W1 Zooplankton and climate: response modes and linkages among regions, regimes, and trophic levels

18 May, 09:40 (W1-4768)

The SCOR WG 125 toolkit: issues and methods for analysing zooplankton time series

Todd D. **O'Brien**[1], David L. Mackas[2], Mark D. Ohman[3], Ángel López-Urrutia[4] and SCOR WG125 Contributors

[1] National Marine Fisheries Service, 1315 East-West Hwy, Silver Spring, MD 21044, USA. E-mail: Todd.OBrien@noaa.gov
[2] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, V8L 4B2, Canada.
[3] Scripps Institution of Oceanography, La Jolla, CA 92093-0218, USA.
[4] Instituto Español de Oceanografia, Avda Principe de Asturias 70, Gijón 33212, Spain.

The SCOR Working Group on Global Comparison of Zooplankton Time series (WG 125) was formed to promote between-region comparisons of longer zooplankton time series from around the globe. With data contributions and participation from 12 countries, over twenty long-term regional zooplankton time series have been identified, and their data have been collated and prepared for numerical analysis. Zooplankton biomass and community composition vary strongly at a range of time scales (e.g. decadal, interannual, seasonal, and diel), and also at a range of spatial scales. Detection and interpretation of variability at one time scale typically requires data transformation, averaging and filtering to reduce aliasing from other scales. A variety of methods were applied to the WG 125 zooplankton time series. In this paper, we illustrate how choice of method can influence the output time series, and introduce the SCOR WG 125 toolkit of numerical choices and methods.

18 May, 10:00 (W1-4767)

SCOR WG 125: global comparison of zooplankton biomass time series

Todd D. **O'Brien**[1], David Mackas[2], Hans M. Verheye[3] and SCOR WG125 Contributors

[1] National Marine Fisheries Service, 1315 East-West Hwy, Silver Spring, Maryland, USA. E-mail: Todd.OBrien@noaa.gov
[2] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, V8L 4B2, Canada.
[3] Research Aquarium, Beach Road, Sea Point, Cape Town, South Africa.

The SCOR Working Group on Global Comparison of Zooplankton Time series (WG 125) has compiled a global assortment of longer zooplankton time series, with the goal of identifying dominant modes of zooplankton variability, their amplitudes and time scales, and the degree of correlation/synchrony among regions, zooplankton variables, and climate indices. Although the level of taxonomic resolution varies widely among our data sets, each provides indices of total mesozooplankton biomass or biovolume, which have been processed to give time series of anomalies relative to local average seasonal cycles. Strong low frequency fluctuations and trends were evident in most regions. In general, boundary current upwelling regions tend to have the largest amplitude of variation, followed by high-latitude continental margins. Sustained trends in response to global warming, where detected, include examples of both increases and decreases. Evidence of temporal synchrony and/or large-scale spatial teleconnection among zooplankton time series, or with climate indices, varied from site to site, with trends found in one site being completely absent from an immediately adjacent site. Changes and synchrony appeared to be influenced by local environmental conditions (e.g. upwelling regions versus continental shelf versus sheltered bays), as well as corresponding changes in species composition (discussed in other papers in this workshop).

18 May, 10:20

18 May, 10:40 (W1-4761)

Climate-associated latitudinal shifts of zooplankton species and species assemblages

David L. **Mackas**[1], Anthony J. Richardson[2], Hans M. Verheye[3], William Peterson[4], Sanae Chiba[5], Gregory Beaugrand[6], Bertha Lavaniegos[7] and SCOR WG125 Contributors

[1] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, V8L 4B2, Canada. E-mail: mackasd@pac.dfo-mpo.gc.ca
[2] CSIRO Marine and Atmospheric Research, Hobart, Tasmania, Australia.
[3] Marine and Coastal Management, DEAT, Cape Town, South Africa.
[4] Hatfield Marine Science Center, NOAA-Fisheries, Newport, OR, USA.
[5] Frontier Research Center for Global Change/JAMSTEC, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan.
[6] CNRS, Université des Sciences et Technologies de Lille1, BP 80 62930, Wimereux, France.
[7] CICESE, Ensenada, Baja California, Mexico.

Taxonomically-resolved zooplankton time series from individual ocean regions reveal low frequency fluctuations and trends in zooplankton community composition that are correlated with indices of ocean climate. Species-level variations are often 3-10 fold more intense than accompanying responses of total zooplankton biomass. One common mode of zooplankton community change is decreased abundance/biomass of historically endemic taxa, accompanied by increased abundance of taxa previously found in adjoining equatorward (or sometimes seaward) ocean regions. Spatial comparisons among regions and large-scale CPR surveys show that local changes reflect larger-scale shifts of zoogeographic distributions, equivalent to about 10° poleward displacement in both the NE Atlantic and NE Pacific Oceans. Patterns are qualitatively similar for both abundance of dominant taxa and rate of occurrence of rare "indicator" taxa. The proximate causes for the shifts in distribution are less clear, but almost certainly involve both initial changes in advective supply-loss rates associated with changing current patterns, and subsequent altered environmental conditions related to changing temperature, stratification, and prey/predator communities. The zooplankton distribution shifts tend to be step-like, associated with relatively short-term (1-2 year) advection and warming events, but time-lagged (by weeks to months) and more persistent (by months to years) than the physical anomalies.

18 May, 11:30 (W1-4946)

Long-term changes in zooplankton community size structure: a global comparison

Hans M. **Verheye**[1], Dave Checkley[2], Sanae Chiba[3], Young-Shil Kang[4], Webjørn Melle[5], Mark D. Ohman[6], Anthony J. Richardson[7] and SCOR WG 125 Contributors

[1] Marine and Coastal Management, DEAT, Private Bag X2, Rogge Bay 8012, Cape Town, South Africa. E-mail: hverheye@deat.gov.za
[2] Scripps Institution of Oceanography, UCSD, 2220 Sverdrup Hall, 8615 Discovery Way, La Jolla, CA 92037, USA.
[3] Frontier Research Center for Global Change/JAMSTEC, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan.
[4] National Fisheries Research and Development Institute, 408-1 Sirang-ri, Gijang-eup, Gijang-kun, Busan 619-705, Republic of Korea.
[5] Research Group Plankton, Institute of Marine Research, Box 1870, Nordnes, N-5817 Bergen, Norway.
[6] Scripps Institution of Oceanography, La Jolla, CA 92093-0218, USA.
[7] CSIRO Marine and Atmospheric Research, Hobart, Tasmania, Australia.

The distribution of body size can be an important characteristic of a zooplankton community. Body size is a major determinant of various production rate processes, with growth rate generally decreasing with increasing body size. Size also strongly influences predator-prey relationships, with pelagic organisms tending to feed on others smaller in size. Here we examine and compare long-term changes in the size composition of zooplankton communities from different regions globally. This is the largest comparative analysis of copepod size to date in the world's oceans. The focus is on copepods, which are generally the most abundant members in most zooplankton communities and provide the dominant trophic link between primary producers and fish. Unlike most other taxonomic groups, copepods are usually identified to species level and there is generally good knowledge of their body size. Tracking changes through time of mean size of copepod communities enables detection of major changes in the community structure as a consequence of shifts in environmental conditions. Moreover, average zooplankton community size can be considered as an indicator of food for fish and fluctuations in fish recruitment have been attributed to changes in zooplankton community structure. We conclude that because warm-water copepods are often smaller than their cold-water counterparts, a shift to a smaller average size is indicative of warming of the system and has a fundamental effect on community rate processes.

18 May, 11:50 (W1-4704)

Changing seasonal timing of zooplankton populations, and their link to ocean climate

David **Mackas**[1], Wulf Greve[2], Martin Edwards[3], Sanae Chiba[4], Gregory Beaugrand[5], Aljona Arashkevich[6] and SCOR WG125 Contributors

[1] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, V8L 4B2, Canada. E-mail: mackasd@pac.dfo-mpo.gc.ca
[2] Senckenberg Research Institute, D-22607 Hamburg, Germany.
[3] Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, Plymouth PL1 2PB, UK.
[4] Frontier Research Center for Global Change/JAMSTEC, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan.
[5] CNRS, Université des Sciences et Technologies de Lille 1, BP 80 62930, Wimereux, France.
[6] Shirshov Institute of Oceanology RAS, 36 Nakhimovsky pr. 117997 Moscow, Russia.

The short life span (weeks to a year) of most mesozooplankton allows their population size to respond rapidly to interannual environmental changes, and also leads to large seasonal cycles producing 3-10 fold (or more) variation of abundance, biomass, species composition, and age structure within species. Although the zooplankton seasonal response is somewhat predictable and repetitive, recent analyses have found that the detailed phasing is highly sensitive to interannual differences in environmental conditions: there can be year-to-year differences of one to several months in the timing of the 1-2-month wide annual peak of abundance and biomass. The resulting potential for timing match-mismatch between prey and predators makes this an important and interesting signal, which can be tracked by either population size or age-stage structure. Within species, the usual trend is a shift to earlier development in years when temperatures are higher and stratification stronger. However, temperature-timing regressions frequently differ among species and functional groups, leading to different amounts of timing offset for a given temperature perturbation. Climate warming can also drive changes in community composition that favour summer-dominant over spring-dominant taxa.

18 May, 12:10 (W1-4968) - check id number

Long-term changes in zooplankton phenology at Helgoland Roads

Merja H. **Schlueter**[1], Agostino Merico[1], Karen H. Wiltshire[2] and Wulf Greve[3]

[1] GKSS Research Center, Institute of Coastal Research, Max-Planck-Str. 1, D-21502 Geesthacht, Germany. E-mail: merja.schlueter@gkss.de
[2] Biologische Anstalt Helgoland, Alfred Wegener Institute for Polar and Marine Research, P.O. Box 180, 27483 Helgoland, Germany.
[3] Senckenberg Research Institute, Notkestr.85, D-22607 Hamburg, Germany.

An in-depth analysis of biotic and abiotic long-term time series suggested a climatic regime shift in the German Bight in 1987/88, confirming earlier investigations that extended across the entire North Sea. The main outcome of this study was that temperature plays an important role in the regime dynamics of the German Bight ecosystem. A principal component analysis on this multiple time series data set also suggested that the variability of a number of zooplankton species contributes only marginally to the regime shift. However, here we report that further investigations, which are focused specifically on the long-term (1975-2005) changes of zooplankton phenology, do suggest drastic shifts. Recent analyses based on Bayesian inference show that the annual peaks in zooplankton abundance appear earlier in the year after the regime shift of 1987/88 compared to before the regime shift when seasonal abundance peaks generally occurred later in the year. We also observe that the periods of high abundance have a longer duration since the regime shift. Interestingly, five small calanoid copepods, typical of the German Bight assemblage, do not appear to be affected by these changes.

