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Bachelor thesis

Foehn in Greenland

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February 18, 2017

Abstract

Some communities in Greenland have truly bad weather as a result of cold katabatic winds, named piteraq's. Those winds can be described as cold foehn winds, while foehn winds are normally very warm. These winds sweep down the East coast that has the steepest slope of South Greenland. The regional climate model RACMO2.3 made a reconstruction of past weather at a resolution of 2,2 km, the model made a run from September 2006 until October 2014. In this reconstruction several cases were identified when searching for dates with high wind speeds. Further research in those cases showed that there were indeed piteraq's. When the wind swept down the East coast the fjords also played a role by canalizing the wind. There were also cases when the wind traveled westward ascending on to the East coast with high speeds. The fjords did not canalize these winds and it did not result in a foehn or piteraq.

Contents

1 Introduction

Foehn is the generic name for all warm, dry downslope winds. The generic name originated in the alps and the phenomena is observed all over the world under different local names. Usually it is a warm and dry descending wind and can have both negative and positive influences. The warmth for example could cause glacial melt that results in flooding, but it could also prolong a crop growing season through its influence on the climate. There is also a cold variant that is observed in Greenland and is called a piteraq. The piteraq only has negative influences and can have devastating effects on communities that live there. It sweeps down the East coast where there are several fjords and its wind speeds make the area very dangerous. "Clearly, katabatic winds and especially the piteraqs, have a large impact on the ice sheet and its immediate surroundings. Given increasing commercial activity around the periphery of the Greenland ice sheet, there is a growing impetus for understanding these winds and their response to climate change."[2]

Understanding of the physical processes behind this phenomenon is required for good weather forecasts and accurate interpretation of model results. In order to analyze the climate of South Greenland including the piteraqs, the model output of the regional climate model RACMO2.3 is used. These models are driven on their margins with a reconstruction of past weather, in this case ECMWF (European Centre for Medium-range Weather Forecasts) operational analyses. The interior domain of a regional climate model can evolve freely and will be used to analyze the weather and climate of e.g. Greenland. The model can be run under different resolutions and is mostly used with a resolution of 11 km over all of Greenland, as in a research done on Summer snowfall on the Greenland Ice Sheet [3]. It was also used with a resolution of 27 km for an Improved representation of the East Antarctic surface mass balance.[5]

For this study, data is used of a reconstruction of the weather of South Greenland using the regional climate model RAMCO2.3, which was run with a very high 2.2 km resolution. The simulation spans almost a decade from September 2006 till October 2014. The data contains the wind speeds and directions, the modelled temperature, the surface pressure, the humidity, precipitation and one could extract more information by using the presented data to calculate the pressure and potential temperature.

This dataset is used to assess if this reconstruction also shows piteraq and foehn events, and if so, how these events are influenced by the topography of South-East Greenland, where the ice sheets terminates in incised fjords surrounded by rugged mountains.

2 Foehn

The foehn is a type of warm and dry descending wind that occurs in the lee of a mountain range. It is the generic name for all warm, dry downslope winds and finds it origins in the Alps. Locals however tend to use a variety of names such as the chinook of the Rocky Mountains, the koschava and ljuka of Yugoslavia, the germich of the south-western part of the Caspian Sea, the afganet and ibe of Central Asia, thee kachchan of Ceylon, the berg wind of South Africa, the Santa Ana of southern California, the zonda and puelche of the Andes, the north-wester of New Zealand. All different names for the same phenomenon.

There is also a cold and dry descending wind, a variant of foehn, called a piteraq in Greenland. In the local language "piteraq" means "That which attacks you." and this phenomenon is most common in the autumn and winter.

2.1 Impact

Foehn can have both positive as negative influences to regions. The positive effects include warmer, drier climates and a prolonged crop growing season. The negative effects however far outweigh the positive. The foehn is a warm wind which means that the warmth it brings can cause glacial melt which in turn causes downstream flooding. The warmth will also increase the likelihood of avalanches and contribute to warm the polar regions. A foehn can also have some more direct negative effects if it occurs as a windstorm, as it does in the Appalachians in Eastern North America [6]. These foehn windstorms are a serious danger to climbers. Because the windstorm consists of warm, dry air moving at high speeds it promotes both the ignition and rapid spread of wildfires.

Piteraq's can also cause severe damage due to the very high wind speeds, with the worst documented piteraq having a wind speed of an estimated 90 m/s. The wind rips roofs apart and blows windows in, it even sends boats flying. Since 1970 the Danish Meteorological Institute started issuing special piteraq warnings, after a local community was devastated by a piteraq in the beginning of that year.

2.2 Causes

The most popular explanation that is used for foehn is just one casual mechanism(number 1 in figure 1) [8], but there are not one but four causes. These four mechanisms are not all as easily observed. They often act together, but depending on the meteorological conditions and the size and shape of the mountain barrier the contribution of each mechanism may vary. The four mechanisms that combine to create the foehn effect are shown in figure 1.

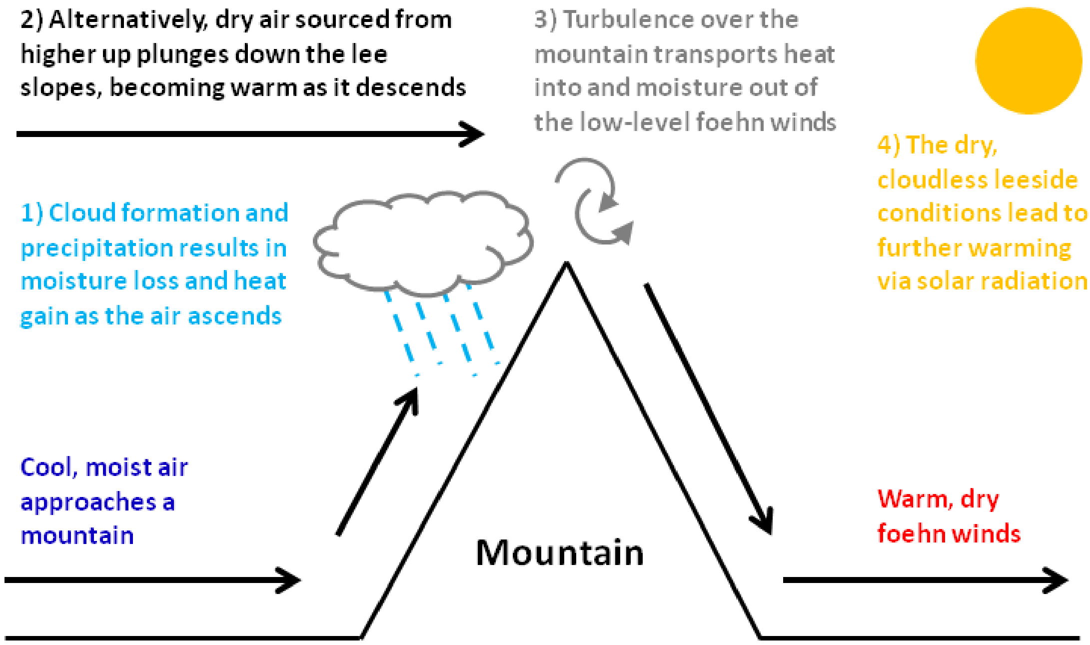


Figure 1: This figure shows the four mechanisms that cause foehn.

