AGENDA 2030 DI BOLOGNA

# L'ITALIA SOSTENIBILE

## IDEE E AZIONI PER IL FUTURO

BOLOGNA 20-21 MAGGIO 2016

C.N.R. AREA DELLA RICERCA DI BOLOGNA

# Le onde estreme e i cambiamenti climatici

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BOLOGNA 20-21 MAGGIO 2016 C.N.R. AREA DELLA RICERCA DI BOLOGNA

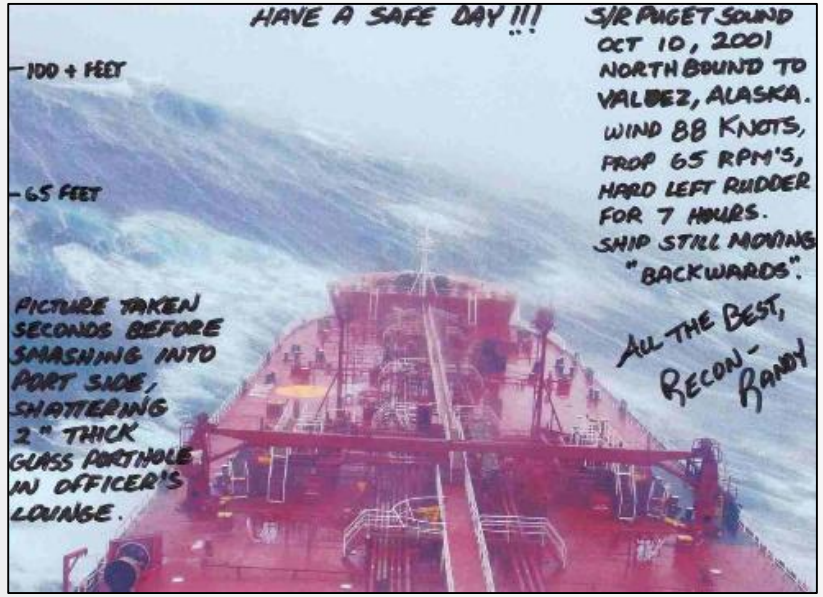
# Contesto:
# Sicurezza Marittima e Cambiamento Climatico

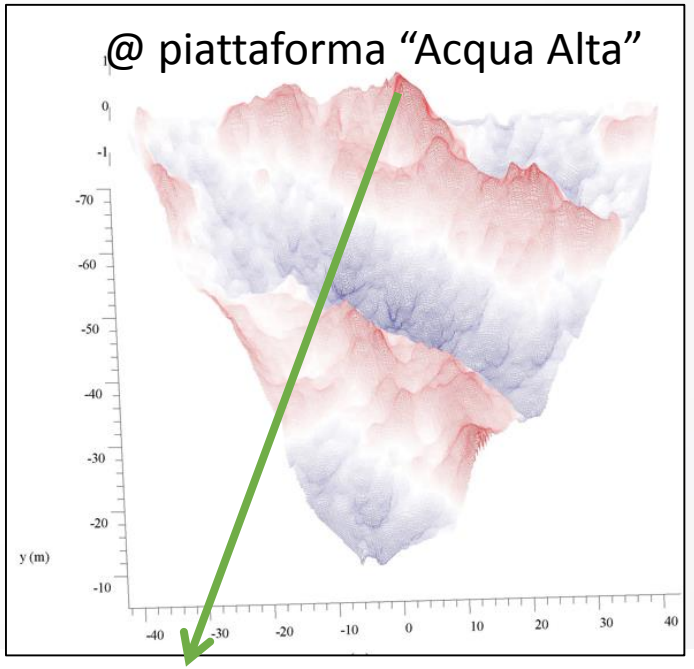
- La **sicurezza** delle strutture a mare è una delle maggiori preoccupazioni delle imprese di navigazione ed off-shore.
- E' riconosciuta l'importanza di includere negli standard progettuali la conoscenza **stato dell'arte** in ambito marino (onde, livello, correnti,…).
- Massima attenzione è rivolta agli **eventi estremi (di progetto)** e alla loro relazione con il **riscaldamento** globale.
- Recenti **incidenti** marini hanno evidenziato l'importanza di valutare miglioramenti della **conoscenza** dei fenomeni e degli standard progettuali.

