On the use of downscaled ARPEGE winds in the storm surge and wave models of Météo-France

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OUTLINE

1- INCREO EU-project

2- Downscaling method in ARPEGE system

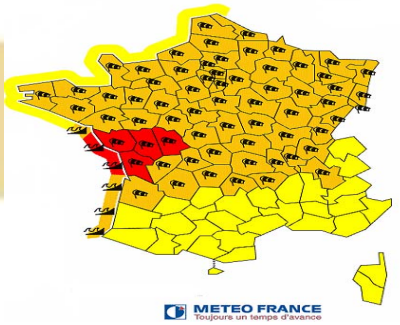
3- Storm cases (results and validation)

4- Conclusions

Etretat, 1990,

courtesy of R Caspar

MOTIVATION



- **Increasing REsilience to Earth Observation (IncREO) EU-FP7 project**
  2-years European project with 9 partners from industry, science and public institutions

- **Risk and vulnerability mapping as a contribution to the enhancement of mitigation and preparedness measures for some selected natural disasters (landslide survey, dam failure, storm surge…)**

- **The goal of the work package W202 in IncREO is to improve the wind forcing at the ocean surface for waves and storm surge applications**

➡ **Studying the past extreme events to better understand the coastal hazards and improve disaster management.**

Two regions of interest : French and Bulgarian coasts

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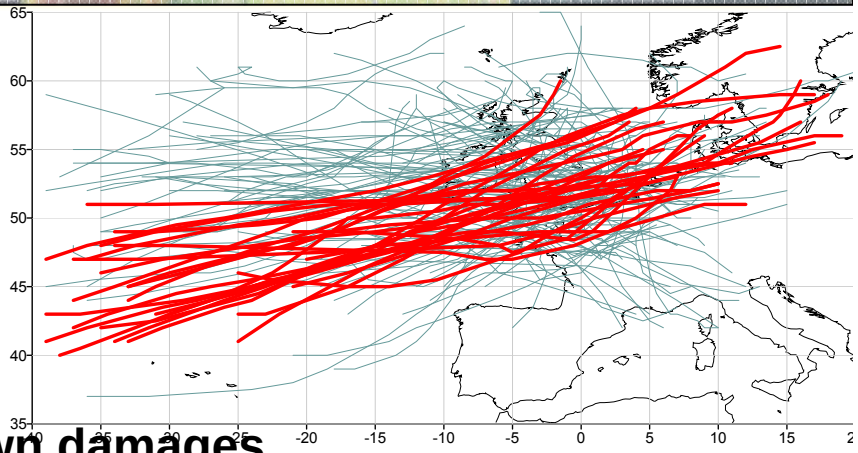
Historical storm cases

WP202: Winds, waves, storm surges



How to select out cases of study ?

- **FRANCE: 20 cases from 1924 until 2010**

- **Availability of data**

- **High intensity of the event in terms of known damages**

- **Other specific selection criteria for each coasts:**

ATLANTIC	MEDITERRANEAN SEA
•Total sea level (= tide + storm surge) > High Atmospheric Tide + 20cm (Atlantic coast) • Storm surge > threshold defined by station • Instantaneous storm-surge > 1.75 * previous threshold •Large geographical extent Large variety of situations	•Total sea level (= tide + storm surge) > HAT+15cm (Mediterranean coast) • Instantaneous storm-surge > 41cm (Mediterranean coast) •Large geographical extent • Large variety of situations

Simple downscaling
Case of Johanna storm – 10 March 2008

Description of the case

Extensive area of westerly winds over Atlantic coast lasted a long time
+ Extreme waves breaking onshore during very high tides (tide coeff. 106)
+ Low-pressure and wind generated a storm surge ≃ 1 m

ATL_200803: Saint Guénolé (France), March 200

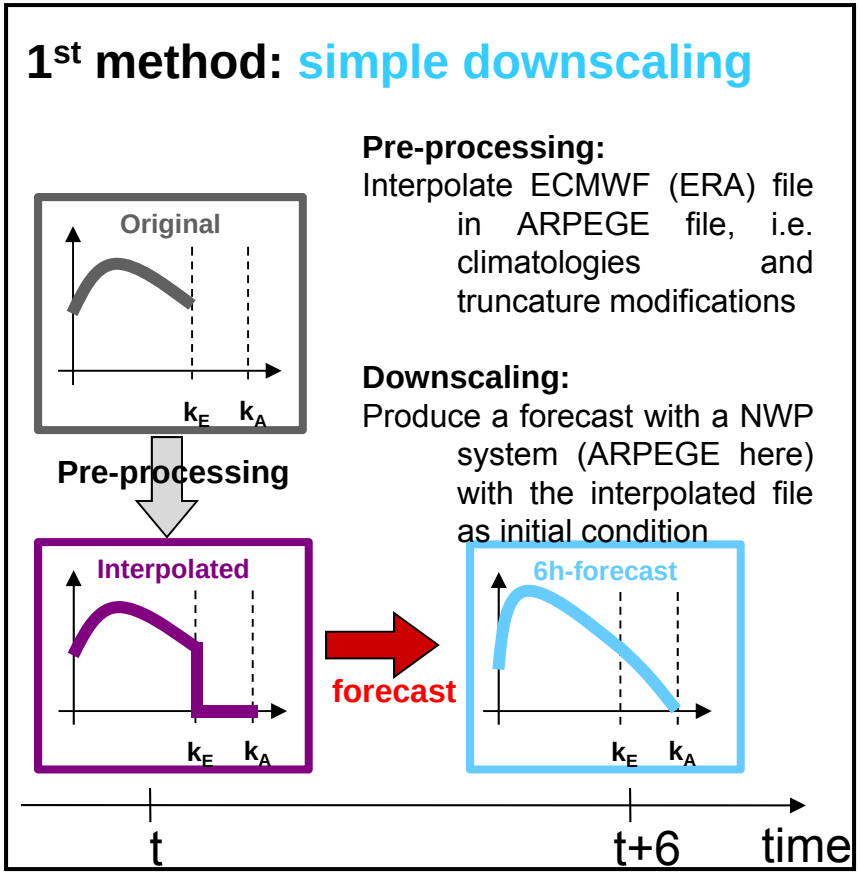
Methodology

Description of two downscaling :

The advantage of using ERA is more Observations have been assimilated

k_A: ARPEGE truncature
k_E: ECMWF truncature

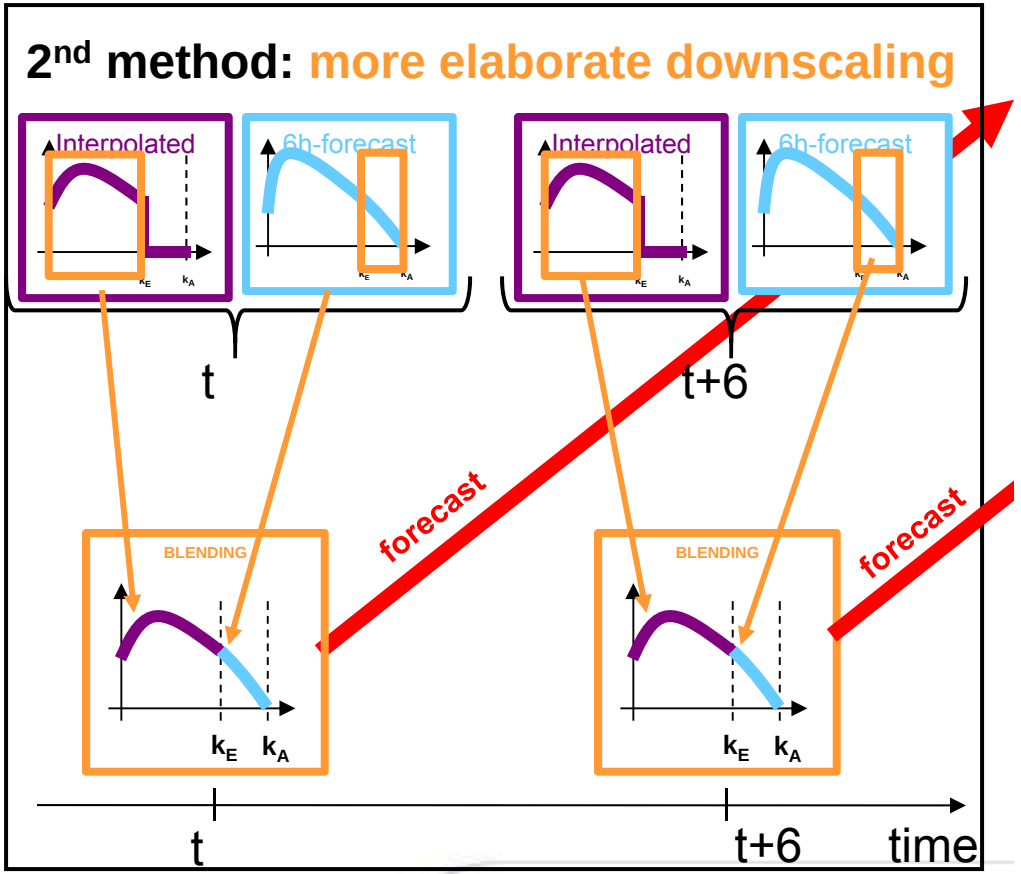
1st method: simple downscaling



Pre-processing:
Interpolate ECMWF (ERA) file in ARPEGE file, i.e. climatologies and truncature modifications