2.2.1 Condensation and precipitation

This is the most popular explanation and was discover as early as 1835 by Espy, but the credit for the theory generally goes to Hann who showed its effect in 1866 ??. Hann showed that humid air is forced upwards by the wind and rises on the slopes, the air starts to cool down, because of the cooling the air loses its ability to hold its moisture which condenses and is removed from it through precipitation. Because the water changes its state from vapour to liquid there is latent heat that is released during the process. The heat gain is irreversible because of the precipitation and that results in warm and dry foehn conditions in the lee of the mountain. However, because there are also foehn events where there is no precipitation, it implies that there must be other mechanisms.

2.2.2 The draw-down air from aloft

The foehn air could also come from higher, potentially warmer and drier altitudes. This happens if the cool and moist air from the lower levels is blocked by the mountain barrier, this is the case if the winds are insufficiently strong enough. In that case the cool moist air cannot be propelled up and over the mountain and only air from higher altitudes is able to pass over and down the slope of the mountain. This is called isentropic drawdown[9].The higher altitude air that descends becomes warmer and drier after it is compressed due to the increase in pressure at lower altitudes.

2.2.3 Turbulent mixing

As air passes over mountains there is turbulence which causes the air to be mixed in the vertical. This mechanical mixing causes sensible heating and drying of the low-level flow. It could be compared to when river water passes over rocks, the rapids that are generated by the turbulence then reveal white water, this is a direct result of the turbulent mixing with the air above. When it happens over a mountain this mixing generally leads to upward moistening and downward warming of the air. "This mechanism has gained only little interest so far in relation to the foehn air-warming problem."[10].

2.2.4 Radiative warming

The last mechanism is due to the rain shadows that are observed with dry foehn conditions. Rain shadows occur in the lee of the mountain and results in clear and sunny conditions. This again leads to greater solar(radiative) warming, because there are no clouds to block the sunlight. In cold regions this could cause concern because of snow or ice melt and therefore risks of avalanches.

To conclude on the four mechanisms there is no unifying theory on foehn and it remains elusive.[10]

3 RACMO 2.3

RACMO2 is a combination of the dynamical core of the HIRLAM (High Resolution Limited Area Model) model with the ECMWF(European Centre for Medium-range Weather Forecasts) and Integrated Forecast System (ISF) physics. RACMO version 2.3 includes HIRLAM version 6.3.7 and ISF cycle CY33r1. This model has not only been applied to the Antarctic Ice Sheet and Greenland, but also to smaller regions like Dronning Maud Land[11] and Patagonia[12].

The dynamical core of the model solves transport equations of momentum as well as temperature and moisture on grid box scales and larger. And with all that combined hence resolves the large scale circulation. However there are also a lot of mechanisms that are active at scales smaller than the horizontal grid size. For those processes the physics package is needed. Parametrization schemes of the package are used to formulate the subgrid-scale processes like radiative transfer, moist convection, turbulent mixing, surface/soil processes and subgrid-scale orographic drag. They are formulated in terms of the resolved grid-scale variables. In this study also the atmosphere-ice sheet interaction and the calculation of the net surface mass gain or loss of the ice sheet.

In general the grids of the model are defined over the equator and then rotated to the area and the grid distance is defined in fraction of degrees, as long as the domain is small enough the grid points will have equal distance between them. The amount of horizontal grid points is determined by the resolution that is used for the run. There are a total of 40 vertical layers, for the layers the model adopts a system of hybrid sigma levels. These levels evolve from terrain following sigma levels close to the surface to pure pressure levels at higher altitudes. There is no equal distance or pressure between the levels.[4]

RACMO is a regional model and the interior of the model is allowed to evolve freely, but this is not the case at the lateral boundary zone where it is dependant on external information. Certain parameters are relaxed towards a global model every six model hours, such as the wind components, humidity and temperature. At the model top RACMO is not forced.

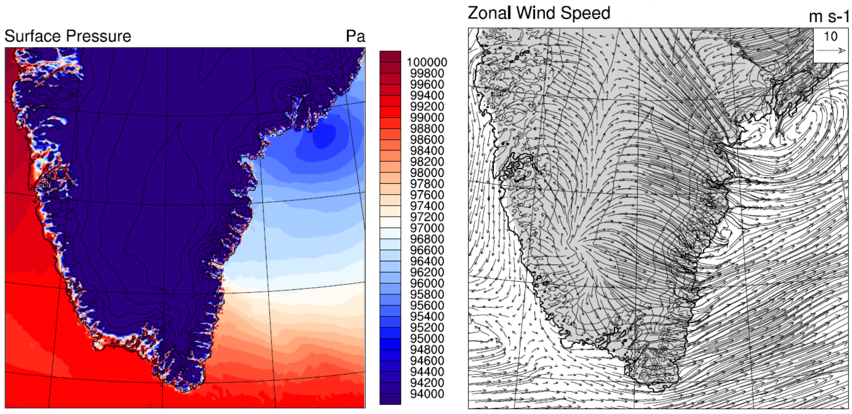
For this study RACMO reconstructed the weather of South Greenland, which from now on will just be referred to as Greenland, with a resolution of 2,2 km. The reconstruction started at September 2006 and ended on October 2014. The data was not based on observations and unfortunately there was no time to compare it to actual observations.

4 Results

Out of all the data four cases were identified. They were picked through timeseries of the wind speed that were made at certain coordinates (305,315) along the east coast. Strong winds are necessary for foehn and by making timeseries, the dates at which foehn occurs can easily be identified. This resulted in several dates and thus cases to choose from.

I chose 4 cases for this report from the years 2008 and 2009, all the cases are in January and February of those years. There are 2 different type of cases, an offshore and an onshore case. With offshore I mean a positive zonal wind direction, in those cases the wind travels from the West to the East at the East coast of Greenland. And at the onshore cases the wind travels from the East to the West. In both years there is an onshore case in January and an offshore case in February.

