Contribution of Foehn Effect to the January 2016 West Antarctic Melt Event

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Outline

- Background
- Identification of the Foehn Effect at the beginning of the melt event
- Quantification of the Foehn Effect based on RIP4 output
- Conclusions and future plans

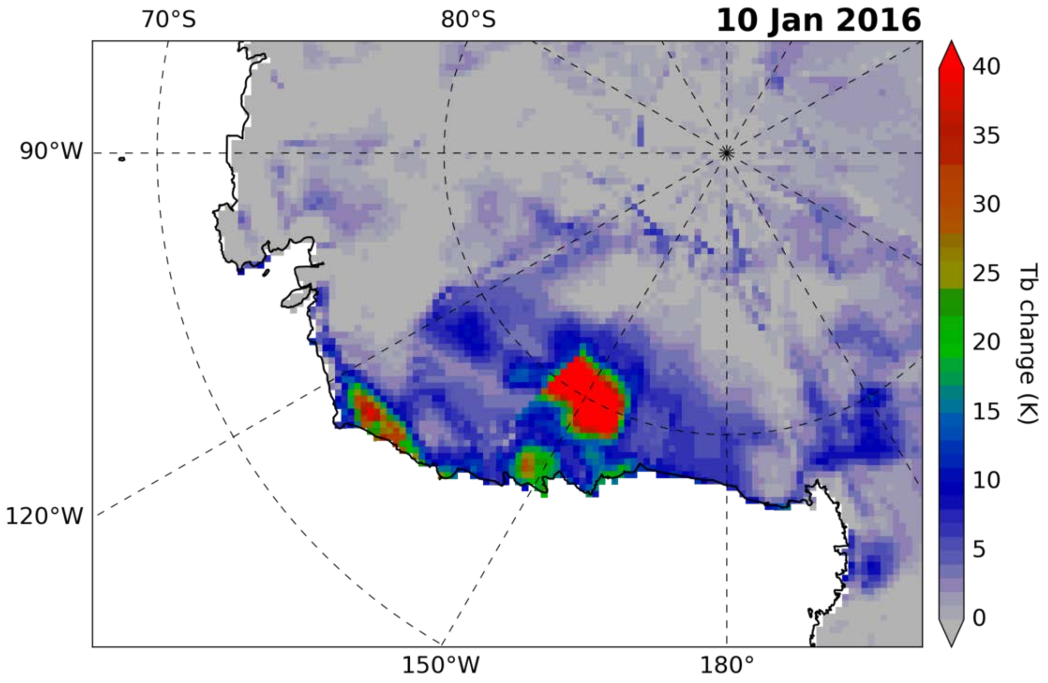
A Major West Antarctic Surface Melt Event

Location: Over the Ross Ice Shelf and adjacent sector of Marie Byrd Land

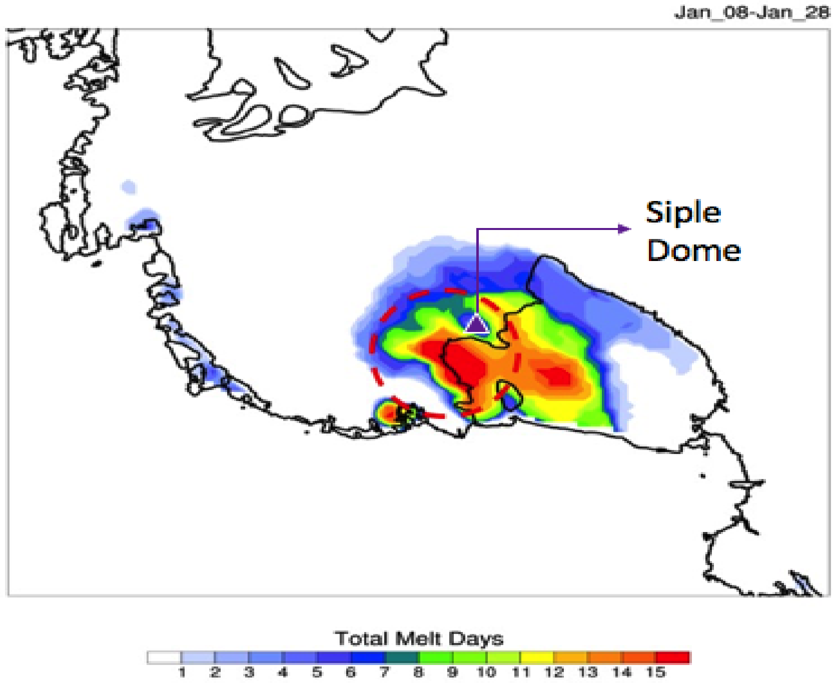
Time: Jan. 10th to Jan. 28th (Nicolas et al. 2017).

The melt started right near the Siple Dome. (Melting Spot)

Melting Area on January 10th



Sum of the melting days from 8 January to 28 January 2016

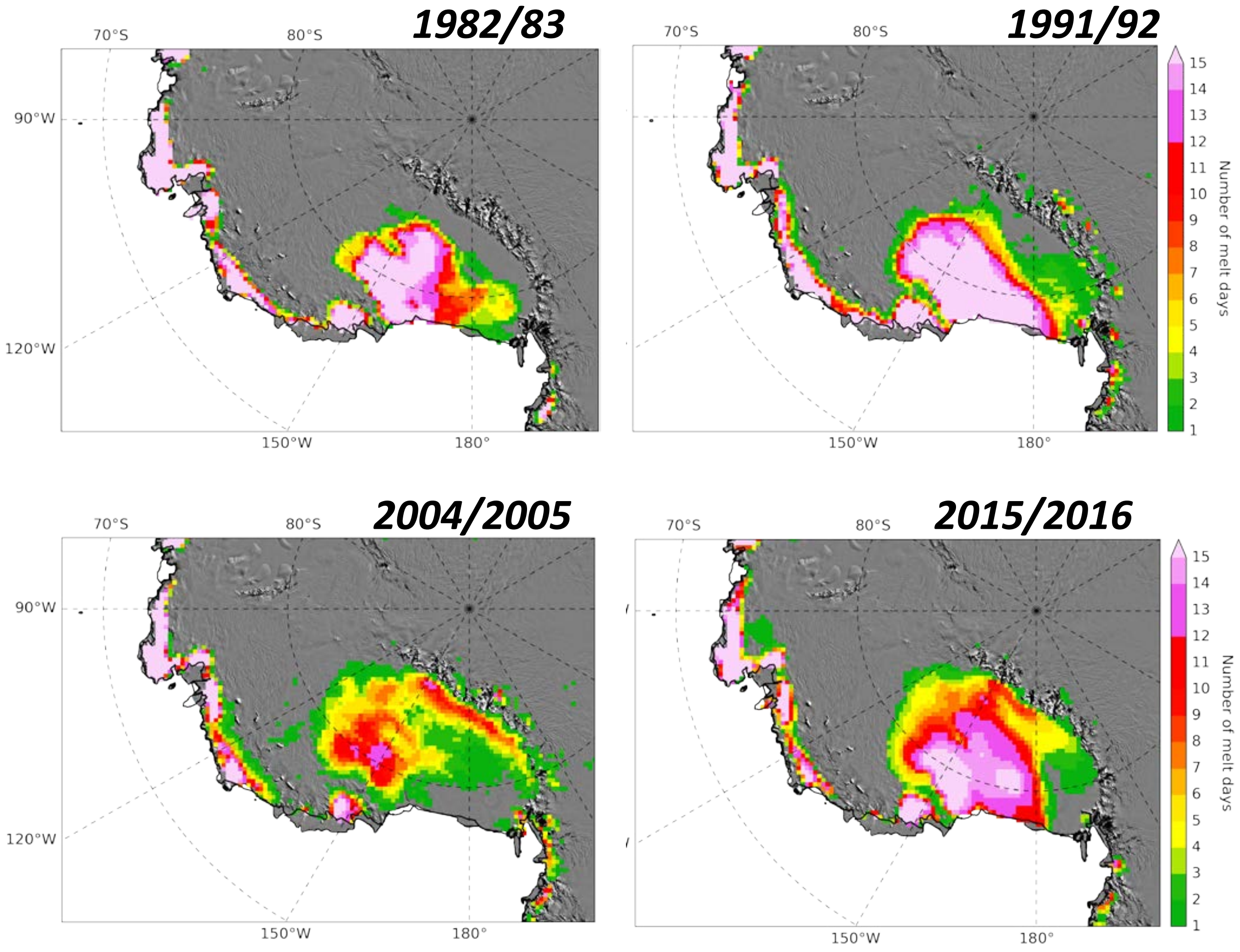


Previous Melt Events

- Why does the melt usually start right near Siple Dome?
- Why is melting more frequent in this area?

Based on temperature and wind field, we assume that ***Foehn Effect*** plays a role at the beginning of the melt event.

