Port Engineering Teaching and Maritime Research at the University of Melbourne

Alex Babanin

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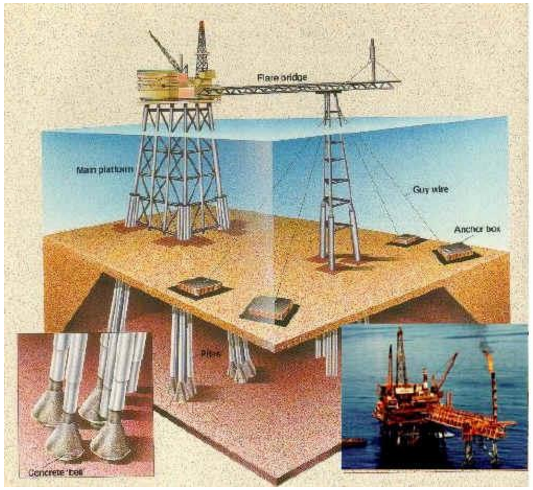
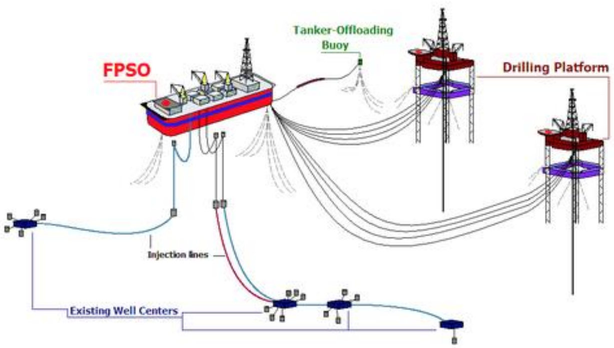
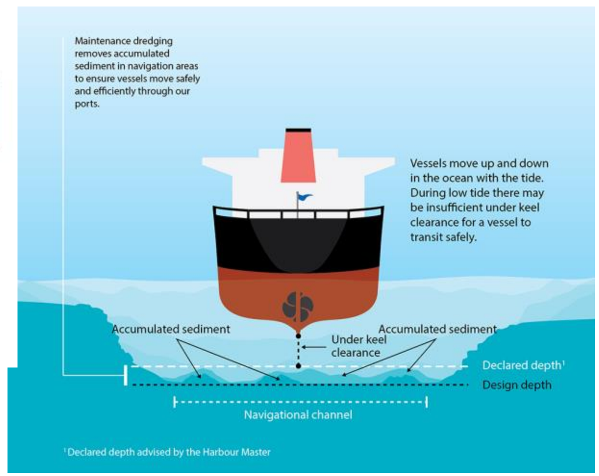
Valparaiso

26 October 2022


Flare bridge
Main platform
Guy wire
Anchor box
Concrete bell


FPSO
Tanker-Offloading Buoy
Drilling Platform
Injection lines
Existing Well Centers


Maintenance dredging removes accumulated sediment in navigation areas to ensure vessels move safely and efficiently through our ports.
Vessels move up and down in the ocean with the tide. During low tide there may be insufficient under keel clearance for a vessel to transit safely.
Accumulated sediment
Under keel clearance
Accumulated sediment
Declared depth[1]
Design depth
Navigational channel
[1] Declared depth advised by the Harbour Master

Port Engineering Course

Port and Harbour Engineering is a suit of engineering subjects to teach design, maintenance and operation of ports

The only *port engineering* formal university qualification in Australia and New Zealand

- Graduate Certificate in Port Engineering
- the only formal Port Engineering qualification in Australia (68 ports) and New Zealand (18 ports)
- 4 port engineering subjects + Metocean Engineering
- Developed in collaboration with peak body Ports Australia
- available to University and industry students
- lectures in intensive mode (1 week per subject) + assignments by distance over semester
- accommodates travel needs of industry students (port employees)
- academics and industry lecturers

Contact: Prof. Alex Babanin
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Graduate Certificate in Port Engineering

As the only course of its kind in Australia, Swinburne's Graduate Certificate in Engineering (Port and Harbour) provides the necessary skills to enhance your engineering career in an industry that continues to grow.

Designed in conjunction with Ports Australia, the national, peak industry body representing all port authorities and corporations, the Graduate Certificate in Engineering (Port and Harbour) is specifically designed for the industry. It covers a broad range of specialist subjects to equip graduates to lead and apply advanced technical and engineering skills to the projects in port environments. With over 50 years' experience in Australia, Boskalis – a leading global services provider operating in the dredging, maritime infrastructure and marine terminal sectors – is a key partner in this program through its academic sponsorship of the Dredging Engineering unit.

Developed in conjunction with Ports Australia, Swinburne University of Technology offers a postgraduate qualification in Port Engineering, comprising four units of study:

Semester 1

- HES6DRE Dredging Engineering
- HES6PHE Port and Harbour Engineering

Semester 2

- HES6PAN Port Access and Navigation
- HES6PSD Port Structural Design

All units are run in an intensive mode: full-time classes (9.00am–4.30pm, with breaks) over one week for each unit, followed by assignments conducted by correspondence during the semester. Each unit is also available to be completed as a single unit during the regular semester period.

Career outcomes

As a graduate of the Graduate Certificate in Engineering (Port and Harbour) you will gain theoretical and practical knowledge that will enhance your job performance and provide opportunities for career advancement in the maritime and port and harbour industry.