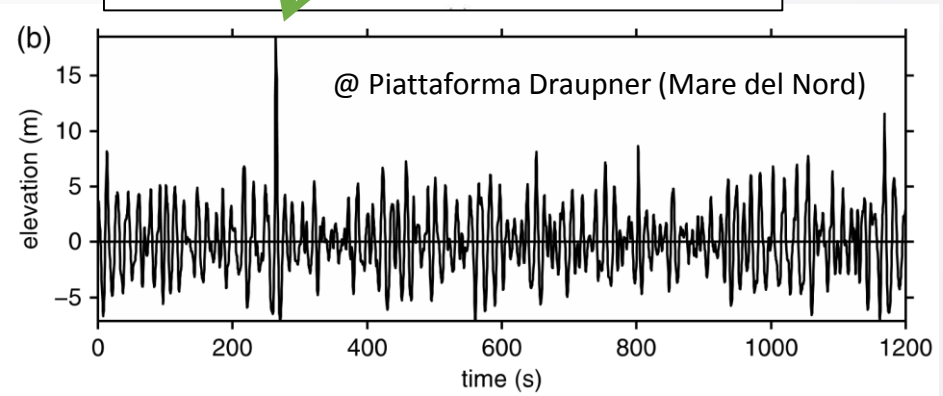
➢ In questo senso un aumento della conoscenza delle **onde estreme** e del loro rapporto con il **cambiamento climatico** previsto è cruciale per l'aggiornamento dei carichi ("**onda di progetto**") cui le strutture a mare devono / dovranno resistere.

# Onde estreme ("Freak Waves")

- Onde "molto" **alte** (fino a 20-30 m) rispetto a quelle medie della mareggiata
- **Localizzate** nello spazio e nel tempo



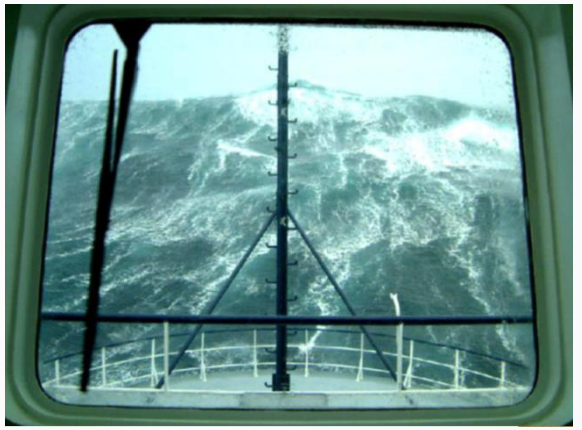



# Wall of Water!

*"… a great **wall of water** – it looked as if we were going into the White Cliffs of Dover!"*

(La nave da crociera Queen Elizabeth II incontrò nel nord Atlantico nel 1995 una freak wave alta circa 30 m)



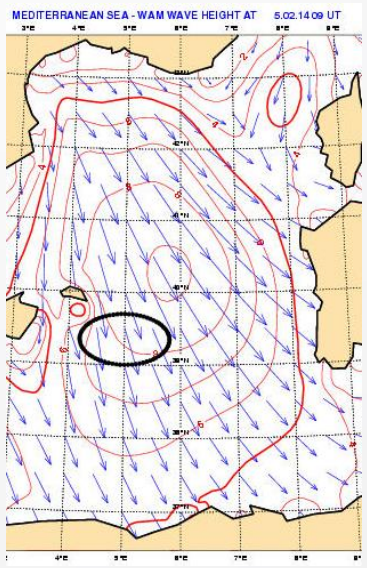
- "We were in a storm and the tanker was running before the sea. This amazing wave came from the aft and **broke over the deck**. I didn't see it until it was alongside the vessel but it was special, **much bigger than the others**. It took us by surprise. I never saw one again."
- Philippe Lijour, first mate of the oil tanker Esso Languedoc, describing the **huge wave (20 m high)** that slammed into the ship off the east coast of South Africa in 1980
- Rogue waves are often preceded by a **deep trough**"

(New Scientist, 2001)

