Joint WMO-IOC Technical Commission
for Oceanography and Marine Meteorology

JCOMM Technical Workshop on Wave Measurements from Buoys

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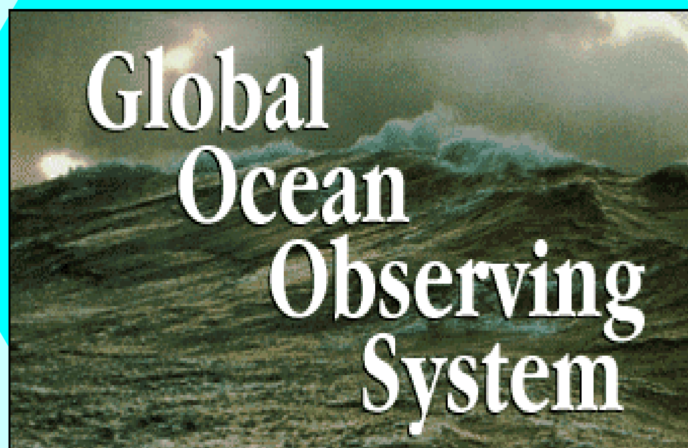
WIND WAVES AND



Peter Taylor

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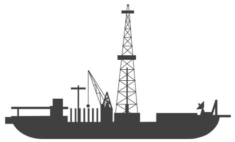
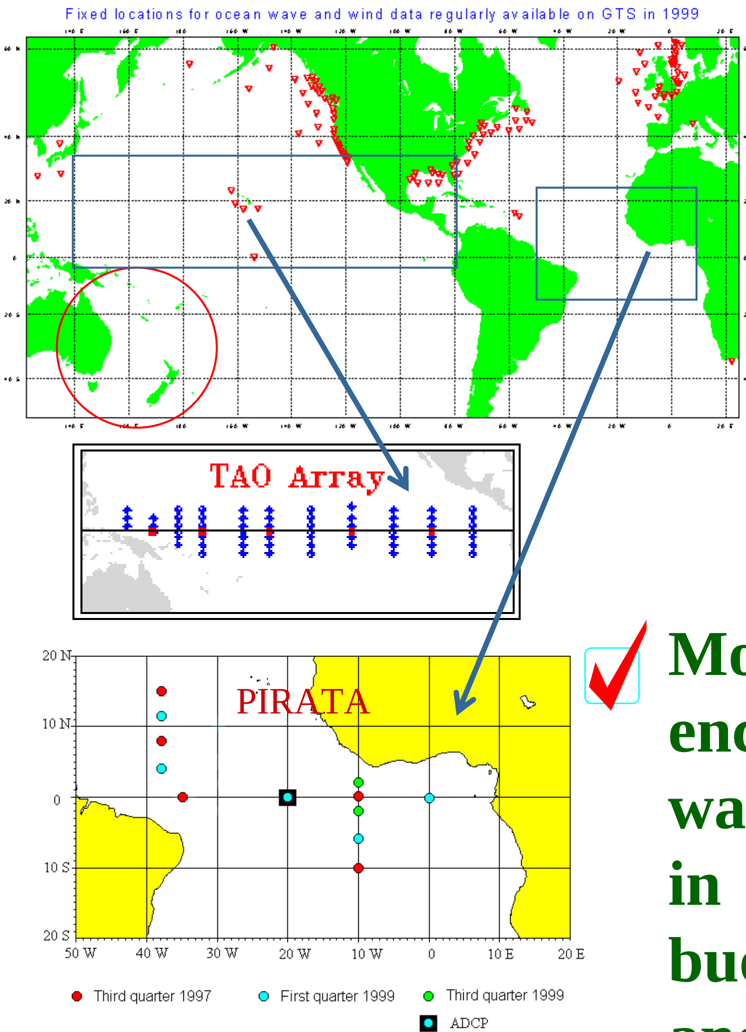
OceanObs99

Wind Wave Observations | Instrumented





"+" : objective, precise, spectral (1-D or 2-D), represent off-shore industry feedback, useful for verification, as ground truth for remote sensing (<u>some!</u>), for local climate purposes.

"-" : impact on DaS usually short-living, insufficient amount of spectral data, particularly directional spectra.