Industry links

original

more recent

- a number of local and interstate consulting companies

- our graduates in major ports of every Australian State and NZ
- *beyond teaching*: internships, employment, scholarships, research

Course Description

Teaching Methods

New teaching methods tested in PHE: intensive courses, industry lecturers and students, using industry software in learning and assignments, partial online delivery, video streaming of the classes interstate

Graduate Certificate in Port Engineering

The course includes 5 specific subjects:

Port and Harbour Engineering Port Structural Design Port Access and Navigation	PORT
Metocean Engineering	OCEAN/COASTAL/PORT
Dredging	COASTAL/PORT

Port and Harbour Eng., Day 1

The Business of Ports (introduction session)
8:30 – 10:30
Venket Naidu, AECOM *(2 hours)*

- Historical synergy of marine trade routes, ports and cities
- Great ports and marine infrastructure of the past and present
- Current trade routes, globalization and drivers of trade
- Different types of ports cargo

Design Consideration - Port Infrastructure
10:30 – 12:30
Venket Naidu, AECOM *(2 hours)*

- Ship types and characteristics
- Wharf and jetty types
- Bollards and quick release hook
- Crane rails
- Moorings

Design Considerations
13:30 – 14:30
Venket Naidu, AECOM *(1 hours)*

- Fender Design

14:30 – 16:30
Andrew McArthur, AECOM *(2 hours)*

Dredging Engineering, Day 1

Introduction to Dredging *(1.5 hours)* 08:30 – 10:00 (**F. Schlack, Pilbara Ports**)
Dredging industry history and development drivers
Dredging Applications:

- Capital Dredging
- Maintenace Dredging
- Environmental Dredging
- Mining
- Dredging Projects Management; (Inter)national, Local and Industry Challenges:
  - Competition
  - Shipping
  - Changing Soil Conditions
  - Weather / Sea state
  - Ammunition and Blockages
  - Reclamation issues
  - Legislation, Regulations and Laws
  - Public image and Media
  - Experienced Personnel
  - Ignorance
  - Care for the Environment
  - Maintenance and Wear & Tear
  - Local Cultures
- General Dredging Project development processes:

  - Project Development

Port Structural Design, Day 2

Loadings

Andrew McArthur, AECOM

(2 hours)   8:30 – 10:30

- Metocean introduction
- Loads, factors, combination of loads
- Environmental – waves, cyclone, earthquake
- Vessel Loads – mooring and berthing
- Fixed superstructure loads
- Deck live loads
- Winds
- How to have it all assessed

Design issues. Deck on Piles (i)

Andrew McArthur, AECOM

(1 hours)   10:30 – 11:30

- Beams and precast slabs
- Cast in situ
- Underlying seawalls for wharves

Design issues. Deck on Piles (ii)

Andrew McArthur, AECOM

(1 hours)   11:30 – 12:30

- Effects of bow thrusters

Design Issues. Bulkhead Wharves

Ian Cookson, AECOM

Port Access and Navigation, Day 4

Navigation aids – Different types and their application *(1 hours) 08:30 – 09:30*
Captain Eric Atkinson, Atkinson International Maritime Services

- Aids to Navigation
- Portable Pilot Unit (P.P.U.)
- The Hydrographer
- Notice to Mariners

Port Safety – The risks *(3 hours) 09:30 – 12:30*
Captain Eric Atkinson, Atkinson International Maritime Services

- Port Safety
- Mooring a ship
- The Missing Link – Improving the mooring process
- Look out overhead
- The Chain – Awareness and best practices in the nautical chain

Port Organisation and Modification *(2 hours) 13:30 – 15:30*
Captain Eric Atkinson, Atkinson International Maritime Services

- The Approval Process
- Modification a port or port facility to accommodate the introduction of next generation ships
- Designing a new port from the beginning

Metocean Engineering

<u>Lectures:</u>

Week 31: Ocean Waves and Linear Theory (i) (*2 hours*); F. Nelli

Week 32: Ocean Waves and Linear Theory (ii) (*2 hours*); I. Young

Week 33: Wave Modelling (*2 hours*); A. Babanin

Week 34: Physics of Wave Models, and role of waves in air-sea interactions *(2 hours*); A. Babanin

Week 35: Long Waves *(2 hours*); A. Toffoli

Week 36: Wave Measurements and **Time series analysis** (*2 hours*); A. Toffoli

Week 37: Laboratory demonstration (*3 hours*); A. Toffoli and F. Nelli

Week 38: Second-order wave theory (*1 hour*); A. Toffoli

Wave-current interaction (*1 hour*); A. Toffoli

Week 39: Short term wave statistics (i) (*2 hours*); A. Toffoli

Week 41: Long term wave statistics (ii) (*2 hours*); I. Young

Week 42: Near shore processes (*2 hours*); A. Toffoli

Week 43: Wave loads (2 *hours*); F. Nelli

<u>Tutorials:</u>

Week 30: Linear Wave Theory (ii) (*1 hours*); F. Nelli

Week 31: Linear Wave Theory (ii) (*1 hours*); F. Nelli

Metocean Research at the University of Melbourne

Definitions/ introduction

- Metocean applications cover marine meteorology, oceanography, dynamics of surface waves, air-sea interactions and air/sea boundary layers, coastal engineering, marginal ice zone, marine climate
- Ocean interface and ocean waves are in the centre of metocean applications
- example: loads on on offshore structures, ~10% due to wind, ~20% currents, ~70% waves
- in polar seas, ice is a major metocean factor

WIND-GENERATED WAVES, OCEAN, COASTAL and ARCTIC ENGINEERING, AIR-SEA INTERACTIONS, OCEAN TURBULENCE, OCEAN DYNAMICS, CLIMATE, REMOTE SENSING

