Can running the ocean wave component of the Earth System Model over lakes

have an impact on the evolutions of the atmosphere?

Very preliminary results

Jean Bidlot, Margarita Choulga

European Centre for Medium-range Weather Forecasts

jean.bidlot@ecmwf.int

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Outline

- Global wave model simulation at 1.4 km with resolved lakes included.

- Impact of running wave model on resolved lake in ECMWF Earth System Model.

- Modelling waves on lake Titicaca.

Isla de la Luna and Cordillera Real, Lake Titicaca, Bolivia

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Introduction

- ECMWF atmospheric model has a simple lake model (Flake) to represent water bodies over land.

- Flake needs information on the fraction of the gid box covered by water bodies (**lake cover**) and the corresponding water depth (**lake depth**).

- These are part of the climate fields that are regularly updated as part of ECMWF model upgrade.

- So,

- Could we use the lake cover and lake depth information to run the wave model (ecWAM) over lakes?

Lake cover
Tco1279 grid (9km)

Lake depth (m)
for lake cover > 0.65
Tco1279 grid (9km)
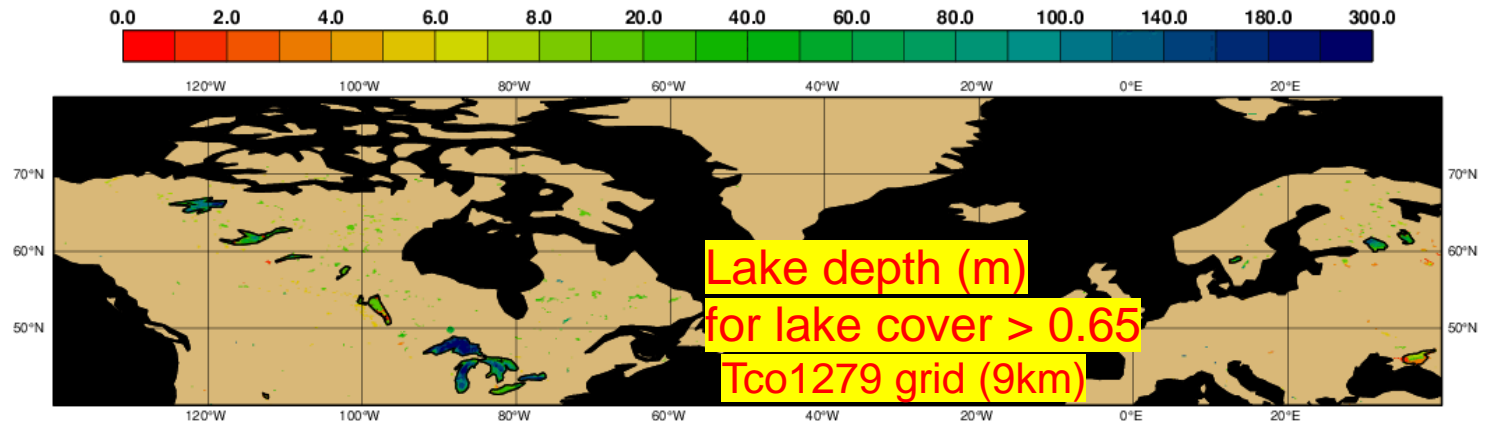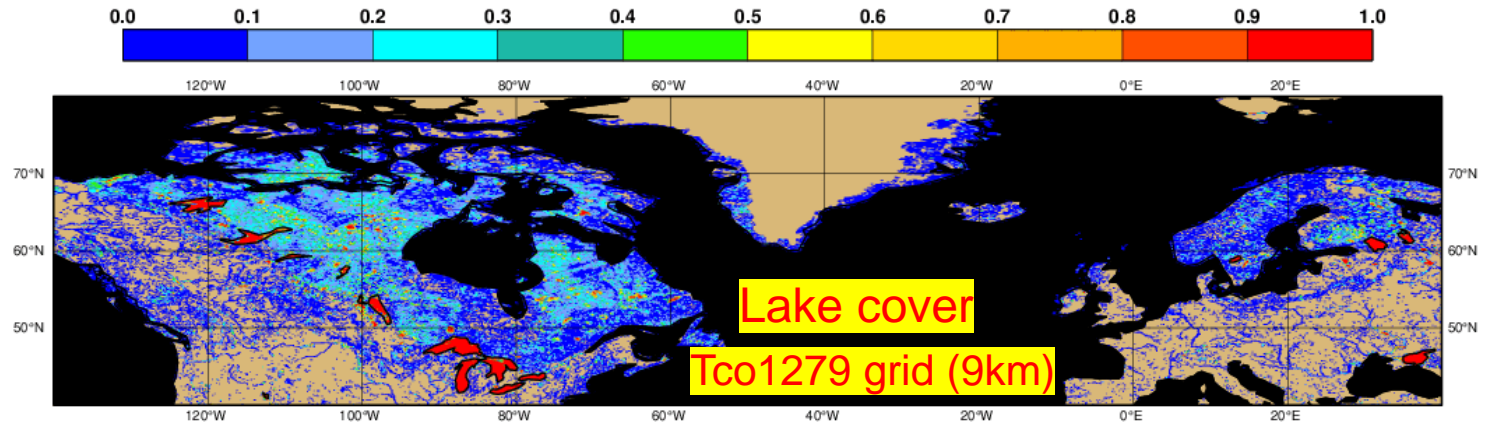
ecWAM <u>stand alone</u> on Tco7999 grid on oceans and lakes:

- With my Team leader departure to WMO, I joked that I could run the wave model on Lake Geneva.

- Well,

- With the next model update (CY49R1), the wave model (ecWAM) will be using the same grid as the atmosphere.

- Therefore, it is easy to blend the bathymetry information with the lake information from the climate fields.

- Lake depth for lake with cover > 65% were blended with the existing model bathymetry.

- Using the triangular–cubic–octahedral Tco7999 grid with a grid spacing of the order of **1.4 km.**

- A total of 182,533,607 water points are used with 36 frequencies and 48 directions for the spectrum.

- Ran 4 days on ECMWF Atos HPC with NPES=2048 and THREAD=16.

- with 6 hourly operational analysis forcing.

- 4-day simulation in slightly less than 1 hour.

- NB: not coupled yet.

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ecWAM stand alone on Tco7999 on <u>oceans</u>: first results

5th November 2023, 0 UTC,

Impact of storm Domingos
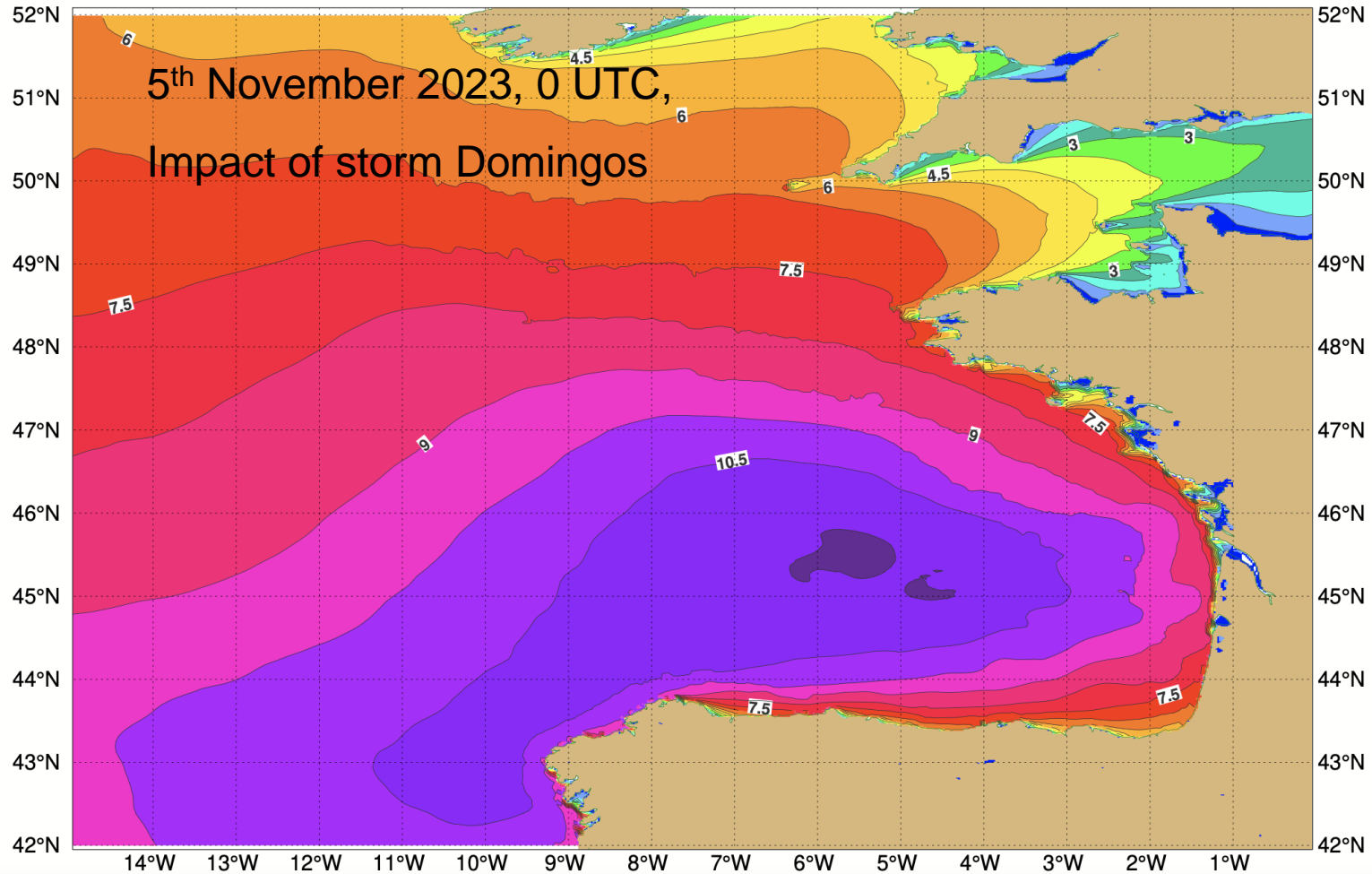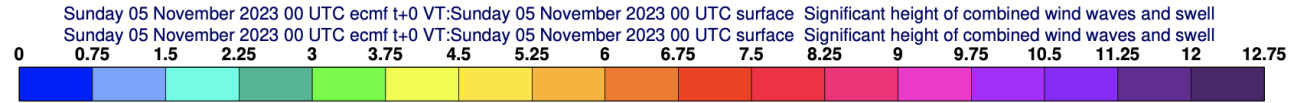
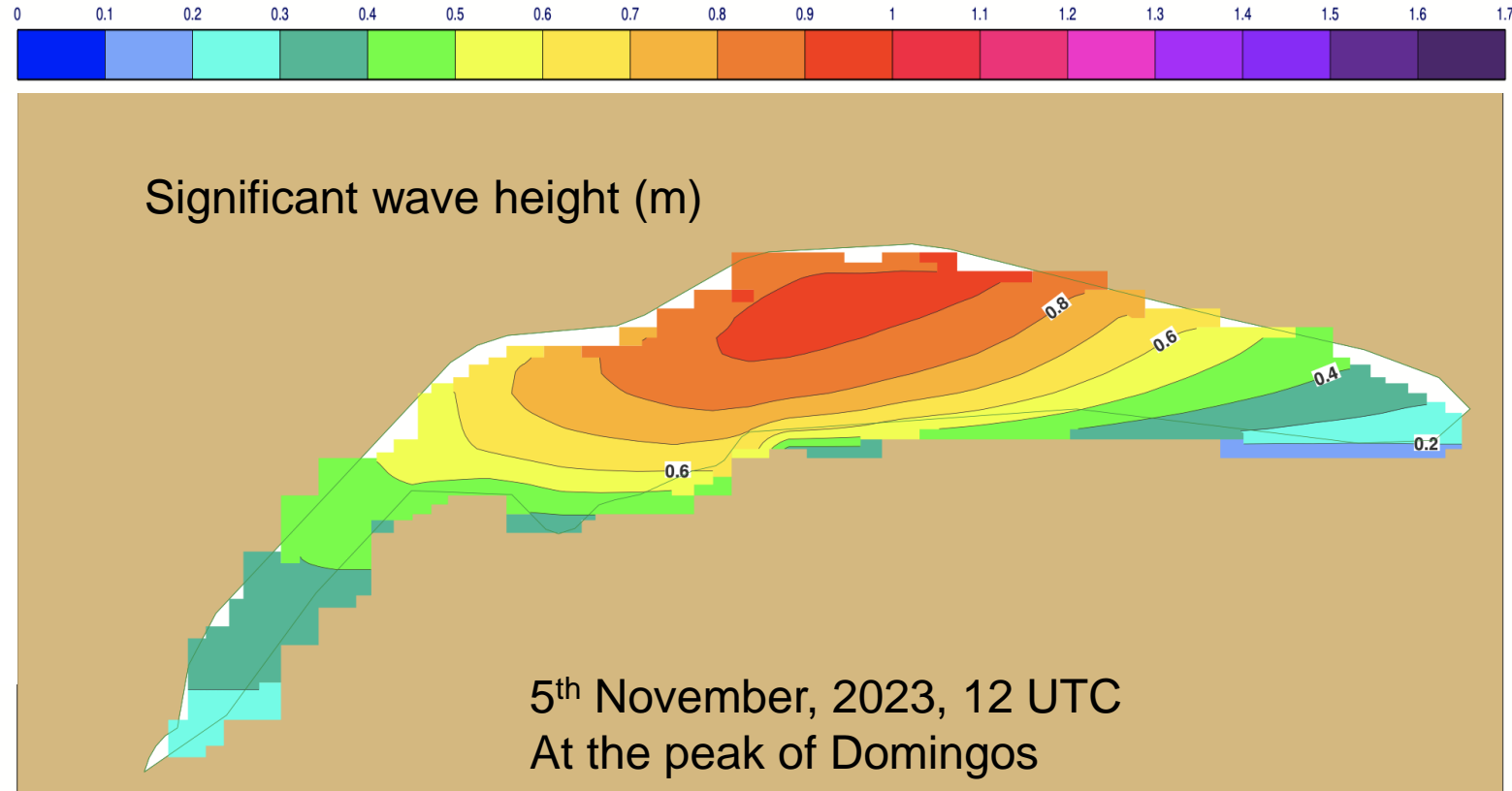# ecWAM stand alone on Tco7999 on <u>lakes</u>: first results

