Russian Arctic COSMO-CLM hindcast 1980 – 2016: surface wind speed and temperature evaluation

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Outlook

- The novel **COSMO-CLM Russian Arctic hindcast** (0.12^0 grid size) was created for **1980 – 2016** period: ***overview***.
- First step of evaluation: ***'added value'*** against the **ERA-Interim** driving conditions for *2 m temperature* and *10 m wind speed*.
- 2 m temperature and 10 m wind speed evaluation against **stations observations**.
- 10 m wind speed statistics evaluation with the **ASRv2 reanalysis** (2000 – 2016).
- High wind speeds and direction evaluation for ***downslope windstorms cases*** within the Russian Arctic.
- **Conclusions and future prospects**

COSMO-CLM Russian Arctic hindcast



CONSORTIUM FOR SMALL SCALE MODELING
COSMO

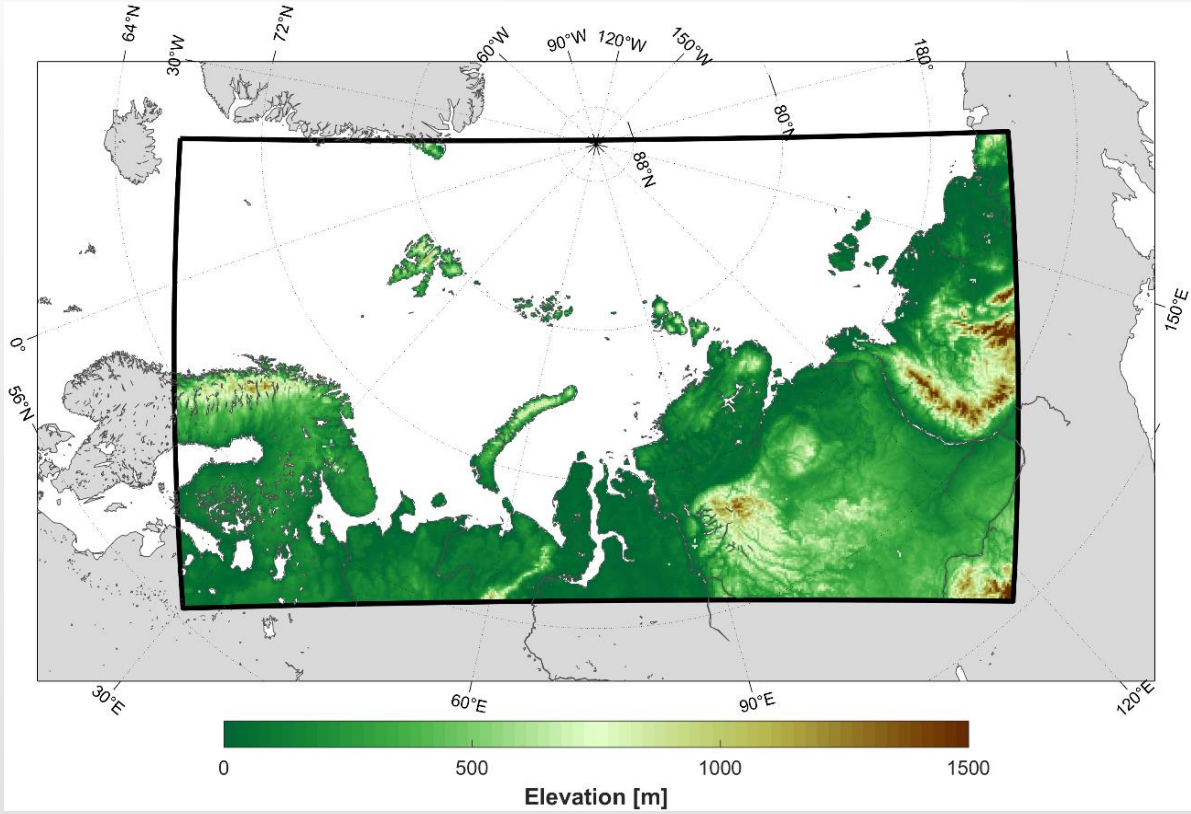
The main tool is the **COSMO-CLM** regional non-hydrostatic climate model.



COSMO-CLM (ver. 5.05)

Main characteristics of the hindcast:

- **1980 – 2016** time period;
- MSU Supercomputer Complex **"Lomonosov-2"**;
- **50** vertical model levels (**11** levels in the **PBL**);
- **Arctic Domain** with **0.12⁰** (~**13** km) horizontal grid size, **1-hour** output;
- Many **dozens** of meteorological variables at surface and model levels;



Vladimir Platonov and Mikhail Varentsov. Introducing a New Detailed Long-Term COSMO-CLM Hindcast for the Russian Arctic and the First Results of Its Evaluation. *Atmosphere*, 12(3):350; 2021. http://dx.doi.org/10.3390/atmos12030350

Experimental design

Test experiments included:

- **Spectral nudging** on/off;
- Vertical turbulence diffusion parameterization correction: **tkhmin = tkmmin = 0.1** [Cerenzia et al., 2014];
- Using COSMO-CLM **ver. 5.0** and **5.05** with **ICON-based physics** [Zangl et al., 2015; Giorgetta et al., 2018];
- **ERA-Interim** and **ERA5** forcing data;
- **Spin up**: **off** or **1 month**.

Based on test experiments and verification results, the following **optimal model configuration** chosen:

- 'spectral nudging';
- new model version 5.05 included the ICON-based physics;
- ERA-Interim reanalysis used as driving conditions.

Each month model was initialized by the ***most atmospheric*** and ***soil variables*** from the last output file (**lffd***), except for ***deeper soil variables*** (>2.5 cm), which were substituted by ***reanalysis data*** (from **laf***).

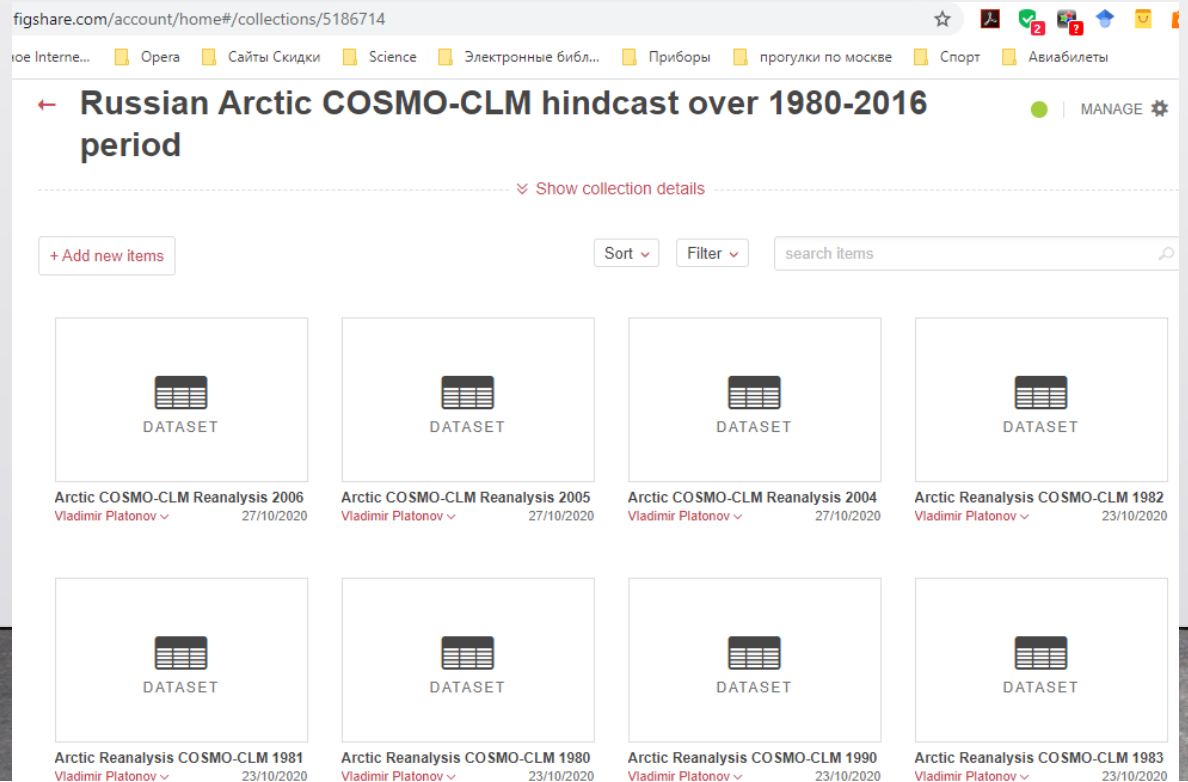
V. Platonov, M. Varentsov. Creation of the long-term high-resolution hydrometeorological archive for Russian Arctic: methodology and first results. *IOP Conference Series: Earth and Environmental Science*, 386(012), 2019. http://dx.doi.org/10.1088/1755-1315/386/1/012039

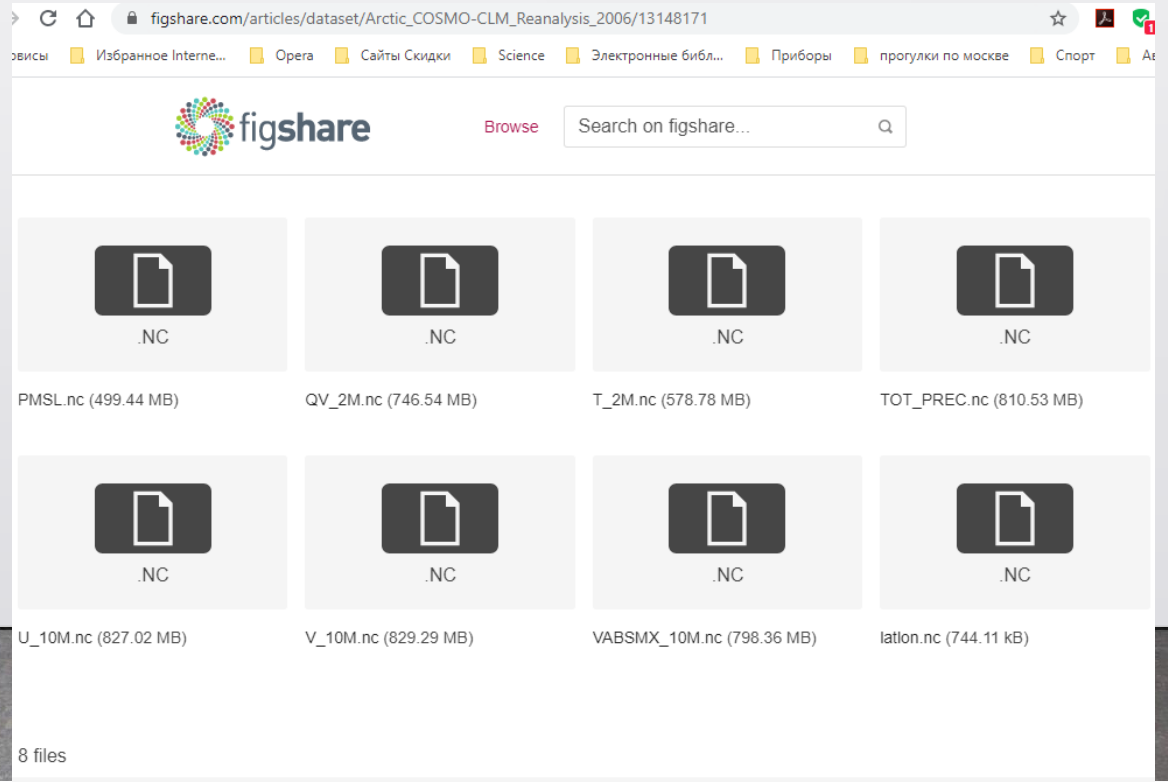
COSMO-CLM Russian Arctic hindcast accessibility

Surface **sea level pressure, temperature, specific humidity, wind speed and precipitation** are **available now online** for a periods **1980 – 1995, 2000 – 2008, 2010 – 2016**, and would be updated regularly.

Figshare *repository* (free access according to license CC BY 4.0): https://figshare.com/collections/Arctic_COSMO-CLM_reanalysis_all_years/5186714

Platonov Vladimir, Varentsov Mikhail (2020). *Russian Arctic COSMO-CLM hindcast over 1980-2016 period. figshare. Collection. https://doi.org/10.6084/m9.figshare.c.5186714*





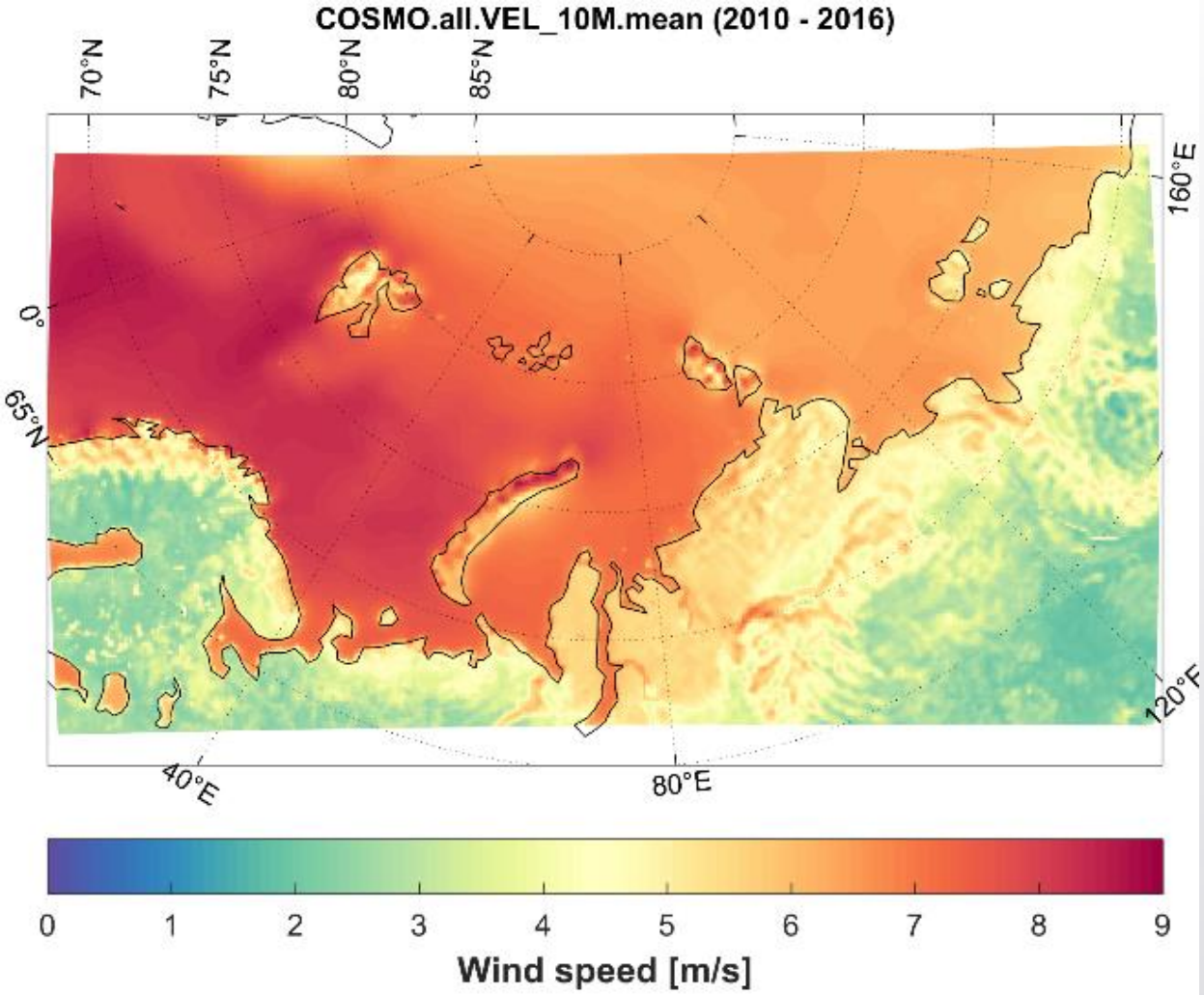
Datasets used for evaluation

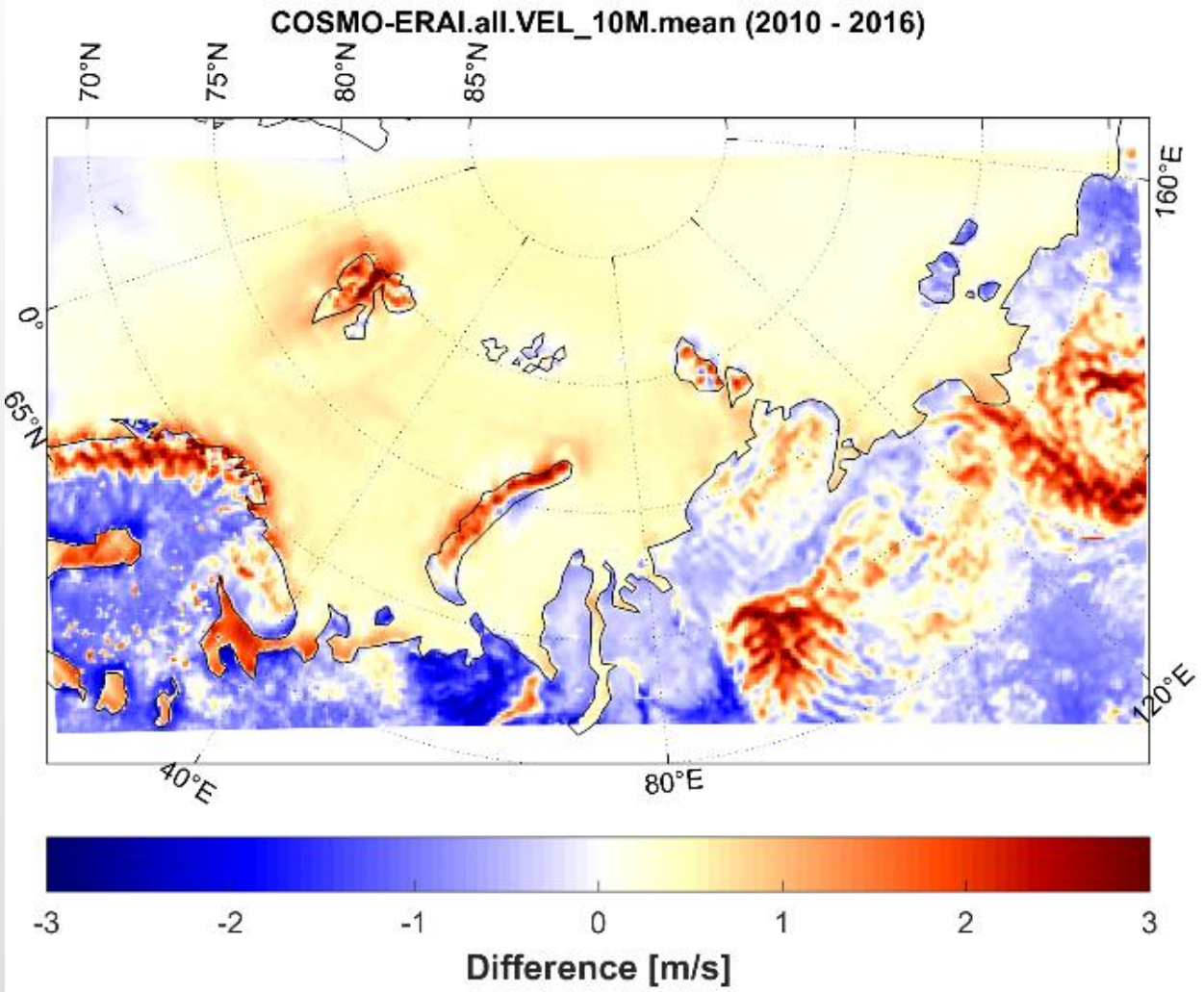
- *COSMO-CLM Russian Arctic hindcast* (2000 – 2008, 2010 – 2016);
- 10 m wind speed and direction, 2 m temperatures *stations measurements* (~100 weather stations over Arctic, 2000 – 2016);
- *ERA-Interim* reanalysis (1980 – 2016);
- *Arctic System Reanalysis v2* (ASR v2, 2000 – 2016);
- Specific statistics for extreme wind speed stations during *downslope windstorms cases* (*Ny-Alesund, Malye Karmakuly, Gessena, Ledovaya Gavan, Opasny, Tiksi*);
- Very high resolution *SAR Radarsat-2* data, ERA-Interim, ERA5 and NCEP-CFSR reanalyses (for cases: *07 Feb 2014, 07 Dec 2014, 03 – 04 May 2015, 28 Nov 2015*).

