# High-resolution wind speed modeling, and an assessment of mesoscale peculiarities caused by coastline parameters and relief at near-shore Kara Sea regions

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# Motivation

- The **Arctic** is the region most sensitive to ***climate change*** on the globe.
- ***Poor observational network*** and the increasing number of ***severe events*** in the region requires its ***more detailed*** investigation.
- Available data covering Arctic – ***satellite*** (QuikSCAT, AMSR-E, ... grid >~20 km), ***reanalyses*** (e.g., ASR, 15 and 30 km grid) has ***not enough*** resolution to reproduce mesoscale extreme events and many other important circulation features.
- One of the most efficient tool to get more information and to ***study severe events*** in Arctic is **regional climate modeling**.
- The **main goal** is to investigate the ***capability*** of mesoscale, non-hydrostatic ***model*** to ***reproduce*** atmospheric circulation features over the Kara Sea ***coastal areas***, under conditions of ***strong winds*** and ***diverse surface inhomogeneity***, using different spatial scales.

# Methods

The main tool is the **COSMO-CLM** regional non-hydrostatic atmospheric climate model.

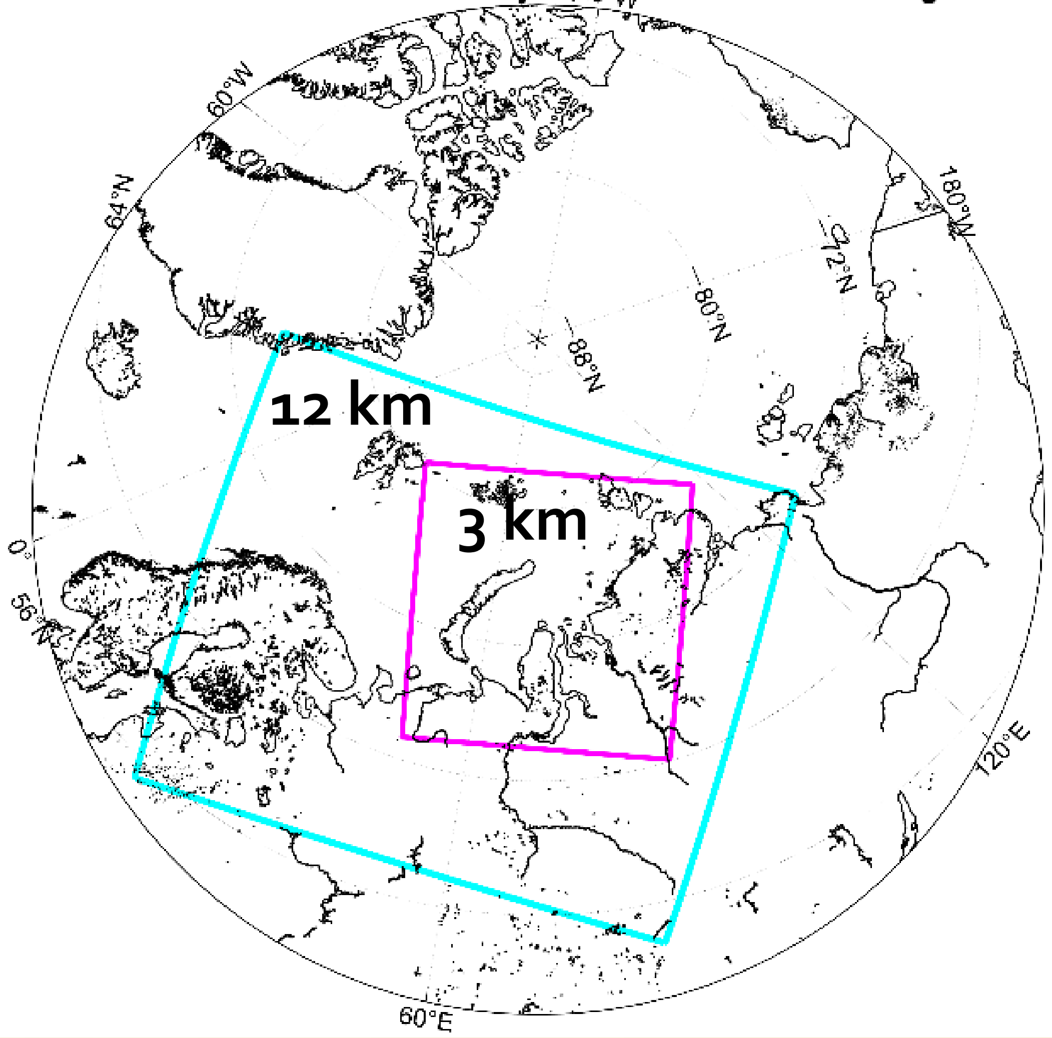
**COSMO-CLM (ver. 5)** is the climate version of the well-known mesoscale model **COSMO** developed by DWD and CLM-Community (https://wiki.coast.hzg.de/clmcom).

| ***Brief model description*** |
| --- |
| Runge-Kutta integration scheme with 5th advection order |
| height-based hybrid Gal-Chen coordinate |
| Ritter and Geleyn radiation scheme |
| bulk microphysics parameterization |
| Tiedtke mass-flux schemes used for moist and shallow convection |
| turbulence is described by a prognostic TKE-based scheme, with 2.5 order closure |
| Smagorinsky diffusion; |


MSU Supercomputer Complex **"Lomonosov-2"**

# Experiments design

- **Downscaling scheme** includes two steps of nested domains. The first step is the domain horizontal resolution ~12 km, ***forced by global reanalysis*** ERA-Interim.
- The high-resolution domain (~3 km) covers **Kara Sea** in the second step.




**Test experiments** carried out using following configuration changes:

- Switch on the **'spectral nudging'** technique (***_sn**);
- Model time step was changed from **dt=100 s** to **dt=80 s** (***_dt**);
- The ***nested domain*** was enlarged to the South on **50 model grids** (***_large**).

