Intergovernmental Oceanographic Commission

Workshop Report No. 281

Workshop on Sea-Level Measurements in Hostile Conditions

Moscow, Russian Federation
13–15 March 2018

UNESCO

Intergovernmental Oceanographic Commission

Workshop Report No. 281

Workshop on Sea-Level Measurements in Hostile Conditions

Moscow, Russian Federation
13–15 March 2018

N.N. Zubov State Oceanographic Institute (SOI)
of Roshydromet

UNESCO 2018

IOC Workshop Reports, 281
Paris, April 2018
English and Russian*

For bibliographic purposes this document should be cited as follows:

Intergovernmental Oceanographic Commission. 2018. *Workshop on Sea-Level Measurements in Hostile Conditions, Moscow, Russian Federation, 13–15 March 2018*. IOC Workshop Reports, 281. Paris, UNESCO, pp.28. English/Russian.

Published in 2018
by the United Nations Educational,
Scientific and Cultural Organization
7, place de Fontenoy, 75352 Paris 07 SP

(IOC/2018/WR/281)

*Annexes in English only

TABLE OF CONTENTS

CONCLUSIONS AND RECOMMENDATIONS

1. BACKGROUND

The international workshop on Sea-level Measurements in Hostile Conditions was held from 13 to 15 March 2018 at the N.N. Zubov State Oceanographic Institute (SOI) of Roshydromet, Moscow, Russian Federation. The workshop was co-chaired by Dr Alexander Postnov (SOI) and Dr Laurent Testut (Laboratoire d'Etudes en Géophysique et Oceanographie Spatiales, LEGOS, France). The workshop was co-sponsored by the SOI and the Intergovernmental Oceanographic Commission (IOC) of UNESCO.

Sea level observations are needed for a number of scientific and practical applications. Such observations often need to be carried out in what can be characterized as harsh or hostile environmental conditions. A significant part of the seas on the planet are covered with ice on either a permanent or seasonal basis. Many of them, in addition, often experience storms, high waves and/or high tides. Biological/environmental/logistic factors as well as increasing requirements and expectations for performance can add to the challenges of operating a sea level measurement station in these conditions.

The topic of sea level measurements in hostile conditions was first addressed by the Global Sea Level Observing System (GLOSS) in 1988 at an IOC sponsored workshop in Bidston (UK) and a subsequent one in 1990 in Leningrad (former USSR). The topic has not been addressed since and the Group of Experts of GLOSS recommended at their 15th Session (8-9 July 2017, New York, USA) to revisit the issues and to convene a new workshop which would review inter alia new measurement systems, instrument-protecting technologies (e.g. robust mountings), data transmission methods and Global Navigation Satellite System (GNSS) at tide gauges, and summarize the experiences gained.

Experts from 10 countries (Australia, Canada, Finland, France, Germany, Norway, Russian Federation, Sweden, United Kingdom, and USA) attended the workshop and made a total of 19 oral presentations and 4 posters. As required, the presentations and discussions at the workshop focused on problems of sea level measurements in regions exposed to several different kinds of adverse environmental impact. Such regions primarily include the coastal zones of the polar regions, as well as the seas covered with ice during winter. The workshop addressed the impacts of extreme events, such as major storms and high wave conditions. The workshop also discussed new measurement systems and instrument protection technologies, together with methods for sustainable transmission of observational data.

All presentations are available from:
http://www.ioc-unesco.org/hostile-conditions-sea-level-workshop

2. GENERAL FINDINGS

- The workshop noted the achievements since the Workshops (1988, 1990) in lower power requirements, global communication, operational methodology, which demonstrates encouraging progress in many aspects of this area of work.

- The workshop noted the decline in the observing network in the Arctic and notably along the Russian Coast and stated the need for a plan for the reorganization and re-equipment of a network of sea level observations in the Arctic.

- The workshop had extensive discussion on advantages and disadvantages of the available sea level measurement technologies. While conventional float gauges in heated stilling wells are used by some groups in ice areas (e.g. Canada and Antarctic Peninsula), they will in general likely be more difficult to install and operate in these areas than alternative methods (i.e. pressure gauges). Several participants reported on the use of radar-based sea level sensors in polar regions, although it is recognized that additional research and/or technological solutions are required in ice impacted seas.

- The workshop reiterated in line with the GLOSS Implementation Plan (2012): (i) that even under adverse conditions automatic sea level gauges should provide sea level accuracy within 1 cm and with continuity and consistency of observation series; and (ii) prior to introduction of a new gauge type at an observation site, parallel measurements from existing and new equipment should be carried out for a minimum of one year to ensure consistency.

- The workshop stressed the need to make maximum use of station equipment for multiple applications.

- The workshop further stressed that there is not a single approach or design (i.e. sensors, power, communications, etc.) that works at all locations and addresses all hostile conditions. One must select the appropriate technologies when designing a station taking into account the advantages and disadvantages of each technology.

- The workshop acknowledged that the cost of establishing a station should be based on well-defined user requirements (including the cost of losing data in a crisis situation), and a balance between the initial investment and the long term maintenance costs. The accumulated costs over the lifetime of a sea level station are mainly due to steel mountings, infrastructure and maintenance. If steel mountings and infrastructure are robust and designed for long life, this investment can be amortised over a long time period. It is recognized that the cost of replacing an inexpensive station multiple times may be less in the long run than trying to design a station for extreme conditions. (Again this assumes the operating institution and users can “afford” data loses even in a critical situation).

- The workshop encouraged data archeology and data rescue worldwide and especially concerning observations taken in regions with hostile environments.

- The workshop acknowledged that local engagement could be beneficial in facilitating minor repairs, preventing vandalism, weekly checking of operation and data flow.

- The workshop acknowledged that national regulatory standards and laws may demand mandatory testing of gauges in the laboratory prior to installation.

- The workshop recommended that quality assurance/quality control for sea level data should be standardized. The workshop noted that several agencies have developed automated procedures for quality checking/flagging real time data. The workshop noted that a draft (GLOSS) manual addressing this topic has been developed and recommended it be finalized (with the inclusion of a chapter on quality checking real time sea level observations) prior to the next GLOSS Group of Experts meeting.

The workshop made a number of recommendations pertaining to both general issues and also research and development issues.

3. RECOMMENDATIONS – GENERAL

- Define requirements and work closely with the users – identify users’ needs, conduct customer surveys, monitor, validate and implement user feedback.

- A sea level station should have multiple sensors and use different technologies are encouraged.

- Inexpensive sensors can provide high frequency observations in coastal areas for monitoring tsunamis, meteo-tsunamis, seiches, etc.

- Design redundancy in tide gauges is recommended in remote areas, including redundant power supplies (e.g. battery, mains, solar, wind), together with redundancy in tele-communications.

- Real time two-way communication for operational uses and fault identification and station maintenance/upgrade can be highly useful.

- Datum control for benchmark and sensor stability is needed for mean sea level studies (e.g. for multiple/optimal use of gauges used for tsunami monitoring to justify equipment investment).

- Tide gauges must be calibrated in accordance with their operational standards taking into account manufacturers' recommendations (and, for example, including determination of the zero point offsets of radar gauges).

- Tide gauges should be connected to benchmarks and co-located with GNSS as required by the GLOSS standards.

- The choice of automatic tide gauge (as far as possible) in polar regions depends on local conditions. In some cases, normal installation and maintenance procedures can be followed. In other situations, various kinds of pressure gauges with ancillary datum control methods may be used (e.g. use of temporary gauges in summer and/or GNSS methods such as GNSS buoys).

- General guidance on aspects of site selection, and tide gauge operations should follow advice in the IOC manuals.

- As far as possible, tide gauge siting and design should be made to avoid potential damage due to harbor construction, and areas subject to impact from ship operations.

- Where gauges are required to monitor tsunamis and large storm surges, there is advantage in having the sensor as high as possible above sea level.

4. RECOMMENDATIONS – RESEARCH AND DEVELOPMENT ISSUES

The workshop identified a number of areas where further research and/or technical development is needed:

- Effects of waves on sea level measurements must be researched in greater detail (e.g. either mechanical or temporal filtering).

- Further integration of GNSS and tide gauges technology should be explored/welcomed.

- Further exploration is required of "tides under the ice" technology for remote areas i.e. where there is no or limited physical infrastructure.

- If conditions are too difficult for conventional observing methods, novel and new techniques (e.g. GNSS reflectometry) should be investigated.

5. REFERENCES

- Workshop on sea-level measurements in hostile conditions, Bidston, UK, 28–31 March 1988. Summary report and submitted papers. IOC Workshop Report No. 54. (English only)

- Workshop on Sea-Level Measurements in Antarctica, Leningrad, USSR, 28-31 May 1990. IOC Workshop Report No. 69 and Supplement. (English only)

- The Global Sea-Level Observing System (GLOSS): implementation plan, 2012. IOC Technical series No. 100. (English only)

- Manual on Sea Level Measurement and Interpretation. IOC Manuals and Guides No. 14:
  - Volume I: Basic procedures (English/French/Spanish/Russian/Portuguese)
  - Volume II: Emerging technologies (English only)
  - Volume III: Reappraisals and recommendations as of the year 2000 (English only)
  - Volume IV: An Update to 2006 (English/Arabic)
  - Volume V: Radar gauges (English/French/Spanish)

СЕМИНАР ПО ИЗМЕРЕНИЮ УРОВНЯ МОРЯ В НЕБЛАГОПРИЯТНЫХ УСЛОВИЯХ ОКРУЖАЮЩЕЙ СРЕДЫ

Государственный океанографический институт,

Москва, Российская Федерация, 13-15 марта 2018 г.

ВЫВОДЫ И РЕКОМЕНДАЦИИ

1. ИСТОРИЯ ВОПРОСА

В период 13-15 марта 2018 г. в Москве, в Государственном океанографическом институте им. Н.Н. Зубова Росгидромета проходил международный семинар по измерениям уровня моря в неблагоприятных условиях окружающей среды. Сопредседателями семинара были д-р Александр Постнов (ГОИН) и д-р Лоран Тестю (Лаборатория геофизических и океанологических исследований, Франция). Семинар финансировался совместно ГОИН и Межправительственной океанографической комиссией ЮНЕСКО.

Наблюдения за уровнем моря необходимы для ряда научных и практических применений. Такие наблюдения часто приходится проводить в неблагоприятных условиях окружающей среды. Значительная часть морей на планете покрыта льдом либо постоянно, либо в отдельные сезоны года. На многих из них, кроме того, часто наблюдаются штормовые волны и/или высокие приливы. Дополнительные проблемы в таких условиях создают биологические/экологические/логистические факторы, а также растущие требования к качеству измерений.

К теме измерения уровня моря в неблагоприятных условиях впервые обратились в рамках Глобальной системы наблюдений за уровнем моря (ГЛОСС) в 1988 г. на организованном МОК семинаре в Бидстоне (Великобритания) и последовавшем за ним в 1990 г. семинаре в Ленинграде (СССР). С тех пор к этой теме не возвращались и Группа экспертов ГЛОСС на своей 15-й сессии (8-9 июля 2017г., Нью-Йорк, США) рекомендовала вновь рассмотреть этот вопрос и собрать новый семинар, который, среди прочего, рассмотрел бы новые системы измерений, технологии защиты средств измерения (например, путем их надежной установки), методы передачи данных и установку GNSS на измерителях уровня моря и обобщить накопленный в этой области опыт.

В работе семинара приняли участие эксперты из 10 стран (Австралия, Великобритания, Германия, Канада, Норвегия, Российская Федерация, США, Финляндия, Франция и Швеция), которые представили в общей сложности 19 устных сообщений и 4 постеров. Как и требовалось, в презентациях и обсуждениях, на семинаре основное внимание было уделено проблемам измерений уровня моря в регионах, подверженных неблагоприятному воздействию окружающей среды. К таким районам, в первую очередь, относятся прибрежные зоны полярных областей, а также моря, покрытые льдом в холодное время года. Семинар рассмотрел последствия экстремальных явлений, таких как сильные шторма и интенсивное волнение. Участники семинара обсудили также новые системы измерения и технологии защиты средств измерения, а также методы надежной передачи данных наблюдений.

Все презентации представлены на сайте http://www.ioc-unesco.org/hostile-conditions-sea-level-workshop.

2. ОСНОВНЫЕ РЕЗУЛЬТАТЫ

- Участники семинара отметили достижения, полученные со времени проведения семинаров (1988, 1990), в части уменьшения потребности оборудования в электроэнергии, технологий глобальной телекоммуникации, методов оперативного использования данных, которые демонстрируют обнадеживающий прогресс во многих аспектах этой деятельности.

- Участники семинара отметили сокращение наблюдательной сети в Арктике и, в особенности, вдоль побережья России и констатировали необходимость разработки плана реорганизации и переоснащения сети наблюдений за уровнем моря в Арктике.

- Во время семинара состоялось интенсивное обсуждение преимуществ и недостатков имеющихся технологий измерения уровня моря. Хотя в некоторых регионах со льдом (например, в Канаде и Антарктике) используются поплавковые измерители уровня в отапливаемых колодцах, их, по-видимому, в большинстве случаев будет труднее устанавливать и эксплуатировать в этих районах, чем альтернативные (т.е. гидростатические) датчики. Несколько участников сообщили об использовании ими в полярных районах радиолокационных датчиков, хотя следует признать, что для подверженных воздействию льда морей необходимо проведение дополнительных исследований и/или выработка новых технологических решений.

- В соответствии с Планом реализации ГЛОСС (2012 г.) семинар подтвердил, что: (i) даже в неблагоприятных условиях автоматические датчики уровня моря должны обеспечивать точность измерения не хуже 1 см при обеспечении непрерывности и однородности рядов наблюдений и (ii) в целях обеспечения однородности рядов до ввода в эксплуатацию в конкретном месте измерителей уровня нового типа необходимо выполнить их предварительное тестирование с проведением параллельных измерений с помощью имеющихся и новых средств измерения в течение как минимум одного года.

- Участники семинара подчеркнули необходимость использования оборудования уровнемерных станций для решения максимально широкого круга задач.

- Было далее подчеркнуто, что не существует единого подхода/технического решения (в части датчиков, электропитания, передачи данных и т.п.), который был бы применим во всех точках и противодействовал воздействию всех видов неблагоприятных условий. При проектировании каждой станции необходимо выбирать подходящие технологии с учетом положительных и отрицательных свойств каждой из них.

