Wind-wave coupled mesoscale modelling systems for coastal extreme wind and wave conditions

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We are

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Project name: XWIWA, Funded by PSO ForskEL

We aim at

- Exploring the full potential of the different model components (atmospheric, wave and ocean model)
- Improving the physics and numerical descriptions for fast developing weather conditions
- Providing a coupled system that uses the strength of each model component for the challenging storm and coastal conditions
- Reducing uncertainties and therefore risk and cost for offshore, port or coastal development

Offshore challenges

Towards lower risk and cost

Design, operation and maintanance

Modeling Systems

WRF

MIKE

- Mesh grid
- Offline coupling
- High resolution for coastal zones
- Ocean

WRF

SWAN

- Nested
- Online coupling
- Interface 1: roughness length
- Interface 2: momentum stress (Wave Boundary Layer Model)

Modeling Systems

Main research topics in X-WiWa - scientific and technical:

- **The online / offline coupling approaches**
- **The important coastal parameters (atmospheric and wave) for modeling**
- **The elements for a good modeling of storm winds in the North Sea – WRF setup**
- **The impact of the use of various SST data in modeling storm wind and waves**
- **The coupling interface between the atmospheric and wave models**

Modeling Systems

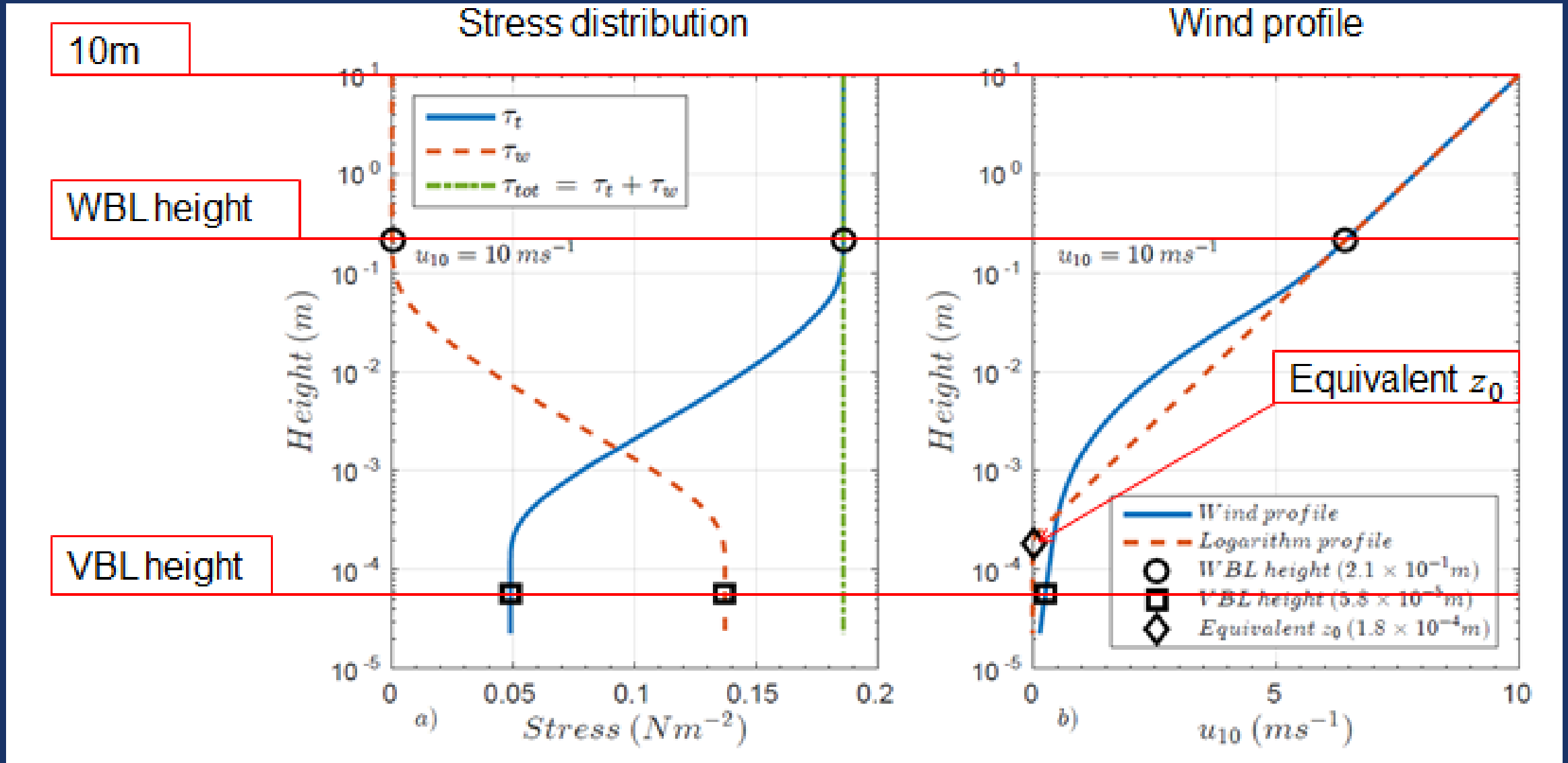
Main scientific contribution:

- **Wave Boundary Layer Model – interface for WRF and SWAN through stress**

- **Ensures a consistent calculation of the momentum flux in both the atmospheric and wave modeling**

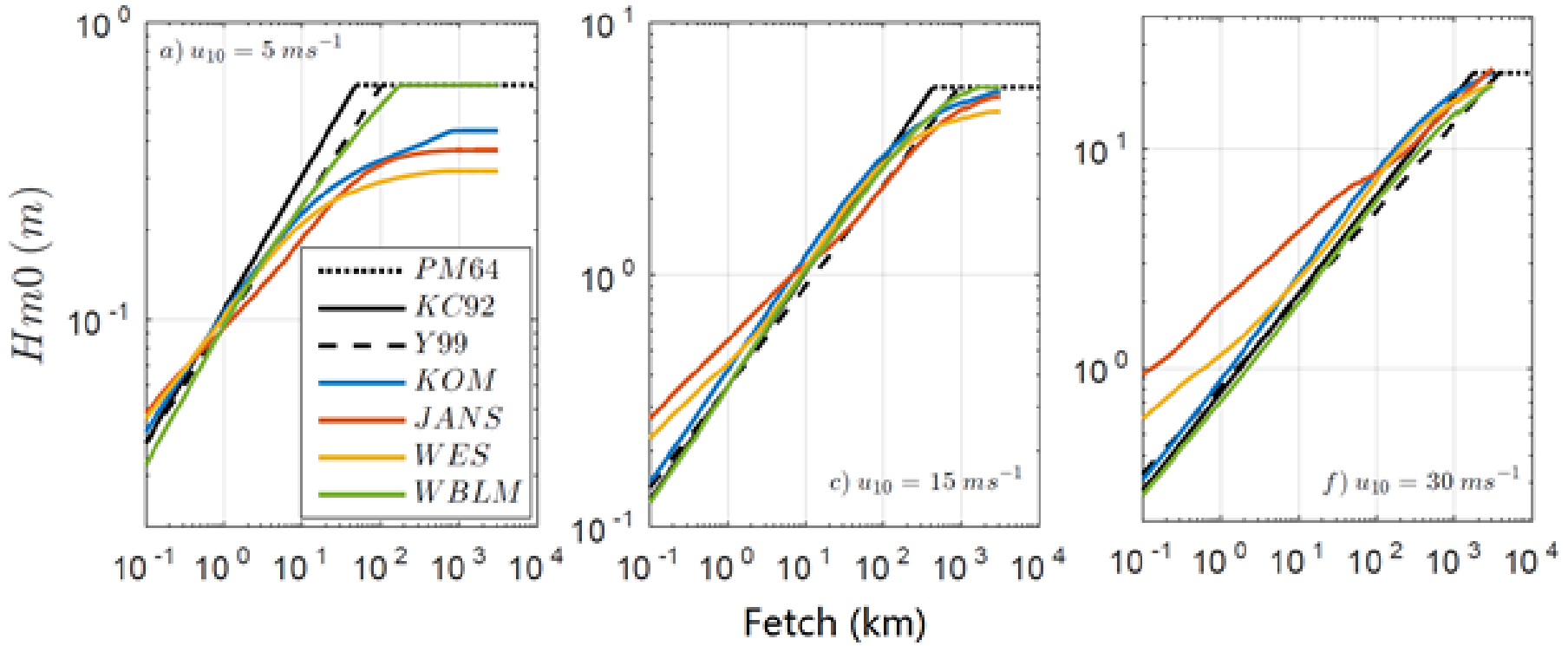
Du et al. (2016): The use of a wave boundary layer model in SWAN, In Revision, JGR-Oceans.