**Experiments periods:**

***August–October 2012***, ***July–September 2014***

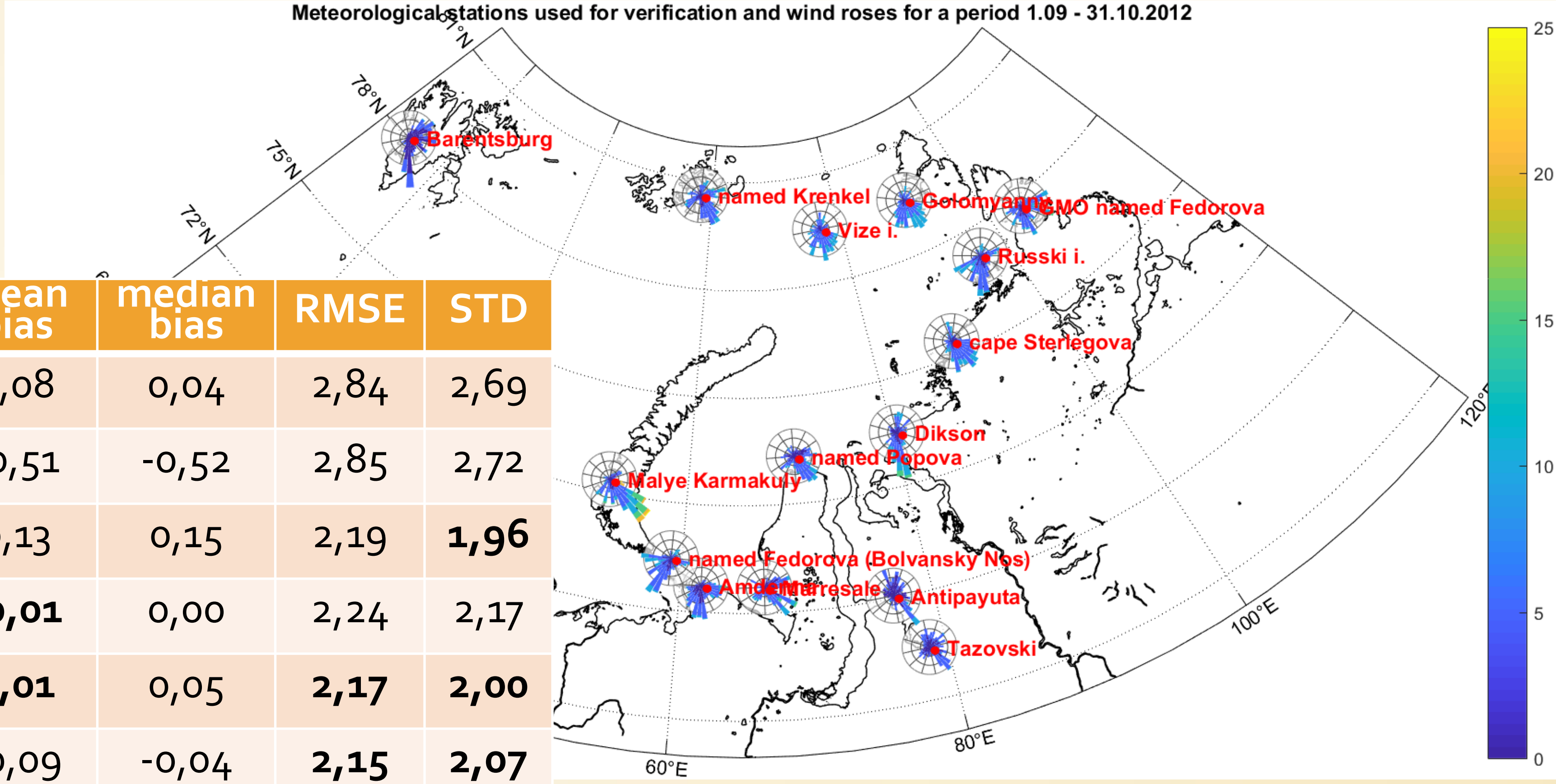
First months were used as ***'cold start'*** and didn't verified in analysis.

**14 experiments** run total.

# Experiments verification

**Spectral nudging + reduced dt** configuration was chosen as the best one

| 2012 | correlation coefficient | mean bias | median bias | RMSE | STD |
|---|---|---|---|---|---|
| 2012 13 km | 0,61 | 0,08 | 0,04 | 2,84 | 2,69 |
| 2012 3 km | 0,58 | -0,51 | -0,52 | 2,85 | 2,72 |
| 2012 13 km sn | **0,77** | 0,13 | 0,15 | 2,19 | **1,96** |
| 2012 3 km sn | **0,75** | **-0,01** | 0,00 | 2,24 | 2,17 |
| 2012 13 km sn dt | **0,78** | **0,01** | 0,05 | **2,17** | **2,00** |
| 2012 3 km sn dt | **0,77** | -0,09 | -0,04 | **2,15** | **2,07** |
| 2012 3 km sn large | 0,76 | -0,10 | -0,05 | 2,22 | 2,13 |
| reanalyses | | | | | |
| ERA-Interim | 0,73 | 0,39 | 0,43 | 2,25 | 2,05 |
| ERA5 | 0,79 | 0,25 | 0,31 | 2,05 | 1,80 |
| NCEP-CFSRv2 | 0,79 | 0,43 | 0,46 | 2,21 | 1,98 |

