INSTITUTE OF MARINE RESEARCH

Resolving spatial variability of environmental conditions in Norwegian fjords by a numerical ocean model

Jon Albretsen, Lars Asplin, Anne Sandvik, Jofrid Skardhamar, Ingrid A. Johnsen, Mari Myksvoll & Bjørn Ådlandsvik **(Institute of Marine Research)**

JONSMOD Conference, 10-12 May 2016, Oslo

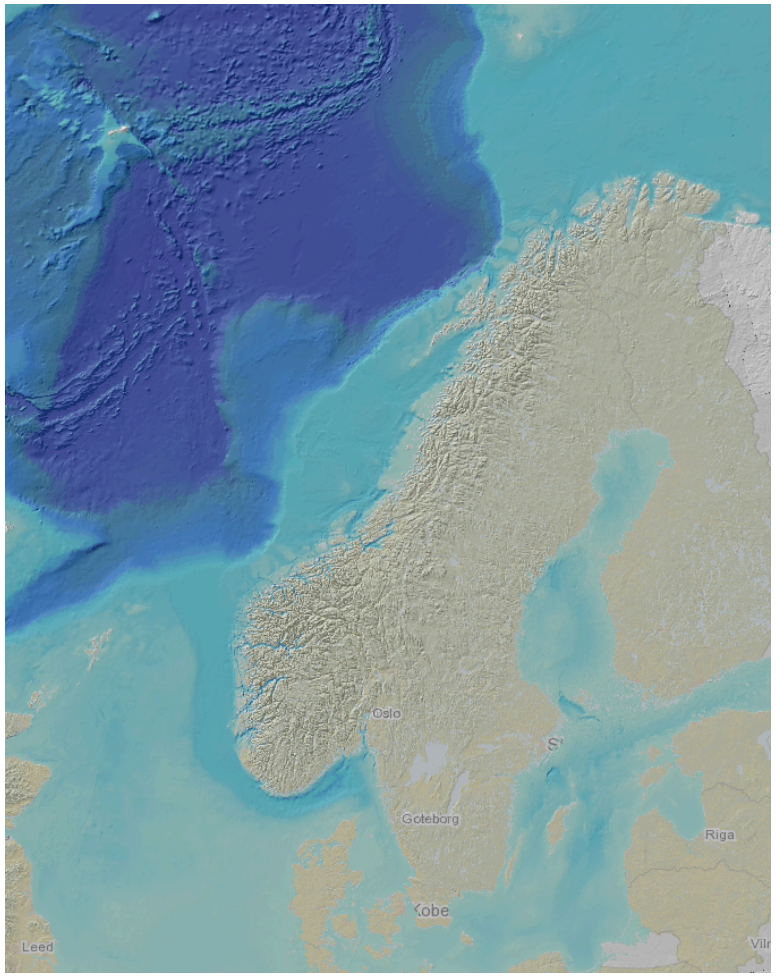
Content

- The Norwegian Coastal model (NorKyst800)
- The need for increased resolution
- Modelling the Norwegian fjords: numerical and scientific challenges
- Validation examples
- User applications

The Norwegian Coastal model

NorKyst800

- Motivated by an increased need of describing the environmental conditions along the Norwegian coast and in the largest fjords with sufficient resolution
- For most user applications within the coastal zone the open ocean models (~4km) were too coarse



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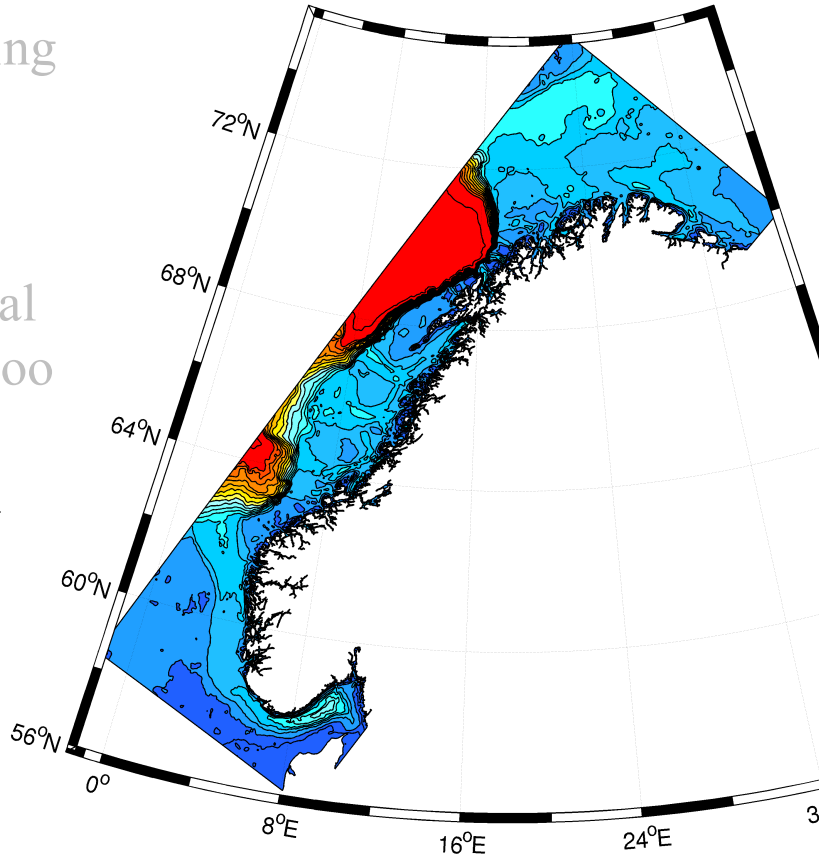
- Is run operationally at the Norwegian Meteorological Institute



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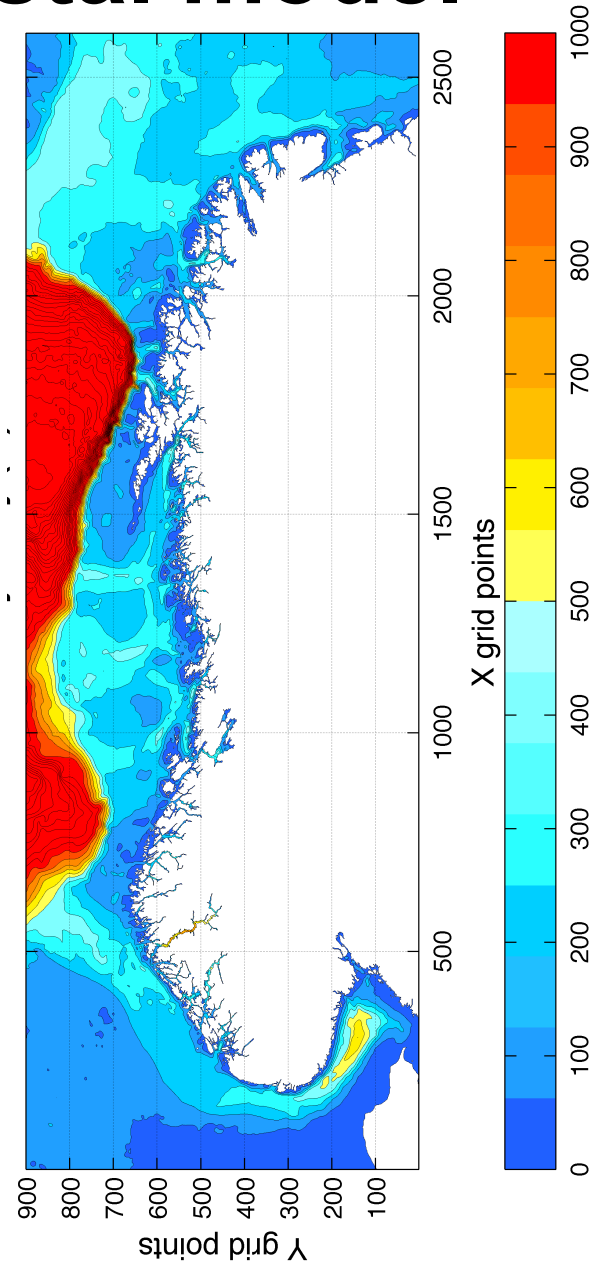
- For most user applications within the coastal zone the open ocean models (~4km) were too coarse
- Implemented with ROMS as the numerical ocean circulation model
- Is run operationally at the Norwegian Meteorological Institute
- Main usage includes:
  - patches of infectious agents (salmon lice monitoring)
  - spread of early life history of fish (eggs/larvae)
  - boundary conditions for fjord models



NorKyst800 – performance

A recent 10-yr hindcast (2005-2014) is run.

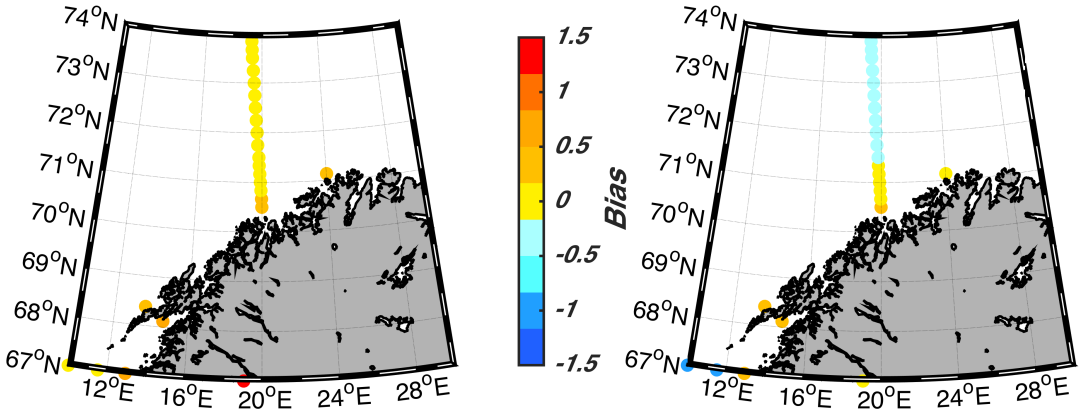
Inputs from:

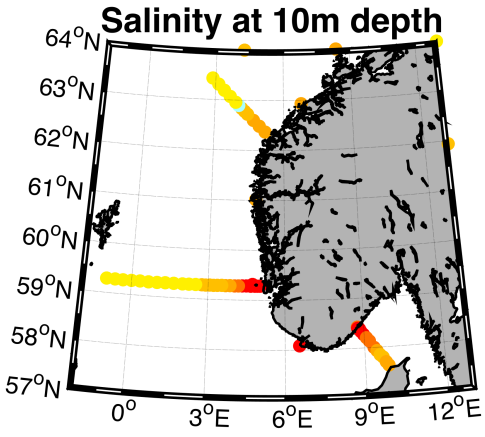
- Nordic-4km (SVIM, 1960->, Lien et al. 2014)
- WRF-3km
- TPXO7.2
- Daily, realistic runoffs from the 247 catchment areas (1962->)

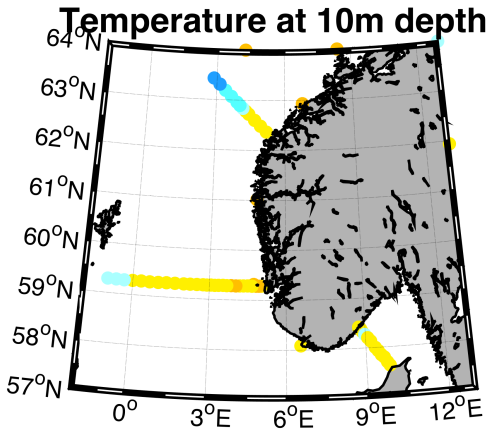
Configuration:

- 800m x 800m hor. resolution
- 35 terrain-following s-levels
- A priority on near-surface (0-50m) resolution

Bias (mod – obs)







V.S. Lien, Y. Gusdal, and F.B. Vikebø 2014, Along-shelf hydrographic anomalies in the Nordic Seas (1960–2011): locally generated or advective signals? *Ocean Dyn.*, **64**, 1047–1059.

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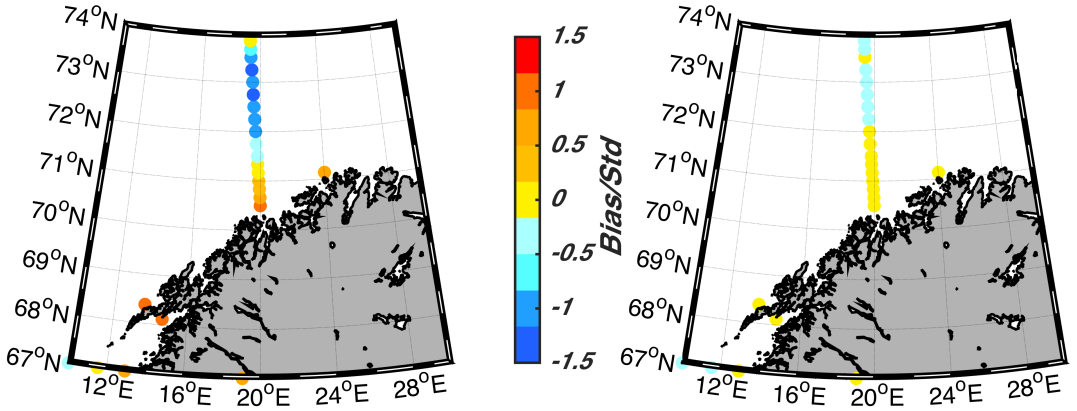
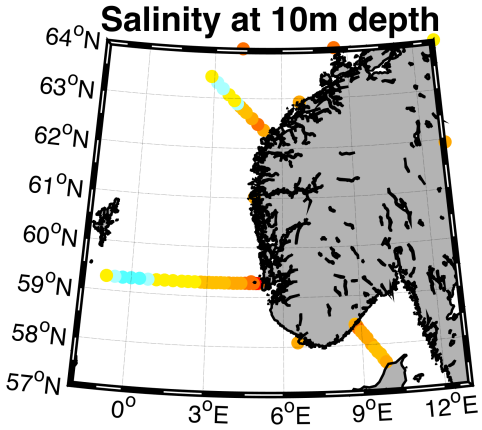
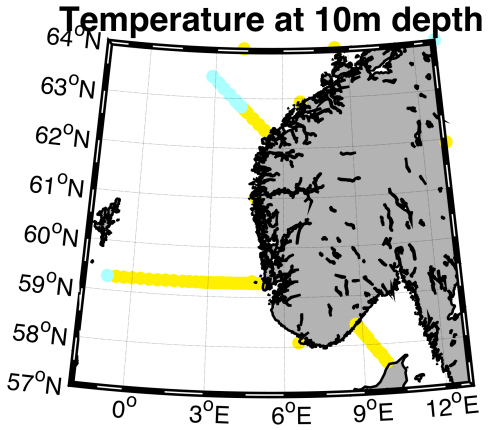
Bias (mod – obs)/std(obs)







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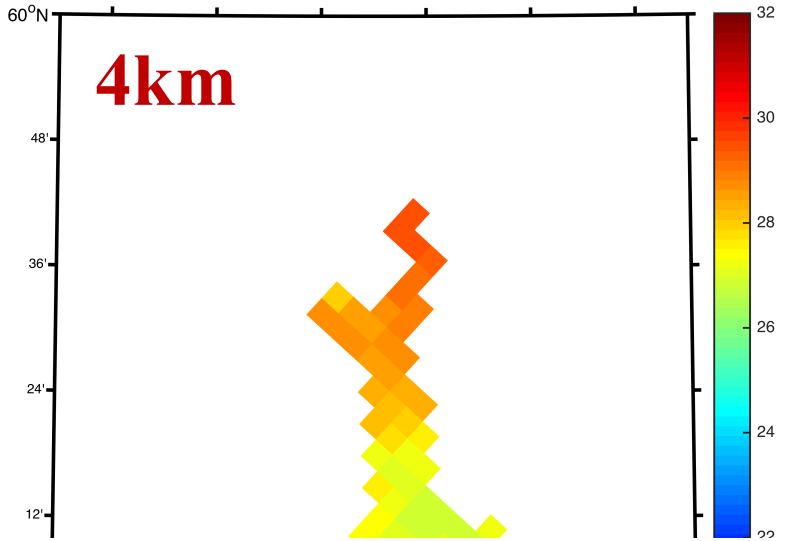
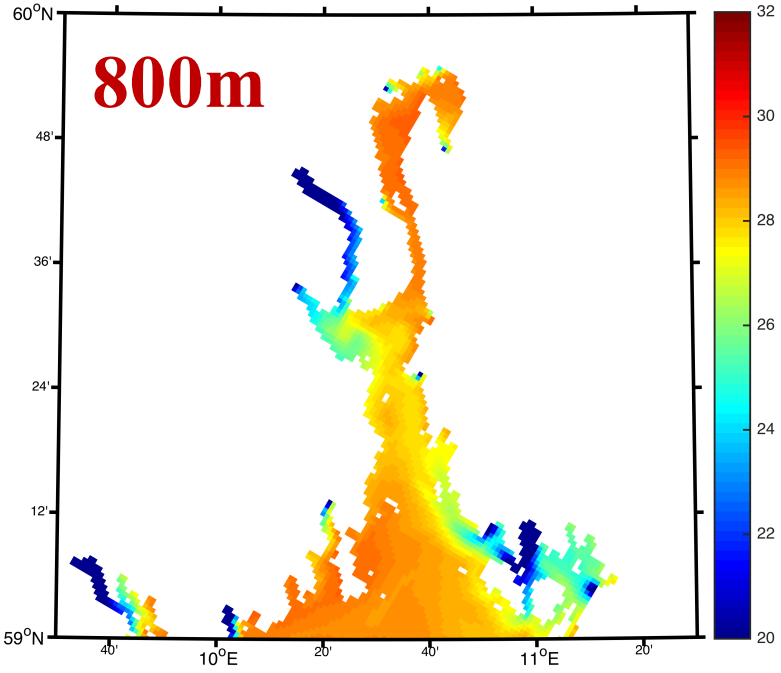
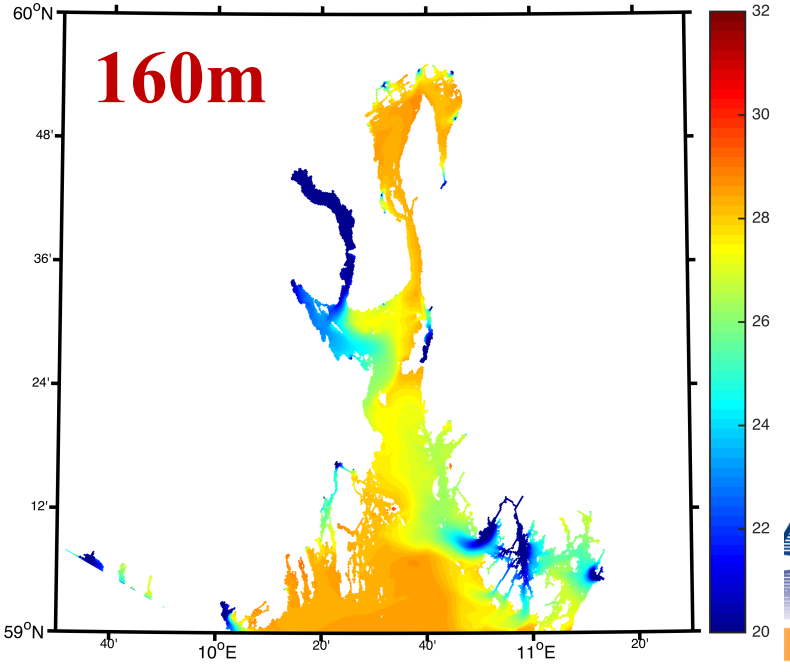
The need for increased resolution

Exemplified by the Oslofjord







Modelling the Norwegian fjords

NorFjords160

- The topographical complexity of Norwegian fjords introduces essential challenges related to spatial (and temporal) resolution that squeezes our computational resources