- Voila:

PLUIE ET VENTS VIOLENTS

Actualisé 5. novembre 2023, 16:12

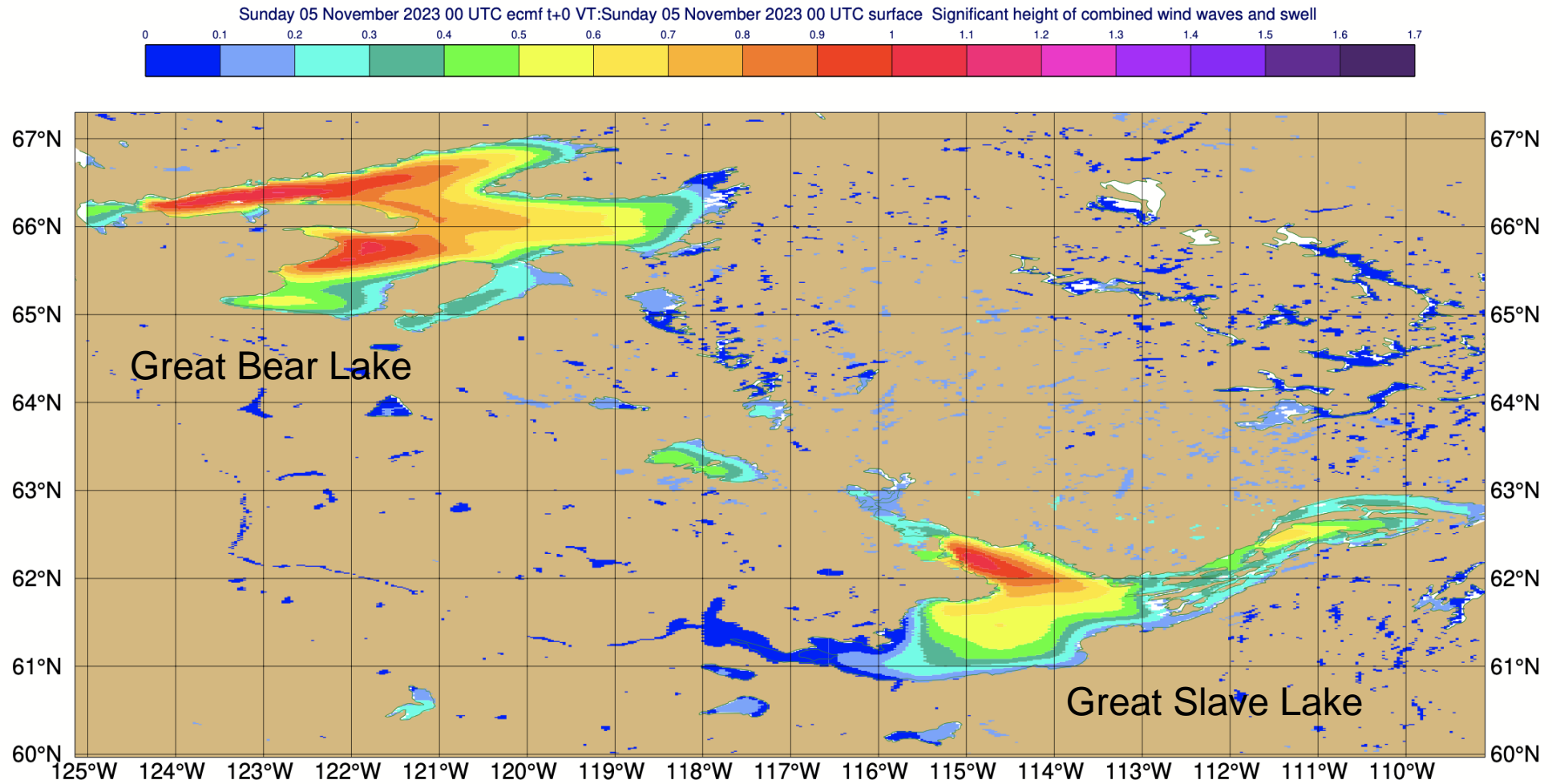## Chute d'arbres, bateau coulé, la tempête Domingos a secoué la Suisse romande

Après avoir traversé la France, la tempête Domingos a décoiffé notre pays. De nombreux bateaux ont dû interrompre leur service.
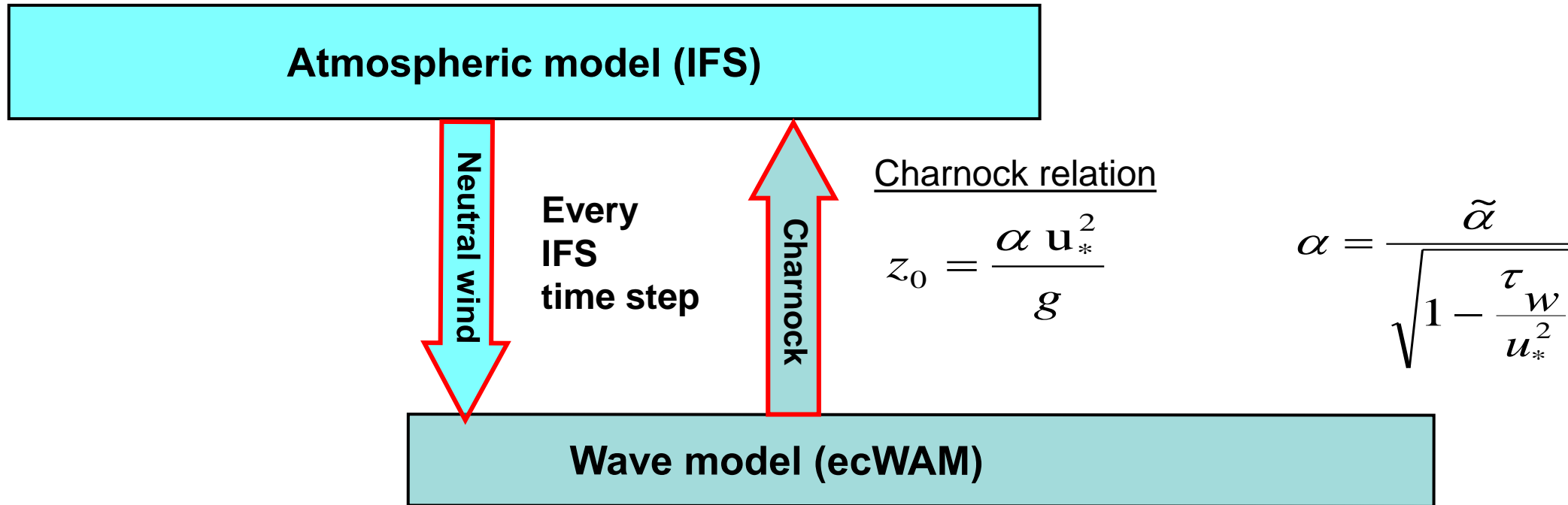
Significant wave height (m)

5th November, 2023, 12 UTC
At the peak of Domingos

https://www.lematin.ch/story/suisse-la-tempete-domingos-met-a-quai-la-cgn-734402605380

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ecWAM stand alone on Tco7999 on lakes: first results

Sunday 05 November 2023 00 UTC ecmf t+0 VT:Sunday 05 November 2023 00 UTC surface Significant height of combined wind waves and swell

Great Bear Lake

Great Slave Lake

Atmosphere- ocean wave system

Atmospheric model (IFS)

Neutral wind

Every IFS time step

Charnock

Wave model (ecWAM)

Charnock relation

$$z_0 = \frac{\alpha \, \mathbf{u}_*^2}{g}$$

$$\alpha = \frac{\widetilde{\alpha}}{\sqrt{1 - \dfrac{\tau_w}{u_*^2}}}$$

Wave induced kinematic stress:

$$\tau_w = \frac{\rho_w}{\rho_a} g \int d\omega \, d\theta \, \frac{1}{c} S_{in}$$

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NB: there is also a two-way coupling with the ocean, Not shown here.

Coupled runs

• To calculate surface exchanges, the IFS splits each grid box into a number of tiles that represent the different surface types.

• Over the lake tile, the aerodynamical roughness length scale is modelled with the Charnock relation with a constant Charnock coefficient (0.018).

Could we consider running the wave model to update Charnock over all **resolved lakes** as done for the oceans.

From the distribution of lake cover at very high resolution (30m),we have determined that on average, lakes with **lake cover > 0.65** had enough connected water surface to warrant the use of the wave model.

