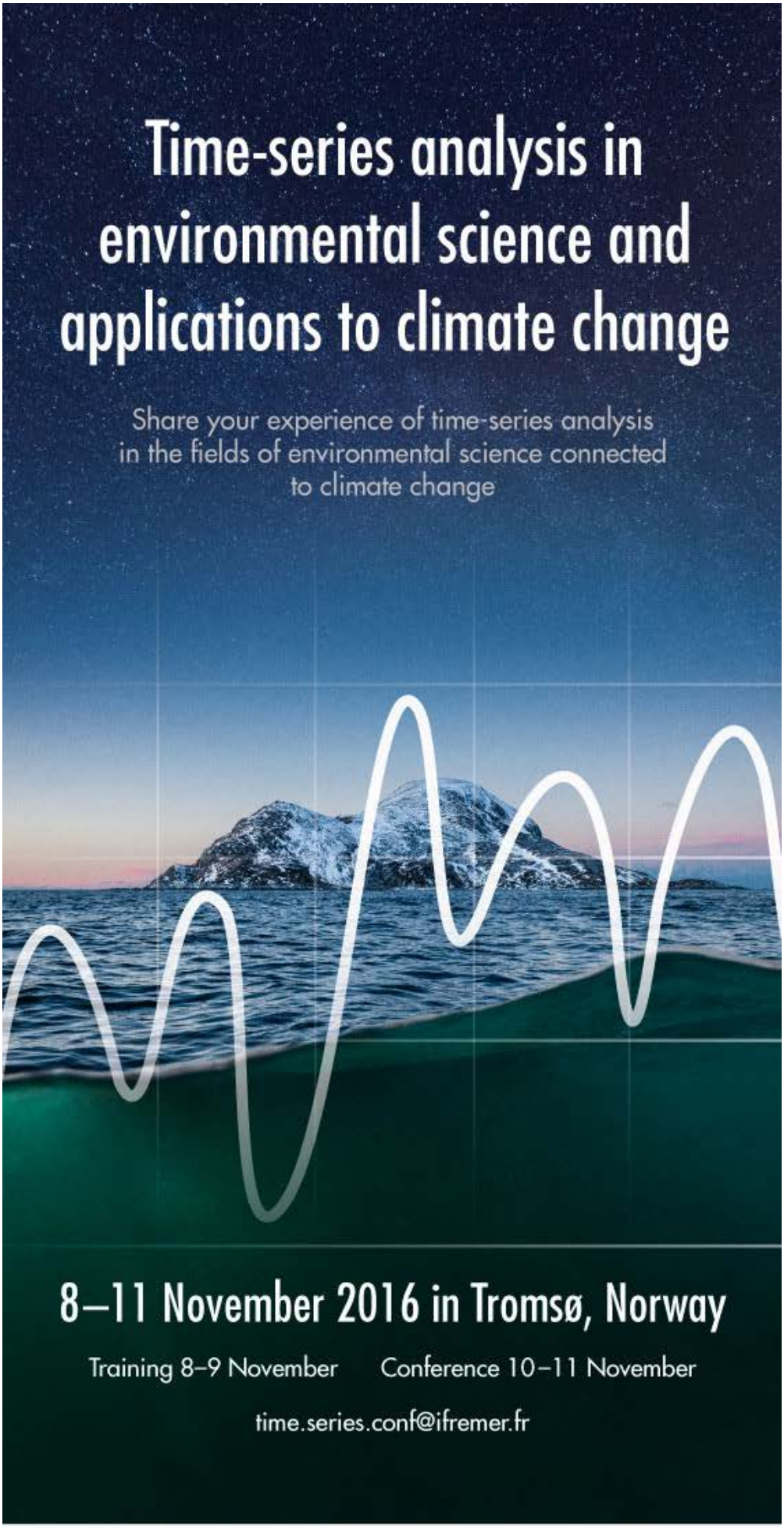
Time-series analysis in environmental science and applications to climate change

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 · AMAGE Trainee School in Arctic Marine Geology & Geophysics · Ifremer · FixO3 · ENVRI

Content

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 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	Davide Embriaco and 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
selipot@rsmas.miami.edu

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: Davide Embriaco
Istituto Nazionale di Geofisica e Vulcanologia,
Portovenere, Italy
davide.embriaco@ingv.it

And: Mariagrazia De Caro
Istituto Nazionale di Geofisica e Vulcanologia,
Roma, Italy
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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
karl.fabian@ngu.no

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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mark.carson@uni-hamburg.de

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: 9:00-17:00

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	Fanny Girard-Ardhuin & Jean Tournadre (LOPS-Ifremer)	SEA ICE AND ICEBERGS DETECTION FROM SATELLITE REMOTE SENSING : BUILDING TIME SERIES FROM VARIOUS SENSORS OVER 25 YEARS
14:30	Ingvar Eide (STATOIL)	ONLINE MULTIVARIATE ANALYSIS OF MULTISENSOR DATA FROM THE LOVE OCEAN OBSERVATORY

15:00 -17:30	***Session 2:*** *Time series analysis for greenhouse gases and carbon cycle* *Chair: Jürgen Mienert (UiT/CAGE)*	
15:00	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
15:30	Jack Triest (LGGE)	A NEW FAST-RESPONSE, REAL-TIME AND CONTINUOUS METHANE SENSOR: MILLIONS OF DATA TO SCREEN MARINE PROCESSES
16:00	Break	
16:30	Tuomas Laurila (FMI)	TIME-SERIES ANALYSIS OF ATMOSPHERIC GREENHOUSE GAS CONCENTRATION DATA
17:00	Cathrine Lund Myhre (NILU)	TIME SERIES AND INTERPRETATION OF ATMOSPHERIC MEASUREMENTS WITH FOCUS ON THE ARCTIC REGION
TBD	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: Laura Beranzoli (INGV, ENVRI+)*	
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
Laboratoire de Glaciologie et Géophysique de l'Environnement, Grenoble, France
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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

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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

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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

Stephanie Henson, Claudie Beaulieu, Richard Lampitt
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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

SEA ICE AND ICEBERGS DETECTION FROM SATELLITE REMOTE SENSING : BUILDING TIME SERIES FROM VARIOUS SENSORS OVER 25 YEARS

Fanny Girard Ardhuin and Jean Tournadre
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Microwave sensors onboard satellites are used for sea ice monitoring at high latitude: radiometers are routinely used for this application and scatterometers have also shown they can contribute significantly to it. Since 1992, numerous sensors of different types/frequencies are available. We will show how these sensors could be used to build Earth Observation data time series for monitoring for both Arctic and Antarctic areas. Backscatter data enable to discriminate sea ice from open ocean areas, and can be used for sea ice type detection or sea ice displacement estimate. Small icebergs (<1km2) can be detected through an original method developed from the analysis of altimeters wave forms.

These products are inferred from non-dedicated sensors for these applications, we will show how these observations are useful and how time series are built at IFREMER/CERSAT over 25 years from different remote sensing sensors and satellites. They provide an exceptional basis for analysis of long-term variations of sea ice and icebergs in both Arctic and Antarctic polar areas.

This presentation will enhance i) the need of continuity of satellites missions for Earth Observation; ii) the need of homogeneisation of sensors and datasets for a long-term observation of the polar areas.

Keywords:

Satellite, remote sensing, sea ice, icebergs, homogeneous time series

ONLINE MULTIVARIATE ANALYSIS OF MULTISENSOR DATA FROM THE LOVE OCEAN OBSERVATORY

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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

Tuomas Laurila
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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 bio-geochemistry 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

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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.