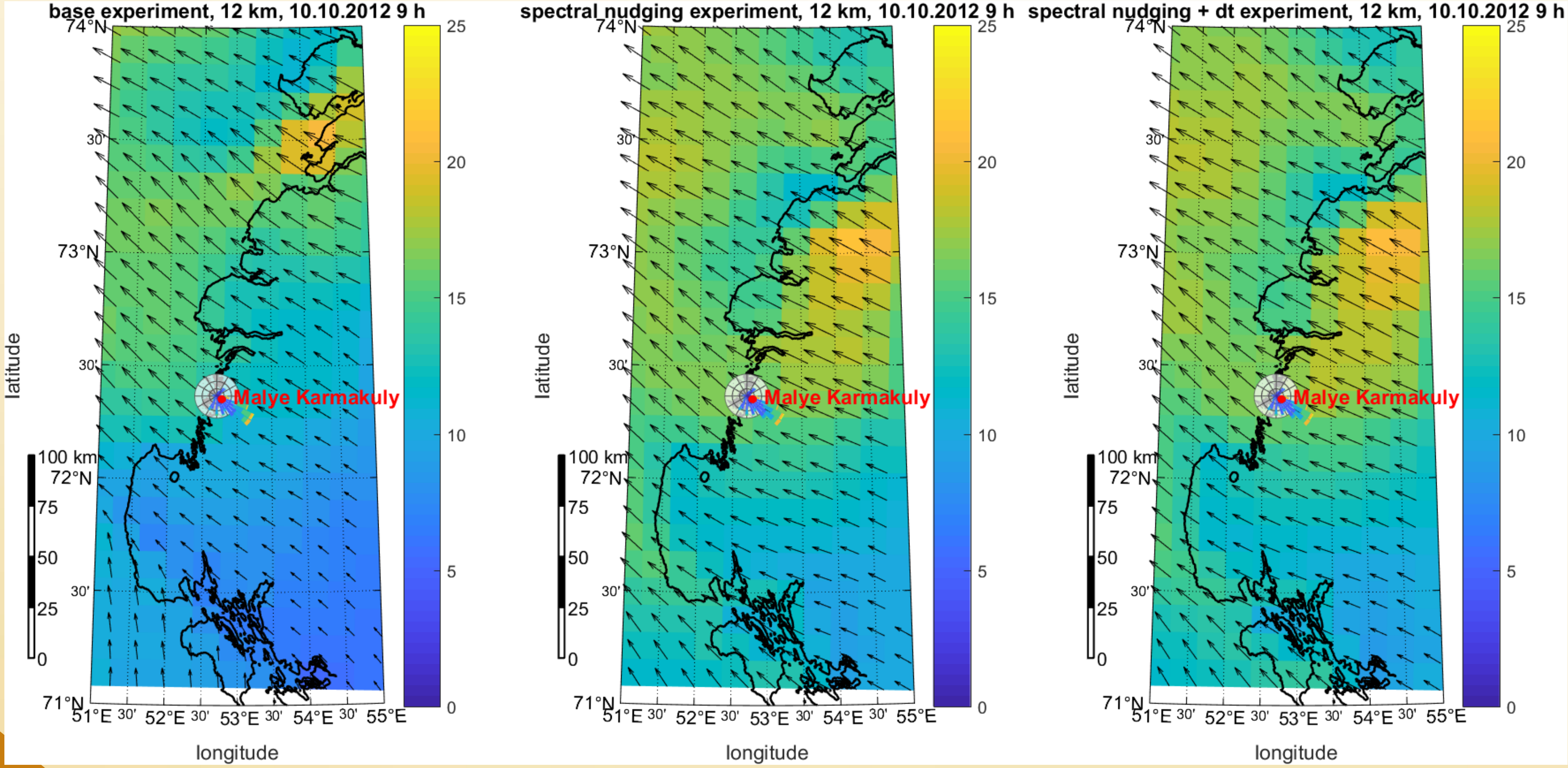



**Meteostations and wind roses** for 2012 period

Model outputs were verified using the **'nearest neighbor'** method on given stations over the Kara Sea

# Detailed case studies

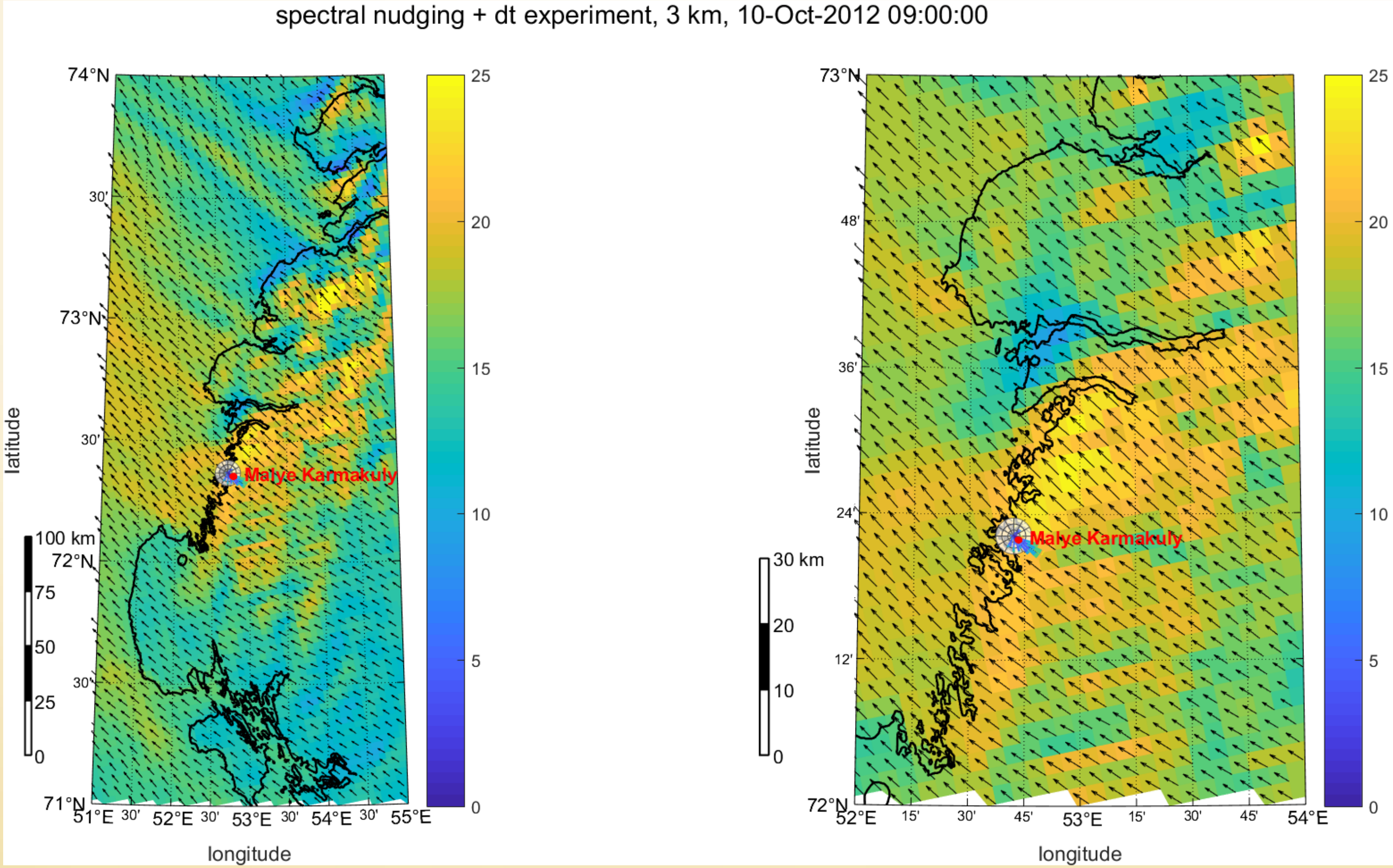
**10-11.10.2012** and **19-20.10.2012** periods were analyzed in detail at **Malye Karmakuly**, **Dikson Island** and **named Popova** stations as **strong winds cases**




Different model configurations comparison on example of Malye Karmakuly (Novaya Zemlya Island), ~12 km grid. Wind speed (m/s) and direction.

