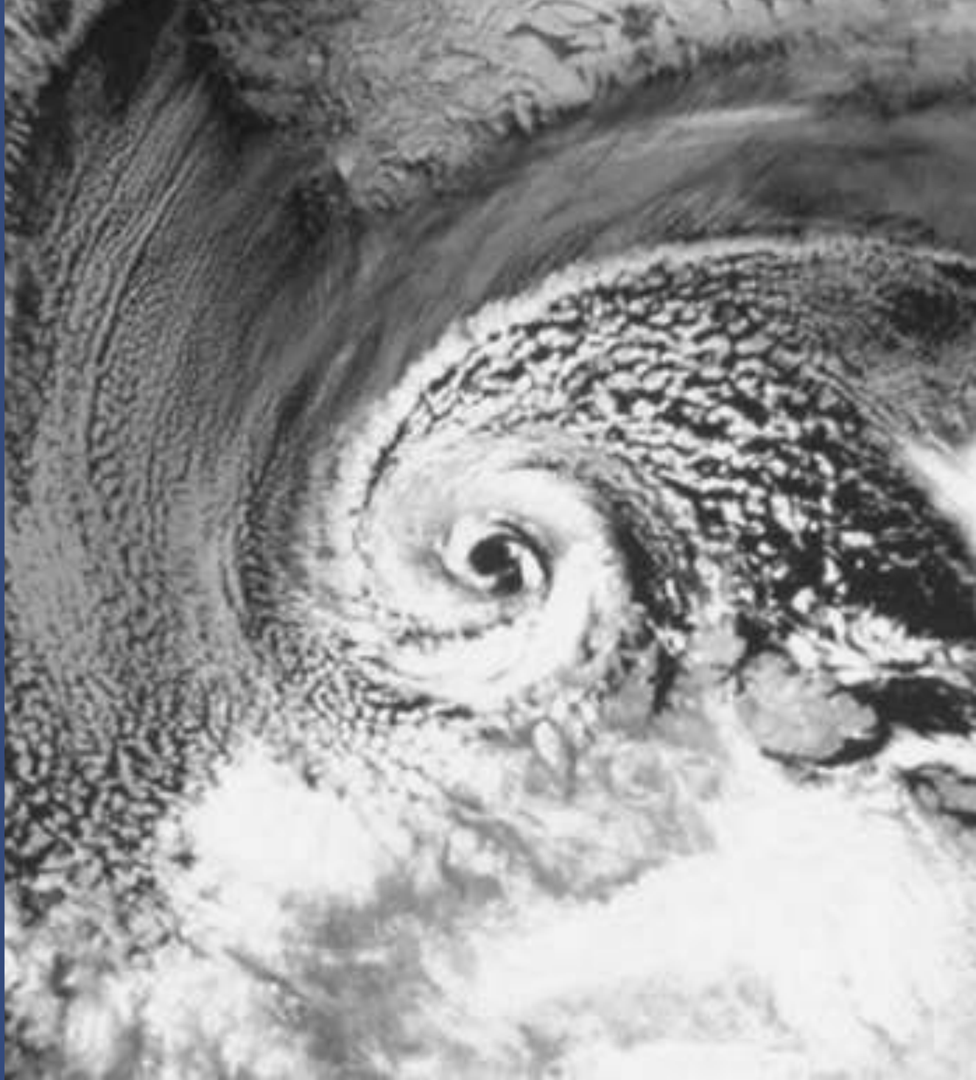
Convection-permitting forecasting of polar lows

Matilda Hallerstig, Linus Magunsson, Erik W. Kolstad, Stephanie Mayer

How well does ECMWF IFS predict polar lows?

What added value does the limited area model AROME-Arctic give?



ECMWF IFS experiments

European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecasting System (IFS)

Global model

Hydrostatic

Deep convection is parameterized

Our sensitivity experiments with finer resolutions and/or explicit deep convection:

grid spacing	**Parameterized deep convection**	**Resolved deep convection**
5 km	EC5	EC5N
9 km	EC9*	EC9N
18 km	EC18*	-

* In operational use

AROME-Arctic

Regional Numerical Weather Prediction (NWP) model

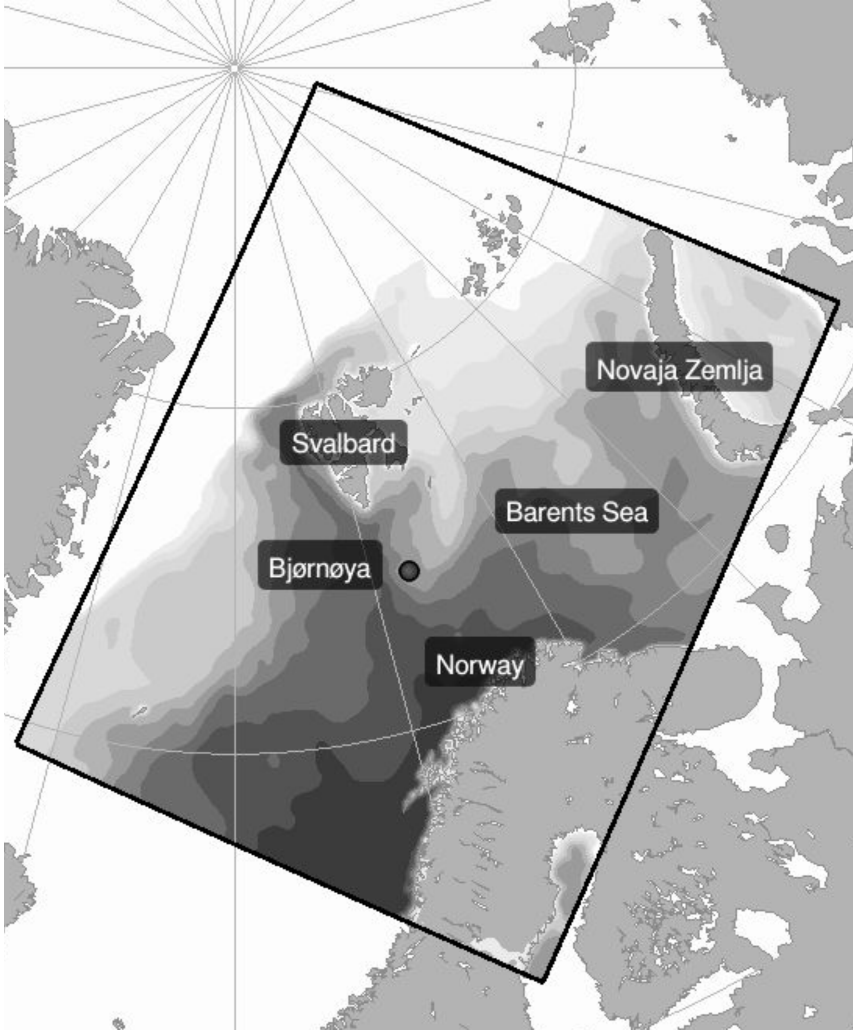
Developed by Meteo France

Adopted by and in operational use at MET Norway and several other European weather services

2.5 km horizontal grid spacing

Non-hydrostatic

Explicit deep convection



AROME-Arctic domain

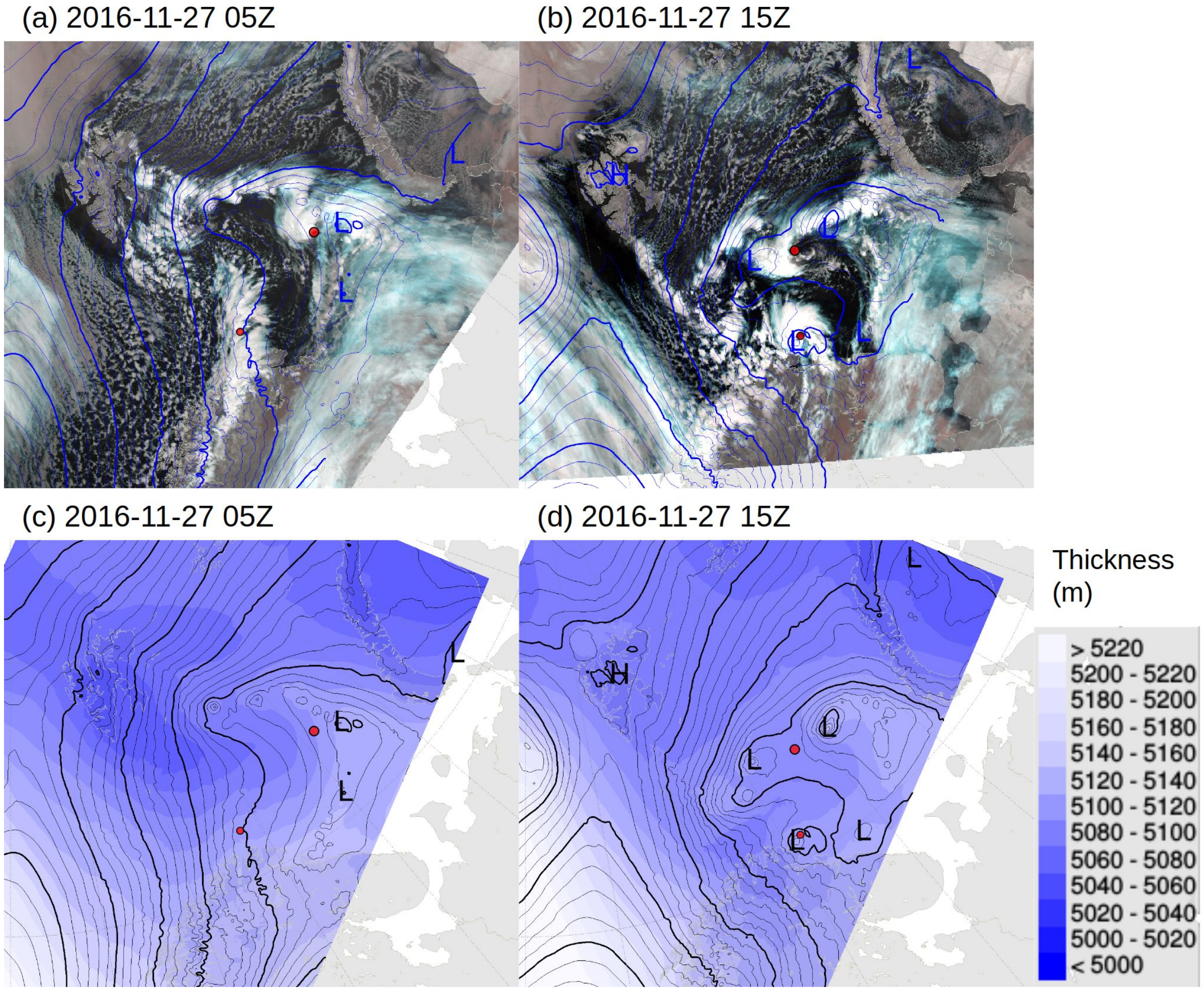
Test case one: November 2016

Multiple polar lows and large area of disorganized convective cells in the Barents Sea.

Mainly cold, convective air mass.

Two of the polar lows developed tropical hurricane-like features with a clear eye.

The weaker one of those made landfall of the coast of Northern Norway.



Test case two: December 2016

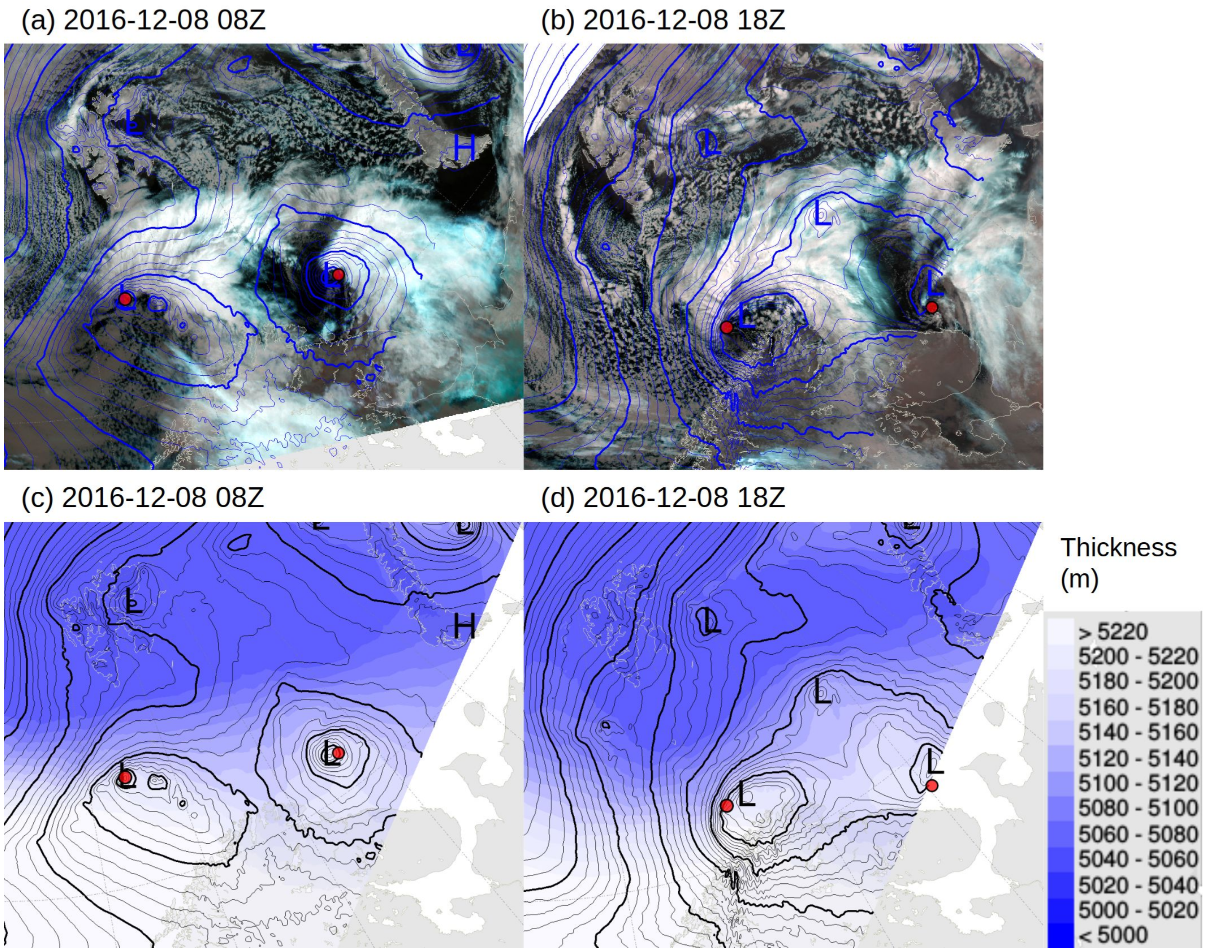
Two polar lows propagated along a strong, baroclinic zone.

The most intense one of these made landfall on the coast of Northern Norway.

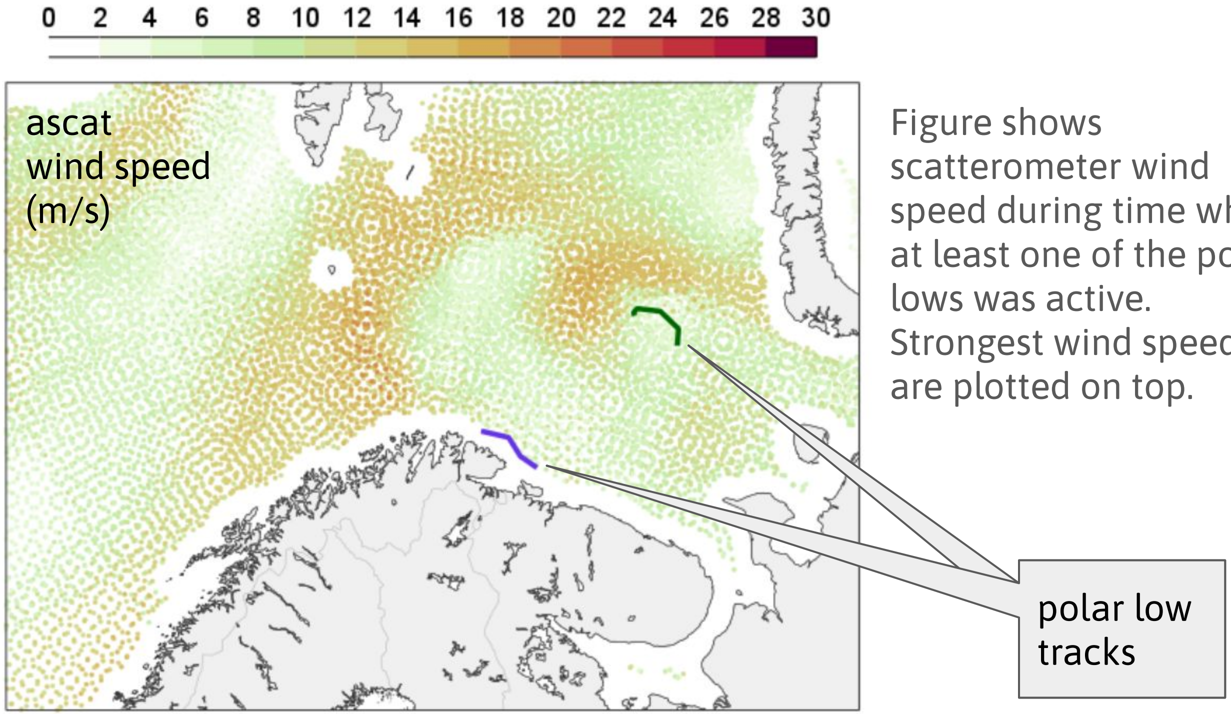
It was among the 5 % strongest polar lows that has been observed in the area (Müller et al. 2017).