More spectral, better 2-D, data needed, encourage the exchange of measured wave data over the GTS, inclusion of in situ wave data on operational moored buoys, need for co-locations of i) satellite and moored buoy wave heights ii) 2-D wave spectrum and wind data series

OBSERVATION REQUIREMENTS FOR WIND WAVES

(developed by the JCOMM Expert Team on Wind Waves and Storm Surges)

Applications:

- Assimilation into offshore wave forecast models
- Validation of wave forecast models
- Calibration / validation of satellite wave sensors
- Ocean wave climate and variability
- Role of waves in coupling

- Reference:
- *OceanObs99 paper Swail et al.*
- *DBCP-22 Meeting Report October 2006*
- *ETWS-II Meeting Report March 2007*
- *CBS/OPAG-IOS/ET-EGOC-3 Doc. 7.2.6*

WMO IOC/UNESCO

GCOS - 92 (October 2004)
Sea State

Observations of sea state are particularly relevant to coastal and offshore impacts on human activities, but also affect climatically important air-sea exchanges and can also provide complementary information of relevance to monitoring changes in the marine environment, e.g., in winds, storms, air-sea fluxes and extreme events.

There is no sustained global observing effort at present for sea state

Present best estimates of sea state are computed from model reanalysis and analysis systems.

:

GCOS - 92 (October 2004) Sea State (2)

Issues relative to sea state observations and analysis include:

- The accuracy of NWP products is limited by validation and calibration data, and their utility is limited over the shallower coastal regions.
- The existing sea state reference buoys are limited in terms of global distribution and location (few open ocean sites and insufficient coastal measurements), and are not collocated with other ECV reference sites.
- Altimetry only provides significant wave height, and coverage is limited relative to synoptic scales of variability. SAR gives the most useful data but is rarely exchanged or available in a way that impacts estimates for climate.
- The JCOMM Expert Team on Waves and Surges will implement wave measurement systems as part of the Surface Reference Mooring Network.!!?

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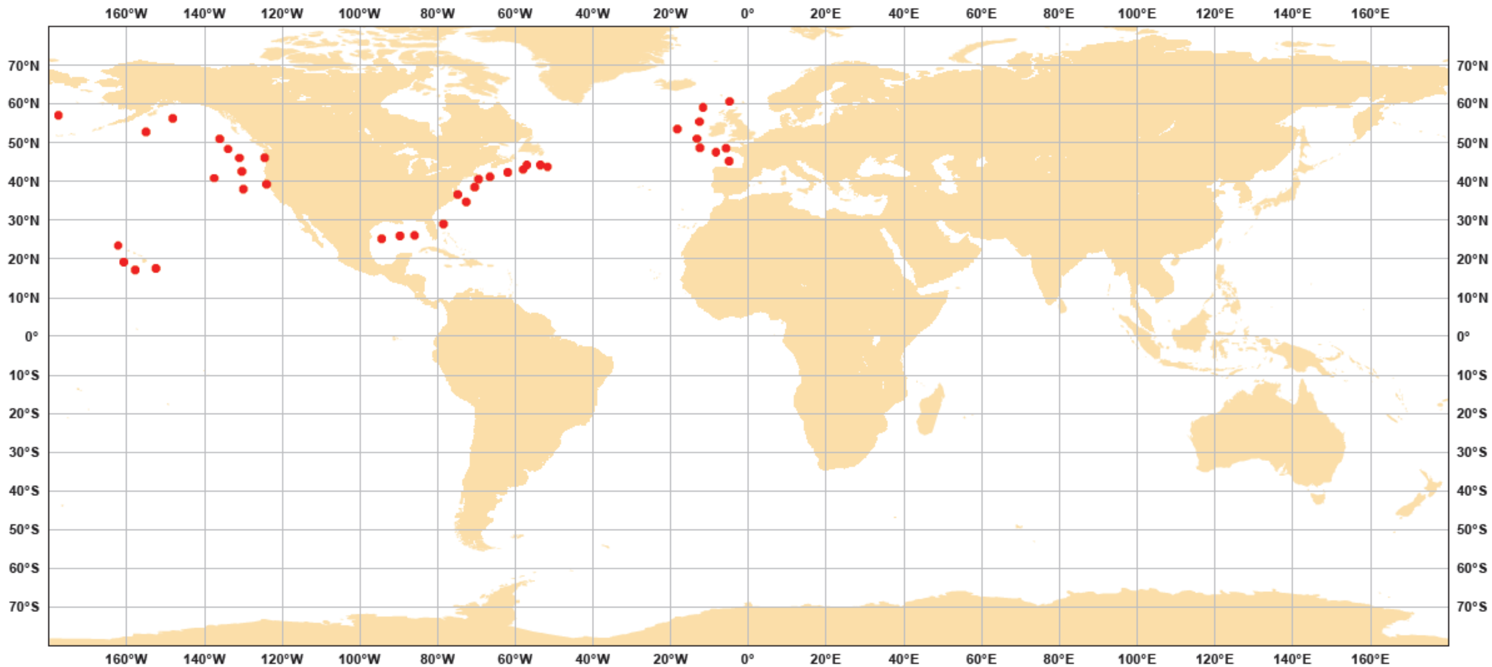
Application	Parameter	Unit	Area	Horizontal Resolution (km)		Temporal frequency (hours)		Accuracy			Delay of Availability (hours)		Decadal Stability	Remarks
				Min	Max	Min	Max	Min	Max	Units	Min	Max		
(a) Assimilation into / real-time validation of global wave forecast models	(1) Significant wave height	m	Global	60	5	24	0.1	10% 0.25m	2% 0.1m	% / m	6	No delay		Data with spatial coverage would be advantageous. Collocated surface wind data advantageous for real-time validation
	(2) Dominant wave direction	degrees	Global	60	5	24	0.1	22.5	5	degrees	6	No delay		
	(3) Wave period	s	Global	60	5	24	0.1	1	0.1	s	6	No delay		
	(4) 1D frequency spectral wave energy density	m^2 / Hz	Global	300	25	24	0.1	20%	10%		6	No delay		
	(5) 2D frequency direction spectral wave energy density	m^2 / Hz	Global	300	25	24	0.1	20%	10%		6	No delay		Directional accuracy requirements for 2D spectra as for wave direction data.
(b) Assimilation into / real-time validation of regional wave forecast models	(1) Significant wave height	m	Regional	20	0.1	24	0.1	10% 0.25m	2% 0.1m	% / m	6	No delay		Strong requirement for data with spatial coverage. Collocated surface wind data advantageous for real-time validation.
	(2) Dominant wave direction	degrees	Regional	20	0.1	24	0.1	22.5	5	degrees	6	No delay		
	(3) Wave period	s	Regional	20	0.1	24	0.1	1	0.1	s	6	No delay		
	(4) 1D frequency spectral wave energy density	m^2 / Hz	Regional	100	1	24	0.1	20%	10%		6	No delay		
	(5) 2D frequency direction spectral wave energy density	m^2 / Hz	Regional	100	1	24	0.1	20%	10%		6	No delay		
(c) Delayed mode validation of wave forecast models	(1) Significant wave height	m	Global	1000	50	240	6	10% 0.25m	1% 0.05m	% / m	720	24		Priority is increased coverage of high quality spectral observations. Additional parameters of use for delayed mode validation (e.g. surface wind data, full time series of sea surface elevation)
	(2) Dominant wave direction	degrees	Global	1000	50	240	6	22.5	1	degrees	720	24		
	(3) Wave period	s	Global	1000	50	240	6	1	0.1	s	720	24		
	(4) 1D frequency spectral wave energy density	m^2 / Hz	Global	1000	50	240	6	20%	10%		720	24		
	(5) 2D frequency direction spectral wave energy density	m^2 / Hz	Global	1000	50	240	6	20%	10%		720	24		