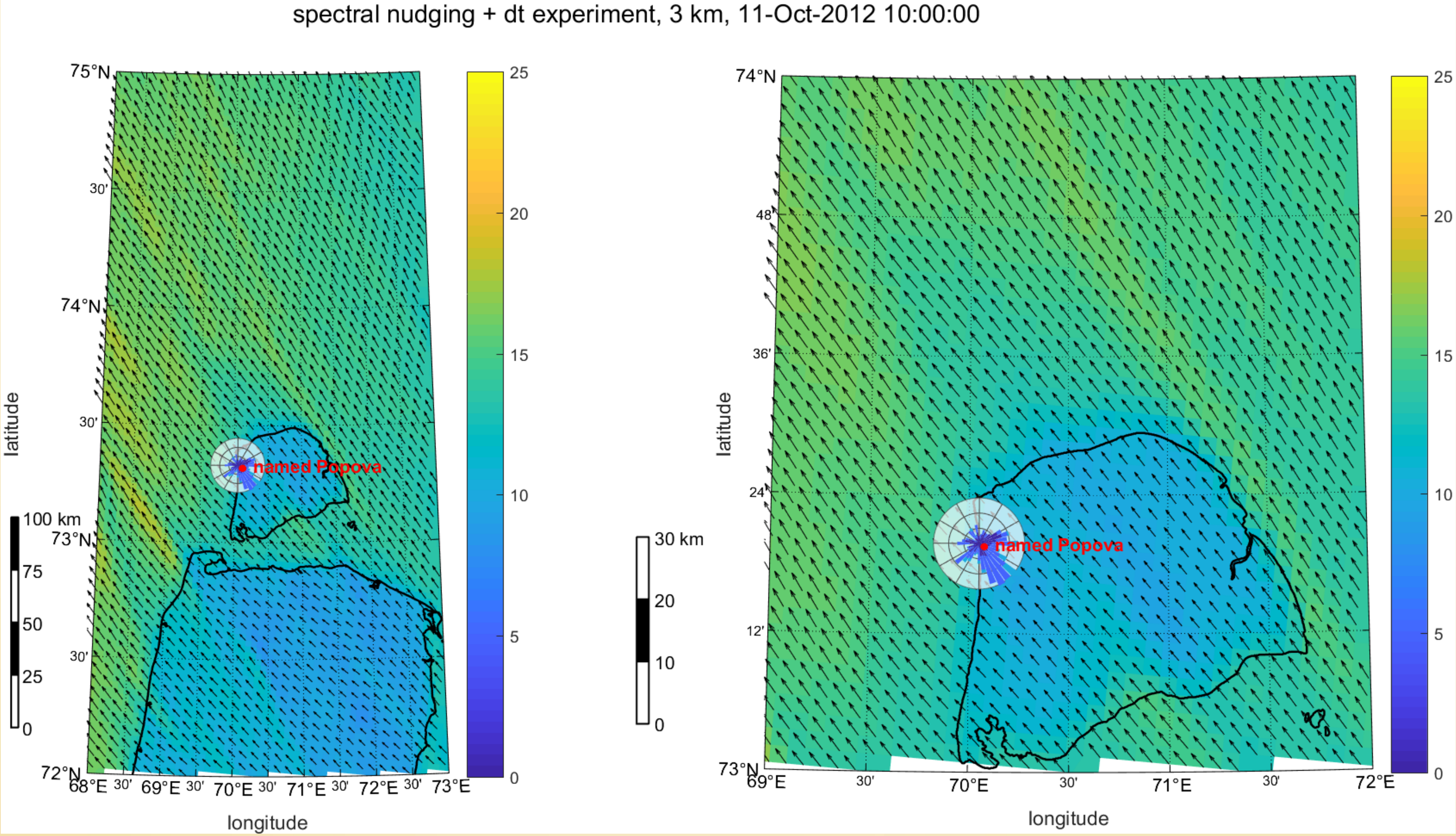
# Detailed case studies

**<u>10-11.10.2012</u>** and **<u>19-20.10.2012</u>** periods were analyzed in detail at **<u>Malye Karmakuly</u>**, **<u>Dikson Island</u>** and **<u>named Popova</u>** stations as **strong winds cases**