18 May, 12:30 (W1-4633)

Pan-North Pacific synthesis of long-term variation of *Neocalanus* spp. based on stable isotope analysis (SCOR WG125 contribution)

Sanae **Chiba**[1], H. Sugisaki[2], K. Tadokoro[3], A. Kuwata[3], T. Kobari[4], A. Yamaguchi[5] and D.L. Mackas[6]

[1] Frontier Research Center for Global Change, JAMSTEC, 3173-25 Showa-machi, Kanazawa-ku, Yokohama 236-0001, Japan. E-mail: chibas@jamstec.go.jp

[2] National Research Institute of Fisheries Science, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa-ku, Yokohama 236-8648, Japan.

[3] Tohoku National Fisheries Research Institute, 3-27-5 Shinhama, Shiogama, Miyagi 985-0001, Japan.

[4] Aquatic Resource Division, Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima 890-0056, Japan.

[5] Graduate School of Fisheries Science, Hokkaido University, 3-1-1 Minato-cho, Hakodate, Hokkaido 041-8611, Japan.

[6] Institute of Ocean Science, Fisheries and Oceans Canada, Sidney, BC, V8L 4B2, Canada.

Previous detailed retrospective analyses of historical collections of zooplankton have revealed phenological and biogeographical shifts of zooplankton species on both sides of the North Pacific after the 1970s. It was suggested that these shifts were influenced by variability of the coastal currents induced by the Aleutian Low dynamics and/or by recent warming. However, the regionally specific food web processes which link climate to zooplankton variation are less clear partly because (in contrast to zooplankton) there are no detailed time series data available for phytoplankton. Nitrogen stable isotope ratio ($\delta^{15}N$) of zooplankton is indicative of the abundance of phytoplankton in the zooplankton diet, and can provide a useful clue to understanding the bottom-up control of lower trophic level productivity. In this study, we investigated regional differences in ecosystem responses to the common climatic forcing in the North Pacific based on $\delta^{15}N$ of *Neocalanus* species, which were widely distributed and dominant in the subarctic North Pacific. Time series of $\delta^{15}N$ of *Neocalanus cristatus*, *N. plumchrus* and *N. flemingeri* collected in the western, central and eastern North Pacific were compared. Within each region, interannual variation of $\delta^{15}N$ was similar among the three species, indicating shared patterns of bottom-up control. In all three regions, $\delta^{15}N$ declined by *ca*. 0.3% in the late 1980s and increased in the late 1990s. This suggests favourable conditions of phytoplankton availability for *Neocalanus* during the late 1980s to late 1990s, although interspecific and regional differences in the extent and timing of the change were noted. Causes of the suggested changes in phytoplankton availability will be discussed for each region.

18 May, 12:50 (W1-4882)

Are pelagic systems bottom-up or top-down controlled?

Anthony J. **Richardson**, Patricia Ayon and SCOR WG125 Members

[1] CSIRO Marine and Atmospheric Research, Hobart, Tasmania, Australia. E-mail: anthony.richardson@csiro.au

[2] Area de Evaluación de Producción Secundaria, Unidad de Oceanografía Biológica, Dirección de Investigaciones Oceanográficas, Instituto del Mar del Perú, Apartado 22 Callao, Perú.

An appealing conceptual framework for investigating mechanisms controlling ecosystem dynamics is the potential importance of "bottom-up" (resource limitation) and "top-down" (predation pressure) forcing across successive trophic levels. In pelagic ecosystems, climate change might be expected to have substantial impacts if signals propagate up the food web (bottom-up control), whereas overfishing might be more influential if signals cascade down the food web (top-down control). Unfortunately, many studies of this nature have been limited in terms of spatial scale (mesocosms, bays, seas), temporal scale (months to a few years), taxonomic resolution (populations of selected species), or have no replication and thus no generality. Further, top-down control has generally only been found in enclosed lakes or seas, although some recent evidence suggests oceanic pelagic ecosystems may also operate in this manner. Here we use assembled time series of phytoplankton, zooplankton, planktivorous fish, and piscivorous fish from eastern boundary upwelling zones, shelf regions, and the open ocean to assess the relative importance of top-down and bottom-up control. We use a meta-analytic approach to provide a robust synthesis of global relationships between successive trophic levels. We find strong evidence for bottom-up control between phytoplankton and zooplankton in many regions, but weaker relationships between zooplankton and planktivores, and between planktivores and piscivores. We conclude that bottom-up control operates over the broad temporal and spatial scales of our analyses, but there is little support for top-down control. This finding suggests that impacts of climate change on plankton are likely to propagate upwards to higher trophic levels.

18 May, 14:30 (W1-4975)

Comparison of early stages of *Mnemiopsis leidyi* invasion into the Black, Caspian and Baltic Seas

Juha **Flinkman**[1], E. Arashkevich[2], M. Lehtiniemi[1] and S. Viitasalo[1]

[1] Finnish Institute of Marine Research, P.O. Box 2, FI-00561 Helsinki, Finland. E-mail: Juha.flinkman@fimr.fi

[2] Shirshov Institute of Oceanology RAS, 36 Nakhimovsky pr. 117997 Moscow, Russia.

We compare the early stages of comb jelly *Mnemiopsis leidyi* invasion into the Black and Caspian Seas (starting 1982 and 1999, respectively), and recently into the Baltic Sea (from 2006). There are differences in all aspects of invasions: rapidity of dispersion, growth rate, feeding and reproductive behaviour, and vertical and seasonal distribution in the water column in relation to hydrography. So far, maximum *Mnemiopsis* abundances (January 2008) in the Baltic Sea have been 50% and 24% of the maximum abundances in the Black and Caspian Seas (1988), respectively. However, expressed as biomass, the current high values in the Baltic are only 0.2% and 0.4% of those observed in Black and Caspian Seas. This implies that the specimens are much smaller in the Baltic than in the Black and Caspian Seas. Vertical distributions are also dissimilar. In the Black and Caspian Seas, *Mnemiopsis* occupies the upper mixed layer during late spring-summer-autumn period. In winter, single individuals are also found in the upper 30 m layer. In the Baltic Sea, only larval stages are in the upper water column, whereas all the larger individuals are concentrated around the halocline at 60-80 m depth, where conditions are very stable all year. In the Baltic, the abundances as well as maximum size of individuals were higher in December-January than in August-September, when zooplankton abundances are highest. This indicates a steady population increase, as well as independence of food sources confined to the surface layer. We discuss the differences in dispersion, growth and reproduction rates, and food utilisation in relation to differences in hydrography between the Baltic, Black and Caspian Seas, as well as observed and possible impacts on the ecosystems of these brackish water inland seas.

18 May, 14:50 (W1-4784)

Retrospective analysis of zooplankton decadal time series in the western Mediterranean Sea using an automated imaging system

Maria Grazia **Mazzocchi**[1], Lars Stemmann[2,3], Carmen Garcia Comas[1,2,3], Maurizio Ribera d'Alcala[1], Gregory Beaugrand[4], Stéphane Gasparini[2,3], Frederic Ibañez[2,3], Stéphane Pesant[2,3], Marc Picheral[2,3] and Gabriel Gorsky[2,3]

[1] Stazione Zoologica 'A. Dohrn', Villa Comunale, 80121 Napoli, Italy. E-mail: grazia@szn.it

[2] Université Pierre et Marie Curie-Paris 6, UMR 7093, Villefranche sur Mer, F-06234 France.

[3] Laboratoire d'Océanographie de Villefranche (LOV), Observatoire Océanologique, BP 28, 06234 Villefranche sur mer Cedex, France.

[4] CNRS, Université de Lille 1, 28 avenue Foch, BP 80, 62930 Wimereux, France

The Mediterranean Sea is a semi-enclosed basin that in the past decade has shown significant variability related to climate change. Plankton communities have been monitored at a few locations in the Mediterranean for which long-term time series of variable duration exist. We present two ongoing time series conducted in the coastal zone of the Ligurian and Tyrrhenian seas, showing mesozooplankton abundances and size spectra derived from image analysis of historical samples collected over the last 40 and 20 years respectively. The initial results are compared with available environmental and climatic data at different temporal and spatial scales. To our knowledge, this is the first comparative study based on retrospective analysis of plankton samples using an automatic imaging system. We discuss the use of rapid imaging technology to build homogeneous data sets for comparative study of plankton time series. Our work is still in progress and this contribution is mainly intended as an opportunity for open discussion of issues and perspectives when comparing zooplankton time series.

18 May, 15:10 (W1-4906)

Zooplankton time series related to North Atlantic climate changes in waters of the Balearic Sea: a case of boundary area in the central western Mediterranean

Maria Luz **Fernandez de Puelles**[1], Juan Carlos Molinero[2], Laura Vicente[1], Ana Morillas[1] and Javier Jansá[1]

[1] Centro Oceanográfico de Baleares, Instituto Español de Oceanografía, P.O. Box 291, Palma de Mallorca, Spain. E-mail: mluz.fernandez@ba.ieo.es

[2] Leibniz-Institut für Meereswissenschaften, IFM-GEOMAR, FB3, Marine Ökologie, Düsternbrooker Weg 20, 24105 Kiel, Germany.

Temporal distribution patterns of major zooplankton groups are presented in relation to the regional hydrography at a monitoring station in the Balearic Sea (western Mediterranean) over an 11-year period. The study is based on samples collected every 10 days from 1994 to 2004 and results are related to the North Atlantic climate variability. Strong but different relationships are apparent between the abundance of major zooplankton groups and the influence of local surface water masses as the main drivers of their biological variability. Dominant species of major zooplankton groups were identified and related to patterns of phytoplankton biomass (chlorophyll) and the principal physico-chemical variables characterising the area. The hydrological regime of the boundary Balearic waters showed manifested interannual changes characterised by a clear increase in the long-term trend of salinity, whereas temperature, does not show a significant trend. Chlorophyll pigment concentration and the abundance of smaller zooplankton increased, but average size, biomass and abundance of total mesozooplankton declined. The synchronous variability of major zooplankton groups and hydrography indicates the rapid response of this community to the influx of cold northern and warm southern Atlantic water masses into the study area. We suggest that changes in the hydrography of the Balearic Sea are linked to large-scale changes likely occurring on a basin scale, which is reflected in mesoscale hydrographic changes in the western Mediterranean. The relationship between the zooplankton and changes in the hydrological regime in the context of the North Atlantic climate is discussed.