Lake cover > 0.65
Tco1279 grid (9km)

Lake depth (m) for lake cover > 0.65
Tco1279 grid (9km)

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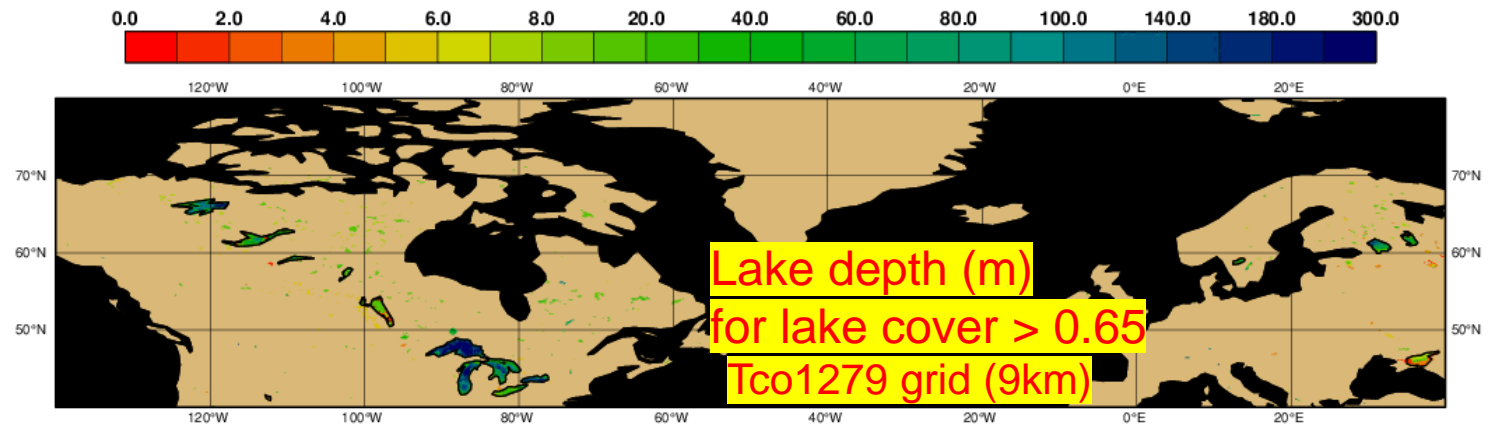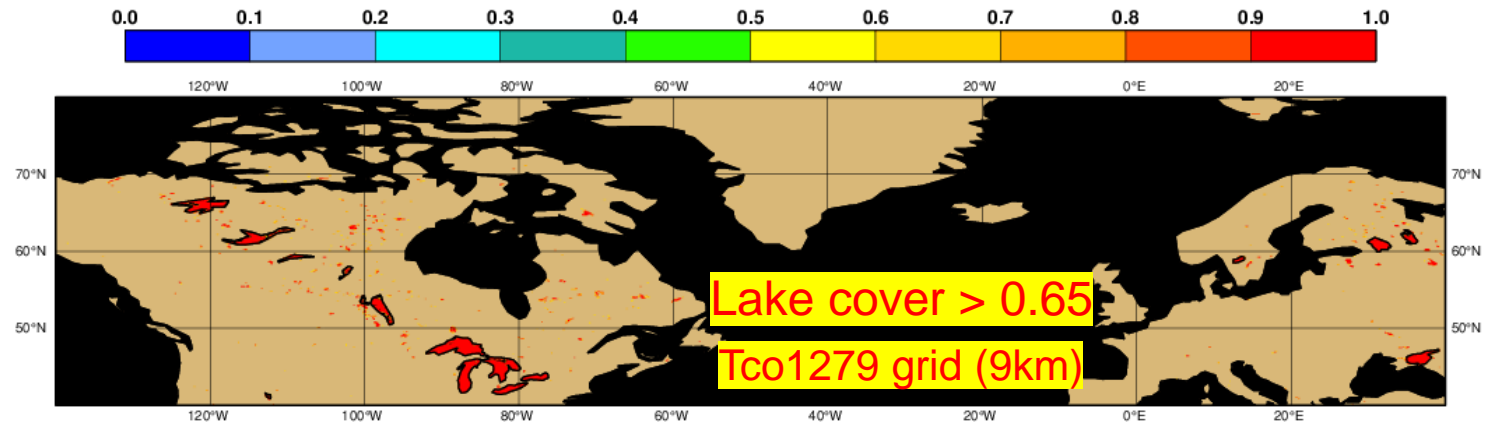
Coupled runs, preliminary results

- 10-day forecast experiments at Tco1279 (9km) resolution were run from June to November 2023.

- Verification against operational analysis.

- No real impact detected

- …

Change in RMS error in Z (CY49R1.0_for_CY49R2_with_lakes−CY49R1.0_for_CY49R2)
1−Jun−2023 to 14−Nov−2023 from 157 to 167 samples. Verified against 0001.
Cross−hatching indicates 95% confidence with Sidak correction for 20 independent tests.

Geopotential
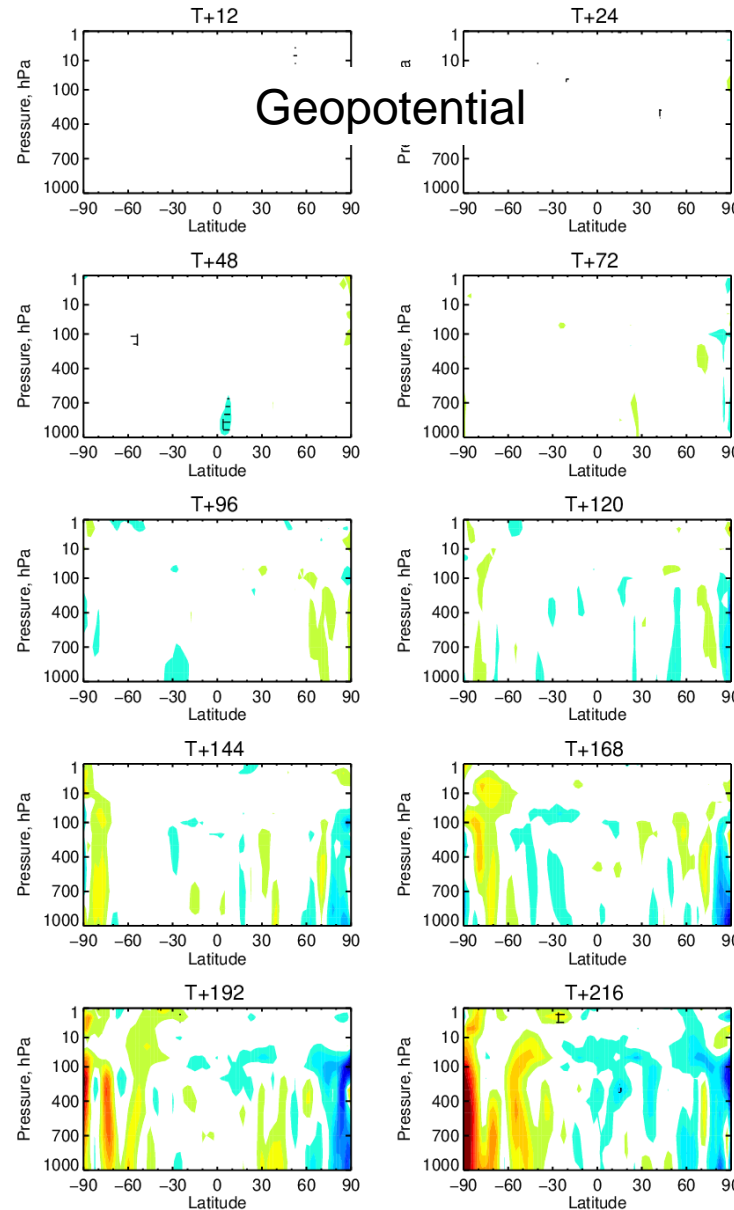
Change in RMS error in T (CY49R1.0_for_CY49R2_with_lakes−CY49R1.0_for_CY49R2)
1−Jun−2023 to 14−Nov−2023 from 157 to 167 samples. Verified against 0001.
Cross−hatching indicates 95% confidence with Sidak correction for 20 independent tests.

Temperature
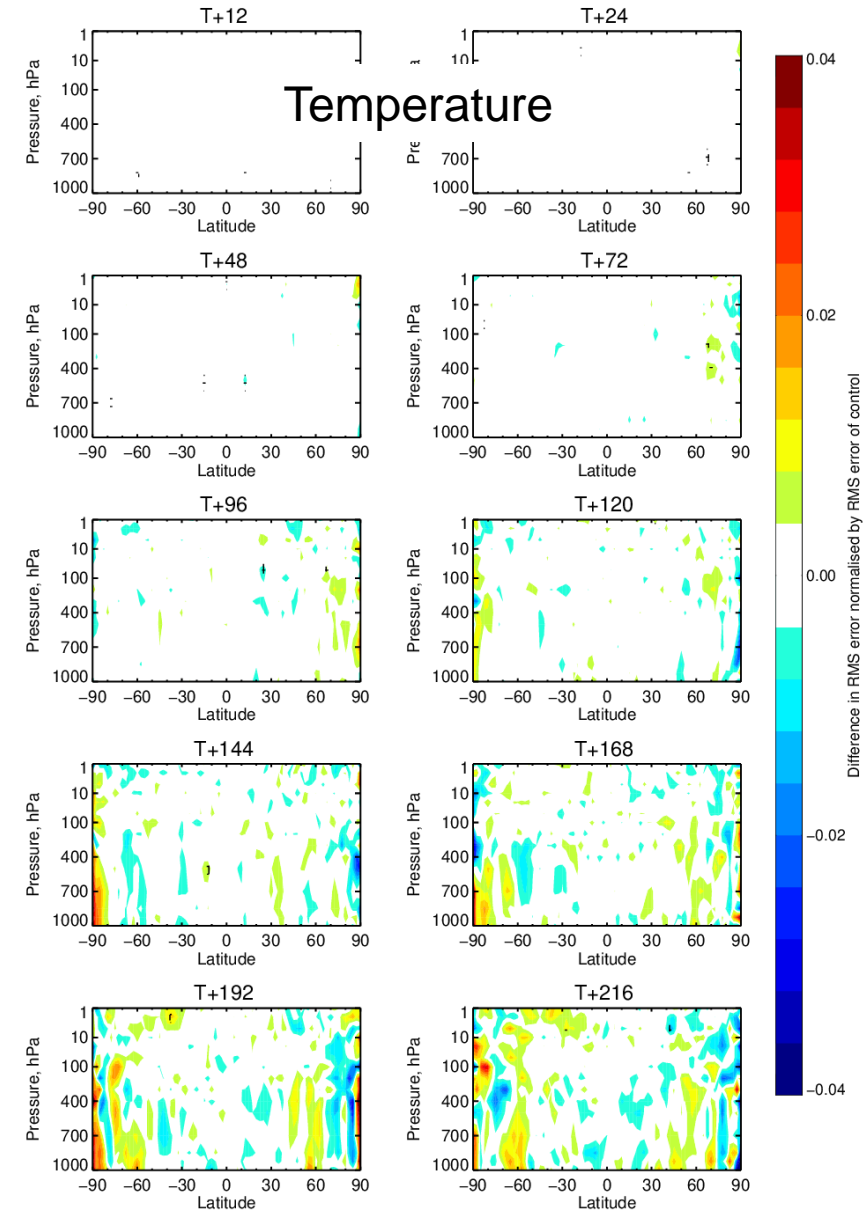
ecWAM stand alone on Tco7999 on lake Titicaca : first results

Sunday 05 November 2023 12 UTC ecmf t+0 VT:Sunday 05 November 2023 12 UTC surface Significant height of combined wind waves and swell
Sunday 05 November 2023 12 UTC ecmf t+0 VT:Sunday 05 November 2023 12 UTC surface Significant height of combined wind waves and swell

NB: still with sea level air density

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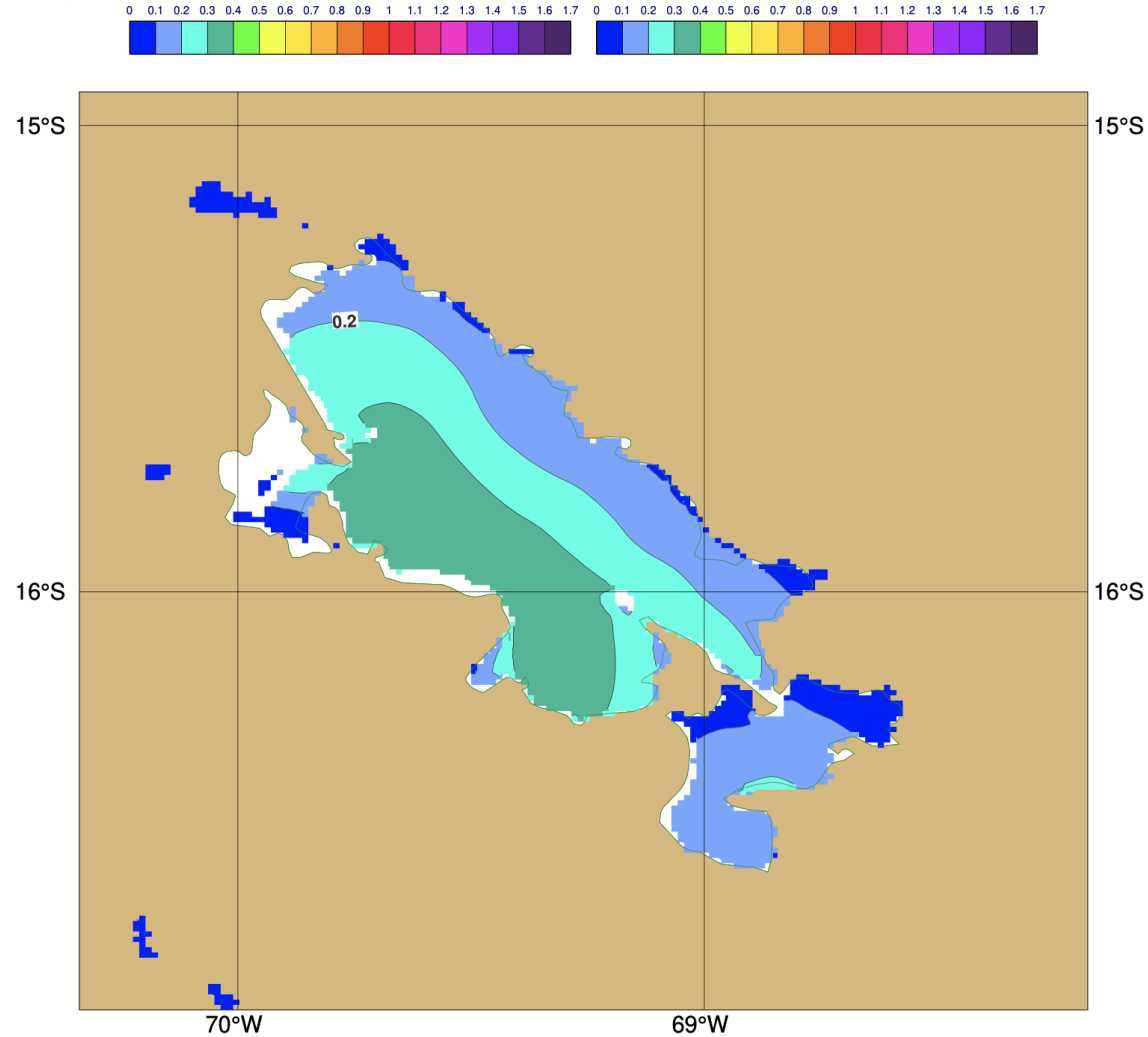
Wave observations from lake Titicaca