Coastal stations observed hurricane force 12.

Müller,M.,Homleid,M.,Ivarsson,K.-I.,Køltzow,M.A.,Lindskog, M.,Midtbø,K.H.,Andrae,U.,Aspelien,T.,Berggren,L.,Bjørge,D.et al.(2017)Arome-metcoop:Anordicconvective-scaleoperationalweatherpredictionmodel.WeatherandForecasting ,32 ,609–627.



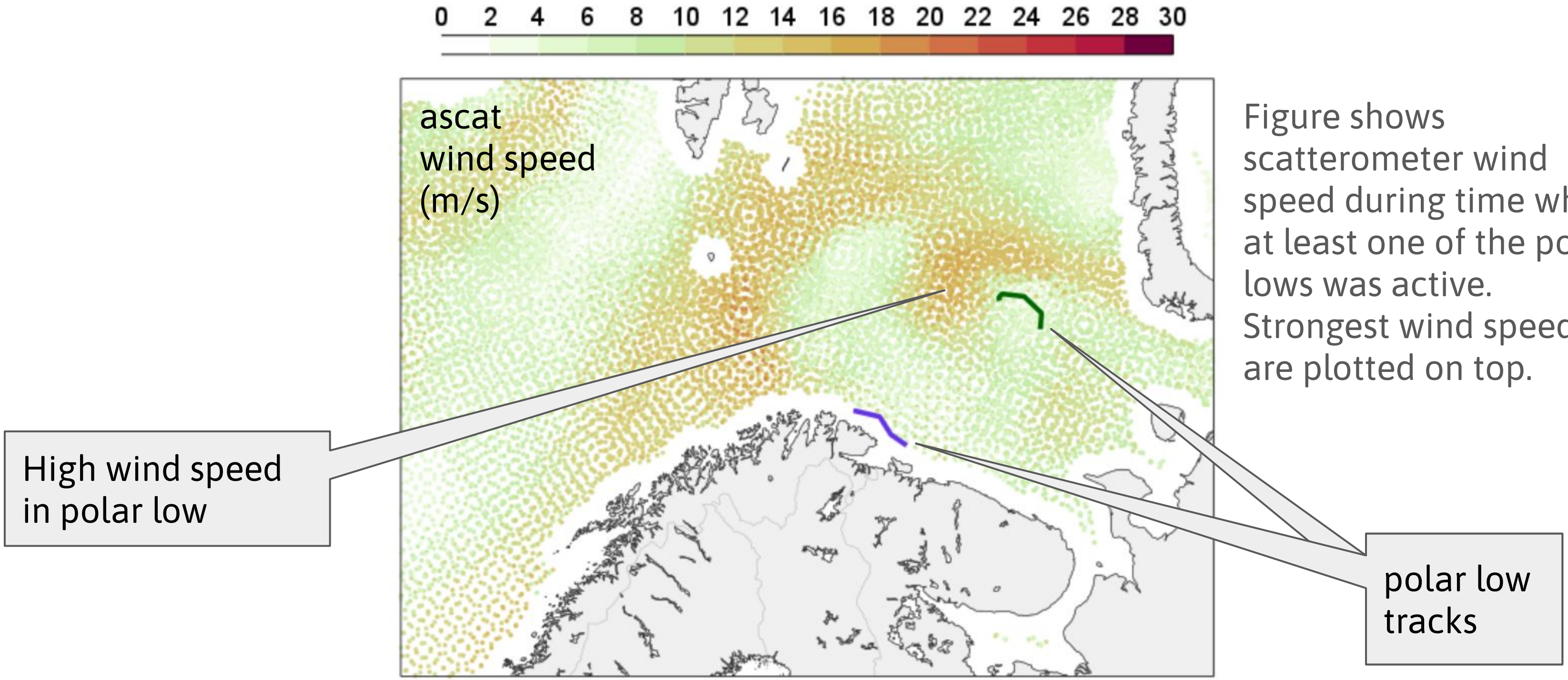
A comparison to ascat, November case



(a)

Figure shows scatterometer wind speed during time when at least one of the polar lows was active. Strongest wind speeds are plotted on top.

A comparison to ascat, November case



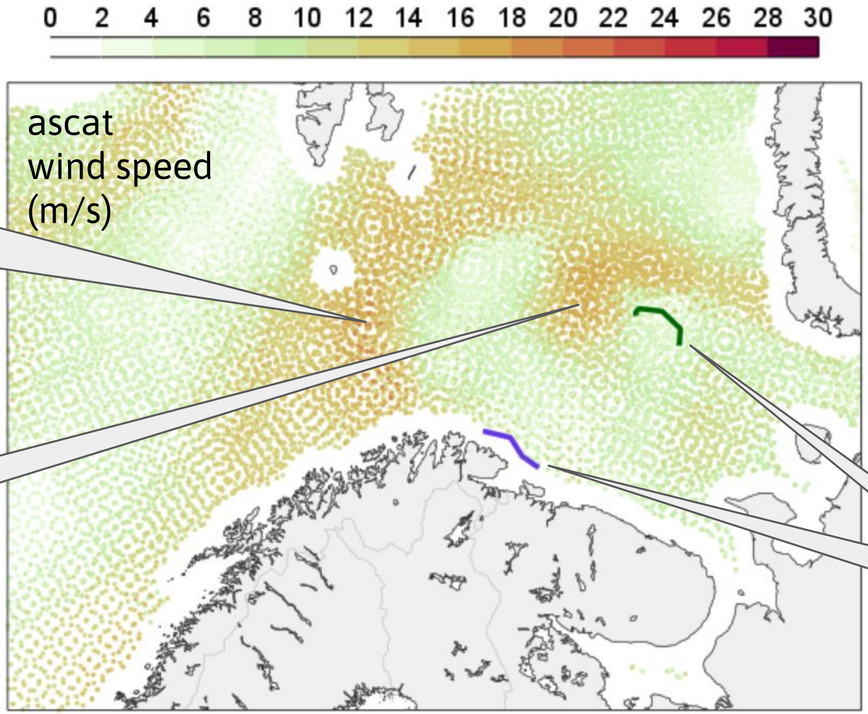
(a)

Figure shows scatterometer wind speed during time when at least one of the polar lows was active. Strongest wind speeds are plotted on top.

A comparison to ascat, November case

High wind speed in disorganized convective cells

High wind speed in polar low

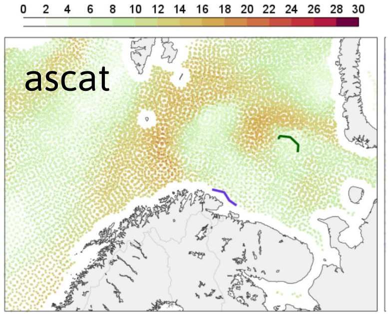


(a)

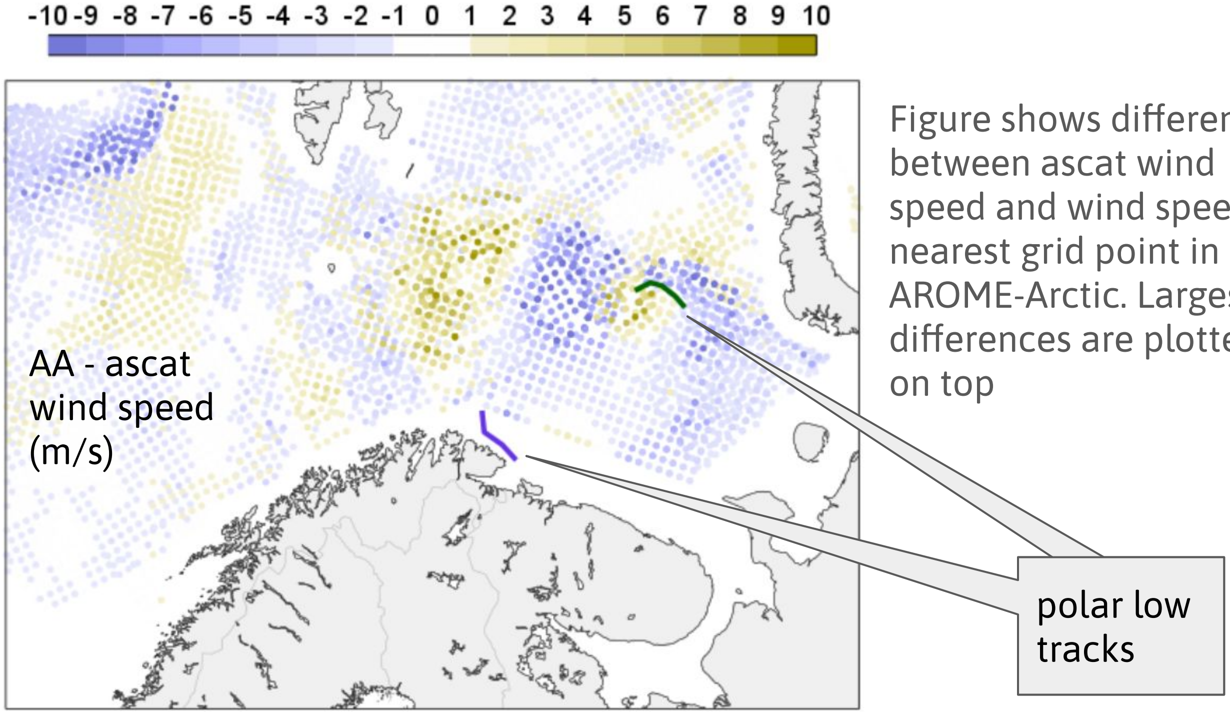
polar low tracks

Figure shows scatterometer wind speed during time when at least one of the polar lows was active. Strongest wind speeds are plotted on top.

A comparison to ascat, November case



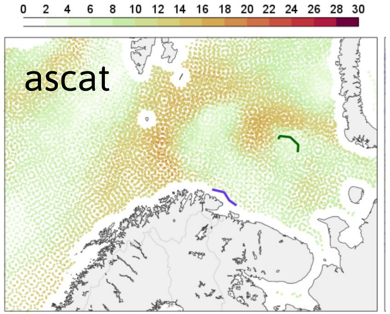
(a)



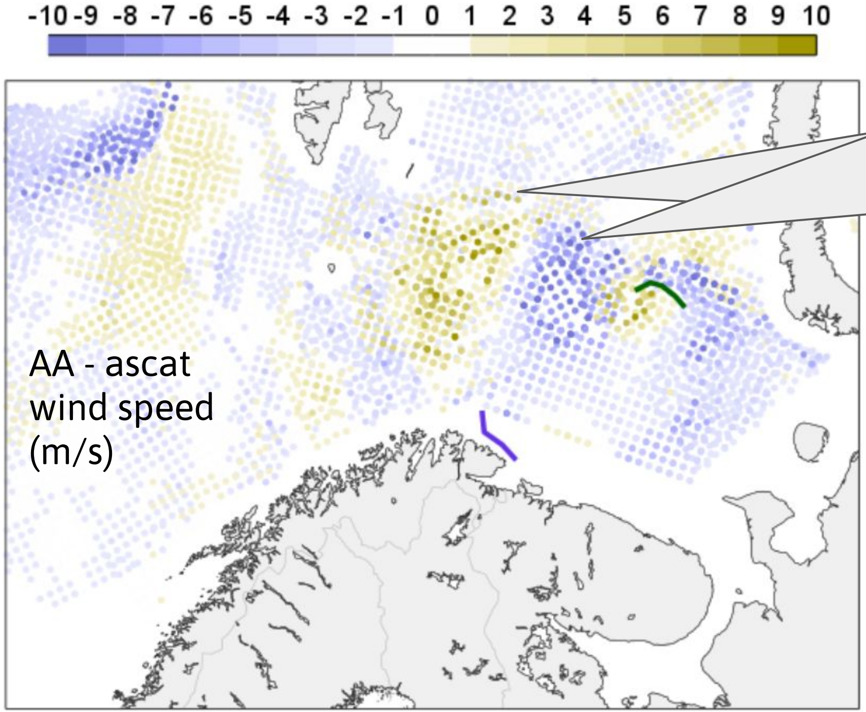
(b)

Figure shows difference between ascat wind speed and wind speed in nearest grid point in AROME-Arctic. Largest differences are plotted on top

A comparison to ascat, November case



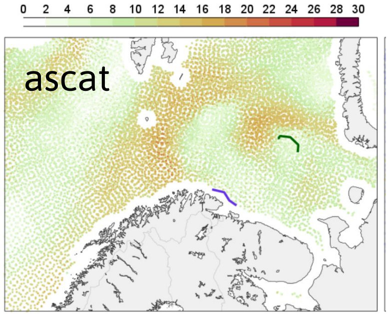
(a)



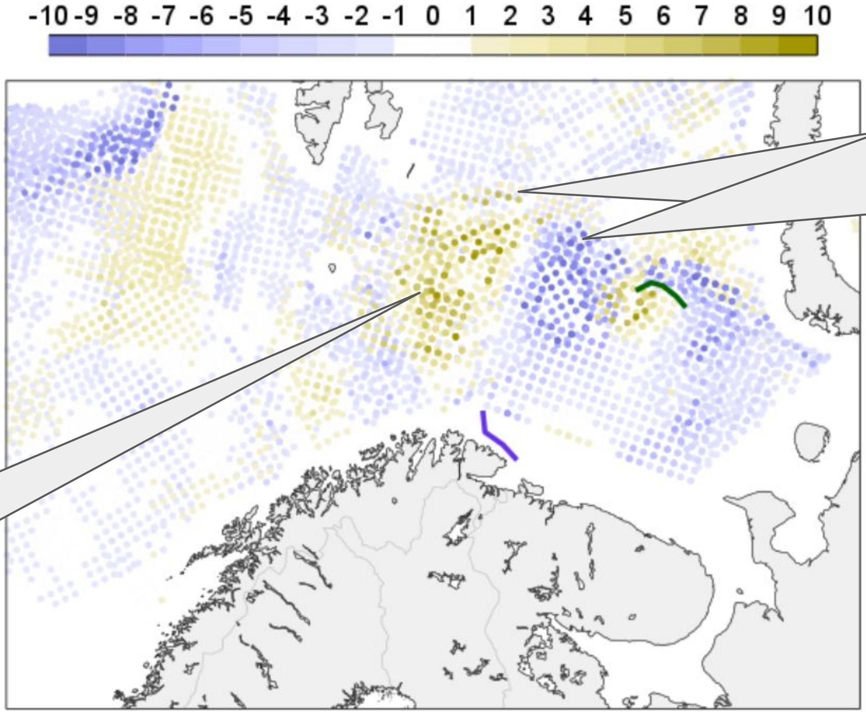
(b)

Successive areas of over- and under-estimation of wind speed because of a displacement in model

A comparison to ascat, November case



(a)

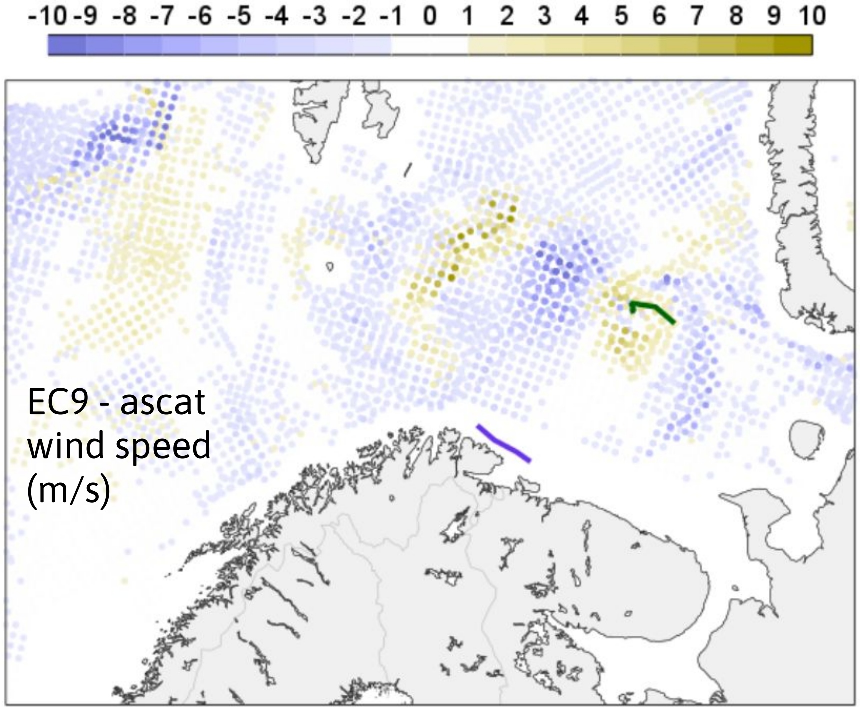


(b)

