Modelling high-frequency sea level oscillations associated with meteotsunamis over the Balearic shelf

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SOCIB Balearic Islands Coastal Observing and Forecasting System

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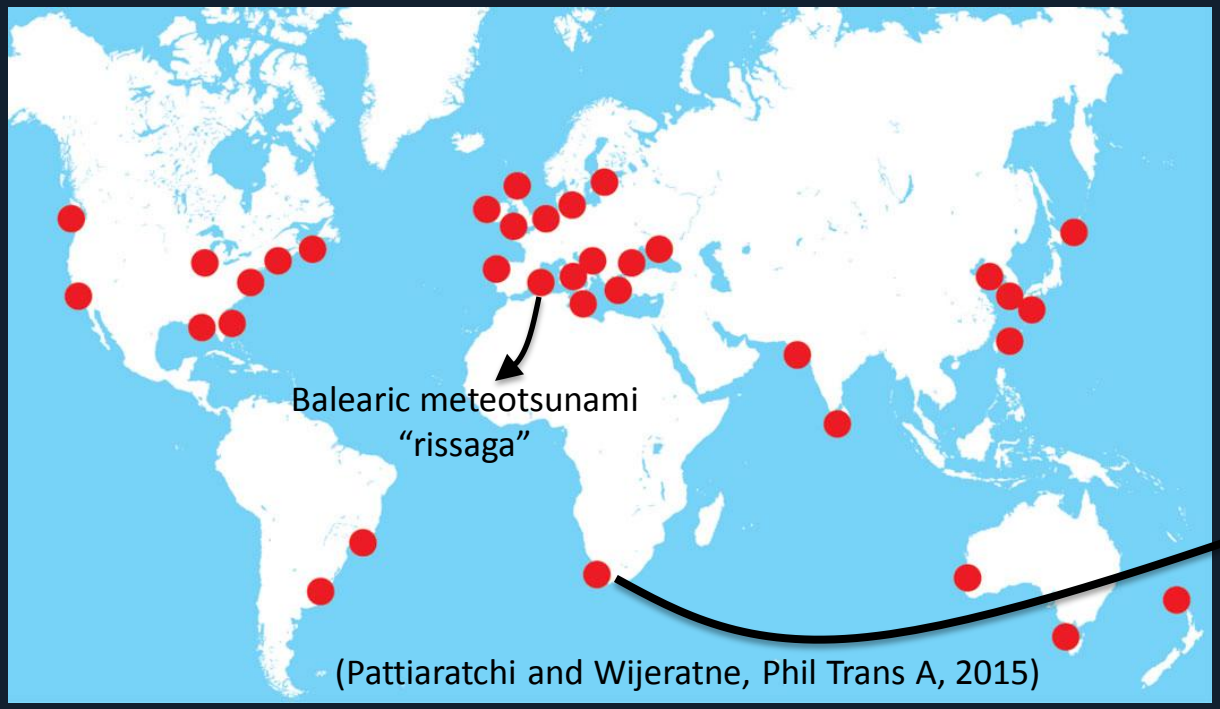
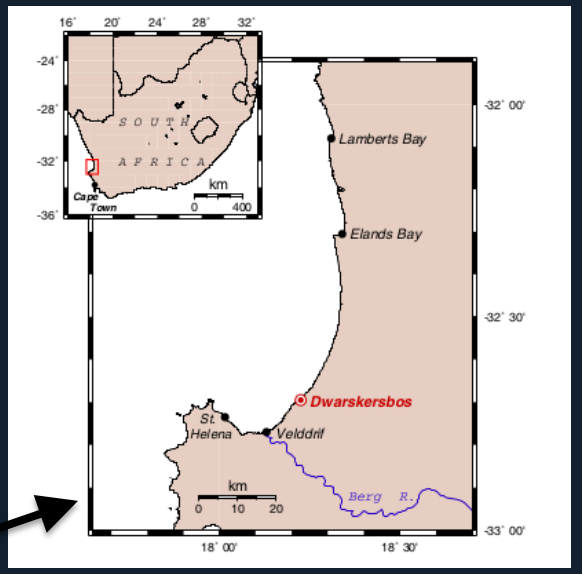
Meteotsunamis

Meteorological tsunami: tsunami-like wave of meteorological origin



Locations of meteotsunami occurrences as reported in the literature

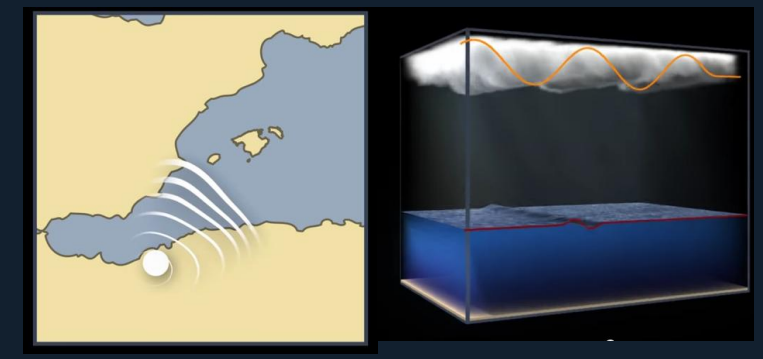


South-African meteotsunami, Dwarskersbos, August 27, 1969 (Okal et al., Nat Hazards, 2014)

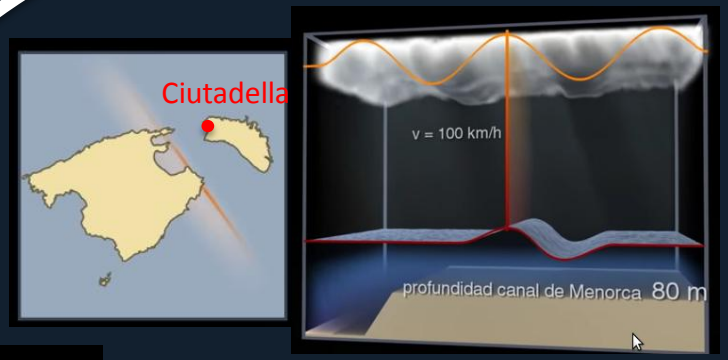
Introduction to the *Rissaga phenomenon*

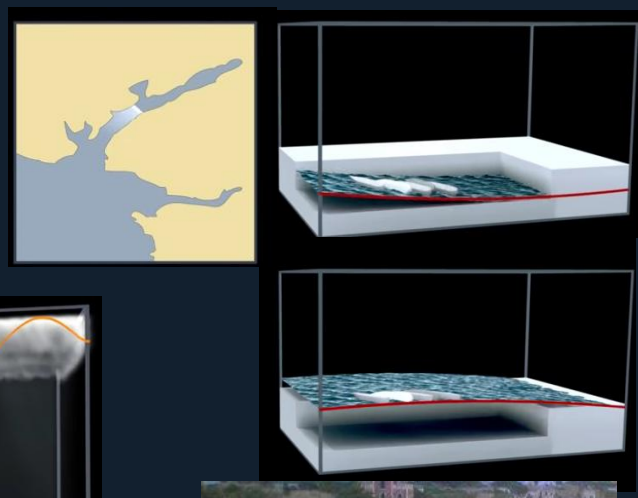
Rissaga: meteotsunami leading to large (up to 4m) and high-frequency (~10 min) sea level oscillations in Ciutadella harbour (Menorca, Spain)

Resonant amplication mechanisms over the shelf and in Ciutadella inlet



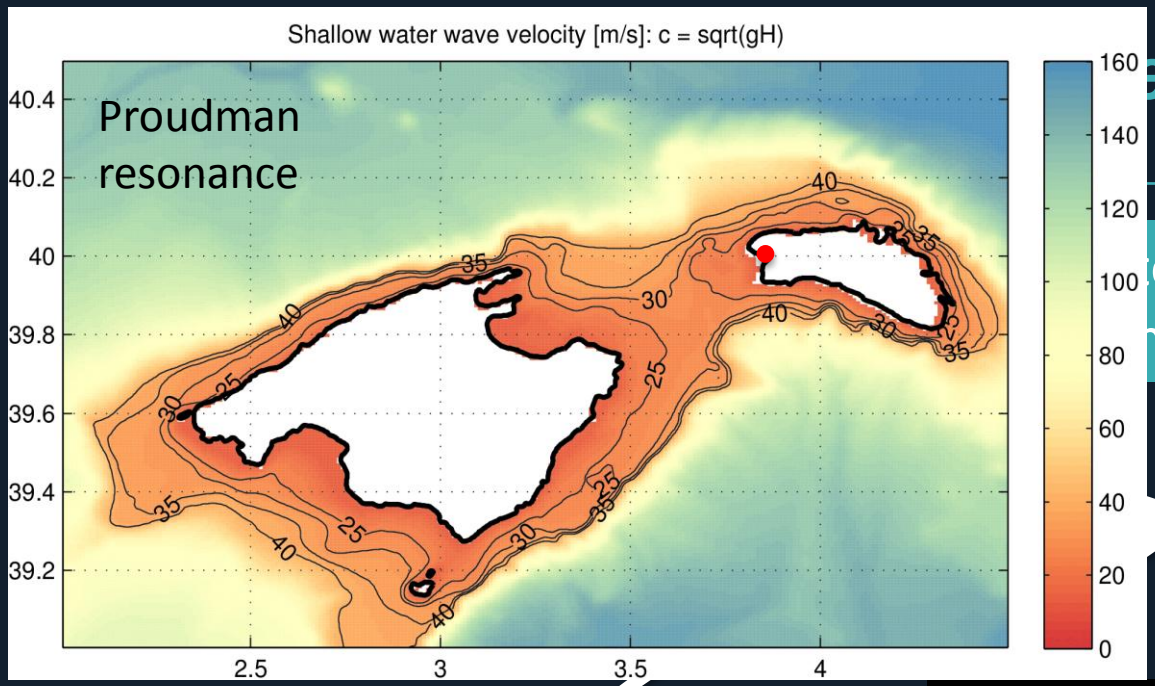
Western Mediterranean Sea

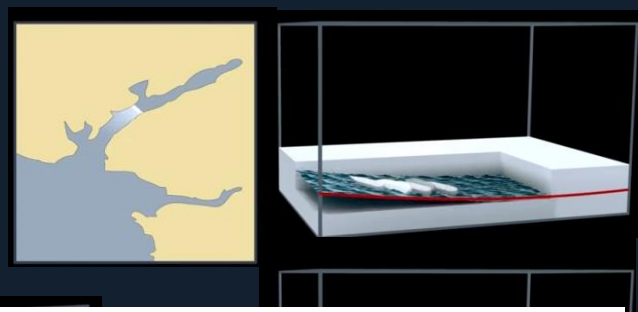


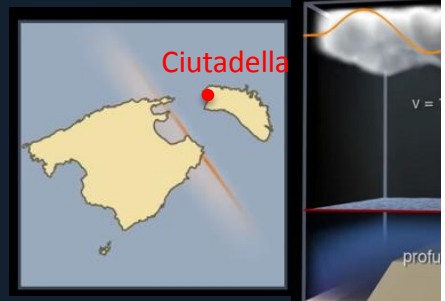


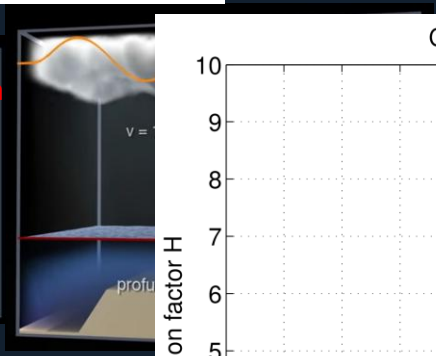
enomenon

o 4m) and high-frequency
harbour (Menorca, Spain)