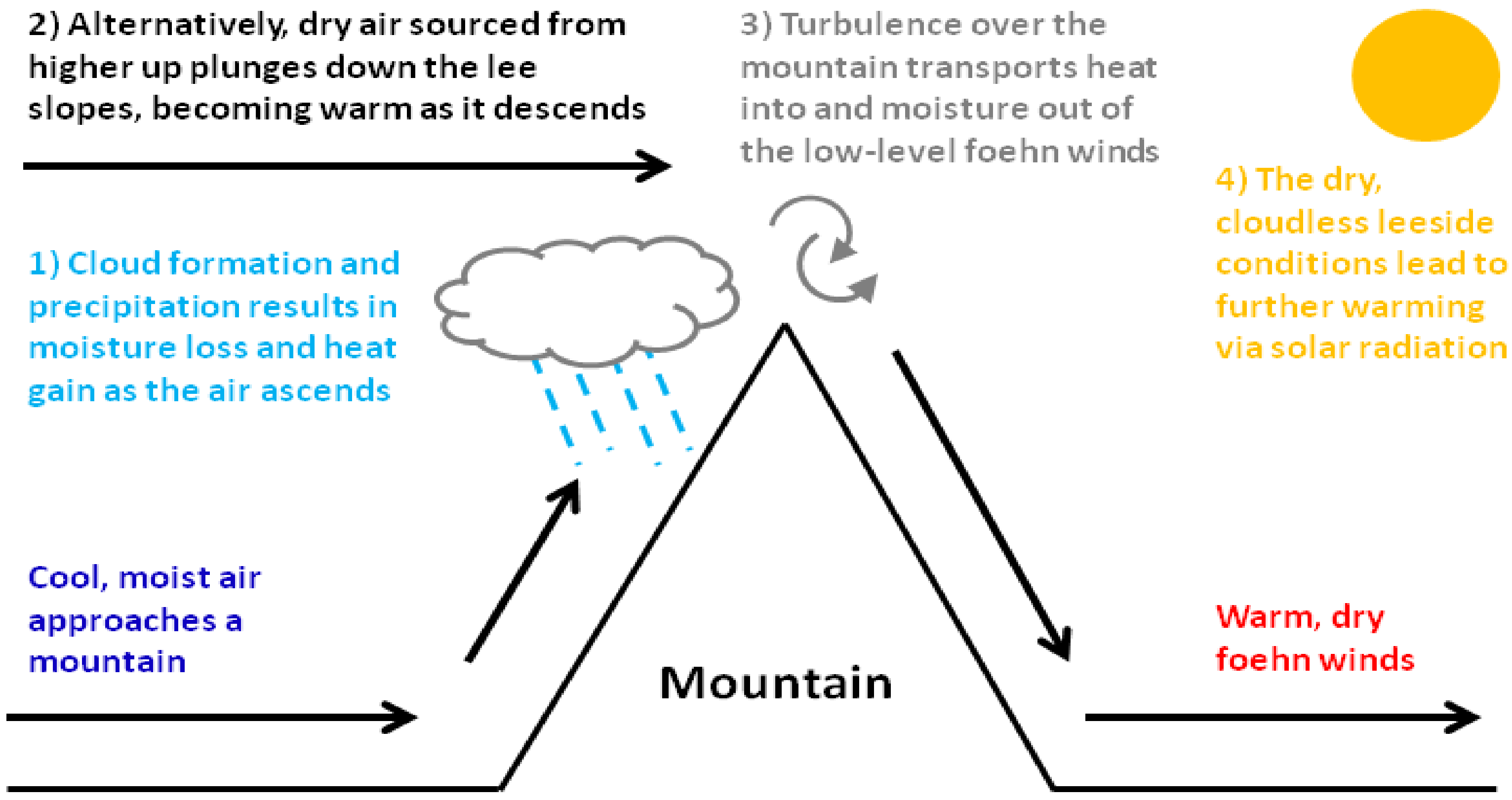
Melt Events Occurred before



Data based on SSMIS passive microwave observations provided by NSIDC

Foehn Effect

The causes of the Foehn Effect in the lee of mountains.



Adapted from (Elvidge and Renfrew 2016).
(https://en.wikipedia.org/wiki/Foehn_wind#/media/File:Foehn_effect_mechanisms.png)

Data

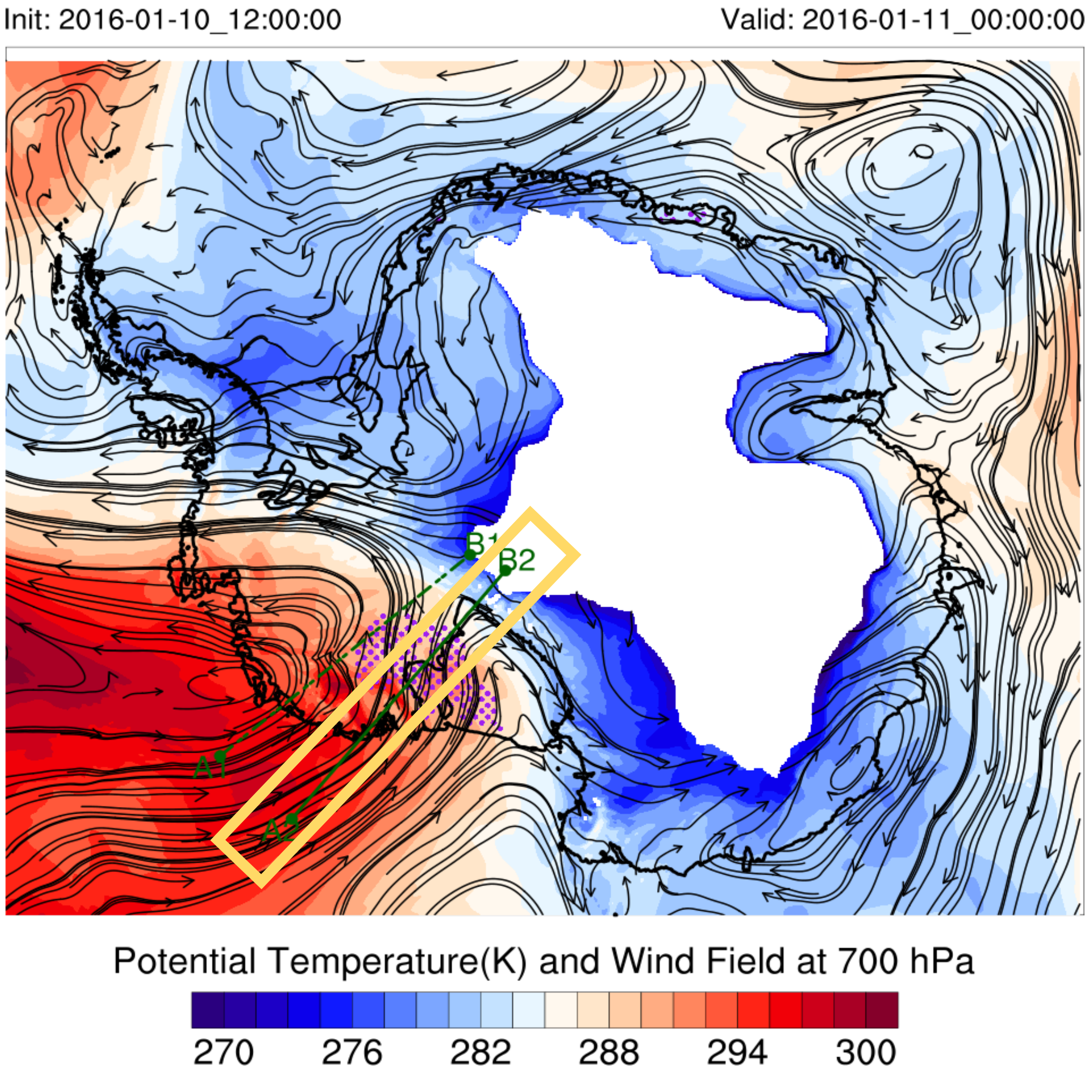
- AMPS data in domain 2
- Horizontal resolution: 10 km
- 12-hour forecast for the surface map and cross section

Identification

- The purple dots represent the melt area on 11 January 2016.
- A2B2 is the cross section chosen in this study.
- Data are missing in the white area due to the topography.

Wind blew nearly perpendicular to the Flood Range and Alexander Mountains, and brought relatively warm and moist air from the Amundsen Sea.

700 hPa wind and potential temperature field at 00 UTC on 11 January 2016.