dynamics of surface ocean waves

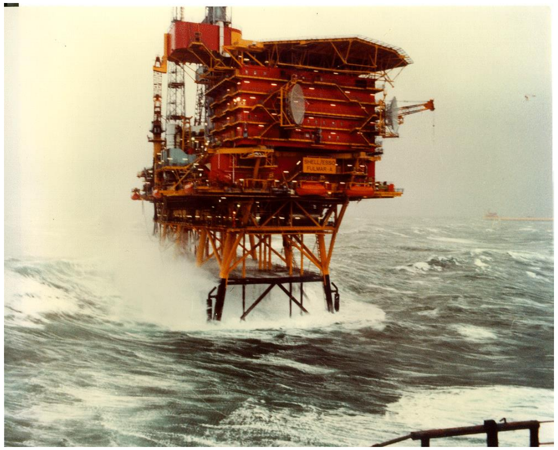
wave breaking and dissipation

spectral and phase-resolving modelling of the wind-generated waves

extreme waves

wave statistics

wave-bottom interactions



wave-current interactions

wave-structure interactions

air-sea boundary layer

air-sea interactions

ocean turbulence

ocean mixing

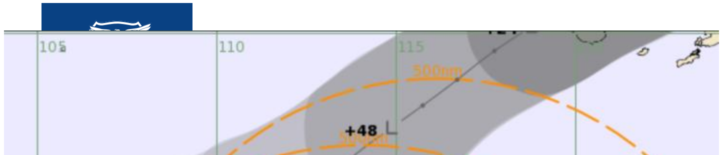
wave climate

climate change

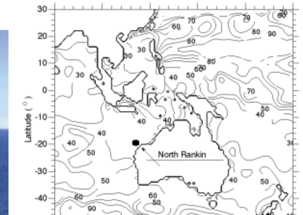
extreme oceanic conditions

environmental measurements and instrumentation

ocean remote sensing



Facilities



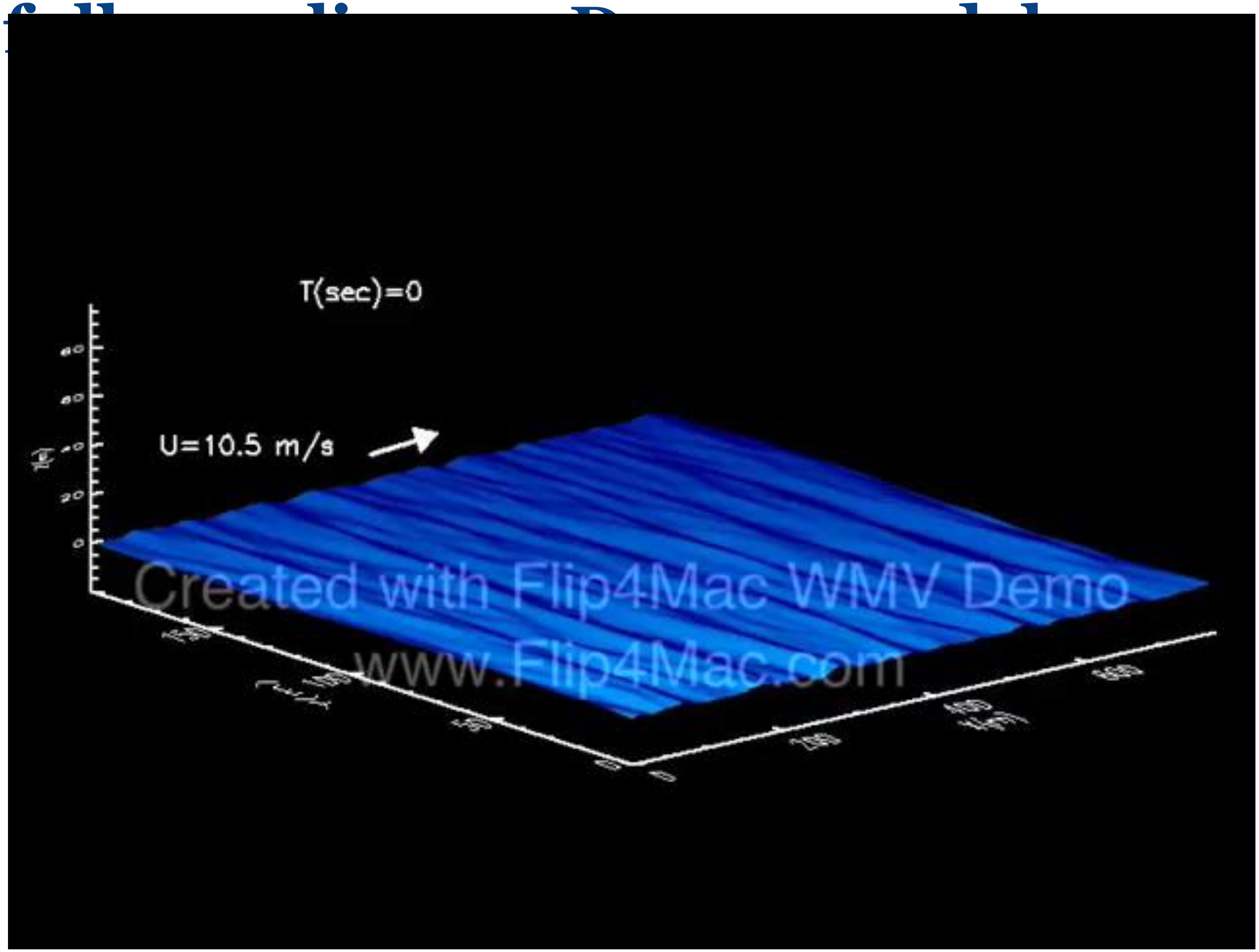
UoM pilot deployments and wave heights, *MIZ* (2017), *fast ice* (2019, 2020)

Global satellite database and wave hindcast, 40 years

phase resolving modelling

state of the art models, developed in house

explicit simulations of surface elevations, turbulent wind, underwater kinematics and dynamics



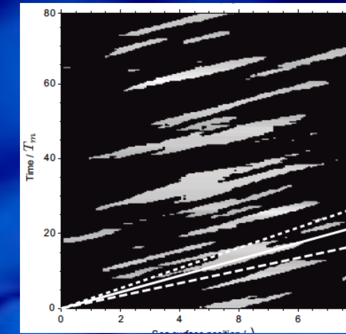
engineering problems: breaking probability, short-crestedness, kinematics
Chalikov & Babanin, *OMAE,* 2013