Application	Parameter	Unit	Area	Horizontal Resolution (km)		Temporal frequency (hours)		Accuracy			Delay of Availability (hours)		Decadal Stability	Remarks
				Min	Max	Min	Max	Min	Max	Units	Min	Max		
(d) Calibration / validation of satellite wave sensors	(1) Significant wave height	m	Global	1000	10	24	1	10% 0.25m	1% 0.05m	% / m	720	24		Collocation with satellite ground tracks advantageous
	(2) Dominant wave direction	degrees	Global	1000	10	24	1	5	1	degrees	720	24		
	(3) Wave period	s	Global	1000	10	24	1	1	0.1	s	720	24		
	(4) 1D frequency spectral wave energy density	m^2 / Hz	Global	1000	100	24	1	20%	10%		720	24		
	(5) 2D frequency direction spectral wave energy density	m^2 / Hz	Global	1000	100	24	1	20%	10%		720	24		
(e) Ocean wave climate and variability	(1) Significant wave height	m	Global	1000	100	24	6	10% 0.25m	1% 0.05m	% / m	720	24	0.01m	Wave climate applications may rely on nearshore wave modelling. Hence validation data for use in nearshore wave models is an additional requirement for climate applications.
	(2) Dominant wave direction	degrees	Global	1000	100	24	6	22.5	1	degrees	720	24	1.0 degrees	
	(3) Wave period	s	Global	1000	100	24	6	1	0.1	s	720	24	0.05s	
	(4) 1D frequency spectral wave energy density	m^2 / Hz	Global	1000	100	24	6	20%	10%		720	24		
	(5) 2D frequency direction spectral wave energy density	m^2 / Hz	Global	1000	100	24	6	20%	10%		720	24		
(f) Role of waves in coupling	(1) Significant wave height	m	Global	1000	10	6	0.5	10% 0.25m	1% 0.05m	% / m	720	24		Additional collocated measurements required. Process studies likely to require dedicated dense sampling in small regions, and sampling to higher frequency than routine monitoring. Wave observations should be included routinely in studies of air-sea interaction.
	(2) Dominant wave direction	degrees	Global	1000	10	6	0.5	22.5	1	degrees	720	24		
	(3) Wave period	s	Global	1000	10	6	0.5	1	0.1	s	720	24		
	(4) 1D frequency spectral wave energy density	m^2 / Hz	Global	1000	10	6	0.5	20%	10%		720	24		
	(5) 2D frequency direction spectral wave energy density	m^2 / Hz	Global	1000	10	6	0.5	20%	10%		720	24		

