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Non-hydrostatic modelling of extreme water levels on Banneg island, France

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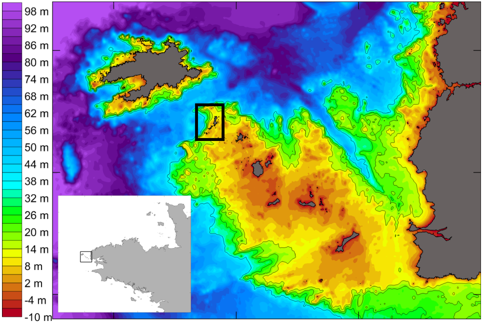
Why are we interested in extreme water levels ?

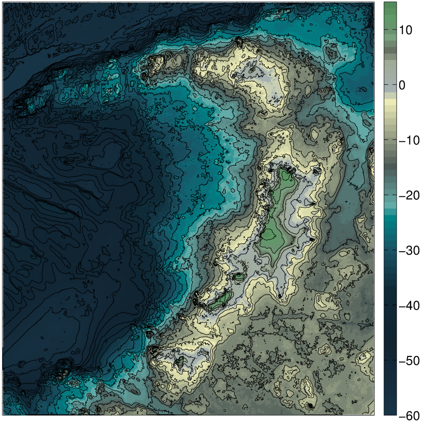
Giant waves at Porthleven, UK, on Feburary 5 2014 (Hercule storm)

Banneg island : an adequate "laboratory"



Bathymetry of Molene Archipelago

Bathymetry of Banneg island



Geomorphological evidences of the extreme hydrodynamic activity occuring on Banneg island (Suanez et al., 2009 ; Fichaut and Suanez, 2011)

Can you spot the differences between the two pictures ?

Banneg on April 2008

Banneg on April 2014


April 2008

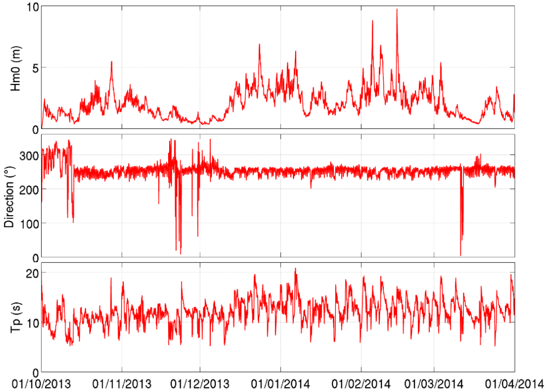

April 2014

Displaced blocks between 2008/04 - 2014/04 (mostly during 2013/14 winter)

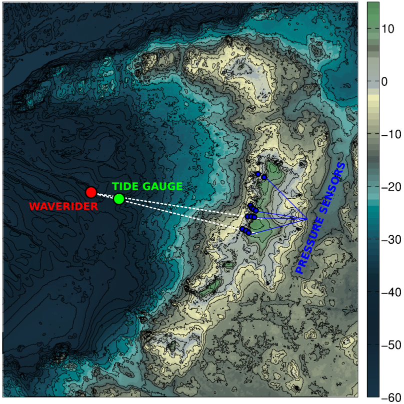
Presentation outline

1. Hydrodynamic measurements
   - Instruments deployment
   - Wave heights in February 2014
   - Water levels on February 5 2014
2. SWASH modelling
   - Model description and implementation
   - Model validation against observations
3. Model results
   - Extreme water levels on February 5 2014
   - Propagation of infragravity waves
4. Conclusion & Perspectives

