



Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

Storm Surges in the North Sea

Hans de Vries

KNMI, The Netherlands



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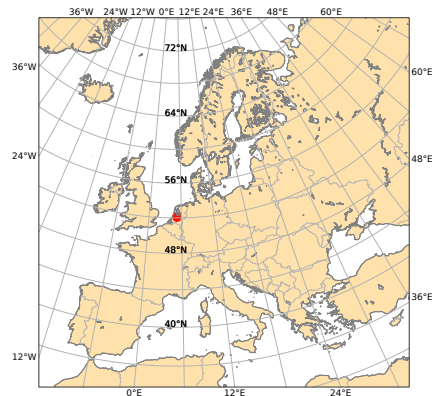


Studied experimental physics

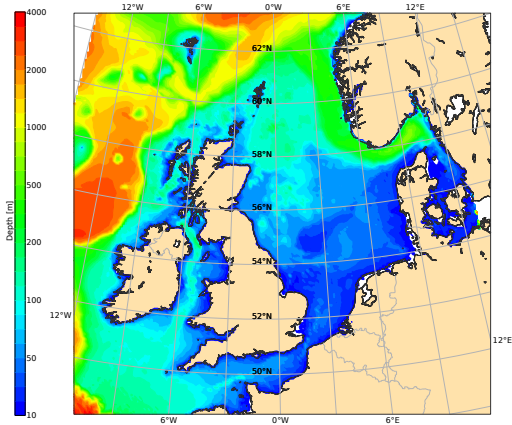
Royal Netherlands Meteorological Institute (KNMI)
Department R&D Weather and Climate Modelling

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- Storm surge forecasting for the coast of The Netherlands
- Focus on how to use meteorological (model) input
- Probability forecasts



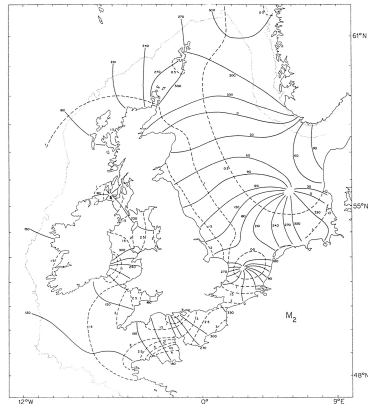
The North Sea



- NW European Continental Shelf
- Up to 100 m deep, apart near the Norwegian coast
- Low-lying economic and political centres: London, Rotterdam/Den Haag, Hamburg
- Major harbours: London, Antwerpen, Rotterdam, Hamburg

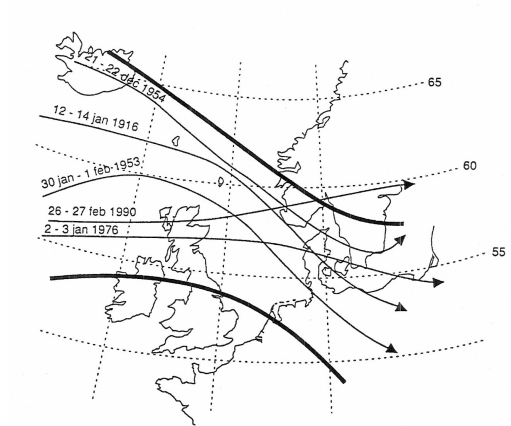
Astronomical tides

- Predominantly semi-diurnal (M2)
- Enter from the Atlantic
- Part crosses directly from the UK coast to the German Bight
- Part goes more south: Thames, Belgium, Netherlands
- Two amphidromes

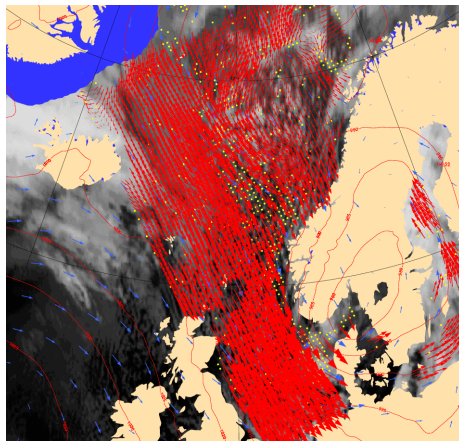


(Storm) Surges

- Large-scale storm depressions over the North Sea
- External surges
- Small-scale meteorological effects

