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ON THE AVAILABILITY OF EUROPEAN MEAN SEA LEVEL DATA

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Abstract

Over the past two years a major effort has been made to bring up-to-date the European Mean Sea Level (MSL) data set with the result that significant updates have been obtained from all European coastlines, except one, which are known to operate tide gauges. Several important historical time series, not hitherto included in the Permanent Service for Mean Sea Level (PSMSL) data bank, have also been acquired. The resulting total European MSL data set, which is available for analysis by any interested research worker, will be employed subsequently in extensive climatological and geological investigations of European MSL inter-annual variability and long-term trends. This report presents a review of the quantity and quality of available European MSL data with particular emphasis on the recently-obtained information.

INTRODUCTION

Sea levels have been measured throughout Europe for several centuries by means of tide poles, tide gauges and similar techniques. Some of the longest records are from Amsterdam (1682), Stockholm (1774), Brest (1807), Swinoujcie (1811) and Sheerness (1832). Nowadays, tide gauges are operated in almost every port for navigation purposes and along populated coastlines for storm surge flood warning. Most gauges sample the sea level every hour, or more frequently, or record the level as a continuous time series on paper charts. Inspection of a typical record would show primarily the semi-diurnal and diurnal ocean tides, individual positive and negative storm surges and, occasionally, high frequency phenomena such as seiches. When the sea surface heights are time averaged over periods long enough such that the large signals due to tides and surges are smoothed out, then one has the Mean Sea Level (MSL).

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Terms such as 'height' and 'level' demand a definition of what datum, or reference level, the tide gauge measurements are made relative to. This datum is the Tide Gauge Benchmark (TGBM), or network of several TGBM's, usually located on a rock face or harbour installation close enough to the gauge such that conventional levelling methods can be employed, with good accuracy, to relate the sea level measurements to the TGBM height. MSL is, therefore, a measure of the relative height between ocean and nearby land and a MSL record will contain contributions both from real sea level changes and from vertical land movements which cannot be decoupled without additional information.

The main signals in a typical European MSL record over timescales from months to decades are due to seasonal and inter-annual fluctuations in meteorology (winds, air pressures and rainfall) and in ocean densities and circulation. Over 10 to 100 year intervals, the dominant components of the time series stem from low frequency meteorological and ocean circulation changes, from eustatic sea level variations due to climate change and from vertical land movements. Consequently, the records are of great interest to oceanographers, climatologists and geologists. In addition, because the time averaged sea surface is equivalent to the geoid to decimetric accuracy, MSL has conventionally been employed by geodesists and surveyors as a vertical datum. For example, Ordnance Datum Newlyn (ODN), to which all heights in the U.K. are referred, is defined in terms of MSL at Newlyn during 1915-21. Therefore, the secular variations of MSL are also of interest to geodesists for the vertical control of geodetic networks. Pugh (1987a) contains a detailed review of the history and technology of tide gauge measurements and the range of scientific analyses in which they are employed.

DESCRIPTION OF THE CURRENT PROJECT

The international repository for MSL information is the Permanent Service for Mean Sea Level (PSMSL) which was established at Bidston Observatory in 1933 and which operates under the auspices of the International Council of Scientific Unions through the Federation of Astronomical and Geophysical Services. Records of monthly and annual values of MSL have been assembled from over 1300 sea level stations in more than 100 countries and approximately one quarter of these stations are in Europe. The PSMSL receives data from national authorities, checks them as far as possible (see below) and redistributes them to the worldwide community of research workers.

Historically, most MSL data have been obtained from the northern hemisphere, particularly Europe, North America and Japan (Pugh, Spencer and Woodworth, 1987; Spencer, Woodworth and Pugh, 1988). However, over the last two decades great efforts have been made by many countries to extend measurements to the tropics and to the southern hemisphere; the Tropical Ocean Global Atmospheres (TOGA) sea level network on Pacific islands is a major example. Unfortunately, over this same period the supply of European data fell significantly behind, in spite of repeated efforts by the PSMSL to obtain such information. This was partly due to insufficient resources in several countries to effect the necessary data reductions from tide gauge records to MSL and, in certain cases, owing to a lack of perception of the scientific importance of long term MSL recording. The latter situation has been recently ameliorated somewhat due to the widespread concern over a possible rise in global levels as a result of the 'greenhouse effect'.