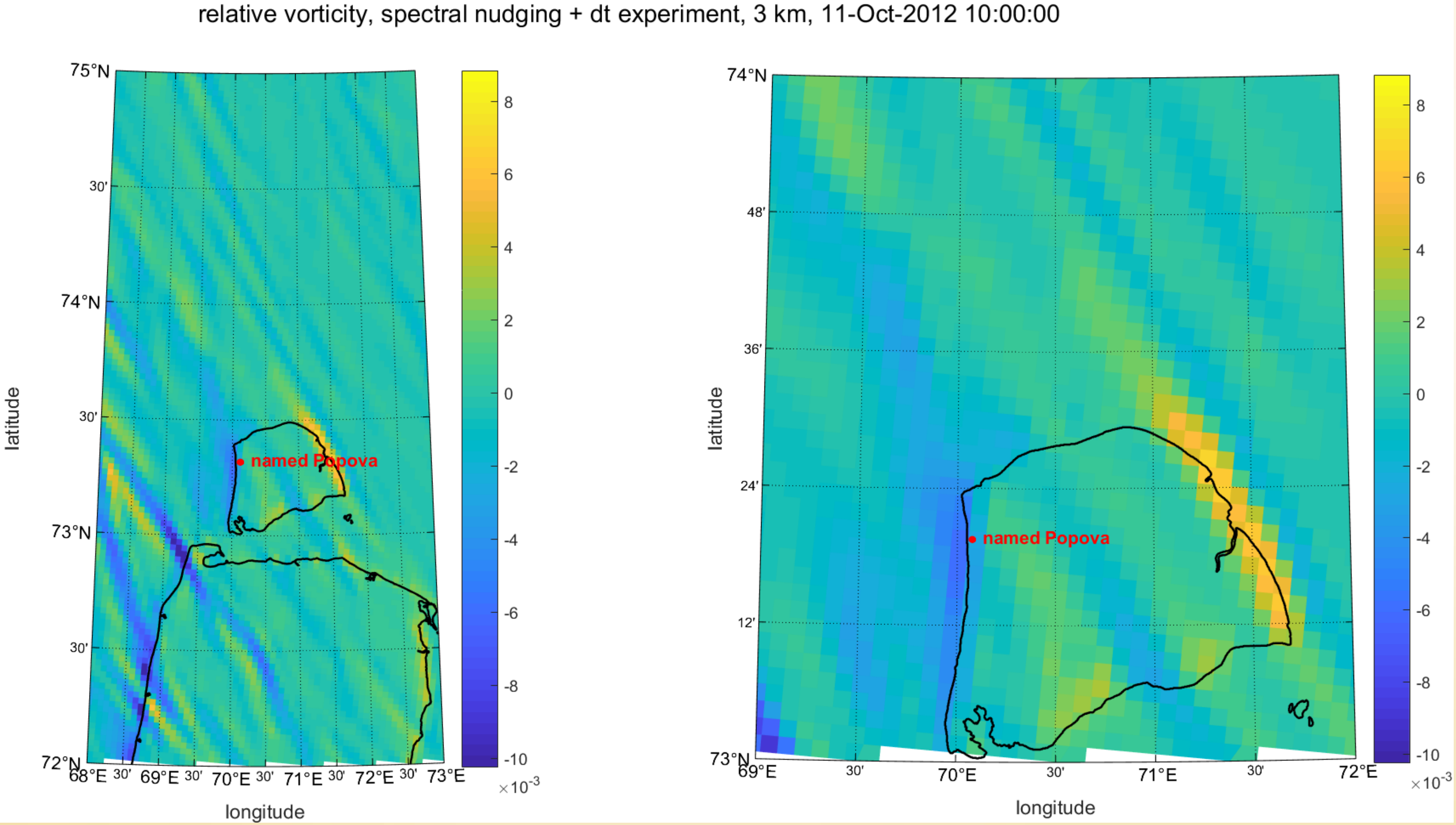

Different model configurations comparison on example of Malye Karmakuly (Novaya Zemlya Island), ~3 km grid. Wind speed (m/s) and direction.

# Detailed case studies



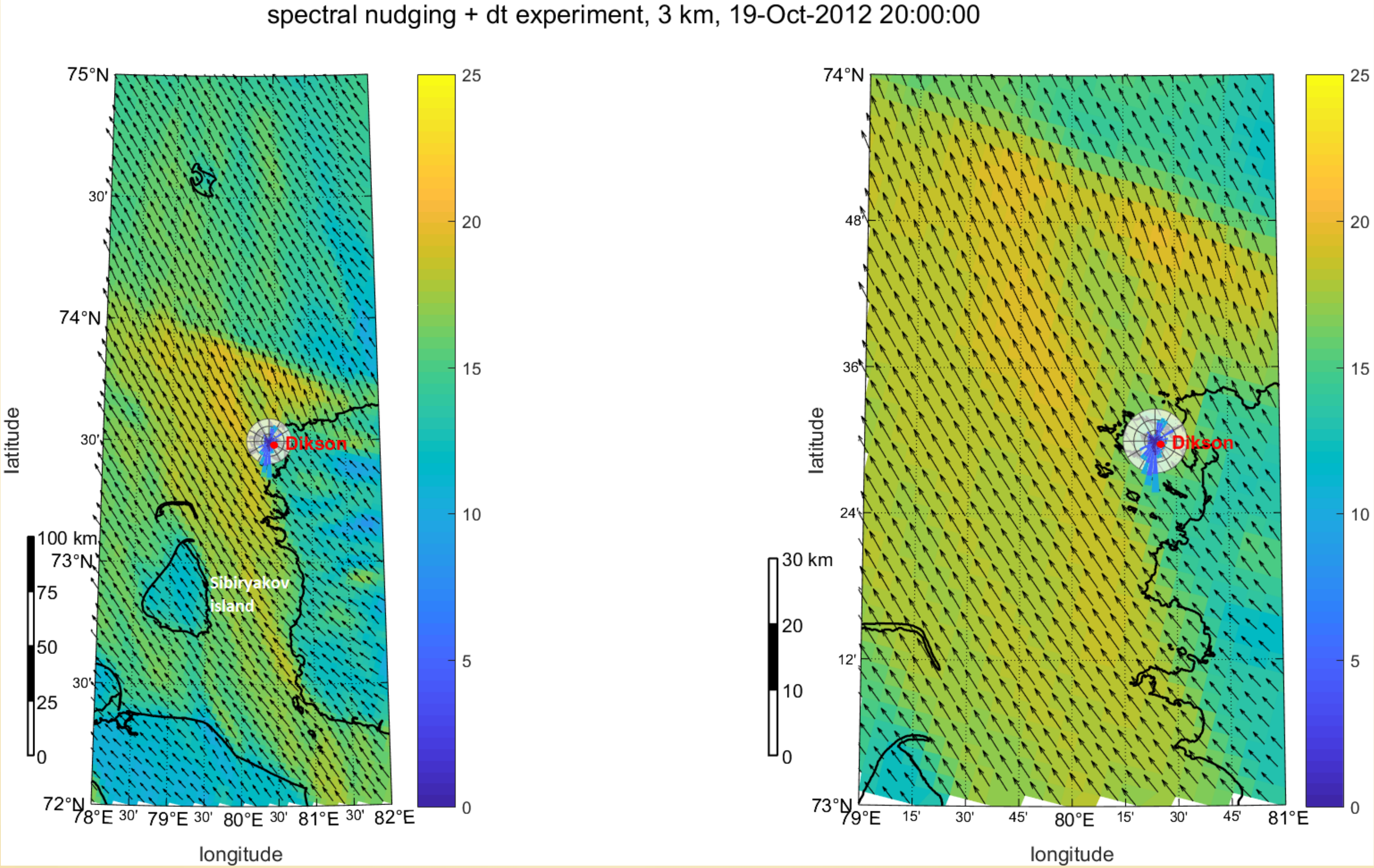

Example of named Popova (Belyi Island), ~3 km grid, **sn+dt**. Wind speed (m/s) and direction.