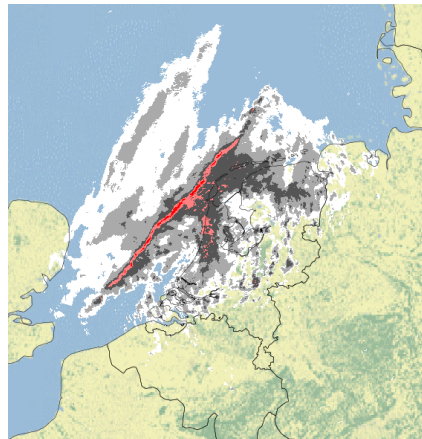
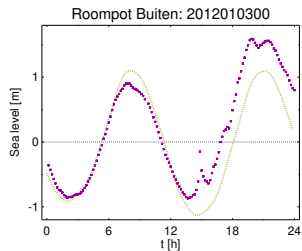
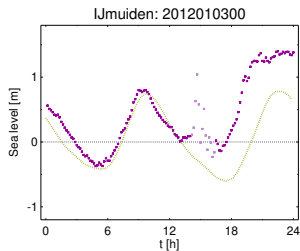


QuikScat, November 2007



Meteotsunami

- Sharp squall line
- Right propagation speed
- Short local surge, up to 1 m



The Netherlands

Meteorological forecasts

KNMI

Sea level forecasts

Rijkswaterstaat – Hydro-meteo Centre

Storm surge forecasts

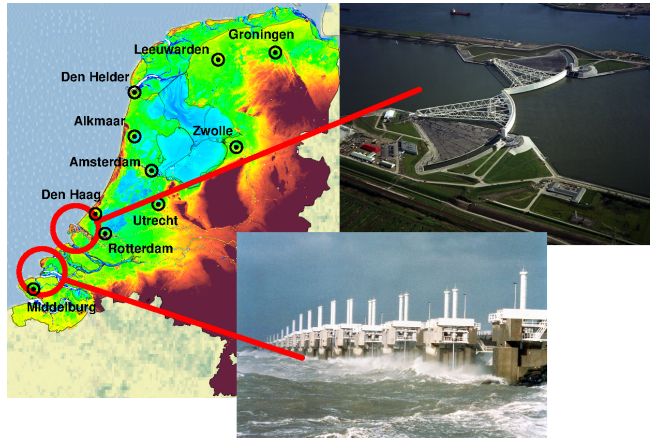
Rijkswaterstaat – Water Management Centre
Netherlands

Storm surge barriers

Rijkswaterstaat – Local divisions

Dikes

Local authorities



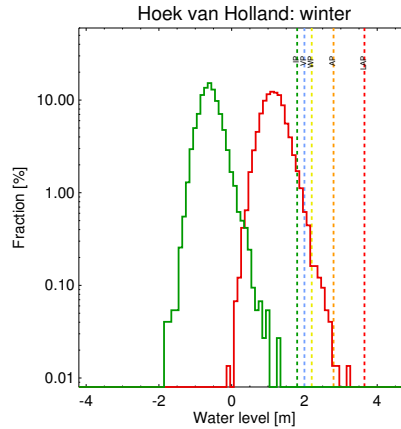
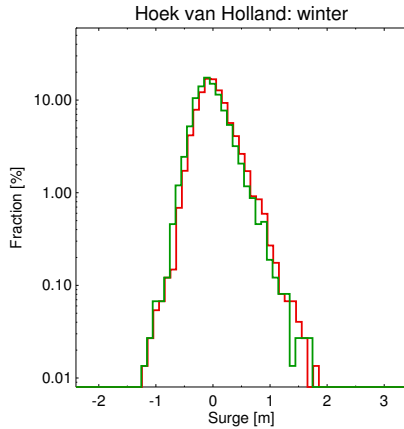