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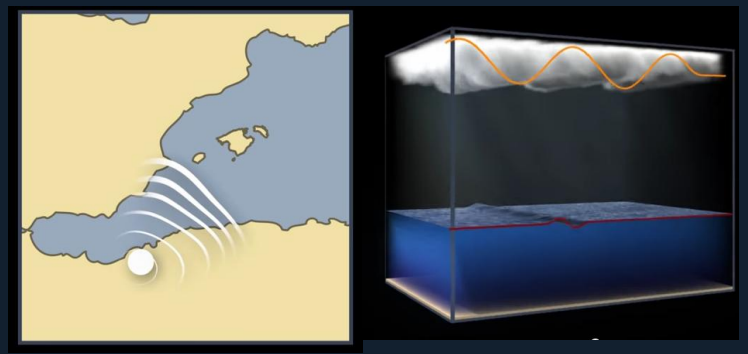


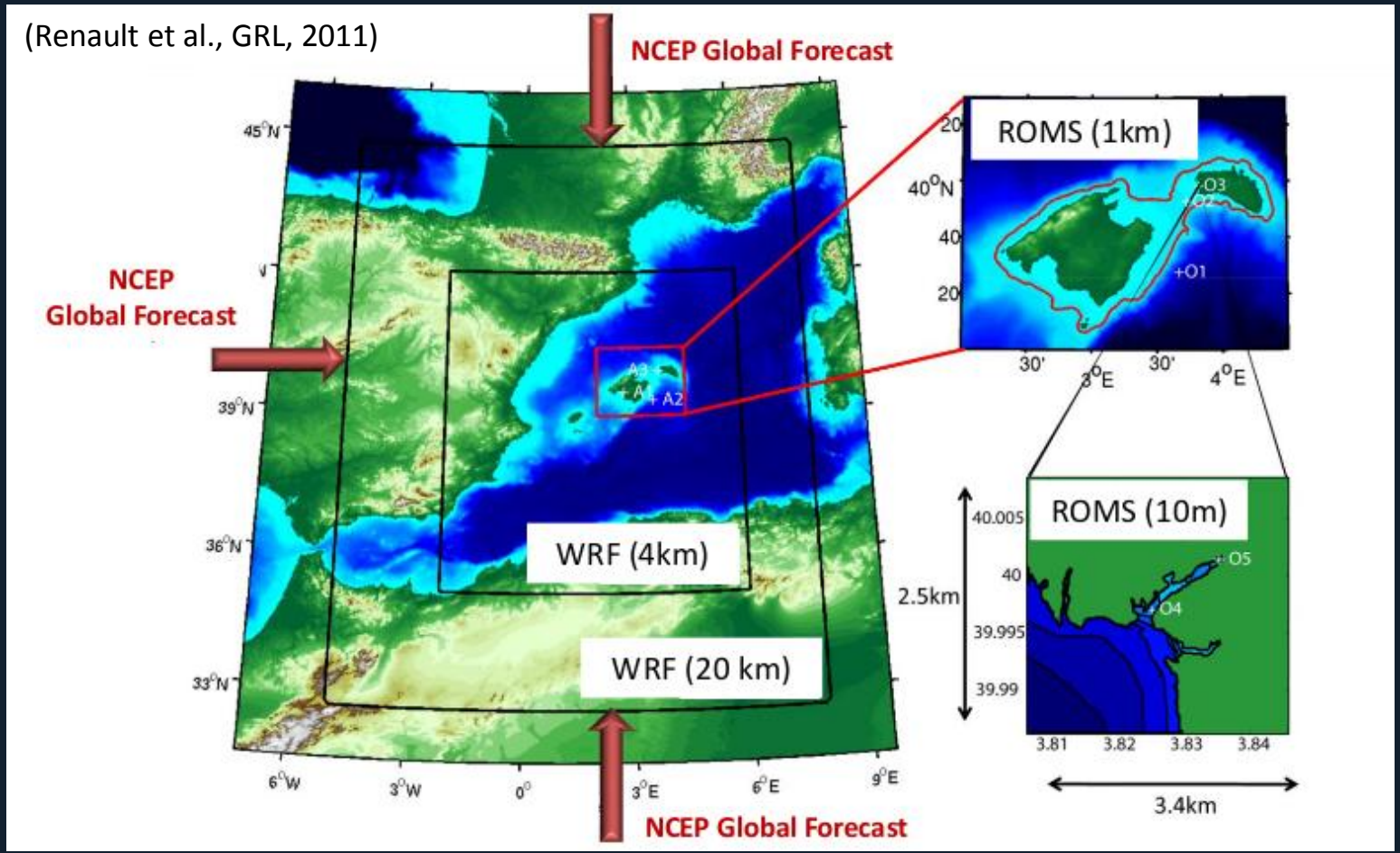
Outline

1. BRIFS - *Balearic RIssaga Forecasting System*
2. Meteotsunami propagation under synthetic atmospheric gravity wave forcing
3. BRIFS results for past rissagas
4. What contribution from altimetry ?

BRIFS - *Balearic RIssaga Forecasting System*

Ocean-atmosphere modelling prediction system

(Renault et al., GRL, 2011)

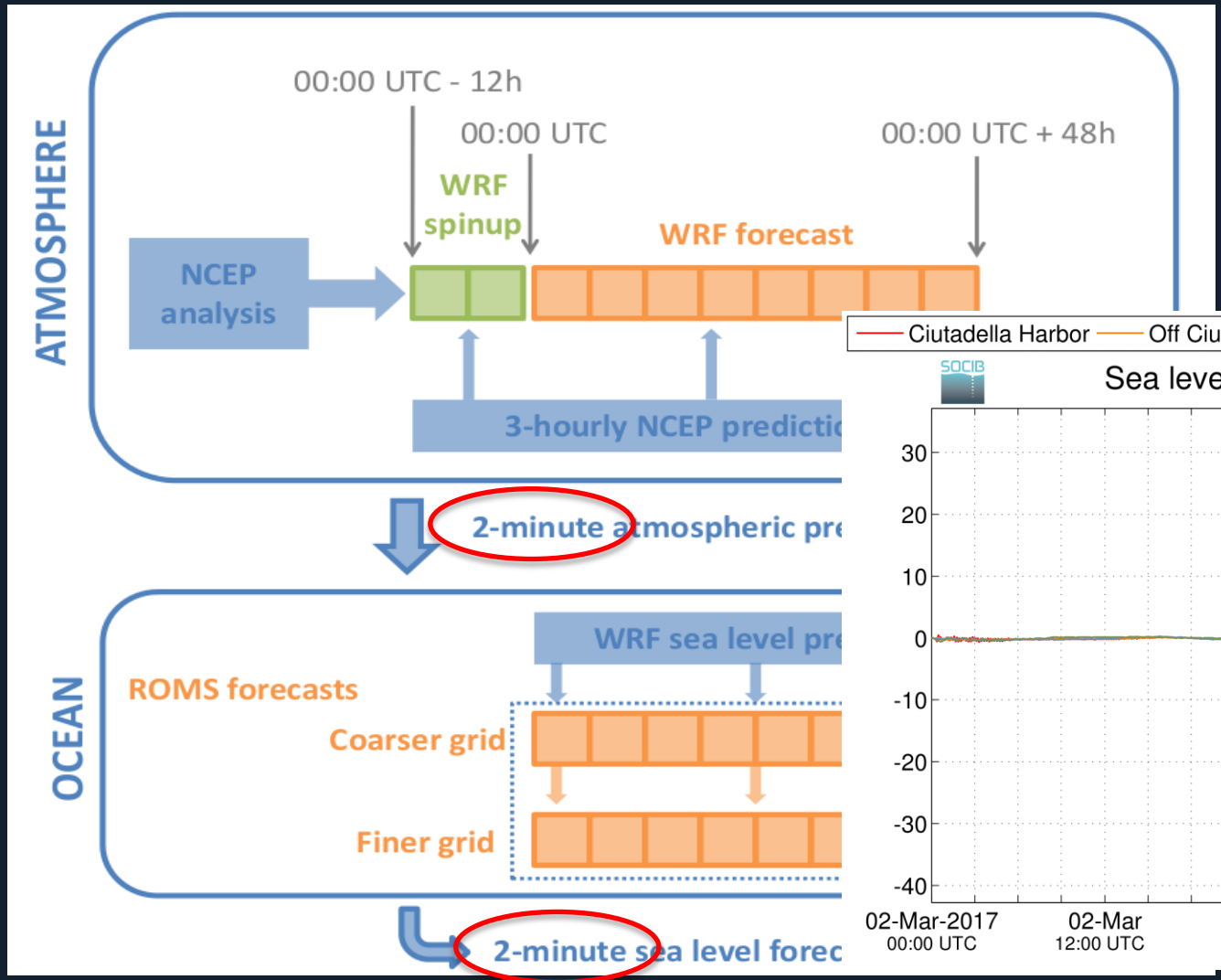


WRF: Weather Research and Forecasting Model
NCEP: National Centers for Environmental Prediction

