

SP-614
July 2006

Proceedings of the Symposium on

15 years of Progress in

Radar Altimetry

13-18 March 2006
Venice, Italy

Organisers:

European Space Agency

Centre National d'Etudes Spatiales



European Space Agency
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Publication: Proceedings of the Symposium on 15 Years of Progress in Radar Altimetry
13-18 March 2006, Venice, Italy (ESA SP-614, July 2006)

Editor: D. Danesy, ESA Publications Division

Published and distributed by: ESA Publications Division
ESTEC, Postbus 299
2200 AG Noordwijk
The Netherlands

Printed in: The Netherlands

Price: € 60

ISBN: 92-9092-925-1

ISSN: 1609-042X

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Preface

Fifteen years after the launch of ERS-1 and TOPEX/Poseidon, the European Space Agency, in collaboration with the French Space Agency, CNES, has organised an exceptional Symposium on "15 Years of Progress in Radar Altimetry" in Venice Lido, Italy, from 13 to 18 March 2006. Within the framework of this Symposium, three related events were scheduled: the Ocean Surface Topography Science Team Meeting, the International DORIS Service Workshop and the Argo Workshop.

After many years of development and data exploitation, radar altimetry is at the turn of an epoch. Radar altimetry is going operational for oceanography and entering a new generation with higher resolution and higher precision radar altimeters. The Symposium is about looking back at the progress made since the launch of ESA's ERS-1, back in 1991, and Topex/Poseidon in 1992, followed by ERS-2 in 1995, Geosat Follow-On in 1998, Jason-1 in 2001 and ENVISAT in 2002. The Symposium drew together six scientific communities: Oceanography, Marine Meteorology, Land Hydrology, Cryosphere, Geodesy and Geophysics.

Three different scientific communities, geodesy, geophysics, and oceanography, learned to work closely together on common goals over many decades, developing new technologies with much improved accuracies. The cryosphere community benefited from all the technological and data processing progress made for oceanographers when adapting these techniques to monitoring the ice caps and sea-ice. More recently, it became clear that exploiting radar altimetry to monitor inland water levels was feasible, even if quite complex, and the accuracy over these difficult targets is improving rapidly. Many countries, especially those in Europe and the USA - countries with different cultures and ambitions - learned to work closely together on common goals. By 1992, the progress and results laid a very strong foundation for the future of satellite altimetry and the Jason, Envisat, and Geosat Follow-On missions were decided. The accuracy of global geodetic measurements increased from a few hundred meters at the beginning of the satellite era to a few centimeters during the last fifteen years. As a result, we know much more about the Earth, ocean dynamics and the cryosphere than we would have known without altimetry, and we have laid the foundations for fully operational 3-D oceanography. Satellite altimetry has expanded from conferences attended by a handful of scientists to this Symposium attended by around 500 scientists submitting papers with more than 1200 authors and co-authors.

The "15 Years of Progress in Radar Altimetry" Symposium covered all the themes mentioned above and full papers are collected in these proceedings. In particular, a summary of the recommendations gathered during the plenary session on the future of altimetry and the panel discussion brings guidance on the requirements for future radar altimetry missions. The main message is the need for continuity of a multi-mission radar altimetric system making the best use of new technology arising for a new generation of instruments in support of both science and GMES.

One remarkable expression was the appreciation of the richness and the usefulness of such an exceptional Symposium stimulating a precious exercise of analyzing the past difficulties and the progress made so far. A noteworthy recommendation calls for holding a sequel to this Symposium in five years, hopefully joining-up with the famous Venetian meeting held every ten years since 1980, called "Oceans from Space".

In closing we would like to recognize the contribution of the partner agencies, institutions and organizations supporting the development of altimetry, in particular NASA, NOAA, EUMETSAT, IAG, IAPSO, INSU, IRD, IFREMER, EMS and IOC. As well, we express our gratitude to the Scientific Committee members, the Chairs and the Keynote Speakers, and to the contributors and the participants who made this Symposium a success. *Bonne lecture!*

Jérôme Benveniste (ESA) and Yves Ménard (CNES)
Organising Committee Chairs
<http://earth.esa.int/venice06>