- Было признано, что оценка стоимости установки станции должна основываться на четко определенных требованиях пользователей (включая возможные затраты при потере данных в кризисной ситуации) и на балансе между первоначальными инвестициями и долгосрочными эксплуатационными расходами. Основной вклад в суммарную (за весь период эксплуатации) стоимость уровнемерной станции вносит стоимость стальных конструкций, инфраструктуры и обслуживания. Если стальные конструкции и инфраструктура мало подвержены старению и рассчитаны на длительную эксплуатацию, инвестиции амортизируются в течение длительного периода времени. Признано, что многократная замена недорогой станции может оказаться дешевле в долгосрочной перспективе, чем попытка спроектировать станцию для экстремальных условий. (Опять-таки, это предполагает, что можно допустить потерю данных даже в критической ситуации).

- Участники семинара призвали способствовать работам по археологии и спасению данных наблюдений во всем мире и, в особенности, в районах с неблагоприятными условиями окружающей среды.

- Участники семинара признали, что взаимодействие с местными властями и организациями может быть полезно для упрощения проведения небольшого ремонта, предотвращения вандализма, для еженедельной проверки работы оборудования и потока данных.

- Участники семинара признали, что в соответствии с требованиями национальных нормативных документов и законодательства до установки измерителей уровня моря может потребоваться их предварительная проверка в лабораторных условиях.

- Участники семинара рекомендовали, чтобы процедуры по обеспечению и контролю качества данных были стандартизованы. Было отмечено, что в некоторых агентствах были разработаны автоматизированные процедуры контроля и маркировки качества данных в реальном режиме времени. Участники семинара отметили, что был разработан проект руководства (ГЛОСС), относящегося к этой проблеме, и рекомендовали, чтобы его подготовка была завершена (с включением в него главы о контроле качества данных наблюдения за уровнем моря в режиме реального времени) до следующего совещания Группы экспертов ГЛОСС.

Участники семинара сделали ряд рекомендаций, относящихся как к проблемам общего характера, так и к проведению НИОКР.

3. РЕКОМЕНДАЦИИ ОБЩЕГО ХАРАКТЕРА

- Необходимо выявлять требования пользователей и непосредственно работать с ними – определять их потребности, проводить опросы, мониторинг, осуществлять оценку и внедрение предложений пользователей.

- Необходимо иметь на уровнемерных станциях несколько датчиков и способствовать использованию различных технологий.

- Высокочастотные наблюдения в прибрежных районах в целях мониторинга цунами, метео-цунами, сейшей могут обеспечиваться с помощью недорогих датчиков.

- В отдаленных районах рекомендуется предусматривать наличие резервного оборудования: резервных источников питания, использование различных видов энергии (например, аккумуляторов, электросети, солнечной энергии, ветра) вместе с резервными средствами связи.

- Весьма полезно наличие двусторонней связи для оперативного использования, выявления неисправностей и обслуживания станции и обновления ее программного обеспечения.

- Для обеспечения возможности определения среднего уровня моря (например, для многоцелевого/оптимального использования уровнемеров, предназначенных для мониторинга цунами в целях оправдания инвестиций в оборудование) необходим контроль уровня нуля относительно репера и стабильности датчиков.

- Измерители уровня моря должны быть откалиброваны в соответствии с эксплуатационными требованиями с учетом рекомендаций производителей (и включая, например, определение смещения нуля радара).

- Измерители уровня моря должны быть привязаны к реперам и совмещены с GNSS в соответствии со стандартами ГЛОСС.

- Выбор типа автоматического измерителя уровня моря (насколько это возможно) в полярных регионах зависит от местных условий. В некоторых случаях могут применяться обычные процедуры установки и обслуживания оборудования. В других ситуациях могут использоваться различные виды гидростатических датчиков с использованием вспомогательных методов контроля нуля поста (например, использование измерителей уровня, установленных временно, на летний период, и/или методов GNSS, таких как буев GNSS).

- В целом, при выборе места установки измерителей уровня моря и их эксплуатации необходимо следовать рекомендациям, содержащимся в руководствах МОК.

- По возможности следует выбирать места расположения и конструкцию измерителей уровня моря таким образом, чтобы предотвратить возможность их повреждения при проведении в гавани строительных работ, а также избегать мест, подверженных воздействию судоходства.

- В случаях, когда датчики предназначены для мониторинга цунами и крупных штормовых нагонов, целесообразно устанавливать их максимально высоко над уровнем моря.

4. РЕКОМЕНДАЦИИ ПО ПРОВЕДЕНИЮ НИОКР

Участники семинара определили ряд областей, в которых необходимо дальнейшее проведение исследований и/или технических разработок:

- Более подробно должно быть исследовано влияние волнения на измерения уровня моря (например, с помощью механической или временной фильтрации).
- Необходимо изучить возможность и приветствовать дальнейшую интеграцию технологий GNSS и измерения уровня моря.
- Требуются дальнейшие исследования в области технологии определения колебаний уровня моря подо льдом для отдаленных районов, т.е. там, где отсутствует или плохо развита физическая инфраструктура.
- Если условия слишком сложны для применения обычных методов, необходимо изучить возможность применения новых методов (например, рефлектометрии GNSS).

5. ССЫЛКИ

- Workshop on sea-level measurements in hostile conditions, Bidston, UK, 28-31 March 1988. Summary report and submitted papers. IOC Workshop Report No. 54. (English only)

- Workshop on Sea-Level Measurements in Antarctica, Leningrad, USSR, 28-31 May 1990. IOC Workshop Report No. 69 and Supplement. (English only)

- The Global Sea-Level Observing System (GLOSS): implementation plan, 2012. IOC Technical series No. 100. (English only)

- Manual on Sea Level Measurement and Interpretation. IOC Manuals and Guides No. 14 (*Руководство по измерению уровня моря и интерпретации результатов. Справочники и руководства МОК № 14*):

    - Volume I: Basic procedures (English/French/Spanish/Russian/Portuguese)

    - Volume II: Emerging technologies (English only)

    - Volume III: Reappraisals and recommendations as of the year 2000 (English only)

    - Volume IV: An Update to 2006 (English/Arabic)

    - Volume V: Radar gauges (English/French/Spanish)

ANNEX I

PROGRAMME

Tuesday, 13 March 2018	
10:00 – 10:30	Opening of workshop. Introduction of participants Welcome from: — Yury Sychev, Director of the State Oceanographic Institute — Valery Martyschenko, Representative of Roshydromet — Alexander Postnov, Vice Chair of IOC — Thorkild Aarup, IOC, Technical Secretary GLOSS
10:30 – 11:00	Working arrangements and logistics *Vladimir M. Gruzinov (Organizing Committee)*
11:00 – 11:30	Election of Chairperson and adoption of workshop agenda *Thorkild Aarup (IOC Secretariat)*
11:30 – 12:00	Coffee break
12:00 – 12:30	The need for reliable tide gauges with datum control *Philip Woodworth (United Kingdom)*
12:30 – 13:00	Measuring sea level oscillations in the Arctic Seas of the Russian Federation *Igor Ashik (Russia)*
13:00 – 13:30	Practice of sea level oscillations measurements in the inshore zone *Peter Kovalev, D. Kovalev*
13:30 – 15:00	Lunch
15:00 – 15:30	The French tide gauges network in Southern Ocean and Antarctica: Conclusions and recommendations after 25 years of experience *Laurent Testut, P. Téchiné, M. Calzas, A. Guillot, C. Guillerm, C. Brachet, C. Drezen, L. Fichen and T. Donal (France)*
15:30 – 16:00	Russia's Participation in GLOSS *Oleg Nikitin (Russia)*
16:00 – 16:30	Measuring sea level data under various conditions *Anna v. Gyldenfeldt (Germany)*
16:30 – 17:00	Coffee break
17:00 – 17:30	Collection, accumulation and quality control of GLOSS sea level data intended for submission to the International sea level data centers *Alexander Vorontsov (Russia)*
17:30 – 18:00	Challenges of obtaining timely, accurate and reliable water level observations across the United States diverse coastal environments *Richard Edwing, Chung–Chu Teng, Robert Heitsenrether (USA)*
Wednesday, 14 March 2018	
10:00 – 10:30	Stilling well measurements in coast of Finland *Katri Leinonen, Pertti Jämsén (Finland)*
10:30 – 11:00	Challenges related to sea-level measurements at Jan Mayen *Egil Sølvberg and Aksel Voldsund (Norway)*

11:00 – 11:30	Sea level variability on the Russian coast of the inland seas: measurements and analysis *Evgenii Kulikov, Igor Medvedev (Russia)*
11:30 – 12:00	Coffee break
12:00 – 12:30	Sea level trends in the Commonwealth Bay over the last century from historical data *Laurent Testut, B. Legrésy, C. Watson, R. Coleman, H. Brolsma, R. Handsworth (France)*
12:30 – 13:00	Mounting and operating automatic sea level measuring systems in hostile environment conditions *Alexey Paley, Leonid Ostroumov, Michail Ostroumov (Russia)*
13:00 – 13:30	Experience from the Pacific Sea Level Monitoring Project (PSLMP) *Jeff Aquilina (Australia)*
13:30 – 15:00	Lunch
15:00 – 15:30	The UK South Atlantic tide gauge network: remote sea level measurement technology developments *Peter Foden, Philip Woodworth (United Kingdom)*
15:30 – 16:00	Coffee break
16:00 – 16:30	Canadian water level gauging strategies for harsh environmental conditions: *cold, ice, large tide range and heavy sea state* *Philip MacAulay et al. (Canada, via Skype)*
16:30 – 17:00	Difficulties for tide gauge in the tropics *Jerard Jardin (Hawaii, USA,* presented by *Thorkild Aarup)*
17:00 – 17:30	Upgrade of the Swedish sea level network *Thomas Hammarklint, Christian Kark (Sweden)*
17:30 – 18:00	Australian Antarctic tide gauges *B. K. Galton–Fenzi,, B. Legresy, C. Watson, M. King, J. French and D. Libaros (Australia, presented by Laurent Testut)*
Thursday, 15 March 2018	
10:00 – 10:30	Poster presentations: questions and discussion
10:30 – 11:00	Workshop recommendations
11:30 – 12:00	Coffee break
12:00 – 13:30	Workshop recommendations (continued)
13:30 – 13:45	Closure of the workshop

Poster Presentations	
M. Calzas (CNRS, France)	Development of devices for measuring sea level in hostile environment: tide sensor for coastal and deep sea area, tools for referencing tide sensor and to measure sea geoid: GNSS Buoy (for static and towed use)
O.B. Hansen and P. Knudsen (Denmark)	Tide Gauge Operations in Greenland – Technological Aspects
M. Kulikov, I. Medvedev, E. Kulikov, A. Kondrin (Russia)	Seasonal variability of tides and storm surges in the Arctic seas of Russia
D. Metters (Australia)	Storm–tide gauge operations: Experiences from Queensland

ANNEX II

LIST OF PARTICIPANTS

WORKSHOP CO-CHAIRS

Alexander POSTNOV
Deputy Director
State Oceanographic Institute
6, Kropotkinskiy Lane
Moscow 119034
Russian Federation
Email: alexander.postnov@mail.ru

Laurent TESTUT
Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
18, av. Edouard Belin
Toulouse 31401 cédex 9
France
Email: laurent.testut@legos.obs-mip.fr

PARTICIPANTS

Jeff AQUILINA
Observing Operations Hub - Adelaide
Australian Bureau of Meteorology
Unit 1, 5-9 Marker Ave,
GPO Box 1289
Marleston South Australia 5033
Australia
Email: jeff.aquilina@bom.gov.au

Igor ASHIK
Head, Oceanology Department
Arctic and Antarctic Research Institute
38 Bering Street
Saint Petersburg 199397
Russian Federation
Email: ashik@aari.nw.ru

Michel CALZAS
Research Engineer
UPS855 Division technique de l'INSU (DT INSU)
Institut national des sciences de l'Univers - CNRS
Plouzane 29280
France
Email: Michel.CALZAS@cnrs.fr

Richard EDWING
Director
NOAA/National Ocean Service
NOAA Center for Operational Oceanographic Products and Services (CO-OPS)
1305 East West Highway, Room 6650
Silver Spring Maryland 20910
United States
Email: richard.edwing@noaa.gov

Vladimir GRUZINOV
Deputy Director
State Oceanographic Institute
6 Kropotkinsky Lane
Moscow 119034
Russian Federation
Email: adm@oceanography.ru

Thomas HAMMARKLINT
Oceanographer – Information
Sveriges meteorologiska ochydrologiska institut
Folkborgsvägen 1
Norrköping SE-601 76
Sweden
Email: Thomas.Hammarklint@smhi.se

Pertti JÄMSÉN
Finnish Meteorological Institute
Erik Palménin aukio 1, FI-00560 HELSINKI
P.O. BOX 503
Helsinki FIN-00101
Finland
Email: pertti.jamsen@fmi.fi

Christian KARK
Swedish Maritime Administration
Östra Promenaden 7
Norrköping S-601 78
Sweden
Email: christian.kark@sjofartsverket.se

Alexander KORSHENKO
State Oceanographic Institute
6 Kropotkinsky Lane
Moscow 119034
Russian Federation
Email: Korshenko58@mail.ru

Peter KOVALEV
Leading Researcher, Laboratory of wave dynamics and coastal currents
Institute of Marine Geology and Geohysics FEB RAS
Yuzhno-Sakhalinsk Sakhalin 693022
Russian Federation
Email: kovalev_dp@hotmail.com

Evgueni KULIKOV
Head of the Tsunami Lab
P.P.Shirshov Institute of Oceanology of Russian Academy of Sciences
36, Nahimovski prospect
Moscow 117997
Russian Federation
Email: kulikove@gmail.com

Mikhail KULIKOV
Junior researcher of the Tsunami Lab
P.P.Shirshov Institute of Oceanology of Russian Academy of Sciences
36, Nahimovski prospect
Moscow 117997
Russian Federation
Email: meksonesk@gmail.com

Katri LEINONEN
Finnish Meteorological Institute
Erik Palménin aukio 1, FI-00560
HELSINKI
P.O. BOX 503
Helsinki FIN-00101
Finland
Email: katri.leinonen@fmi.fi

Phillip MACAULAY
Head Tidal Section Atlantic Canadian Hydrographic Service
Department of Fisheries and Oceans Canada
Canadian Hydrographic Service
Dartmouth B2Y 4A2
Canada
Email: phillip.macaulay@dfo-mpo.gc.ca

Sergey MARTYNOV
Federal Service for Hydrometeorology and Environmental Monitoring, Moscow
Novovagankovsky Per., 12
Moscow 123995
Russian Federation
Email: s.martinov@meteorf.ru

Valery MARTYSCHENKO
Deputy Director General
Federal Service for Hydrometeorology and Environmental Monitoring, Moscow
Novovagankovsky Per., 12
Moscow 123995
Russian Federation
Email: v.martishenko@meteorf.ru

Igor MEDVEDEV
Senior Researcher of the Tsunami Lab
P.P.Shirshov Institute of Oceanology of Russian Academy of Sciences
36, Nahimovski prospect
Moscow 117997
Russian Federation
Email: medvedev@ocean.ru