Modeling Systems



Modeling Systems

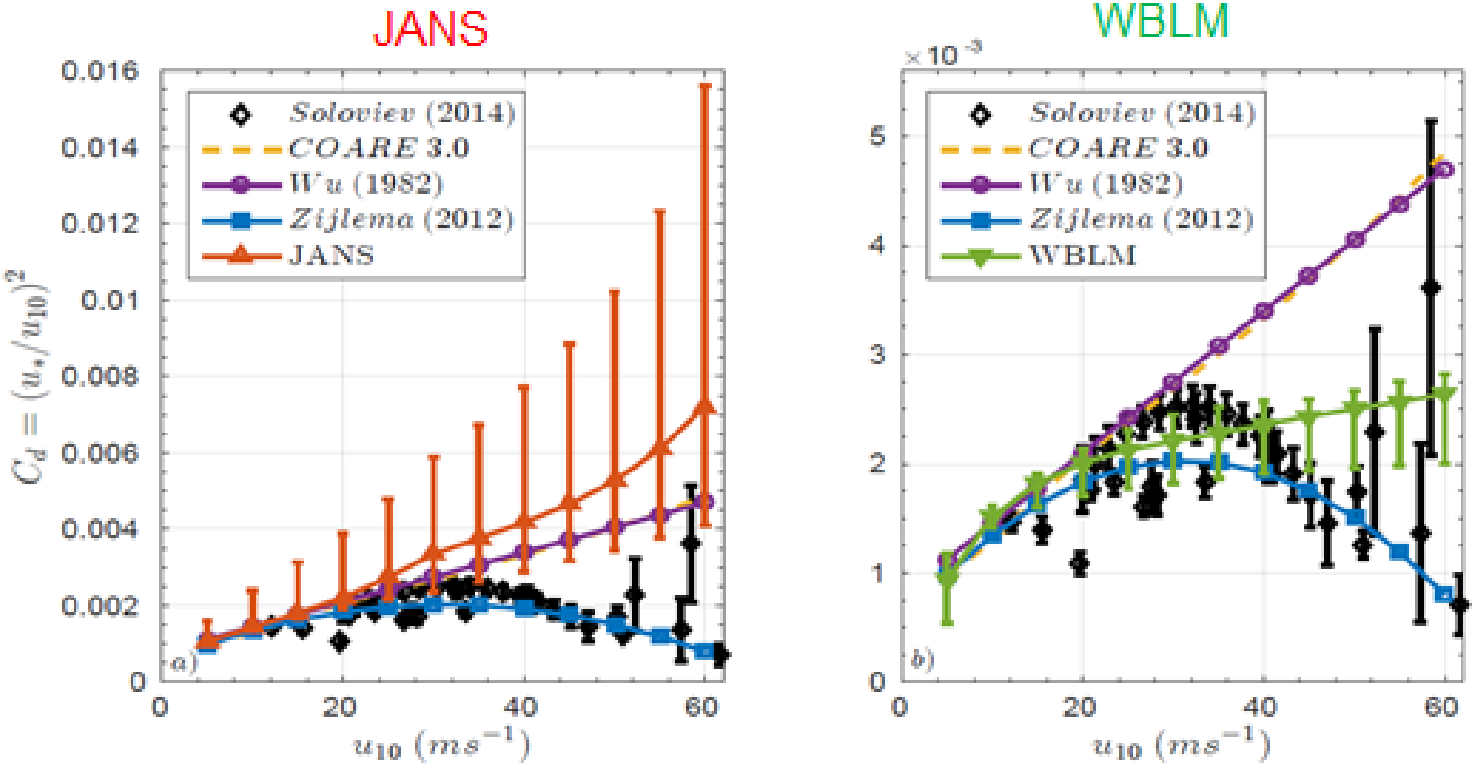
Ideal case study: significant wave height as a function of fetch



- WBLM closely reproduces the **Kahma and Calkoen (1992) and Young (1999)** curves at all wind speeds and fetches.
- The three original wind-input source functions in SWAN (KOM, JANS, and WES) tend to overestimate/underestimate H_{m0} in short/long fetches.