Downscaling:
Produce a forecast with a NWP system (ARPEGE here) with the interpolated file as initial condition

2nd method: more elaborate downscaling



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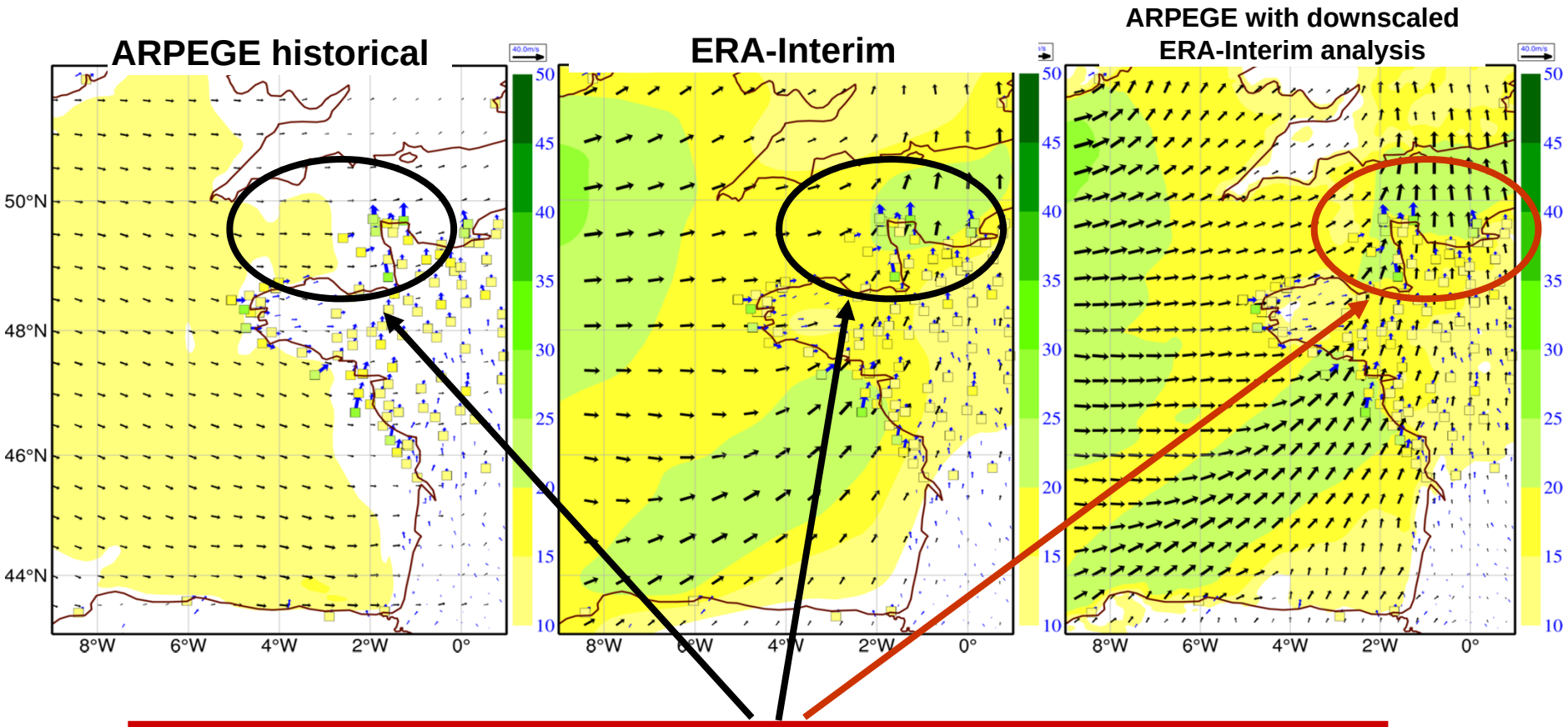
Simple downscaling

First example: Johanna storm – 10 March 2008

18h-forecast of 10-m wind
(model: black arrows and colored area; obs: blue arrow and colored squares)
VT: 20080310-06UTC

Downscaled meteorological quantities
Example of 10-m wind



Forecast using downscaled ERA-Interim reanalysis is closer to the observations than historical ARPEGE forecast or ERA-Interim forecast

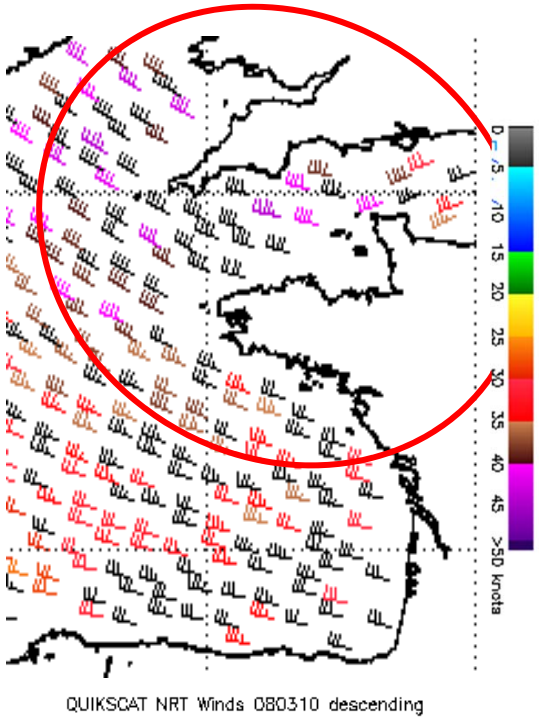
FRANCE
emps d'avance

More elaborated downscaling

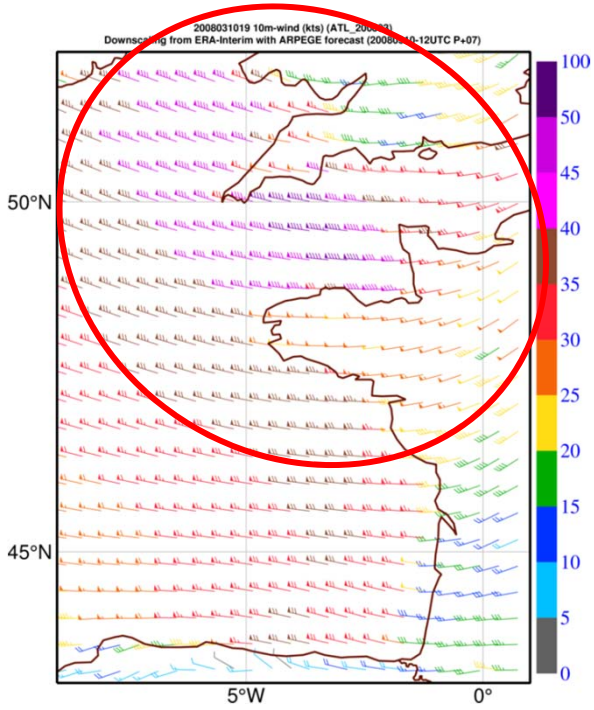
Johanna storm

Downscaled meteorological quantities:

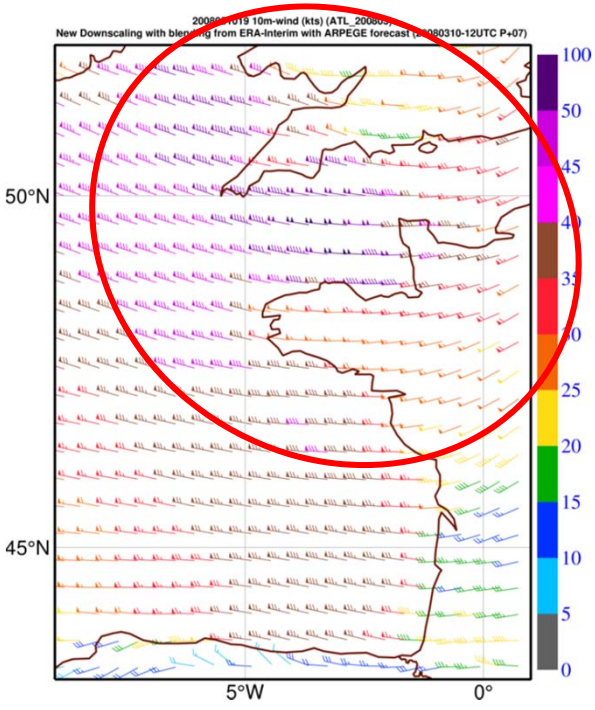
Example with QUIKSCAT observations and 10-m wind



10-m wind (knots, barbs) obtained with QUIKSCAT scatterometer on 20080310 at 18:53 UTC