In 1987, the Proudman Oceanographic Laboratory (POL), in collaboration with the PSMSL and with seven other European laboratories, initiated a project to bring up-to-date the European MSL data set, to search for MSL or Mean Tide Level (MTL) information not hitherto held by the PSMSL, and to compile an inventory of additional European tide gauge records which could be reduced to MSL given further resources. (MTL, the average of high and low waters, differs slightly from MSL due to shallow water effects and normally the two data types are data banked separately. The term 'MSL' below should be taken to mean either MSL or MTL data). The results of this project are described in the present report while all technical information has been passed to the PSMSL for distribution to any interested scientists. Analysis results from the enhanced PSMSL data set have already been given (Woodworth, 1989) and further studies are in progress.

EUROPEAN MSL DATASET ENHANCEMENT

The difficulties of European MSL data acquisition are not confined to any one country or region. Mostly, they stem from the fact that Europe contains a large number of countries, each having a relatively short coastline. In addition, there is the problem that in several countries there is no central authority responsible for the measurement and analysis of sea level data.

The first task was the establishment or re-establishment of contact, either by letter or by personal visits, with all European tide gauge authorities, with 'Europe' defined in the widest geographical sense from Iceland to Turkey and from Svalbard to Malta and Cyprus. An intensive programme of correspondence, followed by personal visits to seven European countries, resulted in the supply of back MSL data or information from all countries which are known to operate tide gauges with one exception, Romania. In Romania's case, tide gauges are known to be operational, and to have been so since the 1920's, and it is to be hoped that data may eventually be forthcoming. No data or information were acquired either from Albania. However, there is no knowledge of tide gauge measurements currently being undertaken in that country.

Table 1 describes, country by country, the progress made in the acquisition of European MSL data since a report on the data holdings of the PSMSL in January 1987 by Pugh, Spencer and Woodworth. In almost all cases it can be seen that a significant update of the data set has occurred. The total contents of the PSMSL European data set (as of April 1989) are summarised in Table 2(a). For each country is shown the number of station records which contain 1-20, 21-40, 41-60, 61-80 or over 80 years of data. These records comprise MSL measurements made relative to a common datum in any one year but not necessarily measured to the same datum throughout their entire record length. These values, which are called 'Metric' data in PSMSL terminology, can, therefore, be used for studies of the seasonal cycle of sea level but cannot be employed to construct long time series. The record lengths of the subset of stations which have been measured to a common datum, called 'Revised Local Reference (RLR)' data, are shown in Table 2(b). It is only 'RLR' records which in general can be used for the study of MSL trends and inter-annual variability. Entries in the '0' column of Table 2(b) demonstrate the existence of station records which are entirely 'non-RLR', in other words contain zero year of data measured to a common local datum.

Dutch data are a major exception to the general rule that only RLR records can be used for time series analysis. They appear only in the 'Metric' data set because the available data are expressed relative to the national levelling system (NAP) rather than to a local TGBM, as required for RLR purposes. In fact, large amounts of recent Dutch data have been recorded to a local TGBM and this situation is currently being reviewed by the Rijkswaterstaat and the PSMSL; in any event, the accuracy of the 'Metric' data is known to be quite acceptable for time series work. Some of the longer records from the European Atlantic region and from the Mediterranean — Black Sea region are shown in Figures 1(a) and 1(b).

Figure 2 demonstrates graphically the uneven geographical distribution of the European PSMSL data set, even following the recent updating. Many long records exist for the Baltic region which have been used in studies of sea level in the Scandinavian uplift area (Rossiter, 1972; Emery and Aubrey, 1985). Unfortunately, the number of long records is much reduced along the southern European Atlantic coastline and in the Mediterranean and Black Sea areas. In particular, this limits the usefulness of the data set for geological studies in the areas of highly spatially varying vertical land movements, although previous versions of the data set have been employed in such analyses (Emery, Aubrey and Goldsmith, 1988; Flemming and Woodworth, 1988; Pirazzoli, 1987). Oceanographic variations, being of larger spatial scale in general than geological variations in the Mediterranean region, should be less affected by there being a lower density of gauges. Small inconsistencies exist between Figure 2 and Table 1 owing to a short time delay between data being received by the PSMSL and being checked and entered into the databank.