Session 1

OCEANOGRAPHY

OCEANOGRAPHY - HIGH FREQUENCY

Chairs: D. Stammer & L. Alberotanza

SESSION SUMMARY

PROGRESS ON DYNAMICS AND THERMODYNAMICS IN WESTERN BOUNDARY CURRENTS

K.A. Kelly, L. Thompson & S. Dickinson

CHARACTERIZING THE VARIABILITY OF THE EASTERN NORTH PACIFIC IN TIME AND SPACE

R. Tokmakian

DECORRELATION SCALES OF HIGH RESOLUTION TURBULENT FLUXES AT THE OCEAN-SURFACE

A. Romanou, W.B. Rossow & S.-H. Chou

EDDIES AND MEAN FLOW IN THE ANTARCTIC CIRCUMPOLAR CURRENT

S.T. Gille & S. Elipot

VARIATION OF SEA SURFACE HEIGHT IN THE SOUTH CHINA SEA

Y. Jia & Q. Liu

COMBINATION OF NOAA / AVHRR IMAGES AND TOPEX/POSEIDON DATA TO ANALYSE THE MESOSCALE PHENOMENA IN THE ALGERIAN BASIN

N. Mega, A. Lansari & M.S. Karoui

SEASONAL AND INTERANNUAL VARIABILITY OF EDDY FIELD AND SURFACE CIRCULATION IN THE GULF OF ADEN

M.A. Al Saafani & S.S.C. Shenoi

FORMATION PROCESS OF THE KUROSHIO LARGE MEANDER IN 2004

N. Usui, H. Tsujino, Y. Fujii & M. Kamachi

SATELLITE ALTIMETRY FOR INDIAN OCEAN STUDIES

M.M. Ali & S. Jain

THE USES OF SATELLITE ALTIMETRY IN MODEL VALIDATION AND VARIABILITY STUDIES FOR THE AGULHAS CURRENT

B.C. Backeberg, J.A. Johannessen, L. Bertino, N.G. Winther & K.A. Lisæter

WHAT DO WE KNOW AND WHAT CAN WE PREDICT ABOUT THE TIMING OF LOOP CURRENT EDDY SEPARATION?

R.R. Leben & D.J. Honaker

OCEANOGRAPHY - COASTAL

Chairs: P. Challenor & J. Fernandes

A NEW APPROACH TO RETRACKING OCEAN AND COASTAL ZONE MULTIMISSIION ALTIMETRY
J. Freeman & P.A.M. Berry

ADVANCES IN COASTAL ALTIMETRY OVER THE NORTHWESTERN MEDITERRANEAN
P. Cipollini, S. Vignudelli, L. Roblou, F. Lyard, G.P. Gasparini, G.M.R. Manzella & M. Astraldi

NEAR COASTAL SEA SURFACE HEIGHT VARIABILITY IN THE NORTH SEA – BALTIC SEA SYSTEM
K.S. Madsen & J.L. Høyer

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OBSERVING THE OCEAN VARIABILITY IN THE WESTERN MEDITERRANEAN SEA BY USING COASTAL MULTI-SATELLITE DATA AND MODELS
M. Bouffard, L. Roblou, Y. Ménard, P. Marsaleix & P. De Mey

SATELLITE ALTIMETRY OF THE CASPIAN SEA
A.G. Kostianoy & S.A. Lebedev

EVALUATION OF TANDEM TOPEX/POSEIDON-JASON DATA IN THE NEWFOUNDLAND OFFSHORE
G. Han & J. Li

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THE SEASONAL VARIABILITY OF THE SOUTH INDIAN OCEAN CIRCULATION
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Q. Liu, L. Li & W. Liu

DYNAMICAL AND THERMODYNAMICAL SIGNATURES OF ROSSBY WAVES IN PRESENCE OF MEAN FLOW AND TOPOGRAPHY
R. Tailleux

CAUSES OF LARGE-SCALE SEA LEVEL VARIATIONS IN THE SOUTHERN OCEAN: ANALYSES OF ALTIMETER SEA LEVEL AND A SIMPLE FINITE ELEMENT BAROTROPIC MODEL
F. Vivier, K.A. Kelly & M. Harismendy

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S. Pierini

STERIC SEA LEVEL VARIATIONS INFERRED FROM COMBINED TOPEX/POSEIDON ALTIMETRY AND GRACE GRAVIMETRY
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INTERANNUAL AND ANNUAL VARIATIONS IN THE MEDITERRANEAN SEA FROM SATELLITE ALTIMETRY AND GRACE DATA
D. Garcia, I. Vigo, B.F. Chao & J. Del Río