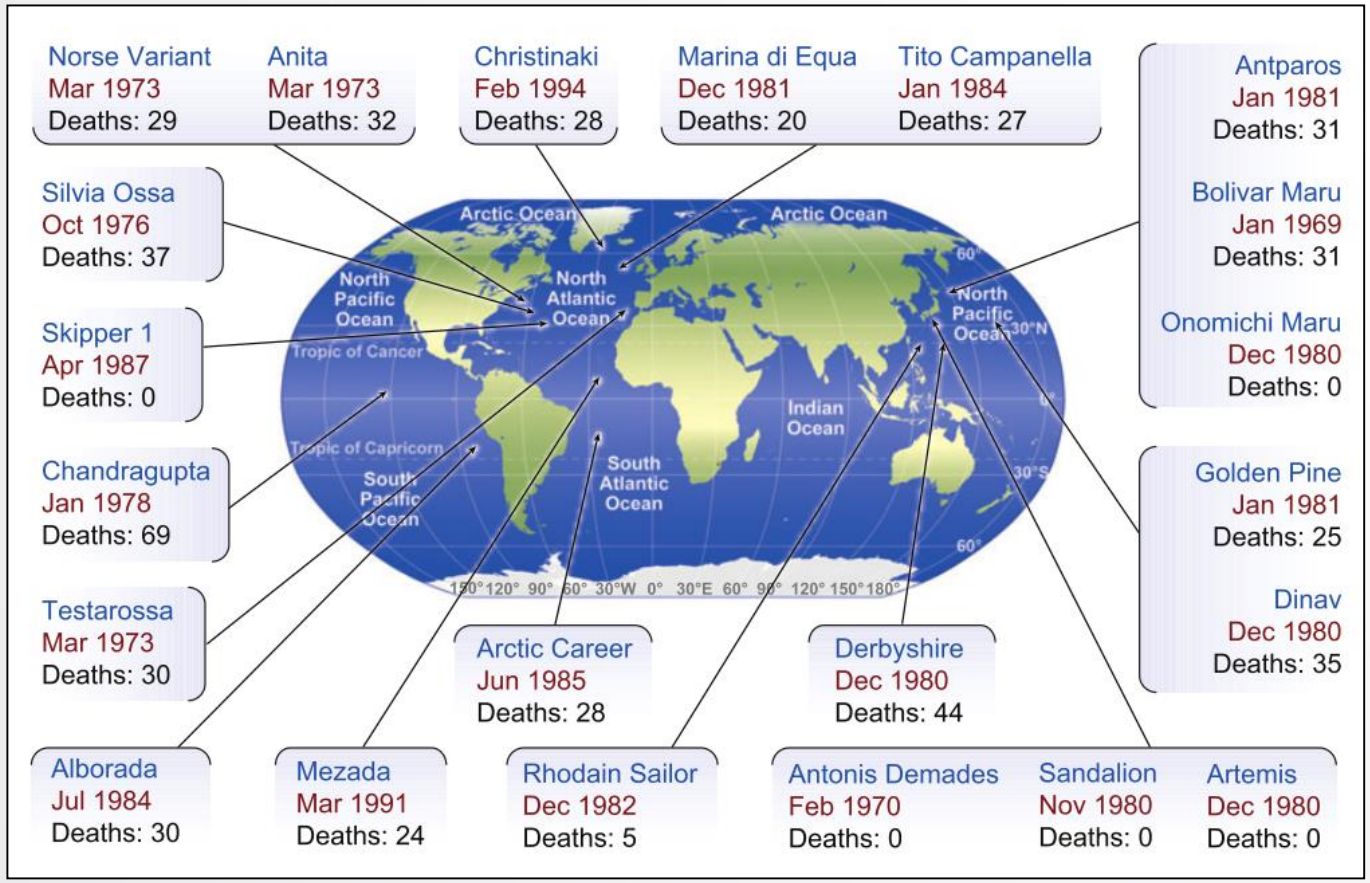
# L'incidente della *Voyager*

- On 14 February 2005 the passenger cruiser "**Voyager**" with about 800 people on board was on route between Tunis (Tunisia) and Barcelona (Spain), when it came across a **severe mistral storm**. In particular, at about 08:00 UTC the ship was struck by one or more **major waves**
- … shattered window(s) in the upper control room led to flooding of the general control system and **brought all the engines to a halt**.

(Bertotti and Cavaleri, 2008)



# Marine Safety




Posizione delle 22 navi affondate a seguito dello scontro con una freak wave tra il 1969 e il 1994. (copyright C. Kharif and E. Pelinovsky, 2003).

# Onde Estreme: a puzzling problem

- Non-linearità
- Interferenze
- Risonanza
- Interazione
- Space-Time
- …

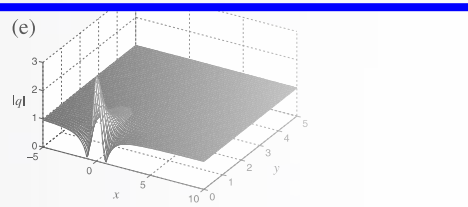



**Fig. 4.4** Breather solutions (4.73) of the NLS equation. (**a**) A traveling Ma soliton-like solution ($\lambda = 1.2+0.2i$). (**b**) A traveling envelope-like solution ($\lambda = 0.5+0.2i$). (**c**) The time-periodic Ma soliton ($\lambda = 1.2$). (**d**) The space-periodic Akhmediev solution ($\lambda = 0.8$). (**e**) The rational solution of Peregrine ($\lambda = 1$)

