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Simulation and observations of wave conditions in Norwegian fjords

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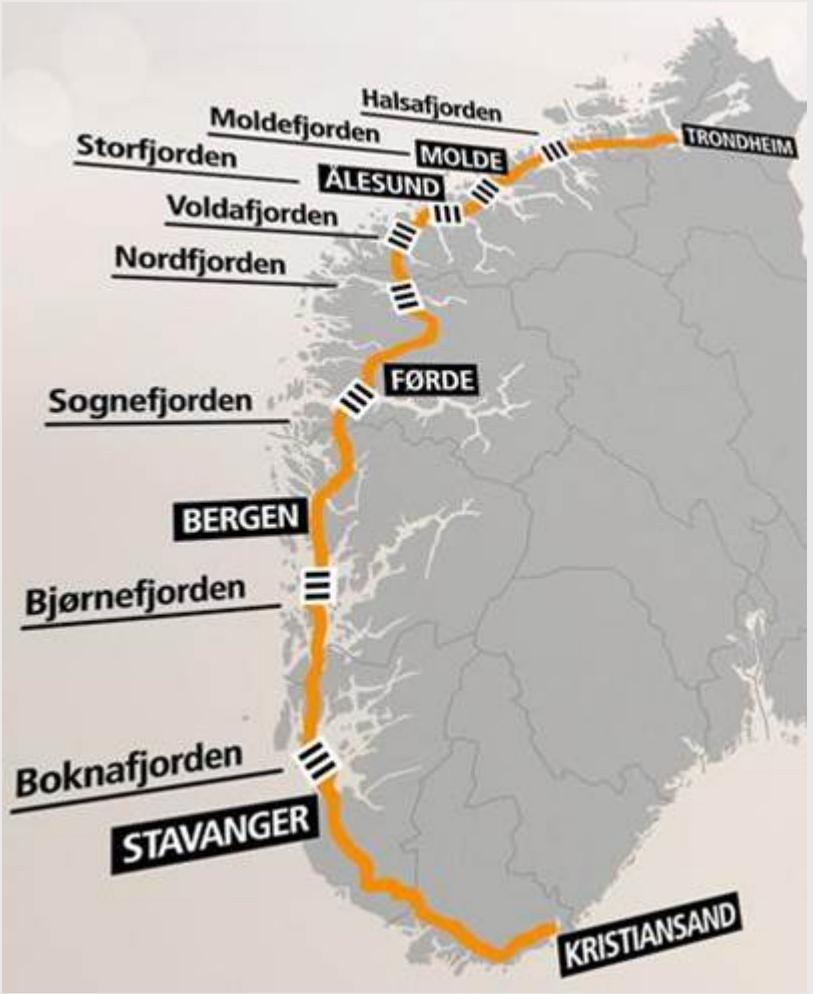
17/01/18

Statens vegvesen
Norwegian Public Roads Administration

Outline

- Background and motivation
- Observations
- Operational forecast models of wind and waves
  - Setup and forcing
  - Verification
- SWAN hindcast
  - Setup for ferry-free E39
  - NORA10
  - Atmosphere model
- Results
  - Statistics
  - Case
- Summary

Ferry-free E39



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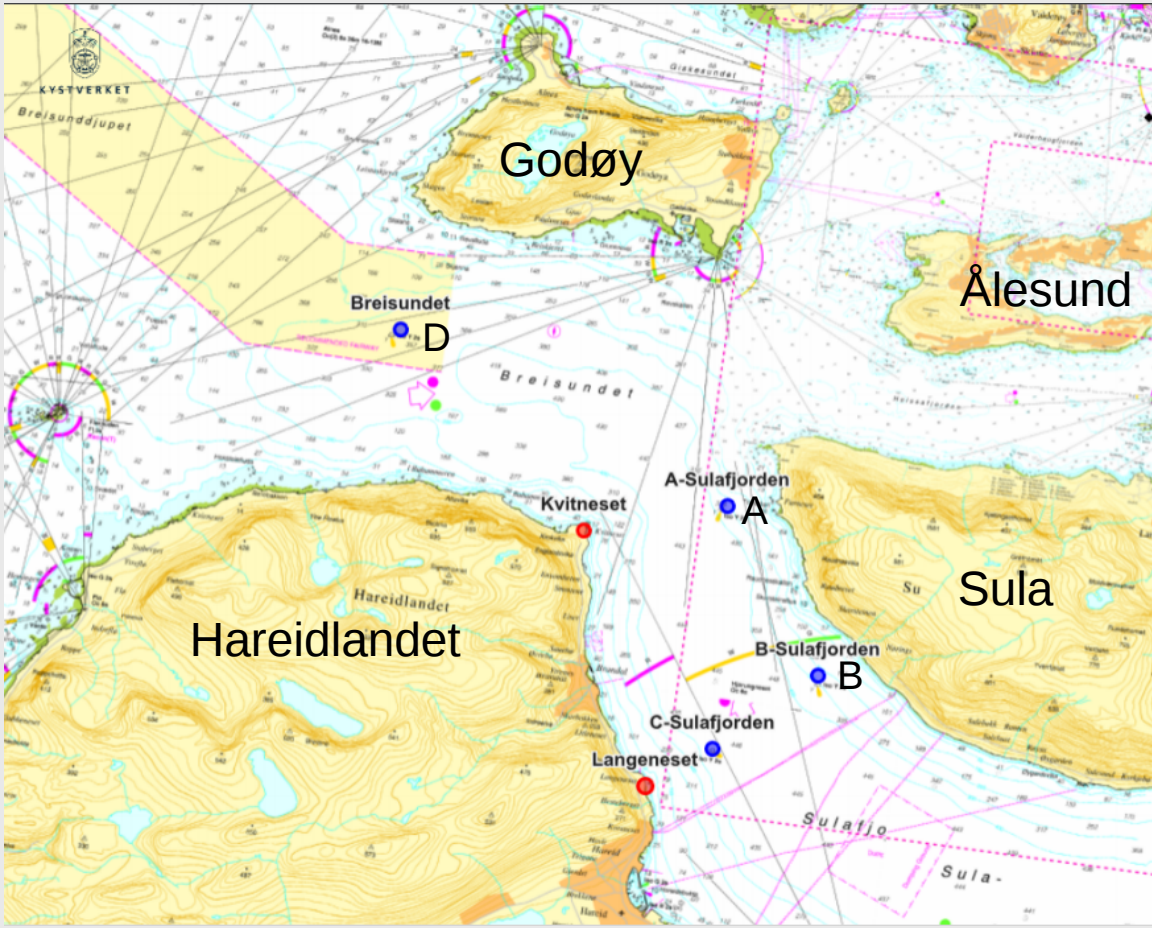
Measurements in Sulafjord - unique data set, freely available

Tall met-masts with sonic wind measurements in three heights, around 100m, 70m and 50m (red)

Wave buoys (A, B, D) and under water rigs for oceanographic measurements (blue)