Platform	Relevant requirements	Required network	Comments
In situ (non-spectral) buoys	a1, c1, d1, e1, f1 a3, c3, d3, e3, f3 c4, d4, e4, f4	Validation requirement is for average 10º spacing requiring a network of around 400 buoys with minimum 10% / 25cm accuracy for wave height and 1 second for wave period. Higher density would be advantageous for data assimilation. Standardized measurements and meta data are essential to ensure consistency between different stations. Provision of 1D spectra from buoys with suitable instrumentation is valuable.	Primary requirement is for high quality observations for validation and calibration of altimeter data. Secondary requirement for use in assimilation. Lack of open ocean buoy observations currently makes assimilation on a global scale unfeasible. Improvement to the network would make this viable, and a potential primary requirement. An (approximately) uniform distribution of buoy observations is desirable. Collocated surface wind observations are advantageous for validation activities. Further additional parameters are of value for use in delayed mode validation. Current in situ reports are not standardised resulting in impaired utility.
In situ spectral buoys	c5, d5, e5, f5	Validation requirement is for average 10º spacing requiring a network of around 400 buoys. Higher density would be advantageous for assimilation.	Primary requirement is for high quality observations of 2D spectra for use in validation and in calibration of SAR data. At present this type of data are not widely available, and in consequence validation and calibration activities of this type are not common. Secondary requirement for use in assimilation.
Satellite altimeter	a1, b1, c1, e1 a3, b3, c3, e3	Minimum 20km resolution required for use in regional models. Along track spacing is likely to be adequate to meet this requirement; cross-track spacing is not. Multiple altimeters are therefore required to provide adequate cross track sampling. Fast delivery (within 6 hours at most) required with accuracy of 10% / 25cm for wave height, and 1 second for wave period. Long-term, stable time series of repeat observations required for climate applications.	Primary requirements arise from data assimilation. Secondary requirement for use in validation. Swath data would be advantageous. Precise specification of wave period products is required.

Results based on original list of buoy locations

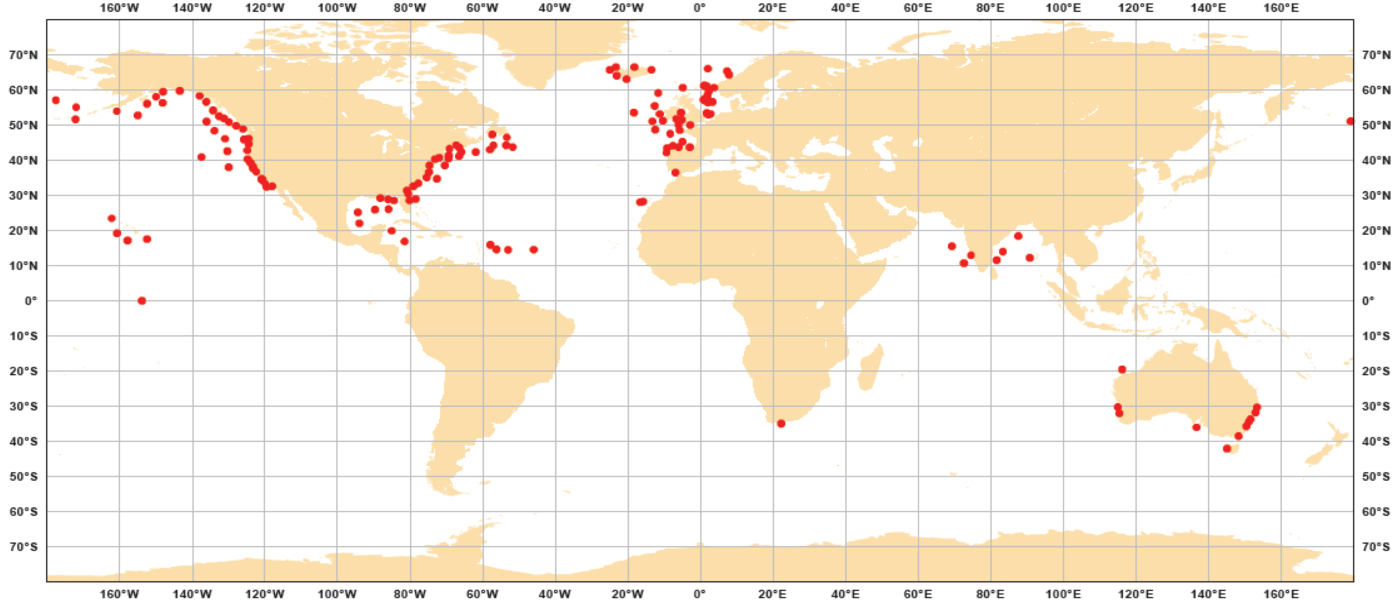
Wind and wave observations at common locations for all buoys from 200706 to 200708