An investigation has also been made by means of a literature search to identify MSL time series which have never been included in the PSMSL databank and which would not necessarily be the responsibility of national authorities in operation today. The existence of several records from the U.K. and from North Sea and Black Sea coasts was identified in this way and efforts are being made to obtain the corresponding data. A request for further information on such records was made in a circular letter to individual European researchers and tide gauge authorities in January 1989. This letter also included a request for knowledge of all historical European tide gauge records of at least several years duration which have never been reduced to MSL but which are safely stored in archives in the form of continuous charts or hourly heights and which have good

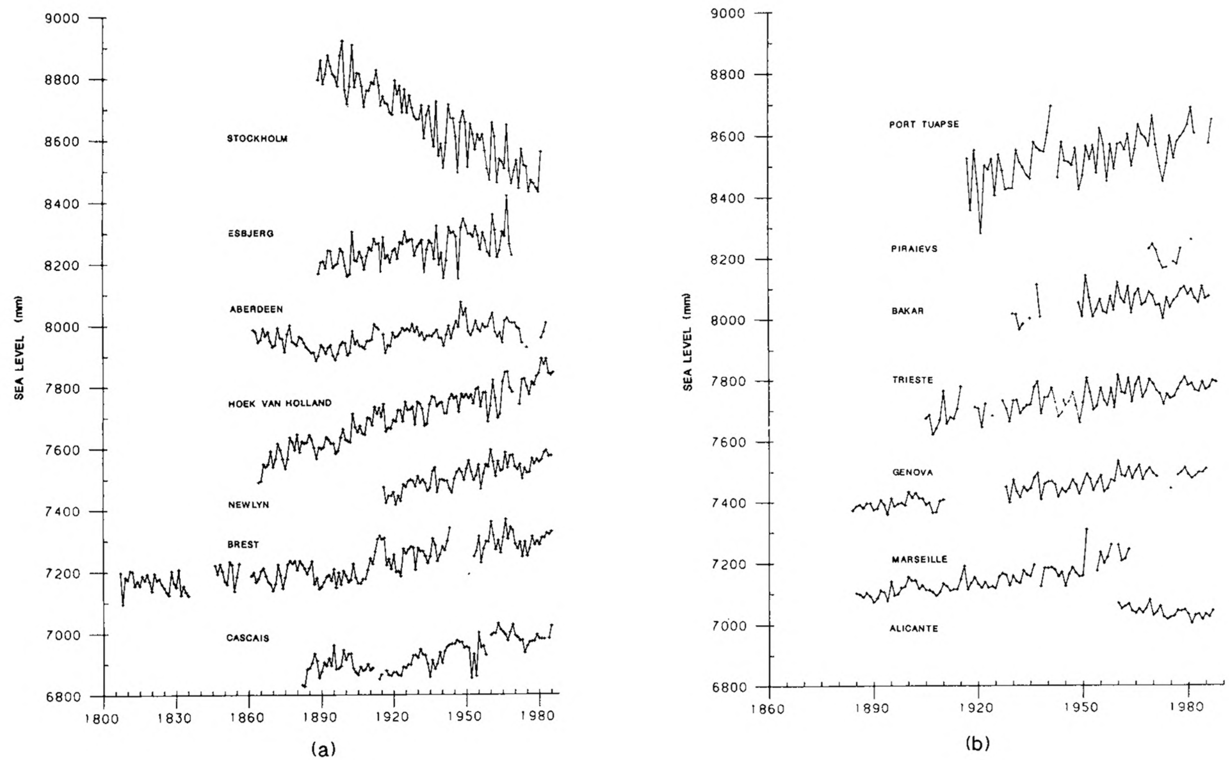

FIG. 1.— Representative long time series of annual mean sea level for (a) Stockholm (Sweden), Esbjerg (Denmark), Aberdeen (Scotland), Hoek van Holland (Netherlands), Newlyn (England), Brest (France) and Cascais (Portugal) in the European Atlantic region, and (b) Port Tuapse (USSR), Piraievs (Greece), Bakar (Yugoslavia), Trieste and Genova (Italy), Marseille (France) and Alicante (Spain) in the Mediterranean-Black Sea region. Each record has been given an arbitrary vertical offset for presentation purposes.