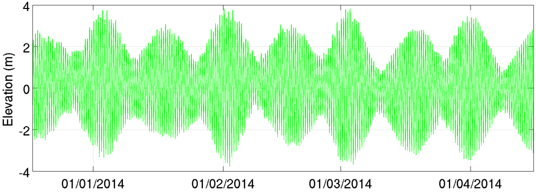
Presentation outline



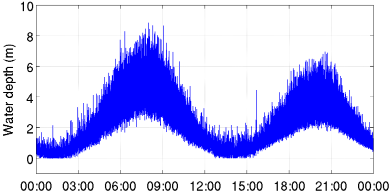
Offshore wave parameters



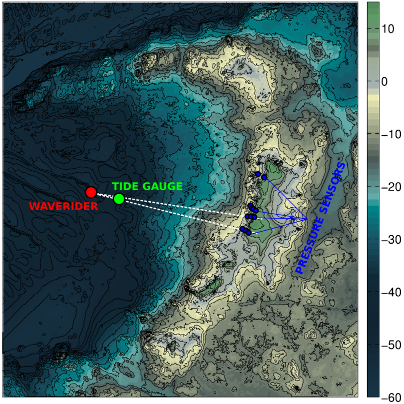
Location of instruments



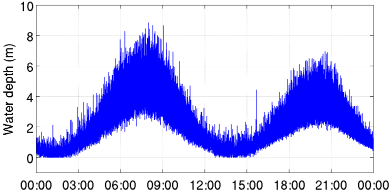
Offshore elevation time series



Nearshore elevation time series

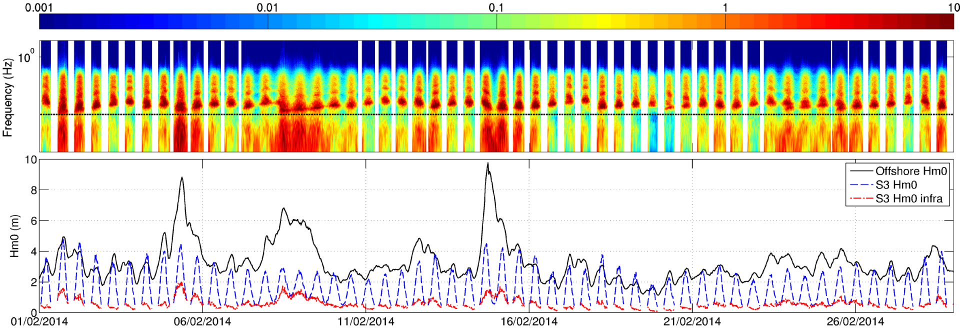


Location of instruments

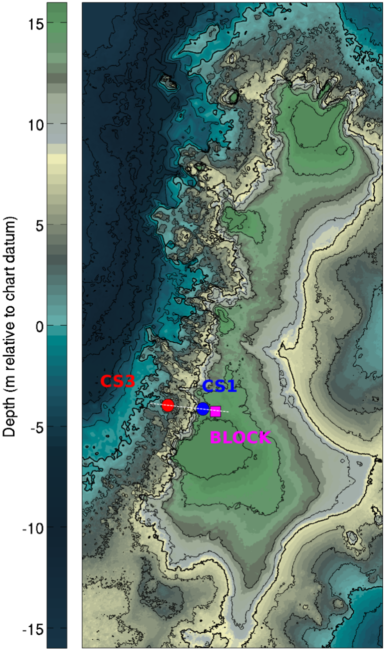


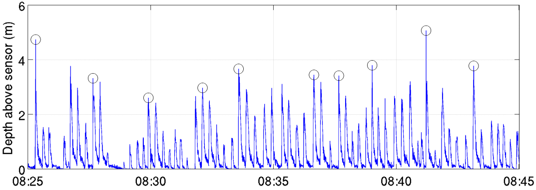
Nearshore elevation time series

- February 2014 : stormiest month of the year (decade ?) with Hm0 > 3 m 46% of the time and Hm0 over 8 m on February 5 and February 14
- Significant 12-hr modulation of offshore wave parameters
- Strong 12-hr and fortnight modulation of Hm0 in the surfzone
- Very high infragravity energy levels in the surf zone ($Hm0_{inf}$ up to 2 m)
- Tidal modulation and asymmetry of $Hm0_{inf}$ in the surfzone

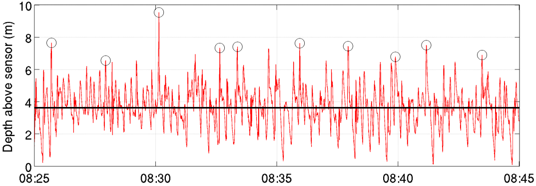


Time-series of spectral density, incident and infragravity Hm0 on February 2014

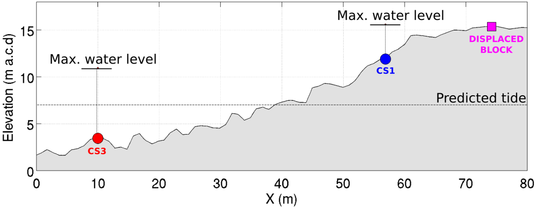




Water levels at CS1 on February 5 2014



Water levels at CS3 on February 5 2014



Presentation outline

SWASH (Simulated WAves till SHore), Zijlema *et al.*, 2011

$$\frac{\partial u}{\partial t} + \frac{\partial uu}{\partial x} + \frac{\partial wu}{\partial z} = -\frac{1}{\rho}\frac{\partial(p_h + p_{nh})}{\partial x} + \frac{\partial}{\partial x}\left(\nu^h \frac{\partial u}{\partial x}\right) + \frac{\partial}{\partial z}\left(\nu^v \frac{\partial u}{\partial z}\right)$$

