Investigation of polar mesocyclones in Arctic Ocean using COSMO-CLM and WRF numerical models and remote sensing data

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1. Abstract

Polar lows (PL), high latitude marine mesoscale cyclones, are an enigmatic atmospheric phenomena, which could result in windstorm damage of shipping and infrastructure in high latitudes. Because of their small spatial scales, short life times and their tendency to develop in remote data sparse regions (Zahn, Storch, 2008), our knowledge of their behavior and climatology lags behind that of synoptic-scale cyclones. In case of continuing global warming (IPCC, 2013) and prospects of the intensification of economic activity and marine traffic in Arctic region, the problem of relevant simulation of this phenomenon by numerical weather and climate models is especially important.

This research is devoted to investigation of the ability to simulate polar lows of two modern nonhydrostatic mesoscale numerical models, driven by realistic lateral boundary conditions: regional climate model COSMO-CLM and weather prediction and research model WRF. Fields of wind, pressure and cloudiness, simulated by models, were compared with remote sensing data and ground meteorological observations for three cases, when polar lows were observed in different regions: Norwegian sea (p. 4), Kara sea (p. 5) and Laptev sea (p. 6).

2. Data & methods

<u>COSMO-CLM (CCLM)</u> - nonhydrostatic regional climate model (Böhm et all, 2006), developed by CLM-community and DWD:

- Experiments launched for two month, **starting at least one before the analyzed PL case**;
- Resolution: 0.1 lat/lon º of the rotated coordinate system (aprox. 11 km) – 320x220 grid cells, 40 vertical levels;
- Lateral boundary conditions and SST from **ERA-Interim** reanalysis (0.75 º res.);
- Experiments **with spectral nudging technique (CCLM SN)** according (Storch et al, 2000) with minimum wavelength to nudge about 500 km and without in (CCLM WN) were examined.
- Version 5.0_clm2 with standard options, Tiedke convection;

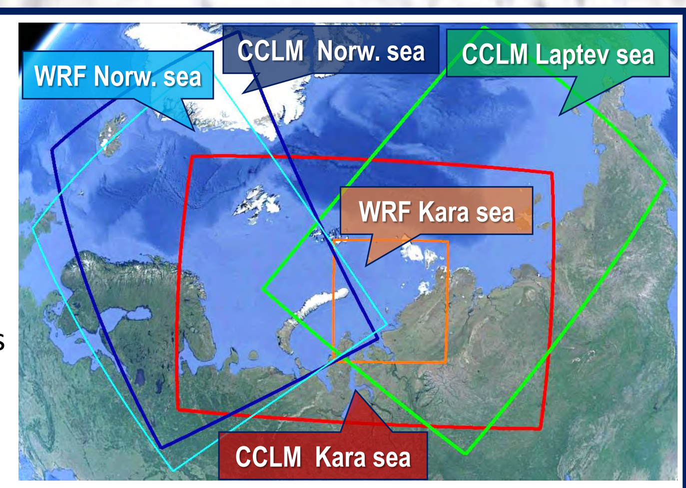


Fig. 2.1. Domains used for the numerical experiments with CCLM and WRF models

<u>WRF</u> – well-known weather forecast and research model (Skamarock et al, 2008):