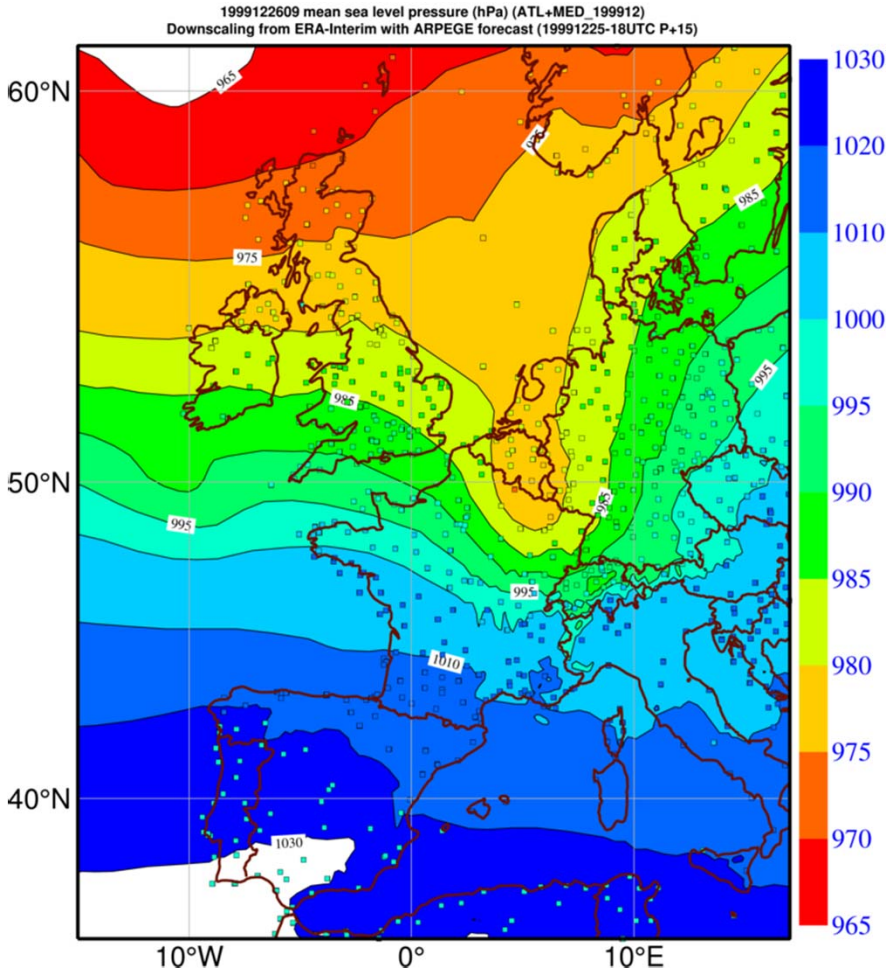
10-m wind (knots; barbs) from the simple downscaling procedure on 20080310 at 19 UTC.



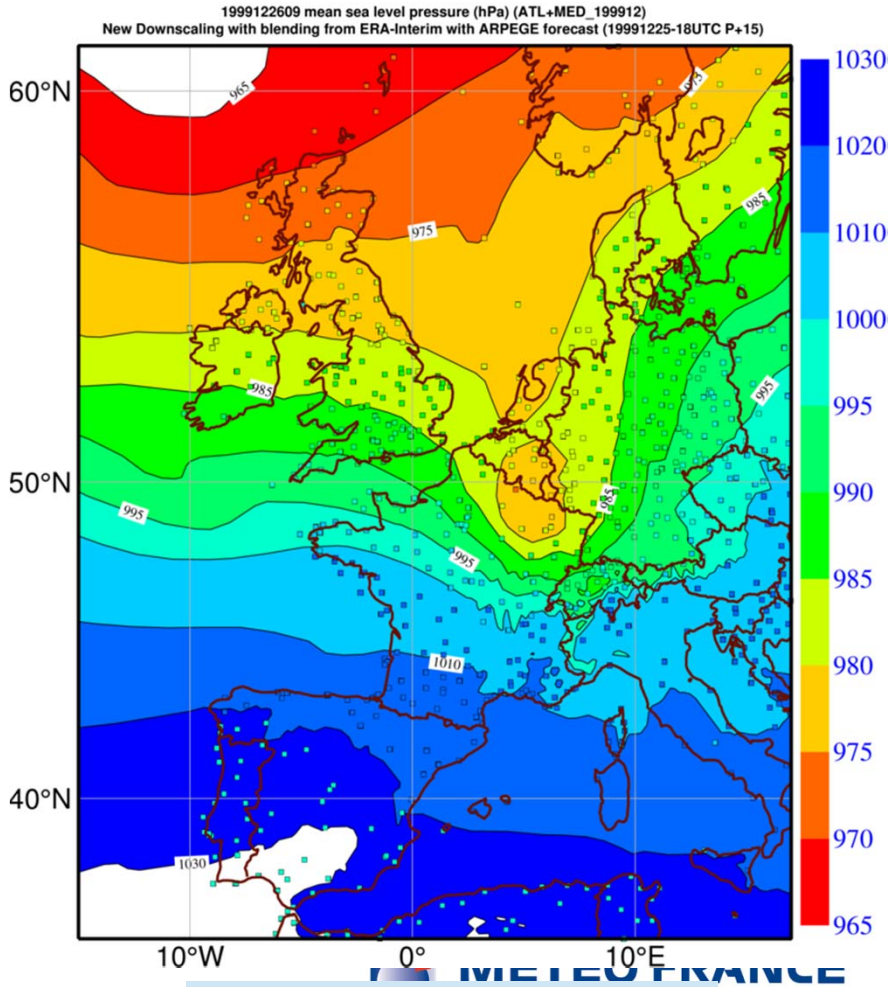
10-m wind (knots; barbs) from the more elaborate downscaling procedure on 20080310 at 19 UTC.

More elaborated downscaling
Example of storm Lothar (26 Dec 1999)

Forecast (15h) for 26 Dec 1999 at 9:00 UTC



Simple Downscaling



Blended downscaling

Models used in IncREO runs

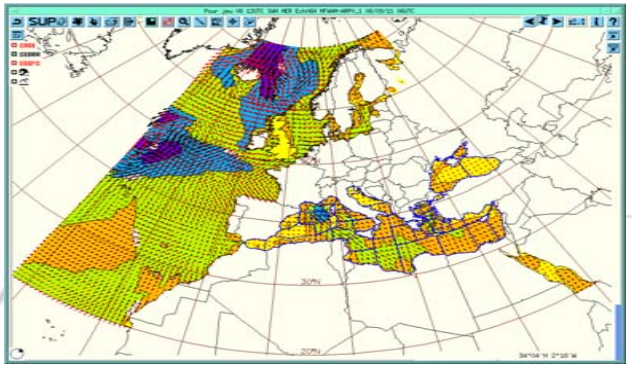
- **The operational surge model of Météo-France is a barotropic 2-dimensional version of HYCOM ocean model. For IncREO runs the storm surge model is forced hourly.**

- The North-East Atlantic (Bay of Biscay,British Channel and North Sea) domain from 9°W to 10°E and 43°N to 62°N. 2 km mean (curvilinear) grid size for the new HYCOM.

- The Mediterranean Sea : domain 9°W to 42°E and 30°N to 47°N with 10 km (curvilinear) grid size

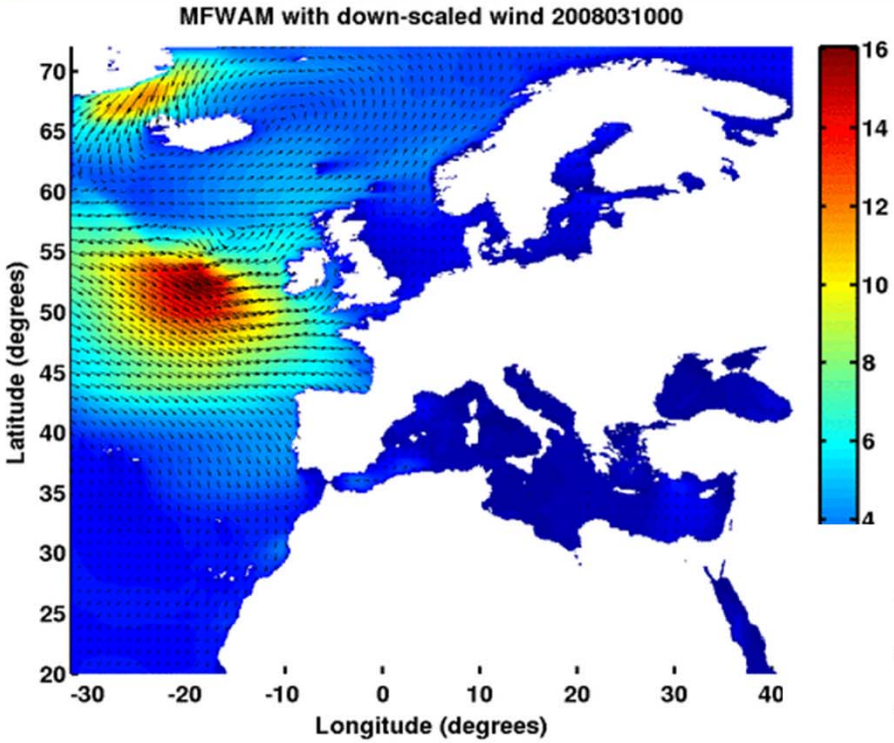
- **The operational wave model MFWAM (version 441)**

- Nested regional Europe-Atlantique (including Med Sea)
  Boundary conditions from North-Atlantic MFWAM
  Dedicated to IncREO