18 May, 15:30 (W1-4666)

The Gulf of Trieste, 1970-2005: a changing ecosystem

Alessandra **Conversi**[1], T. Peluso[1] and S. Fonda-Umani[2]

[1] CNR - Consiglio Nazionale delle Ricerche, ISMAR - La Spezia, Forte S. Teresa, Loc. Pozzuolo, 19032 Lerici (SP), Italy. E-mail: a.conversi@ismar.cnr.it

[2] Department of Biology, University of Trieste, V.A. Valerio, 28/A, 34127 Trieste, Italy.

The Gulf of Trieste, in the North Adriatic Sea, hosts one of the longest (since 1970) mesozooplankton time series in the Mediterranean Sea. In this study we investigate interannual variability of copepod abundance over 36 years, with particular attention to species trends and phenology. Two periods are identified, 1970-1987 and 1988-2005, which are characterised by ecosystem-wide changes. These changes include: the arrival of new species (*Diaixis pygmoea*), establishment of previously rare species (*Oithona similis* and *Oithona nana*), the rise (*Oncaea* spp. and *Euterpina acutifrons*) or decline (*Pseudocalanus elongatus*, *Clausocalanus* spp.) of several species, and changes in the phenology in the majority (65%) of species, with predominantly forward shifts in the timing of the seasonal peak. While *Acartia clausi* remains the dominant species, there is a general trend toward dominance by smaller species in the second period. We hypothesize that the changes in copepod abundance patterns in the Gulf of Trieste are related to the general warming (SST), and associated northerly displacements within the system (the climate envelope hypothesis), and to the changes in the Mediterranean surface circulation that started at the end of the 1980s and affected the whole basin in the following years.

18 May, 16:20 (W1-4727)

Large-scale geographic variations in diversity of marine zooplankton: theories, environmental controls, and functioning of pelagic ecosystems

Isabelle **Rombouts**[1], G. Beaugrand[2], F. Ibañez[1] and L. Legendre[1]

[1] Université Paris VI Laboratoire d'Océanographie de Villefranche-sur-mer, UMR CNRS 7093 (LOV) B.P. 28, 06234 Villefranche-sur-mer cedex, France. E-mail: isabelle.rombouts@etu.upmc.fr

[2] Université des Sciences et Technologies de Lille - Lille 1, Laboratoire d'Océanologie et de Géosciences, UMR CNRS 8187 (LOG), 28 avenue Foch, 62930 Wimereux, France.

One of the most consistent patterns in biogeography is the tendency for an increase in species diversity from the poles to the equator. For several decades, extensive research has been carried out to provide ecological explanations for these large-scale spatial patterns in biodiversity. Hydro-climatic forcing on pelagic marine diversity has been

investigated at the ocean basin scale using zooplankton species composition time series. However, an examination of environmental controls on the temporal and spatial variation of zooplankton diversity on a global scale has not yet been attempted. This macro-ecological approach can elucidate the future effects of a changing climate on the diversity of copepods and functioning of pelagic ecosystems on a large geographical scale. In a first stage, this study will try to identify the most important physico-chemical factors that control the variability in diversity of copepods in different biomes and examine the covariance between environmental variability and zooplankton diversity along a latitudinal gradient. Understanding the causes of variation in zooplankton diversity enables the development of a model to predict copepod diversity as a function of its most important environmental descriptors and forecast responses in ecosystem structure to environmental changes.

18 May, 16:50 (W1-4883)

Are there teleconnections among zooplankton time series within and between ocean basins?

Chris Reason[1], Anthony J. **Richardson**[2] and SCOR WG 125 Contributors

[1] University of Cape Town, Private Bag X3, Rondebosch, Cape Town 7701, South Africa.
[2] CSIRO Marine and Atmospheric Research, Hobart, Tasmania, Australia.

Much of the impact of climate change on zooplankton is likely to act through existing modes of variability in the Earth's climate system. Such climate modes are expressed as differences in synoptic atmospheric pressure fields. They alter regional wind fields, current strengths, nutrient dynamics and water temperatures. Here we use a global data set of zooplankton time series to re-analyse and update several published relationships between zooplankton and large-scale climate indices. We then examine the evidence for teleconnections among zooplankton time series both within and between ocean basins. Such relationships between plankton composition or abundance and integrative climate indices provide insight into how climate change may affect the world's oceans in the future, as climate models project changes in many important climate indices.

18 May, 10:20 (W1-4859)

Global zooplankton time series comparisons: where is the synchrony?

Harold **Batchelder**[1], David Mackas[2], Todd D. O'Brien[3] and SCOR WG 125 Contributors

[1] Oregon State University, College of Oceanic & Atmospheric Sciences, Corvallis, OR 97331-5503, USA.
E-mail: hbatchelder@coas.oregonstate.edu
[2] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, V8L 4B2, Canada.
[3] Marine Ecosystems Division, NOAA-Fisheries, 1315 East-West Highway, Silver Spring, MD 20910-3282, USA.

A global analysis of zooplankton time series data from multiple geographic locations might provide new insights and scientific stimulation similar to that resulting from a similar analysis of small pelagic fish populations in the early 1980s. Zooplankton time series have both advantages and disadvantages when compared to time series of fish stocks: they are not impacted by "harvesting" but they are few in number. SCOR-WG 125 has been "identifying and consolidating a globally representative set of long zooplankton time series". To be considered for this analysis a data set must be nearly continuous and extend 10+ years. Very few time series extend the 50+ years necessary to examine multiple transitions of climate forcing (e.g. PDO, NPI, AO, NAO) at hemispheric or global scales. Examination of synchrony demands that zooplankton data sets overlap in time. Time series may start, stop, and be intermittent or irregular due to funding issues or changing scientific interest. To examine synchrony, we consider the zooplankton time series that have nearly complete (i.e. uninterrupted) records and that overlap 15+ years for inter-basin or inter-hemisphere comparisons, and overlap 10+ years for regional to within-basin comparisons. We compare standardized anomalies to eliminate issues regarding order of magnitude and measurement unit. Our analysis provides evidence of within-basin synchrony at regime and ENSO time scales for geographic separations extending to a few thousand kilometres. Evidence for "global" synchrony of zooplankton populations is weak or perhaps present but not discernable due to the short (<50 years) period of observations available.

W2/3 Linking global climate model output to a) trends in commercial species productivity and b) changes in broader biological communities inthe world's oceans

20 May, 11:35 (S2/3-4622)

A method for using IPCC model simulations to project changes in marine ecosystems

Nicholas A. Bond[1], James E. Overland[2] and Muyin Wang[1]

[1] Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, 7600 Sand Point Way NE, NOAA/PMEL, P.O. Box 354925, Seattle, WA 98195-4925, USA. E-mail: nicholas.bond@noaa.gov

[2] Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, 7600 Sand Point Way NE, Seattle, WA 98115, USA.

In preparation for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, an international group of modelling centres carried out sets of global climate simulations. A total of 23 different coupled atmosphere-ocean general circulation models were employed under common emission scenarios. The objective of this paper is to describe a protocol for using these simulations towards the projection of the future states of marine ecosystems, drawing on examples from the North Pacific and Bering Sea. Our method relies on critical evaluation of the models' 20th century hindcasts of variables pertaining to the ecosystems of interest. Experience indicates that typically about one-half of the models are able to replicate the spatial pattern, temporal scale and magnitude of variance in the basin-scale climate forcing observed in the 20th century. Different models tend to have different strengths; a model's capability to hindcast an individual parameter such as sea ice does not guarantee it performs equally well for other parameters such as precipitation. Therefore, the subset of models used for projections into the 21st century should be tailored to the specific application. At the same time, it is desirable to retain as many independent simulations for the 21st century as possible (at least 5) in that an ensemble of simulations is required to ascertain the probable ranges of future extremes in the climate forcing, and the uncertainties in the projections in general.

18 May, 11:30 (W2/3-4974)

Climate change, oceanic response and possible effects on fish stocks in New Zealand waters

Mary E. **Livingston**

Ministry of Fisheries, Science Group, PO Box 1020, Wellington, New Zealand. E-mail: mary.livingston@fish.govt.nz

A relatively isolated island nation ~2000 km from the nearest continental land mass, climate-change related trends in New Zealand waters have been equivocal over the past 50 years compared with some other parts of the world. Bathymetric topography in the region constrains the location of the subtropical front relative to our more productive fishing grounds, and although sea temperatures have been rising over the last decade, mean temperatures are little higher than those of the 1950s. New information suggests that this is about to change. New Zealand prides itself in its approach to fisheries management through the Quota Management System introduced in the mid-1980s. However, we are significantly stretched when it comes to planning fisheries management within the context of climate variability or change. Short time series make it difficult to draw definitive conclusions about the interactions between climate variables, ocean productivity and fish abundance. This paper provides an overview of results from recent studies and how we plan to integrate investigation of climate change with current fisheries research planning.

18 May, 11:45 (W2/3-4935)

Forecasting climate change impacts on the distribution and abundance of jack mackerel around Korean waters

Jae Bong **Lee**[1], Anne B. Hollowed[2], Nicholas A. Bond[3], James E. Overland[4], Chang Ik Zhang[5] and Dong Woo Lee[1]

[1] National Fisheries Research & Development Institute, Busan 619-905, Republic of Korea. E-mail: leejb@nfrdi.re.kr
[2] Alaska Fisheries Science Center, NOAA, Seattle, WA 98115, USA.
[3] Joint Institute for the Study of Atmosphere and Ocean (JISAO), University of Washington, Seattle, WA 98195, USA.
[4] Pacific Marine Environmental Laboratory, NOAA, Seattle, WA 98115, USA.
[5] Pukyong University, Dayeon3-dong, Nam-gu, Busan 608-737, Republic of Korea.