4.1 09-02-08 Offshore



(a) The surface pressure

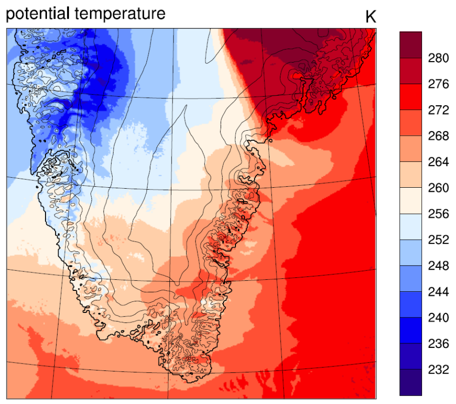
(b) The 10 m wind field

Figure 2: General surface plots of the offshore wind event of 09-02-08

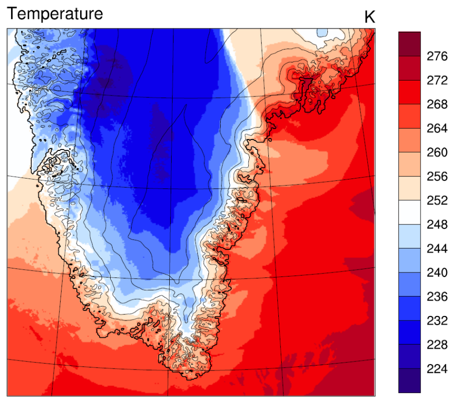
Figure (2a) shows the pressure at the surface in Pa. Since the atmospheric pressure is strongly depending on elevation, this figure focuses on the pressure at sea level, where the gradients directly relate to the wind field. During the case investigated here, a depression was located at (408,337); in the top right of the model domain. The depression indicates unstable weather conditions.

The 10 m wind field contains many interesting things. The figure shows the wind circling around the depression in the top right. But North of the depression centre there is a very sharp front, the wind suddenly changes its direction by 90 degrees.

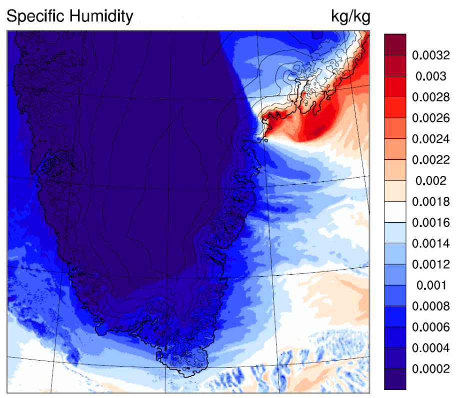
On the left side the wind diverges on Greenland, the wind that travels to the East gains very high speeds. The wind converges into the fjords and gains speeds up to 60 m/s. In the middle of the East coast (320,229) of Greenland the winds makes a small circular motion as it descended, if we look closely at the pressure(2a) we can see a very small depression at that exact spot.



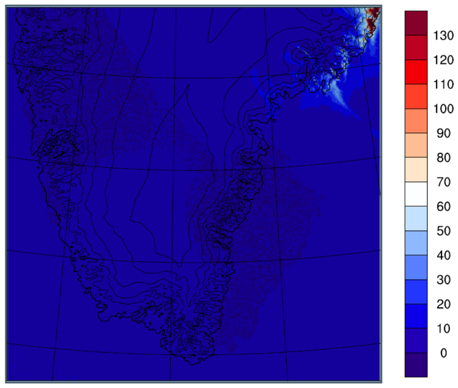
(a) The potential temperature



(b) The temperature



(c) The humidity



(d) Precipitation in mm/day

Figure 3: Surface parameters during the offshore wind event of 09-02-08

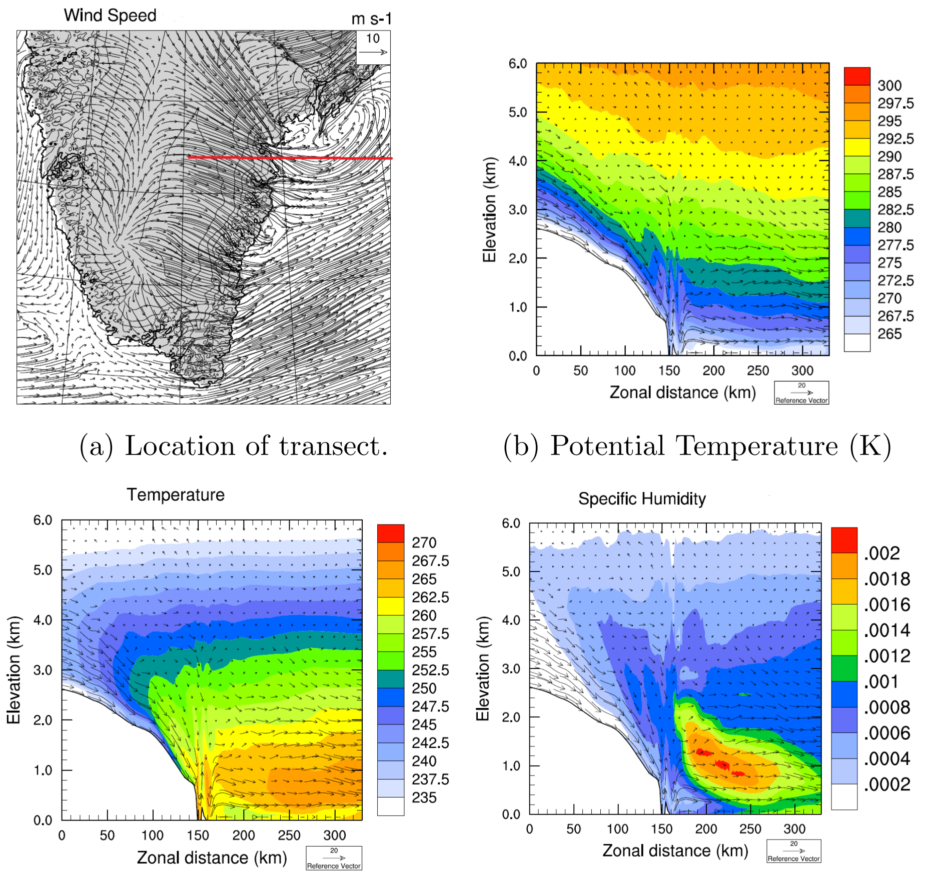
The temperature of the air is dependent on the pressure. Air at low pressure is colder than air at higher pressures. The potential temperature shows the temperature of the air if it were on a certain reference pressure. That gives us more information about the air on different levels, because at higher levels the air could be cold, but still have a lot of heat, which makes the air potentially warm. The modelled temperature does not show this additional information. The air at higher elevations could be potentially warm and if it rapidly descended to higher pressure it would increase in temperature.