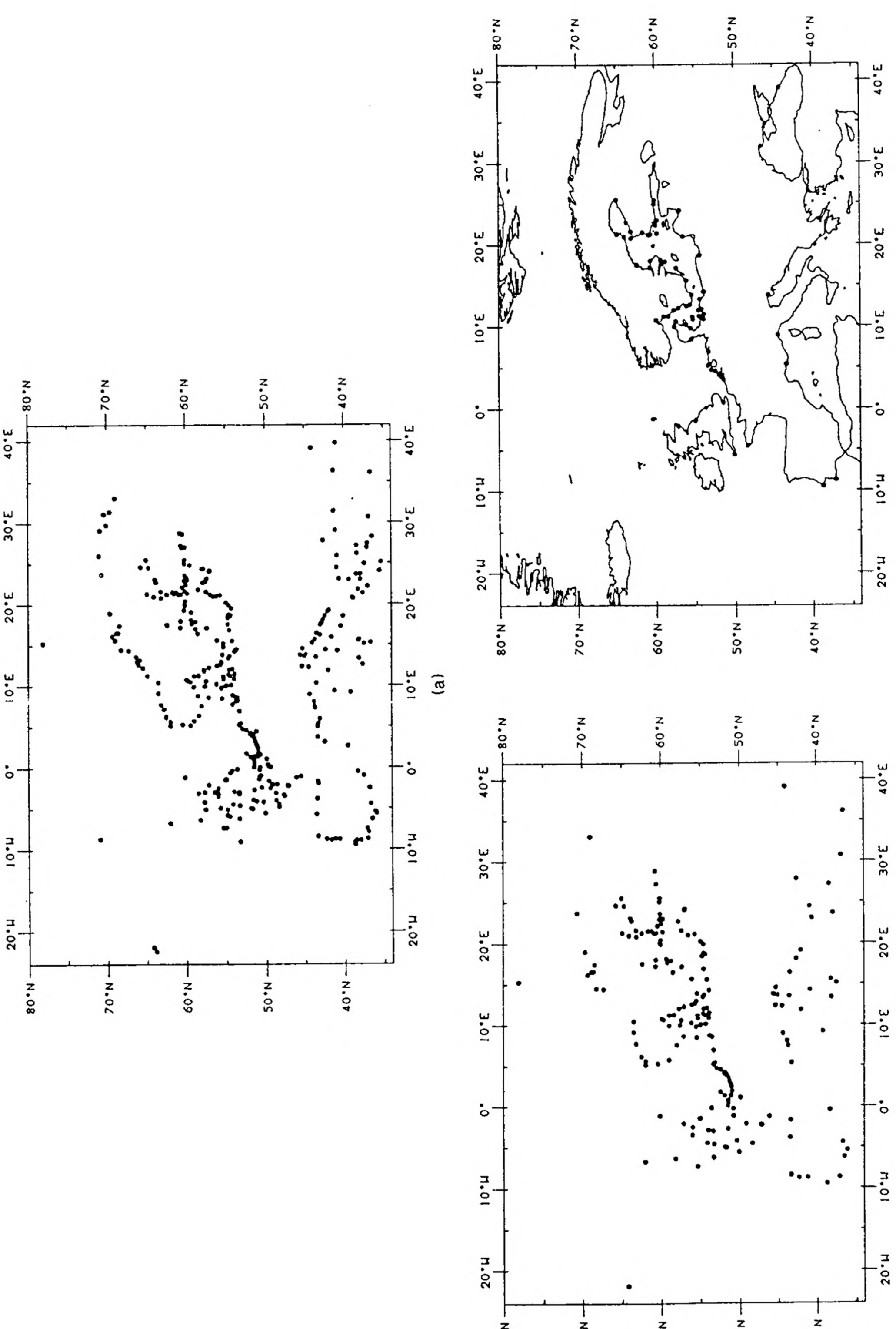

FIG. 2.— Geographical distribution of European tide gauge records available from the Permanent Service for Mean Sea Level (as of April 1989): (a) all records; (b) records with 20 or more years of data; (c) records with 60 or more years of data. Land outlines have been suppressed for (a) and (b); coastlines can be easily identified from the distribution of gauges.

benchmark datum control. The PSMSL has since begun to compile an inventory of such measurements in order to make an assessment of the maximum potential size of the historical European MSL dataset. In addition, there is the possibility that, if at some point a researcher with an interest in the MSL changes of a particular area has the resources to make the data reductions, he will have the information on which historical sea level measurements are available. There is also the possibility that, if TGBM's still exist, sea level recording could be recommenced at some future date at the same location and relative to the same TGBM heights.

DATA QUALITY

In general, the PSMSL does not receive copies of original tide gauge hourly height measurements or continuous charts but accepts monthly and annual MSL values from national authorities on the understanding that these quantities have been computed accurately. Inevitably, this will occasionally not be the case.

The PSMSL has devised a range of tests on the supplied MSL information which guard against gross errors in the data set, such as transcription errors or large unrecorded datum changes:

(1) A check is made that the average of the quoted monthly mean values is consistent with the quoted annual mean.