We used the existing knowledge of the functional relationships between climate and fish production and distribution to forecast climate change impacts on Korean fisheries. The surface current drifted westward during the 1980s and moved eastward to the western area of Kyushu of Japan during the 1990s. The role of transport to nursery grounds as a factor contributing to survivorship of jack mackerel was evaluated by comparing of the amount of variance explained by a Ricker spawner-recruitment relationship with and without transport indices. Climate change impacts were projected for the 21st century using output from a large number of coupled Atmosphere-Ocean General Circulation Models made available through the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. We provided individual model realisations of future SST, ocean drift and other oceanographic variables which are factors that influence year-class success of jack mackerel around Korean waters. These variables will be incorporated into a stock projection model to forecast future production scenarios. We incorporated environmental forcing into a stock projection model by modifying the spawner-recruitment relationship.

18 May, 12:00 (W2/3-4925)

Techniques for forecasting climate-induced variation in the distribution and abundance of mackerels in the northwestern Pacific

Sukyung **Kang**[1], Jae Bong Lee[1], Anne B. Hollowed[2], Nicholas A. Bond[3] and Suam Kim[4]

[1] National Fisheries Research & Development Institute, Busan 619-902, Republic of Korea.
[2] Alaska Fisheries Science Center, NOAA, Seattle, WA, USA.
[3] Joint Institute for the Study of Atmosphere and Ocean (JISAO), University of Washington, Seattle, WA, USA.
[4] Pukyong University, Dayeon3-dong, Nam-gu, Busan 608-737, Republic of Korea.

Scientists have compared temporal trends in interannual variability in oceanographic, climatic, and fishery data with temporal trends in the production or distribution of marine fish to evaluate the potential impact of climate variability on fisheries resources. In this investigation we examine time series of mackerel production in relation to ocean conditions in the marginal seas of the northwestern Pacific Ocean. SST in the Yellow Sea, the East China Sea (ECS) and the East/Japan Sea were compared to the national landings of mackerels in China, Japan and Korea. Data sets included time series of landings from Korean and Japanese fisheries from 1950 to the present. Analysis of temporal trends in SST revealed a decadal signal in SST that was negatively correlated to the PDO before and after 1981. Analysis of the spatial pattern of SST revealed an inverse phase relationship in SST anomalies between the eastern (130°E) and western (123°E) ECS. We hypothesize that mackerel production is positively influenced by warm ocean conditions in the ECS through its influence on the volume of suitable spawning habitat. We forecast the impact of climate change on mackerel production by embedding temporal trends in the volume of spawning habitat into a stock projection model. We downscale time forecasts of atmospheric/ocean conditions from the Intergovernmental Panel on Climate Change models to extract trends for local ocean conditions in the ECS. These trends are incorporated into stock projection models by adding terms governing density dependent competition for spawning habitat.

18 May, 12:15 (W2/3-4720)

Effects of climate change on sole and plaice: timing of spawning, length of the growth period and rate of growth

Adriaan D. **Rijnsdorp**[1], Joep J. de Leeuw[1], Lorna R. Teal[1] and Henk W. van der Veer[2]

[1] Wageningen IMARES, Institute for Marine Resources and Ecosystem Studies, P.O. Box 68, 1970 AB Ijmuiden, The Netherlands. E-mail: Adriaan.rijnsdorp@wur.nl

[2] Royal Netherlands Institute for Sea Research, NIOZ, P.O.Box 59, 1790 AB, Den Burg, The Netherlands.

The effect of the rising sea water temperature on the timing of spawning, the duration of the growth period and the growth rate of 0-group sole and plaice in the southeastern North Sea was investigated for the period 1970-2004. Increasing water temperature in winter significantly advanced the timing of spawning and increased the growth period of sole, a warm-water species that spawns in spring, but not of plaice, a temperate species that spawns in winter. Growth rate increased with higher summer temperatures in sole and to a lesser degree in plaice. Compared with experimental growth rates at ambient temperatures and unlimited food, observed growth rates were close to experimental values until mid June, but were much lower in July-September, suggesting food limitation in summer. The higher temperatures observed since 1989 positively affected the quality of the shallow coastal waters as a nursery area for sole but not for plaice. However, a further increase in summer may negatively affect the nursery quality if the production rate of benthic food cannot meet the increase in energy requirements of 0-group flatfish and/or exceed the temperature tolerance range.

18 May, 12:30 (W2/3-4540)

The impact on management performance of including indicators of environmental variability in management strategies for the Gulf of Alaska walleye pollock fishery

Z. Teresa **A'mar**[1], André E. Punt[2] and Martin W. Dorn[3]

[1] University of Washington, Quantitative Ecology and Resource Management, Box 352182, Seattle, WA 98195-2182, USA. E-mail: zta@u.washington.edu

[2] University of Washington, School of Aquatic and Fishery Sciences, Box 355020, Seattle, WA 98195-5020, USA.

[3] Alaska Fisheries Science Center, NOAA Fisheries, 7600 Sand Point Way NE, Bin C15700, Seattle, WA 98115-0070, USA.

Management strategy evaluation (MSE) is the process of using simulation testing with feedback to examine the robustness of candidate management strategies to error and uncertainty. The MSE framework includes an operating model of 'true' population dynamics, from which data are generated and used in the estimation model; an estimation model which provides derived measures of population metrics (e.g. spawning biomass, fishing mortality, etc.) to assess the stock relative to target and limit reference points; and a decision rule which determines management action based on the stock status. The latter two steps constitute the management strategy. The structure of the management strategy can be selected to attempt to satisfy desired (but conflicting) management goals and objectives. Performance measures are used to quantify the effectiveness of the management strategy relative to the management objectives of avoiding low stock size and achieving high, stable catches given error and uncertainty in biological processes and data collection. MSE is used in this paper to assess the performance of the current management strategy for the fishery for walleye pollock, *Seriola quinqueradiata*, in the Gulf of Alaska when subject to the effects of regime shifts and environmental variability. These effects are of particular interest in this fishery, where such changes can modify stock production. The results indicate that management strategies more responsive to fluctuations in productivity due to environmental influences demonstrate the best performance.

18 May, 12:45 (W2/3-4862)

Simulation testing two methods of including environmental data in stock assessments

Michael J. **Schirripa**[1], Richard D. Methot[2] and C. Phillip Goodyear[3]

[1] NOAA Fisheries, Northwest Fisheries Science Center, 2032 SE OSU Drive, Newport, OR 97365, USA. E-mail: Michael.Schirripa@noaa.gov
[2] NOAA Fisheries, Office of Science and Technology, 2725 Montlake Blvd., Seattle, WA 98112, USA.
[3] 1214 N Lakeshore Drive, Niceville, FL 32578, USA.

The North Pacific Marine Science Organization (PICES) Working Group 16 report on the impacts of climate and climate change concluded that climate is a major factor affecting the productivity of virtually all key commercial species. However, almost none of the stock assessments conducted on these species explicitly include climate effects in the assessment model. The objective of this investigation is to evaluate two methods of including environmental variability directly into the assessment and its effect on the estimation of recruitment parameters, stock status, and the conservation benchmarks used to manage a stock. Two methods of incorporating environmental effects will be tested using the stock assessment model Stock Synthesis II. The first method models annual deviations in the stock-recruitment curve assuming no observation error in the environmental data by recalculating the expected value of recruitment according to anomalies in the environmental time series for a given year. The second method allows for observation error in the environmental time series and uses this data as an index to tune the vector of estimates of annual recruitment deviations. Both methods are tested against simulated data sets in an effort to determine which method produces the most accurate results and are suitable for future use. Response variables to the two methods include estimates of key benchmarks such as virgin recruitment and biomass, stock-recruitment steepness parameter, maximum sustainable yield and depletion.

18 May, 13:00 (W2/3-4846)

Climate change and changing fisher behaviour in the Bering Sea pollock fishery

Alan **Haynie**

NOAA Fisheries, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, USA. E-mail: Alan.Haynie@noaa.gov

One component of the recently initiated Bering Sea Integrated Ecosystem Research Project (BSIERP) is a spatial economic model that predicts changes in fishing activity in the Bering Sea pollock fishery that may result from climate change. Random utility models such as the model employed here have been used in the Bering Sea and elsewhere to model how fishers make decisions about where to fish. Commercial fishers choose different areas to fish based on a myriad of observable and unobservable characteristics of the area and the fisher. We commonly model location choice as a function of the expected catch (or revenue) in an area, fuel and fish prices, distance to an area, vessel characteristics, and to a more limited degree, institutional and environmental conditions. In the Bering Sea pollock fishery, climate variables affect many aspects of the fishing decision. Key among these impacts is the role that climate has on fish location and abundance and the impact that weather plays in daily participation choices for smaller vessels. In this paper, we expand a robust spatial economic model to include climate data (e.g. ice cover, SST, wind). Including this information in the model will allow us to determine the relative impact of observable contemporaneous environmental conditions on location choices. We also develop a framework to include predictions of changing pollock abundance in the model, which will allow us to estimate fisher response to scenarios developed by oceanographic and ecosystem modellers involved in the BSIERP project.

18 May, 13:15 (W2/3-4572)

Large scale circulation over the west Indian Ocean and the south west monsoon

U.K. **Singh** and P.S. Salvekar

Indian Institute of Tropical Meteorology, Pune-08, India. E-mail: umesh@tropmet.res.in

The focus of this study is to document the role of the west Indian Ocean over the Indian monsoon during the last decade (1998-2007). Understanding the interannual variability of the southwest monsoon is an important and challenging factor. To date the relationship of the Mascarian high and the southwest monsoon has been well documented in the literature. However, the temporal variation of meteorological parameters, over the region east of Madagascar to the west coast of India, are not yet examined in detail. In the present study extensive analyses of daily outgoing longwave radiation (OLR), zonal wind (u) at 850 and 200 hpa and Global Precipitation

Climatology Project (GPCP) rainfall over the region 50-80°E and 30°S-30°N from April to September for all 10 years was carried out. In all cases, a 5-day running mean smoother was applied to the data to reduce the large day-to-day oscillations. We have prepared time-latitudinal plots averaged over longitude 50-80°E. Northward movement of large scale circulation and the core of maximum winds are clearly depicted and are found to be closely related with the GPCP rainfall region. The study was very useful for understanding monsoon performance in the last decade. It is suggested that large scale circulation over the west Indian Ocean may be the dominating factor in the overall performance of the southwest monsoon over India.