Data are available on http://thredds.met.no/thredds/obs.html



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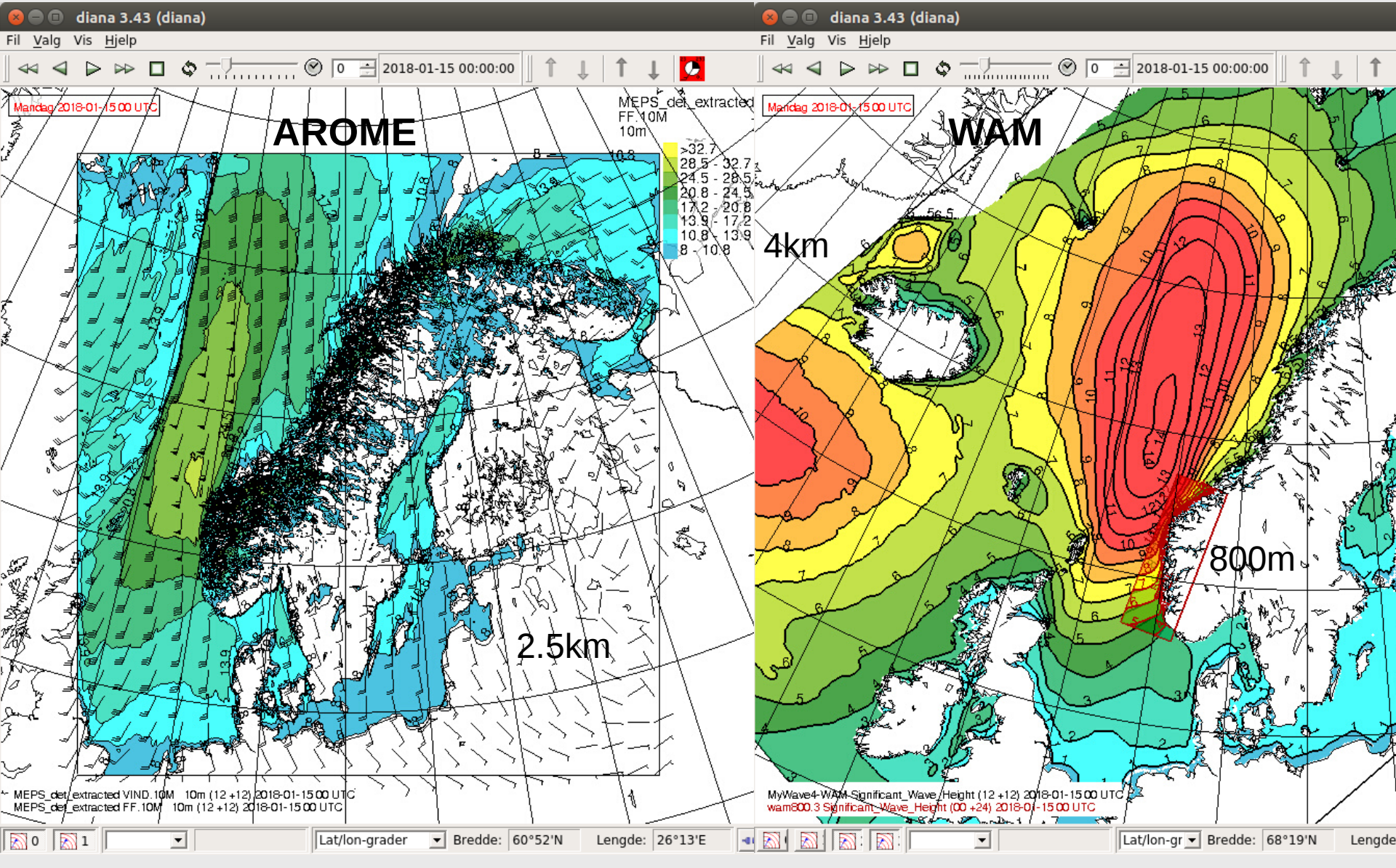
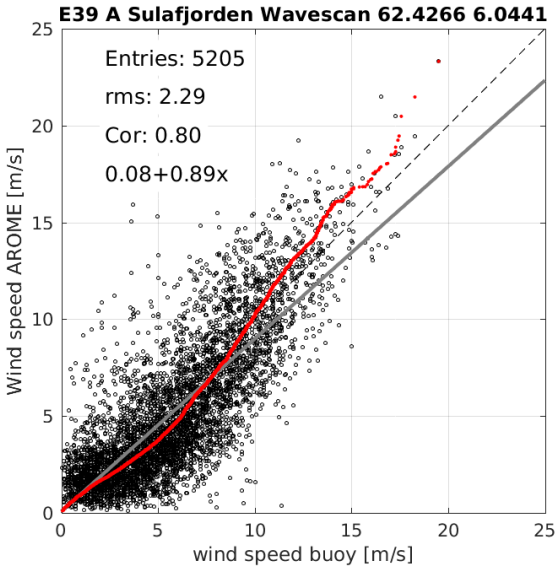
Forecast models at MET

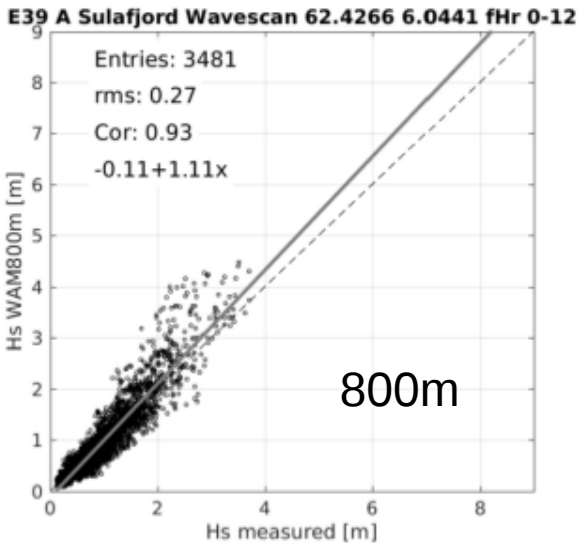


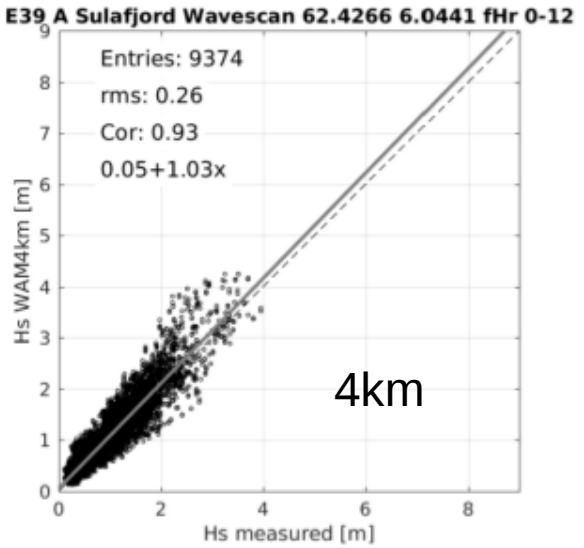
Verification of forecasts in Sulafjord

AROME wind speed



WAM significant wave height





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Wave hindcast using SWAN

- Version 41.10
- 3rd generation wave model
- Temporal and spatial development of 2D wave spectra in each grid point
- Variable wind input and spectra on the open borders

- 36 directions, 31 frequencies (0.04-1Hz)
- Domain with 250mx250m grid cells nested into outer grid (1kmx1km)

- Wind from *Kjeller Vindteknikk* hindcast with WRF (500mx500m)
- Border spectra from the Norwegian wind and wave hindcast (10-11km)
- January 2007 – june 2017

- Hourly output of integrated wave parameters (Hs, Tp, Tm02, Peak dir., Mdir etc.) and spectra in selected locations

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Norwegian Reanalysis 10 km (NORA10)

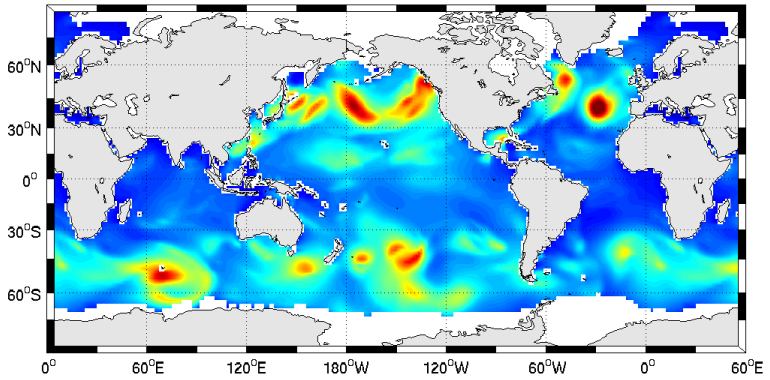
dynamical downscaling of ERA-40 and standalone wave hindcast