Following Alex Babanin efforts, colleagues in Bolivia have managed to deploy a moored Spotter buoy for a short period (29 March to 17 May 2023) just north of Isla de la Luna:
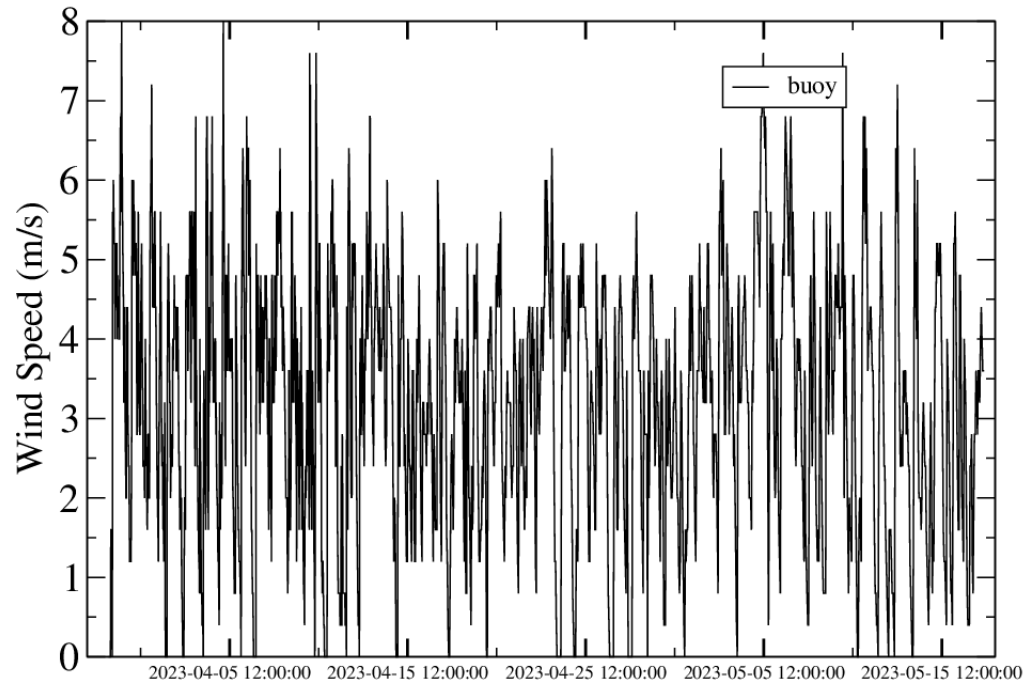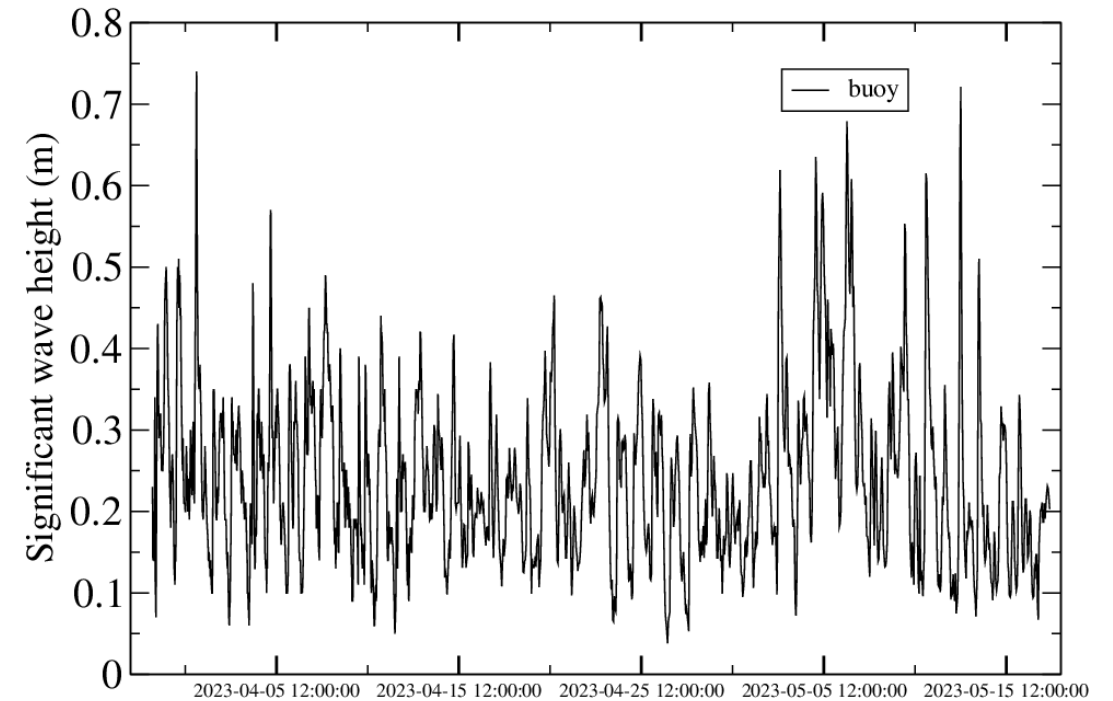
Data were kindly provided by Joey Voermans at University of Melbourne
Wind data were derived from an experimental algorithm using the buoy spectra.

Lake Titicaca

Peru

Lake altitude: 3,812m

Bolivia

buoy
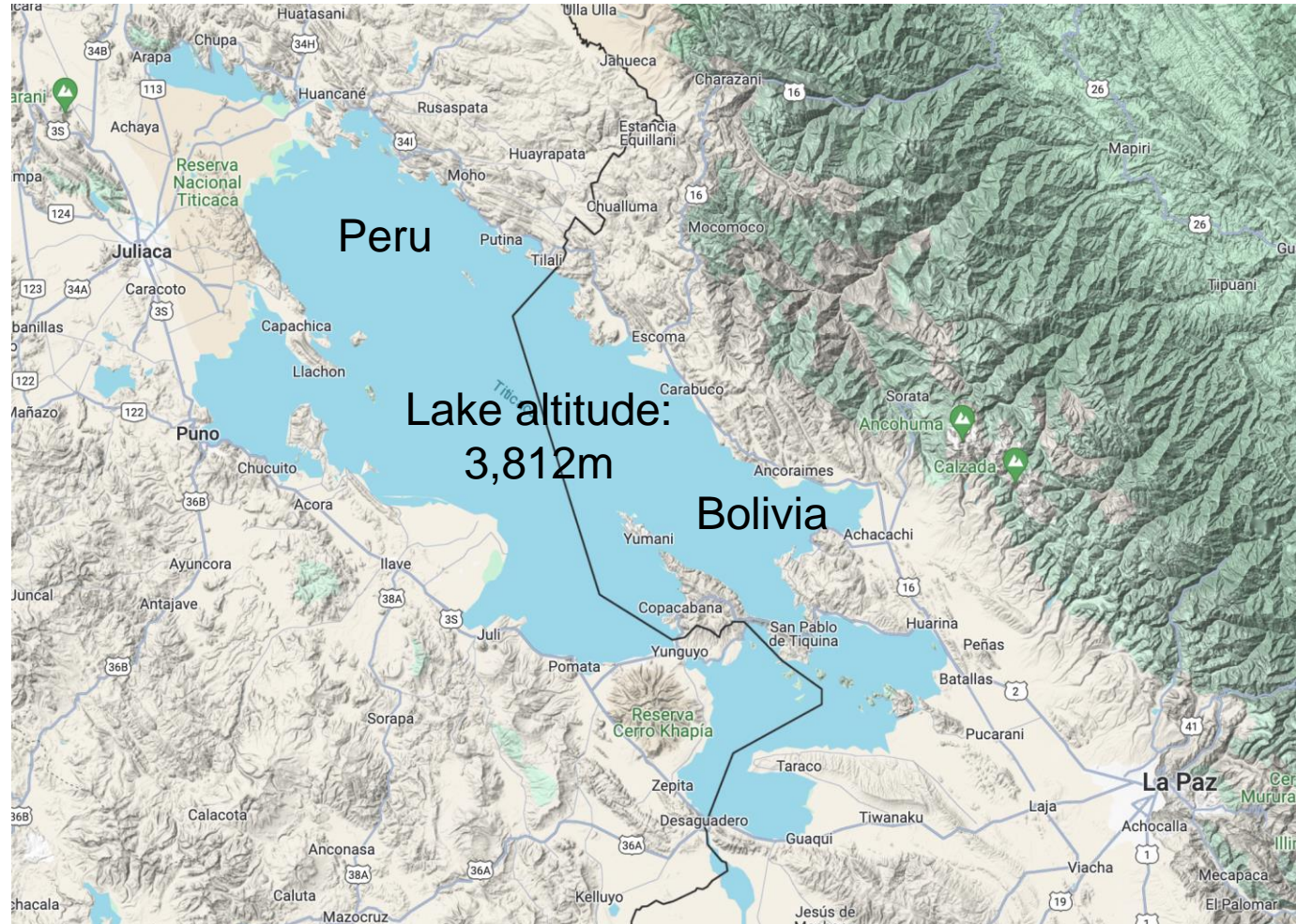
Lake Titicaca: lake cover on a 0.08° x 0.08° grid