(2) A search for outliers is made on data for each calendar month of the year separately, and for the annual means, for all possible 40-year time spans containing at least 20 years of data. A linear fit is made to the time series and any individual monthly mean value more than 4.5 standard deviations from the fitted line is flagged.

(3) A search is made for incorrect datum information by performing a set of linear regressions of RLR annual mean values against the supplied datum correction factors ('RLR factors' in PSMSL terminology) in all possible 20-year time spans. A correctly adjusted RLR time series should be uncorrelated with the RLR factors.

(4) A search for jumps in the RLR time series is made for each calendar month of the year separately and for the annual means. The difference between a mean value and the corresponding value for the next year of data is plotted on histogram and any outlier more than 4.5 standard deviations from the mean difference is flagged.

(5) A test is made for 'upside down' data. In several European countries the main research interest is the study of vertical land movements, rather than sea level changes, with the result that MSL data are often quoted as the distance below a benchmark height rather than above it. The most sensitive test to guard against such an error is an inspection of the seasonal cycle which, for 'upside down' data, would appear opposite to that observed in neighbouring records and opposite to oceanographic and meteorological expectations.

(6) A set of 'buddy checking' is made in which the RLR data from one station is subtracted from that of a neighbouring station (or 'buddy') which is less than 400 km away. Over this short distance most of the MSL variability due to oceanographic and meteorological forcings in the two records should be similar and will cancel out, giving a difference time series primarily composed of relative vertical land movements, instrumental and datum errors and any small spatially varying ocean and weather influences. The previous tests are then applied to the difference time series and any discrepancies are flagged.

These tests have been applied to the entire European MSL data set, including the information newly acquired as a result of this project, and inconsistencies have been referred back to the national authorities. Although the possibility of remaining errors in a record cannot be excluded, further checking cannot take place without inspection of the original data which at present is not routinely acquired by the PSMSL and which, for very old recordings, may have been lost or destroyed. As tide gauge measurements become standardised throughout Europe, and as the storage of large volumes of sea level information becomes technically feasible, then the central data banking and checking of original data may become practicable.

EUROPEAN NETWORK OF INTEREST IN MSL

In order to clearly define the European community involved in the acquisition and analysis of tide gauge MSL data, we have also compiled a 'network' or mailing list of researchers and institutions involved in this research topic (Woodworth, Spencer and Alcock, 1989). It is hoped that this network will be of use to those involved in the organisation of working groups and conferences on sea level matters and will enable the maximum possible circulation for analysis of the European MSL data set.

DEVELOPMENT OF THE EUROPEAN TIDE GAUGE NETWORK

The Intergovernmental Oceanographic Commission (IOC) is coordinating the development of the Global Level of the Sea Surface (GLOSS) worldwide network of approximately 300 tide gauges situated along continental coastlines and in all island groups (IOC, 1989; Pugh, 1987b). This is intended to be a high quality global core network to serve large oceanographic programmes such as the World Ocean Circulation Experiment (WOCE) and TOGA and to provide a comprehensive monitoring of global levels in view of the potential large changes expected as a result of 'greenhouse effect' warming. Fourteen gauges from the European Atlantic coastline, four from the Mediterranean, and one from the Black Sea are included in GLOSS. Eventually, the geocentric heights of the TGBM's (i.e. their radial distances in an earth-centred coordinate system) will be routinely monitored by advanced geodetic techniques such as Satellite Laser Ranging (SLR), Very Long Baseline Interferometry (VLBI) and the Global Positioning System (GPS) with the geodetic information stored at the PSMSL alongside the MSL data. This will provide a decoupling of the low frequency sea and land level changes in the tide gauge records and will enable a direct measurement of eustatic sea level change (Carter et al., 1986). GLOSS should also be a stimulus for standardisation of data processing and exchange methods.

The completion of the present European sea level project is an appropriate point to consider how the European tide gauge network of both GLOSS and non-GLOSS gauges should develop in the future. It can be assumed that any future network will be largely based on that which has evolved from the set of individual gauges installed for different reasons, although it is to be hoped that new gauges might be installed in the low-lying areas which are sociologically, economically or environmentally sensitive to any future large sea level changes.