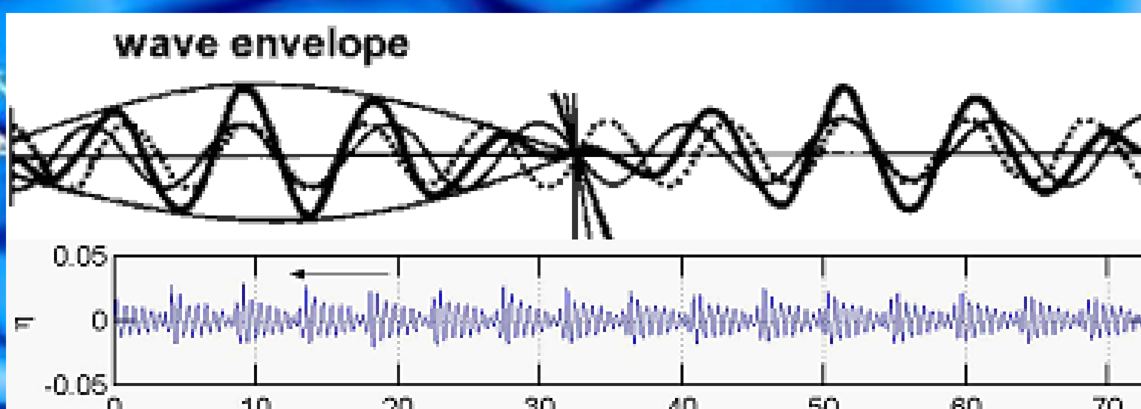
1/128 of total domain

Nieto Borge et al., OM, 2013

2D freak wave appearance

freak wave, H =2Hs





spectral wave modelling

new physics in official models used for wave forecast, ocean/coastal engineering

Radiative Transfer Equation is used in spectral models for wave forecast

$$\boxed{\frac{dE(k,f,\theta,x,t)}{dt} = S_{tot} = S_{in} + S_{ds} + S_{nl} + S_{bf}}$$

➢ **Describes temporal and spatial evolution of the wave energy spectrum E(k,f,θ,t,x)**

S_{tot} – all physical processes which affect the energy transfer

S_{in} – energy input from the wind

S_{ds} – dissipation

S_{nl} – nonlinear interaction between spectral components

S_{bf} – dissipation due to interaction with the bottom

$$S_{ds} = S_{breaking} + S_{adverse\_wind} + S_{swell} + \ldots$$

Observation-based physics

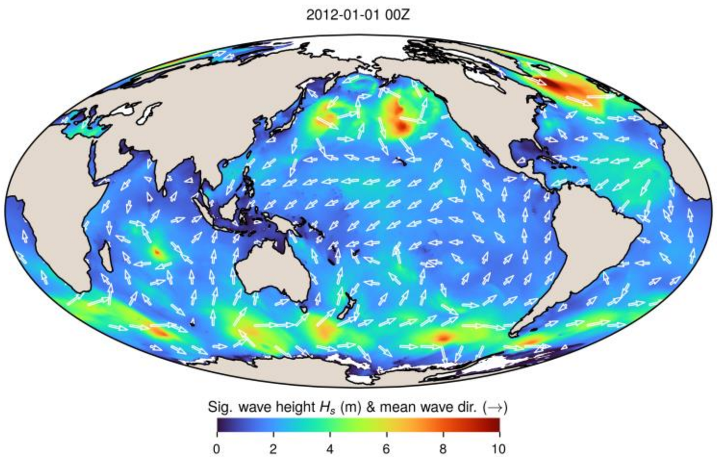
$$\frac{dE(k,f,\theta,x,t)}{dt} = S_{tot} = S_{in} + S_{ds} + S_{nl} + S_{bf}$$

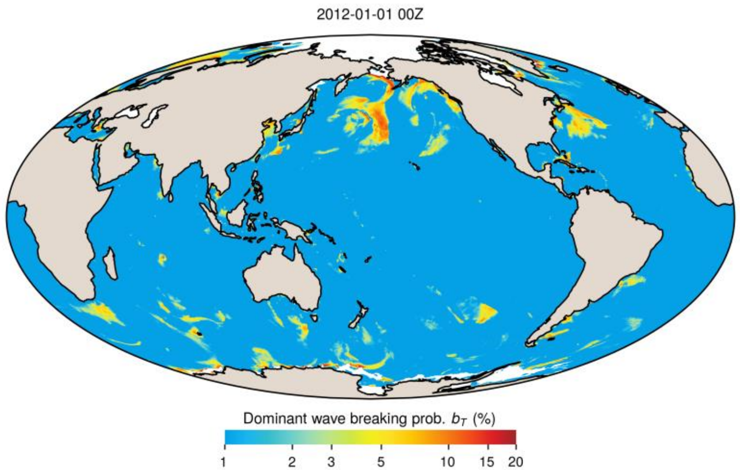
- replaced previous physics
- ***implemented in official releases of WAVEWATCH-III (US NOAA wave-forecast model, 2014, 2016, 2019, 2020), SWAN (European coastal engineering model, 2012, 2018), WWM-III (Germany, 2020), WAM (2022)***
- new source terms: wind input, whitecapping dissipation, swell dissipation, wave-bottom interaction, interaction with adverse winds, wave-ice interactions, nonlinear wave-current interactions, nonlinear wave-wave interactions quantitatively: based on measurements
- qualitatively: new physical features, previously unknown
- in progress:, coupling with phase-resolving models, wave-ice modules, infragravity waves, directional source functions

Liu et al., 2019, JPO, 2021, JAMES

THE UNIVERSITY OF

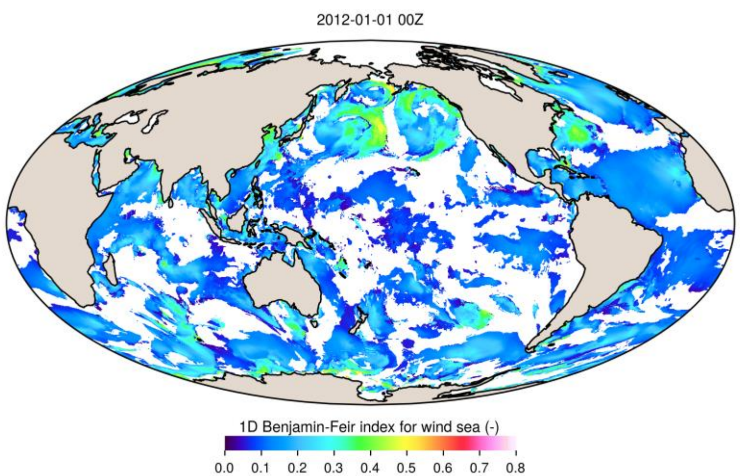
Unconventional wave parameters





Apart from traditional wave parameters (wave height, period), we also provide

- dominant wave breaking probability
- wave-induced mixed layer depth
- wave spreading factor
- 1D & 2D Benjamin-Feir index
- space-time extreme crest height and wave height