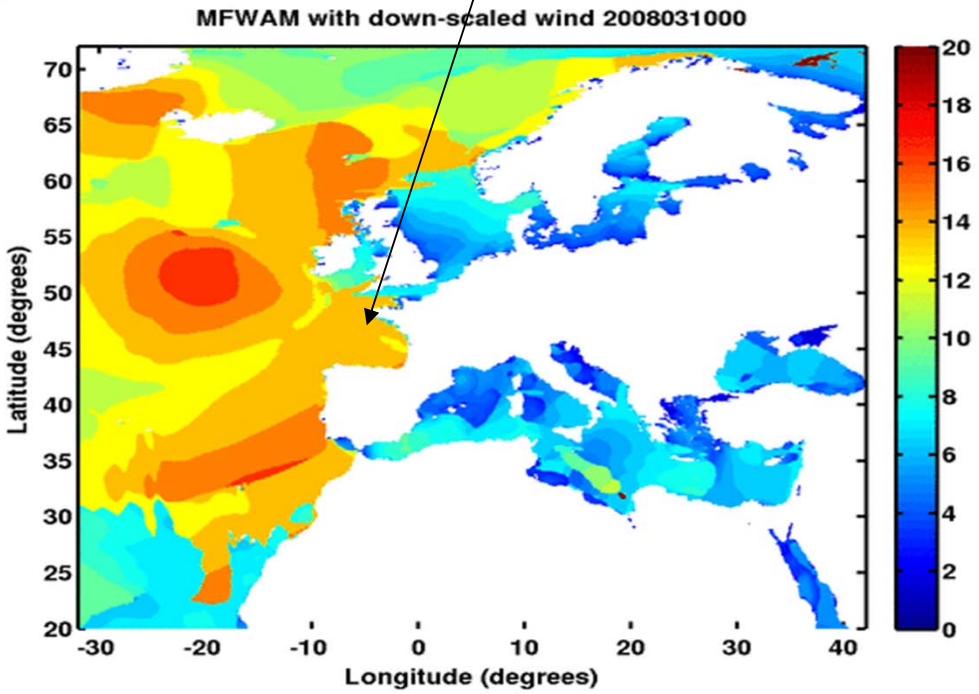
Simple downscaling

Storm Johanna, 10 march 2008



Snapshots of SWH and peak period with a step of 6h, from 10 march 2008 at 0:00 UTC until 11 march at 0:00 UTC.

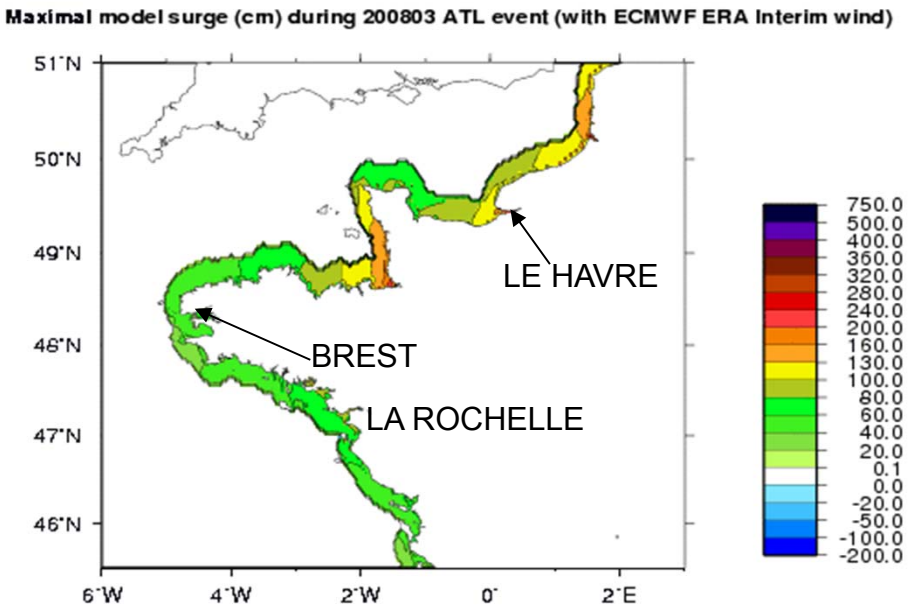
Powerful swell (Tp~20 sec) hitting the French Atlantic coasts



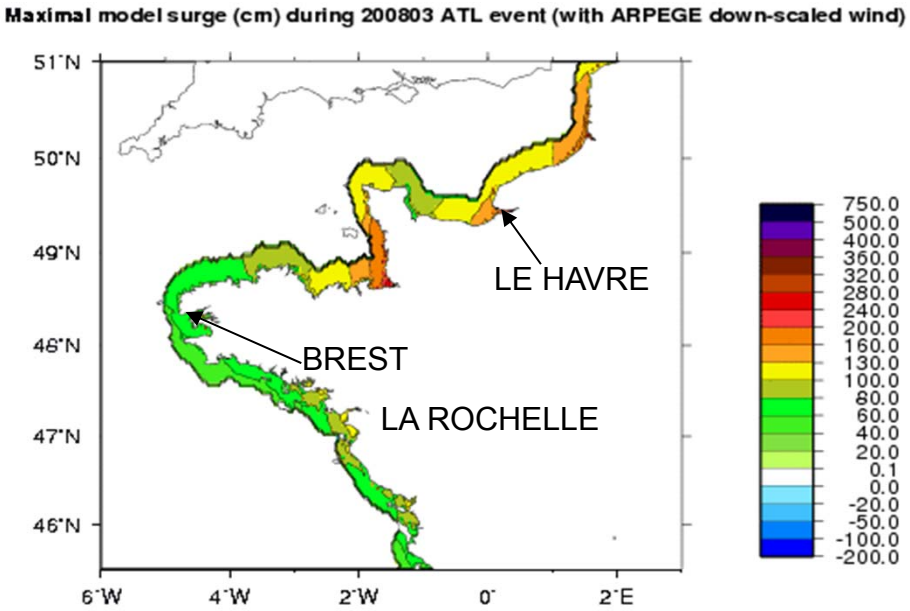
Simple downscaling

Example : storm Johanna, 10 mars 2008

Wind from ERA-Interim



Wind from downscaled ARPEGE



Maximum surge (cm) profile for Atlantic coast

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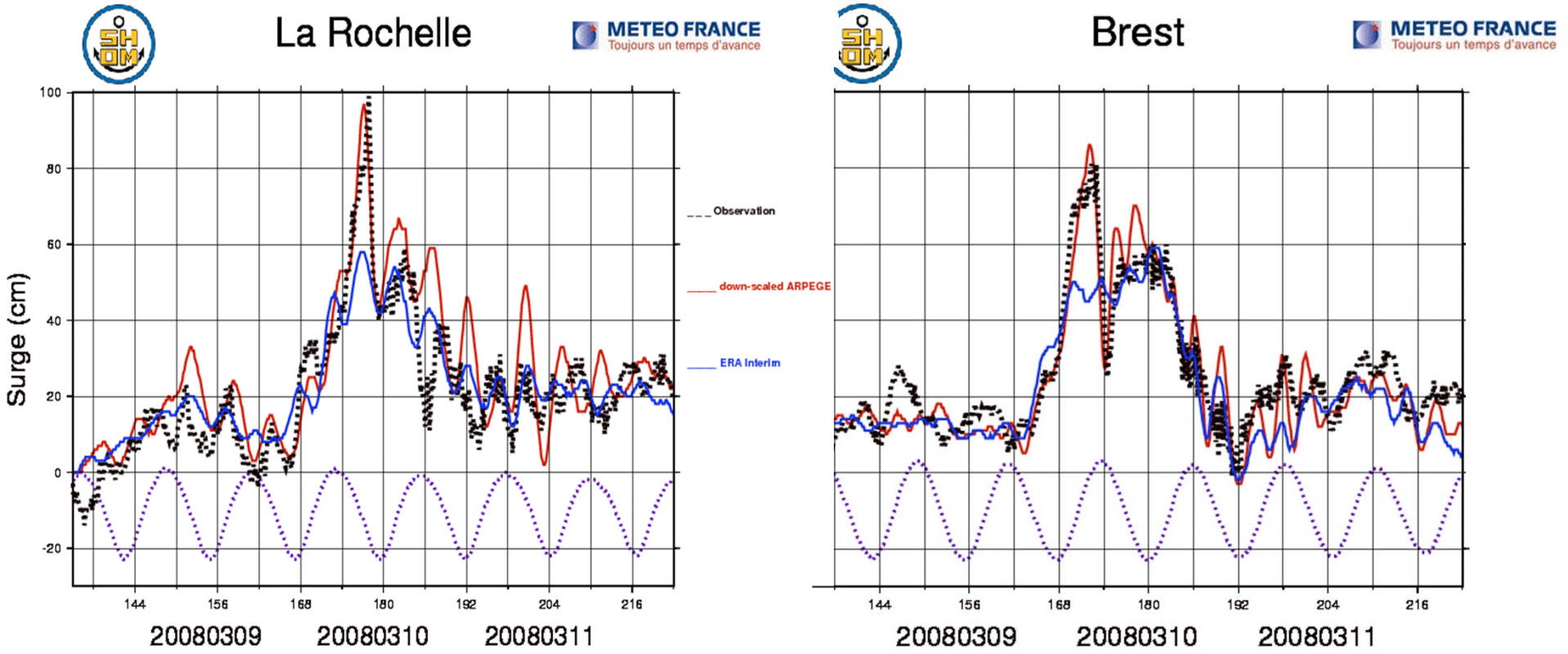
Simple downscaling
Example : storm Johanna, 10 mars 2008