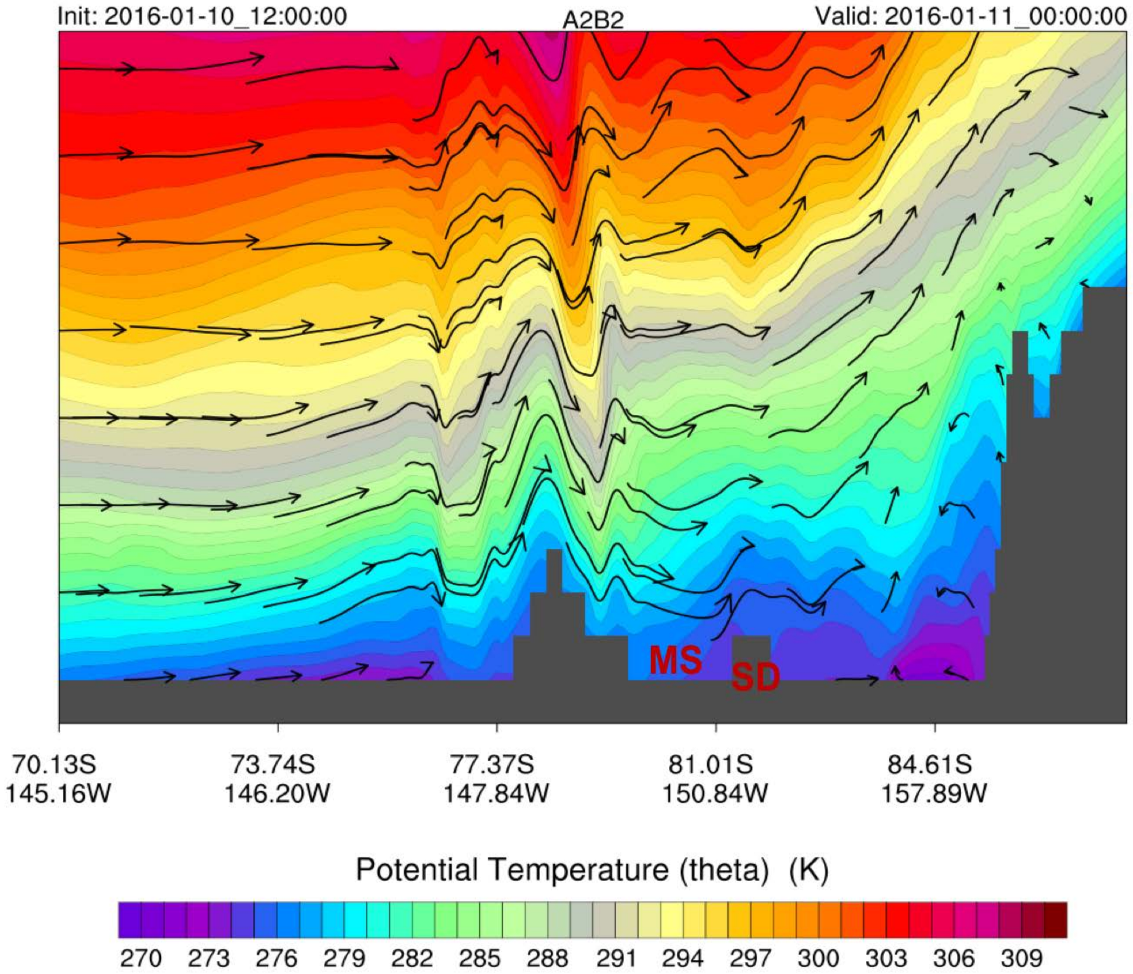


Cross Section

- Warm and moist air from the Amundsen Sea (warm advection) was carried by wind and lifted by the slope of mountains and propagated inland
- Then warmer and drier air flow descended on the leeside of the mountains.

- Thermodynamic (Latent heat release via adiabatic condensation)
- Isentropic drawdown - potentially warm and drier air reaches the leeside of the mountain due to the blocking of the cold low-level flow on the upwind side

Cross section of wind and potential temperature at 00 UTC on 11 January 2016.

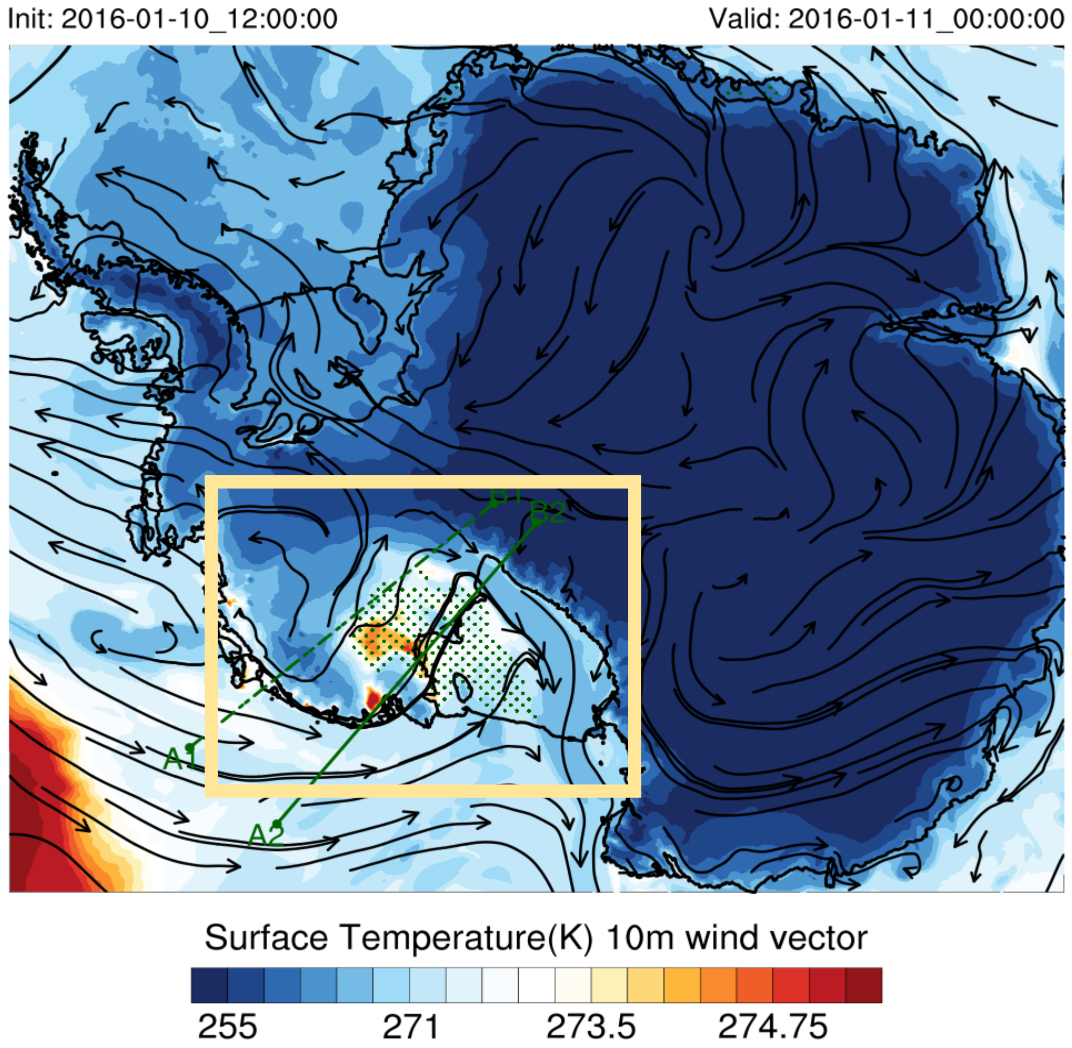


(MS-Melting Spot, SD-Siple Dome)

Surface Map

- Surface temperature on the leeside of the mountain is slightly higher than the temperature on the upwind side
- There are warm belts behind the Ames Range, Flood Range and Alexander Mountains