lake cover

lake cover > 0.65

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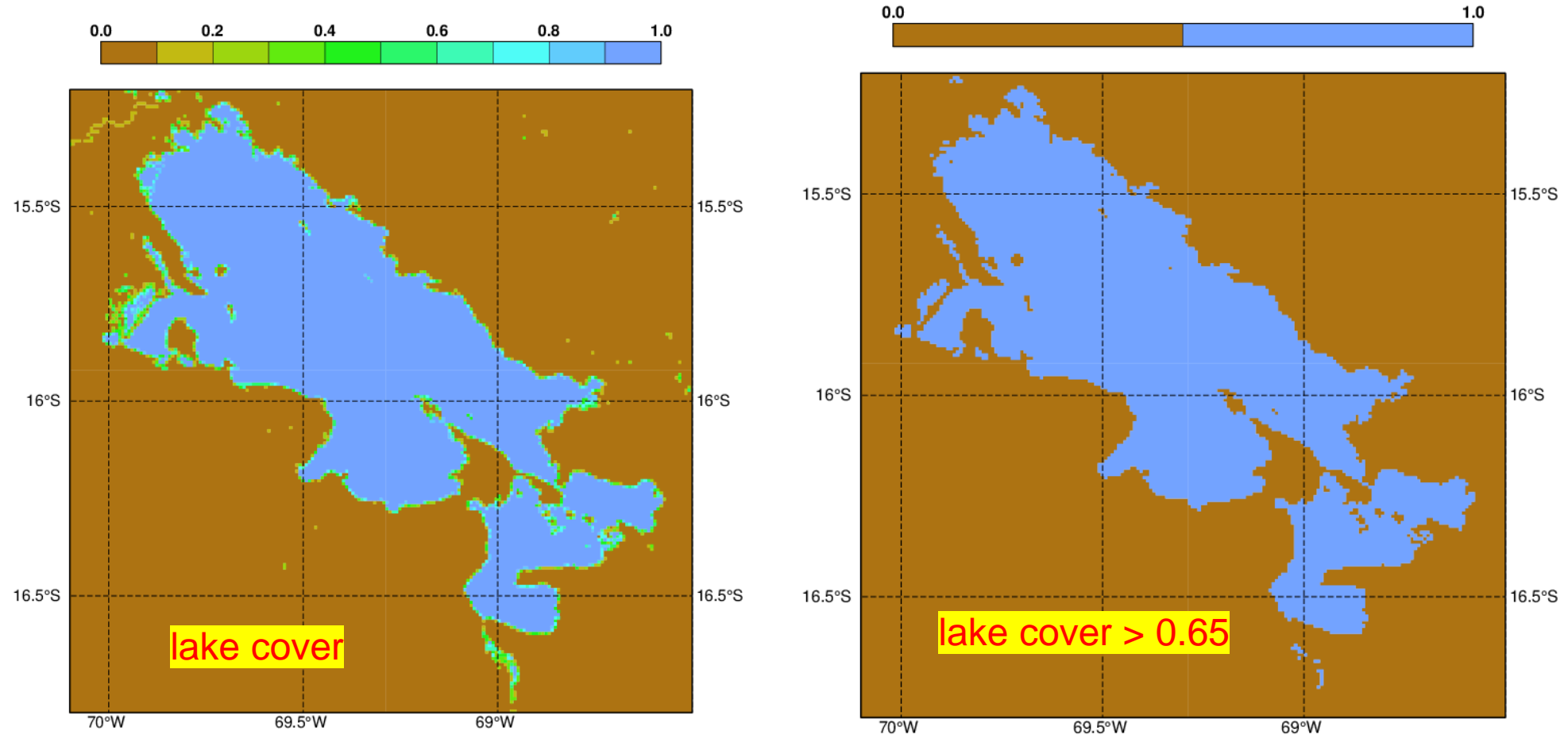
Reconstructed lake depth on a 0.08° x 0.08° grid

Using the lake cover data and the bathymetric data, we have restructured the lake depth map:
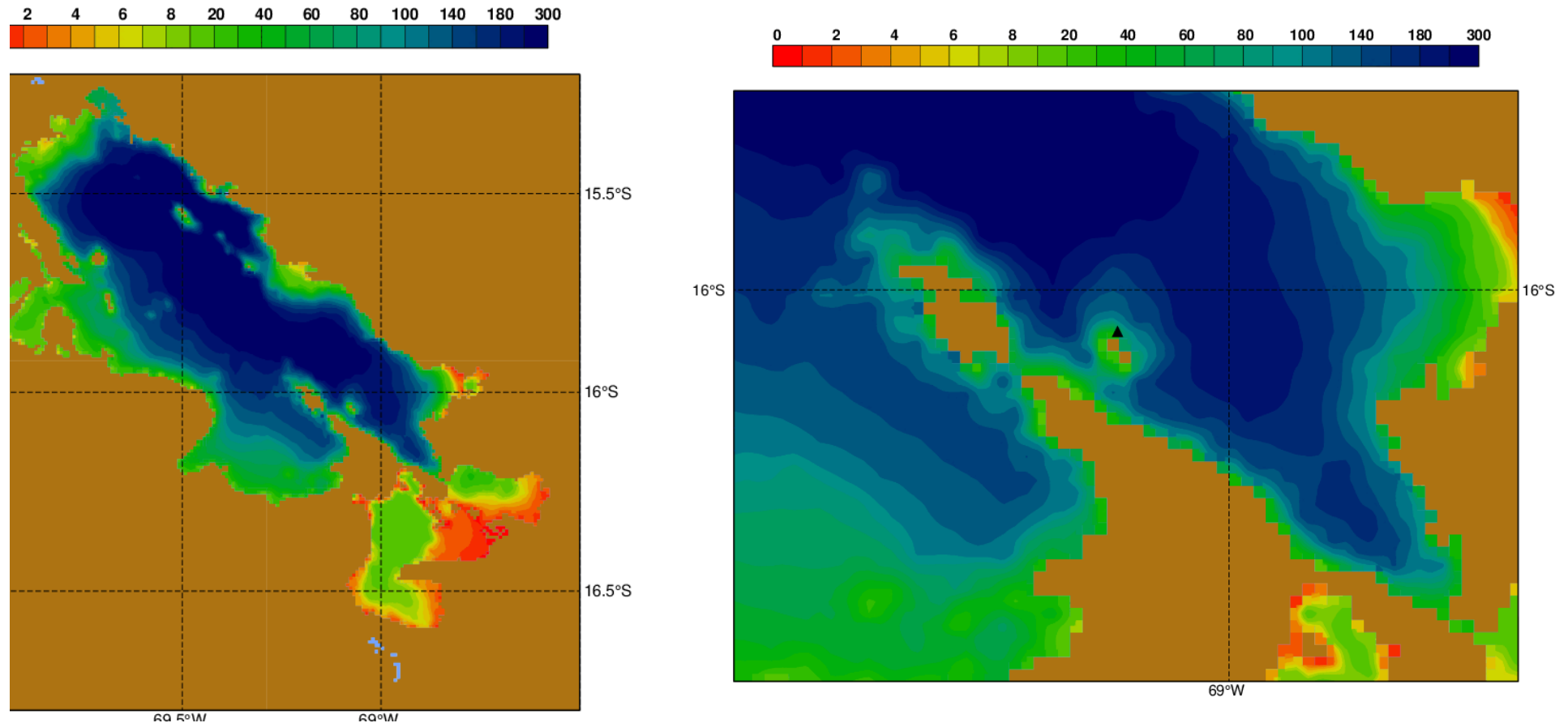
Bathymetric data kindly provided by Francois Duquesne
Duquesne et al. 2021:
https://doi.org/10.1016/j.ecolmodel.2020.109418

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ecWAM <u>stand</u> alone simulation for lake Titicaca only:

- 0.08° x 0.08° (~ 1km) grid, 36 frequencies, first frequency 0.06 Hz, 48 directions.

- 45 s time steps.

- ecWAM CY49R1 (physics Ardhuin et al. 2010 + Janssen and Bidlot 2023).

- Air density changed from 1.225 kg/m^3 to 0.785 kg/m^3.

- Wind forcing:
  - ERA5 cannot be used as too low resolution.
  - Operational analysis is only available every 6 hours (need hourly forcing).
  - Use short range forecasts from 0 and 12 UTC (steps 3 to 14 hours) at operational resolution Tco1279 (9 km) and DestinE resolution Tco2559 (4.4 km) based on the latest CY49R1 with resolved lakes.
  - ...

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Wind and waves

2023-05-05 0 UTC
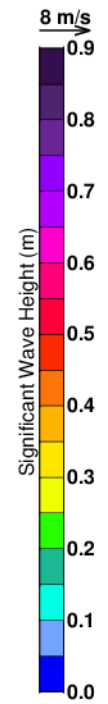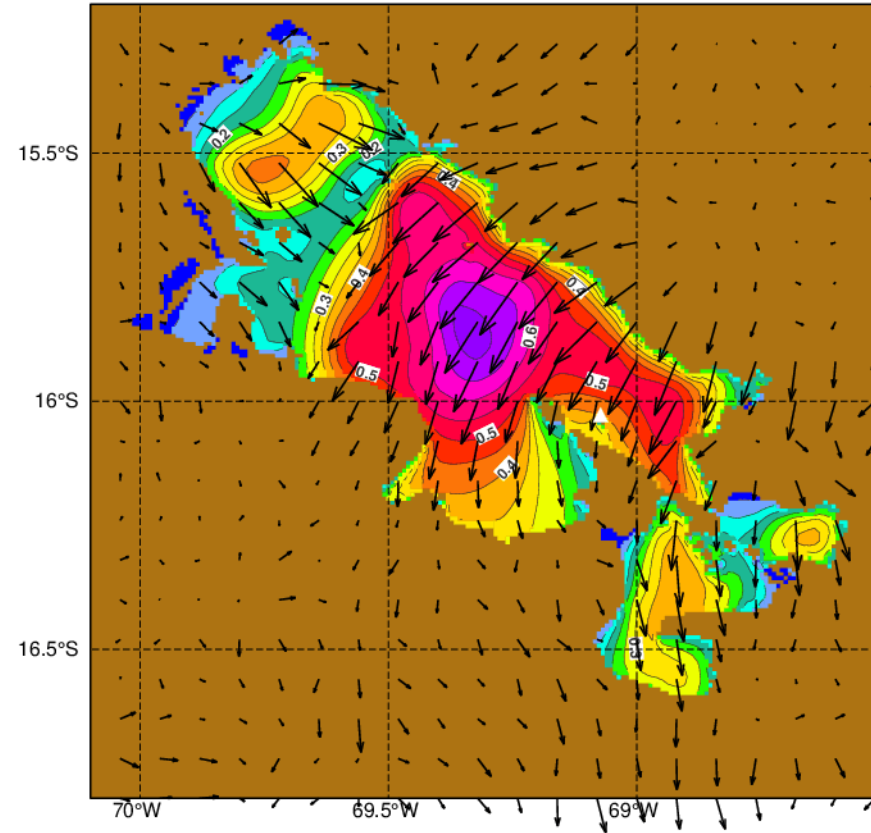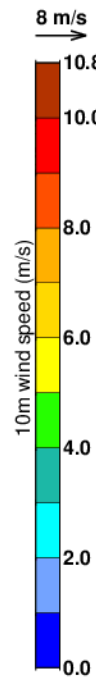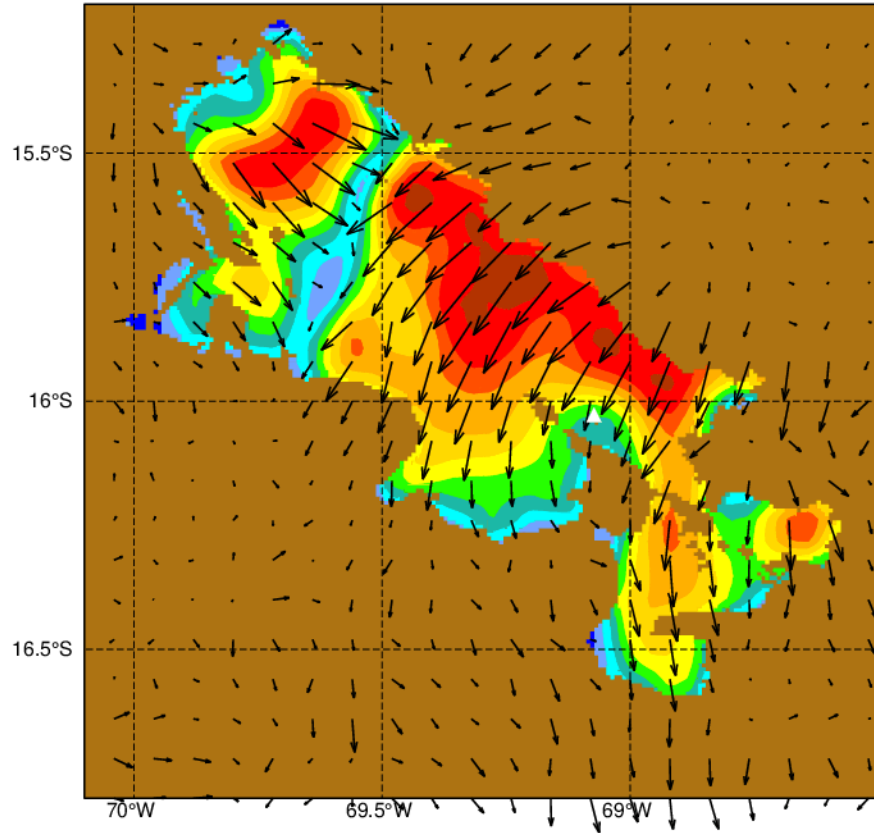
Wind and waves