Modeling Systems

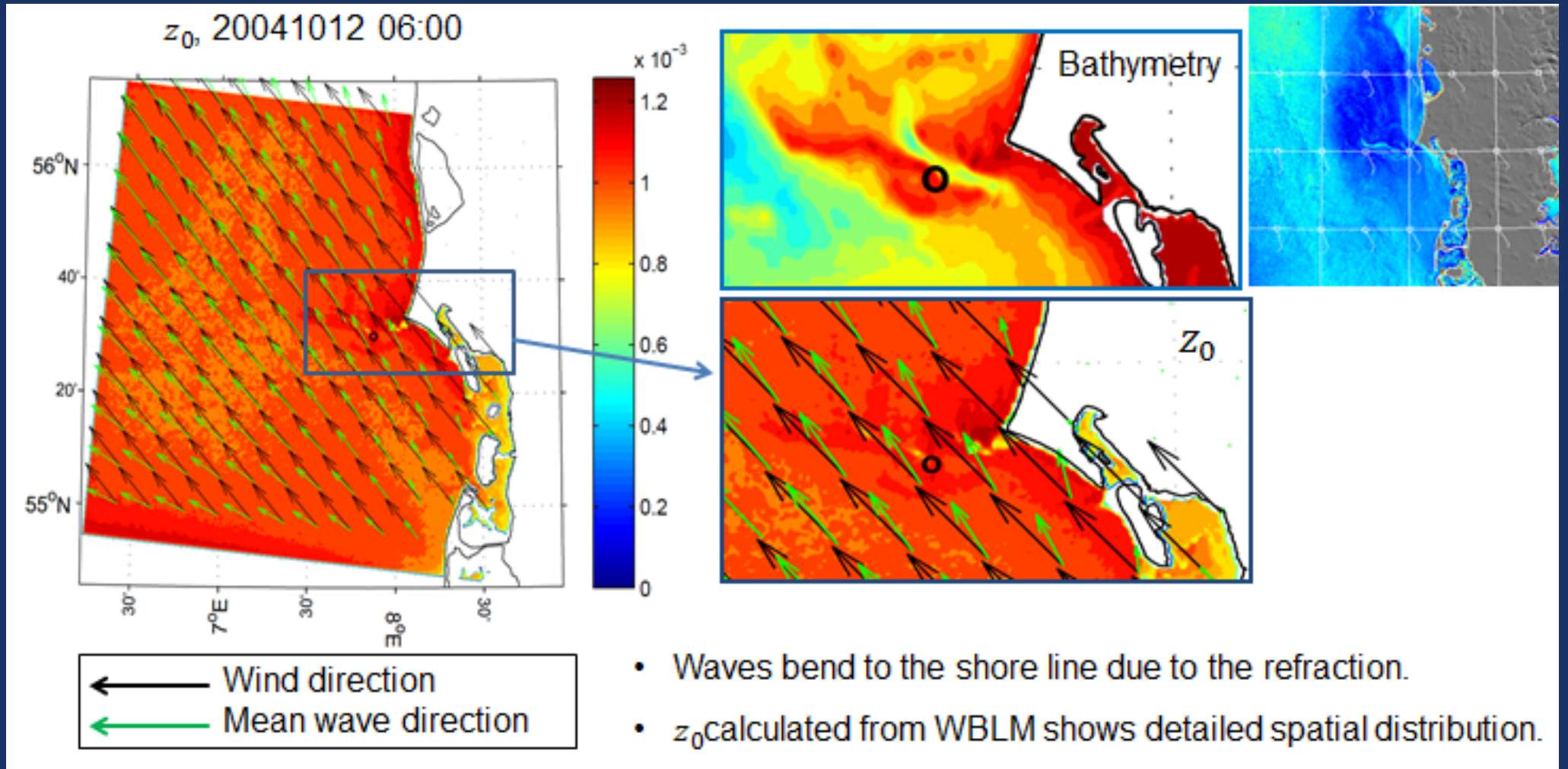
Drag coefficient from models and measurements (Soloviev,2014)



- JANS significantly overestimates C_d.
- C_d of WBLM follows the trend of the measurement data and its distribution gives a wide overlapping with the measurement data for $u_{10} \leq 40ms^{-1}$.