ROMS: Regional Ocean Modeling System

BRIFS - *Balearic RIssaga Forecasting System*

Daily forecast production



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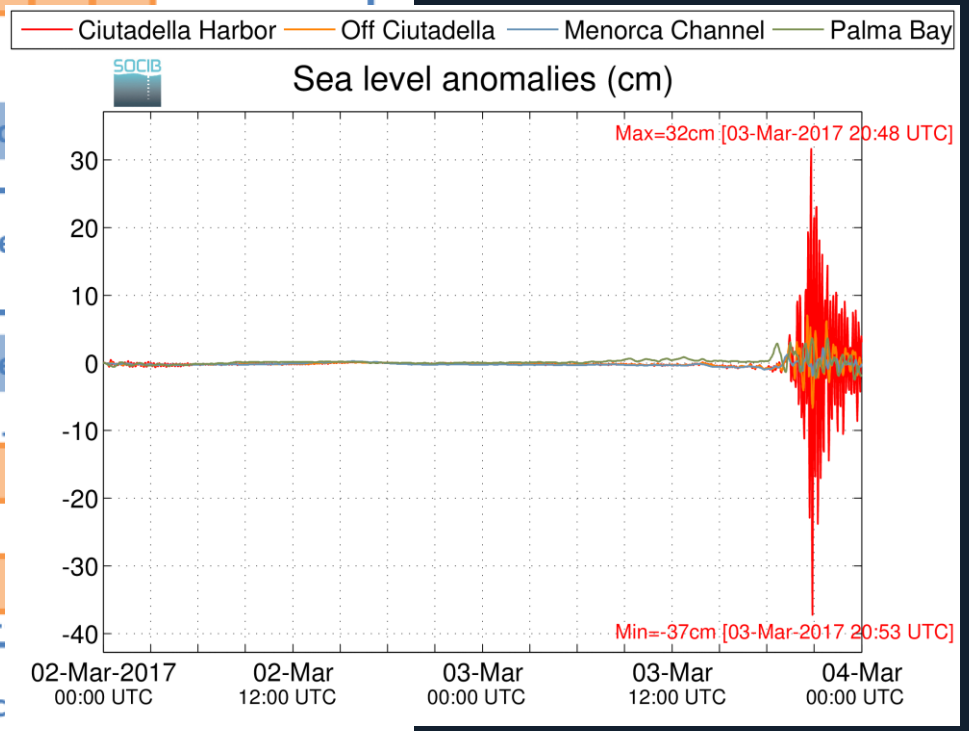

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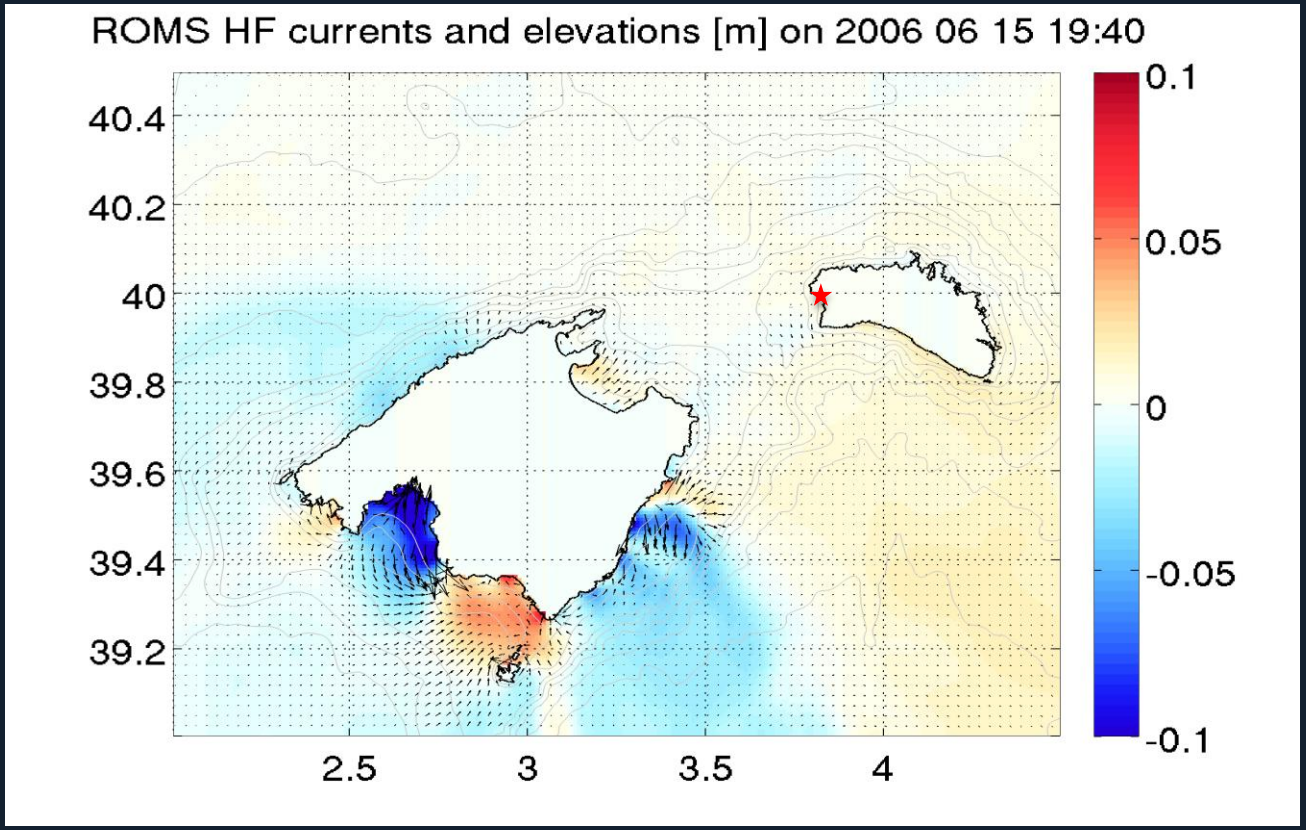
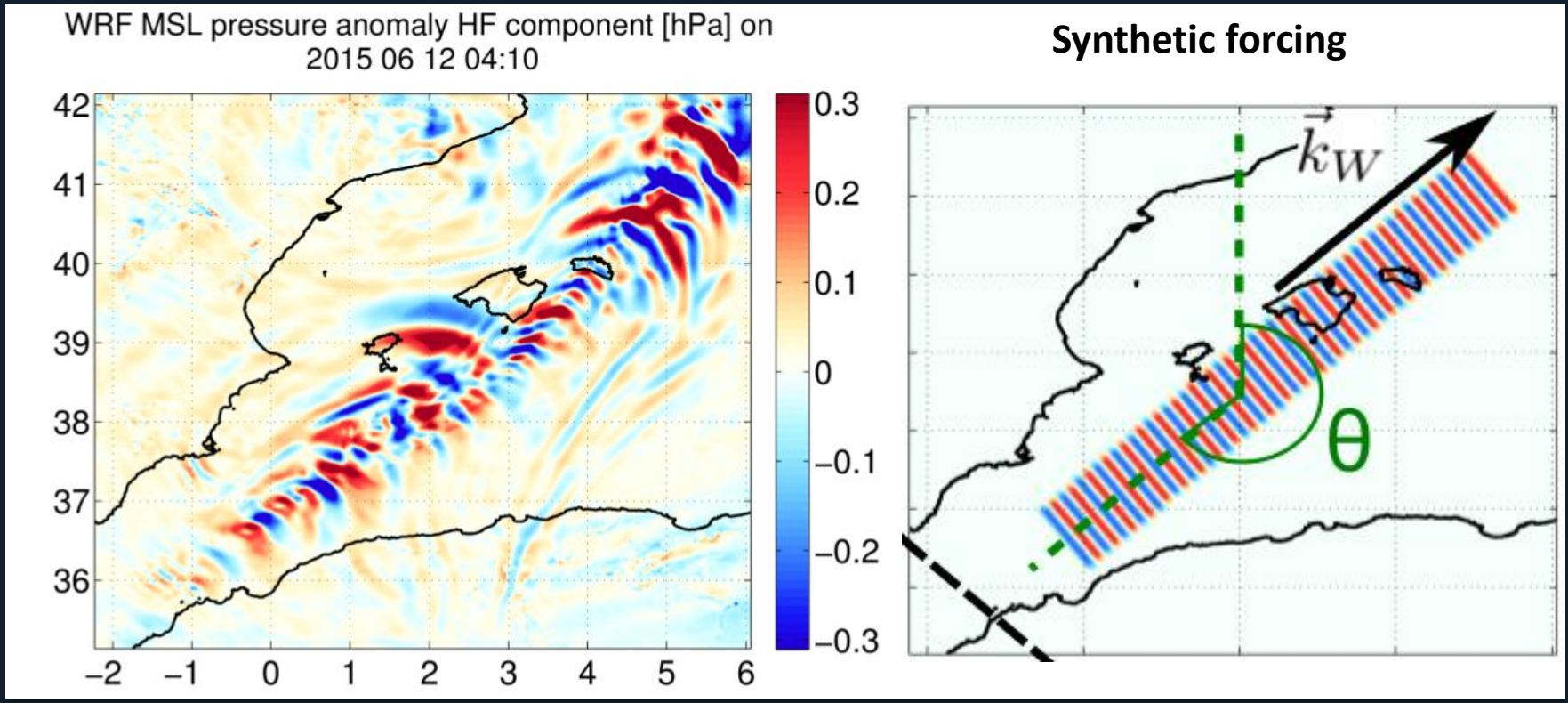
Synthetic gravity wave forcing



Generation, propagation, amplification according to atmospheric wave speed, direction and extension ?

Synthetic gravity wave forcing

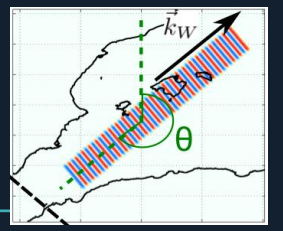
(Ličer et al., Ocean Modelling, 2017)