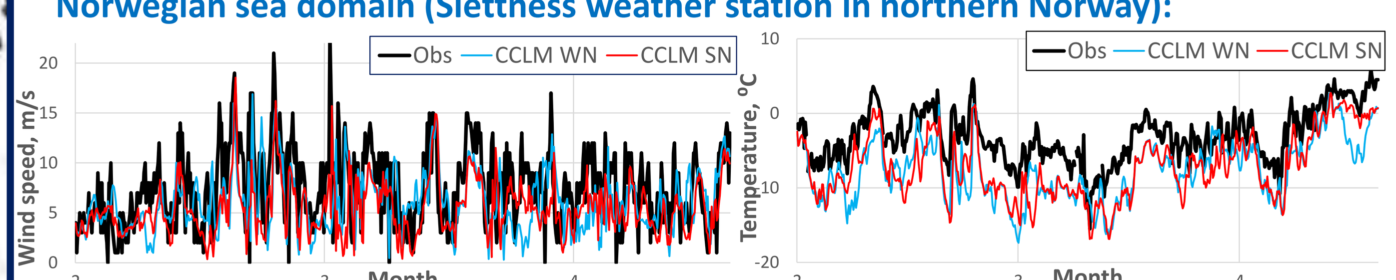
- **Experiments lunched for several days starting just before the analyzed PL case;**
- Lateral boundary conditions and SST from **ERA-Interim reanalysis** (0.25 º res.);
- Resolution: Norway and Barents seas - 10 km, 40 vertical levels, Kara sea - 5 km, 50 vert levels.
- Version 3, **No spectral nudging,** radiation parameterizations from CAM (Community atmospheric model), boundary layer- Monin-Obukhov, microphysics - Goddard center, convection - only shallow by Grell-Devenyi, urbulence in PBL - Mellor-Yamada- Janich. In Kara sea modeling convection was resolved directly.

Models were run on Lomonosov supercomputer of Moscow Stare University (Sadovnichy at. al, 2013).

<u>Remote sensing data</u>: satellite cloud fields of **MODIS** (AQUA and TERRA), band №5 (1230 – 1250 µm); data from microwave radiometer **AMSR-E** and **AMSR-2** microwave radiometer data (MODIS Aqua, GCOM-W1) for wind speed on 10 meters level and integrated atmospheric cloud liquid water; data from **QuikSCAT** scatterometer for wind speed and direction on 10 meters level.

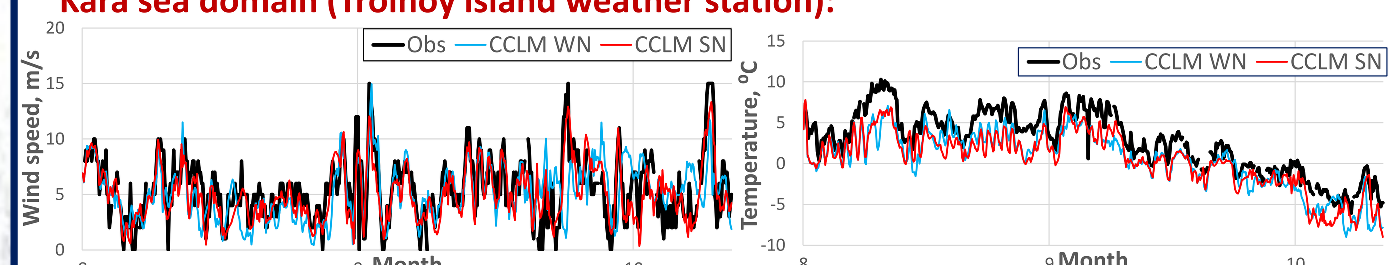
3. Model verification vs observations

Norwegian sea domain (Slettness weather station in northern Norway):



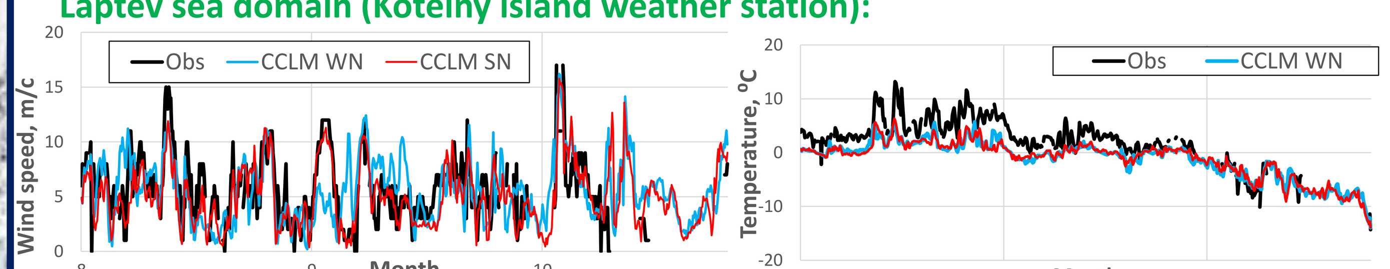
	WN	SN
T bias, °C	-4.3	-4.0
T correl.	0.77	0.84
SPD bias, m/c	-1.5	-2.0
SPD correl.	0.37	**0.52**