Data	Spatial resolution
SAR Radarsat-2	~10 m
ERA-Interim	~80 km
ERA 5	~30 km
CFSR	0.2° (~6 km x ~22 km)
ASR v.2	15 km
COSMO-CLM	~13 km

We applied basic statistics and pattern correlation R; and **feature-based method SAL (*S* – *structure*, *A* – *amplitude*, *L* – *location*)** for SAR Radarsat-2 data evaluation developed by [Wernli et al. (2008, 2009)].

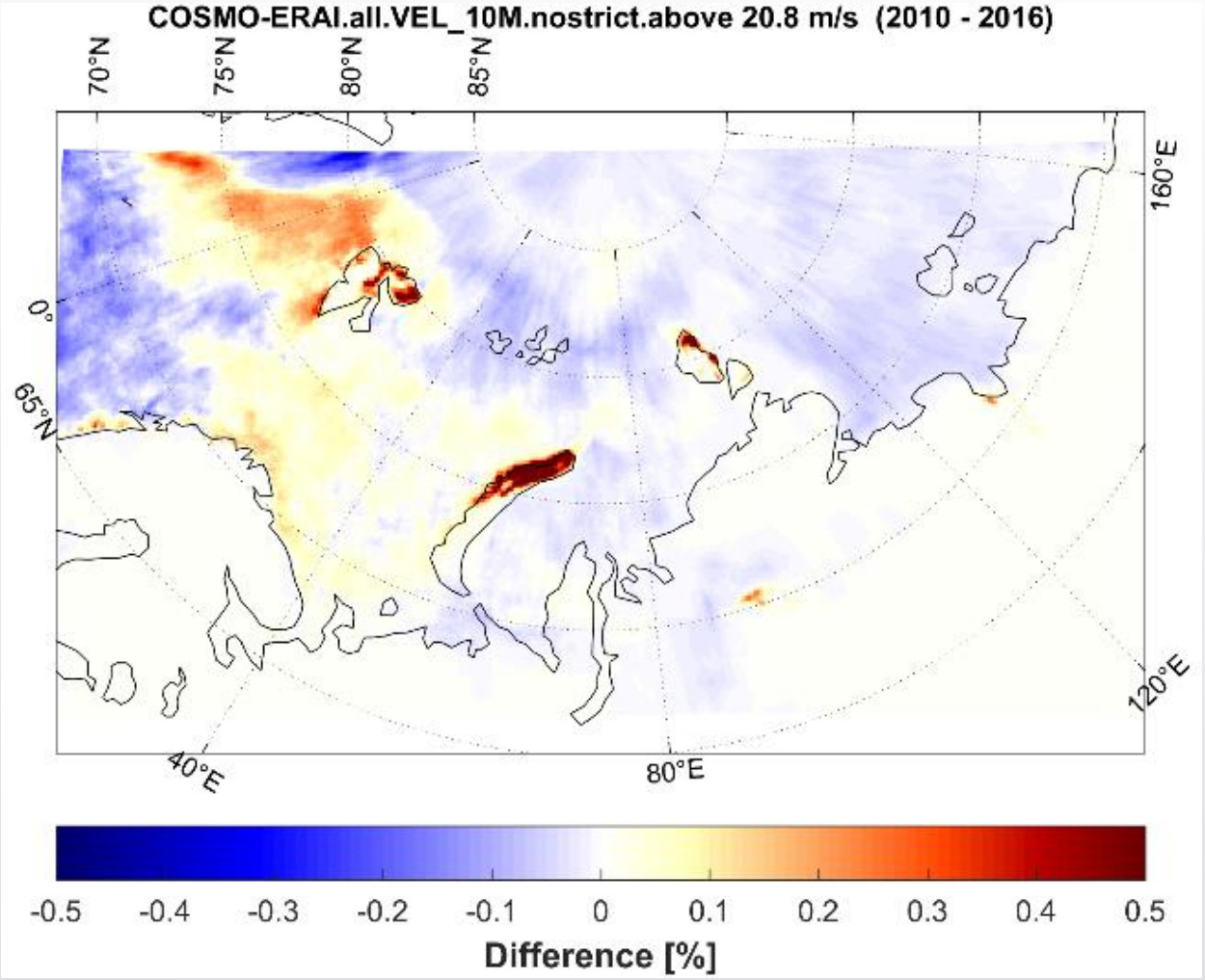
CCLM and ERAI comparison. Wind speed.

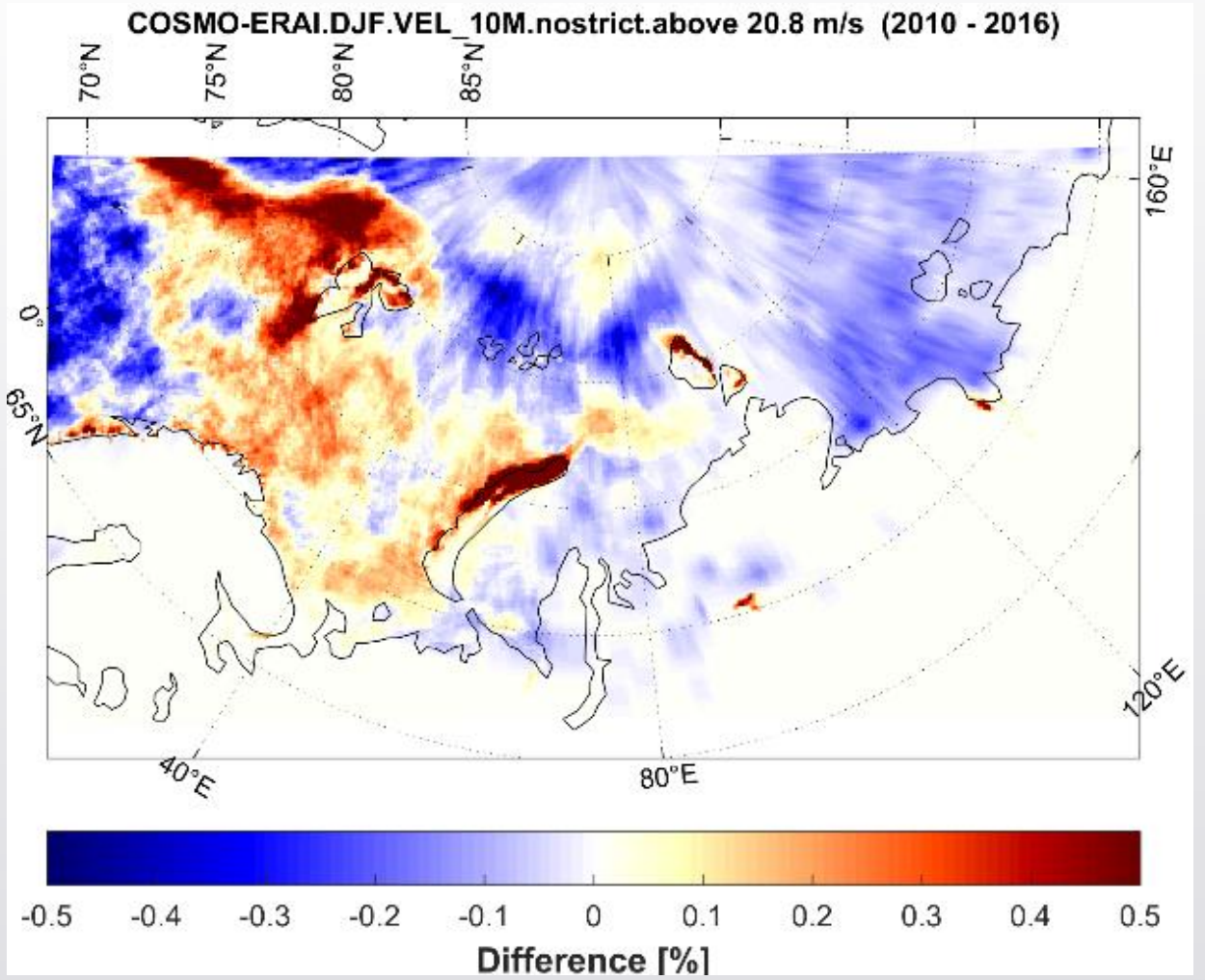




COSMO-CLM hindcast **10 m mean wind speed** (m/s, *left*) and *"COSMO-CLM–ERA-Interim"* **wind speed difference** (m/s, *right*) for 2010 – 2016 period.

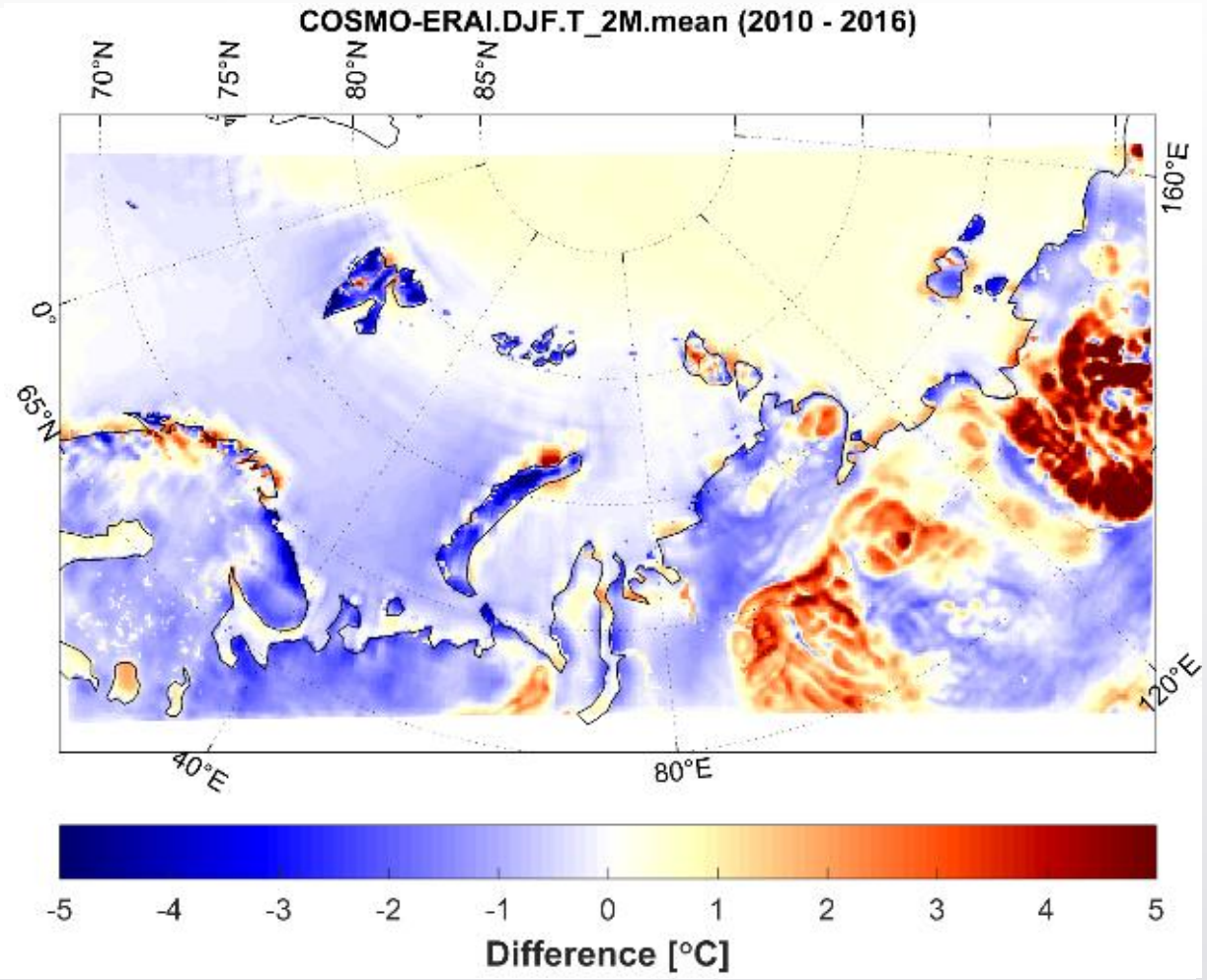
CCLM and ERAI comparison. Wind speed.

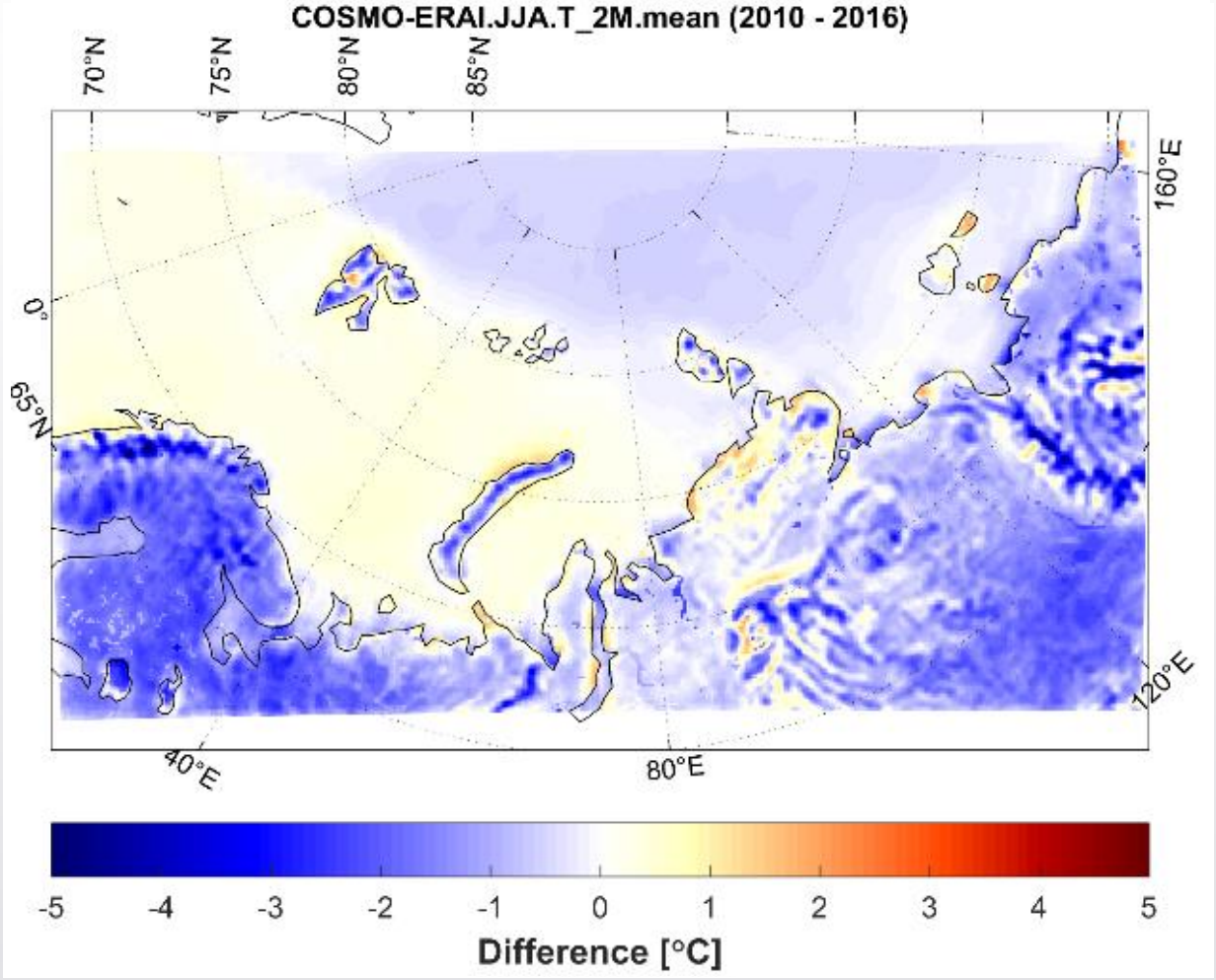




"COSMO-CLM–ERA-Interim" **difference** in **repeatability** (%) of the 10 m wind speed **above 20.8 m/s** for 2010 – 2016 over ***all months*** (*left*) and for the ***winter season*** (***DJF***, *right*).

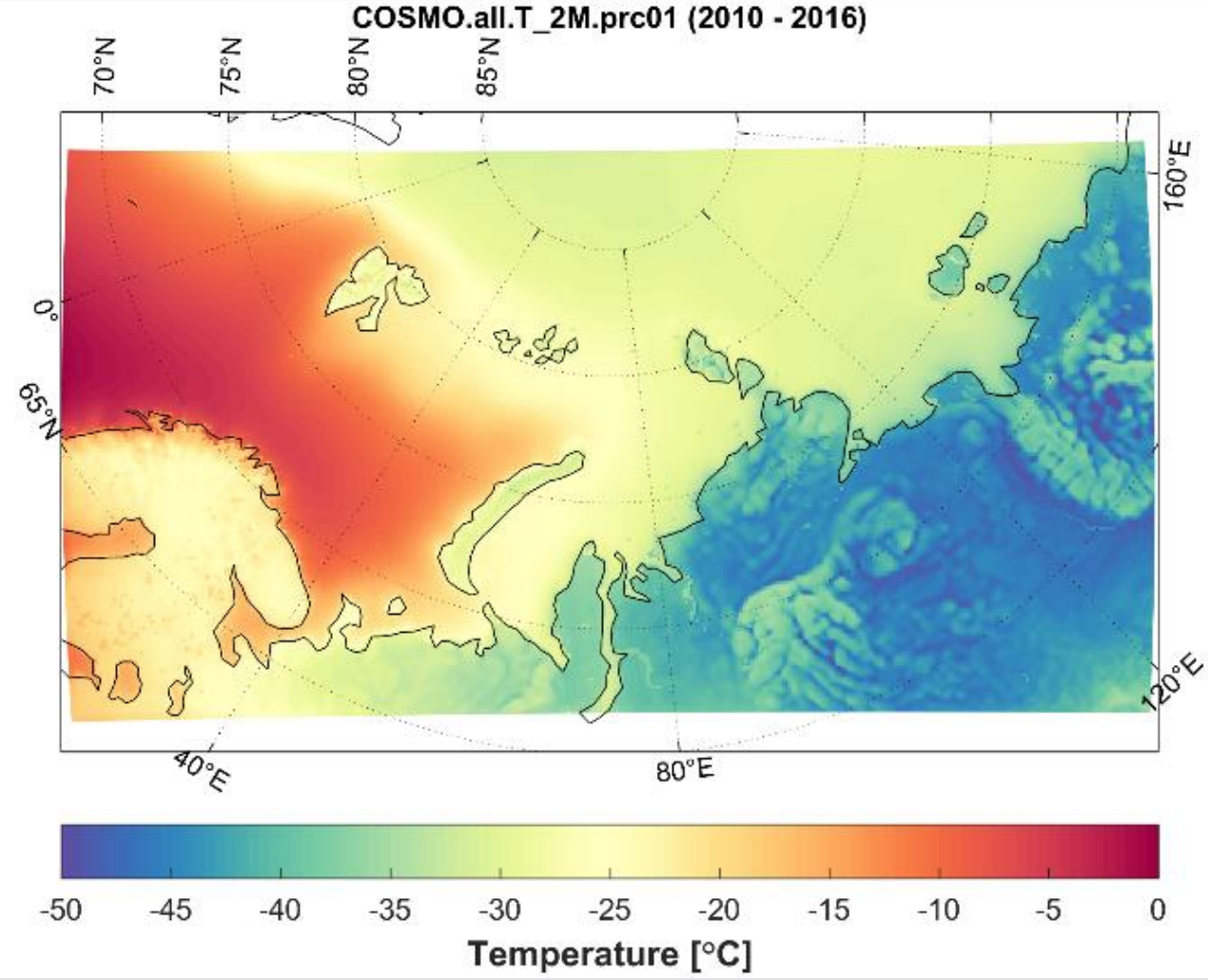
CCLM and ERAI comparison. Temperature.