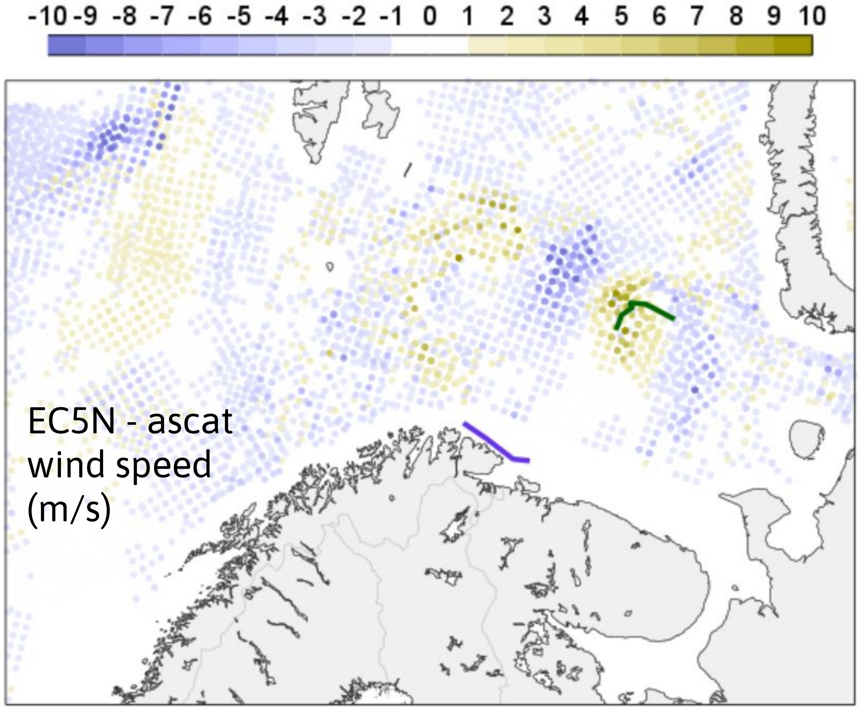
Successive areas of over- and under-estimation of wind speed because of a displacement in model

Strongest over-estimation in area of disorganized conective cells

A comparison to ascat, November case

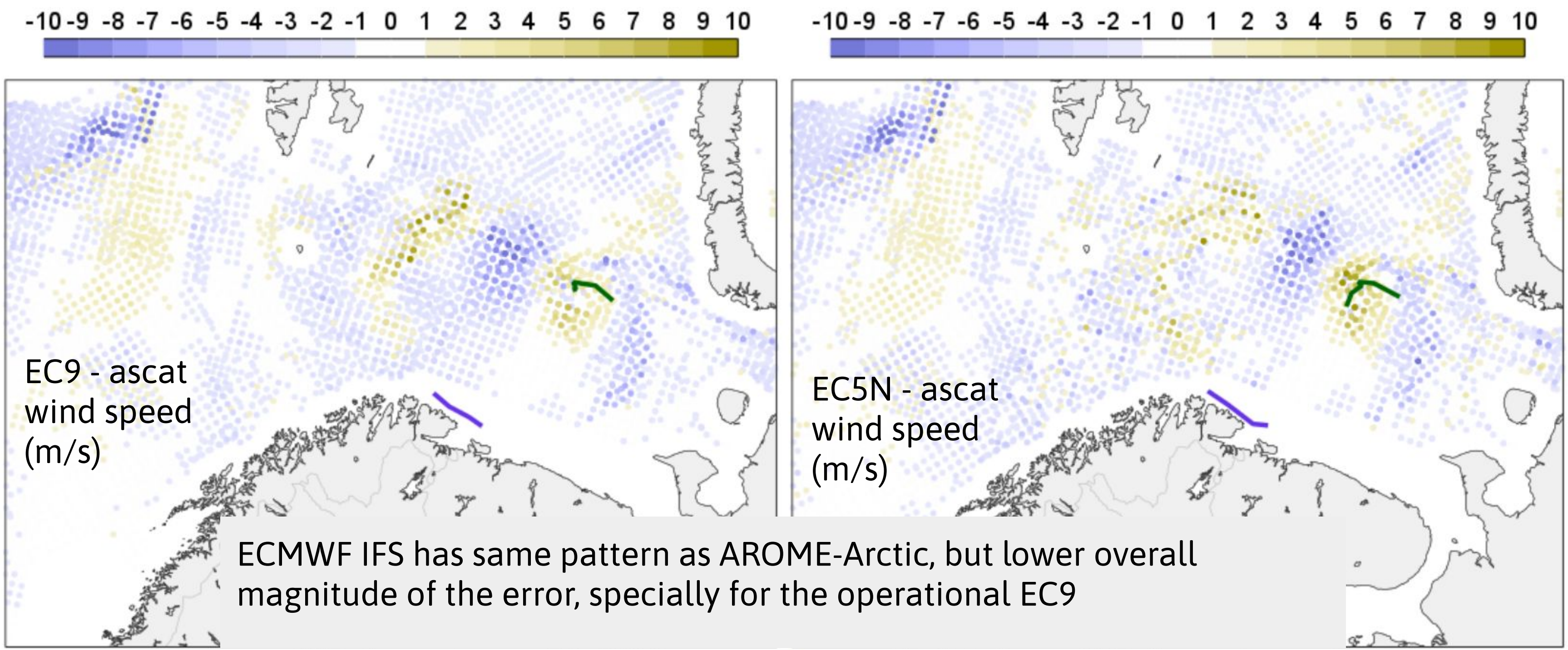


(c)



(d)

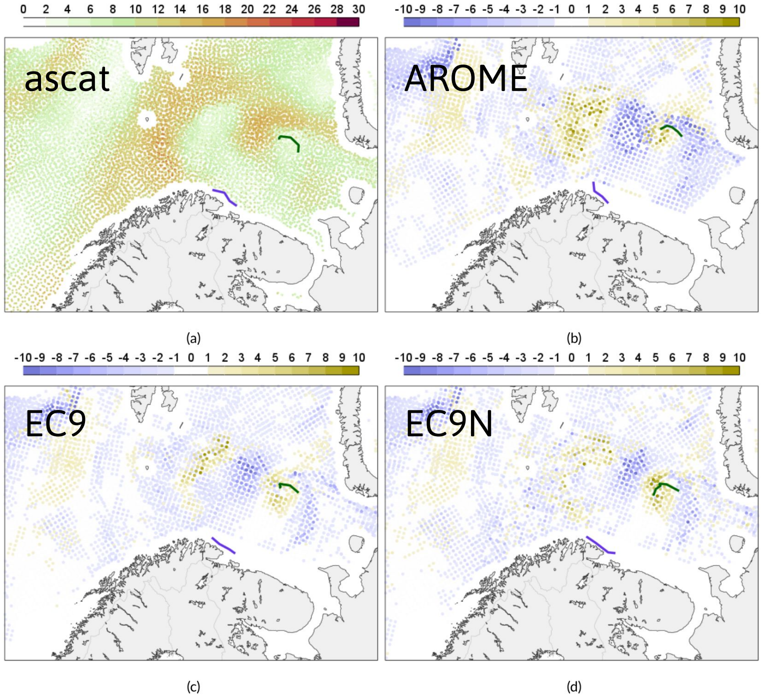
A comparison to ascat, November case



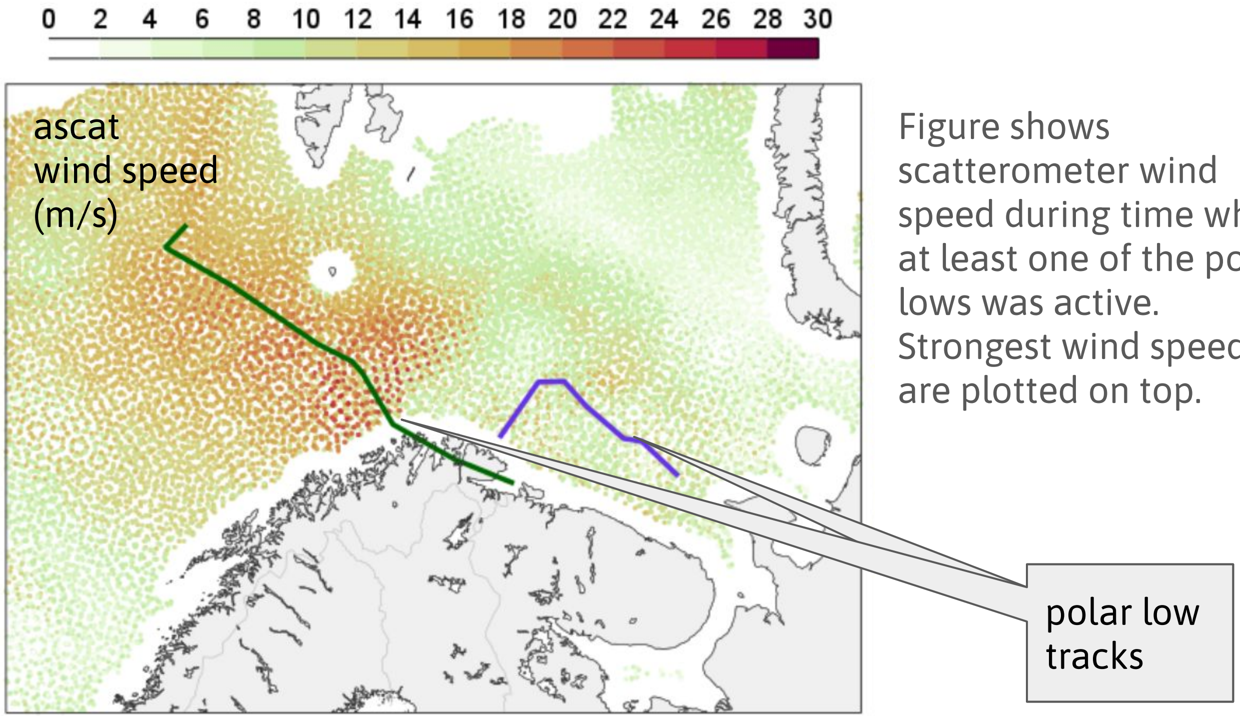
ECMWF IFS has same pattern as AROME-Arctic, but lower overall magnitude of the error, specially for the operational EC9

(c) (d)

A comparison to ascat, November case



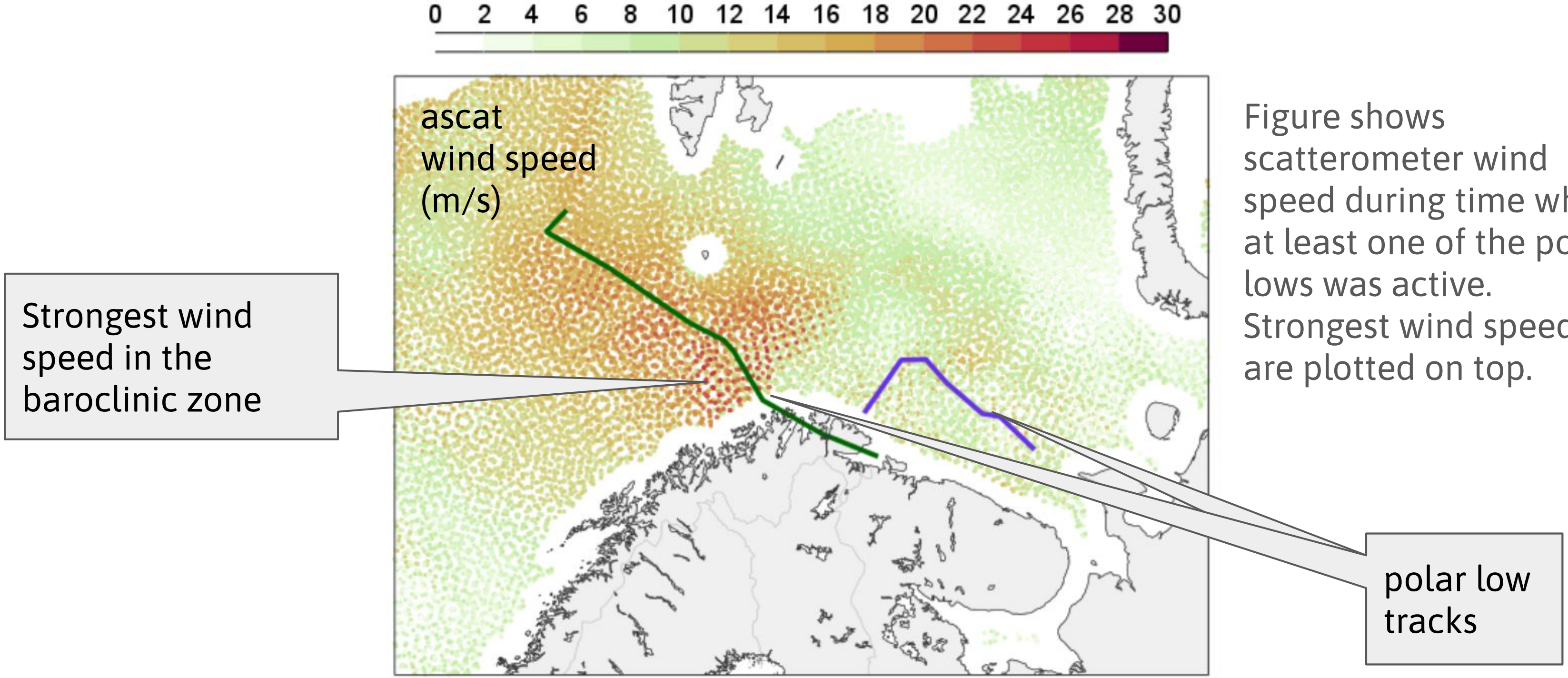
A comparison to ascat, December case



(a)

Figure shows scatterometer wind speed during time when at least one of the polar lows was active. Strongest wind speeds are plotted on top.

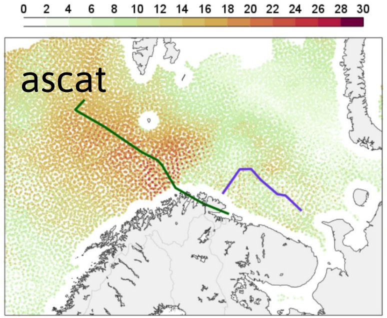
A comparison to ascat, December case



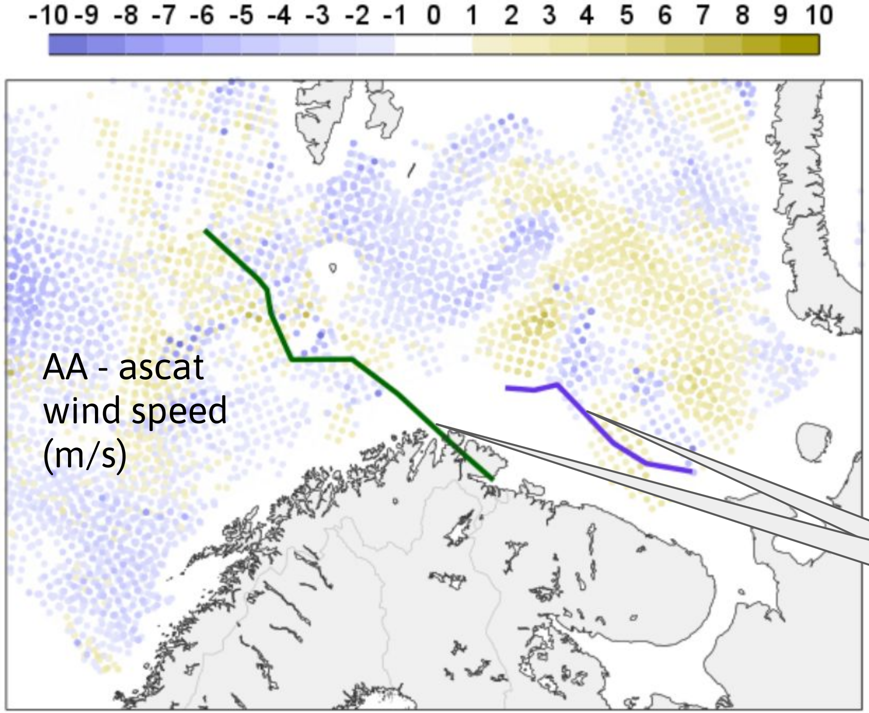
(a)

Figure shows scatterometer wind speed during time when at least one of the polar lows was active. Strongest wind speeds are plotted on top.