A minimum recommendation would be that all European tide gauge authorities should adopt GLOSS standards for data processing and data exchange and that the resulting MSL values should be routinely sent to the PSMSL. That would obviate the need for any further exercise in back data acquisition such as the present one. A second recommendation would involve the definition of a 'European regional GLOSS network' comprising a high quality sub set of available European gauges but a larger number than those already allocated to GLOSS itself. One gauge approximately every 500 km of coastline, for which the TGBM's are regularly surveyed by the advanced geodetic methods, would be a reasonable initial description. The European network would provide accurate monitoring of regional eustatic sea level change for input to climate modelling and impact studies. In addition, if eustatic changes in sea level can be shown to be spatially coherent from the analysis of data from the regional network, then the results would provide a decoupling of land and ocean level changes for the full set of European tide gauge records.

Acknowledgements

We would like to thank European national tide gauge authorities for their cooperation without which the recent improvement in the MSL dataset would not have been possible. Our colleagues from the Rijkswaterstaat (Netherlands) were of great assistance in providing communication with several European tide gauge authorities. Collaboration with other laboratories, including the Universita degli Studi di Napoli (Italy), has also proved most fruitful. Partial funding for this project was provided from the Commission of the European Communities and from the U.K. Natural Environment Research Council.

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Table 1

Compilation of European tide gauge authorities which contribute data to the PSMSL; a '*' preceding the authority name indicates that the authority is no longer a responsible tide gauge agency in the country in question. The 'Jan87' column specifies the date of the latest data in the PSMSL data bank as of January 1987 (Pugh et al., 1987). The 'Apr89' column gives the data of the latest data received as of April 1989; a'—' indicates no change. The 'NTG' column shows the number of tide gauges involved in the update.

	Jan87	Apr89	NTG
Iceland			
ICELANDIC HYDROGRAPHIC SERVICE	1983	1986	1
(*)LAMONT GEOLOGICAL OBSERVATORY (USA)	1965	—	
Jan Mayen			
NORGES SJOKARTVERK	—	1983	1
Faroe Islands			
DEN DANSKE METEOROLOGISKE INSTITUT	1969	1986	1
Spitsbergen			
WORLD DATA CENTRE B1 (MOSCOW, USSR)	1982	1988	1
U.S.S.R. (Arctic)			
WORLD DATA CENTRE B1, (MOSCOW, USSR)	1982	1988	2
(*)INST. FOR MARINE RESEARCH (FINLAND)	1939	—	
Norway			
NORGES GEOGRAFISKE OPPMALING	1973	1986	13
NORGES SJOKARTVERK	1983	1987	9
NORWEGIAN POLAR INSTITUTE	—	—	

The Norges Geografiske Oppmaling is now called Norges Statens Kartverk and the gauges it once operated are being taken over by the Norges Sjokartverk. The Norwegian Polar Institute has several short records from Svalbard which will become available shortly.

	Jan87	Apr89	NTG
Sweden			
SWEDISH METEOROLOGICAL AND HYDROLOGICAL INSTITUTE	1981	1986	11
Finland			
INST. FOR MARINE RESEARCH	1978	1987	13
U.S.S.R. (Baltic)			
(*)INST. FOR MARINE RESEARCH (FINLAND)	1944	—	
WORLD DATA CENTRE B1 (MOSCOW, USSR)	1982	1988	1
(*)GEODAETISCHES INSTITUT, POTSDAM (DDR)	1943	—	
Poland			
INSTITUTE FOR METEOROLOGY AND WATER ECONOMY	1982	1987	6

	Jan87	Apr89	NTG
German Democratic Republic			
(*)GEODAETISCHES INSTITUT, POTSDAM	1980	—	
WAESSERWIRTSCHAFTSDIREKTION, STRALSUND	1980	1987	3

Updated annual mean values have been supplied from the Waesserwirtschaftsdirektion but no monthly means as yet.

	Jan87	Apr89	NTG
Federal Republic of Germany			
(*)GEODAETISCHES INSTITUT, POTSDAM (DDR)	1943	—	
(*)WAESSER UND SCHIFFAHRTSDIREKTION NORD, KIEL	1979	—	
BUNDESANSTALT FUER GEWAESSERKUNDE	1960	—	
DEUTSCHES HYDROGRAPHISCHES INSTITUT	1959	1986	12

Data from the Waesser und Schiffahrtsdirektion Nord, Kiel will in future be supplied from the Bundesanstalt fuer Gewaesserkunde although no recent data have been received as yet.