INTERANNUAL VARIATION OF SEA LEVEL IN THE SOUTH ATLANTIC BASED ON SATELLITE ALTIMETRY

S.A. Grodsky & J.A. Carton

INTERANNUAL AND SEASONAL VARIATION OF AXIS POSITION AND INTENSITY OF THE ANTARCTIC CIRCUMPOLAR CURRENT BY SATELLITE ALTIMETRY

S.A. Lebedev

KELVIN WAVES ACTIVITY IN THE EASTERN TROPICAL ATLANTIC

A. Lazar, I. Polo, S. Arnault & G. Mainsant

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Chair: R. Ray

TIDAL SIMULATION USING REGIONAL OCEAN MODELING SYSTEM (ROMS)

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THE OBSERVATION OF SAR, OPTICAL AND ALTIMETER DATA TO STUDY THE GENERATION OF INTERNAL WAVE IN TSUSHIMA STRAIT

Y. Arvelyna & M. Oshima

OCEANOGRAPHY - MARINE METEOROLOGY

Chairs: P. Janssen & J.-M. Lefevre

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P. Challenor, D. Woolf, C. Gommenginger, M. Srokosz, D. Cotton, D. Carter & N. Sykes

CONTRIBUTION OF SATELLITE ALTIMETRY TO WAVE ANALYSIS AND FORECASTING

J.-M. Lefèvre, L. Aouf, C. Skandrani & P. Queffelec

A WIND AND WAVE ATLAS FOR THE MEDITERRANEAN SEA

L. Cavaleri & M. Sclavo

USE OF ALTIMETER AND SAR WAVE DATA AT THE MET OFFICE AND RECENT COMPARISON WITH WAVE MODEL AND BUOYS

M. Holt & J.-G. Li

THE INDIAN OCEAN TSUNAMI OF DECEMBER 26, 2004, OBSERVED BY HIGH RESOLUTION ALTIMETRY

M. Ablain, J. Dorandeu, P.Y. Le Traon & A. Sladen

ON THE COMBINED ASSIMILATION OF RA-2 ALTIMETER AND ASAR WAVE DATA FOR THE IMPROVEMENT OF WAVE FORECASTING

L. Aouf, J.-M. Lefèvre, D. Hauser & B. Chapron

SATELLITE SIGNIFICANT WAVE HEIGHT OBSERVATIONS IN COASTAL AND SHELF SEAS
J.L. Høyer & J.W. Nielsen

COMPARISON OF ALTIMETRY WAVE AND WIND DATA WITH MODEL AND BUOY DATA
C. Sølvssteen & C. Hansen

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Chairs: S. Arnault & T. Busalacchi

TROPICAL PACIFIC LONG WAVES FOR THE 1994-1998 EL NIÑO-LA NIÑA EVENT FROM AN
ALTIMETRIC DATA ASSIMILATION EXPERIMENT
B. Dewitte, S. Illig, L. Parent, Y. duPenhoat, L. Gourdeau & J. Verron

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CRYOSPHERE

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Chairs: F. Rémy & D. Wingham

STUDIES OF AUSTFONNA ICE CAP (SVALBARD) USING RADAR ALTIMETRY IN AND OTHER SATELLITE TECHNIQUES

A.V. Kouraev, B. Legresy, F. Rémy

ICE SHEET TOPOGRAPHY FROM ERS RADAR ALTIMETRY

J. Bamber

ALTIMETER AS A SOUNDING RADAR ON THE AMERY ICE-SHELF

P. Lacroix, B. Legrésy, R. Coleman & F. Rémy

ARCTIC OCEAN GEOID, ICE THICKNESS AND MEAN SEA LEVEL – THE ARCGICE PROJECT

R. Forsberg, H. Skourup, O. Andersen, P. Knudsen, S. W. Laxon, A. Ridout, A. Braun, J. Johannessen, C.C. Tscherning & D. Arabelos

