Multi-Scale Flow Interactions

Observations during MATERHORN

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MATERHORN Investigator Meeting, 6 Sept. 2013, South Bend, IN

Introduction

Synoptic forcing

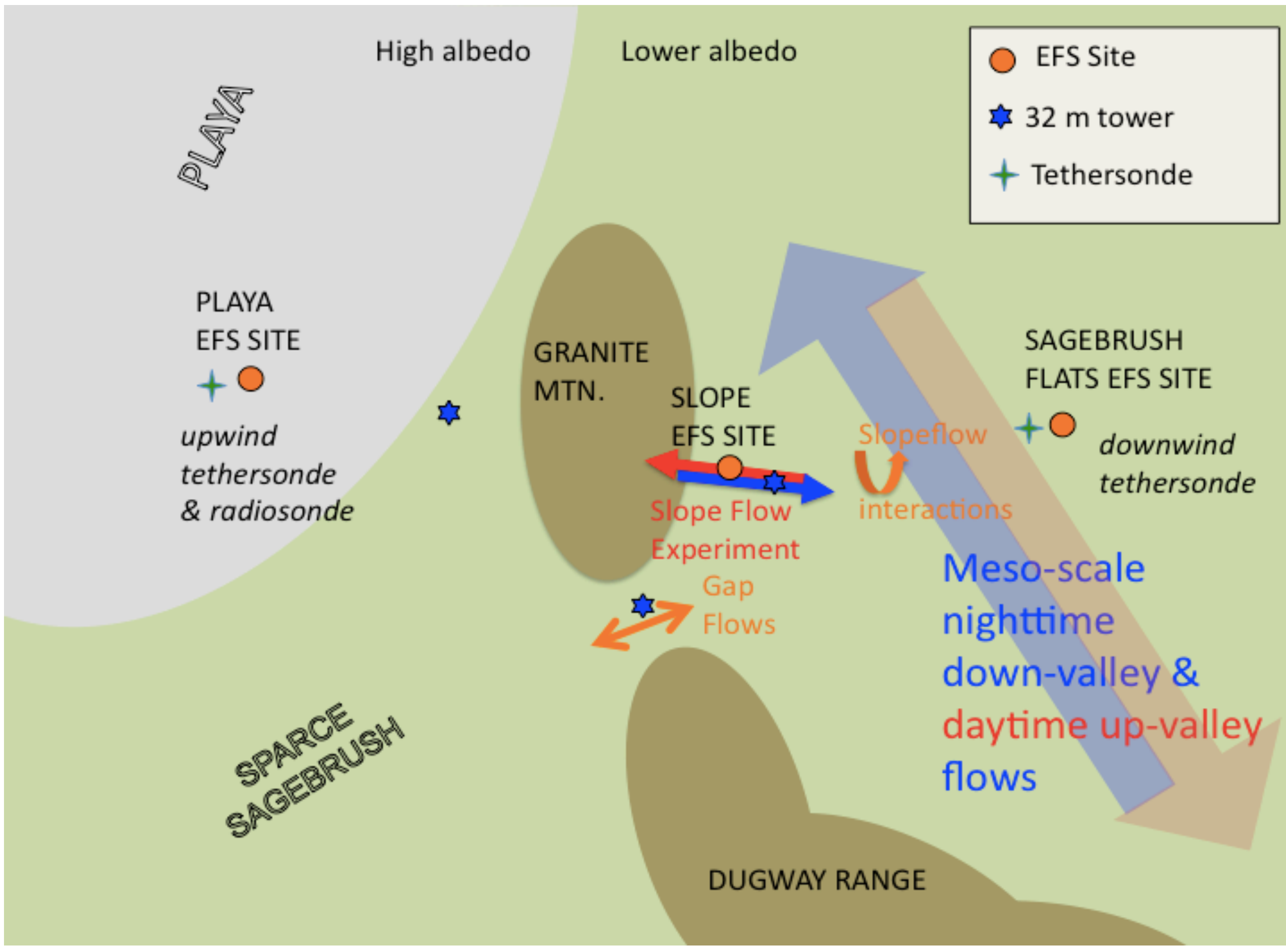
Land surface contrasts

Topography

Land-Atmosphere energy exchange

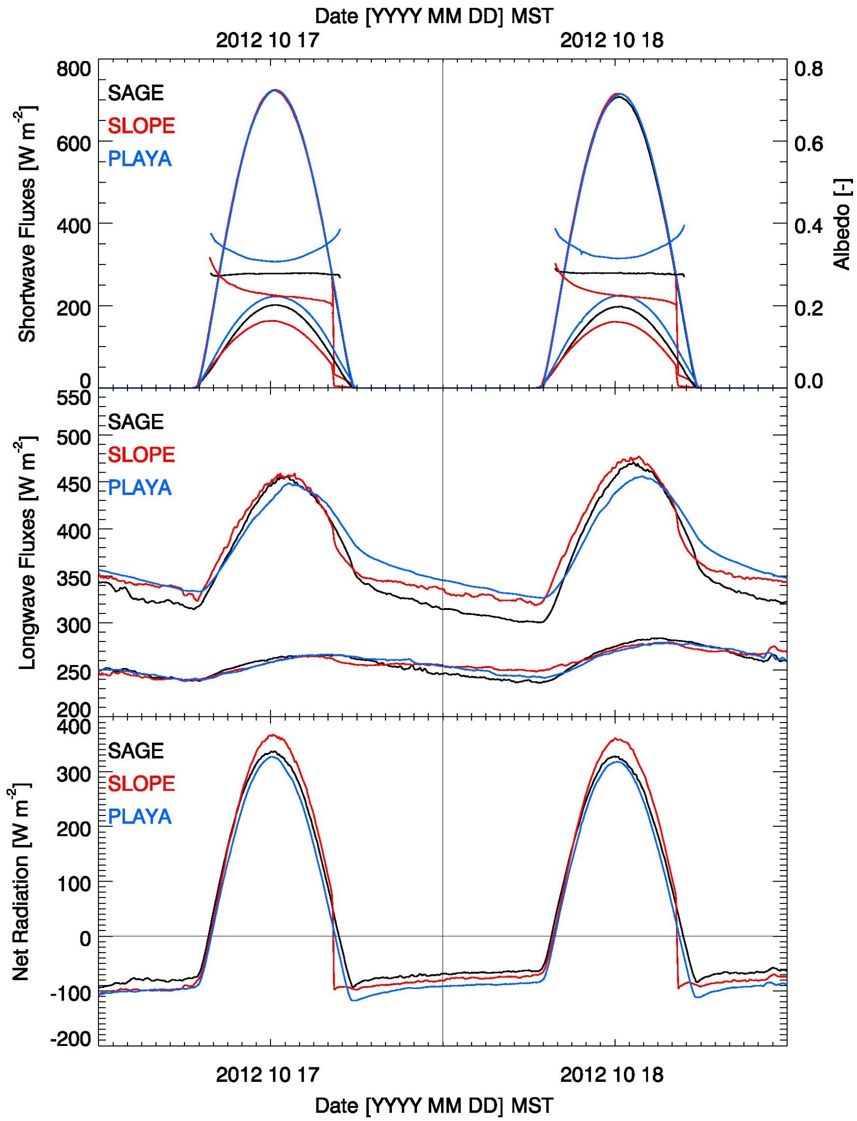
Boundary Layer Evolution

Circulation patterns



Radiation Balance at EFS-Sites