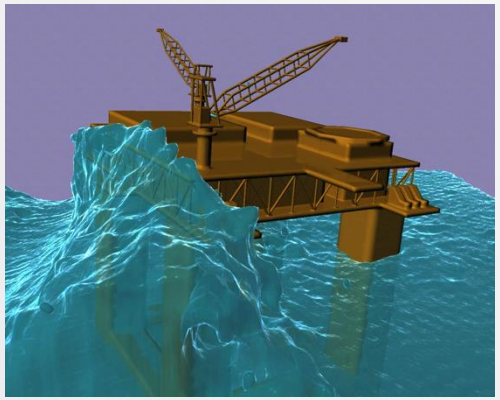
$$q_{br}(x,t) = e^{2it+i\varphi_0} \times \frac{\cos\mu\cos(2\gamma(x-x_0)) - \cosh(\sigma t - 2i\mu)}{\cos\mu\cos(2\gamma(x-x_0)) - \cosh(\sigma t)}, \qquad (4.79)$$

where

$$\gamma = \sin\mu, \quad \sigma = 2\sin(2\mu), \quad \lambda = \cos\mu.$$

- Osservazione
- Previsione

# Dalla *Teoria* alla *Pratica* … L'onda di progetto



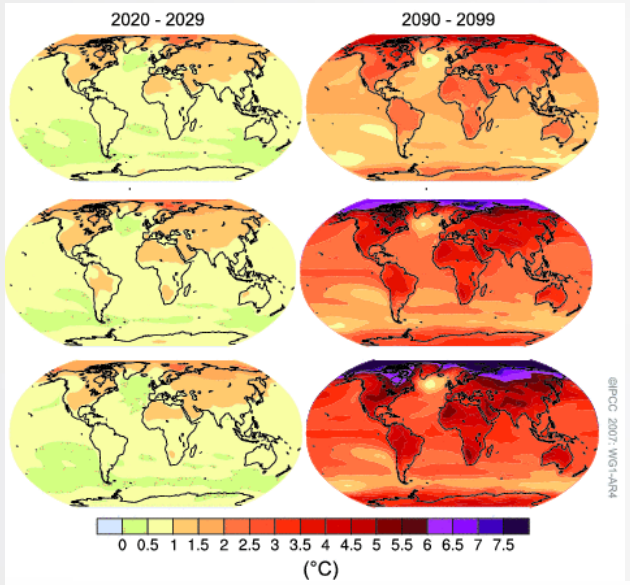
RECOMMENDED PRACTICE
DNV-RP-C205

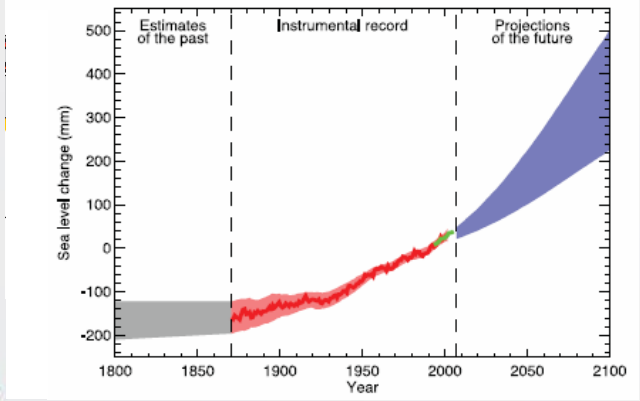
ENVIRONMENTAL CONDITIONS
AND ENVIRONMENTAL LOADS

**3.5.13 Freak waves**

*3.5.13.1* The occurrences of unexpectedly large and/or steep waves, so called freak or rogue waves, are reported. Even though the existence of freak waves themselves is generally not questioned, neither the probability of occurrence of these waves nor their physics is well understood. It has been suggested that freak waves can be generated by mechanisms like: wave-current interaction, combined seas, wave energy focusing. No consensus has been reached neither about a definition of a freak event nor about the probability of occurrence of freak waves.

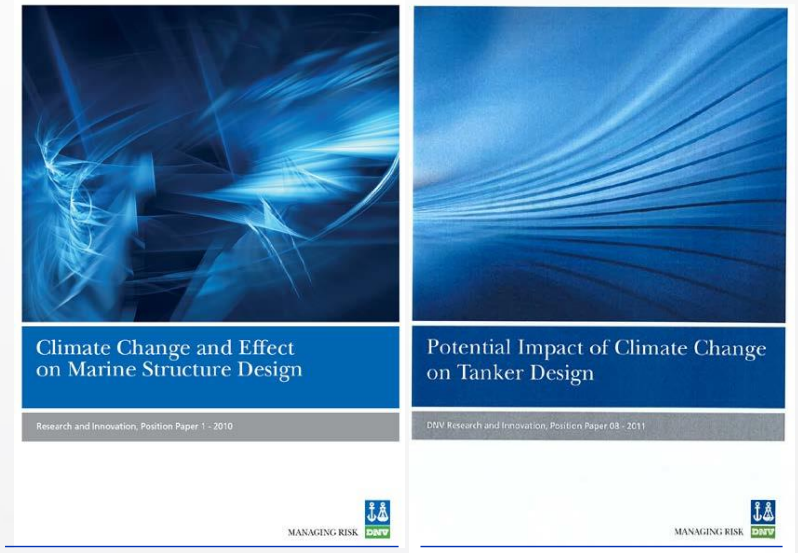
# Onda di progetto…e se il clima (ondoso) cambiasse?