Vasiliy MELNIKOV
P.P.Shirshov Institute of Oceanology of Russian Academy of Sciences
36, Nahimovski prospect
Moscow 117997
Russian Federation
Email: vmelnikov@ocean.ru

Oleg NIKITIN
State Oceanographic Institute
6 Kropotkinsky Lane
Moscow 119034
Russian Federation
Email: opnikitin@mail.ru

Leonid OSTROUMOV
Head of Lab, State Oceanographic Institute
6 Kropotkinsky Lane
Moscow 119034
Russian Federation
Email: ostleonid@yandex.ru

Mikhail OSTROUMOV
State Oceanographic Institute
6 Kropotkinsky Lane
Moscow 119034
Russian Federation
Email: ostmike@mail.ru

Valeriy OSTROUMOV
State Oceanographic Institute
6 Kropotkinsky Lane
Moscow 119034
Russian Federation
Email: vostroumov@mail.ru

Lyubov OSTROUMOVA
State Oceanographic Institute
6 Kropotkinsky Lane
Moscow 119034
Russian Federation
Email: Lostroumova@mail.ru

Alexey PALEY
State Oceanographic Institute
6 Kropotkinsky Lane
Moscow 119034
Russian Federation
Email: a_paley@mail.ru

Vladimir SOKOLOV
State Oceanographic Institute
6 Kropotkinsky Lane
Moscow 119034
Russian Federation
Email: vasokolov@inbox.ru

Egil SØLVBERG
Hydrographic Service
Norwegian Mapping Authority, Hønefoss
Sb15
Honefoss 3507
Norway
Email: Egil.Solvberg@kartverket.no

Yury SYCHEV
Director
State Oceanographic Institute
6 Kropotkinsky Lane
Moscow 119034
Russian Federation
Email: yury.sychev@gmail.com

Irina VISHNEVSKAYA
State Oceanographic Institute
6 Kropotkinsky Lane
Moscow 119034
Russian Federation
Email: goin@bk.ru

Aksel VOLDSUND
Hydrographic Service
Norwegian Mapping Authority, Hønefoss
Sb15
Honefoss 3507
Norway
Email: Aksel.Voldsund@kartverket.no

Anna VON GYLDENFELDT
Marine Sciences
Bundesamt fuer Seeschifffahrt und
Hydrographie
(Federal Maritime and Hydrographic
Agency)
Bernhard-Nocht Straße 78
Hamburg 20359
Germany
Email: anna.gyldenfeldt@bsh.de

Alexander VORONTSOV
Head of Lab,
National Ocean Data Centre
All-Russian Research Institute
Hydrometeorological Information -
World Data Center, Obninsk
6, Koroleva Street
Obninsk Kaluga region, 249020
Russian Federation
Email: vorv@meteo.ru

Philip WOODWORTH
Physical Oceanographer
National Oceanography Centre, Natural
Environment Research Council
Joseph Proudman Building
6 Brownlow Street
Liverpool L3 5DA
United Kingdom
Email: plw@noc.ac.uk

IOC/UNESCO SECRETARIAT

Thorkild AARUP
Head Tsunami Unit,
Technical Secretary of GLOSS
Intergovernmental Oceanographic
Commission of UNESCO
7, place de Fontenoy
Paris cedex 07 75732
France
Email: t.aarup@unesco.org

ANNEX III

WORKSHOP GROUP PHOTO

ANNEX IV

ABSTRACTS

Tuesday, 13 March 2018

The need for reliable tide gauges with datum control

Philip Woodworth
National Oceanography Centre, Liverpool, UK

Many types of tide gauge are operated around the world. Some of them are conventional float and stilling well devices, while others employ more modern acoustic, pressure or radar technology. They are used for many different practical purposes (notably harbour operations or flood warning) as well as for science.

The most challenging aspect of a tide gauge is to with datum control. The various editions of the IOC manual on sea level measurements and interpretation demonstrate how sea levels recorded by a gauge can be expressed relative to a reference level marked on the device (sometimes called a Contact Point) and thereby via local levelling relative to the height of benchmarks on the nearby land. As a result, one obtains data sets of Relative Sea Level (RSL) change (i.e. relative to the land) which can be used as time series of Mean Sea Level (MSL) in many areas of science (geology, oceanography etc.) and most obviously in studies of sea level rise due to climate change.

One problem we are faced with as a community is that operators are often reluctant to put in the required work in order to calibrate the heights recorded by the gauge and to perform the necessary local levelling so as to relate the sea levels to land benchmarks. One reason is because their main interests are in topics such as tsunami detection or storm surge monitoring, for which datum control is not essential. It is, however, a waste of a potentially valuable resource for MSL studies. As examples, one can point to the many records available from the IOC Sea Level Station Monitoring Facility (SLSMF, http://www.ioc-sealevelmonitoring.org/) which are admirably available in real-time but have no datum control whatsoever.

A second problem relates to the need for MSL records from high latitudes for inclusion in studies of climate change (e.g. those of the Intergovernmental Panel on Climate Change). The presence of ice may preclude the use of some types of tide gauge (e.g. radar) and so pressure gauges are to be preferred. However, pressure gauges are known to have instrumental drift and so it may not be possible to provide the same sort of year-round datum control as for gauges elsewhere. In these cases, it may be adequate to employ temporary gauges (e.g. radar or even tide pole) in summer months alongside the pressure gauges in order to relate the measurements to land benchmarks. Where it is impossible to install normal benchmarks, then it might be feasible to consider datum control in summer months using GNSS.

A final set of problems to be mentioned are to with waves. Most obviously, waves can inflict major damage on equipment installed at the coast (e.g. at Southern Ocean islands), with implications for the use of gauges that are least vulnerable. Waves are known to introduce a negative bias into measurements by some tide gauges (e.g. float gauges or bubbler pressure systems). However, the effect can usually be limited by good design (see the IOC manuals). Experience with radar gauges has shown that waves can have a much larger effect on the measurements (both negatively and positively depending on the equipment), leading to the need for high-rate sampling (IOC, 2016). Waves can also result in wave setup that can contribute to the recorded sea level measurements; this aspect is common to all types of gauge and can usually be reduced by suitable positioning of the equipment.

These aspects will be discussed in this talk, with the aim of encouraging long-term measurements of MSL on all coastlines and at all latitudes.

References

IOC. 2016. Manual on Sea-level Measurements and Interpretation, Volume V: Radar Gauges. Paris, Intergovernmental Oceanographic Commission of UNESCO. 104pp. (IOC Manuals and Guides No.14, vol. V; JCOMM Technical Report No. 89).
Available from http://unesdoc.unesco.org/images/0024/002469/246981E.pdf which includes a Supplement: Practical Experiences.

Measurements of the sea level in the Arctic seas of Russia and its long-term variability

I.M. Ashik
Arctic and Antarctic Research Institute,
St. Petersburg, Russia

Sea level, being an integral indicator of hydrometeorological processes over a wide space-time range, allows one to assess the direction and intensity of changes in the state of natural conditions of different scale: from synoptic to climatic. Large-scale long-term changes in the position of mean sea level have a significant impact on economic activity in the coastal regions of the seas, on their coasts and in estuaries of rivers. Especially close attention to the problem of modern changes in the position of the middle level of the Arctic seas was manifested in the late XX - early XXI century. In these years, there was a widespread significant increase in the level in Arctic seas, leading to a sharp intensification of the processes of destruction of the coast and the retreat of the coastline. An assessment of the long-term variability of the position of the average level of the Arctic seas, the identification of the main factors affecting this variability, and the determination of the degree of their influence is an important complex scientific problem of direct applied importance.

Practice of sea level oscillations measurements in the inshore zone

Peter D. Kovalev[1], Dmitry P. Kovalev[1]
[1] *Institute of Marine Geology and Geophysics Far Eastern Branch Russian Academy of Science,*
Yuzhno-Sakhalinsk, Russia

The possibility of developing the continental shelf, including the hostile Arctic, largely depends on the wave regime of a specific sea area. Examples of developments include exploratory drilling and production of hydrocarbons on the shelf, construction of underwater pipelines with shore access and coastal engineering facilities, and near shore fishing. There are several types of waves that can pose a serious threat to coastal infrastructure and engineering facilities in the coastal zone, so a preliminary study of the wave regime in the area is necessary.

In this study autonomous bottom recorders for measuring sea-level fluctuations have been considered. Devices were designed and manufactured in Russia and include models ARV14, ARV-T, ARV-A and a cable system. Their main characteristics, advantages and disadvantages are given and comparison with foreign analogues is made. The problems of sea level discretization and recalculation of fluctuations of pressure into surface waves are considered.

The main types of waves that determine safety in the coastal zone are considered and examples of recording such waves are given. Storm surges pose a threat as a rise in sea level of even just half a meter is considered dangerous. Against the background of storm surges, the impact of wind waves and swell significantly increases.

Seiches also play an important role in the dynamics of bays and coves, and have a significant impact on the working conditions of ports located on the coast and other industrial facilities. For most bays, the resonance periods of seiches are close to the characteristic periods of tsunami waves, and as a result a tsunami manifests itself in these bays primarily as a sharp increase in the wave's amplitude.

In the coastal zone and on the shelf, infragravity waves can be generated, which are the result of the nonlinear interaction of wind waves and swell and are responsible for the destruction of the shores. Infragravity waves promote the generation of harbor oscillations - strong reciprocating movements of water in open bays, which can lead to collisions of vessels with piers and other ships, breaking of moorings and the disturbance of loading and unloading operations.

Upgrade of the Swedish sea level network

Thomas Hammarklint, Christian Kark
Swedish Maritime Administration, Gothenburg
Sweden

The Swedish seas are heavily subjected to severe conditions, especially during the winter time when ice, temperature shifts, waves and storm surges creates a tough environment. Robust and sustainable installation of equipment to accurate measure and follow the sea level variations around the Swedish coastline is a major challenge. The sea level has been recorded in Stockholm since 1774. In the beginning, the observations were made from visual observations at some marks at the Sluice in Stockholm.

Traditionally, since the late 18th century, the Swedish sea level measurements have been conducted at mareographs, with the use of wires and stilling well techniques. The wells are well protected from the outside. Recently, additional measurements have been established where the conditions are slightly different and no wells are available. Several agencies and local authorities have established their own stations for their own needs. We now collect sea level measurements from both Swedish Meteorological and Hydrological Institute (SMHI) and Swedish Maritime Administration (SMA) in one common and harmonized Swedish Sea Level Network (SHIP) using the same technique.

The stations will be equipped with radar and pressure sensors. As long as possible, the existing infrastructure for example the wells at mareographs, will be used. At some places heated pipes will be used to avoid problems with waves, ice and condensation. The sampling period is 1 minute and the targeted accuracy of the measurements is 1 cm. The users will be able to access real time data within 1 minute. All sea level data will be referred to the Swedish land survey datum (RH2000) or the Baltic Sea Chart Datum (BSCD2000), which is the same reference level used in the new Swedish charts. The datum is the Swedish realization of the European Vertical Reference System (EVRS), which is connected to the Normaal Amsterdams Peil (NAP), nowadays used by several Baltic countries.

The upgrade of the station network is partly financed by the European Union in the project FAMOS Odin and is ongoing since beginning of 2017 and is targeted to be finalized before the end of 2018.

Russia’s participation in GLOSS

Oleg Nikitin
State Oceanographic Institute, Moscow, Russia

The Russian state marine tide gauge network is described as well as the tide gauge devices being used in the network. Information on the current state of the Russian part of the international Global Sea Level Observing System (GLOSS) is given.

Measuring sea level data under various conditions

Anna v. Gyldenfeldt,
Maritime and Hydrographic Agency (BSH), Hamburg, Germany

The German coasts witness a broad variability in weather conditions, from moderate to harsh conditions such as storms, high waves or ice formation that can affect the sea level measurements. Other man-made influences, including shipping itself, can pose problems to high quality sea level measurements as well. The German coastal waters are monitored by a dense network of tide gauges, some of which have been installed over a century ago. A number of off-shore stations provide data on sea level and sea state. Strategies on how to maintain the quality of measurements and what difficulties are encountered in the interpretation of the signals will be presented.

Germany looks back to a long tradition in polar research. Through the years sea level measurements were conducted in the northern and southern hemispheres. Some aspects on the experiences made are highlighted.

Collection, accumulation and quality control of GLOSS sea level data intended for submission to the International Sea Level Data Centers

Alexander Vorontsov
All-Russia Research Institute for Hydrometeorlogical Information – World Data Center (RIHMI-WDC), Obninsk, Russia

The Global Sea Level Observing System (GLOSS) was established to provide information on changes in sea level for scientific and practical purposes. Russia takes part in this project. The basis for the GLOSS in Russia is the marine hydrometeorological network of the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet).

Currently, data from stations Murmansk (No. 274), Barentsburg (No. 231), the Bay Nagaevo (No. 92), Petropavlovsk-Kamchatsky (No. 93), Tuapse (No. 98), Kaliningrad (No. 97) are provided to the Permanent Service for Mean Sea Level (PSMSL). At the same time, the GLOSS implementation Plans include some more Russian stations. However, a number of stations, including some of those previously reported to the PSMSL, are no longer operational.

Preparation of sea level data for providing to PSMSL follows a standard procedure.

The quality of observations of existing Russian GLOSS-stations satisfies the international requirements for accuracy (error of sea level measurements is no more than 1-2 cm and the error in time not more than 1 min).

The sea level measurements are sent to RIHMI-WDC where data control and processing are made. Data are checked against the local sea level variability intervals (range between historic maximum and minimum). Averaging of data is carried out according to the following scheme. First, hourly data is daily averaged. Then, based on the daily average series, average values for each 10-day periods are calculated. Finally, the average monthly values are derived from 10-day average data.

The average monthly values of sea level from the Russian GLOSS stations are sent to the PSMSL once a year.

Challenges of obtaining timely, accurate and reliable water level observations across the United States diverse coastal environments

Richard Edwing, Chung-Chu Teng, Robert Heitsenrether
National Oceanic and Atmospheric Administration, USA

The United States National Oceanic and Atmospheric Administration (NOAA) National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) is responsible for maintenance and continued development of the National Water Level Observation Network (NWLON). NWLON consists of over 200 long-term stations that maintain the vertical reference frame (tide and water level datums) for communicating water level elevations throughout all U.S. coastal regions, including Atlantic, Pacific, and Arctic Ocean coasts, Gulf of Mexico, the Great Lakes, and Pacific and Caribbean island territories. Long term, high quality data series spanning over a century in length have been established at many locations. The NWLON also provides real-time water level observations critical for supporting safe and efficient maritime commerce, storm surge and tsunami warnings, and many other uses.