Responsibilities in case of Storm Surges

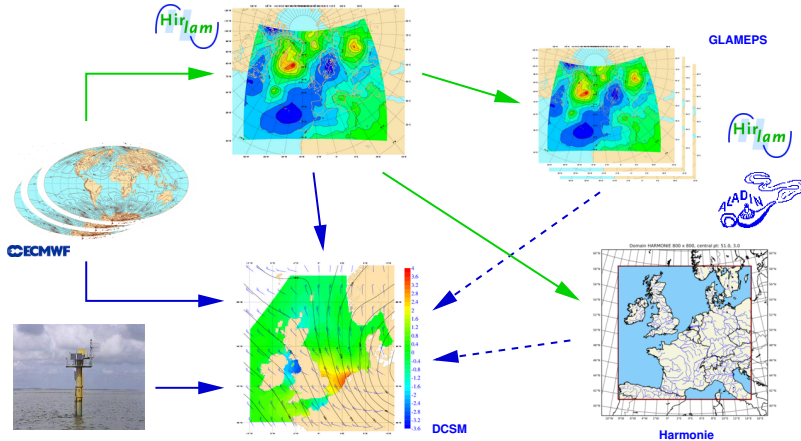
LCO	WMCN		HW per year	Hoek van Holland
Normal				
	Information	IP	10	180
Pre-warning	Pre-warning	VP	5	200
Warning	Warning	WP	3.5	220
Alarm	Alarm	AP	0.2	280
National Alarm	National Alarm	LAP	0.01 – 0.05	365
	Design	MHW	0.0001 – 0.0005	510

	KNMI	WMCN	LCO	DG-RWS NCC
Warning	$\xrightarrow{> 25\%}$ $\xleftarrow{< 8 \text{ d}}$			
Regional Alarm		$\xrightarrow{> 20\%}$ $\xleftarrow{< 8 \text{ d}}$		
National Alarm			$\xrightarrow{> 20\%}$ $\xleftarrow{5 - 7 \text{ d}}$	level 2
Critical				level 3

(Storm) Surge Climatology

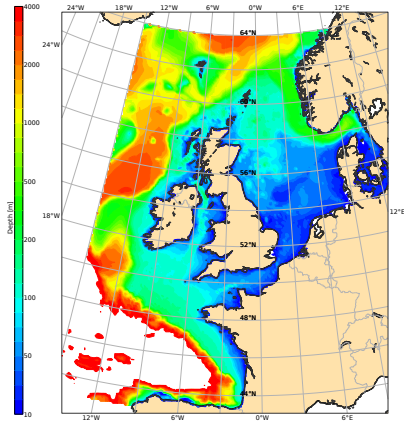


Storm surges: forecast models



- ECMWF
- Hirlam/ALADIN
- KNMI
- Rijkswaterstaat Deltares

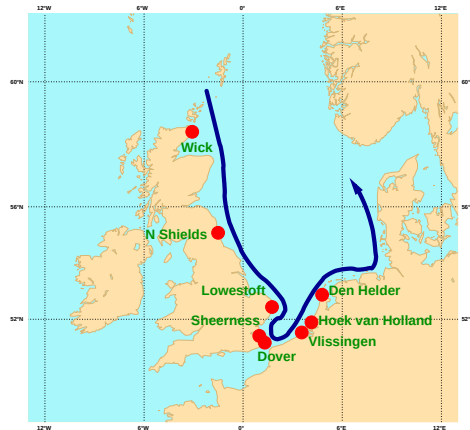
Storm surge forecasting: short range



- $t_f < 48h$
- Deterministic
- Meteo from Hirlam, Harmonie or ECMWF HRES
- Storm surge model WAQUA/DCSMv6 (1600 m)
- 4× per day, ready at T+4
- Used for decision-making

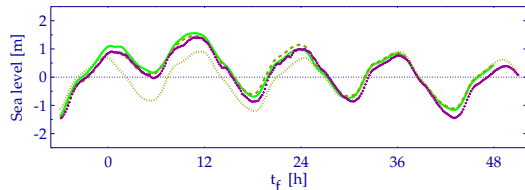
Storm surges: assimilation of observed water levels

- UK Coast before NL coast
- Steady state Kalman Filter
- Automatic quality control