The potential temperature(3a) shows a gradual increase on the surface from West to East. It should be noted that adiabatic effects are excluded in the potential temperature. It also shows a gradual heating of the boundary layer due to turbulent mixing. In the fjords the air remains colder, because the convergence of wind makes the layer of cold air thicker, and hence the downward mixing of heat less efficient. And there are very high temperatures North of the depression centre.

Figure 3b shows higher temperatures in the East, which is in the direction of the wind. The air gets heated because of turbulent mixing and descend to higher pressure. On the left side of the image where the wind diverges on Greenland, the air is roughly of the same temperature. At the top of the image we again see a very sharp front which complements what we saw earlier with the wind(2b). At the front in just a distance of a few dozen kilometers we see changes in temperature of up to 30 degrees Kelvin.

If the near surface temperature(figure 3b) is compared the near surface potential temperature(figure 3a) it can be concluded that most of the heating of the air descending at the East coast of Greenland is adiabatic. This air is cold, even once it has been brought at sea level. Hence, it can be seen that the cold continental air heats up once it flows over the ocean. Figure 3b shows the sharp front in the top right and high temperatures above/at the depression.

As the wind descends from Greenland to the East figure 3c shows an increase in humidity. The wind flows can clearly be recognized and as the wind flows across the ocean heat exchange occurs and water gets vaporized. There is also snow sublimation on Greenland which increases the humidity. It is especially humid at the depression, where the unstable conditions could cause precipitation. And figure 3d shows some precipitation at the depression.



(a) Location of transect.

(b) Potential Temperature (K)

(c) Temperature (K)

(d) Humidity (kg/kg)

Figure 4: Transect parameters during the offshore wind event of 09-02-08

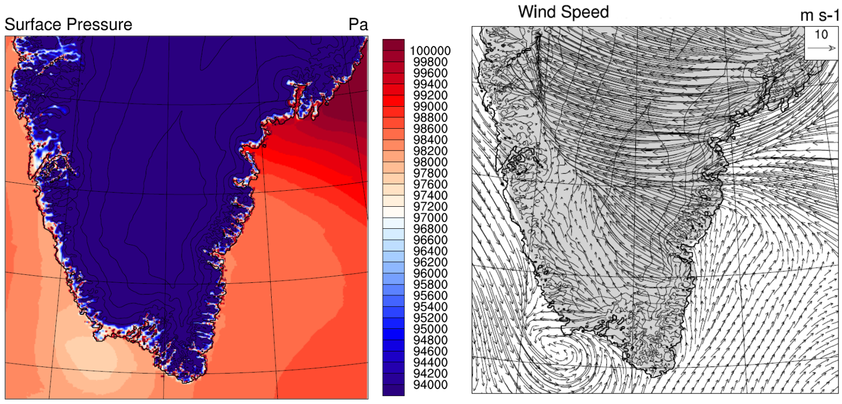
This study focuses on foehn and piteraq's which are downslope winds and thus have a vertical structure as explained in figure 1. Near surface figures do not show the vertical structure of the airflow as it descends, and as such cannot be used to compare the flow of the air at higher elevations. The characteristics for foehn are strong, dry and warm downslope winds, while the characteristics of piteraq's are strong, dry and cold downslope winds. Thus vertical transects were made of different parameters in order to investigate the speed, temperature and humidity of the winds.

The transect is located at the East coast(figure 4a); the graph with potential temperature (figure 4b) shows that most of the wind vectors align with the layers of the potential temperature indicating that the air does not increase or decrease its potential temperature as it travels. For the wind vectors seen in the transects (figure 4b,4c,4d) the wind trajectories were conserved, not the wind angles.

In the figures of the transect there is a windflow with high speed over the surface of Greenland, but it stays relatively dry(figure 4d). On close inspection the image shows that the dry wind flows under the already present humid air above the ocean. Rather than a warm dry foehn effect that causes high increases in temperature and thus large melt and evaporation of seawater, there actually is a cold katabatic wind(figure 4c). The air that flows at a high speed offshore stays relatively dry and cold. It is not a normal warm foehn, but rather a cold foehn. While there was a strong down slope wind that resembles foehn, many of the causes of the heat of foehn were missing. The wind resulted in a piteraq.

These cross sections again show strange things happening with the wind model as the wind passes an obstacle. Waves are forming up to 6 km elevation. It is strange that the model does this, as wind passes over an obstacle it forms waves, but it shouldnt have such a large effect all the way up the atmosphere. Why the model does this is uncertain.

4.2 21-01-08 Onshore



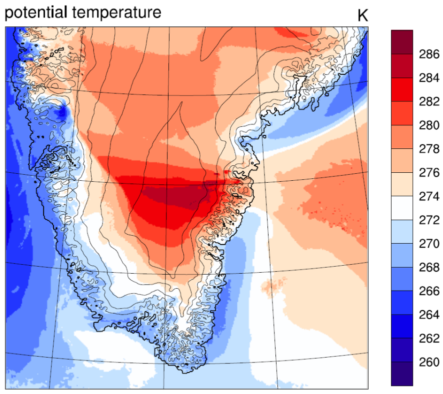
(a) The surface pressure

(b) The 10 m wind field

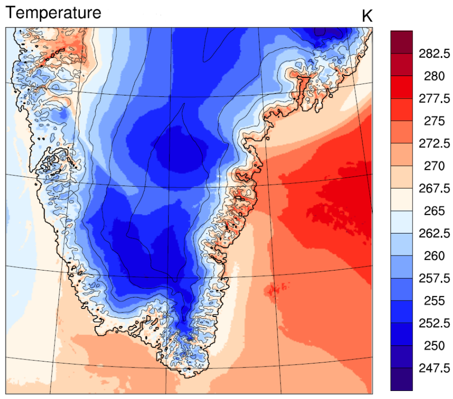
Figure 5: General surface plots of the onshore wind event of 21-01-08

The surface pressure(figure 5a) this time shows that the depression/low pressure area is on the other side of Greenland. The wind travels from the East to the West and this time ascends on to Greenland as opposed to the previous case. On the East side, the bottom right side of the image, we see a rather large area with relatively the same pressure. In the top right of the image there is a high gradient of the pressure, causing very high wind speeds. There is no conversion of the wind into the fjords.