APPLICATION OF RADAR ALTIMETRY TO ESTIMATE SEA ICE EXTENT AND THICKNESS EAST OF GREENLAND

A. Molteni, L. Pertusini & H. Skourup

ALONG TRACK REPEAT ALTIMETRY FOR ICE SHEETS AND CONTINENTAL SURFACE STUDIES

B. Legrésy, F. Rémy & F. Blarel

SIMULATION OF RADAR ALTIMETER WAVEFORMS OVER OCEAN AND ICE-COVERED REGIONS

V. Seuffer

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MARINE GEODESY, GRAVITY, BATHYMETRY

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Chairs: D. Sandwell & W. Smith

ON COMBINING BATHYMETRIC AND OCEAN CIRCULATION ALTIMETER MISSIONS

F.M. Monaldo & D.L. Porter

FROM THE ALTIMETRIC SEA LEVEL MEASUREMENT TO THE OCEAN ABSOLUTE DYNAMIC TOPOGRAPHY: MEAN SEA SURFACE, GEOID, MEAN DYNAMIC TOPOGRAPHY, A THREE-COMPONENT CHALLENGE

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THE BENEFIT OF EIGEN GRAVITY FIELD MODELS FOR ALTIMETRY AND VICE VERSA

F. Flechtner, R. Schmidt, U. Meyer, T. Schöne, S. Esselborn, C. Förste, R. Stubenvoll, S. Rudenko, R. König, K.H. Neumayer & M. Rothacher

COMBINING SATELLITE ALTIMETRY, TIDE GAUGE OBSERVATIONS AND AN OCEANOGRAPHIC MODEL TO DERIVE THE BALTIC SEA MEAN SEA SURFACE TOPOGRAPHY

K. Novotny, G. Liebsch, A. Lehmann & R. Dietrich

HOW RADAR ALTIMETRY DISCOVERED MARINE GEODYNAMICS

A. Braun, G. Marquart, M.G. Sideris & C.K. Shum

DETERMINATION OF THE EARTH GRAVITY FIELD PARAMETERS IN PERSIAN GULF AND OMAN SEA WITH THE SATELLITE ALTIMETRY DATA

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ACCURACY OF THE 2500 METER ISOBATH FROM SATELLITE BATHYMETRY

K.M. Marks & W.H.F. Smith

GENERATION OF A HIGH RESOLUTION GRID OF GRAVITY ANOMALIES BY INVERSION OF ALTIMETRIC DATA FROM GEOSAT, TOPEX/POSEIDON, ERS-1/2 AND JASON-1 SATELLITES IN THE AZORES REGION

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M.F. LeQuentrec-Lalancette, D. Rouxel & O. Sarzeaud

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M. Maia

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L. Géli, J.-Y. Royer, J. Goslin & R.D. Dziak

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HYDROLOGY AND LAND PROCESSES

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Chairs: Ph. Berry & D. Alsdorf

GLOBAL ANALYSIS OF MULTI-MISSION ECHOES OVER THE EARTH'S LAND SURFACE FROM 15 YEARS OF ALTIMETER MISSIONS

M. Dowson & P.A.M. Berry

TWO DECADES OF LAND ALTIMETRY – ACHIEVEMENTS AND CHALLENGES

P.A.M. Berry

ESTABLISHMENT OF AN ALTIMETRIC REFERENCE NETWORK OVER THE AMAZON BASIN USING SATELLITE RADAR ALTIMETRY (TOPEX POSEIDON)

P. Kosuth, D. Blitzkow & G. Cochonneau

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J. Harrison, P.A.M. Berry & J.A. Freeman

A DECADE OF GLOBAL RIVER AND LAKE HEIGHTS FROM ESA ALTIMETER MISSIONS

P.A. Berry, J.A. Freeman & J. Benveniste

ICE AND SNOW COVER ON LAKES FROM RADAR ALTIMETRY AND RADIOMETRY: CASE OF THE LAKE BAIKAL

A.V. Kouraev, S.V. Semovski, M.N. Shimaraev, N.M. Mognard, B. Legresy & F. Remy

IMPROVEMENT OF THE TOPEX/POSEIDON ALTIMETRIC DATA PROCESSING FOR HYDROLOGICAL PURPOSES (CASH PROJECT)