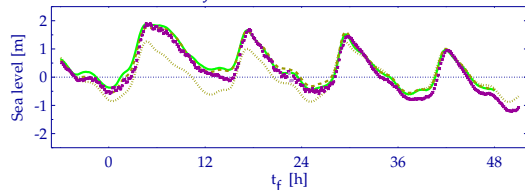


Storm surges: data assimilation

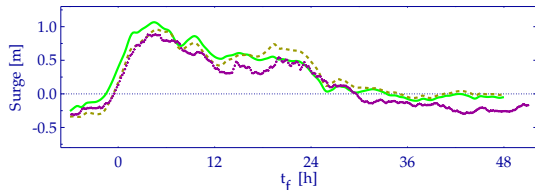
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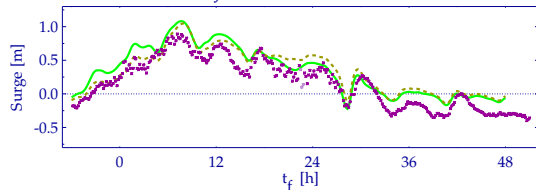
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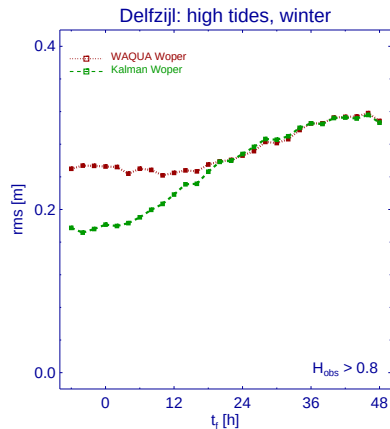
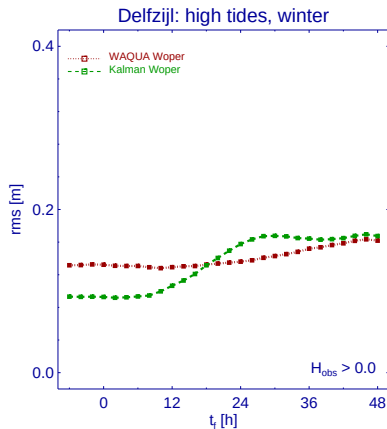
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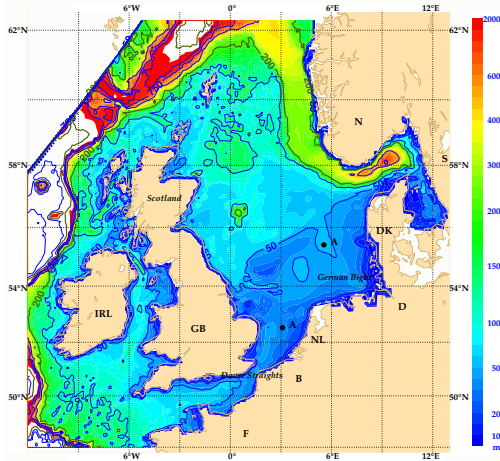
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Storm surges: data assimilation