18 May, 15:00 (W2/3-4757)

Modelling the response of ocean biology to climate warming using an empirical approach

Jorge L. **Sarmiento**, Patrick Schultz, Michael Hiscock and Stephanie Henson

Princeton University, Atmospheric and Oceanic Sciences Program, 300 Forrestal Road, Sayre Hall, Princeton, NJ 08544, USA.
E-mail: jls@princeton.edu

We previously used sea ice extent, upwelling velocity, and wintertime mixed layer depth to define six physically based biomes and how these respond to climate warming as predicted by coupled climate models. Here, we discuss results of a new study using statistical approaches to identify patterns in satellite observations of chlorophyll and biomass, and then use these to define an alternative set of biomes. We next analyse the results for correlations between the biomes and physical processes that we can use to estimate how the boundaries of the biomes might shift in response to climate warming. We suggest that such an empirical modelling approach offers a useful alternative to the traditional NPZ type ecosystem modelling usually used to predict ecosystem responses to climate warming.

18 May, 15:15 (W2/3-4793)

Future ecosystem changes projected by a 3-D high-resolution ecosystem model

Taketo **Hashioka**[1,2], Takashi T. Sakamoto[1], Takeshi Okunishi[3] and Yasuhiro Yamanaka[1,2,4]

[1] Frontier Research Center for Global Change (FRCGC) / Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 3173-25, Showa-machi, Kanazawaku-ku, Yokohama, Japan. E-mail: hashioka@jamstec.go.jp

[2] Core Research for Evolutional Science and Technology (CREST) / Japan Science and Technology Agency (JST), 4-1-8, Honcho, Kawaguchi-shi, Japan.

[3] Tohoku National Fisheries Research Institute, Fisheries Research Agency (FRA), 3-27-5, Shinhamacho, Shiogama, Miyagi 985-0001, Japan.

[4] Hokkaido University, Faculty of Environmental Earth Science, 060-0010, N10W5, Kita-ku, Sapporo, Japan.

In recent years, several studies have tried predicting future impacts of global warming on marine ecosystems using results obtained from climate models. As an approach to modelling responses to global warming, we developed a 3-D high-resolution ecosystem model (COCO-NEMURO; which has a horizontal resolution of 1/4 by 1/6 degrees) with an off-line calculation method that can directly use predicted results of climate models as a physical field of the ecosystem model. COCO-NEMURO consists of PICES NEMURO (North Pacific Ecosystem Model for Understanding Regional Oceanography) coupled with COCO (CCSR Ocean Component Model). As a first step, we applied this model to the western North Pacific, and conducted a global warming experiment using physical fields predicted by a high-resolution climate model (the CCSR/NIES/FRCGC climate model, which contributed to the IPCC-AR4). We conducted the global warming experiment following an idealised scenario in which atmospheric CO_2 concentration increases by 1% per year. Under the global warming condition, our model predicted significant changes in the maximum phytoplankton biomass during the spring bloom period (i.e. 20% increase in the subarctic region and 25% decrease in the subarctic-subtropical transition region). Since these changes would affect the higher-trophic level ecosystem, we have been also developing an integrated marine ecosystem model explicitly representing linkages between the lower-trophic level ecosystem and major pelagic fishes based on COCO-NEMURO. In this workshop, we present our approach to the projection of future ecosystem changes.

18 May, 15:30 (W2/3-4803)

Dynamic bioclimate envelope model to predict climate-induced changes in distribution of marine fishes and invertebrates

William W.L. **Cheung**, Vicky W.Y. Lam and Daniel Pauly

Sea Around Us Project, Fisheries Centre, Aquatic Ecosystems Research Laboratory, 2202 Main Mall, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada. E-mail: w.cheung@fisheries.ubc.ca

Global climate change is recognised as an important determining factor for the future distributions of marine organisms, notably fishes and invertebrates. Shifting of distribution ranges may affect the structure and function of marine ecosystems and global marine fisheries. In this study, we develop a dynamic bioclimate envelope model to predict the effect of climate change on the distributions of marine species with an emphasis on commercially exploited fishes and invertebrates. Firstly, the model infers, for various species, bioclimate envelopes based on their current distribution. Bioclimate envelopes are defined by sea water temperature, bathymetry, habitats, salinity and distance from sea ice. Secondly, the model predicts the shifting of the bioclimate envelopes induced by changes in climate variables. Simultaneously, following the shifting of the bioclimate envelopes, the model simulates movement of relative abundance through changes in population growth, mortality, larval dispersal and adult movement. We test the model with several commercially exploited fish species with widely different biogeography. The model provides reasonable and robust predictions of future distribution ranges of the four species under different scenarios of sea water warming. Moreover, the predictions are robust to major model assumptions and parameter uncertainty. Using realistic climate change predictions from the global circulation models, our model can predict the possible shifts in distribution of marine species under different climate change scenarios. Such predictions can be incorporated into ecosystem simulation models to assess the synergistic effects of trophic interaction, climate change and anthropogenic impacts, such as fishing, on marine biological communities and fisheries.

18 May, 15:45 (W2/3-4805)

Informing location choices for ecosystem model development using a vulnerability index

Alistair J. **Hobday**[1,2], Thomas J. Kunz[1], Thomas A. Okey[3,4,5], Elvira S. Poloczanska[1] and Anthony J. Richardson[3,6]

[1] Climate Adaptations Flagship, CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart, Tasmania 7001, Australia. E-mail: Alistair.Hobday@csiro.au
[2] School of Zoology, University of Tasmania, Private Bag 5, Hobart, Tasmania 7001, Australia.
[3] Climate Adaptations Flagship, CSIRO Marine and Atmospheric Research, PO Box 120, Cleveland, Qld 4163, Australia.
[4] Bamfield Marine Sciences Centre, PO Box 100, Bamfield, BC, V0R 1B0, Canada.
[5] University of Victoria School of Environmental Studies, PO Box 1700 STN CSC, Victoria BC, V8W 2Y2, Canada.
[6] Department of Mathematics, University of Queensland, St Lucia, Queensland 4072, Australia.

Vulnerability assessments can provide information on potential climate impacts and underpin strategic prioritisation for allocation of scientific and management resources. One way such a vulnerability assessment can underpin research strategy is to provide quantitative frameworks for identifying ecosystems, habitats, biological components, or human values at greatest risk. This can then guide locations where ecosystem models should be developed, and what drivers are likely to be critical for model inclusion. To illustrate this, we describe a novel approach for assessing vulnerability of marine life to climate change using a bioregional approach for Australia. We score the vulnerability for each of seven large marine domains based on 22 quantitative indicators categorised into three dimensions of vulnerability. These dimensions represent the different aspects of stress that impact marine life and the different characteristics that mediate stressors: one dimension measures exposure to climate change, one measures sensitivity in each region, and one measures adaptive capacity. Four to eight indicators were scored for each dimension. Indicators of climate change (difference between projections for the 2070s from the 1990s) were obtained from the CSIRO Mk 3.5 model, and non-climate indicators from existing Australian data sets. Our approach identified the principal stressors for each domain. In each region, policies can be targeted toward major non-climate stressors that could mitigate future impacts of climate change. What is then needed is to consider impacts on a finer scale in the most vulnerable habitats using downscaled climate models to force ecosystem models in these regions at greatest risk.

18 May, 16:30 (W2/3-4913)

Towards the integration of biogeochemical and food web models for a comprehensive description of marine ecosystem dynamics

Simone **Libralato**[1], Cosimo Solidoro[1] and Villy Christensen[2]

[1] Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Dept. Oceanography, Borgo Grotta Gigante - Brisciki 42/c - 34010 Sgonico - Zgonik (TS) Italy. E-mail: slibralato@ogs.trieste.it

[2] Fisheries centre, University of British Columbia, 2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada.

A truly comprehensive perspective on the effects of climatic changes on marine ecosystems requires a contemporaneous accounting of both biogeochemical/physical processes and food web dynamics in an end-to-end modelling description of the ecosystem. The development of end-to-end models (e.g. from viruses to fishes, from nutrients to fisheries, including climatic changes) can be performed in different ways, depending on the peculiarity of the starting models, the methods used for their integration, the variables used as linkage and forcing, and the ultimate goal of the analysis. For this workshop, we will summarise the main outcomes of the November 2007 workshop held in Trieste (Italy) on "Biogeochemical processes and fish dynamics in food web models for end-to-end conceptualisation of marine ecosystems: theory and use of Ecopath with Ecosim". The workshop was attended by 56 participants from 25 different countries and was intended to explore the capabilities of the Ecopath with Ecosim package for building End-to-End models of marine ecosystems. Contributions to the workshop presented possibilities for including external forcings into food web dynamics as well as for linking and coupling biogeochemical and food web models. This work is intended to give a summary of the main challenges identified, of the ideas and future prospects, and of the preliminary applications presented during the workshop.

18 May, 16:45 (W2/3-4822)

Which forcing factors fit? Using ecosystem models to investigate the relative influence of fishing and primary productivity on the dynamics of marine ecosystems

Steven **Mackinson**[1], G. Daskalov, S.J.J. Heymans, S. Neira, H. Arancibia, M. Zetina-Rejón, D. Lecari, J. Hong, C. Hequin, M. Coll, F. Arreguin-Sanchez, L. Shannon and K. Lees

[1] Cefas, Pakefield Road, Lowestoft, Suffolk NR33 0HT, UK. E-mail: steve.mackinson@cefas.co.uk

Estimates of fishing mortalities and primary production (or proxies for primary production) were used to drive the past dynamics of fish assemblages in 10 contrasting trophodynamic models of marine ecosystems. Historical trends in fish abundance were reconstructed by fitting model predictions to observations from stock assessments and fisheries independent survey data. We measured how much better or worse were model predictions when changes in primary production were combined with forcing by fishing. Searching for cross system patterns, the relative contribution of fishing and changes in primary production are evaluated for the ecosystem as a whole and for selected similar species in different ecosystems. The analysis enables us to provide a simple qualitative way to explain which forcing factors have the most influence on modelled dynamics. However, because past relationships of the role of fishing and changes in primary production on ecosystems cannot be used reliably to predict future responses to climate change, integration of biogeochemical models with higher trophic level models will be required. Such work has already been initiated; the principles behind which are discussed here.