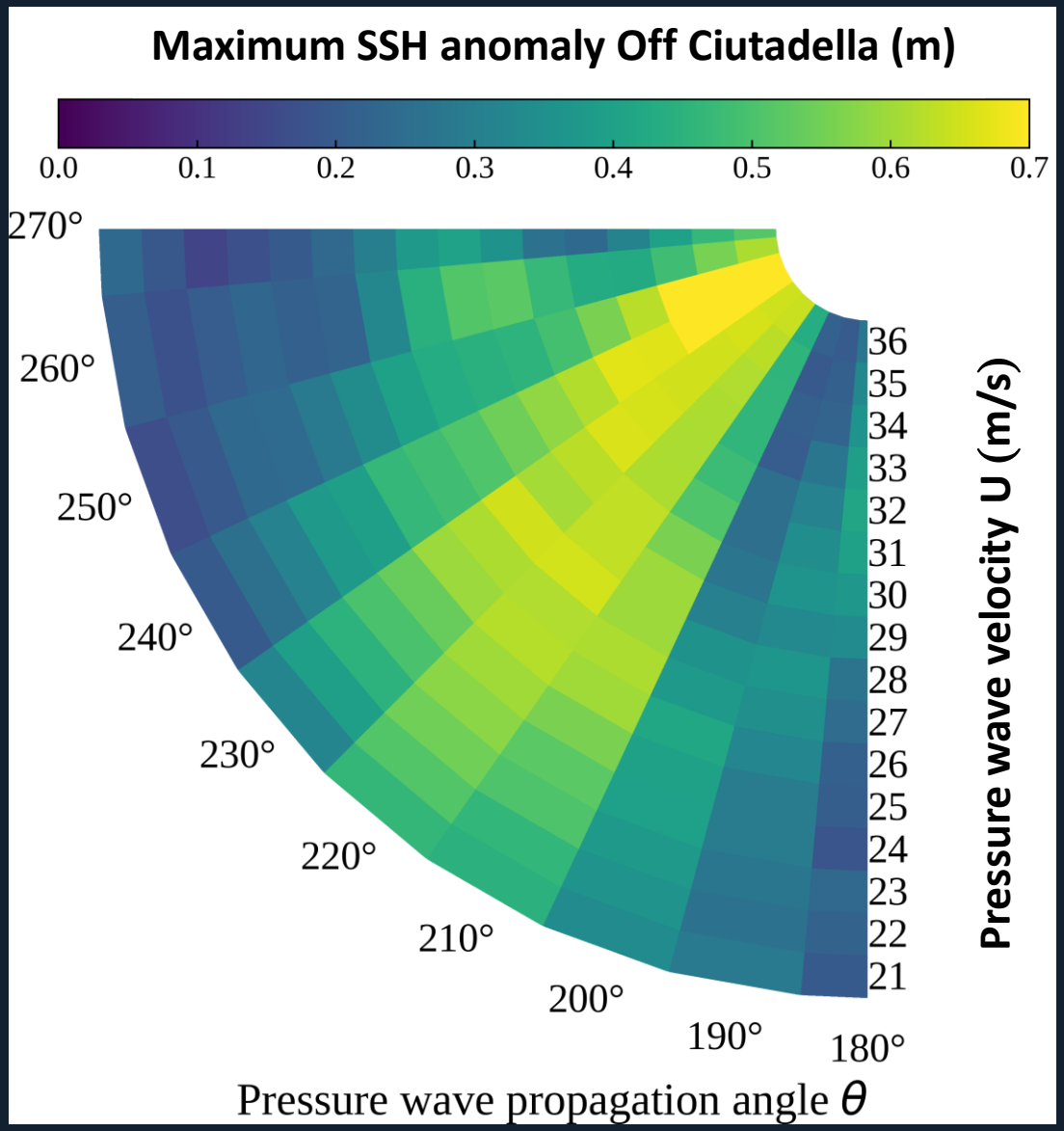


- ✓ 3hPa pressure wave amplitude with a 17-minute period (~0.7hPa change in 1 minute)
- ✓ Varying direction and propagation speed

Synthetic gravity wave forcing

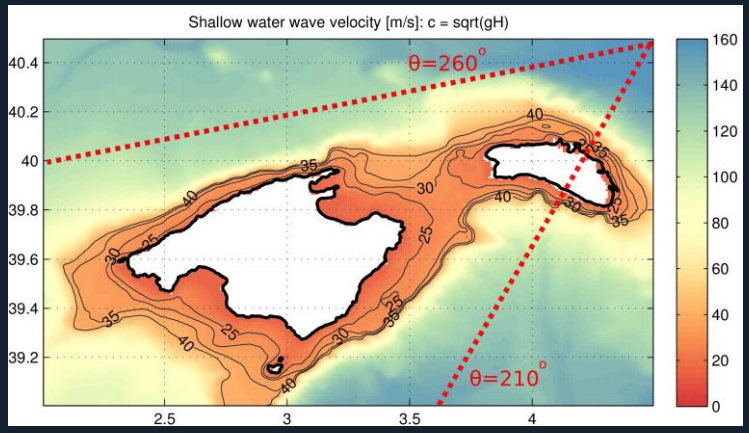
(Ličer et al., Ocean Modelling, 2017)





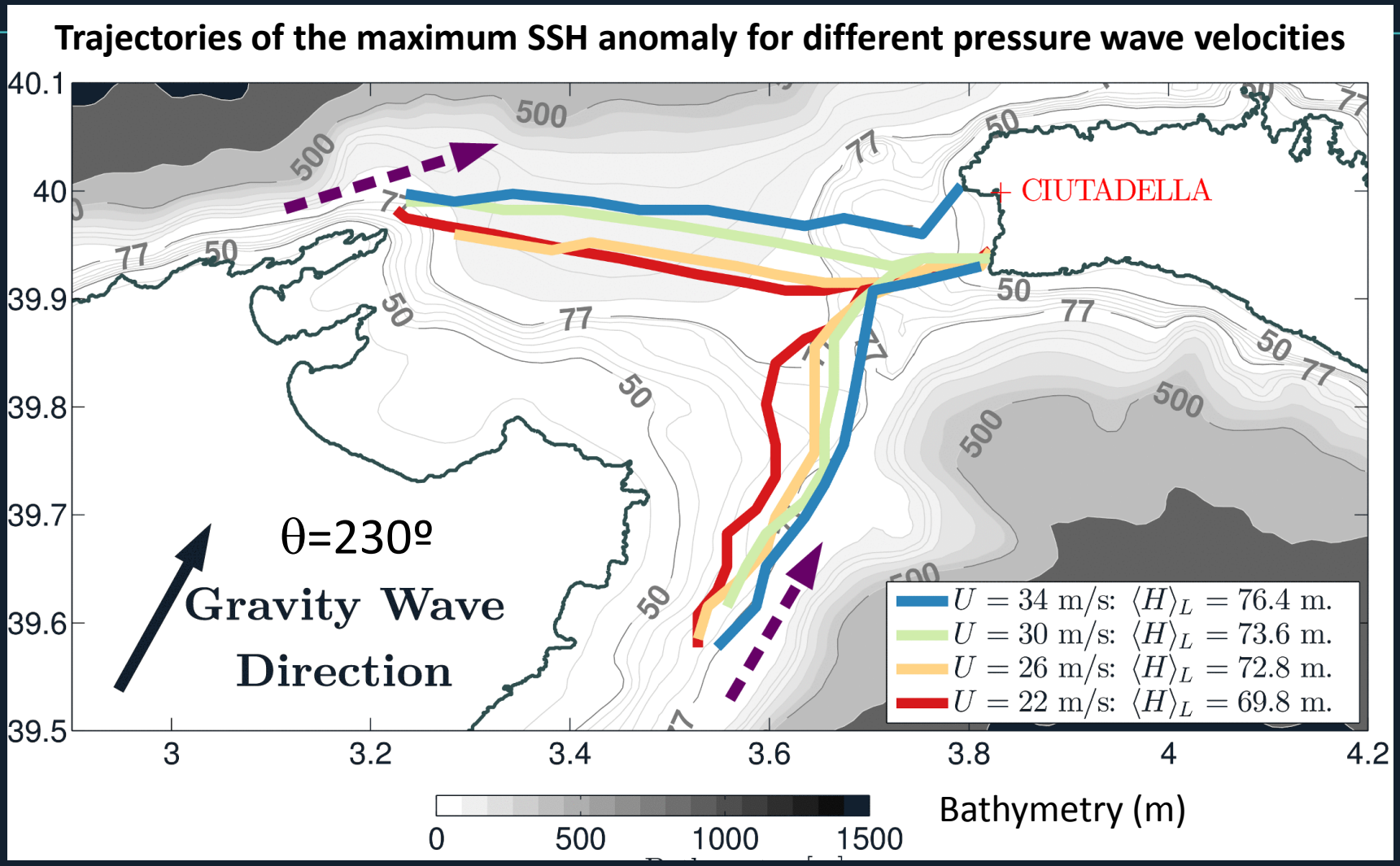
→ SSH maxima larger than 0.5m occur with wave direction between 210º and 260º and with a large range of wave velocities

→ Relative maxima around θ=230º and U=28m/s and θ=250º and U=35m/s



Synthetic gravity wave forcing

(Ličer et al., Ocean Modelling, 2017)

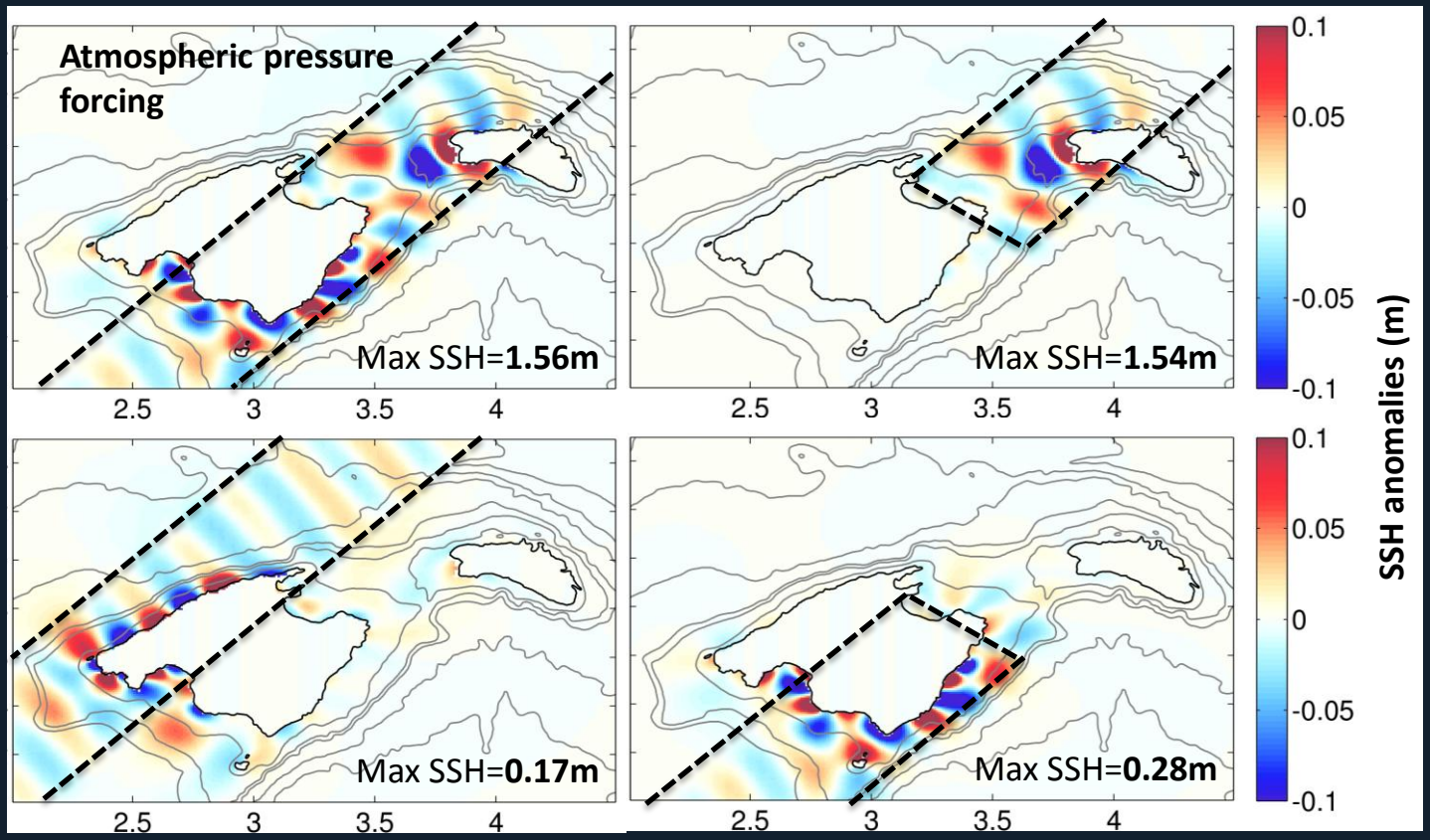


→ Amplification associated with Proudman resonance occurs in deeper water as the atmospheric wave goes faster