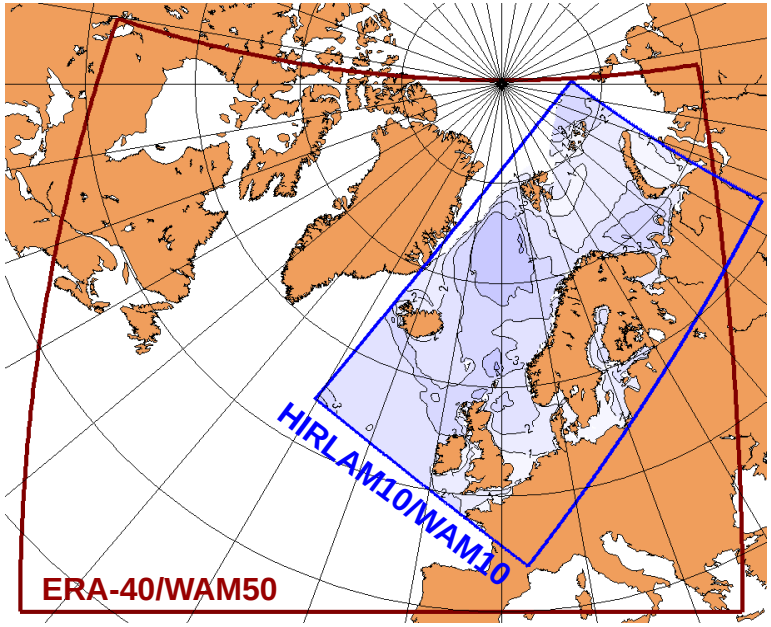
Atmospheric component – HIRLAM 10 km:

- ERA-40 on boundaries (6-hourly)
  - 40 levels: temp, wind, humidity, cloud water
  - Surface: pressure
- Blended with ERA-40 in interior (digital filter)
  - Maintain large-scale features
  - Preserve mesoscale features (polar lows)
- Sequence of 9-hour model runs (3 hourly data)
- 248 x 400 grid points

Wave component – nested WAM-model

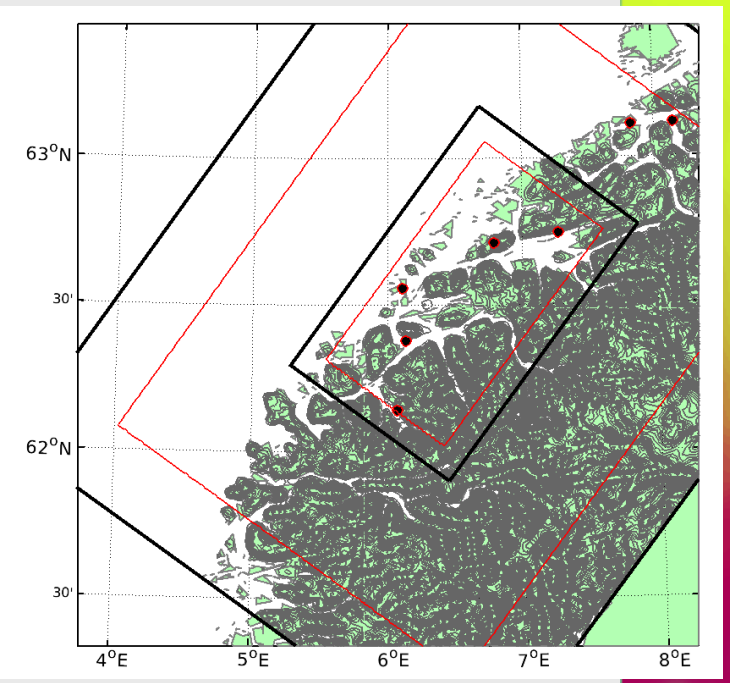
- WAM 50 km forced by ERA-40 winds
- WAM 10 km forced by HIRLAM10 winds
  - 2D spectrum: 24 by 25 directional/frequency bins
- September 1957 onwards