	Jan87	Apr89	NTG
Denmark			
DEN DANSKE METEOROLOGISKE INSTITUT	1969	1986	12
Netherlands			
RIJKSWATERSTAAT	1984	1986	9
Belgium			
(*)MINIST. VAN OPENBARE WERKEN, BRUSSELS	1944	—	
MINIST. VAN OPENBARE WERKEN, OSTEND	1980	1987	3
United Kingdom			
PROUDMAN OCEANOGRAPHIC LAB., BIDSTON	1983	1988	35
MINISTRY OF AGRICULTURE	1984	—	
ABERDEEN HARBOUR BOARD	1965	—	
ISLE OF MAN HARBOUR BOARD	1977	—	
ORDNANCE SURVEY	1983	—	
STORM TIDE WARNING SERVICE (MET.OFFICE)	1982	—	
HYDROGRAPHIC UNIT, TAUNTON	1985	1988	3

Data formerly from most authorities are now supplied from the Proudman Oceanographic Laboratory, Bidston.

	Jan87	Apr89	NTG
Ireland			
ORDNANCE SURVEY OFFICE, DUBLIN	1985	1988	1
DUBLIN PORT AND DOCKS BOARD	1983	1988	1
(*)PROUDMAN OCEANOGRAPHIC LAB. (U.K.)	1964	—	
Channel Islands			
(*)PROUDMAN OCEANOGRAPHIC LAB. (U.K.)	1944	—	
DEPT. OF PUB. BUILDING AND WORKS, JERSEY	1984	1988	1
France			
(*)PROUDMAN OCEANOGRAPHIC LAB. (U.K.)	1942	—	
SERVICE HYD.+OCEAN. DE LA MARINE, BREST	1984	1987	11
INSTITUT GEOGRAPHIQUE NATIONAL	1984	—	

	Jan87	Apr89	NTG
Spain			
INST. GEOGRAFICO NACIONAL	1978	1985	4
INST. ESPANOL DE OCEANOGRAFIA	1968	1987	4
Portugal			
INST. GEOGRAFICO E CADASTRAL, LISBON	1984	1987	2
INSTITUTO HIDROGRAFICO, LISBON	1984	1987	10

The 10 gauges from the Instituto Hidrografico include those in the Azores and Madeira.

	Jan87	Apr89	NTG
Gibraltar			
HYDROGRAPHIC UNIT, TAUNTON (U.K.)	1985	1988	1
Balearic Islands			
INST. ESPANOL DE OCEANOGRAFIA	1966	—	
Monaco			
INSTITUT GEOGRAPHIQUE NATIONAL (FRANCE)	1980	—	
Italy			
IST. IDROGRAFICO DELLA MARINA, GENOVA	1982	1985	1
ISTITUTO TALASSOGRAFICO DI TRIESTE	1985	1988	1
UFFICIO HIDROGRAFICO DEL MAGISTRATO ALLE ACQUE, VENICE	1934	1987	1
(*)ISTITUTO GEOGRAFICO MILITARE, FIRENZE	1916	—	

All Italian tide gauge data will in future be supplied from a new national tides service at Ministry of Public Works in Rome. Recent Venice data were processed at the National Research Council from measurements obtained from Venice local authorities.

	Jan87	Apr89	NTG
Yugoslavia			
HIDROGRAFSKI INSTITUT, SPLIT	1974	1987	12
HIDROMETEOROLOSKI ZAVOD, LJUBLJANA	1974	—	
UNIVERSITY OF ZAGREB	1974	—	
INST. ZA OCEANOGRAFIJU I RIBARSTVO, SPLIT	1974	—	
HIDROMETEOROLOSKI ZAVOD, TITOGRAD	1974	—	

The Hidrografski Institut, Split is now the major data supplier.

Albania

No information available.

	Jan87	Apr89	NTG
Greece			
HYDROGRAPHIC SERVICE	1983	1984	16
Bulgaria			
NATIONAL HYDROMETEOROLOGICAL SERVICE	—	1987	1
Romania			
NATIONAL INST. OF HYDROTECHNICAL RESEARCH, BUCHAREST	—	1969	1

This year of data comprises a one year record from Constanta discovered in PSMSL archives; no recent information is available.

	Jan87	Apr89	NTG
U.S.S.R. (Black Sea)			
WORLD DATA CENTRE B1 (MOSCOW, USSR)	1982	1988	1
Turkey			
(*)TURKISH STATE METEOROLOGICAL SERVICE	1972	1973	6
(*)KANDILLI OBSERVATORY, ISTANBUL	1943	—	

Tide gauge recording stopped temporarily in Turkey in 1972-73. Measurements have since restarted in 1984 by the Turkish Military Mapping Command. Hourly heights from 4 stations have been received and monthly and annual means requested.