$$\frac{\partial w}{\partial t} + \frac{\partial uw}{\partial x} + \frac{\partial ww}{\partial z} = -\frac{1}{\rho}\frac{\partial(p_h + p_{nh})}{\partial z} + \frac{\partial}{\partial x}\left(\nu^h \frac{\partial w}{\partial x}\right) + \frac{\partial}{\partial z}\left(\nu^v \frac{\partial w}{\partial z}\right) - g$$

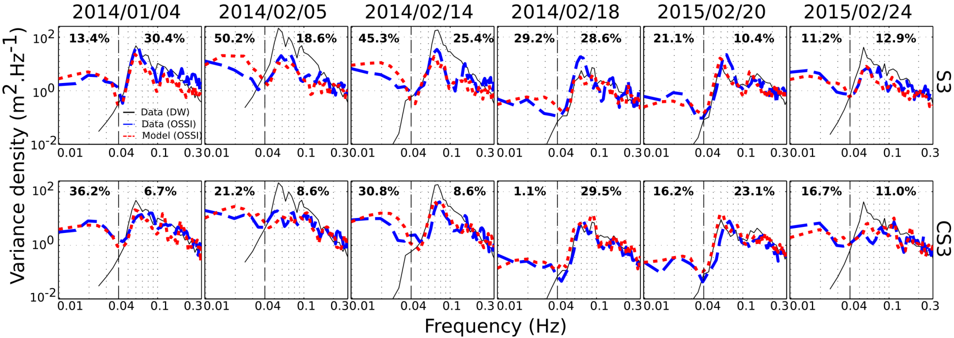
$$\frac{\partial u}{\partial x} + \frac{\partial w}{\partial z} = 0$$

Implementation to Banneg island

- 2DV profiles with 0.5 m resolution, starting in 50 m depth (waverider), intersecting pressure gauges, and ending at the centre of the island
- Two vertical layers (accuracy ok for dispersive effects up to 0.2 Hz)
- Spectral forcing based on waverider observations
- Constant water level estimated from tide gauge observations
- Time step comprised between 0.0015 - 0.006 s (CFL < 0.5)

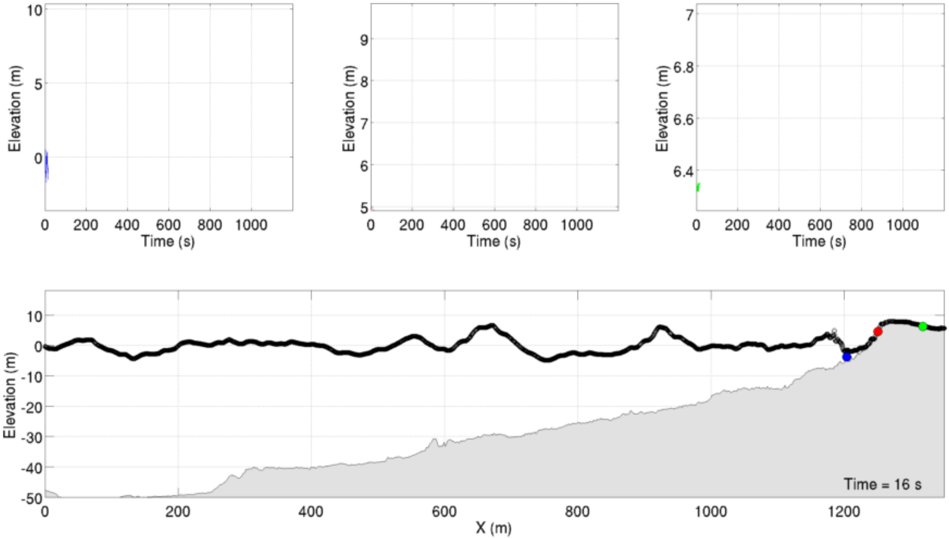
Elevation and offshore wave parameters of 6 selected storms