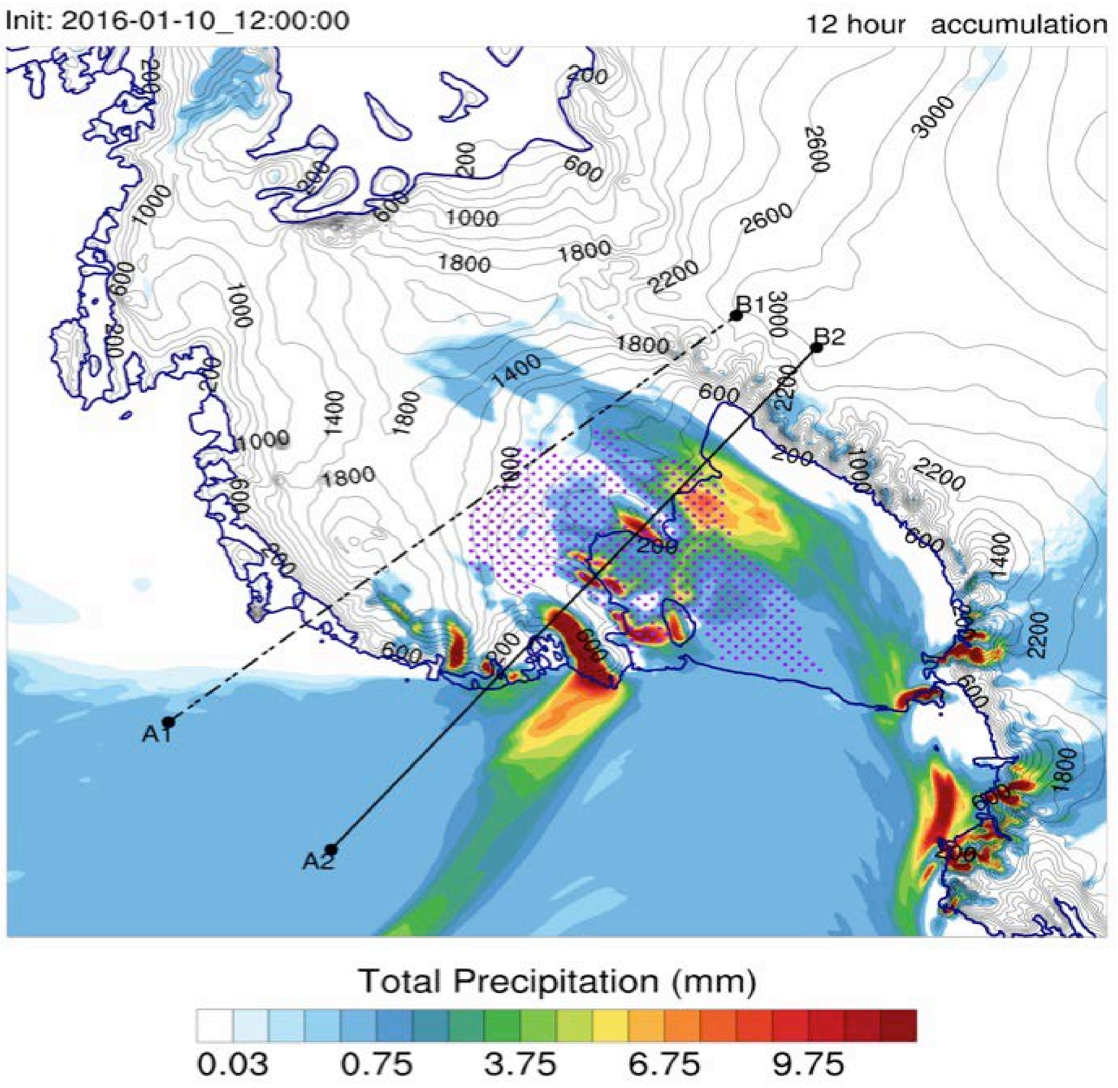
Surface physical temperature and 10m wind at 00 UTC on 11 January 2016.



Precipitation

12-hour total precipitation from 12 UTC on 10 to 00 UTC on 11 January 2016.

Precipitation has been predicted on the upwind side of the mountain, which confirms that the Foehn Effect has contributed to the beginning of the melt event.

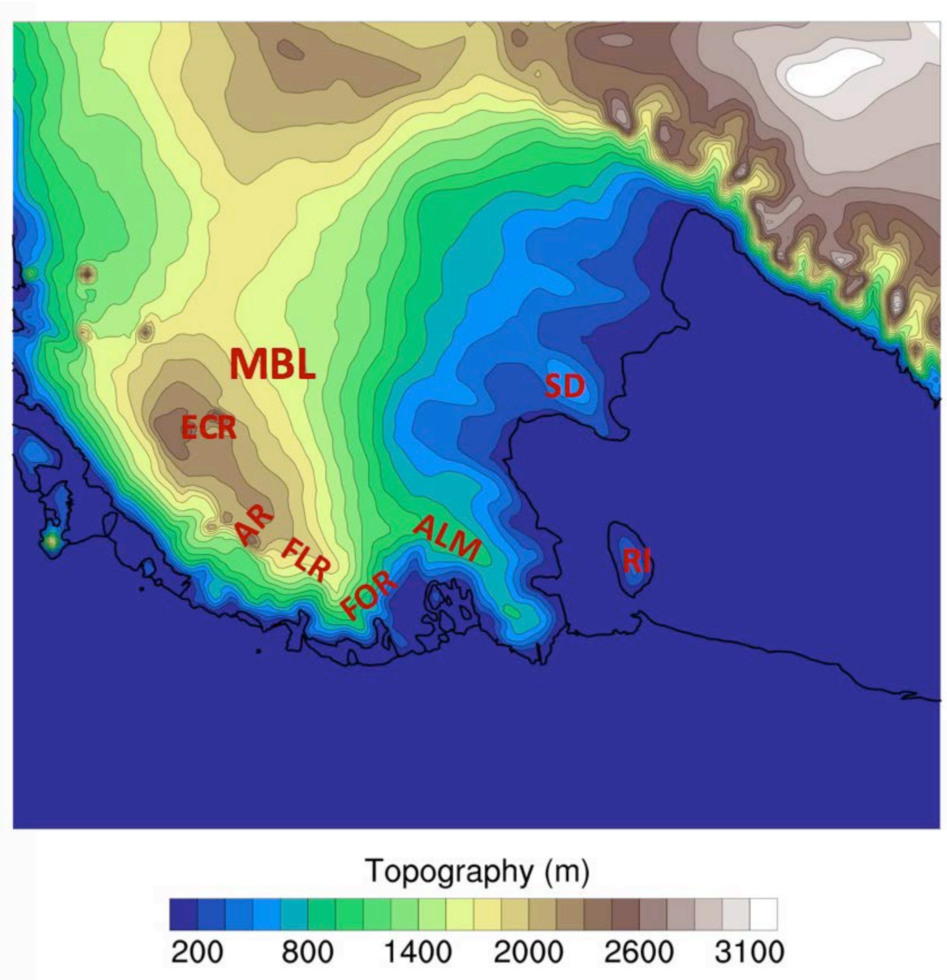


Quantification

Read Interpolate Plot (RIP4) software is used to track the airflow over the surface melting spot to quantify the contribution of the Foehn Effect

- Input: AMPS data
- Time: ~24h
- Routine: Above Ocean - Melting spot
- Direction: Backward trajectory

Topography Around the Ross Ice Shelf

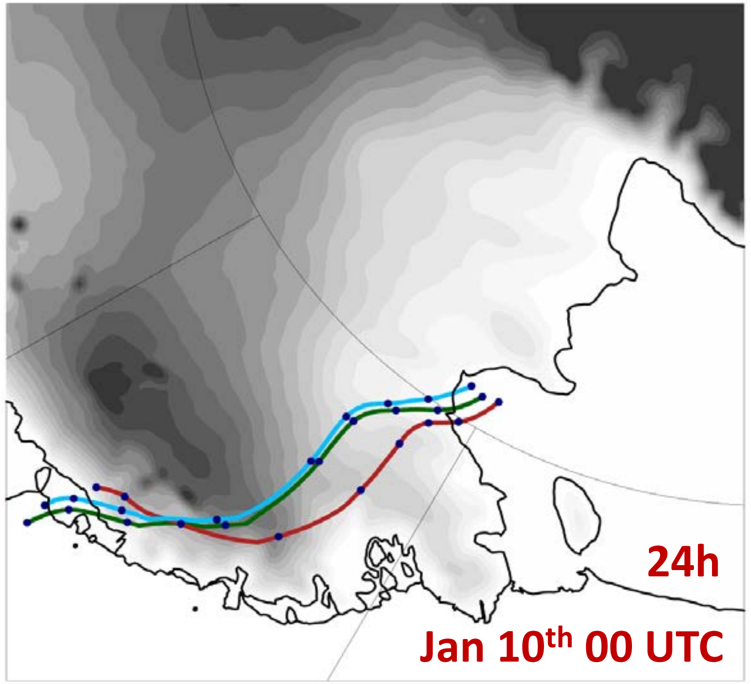


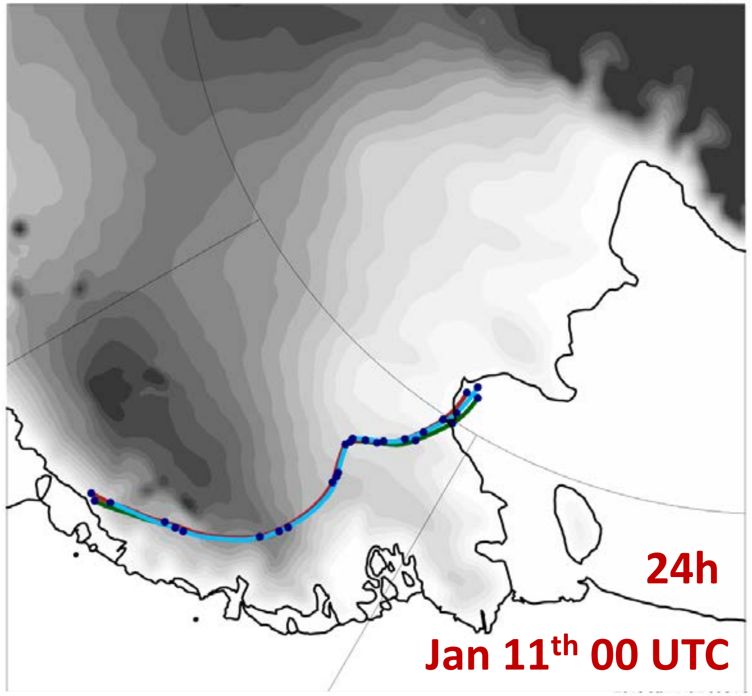
The data come from AMPS. Abbreviations: ECR-Executive Committee Range, AR-Ames Range, FLR-Flood Range, FOR-Ford Range, ALM-Alexander Mountains, MBL-Marie Byrd Land, RI-Roosevelt Island, SD-Siple Dome.