One major challenge of maintaining the NWLON is ensuring the provision of timely, accurate and reliable water level data needed to support a broad spectrum of societal needs given the dynamic nature of the coastal ocean and Great Lakes waters, along with the great diversity of environmental conditions encountered along U.S. and its island territories coastlines. Meeting this challenge requires utilizing the best water level measurement technology suited for an environment along with sound engineering design of the underlying support platform to ensure long-term survivability. CO-OPS' biggest measurement system challenges involve stations located in following hostile environment types: open ocean coasts with high wave energy; regions impacted by passage of tropical cyclones and large storm surges; small, and/or remote islands and regions (such as Arctic) with limited infrastructure; Great Lakes and Alaska where harsh winter conditions and significant ice coverage are experienced for a significant period every year. Lesser challenges are presented by biofouling, corrosion, vandalism and other factors, which can also vary significantly by location.

Perhaps the two most significant environmental challenges are ensuring water level data observations at locations that experience high wave energy and extreme weather events, and in environments subject to extreme winter and ice conditions. To address the first, a station hardening effort has been underway across southeast to mid-Atlantic NWLON sites where direct passage of tropical cyclones is certain to occur over a station's desired lifespan. Design specifications based on modelled Category 4 hurricane wind (59-69 m/s), wave action, and storm surge conditions are being applied to update existing stations and to establish new stations. Along the Gulf of Mexico, several recently hurricane damaged stations have been replaced with single-pile, offshore structures. The design basis is a 4 foot diameter single pile driven 60-80 feet into the seafloor with a protected instrumentation platform at least 7.5 m (25 ft.) above mean sea level. The single-pile structure presents a minimal profile to a storm coming from any direction and provides elevation above the highest expected Category 4 storm surge. At many other Gulf and Atlantic sites where installation of a single pile structure offshore is not feasible, several other types of shore-side, elevated platforms have been designed and installed, following the same Category 4 specifications. Employing radar water level sensors at many of the new elevated stations has avoided multiple challenges associated with elongated well infrastructure that would be required by other sensor types. An additional challenge common to open ocean sites is accurately resolving the true air-sea interface during extreme wave events. CO-OPS continues long term field studies with multiple, collocated sensor technologies at both Pacific and Atlantic open ocean sites. Results are used to assess potential wave induced measurement error of each sensor type and to determine optimal methods for resolving accurate, long-term water level records at open ocean coasts.

The second major challenge of extreme winter and ice conditions is most common to U.S. water level sites throughout the Great Lakes region and the state of Alaska. In the Great Lakes, CO-OPS' traditional system design, a large, enclosed concrete well on land coupled with a subsurface intake pipe extending into the lake, remains the station design of choice for surviving harsh winter conditions and extensive ice coverage. Along Alaska's south and southwest coasts, a mix of different CO-OPS station designs have been employed, along with strategic use of existing coastal infrastructure. At several Alaska sites where seasonal surface ice is certain to occur, use of a dual bubbler pressure sensor system for water level observations has proven successful. Where existing infrastructure permits, a strategic run of the bubbler air line from an indoor sensor to a subsurface orifice pair has resulted in long-term survivability of components below the ice. Dual pressure readings from the orifice pair at a known vertical separation mitigates measurement error induced by a vertical density gradients in the water column.

CO-OPS latest water level measurement system development work includes efforts to expand observations along Alaska's remote western and northern coasts where large observing system gaps remain. Recent trends of increased Arctic sea ice loss have led to waterways along Alaska's northern coasts becoming more accessible during summer seasons. As a result, a significant increase in maritime transport throughout the region is anticipated, along with a corresponding need for navigational support services. One particular system design under development and test, which is called the Hermit system, consists of two main system components: 1) a long term ocean sensor platform that resides on sea floor, to be deployed in the summer and left year round measuring under the ice, and 2) a small surface buoy that provides real-time telemetry from the bottom platform, to be deployed short term, during ice free conditions only, when real-time information will be of most interest. In addition to new water level measurement systems, CO-OPS has been pursing options for extended use of GNSS systems to be used as the primary source for water level vertical referencing at prospective Alaskan station sites where establishing a traditional benchmark network is not feasible due to extensive tundra with permafrost.

The presentation will provide an overview of CO-OPS existing long-term water level stations located in extremely challenging environment types along with CO-OPS' latest measurement system research and development efforts to address the future network expansion plans.

Wednesday, 14 March 2018

Stilling well measurements in coast of Finland

Katri Leinonen, Pertti Jämsén
Finnish Meteorological Institute, Helsinki, Finland

Sea level is measured at fourteen tide gauge stations, so-called mareographs, on Finland's coast, and operated by the Finnish Meteorological Institute (FMI). Most of the mareographs have been in operation already for several decades. Sea level is measured related to a fixed reference level at each mareograph. The possible movement of a mareograph related to its reference level is checked by annual levelling to a nearby benchmark.

All fourteen stations have a similar setup with a float in a stilling well. The stilling well is connected to sea by a connecting pipe. The purpose of the pipe is to attenuate the effect of waves. The stilling well is located in a small building which is heat controlled to avoid problems caused by weather and extreme temperatures.

Challenges related to sea-level observations at Jan Mayen

Egil Sølvberg and Aksel Voldsund
*Norwegian Mapping Authority, Hydrographic Servic*e

The Norwegian Mapping Authority has been carrying out sea-level measurements at a small volcanic island named Jan Mayen for many years. This island is situated in the Arctic Ocean about 560 km Northeast of Iceland and 460 km East of Greenland.

The water level measurements were originally carried out in a well with no direct connection to the open ocean. There is about 10 meters of rock between the well and the ocean. As the volcanic rock at Jan Mayen is porous, the water level inside the well is to some extent depending of the water level of the open ocean. The problem is that this relationship, regarding phase and range, could not be fully determined. The mean sea level seems most likely not to be the same inside the well as in the open ocean outside.

This is why the Norwegian Mapping Authority in 2011 decided to try to measure the real water level in the open ocean directly.

With challenges related to the lack of quays or other appropriate locations for such an installation, together with very rough weather conditions, it was decided to make the new installation in direct connection to the well.

The first attempt was to drill from inside the well through the wall and into the open ocean. The plan was to install a pressure gauge in a tube. Drilling in volcanic rock gave us some unexpected challenges, and this plan had to be discarded.

In the second attempt, a pipe with pressure gauges inside was fixed along the rocks outside the well, while all the electronics was placed inside the well. This seemed to operate well, but after about a year it was observed that the pipe was bended. A couple of months later, the lower part of the pipe disappeared.

Sea level variability in the inland Russian seas: measurements and analysis

E.A. Kulikov[1] and **I.P. Medvedev**[1,2]
[1] *PP Shirshov Institute of Oceanology RAS, Moscow, Russia*
[2] *Fedorov Institute of Applied Geophysics, Moscow, Russia*

In this research, the spatial and temporal coverage of tide gauge networks in the Baltic, Black and Caspian Seas are considered. An overview has been provided of long records of monthly mean sea level data that can be used to analyze long period changes of the mean sea level. The Russian coast of the Baltic Sea has a detailed spatial network of hourly sea level observations, whereas for the Black and Caspian Seas the spatial coverage of tide gauges with hourly sea level data is inadequate.

The hourly series of observations in these seas, due to the small tidal amplitudes, has revealed interesting dynamic effects that are not characteristic of marginal seas. For example, the radiational tides are quite strong in all three seas. The long series of mean monthly sea level allowed us to accurately estimate the amplitude of the pole tide in the Baltic Sea and, in particular, at the head of the Gulf of Finland.

Secular sea level change estimation at Cap Denison (Antarctica) from historical tide gauge records

L. Testut, B. Legrésy, C. Watson, H. Broslma,
R. Coleman, M. Calzas, A. Guillot
France

The Australasian Antarctic Expedition (AAE) led by Sir Douglas Mawson explored part of the East Antarctic coast between 1911 and 1914. The AAE spent the winter of 1912 and 1913 in a station built in Commonwealth Bay, Cape Denison (67°S, 142.66 °E). During this period a mechanical float tide gauge was deployed on fast ice and observed 98 days of sea level in 1912. The sea level was tied to a benchmark on the rock, which is still present and located near Mawson's original huts. As part of a collaboration between French and Australian teams, two bottom pressure gauges have been installed in Boat Harbour (a few tens of metres from the historical gauge location) during the French expedition in January 2008. The analysis of the present and past sea level allows to estimate the relative sea level change in this part of the Antarctic continent. We will present the historical and modern tide gauge system and the analysis performed on the data to estimate the sea level changes and its associated error budget.

Installation and operational use of automatic instruments for sea level measurements at hard climatic conditions

A.A. Paley, L.V. Ostroumov, M.V. Ostroumov
State Oceanographic Institute, Roshydromet, Russia

A special approach is necessary in order to support operation of automatic instruments in harsh climatic conditions. The approach includes specific infrastructure, long-term geodetic servicing as well as regular datum control. Scientists and methodologists from Russian oceanographic institutes have made comparative analyses of sea level data collected with the use of automatic and traditional (mechanical mareographs, submerged gauges and poles) instruments in various climatic zones. Results of this analysis show that automatic facilities do not provide necessary accuracy of measurements in harsh climatic conditions. Besides, the Roshydromet sea level observing system of stations and posts would not be able to provide necessary stability of operation of automatic instruments and, thus, would not provide continuous and homogeneous sea level measurements. The main reasons for such disturbances in normal operation of automatic facilities are ice formation, as well as silt and seagrass cover of pressure sensors. As a result, it is concluded that the most useful automatic instruments for sea level measurements in harsh climatic conditions are those equipped with floats and laser sensors. Such type of automatic instruments requires stilling wells, whose construction and maintenance involves additional costs. However, in case of harsh climatic conditions, such expenditures look justified. For automatic instruments with laser sensors, some improvement is proposed by preventing vapour formation within the laser beam. Besides infrastructure of sea level observation system, it is also important to run parallel measurements in order to assess reliability of automatic systems. To ensure consistent operation of automatic systems periodic sets of parallel observations and analysis of collected information should be carried out.

The UK South Atlantic tide gauge network – remote sea level measurement technology developments

Peter R. Foden, Jeff P. Pugh, Angela Hibbert and **Philip L. Woodworth**
National Oceanography Centre, Liverpool, UK

The South Atlantic Tide Gauge Network (SATGN) has been operated by the National Oceanography Centre (NOC) for over 30 years as a UK contribution to programmes such as the World Ocean Circulation Experiment (WOCE) and Global Sea Level Observing System (GLOSS). The network comprises coastal tide gauges at seven islands in the South Atlantic (Ascension, Saint Helena, Tristan da Cunha, Falkland Islands and South Georgia). It also includes tide gauges at Gibraltar and on the Antarctic Peninsula (Vernadsky and Rothera). The tide gauges were complemented for many years (1988-2016) by bottom pressure recorders (BPRS) either side of the Drake Passage in order to monitor changes in transport of the Antarctic Circumpolar Current (ACC). Details of the programme may be found in Spencer et al. (1993) and Woodworth and Hibbert (2015), while the ACC monitoring was reviewed by Meredith et al. (2011). Data from the network may be obtained via http://www.ntslf.org and are submitted to real-time and delayed-mode databanks associated with the GLOSS programme.

The remote character of many of the islands in the South Atlantic meant that tide gauge technology had to be developed that was accurate and robust and capable of operating autonomously for extended periods without maintenance. As a result, the programme saw the development of the 'B gauge' (a type of pressure tide gauge) which was arguably the most accurate type of gauge available (Woodworth et al., 1996). Aspects of the B gauge were also incorporated into the design of bubbler pressure gauges in the UK network. However, B gauges were expensive to make and operate and they have since been replaced by radar tide gauges at most locations. Some early experiences with radar gauges in the South Atlantic can be found in the chapter by Jeff Pugh and others in IOC (2016).

Remote operations also required the development of different kinds of telemetry for tide gauge data. Over the years we have experimented with many kinds of commercial methods: dial-up and broadband fixed line, GSM, Orbcomm, BGAN, Iridium etc., together with the systems provided by meteorological agencies (Meteosat, GOES etc.). Some of our experiences were combined with those of other groups for input to the telemetry chapter of the recent IOC Manual-5 (IOC, 2016).

Many of our experiences with tide gauges and telemetry have been of use to IOC. For example, aspects of our work at Vernadsky (then called Faraday) contributed to the discussion at an earlier workshop of sea level measurements in hostile regions (Koltermann et al., 1988). They have also been of use to IOC in programmes such as GLOSS, ODINAFRICA etc. Consequently, this talk will mention as many as possible aspects of the history of the development of the South Atlantic network, its tide gauges (including radar sensing technology capable of operating in harsh and extreme environments) and experiences with different kinds of telemetry.

References

IOC. 2016. *Manual on Sea-level Measurements and Interpretation, Volume V: Radar Gauges*. Paris, Intergovernmental Oceanographic Commission of UNESCO. 104pp. (IOC Manuals and Guides No.14, vol. V; JCOMM Technical Report No. 89).
Available from http://unesdoc.unesco.org/images/0024/002469/246981E.pdf which includes a Supplement: Practical Experiences.

Koltermann, K.P., Pugh, D.T. and Woodworth, P.L. 1988. *Workshop on sea-level measurements in hostile conditions, Bidston, UK, 28-31 March 1988. Summary report and submitted papers*. Intergovernmental Oceanographic Commission, Workshop Report No.54, 81pp.

Meredith, M.P. et al. 2011. *Sustained monitoring of the Southern Ocean at Drake Passage: past achievements and future priorities.* Reviews of Geophysics, 49, RG4005 (doi: 10.1029/2010RG000348)

Spencer, R., Foden, P.R., McGarry, C., Harrison, A.J., Vassie, J.M., Baker, T.F., Smithson, M.J., Harangozo, S.A. and Woodworth, P.L. 1993. *The ACCLAIM programme in the South Atlantic and Southern Oceans*. International Hydrographic Review, 70, 7-21.

Woodworth, P.L., Vassie, J.M., Spencer, R. and Smith, D.E. 1996. *Precise datum control for pressure tide gauges*. Marine Geodesy, 19(1), 1-20.

Woodworth, P.L. and Hibbert, A. 2015. Sea-level monitoring in the British Overseas Territories. Journal of Operational Oceanography, 8, 123-132 (doi: 10.1080/1755876X.2015.1087188)

Canadian water level gauging strategies for harsh environmental conditions: cold, ice, large tide range and heavy sea state sea level measurements in Canada

Phillip MacAulay, *CHS Atlantic;* **Andre Godin**, *CHS Quebec;* **Terese Herron**, *CHS Central and Arctic;* **Denny Sinnott**, *CHS Pacific (Canada, via Skype)*

Canada deploys and maintains water level gauges that must survive a wide range of conditions: oceanic salt water and stratified estuarine tidal environments; temperate inland lakes and waterways; arctic and sub-arctic cold and ice; two regions with the world's highest tides, Bay of Fundy and Ungava Bay; and exposed North Pacific heavy sea states. In Canada these gauges are designed, built, installed, maintained and run by the Tidal Sections of the Canadian Hydrographic Service (CHS). Their data are used to support hydrographic and navigational systems, sea-level rise studies and both national and international storm surge and tsunami warning systems.