## Questioni chiave

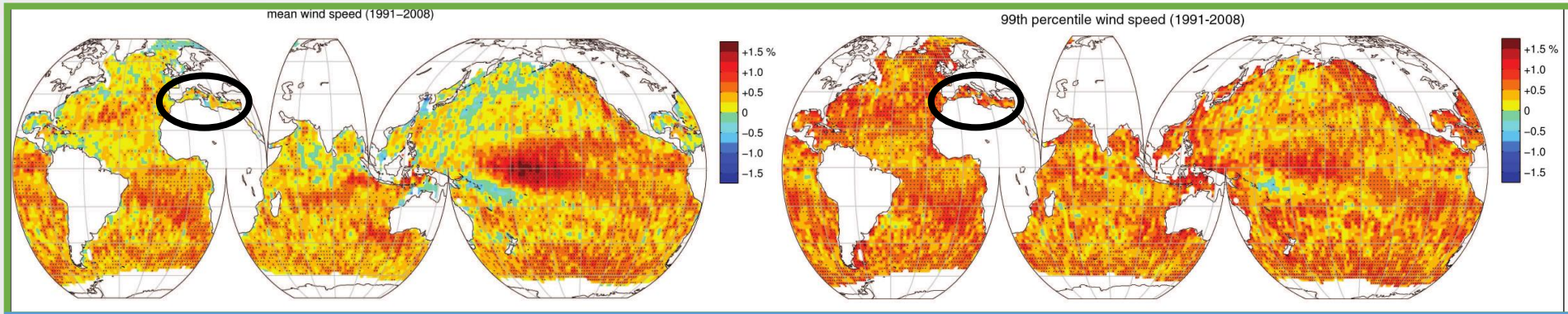
- La probabilità di **occorrenza** degli eventi estremi aumenterà in futuro?
- Quali **zone** saranno maggiormente interessate?
- Quanto il cambiamento climatico avrà effetto sul **traffico** navale e sulla **progettazione** delle navi e delle strutture a mare?
- Le **regole** e gli **standard** per le strutture off-shore devono essere aggiornati?

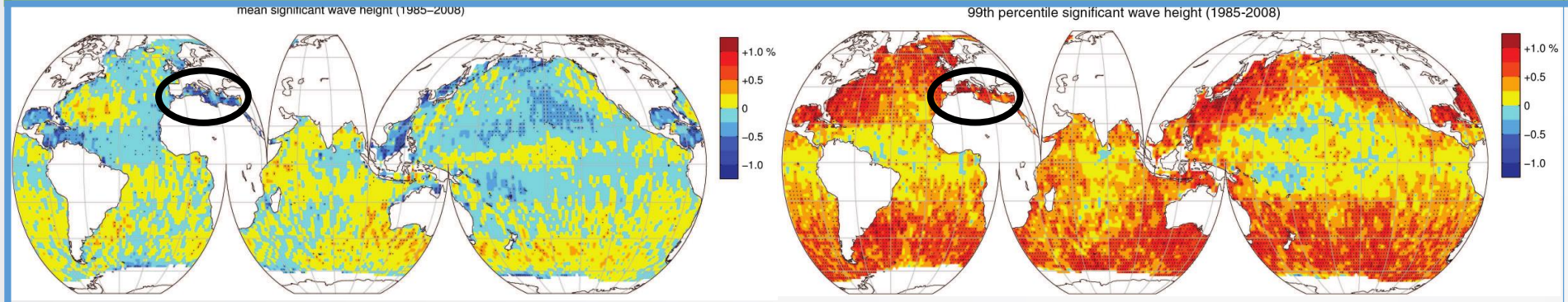


# Il "clima ondoso" sta cambiando?

**MEDIA (1985,1991-2008)**

**99-percentile (1985,1991-2008)**




**Vento**

- Media e 99-perc. crescono.
- Estremi crescono più velocemente della media.

**Onde**

- Media: condizione neutrale.
- 99-perc: trend positivo alle alte latitudini.