Date	Elevation (m amsl)	Hm0 (m)	Tp (s)	Direction (°)
2014/01/04	3.7	5.0	16.7	264
2014/02/05	3.1	9.0	18.2	262
2014/02/14	3.0	8.4	13.3	238
2014/02/18	2.6	2.5	11.1	270
2015/02/20	3.9	2.9	16.7	267
2015/02/24	2.6	4.1	18.2	264

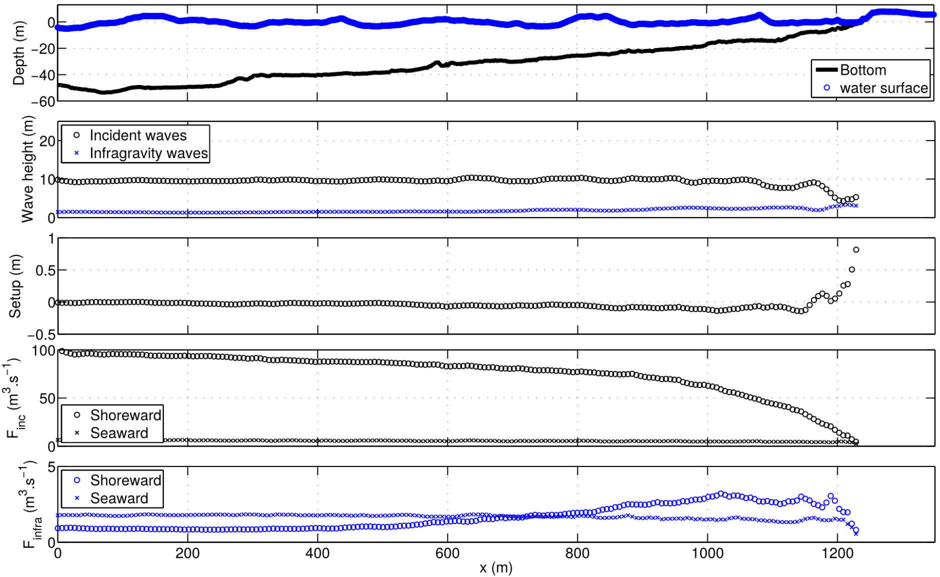


Comparison of modelled and observed wave spectra

Presentation outline



Simulated water levels for the conditions of February 5 2014



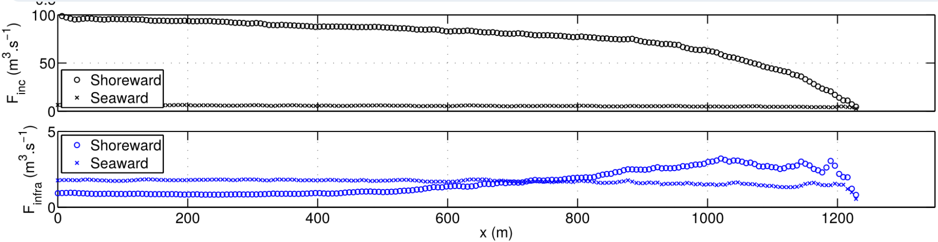
Profiles of water elevation, incident and infragravity wave height, mean water level, shoreward and seaward incident and infragravity energy fluxes

Shoreward/seaward energy fluxes, Sheremet *et al.*, 2002

$$F^{\pm}(f,x) = \frac{\sqrt{gh}}{4}\left[Co_{pp}(f,x) + (h/g)Co_{uu} \pm \left(2\sqrt{h/g}\right) Co_{pu}(f,x)\right]$$

$$\mathbf{F}^{\pm}_{inc}(x) = \int_{0.04Hz}^{2.5Hz} F^{\pm}(f,x)df$$

$$\mathbf{F}^{\pm}_{infra}(x) = \int_{0.01Hz}^{0.04Hz} F^{\pm}(f,x)df$$



Profiles of water elevation, incident and infragravity wave height, mean water level, shoreward and seaward incident and infragravity energy fluxes

Conclusion

- Hydrodynamic measurements revealed large waves off Banneg island and potential submersion of the island during winter 2013/14
- The SWASH model was shown to reproduce correctly the wave propagation during episodes of high water levels (wave + tide)
- Episodic submersions of the island were reproduced by the model on Feburary 5 2014
- Infragravity waves were shown to be strongly reflected at the coastline

Perspectives

- Correlation between hydrodynamic data and geomorphological changes
- 3-D modelling with SWASH
- Infragravity wave dynamics on steep cliffs

Thank you for your attention !

Soil erosion and storm deposits after the overwashing of the island in February 1990
Credits : Bernard Hallegoüet