To meet Canadian environmental challenges and to supply the best possible data the CHS continually reviews new technologies; encourages internal experimentation and innovation covering gauge infrastructure and water level sensors; and when needed develops or adapts new data acquisition systems, data analysis methods and quality control tools and applications

In this presentation we will overview the range of Canadian gauging solutions presently employed to address the range of environmental conditions experienced in Canadian waters, we will discuss their advantages and challenges, and we will focus on specific CHS 'in-house' developed potentially innovative solutions and their associated equipment.

Finally, we will review a new ongoing CHS initiative, Dynamic Hydrographic Products (DHP), part of Canada's new interdepartmental Ocean Protection Plan (OPP). This initiative includes re-development of Canadian water level and current observation systems:

- Standardization and renewal of Canadian gauging systems: electronics, sensors and communications to provide consistent, redundant data streams; upgrades to regionally consistent physical infrastructure based on environmental realities,

- Development of a new National water level and current Oracle database structure to: house all Canadian water level and current observations, predictions, forecasts (ocean model and Kalman filter); all water level station meta data; and to provide both standardized real-time automated and manual follow-up data QC,

- New data access tools and automated applications to package and provide data to clients in existing formats and in new S104 and S111 International Hydrographic Organization (IHO) file formats for use with shipboard dynamic E-navigation systems, and

- The development and operationalization of high resolution ocean model solutions with corresponding S104 and S111 data to client applications for a number of high risk Canadian Ports.

Tide gauges in the tropics: hazards and challenges

Jerard Jardin
Hawaii, USA

The UH Sea Level Center primarily maintains tide gauges in the tropics, but these usually benign environments are not without challenges and hazardous conditions. For example, lightning strikes have affected or damaged the electronics of the data logger/transmitter, and hurricanes have damaged or destroyed tide gauges. In the case of the latter, we have found that it is not the wind or waves that did the damage, but more likely it is debris that is carried and thrown into the tide gauge structure. The frequency of such events has been few and far between, but they need to be considered in the station design decisions. In the tropics, routine hazards to the instruments related to marine life and corrosion, as well as the unique aspects of managing very remote equipment are the biggest concern. These routine hazards become compounded when dealing with many different governments and cultures to keep the stations running.

Given these challenges, site selection and design are the most critical aspects for having a long lasting tide gauge. Tide gauges should have several layers of redundancy built in so that if there is ever damage, it is more likely that they will have at least one channel of data that remains active. Another priority is designing a station to have a low profile and be very simple in design to minimize exposure to the elements. All of the components that make up the tide gauge should be selected individually for reliability and flexibility. The system should be designed to be relatively modular so that local support can easily be trained and/or sent instructions to replace individual parts when needed. Transmissions should include redundant data so that in the case of sporadically missed transmissions the chance of receiving an uninterrupted data set is higher. The multiple levels of redundancy allow for less frequent station visits and give more time to resolve specific problems. With these design aspects, it is possible to keep the overall cost of the tide gauge network low and the data records continuous.

The 25 years of the French tide gauge network in the Southern Ocean

L. Testut, P. Téchiné, M. Calzas, C. Brachet, A. Guillot, C. Guillerm,
C. Drezen, T. Donal, E. Poirier and **P. Bonnefond**
France

ROSAME is a French tide gauges network located in South Indian Ocean Islands (Kerguelen, Crozet and Saint-Paul) and in Dumont d'Urville in Antarctica. This network was gradually built from the early 1990 in the frame of the IOC/UNESCO GLOSS program. This network is composed of four coastal stations and moorings located offshore for satellite altimetry calibration. This presentation will summarize 25 years of experience of maintaining the network in operational condition.

Australian Antarctic tide gauges

B. K. Galton–Fenzi[1, 2], B. Legresy[3, 2], C. Watson[4], M. King[4], J. French[1, 2] and D. Libaros[5]
Australia (to be presented by Laurent Testut)
[1] Australian Antarctic Division, Hobart Australia
[2] Antarctic Climate and Ecosystem Cooperative Research Centre, Hobart Australia
[3] CSIRO Climate Science Centre, Hobart Australia
[4] University of Tasmania, Hobart Australia
[5] Institute of Marine and Antarctic Science, Hobart Australia

The modern Australian Antarctic tide gauges have been operating since the 1990s. They are situated on Macquarie Island at 56°S and on the Antarctic coastline at the stations of Casey, Davis and Mawson. We will describe the setup of these tide gauges, developed to cope with the harsh Antarctic environment. Different situations require a different technical set up. Macquarie Island has a well in the shape of a pipe drilled through rock, which avoids destruction by waves and storms, but brings the challenge of knowing the density of the sea water in the pipe as it may differ from the surrounding open waters. Casey has a pier-mounted double pressure gauge at two fixed different depths to interpret changes in density of the water column. Davis and Mawson have bottom moorings, metres from the coast. The tide gauges being all based on bottom pressure measurements, it is necessary to calibrate them for drift in time and pressure sensor. The latter is done using GPS buoys measurement sessions, ideally both before and after each replacement of the sensors. Ideally, an Antarctic tide gauge with present technology would use a bottom pressure instrument placed in a sheltered place close to the shore where icebergs would not reach and sea ice would not form down to the bottom, a cable trench and tube would be constructed to pass the sea ice tide crack so that the instruments be connected to shore power and communication. It would also come with temperature and salinity measurements and atmospheric pressure and be connected to a permanent geodetic site.

The extra cost of the setup would usually largely be compensated by the diminished need for underwater work. Regular GPS buoy calibration usually remains a necessity to ensure a viable sea level record.

Thursday, 15 March 2018

Experience from the Pacific Sea Level Monitoring Project

Jeff Aquilina
Bureau of Meteorology, Australia

The Pacific Sea Level Monitoring Project (PSLMP) continues the work of the South Pacific Sea Level and Climate Monitoring Project under a wider Climate and Oceans Support Program in the Pacific initiative begun in 2012. The Project was originally developed as an Australian response to concerns raised by the member countries of the South Pacific Forum over the potential impacts of global warming on climate and sea levels in the Pacific with the principal objective of 'the provision of an accurate long term record of sea level in the South Pacific for partner countries and the international scientific community which enables them to respond to and manage related impacts'.

The project's sea level monitoring network consists of 14 sea level stations providing wide coverage across the Pacific Islands Forum region. These stations operated by the Bureau of Meteorology in conjunction with partner agencies in Australia and the region not only measure sea level, but also observe a number of "ancillary" variables - air and water temperatures, wind speed, wind direction and atmospheric pressure. An associated geodetic measurement program, implemented by Geosciences Australia, supports levelling surveys to first order, to determine shifts in the vertical of the sea level sensors due to local land movement, as well as continuous Global Positioning System stations to determine the vertical movement of the land with respect to the International Terrestrial Reference Frame.

After the Indonesian Tsunami in 2004, the Australian Government invested in a Tsunami Warning Network covering Australia and the South Pacific region. As a result of these measures and due to the age of the existing network approaching nearly twenty years, the tide gauges in the Pacific were upgraded in 2010 with better (redundant) real-time satellite communications, new data-loggers and additional Vega radar sea level sensors added to the suite of sensors. In addition, a further 4 early warning tsunami tide gauges in other locations were established with radars as primary sensors.

The network is located in cyclone prone areas, very active deep water trenches, and in areas of strong storms with heavy rain. Coupled to this, there are stations with active vertical land motions due to tectonic activity. There is also the potential risk of vandalism or damage to the equipment by boats. Couple those hazards with the natural salt water environment and you have a recipe that is challenging to equipment and its ongoing capabilities.

Concurrently with the maintenance of instrumentation, there is a program to repair and improve the infrastructure of each tide gauge and to investigate new surveyable mounting designs for the Vega radar sea level sensor.

Further improvement to the design includes a GNSS antenna virtually on the tide gauge. This has provided a more accurate, real time data set of sea level heights, with respect to the mounting of the equipment attached to the wharf. It is also building onto the existing established inland GNSS antenna network through precise surveying connections.

As domestic and commercial activity on some wharves became more demanding, it was recognized that the location of choice needed to be re-evaluated to minimise damage to the equipment. This means some sites have been targeted for relocation nearby.

The aim is to continue the Pacific Sea Level Monitoring for at least another 20 years, so the team is continuing to develop a more reliable network, with better sensors, improved wiring connections, communication and power autonomy, and minimum infrastructure maintenance.

Poster presentations

Development of devices for measuring sea level in hostile environment: tide sensor for coastal and deep sea area, tools for referencing tide sensor and to measure sea geoid: GNSS Buoy (for static and towed use)

M. Calzas
CNRS INSU, Plouzané, France

The observations of the sea level are performed with different types of material:

- **Coastal tide stations** (Crozet, Kerguelen and Saint Paul & Dumont D'Urville in Antarctica): These are radars, or tide recorders equipped with pressure, temperature and conductivity sensors immersed along docks or rocks. They are supplied continuously thanks to a land station. The data are transmitted in real time by satellite (Argos). A reference level for the absolute measurement of the water height is determined by a leveling process with respect to a known geodesic point, or with respect to the position relative to the sea surface given by a GPS buoy.

- **Autonomous mooring** of the tide recorders (to decouple the signal from offshore coastal **effects**) nearby Kerguelen. These are pressure temperature and conductivity sensors managed by a controller board with an internal clock. They have their own power supply and local data storage. The tide recorders are immersed during one year, then retrieved using acoustic releases and buoyancy. They can also monitor waves (typical 3 samples of 20 minutes at 1Hz per day).

- **The GPS buoy**

  The buoy consists of a geodetic GNSS with an antenna on a surface float coupled to a GPS base station located on land above a geodetic point. It allows to define an absolute level of the sea level:

  - Acquisition of high-frequency data (1-10 Hz)
  - Sub-centimeter accuracy in post-processing (associated with a base station)
  - Ability to deploy in the open ocean in PPP mode
  - Measurement of the position of the free sea surface to calibrate altimetric satellites (JASON, ENVISAT, SENTINEL3A,3B, SARAL/ALTIKA)
  - Weight 20 Kg, 2 m diameter
  - A floating drogue is tied up at the 3 ends and the center of the buoy to improve stability.

- **The towed GPS buoy:** CalNaGeo

  This system consists of a geodetic GNSS antenna put on a soft shell (to avoid artefacts due to rigid structures) to follow the sea surface. The antenna is gimbaled and towed (up to 10 knots) by a ship. This is used for in-situ CAL/VAL calibration of altimetric height (SSH for ocean surfaces), to measure the slope of the geoid and for waves monitoring (up to 50 Hz).

These developments are funded by CNES (Centre National d'Etudes Spatiales) project FOAM (From Ocean to inland waters Altimetry Monitoring).

		
Tide sensor	Static GNSS buoy	Towed GNSS buoy

Tide gauge operations in Greenland: technological aspects

Ole Bjerregaard Hansen and **Per Knudsen**
DTU Space, Denmark

The Technical University of Denmark (DTU Space) is responsible for operating the tide gauges in Greenland, beginning in 2005 (Thule, Qaqortoq). The Greenland network of tide gauge stations consist of 4 stations located at Nuuk, Thule, Qaqortoq and Scoresbysund. As for other stations in the Arctic region the main challenges are related to sea ice, inaccessibility, and poor connectivity. Lack of local support and sufficient budget adds to the challenges of operating the stations continuously. Currently, the stations are equipped with pressure gauges and have continuous GNSS stations collocated. All stations are sampling at 5 minute intervals, and data are transferred in 'real time' to our central server and subsequently forwarded to IOC. A description of the installations will be presented, along with examples of successes and failures. Data are available at: http://www.ioc-sealevelmonitoring.org/map.php.

Seasonal variability of tides and storm surges in the Arctic Seas of Russia

M.E. Kulikov [1,2], **I.P. Medvedev** [1,2,3], **E.A. Kulikov** [1] and **A.T. Kondrin** [2]
[1] *PP Shirshov Institute of Oceanology RAS, Moscow, Russian Federation*
[2] *Lomonosov Moscow State University, Russian Federation.*
[3] *Fedorov Institute of Applied Geophysics, Moscow, Russian Federation*

Tides contribute significantly to general patterns of hydrography and circulation in the World Ocean through their effect on mixing. The semidiurnal tide M2 is generated in the Arctic Ocean by the Kelvin wave propagating from the North Atlantic. The marginal seas of the Siberian continental shelf have a chain of left-rotating amphidromies emerging due to the interference of incident and reflected Poincaré waves and the prevalence of the eastward propagating wave over the westward. The sea-ice cover and river runoff lead to seasonal changes of tidal features in coastal zone of the Russian Arctic Seas.
The long-term hourly data from 6 tide gauges were used to examine seasonal variability of tides and storm surges in the seas of the Russian Arctic. Three tide gauges with time coverage from 2004 to 2015 were used in the White Sea. The longest hourly sea level record (1981–2005) were that for Tiksi tide gauge (Laptev Sea). Harmonic analysis of tides for individual monthly series with consecutive vector averaging over the entire observational period was applied to estimate mean amplitudes and phases of six major tidal constituents: diurnal O1 and K1, semidiurnal N2, M2 and S2, and shallow M4.

The amplitude of the semidiurnal tide in summer-autumn period is greater than in the winter-spring period for tide gauges located in the White and the East Siberian Seas. Thus, at the Vrangel tide gauge (the East Siberian Sea), the mean spring tidal range in summer-autumn is 82 cm, and in summer-autumn – 43 cm. The anomalous character of seasonal variability of the tides with maximum amplitudes in winter-spring period with a developed sea-ice cover is characteristic for Tiksi Bay (Laptev Sea).

Probably, similar anomalies are caused by deformation of a semidiurnal tidal amphidromy near the Tiksi Bay.

Spectral analysis of summer and winter sea level records showed the predominance of variance of residual sea level variability in the winter period over the summer in the White Sea. This is most pronounced in the synoptic frequency band, which is due to the dynamic atmospheric activity in the cold period. In Tiksi Bay, on the contrary, in the synoptic and high-frequency band of the sea level variability, the summer spectrum substantially prevails over the winter one, which is caused by the influence of the ice cover. Storm surges in the White Sea are also more pronounced in the winter, while for the seas of the Siberian Arctic seas they are more frequent in the summer.