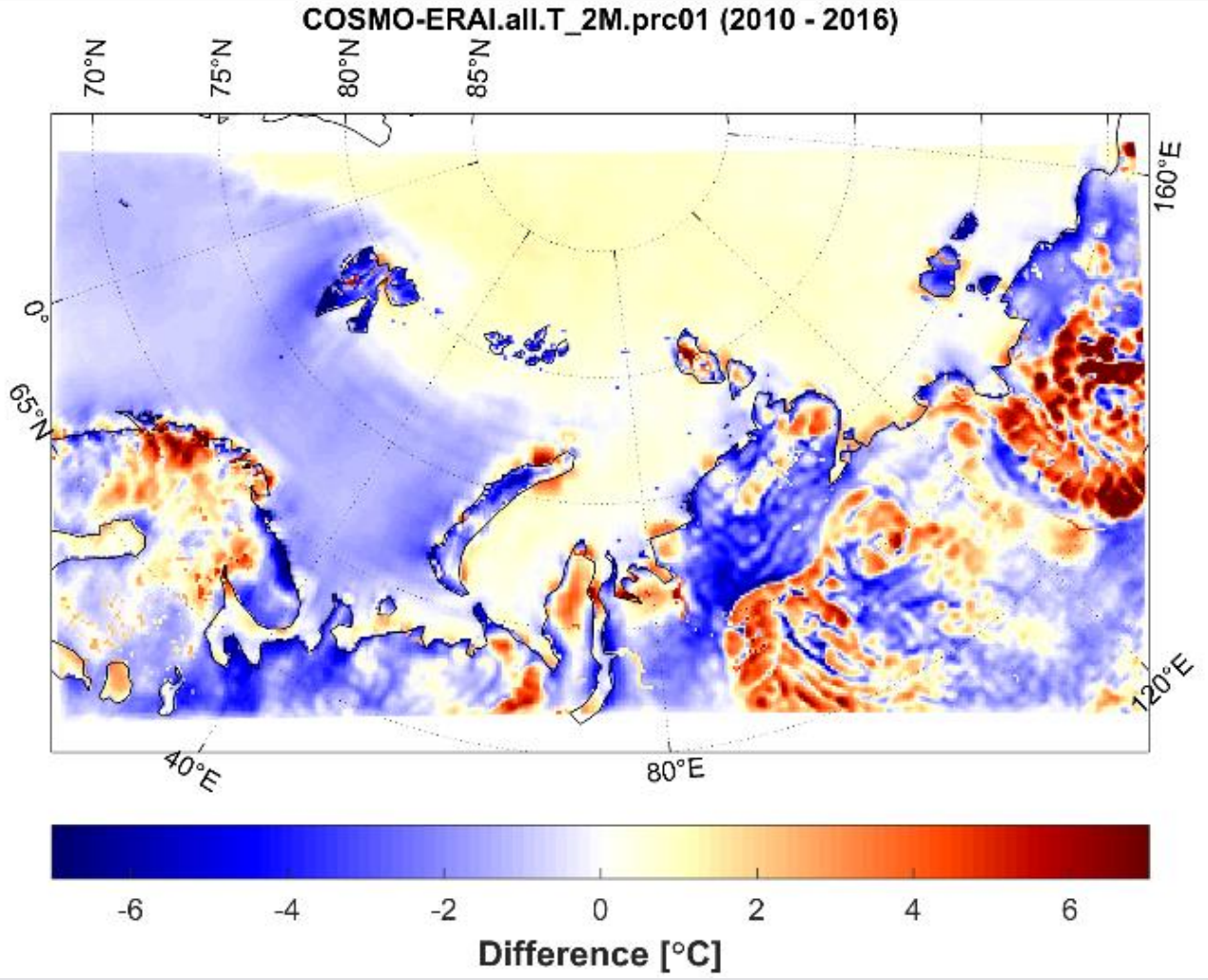




The **2 m temperature difference** (^{0}C) between the 1980 – 1990 and 2010 – 2016 periods for the *COSMO-CLM hindcast* (*left*), the *"COSMO-CLM–ERA-Interim"* **temperature difference** for 2010 – 2016 period for mean annual temperatures (*right*); for **winter** (**DJF**, *left*), for **summer** (**JJA**, *right*).

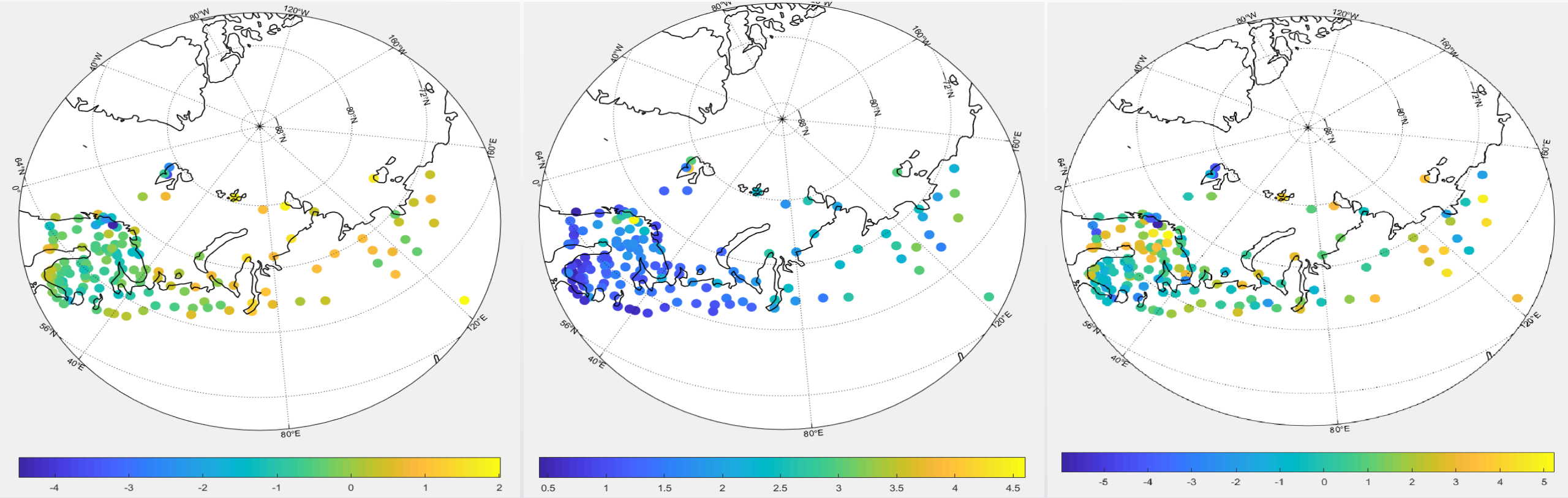
CCLM and ERAI comparison. Temperature.





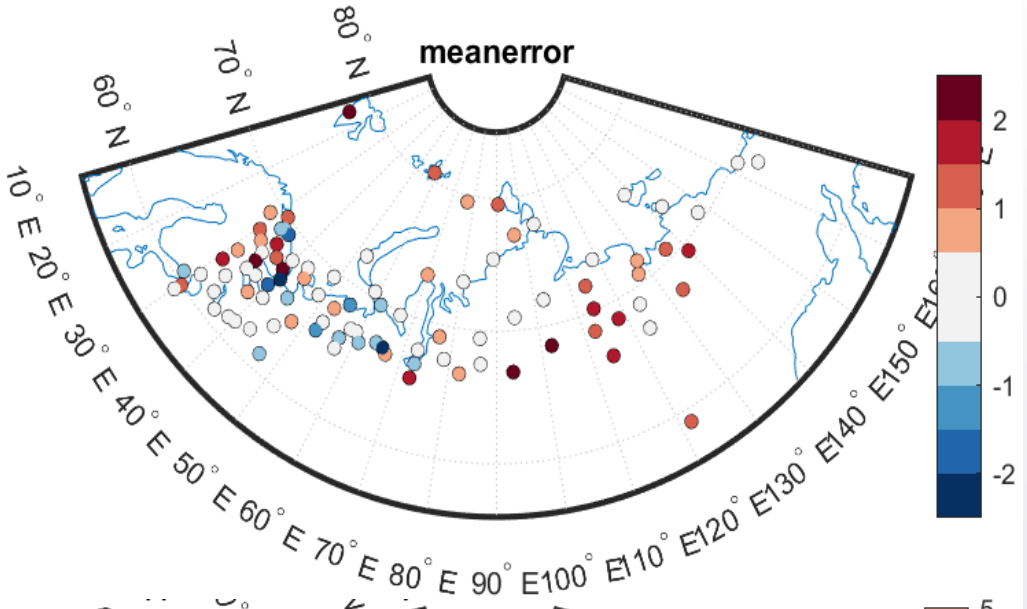
The **2 m temperature 1% percentile** (°C) according to *COSMO-CLM hindcast* for the 2010 – 2016 period (*left*), *"COSMO-CLM–ERA-Interim"* **1% percentiles differences** (*right*) for 2010 – 2016 period.

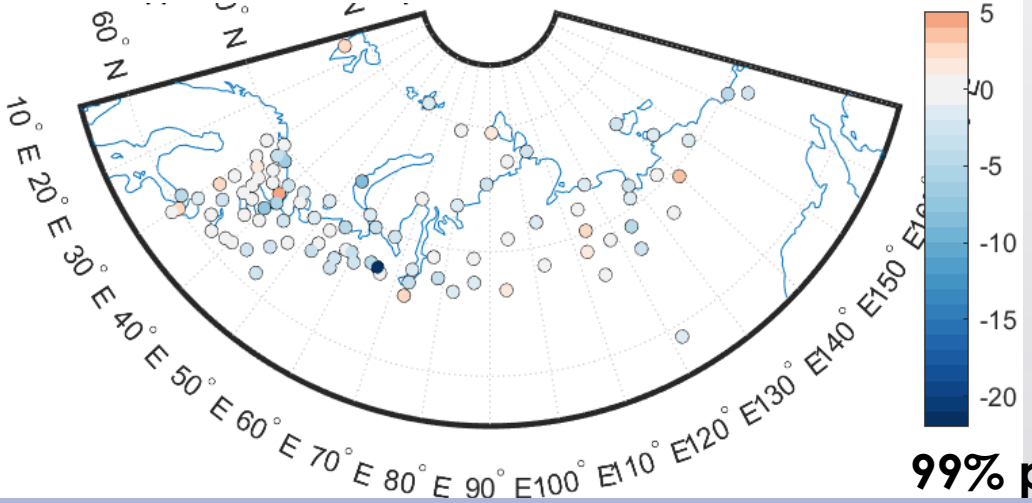
COSMO-CLM temperature evaluation

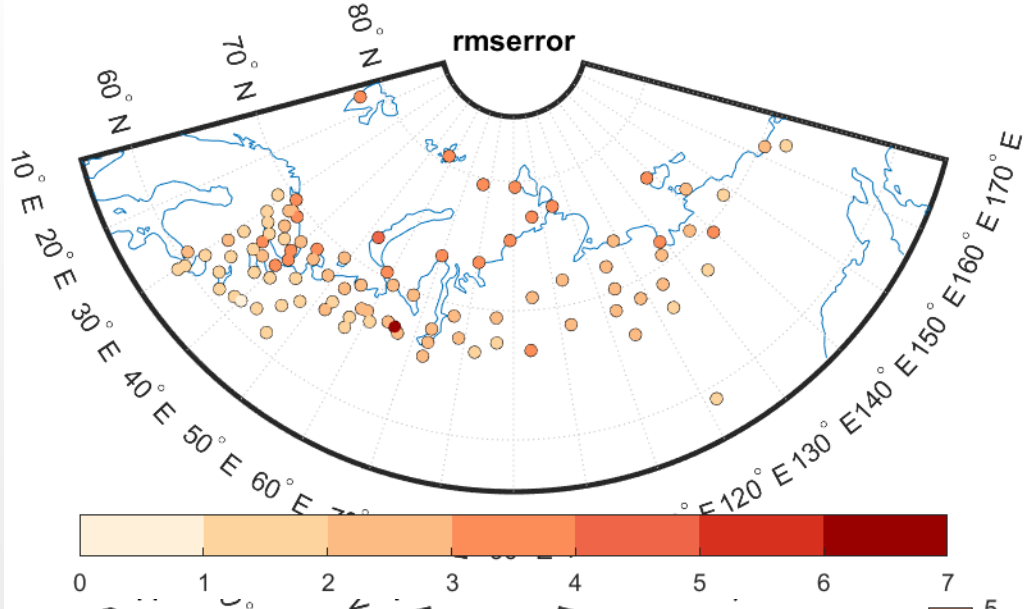


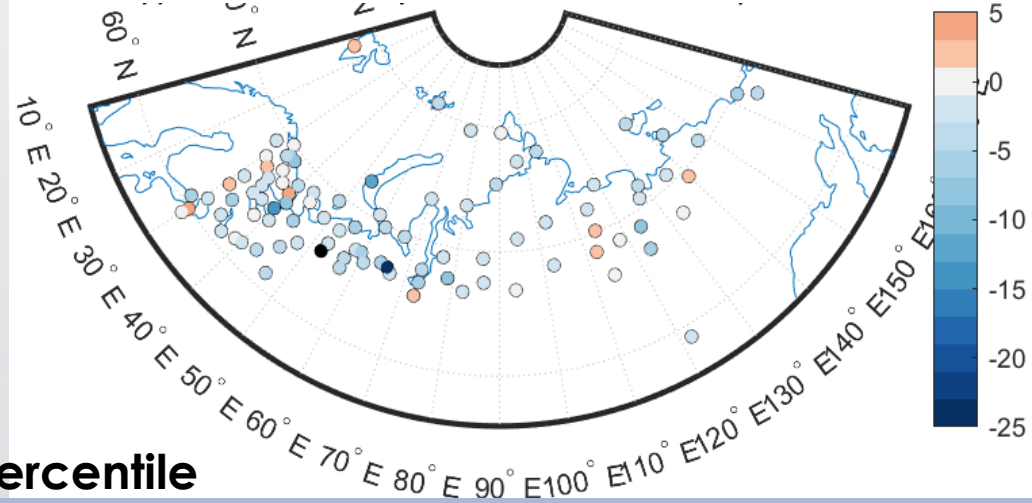
The COSMO-CLM Russian Arctic hindcast **2 m temperature mean errors** (°C, *left*), **RMSE** (°C, *center*) and **1% percentiles difference** (°C, *right*) according to ***observations*** for the 1980 – 1994, 2000 – 2008 and 2010 – 2016 periods.

COSMO-CLM wind speed evaluation





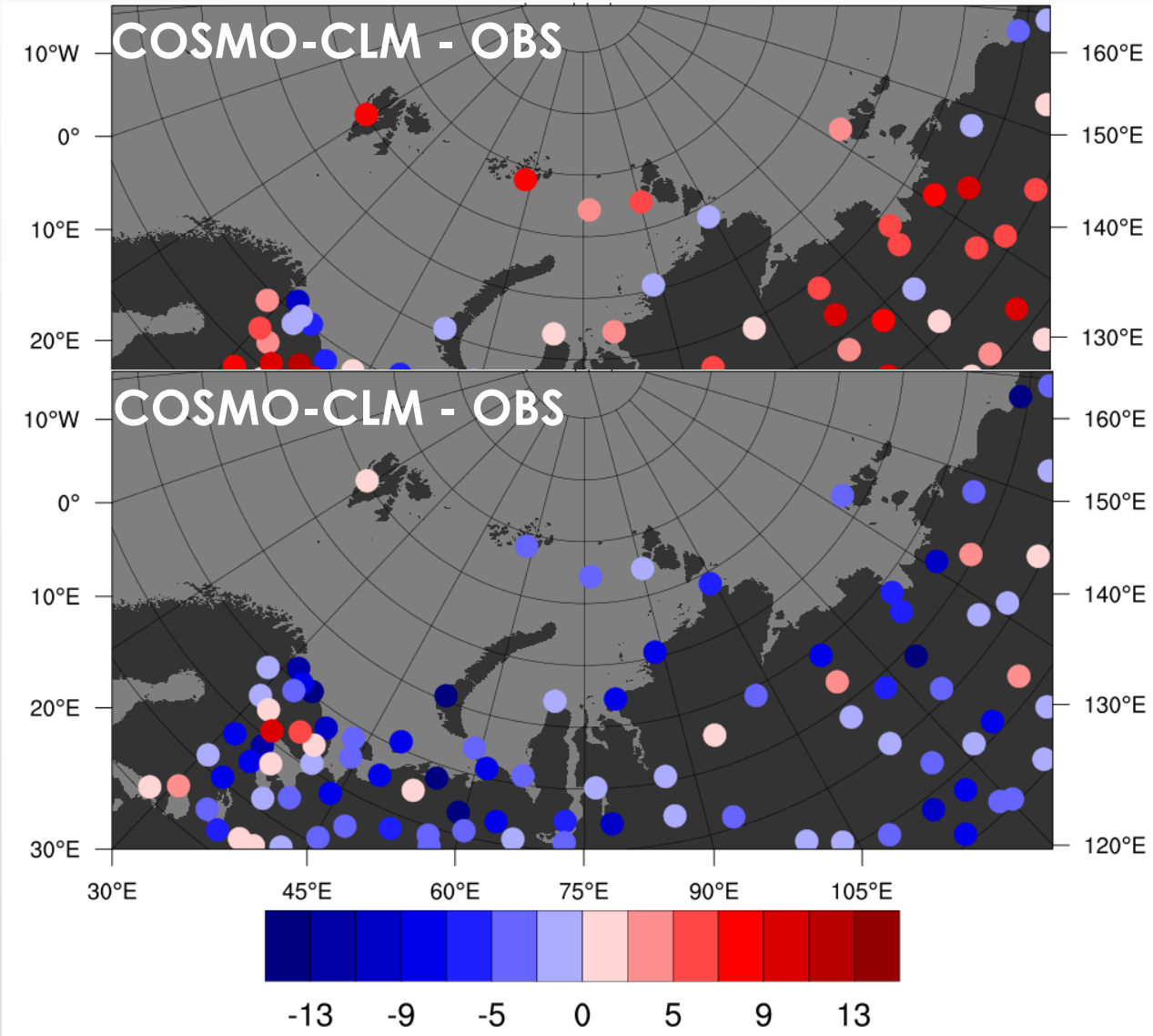


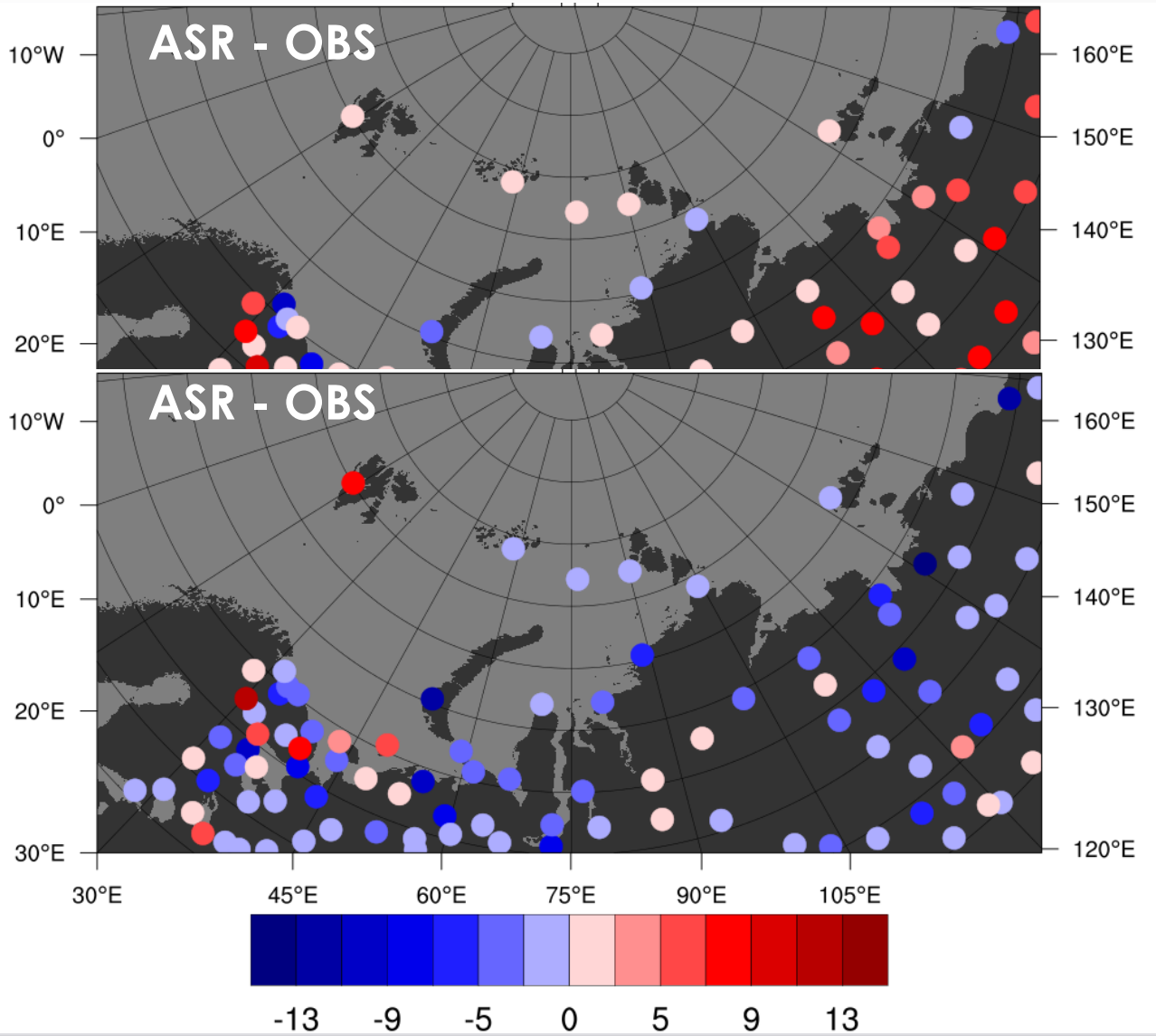


99% percentile **99.9% percentile**

The COSMO-CLM Russian Arctic hindcast **10 m wind speed mean errors** (m/s, *left top*), **RMSE** (m/s, *right top*), **99% and 99.9% percentiles difference** (m/s, *left and right bottom*) according to ***observations*** for 1980 – 1994, 2000 – 2008 and 2010 – 2016 periods.