Global hindcast 1950-2022
Data are available to the public

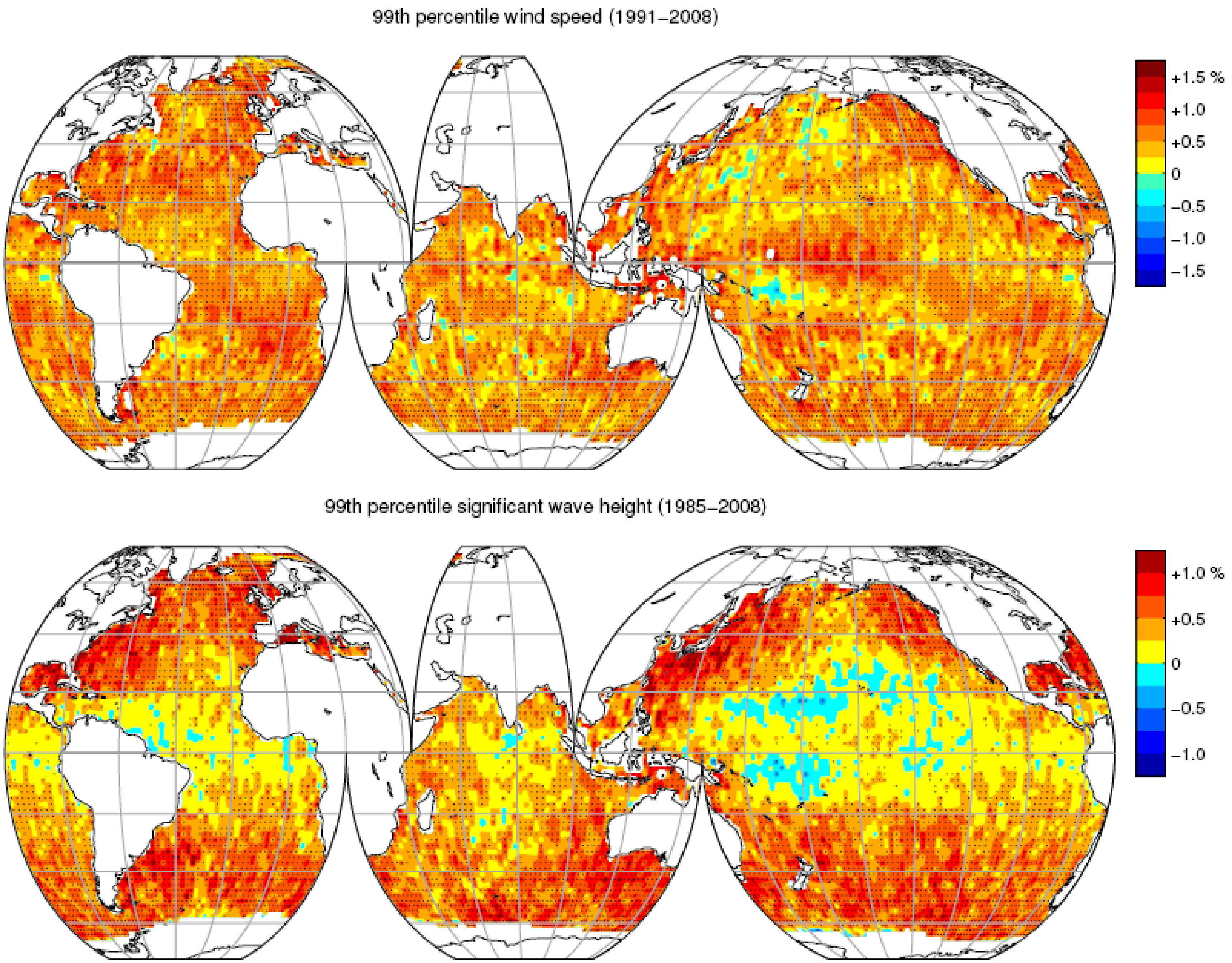
global wind/wave climate

new research field

satellite observations provide information on Metocean properties globally, over ~40 years

waves can also serve as a climate proxy, and influence the atmospheric and oceanic climate

satellite observations, global wind and wave trends, 25 years



Young, Zieger, Babanin, *Science,* 2011

Summary

The only Port Engineering formal qualification in Australia

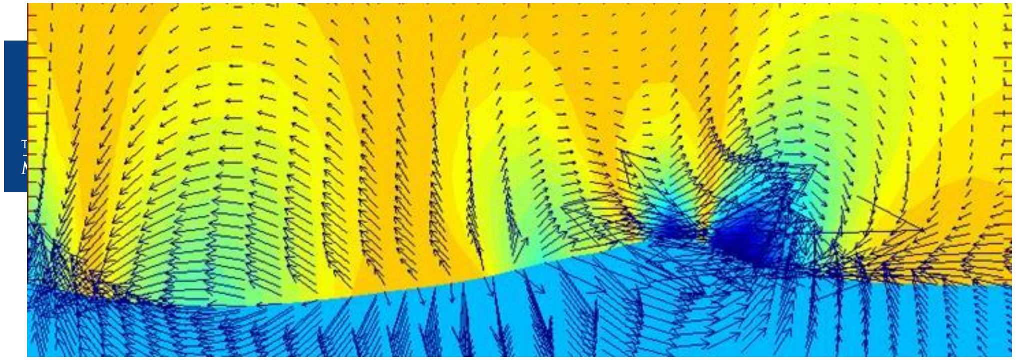
Fluid mechanics of waves: our own fully nonlinear exact 3D wave models, coupled with wind and water turbulence