2023-05-05 6 UTC
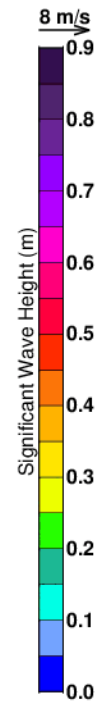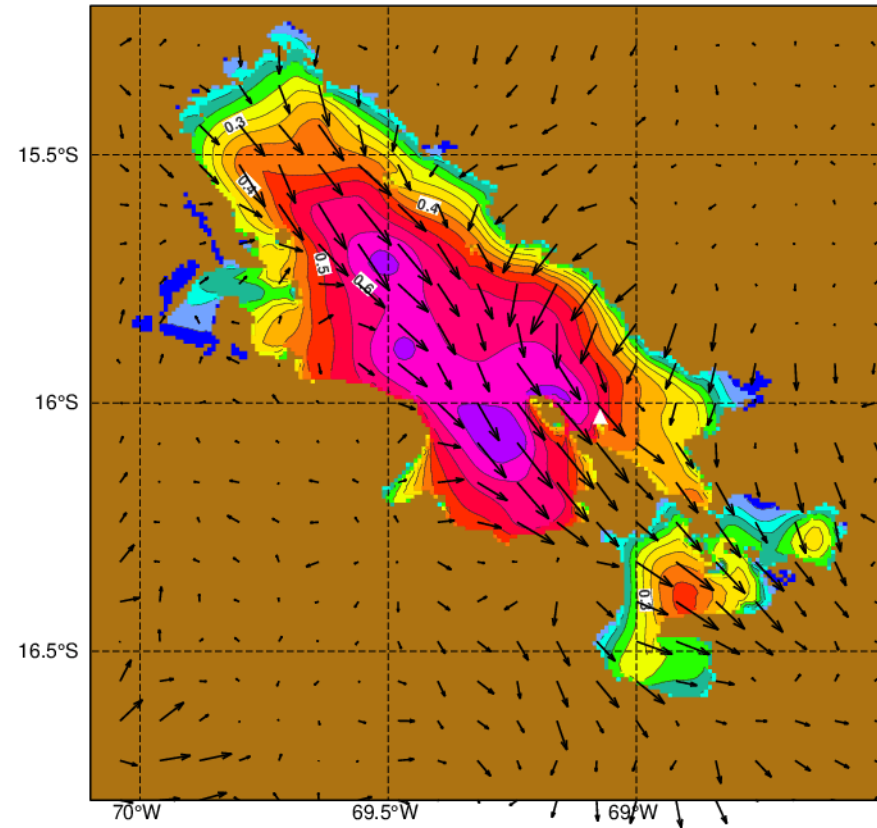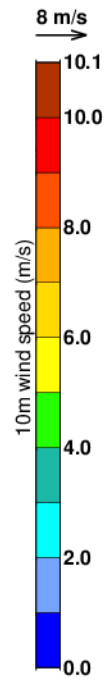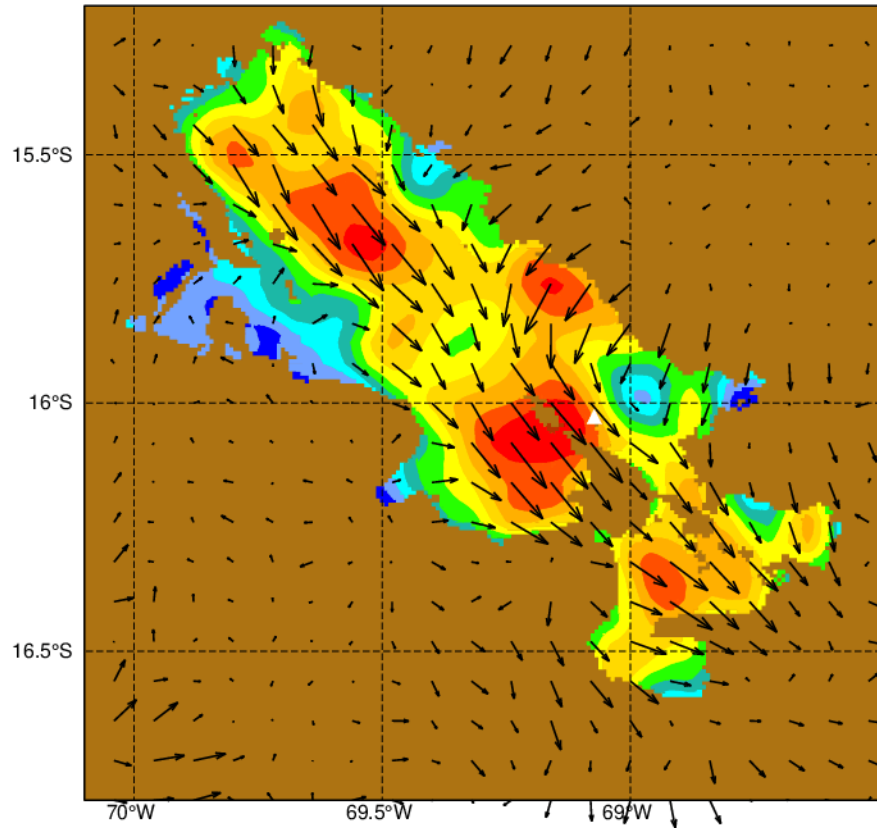
Wind and waves

2023-05-05 12 UTC
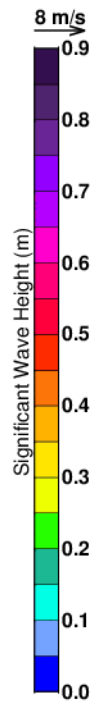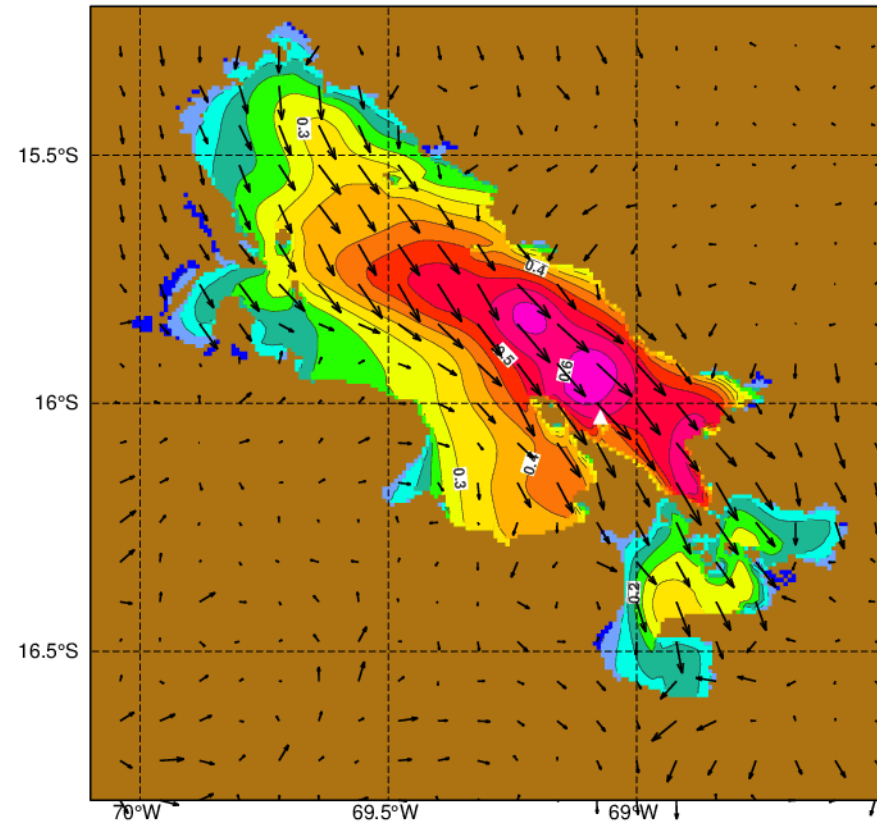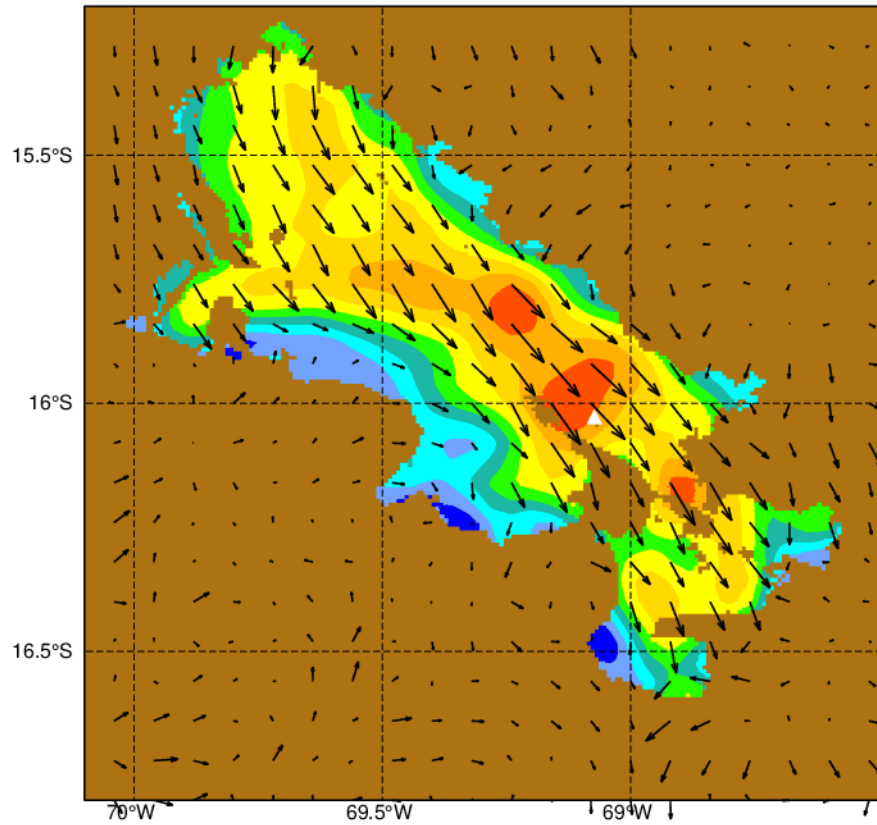
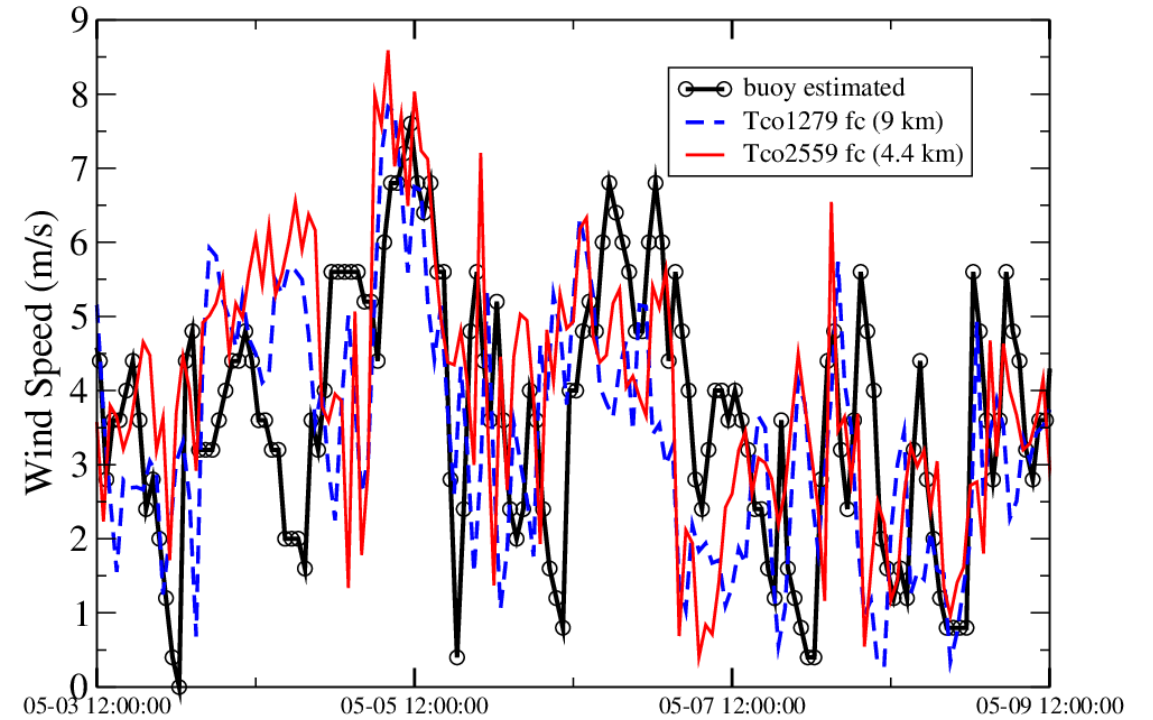# Impact of air density change on waves