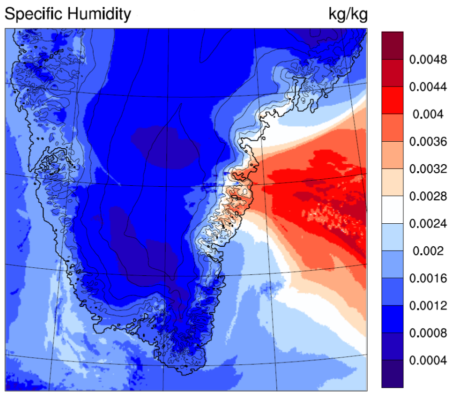
There is circulation of the wind around the depression centre as seen in previous figures. In the bottom right of the image, where the pressure was relatively homogenous, the wind more or less follows the isobars and does that at relatively low speeds. This is not the case in the top right of the image at the high pressure gradient, were the wind flows perpendicular to the isobars, from higher to lower pressure. On Greenland itself there are very high wind speeds and a front on the left side. Up North of the front there is some wind that diverges from it.



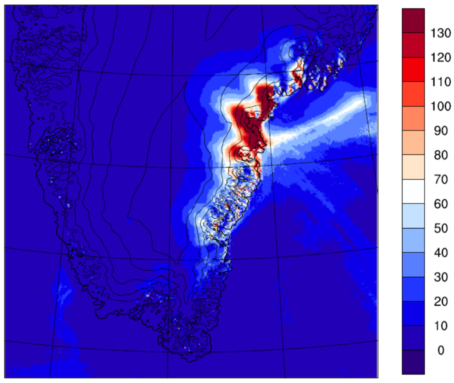
(a) The potential temperature



(b) The temperature



(c) The humidity



(d) Precipitation in mm/day

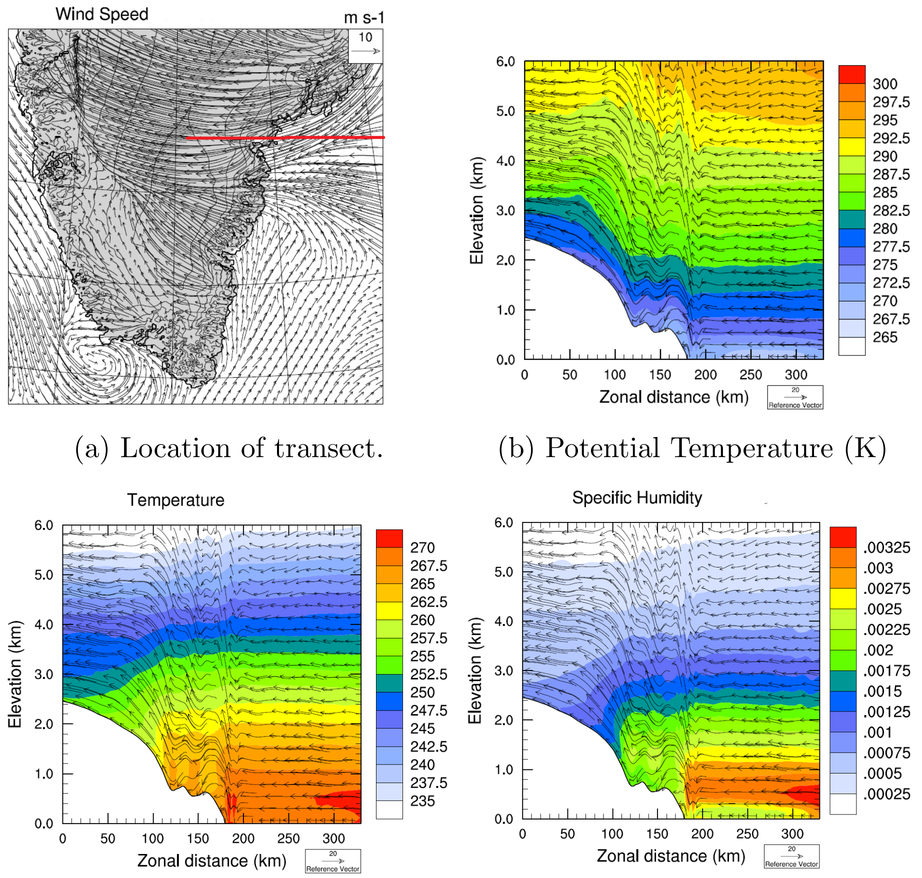
Figure 6: Surface parameters during the onshore wind event of 21-01-08

The potential temperature shows very high values in the middle of Greenland, which is the highest point of the modelled area. The image shows a high heat gain of roughly 10 degrees Kelvin as the air ascends on to Greenland, the cause of heat gain as air ascends is precipitation(figure 1) and that is shown in figure 6d. Figure 6a does not show a gradual increase of the potential temperature over the whole area as was shown in the previous case. On the left of Greenland there are low potential temperatures, while on the right the potential temperatures are higher and the wind flow is recognized.

Figure 6b shows that the high speed wind that came from the Northeast is cold, while the wind that comes in from the East is warm. At the depression center the temperature is slightly higher than the area that surrounds it. The modelled temperature does not show very high temperatures in the middle of Greenland, as one would expect of air at low pressure, but the air is still relatively warm as the potential temperature shows.The modelled temperature does show the warm air that comes in from the East. Figures 6a and 6b show the front in the West of Greenland but it is not as sharp as in the previous case, there is only difference of 7 K which is still significant but much lower than the 30 K change in the previous case(figure 3b). And again there is a higher temperature in the depression centre.

There is warm wind that comes in from the East as seen in figure 6b and which is very humid(figure 6c) compared to the surrounding area that is relatively dry. At the depression centre there is not a lot of humidity or heat, indicating low precipitation.

While the images show heat gain through precipitation as the air ascends, they do not show a warm and dry wind descending down slope to the West coast of Greenland. The slope to the West is not as steep as the slope to the East. It does show a more complete image of the first cause of heat gain for foehn.