ECMWF

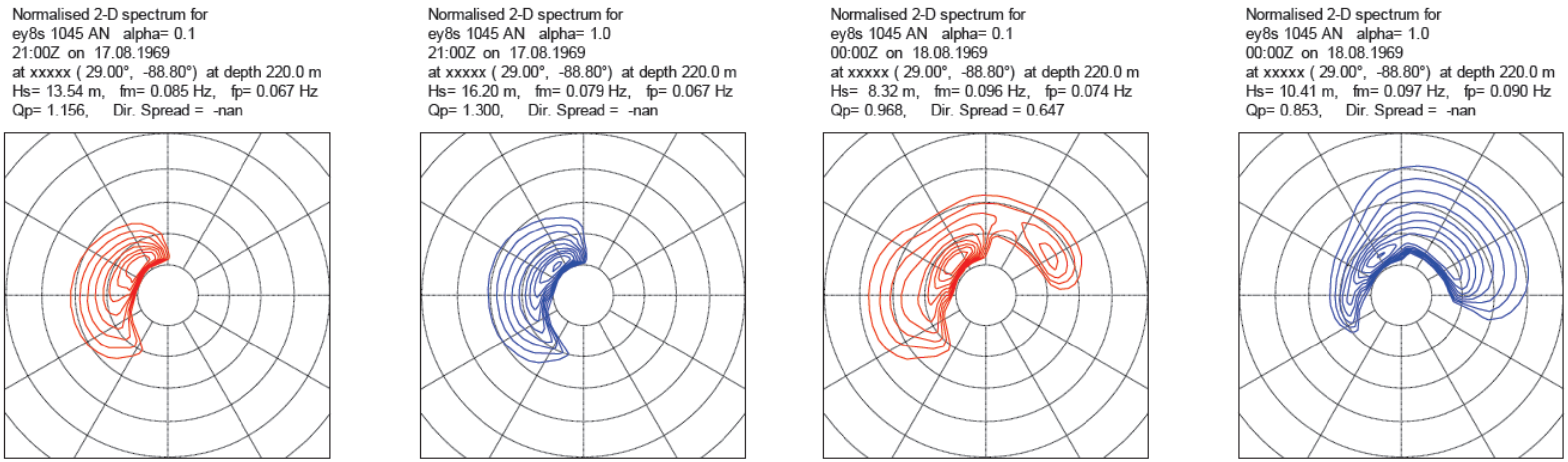
Latest list

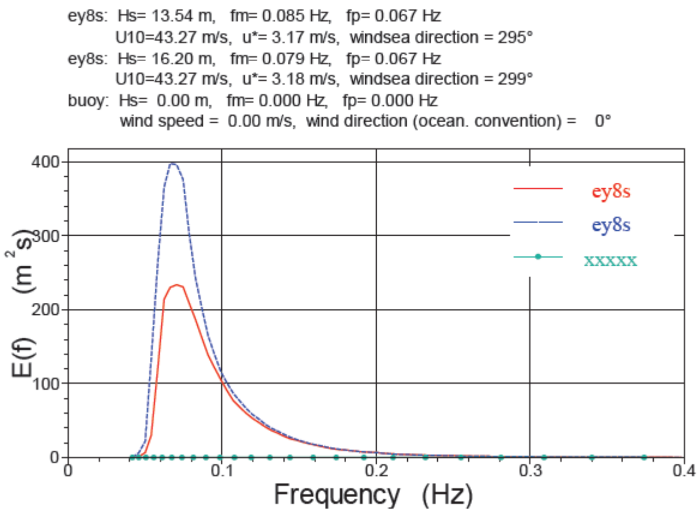
Wind and wave observations at common locations for all buoys from 200708 to 200709