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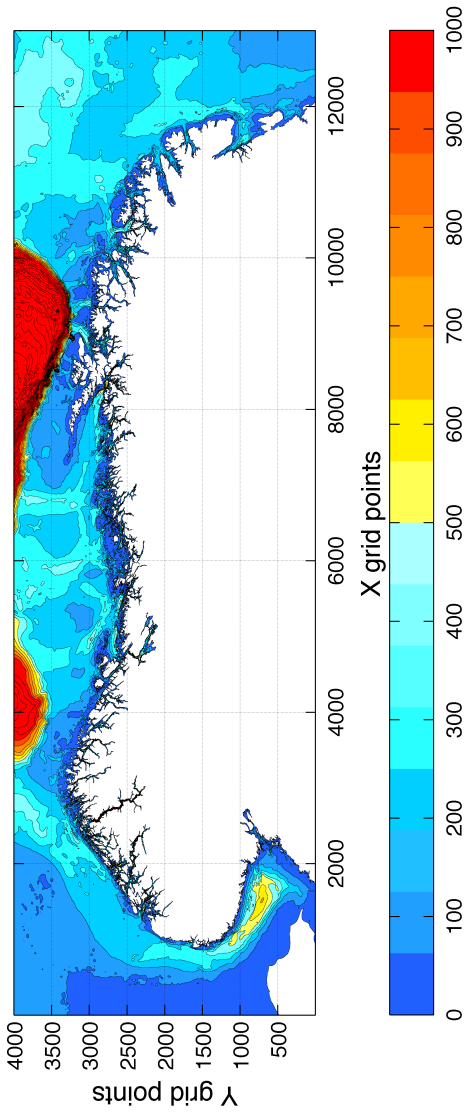
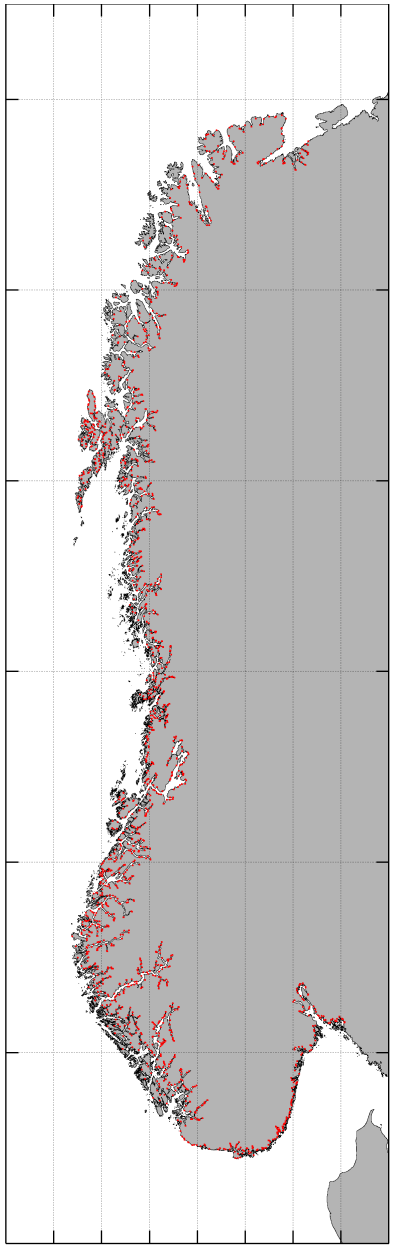
- Bathymetric input from the Norwegian Hydrographic Service: (echo depths ~50m & coast line 1:5000) -> 160m x160m grid



Modelling the Norwegian fjords

NorFjords160

- The topographical complexity of Norwegian fjords introduces essential challenges related to spatial (and temporal) resolution that squeezes our computational resources
- Bathymetric input from the Norwegian Hydrographic Service: (echo depths ~50m & coast line 1:5000) -> 160m x160m grid
- River runoffs distributed to all the 1760 main rivers in Norway (applies runoffs from catchment areas that are distributed according to the upstream area of each river)



NorFjords160 – numerical challenges

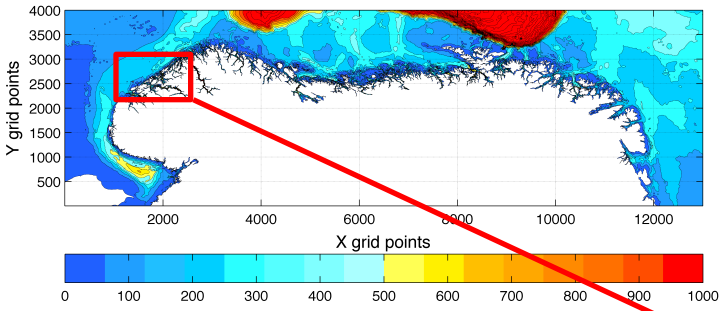
Has to face (at least) two great challenges:

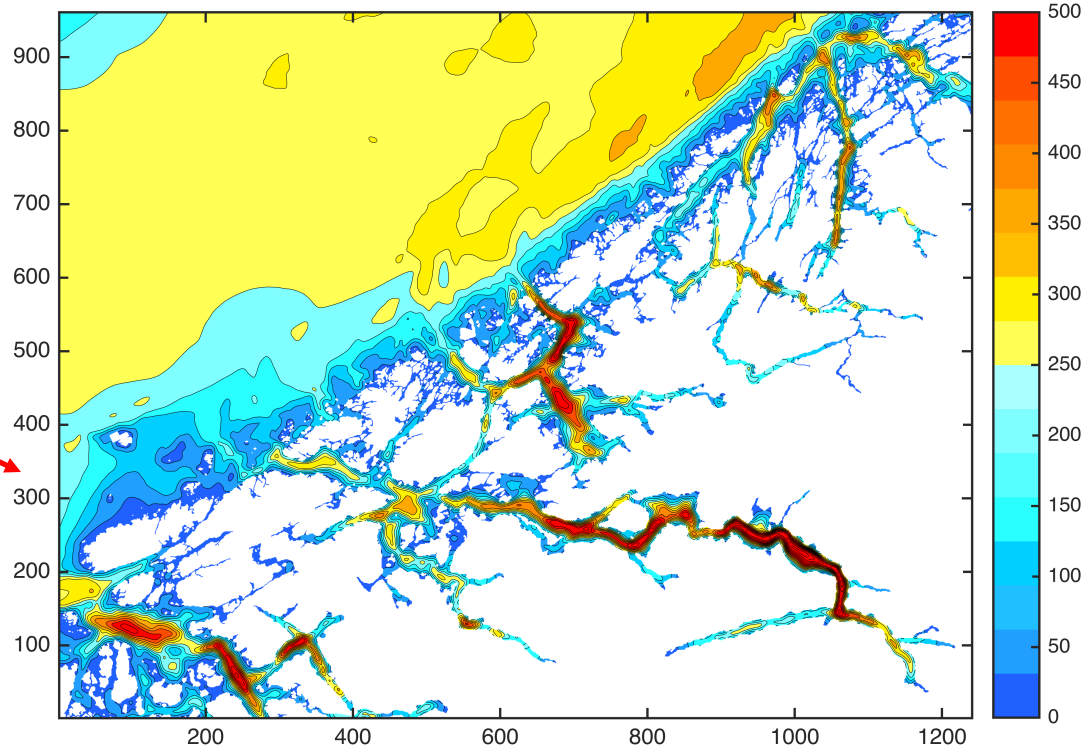
1) The lack of computational power to run a model with 13000 x 4000 (x 35) grid points with 5-10s baroclinic time step

2) Assemble external forcing data with sufficient resolution and accuracy: The forcing is extremely important!

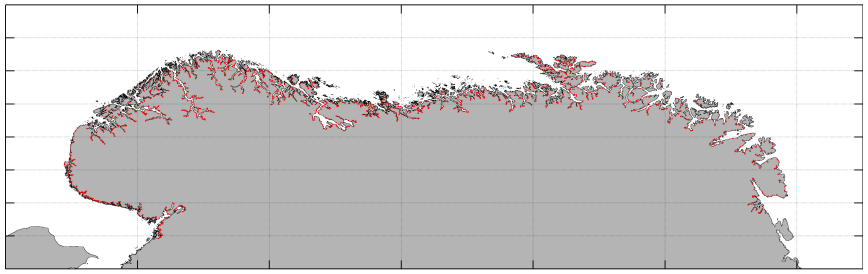
NorFjords160 - subdomain

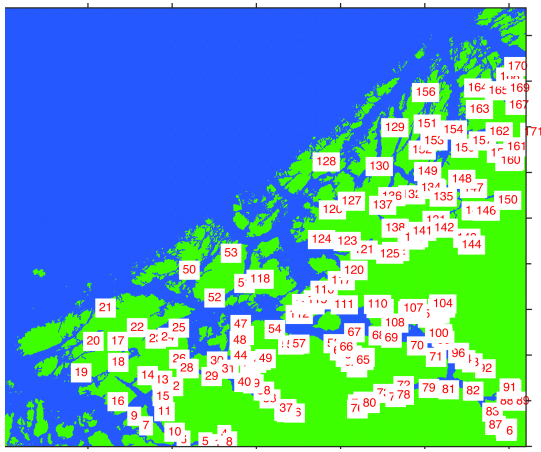
1) Subdividing the model area





Extracting the relevant rivers

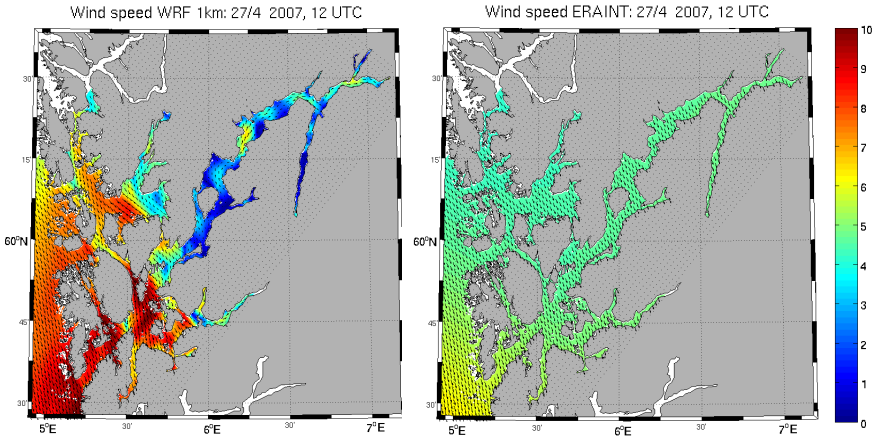




NorFjords160 – external forcing

2) External forcing data for the fjords

- Open boundary conditions from NorKyst800 (hourly, i.e. includes tides)
- High-resolution atmospheric modelling (WRF, at least 3km, should be able to resolve topographic steering of winds)