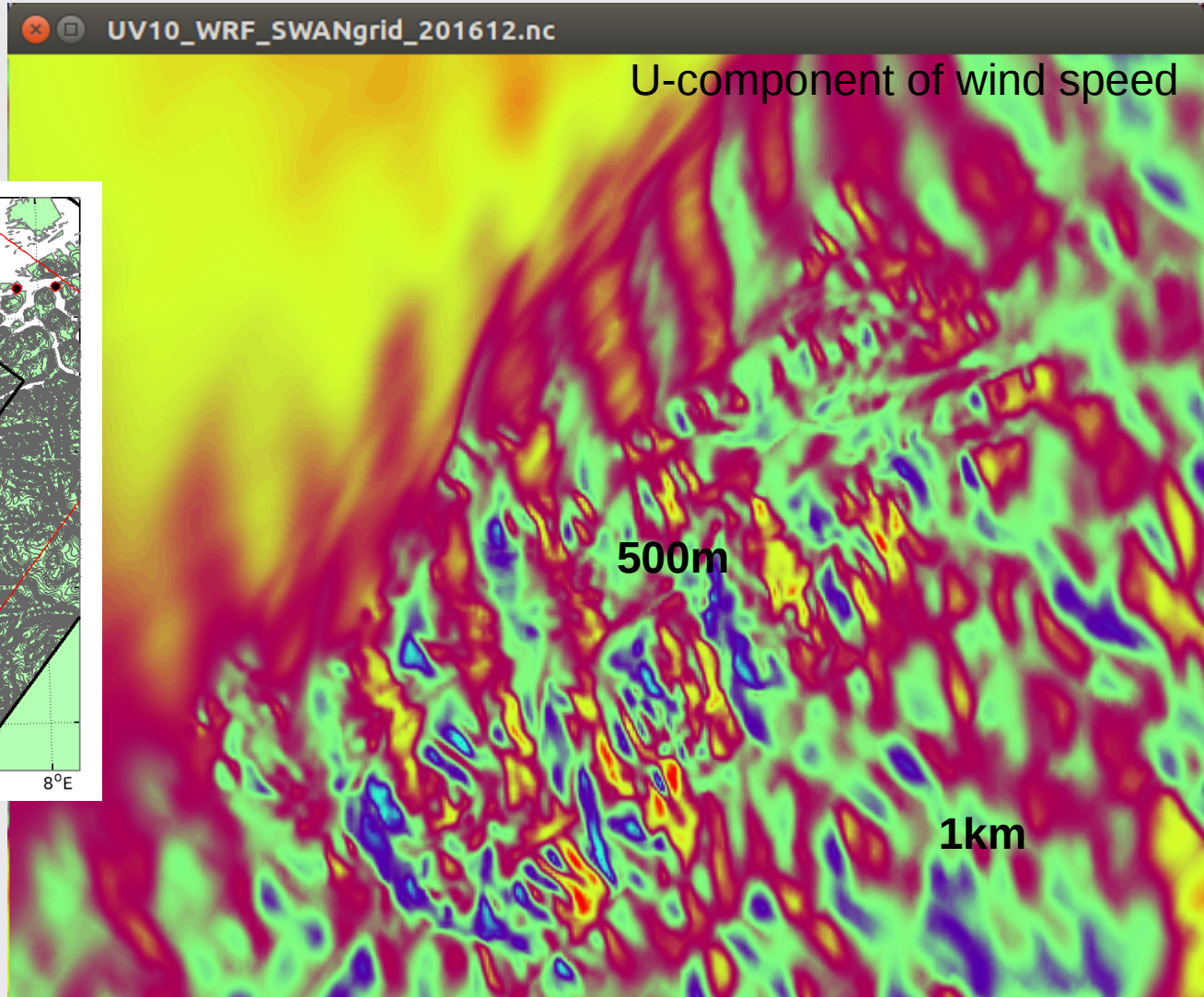




Wind input to SWAN

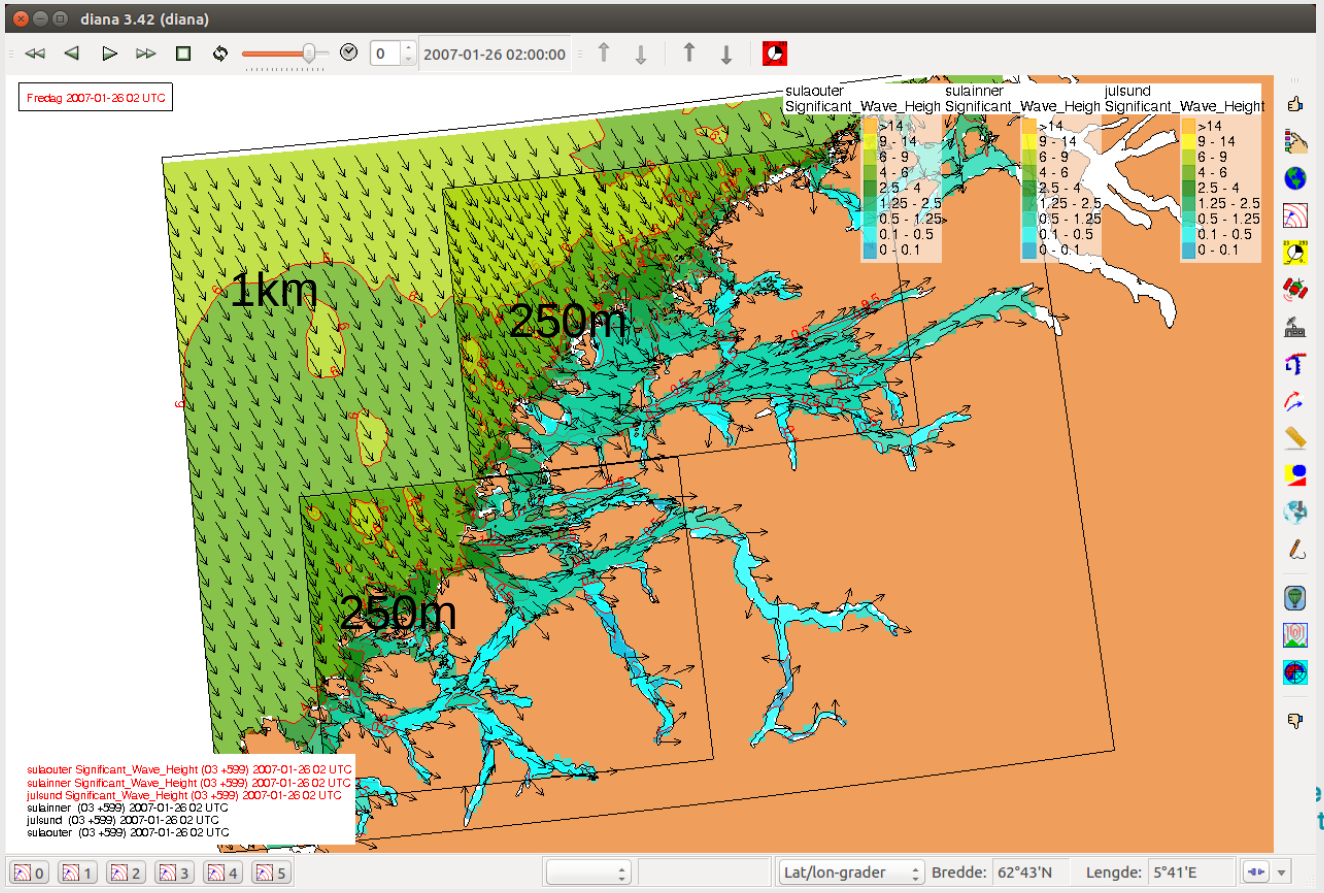
- WRF nested 1500m to 500m



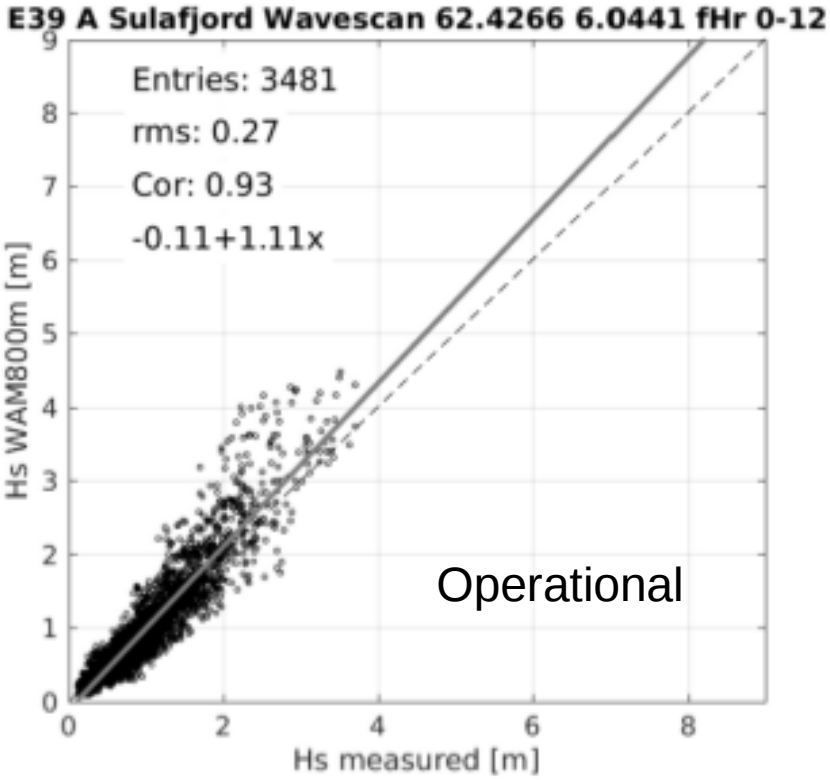


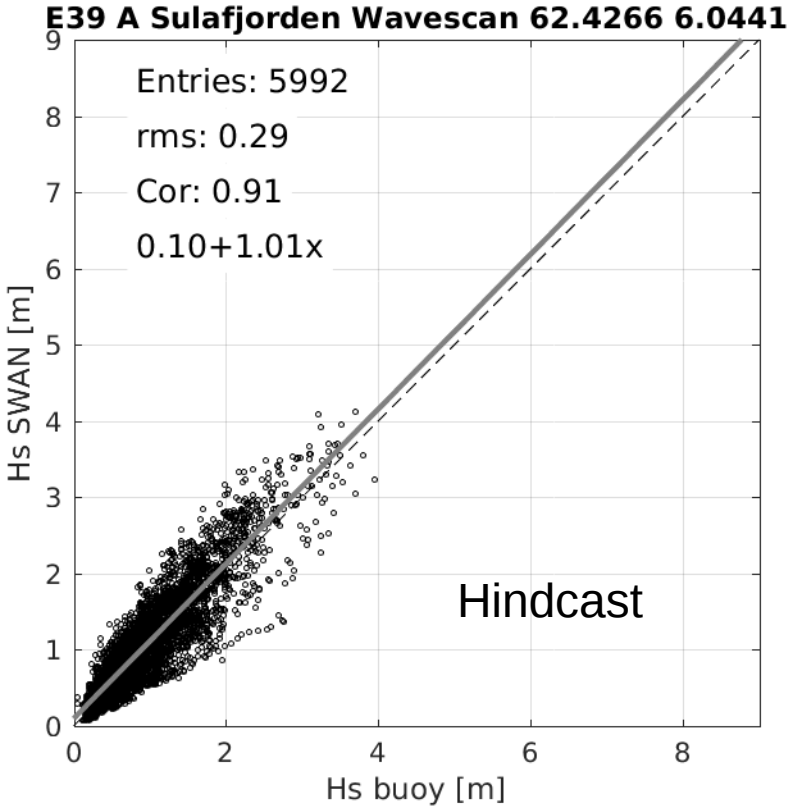
Wave model setup with SWAN

- SWAN 41.10 – with van der Westhuysen (2007) dissipation
  - 1 January 2007 – 30 June 2017
  - 1km to 250m nesting
  - Wind from WRF (500m), Spectra on border from NORA10