# Detailed case studies



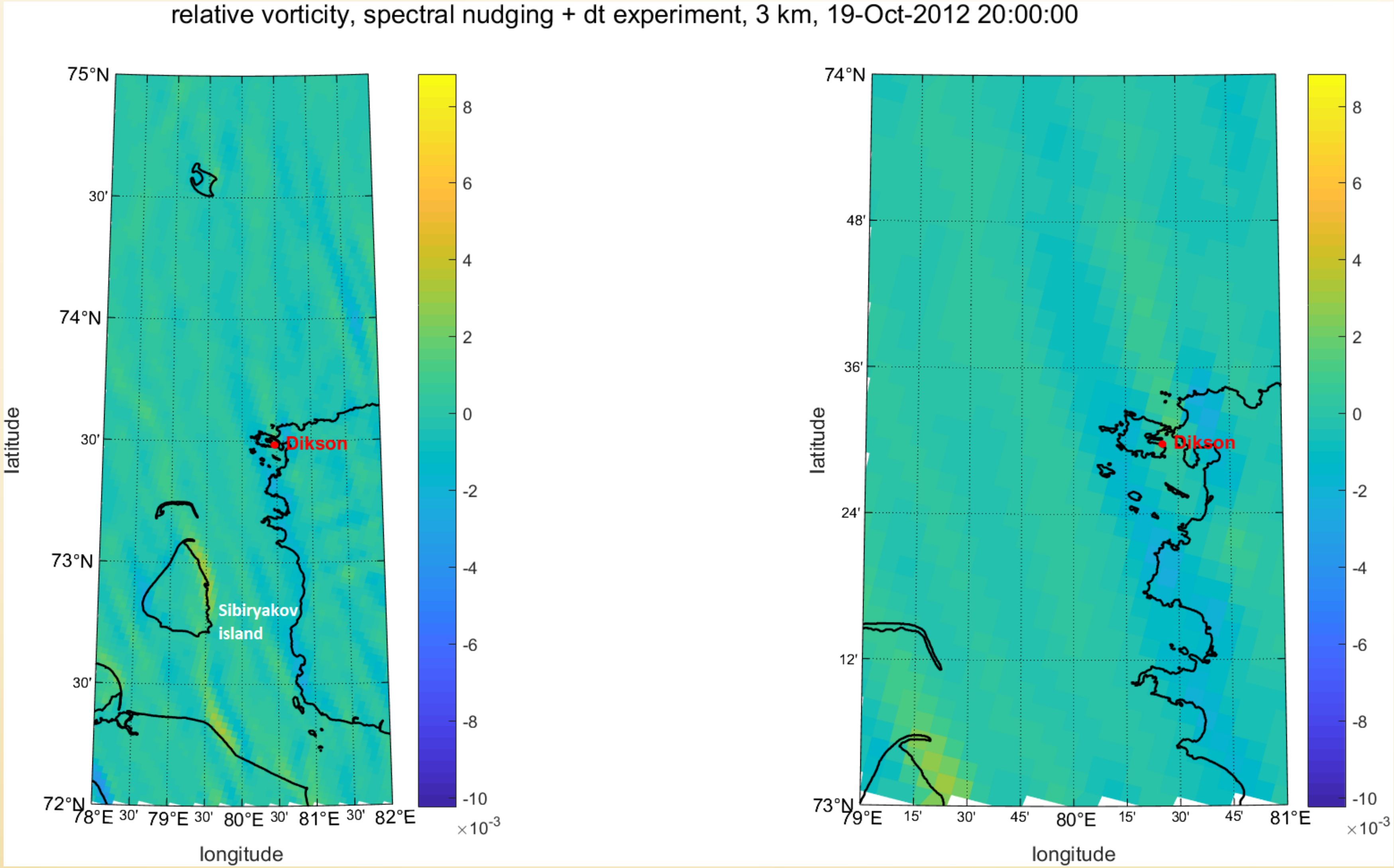

Relative vorticity ($10^{-3}\ s^{-1}$), ~3 km grid, **sn+dt**.

# Detailed case studies



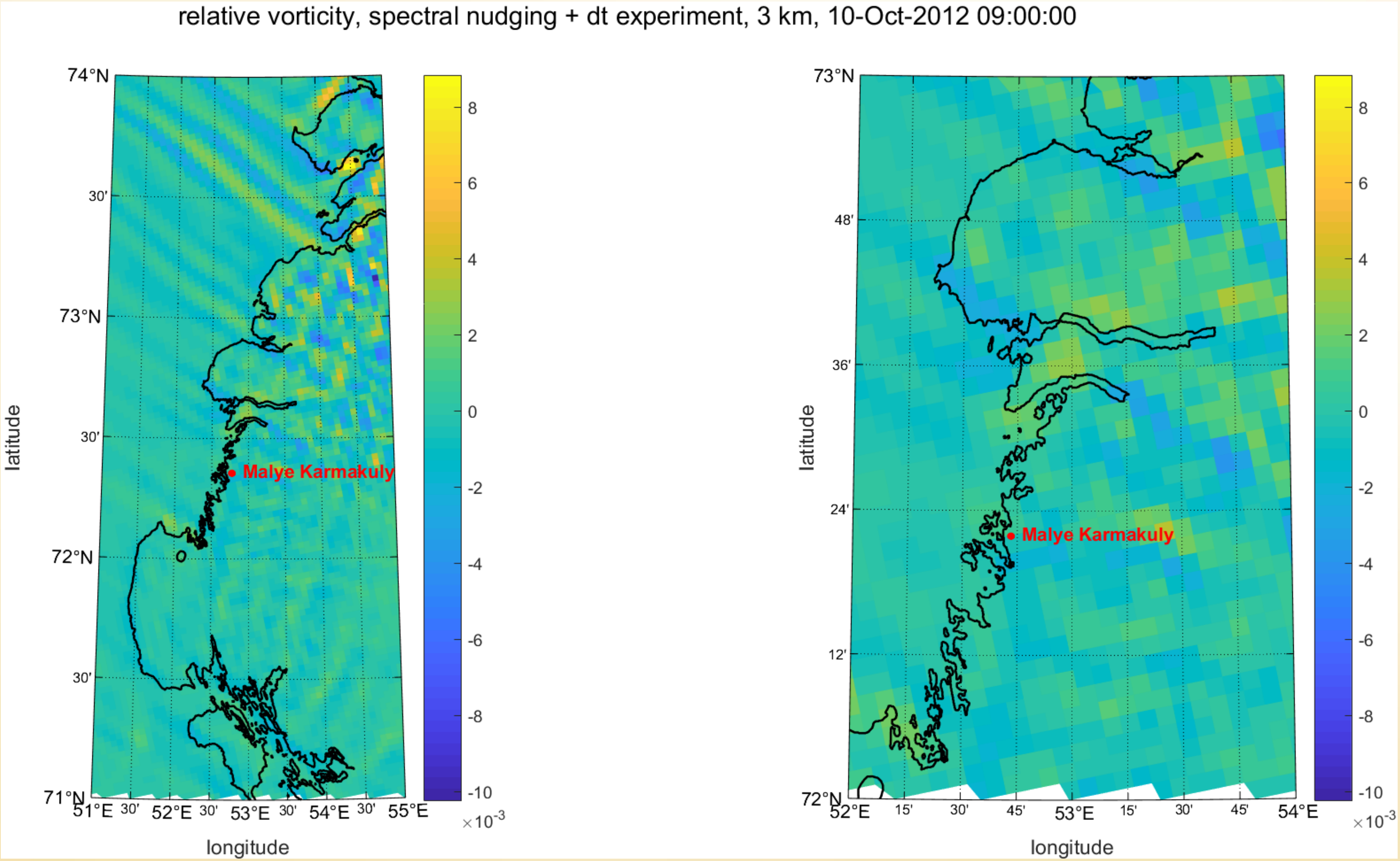

Example of Dikson Island, ~3 km grid, **sn+dt**. Wind speed (m/s) and direction.