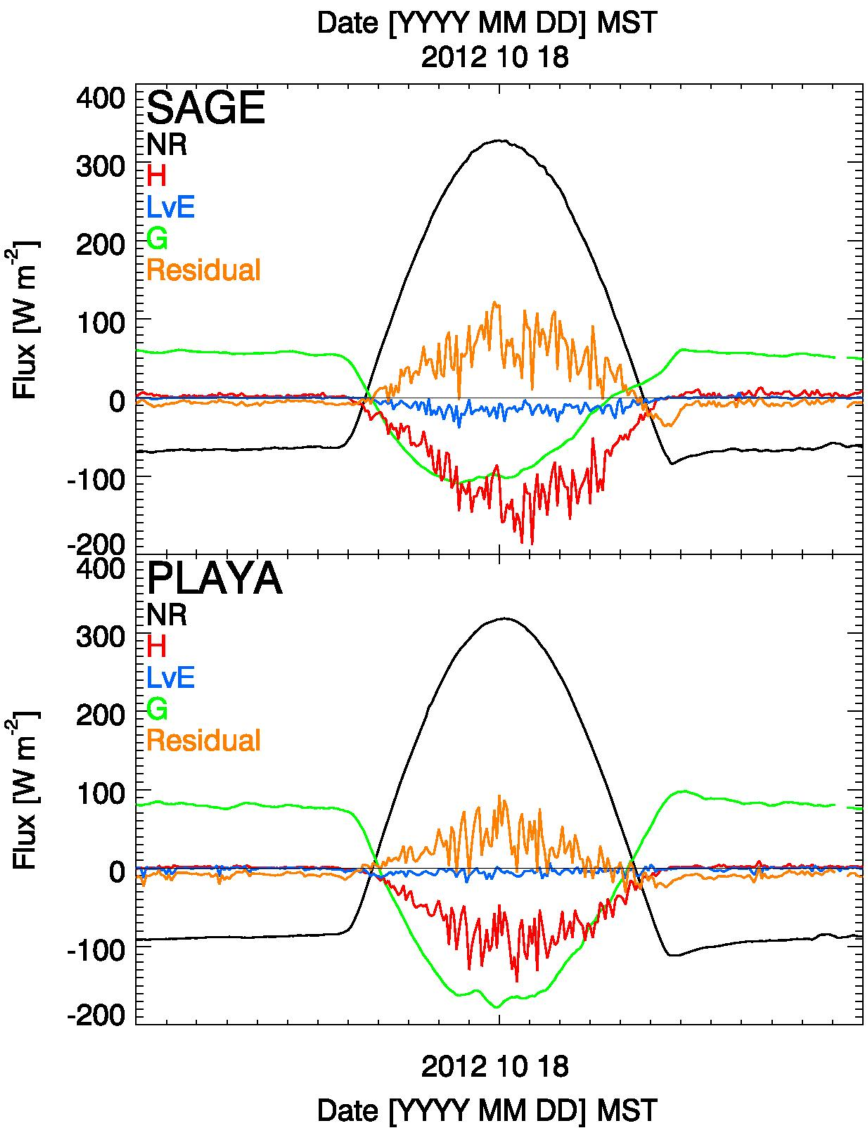
NR = SW↓ – SW↑ + LW↓ - LW↑



- Same shortwave energy input SW↓
- Albedo controls SW↑
- Same daytime NR at EFS-Sage and EFS-Playa
- Differences in SW* are compensated by differences in LW↑
- NR differences (Playa – Sage) are larger at nighttime, pointing to differences in soil thermal properties.

	Albedo [-] (min & max daily means)	**Thermal Conductivity [W / (m K)]**
EFS-Sage	**0.27** (0.18-0.29)	0.58
EFS-Slope	0.23 (0.17-0.24)	0.44