Modeling Systems

Real case study at Horns Rev, North Sea

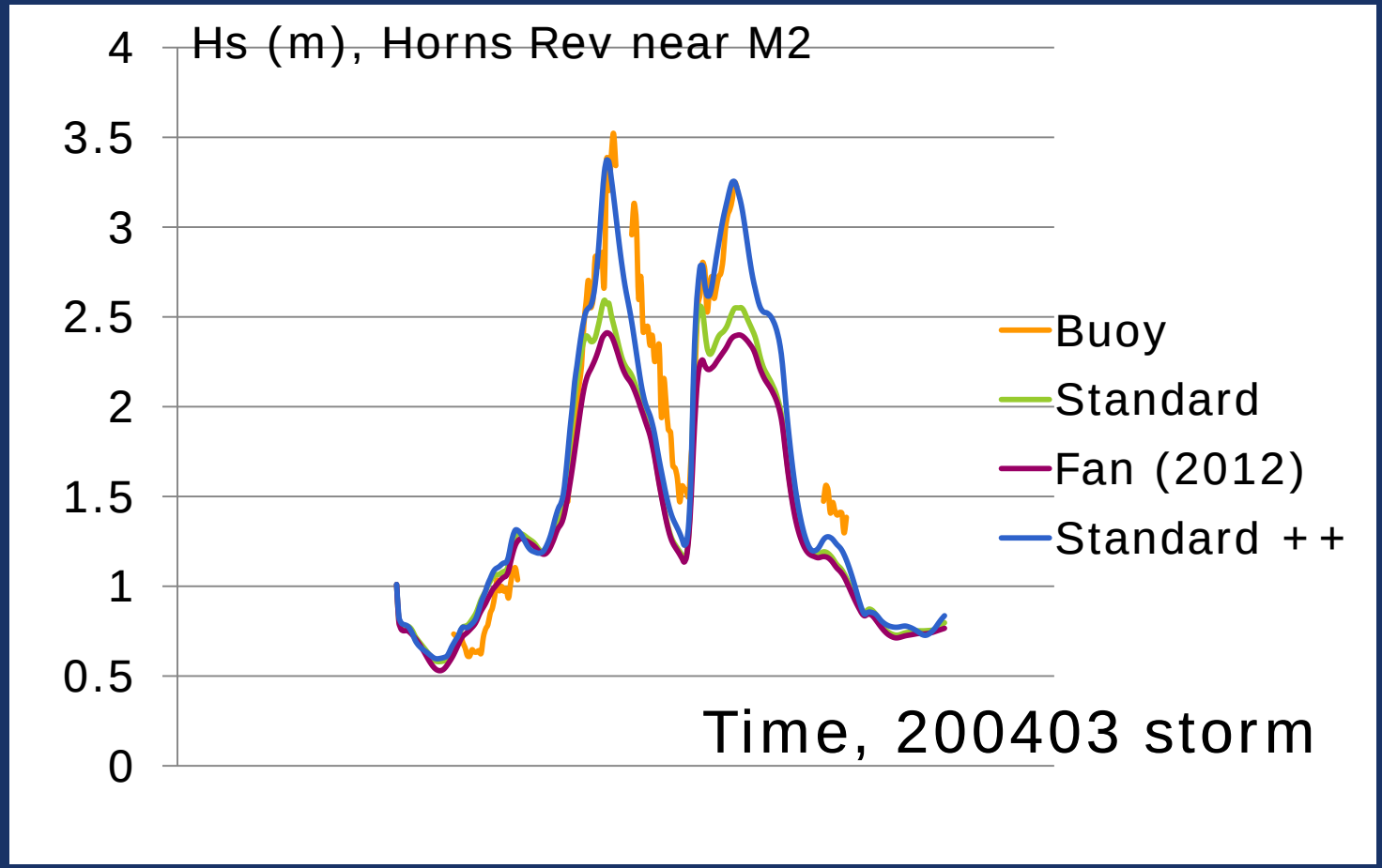


- Waves bend to the shore line due to the refraction.
- $z_0$calculated from WBLM shows detailed spatial distribution.

Modeling Performance

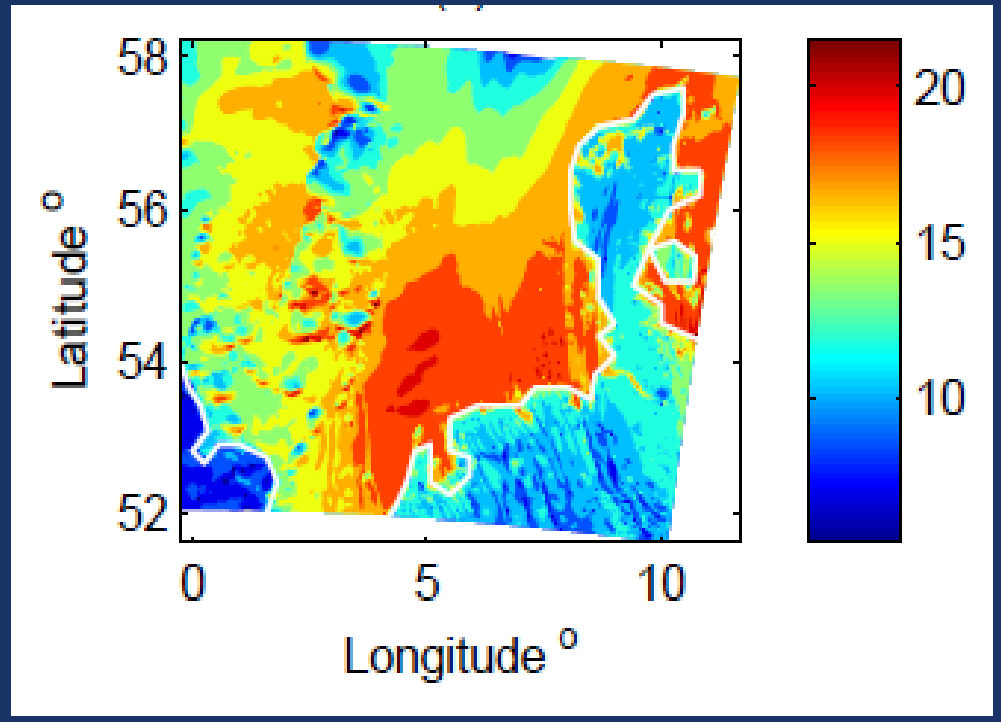
Including SST, current and water level

- Accurate calculation of Hs at a shallow water site during a storm requires the input of water level (Standard + +)
- Only changing the roughness length description is not enough (Standard and Fan 2012)