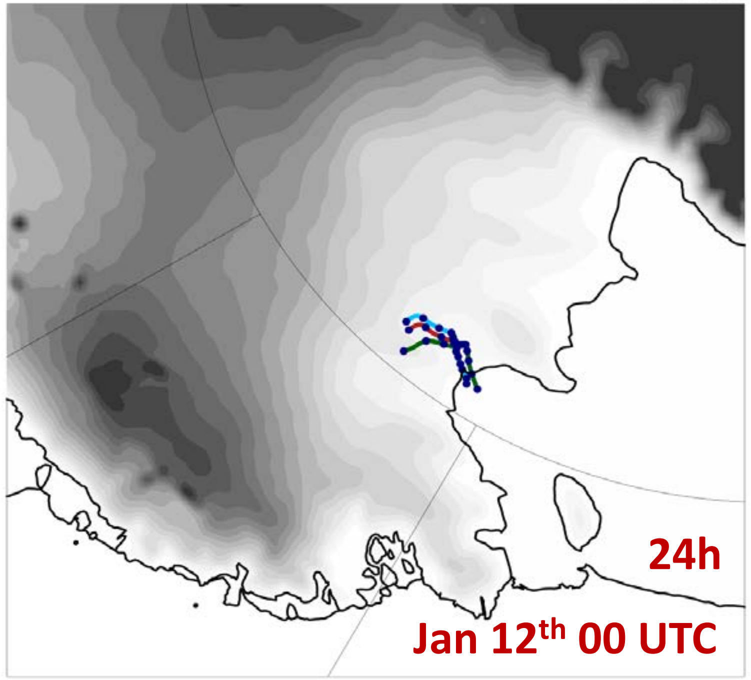
Trajectories

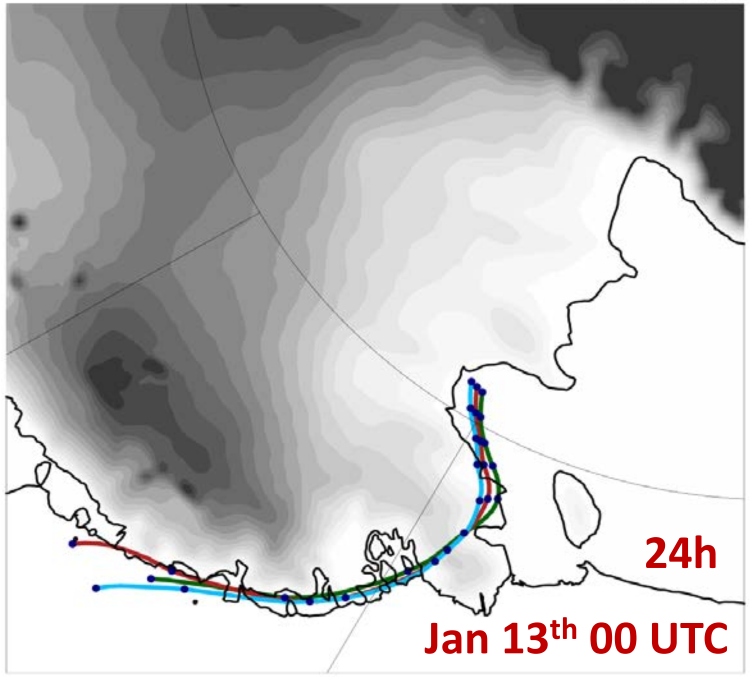
Foehn Effect : Temperature difference between melting spot and the same height above the ocean surface.

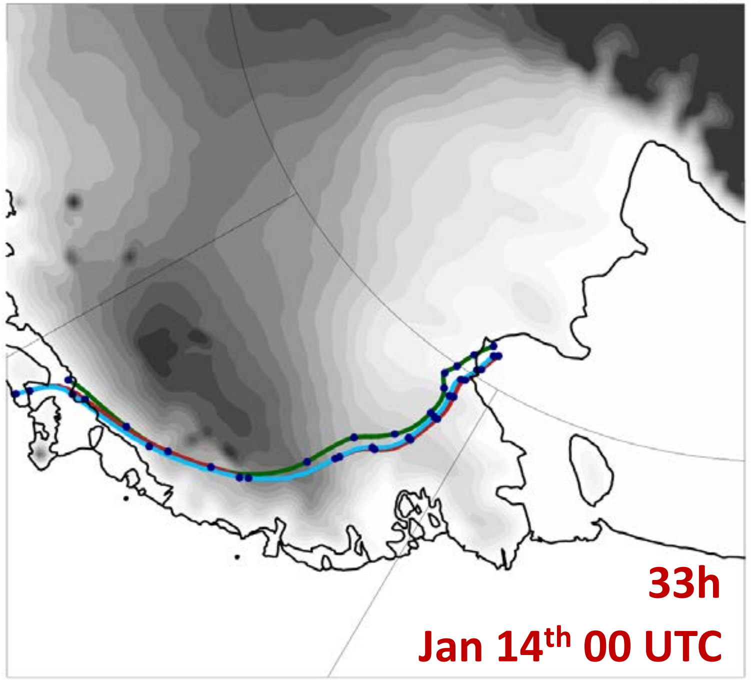
- Jan. 10^{th}, 11^{th} and 14^{th}, wind climbed over the Ames Range and Flood Range.
- Jan. 13^{th} wind climbed over Alexander Mountains
- Jan. 12^{th} wind speed is not high enough.
- Jan. 14^{th} wind speed is smaller than 10^{th} and 11^{th} .