WRF 1km ERA-interim

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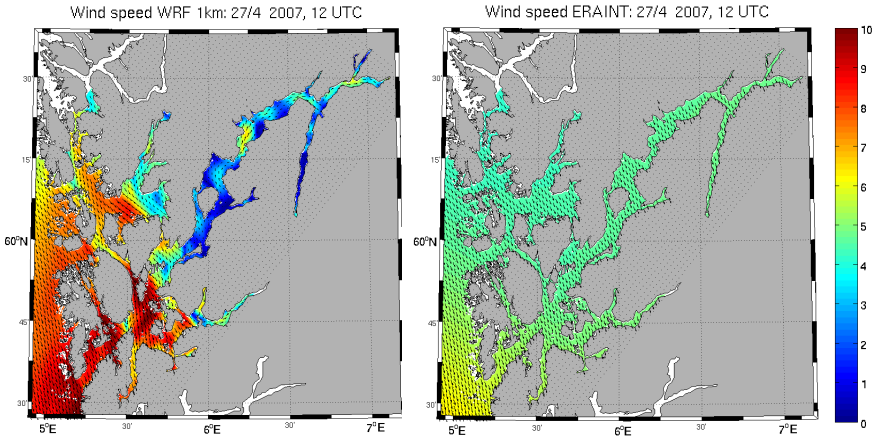
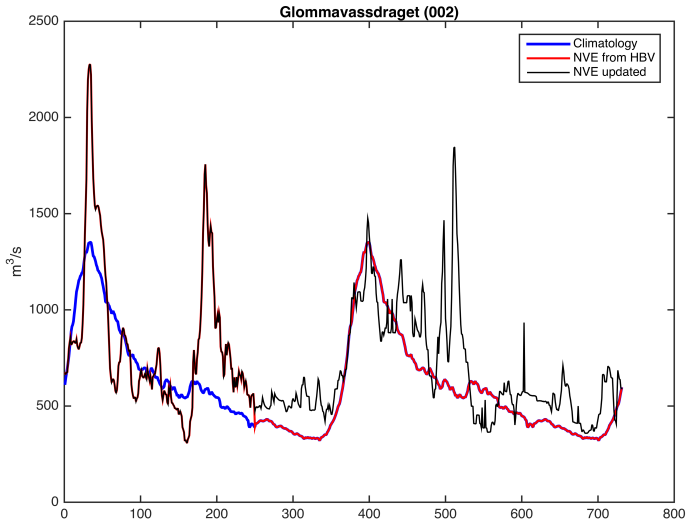


WRF 1km ERA-interim



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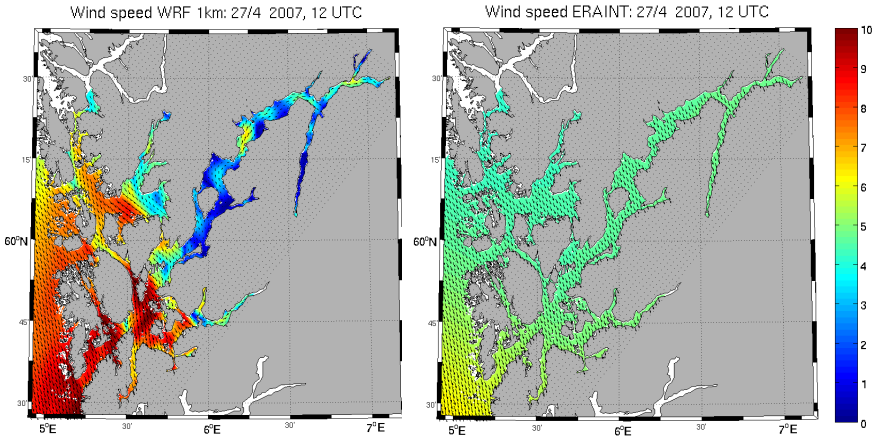

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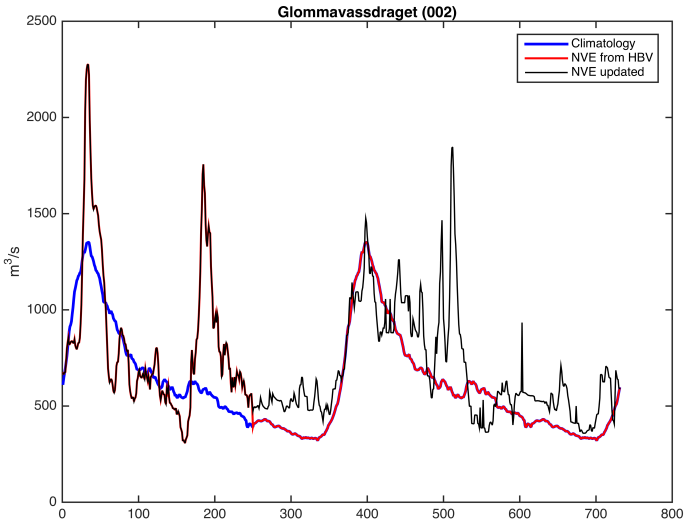


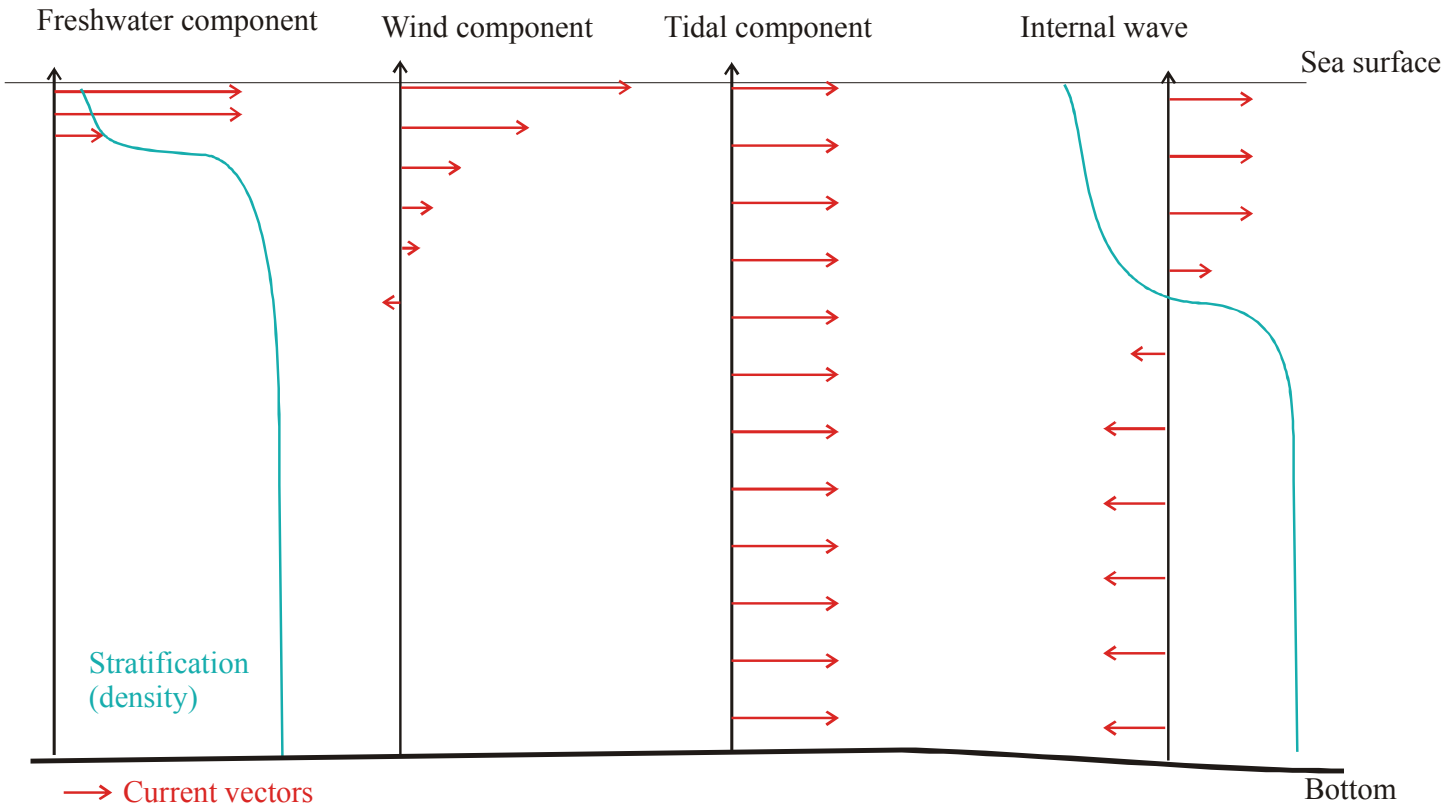
To be able to respond quickly when needed:

Archives are established and maintained for near real-time simulations at the HPC resource, script based system to set up and execute simulations for specified areas and time periods within minutes

NorFjords – scientific challenges

The flow in fjords: simplified as the sum of linear components

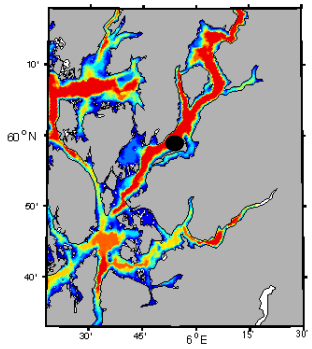
The most important components are driven by external forcing, as winds, tides, freshwater runoff and internal pressure gradients