Storm-tide gauge operations: experiences from Queensland

D. Metters
Coastal Impacts Unit, Department of Science, Information Technology and Innovation, Queensland, Australia

Severe tropical cyclones impact on the Queensland coast in an irregular and random manner. An array of sea level measuring stations operated by the Coastal Impacts Unit (CIU) of the Queensland Government monitors sea level during the passage of tropical cyclones. The supporting infrastructure at each site is designed to protect the sensor and instrumentation from the extreme wind, waves and sea level conditions. The structure of each storm-tide gauge is engineered to withstand the most severe category 5 tropical cyclone. In order to reduce the risk to data integrity, the sensors and electronics are installed one metre above the 1/10,000 year return interval level. Wind driven waves are generally not considered in the design of each structure. Experiences from Queensland have found that all structural failures are due to failure of the infrastructure that the storm-tide gauge is built on and that the storm-tide gauge itself has survived the extreme wind forces. Each site has two operational sensors (1) guided wire microwave sensor within a stilling well and (2) an open to air microwave sensor. The sensor within the stilling well is the primary sensor as the stilling well offers protection from extreme wind forces and from airborne particles. The CIU has used 400 mm diameter steel stilling wells until recently when 150 mm ABS tubes were fitted to new sites. The combination of a guided wire microwave within the smaller stilling well tube was found to be problematic with random false echoes returned from objects and the water level/waves outside of the tube. A new model sensor from Vega (Vega 64) with a narrower beam/footprint and no guiding wire has proven very successful in early in-situ trials. The secondary open to air sensor offers some redundancy should the primary sensor fail but the sensor itself can be adversely influenced by extreme winds which carry a high level of water, foam and bubbles. The effect of water, foam and bubbles on measured water level is reduced by using a low frequency Vega Puls66 K-band microwave sensor.

Severe tropical cyclones impact on the Queensland coast in a destructive and random manner with wind speeds up to 300 km/h. An array of sea level measuring stations operated by the Coastal Impacts Unit (CIU) of the Queensland Government monitors sea level during the passage of tropical cyclones.

ANNEX V

LIST OF ACRONYMS

GLOSS	Global Sea Level Observing System (IOC)
GNSS	Global Navigation Satellite System (GNSS)
IOC	Intergovernmental Oceanographic Commission (UNESCO)
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
UNESCO	United Nations Educational, Scientific and Cultural Organization

IOC Workshop Reports

The Scientific Workshops of the Intergovernmental Oceanographic Commission are sometimes jointly sponsored with other intergovernmental or non-governmental bodies. In most cases, IOC assures responsibility for printing, and copies may be requested from:

Intergovernmental Oceanographic Commission – UNESCO
1, rue Miollis, 75732 Paris Cedex 15, France

No.	Title	Languages
1	CCOP-IOC, 1974, Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia (Report of the IDOE Workshop on); Bangkok, Thailand, 24-29 September 1973 UNDP (CCOP),	E (out of stock)
2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (UNESCO Technical Paper in Marine Sciences, No. 20).	E (out of stock) S (out of stock)
3	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean; Monte Carlo, 9-14 September 1974.	E,F E (out of stock)
4	Report of the Workshop on the Phenomenon known as 'El Niño'; Guayaquil, Ecuador, 4-12 December 1974.	E (out of stock) S (out of stock)
5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources; Kingston, Jamaica, 17-22 February 1975	E (out of stock) S
6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Suva, Fiji, 1-6 September 1975.	E
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/UNESCO/ EAC; Nairobi, Kenya, 25 March-2 April 1976.	E, F,S, R
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters; Penang, 7-13 April 1976	E (out of stock)
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience; Mauritius 9-13 August 1976.	E, F, S, R
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring; Monaco, 14-18 June 1976	E, F E (out of stock) R
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions; Port of Spain, Trinidad, 13-17 December 1976.	E, S (out of stock)
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions; Port of Spain, Trinidad, 13-17 December 1976	E (out of stock), S
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects; Fort-de-France, Martinique, 28 November-2 December 1977.	E, F, S
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area; Port of Spain, Trinidad, 16-18 January 1978.	E, S
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas; Abidjan, Côte d'Ivoire, 2-9 May 1978	E, F
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific; Santiago de Chile, 6-10 November 1978.	E (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	E, F, R
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS); Moscow, 9-11 April 1979.	E
17 suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System; Moscow, 2-6 April 1979.	E
18	IOC/UNESCO Workshop on Syllabus for Training Marine Technicians; Miami, U.S.A., 22-26 May 1978 (UNESCO reports in marine sciences, No. 4 published by the Division of Marine Sciences, UNESCO).	E (out of stock), F, S (out of tock), R
19	IOC Workshop on Marine Science Syllabus for Secondary Schools; Llantwit Major, Wales, U.K., 5-9 June 1978 (UNESCO reports in marine sciences, No. 5, published by the Division of Marine Sciences, UNESCO).	E (out of stock), S, R, Ar
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources; Bandung, Indonesia, 17-21 October 1978	E
21	Second IDOE Symposium on Turbulence in the Ocean; Liège, Belgium, 7-18 May 1979.	E, F, S, R
22	Third IOC/WMO Workshop on Marine Pollution Monitoring; New Delhi, 11-15 February 1980.	E, F, S, R
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific; Tokyo, 27-31 March 1980.	E, R
24	WESTPAC Workshop on Coastal Transport of Pollutants; Tokyo, Japan, 27-31 March 1980.	E (out of stock)
25	Workshop on the Inter-calibration of Sampling Procedures of the IOC/ WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters; Bermuda, 11-26 January 1980.	E (Superseded by IOC Technical Series No.22)
26	IOC Workshop on Coastal Area Management in the Caribbean Region; Mexico City, 24 September- 5 October 1979.	E, S
27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Nouméa, New Caledonia, 9-15 October 1980.	E
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes. Lima, 20 April-5 May 1980.	E
29	WESTPAC Workshop on Marine Biological Methodology; Tokyo, 9-14 February 1981.	E
30	International Workshop on Marine Pollution in the South-West Atlantic; Montevideo, 10-14 November 1980.	E (out of stock) S
31	Third International Workshop on Marine Geoscience; Heidelberg, 19-24 July 1982.	E, F, S
32	UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E, F, S
32 Suppl.	Papers submitted to the UNU/IOC/ UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR); Halifax, 26-30 September 1963.	E
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa); Tenerife, 12-17 December 1963.	E, F, S
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific; Suva, Fiji, 3-7 October 1983.	E
36	IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, Portugal, 28 May-2 June 1984.	E
36 Suppl.	Papers submitted to the IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, 28 May-2 June 1984	E
37	IOC/UNESCO Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs; Colombo, 8-13 July 1985.	E
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region; Basrah, Iraq, 8-12 January 1984.	E
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific; Suva, Fiji, 24-29 September 1985.	E
40	IOC Workshop on the Technical Aspects of Tsunami Analysis, Prediction and Communications; Sidney, B.C., Canada, 29-31 July 1985.	E
40 Suppl.	First International Tsunami Workshop on Tsunami Analysis, Prediction and Communications, Submitted Papers; Sidney, B.C., Canada, 29 July-1 August 1985.	E
41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2); Dakar, Senegal, 28 October-1 November 1985.	E
43	IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean; Venice, Italy, 23-25 October 1985.	E
44	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E (out of stock) S
44 Suppl.	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities, Submitted Papers; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E
45	IOCARIBE Workshop on Physical Oceanography and Climate; Cartagena, Colombia, 19-22 August 1986.	E
46	Reunión de Trabajo para Desarrollo del Programa "Ciencia Oceánica en Relación a los Recursos No Vivos en la Región del Atlántico Sud-occidental"; Porto Alegre, Brasil, 7-11 de abril de 1986.	S
47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence; Townsville, 1-6 December 1966	E
48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on 'Ocean Science in Relation to Non-Living Resources (OSNLR)'; Havana, Cuba, 4-7 December 1986.	E, S
49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on 'El Niño'; Guayaquil, Ecuador, 27-31 October 1986.	E
50	CCALR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR); Paris, France, 2-6 June 1987.	E
51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations; Lae, Papua-New Guinea, 1-8 October 1987.	E
52	SCOR-IOC-UNESCO Symposium on Vertical Motion in the Equatorial Upper Ocean and its Effects upon Living Resources and the Atmosphere; Paris, France, 6-10 May 1985.	E
53	IOC Workshop on the Biological Effects of Pollutants; Oslo, 11-29 August 1986.	E
54	Workshop on Sea-Level Measurements in Hostile Conditions; Bidston, UK, 28-31 March 1988.	E
55	IBCCA Workshop on Data Sources and Compilation, Boulder, Colorado, 18-19 July 1988.	E
56	IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Cleveland, Australia, 24-30 July 1988.	E
57	IOC Workshop on International Co-operation in the Study of Red Tides and Ocean Blooms; Takamatsu, Japan, 16-17 November 1987.	E
58	International Workshop on the Technical Aspects of the Tsunami Warning System; Novosibirsk, USSR, 4-5 August 1989.	E
58 Suppl.	Second International Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness,	E

No.	Title	Languages
	Observation and Instrumentation. Submitted Papers; Novosibirsk, USSR, 4-5 August 1989.	
59	IOC-UNEP Regional Workshop to Review Priorities for Marine Pollution Monitoring Research, Control and Abatement in the Wider Caribbean; San José, Costa Rica, 24-30 August 1989.	E, F, S
60	IOC Workshop to Define IOCARIBE-TRODERP proposals; Caracas, Venezuela, 12-16 September 1989.	E
61	Second IOC Workshop on the Biological Effects of Pollutants; Bermuda, 10 September-2 October 1988.	E
62	Second Workshop of Participants in the Joint FAO-IOC-WHO-IAEA-UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region; Accra, Ghana, 13-17 June 1988.	E
63	IOC/WESTPAC Workshop on Co-operative Study of the Continental Shelf Circulation in the Western Pacific; Bangkok, Thailand, 31 October-3 November 1989.	E
64	Second IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Phuket, Thailand, 25-31 September 1989.	E
65	Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) in the Southwest Atlantic; Montevideo, Uruguay, 21-23 August 1989.	E
66	IOC ad hoc Expert Consultation on Sardine/ Anchovy Recruitment Programme; La Jolla, California, U.S.A., 1989	E
67	Interdisciplinary Seminar on Research Problems in the IOCARIBE Region; Caracas, Venezuela, 28 November-1 December 1989.	E (out of stock)
68	International Workshop on Marine Acoustics; Beijing, China, 26-30 March 1990.	E
69	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E
69 Suppl.	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Submitted Papers; Leningrad, USSR, 28-31 May 1990.	E
70	IOC-SAREC-UNEP-FAO-IAEA-WHO Workshop on Regional Aspects of Marine Pollution; Mauritius, 29 October - 9 November 1990.	E
71	IOC-FAO Workshop on the Identification of Penaeid Prawn Larvae and Postlarvae; Cleveland, Australia, 23-28 September 1990.	E
72	IOC/WESTPAC Scientific Steering Group Meeting on Co-Operative Study of the Continental Shelf Circulation in the Western Pacific; Kuala Lumpur; Malaysia, 9-11 October 1990.	E
73	Expert Consultation for the IOC Programme on Coastal Ocean Advanced Science and Technology Study; Liège, Belgium, 11-13 May 1991.	E
74	IOC-UNEP Review Meeting on Oceanographic Processes of Transport and Distribution of Pollutants in the Sea; Zagreb, Yugoslavia, 15-18 May 1989.	E
75	IOC-SCOR Workshop on Global Ocean Ecosystem Dynamics; Solomons, Maryland, U.S.A., 29 April-2 May 1991.	E
76	IOC/WESTPAC Scientific Symposium on Marine Science and Management of Marine Areas of the Western Pacific; Penang, Malaysia, 2-6 December 1991.	E
77	IOC-SAREC-KMFRI Regional Workshop on Causes and Consequences of Sea-Level Changes on the Western Indian Ocean Coasts and Islands; Mombasa, Kenya, 24-28 June 1991.	E
78	IOC-CEC-ICES-WMO-ICSU Ocean Climate Data Workshop Goddard Space Flight Center; Greenbelt, Maryland, U.S.A., 18-21 February 1992.	E
79	IOC/WESTPAC Workshop on River Inputs of Nutrients to the Marine Environment in the WESTPAC Region; Penang, Malaysia, 26-29 November 1991.	E
80	IOC-SCOR Workshop on Programme Development for Harmful Algae Blooms; Newport, U.S.A. 2-3 November 1991.	E
81	Joint IAPSO-IOC Workshop on Sea Level Measurements and Quality Control; Paris, France, 12-13 October 1992.	E
82	BORDOMER 92: International Convention on Rational Use of Coastal Zones. A Preparatory Meeting for the Organization of an International Conference on Coastal Change; Bordeaux, France, 30 September-2 October 1992.	E
83	IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 12-13 October 1992.	E
84	Workshop on Atlantic Ocean Climate Variability; Moscow, Russian Federation, 13-17 July 1992	E
85	IOC Workshop on Coastal Oceanography in Relation to Integrated Coastal Zone Management; Kona, Hawaii, 1-5 June 1992.	E
86	International Workshop on the Black Sea; Varna, Bulgaria, 30 September – 4 October 1991	E
87	Taller de trabajo sobre efectos biológicos del fenómeno «El Niño» en ecosistemas costeros del Pacífico Sudeste; Santa Cruz, Galápagos, Ecuador, 5-14 de octubre de 1989.	S only (summary in E, F, S)
88	IOC-CEC-ICSU-ICES Regional Workshop for Member States of Eastern and Northern Europe (GODAR Project); Obninsk, Russia, 17-20 May 1993.	E
89	IOC-ICSEM Workshop on Ocean Sciences in Non-Living Resources; Perpignan, France, 15-20 October 1990.	E
90	IOC Seminar on Integrated Coastal Management; New Orleans, U.S.A., 17-18 July 1993.	E
91	Hydroblack'91 CTD Intercalibration Workshop; Woods Hole, U.S.A., 1-10 December 1991.	E
92	Réunion de travail IOCEA-OSNLR sur le Projet « Budgets sédimentaires le long de la côte occidentale d'Afrique » Abidjan, côte d'Ivoire, 26-28 juin 1991.	E
93	IOC-UNEP Workshop on Impacts of Sea-Level Rise due to Global Warming. Dhaka, Bangladesh, 16-19 November 1992.	E
94	BMTC-IOC-POLARMAR International Workshop on Training Requirements in the Field of Eutrophication in Semi-enclosed Seas and Harmful Algal Blooms, Bremerhaven, Germany, 29 September-3 October 1992.	E
95	SAREC-IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 23-25 November 1993.	E
96	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Zanzibar, United Republic of Tanzania, 17-21 January 1994.	E
96 Suppl.	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 1. Coastal Erosion; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
96 Suppl	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 2. Sea Level; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
97	IOC Workshop on Small Island Oceanography in Relation to Sustainable Economic Development and Coastal Area Management of Small Island Development States; Fort-de-France, Martinique, 8-10 November, 1993.	E
98	CoMSBlack '92A Physical and Chemical Intercalibration Workshop; Erdemli, Turkey, 15-29 January 1993.	E
99	IOC-SAREC Field Study Exercise on Nutrients in Tropical Marine Waters; Mombasa, Kenya, 5-15 April 1994.	E
100	IOC-SOA-NOAA Regional Workshop for Member States of the Western Pacific - GODAR-II (Global Oceanographic Data Archeology and Rescue Project); Tianjin, China, 8-11 March 1994.	E
101	IOC Regional Science Planning Workshop on Harmful Algal Blooms; Montevideo, Uruguay, 15-17 June 1994.	E
102	First IOC Workshop on Coastal Ocean Advanced Science and Technology Study (COASTS); Liège, Belgium, 5-9 May 1994.	E
103	IOC Workshop on GIS Applications in the Coastal Zone Management of Small Island Developing States; Barbados, 20-22 April 1994.	E
104	Workshop on Integrated Coastal Management; Dartmouth, Canada, 19-20 September 1994.	E
105	BORDOMER 95: Conference on Coastal Change; Bordeaux, France, 6-10 February 1995.	E
105 Suppl.	Conference on Coastal Change: Proceedings; Bordeaux, France, 6-10 February 1995	E
106	IOC/WESTPAC Workshop on the Paleographic Map; Bali, Indonesia, 20-21 October 1994.	E
107	IOC-ICSU-NIO-NOAA Regional Workshop for Member States of the Indian Ocean - GODAR-III; Dona Paula, Goa, India, 6-9 December 1994.	E
108	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; Paris, France, 9-12 May 1995.	E
108 Suppl.	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; Submitted Papers; Paris, France, 9-12 May 1995.	E
109	First IOC-UNEP CEPPOL Symposium; San José, Costa Rica, 14-15 April 1993.	E
110	IOC-ICSU-CEC regional Workshop for Member States of the Mediterranean - GODAR-IV (Global Oceanographic Data Archeology and Rescue Project) Foundation for International Studies, University of Malta, Valletta, Malta, 25-28 April 1995.	E
111	Chapman Conference on the Circulation of the Intra-Americas Sea; La Parguera, Puerto Rico, 22-26 January 1995.	E
112	IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials (GESREM) Workshop; Miami, U.S.A., 7-8 December 1993.	E
113	IOC Regional Workshop on Marine Debris and Waste Management in the Gulf of Guinea; Lagos, Nigeria, 14-16 December 1994.	E
114	International Workshop on Integrated Coastal Zone Management (ICZM) Karachi, Pakistan; 10-14 October 1994.	E
115	IOC/GLOSS-IAPSO Workshop on Sea Level Variability and Southern Ocean Dynamics; Bordeaux, France, 31 January 1995	E
116	IOC/WESTPAC International Scientific Symposium on Sustainability of Marine Environment: Review of the WESTPAC Programme, with Particular Reference to ICAM, Bali, Indonesia, 22-26 November 1994.	E
117	Joint IOC-CIDA-Sida (SAREC) Workshop on the Benefits of Improved Relationships between International Development Agencies, the IOC and other Multilateral Inter-governmental Organizations in the Delivery of Ocean, Marine Affairs and Fisheries Programmes; Sidney B.C., Canada, 26-28 September 1995.	E
118	IOC-UNEP-NOAA-Sea Grant Fourth Caribbean Marine Debris Workshop; La Romana, Santo Domingo, 21-24 August 1995.	E
119	IOC Workshop on Ocean Colour Data Requirements and Utilization; Sydney B.C., Canada, 21-22 September 1995.	E
120	International Training Workshop on Integrated Coastal Management; Tampa, Florida, U.S.A., 15-17 July 1995.	E
121	Atelier régional IOC-CERESCOR sur la gestion intégrée des zones littorales (ICAM), Conakry, Guinée, 18–22 décembre 1995	F
122	IOC-EU-BSH-NOAA-(WDC-A) International Workshop on Oceanographic Biological and Chemical Data Management, Hamburg, Germany, 20-23 May 1996	E
123	Second IOC Regional Science Planning Workshop on Harmful Algal Blooms in South America; Mar del Plata, Argentina, 30 October–1 November 1995.	E, S
124	GLOBEC-IOC-SAHFOS-MBA Workshop on the Analysis of Time Series with Particular Reference to the Continuous Plankton Recorder Survey; Plymouth, U.K.,4-7 May 1993.	E
125	Atelier sous-régional de la COI sur les ressources marines vivantes du Golfe de Guinée ; Cotonou, Bénin, 1-4 juillet 1996.	E