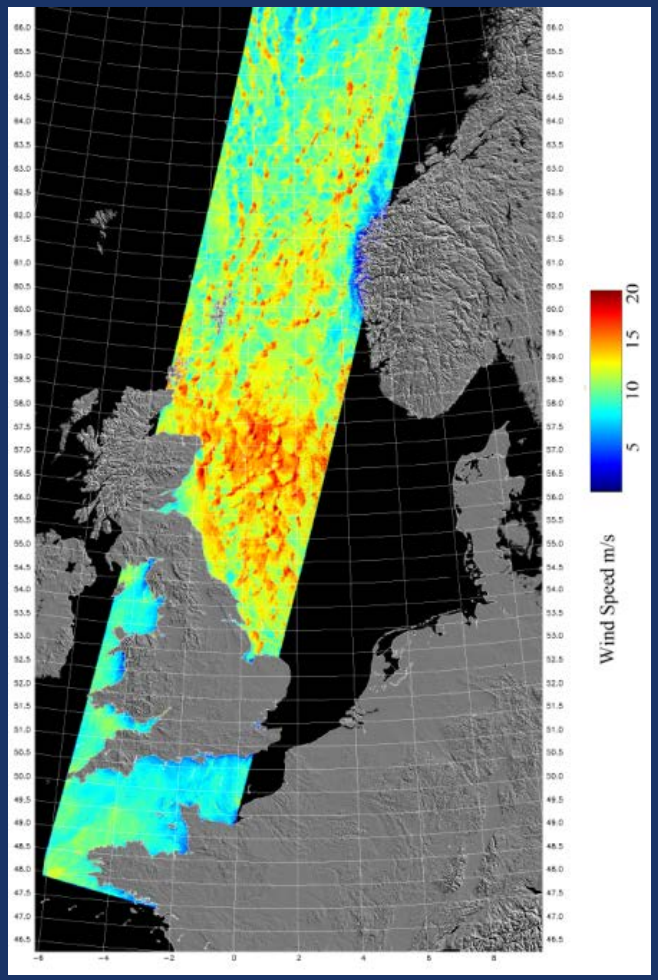


Modeling Performance

Example: Storm Britta



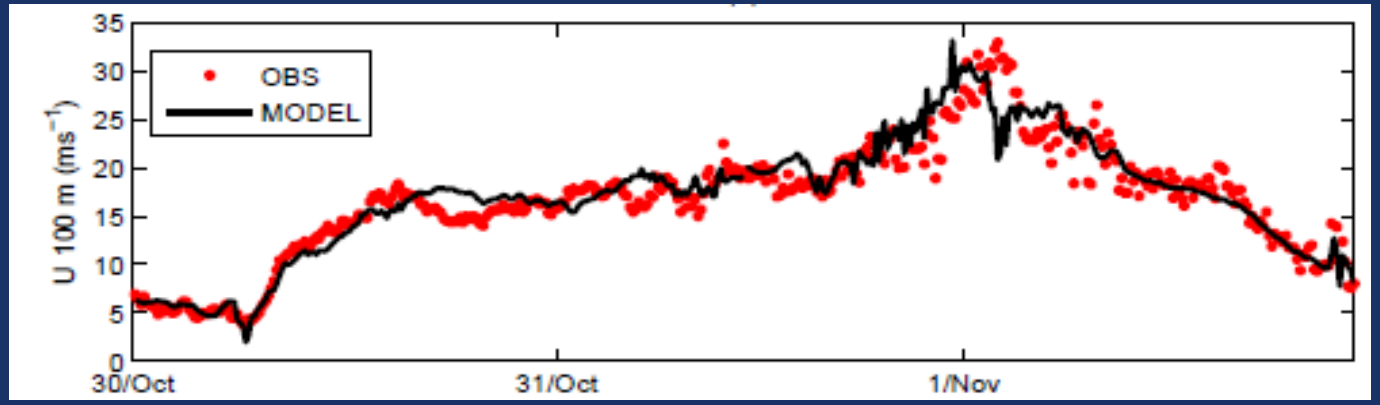
U at 10 m (m/s), model



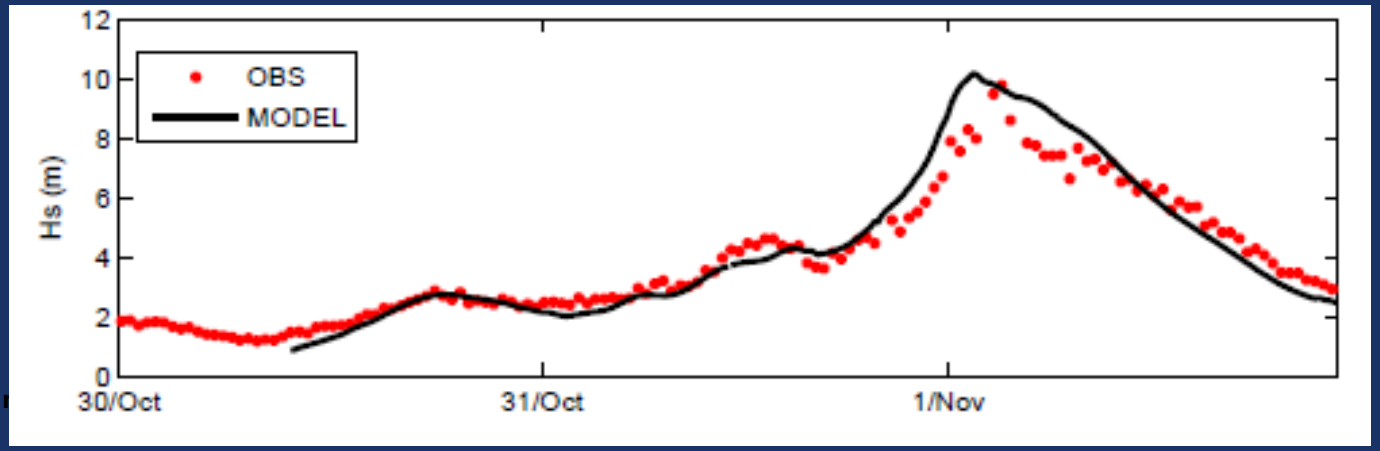
U at 10 m (m/s), SAR

Modeling Performance

WRF and SWAN modeling system captured the main storm characteristics



U100m, FINO 1

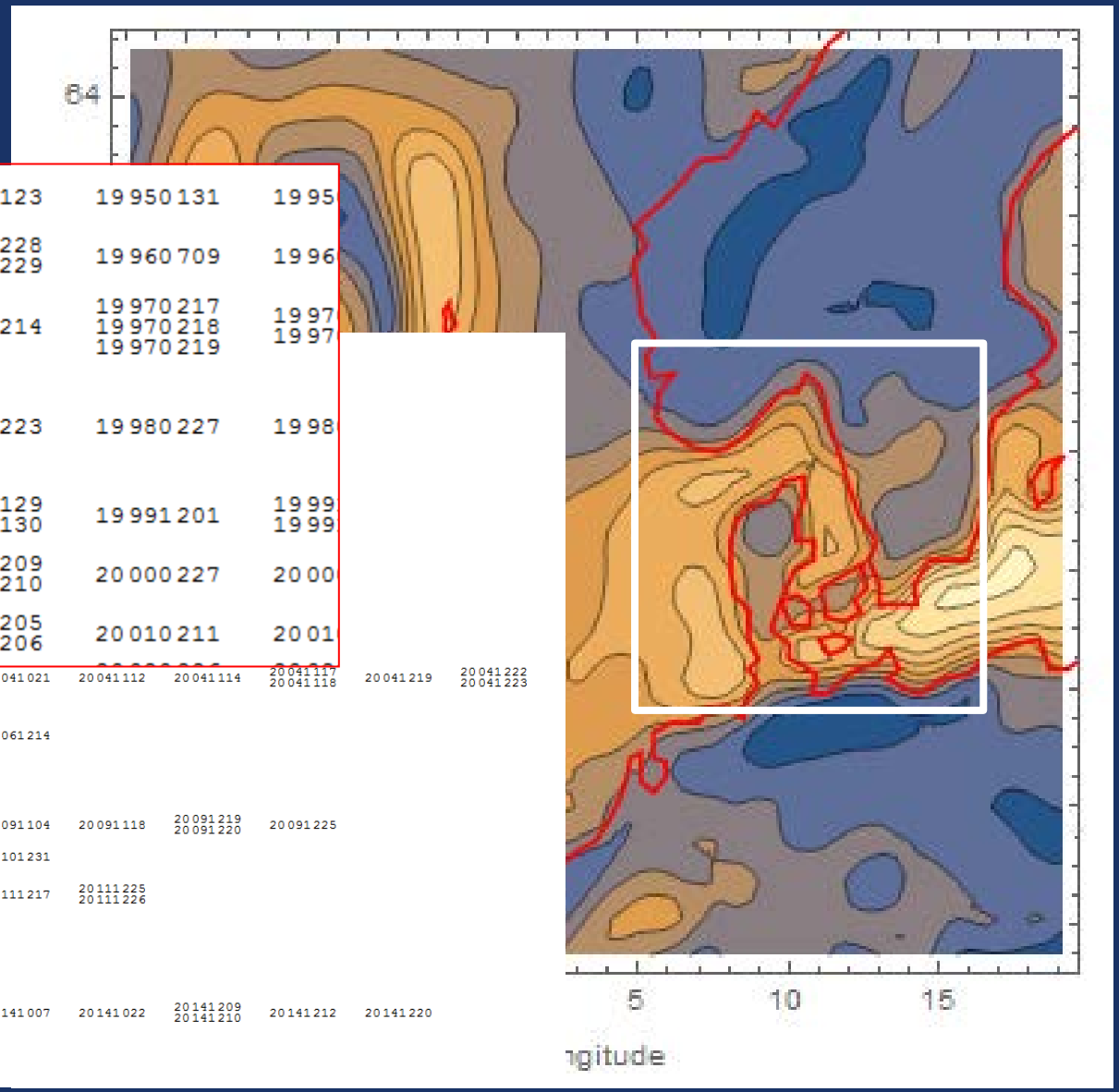


Hs, FINO 1

Extreme wind and wave atlases for the Danish coasts

~500 storms need to be downscaled

1995	19950110	19950120	19950123	19950131	19950201	19													
1996	19960210	19960218 19960219 19960220	19960228 19960229	19960709	19960912	19													
1997	19970130	19970211	19970214	19970217 19970218 19970219	19970221 19970222	19													
1998	19980105	19980119	19980223	19980227	19980304	19													
1999	19990204 19990205	19990303	19991129 19991130	19991201	19991203 19991204	19													
2000	20000117	20000129 20000130 20000131	20000209 20000210	20000227	20000303	20													
2001	20010101	20010124	20010205 20010206	20010211	20010919	20													
2002	20020128 20020129	20020219 20020220	20020222	20020226 20020227	20021023 20021024	20													