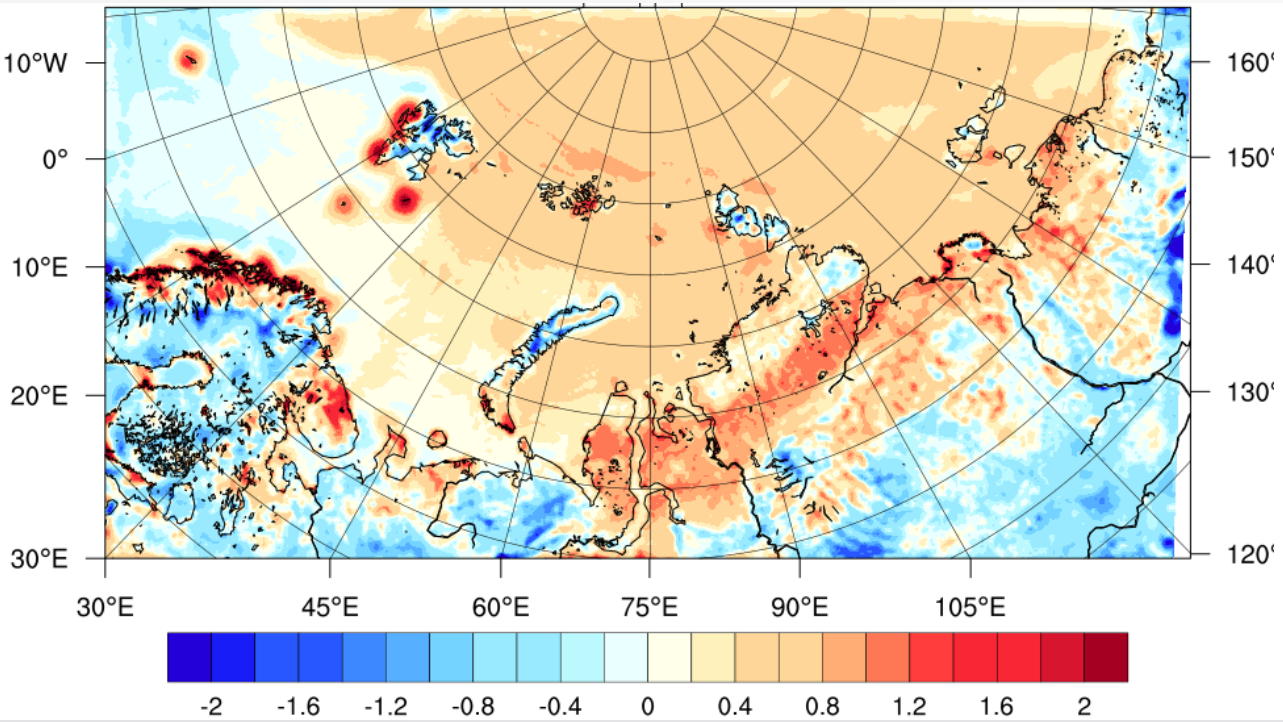
COSMO-CLM and ASRv2 wind speed evaluation

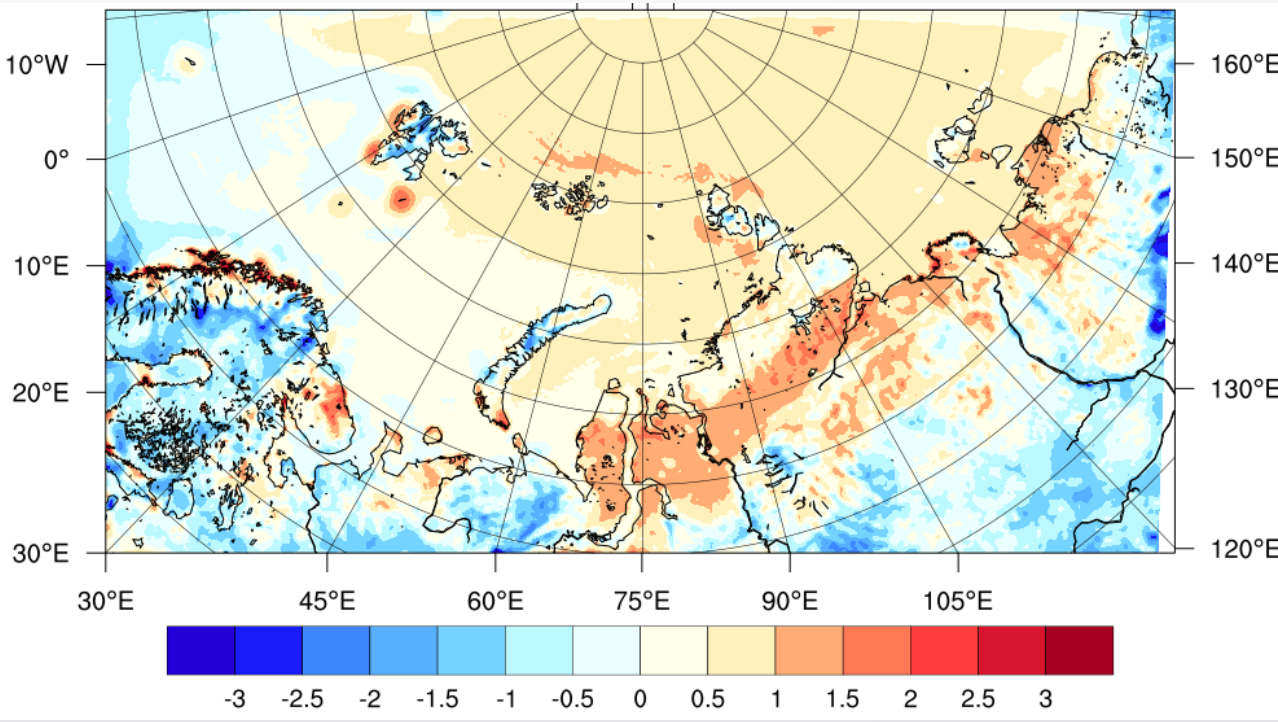




Difference of maximal wind speed, m/s

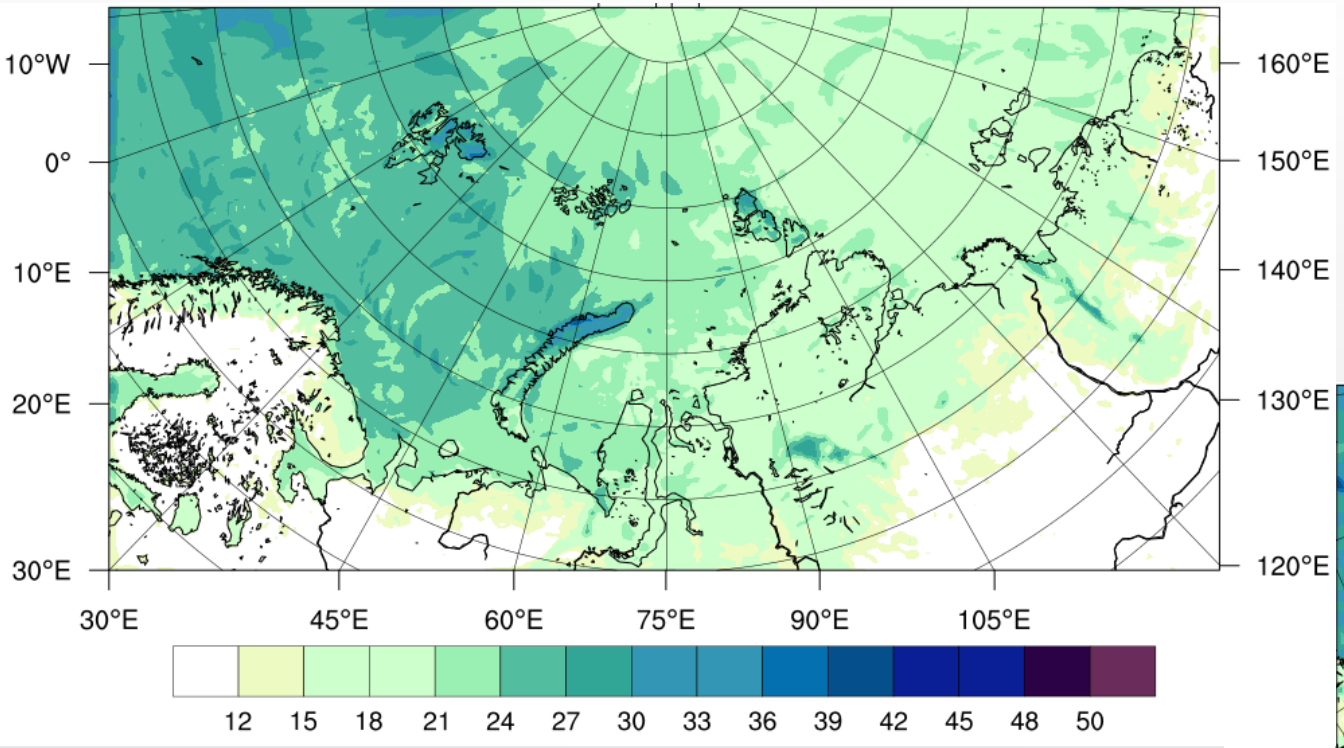
COSMO-CLM and ASRv2 wind speed evaluation

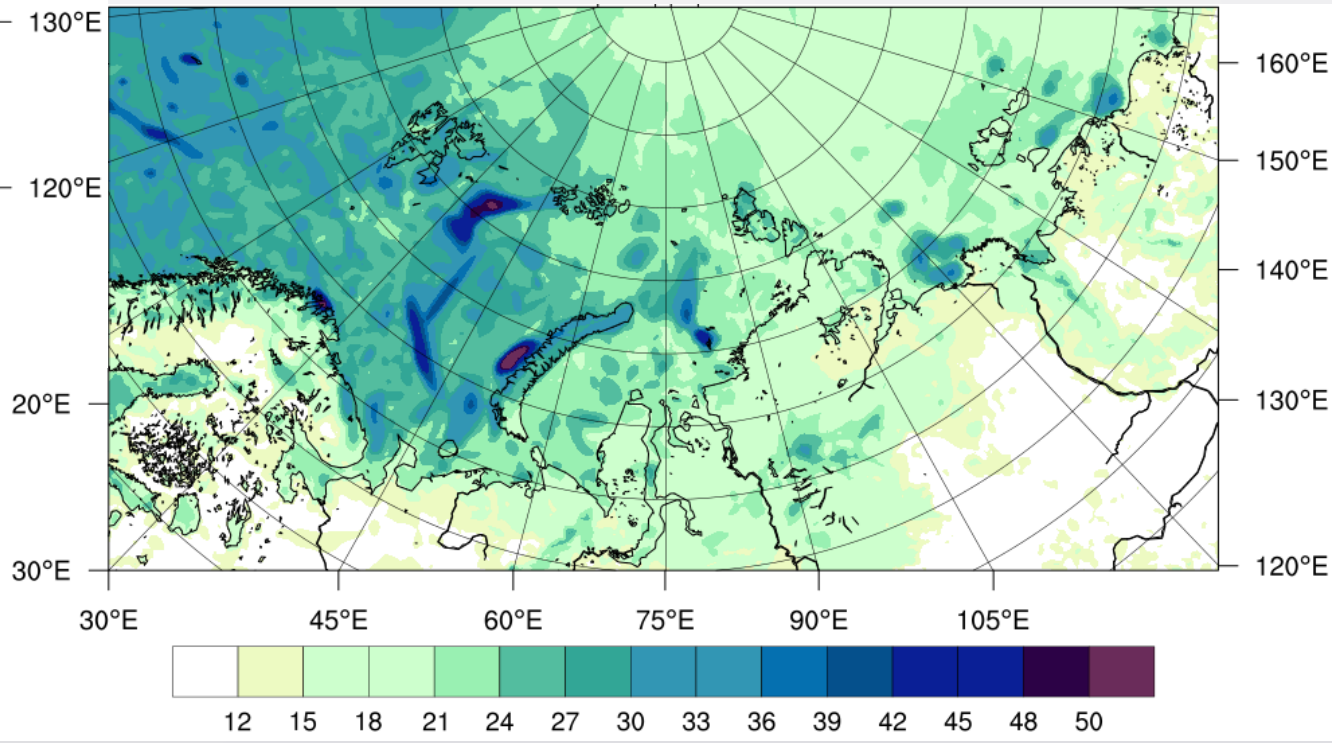




"COSMO-CLM – ASR" difference in **mean** (*left*) and **mean daily maxima** (*right*) 10 m wind speed (m/s).

COSMO-CLM and ASRv2 wind speed evaluation





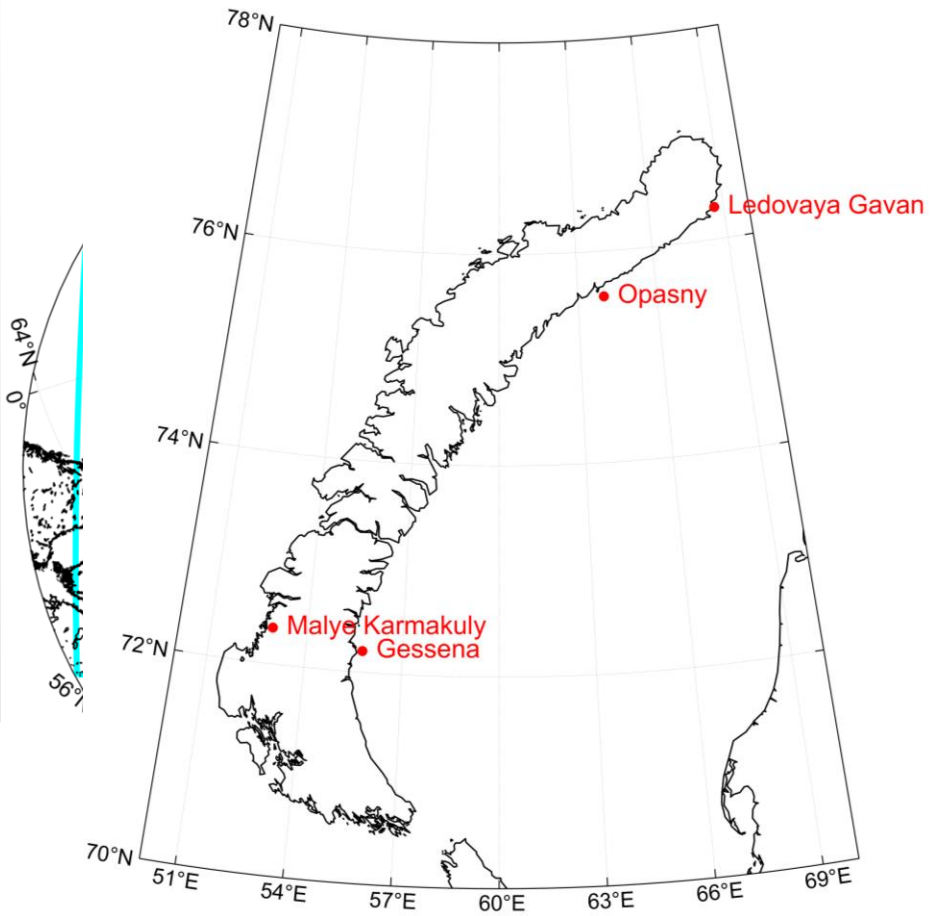
Maximal 10 m wind speed (m/s) according to ***COSMO-CLM hindcast*** (left top) and ***ASRv2 reanalysis*** (right bottom)

COSMO-CLM and ASRv2 wind direction evaluation

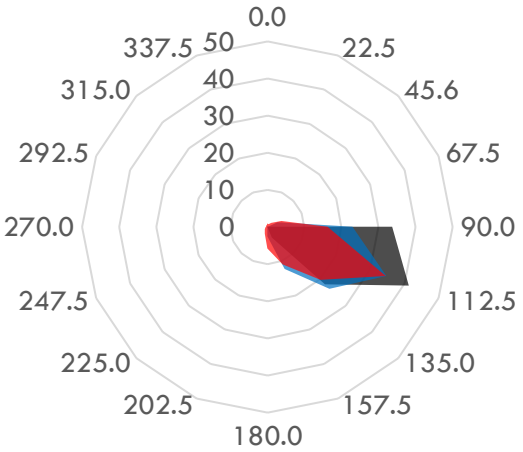
Downslope windstorms (in Tiksi, on Svalbard and Novaya Zemlya) criteria:

wind speed > 8 m/s;
wind direction Ny-Alesund 80 – 140^0;
wind direction Malye Karmakuly 80 – 150^0;
wind direction Gessena 230 – 320^0;
wind direction Ledovaya Gavan 270 – 330^0;
wind direction Opasny 310 – 30^0;
wind direction Tiksi 180 – 240^0.