2023-05-05 12 UTC
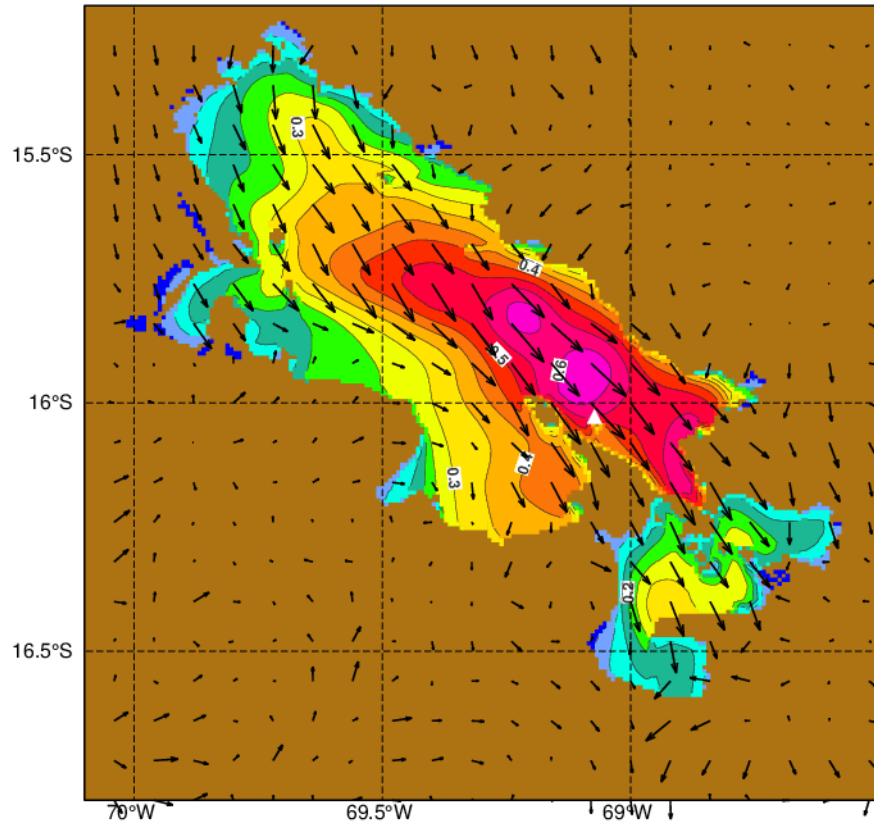
Significant Wave Height
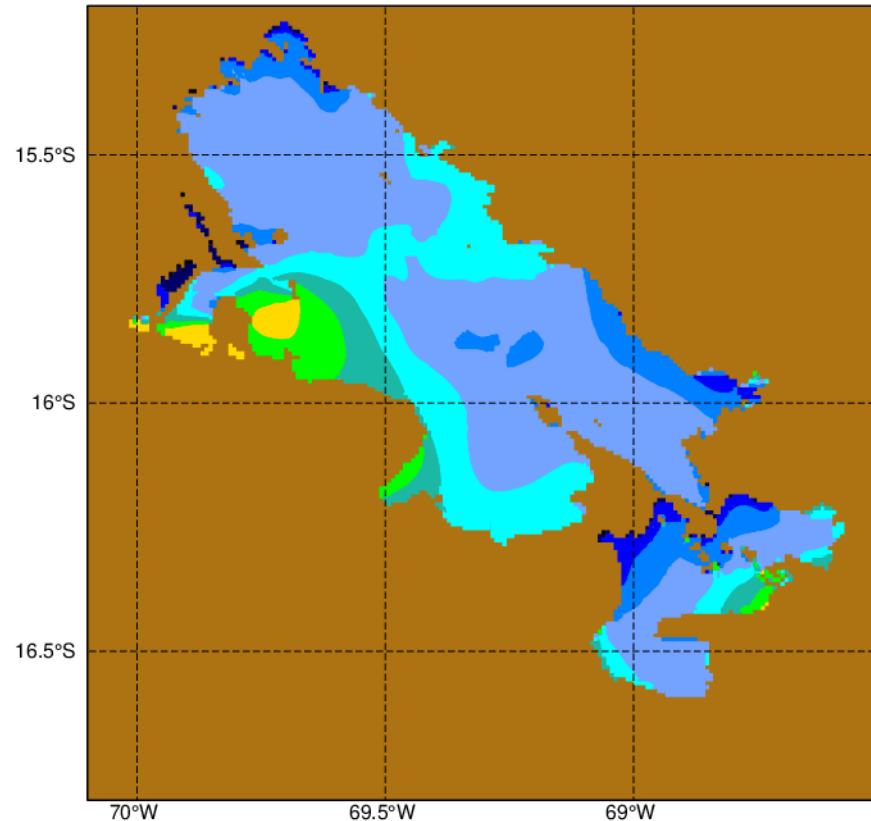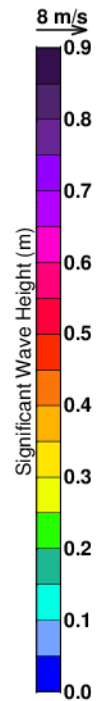
Relative change in Significant Wave Height
(air density 0.785 kg/m^3 - 1.225 kg/m^3)
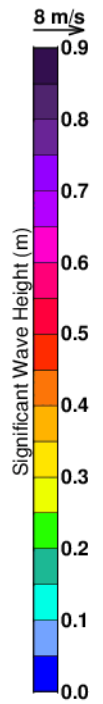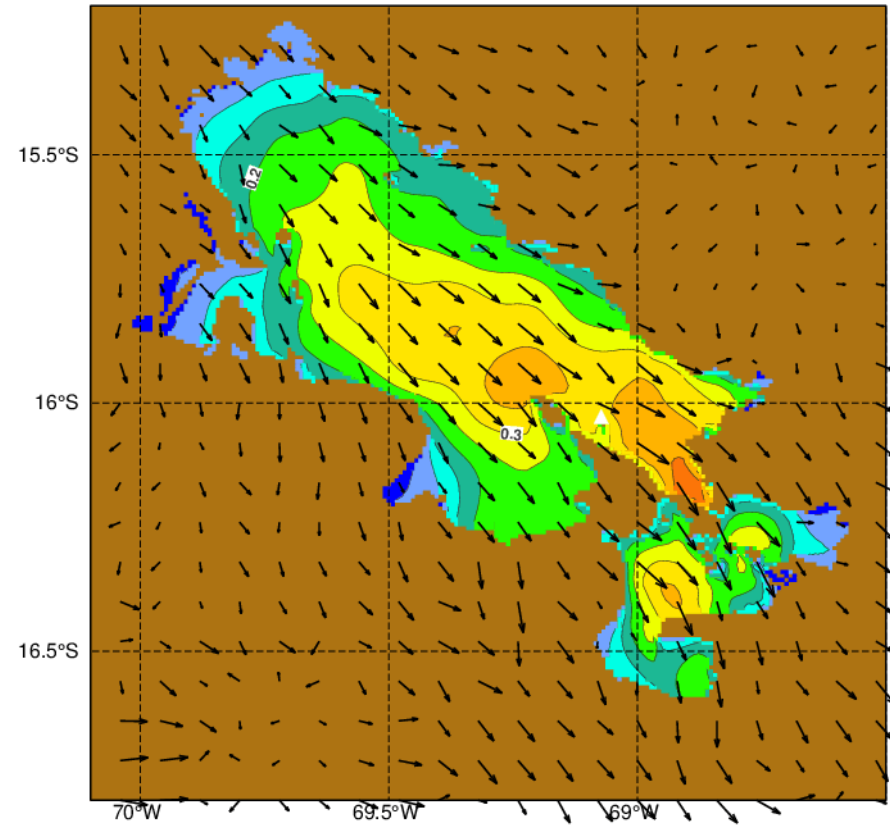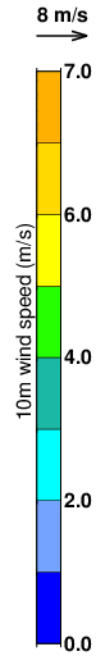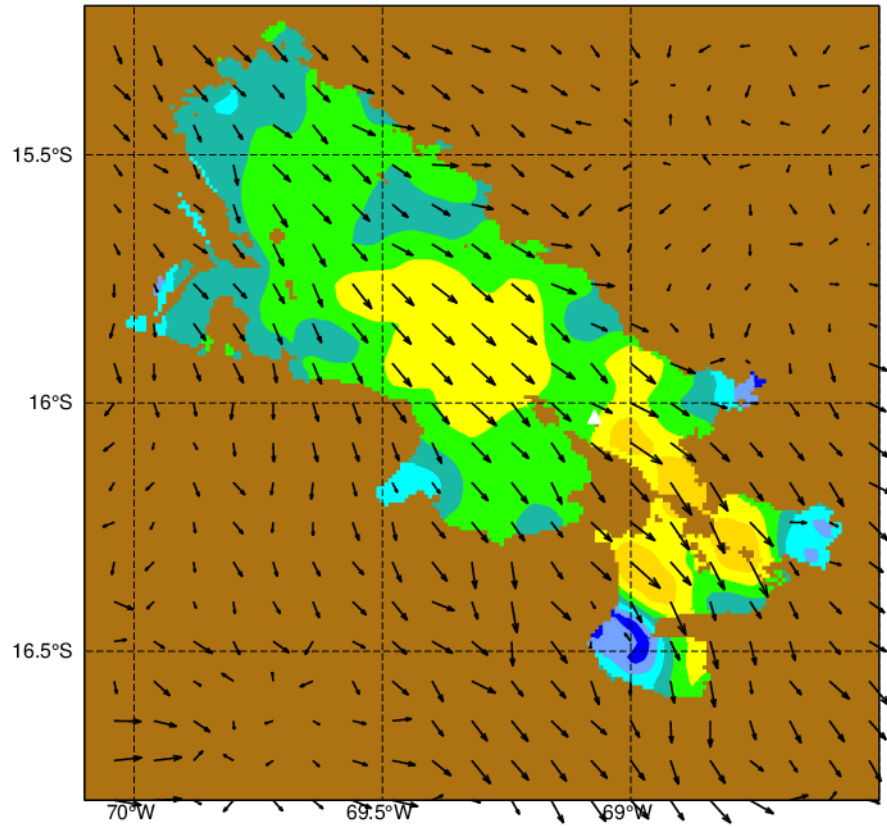
Preliminary comparison to buoy observations
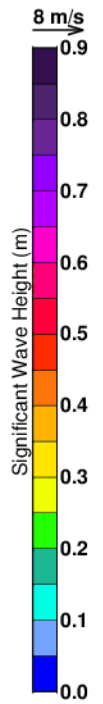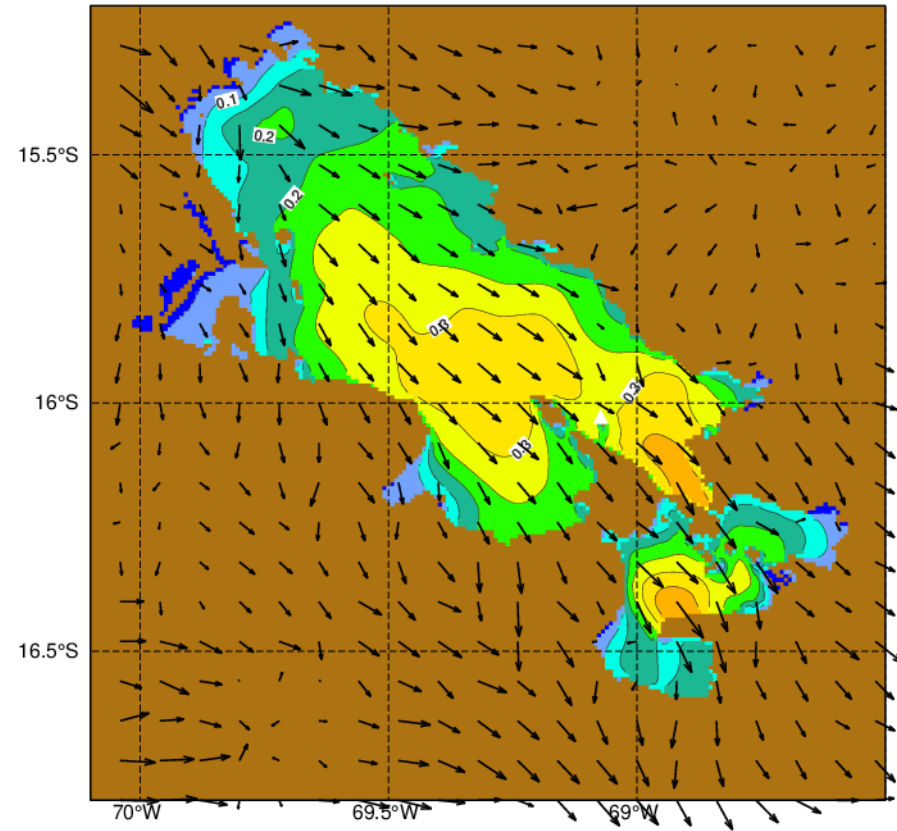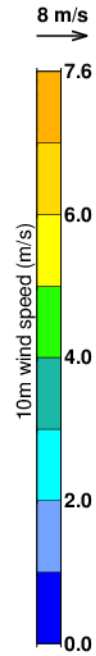