(a) Location of transect. (b) Potential Temperature (K)

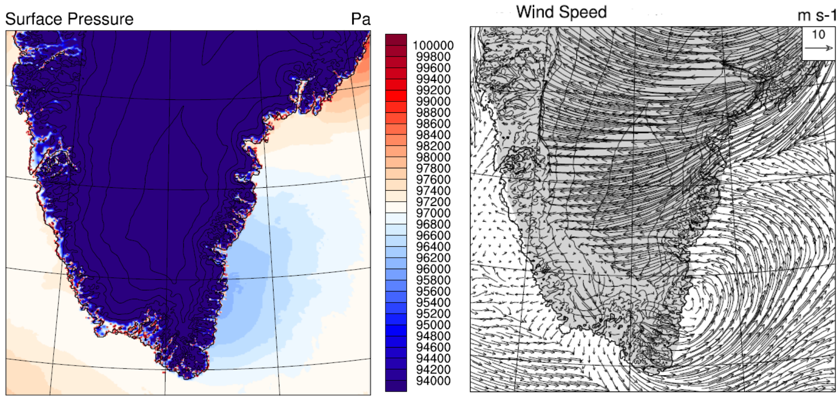
(c) Temperature (K) (d) Humidity (kg/kg)

Figure 7: Transect parameters during the onshore wind event of 21-01-08

The transects show that the air approaches the East coast homogeneously, as soon as it nears the surface of Greenland there is turbulence and the wind starts to form waves. The transect of the potential temperature(figure 7b) and humidity(figure 7d) show that as the air is ascending, it loses its moisture but gains potential temperature. The modelled temperature(figure 7c) shows the air getting colder as it ascends to lower pressure. The transect of the humidity does clearly that the air is forced upwards.

In the layers of the potential temperature at higher levels they follow the vectors of the wind, meaning that the potential temperature of the air does not increase or decrease, but rather stays the same.

4.3 21-01-09 Onshore

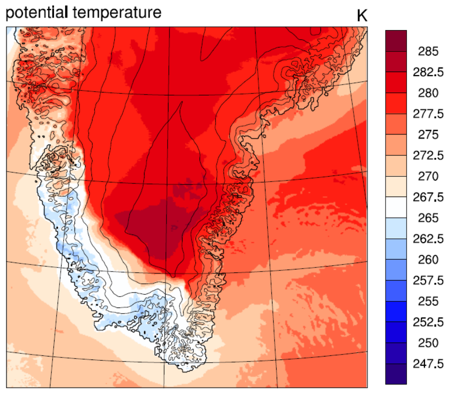


(a) The surface pressure (b) The 10 m wind field

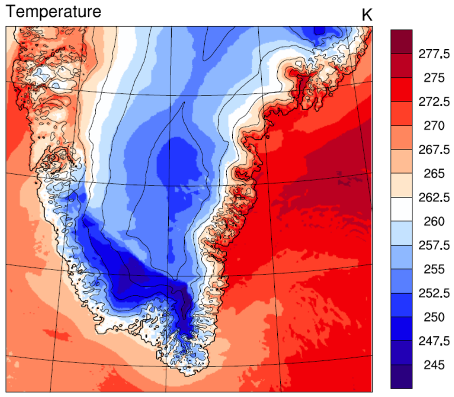
Figure 8: General surface plots of the onshore wind event of 21-01-09

The figures show a relatively low pressure all around the area. The depression is in the Southeast of Greenland. There is some higher pressure in the top right of the image. In figure 8a there are no high pressure gradients as were seen in the previous onshore case.

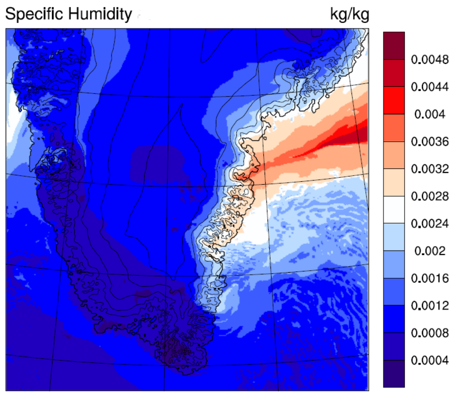
The wind circles around the depression centre and there is a strong wind coming from the Northeast. On the left side there are very low wind speeds compared to the right side. Again the air ascends on to Greenland. There is a very sharp front on the West side of Greenland and it is comparable to the front of the previous negative case, only this time it is convergent.



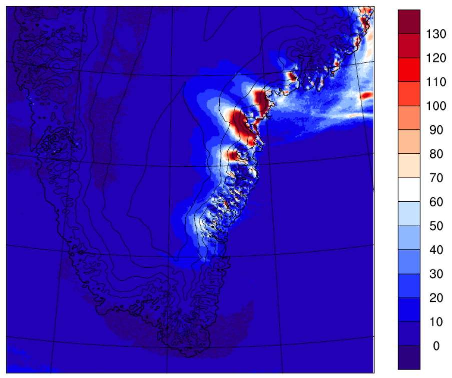
(a) The potential temperature



(b) The temperature



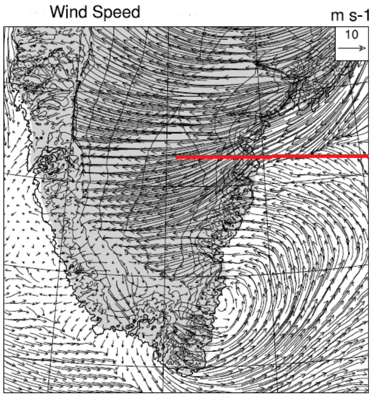
(c) The humidity

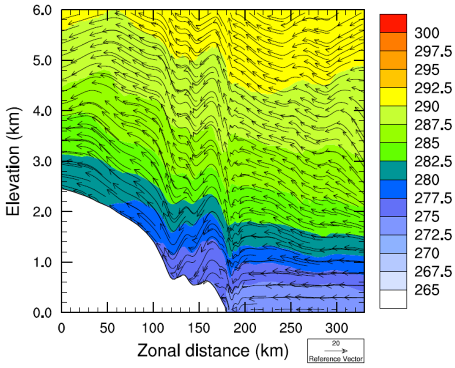


(d) Precipitation in mm/day

Figure 9: Surface parameters during the onshore wind event of 21-01-09

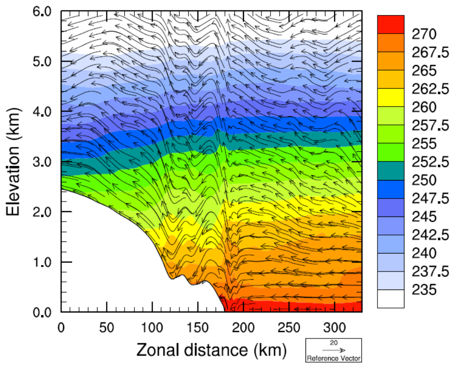
As in the previous case figure 9b of the modelled temperature shows relatively very warm air coming from the East. In the middle of the image(figure 9b) again there are no high temperatures that were shown in figure 9a of the potential temperature. While the figure shows an increase in temperature at an area in the Northwest of Greenland, it is not due to foehn, because there is no strong downslope wind(figure 8b). Figure 8b shows that the air that ascended on the East coast does not reach the West coast of Greenland because of the front that is present, instead the wind curves to the North. The air at the warm region in the Northwest(figure 9b) originates from outside the model domain as the figure of the wind(figure 8b) shows that there is a wind from the West that travels onshore. The front that was in the wind field(figure 8b) separates the coldest region that is in the South of Greenland with the rest of Greenland. Again there is nothing out of the ordinary at the depression centre.