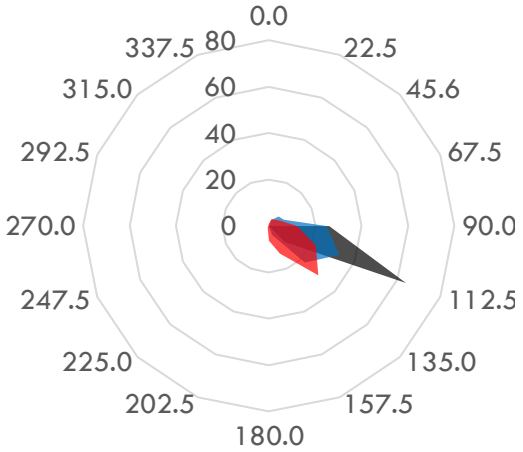
OBS
ASRv2
COSMO -CLM



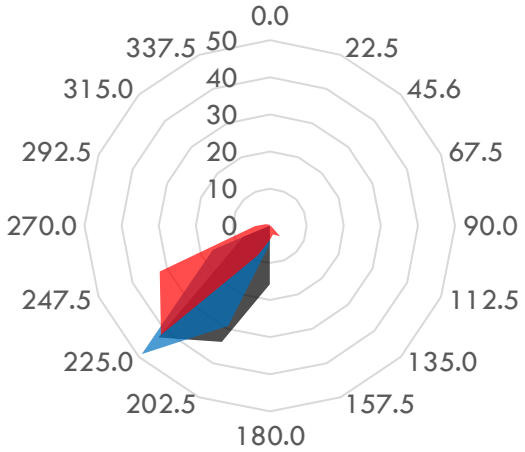
Malye Karmakuly



Ny-Alesund

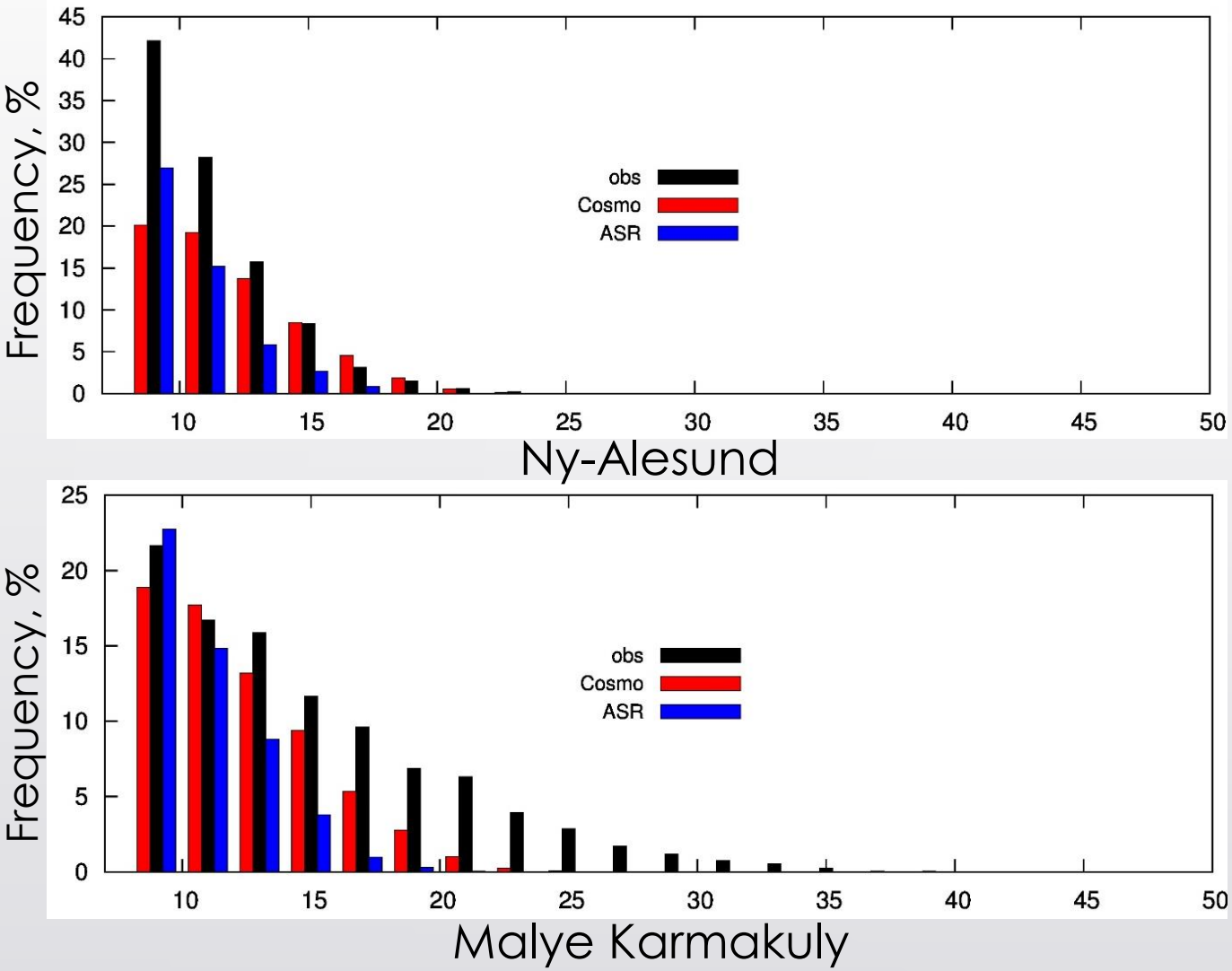


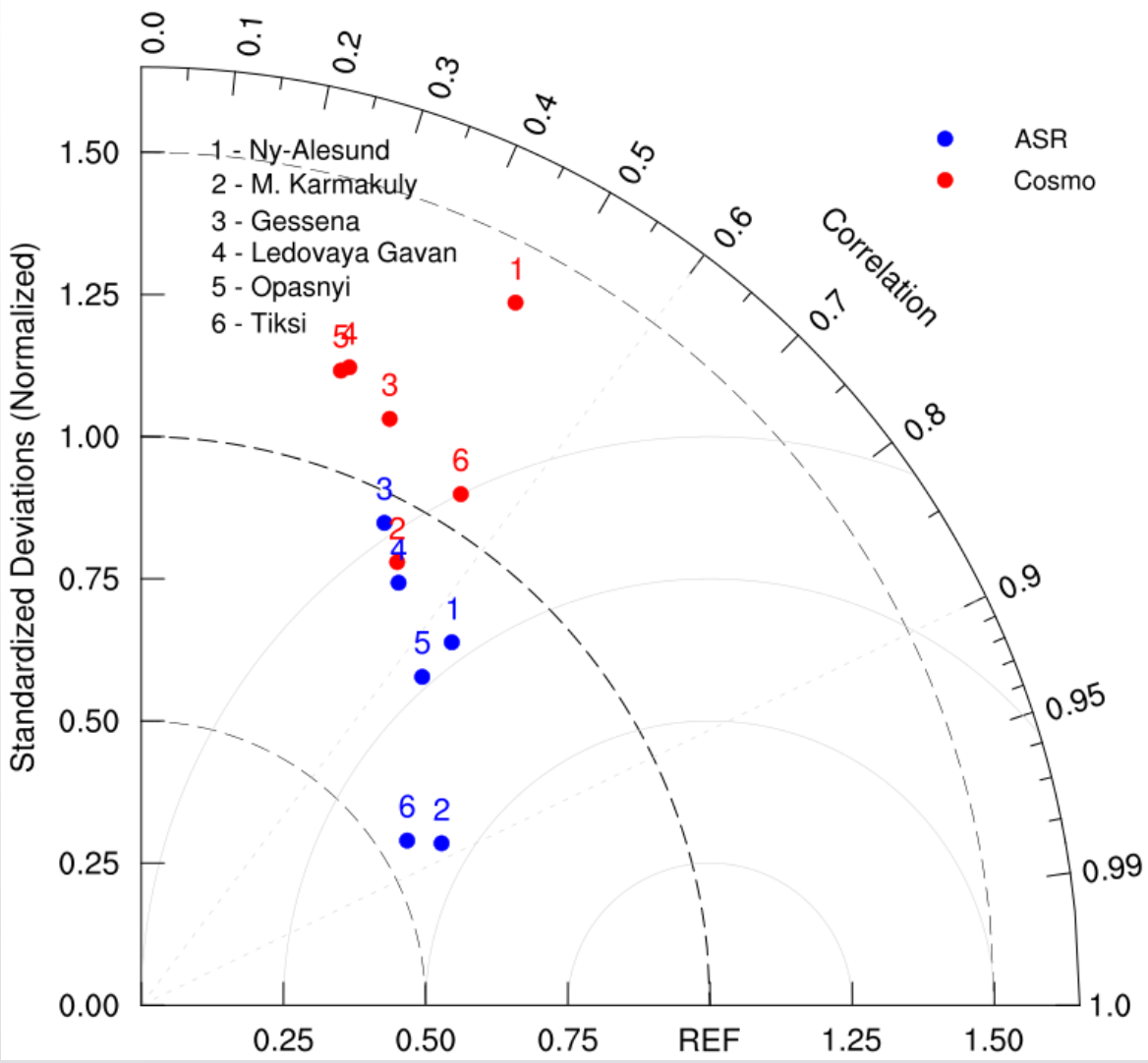
Tiksi



Platonov, V. and Shestakova, A. Downslope windstorms and associated extreme wind speed statistics evaluation according to the COSMO-CLM Russian Arctic hindcast, ASR reanalysis and observations, **EMS2021-300**, https://doi.org/10.5194/ems2021-300, *2021*.

Downslope windstorms statistics evaluation

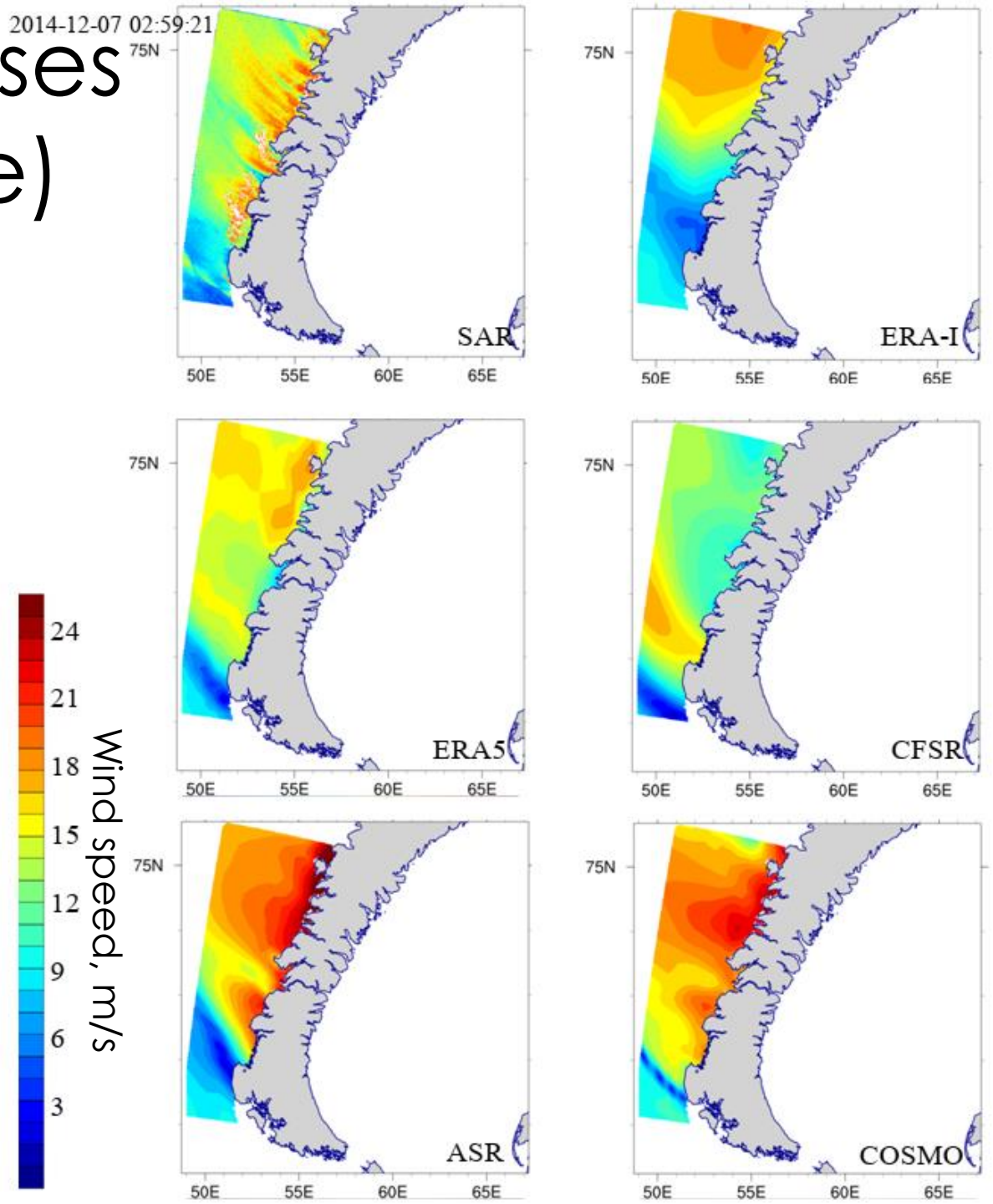




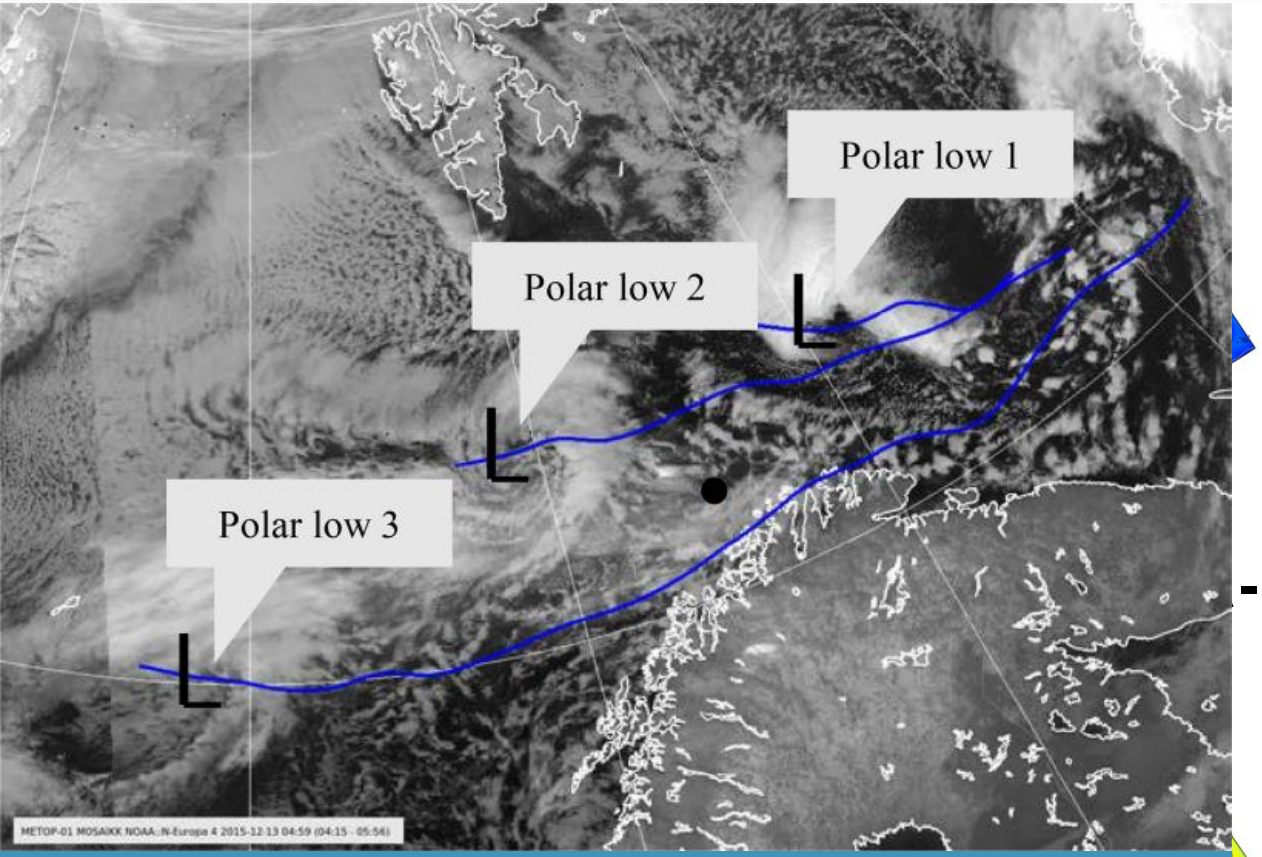
<u>Frequency</u> (%) of *<u>10 m wind speed</u>* (m/s) **during downslope windstorms** (left) at *<u>Ny-Alesund</u>* (top) and *<u>Malye Karmakuly</u>* (bottom) stations. Taylor diagram of COSMO-CLM and ASR wind speed with the observations at 6 stations (right).

Downslope windstorms cases SAR Radarsat-2 (example)

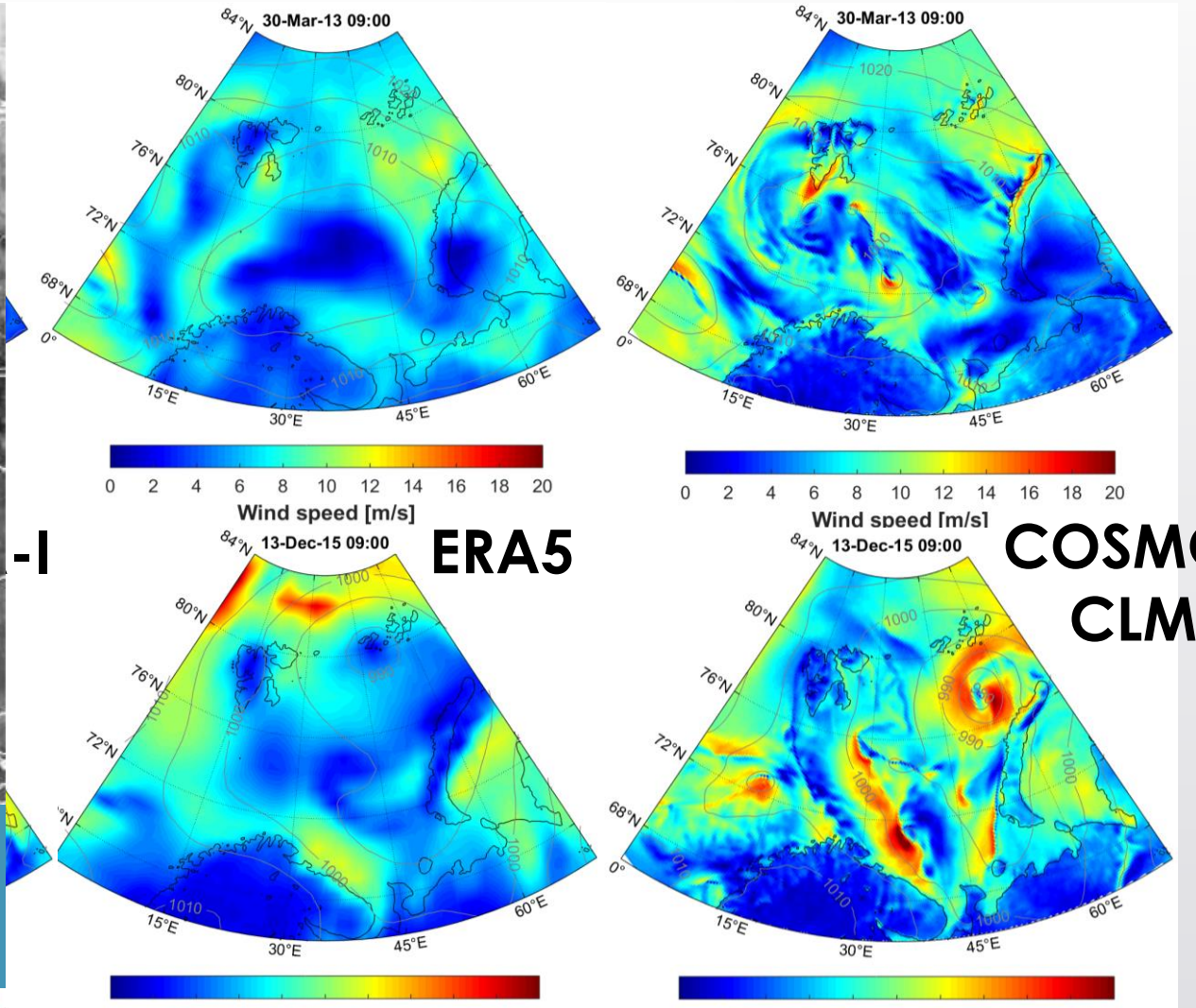
	ERA-I	ERA5	CFSR	ASR	COSMO-CLM
Mean wind speed bias	-0,70	**0,40**	-1,00	2,20	3,70
Minimal wind speed bias	2,80	-0,80	-1,40	-0,70	**0,00**
Maximal wind speed bias	-2,80	-3,20	-4,00	6,60	**2,50**
Magnitude bias	-5,60	**-2,40**	-2,60	7,30	2,50
bias 95%	**-0,40**	-1,60	-1,70	3,90	3,30
bias 99%	**-2,00**	-3,10	-3,10	5,40	2,20
bias 99.9%	-2,80	-3,70	-4,00	6,20	**2,30**
R	0,39	0,68	0,29	0,72	**0,74**
S	1,71	1,61	**1,42**	1,43	1,58
A	-0,05	**0,03**	-0,08	0,15	0,25
L	0,54	0,43	0,61	0,37	**0,36**
dN	-17,00	-16,00	-17,00	**-12,00**	-16,00