WAM and SWAN wave height





Similar performance
Slight overestimation in Hs

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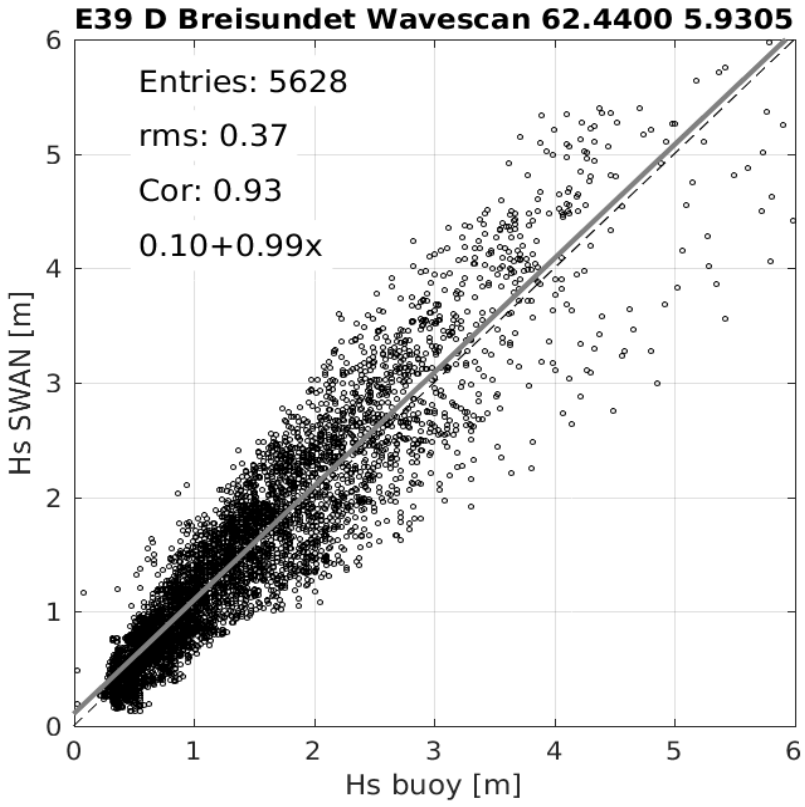
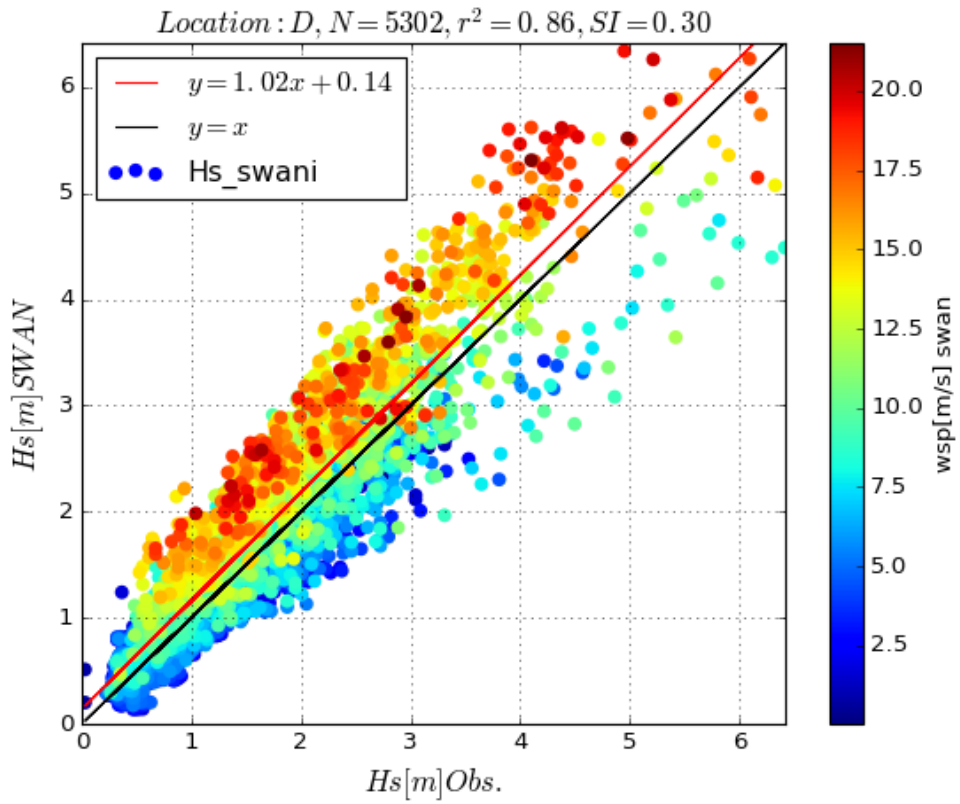
SWAN wave height – statistics