A comparison to ascat, December case



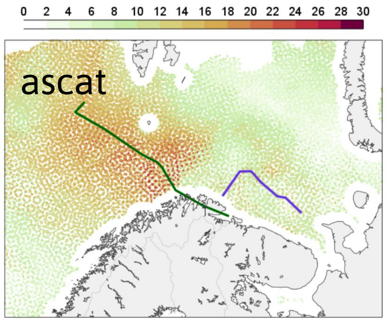
(a)



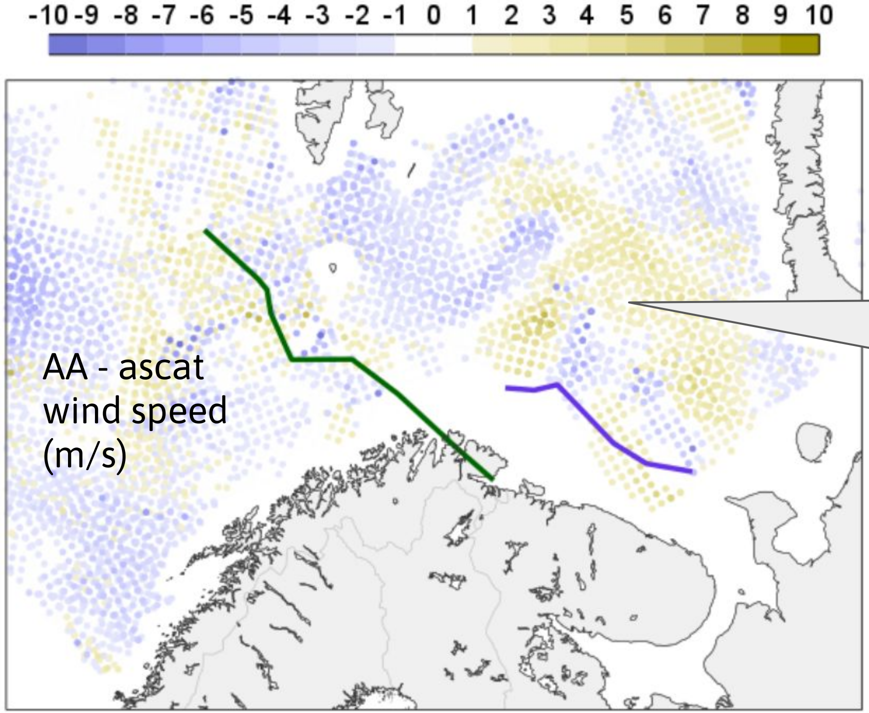
(b)

Figure shows difference between ascat wind speed and wind speed in nearest grid point in AROME-Arctic. Largest differences are plotted on top

A comparison to ascat, December case



(a)

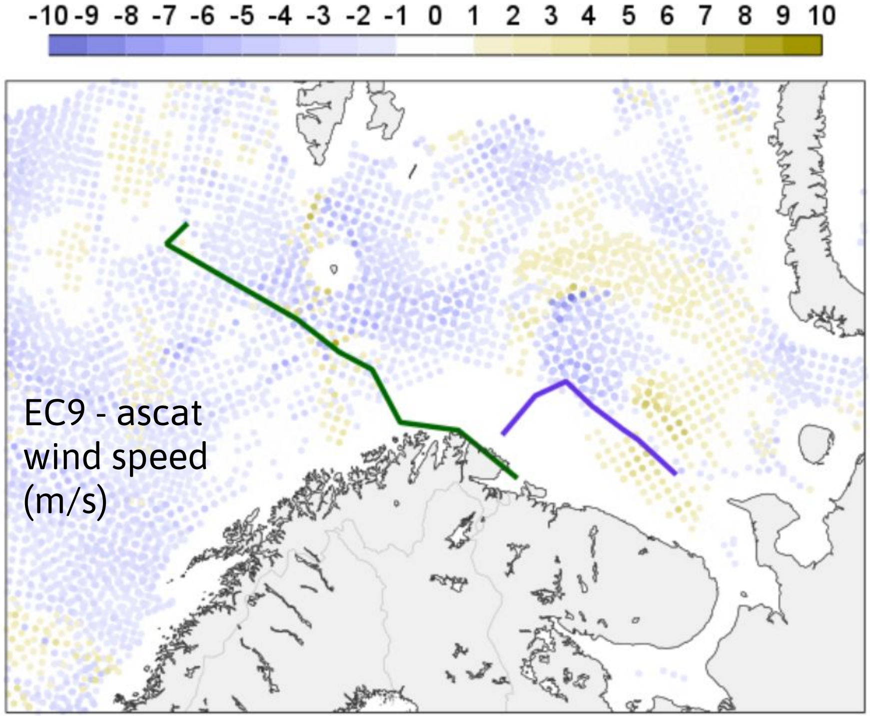


(b)

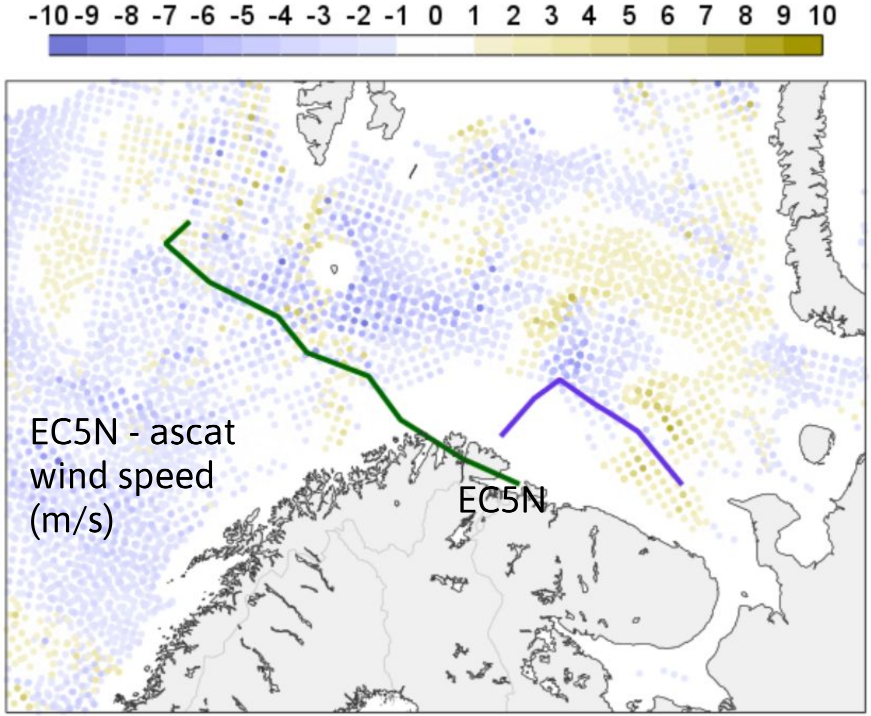
Better location of polar low tracks than in the November case

Strongest over-estimation in the cold, convective air mass

A comparison to ascat, December case

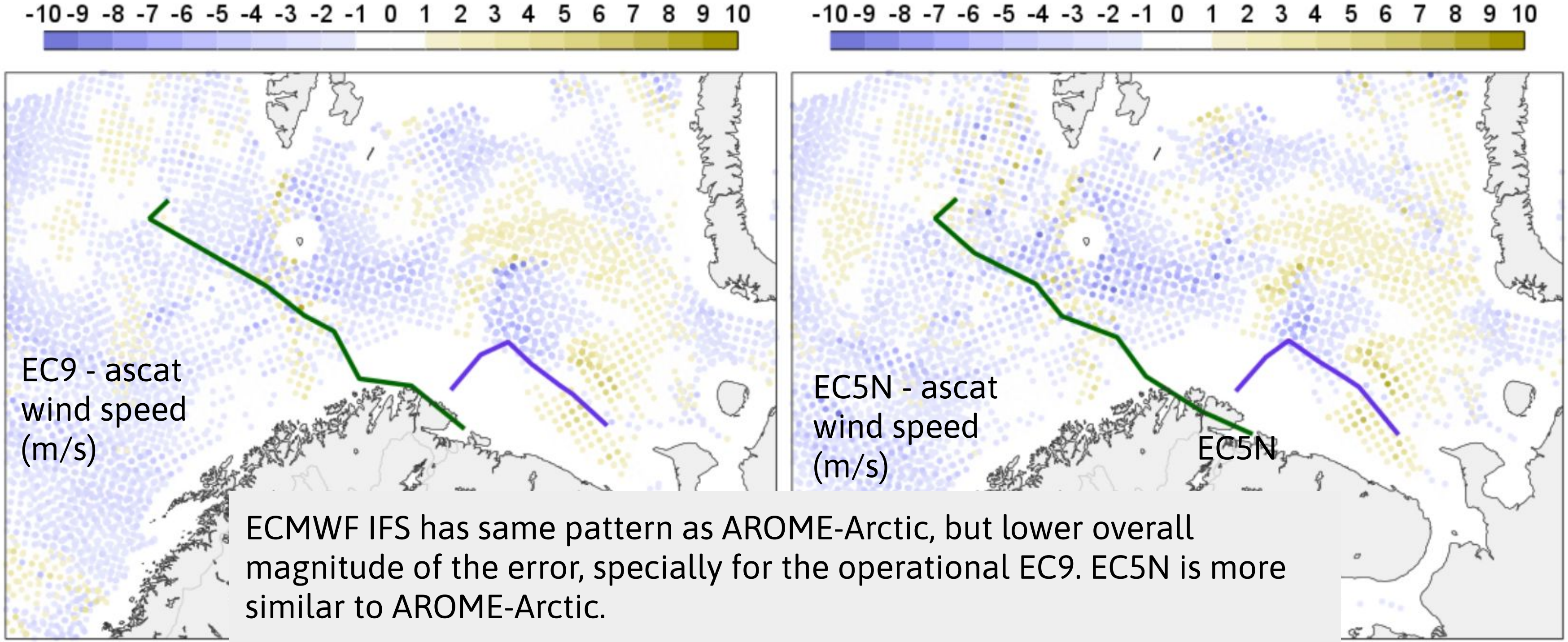


(c)



(d)

A comparison to ascat, December case

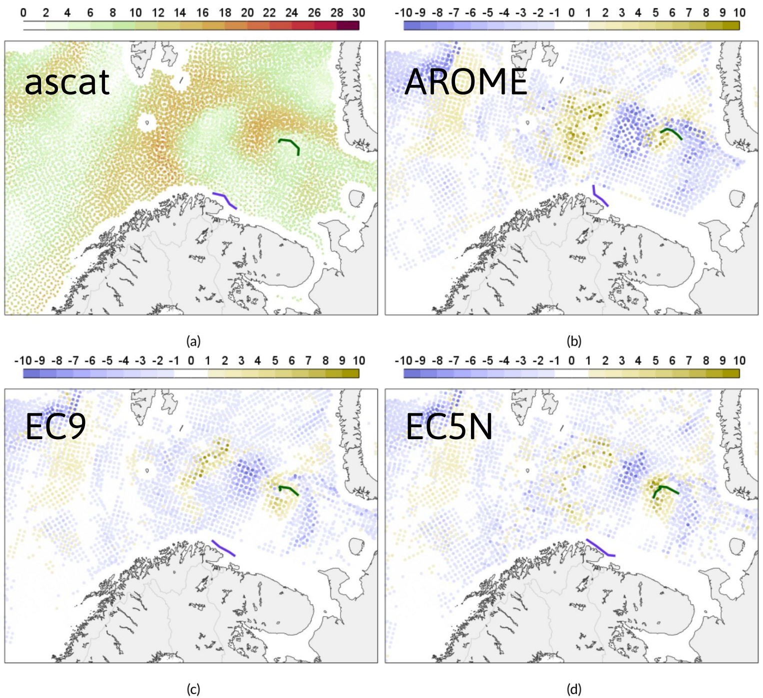


ECMWF IFS has same pattern as AROME-Arctic, but lower overall magnitude of the error, specially for the operational EC9. EC5N is more similar to AROME-Arctic.

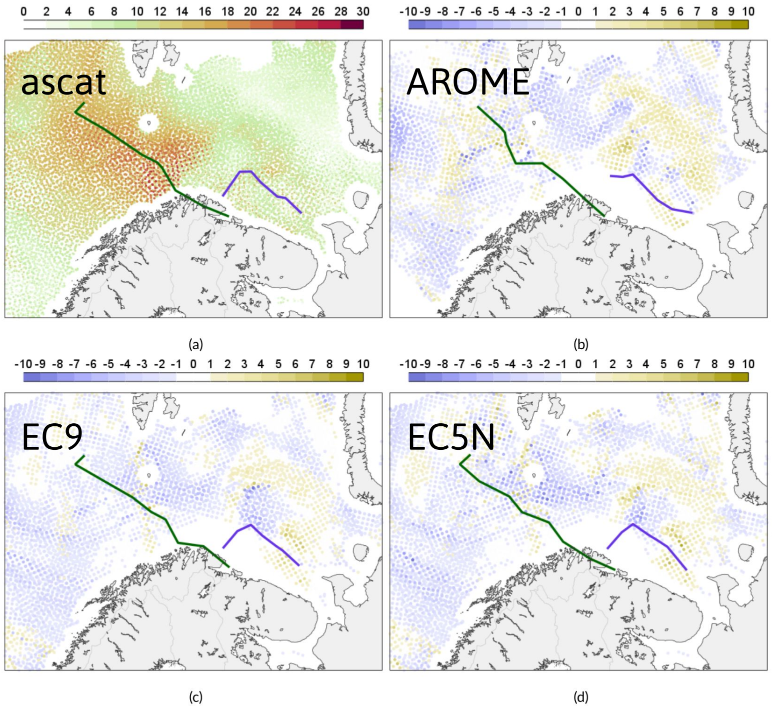
(c) (d)

A comparison to ascat

November



December

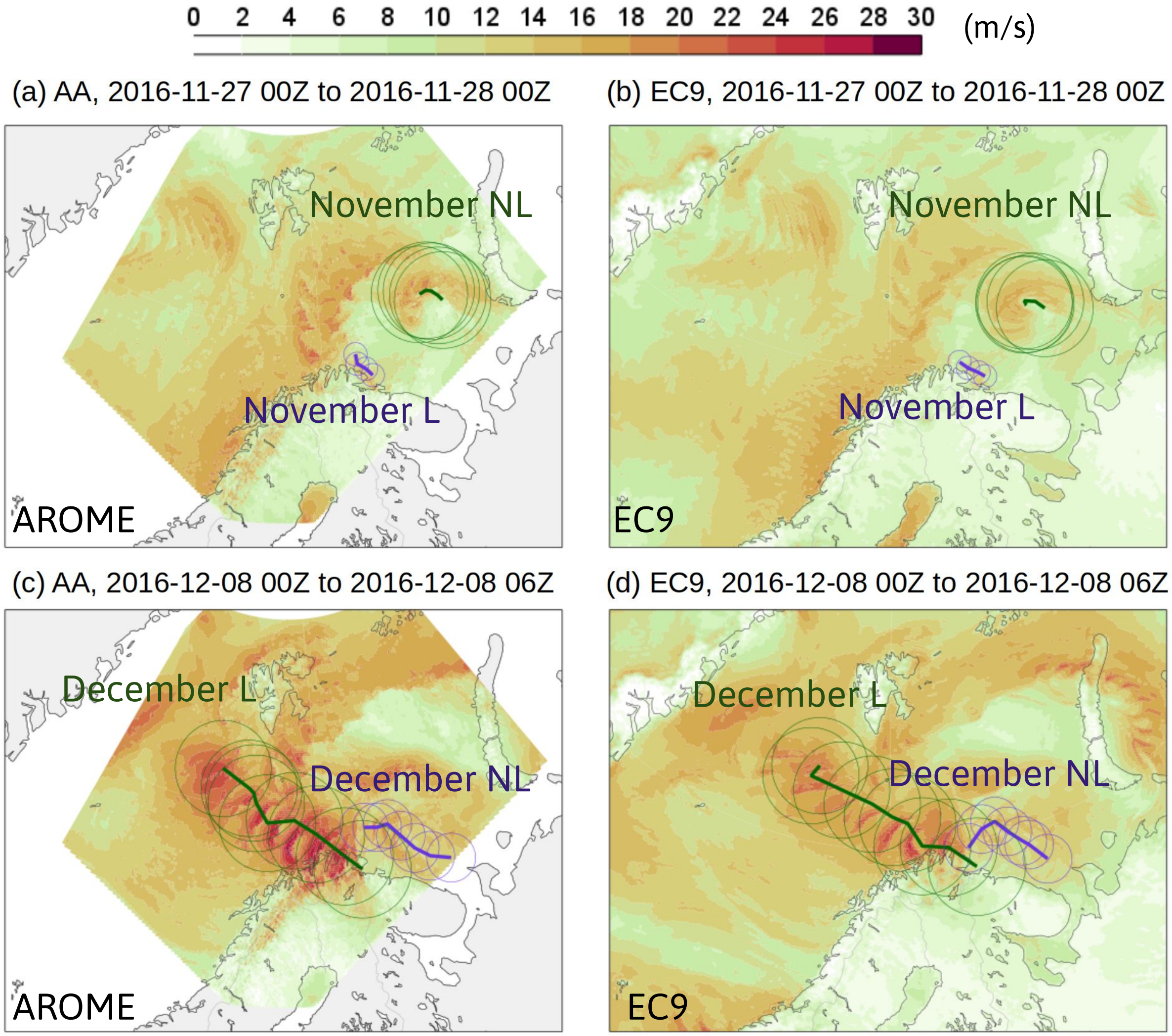


A comparison to ascat

Over sea, ECMWF HRES performs better than AROME for over all magnitude of wind speed