Kara sea domain (Troinoy island weather station):



	WN	SN
T bias, °C	-4.6	-2.2
T correl.	0.91	0.93
SPD bias, m/c	-0.3	-0.44
SPD correl.	0.50	**0.78**

Laptev sea domain (Kotelny island weather station):



	WN	SN
T bias, °C	-2.6	-2.6
T correl.	0.9	0.91
SPD bias, m/c	-0.0	0.5
SPD correl.	0.41	**0.72**

4. Norwegian sea PL case

Three differently–typed polar lows were observed over Norwegian and Barents seas at **29th – 31st March, 2013**. Western one had baroclinic nature and two northern were triggered by convective mechanisms (Verezemskaya P., Master thesis'2014).

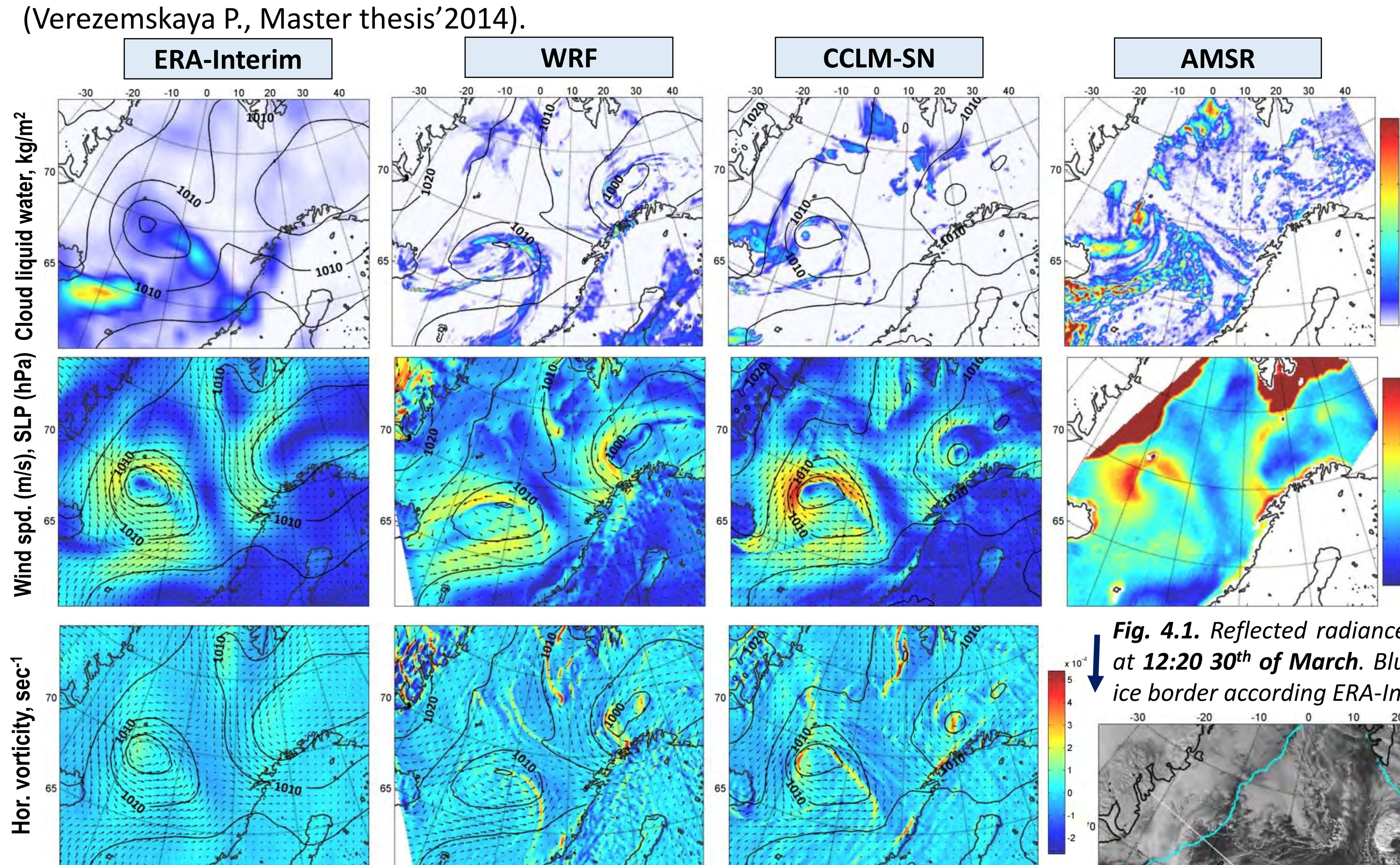
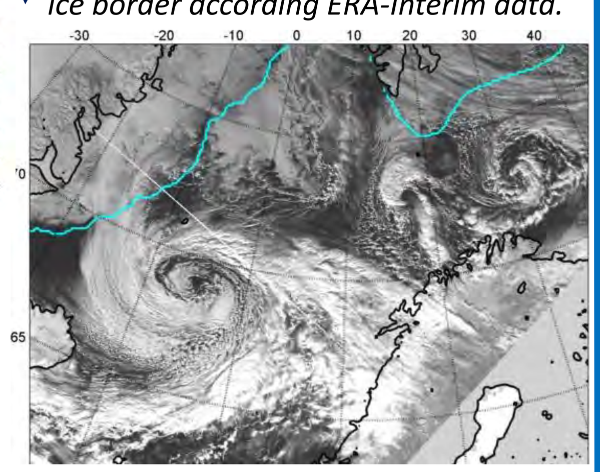