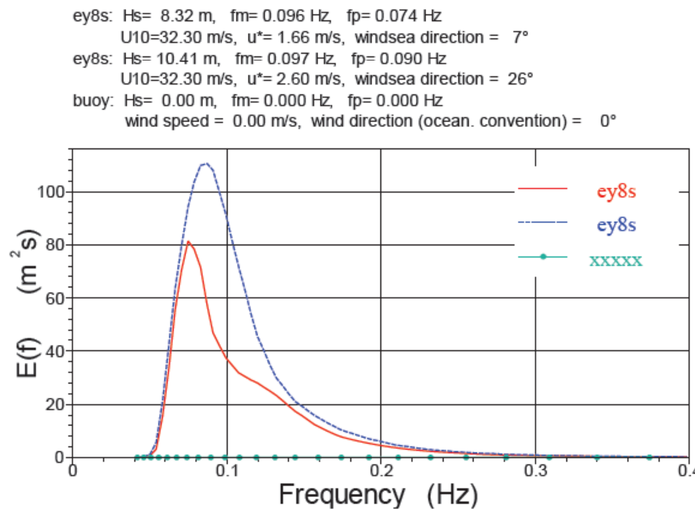


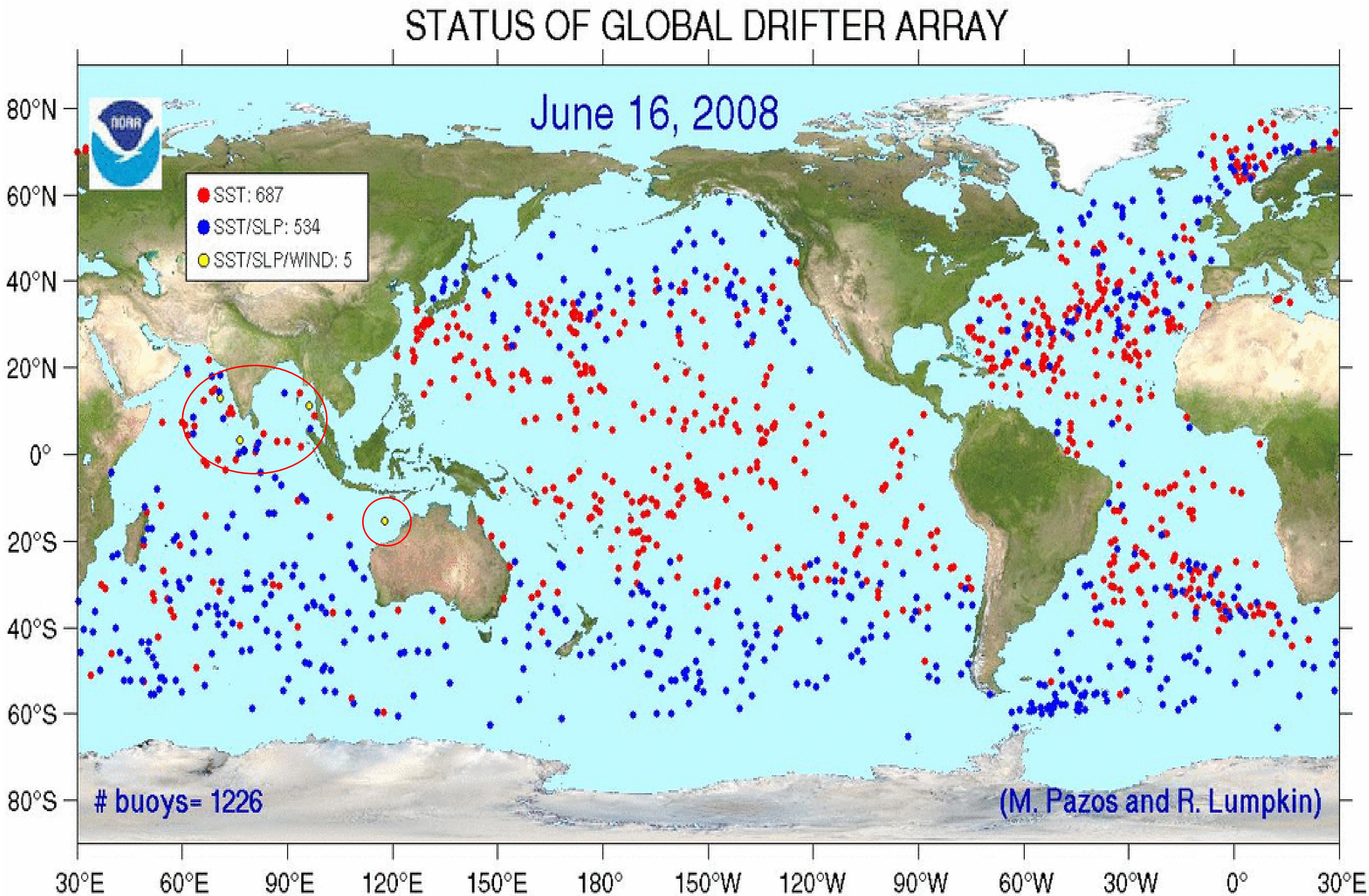
ECMWF

Extension: wave spectra ?