Maximum wind speed

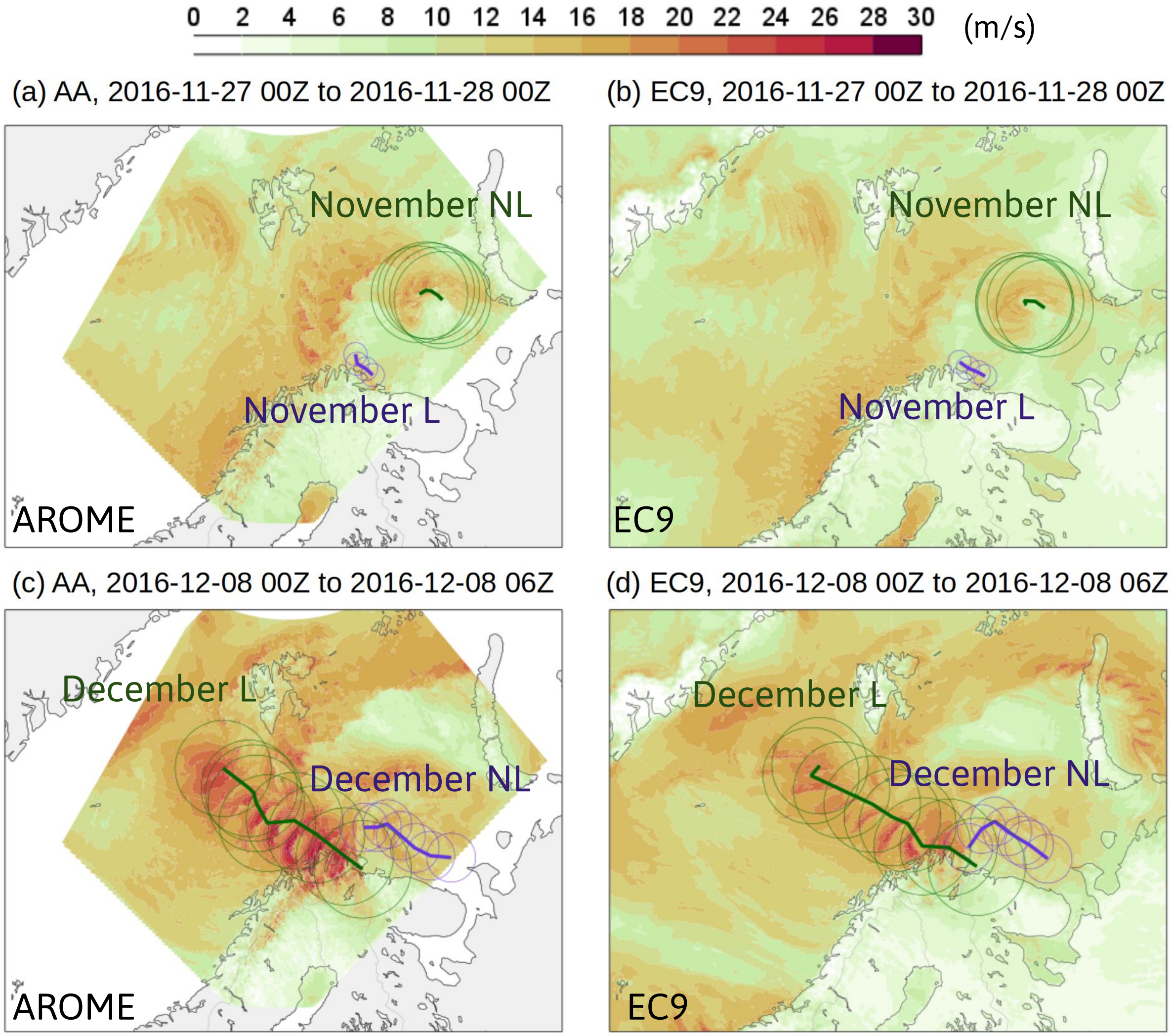
Figures show maximum wind speed in each grid point during the period when the polar lows were active



Maximum wind speed

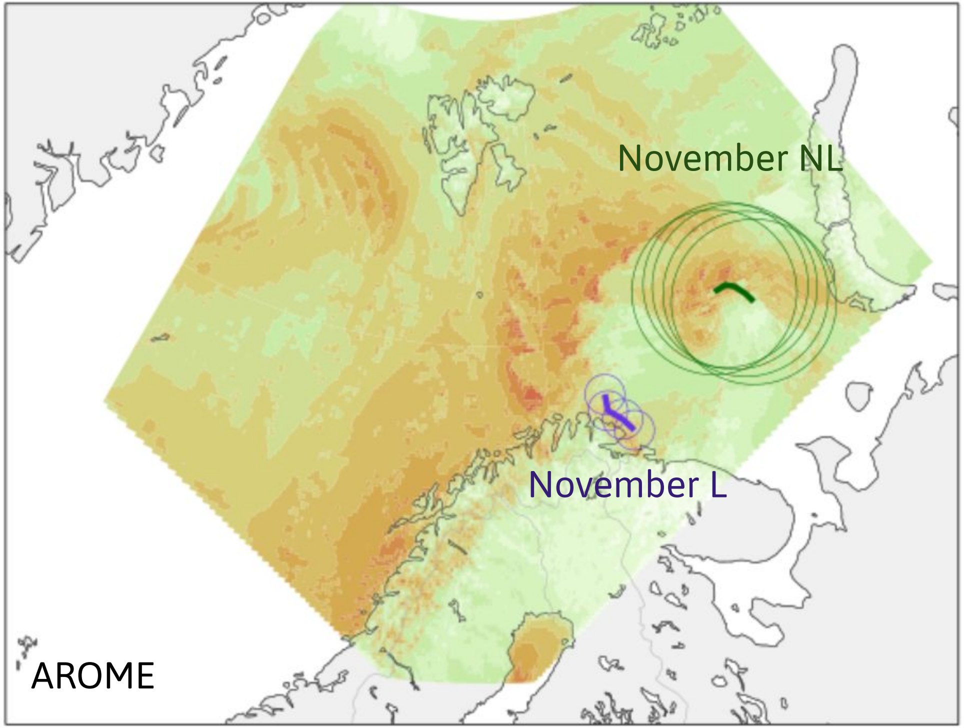
Figures show maximum wind speed in each grid point during the period when the polar lows were active

AROME clearly produces larger maximum wind speed than EC9



Maximum wind speed, November case

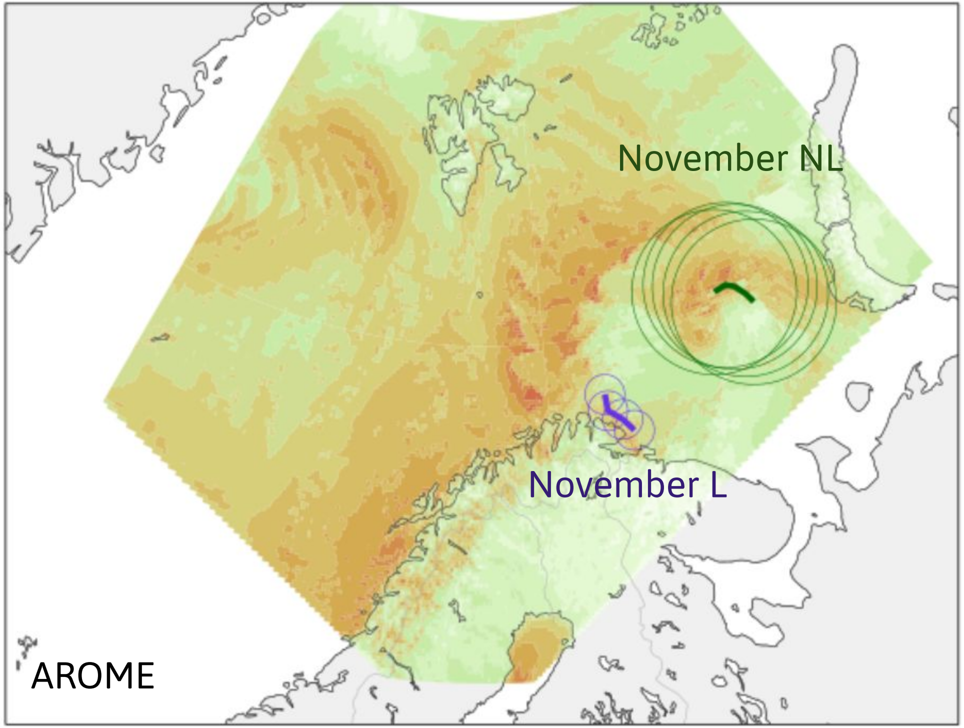
Now let’s take the maximum wind speed associated to the polar lows at each time ste



Maximum wind speed, November case

Now let's take the maximum wind speed associated to the polar lows at each time ste

We do this by drawing a circle around the polar low center at each time step, then take the maximum wind speed within this circle.

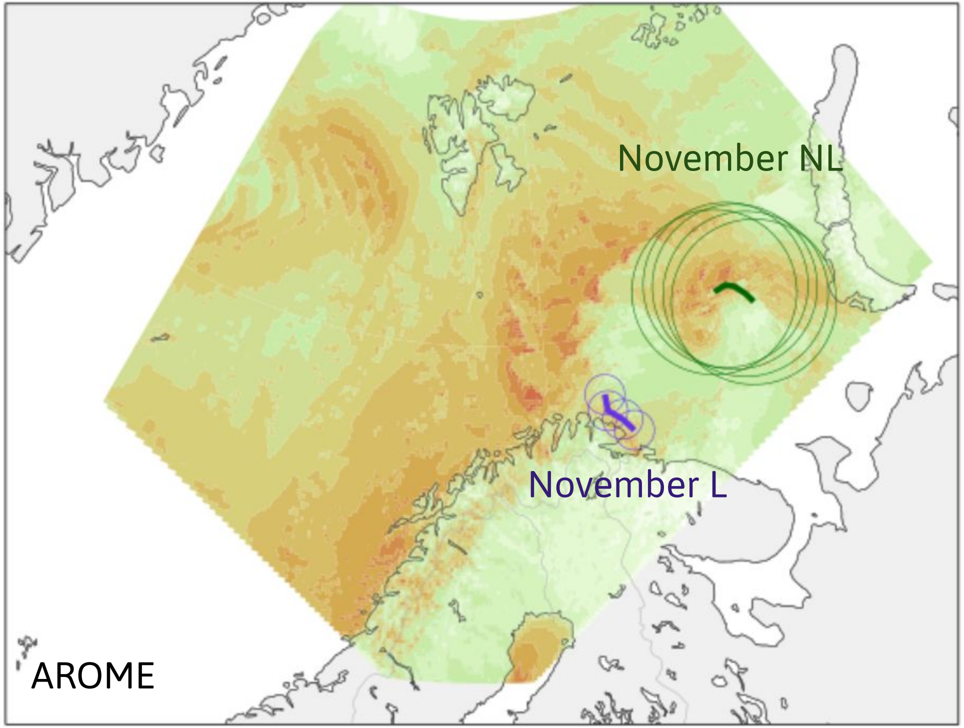


Maximum wind speed, November case

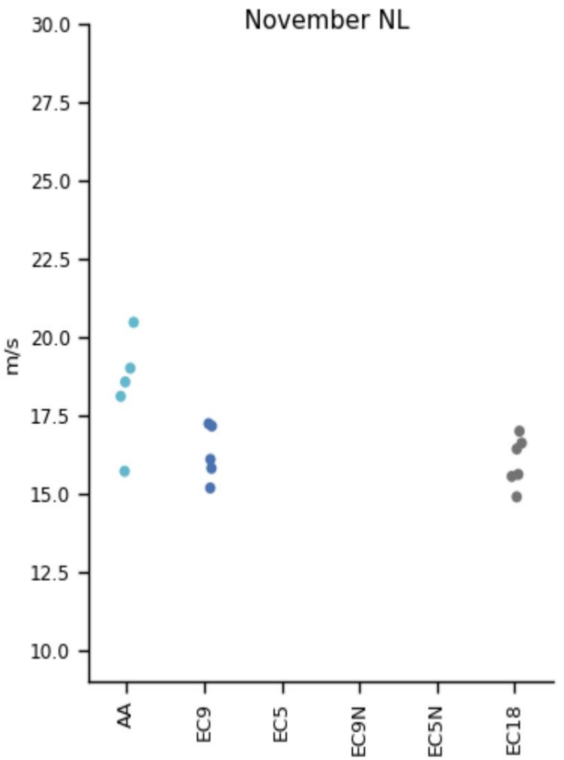
Now let's take the maximum wind speed associated to the polar lows at each time ste

We do this by drawing a circle around the polar low center at each time step, then take the maximum wind speed within this circle.

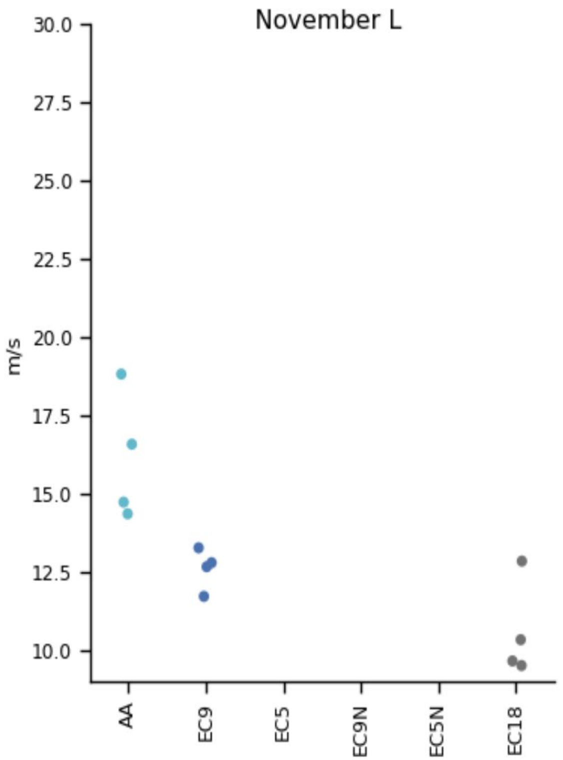
The radius of the circles are large enough to include the maximum wind in the polar low, but not so large that it includes maximum wind that belongs to other features.



Maximum wind speed, November case

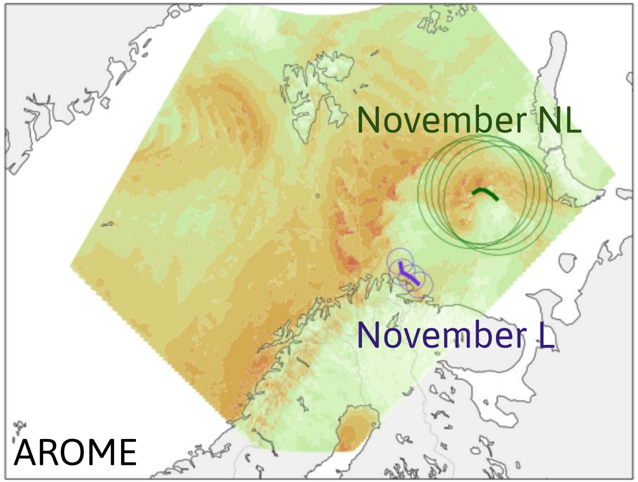


(a)

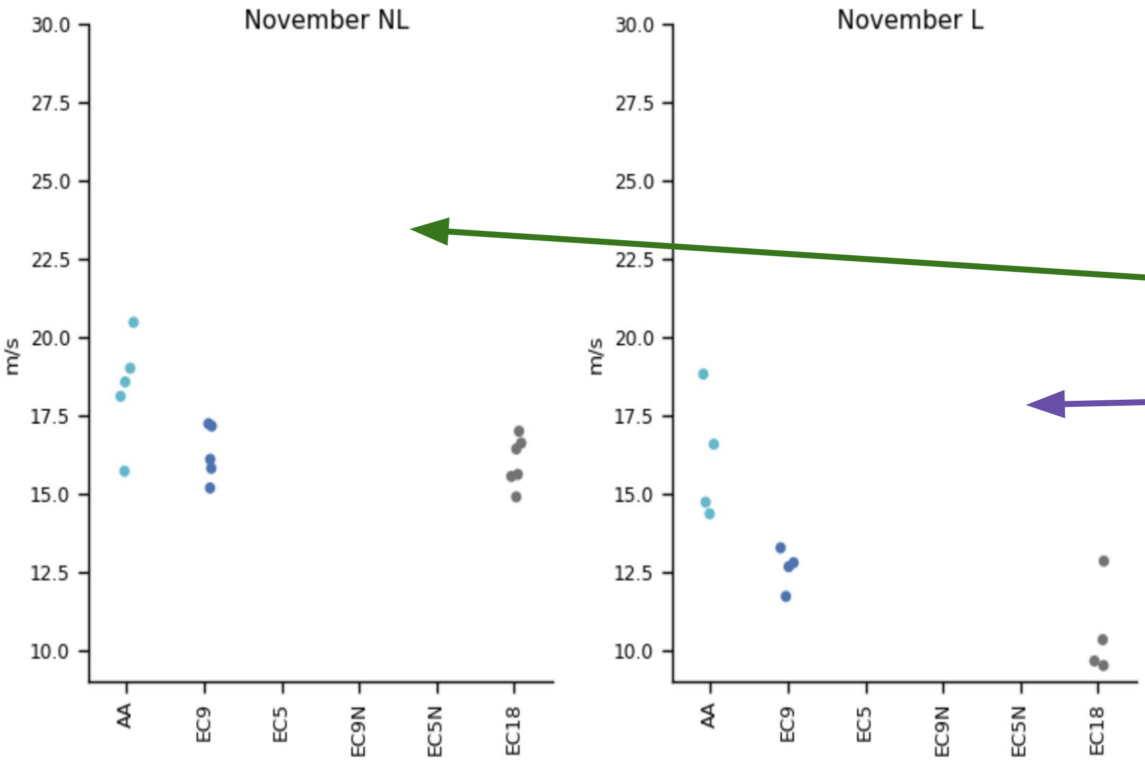


(b)

Now plot the maxmium wind for each experiment!