"The present analysis does, however, indicate that over the past two decades there has been a consistent trend toward **increasing wind speeds**. For **wave height**, the results are more complex, with no clear statistically significant trend for mean monthly values. At more **extreme conditions**, there is a clear statistically significant trend of increasing wave height at high latitudes and more neutral conditions in equatorial regions."

(Young et al., 2011. *Global Trends in Wind Speed and Wave Height*, Science)

➢ Trend anche nel **Mediterraneo**

# Come cambierà il "clima ondoso"?

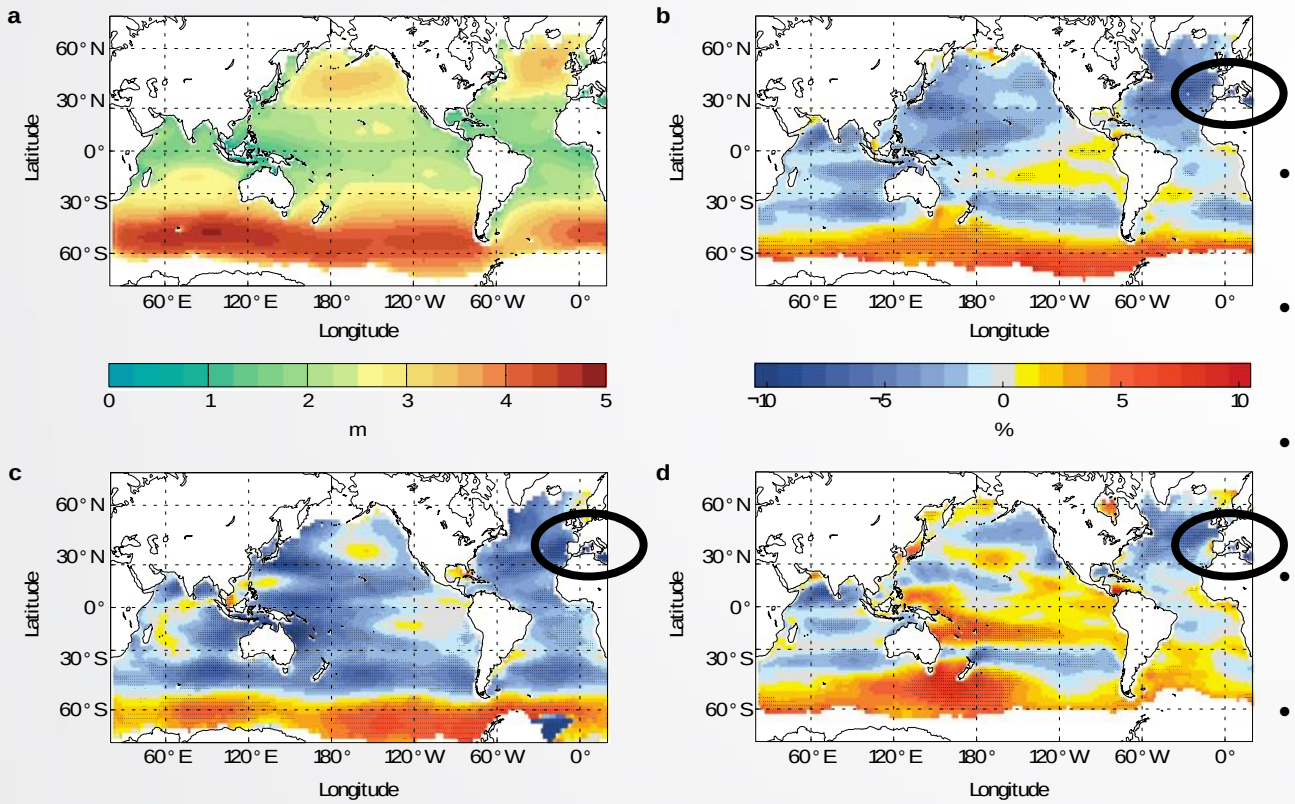



**Figure 2** | Projected future changes in multi-model averaged significant wave height. **a**, Averaged multi-model annual significant wave height ($H_S$, m) for the time-slice representing present climate (←1979–2009). **b–d**, Averaged multi-model projected changes in annual (**b**), JFM (**c**) and JAS (**d**) mean $H_S$ for the future time-slice (←2070–2100) relative to the present climate time-slice (←1979–2009) (% change). Stippling denotes areas where the magnitude of the multi-model ensemble mean exceeds the inter-model standard deviation. Results for individual models are included in the Supplementary Information.