Relation between overestimation in Hs and high wind speeds

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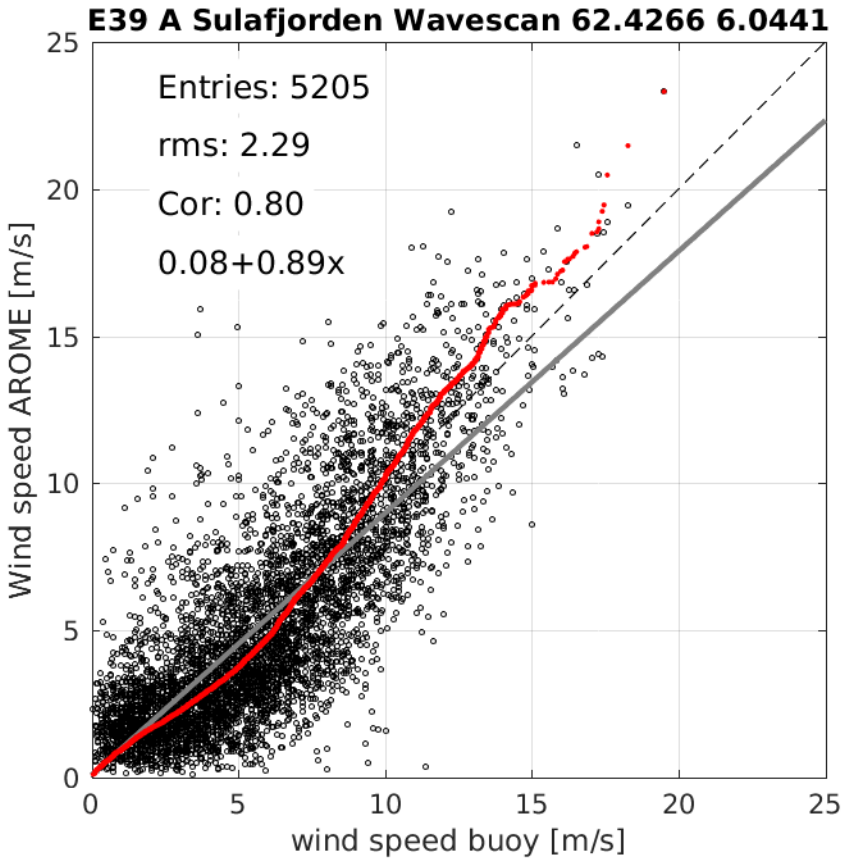
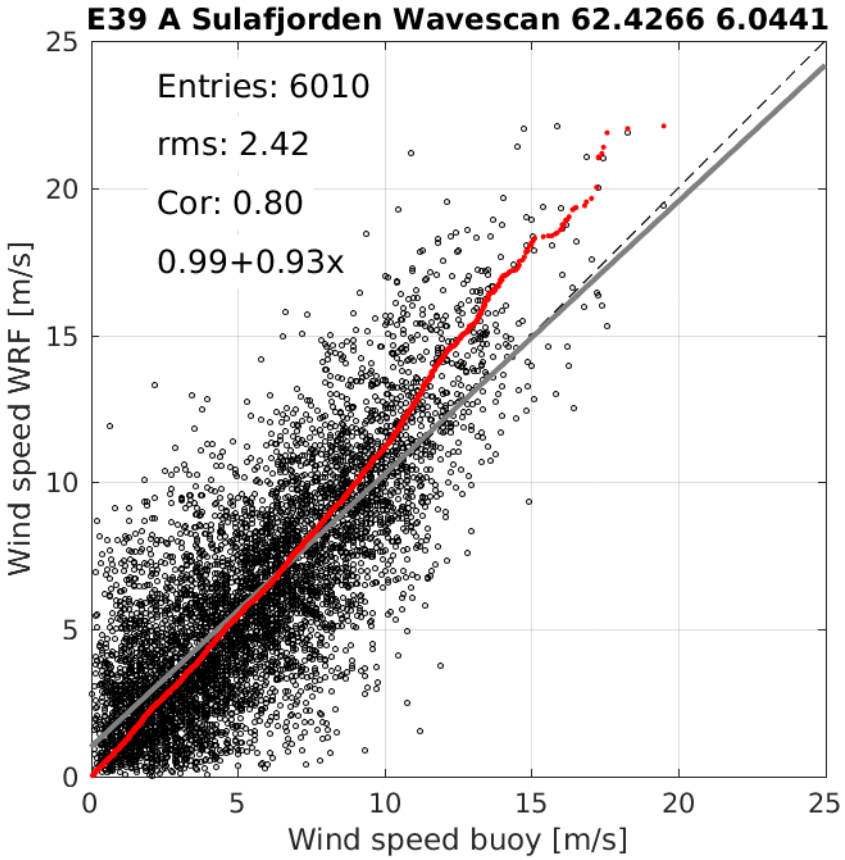
AROME and WRF wind speeds





Too weak winds in AROME at low wind speeds

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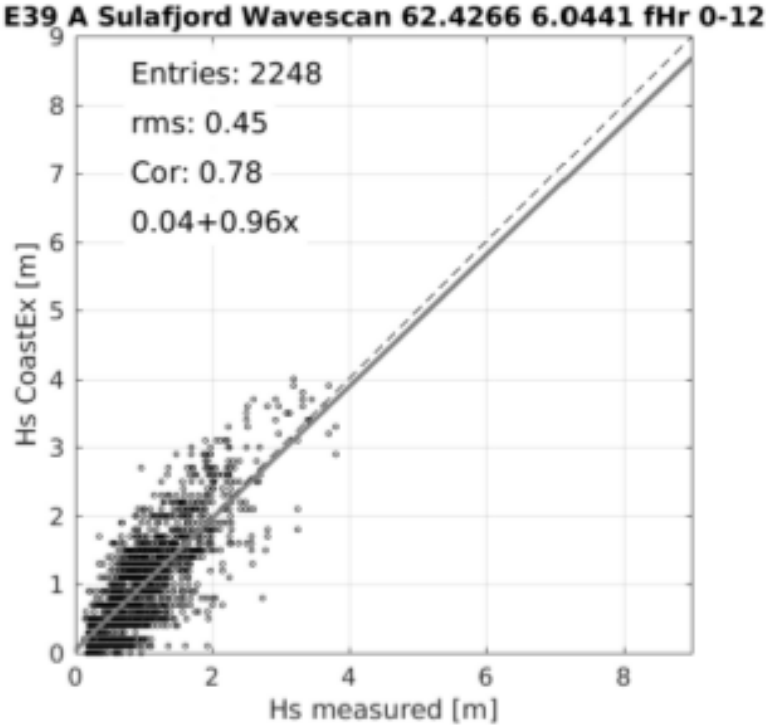
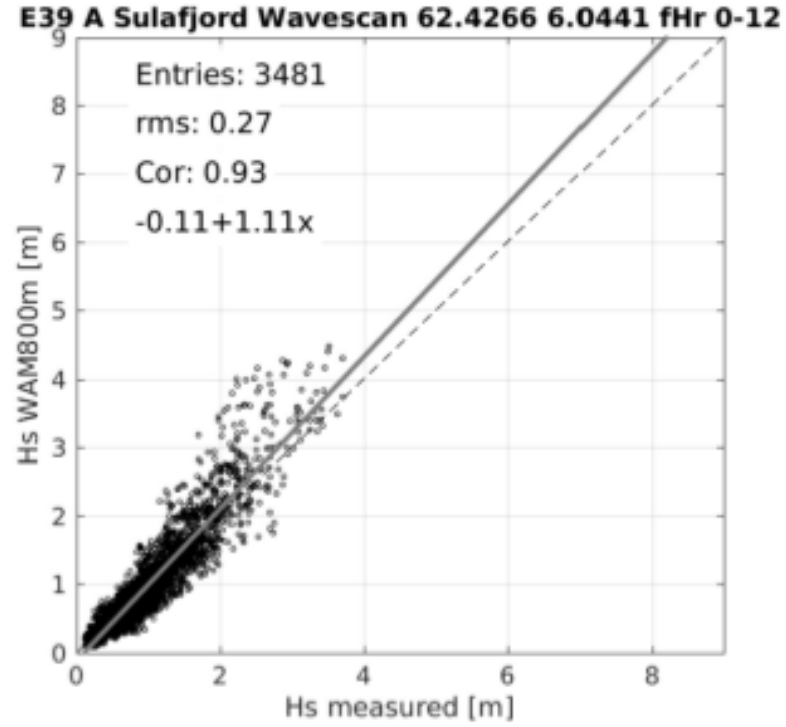
Example of uncertainty due to parameter-based wave spectra