Observations ERA-Interim Downscaled ARPEGE

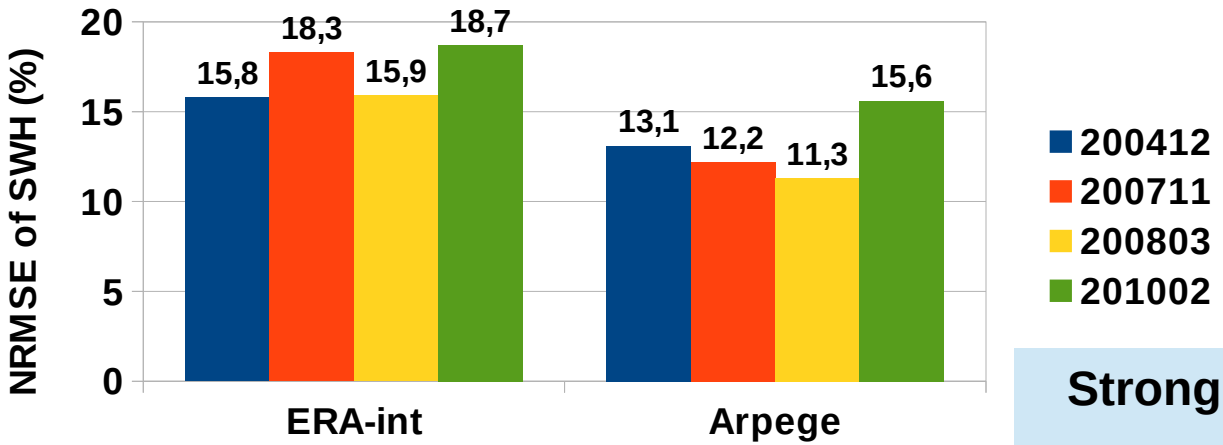
Validation of surge

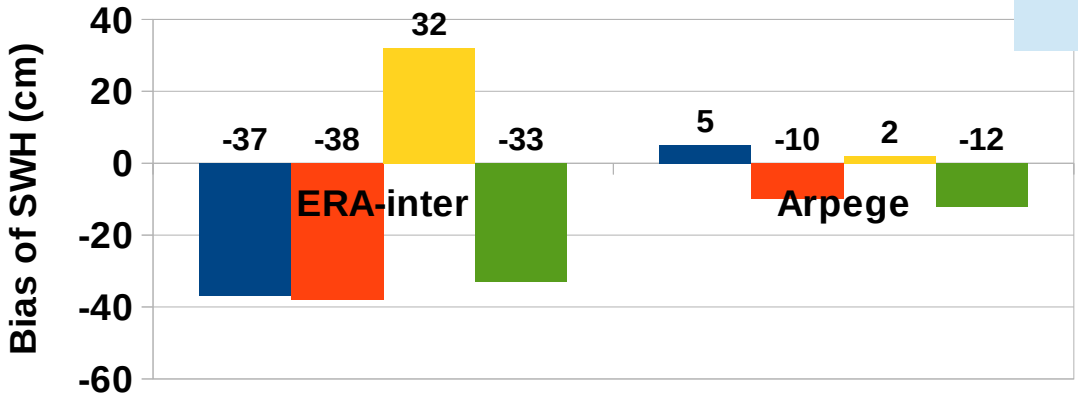


Surge (cm) from 8 march 2008 at 15 UTC until 12 march 2008 at 06 UTC.
Tide height in dashed line to indicate max sea level

The use of downscaled winds improves surge forecast at the peak.

Validation of SWH with altimeters





Strong reduction of RMSE and bias

The improvement of RMSE is between 16%-30%

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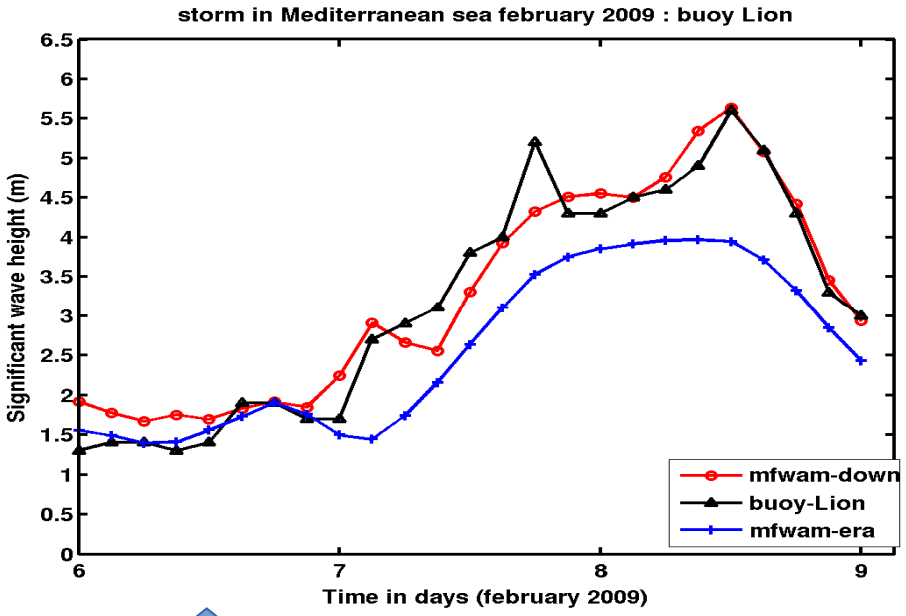
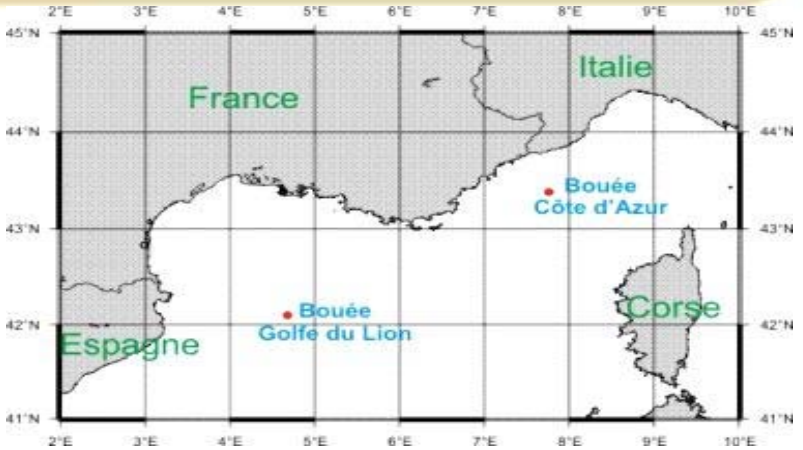
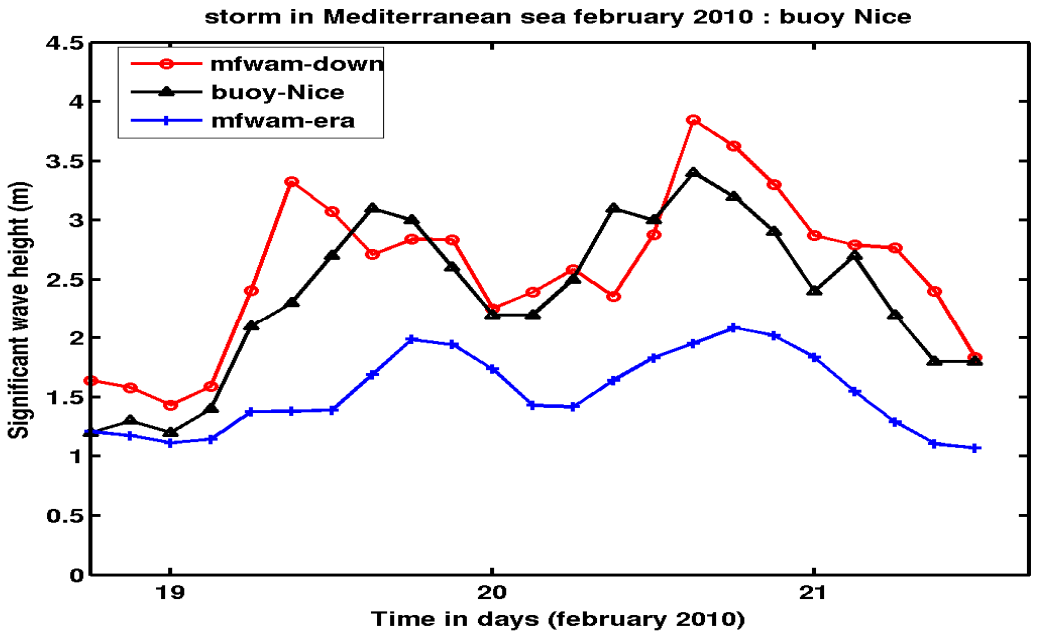
Comparison with buoys in Mediterranean Sea