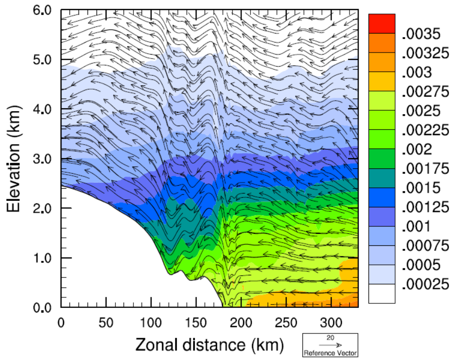




(a) Location of transect

(b) Potential Temperature (K)





(c) Temperature (K)

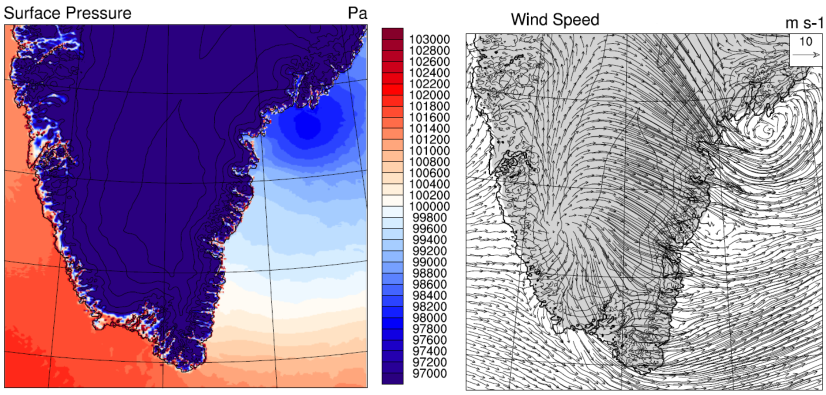
(d) Humidity (kg/kg)

Figure 10: Transect parameters during the onshore wind event of 21-01-09

The transects are very similar to the previous case. The transect of the modelled temperature(figure 10c) shows a decrease in temperature as the air ascends, because it ascends to a lower pressure. Because of precipitation the air loses its moisture and increases in potential temperature, but not as much as the previous case. In the previous case the air was more humid, that caused more precipitation leading to more heat gain.

Both onshore cases showed the wind forming waves as it approached the East coast, they also showed an increase in potential temperature and a decrease in humidity and temperature as it ascended on to the East coast. And in both cases the potentially warm air did not descend as a foehn wind.

4.4 18-02-09 Offshore



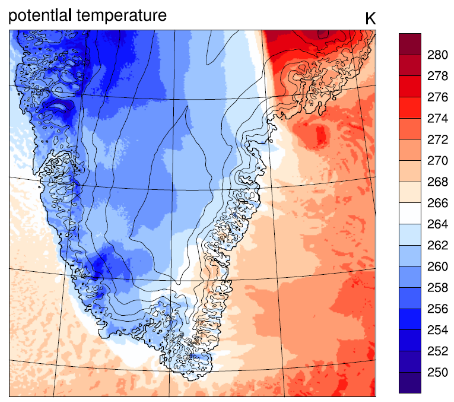
(a) The surface pressure

(b) The 10 m wind field

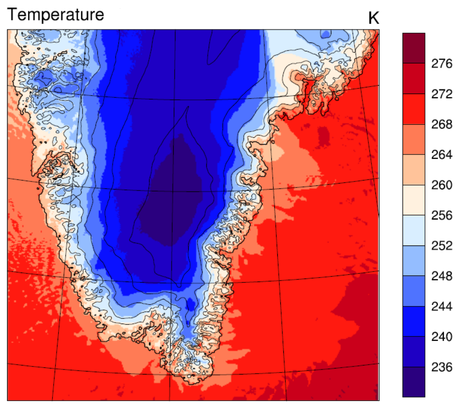
Figure 11: General surface plots of the offshore wind event of 18-02-09

This case is almost identical to the previous offshore case. The figure of the surface pressure shows a depression centre at almost the exact same spot, but in this case the overall pressure is higher then the previous. At the right side of the figure there are high pressure gradients, while the pressure stays relatively the same on the left side.

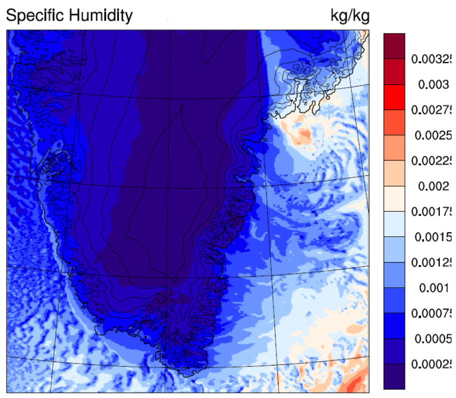
Again figure 11b shows a circulation around the depression centre, the figure 11b also shows the convergence into the fjords and divergence on the West side of Greenland. Off the West coast of Greenland there are collisions of winds with relatively low speeds. Figure 11b again shows a front North of the depression centre, but not with very high speeds or sharp turns as the wind in the previous offshore case. Figure 11b also shows some strange behavior of the wind in the middle right just off the East coast, it also occurred in the previous offshore case, but this time figure 11a does not show a low pressure area.