JONSWAP spectrum based on Hs/Tp
Forecasts from barentswatch.no

Wave model with 2D wave spectra
Forecasts from MET

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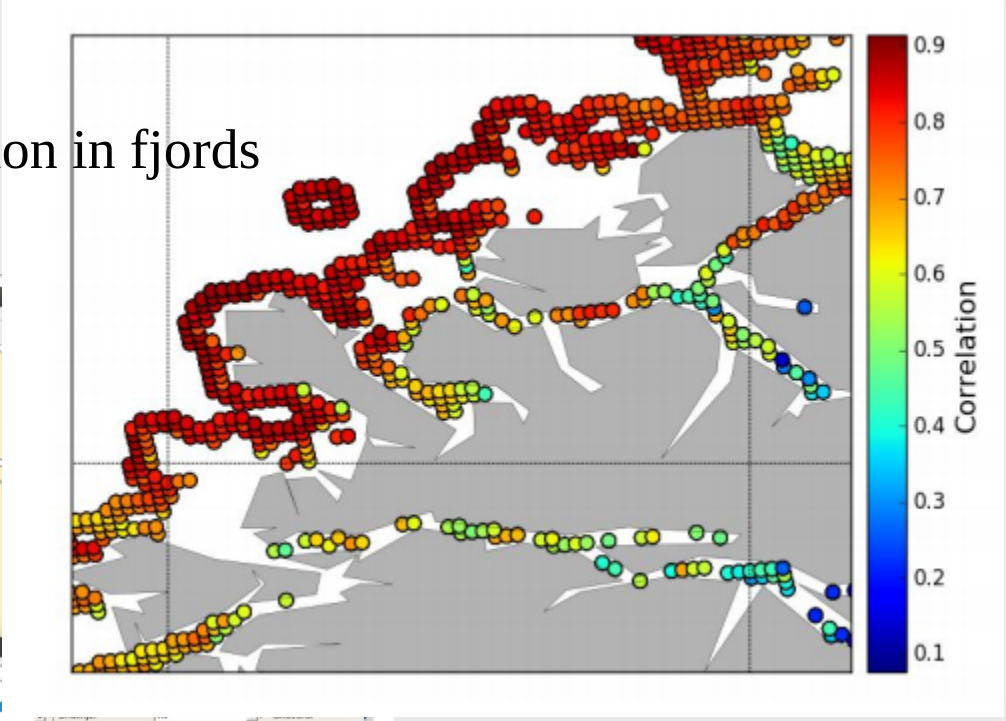
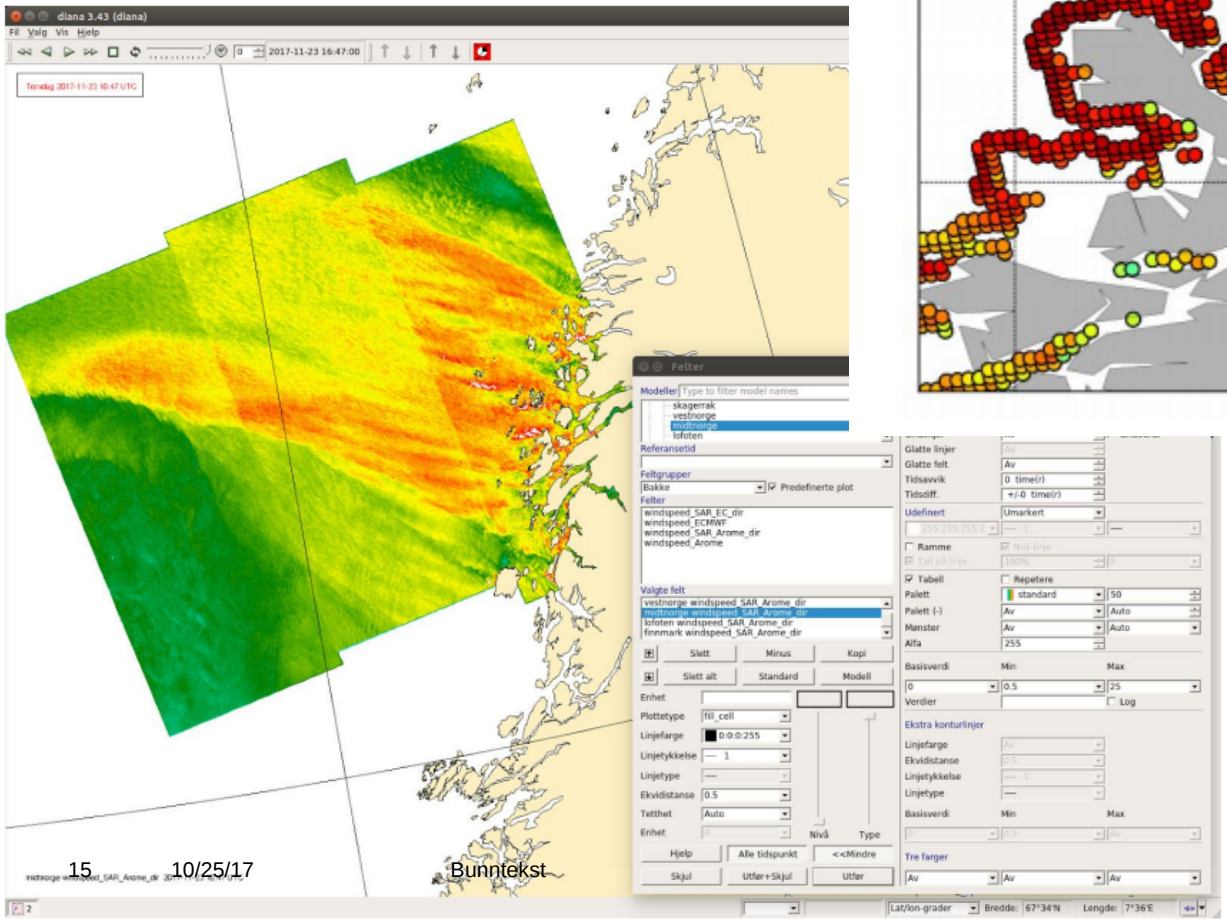
AROME compared to satellite SAR

Weak winds and low correlation in fjords





Final report from project FjordVind funded by the Norwegian Space Center

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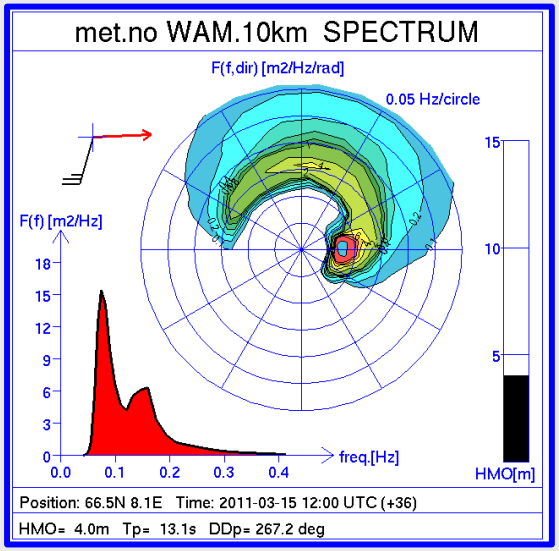
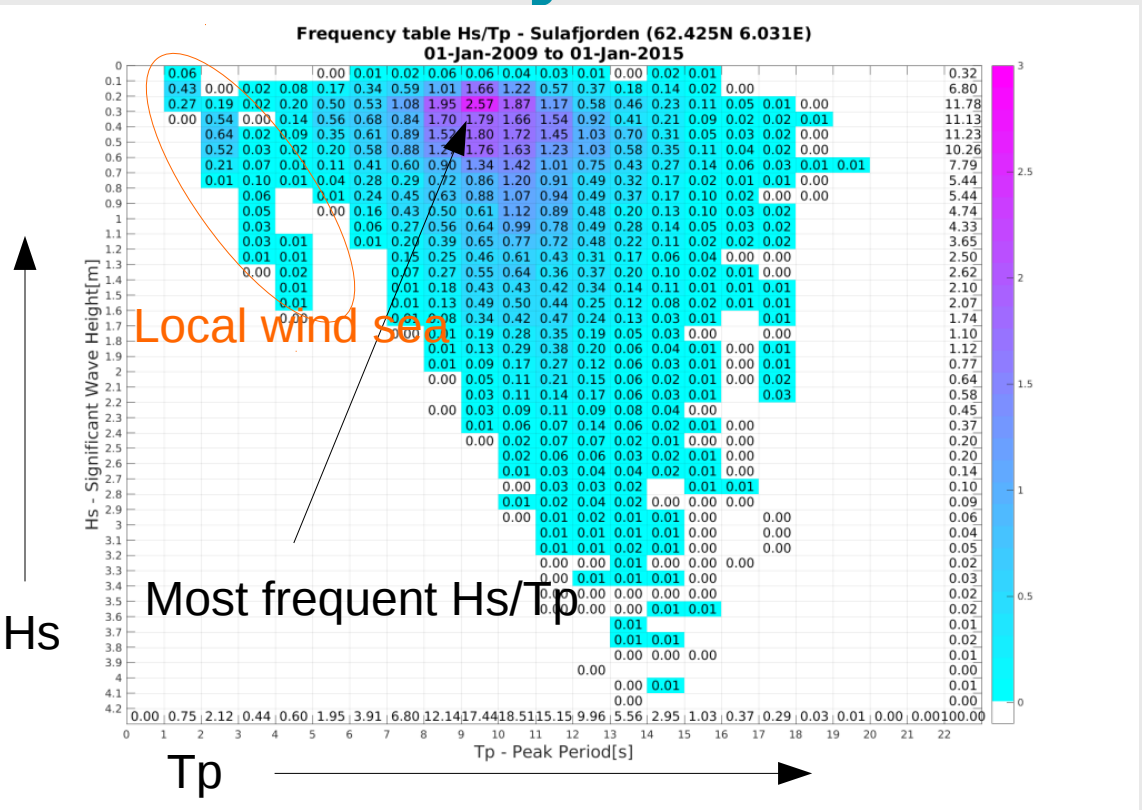
Wave statistics in Sulafjord