Example of polar lows evaluation (wind speed)



MetOp-01 NOAA image showing the three polar lows of **13 December 2015**: the blue lines shows the polar low trajectory (Orimolade et al. 2016)



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Conclusions and future prospects

- ✓ First version of **COSMO-CLM long-term hydrometeorological dataset** was created for the Russian Arctic area, including dozens of variables with ~12 km grid.
- ✓ Preliminary assessments of the ***'added value'*** for surface **wind speed** and **temperature climatology** with respect to the ERA-I reanalysis revealed many details at different Arctic regions caused by more detailed topography and coastline representation.
- ✓ **High wind speed frequencies** based on COSMO-CLM dataset **are increased** compared to ERA-Interim, especially over the Barents Sea, Arctic islands (Novaya Zemlya) and some seacoasts and mainland areas.
- ✓ ***Downslope windstorms cases*** evaluation showed the **ASRv2** is the best for *wind direction*, while **COSMO-CLM hindcast** is the best for *wind speed*. *Extreme wind speed frequency* during downslope windstorms is better reproduced by the **COSMO-CLM hindcast**, while *moderate wind speed frequency* is better reproduced by the **ASRv2**.
- ✓ **COSMO-CLM hindcast** is better in most cases for *maximal wind speed* and *extreme percentiles* according to **SAR Radarsat-2** evaluation.
- ✓ **Future plans**: possible prolongation up to 2019, share more data online; **extreme and severe events** statistics assessment (***downslope windstorms*** cases, ***polar lows***, ***marine cold air outbreaks climatology*** using satellite data); ***comparison with*** other datasets and reanalyses (ERA5, Arctic CORDEX, CARRA, satellites) and quality **estimation** … etc.

Additional slides

Added values statistics

Variable, Period	Mean Difference, Whole Domain	Mean Difference, Land Grids	Mean Difference, Sea Grids	First Percentile of Difference, Whole Domain	99th Percentile of Difference, Whole Domain
VEL_10M, 1980–1990	0.13	0.34	−0.14	−1.63	2.22
VEL_10M, 2010–2016	0.14	0.37	−0.13	−1.63	2.19
VEL_10M, 1980–1990 (DJF)	0.03	0.37	−0.38	−2.25	2.47
VEL_10M, 2010–2016 (DJF)	0.06	0.42	−0.38	−2.14	2.47
VEL_10M, 1980–1990 (JJA)	0.23	0.24	0.23	−1.06	2.15
VEL_10M, 2010–2016 (JJA)	0.25	0.24	0.26	−1.12	2.14
T_2M, 1980–1990	−0.03	0.10	−0.19	−1.67	1.72
T_2M, 2010–2016	−0.24	0.01	−0.56	−1.87	1.39
T_2M, 1980–1990 (DJF)	0.30	0.16	0.48	−2.18	4.81
T_2M, 2010–2016 (DJF)	0.04	0.08	0.00	−2.51	4.85
T_2M, 1980–1990 (JJA)	−0.37	−0.05	−0.76	−2.70	1.31
T_2M, 2010–2016 (JJA)	−0.42	−0.07	−0.85	−2.61	1.14

Results. Preliminary evaluation of added values (mean and extremes)

Now runs are **just finished** for periods **1980 – 2008** and **2010 – 2016** **except 2009** due to objective technical limitations and issues ☹.
Computational resources: ~**62 000** nodes-hours, total data volume – more than **120 Tb**.

Relaxation zone of **10 grids** were excluded from *each side* of the domain.

Test experiments
Brief statistics comparison

	December-January 2012 – 2013			August-September 2015		
Experiments configuration	RMSE/R **T 2m**	RMSE/R **V 10m**	RMSE/R **PMSL**	RMSE/R **T 2m**	RMSE/R **V 10m**	RMSE/R **PMSL**
Interim base	4.22/0.76	2.30/0.55	2.98/0.96	2.38/0.77	2.02/0.65	1.87/0.99
ERA5 base	4.19/0.76	2.30/0.57	2.77/0.97	2.34/0.79	2.00/0.67	1.70/0.99
Interim sn	3.69/0.83	2.12/0.65	2.01/0.99	2.89/0.79	1.89/0.70	1.53/1.00
ERA-5 sn	3.70/0.83	2.10/0.66				
Interim sn+5.05	3.34/0.85	2.22/0.65				
ERA-5 sn+5.05	3.33/0.85	2.24/0.67				
Interim turb+sn	3.38/0.84	2.12/0.65				
ERA-5 turb+sn	3.37/0.85	2.09/0.66				

Based on test experiments and verification results, the following **optimal model configuration** chosen:

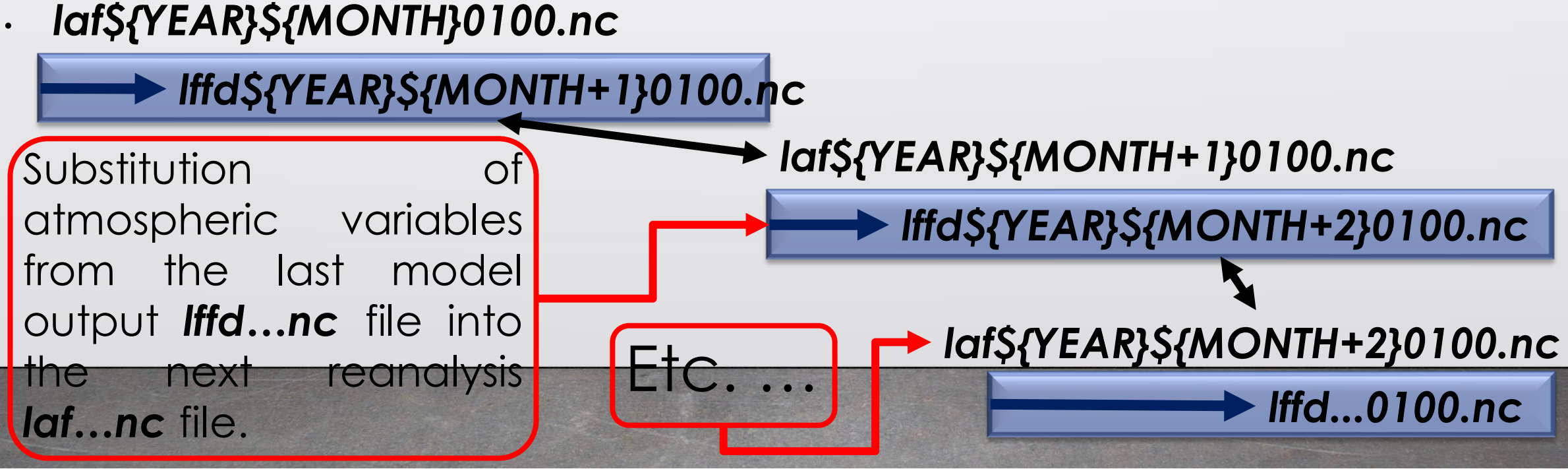
- 'spectral nudging';
- new model version 5.05 included the ICON-based physics;
- ERA-Interim reanalysis used as driving conditions

V. Platonov, M. Varentsov. Creation of the long-term high-resolution hydrometeorological archive for Russian Arctic: methodology and first results. *IOP Conference Series: Earth and Environmental Science*, 386(012), 2019. http://dx.doi.org/10.1088/1755-1315/386/1/012039

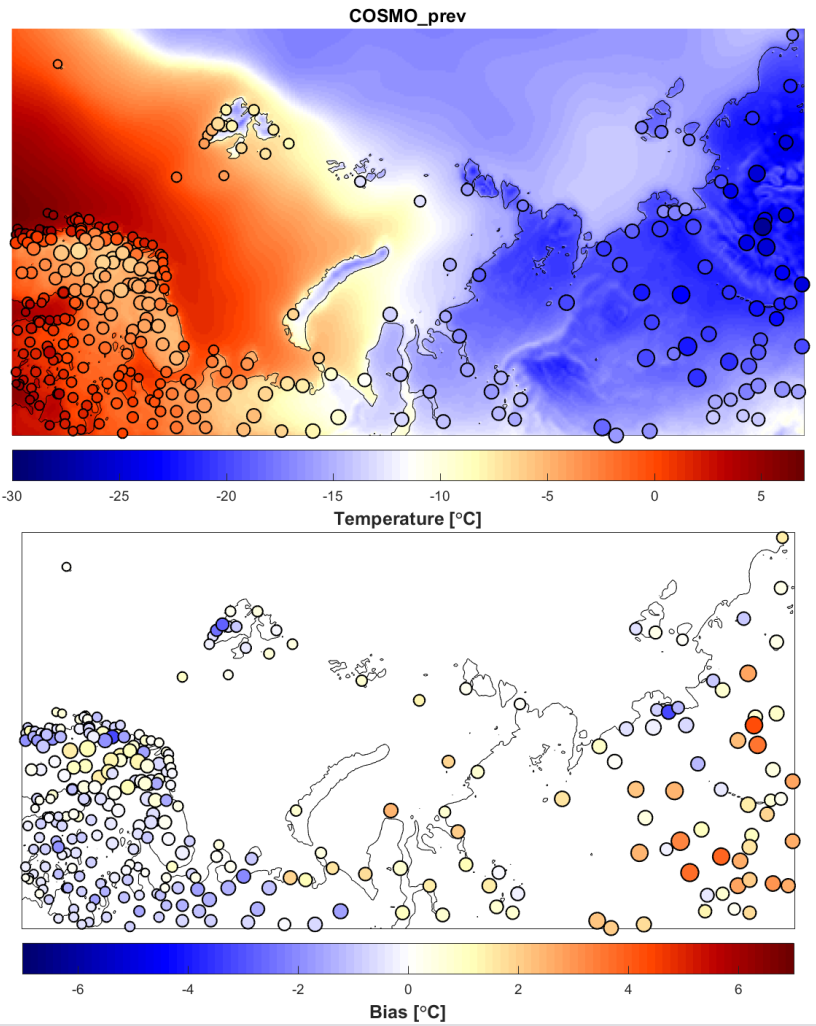
Additional soil data assimilation

Model was ***reinitialized monthly*** to control the *subseasonal elements* of climate system better *during long-term experiments* (*soil heat and moisture content*) and to avoid possible systematic errors.

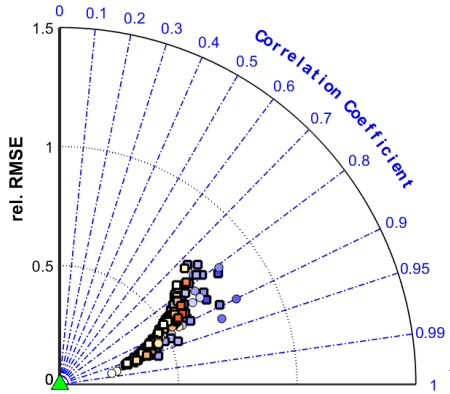
Each month model was initialized by the ***most atmospheric*** and ***soil variables*** from the last output file (**lffd***), except for ***deeper soil variables*** (>2.5 cm), which were substituted by ***reanalysis data*** (from **laf***).

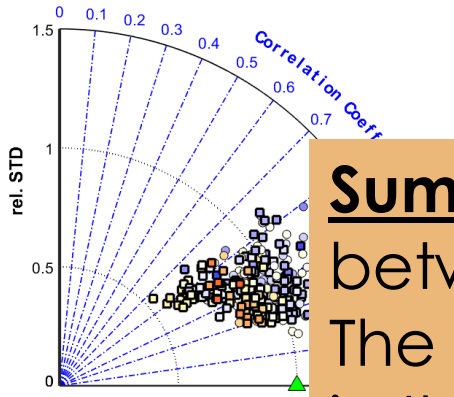


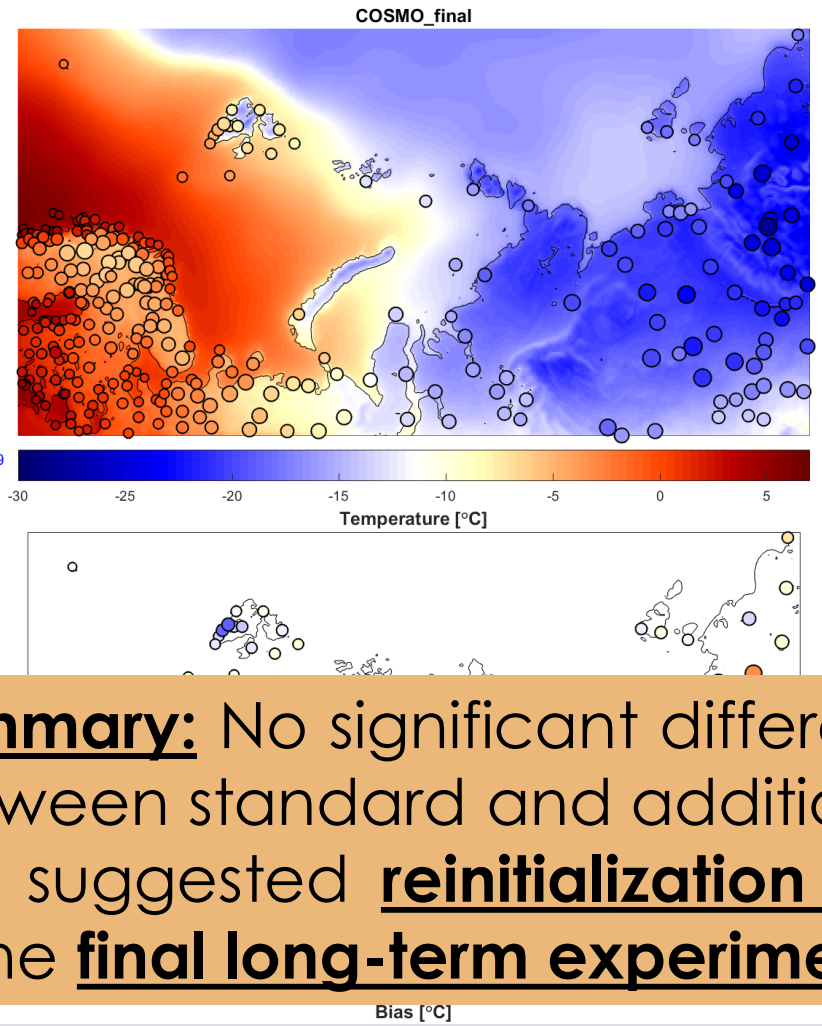
Additional soil data assimilation. Verification



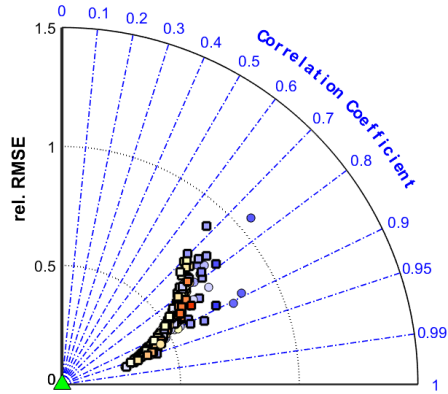
	Bias	RMSE
All	0.07	3.22
Inland	0.07	3.87
Coastal	0.06	2.37

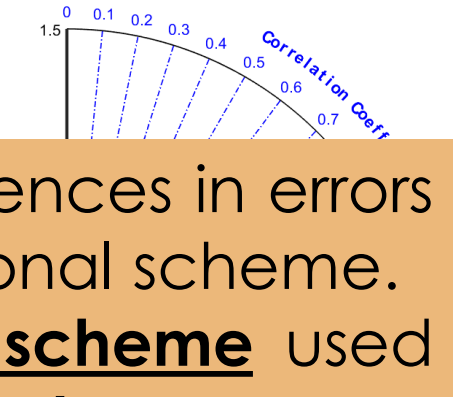






	Bias	RMSE
All	0.09	3.32
Inland	0.11	3.98
Coastal	0.06	2.45





<u>Summary:</u> No significant differences in errors between standard and additional scheme. The suggested **<u>reinitialization scheme</u>** used in the **<u>final long-term experiment</u>**.

Test experiments verification for **2 m temperature**, **<u>OND 2013</u>**
standard model run (***left***), model run with ***reinitialization*** (***right***).