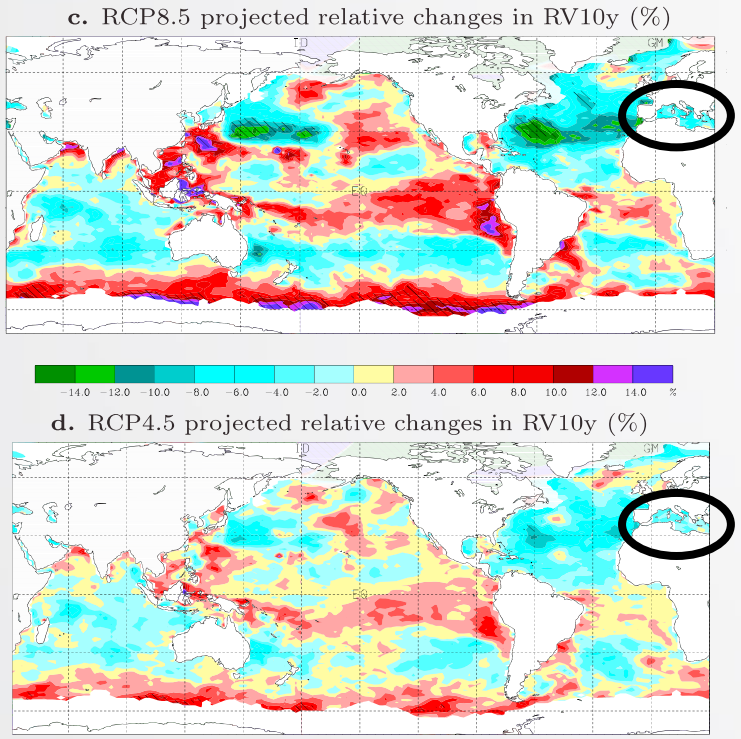
(Hemer et al., 2013. *Projected changes in wave climate from a multi-model ensemble*, Nature Climate Change)

**Proiezioni 2070-2100 ($H_s$ media)**

- E' previsto che il **clima ondoso** cambi durante questo secolo.
- Proiezione di **riduzione** dell'altezza significativa media nei mari globali.
- Alcune zone (oceani meridionali) saranno soggette a **incremento.**
- Vi sono comunque delle **incertezze**.
- Nel Mare **Mediterraneo**, la riduzione (5 %) interesserà tutte le stagioni

# Proiezioni del "clima ondoso" estremo

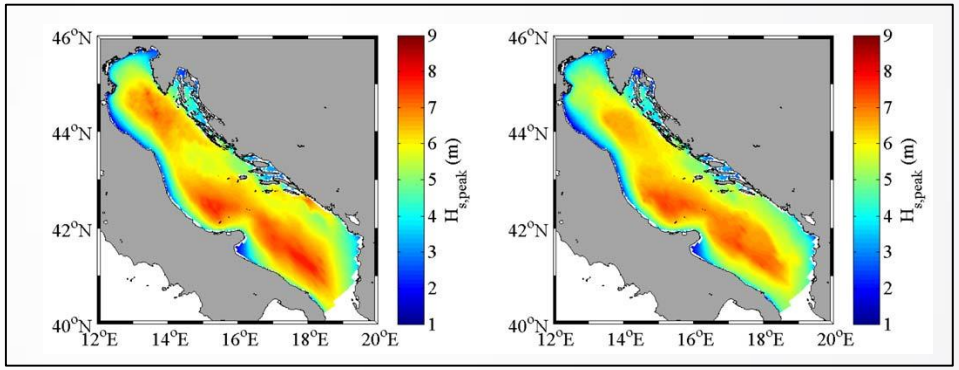
**Hs (Tr = 10 anni) - Variazione % nel 2080-2099**



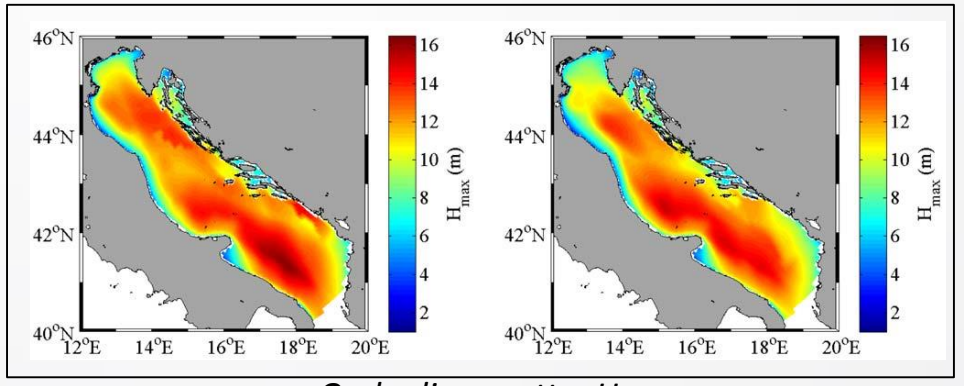

(Wang et al., 2013. *Changes in global ocean wave heights as projected using multimodel CMIP5 simulations*, Geophysical Research Letter)