18 May, 17:00 (W2/3-4831)

The effects of climate change on the northern Benguela ecosystem

Sheila J.J. **Heymans**

Scottish Association for Marine Science, Dunstaffnage Marine Laboratory, Dunbeg, PA37 1QA, Argyll, UK.
E-mail: sheilaheymans@yahoo.com

The Benguela upwelling system is one of the most productive ecosystems in the world. It is driven mainly by the prevailing southwesterly winds off the coast of southern Africa. These winds cause perennial upwelling off Lüderitz and seven other smaller cells up and down the Namibian coast. The upwelled water reduces sea surface temperature and increase the nutrient content of the coastal waters. There is evidence that hake (one of the most important commercial species in the system) recruitment is dependent on low surface temperatures and nutrients.

In contrast, anchovy catches are often favoured by the breakdown of the Lüderitz upwelling cell, which acts as a barrier to the import of recruits from the south. The changes in the northern Benguela ecosystem (from 1956-2000) was shown to be correlated to sea surface temperature and wind stress in the system. In this study the effect of global warming on the northern Benguela system was simulated by using the 1956 Ecopath with Ecosim model fitted to 2000 and imposing possible increased sea surface temperature regimes over the next 50 years. The effects of this possible increase in temperature were then compared in terms of changes in ecosystem function and commercial gain possible from the ecosystem.

W4 Prospects for multidisciplinary long-term ocean observations

21 May, TIME??? (W4-4967)

Ocean variability and trends, and the sustained Global Ocean Observing System

D.E. **Harrison**

NOAA/PMEL/OCRD, 7600 Sand Point Way NE, Seattle, WA 98115, USA. E-mail: harrison@pmel.noaa.gov

While there is much interest at present in how climate change will be expressed in the ocean in coming decades (and longer), recent analyses of the frustratingly incomplete historical ocean temperature data set clearly show that the better sampled areas of the ocean have basin-scale variability on a wide range of time scales. Regional multi-decadal cooling and warming can be substantially greater than longer-term regional trends. Estimating long term trends is quite challenging in many areas, even over the post-World War II period, given the amplitude of oceanic variability. The need for sustained sampling of the ocean on relevant space and times scales is critical for climate assessment, climate research and climate forecasting as well as ecosystem management, carbon budget estimates and other non-physical variable objectives. A plan for an initial sustained global ocean observing system has been agreed and implementation (see GCOS-92) called for by the GEO, UNFCCC and other international groups. Significant progress in implementation has been achieved, with open access to the data collected and to many of the ocean analysis products now being routinely generated by groups participating in the Global Ocean Data Assimilation Experiment (high spatial resolution, near-real-time) and the ocean reanalysis activity led by CLIVAR's Global Synthesis and Observations Panel. It is important to extend the range of variables observed globally and systematically as rapidly as technology permits. An international symposium, OceanObs09, is planned to provide a forum for the ocean observing community to celebrate the accomplishments of the past decade, to demonstrate the utility to society of the information gained and to agree on the plan for the coming decade. A major objective is to provide an opportunity for the biogeochemical and ecosystem communities to present consensus plans for sustained observing activities for feasible variables.

21 May, TIME??? (W4-4977)

High-resolution ocean and atmosphere *p*CO_2 time series measurements from open ocean and coastal moorings

Christopher L. **Sabine**, Richard A. Feely, Stacy Maenner and Christian Meinig

Pacific Marine Environmental Laboratory, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115, USA. E-mail: Chris.Sabine@noaa.gov

Ocean carbon measurements have shown significant biogeochemical variability over a wide range of timescales from sub-diurnal to decadal periods. *In situ* measurements are also providing a growing body of evidence that episodic phenomena are extremely important causes of variability in CO_2 and related biogeochemical properties. Year-to-year variations in ocean physics, bulk biological production, and ecological shifts can drive significant changes in surface water CO_2, and thus air-sea flux. Time series records are essential for characterising the natural variability and secular trends in the ocean carbon cycle and for determining the physical and biological mechanisms controlling the system. The biological and chemical responses to natural perturbations (e.g. ENSO, dust deposition events) are particularly important with regard to evaluating potential responses to anthropogenic forcing and for evaluating the prognostic models used in climate projections. Ship-based time series are impractical for routinely measuring variability over intervals from a week to a month, they cannot be made during storms or high-sea conditions, and they are too expensive for remote locations. Instrumental advances over the past 15 years have led to autonomous moorings capable of sampling properties of chemical, biological, and physical interest with duty cycles of a year or more. Although these new technologies are still under-utilised, they have been identified as a critical component of the global ocean observing system for climate. We will discuss the latest developments in autonomous carbon sensors and how they are helping to improve our understanding of the ocean carbon system.

21 May, TIME??? (W4-4971)

Prospects for using profiling floats and gliders for biogeochemical sustained observations?

Martin **Visbeck**[1], Johannes Karstensen[1], Arne Körtzinger[1] and Nicolas Gruber[2]

[1] IFM-GEOMAR Leibniz-Institut für Meereswissenschaften, Düsternbrooker Weg 20, 24105 Kiel, Germany.
E-mail: mvisbeck@ifm-geomar.de
[2] ETH Zürich, CHN E21.1, Universitätstr. 16, 8092 Zurich, Switzerland.

Over the last decade the physical oceanographic community has made tremendous advances in the exploitation of relatively inexpensive autonomous profiling platforms. Today about 3000 profiling floats observe the upper 2 km of all ice-free ocean roughly every 10 days as part of the Argo project. In regions with strong flows or near the coasts the freely drifting profiling floats are increasingly augmented by a more elaborate and capable platform called a glider. At the moment there are three groups who have developed operational gliders: 1) the Seaglider by APL-University of Washington (shallow and deep versions); 2) the Slocum by Webb Research Corp (shallow, deep and thermal versions) and 3) the Spray by Scripps Institution of Oceanography. Although the designs are different they have many features in common. They all have a small size (1.5 m long, 30 cm diameter, 1.5 m wingspan with a mass of about 50 kg in air and +/-200g in water), their horizontal speeds are ~20-40 cm/s with descent/ascent rates of ~10-20cm/s. For a maximum dive to 1 km depth a typical glider will move 2-6 km horizontally between surfacing. For most applications measurements are carried out during the descent using a variety of sensors including temperature, salinity, and most recently dissolved oxygen. Depending on battery type, sensor load, speed of travel and depth of sampling the typical glider endurance is about 1-3 months (proven average value at the moment) and the glider can travel around 1000-3000 km before planned recovery and maintenance. Several of the gliders and a subset of the profiling floats already have been equipped with dissolved oxygen sensors and LED based fluorometers. As sensor technology keeps advancing the prospects for some global biogeochemical measurements hosted by robotic autonomous platforms become increasingly realistic.

21 May, TIME??? (W4-4970)

Decadal CO_2 uptake by the ocean deduced from the CLIVAR/CO_2 Repeat Hydrography Program

Richard A. **Feely**[1], Christopher L. Sabine[1] and Rik Wanninkhof[2]

[1] Ocean Climate Research Division, NOAA/PMEL, 7600 Sand Point Way NE, Seattle, WA 98115, USA. EMAIL
[2] Ocean Chemistry Division, NOAA/AOML, 4301 Rickenbacker Causeway, Miami, FL 33149, USA.

In 2003, the US CLIVAR/CO_2 Repeat Hydrography Program began re-occupying a subset of the WOCE/JGOFS lines in an effort to evaluate the decadal changes in ocean carbon inventories. The programme has identified 19 hydrographic sections distributed around the global ocean that will be re-occupied approximately every 10 years. This work is being conducted in collaboration with other nations that have similar repeat hydrography programmes in the Atlantic Pacific, Indian and Southern Oceans. Preliminary estimates of anthropogenic CO_2 accumulation along representative north-south cruises indicate that the North Atlantic shows the largest anthropogenic increase, illustrating the importance of North Atlantic Deep Water formation as a mechanism for transporting anthropogenic CO_2 into the ocean interior. The formation of mode and intermediate waters in the southern hemisphere also contributes to the substantial DIC increases in the South Atlantic and South Pacific. The North Pacific shows a relatively modest increase because of the lack of deep-water formation and restricted intermediate water formation in that region. Preliminary estimates of the accumulation of anthropogenic CO_2 in the Indian Ocean between the 1995 WOCE/JGOFS cruises and the 2007 repeat hydrography cruise indicates a similar pattern of accumulation as shown by the earlier work of Sabine *et al*. (1999). These latest results show conclusively that anthropogenic CO_2 is continuing to accumulate in the Atlantic, Pacific and Indian Oceans. In general, they agree with the long-term storage patterns of Sabine *et al*. (2004) that the largest inventories are associated with the regions where water masses are being formed and moving into the ocean interior. However, when studied in detail, the results from the Pacific and Atlantic Oceans have shown that regional circulation changes can have a significant impact on carbon inventories on decadal timescales. In some cases these changes may enhance the storage of carbon and, in other cases, they may decrease the uptake resulting from rising atmospheric CO_2. Because circulation and biological changes can vary on seasonal to decadal scales, it is critical to continue to monitor the changes in ocean carbon inventories and how they interact with the secular increases in anthropogenic CO_2. As additional cruises are completed the full picture of the decadal storage will be developed.

21 May, TIME??? (W4-4969)

The role of fixed-point deep ocean observatories in a global observing system

Richard S. Lampitt, K.E. **Larkin**, S.E. Hartman and M. Pagnani

National Oceanography Centre, European Way, Southampton SO14 3ZH, UK. E-mail: R.Lampitt@noc.soton.ac.uk

At a time of increasing concern about global climate change and environmental degradation, long-term time series observations of the oceans can offer some of the most important insights into the structure and function of this environment and the ways our oceans are changing. Whilst data from research cruises have provided much of our current understanding, these only provide "snapshots" of the oceans and there is an increasing realisation that crucially important processes occur on time scales that can not be observed by such cruises. Furthermore, many of these important processes are outside the reach of satellite sensors. In order to understand the complexity of the oceans, sustained *in situ* observations are required providing high quality data on climatically and ecologically relevant variables at a few key locations. Fixed-point deep ocean observatories are therefore an integral part of the diverse monitoring systems now developing. Historically, fixed-point deep ocean observatories have been developed independently with national funding. As a consequence, observatories have developed in a rather fragmented way. OceanSITES has become the international coordinated framework for fixed point observatories and has been pivotal in creating a philosophy of data management and sharing. The OceanSITES network advocates shared efforts in operations, technical expertise and science exploitation to form an international collaborative network of ocean observatories that are multidisciplinary, open to development with real-time data telemetry and an open data policy. EuroSITES, a 3 year (3.5 Million Euro) FP7 European project, forms an integrated network of the 9 existing deep ocean observatories around Europe. Beginning in spring 2008 and coordinated by the National Oceanography Centre, Southampton, EuroSITES will form the European component of OceanSITES and aims to progress European ocean observation technology beyond the current state-of-the-art. This will be achieved through enhancement and standardisation of existing *in situ* infrastructure through best practice and common data management linking sites both geographically across Europe and through the water column to the seafloor and subseafloor. EuroSITES will also support research and development into novel sensors to measure climatically and ecologically relevant variables that are currently not possible. Close interaction between all relevant international projects and initiatives is essential to develop a unified approach to ocean observation. Only then can the global observational community form an integrated, collaborative network and contribute effectively to GEO tasks and to the greater vision of GEOSS.