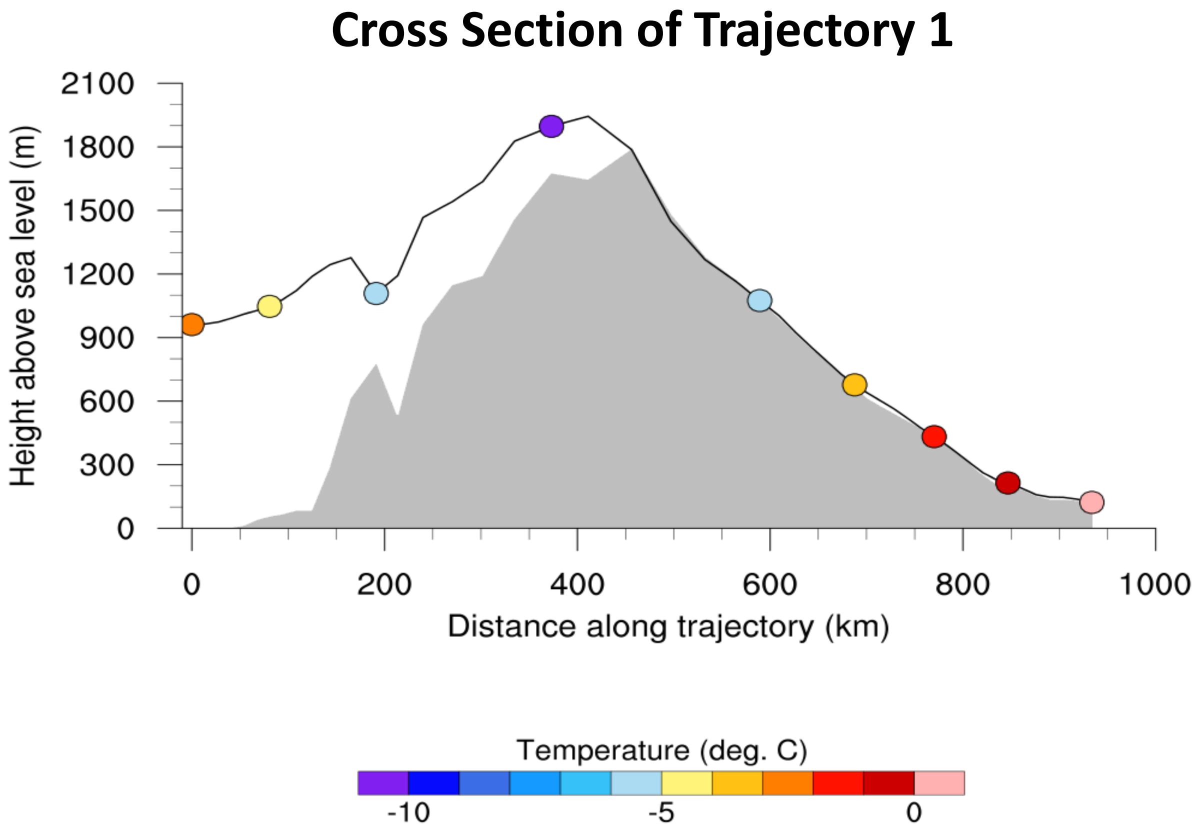




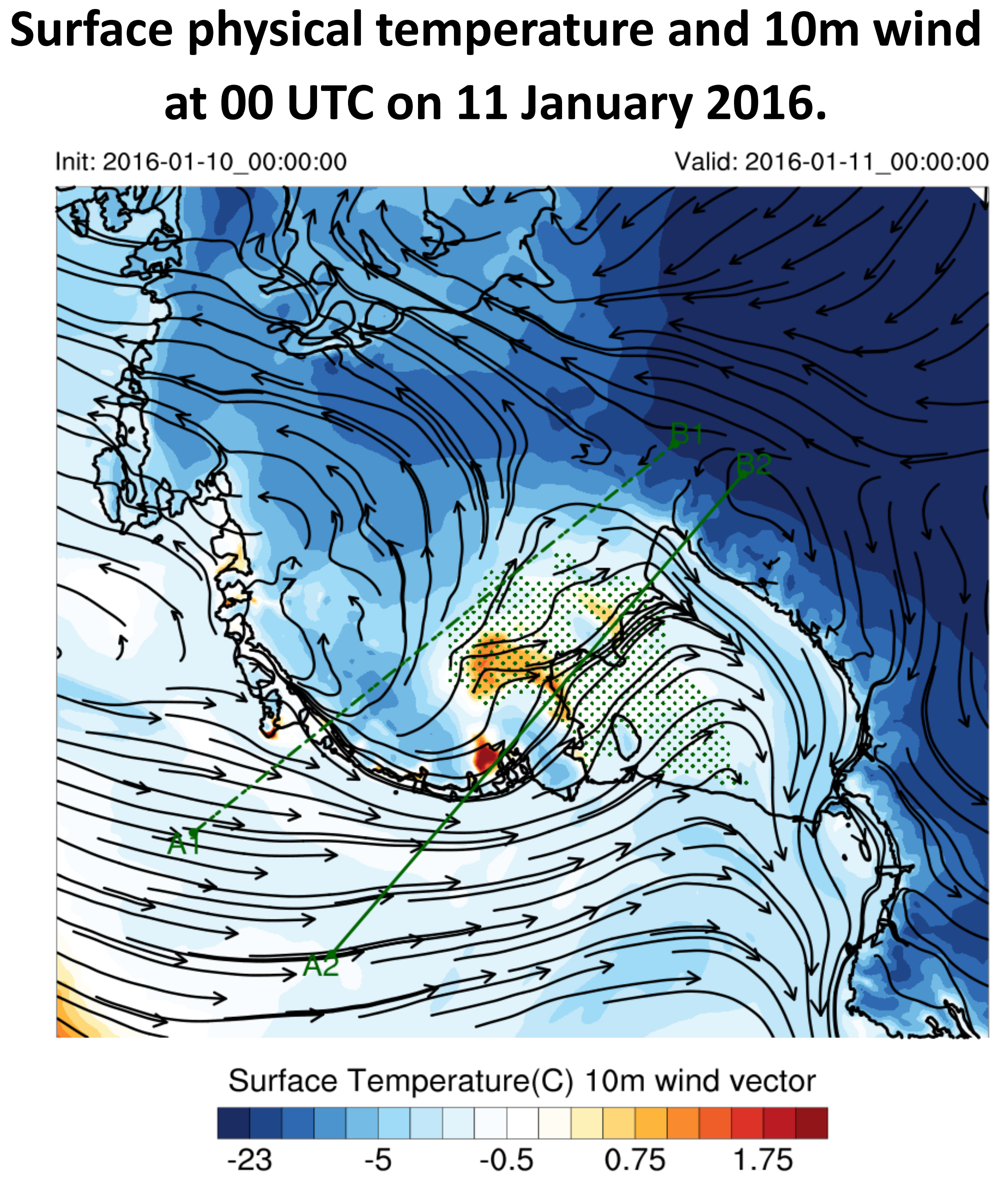




Jan 10th 00UTC – Jan 11th 00UTC

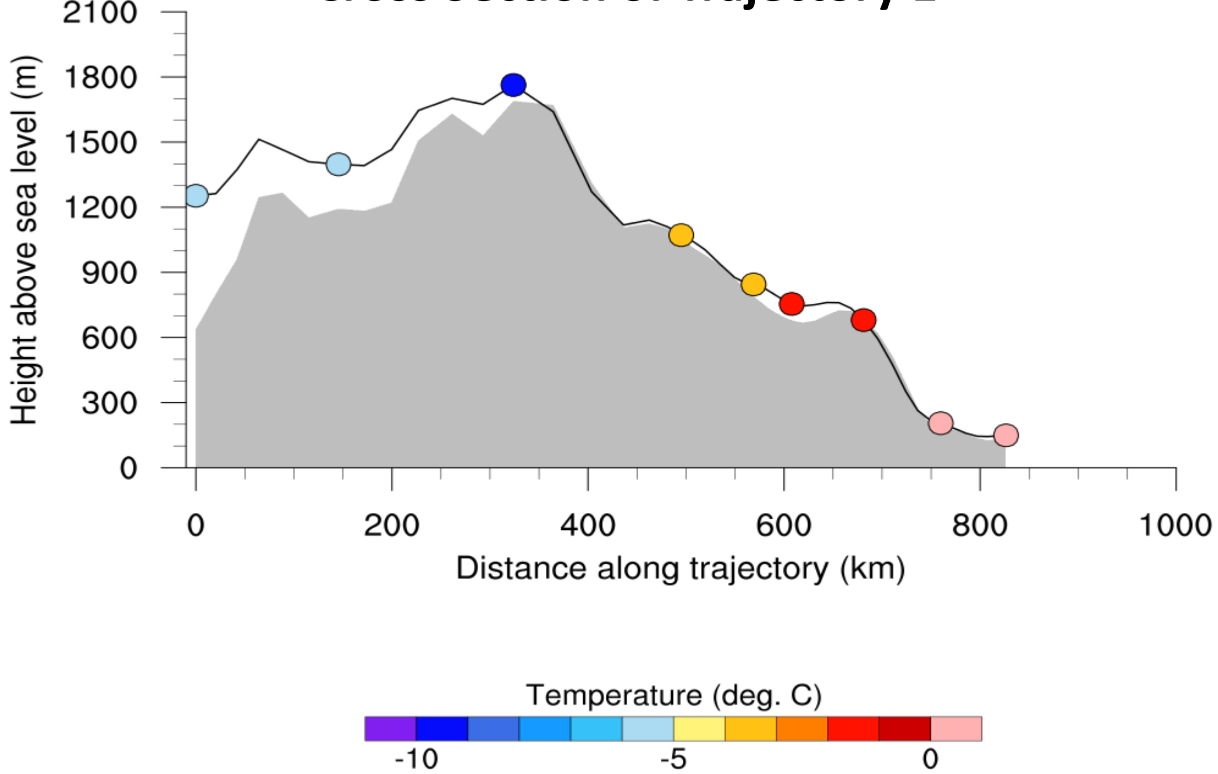


Trajectory	Foehn Effect Diff.	RHI(%) Diff.	Horizontal wind speed (m/s) Diff.
1	2.34	15.91	4.15
2	3.78	1.52	5.68
3	1.91	14.04	5.57