Full variables output list

Variable Acronyms	Variable Full Names	Dimension
U, V, W, T, FI, TKE, POT_VORTIC, H_SNOW, RHO_SNOW, W_SNOW, RELHUM, QV	Zonal, meridional, and vertical velocities, temperature, geopotential, turbulence kinetic energy, Ertel potential vorticity, snow height, density, water content, relative and specific humidity	3D
U_10M, V_10M, VMAX_10M, VABSMX_10M	Zonal, meridional, maximal velocities, and wind gusts on 10 meters	2D
T_2M, TMAX_2M, TMIN_2M, TD_2M, TWATER	2 meters temperature, maximal and minimal, 2 meters dew point, water temperature	2D
PMSL, HPBL	Sea level pressure, planetary boundary layer height	2D
T_S, T_SNOW, T_SO, T_ICE	Surface, snow, soil, ice temperatures	2D
TQC, TQI, TQR, TQS, TQG, TQV	Vertical integrated cloud water, ice, rain, snow, graupel, precipitable water, total water content	2D
CLCM, CLCH, CLCL, CLCT, CLDEPTH	Medium, high, low, total, convective cloud cover, cloud depth	2D
CLC_CON	Convective cloud area fraction	3D
LHFL_S, SHFL_S	Latent and sensible heat fluxes	2D
SWDIRS_RAD, SWDIFDS_RAD, THDS_RAD, THUS_RAD, SOBS_RAD, THBS_RAD, SWDIFUS_RAD, ALB_RAD	Surface radiation components: shortwave direct and diffuse, longwave downward and upward, net shortwave and longwave radiation, reflected, albedo	2D
RELHUM_2M, QV_2M	Relative and specific humidity at 2 meters	2D
FRESHSNW, SNOW_MELT	Freshness of snow, snow melt	2D
TOT_PREC, SNOW_CON, SNOW_GSP, RAIN_CON, RAIN_GSP, RUNOFF_S, RUNOFF_G	Total precipitation, convective and grid-scale snow, convective and grid-scale rain, surface and subsurface runoff	2D
CAPE_MU, CIN_MU, CAPE_ML, CIN_ML	CAPE and CIN indexes of most unstable parcel and mean surface layer parcel	2D

Variables didn't assimilated additionally from ERAI

Variable name	Variable description	Variable name	Variable description
U	U-component of wind	T_ICE	temperature of ice upper surface
V	V-component of wind	H_ICE	sea ice thickness
T	temperature	C_T_LK	shape factor of temperature profile in lake thermocline
TQV	precipitable water	DEPTH_LK	lake depth
TQC	vertical integrated cloud water	H_B1_LK	thickness of the upper layer of bottom sediments
TQI	vertical integrated cloud ice	H_ML_LK	thickness of mixed layer
TQG	total graupel content vertically integrated	T_B1_LK	temperature at bottom of upper layer of sediments
TQR	total rain water content vertically integrated	T_BOT_LK	temperature at water bottom sediment interface
TQS	total snow content vertically integrated	T_MNW_LK	mean temperature of water column
T_S	soil surface temperature	PP	deviation from reference pressure
T_SO [1,2]	soil temperature (1st and 2nd soil layers)		

Vertical levels

1 22000.00
2 21000.00
3 20028.57
4 19085.36
5 18170.00
6 17282.14
7 16421.43
8 15587.50
9 14780.00
10 13998.57
11 13242.86
12 12512.50
13 11807.14
14 11126.43
15 10470.00
16 9837.50
17 9228.57
18 8642.86
19 8080.00
20 7539.64
21 7021.43
22 6525.00
23 6050.00
25 5596.07
26 5162.86
26 4750.00
27 4357.14
28 3983.93
29 3630.00
30 3295.00
31 2978.57
32 2680.36
33 2400.00
34 2137.14
35 1891.43
36 1662.50
37 1450.00
38 1253.57
39 1072.86
40 907.50
41 757.14
42 621.43
43 500.00
44 392.50
45 298.57
46 217.86
47 150.00
48 94.64
49 51.43
50 20.00
51 0.00

$Z_f = 11357.00$

Soil levels	Depth (m)
0	0
1	0.005
2	0.025
3	0.07
4	0.16
5	0.34
6	0.70
7	1.42
8	2.86
9	5.74
10	11.50

Test experiments list

Experiment acronym	Model version	Reanalysis (forcing)	Spin up	Spectral nudging	Turbulence scheme correction
COSMO_interim (reference)	5.0	ERA-Interim	No	No	Standard
COSMO_interim_long	5.0	ERA-Interim	Yes	No	Standard
COSMO_era5	5.0	ERA5	No	No	Standard
COSMO_interim_sn	5.0	ERA-Interim	No	Yes	Standard
COSMO_era5_sn	5.0	ERA5	No	Yes	Standard
COSMO_interim_turb	5.0	ERA-Interim	No	No	Modified
COSMO_era5_turb	5.0	ERA5	No	No	Modified
COSMO_interim_turb_sn	5.0	ERA-Interim	No	Yes	Modified
COSMO_interim_turb_sn_long	5.0	ERA-Interim	Yes	Yes	Modified
COSMO_era5_turb_sn	5.0	ERA5	No	Yes	Modified
COSMO_era5_sn_v505	5.05	ERA5	No	Yes	Modified
COSMO_interim_sn_v505	5.05	ERA-Interim	No	Yes	Modified
COSMO_interim_v505_long	5.05	ERA-Interim	Yes	No	Modified
COSMO_interim_sn_v505_long	5.05	ERA-Interim	Yes	Yes	Modified

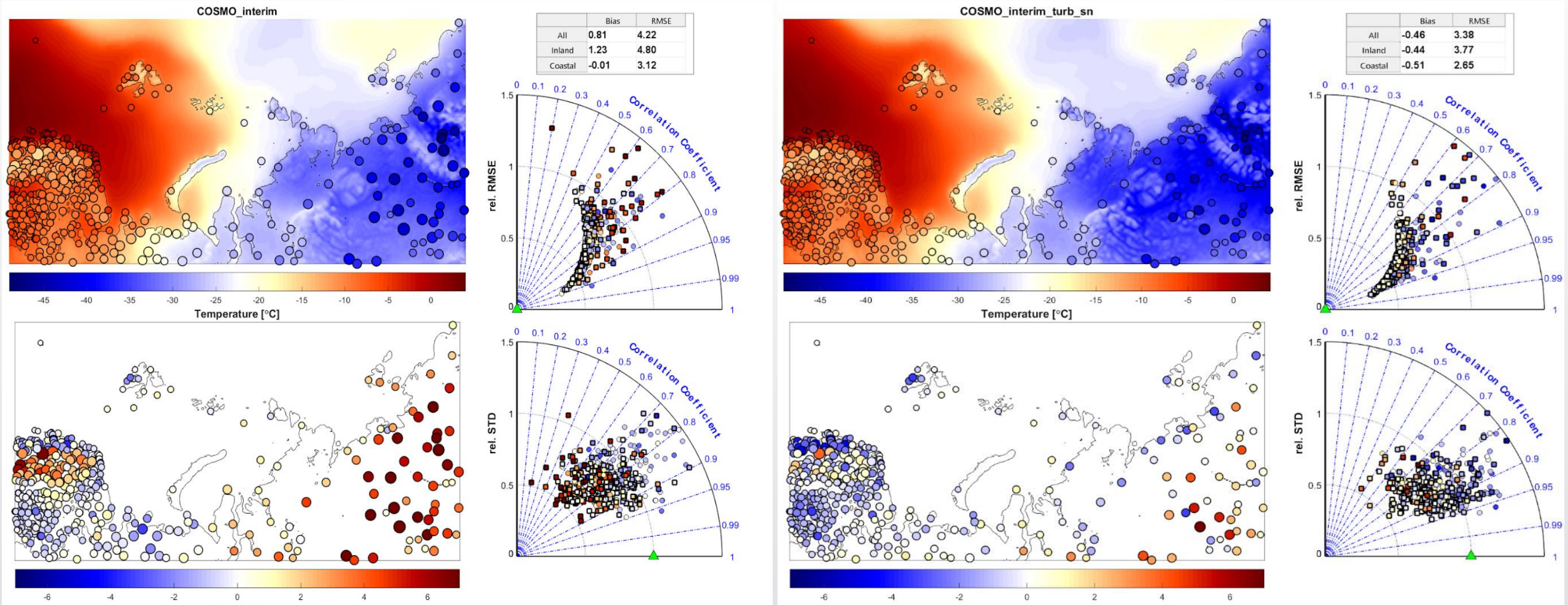
RMSE | Correlation, January 2013

Experiment name	T_2M (all)		T_2M (coast)		T_2M (inland)		VEL_10M (all)		VEL_10M (coast)		VEL_10M (inland)		PMSL (all)	
COSMO_interim	4.22	0.76	3.12	0.78	4.80	0.75	2.30	0.55	3.12	0.59	1.83	0.53	2.98	0.96
COSMO_era5	4.19	0.76	3.07	0.79	4.77	0.74	2.30	0.57	3.11	0.62	1.84	0.55	2.77	0.97
COSMO_interim_sn	3.69	0.83	2.61	0.85	4.25	0.82	2.12	0.65	2.78	0.70	1.74	0.62	2.01	0.99
COSMO_era5_sn	3.70	0.83	2.62	0.86	4.27	0.81	2.10	0.66	2.76	0.71	1.73	0.63	2.13	0.99
COSMO_interim_turb	4.10	0.76	3.29	0.78	4.53	0.76	2.30	0.55	3.12	0.59	1.84	0.53	3.24	0.96
COSMO_era5_turb	4.16	0.76	3.32	0.78	4.60	0.75	2.32	0.57	3.17	0.61	1.84	0.54	3.25	0.96
COSMO_interim_turb_sn	3.38	0.84	2.65	0.85	3.77	0.83	2.12	0.65	2.79	0.69	1.74	0.63	2.08	0.99
COSMO_interim_turb_sn_long	3.57	0.83	2.74	0.85	4.00	0.83	2.11	0.65	2.79	0.70	1.72	0.62	2.14	0.99
COSMO_era5_turb_sn	3.37	0.85	2.67	0.86	3.74	0.84	2.09	0.66	2.77	0.71	1.71	0.64	2.18	0.99
COSMO_era5_sn_v505	3.34	0.85	2.37	0.88	3.85	0.84	2.22	0.67	2.90	0.71	1.84	0.64	1.69	0.99
COSMO_interim_v505_long	3.94	0.78	2.99	0.79	4.44	0.78	2.47	0.54	3.30	0.57	2.00	0.53	2.83	0.96
COSMO_interim_sn_v505_long	3.33	0.85	2.45	0.87	3.80	0.84	2.24	0.65	2.92	0.70	1.86	0.63	1.63	0.99
ERA-Interim	3.10	0.88	2.52	0.89	3.41	0.88	2.31	0.66	2.65	0.72	2.11	0.64	1.10	0.99

RMSE | Correlation, September 2015

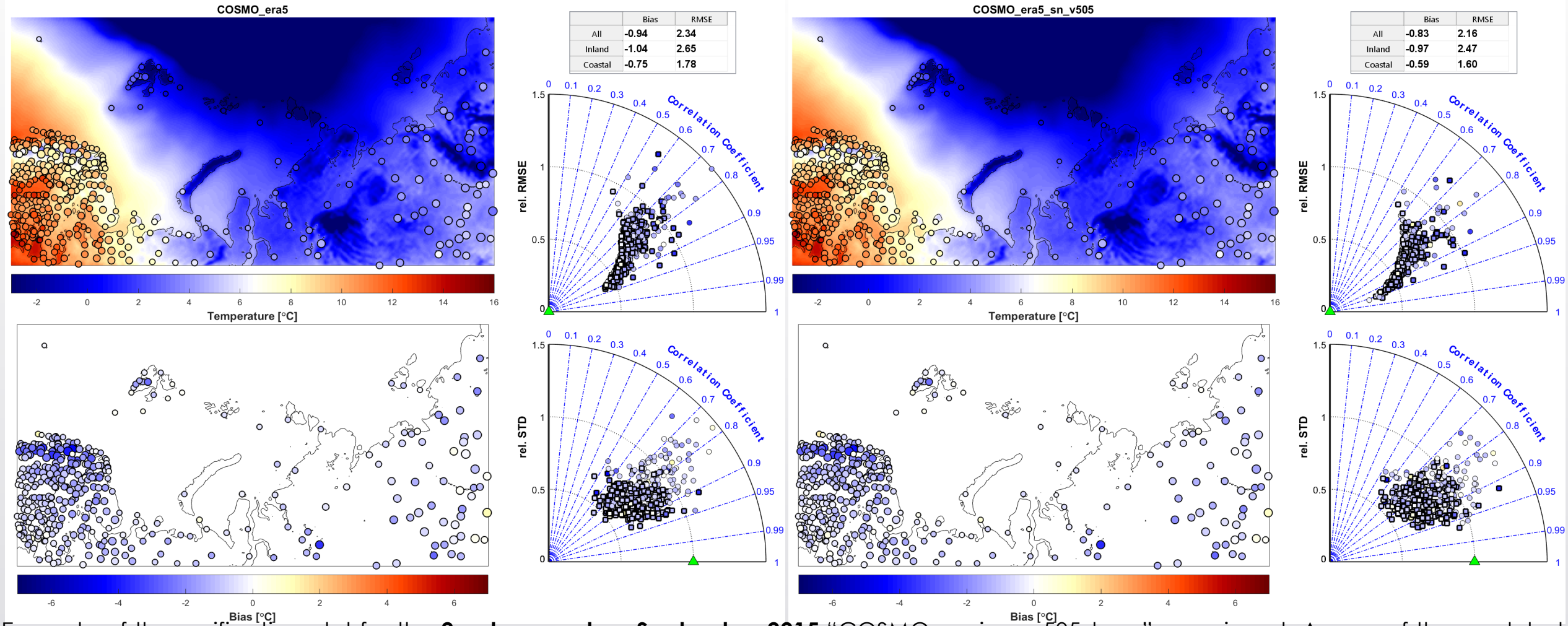
Experiment name	T_2M (all)		T_2M (coast)		T_2M (inland)		VEL_10M (all)		VEL_10M (coast)		VEL_10M (inland)		PMSL (all)	
COSMO_interim	2.38	0.77	1.83	0.75	2.69	0.78	2.02	0.65	2.63	0.67	1.65	0.64	1.87	0.99
COSMO_interim_long	2.41	0.76	1.85	0.75	2.72	0.77	2.06	0.64	2.68	0.66	1.68	0.63	1.96	0.99
COSMO_era5	2.34	0.79	1.78	0.78	2.65	0.80	2.00	0.67	2.59	0.69	1.65	0.65	1.70	0.99
COSMO_interim_sn	2.29	0.79	1.72	0.78	2.60	0.79	1.89	0.70	2.41	0.73	1.58	0.68	1.53	1.00
COSMO_era5_sn	2.29	0.81	1.71	0.80	2.61	0.81	1.87	0.71	2.37	0.74	1.58	0.68	1.42	1.00
COSMO_interim_turb	2.43	0.77	1.87	0.76	2.74	0.78	2.03	0.64	2.67	0.66	1.65	0.64	1.91	0.99
COSMO_era5_turb	2.41	0.80	1.82	0.79	2.73	0.80	1.98	0.67	2.55	0.70	1.64	0.66	1.65	0.99
COSMO_interim_turb_sn	2.35	0.79	1.78	0.79	2.67	0.80	1.89	0.69	2.42	0.73	1.58	0.67	1.57	1.00
COSMO_interim_turb_sn_long	2.25	0.80	1.71	0.80	2.54	0.80	1.90	0.70	2.43	0.73	1.58	0.68	1.51	1.00
COSMO_era5_turb_sn	2.35	0.81	1.76	0.81	2.67	0.81	1.88	0.70	2.38	0.74	1.58	0.68	1.45	1.00
COSMO_era5_sn_v505	2.16	0.82	1.60	0.81	2.47	0.83	1.97	0.70	2.47	0.73	1.67	0.68	1.34	1.00
COSMO_interim_v505_long	2.25	0.78	1.75	0.76	2.53	0.80	2.15	0.64	2.78	0.65	1.77	0.63	1.83	0.98
COSMO_interim_sn_v505_long	2.10	0.81	1.58	0.80	2.39	0.82	1.97	0.70	2.48	0.72	1.67	0.68	1.40	1.00
ERA-														

Test experiments



Example of the verification plot for the **2 m temperature January 2013** "COSMO_erai_sn_v505_long" experiment. A map of the modeled (color background) and observed (round markers) mean monthly temperature is shown on the top left. The marker size is proportional to the RMSE value for the given station. The map of mean errors is shown on the bottom left. Modified Taylor diagrams show the correlation coefficient and RMSE values normalized on the observed standard deviation for each station (top right); t he correlation coefficients and ratio between the modeled and observed standard deviation for each station (bottom right). Green triangles show an ideal accordance case. The table on the top right shows the mean statistics for a given experiment over the domain: bias and RMSE for all and the inland and coastal stations.

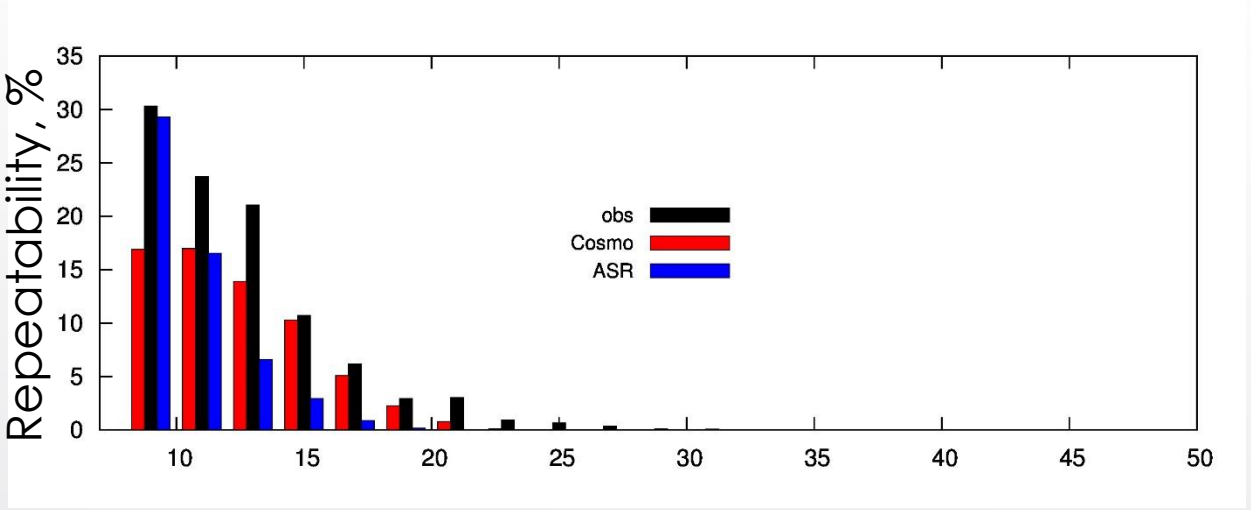
Test experiments



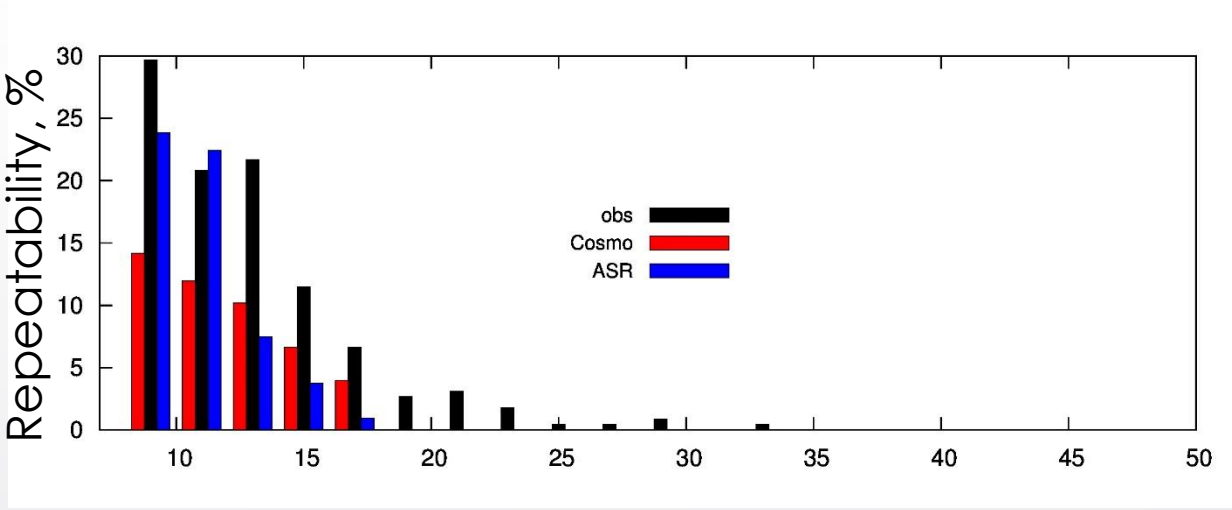
Example of the verification plot for the **2 m temperature September 2015** "COSMO_erai_sn_v505_long" experiment. A map of the modeled (color background) and observed (round markers) mean monthly temperature is shown on the top left. The marker size is proportional to the RMSE value for the given station. The map of mean errors is shown on the bottom left. Modified Taylor diagrams show the correlation coefficient and RMSE values normalized on the observed standard deviation for each station (top right); t he correlation coefficients and ratio between the modeled and observed standard deviation for each station (bottom right). Green triangles show an ideal accordance case. The table on the top right shows the mean statistics for a given experiment over the domain: bias and RMSE for all and the inland and coastal stations.