# Detailed case studies



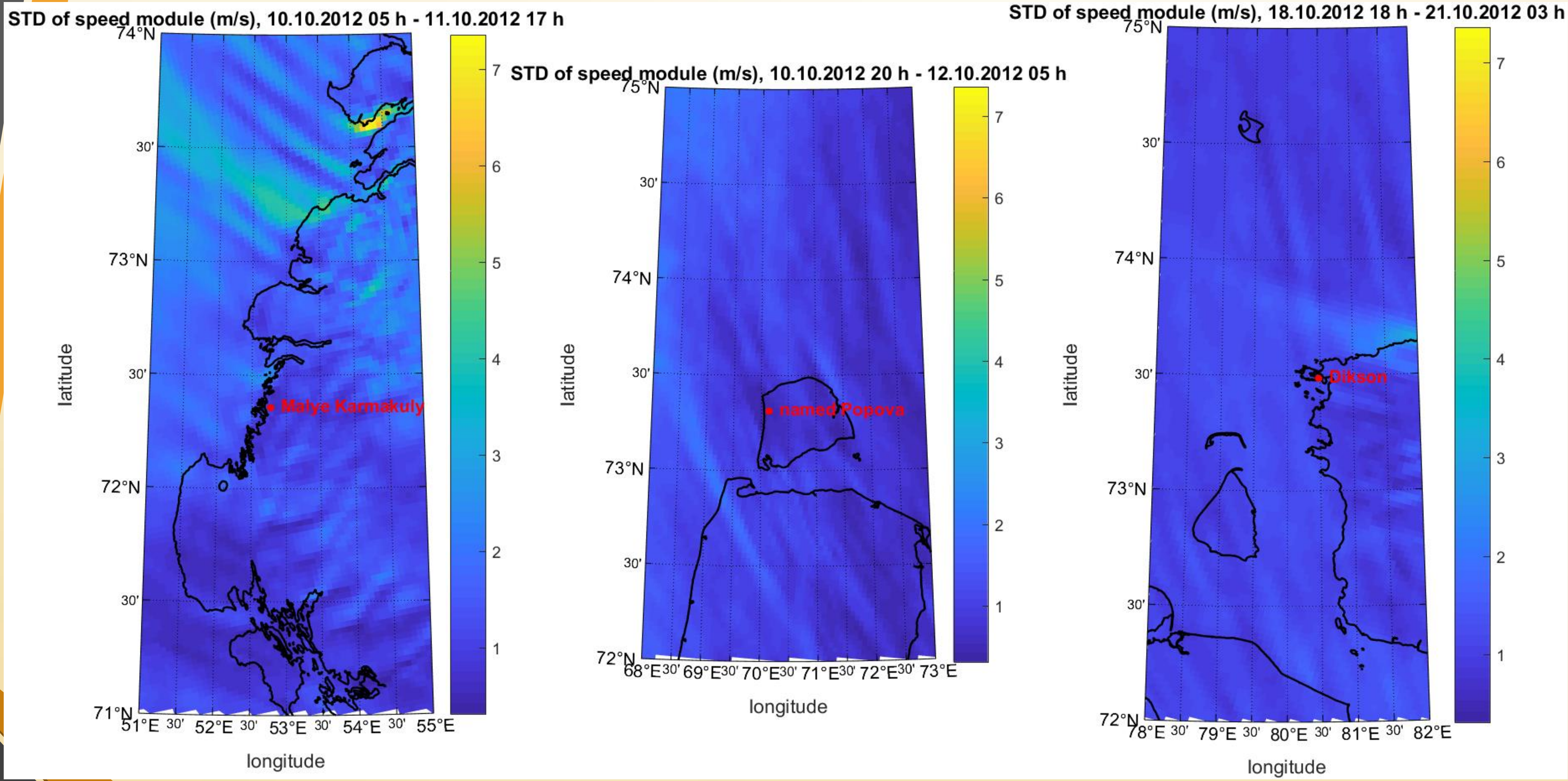

Relative vorticity ($10^{-3}$ $s^{-1}$), ~3 km grid, **sn+dt**.