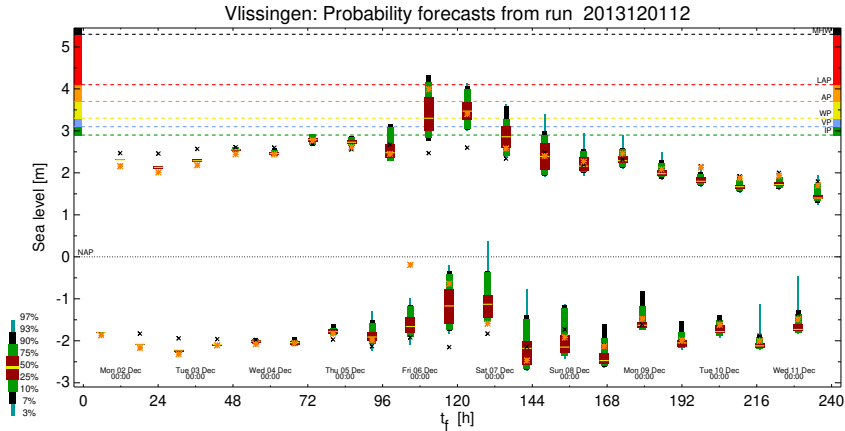


Storm surge forecasting: medium range



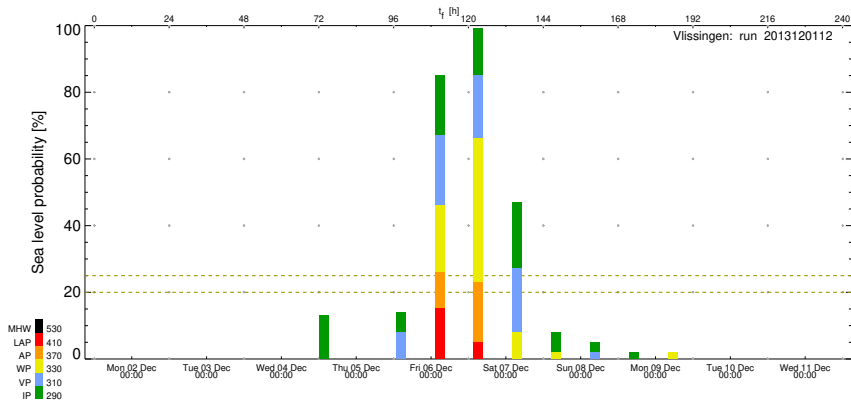
- $48h < t_f < 240h$
- Probabilistic (ensemble)
- Meteo from ECMWF ENS
- Storm surge model WAQUA/DCSMv5 (8 km)
- $2\times$ per day, ready at T+9
- Used for planning

Storm surges: probability forecast

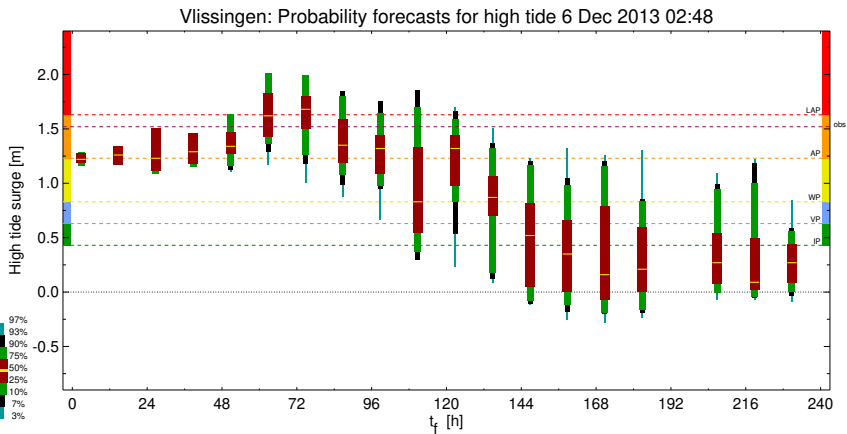




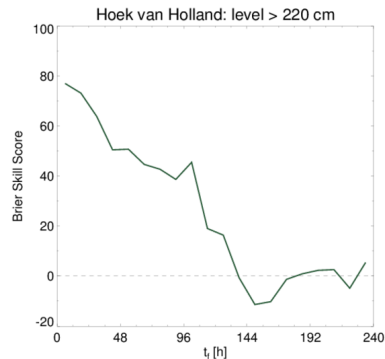
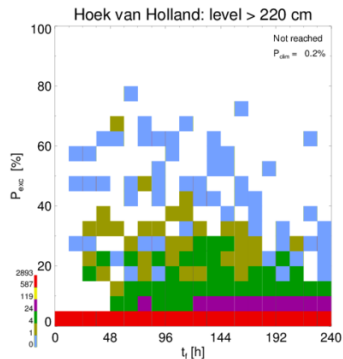
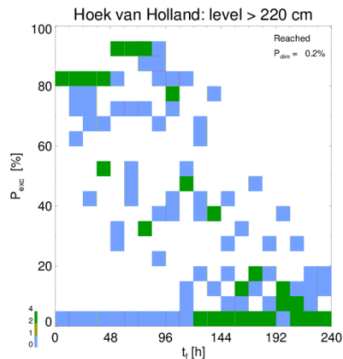
Storm surges: probability forecast



Storm surges: probability forecast



Storm surges: verification





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Thank you