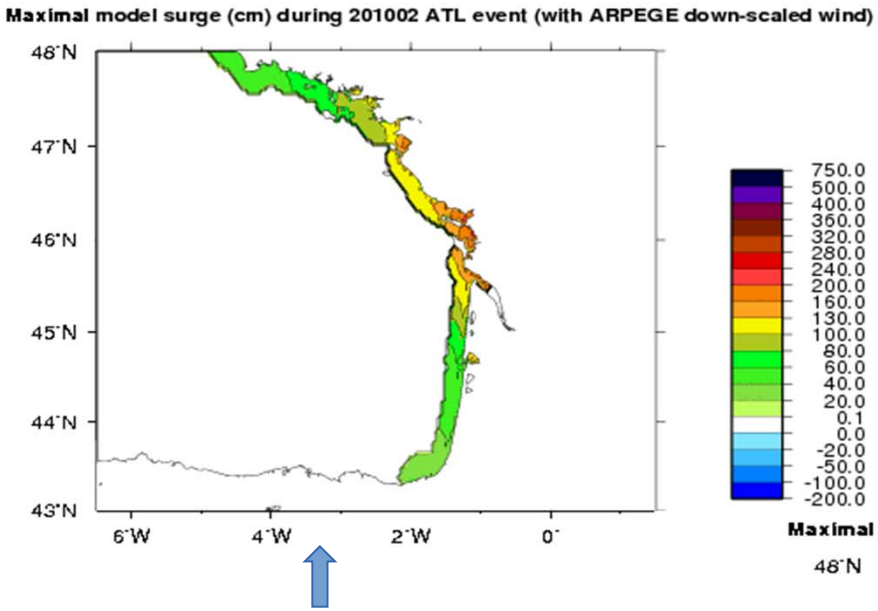
February 2009
At buoy Lion

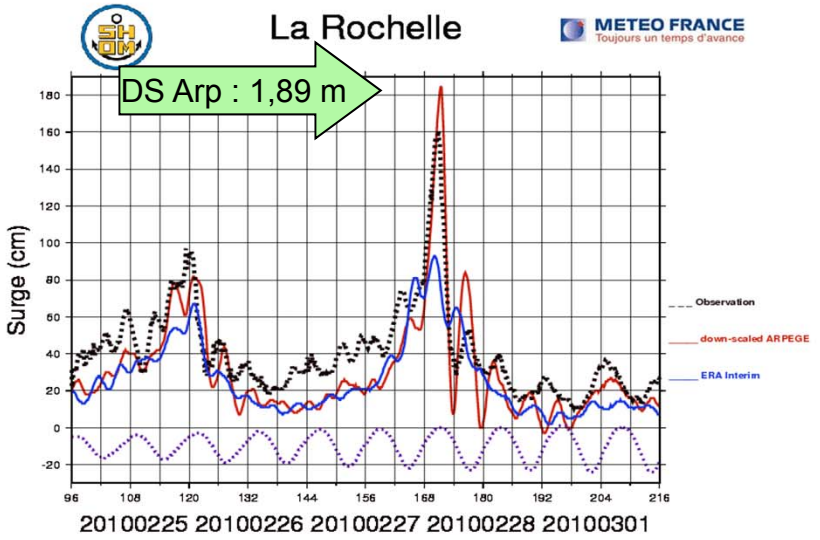
February 2010
At buoy Nice-Azur



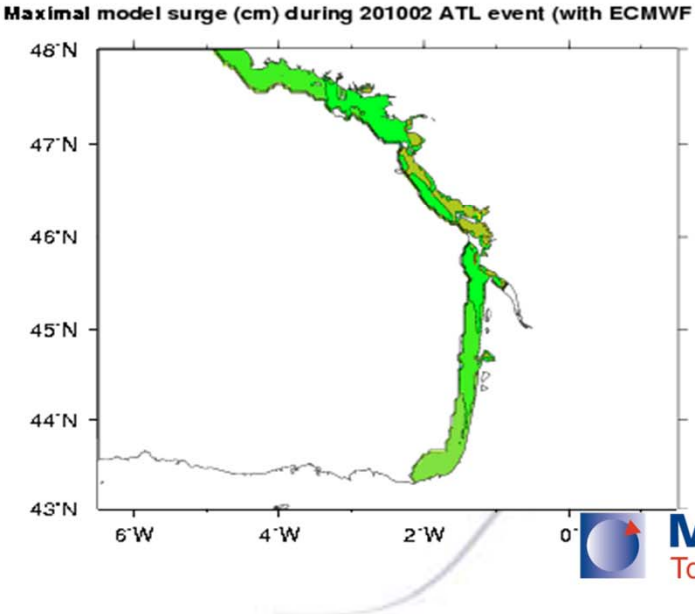
Case of storm xynthia (February 2010)

Comparison with tide gauge at La Rochelle





Down-scaled Arpege



ERA-I

Profile of storm surge for the Atlantic coast

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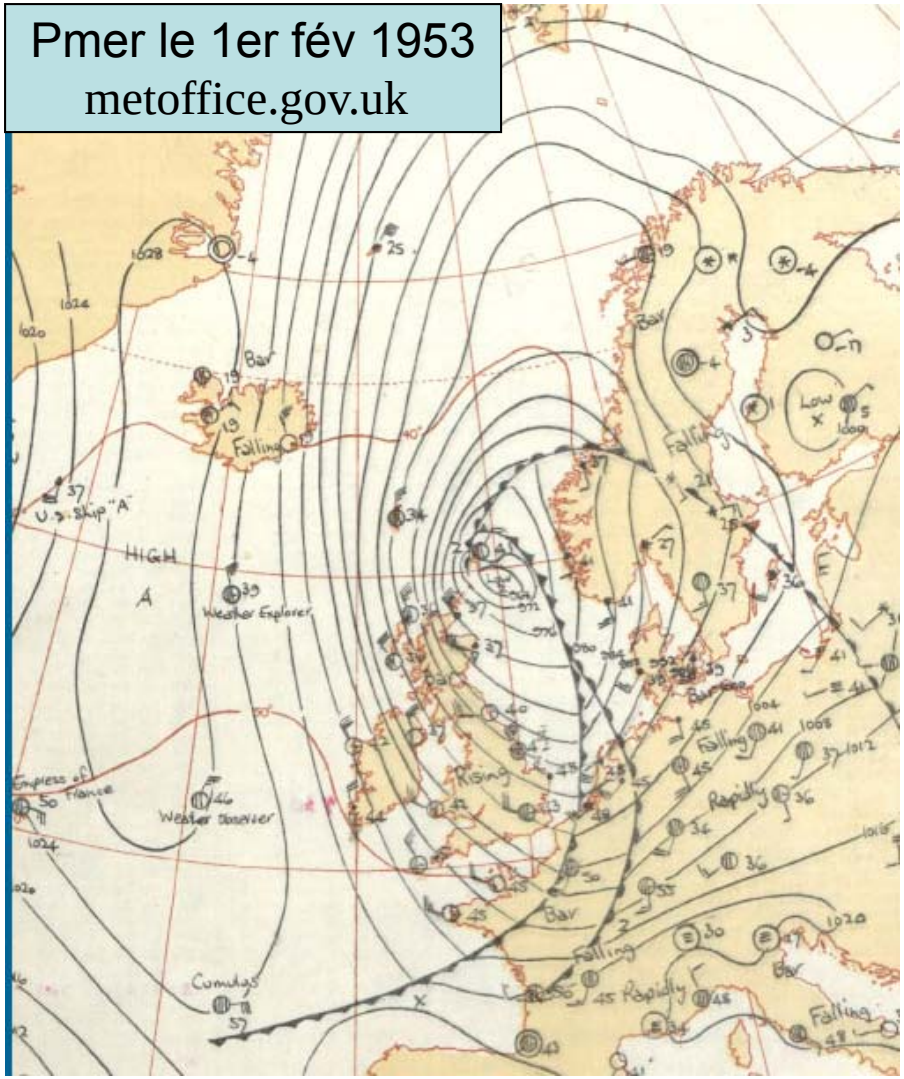
Storm of 1 February 1953

Tempête fév 1953 en Mer du Nord

Pmer le 1er fév 1953
metoffice.gov.uk

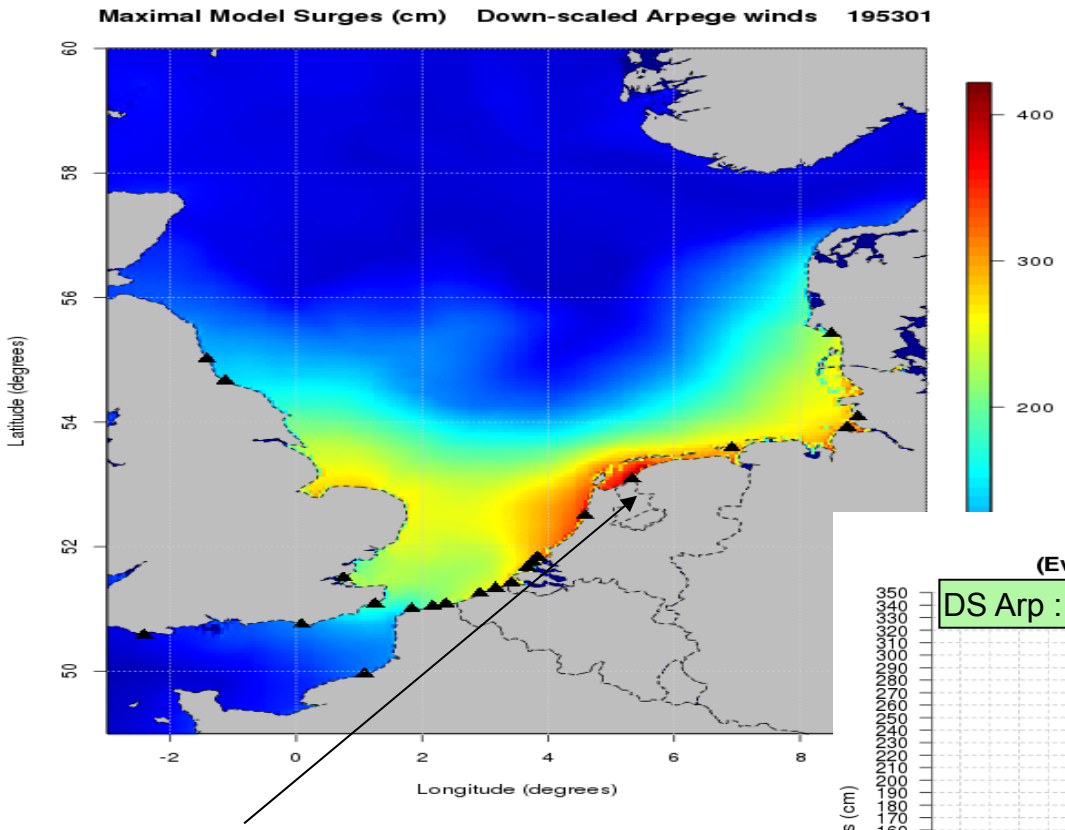


➔ Use downscaled ARPEGE from ERA-Clim

➔1850 people died in Netherland (Zeeland), 300 in England, 30 in Belgium

➔ Leads to Delta Program to build dykes (coast protection in Holland)