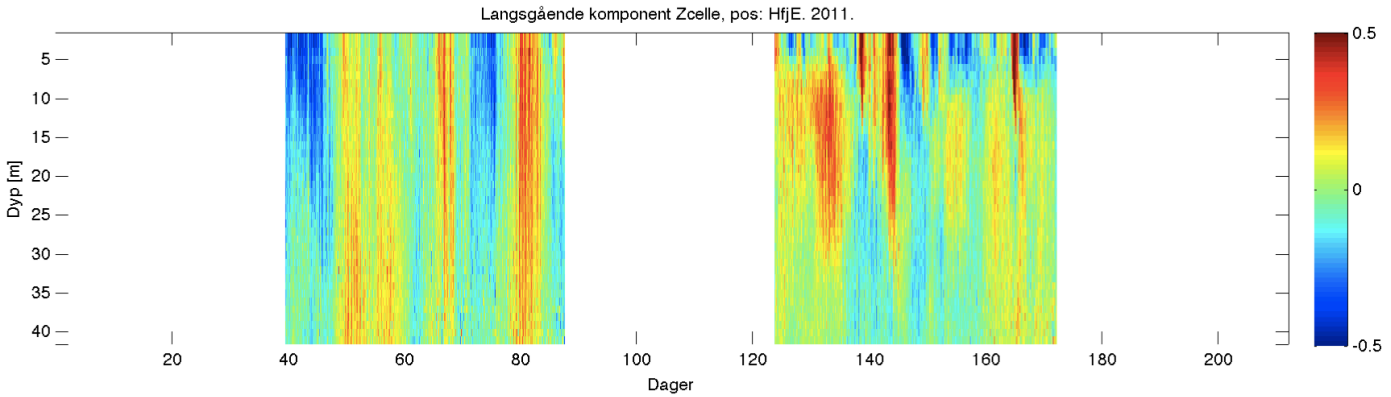


Example from the Hardangerfjord

Vertical profile of along-fjord current

Observations with a vertical profiling current meter:

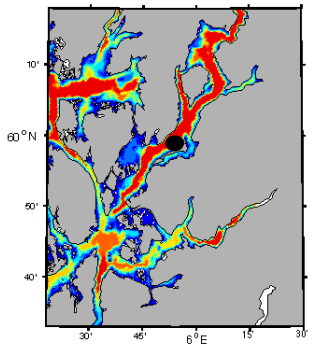


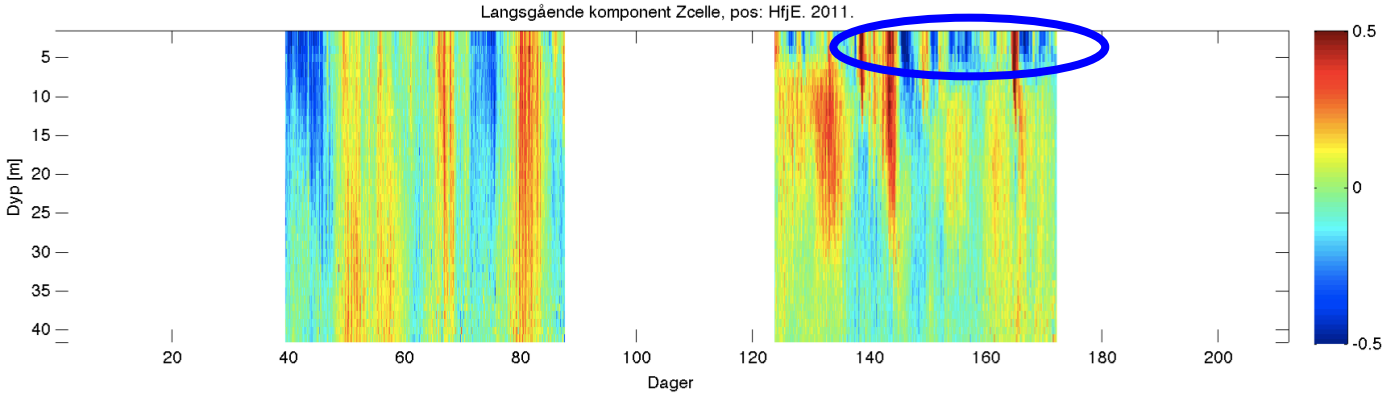


Red: into the fjord

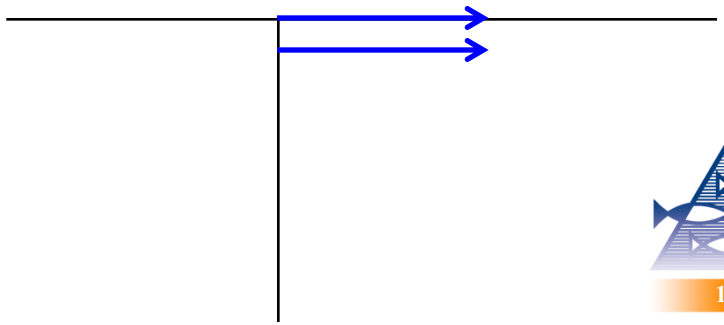
Blue: out of the fjord

Example from the Hardangerfjord





Freshwater driven flow



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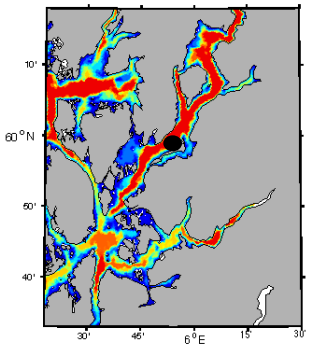
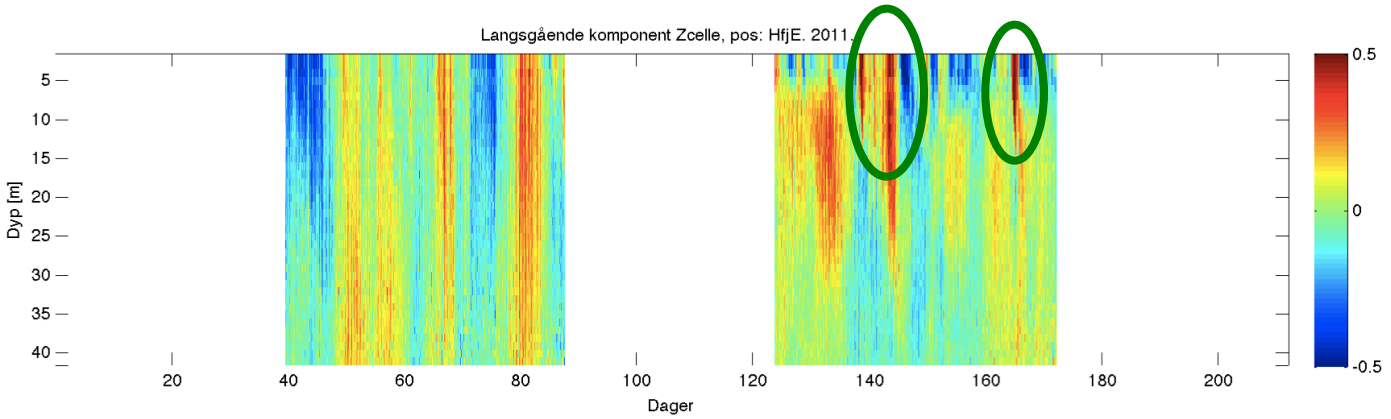
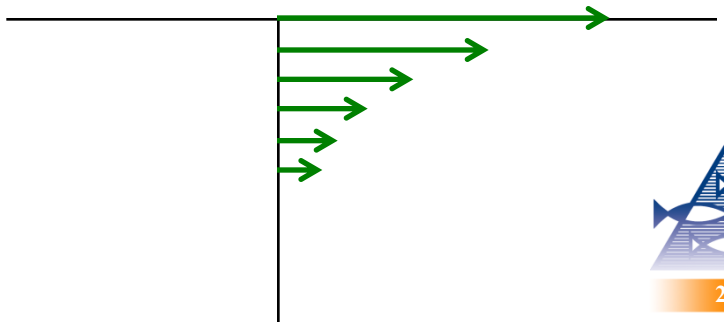




Freshwater driven flow

Wind driven flow



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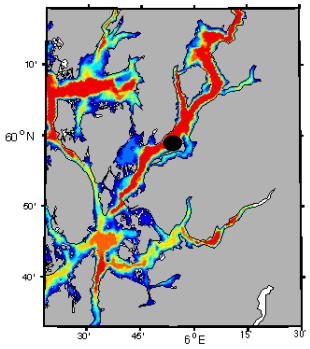
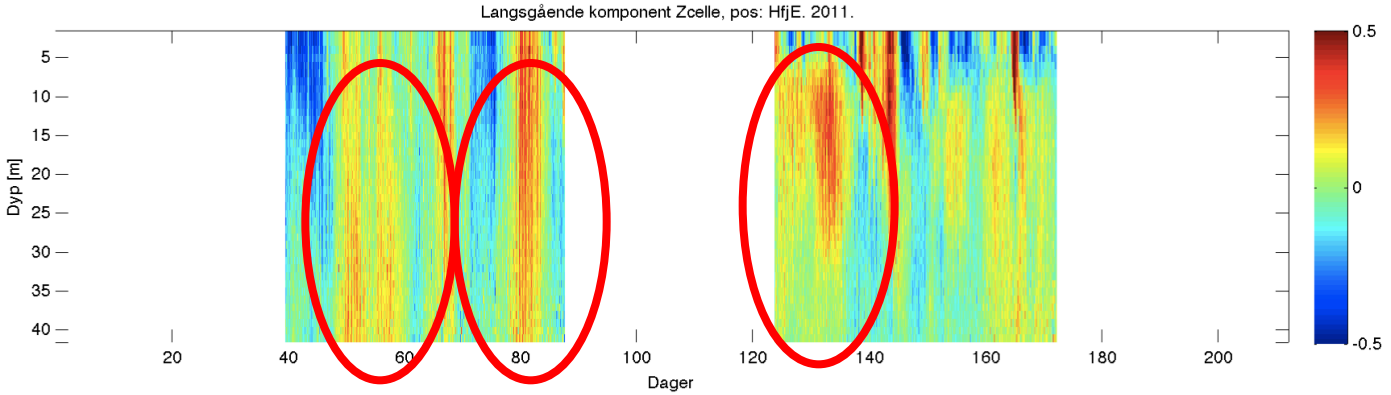
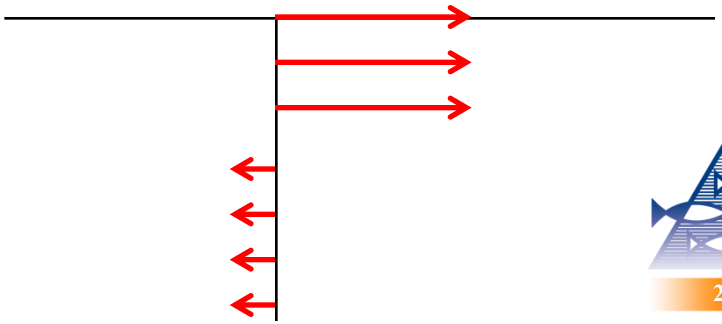