W4 Posters

Poster W4-4536

Long term monitoring of oceans around Southern Africa

Juliet **Hermes**, Angus Paterson and Johan Pauw

South African Environmental Observation Network (SAEON), Private Bag X2, Roggebaai 8012, South Africa. E-mail: Juliet@saeon.ac.za

The South African Environmental Observation Network (SAEON) aims to provide a comprehensive, sustained, co-ordinated and responsive South African Earth observation network that delivers long-term reliable data for scientific research and informs decision making for a knowledge society and improved quality of life. SAEON addresses the environmental observation and information needs of future generations, reaching far and wide, nationally, regionally and globally, and its success as a platform for environmental observations depends on delivery of reliable environmental data and products for science, policy and management. Education-Outreach, based on the environmental sciences, has a specific focus on science educators, learners and research students. The marine offshore node of SAEON aims to fill the gaps in long-term ocean monitoring, helping to understand the impact of climate change on oceans and their resources surrounding South Africa, as well as improving our knowledge of the ocean's influence on climate change. It is vital that we better understand these oceans as they have been shown to play a major role in the weather and climate patterns over southern Africa. Thus the impact of climate change through factors such as increases in temperature and sea level rise, which are already evident, are likely to have devastating effects on the lives of millions of impoverished people.

W6 Storm surges and flooding in the Baltic Sea

I. Observations and analyses of sea level data (Chair: K. Klevannyy)

18 May, 09:50 (W6-4678)

Extreme sea level statistics along the Estonian coast

Aleksander **Toompuu**[1], Evgueni A. Kulikov[2] and Germo Vali[1]

[1] Marine Systems Institute, Tallinn University of Technology, Akadeemia tee 21, 12618 Tallinn, Estonia. E-mail: alex@phys.sea.ee

[2] Shirshov Institute of Oceanology, Russian Academy of Sciences, Nakhimovskiy 36, Moscow 117997, Russia. E-mail: kulikove@cnt.ru

The distributions of daily, weekly and monthly sea level maxima of twenty sea level records along part of the Latvian coast of the Gulf of Riga and along the Estonian coast have been analysed. The five-year (1978 to 1982) sea level data consist of either hourly or bench-stick (two or four times per day) mareograph readings. The estimated maximum sea level histograms were approximated by three extreme-value model distributions of the Gumbel, Frechet and Weibull type. There is a general tendency of westward decrease in the location and scale parameter values of the fitted Gumbel distribution in the Gulf of Finland, where the sea level stations are situated nearly in the east-west direction. A similar trend is also observed for the Gulf of Riga, where the distribution location and scale parameter values are larger for the stations located along the eastern coast of the Gulf. This observed regular trend is most likely related to (a) the bottom topography, which affects water flow in and out of the deep western basins of the gulf, (b) the relatively shallow eastern part of the gulf, and (c) the prevailing forcing by westerly winds in the area, governed by their respective water dynamics. The eastern coasts of these two areas are therefore more at risk from flooding by extreme sea levels than the coasts in the western Gulf of Riga.

18 May, 10:20 (W6-4630)

Calculation of extreme water level rises along the western part of the Gulf of Finland

Alexander S. **Averkiev**[1] and Konstantin A. Klevannyy[2]

[1] Russian State Hydrometeorological University, Malookhtinskii Pr., 98, 195196 St. Petersburg, Russia. E-mail: asav@rshu.ru

[2] St.Petersburg Center for Hydrometeorology and Environmental Monitoring, 23 Linija VO, 2a, 199106 St. Petersburg, Russia.

Because of the recent climate change, floods along the Gulf of Finland coasts are expected to become more frequent and more serious phenomena in the future. In the previous works, the most dangerous cyclone trajectories and extreme possible water level rises were studied with the CARDINAL modelling system for the St. Petersburg, Kronshtadt and Leningrad NPS (nuclear power station) locations in the eastern Gulf of Finland. Simulations were done for an idealised round cyclone with extreme parameters (pressure in the cyclone centre of 960 gPa and maximum wind speed of 30-35 m/s at a distance of 200 km from the centre and behind the cold front). In this paper, similar simulations were done for locations in the western Gulf of Finland (Hanko, Helsinki, NPS in Loviisa and Kotka, and also for Pärnu in the Gulf of Riga) and the same parameters were estimated. In particular for Helsinki, Loviisa and Kotka, it was found that the maximum water levels occur when the cyclone centre moves 150-200 km north from these locations. In some cases and locations, the water level time histories have one peak, while there are usually two peaks when the cyclone moves towards the north-east or to the east. In both cases, the following maximum water level values were obtained relative to the zero-mean sea level: 210 cm in Kotka, 200 cm in Loviisa and 165 cm in Helsinki. As the coastline in these places is very irregular, these results are likely to be amended when using a more refined model of the Baltic Sea.

18 May, 10:50 (W6-4733)

Sea level trends along the coast of the Gulf of Finland of the Baltic sea

Oleg P. **Nikitin**[1] and Andrey O. Koch[2]

[1] State Oceanographic Institute, Kropotkinsky per., 6, Moscow 119034, Russia. E-mail: opnikitin@mail.ru
[2] Russian State Hydrometeorological University, 195196, St.Petersburg, Malookhtinsky Pr., 98, Russia.

Historical time series of monthly mean values of sea level were compiled and analysed for trends for all stations in the Gulf of Finland for time periods starting from the beginning of sea level observations at each station and until the station closed, or the year 2005 for Russian, 2004 for Finnish and 1991 for Estonian stations. It was found that along the northern coast of the Gulf of Finland, the sea level trends change from minus 3-4 mm/year along the western part of this coast (at Turku and Hanko) to plus 0.7 mm/year along the eastern part of the coast (at Lisiy Nos). Along the southern coast of the Gulf of Finland, the sea level trends change from west to east (from station to station) and not as regularly as along the northern coast. However, trend values along the southern coast are considerably less than along the northern coast. It was therefore concluded that within the limits of errors of trend calculations, the sea level trends along the southern coast also change from negative values in the west (minus 0.3 mm/year at Poosaspea) to plus 1.2 mm/year in the east (at Lomonosov). At the head of the Gulf (at Port of Nevskaya), the positive trend was the largest: 3.2 mm/year. Relative to the global sea level rise (about 2 mm/year during the last century) trend values are negative in all points except Saint Petersburg. Their spatial distribution is consistent with the map of post-glacial uplift in Fennoscandia.

18 May, 11:30 (W6-4885)

On diurnal tidal resonance in the Baltic Sea and Gulf of Finland

Alexander B. **Rabinovich** and Evgueni A. Kulikov

P.P. Shirshov Institute of Oceanology, RAS, Moscow 117997, Russia. E-mail: abr@iki.rssi.ru

Tides in the Baltic Sea are quite small; maximum tidal amplitudes are less than 10 cm. Nevertheless, they significantly influence the water masses in the sea and interact with other dynamical processes, including storm surges and seiche (eigen) oscillations in the Baltic Sea as a whole and in large Baltic Sea gulfs, in particular, in the Gulf of Finland. The specific mechanism of tidal generation in the Baltic Sea is quite interesting. The semidiurnal tides are *free* (co-oscillating), as they are driven by the tidal waves arriving from the North Sea. In contrast, the diurnal tides are *forced*, generated directly in the Baltic Sea due to proximity of the diurnal period to the resonant period of the fundamental Baltic Sea mode (~27.7 hrs). Long-term hourly sea level data from a number of tide gauges were used to investigate the tidal motions in this basin. Tidal harmonic analysis of yearly time series by the least squares method was used to estimate 11 tidal constituents, including annual (S_a), semiannual (S_{sa}), five diurnal (K_1, O_1, P_1, Q_1 and S_1) and four semidiurnal (M_2, S_2, N_2 and K_2) harmonics. To increase the accuracy, the computed complex amplitudes for individual years were averaged over the observational period at each station. The tidal amplitudes were normalised by their theoretical tidal potential values and then used to estimate tidal admittance characteristics of the Baltic Sea, which clearly shows the resonance of diurnal tides. This effect is especially pronounced in the Gulf of Finland, where diurnal tides have a character of the Helmholtz mode, in good agreement with the results of numerical modelling. Additional interesting effect was found at some stations in this gulf, exhibiting distinct "radiational" (solar) harmonics: S_1, S_2, S_3, S_4, and S_5. These are likely associated with coastal sea breeze winds.

18 May, 12:00 (W6-4681)

Spectral analysis of sea level in the Gulf of Finland

Evgueni A. **Kulikov**[1], Oleg P. Nikitin[2] and Aleksander Toompuu[3]

[1] Shirshov Institute of Oceanology, RAS, Moscow 117997, Russia. E-mail: kulikove@cnt.ru
[2] State Oceanographic Institute, Kropotkinsky per., 6, Moscow, Russia.
[3] Marine Systems Institute, Tallinn University of Technology, Akadeemia tee 21, Tallinn 12618, Estonia.

Following an earlier study of the stochastic properties of the Baltic Sea level variability, we present results from spectral analysis of sea level data at several of the Gulf of Finland tidal stations located on the Estonian and Russian coasts. Spectral analysis was performed on hourly data sets, with 5 to 20-year duration, and on corresponding atmospheric data from NCEP/NCAR reanalysis. The spectral analysis reveals marked differences between the sea

level spectra for different stations. There is a significant rise of energy toward the head of the Gulf of Finland in the frequency band of 0.5-1 cpd, which is likely related to the natural seiche mode for the Baltic Sea which has a period of about 27 hours. For the most part, the analysis of coherence and phase functions showed that sea level oscillations in the Gulf of Finland can be characterised as standing waves. Cross-spectral analysis between the atmospheric parameters (pressure and winds) and sea level gave insight to the forcing mechanisms of the Baltic Sea level variability. We found that sea level response to the atmospheric pressure changes does not follow the law of the inverted barometer. Actually, the modified relationship between the barometric pressure and sea level is determined by the limitation of the Baltic Sea area, which is a nearly closed basin. The frequency response of sea level to wind forcing in the Gulf of Finland has a resonant character over periods of 27-30 hours. The zonal wind was found to be a more important factor than the meridional wind.