*Fig. 4.2. Fields cloud liquid water content, sea-level pressure (SLP), horizontal wind speed and horizontal vorticity at **03 UTC 30th of March**: ERA-Interim reanalysis (cloud liquid water content data for 06 UTC), results of experiments with COSMO-CLM and WRF models, AMSR remote sensing data (at 03:12 UTC ± 25 min). ERA-Interim and AMSR data is interpolated to the COSMO-CLM grid.*

*Fig. 4.1. Reflected radiance by MODIS at **12:20 30th of March**. Blue line - sea ice border according ERA-Interim data.*



5. Kara sea PL case

Polar low was observed over the Kara sea **at 30th of September 2008** in frontal (warm) sector of the synoptic-scale cyclone. Its developing in so unusual conditions were caused by upper-level potential vorticity forcing (Verezemskaya P., Master thesis'2014).

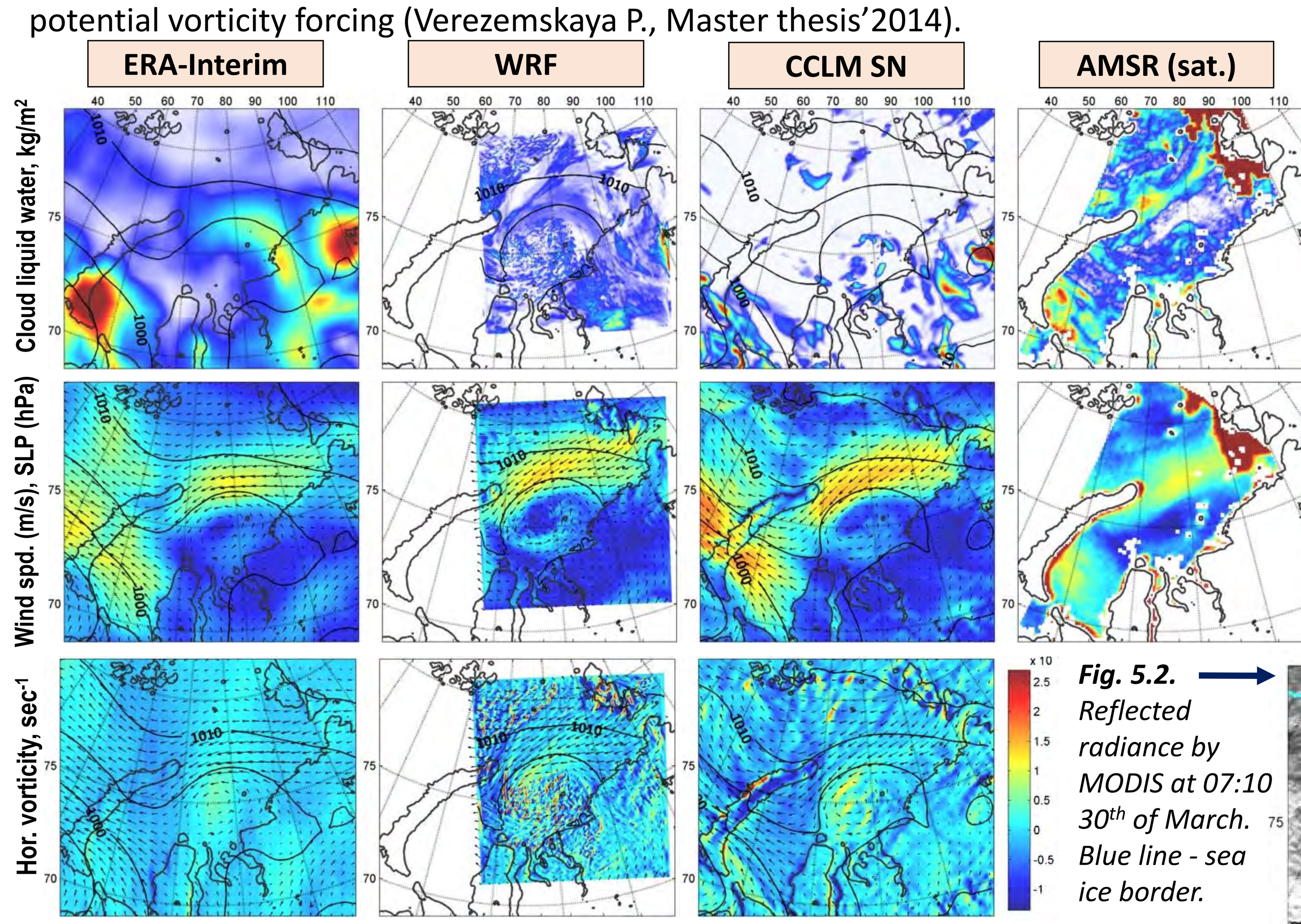
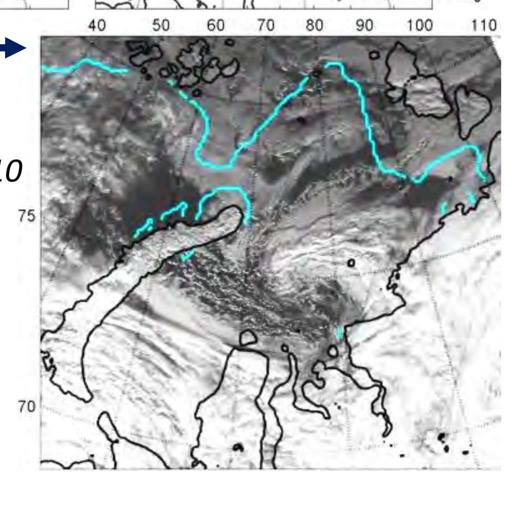


Fig. 5.1. Fields of cloud liquid water, SLP, hor. wind speed and hor. vorticity at 21 UTC 30th of September: ERA-Interim reanalysis (cloud liquid water for 18 UTC), results of experiments with COSMO-CLM and WRF models, AMSR radiometer data (at 22:06 UTC ± 20 min) and QuickSCAT scatterometer data (20:30 ± 15 min). ERA-Interim, AMSR and QuickSCAT data is interpolated to the COSMO-CLM grid.