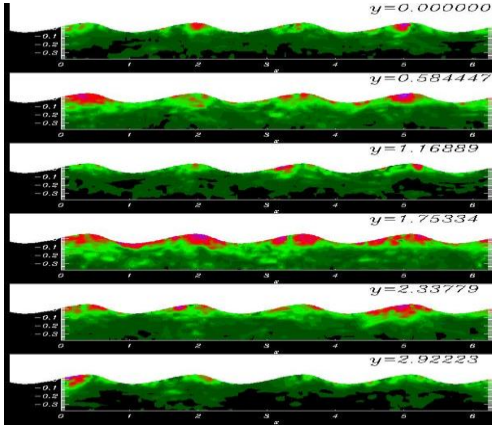
Spectral (wave forecast) models: our own observation-based physics, in official releases of the major wave models (USA, Europe)

Wave-coupled approaches to marine atmospheric boundary layer and upper ocean, from turbulence to climate

Satellite Metocean climatology (waves, wind, ice)

Extreme Metocean conditions: based on our own in situ observations





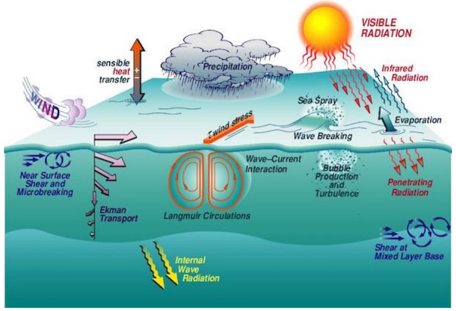
Wave coupled effects in atmosphere, ocean, marginal ice zone

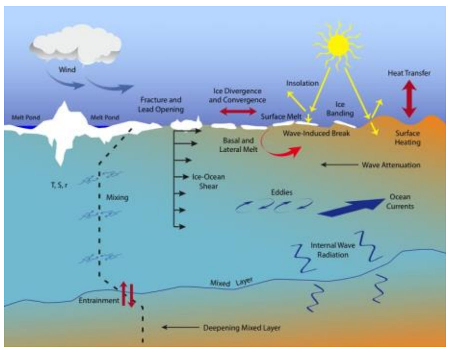
sea drag

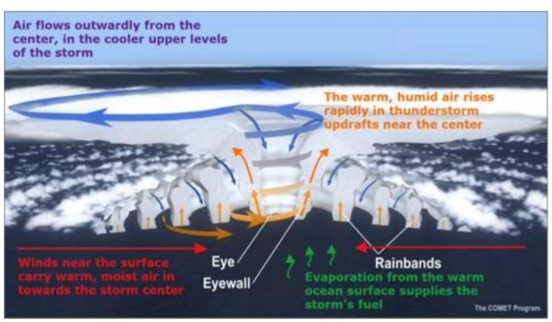
ocean mixing

wave-ice breakup

Waves as Atmosphere/Ocean Link





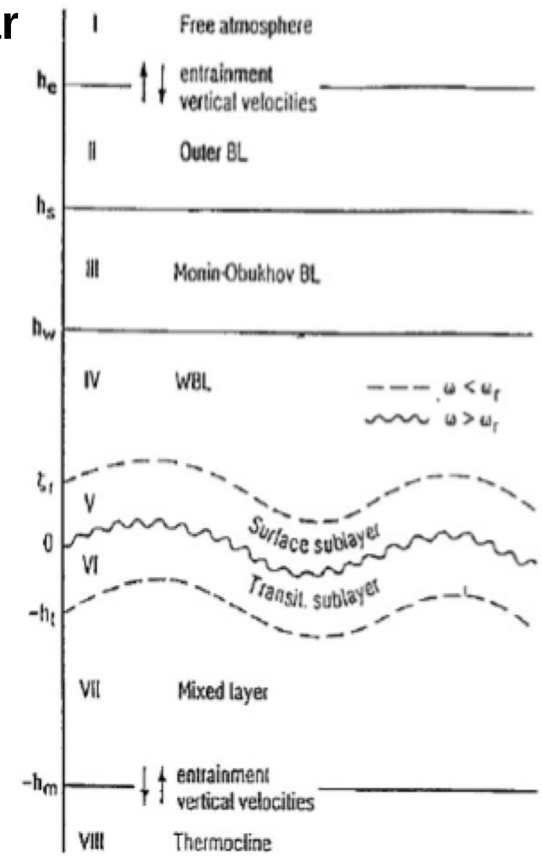


Small/large-scale air-sea processes ar but not in the models

- Atmospheric boundary layer
  - winds generate waves
  - waves provide surface roughness and change the winds
  - waves evolve, fluxes change
  - *waves generate spray*
- Upper ocean mixed layer
  - waves generate currents
  - produce turbulence
  - turbulence: facilitates mixing
  - changes the circulation, SST, nutrient transport
  - *facilitate gas exchange*

Tradition and future

- Small scales and large scales are separated. Models reach saturation in their performance
- They need to be coupled, from turbulence to climate. Understanding exists, computer capacity exists