Significant Wave Height (m)
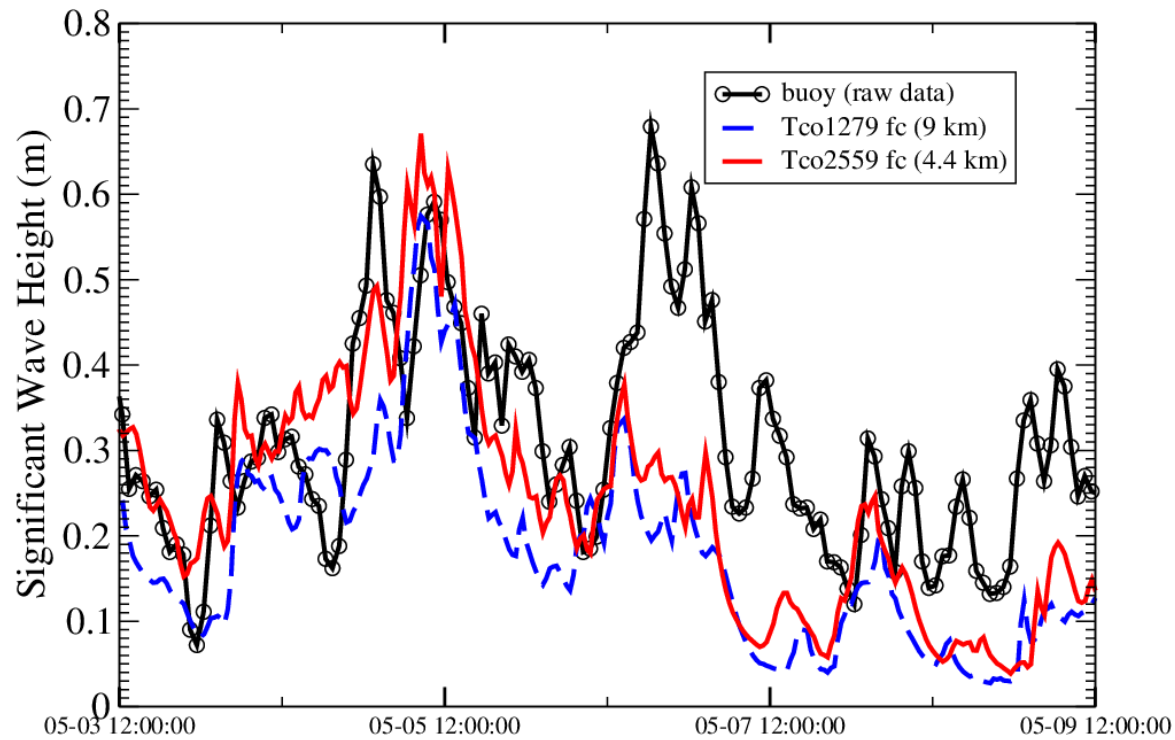
Estimated Wind Speed (m/s)

Wind and waves

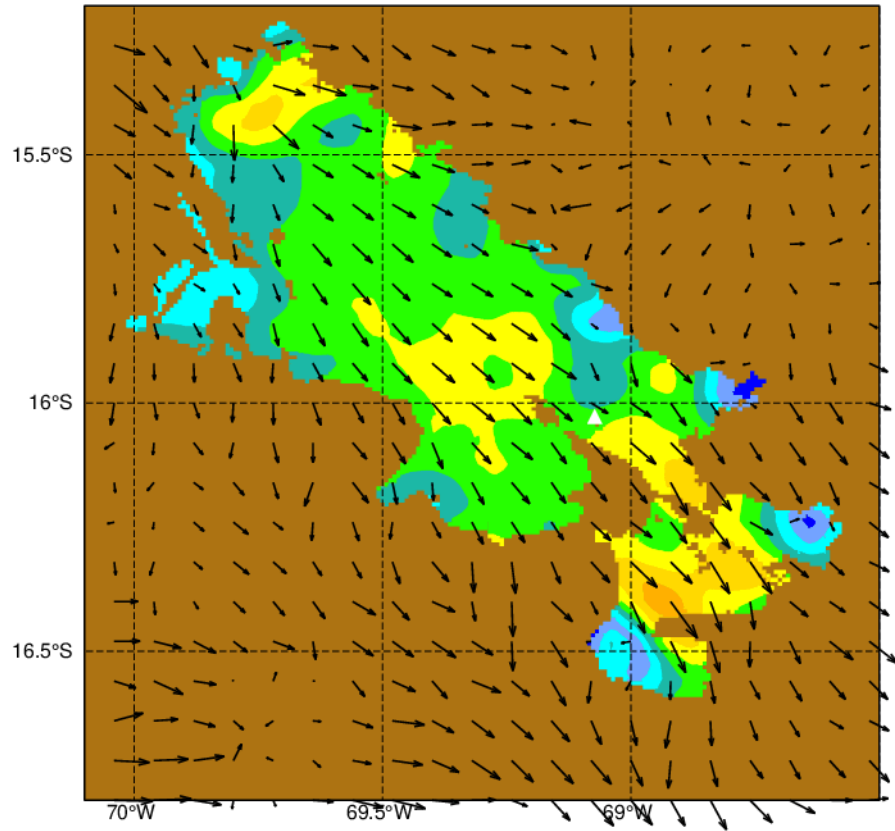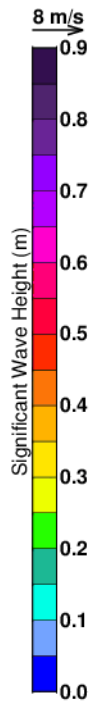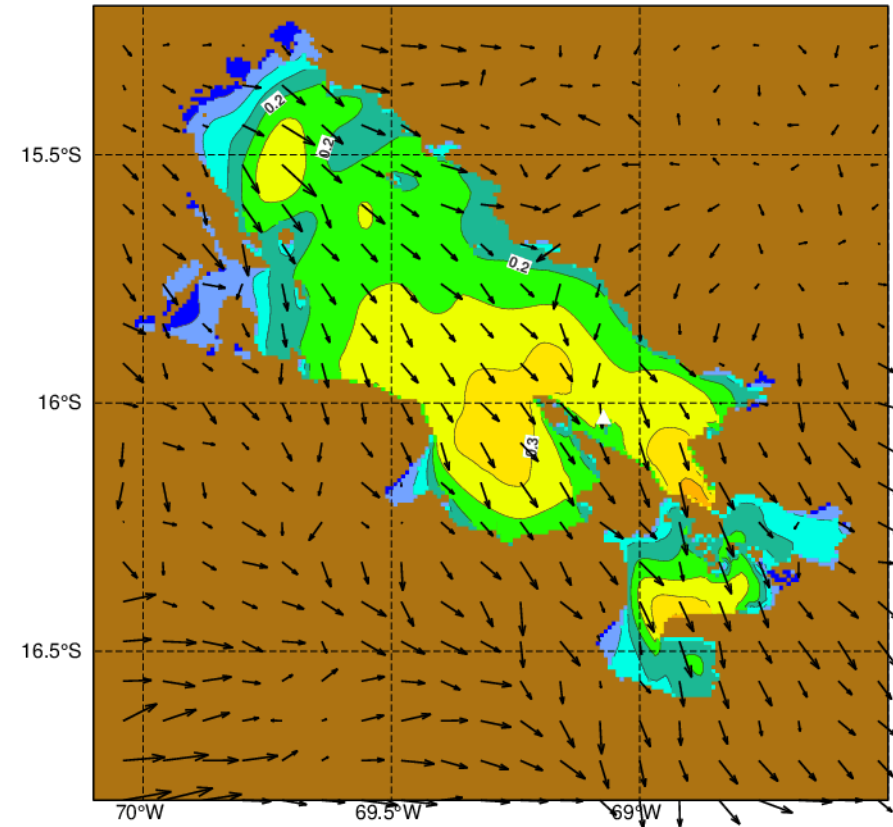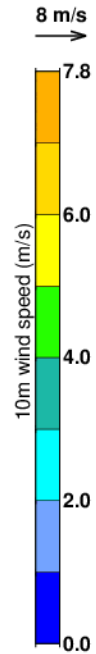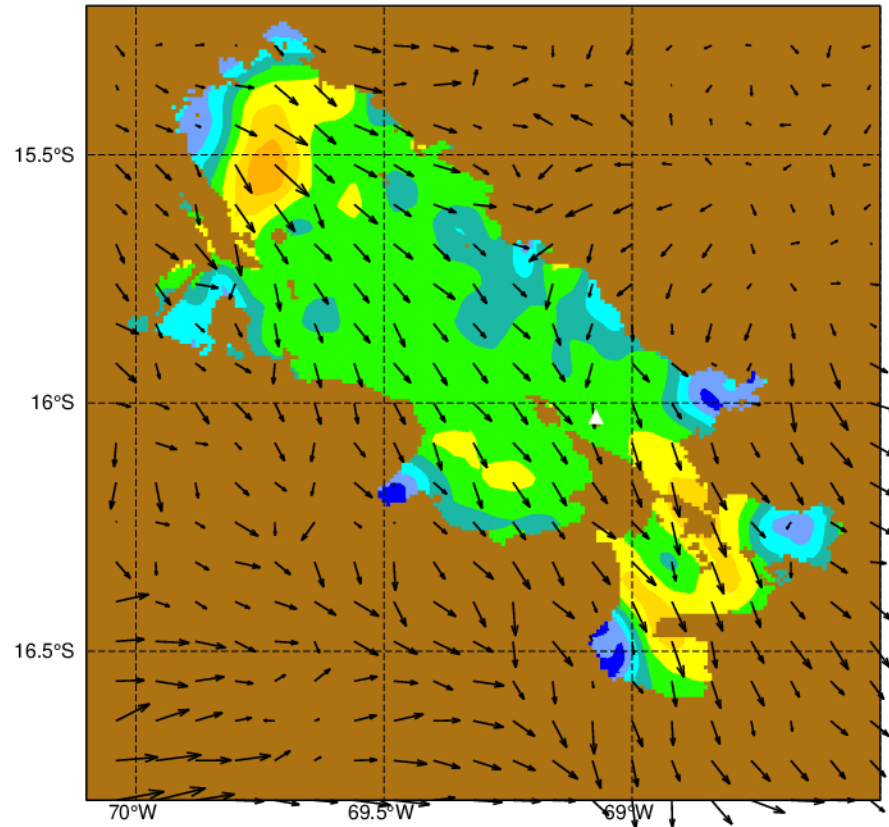2023-05-06 15 UTC

Wind and waves

2023-05-06 16 UTC

Wind and waves

2023-05-06 17 UTC

Conclusions

- Global wave model simulation at 1.4 km with resolved lakes included can be run with ecWAM.

- So far, no impact on atmospheric scores were found when running wave model on resolved lakes .

- But it still means that we can provide wave data on lakes.

- Modelling waves on lake Titicaca is an ongoing challenge.

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