Fig. 5.2. Reflected radiance by MODIS at 07:10 30th of March. Blue line - sea ice border.



6. Laptev sea PL case

Polar low was observed over the Laptev sea **at 12th – 13st October 2007** in frontal part of pressure depression at occlusion front (Zabolotskih et. al. 2015)

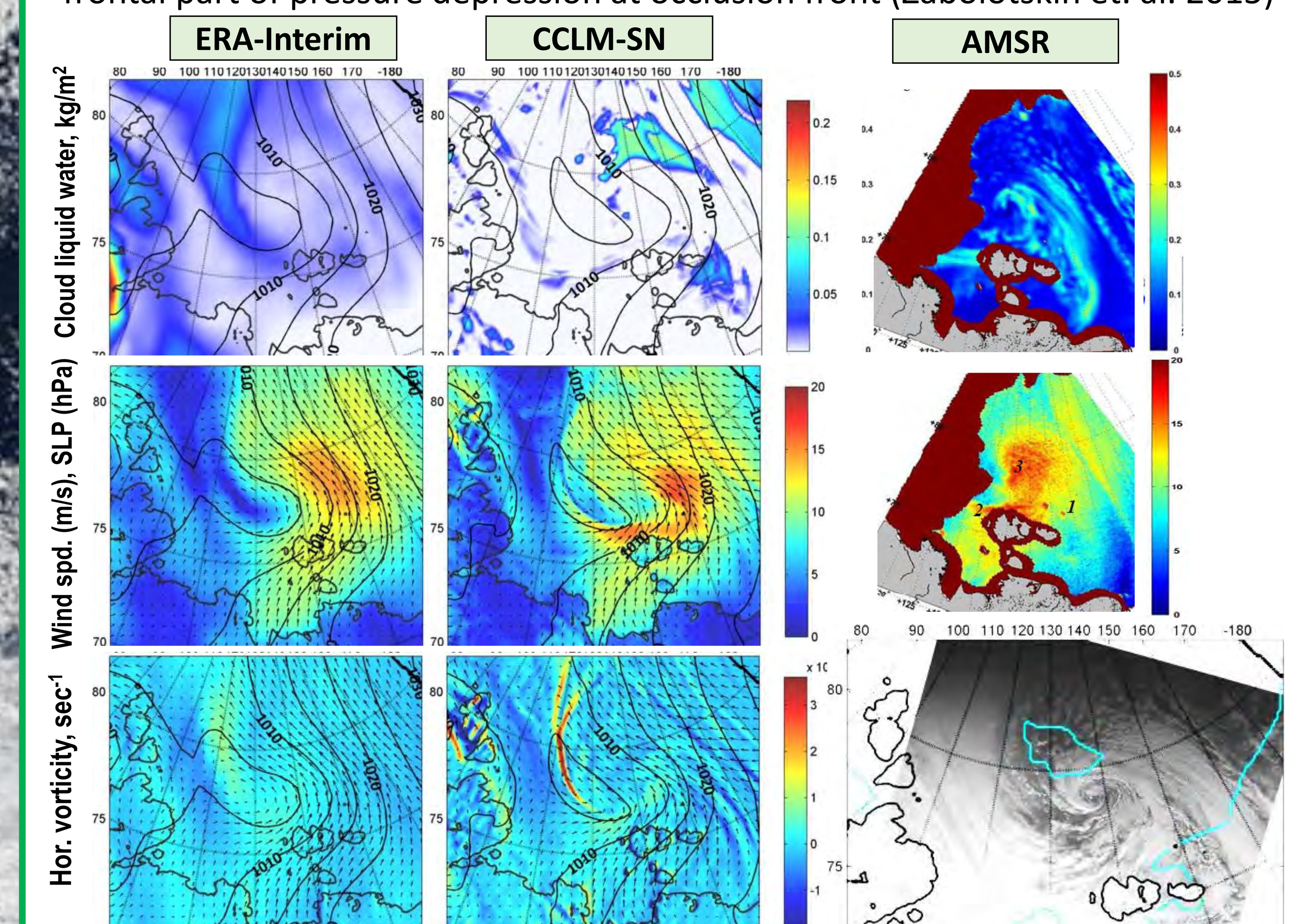
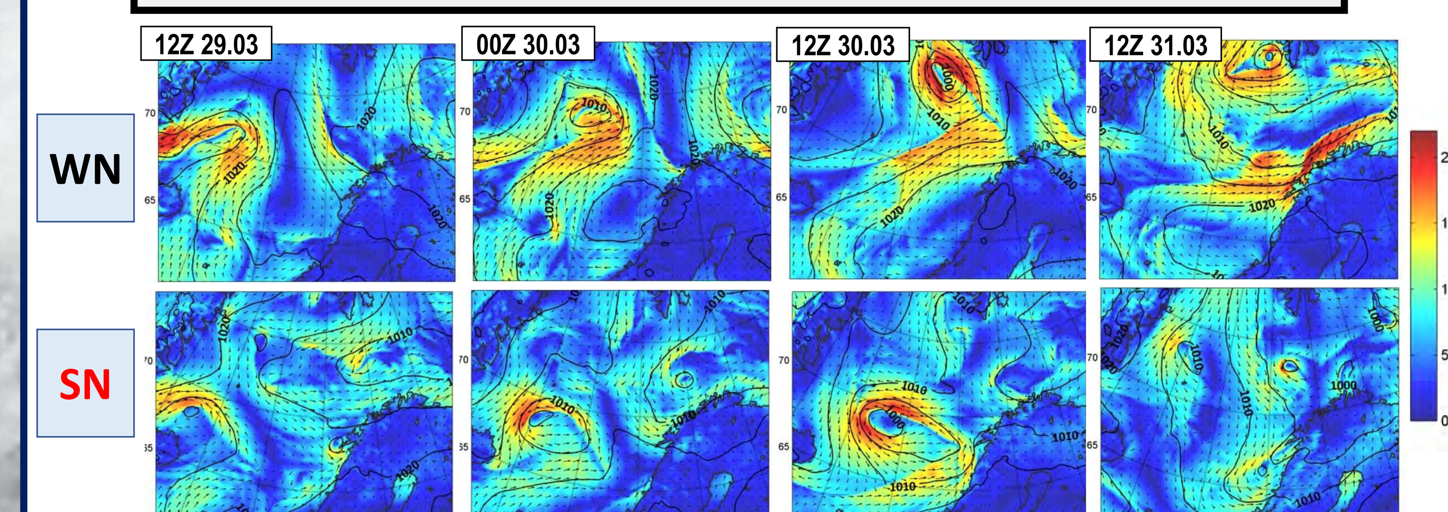


*Fig. 6.1. Fields of cloud liquid water, SLP, hor. wind speed and hor. vorticity at **00 UTC 13th of October**: ERA-Interim reanalysis. results of experiments with COSMO-CLM, AMSR radiometer data at 01:27 from (Zabolotskih et. al. 2015)*

*Fig. 6.2. Reflected radiance by MODIS at **04:45 13th of October**. Blue line - sea ice border according ERA-Interim.*

7. Effect of spectral nudging (example for Norwegian sea case)



8. Results

WRF model in short experiments, driven only by boundary conditions, and CCLM model in longer experiments, driven also by spectral nudging of synoptic-scale circulation from reanalysis, successfully simulated observed morphology and evolution of PLs in three different geographical regions. Experiments with CCLM without spectral nudging shows different from observation evolution of the PLs - the importance of this option for correct PLs simulations was shown.

Comparison between reanalysis fields, modelling data and remote sensing data shows that reanalysis significantly underestimate wind speed and vorticity in PL's and provide unrealistic distribution of cloud water, and the both models are possible to improve and detail this fields, providing better data for PLs diagnostic and research.

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9. References

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