No.	Title	Languages
126	IOC-UNEP-PERSGA-ACOPS-IUCN Workshop on Oceanographic Input to Integrated Coastal Zone Management in the Red Sea and Gulf of Aden. Jeddah, Saudi Arabia, 8 October 1995.	E
127	IOC Regional Workshop for Member States of the Caribbean and South America GODAR-V (Global Oceanographic Data Archeology and Rescue Project); Cartagena de Indias, Colombia, 8-11 October 1996.	E
128	Atelier IOC-Banque Mondiale-Sida/SAREC-ONE sur la Gestion Intégrée des Zones Côtières ; Nosy Bé, Madagascar, 14-18 octobre 1996.	E
129	Gas and Fluids in Marine Sediments, Amsterdam, the Netherlands; 27-29 January 1997.	E
130	Atelier régional de la COI sur l'océanographie côtière et la gestion de la zone côtière ;Moroni, RFI des Comores, 16-19 décembre 1996.	E
131	GOOS Coastal Module Planning Workshop; Miami, USA, 24-28 February 1997	E
132	Third IOC-FANSA Workshop; Punta-Arenas, Chile, 28-30 July 1997	S/E
133	Joint IOC-CIESM Training Workshop on Sea-level Observations and Analysis for the Countries of the Mediterranean and Black Seas; Birkenhead, U.K., 16-27 June 1997.	E
134	IOC/WESTPAC-CCOP Workshop on Paleogeographic Mapping (Holocene Optimum); Shanghai, China, 27-29 May 1997.	E
135	Regional Workshop on Integrated Coastal Zone Management; Chabahar, Iran; February 1996.	E
136	IOC Regional Workshop for Member States of Western Africa (GODAR-VI); Accra, Ghana, 22-25 April 1997.	E
137	GOOS Planning Workshop for Living Marine Resources, Dartmouth, USA; 1-5 March 1996.	E
138	Gestión de Sistemas Oceanográficos del Pacífico Oriental; Concepción, Chile, 9-16 de abril de 1996.	S
139	Sistemas Oceanográficos del Atlántico Sudoccidental, Taller, TEMA;Furg, Rio Grande, Brasil, 3-11 de noviembre de 1997	S
140	IOC Workshop on GOOS Capacity Building for the Mediterranean Region; Valletta, Malta, 26-29 November 1997.	E
141	IOC/WESTPAC Workshop on Co-operative Study in the Gulf of Thailand: A Science Plan; Bangkok, Thailand, 25-28 February 1997.	E
142	Pelagic Biogeography ICoPB II. Proceedings of the 2nd International Conference. Final Report of SCOR/IOC Working Group 93; Noordwijkerhout, The Netherlands, 9-14 July 1995.	E
143	Geosphere-biosphere coupling: Carbonate Mud Mounds and Cold Water Reefs; Gent, Belgium, 7–11 February 1998.	E
144	IOC-SOPAC Workshop Report on Pacific Regional Global Ocean Observing Systems; Suva, Fiji, 13-17 February 1998.	E
145	IOC-Black Sea Regional Committee Workshop: 'Black Sea Fluxes' Istanbul, Turkey, 10-12 June 1997.	E
146	Taller Internacional sobre Formacíon de Capacidades para el Manejo de las Costas y los Oéanos en le Gran Caribe, La Habana, – Cuba, 7–10 de Julio de 1998 / International Workshop on Management Capacity-Building for Coasts and Oceans in the Wider Caribbean, Havana, Cuba, 7–10 July 1998	S/E
147	IOC-SOA International Training Workshop on the Intregration of Marine Sciences into the Process of Integrated Coastal Management, Dalian, China, 19-24 May 1997.	E
148	IOC/WESTPAC International Scientific Symposium – Role of Ocean Sciences for Sustainable Development Okinawa, Japan, 2-7 February 1998.	E
149	Workshops on Marine Debris & Waste Management in the Gulf of Guinea, 1995-97.	E
150	Primera Sesión del Grupo de Trabajo COI sobre Algas Nocivas en el Caribe y Regiones Adyacentes (IOCARIBE-ANCA)/First Meeting of the IOC Working Group on Harmful Algae in the Caribbean and Adjacent Region (IOCARIBE-ANCA), 29 June – 1 July 1998, Havana, Cuba.	S/E ***(electronic copy only)***
151	Taller Pluridisciplinario TEMA sobre Redes del Gran Caribe en Gestión Integrada de Áreas Costeras Cartagena de Indias, Colombia, 7-12 de septiembre de 1998.	S
152	Workshop on Data for Sustainable Integrated Coastal Management (SICOM) Maputo, Mozambique, 18-22 July 1998	E
153	IOC/WESTPAC-Sida (SAREC) Workshop on Atmospheric Inputs of Pollutants to the Marine Environment Qingdao, China, 24-26 June 1998	E
154	IOC-Sida-Flanders-SFRI Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA project) Capetown, South Africa, 30 November-11 December 1998.	E
155	Science of the Mediterranean Sea and its applications UNESCO, Paris 29-31 July 1997	E
156	IOC-LUC-KMFRI Workshop on RECOSCIX-WIO in the Year 2000 and Beyond, Mombasa, Kenya, 12-16 April 1999	E
157	'98 IOC-KMI International Workshop on Integrated Coastal Management (ICM), Seoul, Republic of Korea 16-18 April 1998	E
158	The IOCARIBE Users and the Global Ocean Observing System (GOOS) Capacity Building Workshop, San José, Costa Rica, 22-24 April 1999	E
159	Oceanic Fronts and Related Phenomena (Konstantin Fedorov Memorial Symposium) – Proceedings, Pushkin, Russian Federation, 18-22 May 1998	E
160	Under preparation	
161	Under preparation	
162	Workshop report on the Transports and Linkages of the Intra-americas Sea (IAS), Cozumel, Mexico, 1-5 November 1997	E
163	Under preparation	
164	IOC-Sida-Flanders-MCM Third Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA Project), Cape Town, South Africa, 29 November – 11 December 1999	E
165	An African Conference on Sustainable Integrated Management; Proceedings of the Workshops. An Integrated Approach, (PACSICOM), Maputo, Mozambique, 18 –25 July 1998	E, F
166	IOC-SOA International Workshop on Coastal Megacities: Challenges of Growing Urbanization of the World's Coastal Areas; Hangzhou, P.R. China, 27 –30 September 1999	E
167	IOC-Flanders First ODINAFRICA-II Planning Workshop, Dakar, Senegal, 2-4 May 2000	E
168	Geological Processes on European Continental Margins; International Conference and Eight Post-cruise Meeting of the Training-Through-Research Programme, Granada, Spain, 31 January – 3 February 2000	E
169	International Conference on the International Oceanographic Data & Information Exchange in the Western Pacific (IODE-WESTPAC) 1999, ICIWP '99, Langkawi, Malaysia, 1-4 November 1999	E ***(electronic copy only)***
170	IOCARIBE-GODAR-I Cartagenas, Colombia, February 2000	***under preparation***
171	Ocean Circulation Science derived from the Atlantic, Indian and Arctic Sea Level Networks, Toulouse, France, 10-11 May 1999	E
172	(*Under preparation*)	
173	The Benefits of the Implementation of the GOOS in the Mediterranean Region, Rabat, Morocco, 1-3 November 1999	E, F
174	IOC-SOPAC Regional Workshop on Coastal Global Ocean Observing System (GOOS) for the Pacific Region, Apia, Samoa, 16-17 August 2000	E
175	Geological Processes on Deep-water European Margins, Moscow-Mozhenka, 28 Jan.-2 Feb. 2001	E
176	MedGLOSS Workshop and Coordination Meeting for the Pilot Monitoring Network System of Systematic Sea Level Measurements in the Mediterranean and Black Seas, Haifa, Israel, 15-17 May 2000	E
177	*(Under preparation)*	
178	*(Under preparation)*	
179	*(Under preparation)*	
180	Abstracts of Presentations at Workshops during the 7th session of the IOC Group of Experts on the Global Sea Level Observing System (GLOSS), Honolulu, USA, 23-27 April 2001	E
181	*(Under preparation)*	
182	*(Under preparation)*	
183	Geosphere/Biosphere/Hydrosphere Coupling Process, Fluid Escape Structures and Tectonics at Continental Margins and Ocean Ridges, International Conference & Tenth Post-cruise Meeting of the Training-through-Research Programme, Aveiro, Portugal, 30 January-2 February 2002	E
184	*(Under preparation)*	
185	*(Under preparation)*	
186	*(Under preparation)*	
186	*(Under preparation)*	
187	Geological and Biological Processes at deep-sea European Margins and Oceanic Basins, Bologna, Italy, 2–6 February 2003	E
188	Proceedings of 'The Ocean Colour Data' Symposium, Brussels, Belgium, 25-27 November 2002	E
189	Workshop for the Formulation of a Draft Project on Integrated Coastal Management (ICM) in Latin America and the Caribbean (LAC), Cartagena, Colombia, 23–25 October 2003 Taller de Formulación de un Anteproyecto de Manejo Costero Integrado (MCI) en América Latina y el Caribe (ALC), Cartagena, Colombia, 23–25 de Octubre de 2003	E F ***(electronic copy only)***
190	First ODINCARSA Planning Workshop for Caribbean Islands, Christchurch, Barbados, 15–18 December 2003	E ***(electronic copy only)***
191	North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes — International Conference and Twelfth Post-cruise Meeting of the Training-through-research Programme, Copenhagen, Denmark, 29–31 January 2004	E
192	Regional Workshop on Coral Reefs Monitoring and Management in the ROPME Sea Area, Iran I.R., 14–17 December 2003	E ***(under preparation)***
193	Workshop on New Technical Developments in Sea and Land Level Observing Systems, Paris, France, 14–16 October 2003	E ***(electronic copy only)***
194	IOC/ROPME Planning Meeting for the Ocean Data and Information Network for the Central Indian Ocean Region	***(under preparation)***
195	Workshop on Indicators of Stress in the Marine Benthos, Torregrande-Oristano, Italy, 8–9 October 2004	E
196	International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean within a Global Framework, Paris, France, 3–8 March 2005	E
197	Geosphere-Biosphere Coupling Processes: The TTR Interdisciplinary Approach Towards Studies of the European and North African Margins; International Conference and Post-cruise Meeting of the Training-Through-Research Programme, Morocco, 2-5 February 2005	E
198	Second International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean, Grand Baie, Mauritius, 14–16 April 2005	E
199	International Conference for the Establishment of a Tsunami and Coastal Hazards Warning System for the Caribbean and Adjacent Regions, Mexico, 1–3 June 2005	E
200	Lagoons and Coastal Wetlands in the Global Change Context: Impacts and Management Issues — Proceedings of the International Conference, Venice, 26–28 April 2004 (*ICAM Dossier N° 3)*	E
201	Geological processes on deep-water European margins - International Conference and 15th Anniversary Post-cruise Meeting of the Training-Through-Research Programme, Moscow/Zvenigorod, Russian Federation, 29 January–4 February 2006	E
202	Proceedings of 'Ocean Biodiversity Informatics': an international conference on marine biodiversity data management Hamburg, Germany, 29 November–1 December 2004	E
203	IOC-Flanders Planning Workshop for the formulation of a regional Pilot Project on Integrated Coastal Area Management in Latin America, Cartagena de Indias, Colombia, 16–18 January 2007	*E* ***(electronic copy only)***
204	Geo-marine Research along European Continental Margins, International Conference and Post-cruise Meeting of the Training-through-research Programme, Bremen, Germany, 29 January–1 February 2007	E
205	IODE/ICAM Workshop on the development of the Caribbean marine atlas (CMA), United Nations House, Bridgetown, Barbados, 8–10 October 2007	E ***(electronic copy only)***
206	IODE/JCOMM Forum on Oceanographic Data Management and Exchange Standards, Ostend, Belgium, 21–25 January 2008	*(Under preparation)*
207	SCOR/IODE Workshop on Data Publishing, Ostend, Belgium, 17–18 June 2008	*(Under preparation)*