EFS-Playa	**0.31** (0.24 -0.35)	0.89

Energy balance: EFS-Playa and EFS-Sagebrush differences



Hoch et al. 2013 ICAM presentation

NR + H + LvE + G = Residual

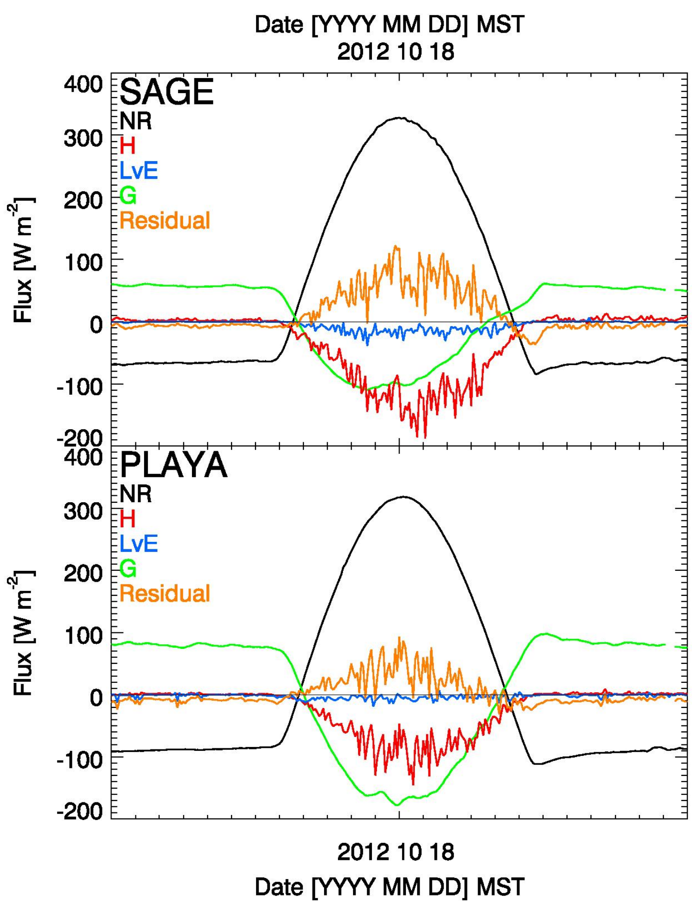
- Energy balance is closed at night (when G=-NR)! A residual remains during daytime.
- Latent heat fluxes (LvE) are small, even at EFS-Playa
- Large ground heat flux / sensible heat flux differences mainly due to soil thermal properties.