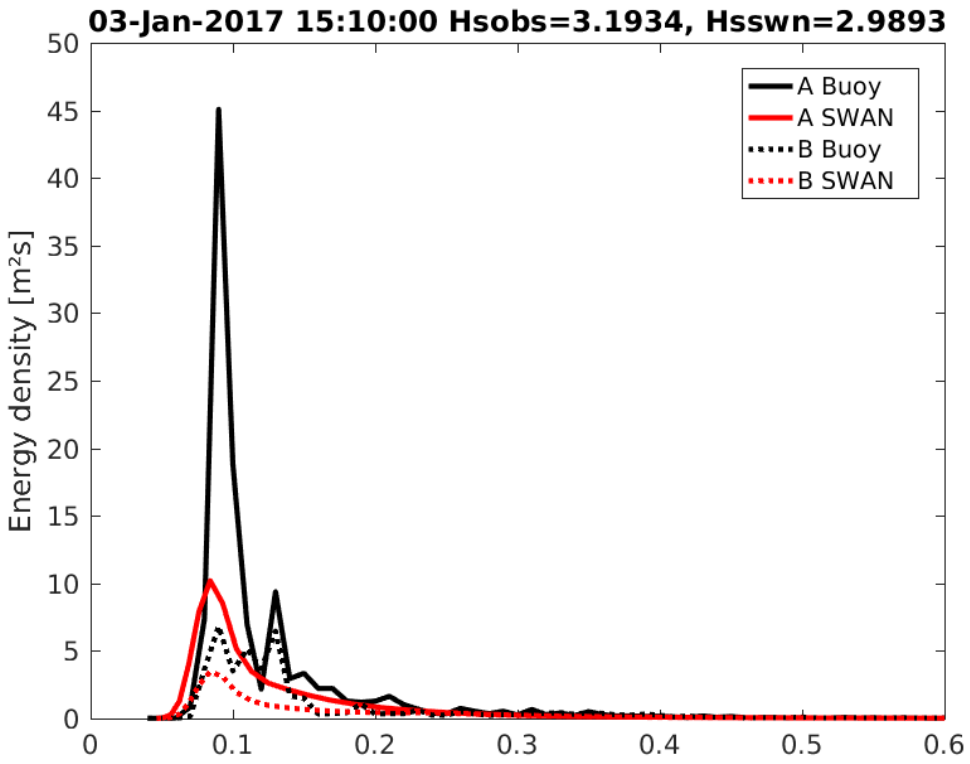
Example of NORA10 mixed sea spectrum

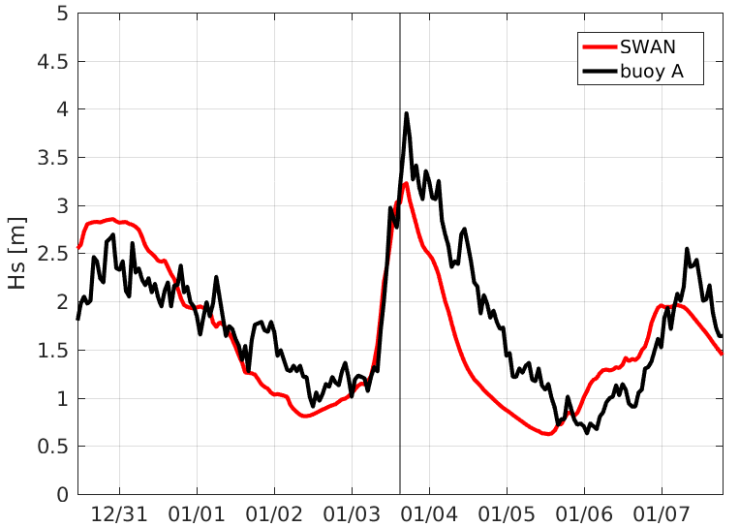


Tabell 7-3 Beregnet 100 års v
Sulafjorden Nord, Sulafjorden m
skravert.

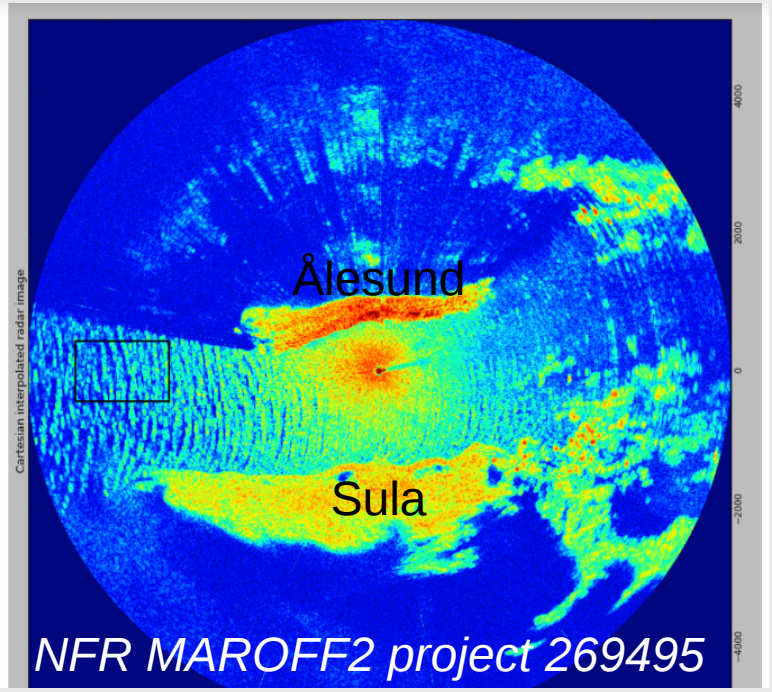
Sector	360	30	60	90	120	150	180	210	240	270	300	330	All
Hs_Sulafj_Nord	1.0	1.0	0.5	0.3	1.0	1.9	2.2	2.2	2.5	2.8	5.2	1.7	5.2
Hs_Sulafj_midt	1.2	1.2	1.1	1.4	1.6	2.0	1.9	1.7	1.6	1.7	3.1	2.9	3.2
Hs_Vartdalsfjorden	0.4	1.0	0.9	0.4	0.4	0.9	1.6	1.9	0.7	0.3	0.3	0.2	1.9

Wave spectra





Marine radar image 2017.01.03 15:14



Model may be right for the wrong reason

Summary and comments

- Large measurement program in several fjords in mid-Norway
- Data freely available, but access is temporarily closed at the moment (until May)

- Working to improve wave and wind modelling in the fjords
- Three PhD students started last year
    - Poster on wind shear by Midjiyawa Zakari outside

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