No.	Title	Languages
208	JCOMM Technical Workshop on Wave Measurements from Buoys, New York, USA, 2–3 October 2008 (IOC-WMO publication)	*(Under preparation)*
209	Collaboration between IOC and OBIS towards the Long-term Management Archival and Accessibility of Ocean Biogeographic Data, Ostend, Belgium, 24–26 November 2008	*(Under preparation)*
210	Ocean Carbon Observations from Ships of Opportunity and Repeat Hydrographic Sections (IOCCP Reports, 1), Paris, France, 13–15 January 2003	E ***(electronic copy only)***
211	Ocean Surface pCO_2 Data Integration and Database Development (IOCCP Reports, 2), Tsukuba, Japan, 14–17 January 2004	E ***(electronic copy only)***
212	International Ocean Carbon Stakeholders' Meeting, Paris, France, 6–7 December 2004	E ***(electronic copy only)***
213	International Repeat Hydrography and Carbon Workshop (IOCCP Reports, 4), Shonan Village, Japan, 14–16 November 2005	E ***(electronic copy only)***
214	Initial Atlantic Ocean Carbon Synthesis Meeting (IOCCP Reports, 5), Laugavatn, Iceland, 28–30 June 2006	E ***(electronic copy only)***
215	Surface Ocean Variability and Vulnerability Workshop (IOCCP Reports, 7), Paris, France, 11–14 April 2007	E ***(electronic copy only)***
216	Surface Ocean CO2 Atlas Project (SOCAT) 2nd Technical Meeting Report (IOCCP Reports, 9), Paris, France, 16–17 June 2008	E ***(electronic copy only)***
217	Changing Times: An International Ocean Biogeochemical Time-Series Workshop (IOCCP Reports, 11), La Jolla, California, USA, 5–7 November 2008	E ***(electronic copy only)***
218	Second Joint GOSUD/SAMOS Workshop, Seattle, Washington, USA, 10–12 June 2008	E ***(electronic copy only)***
219	International Conference on Marine Data management and Information Systems (IMDIS), Athens, Greece, 31 March–2 April 2008	E
220	Geo-marine Research on the Mediterranean and European-Atlantic Margins. International Conference and TTR-17 Post-cruise Meeting of the Training-through-research Programme, Granada, Spain, 2–5 February 2009	E ***(electronic copy only)***
221	Surface Ocean CO_2 Atlas Project Pacific Regional Workshop, Tsukuba, Japan, 18-20 March, 2009 (IOCCP Report Number 12)	E ***(electronic copy only)***
222	Surface Ocean CO_2 Atlas Project Atlantic and Southern Oceans Regional Meeting, Norwich, UK, 25-26 June, 2009 (IOCCP Report Number 13)	E ***(electronic copy only)***
223	Advisory Workshop on enhancing forecasting capabilities for North Indian Ocean Storm Surges, Indian Institute of Technology (IIT), New Delhi, India, 14–17 July 2009	E ***(electronic copy only)***
224	2009 International Nutrients Scale System (INSS) Workshop Report, Paris, France, 10–12 February 2009	E ***(electronic copy only)***
225	Reunión subregional de planificación de ODINCARSA (Red de Datos e Información Oceanográficos para las Regiones del Caribe y América del Sur)/ ODINCARSA (Ocean Data and Information Network for the Caribbean and South America region) Latin America sub-regional Planning Meeting, Universidad Autónoma de Baja California (UABC), Ensenada (México), 7-10 December 2009. 2010	E/S ***(electronic copy only)***
226	OBIS (Ocean Biogeographic Information System) Strategy and Work plan Meeting, IOC Project Office for IODE, Oostende, Belgium, 18–20 November 2009	E ***(electronic copy only)***
227	ODINAFRICA-IV Project Steering Committee, First Session, Ostend, Belgium, 20–22 January 2010. 2010	E ***(electronic copy only)***
228	First IODE Workshop on Quality Control of Chemical Oceanographic Data Collections, Ostend, Belgium, 8–11 February 2010. 2010	E ***(electronic copy only)***
229	Surface Ocean CO_2 Atlas Project Equatorial Pacific, North Pacific, and Indian Ocean Regional Workshop, Tokyo, Japan, 8–11 February 2010. 2010 (IOCCP Report Number 18)	E ***(electronic copy only)***
230	SCOR/IODE/MBLWHOI Library Workshop on Data Publication, Paris, France, 2 April 2010	E ***(electronic copy only)***
231	First ODINAFRICA Coastal and Marine Atlases Planning Meeting, Ostend, Belgium, 12–14 October 2009	E ***(electronic copy only)***
232	Eleventh International Workshop on Wave Hindcasting and Forecasting and Second Coastal Hazard Symposium, Halifax, Canada, 18–23 October 2009	E ***(electronic copy only)***
233	2010 Meeting of the Joint IODE-JCOMM Steering Group on the Global Temperature-Salinity Profile Programme Ostend, Belgium, 5–7 May 2010	E ***(electronic copy only)***
234	Southern and Indian Surface Ocean CO_2 Atlas (SOCAT) Workshop, CSIRO Marine Laboratories, Hobart, Tasmania 16-18 June 2010	E ***(electronic copy only)***
235	The Caribbean Marine Atlas (CMA) Review and Planning Workshop and Saint Lucia National Coastal Atlas Stakeholder Event, Bay Gardens Inn, Rodney Bay, Saint Lucia, 2–6 August 2010	E ***(electronic copy only)***
236	First Session of the IODE Steering Group for the IODE OceanDataPortal (SG-ODP-I), 20–22 September 2010, Ostend, Belgium	E ***(electronic copy only)***
237.	Ad hoc meeting of the IODE Steering Group for OBIS, Ostend, Belgium 18-19 November 2010	E ***(electronic copy only)***
238.	Implementing Adaptation to Climate Change in Western and Eastern Africa, Nairobi, Kenya, 3-5 November 2010	E ***(electronic copy only)***
239.	2nd Advisory Workshop on enhancing forecasting capabilities for North Indian Ocean Storm Surges, 11-15 February 2011, New Delhi, India	E ***(electronic copy only)***
240.	Ocean Biogeographic Information System (OBIS) Infrastructure Meeting, INCOIS, Hyderabad, India, 2–4 March 2011.	E ***(electronic copy only)***
241.	Best Practice on Tsunami and Coastal Hazards Community Preparedness and Readiness in Central America and the Caribbean, 11–13 August 2008, Panama City, Panama	E ***(electronic copy only)***
242.	Integrated Coastal Area Management (ICAM) Training Workshop for the English Speaking Caribbean States, 16–18 March 2011, Bridgetown, Barbados	E ***(electronic copy only)***
243.	*Cancelled*	
244.	SCOR/IODE/MBLWHOI Library Workshop on Data Publication, 4th Session, British Oceanographic Data Centre, Liverpool, United Kingdom, 3-4 November 2011	E ***(electronic copy only)***
245.	*Cancelled*	
246.	NEAMTIC/ICAM Workshop on Coastal Management Approaches for Sea-Level Related Hazards, Paris, UNESCO, 5–7 December 2011	E ***(electronic copy only)***
247.	Technical Workshop on the IODE OceanDataPortal, IOC Project Office for IODE, Ostend, Belgium, 27-29 February 2012	E ***(electronic copy only)***
248.	Inter-sessional working group for updating the IOC Strategic Plan for Oceanographic Data and Information Exchange (2012-2015), Ostend, Belgium, 1-2 March 2012	E ***(electronic copy only)***
249.	Operational Oceanography of IOC (for Group II Member States), 20–22 March 2012 Paris, UNESCO (Advisory Workshop)	E ***(electronic copy only)***
250.	Advisory Workshop on The Future of IOC towards next ten years and its Implications for Member States, Varna, Bulgaria, 19 March 2012	E ***(electronic copy only)***
251	Second Technical Meeting of Ocean Biogeographic Information System (OBIS), Ostend, Belgium, 21–22 June 2012	E ***(electronic copy only)***
252.	SCOR/IODE/MBLWHOI Library Workshop on Data Publication, 5th Session, Woods Hole Oceanographic Institution, Woods Hole, USA, 9-10 October 2012	E ***(electronic copy only)***
253.	Second IODE Workshop on Quality Control of Chemical and Biological Oceanographic Data Collections, 22-24 October 2012, IOC Project Office for IODE, Ostend, Belgium	E ***(electronic copy only)***
254.	Consultation on Scientific and Technical Aspects of Sustained Ocean Observations and Services, 5th March, 2013, Rio de Janeiro, Brazil	E ***(electronic copy only)***
255.	Earthquake and tsunami hazard in Northern Haiti: Historical events and potential sources (Meeting of experts)	E ***(electronic copy only)***
256	Sexto Taller Regional de Planificación Científica sobre Floraciones de Algas Nocivas en Sudamérica, Guayaquil, Ecuador, 22-24 Octubre 2003	S ***(electronic copy only)***
257	*(Under preparation)*	
258	*(Under preparation)*	
259	Noveno Taller Regional-COI de Planificación Científica sobre Florecimientos de Algas Nocivas en Sudamérica, 11-13 enero 2011, Puerto Varas, Chile	S ***(electronic copy only)*** *(Summary in E)*
260	*Caribbean Marine Atlas Review and Planning Meeting, Miami, USA, 10-13 December 2013*	
261	Indo-Pacific Ocean Forum on "Charting the Future of Sustained Ocean Observations and Services", Bangkok, Thailand, 25-28 Nov. 2013	E ***(electronic copy only)***
262	*First Planning Workshop For The Ocean Data And Information Network For The Westpac Region (ODINWESTPAC), Tianjin, China, 4-7 March 2014*	
263	*International Coastal Atlas Network Workshop 6: Expanding Participation in Coastal Web Atlas Development and Use, 16–17 June 2013, University of Victoria, British Columbia, Canada*	
264	9th WESTPAC International Scientific Symposium, Research Directors' Forum: A Healthy and Safe Ocean for Prosperity in the Indo-Pacific region, Nha Trang, Viet Nam, 22 April 2014	E ***(electronic copy only)***
265	Electoral Group 1 Consultation on the Future of the IOC, Utrecht, The Netherlands, 26–27 May 2014	E ***(electronic copy only)***
266	IOC-UNESCO-ISESCO workshop on Improving Tsunami Warning and Emergency Response in the North-Eastern Atlantic, Mediterranean and connected seas Rabat, 23-24 September 2014	A/E/F ***(electronic copy only)***
267	Proceedings of the First IOCAFRICA Ocean Forecasting workshop for the Western Indian Ocean region, Nairobi, Kenya, 11–15 August 2014	E ***(electronic copy only)***
268	Proceedings of the African Summer School on Application of Ocean Data and Modelling Products, Ghana, Kenya, April–September 2014	E ***(electronic copy only)***
269.	*Forum on Sustained Ocean Observations and Services in IOC Group V (Africa and Arab countries)*	*Under preparation*
270.	*Second China-Africa Forum on Marine Science and Technology, 9-10 April 2015, Nairobi, Kenya*	*Under preparation*
271.	WESTPAC Workshop on Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems. Phuket, Thailand, 19–21 January 2015	E ***(electronic copy only)***
272.	Second IOCAFRICA Planning Meeting for the Second International Indian Ocean Expedition (IIOE-2), 6-8 October 2015, Catembe, Mozambique	E ***(electronic copy only)***
273.		
274.		
275.		
276.	Sources of Tsunamis in the Caribbean with Possibility to Impact the Southern Coast of the Dominican Republic, Santo Domingo, Dominican Republic, 6–7 May 2016	E & S
277.	VI IOC Regional Science Planning Workshop on Harmful Algae in the Caribbean and Adjacent Regions, Santo Domingo, Dominican Republic, 26-30 October 2015 / COI – VI Taller Regional de Planificación Científica sobre Algas Nocivas en el Caribe y Regiones Adyacentes, Santo Domingo, República Dominicana, 26-30 Octubre 2015	E/S
278.	Tsunami Hazard in Central America: Historical Events and Potential Sources. Meeting of Experts, San José, Costa Rica, 23-24 June 2016	E
279.	2nd International Conference on Marine/Maritime Spatial Planning, 15-17 March 2017, UNESCO, Paris	E
280.	Information Meeting on North-Eastern Atlantic, the Mediterranean and Connected Seas Tsunami Early Warning and Mitigation System (NEAMTWS) and NEAMWave 17 Tsunami Exercise: Summary Recommendations, Tunis, Tunisia, 13-14 September 2017	E/F/Ar
281.	Workshop on Sea-Level Measurements in Hostile Conditions, Moscow, Russian Federation, 13–15 March 2018	E/R