	Jan87	Apr89	NTG
Malta			
PORT DEPARTMENT, VALLETTA	—	—	

Tide gauge measurements have recently commenced in the Grand Harbour (October 1988) and data will eventually be made available.

	Jan87	Apr89	NTG
Cyprus			
DEPARTMENT OF LANDS AND SURVEYS	—	1940	1

These data comprise a three-year record from Famagusta discovered in PSMSL archives; tide gauge recording is about to be resumed by the Department of Lands and Surveys.

Table 2(a)

Number of station records for each country with 1-20, 21-40, 41-60, 61-80 and 81 and over years of data in the PSMSL databank (as of April 1989).

	1-20	21-40	41-60	61-80	>80
Iceland	1	1	0	0	0
Jan Mayen	1	0	0	0	0
Faroe Islands	0	1	0	0	0
Spitsbergen	0	1	0	0	0
USSR (Arctic)	4	2	0	0	0
Norway	19	10	8	2	0
Sweden	5	2	2	5	9
Finland	6	4	9	10	3
USSR (Baltic)	13	2	4	3	0
Poland	8	5	0	0	2
DDR	0	1	1	0	2
FRG (Baltic)	0	1	0	1	1
Denmark	3	3	0	0	10
FRG (North Sea)	4	1	1	0	0
Netherlands	0	0	0	1	10
Belgium	2	1	1	0	0
United Kingdom	28	18	6	1	3
Ireland	1	1	1	0	0
Channel Islands	2	1	0	0	0
France (Atlantic)	11	8	0	0	1
Spain (Atlantic)	3	2	2	0	0
Portugal	9	1	0	1	1
Gibraltar	0	1	0	0	0
Spain (Mediterranean)	7	2	1	0	0
Spain (Balearic Is.)	1	0	0	0	0
France (Mediterranean)	7	0	0	0	1
Monaco	2	0	0	0	0
Italy (Sardinia)	1	1	0	0	0
Italy (Mediterranean)	2	4	0	0	1
Italy (Sicily)	2	3	0	0	0
Italy (Adriatic)	6	4	1	1	0
Yugoslavia	11	5	2	0	0
Greece	16	3	0	0	0
Bulgaria	0	1	0	0	0
USSR (Black Sea)	0	0	0	1	0
Turkey	5	3	0	0	0

Table 2(b)

Number of station records in the 'RLR' subset of the PSMSL databank; entries in the zero column indicate records which are entirely non-RLR.

	0	1-20	21-40	41-60	61-80	>80
Iceland	0	1	1	0	0	0
Jan Mayen	1	0	0	0	0	0
Faroe Islands	0	1	0	0	0	0
Spitsbergen	0	0	1	0	0	0
USSR (Arctic)	3	1	2	0	0	0
Norway	10	9	12	6	2	0
Sweden	5	2	0	3	4	9
Finland	1	7	2	9	10	3
USSR (Baltic)	13	5	0	2	2	0
Poland	8	1	6	0	0	0
DDR	4	0	0	0	0	0
FRG (Baltic)	3	0	0	0	0	0
Denmark	3	2	1	0	6	4
FRG (North Sea)	6	0	0	0	0	0
Netherlands	11	0	0	0	0	0
Belgium	1	1	1	1	0	0
United Kingdom	33	7	10	2	2	2
Ireland	2	0	0	1	0	0
Channel Islands	3	0	0	0	0	0
France (Atlantic)	4	8	7	0	0	1
Spain (Atlantic)	1	2	4	0	0	0
Portugal	4	5	1	0	1	1
Gibraltar	0	0	1	0	0	0
Spain (Mediterranean)	5	3	2	0	0	0
Spain (Balearic Is.)	1	0	0	0	0	0
France (Mediterranean)	6	1	0	0	1	0
Monaco	1	1	0	0	0	0
Italy (Sardinia)	0	1	1	0	0	0
Italy (Mediterranean)	1	1	4	0	0	1
Italy (Sicily)	2	2	1	0	0	0
Italy (Adriatic)	2	7	2	0	1	0
Yugoslavia	6	5	6	1	0	0
Greece	2	17	0	0	0	0
Bulgaria	1	0	0	0	0	0
USSR (Black Sea)	0	0	0	0	1	0
Turkey	8	0	0	0	0	0