2003	20030114 20030115 20030116	20030202	20031130	20031205 20031206	20031214 20031215	20													
2004	20040101	20040106	20040108	20040111	20040114	20040119	20040201	20040204	20040320 20040321	20041002	20041004	20041021	20041112	20041114	20041117 20041118	20041219	20041222 20041223		
2005	20050108 20050109	20050112	20050212																
2006	20060117	20060119 20060120	20061027	20061031	20061101	20061106	20061117 20061118	20061120	20061123	20061207	20061210 20061211	20061214							
2007	20070101	20070109	20070111 20070112	20070114	20070118 20070119 20070120	20070223	20070318	20070627	20071109										
2008	20080104 20080105	20080119	20080126	20080131	20080222	20080301	20080804 20080805	20081110											
2009	20090108	20090111	20090118	20090120	20090308	20090330	20090730 20090731	20091003 20091004	20091006	20091016	20091101 20091102	20091104	20091118	20091219 20091220	20091225				
2010	20100109 20100110	20100127	20100130	20100220	20100724	20100823 20100824 20100825	20101021	20101102	20101111 20101112 20101113	20101123	20101216	20101231							
2011	20110204 20110205	20110208	20110408	20110913	20111125	20111127	20111130	20111201	20111203	20111207 20111208 20111209	20111213	20111217	20111225 20111226						
2012	20120103 20120104 20120105	20120112 20120113	20120214	20120224	20120514	20121005	20121029	20121125	20121214										
2013	20130131	20131028	20131128	20131201	20131204 20131205 20131206	20131222													
2014	20140106	20140109	20140116 20140117 20140118 20140119	20140125	20140201	20140212	20140215	20140314 20140315	20140326	20140809 20140810	20140922	20141007	20141022	20141209 20141210	20141212	20141220			
2015	20150102	20150109 20150110 20150111	20150116	20150331	20151108	20151129	20151204 20151205	20151222											



Comparison with satellite winds

- Envisat and Sentinel-1 SAR
- Quikscat and ASCAT
- Altimeter winds and waves
- SMOS?
- SMAP?
- ?

Summary for the modeling system from X-WiWa

- Delivers wind and wave information in the coastal zones
  - High resolution
  - From advanced modeling
  - Long term statistics and time series
  - For siting, design, O&M

- Tools
  - A modeling system, particularly for storm conditions, suitable for coastal zones
  - Post-processing program for assessing, evaluating and applying the data for particular use

- Improved knowledge, in technology, science and application

Questions?

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