F. Mercier & O.-Z. Zanife

THE ENVISAT BURST MODE ECHOES – A NEW LOOK FROM SATELLITE RADAR ALTIMETRY

P.A.M. Berry, C. Rogers, J.D. Garlick, J.A. Freeman & J. Benveniste

Session 5

BUILDING THE 15-YEAR ALTIMETRIC RECORD

THE 15-YEAR ALTIMETRIC RECORD - CALIBRATION AND VALIDATION

Chairs: R. Scharroo & J. Lillibridge

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20 YEARS OF IMPROVEMENTS TO GEOSAT ALTIMETRY

J. Lillibridge, W.H.F. Smith, D. Sandwell, R. Scharroo, F. Lemoine, & N. Zelensky

SEA STATE BIAS – 20 YEARS ON

C.P. Gommenginger & M.A. Srokosz

OVERVIEW OF THE IMPROVEMENTS MADE ON THE EMPIRICAL DETERMINATION OF THE SEA STATE BIAS CORRECTION

S. Labroue, P. Gaspar, J. Dorandeu, F. Mertz, N. Tran, O.Z. Zanife, P. Vincent, N. Picot & P. Femenias

THE ALTIMETRIC WET TROPOSPHERIC CORRECTION: PROGRESS SINCE THE ERS-1 MISSION

L. Eymard & E. Obligis

ENVISAT ALTIMETER CALIBRATION AND VALIDATION

M. Otten, R. Zandbergen & J. Dow

ASIRAS AIRBORNE RADAR RESOLVES INTERNAL ANNUAL LAYERS IN THE DRY-SNOW ZONE OF GREENLAND

R.L. Hawley, E.M. Morris, R. Cullen, U. Nixdorf, A.P. Shepherd & D.J. Wingham

FIRST THREE YEARS OF THE MICROWAVE RADIOMETER ABOARD ENVISAT: IN-FLIGHT CALIBRATION, PROCESSING AND VALIDATION OF THE GEOPHYSICAL PRODUCTS

E. Obligis, L. Eymard, N. Tran, S. Labroue & P. Femenias

CROSS-CALIBRATION OF MULTI-MISSION ALTIMETER AND TRMM PR SIGMA0 OVER NATURAL LAND TARGETS

S.M.S. Bramer & P.A.M. Berry

EXPERIENCES ON ALTIMETER CALIBRATION AT IBIZA ISLAND AND CAPE OF BEGUR (SPAIN)

J.J. Martinez Benjamin, M. Martinez Garcia, M.A. Ortiz Castellon, J. Talaya, A. Baron, G. Rodriguez Velasco, J. Martin Davila, J. Garate, P. Bonnefond, C. Garcia & the IBIZA2003 Team

ESA'S NEW RANGE OF RADAR ALTIMETERS FOR THE EXTRACTION OF GEOPHYSICAL PARAMETERS FROM LAND, SEA ICE AND OCEAN SURFACES

R. Cullen, M.W.J. Davidson, M.R. Drinkwater, C.R. Francis, C. Haas, R.L. Hawley, C.M. Mavrocordatos, E.M. Morris, W. Rack, G. Ratier, P. Viau & D.J. Wingham

CRYOSAT LEVEL 1 DATA CALIBRATION WITH TRANSPONDER

C. Bouzinac, R. Cullen, M. Reche & M. Roca

SSALTO/DUACS: 15 YEARS OF PRECISE AND CONSISTENT MULTI-MISSION ALTIMETRY DATA

G. Dibarboure, J. Dorandeu, P.Y. Le Traon & N. Picot

IMPACT OF THE GEOPHYSICAL CORRECTIONS ON STUDIES OF SEA LEVEL VARIATION

M.J. Fernandes & S. Barbosa

PRECISE ORBITS OF ALTIMETRY SATELLITES ERS-1, ERS-2 AND TOPEX/POSEIDON

S. Rudenko, T. Schöne & J.-C. Raimondo

ERS-1/2: A LONG STORY OF ALTIMETER DATA AND IMPROVEMENTS

F. Mertz, J. Dorandeu, Y. Faugère, S. Labroue & F. Mercier

ENVISAT OCEAN ALTIMETRY PERFORMANCE ASSESSMENT: CONTINUITY AND IMPROVEMENT OF THE ERS SERIES

Y. Faugere, J. Dorandeu, N. Picot & P. Femenias

ESA AND CNES RADAR ALTIMETERS MISSIONS, ORBITS, INSTRUMENTS, DATA PROCESSING AND PRODUCTS

J.P. Dumont, P. Thibaut, O.Z. Zanife, B. Soussi, J. Benveniste, P. Femenias, P. Vincent & N. Picot