Synthetic gravity wave forcing

(Ličer et al., Ocean Modelling, 2017)

Contribution of Menorca Channel and Mallorca shelves to the amplification off the rissaga



→ Menorca Channel is found to be the key build-up region

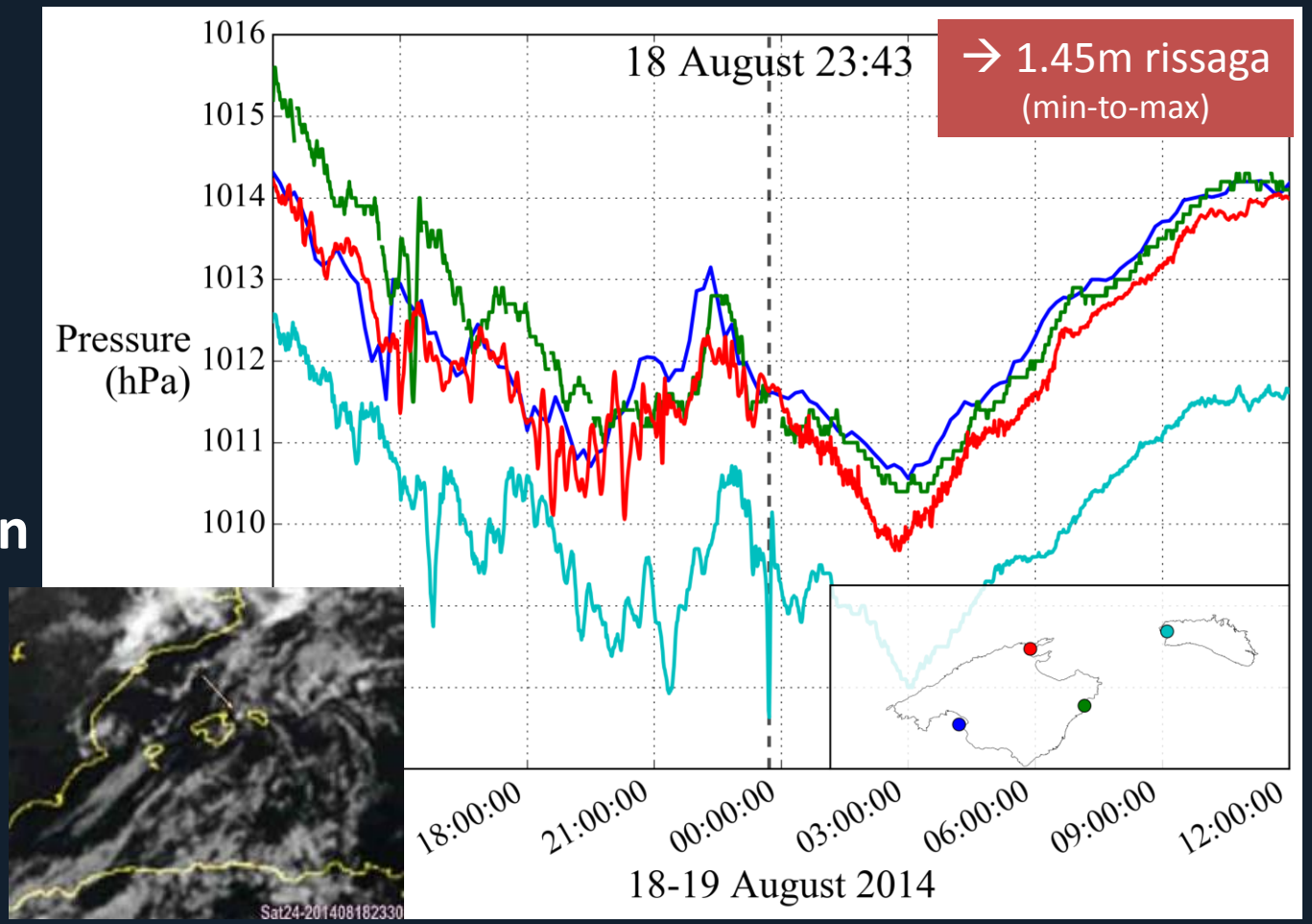
Synthetic gravity wave forcing

(Ličer et al., Ocean Modelling, 2017)

Contribution of Menorca Channel and Mallorca shelves to the amplification off the rissaga

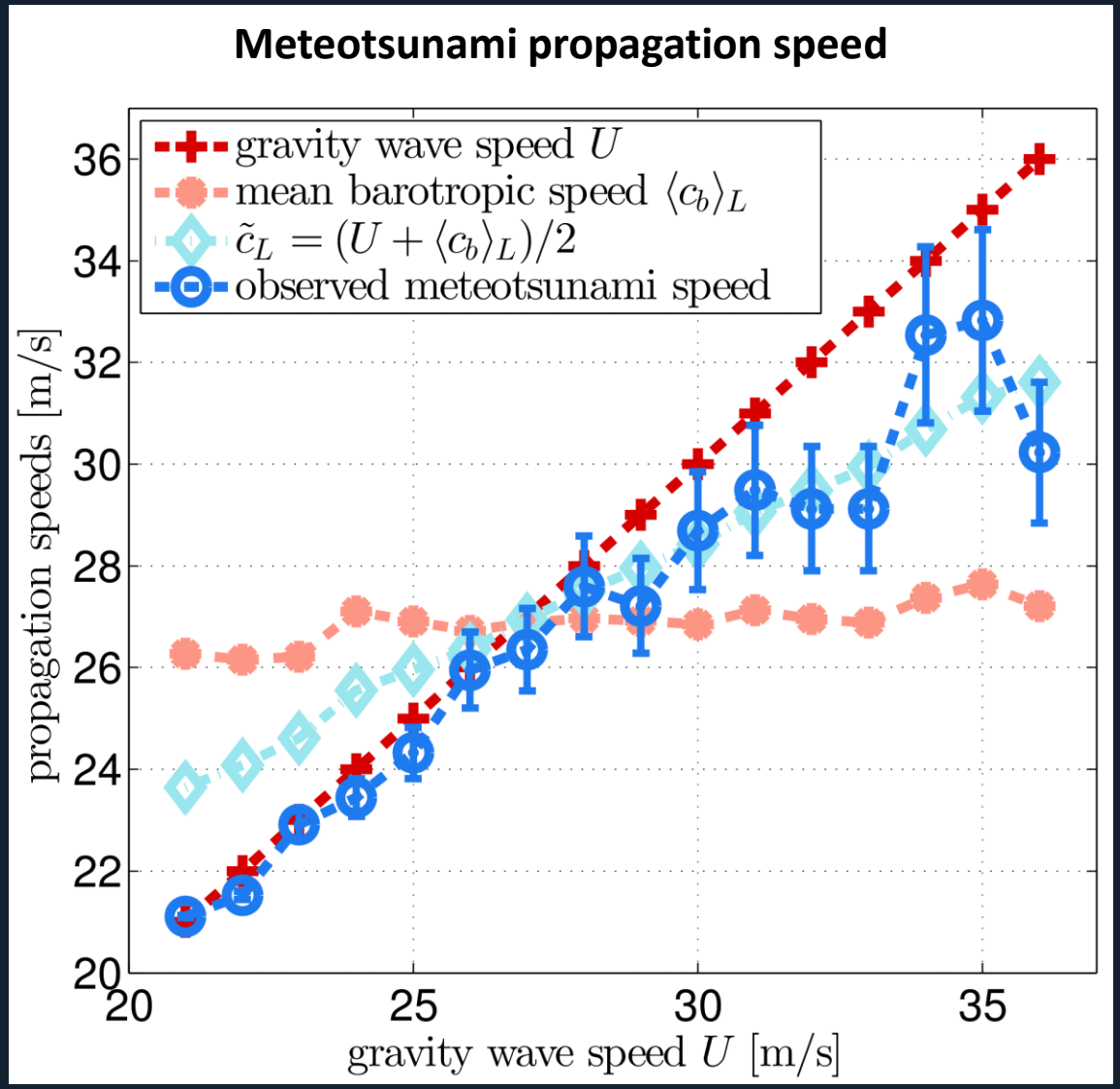
Menorca Channel is found to be the key build-up region

→ Very short early warning alert time in case of locally generated pressure perturbations



Synthetic gravity wave forcing

(Ličer et al., Ocean Modelling, 2017)



- Subcritical regime (U<c): meteotsunami propagates at the same speed as forcing wave

- Supercritical regime (U>c): meteotsunami propagate at a speed below the forcing speed and above the ocean barotropic speed