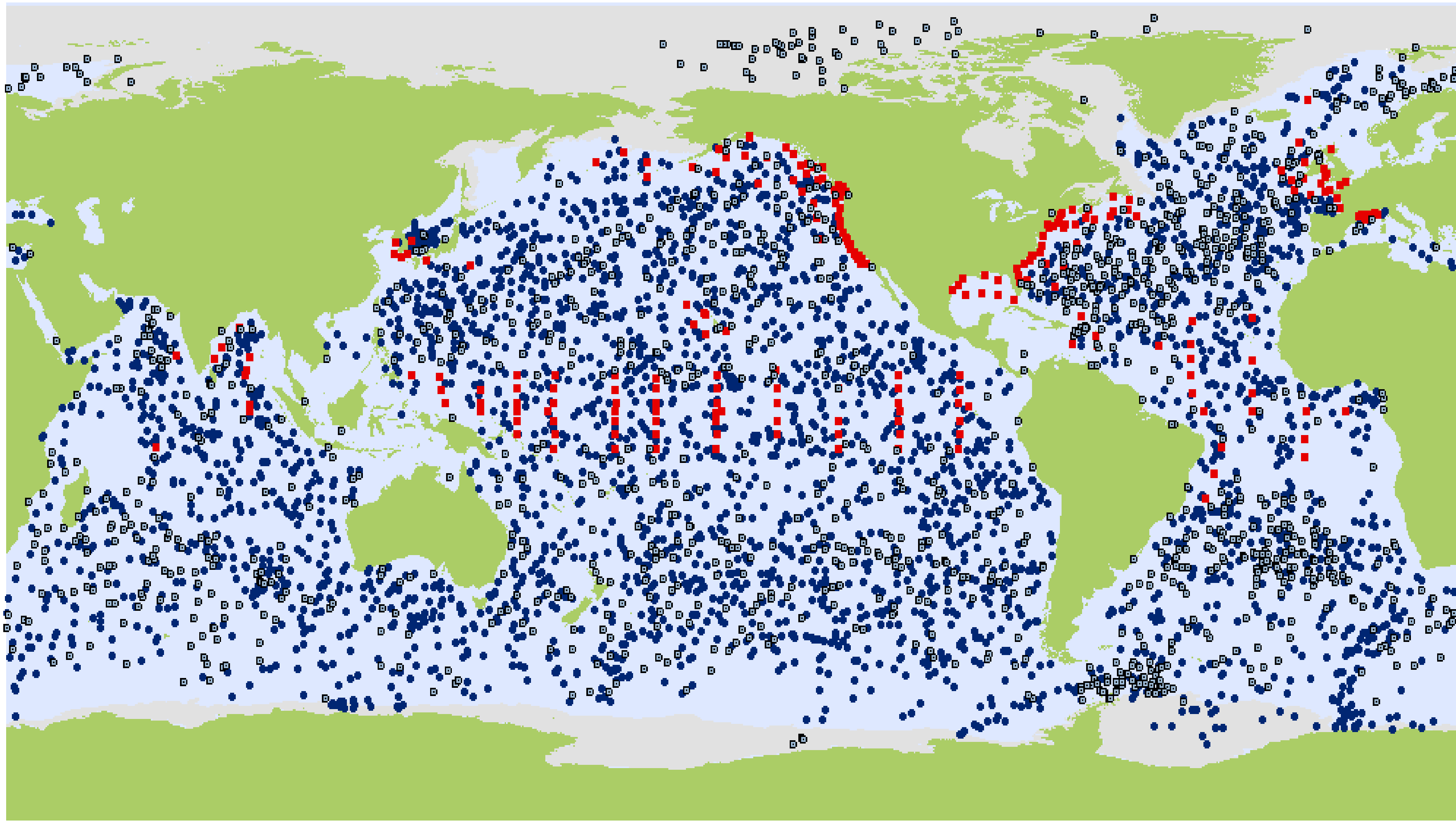








STATUS OF GLOBAL DRIFTER ARRAY
June 16, 2008
SST: 687
SST/SLP: 534
SST/SLP/WIND: 5
buoys= 1226
(M. Pazos and R. Lumpkin)
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S
30°E
60°E
90°E
120°E
150°E
180°
150°W
120°W
90°W
60°W
30°W
0°
30°E