COSMO-CLM and ASRv2 wind direction evaluation

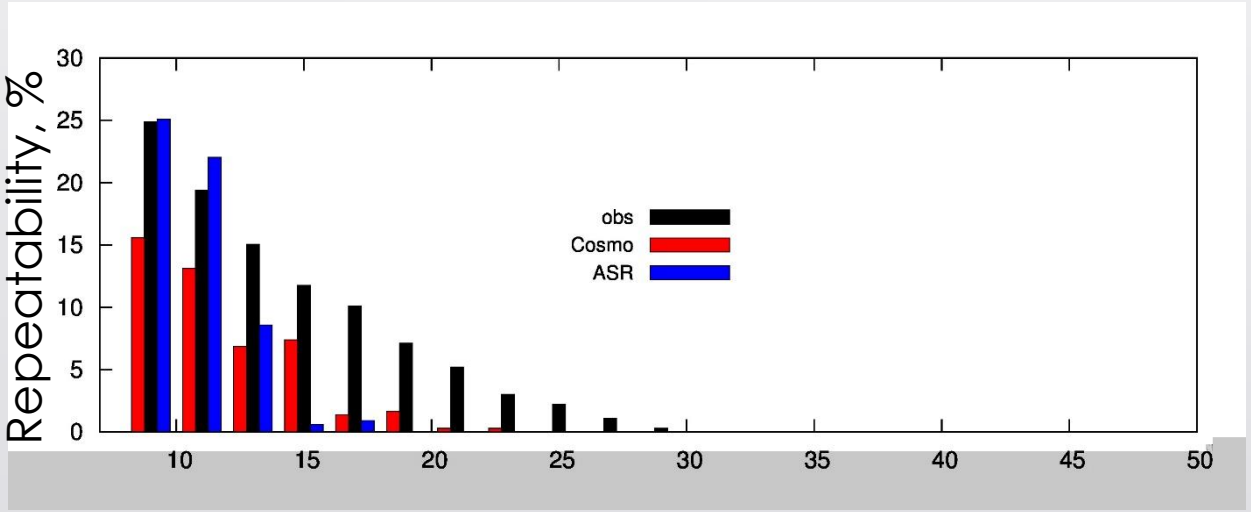
COSMO-CLM	Number of windstorm cases (%) **reproduced**	Number of windstorm cases **not reproduced** because of **wrong wind direction** (% from all cases which are not reproduced)	Number of windstorm cases **not reproduced** because of **wrong wind speed** (% from all cases which are not reproduced)	Number of windstorm cases **not reproduced** because of **wrong wind speed and direction** (% from all cases which are not reproduced)	**ASR**	Number of windstorm cases (%) **reproduced**	Number of windstorm cases **not reproduced** because of **wrong wind direction** (% from all cases which are not reproduced)	Number of windstorm cases **not reproduced** because of **wrong wind speed** (% from all cases which are not reproduced)	Number of windstorm cases **not reproduced** because of **wrong wind speed and direction** (% from all cases which are not reproduced)
Ny-Alesund	43	45	30	25	**Ny-Alesund**	39	20	61	19
Malye Karmakuly	55	29	40	31	**Malye Karmakuly**	44	13	71	16
Gessena	25	14	56	30	**Gessena**	15	13	63	24
Ledovaya Gavan	9	42	13	45	**Ledovaya Gavan**	27	43	27	29
Opasny	39	14	32	48	**Opasny**	47	19	61	20
Tiksi	48	35	38	27	**Tiksi**	49	14	77	9



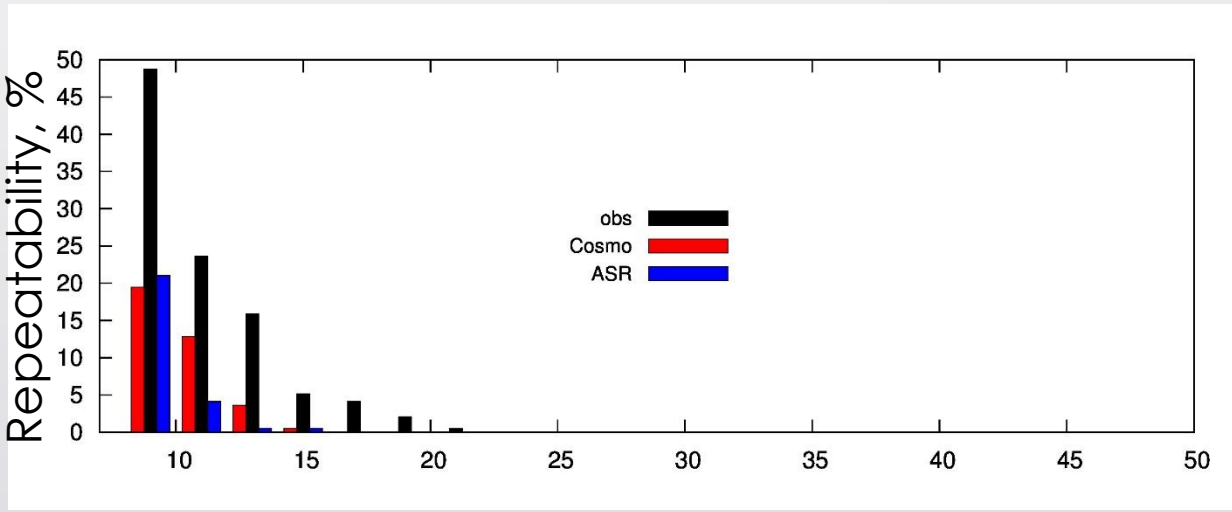
Tiksi



Ledovaya Gavan



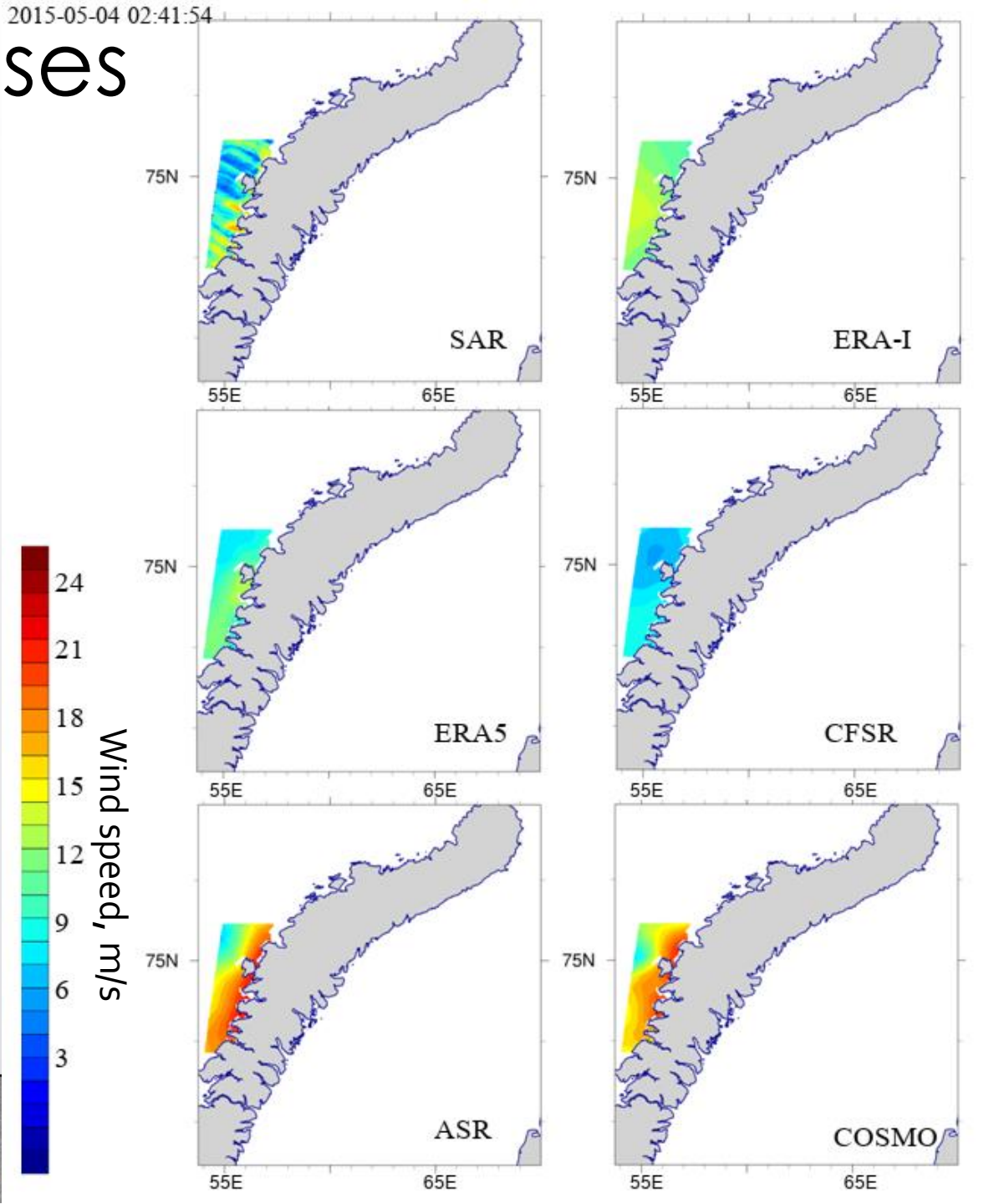
Opasny



Gessena

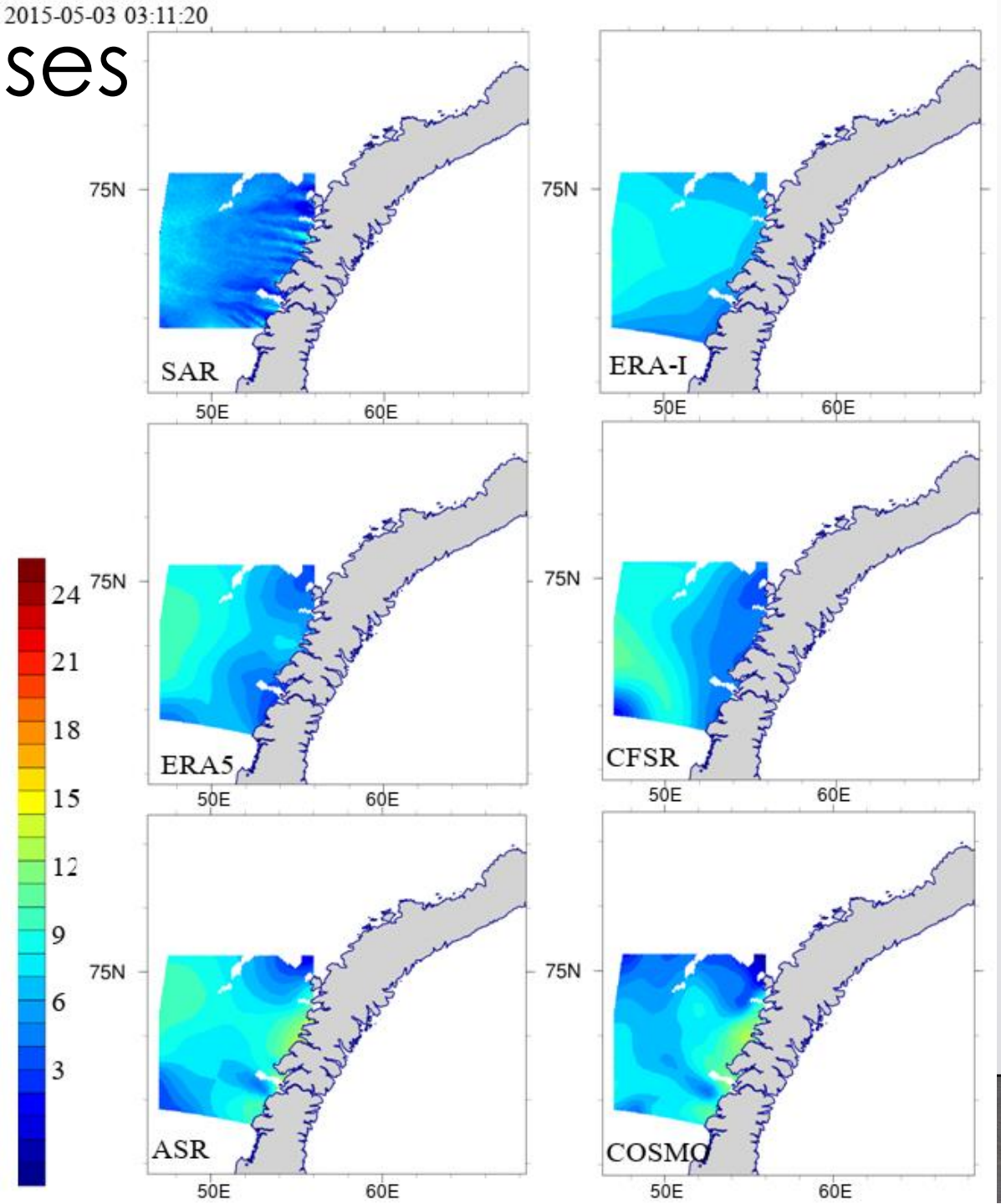
Downslope windstorms cases SAR Radarsat-2

	ERA-I	ERA5	CFSR	ASR	COSMO-CLM
Mean wind speed bias	2,50	**0,40**	-2,20	6,20	6,00
Minimal wind speed bias	8,90	6,20	**4,90**	5,70	6,50
Maximal wind speed bias	-6,90	-7,70	-11,70	0,70	**-0,30**
Magnitude bias	-15,80	-13,90	-16,60	**-5,00**	-6,80
bias 95%	**-1,50**	-2,70	-6,10	5,10	4,20
bias 99%	-3,20	-4,20	-8,00	3,90	**2,90**
bias 99.9%	-5,20	-6,10	-10,00	2,30	**1,30**
R	-0,05	0,37	**0,57**	0,50	0,41
S		0,73		1,17	**0,65**
A		**0,11**		0,53	0,50
L		0,59		**0,18**	0,27
dN		-10,00		**-9,00**	**-9,00**



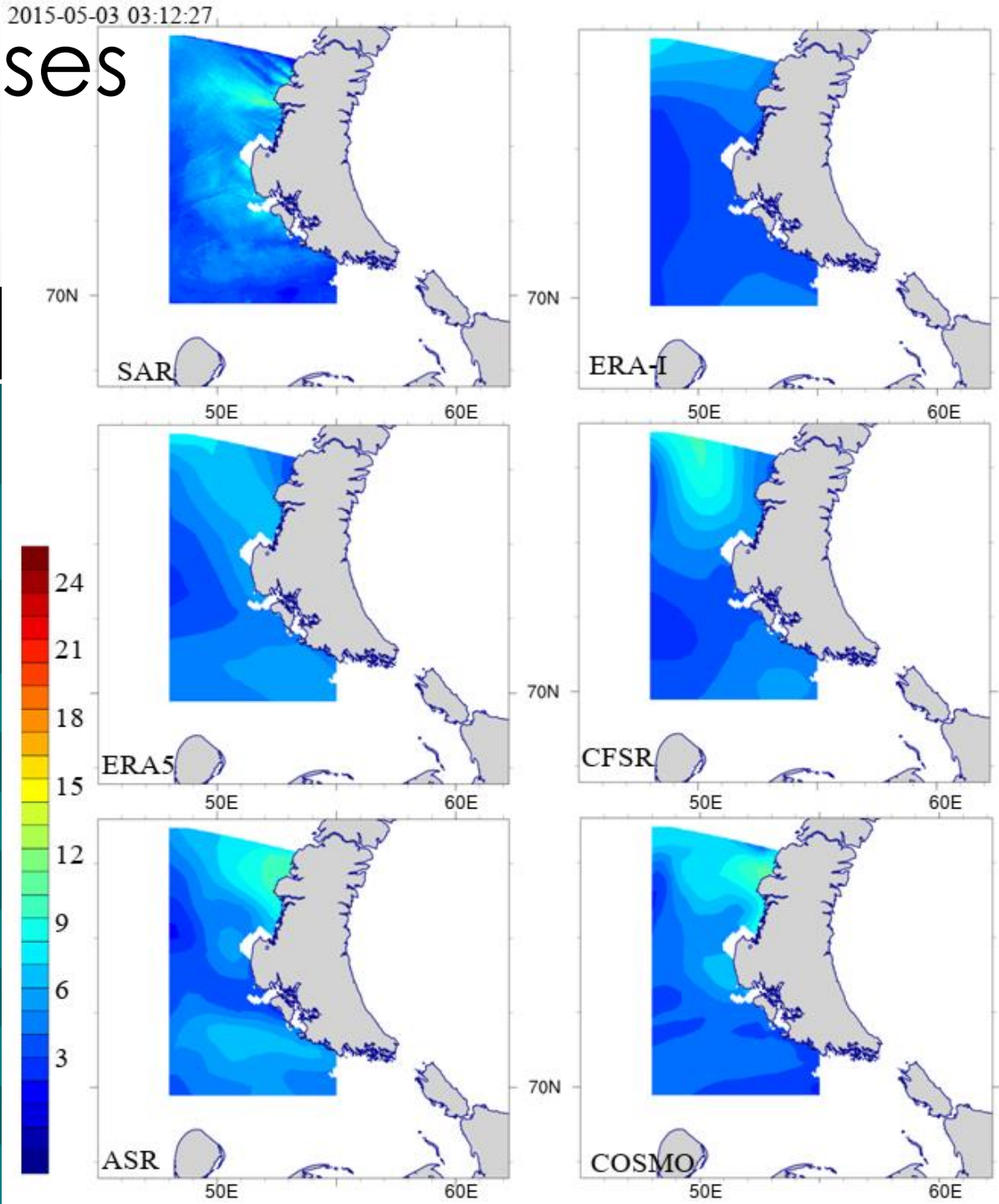
Downslope windstorms cases SAR Radarsat-2

	ERA-I	ERA5	CFSR	ASR	COSMO-CLM
Mean wind speed bias	1,90	1,70	1,60	2,40	**1,50**
Minimal wind speed bias	3,80	1,80	0,50	**0,20**	-0,90
Maximal wind speed bias	-7,70	-6,90	-6,20	**-3,90**	-4,40
Magnitude bias	-11,50	-8,70	-6,70	-4,10	**-3,50**
bias 95%	**1,10**	2,00	2,10	2,50	3,00
bias 99%	**0,60**	1,60	2,10	3,70	3,60
bias 99.9%	-1,10	**-0,20**	0,50	2,40	2,20
R	0,28	**0,63**	0,59	0,25	0,05
S	1,57	1,90	1,90	**1,33**	1,59
A	0,27	0,24	0,23	0,34	**0,22**
L	0,97	0,99	0,87	**0,59**	0,89
dN	-22,00	-22,00	-22,00	**-15,00**	-20,00



Downslope windstorms cases SAR Radarsat-2

	ERA-I	ERA5	CFSR	ASR	COSMO-CLM
Mean wind speed bias	-0,90	0,20	**0,10**	0,50	0,40
Minimal wind speed bias	2,20	2,90	2,60	**1,90**	2,80
Maximal wind speed bias	-9,10	-8,70	-7,50	-6,70	**-6,40**
Magnitude bias	-11,30	-11,60	-10,10	**-8,60**	-9,20
bias 95%	-1,40	**-0,60**	1,00	0,90	0,70
bias 99%	-2,00	-1,80	**0,10**	0,50	0,50
bias 99.9%	-3,30	-3,00	-1,60	-0,80	**-0,50**
R	0,20	0,36	0,41	0,22	**0,64**
S	-1,10	-1,34	1,45	0,70	**0,23**
A	-0,16	0,07	**0,05**	0,12	0,10
L	0,47	0,52	0,32	**0,24**	0,26
dN	-8,00	-8,00	-8,00	**-6,00**	-8,00



Downslope windstorms cases SAR Radarsat-2

	ERA-I	ERA5	CFSR	ASR	COSMO-CLM
Mean wind speed bias	3,50	**2,10**	3,90	4,10	5,10
Minimal wind speed bias	6,70	**3,90**	4,50	4,40	8,00
Maximal wind speed bias	-8,80	-7,80	-6,40	-7,40	**-4,30**
Magnitude bias	-15,50	-11,70	**-10,90**	-11,80	-12,30
bias 95%	1,70	**1,40**	3,70	2,50	5,00
bias 99%	**0,30**	1,10	2,60	1,20	4,30
bias 99.9%	-1,50	-0,60	0,90	**-0,30**	2,80
R	0,42	0,51	**0,63**	0,33	0,51
S	1,33	**0,63**	0,94	1,22	0,80
A	0,34	**0,24**	0,37	0,38	0,44
L	0,66	0,53	0,47	0,64	**0,45**
dN	-7,00	-6,00	**-4,00**	-5,00	-5,00