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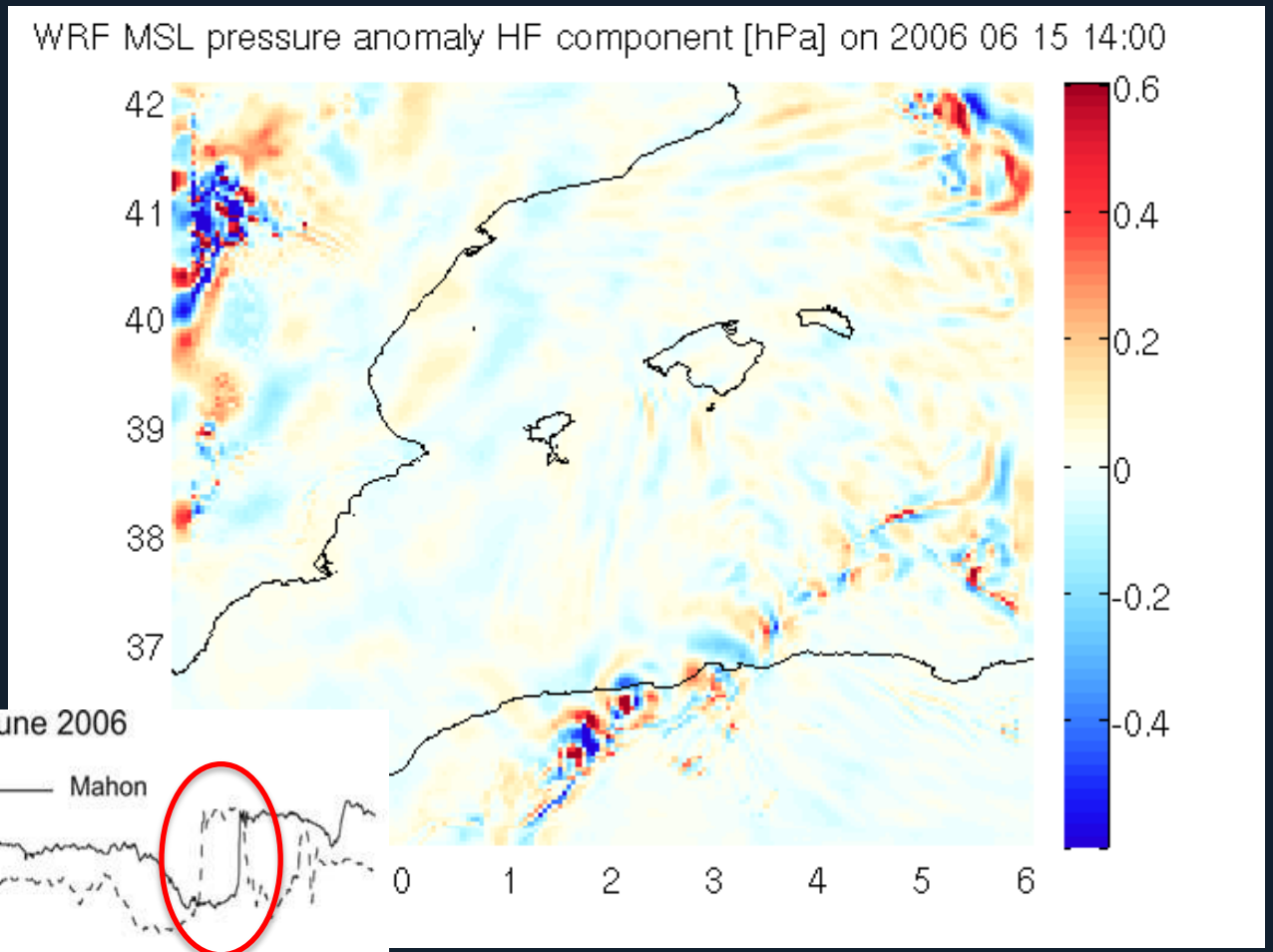
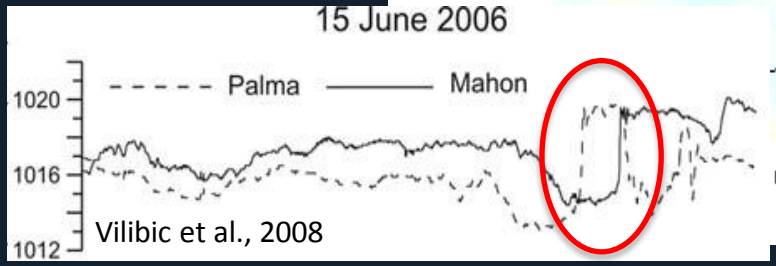
BRIFS representation of the 15 June 2006 rissaga

WRF

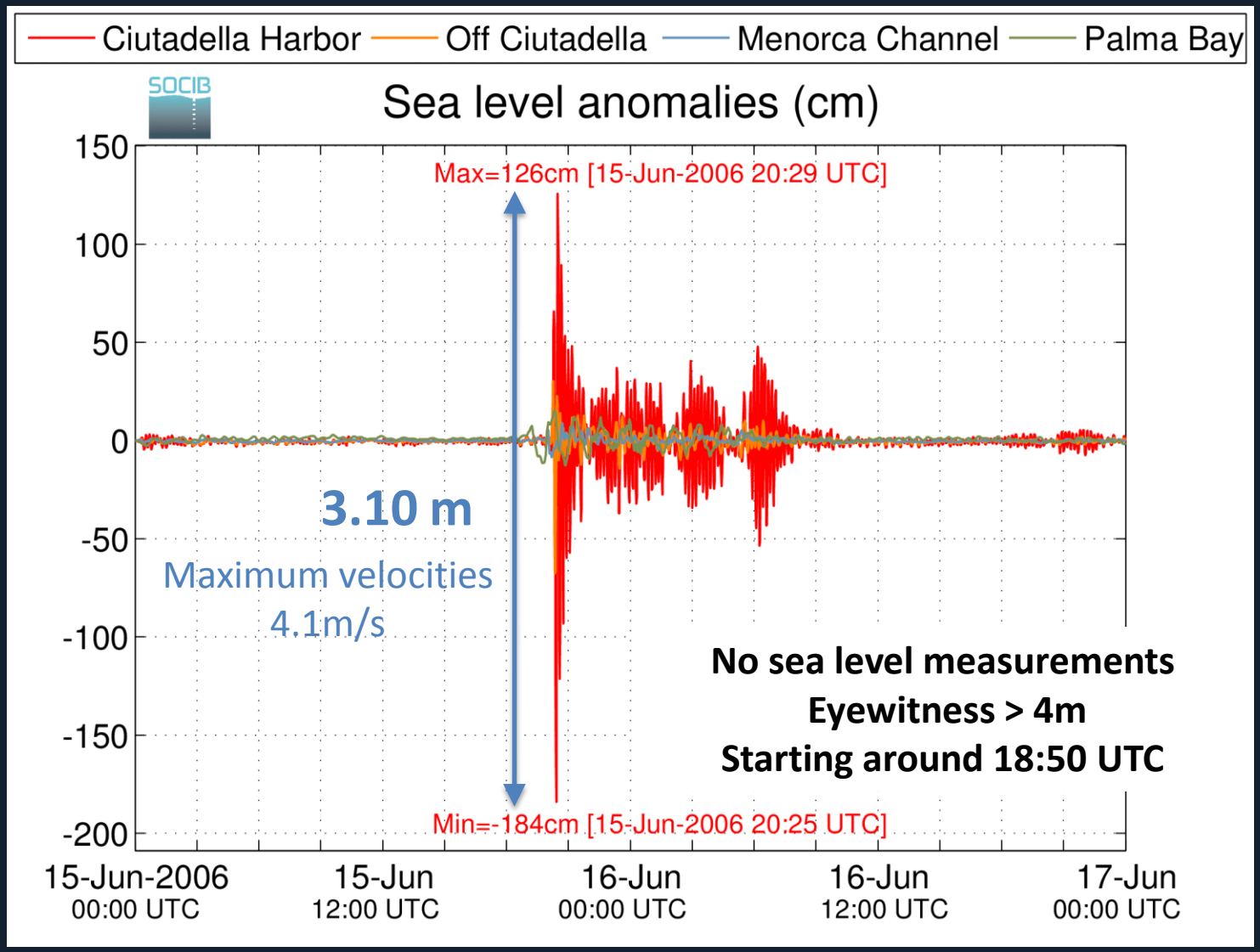




→ Squall line with a ~4hPa pressure jump, as registered in Mahon and Palma airports

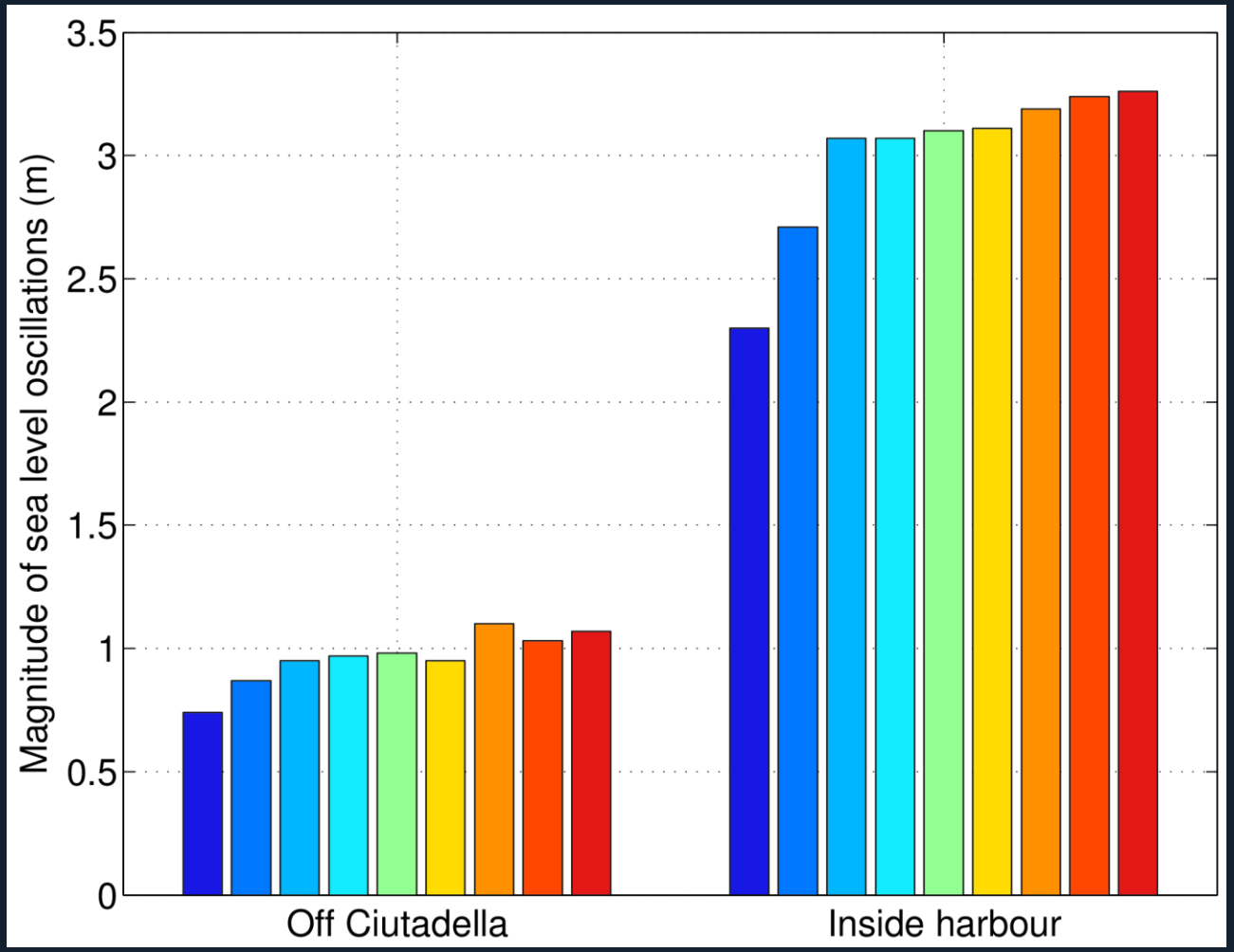
BRIFS representation of the 15 June 2006 rissaga

ROMS



BRIFS representation of the 15 June 2006 rissaga

Stochasticity of small scale processes affecting the rissaga



9 WRF simulations using the same setup: rissagues from 2.30m to 3.26m, average 3.00m

→ need for ensembles ?