ENVISAT RA-2 S-BAND RANGE CALIBRATION VERSUS KU-BAND RANGE, OVER THE SALAR DE UYUNI

M. Reche, M. Roca & S. Laxon

THE 15-YEAR ALTIMETRIC RECORD - LONG TIME SERIES

Chair: J. Verron

HISTORY OF ALTIMETRY, 1960–1992

M. Lefebvre & R. Stewart

SEA LEVEL ANOMALIES IN THE LABRADOR SEA

A. Funk, P. Brandt, F. Schott & W.J. Emery

NORTH-EAST ATLANTIC CURRENT SYSTEMS FROM 10 YEARS OF MULTI-MISSION SATELLITE ALTIMETRY

C. Lázaro, M.J. Fernandes & M. Alves

INTERANNUAL LONG EQUATORIAL WAVES IN THE TROPICAL ATLANTIC (1981-2000)

S. Illig, B. Dewitte, N. Ayoub, D. Gushchina, Y Du Penhoat, G. Reverdin, P. De Mey, F. Bonjean & G.S.E. Lagerloef

MEDITERRANEAN SEA LEVEL ANALYSIS FROM 1992 TO 2005

J. Del Rio Vera, J. Garcia-Lafuente, F. Criado Aldeanueva, D. Garcia, A. Sanchez Cordoba, B. Fong Chao & I. Vigo Aguiar

THE 15-YEAR ALTIMETRIC RECORD - MEAN SEA LEVEL

Chairs: A. Cazenave and C.K. Shum

AN ASSESSMENT OF IPCC 20TH CENTURY CLIMATE SIMULATIONS USING THE 15-YEAR SEA LEVEL RECORD FROM ALTIMETRY

E. Leuliette, S. Nerem & T. Jakub

GLOBAL AND REGIONAL SEA LEVEL CHANGE FROM MULTI-SATELLITE ALTIMETER DATA

R. Scharroo & L. Miller

SATELLITE MEASUREMENTS OF SEA LEVEL CHANGE: WHERE HAVE WE BEEN AND WHERE ARE WE GOING

R.S. Nerem, D. P. Chambers, E.W. Leuliette, G.T. Mitchum & A. Cazenave

APPLICATION OF OCEAN REANALYSIS TO THE PROBLEM OF GLOBAL SEA LEVEL RISE

J.A. Carton, S.A. Grodsky & B.S. Giese

UNDERSTANDING MEASURED SEA LEVEL RISE BY DATA ASSIMILATION

M. Wenzel & J. Schröter

REGIONAL LONG-TERM SEA LEVEL AND SEA SURFACE TEMPERATURE CHARACTERISTICS FROM SATELLITE OBSERVATIONS

O.B. Andersen, P. Knudsen & B. Beckley

MODELING THE SEA LEVEL VARIABILITY IN THE LAST DECADES

L. Fenoglio-Marc & M. Becker

THE 15-YEAR ALTIMETRIC RECORD - OTHER and RETRACKING

Chair: A. Brenner

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OSCAR: LOOKING AT CONTINENTAL SURFACES WITH RADAR ALTIMETRY

B. Legrésy, F. Papa, F. Blarel, J.-F. Créteaux, F. Birol, A. Cazenave, K. Dominh, F. Frappart, S. Calmant, M.-C. Gennero, A. Kouraev & F. Rémy

THE NATIONAL OCEANOGRAPHY CENTRE, SOUTHAMPTON RETRACKING SCHEME

J. Gómez-Enri, C. Gommenginger, P. Villares, P. Challenor, M. Srokosz, J. Benveniste & M. Drinkwater

ESTIMATION OF THE SEA STATE BIAS EFFECT ON THE ALTIMETRIC MEASUREMENTS USING A PARAMETRIC MODEL

A. Rami, M. Khelif, S. Kahlouche & T. Denoukri

Session 6

THE INTEGRATED APPROACH

SESSION SUMMARY

THE INTEGRATED APPROACH - SYSTEMS

Chairs: J. Gould & D. Roemmich

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ADDITIONAL MATERIAL

LIST OF PARTICIPANTS

CONFERENCE PHOTOS