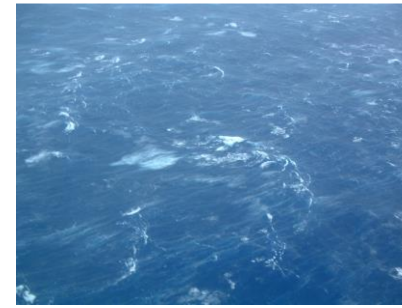


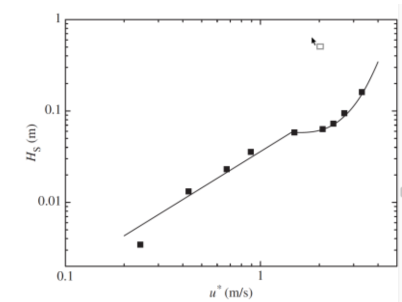
Chalikov & Belevich, 1993, BLM

everything changes at extreme conditions

everything changes at extreme conditions

- At wind speeds U_{10}*>32m/s,* dynamics of the atmospheric boundary layer, of the ocean wave surface and of the upper ocean layer – all change
- At the surface, at U_{10}*~34m/s:*
- wave asymmetry saturates *(Leikin et al., 1995, NPG),* wave breaking happens due to a different reason
- mass transfer velocity and volume flux of droplets increase sharply (*Iwano et al., 2013, Tellus B)*
- Sea drag saturates at U_{10}*=32-33m/s* above the surface *(Powel et al., 2003, Nature)*
- Cross-interface gas fluxes still grow, but at a slow rate if U_{10} *> 35m/s,* additional mechanisms become active below the surface *(McNeil & D'Asaro, 2007, J. Mar. Scie)*
- ***Simultaneous change of the regime in all the three air-sea environments means they are principally coupled***





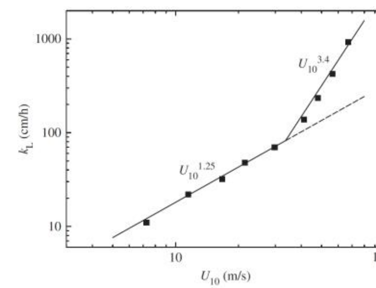


Fig. 3. Mass transfer velocity k_L against wind speed at 10 m height U_{10}.

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Satellite Metocean climatology (waves, wind, ice)

Extreme Metocean conditions: based on our own in situ observations

Potential new subjects in Ocean/ Offshore Engineering

Prepared in collaboration with Dr. Said Mozaheri, Beta Int. Associates Pty Ltd.

Design of Offshore Structures

The main topics covered are: historical development of offshore structures; ocean environment; loads and responses; probabilistic design of offshore structures; fixed offshore platform design; floating offshore platform design; topside facilities layout

Dynamics of Ocean Structures (Fluid-Structure Interactions)

The main topics covered are: introduction to structural dynamics; characteristics of single and multi-degree-of-freedom model; formulation of equation of motion; matrix methods for dynamic analysis; modal analysis; iterative frequency domain approach; response spectrum - narrow band process; return period analysis; fatigue prediction; modal response method; modal mass contribution; vortex-induced vibration

Marine Geotechnics and Foundation Engineering

The main topics covered are: geophysical and geotechnical techniques; in-situ testing systems; operational considerations; industry legislation, regulations and guidelines; laboratory testing; offshore foundation design; shallow foundation design; spud-can penetration predictions; standards

Potential new subjects in Ocean/ Offshore Engineering, slide 2

Prepared in collaboration with Dr. Said Mozaheri, Beta Int. Associates Pty Ltd.

Design and Construction of Marine Pipelines

The main topics covered are; design basis; route selection and marine survey; hydraulic design; buckling and propagation; stability analysis; corrosion; crossing design; construction and installation feasibility.

Mooring and Riser Engineering

The main topics covered are: mooring system design; mooring hardware components; industry standards and classification rules; drilling and production risers; vortex-induced vibration of risers; fatigue analysis; reliability-based design; design codes.

Marine Renewable Energy

The main topics covered are; introduction to marine renewable energy; physics and hydrodynamics setting of marine renewable energy; baseline and monitoring methods for detecting impacts of hydrodynamic energy extraction; fixed and floating wind turbines; wave energy convertors; combined wave-wind-power devices; design aspects; wave and wind theories; aerodynamic and hydrodynamic loads; dynamic response analysis; stochastic analysis

Journal of Advances in Modeling Earth Systems

RESEARCH ARTICLE
10.1002/2016MS000878

Simulated ocean response to tropical cyclones: The effect of a novel parameterization of mixing from unbroken surface waves

Lachlan Stoney[1], Kevin Walsh[2], Alexander V. Babanin[1], Malek Ghantous[3], Pallavi Govekar[4], and Ian Young[1]

Key Points:
- Mixing from unbroken surface waves under tropical cyclones can modify ocean surface temperatures by up to 0.5°C