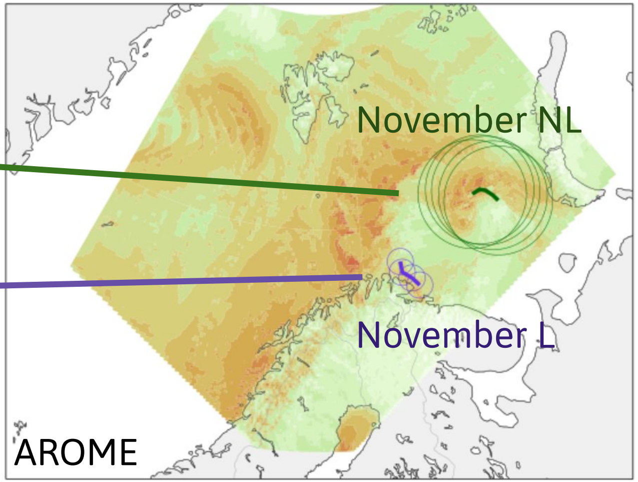
Maximum wind speed, November case



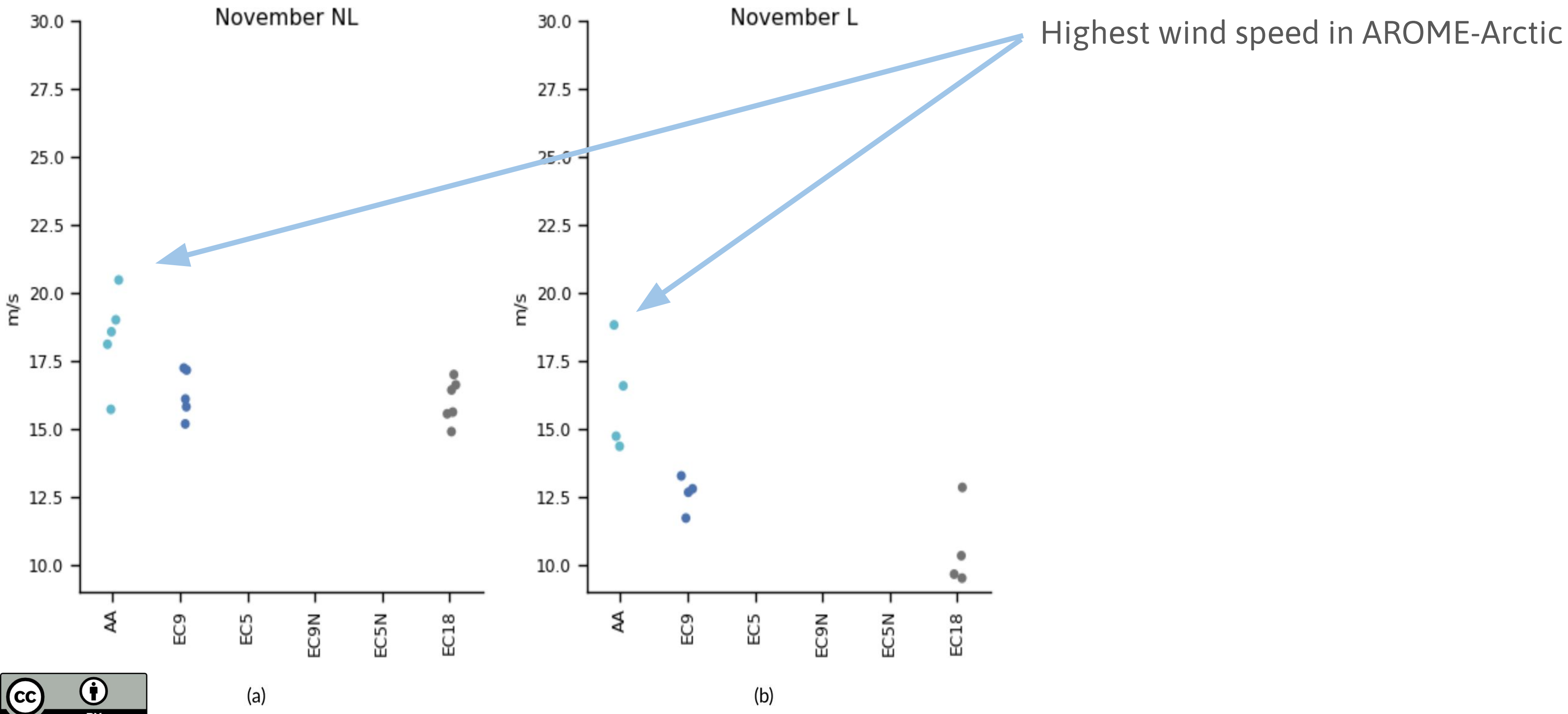
(a)

(b)

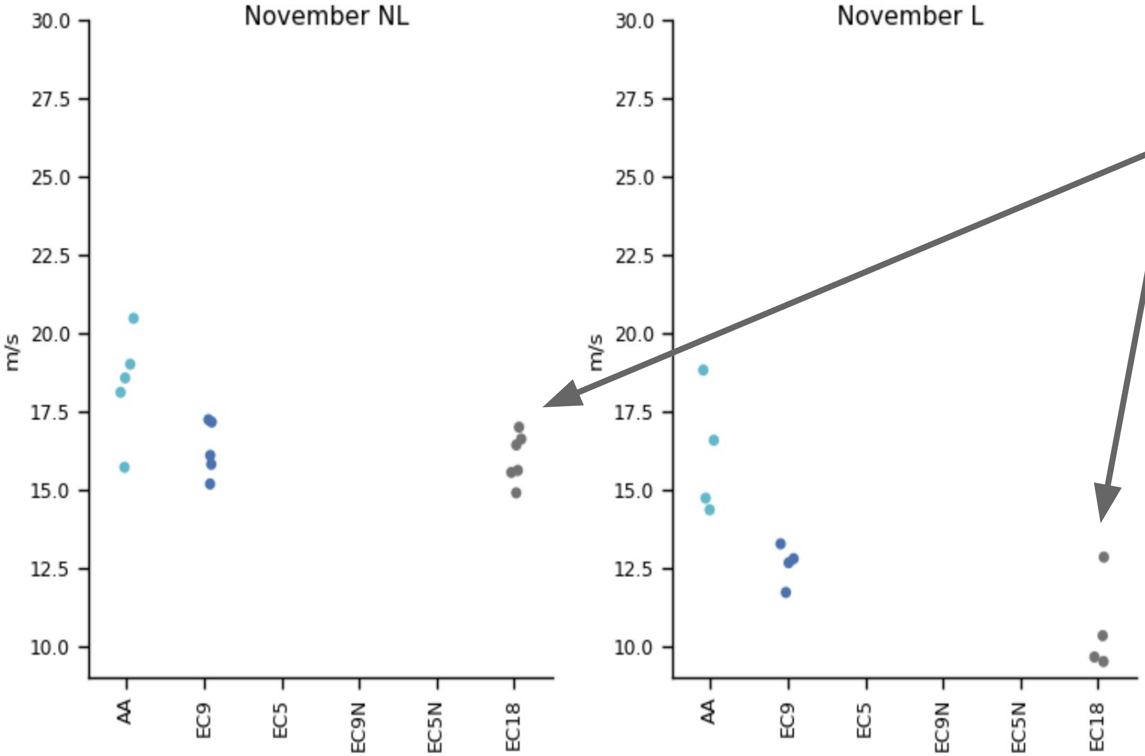
Now plot the maxmium wind for each experiment!



Maximum wind speed, November case



Maximum wind speed, November case



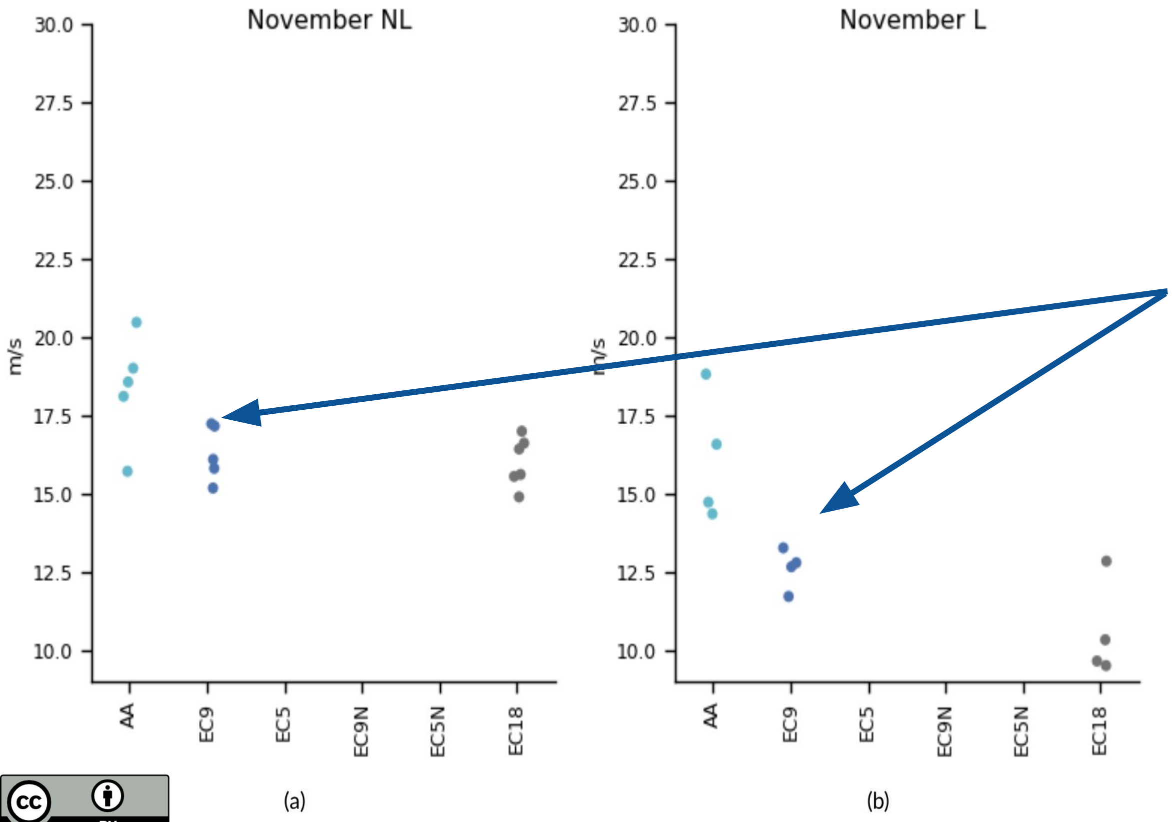
(a)

(b)

Highest wind speed in AROME-Arctic

Lowest wind speed in ECMWF IFS with 18 km grid spacing

Maximum wind speed, November case

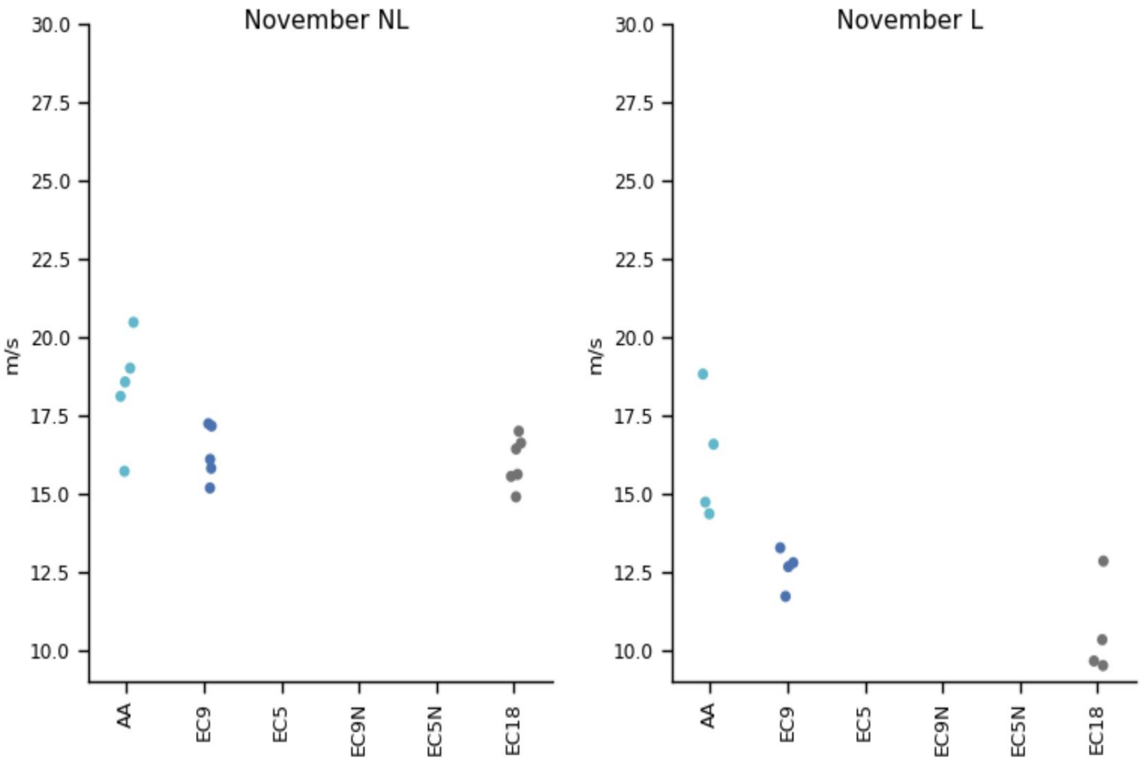


Highest wind speed in AROME-Arctic

Lowest wind speed in ECMWF IFS with 18 km grid spacing

ECMWF IFS with 9 km grid spacing in between

Maximum wind speed, November case



(a) (b)

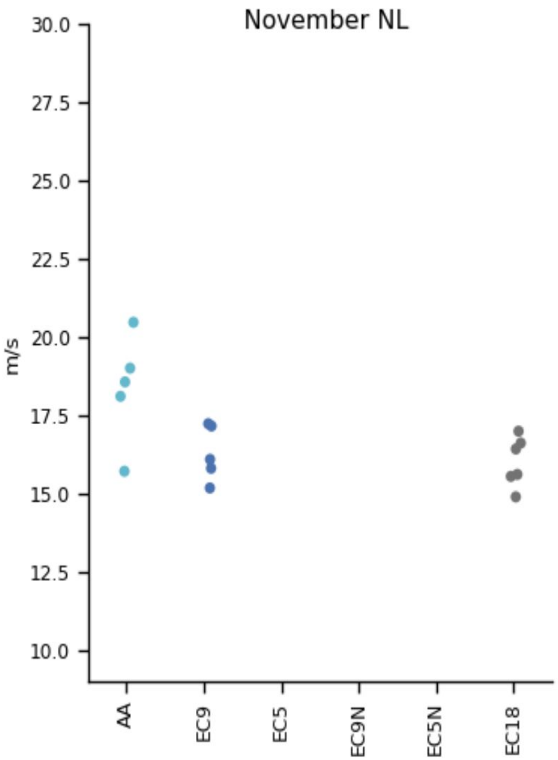
Highest wind speed in AROME-Arctic

Lowest wind speed in ECMWF IFS with 18 km grid spacing

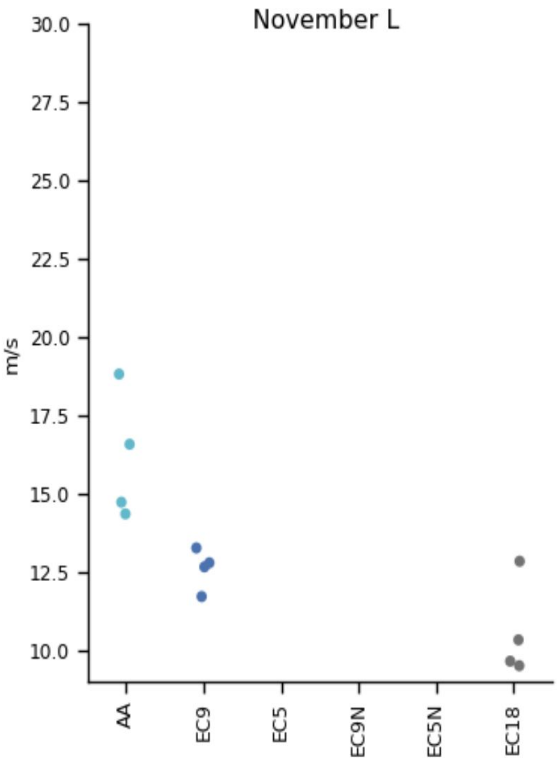
ECMWF IFS with 9 km grid spacing in between

So higher resolution means higher wind speed?