Freshwater driven flow

Wind driven flow

Internal pressure driven flow



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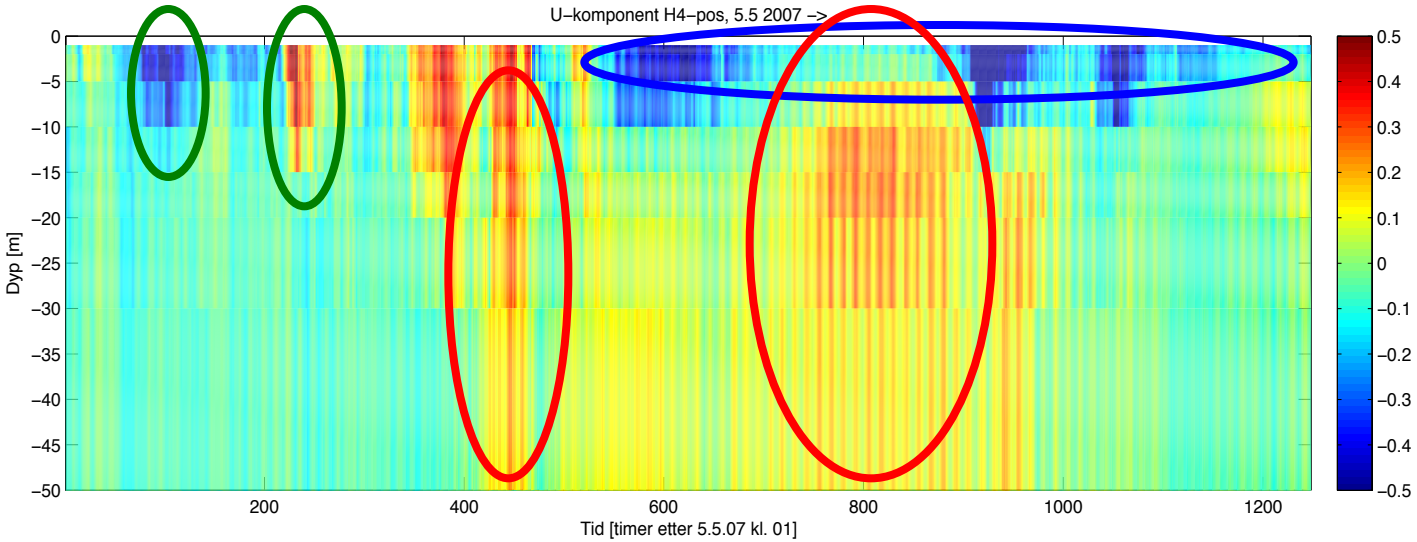


Freshwater driven flow

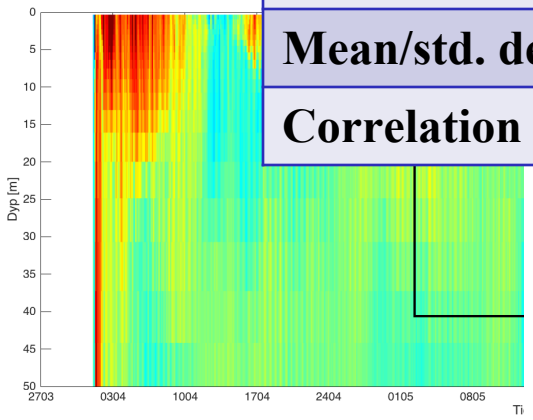
Wind driven flow

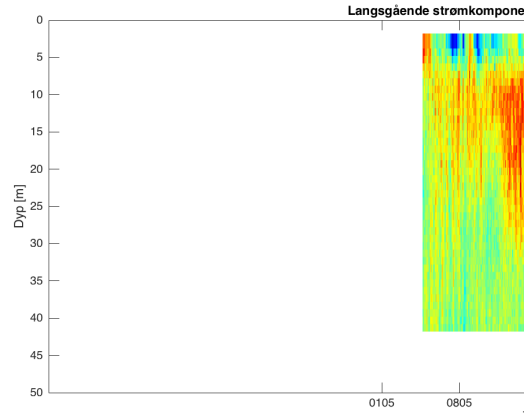
Internal pressure driven flow

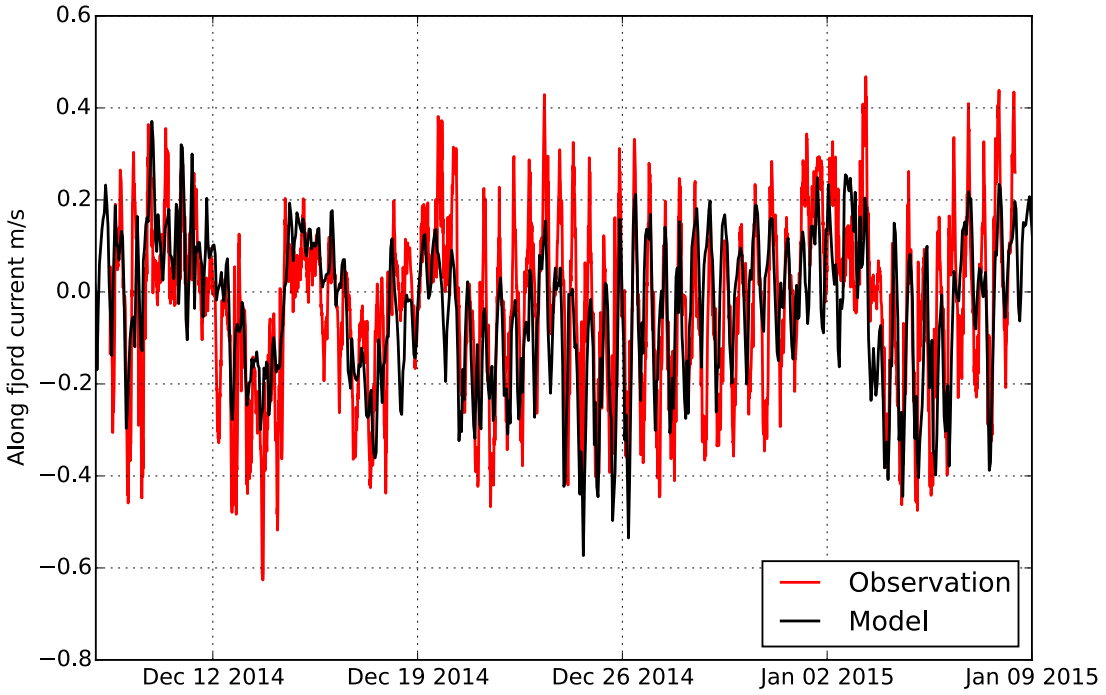
NorFjords160 – performance (I)

Current measurements, the Hardangerfjord

	Inflow		Outflow	
	Obs	**Mod**	**Obs**	**Mod**
Dir. relative time (%)	47	45	53	55
Mean/std. dev. (m/s)	0.12 / 0.09	0.10 / 0.07	0.17 / 0.13	0.16 / 0.11
Correlation	0.64			