BRIFS representation of 2014-2017 events

Date	Measured sea level oscillation (min-to-max)	AEMET warning	BRIFS prediction (sea level oscillation)	Time (CET) of the rissaga	BRIFS prediction (rissaga time CET)
15-Jun-2006	***(> 4m)***	?	3.10m	**20:50**	22:25
26-May-2008	**2.25m**	?	1.16m	**?**	01:00
19-Aug-2014	**1.45m**	Amarillo	1.04m	**01:40**	00:30
22-Apr-2015	**1.40m**	___	0.30m	**15:00**	16:15
01-Aug-2015	**1.30m**	Naranja	1.00m	**06:40**	07:20
01-Apr-2016	**1.23m**	___	0.51m	**07:00**	12:40
31-Jul-2015	**0.92m**	Amarillo	0.40m	**20:10 / 23:00**	23:00
07-Feb-2016	**0.80m**	___	0.11m	**12:20**	11:00
29-Jun-2016	**0.22m**	Amarillo	0.07m	**11:15**	09:00
04-Mar-2017	**1.19m**	___	0.69m	**00:50**	22:00 (3-Mar)

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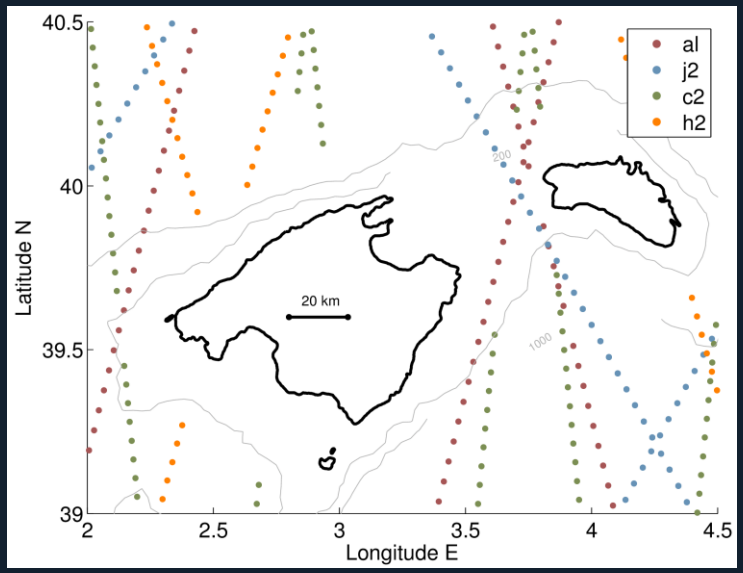
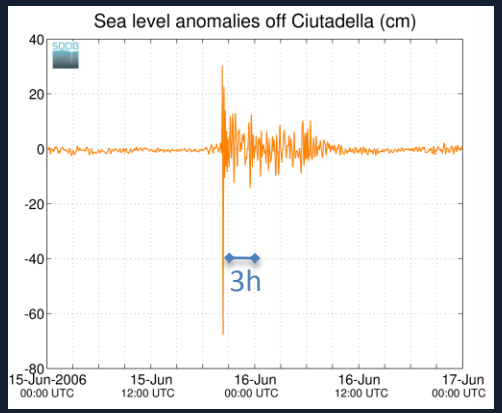
Altimeter tracks over the Menorca Channel

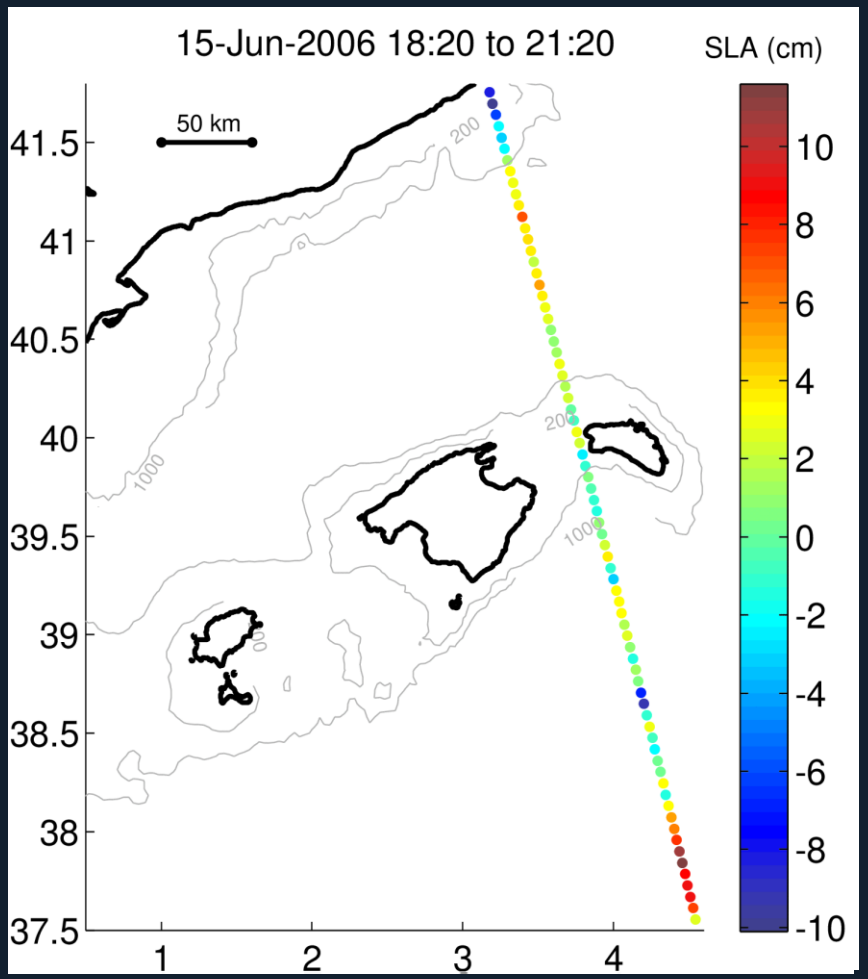
All tracks



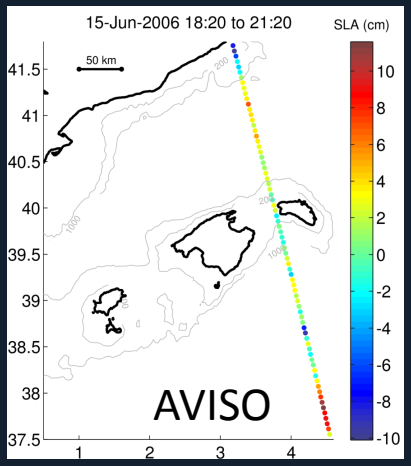
15-Jun-2006 rissaga off Ciutadella (model)

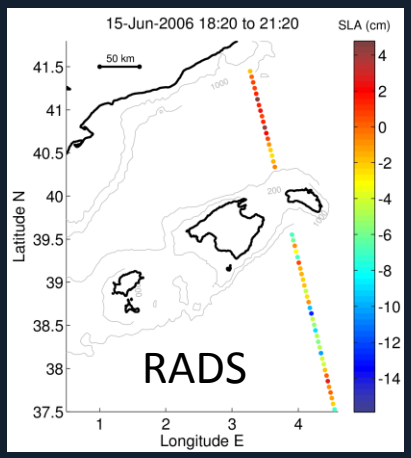


Data availability during rissaga events (3-hour window)