Maximum wind speed, November case



(a)



(b)

Highest wind speed in AROME-Arctic

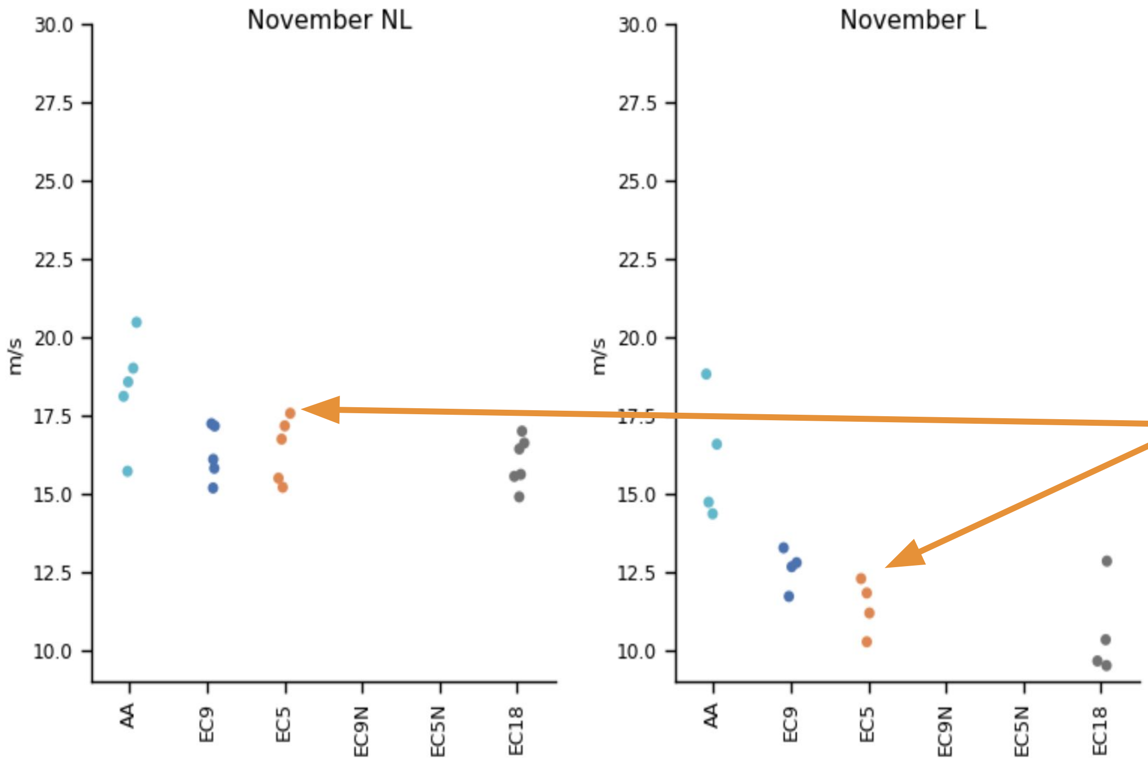
Lowest wind speed in ECMWF IFS with 18 km grid spacing

ECMWF IFS with 9 km grid spacing in between

So higher resolution means higher wind speed?

ECMWF IFS with 5 km grid spacing will make higher wind speed than EC9 then?

Maximum wind speed, November case



(a)

(b)

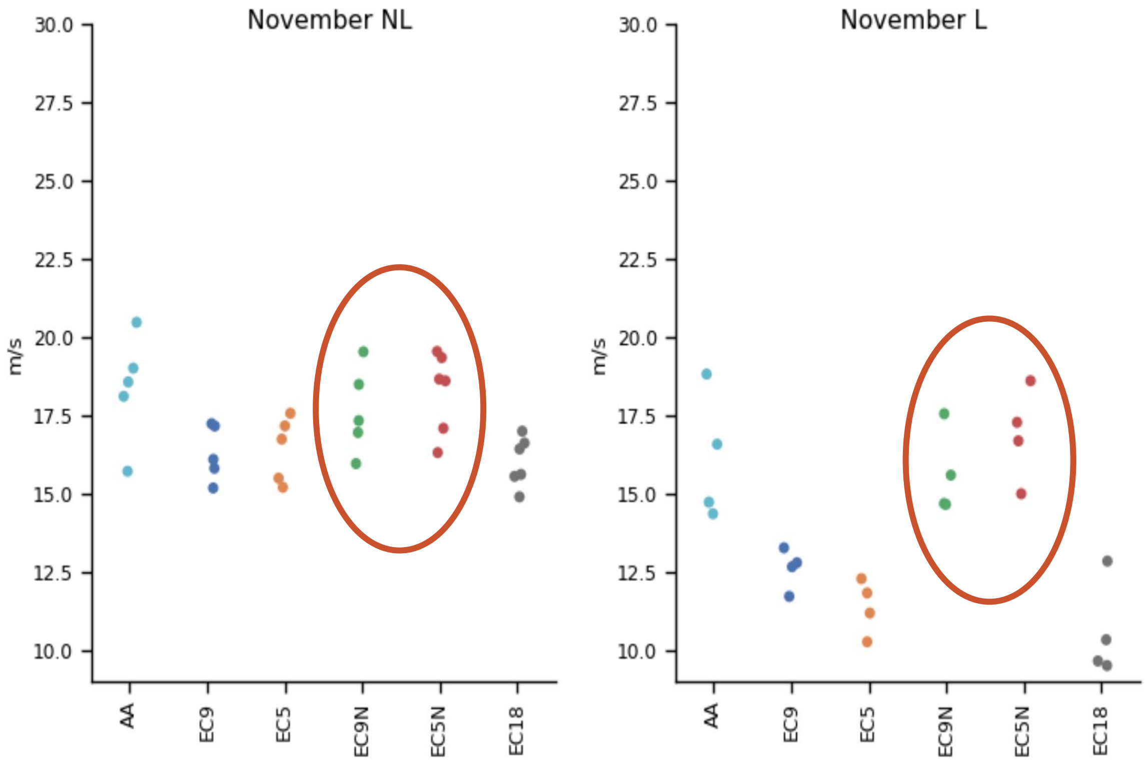
Highest wind speed in AROME-Arctic

Lowest wind speed in ECMWF IFS with 18 km grid spacing

ECMWF IFS with 9 km grid spacing in between

NOPE!

Maximum wind speed, November case



(a) (b)

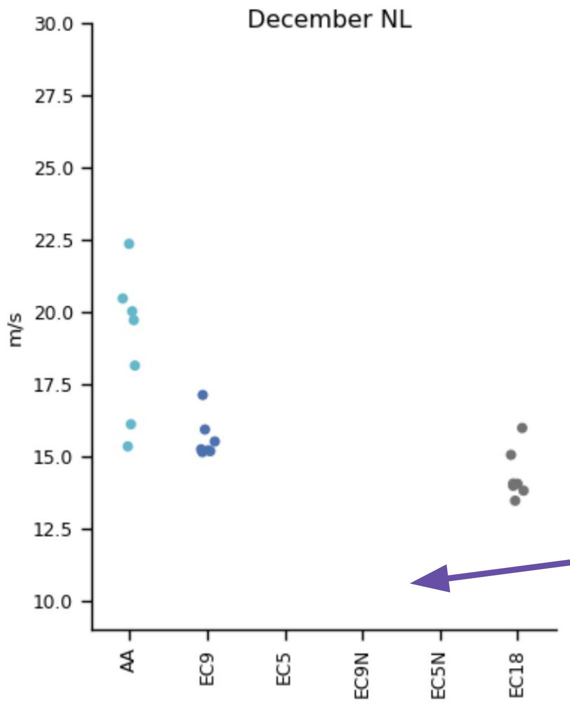
Highest wind speed in AROME-Arctic

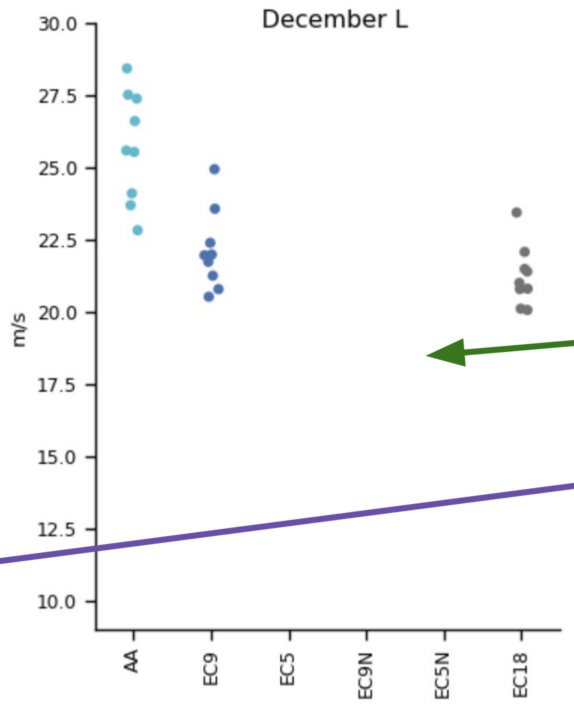
Lowest wind speed in ECMWF IFS with 18 km grid spacing

ECMWF IFS with 9 km grid spacing in between

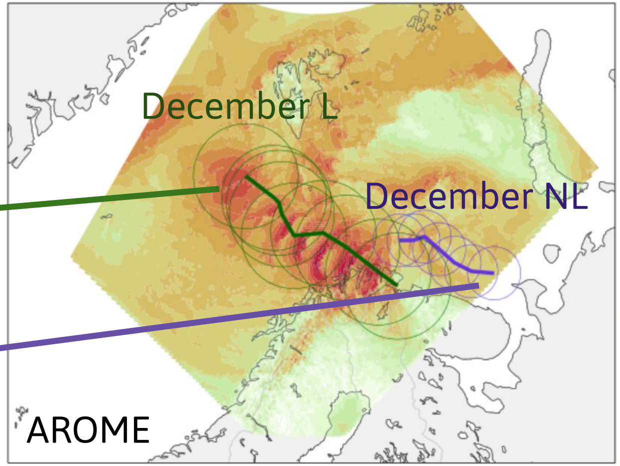
But resolved convection does!

Maximum wind speed, December case

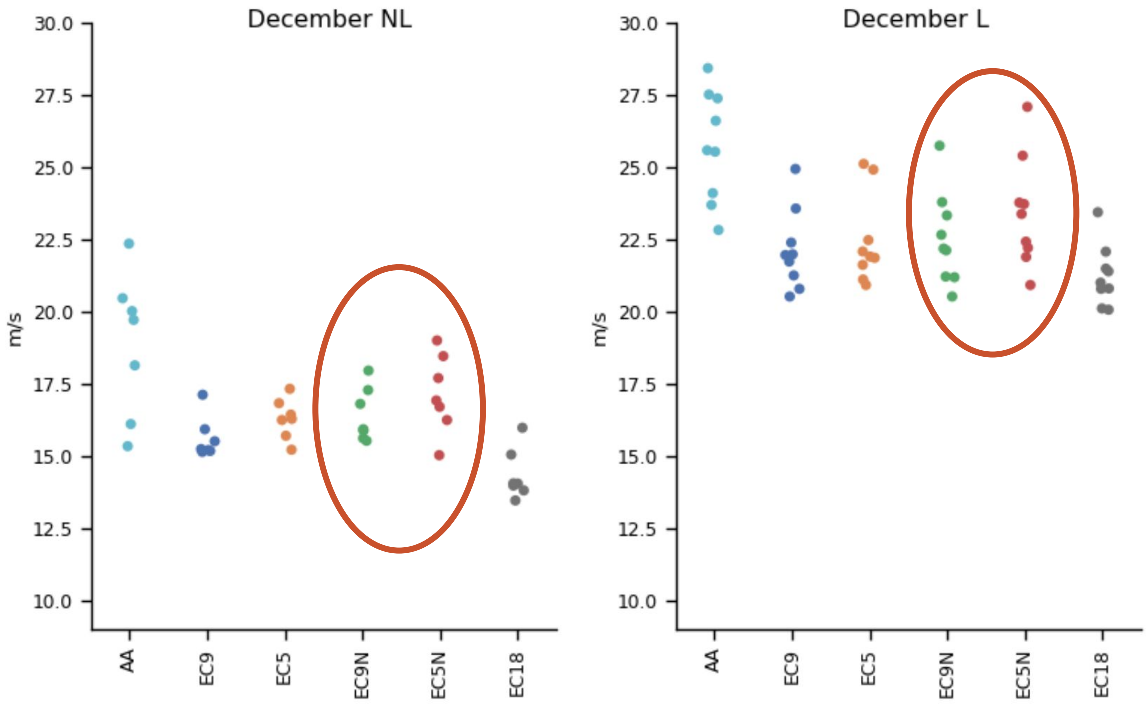




What about the December case?



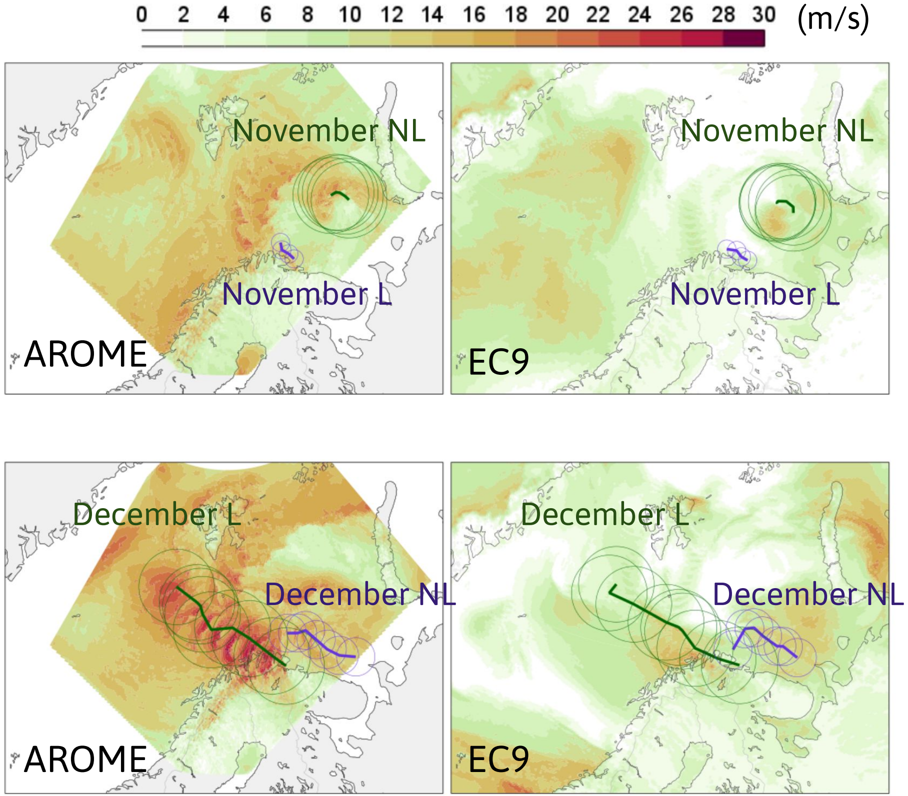
Maximum wind speed, December case

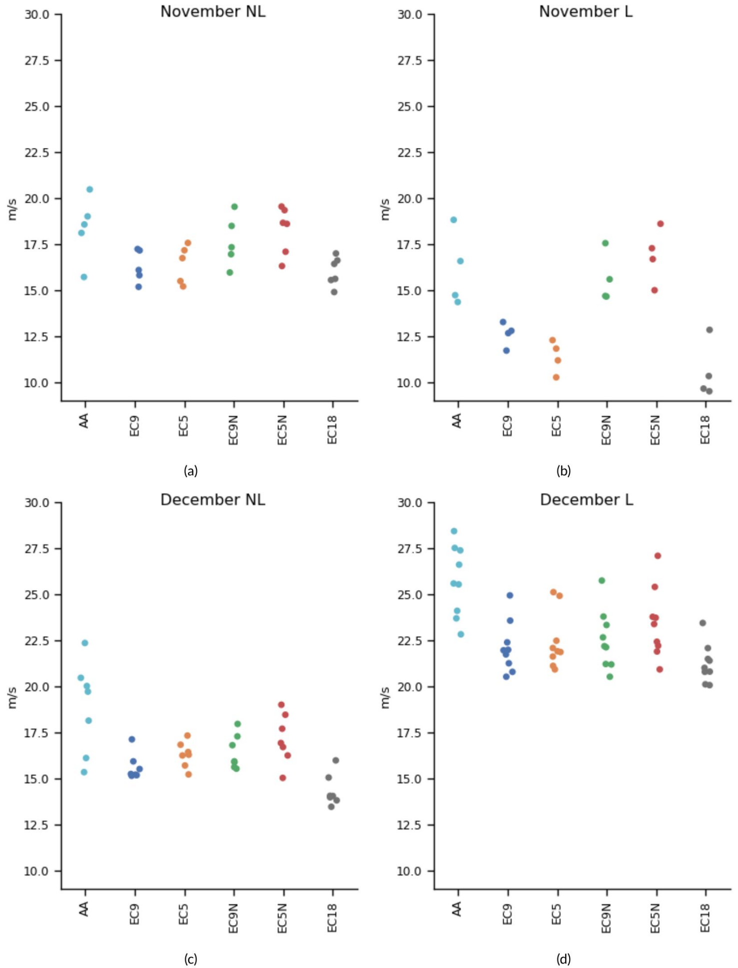


What about the December case?

The same!