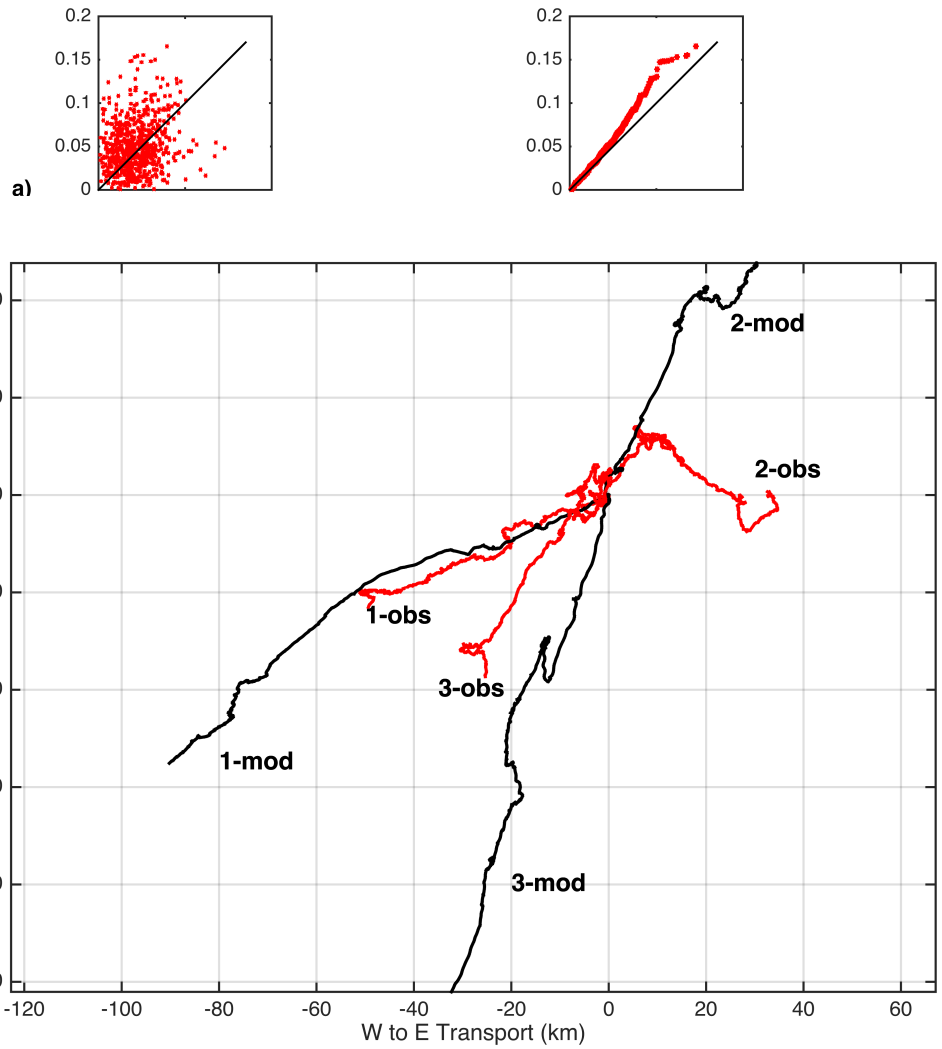


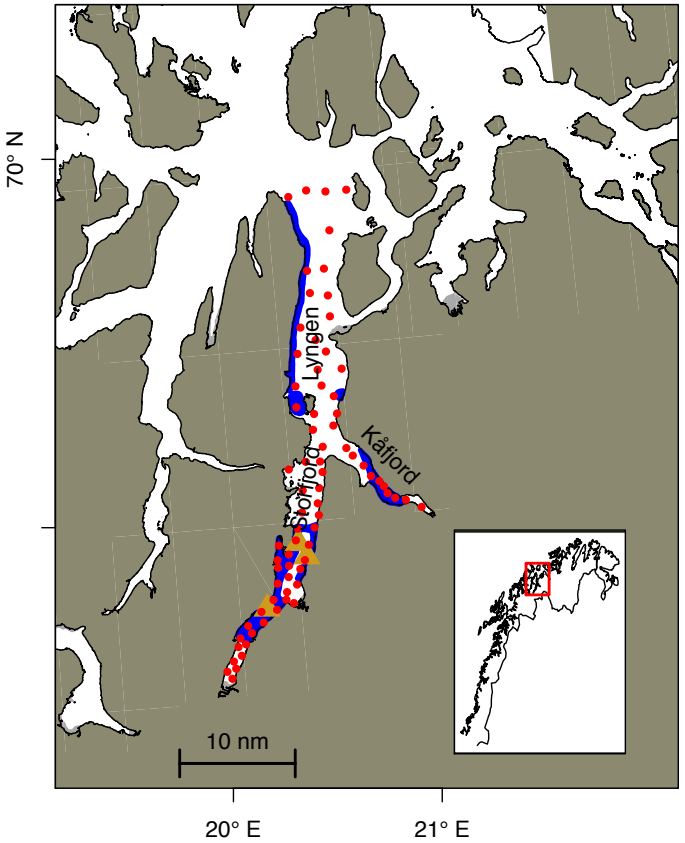




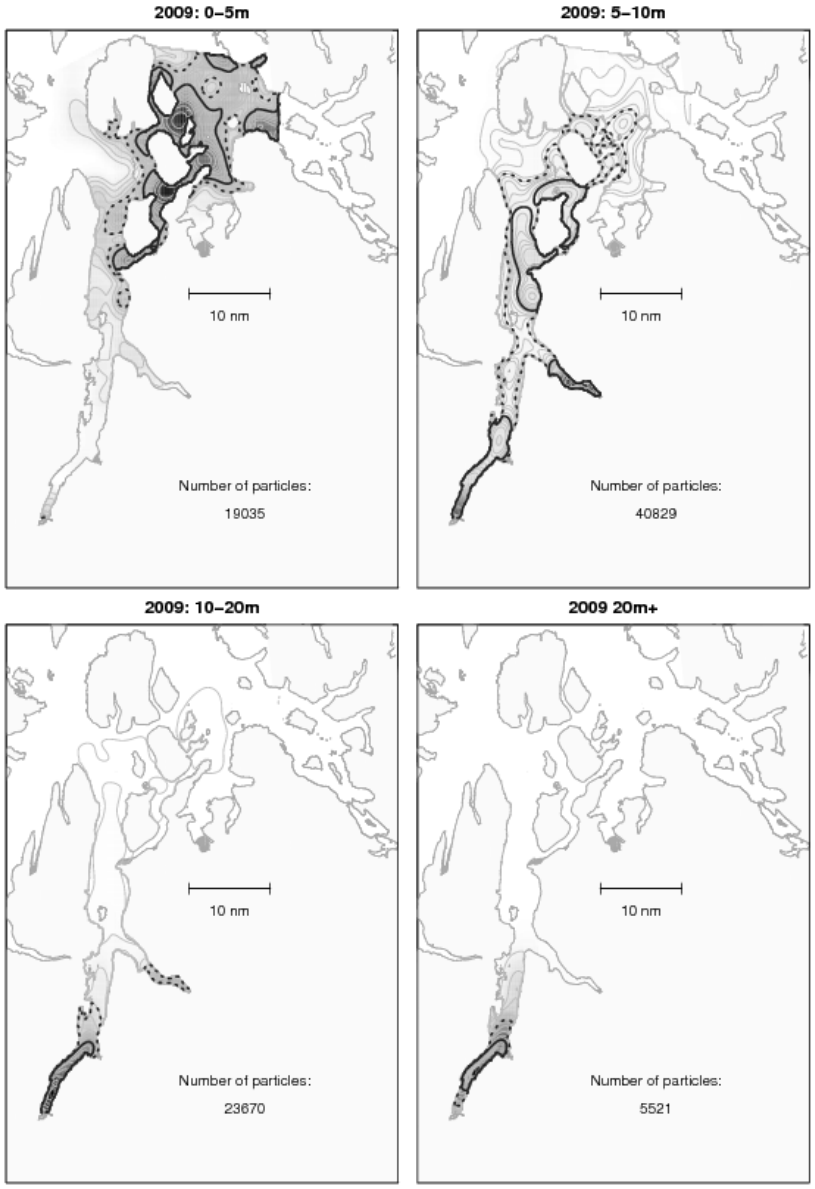
NorFjords160 – performance (II)

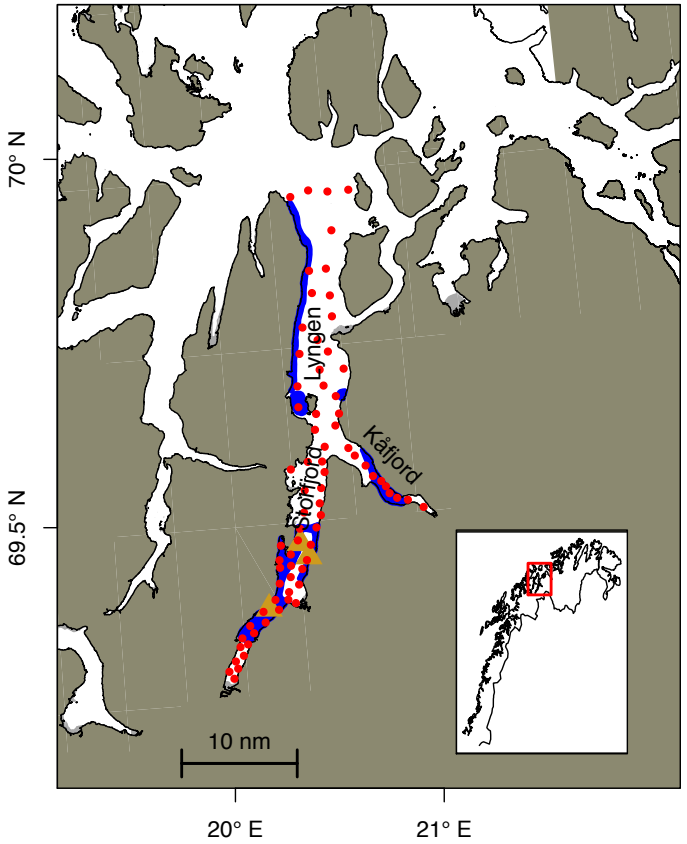
Current measurements, Storfjorden, Northern Norway