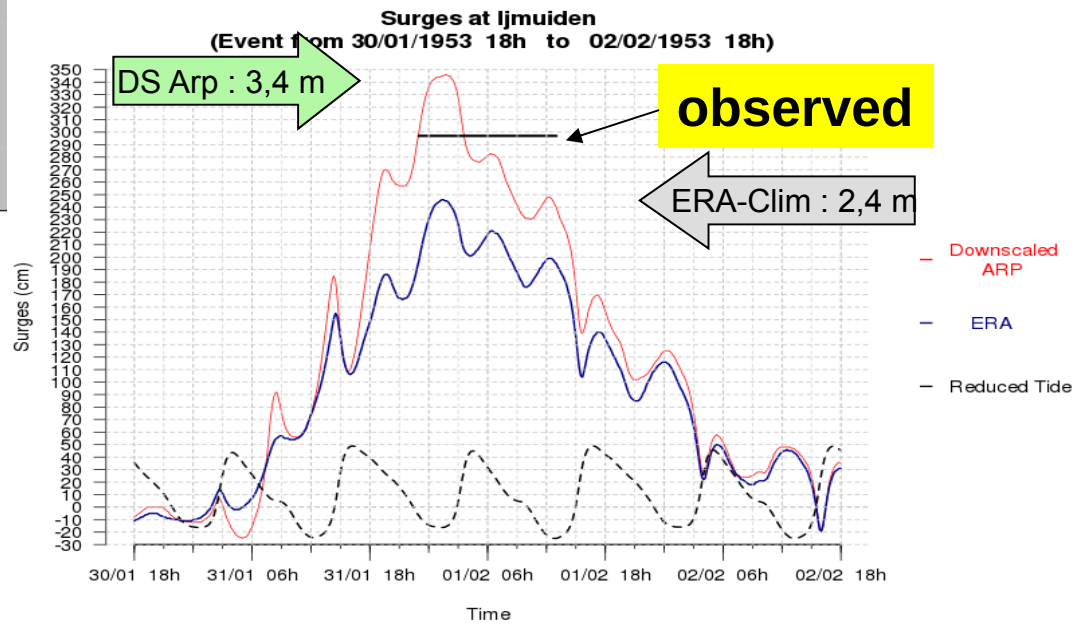
Extreme storm in the North Sea Feb. 1953



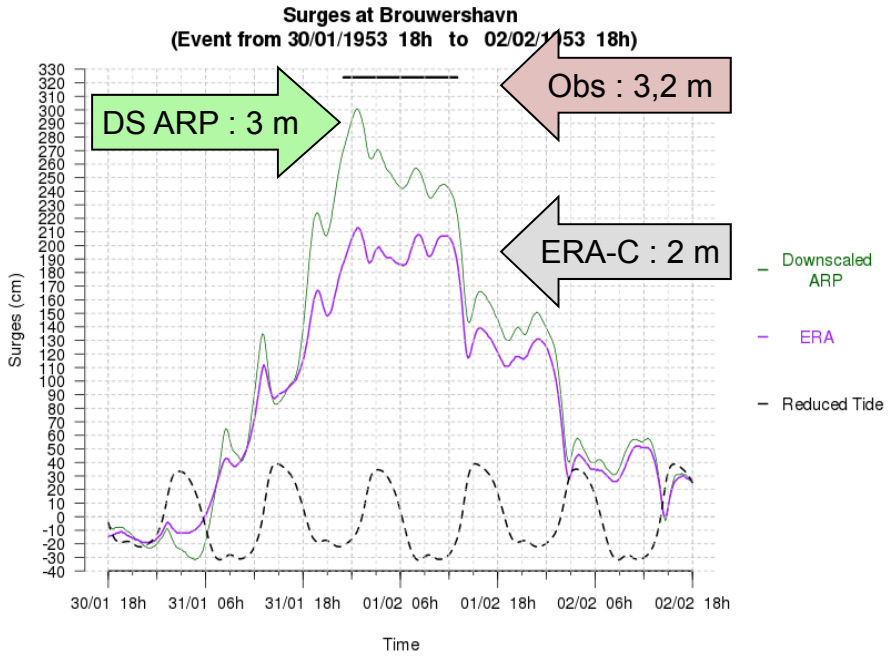
Maximum of Storm surge (cm)

More than 4 meters on the dutch coast

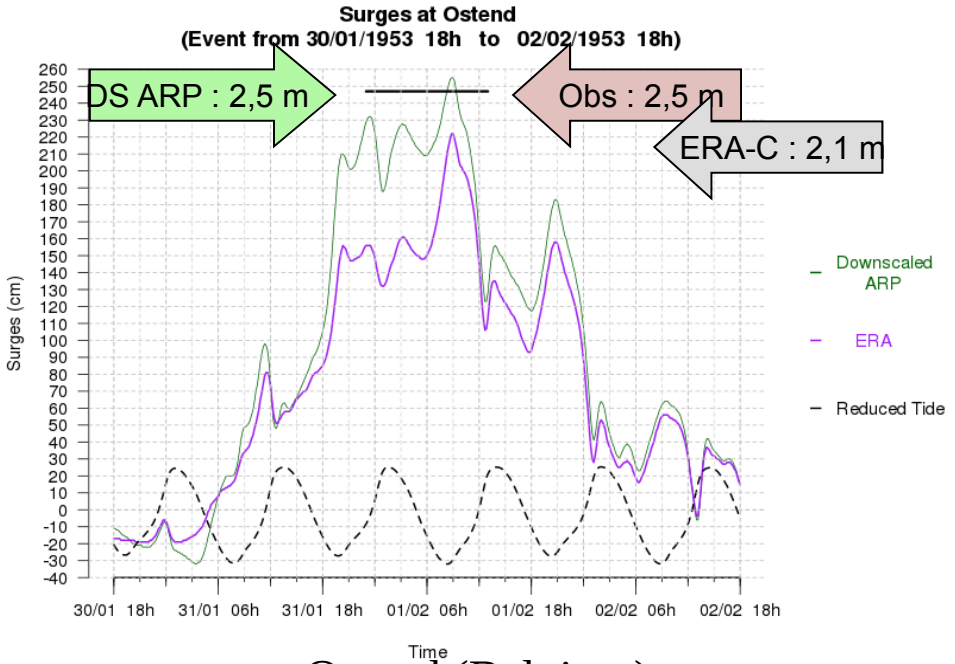
Good fit of the storm surge at Ijmuiden



Extreme storm in the North Sea Feb. 1953



Brouwershavn (Netherland)



Ostend (Belgium)