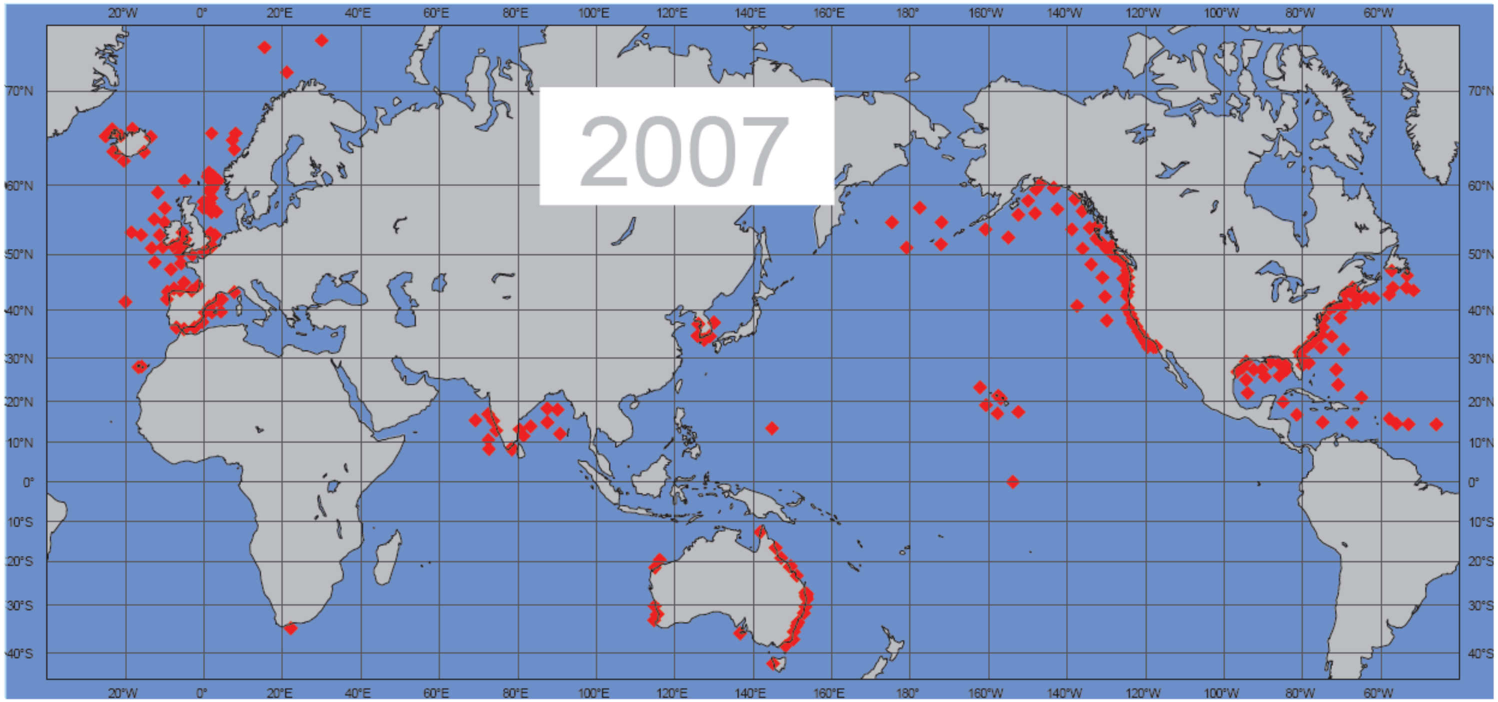


Subsurface Floats • Moored Buoys ■ Surface Drifters

March 2008

jcommops

In-situ observations from buoys and platforms:



Locations where wind and wave data were collocated with ECMWF model.

Sources: mostly via the WMO GTS, but also from the South African Weather Service, and recently from BoM, Puertos del Estado, Oceanor, and SHOM.

Quality control and processing of the data done at ECMWF

Testing and Evaluation

- Continuous testing and evaluation of wave measurement systems is an essential programme activity, of equal importance to the deployment of new assets.

- March 2007 US Wave Sensor Technologies Workshop found :
  - the success of a directional wave measurement network is dependent in large part on reliable and effective instrumentation (e.g. sensors and platforms),
  - a thorough and comprehensive understanding of the performance of existing technologies under real-world conditions is currently lacking
  - independent performance testing of wave instruments is required

Testing and Evaluation (2)

- Principles:
  - basic foundation for all technology evaluations, is to build community consensus on a performance standard and protocol framework.
  - multiple locations are required to appropriately evaluate the performance of wave measurement systems given the wide spectrum of wave regimes that are of interest.
  - protocols and resources could be established to conduct "in-place" evaluations of wave measurement systems which can not easily be moved to the test sites.

Partial List of Technical Issues to be Addressed

- Buoy Response and Transfer Functions
- Power Budget
- Transmission Requirements
- Sensor Accuracy
- Buoy Intercomparison – buoy farm?
- Change in program, e.g. for directional requirement
- Technical documentation and evaluation of differences due to hull, payload, mooring, sampling frequency and period, processing (e.g. frequency bands & cutoff), precision, transmission (e.g. SHIP code)
- Funding

Other Related Activities

- WIGOS: WMO Integrated Global Observing Systems

- WIS: WMO Information System
- META-T Project
- JCOMM Standards and Best Practice Guide

- OGP/JCOMM/WCRP Workshop on Climate Change – data issues