Maximum wind speed





Maximum wind speed

Over sea, ECMWF HRES performs better than AROME for overall magnitude of wind speed

Little difference between 9 and 5 km grid spacing in ECMWF

Maximum wind speed

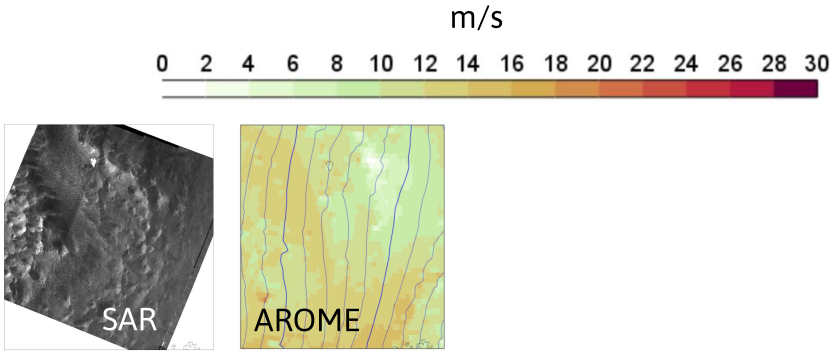
Over sea, ECMWF HRES performs better than AROME for overall magnitude of wind speed

Little difference between 9 and 5 km grid spacing in ECMWF

Large difference between resolved and parameterized deep convection

The structure of convective cells

Hint of some, small convective cells in AROME

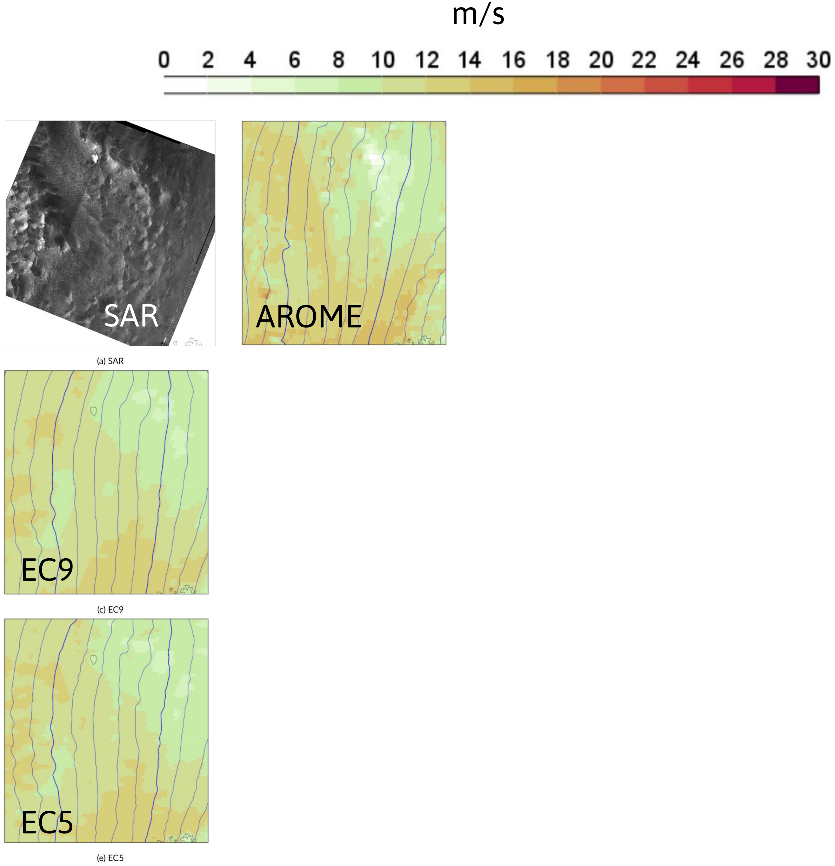


November

The structure of convective cells

Hint of some, small convective cells in AROME

Smooth structure of convective areas in ECMWF experiments with parameterized convection



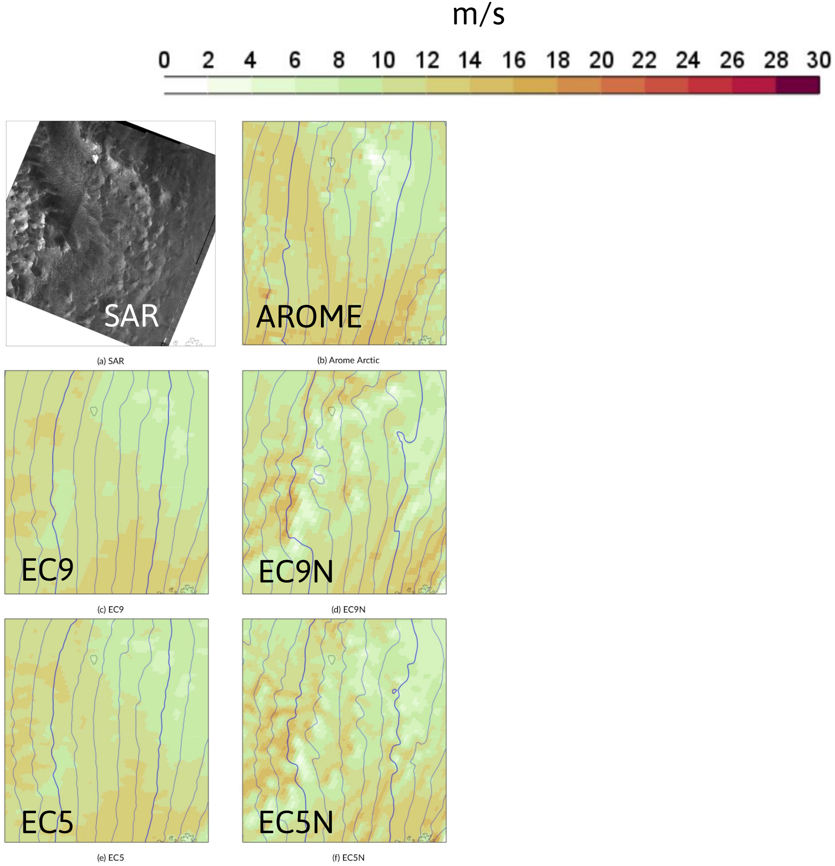
November

The structure of convective cells

Hint of some, small convective cells in AROME

Smooth structure of convective areas in ECMWF experiments with parameterized convection

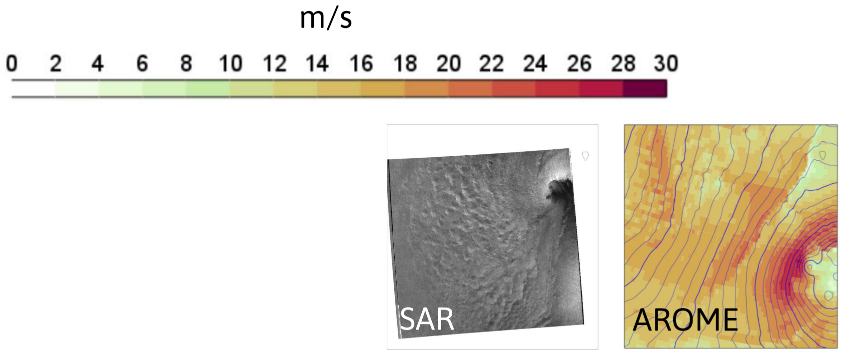
Fewer, but larger convective cells in ECMWF experiments with resolved convection



November

The structure of convective cells

Arome does not capture the mesoscale cyclone just east of Bjørnøya

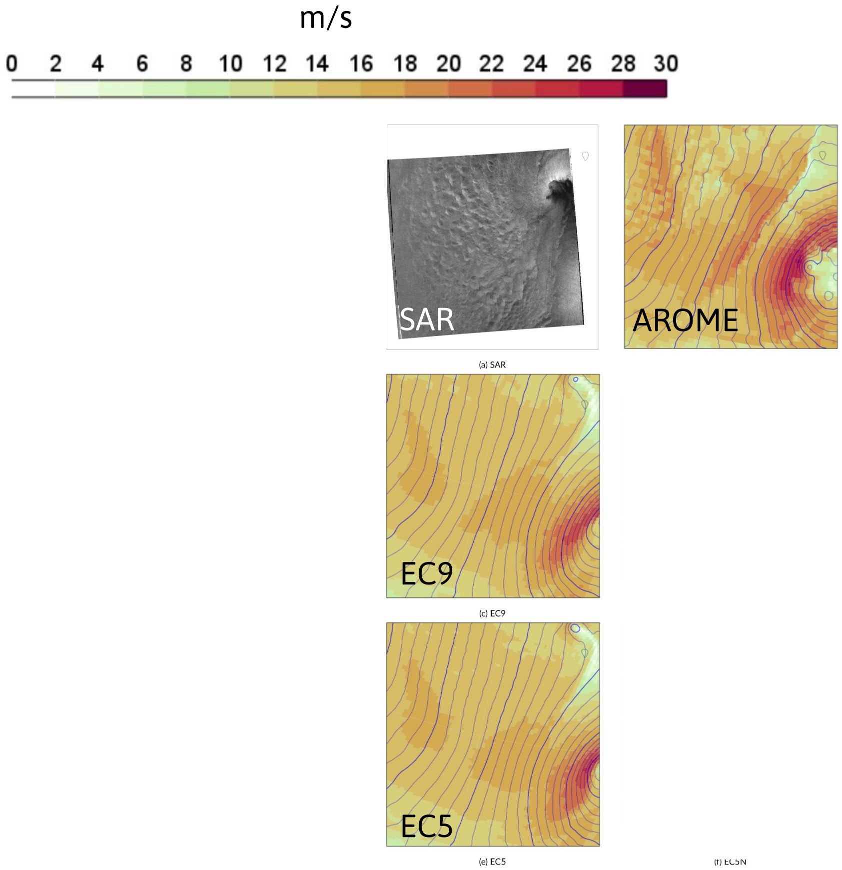


December

The structure of convective cells

Arome does not capture the mesoscale cyclone just west of Bjørnøya

ECMWF with parameterized convection makes the cyclone too weak, and displaced



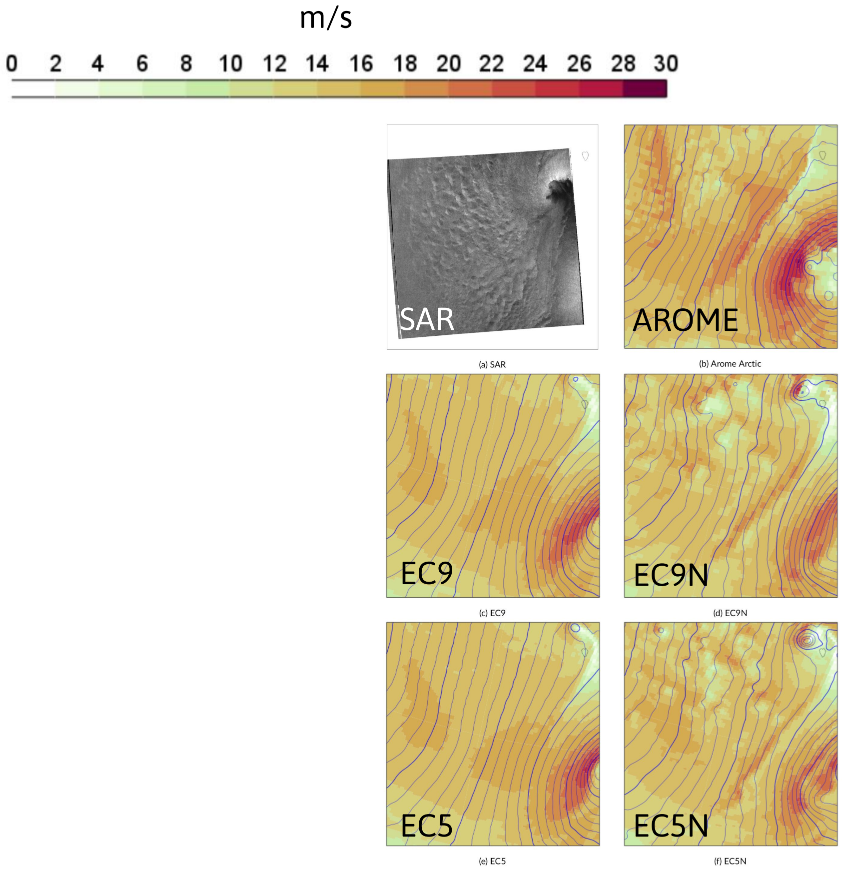
December

The structure of convective cells

Arome does not capture the mesoscale cyclone just west of Bjørnøya

ECMWF with parameterized convection makes the cyclone too weak, and displaced

ECMWF with resolved convection makes the cyclone stronger, but still displaced



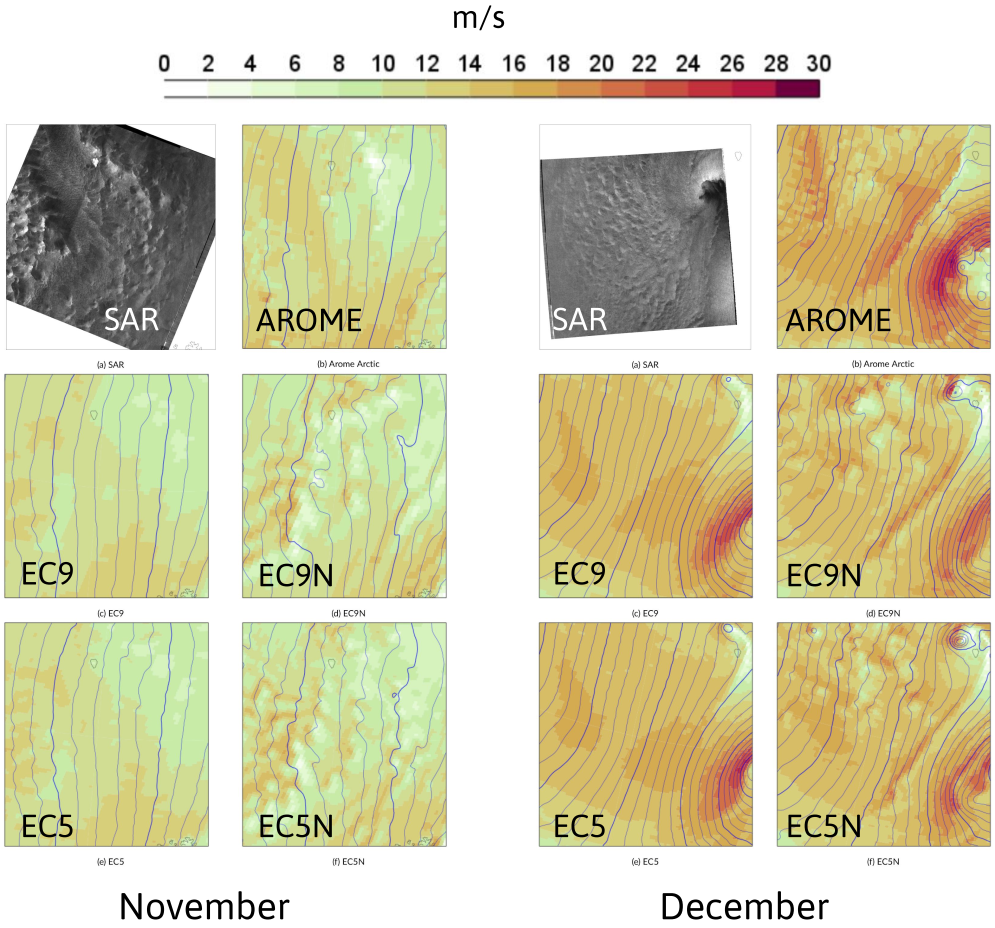
December

The structure of convective cells

AROME-Arctic represents the structure of convective cells better than ECMWF with parameterized convection.

ECMWF with resolved convection produces too big convective cells.

However, ECMWF with resolved convection still produces the most realistic patterns.



The structure of convective cells

Over sea, ECMWF HRES performs better than AROME for over all wind speed

Little difference between 9 and 5 km grid spacing in ECMWF

Large difference between resolved and parameterized deep convection

ECMWF experiments with resolved convection was best in reproducing the structure of the convective cells

So ECMWF with resolved convection is best?

Over sea, ECMWF HRES performs better than AROME for over all wind speed

Little difference between 9 and 5 km grid spacing in ECMWF

Large difference between resolved and parameterized deep convection

ECMWF experiments with resolved convection was best in reproducing the structure of the convective cells

So ECMWF with resolved convection is best?

Over sea, ECMWF HRES performs better than AROME for over all wind speed

Little difference between 9 and 5 km grid spacing in ECMWF

Large difference between resolved and parameterized deep convection

ECMWF experiments with resolved convection was best in reproducing the structure of the convective cells

That model setup may be poor for other latitudes and weather situations!

So ECMWF with resolved convection is best?

Over sea, ECMWF HRES performs better than AROME for over all wind speed

Little difference between 9 and 5 km grid spacing in ECMWF

Large difference between resolved and parameterized deep convection

ECMWF experiments with resolved convection was best in reproducing the structure of the convective cells

And we did not show you how the models perform over land.

So ECMWF with resolved convection is best?

Over sea, ECMWF HRES performs better than AROME for over all wind speed

Little difference between 9 and 5 km grid spacing in ECMWF

Large difference between resolved and parameterized deep convection

ECMWF experiments with resolved convection was best in reproducing the structure of the convective cells

Along the Norwegian coast, all models underestimated the wind speed, but AROME was closest to observations

Conclusions

Over sea, ECMWF HRES performs better than AROME for over all wind speed

Little difference between 9 and 5 km grid spacing in ECMWF

Large difference between resolved and parameterized deep convection

ECMWF experiments with resolved convection was best in reproducing the structure of the convective cells

Along the Norwegian coast, all models underestimated the wind speed, but AROME was closest to observations

Thank you!