18 May, 12:30 (W6-4923)

Sea level variability and trends from satellite altimetry and tide gauges in the eastern Baltic Sea

Josef Y. **Cherniawsky**[1], Evgueni A. Kulikov[2] and Oleg P. Nikitin[3]

[1] Fisheries & Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada. E-mail: cherniawskyj@dfo-mpo.gc.ca
[2] Shirshov Institute of Oceanology of the RAS, Moscow, Russia.
[3] State Oceanographic Institute, Moscow, Russia.

Sea level data from coastal tide gauges show strong variability over synoptic and longer time scales in the eastern Baltic Sea, where intense winter storms produce annual flooding in its coastal cities. Water transport through the Danish Straits affects the mean sea level, while some of the shorter-period variability is attributed to the excitation of characteristic wave modes in the Baltic Sea. We analyse data from satellite altimeters and tide gauge observations from several coastal stations in order to calculate and map monthly and annual statistics, power spectra and sea level trends over the past ~15 years. The implications of these calculations and the potential utility of near-real-time satellite altimeter data in the shallow seas for analyses and predictions of coastal flooding will also be discussed.

II. Modelling and forecasting of water level (Chair: E. Kulikov)

18 May, 14:30 Prof Nekrasov

18 May, 14:50 (W6-4602)

Influence of cyclone parameters upon the characteristics of storm surges in Saint Petersburg

Alexey V. Nekrasov and Stanislav D. **Martyanov**

Russian State Hydrometeorological University, 195196, Malookhtinsky Pr. 98, St. Petersburg, Russia. E-mail: martyanov-sd@rambler.ru

Formation of a storm surge by a cyclone moving to the east along the Gulf of Finland, which typically produces the most dangerous sea level oscillations in St. Petersburg, Russia, can be explained using a combination of a few individual *progressive waves*, arising, according to the concept of Lamb, at both sides of a cyclone and travelling in opposite directions in an idealised uniform channel. The resulting superposition of *forced* and *free* waves in the channel is also being taken into consideration. The character of these individual waves is determined (besides the cyclone dimensions and intensity) by: (a) cyclone propagation speed relative to the long wave speed and (b) displacement of the cyclone centre from the channel axis. The latter determines the position of a prevailing maximum of the effective external forcing and is closely related to the type of the initial disturbance, depending on whether it is produced mainly by wind stress, by pressure depression, or by both. A number of numerical experiments with this simplified conceptual model show that the obtained results are mostly consistent, at least qualitatively, with our primary assumptions. These results help to understand certain elements of the formation of storm surges in the Gulf of Finland and will hopefully assist in improving the flood forecasting system for St. Petersburg.

18 May, 15:20 (W6-4887)

Numerical study of wind-driven circulation in the Gulf of Finland with the Regional Ocean Modelling System (ROMS)

Andrey O. **Koch**[1] and Natalia A. Tikhonova[2]

[1] Department of Mathematics, Russian State Hydrometeorological University, Malookhtinsky pr. 98, St. Petersburg, 195196, Russia. E-mail: andrey_koch@mail.ru

[2] State Oceanographic Institute, Saint-Petersburg Branch, V.O., 23rd line 2A, St. Petersburg 199026, Russia.

A model of circulation in the Gulf of Finland, based on the Regional Oceanic Modelling System (ROMS), has been implemented with 1 km horizontal resolution to study the variability of sea level and currents over different time scales. This study was carried out for the years 1994 and 1999, when several inundations at locations in the eastern Gulf of Finland were observed during the fall, including the 6th largest inundation (in 1999) over more than 300 years of recorded history. The model reproduces accurately the wind-driven dynamics in the Gulf of Finland, verified through comparison with current velocities from moorings and SSH observations from coastal gauges and along-track satellite altimetry. The model also describes satisfactorily seasonal-scale variability in sea level and its modulation by intensified atmospheric activity in the autumn. For those dates when storm surges resulted in extremely high sea level rise at the mouth of Neva River and at some other locations, the model showed a similar pattern to the observed sea level and current velocity changes, thus encouraging the use and development of the ROMS "community code" for investigations of the Baltic Sea dynamics.

18 May, 16:00 (W6-4659)

Numerical modelling of the Baltic sea-level variability

Evgueni A. **Kulikov**[1] and Isaac I. Fine[2]

[1] P.P. Shirshov Institute of Oceanology, RAS, Moscow 117997, Russia, E-mail: kulikove@cnt.ru

[2] Heat and Mass Transfer Institute, NANB, 15, P. Brovka Str., Minsk 220072, Belarus.

This study aims to develop an effective numerical model of the Baltic Sea that can be used for multi-year simulations of wind-driven sea level variations in the Gulf of Finland. We present results from analyses of the observed and simulated statistical characteristics of sea-surface variability. The main purpose of the numerical experiments was to study the resonant sea-level response that is related to characteristic seiche modes in the Baltic Sea. A wind-driven 2D version of the Princeton Ocean Model (POM) has been developed and carefully tested for the Baltic Sea. Six-hourly data from NCEP/NCAR Reanalysis (surface wind and pressure) were used for forcing the model from 1990 to 2006. The computed spectra of simulated sea level variations show a prominent peak with a period of 27-29 hours, a well-known period of the natural seiche mode for the Baltic Sea. Cross-spectral analysis of the observed and simulated sea level records was carried out for Narva and Tallinn. A good agreement was found in the low frequency range of 0-1.5 cpd between the observed and simulated phase values. Phase lags between the stations along the coast of the Gulf of Finland were attributed to dissipative processes in the shallow areas of the gulf. We can, therefore, conclude that the dissipation parameters specified in the model are appropriate for simulations of the wind-driven circulation in the basin. The coherence between along-gulf sea level variations is frequency-dependent and its properties appear to be similar for the observed and model-simulated data. In particular, the frequency of zero coherence is the same for both data sets. The minimum coherence is at the frequency supporting a uninodal standing wave in the Gulf of Finland, with its nodal line located near Tallinn. It was found that for stations inside the Gulf of Finland, the sea level response for the "resonant' mode is stronger for the meridional winds.

18 May, 16:30 (W6-4976)

Model development for flood forecast improvement in the Netherlands

Martin Verlaan and Herman **Gerritsen**

Deltares/Delft Hydraulics, Delft, The Netherlands. E-mail: martin.verlaan@deltares.nl

In the Netherlands, the Storm Surge Warning Service (SVSD) is responsible for warning the coastal authorities in situations of high water threats. The time between warning for dangerous high water and the actual occurrence of high water is an important parameter in the planning of the response, e.g. decisions on closure of the storm surge

barriers, dike watch and potentially even an activation of an evacuation scenario (remember Katrina!). In view of this, SVSD aims to extend the time horizon of the water level forecasts in the near future, and make these forecasts for a dense distribution of locations ("stations") along the Dutch coast, instead of just the current five main stations (Vlissingen, Hoek van Holland, Den Helder, Harlingen and Delfzijl), which up to now are taken as representative for a specific coastal section. The present water level forecast model is not adequate for the above and needs to be replaced. A further SVSD objective is to forecast the wave conditions in parallel to the water level forecasts, for the same densely distributed coastal stations. The relevant parameters are the water level, the significant wave height, wave period and angle of wave attack on the coast. In the near future, SVSD will then be able to make predictions of the hydraulic loads on the local stretches of water defences that are under threat, to advise on focused response actions. The present paper discusses the new water level model grid and the approach to model calibration for tidal motion and storm surges. Varying grid size, domain decomposition and parallel computing are key features. A generic data assimilation environment with optimisation methods such as DUD, Powell and Simpson is used for parameter estimation and objective assessment of results. It is shown how the parameter estimation process can be structured effectively by some simple physically based assumptions. The proposed wave modelling consists of an outer model for calculating the deep water processes until roughly the 20 m depth contour, from which a wave model with full physics will calculate the wave processes from there towards the sea defences. In the near shore area, wave-induced currents are significant for the water level and flow forecasts, while in turn, water level and current variations are key inputs for the wave modelling. The same data assimilation environment has been used to assist the parameter estimation, analysing the effects of constraints, determining confidence bands, etc. Finally, some suggestions for intertwined flow and wave forecasting are discussed.

18 May, 17:00 (W6-4581)

Recent improvements in automated flood forecasting system for St. Petersburg

Konstantin A. **Klevannyy** and Suleiman-Mohammad W. Mostamandi

St.Petersburg Center of Hydrometeorology and Environmental Monitoring, 23 Linija VO, 2a, 199106, St. Petersburg, Russia.
E-mail: klevanny@x-users.ru

Storm surges from the Baltic Sea inundate St. Petersburg, which is located in the shallow end of the eastern Gulf of Finland, on average once per year. In the past, successful forecasts were directly related to proper understanding of the meteorological conditions and to correct forecasts of the western component of the wind over the Gulf of Finland. In the early 1960s, a one-dimensional model of the Baltic Sea was developed and used until 1997 as an additional tool in forecasting the threat of floods. In December 1999, a new and up-to-date automated forecasting system was installed at the North-West Hydrometeorological Service of Russia in St. Petersburg, as a result of two joint Netherlands-Russia projects that are headed by Dr. H. Gerritsen of WL/Delft Hydraulics. The new system is based on a two-dimensional model of the Baltic Sea developed with the CARDINAL modelling system and on weather forecasts provided by the HIRLAM atmospheric model of the SMHI. Forecasts of water flow through the Danish Straits, which can change the mean water level in the Baltic Sea by up to 1 m, are provided by BSH in Hamburg. The advance time of this system is 48 hours. The system is constantly being updated. Recent improvements include: a) a more refined model of the Baltic Sea with double horizontal resolution and b) twice as frequent access to the SMHI weather forecasts. While the first improvement had little effect, the second one resulted in a noticeable increase in the quality of the forecasts.