# Detailed case studies



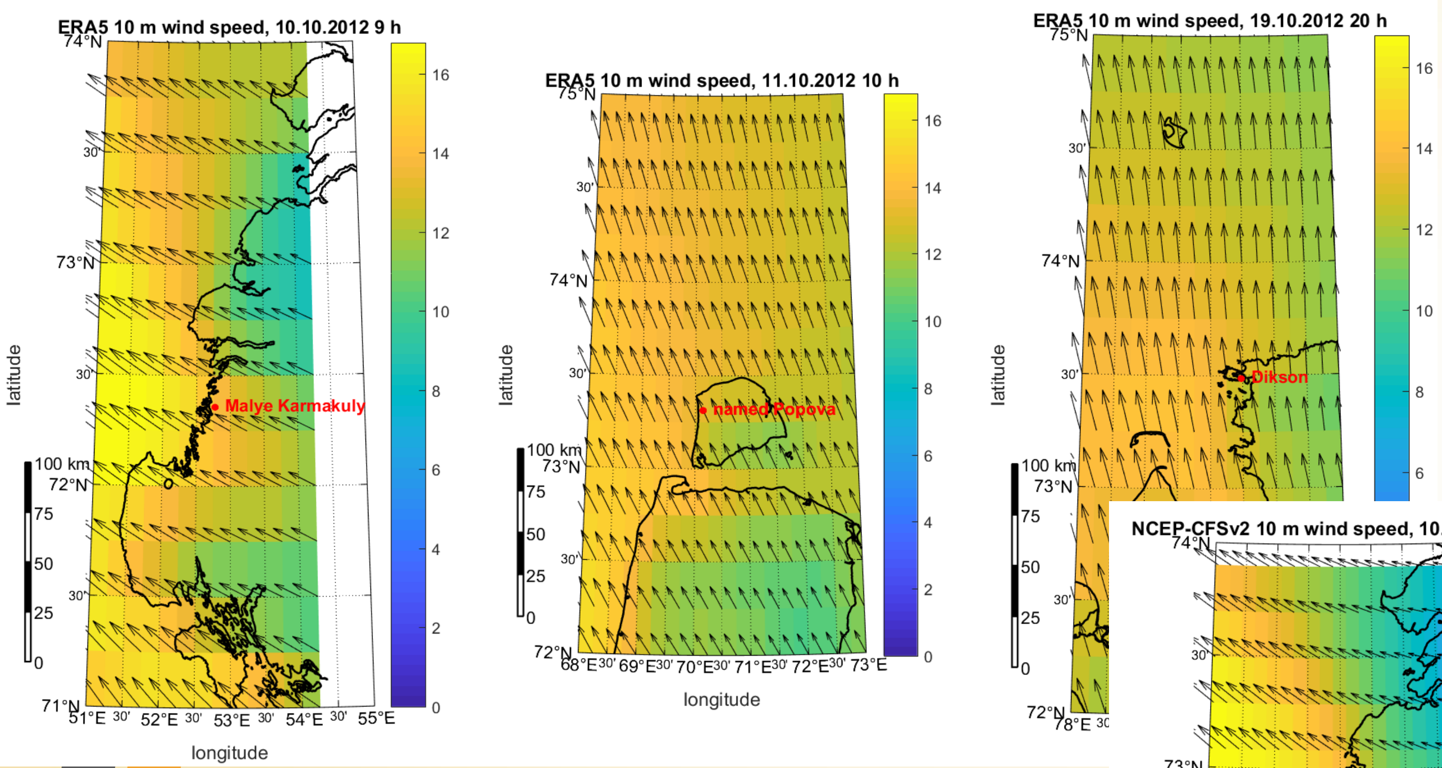

Relative vorticity ($10^{-3}$ $s^{-1}$), ~3 km grid, **sn+dt**.

# Detailed case studies



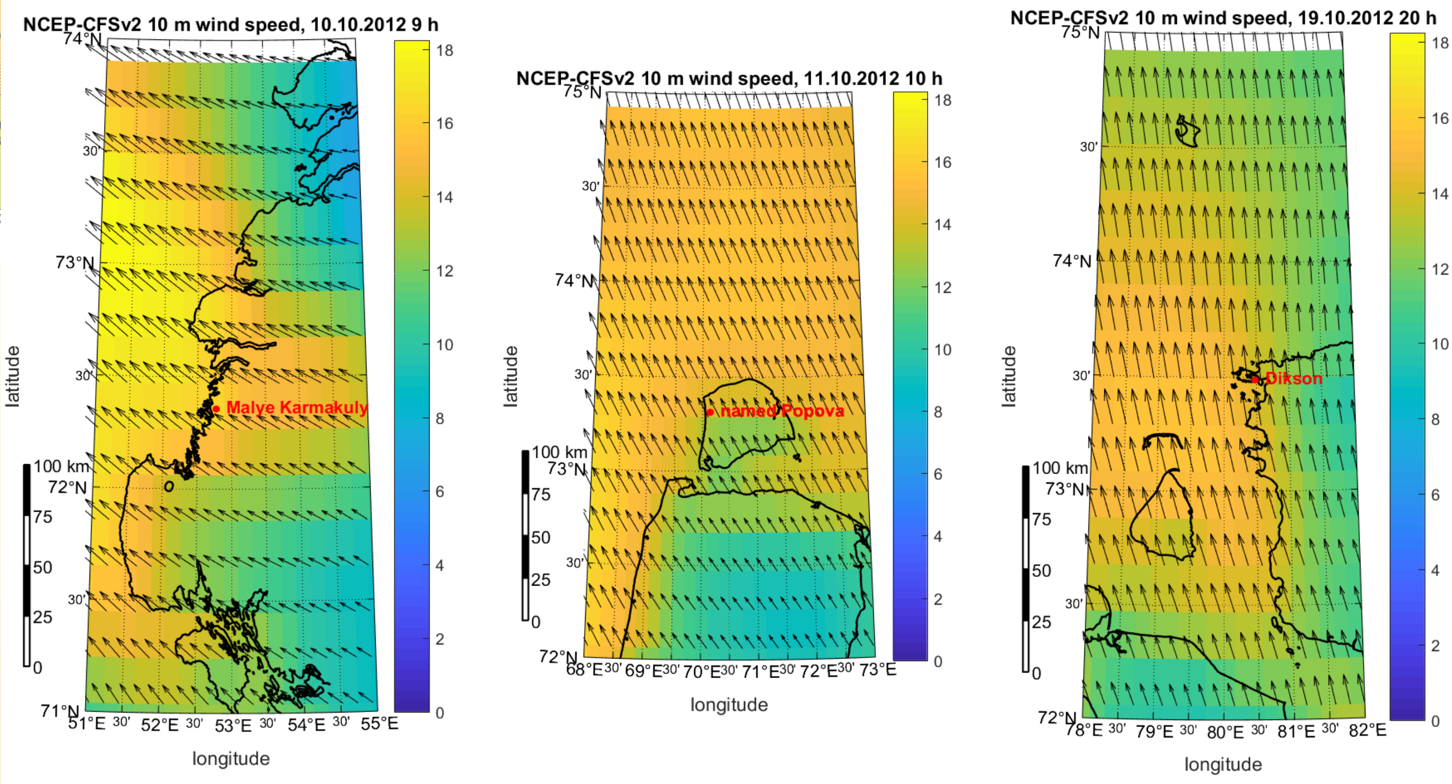

Standard deviation of wind speed module (m/s) for 21, 30 and 17 h periods at three considered regions, ~3 km grid, **sn+dt**.

# Detailed case studies




ERA 5 wind speed (m/s) and direction

NCEP-CFSv2 wind speed (m/s) and direction



# Conclusions and future perspectives

- ✓ Model reproduced ***mesoscale features on ~3 km grid*** clearly in all considered cases; on the contrary, it was or ***not noted on ~13 km grid*** at all, either appeared not clearly and situated in other locations.
- ✓ Influence of obstacles is manifesting in ***vorticity enhancing*** (of the corresponding sign) on its coasts wrapping by flow.
- ✓ Simulation revealed the ***wind shadow*** reproduction because of surface roughness differences. It is extending further along the flow on the distance exceeding island's scale.
- ✓ Wind speed strengthening and ***turbulence enhancing*** was reproduced by mountain range flow on its ***leeward base***, reflecting the main features of ***downslope winds development*** (the Novaya Zemlya bora phenomenon).
- ✓ Model is capable to ***reproduce patterns reliably and physically justified*** including extreme winds, therefore it is a good opportunity to develop physical description of these objects further.
- ✓ This work will be continued in this direction with studying of mentioned mesoscale effects' quantitative parameters, assessment of coastline characteristics and terrain impact on wind properties, etc. ***using finer resolution modeling***.

V. Platonov, A. Kislov. High-resolution COSMO-CLM Modeling and an Assessment of Mesoscale Features Caused by Coastal Parameters at near-shore Arctic Zones (Kara Sea). Submitted to *Atmosphere*, 2020.

relative vorticity, spectral nudging experiment, 3 km, 10-Oct-2012 04:00:00