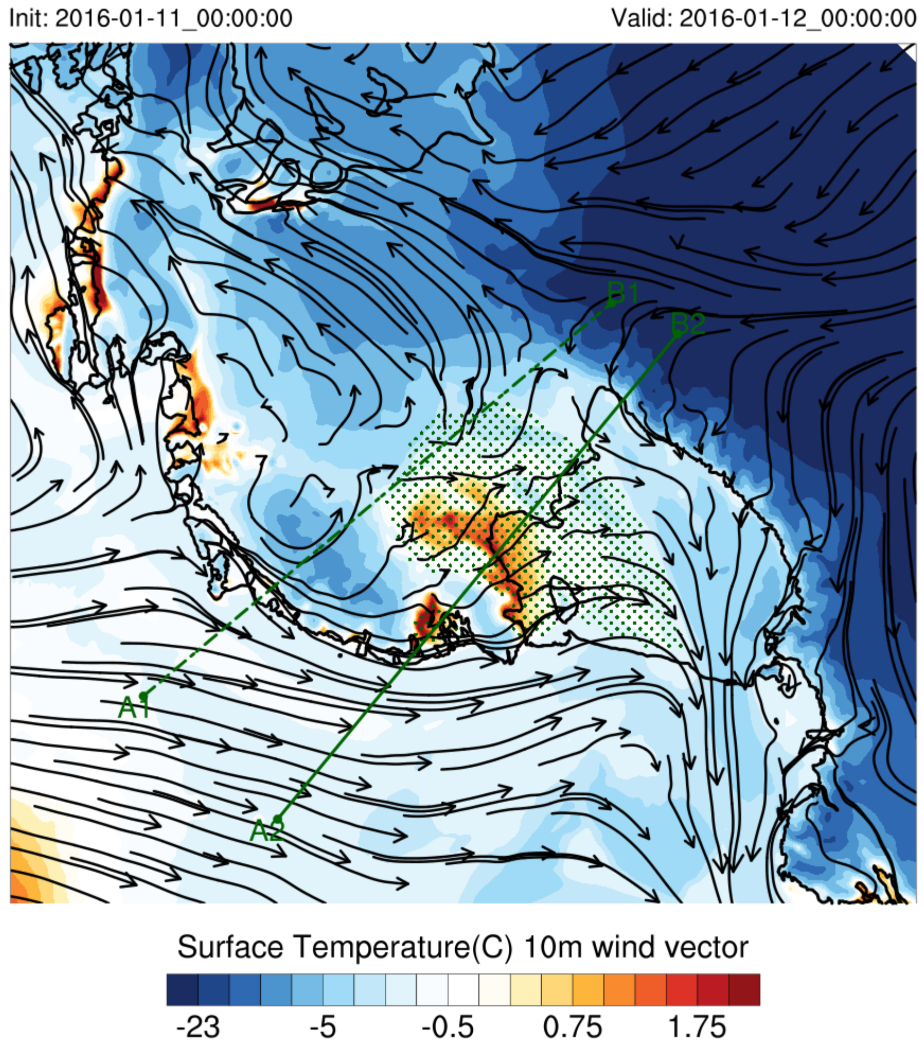


Jan 11th 00 UTC – Jan 12th 00 UTC

Cross Section of Trajectory 1

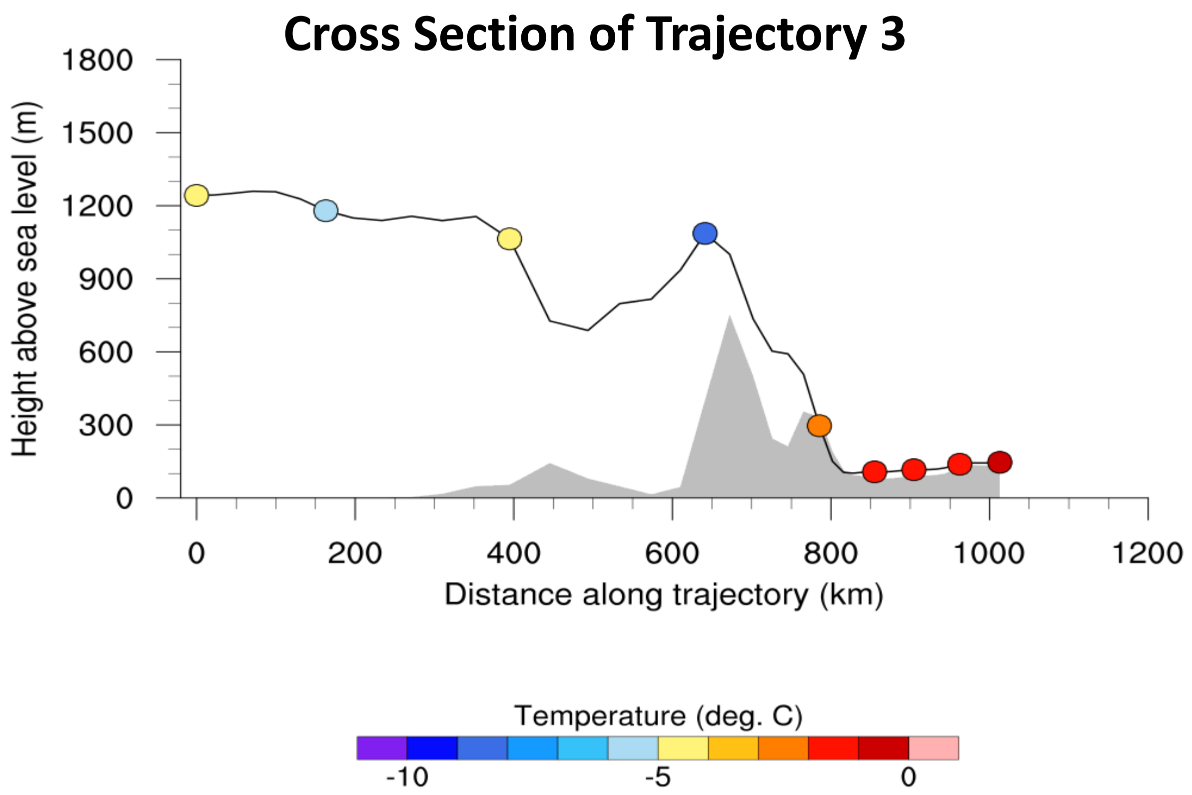


Surface physical temperature and 10m wind at 00 UTC on 12 January 2016

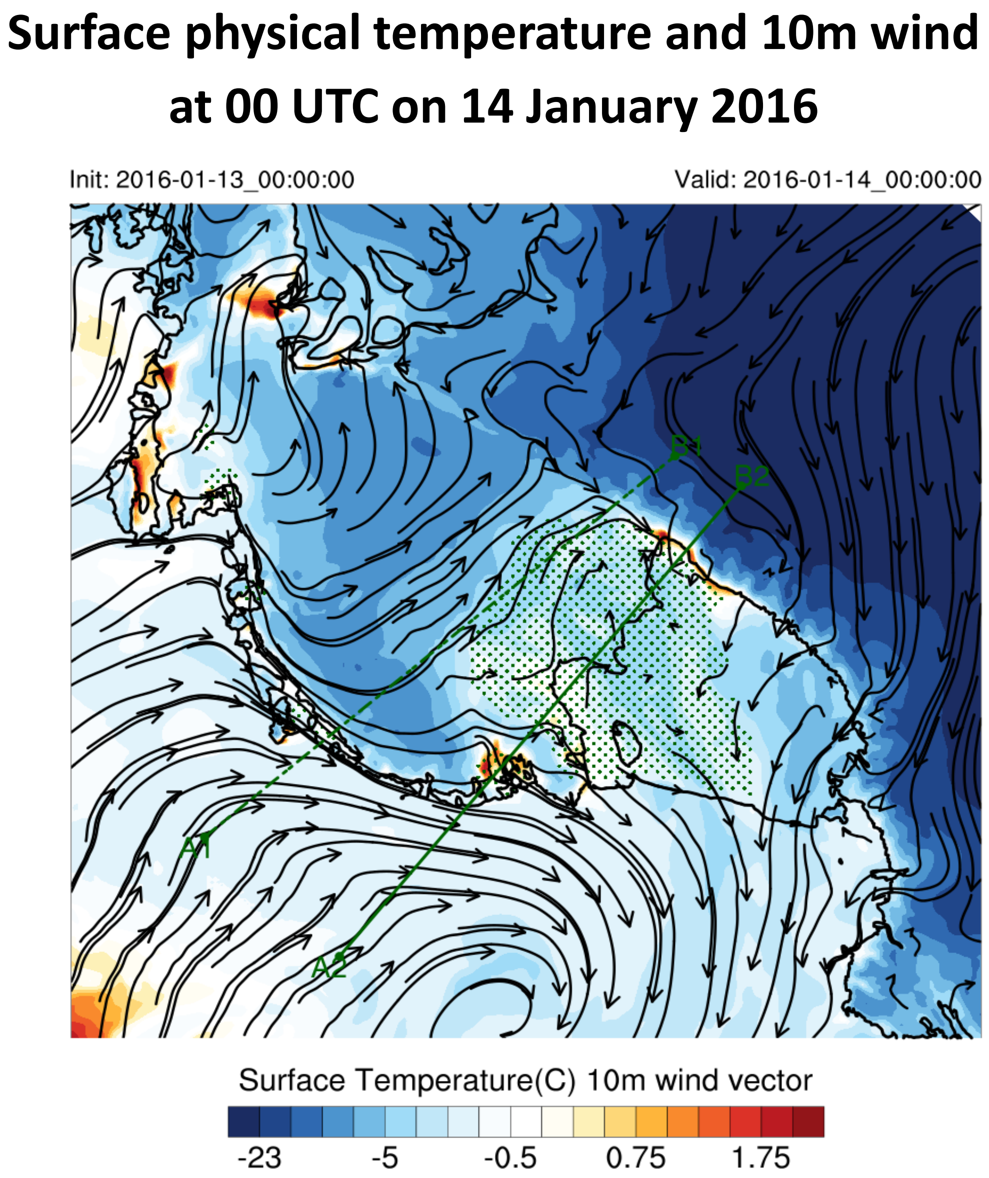


Trajectory	Foehn Effect Diff.	RHI(%) Diff.	Horizontal wind speed (m/s) Diff.
1	3.41	-9.09	-4.3
2	3.39	-8.34	-4.49
3	4.66	-10.55	-4.06