- Dipendenza dallo **scenario** di emissione
- Incremento: Cile, Gulf of Mexico, Canada,…
- Riduzione (2-4 %) nel **Mediterraneo**

**PRESENTE** **FUTURO (2070-2100)**




*Hs* (Tr = 30 anni)




*Onda di progetto: H*max

(Benetazzo et al., 2012. *Wave climate of the Adriatic Sea: a future scenario simulation*, NHESS)

# Adattamento / Prevenzione

## Problemi chiave

- I **modelli delle onde estreme** devono essere aggiornati per tenere conto di una **non-stazionarietà** del clima.
- Verifica dei carichi di **progetto** delle strutture esistenti … sono necessari degli upgrade / downgrade
- Nuovi **criteri** di progettazione
- Rivalutazione del **rischio**

Climate Change and Effect on Marine Structure Design
MANAGING RISK
DNV
Research and Innovation, Position Paper 1 - 2010

Current best estimates of observed and projected climate change indicate that in the coming decades it is likely that marine structures will experience higher environmental loads.

"If significant wave height is increased by 2.0 m, then the necessary increase in deck area is between 10 % to 15 %."

**STEPS OF FORMAL SAFETY ASSESSMENT (FSA)**

| Steps | In layman terminology | Professional language |
|---|---|---|
| 1 | What might go wrong? | Hazard Identification |
| 2a | How often or how likely? | Frequencies or probabilities |
| 2b | How bad? | Consequences |
| 2c | How to model? | Risk = Probability x Consequence |
| 3 | Can matters be improved? | Identify risk management options |
| 4 | What would it cost and how much better would it be? | Cost Benefit Evaluation |
| 5 | What actions are worthwhile to take? | Recommendation |
| IMO | What action to take? | Decision |

**… le onde di progetto stanno "invecchiando" …**

OREGON STATE UNIVERSITY

News and Research Communications

Maximum height of extreme waves up dramatically in Pacific Northwest

*01/25/2010*

CORVALLIS, Ore. – A major increase in maximum ocean wave heights off the Pacific Northwest in recent decades has forced scientists to re-evaluate how high a "100-year event" might be, and the new findings raise special concerns for flooding, coastal erosion and structural damage.

The new assessment concludes that the highest waves may be as much as 46 feet, up from estimates of only 33 feet that were made as recently as 1996, and a 40 percent increase. December and January are the months such waves are most likely to occur, although summer waves are also significantly higher.

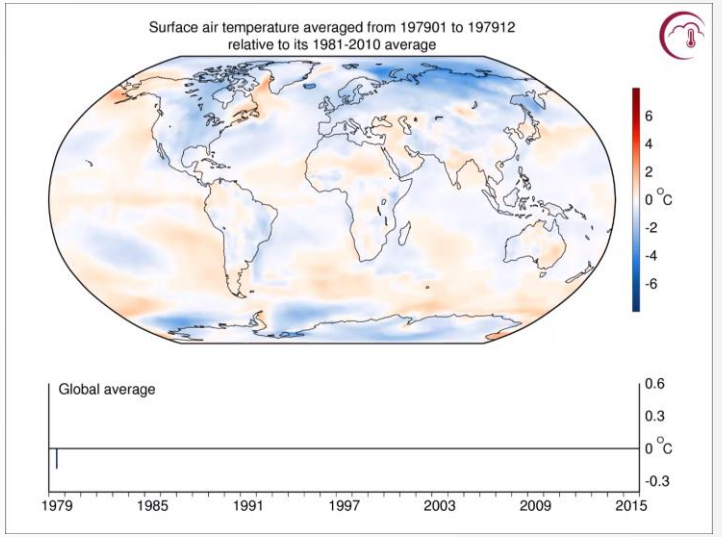
# Take-Home message

- Il **clima** sta cambiando: è evidente (e percepibile) l'effetto sulla **temperatura** dell'aria
- Ma anche gli **mari** stanno mutando

- Perturbazioni atmosferiche e **mareggiate** stanno modificandosi (intensità, direzione, durata)
- **Incertezze**

- Alcune zone del pianeta saranno soggette a **mareggiate** (estreme) più intense
- Problema di **sicurezza** delle strutture esistenti e di **progettazione** di quelle nuove
- Nel **Mediterraneo** le mareggiate "medie" ed "estreme" sono previste in riduzione

- Necessaria una rivalutazione dei **rischi / operatività**

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