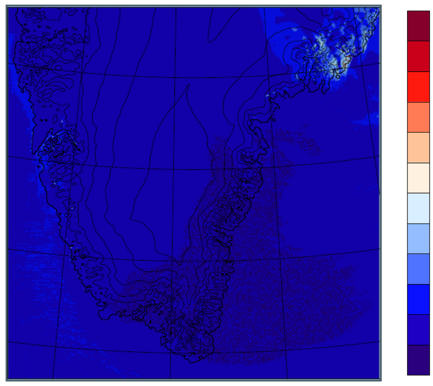
(a) The potential temperature



(b) The temperature



(c) The humidity

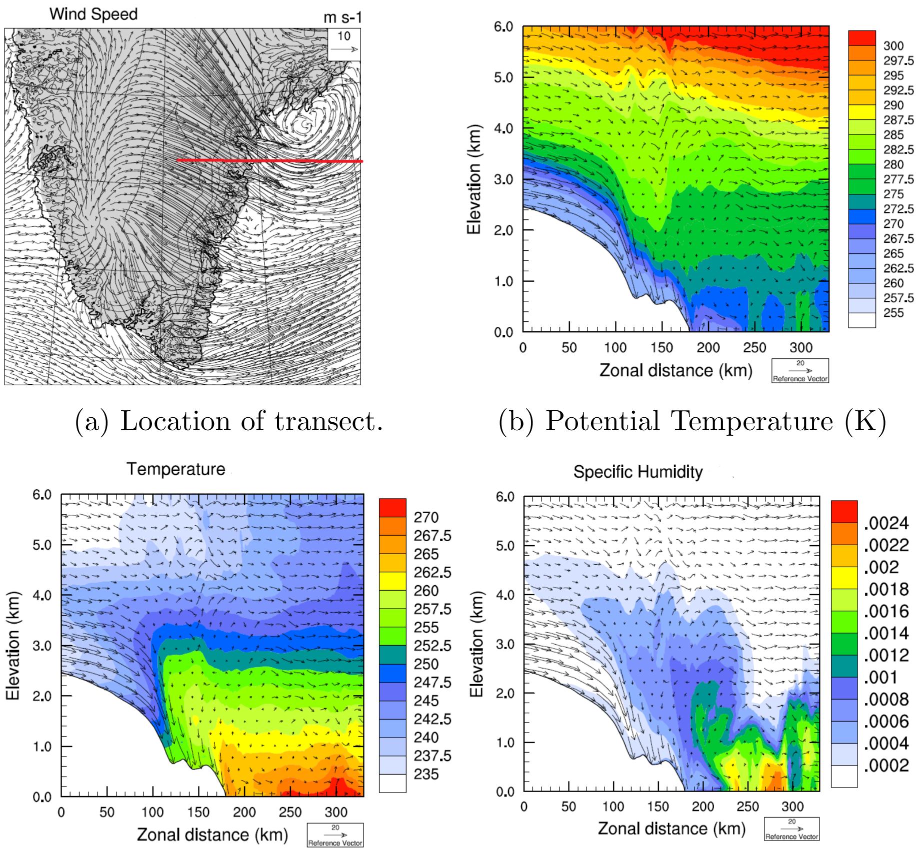


(d) Precipitation in mm/day

Figure 12: Surface parameters during the offshore wind event of 18-02-09

The figures show a front North of the depression, but the front is not as extreme as the on in the previous offshore case. The temperature is slightly higher at the depression centre and while the wind flow is recognized it is not as clear as in the previous figures. The potential temperature is almost identical to the previous offshore case, there is a gradual increase from the West to the East, it does not give us any new insights that were not noticed in the previous offshore case. The modelled temperature shows a clear difference between the surface of Greenland and the surface of the ocean. The modelled temperature does not show a gradual increase in temperature from the West to the East, only from the right side of Greenland to the East. Meaning that the change in temperature from the West to the East is mostly adiabatic, but from the East coast onto the ocean surface the effects of turbulent mixing are dominant.

In the figure of the humidity we recognize the wind flow and notice the front. As the wind flows over the ocean heat exchange occurs, and at the center of the depression the air is the most humid. There are wavelike patterns of the humidity(figure 12c) around the depression which could indicate a super cell.



(a) Location of transect. (b) Potential Temperature (K)

(c) Temperature (K) (d) Humidity (kg/kg)

Figure 13: Transect parameters during the offshore wind event of 18-02-09

These figures are slightly different than the ones of the previous offshore case. The modelled wind shows strange behavior in the zonal direction. The figure of the potential temperature(figure 13b shows waves forming as the cold air encounters warmer air. The model shows wind slightly diverging in all directions, indicating that there is a lot of movement in the meridional direction.

It is relatively dry and cold air that dives underneath the moist air as shown in the figures 13c and 13d. The vectors of the wind align with the layers of potential temperature. Again a piteraq is observed, a strong down slope wind that is cold and dry. It is the same scenario as in the previous offshore case, a lot of mechanisms that cause heat gain are not present or not strong enough. While there is turbulent mixing it is not strong enough to cause massive heat gains.

5 Discussion

During the research, the model showed some strange things in the wind model. It showed winds at higher elevations that could be physically incorrect, turbulence does cause forming of waves but to form waves to such an extent does not seem likely. While the model did show piteraqs, I do not think that the parameters that were shown during the event are reliable because of the strange behavior of the wind model at certain times. Another model will likely also show a piteraq, but it could have different parameters.

Unfortunately observations from radiosondes can not give us the temperature and speed of the horizontal winds that were researched. If the same research is done with another model it could still not easily be compared to see which one gives the better parameters.

The onshore events showed an increase in potential temperature that did not result in foehn later on. What happened to the potentially warm air could be researched further by looking at that region and the weather conditions prior to the descend of the potentially warm air. It could be that the potentially warm air eventually flows over the cold air that is observed in the figures, but further research could shine more light on that.

6 Conclusions

I can conclude that there is foehn, only it is not as it was described at first. What was described is a strong down slope wind that is very warm and dry. Instead there was a strong down slope wind that was cold and dry and there are a few reasons for it happening.

There were a total of four mechanisms that influenced the heat of the foehn wind, throughout the research I encountered some of the mechanisms. These mechanisms were not observed together at the same time the research did show the difference in heat gain from the different mechanisms.

In the offshore cases there were strong down slope winds on the East coast, the winds were also canalized by the fjords. The winds descended with high speeds that prevented mixing of the air. The air that descended was not potentially warm, so when it descended into higher pressure it did not increase in temperature. Rather it remained cold and dry resulting in a cold foehn, a piteraq.

In the negative cases there were strong descending winds, only they occurred at less steep slopes. As the air was forced upwards and ascended on to Greenland it gained a lot of heat and became potentially very warm, while losing its moisture and becoming dry. Some good preconditions for foehn wind, but alas it did not result in actual foehn. As the air descended to the West it curved to the North and did not continue down to the steep slope.

The fjords canalize descending wind, but does not do the same with ascending wind. In the fjords the air remains colder, because the convergence of wind makes the layer of cold air thicker, and hence the downward mixing of heat less efficient.

The most heat gain comes from precipitation while the air ascends, and the more precipitation the more heat gain. It is the most important mechanism for warm and dry foehn winds, but does not necessarily result in foehn. While the absence of this mechanism also not necessarily discards foehn.

Acknowledgements

Special thanks to Stan Jakobs for setting me up with NCL on my Windows computer and helping me with my plots. Also special thanks to Melchior van Wessem for helping me with understanding NCL and making plots.

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