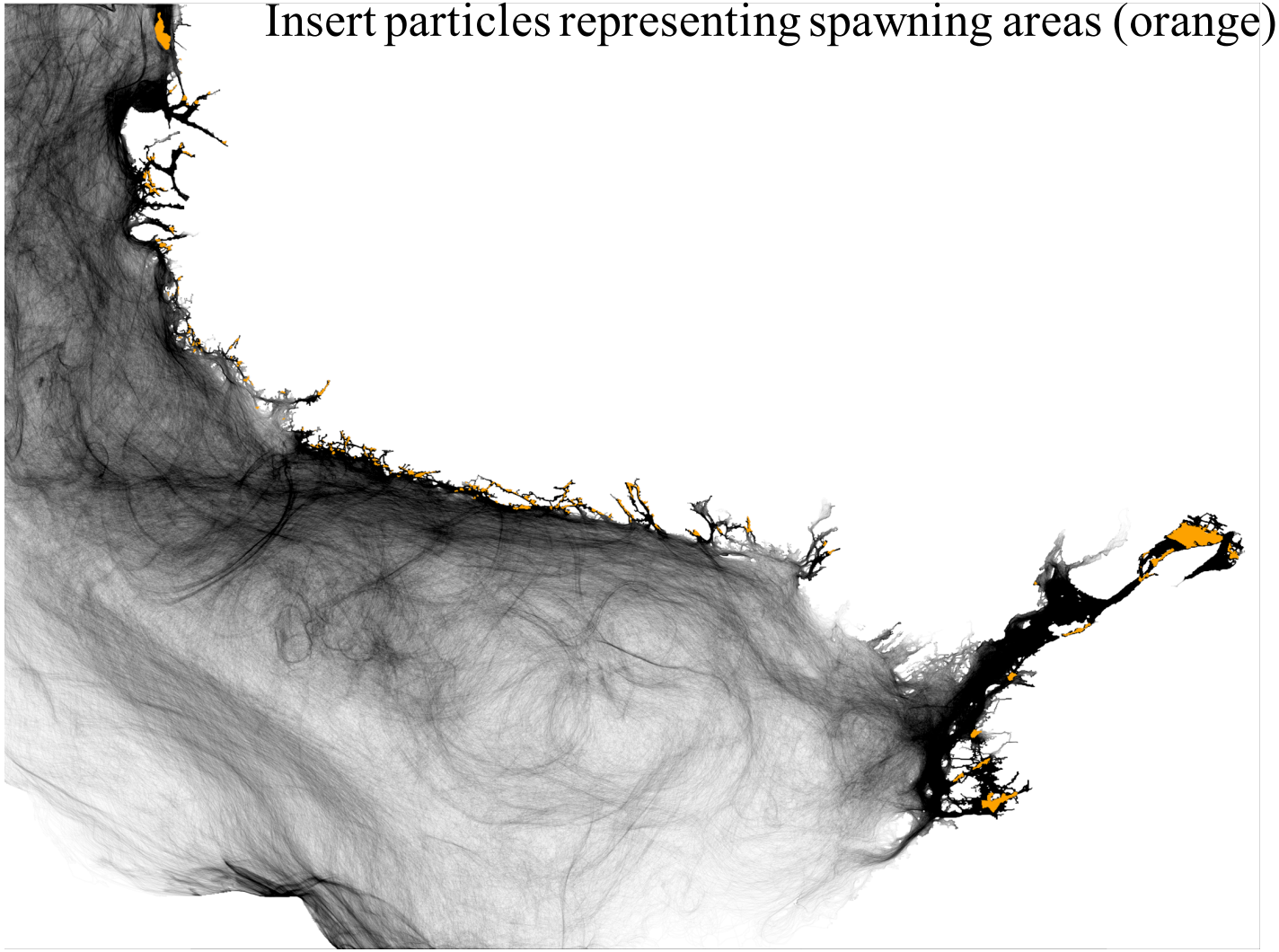
Modelling drift of pelagic offspring





Probability density distributions for cod eggs at different depths

Drift of cod eggs/larvae in the Skagerrak



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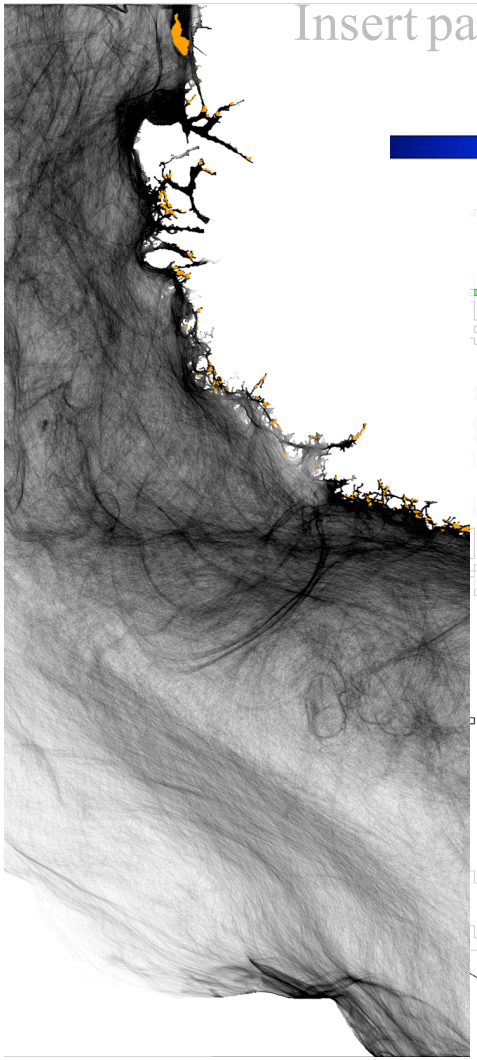
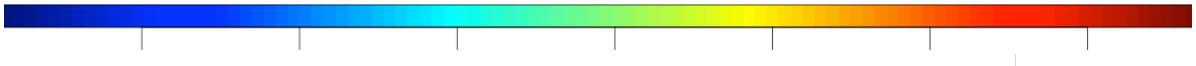
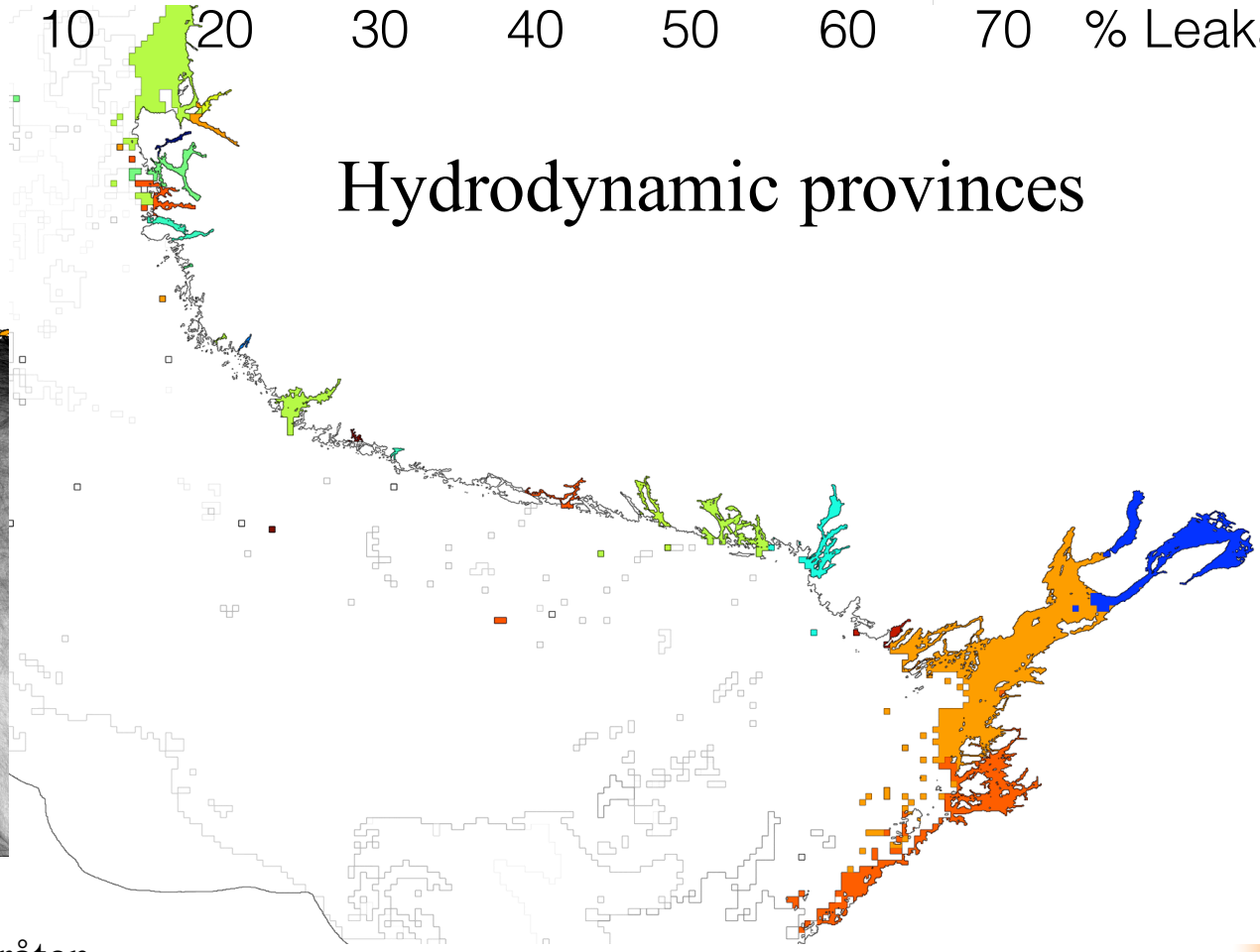


Insert particles representing spawning areas (orange)



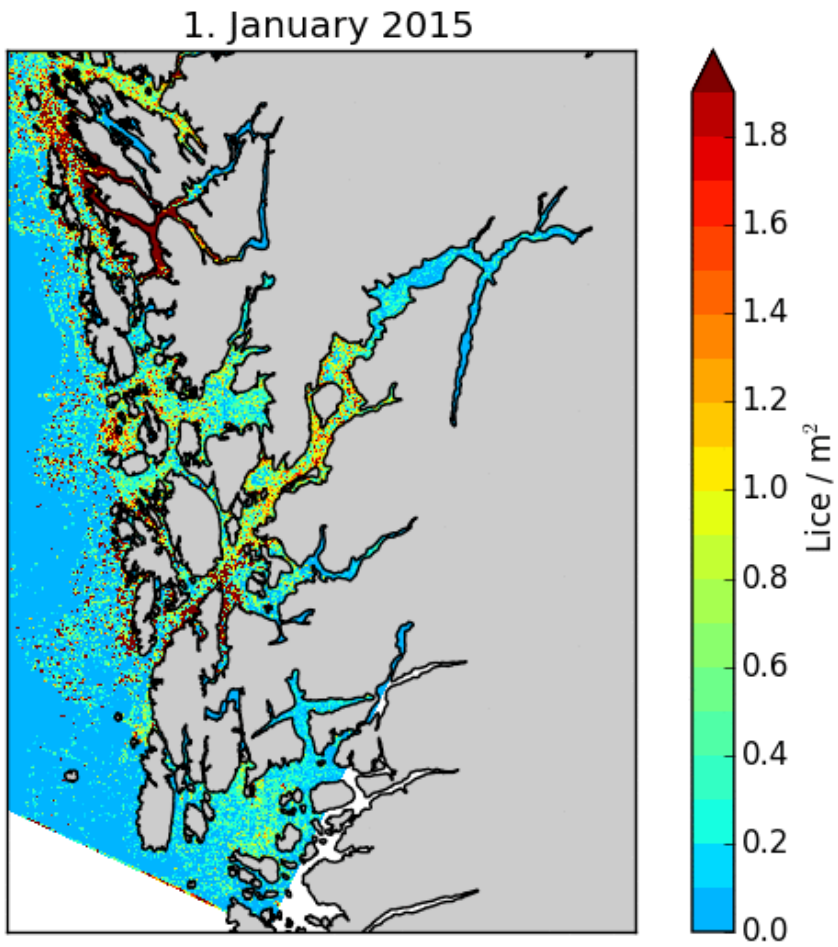
Hydrodynamic provinces



Thanks to Mats Huserbråten

Infective salmon lice copepodids

Based on nauplie released from salmon farms (Southwest of Norway)



Summary

- Modelling the Norwegian coastal areas and fjords challenge our models to apply high-resolution bathymetry and time-variant external forcing in order to reproduce the environmental conditions

- And when we manage to generate realistic model archives of currents and hydrography, the spectre of users widens and they are very enthusiastic!