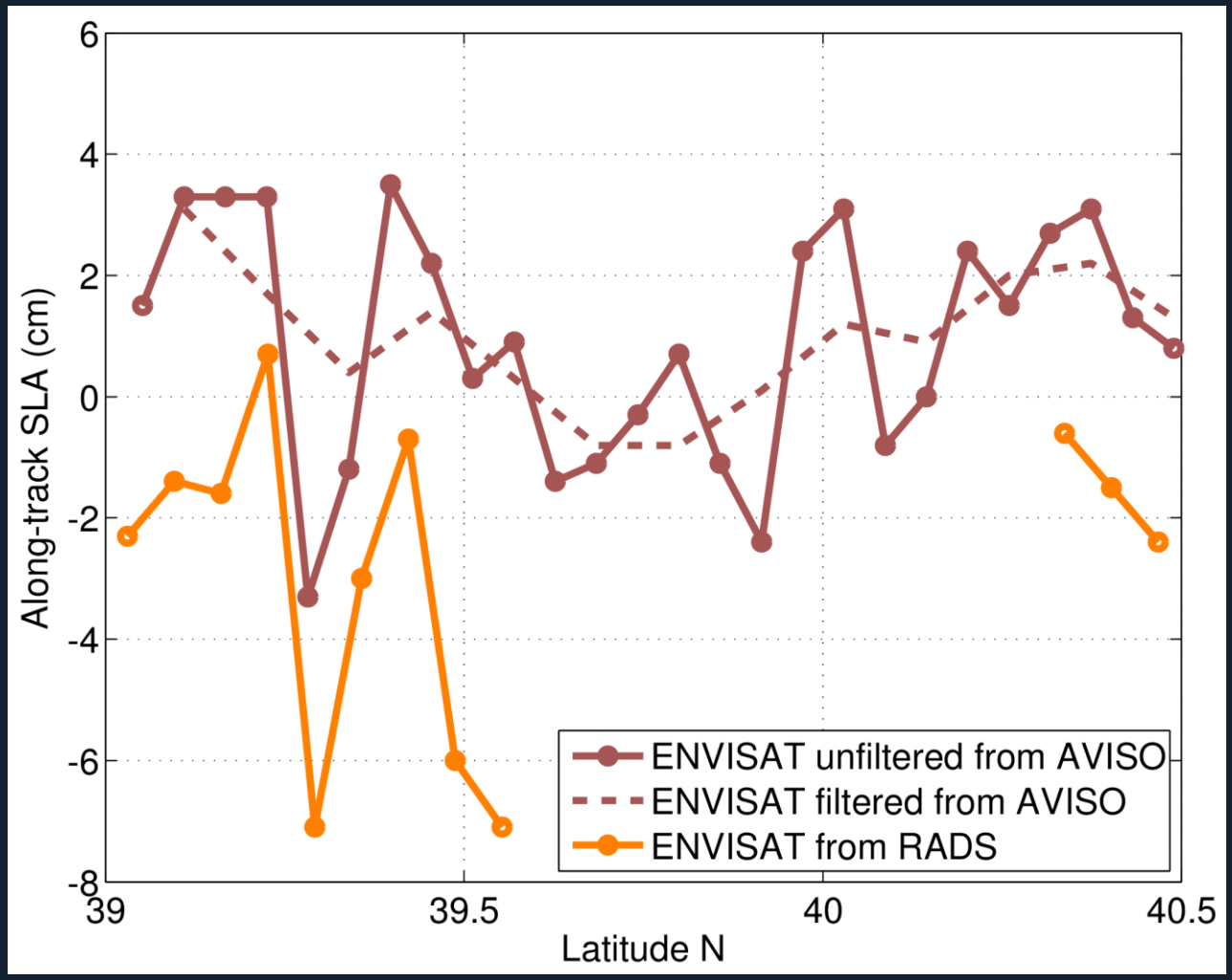


Altimeter tracks over the Menorca Channel





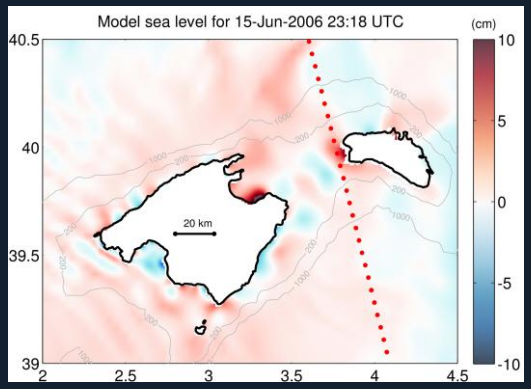
Along -track altimetry

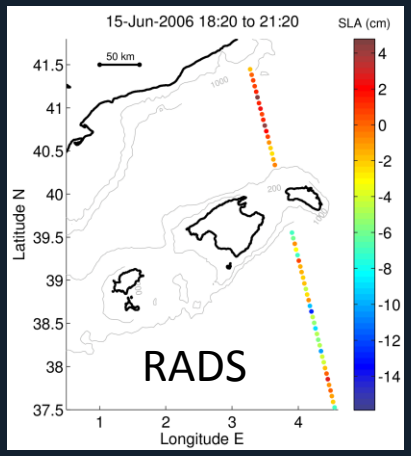


Altimeter tracks over the Menorca Channel

Model sea level

Illustration:
2h50 after squall line





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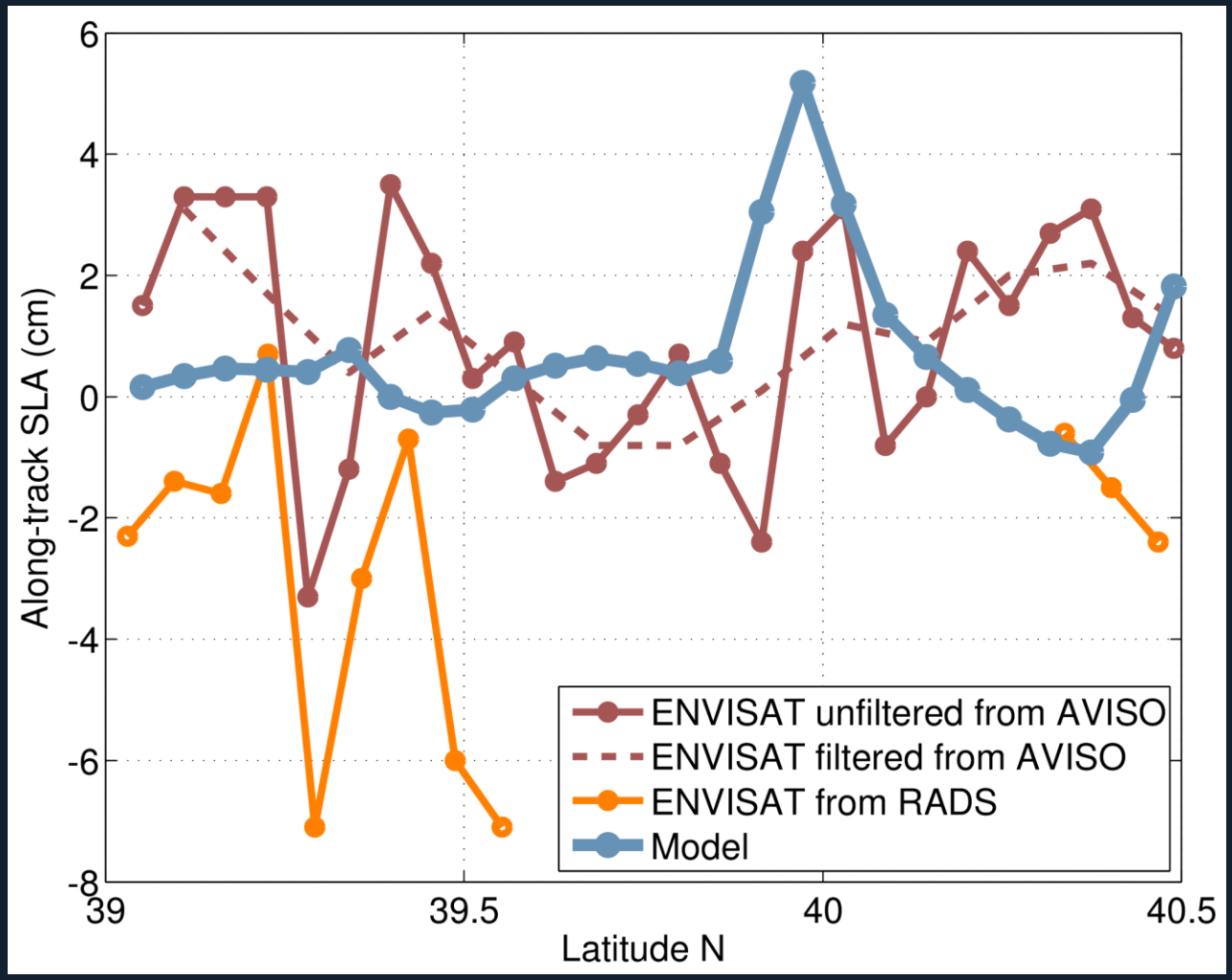


Conclusions

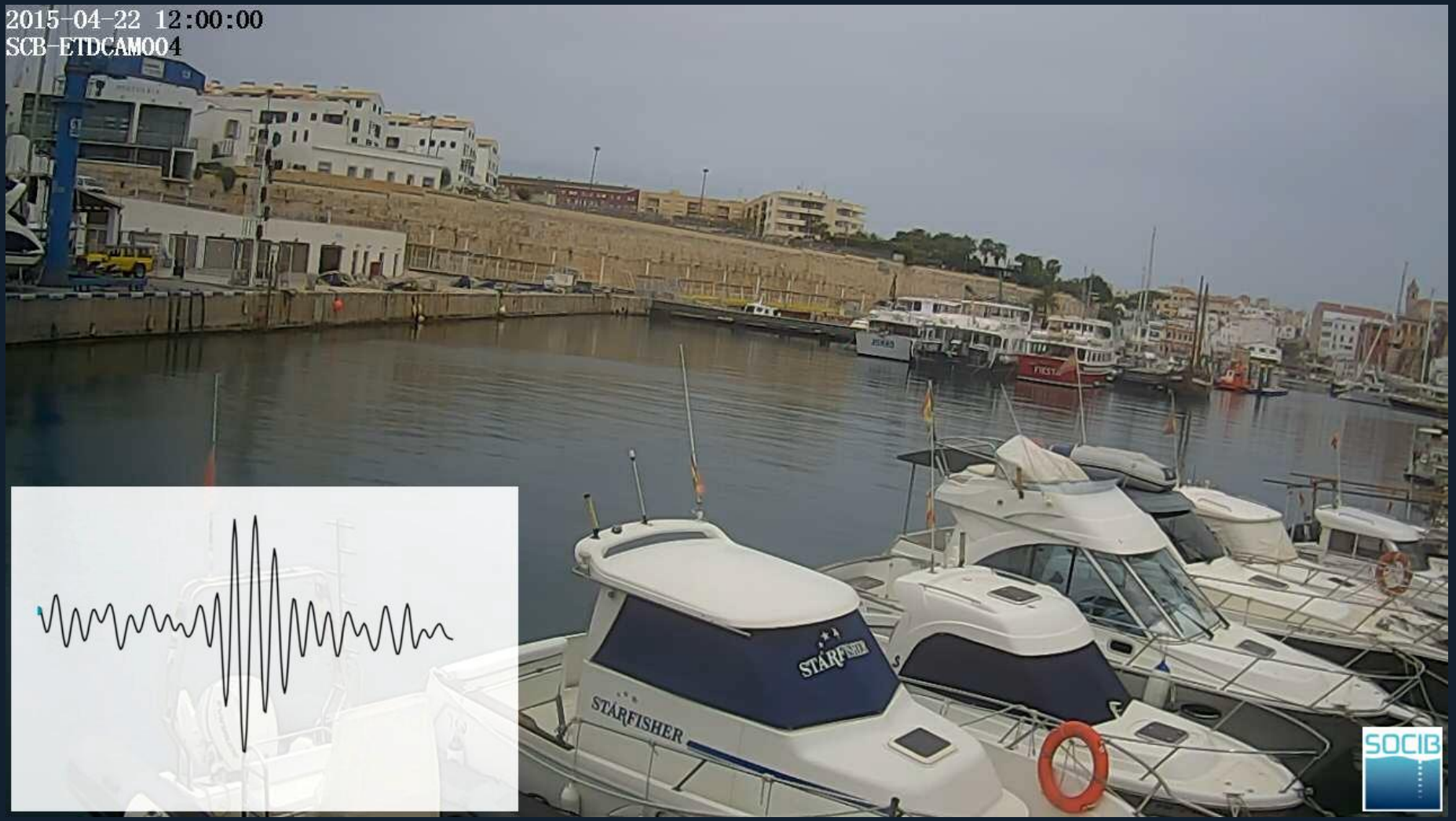
- ✓ BRIFS: operational daily 48-hour rissaga prediction system
  → Quantification of sea level oscillations in Ciutadella **www.socib.es**

- ✓ Synthetic atmospheric forcing allows to evaluate the physical soundness of the ocean modelling system and to investigate the amplification and propagation of meteotsunamis

- ✓ Realistic high-frequency and high-resolution atmospheric forcing is essential
  → This is the challenge, small scales are crucial !

- ✓ BRIFS evaluation: reasonably realistic results for the destructive June 2006 rissaga, some significant events missed over the last 3 years, overall underestimation of the measured sea level oscillations.

- ✓ Altimetry: very low probability (~1%) of data due to the short duration and small extension of the phenomenon. Additional issues associated with proximity to the coast.



Thank you for your attention