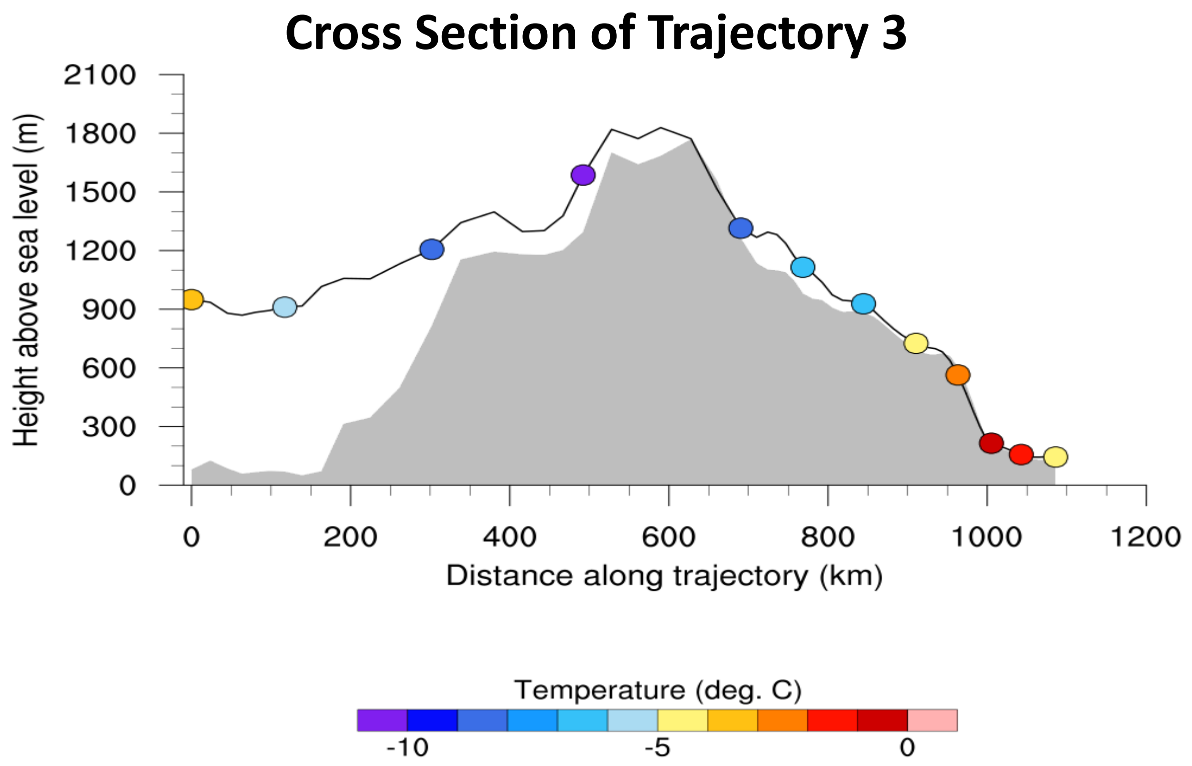
Jan 13th 00 UTC– Jan 14th 00 UTC



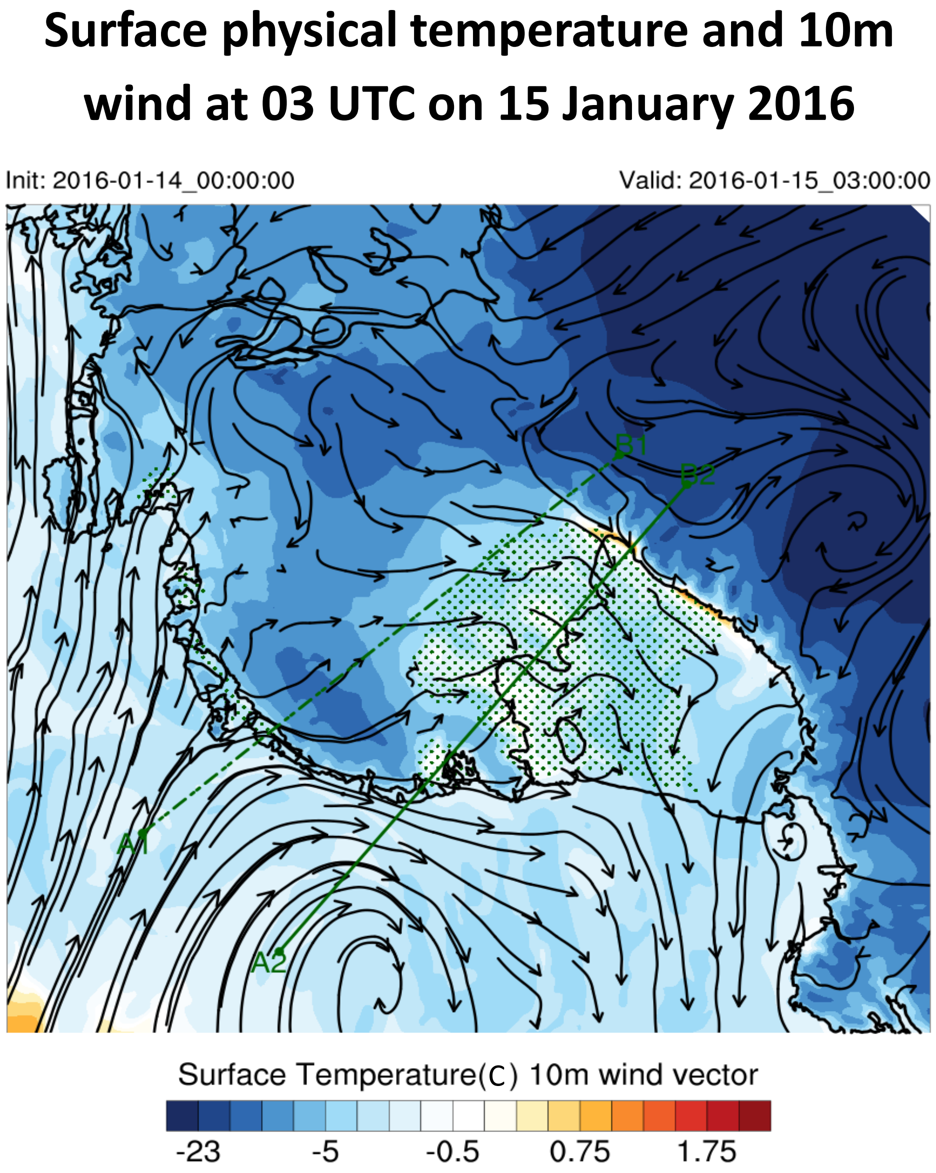
Trajectory	Foehn Effect	RHI(%)	Horizontal wind speed (m/s)
1	0.29	6.52	-15.16
2	0.82	5.34	-9.96
3	0.83	3.62	-8.36



Jan 14th 00 UTC – Jan 15th 03 UTC



Trajectory	Foehn Effect Diff.	RHI(%) Diff.	Horizontal wind speed (m/s) Diff.
1	0.42	-22.86	-5.35
2	0.14	-16.34	-6.14
3	0.68	-21.86	-5.47



Conclusions

- Foehn Effect has been observed at the beginning of the 2016 melt event. (Jan. 10th, Jan 11th), which brings 2-4K temperature increase to the melting spot. This warming effect is important since it pushes the temperature over 0 ℃.
- Foehn Effect occurs - Warm advection climbs over Ames Range and Flood Range, which is higher than Alexander mountains. And the wind speed should be large enough.
- This partially explain why the melt always occur over this area.

Future Plan

- Latent heat release or isentropic drawdown, which one contributes more to the Foehn Effect?

- Are there other factors playing a role in this warming effect? ***Surface energy balance affected by cloud?** Enhancing downwelling longwave radiation and attenuating incoming solar radiation (Nicolas et al. 2017)

References:

Elvidge, A. D., and I. A. Renfrew, 2016: The Causes of Foehn Warming in the Lee of Mountains. *Bull. Am. Meteorol. Soc.*, **97**, 455–466.

Nicolas, J. P., A. M. Vogemann, R. C. Scott, A. B. Wilson, M. P. Cadeddu, D. H. Bromwich, J. Verlinde, D. Lubin, L. M. Russell, C. Jenkinson, H. H. Powers, M. Ryczek, G. Stone, and J. D. Wille, 2017: January 2016 extensive summer melt in West Antarctica favoured by strong El Niño. Nat. Commun., 8, 15799, doi:10.1038/ncomms15799.