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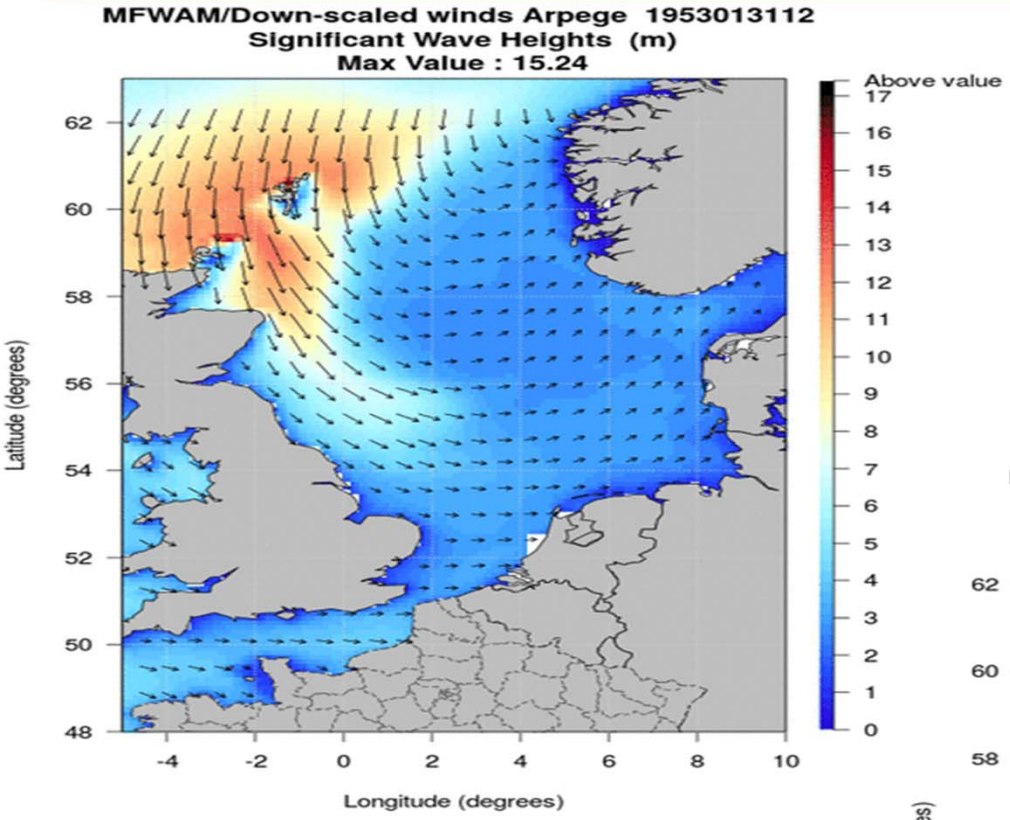
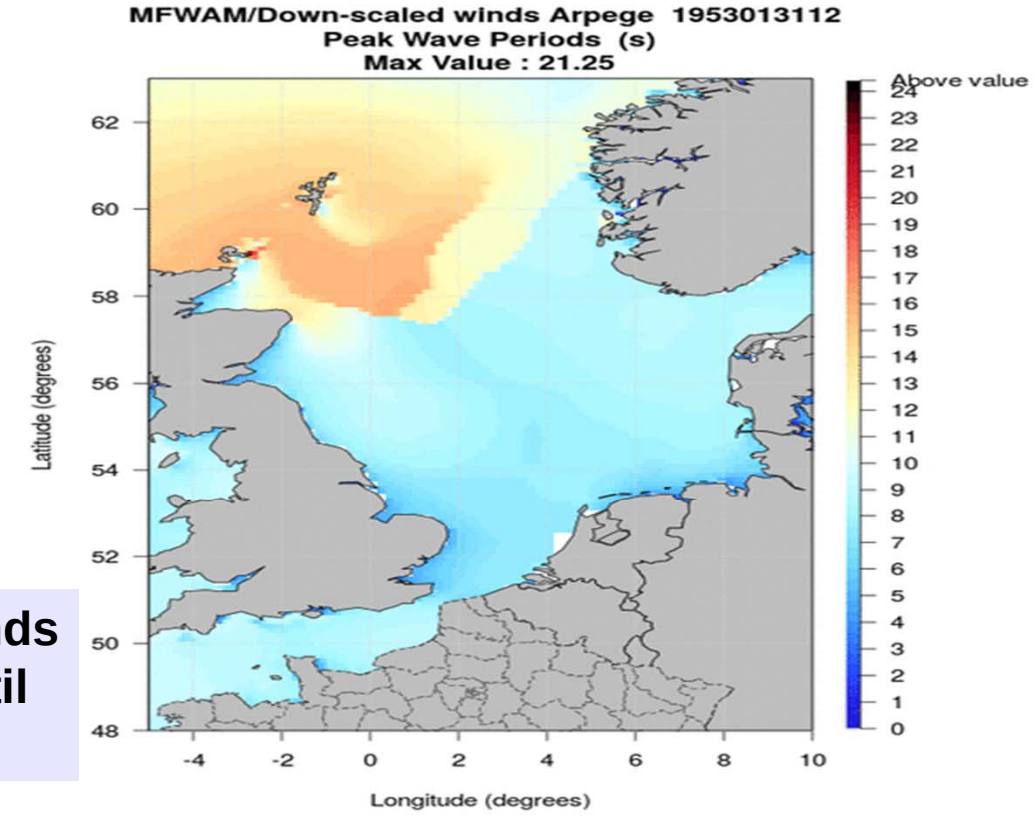
Extreme storm in the North Sea Feb. 1953



Sig. Wave height

Large swell with Tp >20 sec and Max swh of 16,4 m

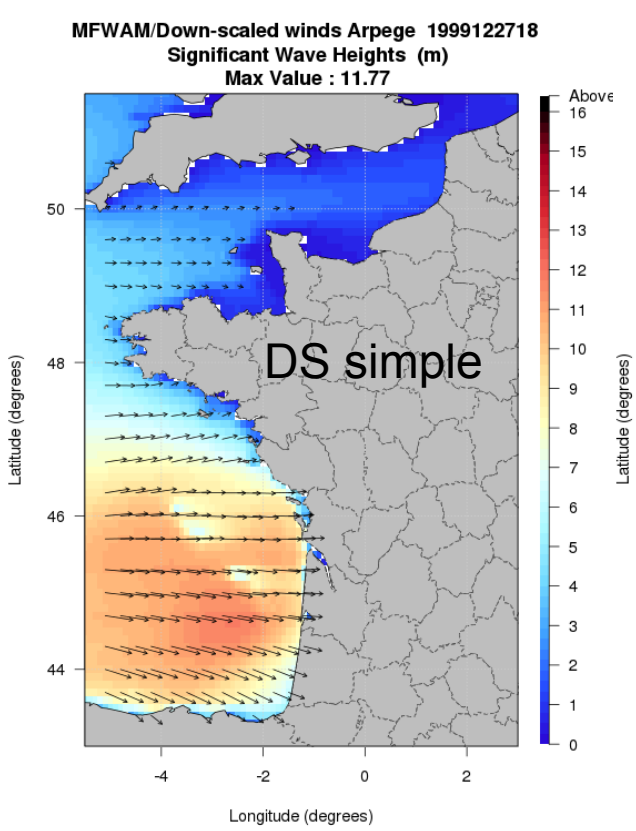
Peak period

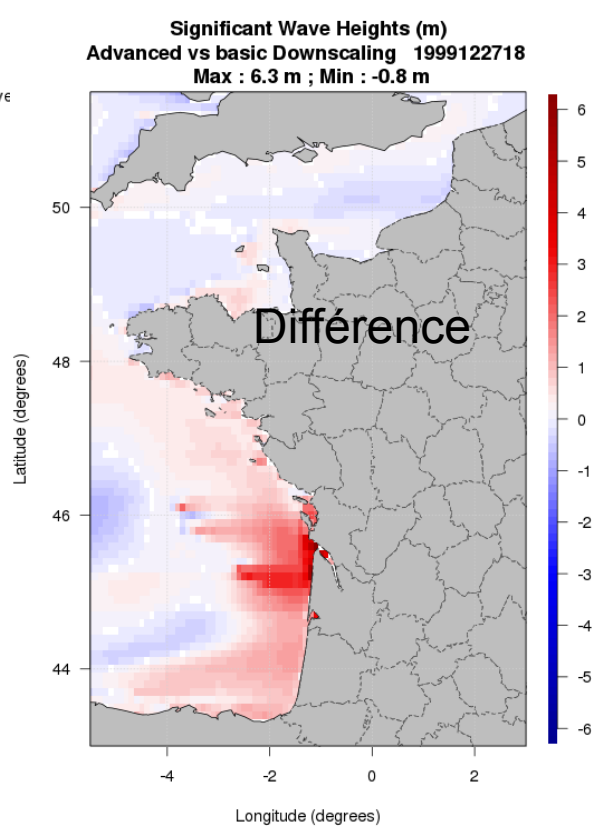


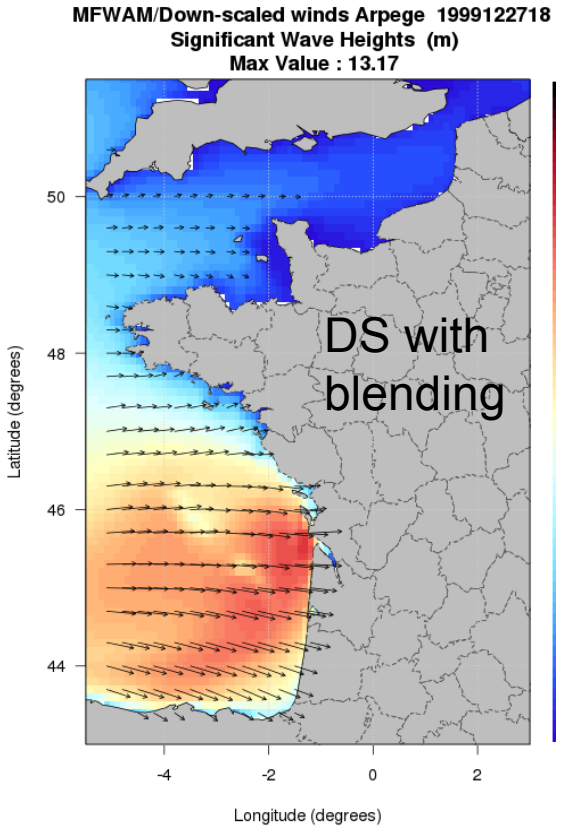
Output from run with DS winds from 31 Jan 12:00 UTC until 1 Feb. 1953 at 12:00 UTC

Difference between the two downscaling

Storm Martin on 27 december 1999 : impact of the two downscaling methods on sig. Wave height







The use of blended downscaling induces in storm MARTIN to a large difference (up to 5 m) for SWH regarding to simple downscaling

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Conclusions

- **The ARPEGE downscaling technique is very promising and the use of these winds leads to a better forecast of waves and storm surges.**

- **20 historical storms have been successfully investigated. good estimate of waves parameters and storm surges in order to evaluate the risk of natural diasters on the European coasts.**

- **The validation of significant wave heights with altimeter data shows a very good performance. The storm surges at the peak of events is significantly improved regarding to ERA-interim winds.**

- **Models with downscaled ARPEGE show good ability for extreme storms such as the one of 1953**

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