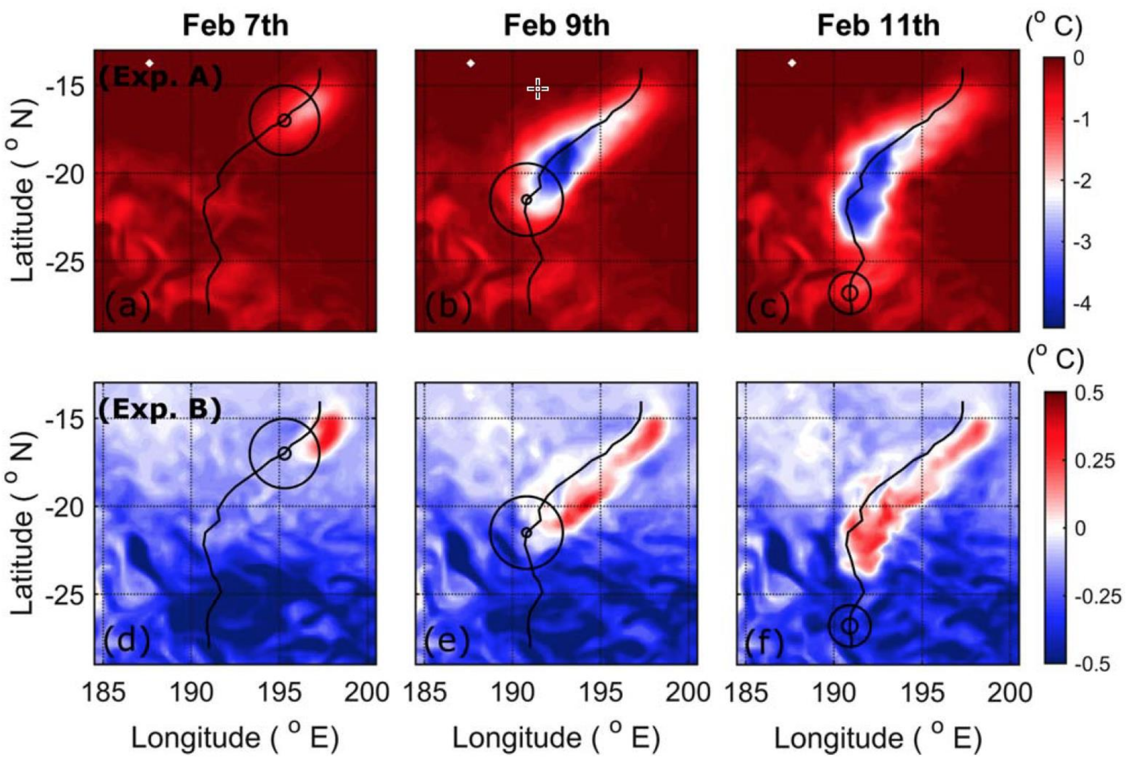


Figure 3. The development of the cold wake from Tropical Cyclone Dovi, 2003. The top plots (a–c) show the potential temperatures at 5 m depth from Experiment A, while the bottom plots (d–f) show the wave-induced anomalies thereof from Experiment B. Values are daily averages. The storm moved along the black line from top right to bottom left, with the inner and outer circles representing the *RMW* and R34, respectively, for each day at 12:00 UTC. Note the different color scales.

- Southern Hemisphere TC
- MOM5
- (top) no waves
- (bottom) warm anomalies on the side with the strongest winds and cool anomalies in other regions
- initial wave-induced deepening of the mixed layer, which can modify the subsequent shear-induced entrainment and upwelling
- could potentially influence tropical cyclone intensity and structure

Altimeter and other Metocean Data

Continuous satellite global coverage since 1991

ERS1 , ERS2 and ENVISAT cover up to 82º lat.

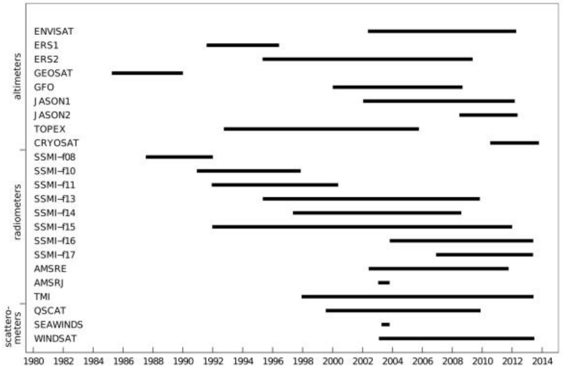
GEOSAT and GFO cover up to 72º latitude

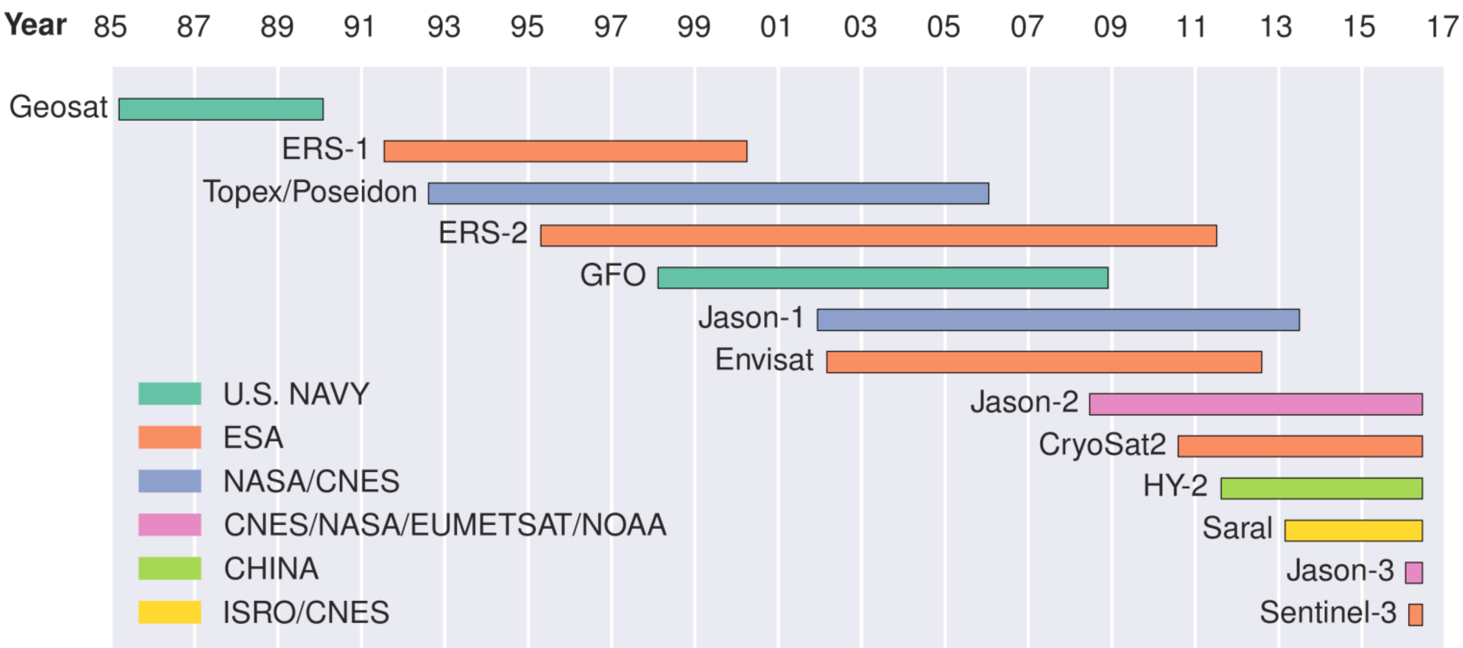
JASON and TOPEX reach 66º latitude

CRYOSAT2 covers areas up to 88º

HY-2 covers areas up to 80º

SARAL covers areas up to 81º





Global measurements of waves, winds, currents, ice, sea surface temperature, among other metocean properties