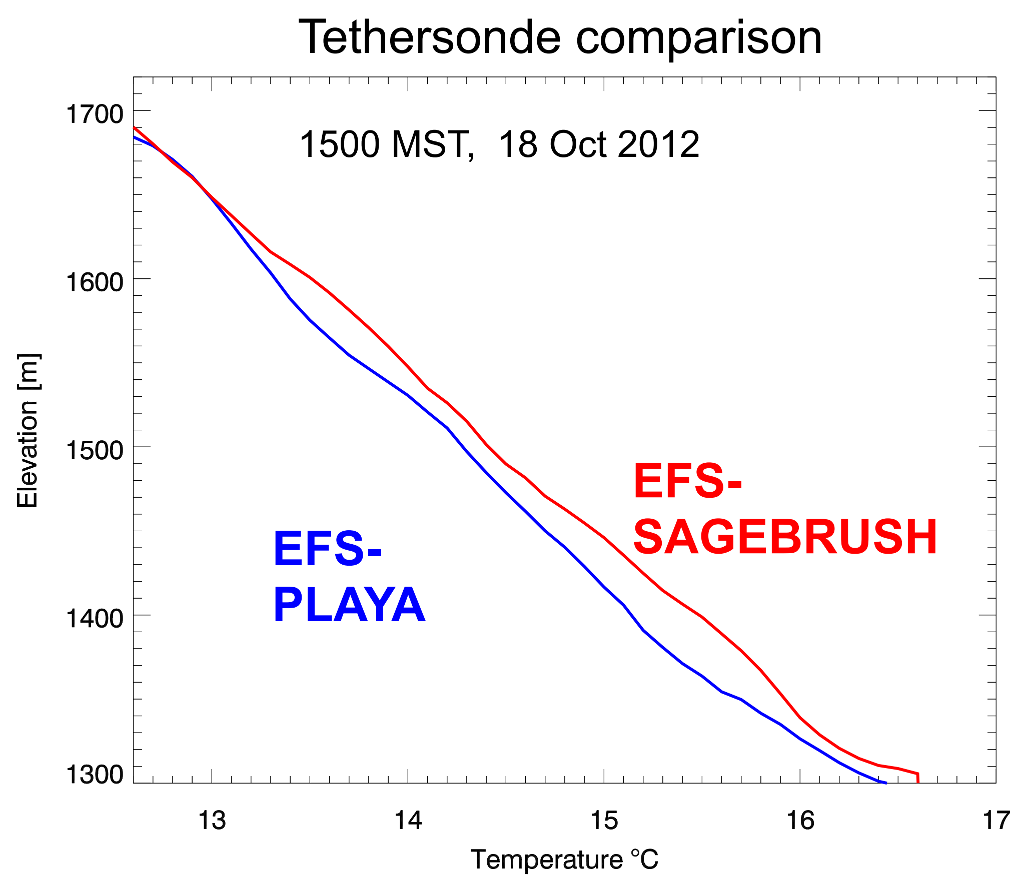
Massey et al. 2013, JAMC,submitted

Energy balance differences and boundary layer development

Large differences in sensible heating …

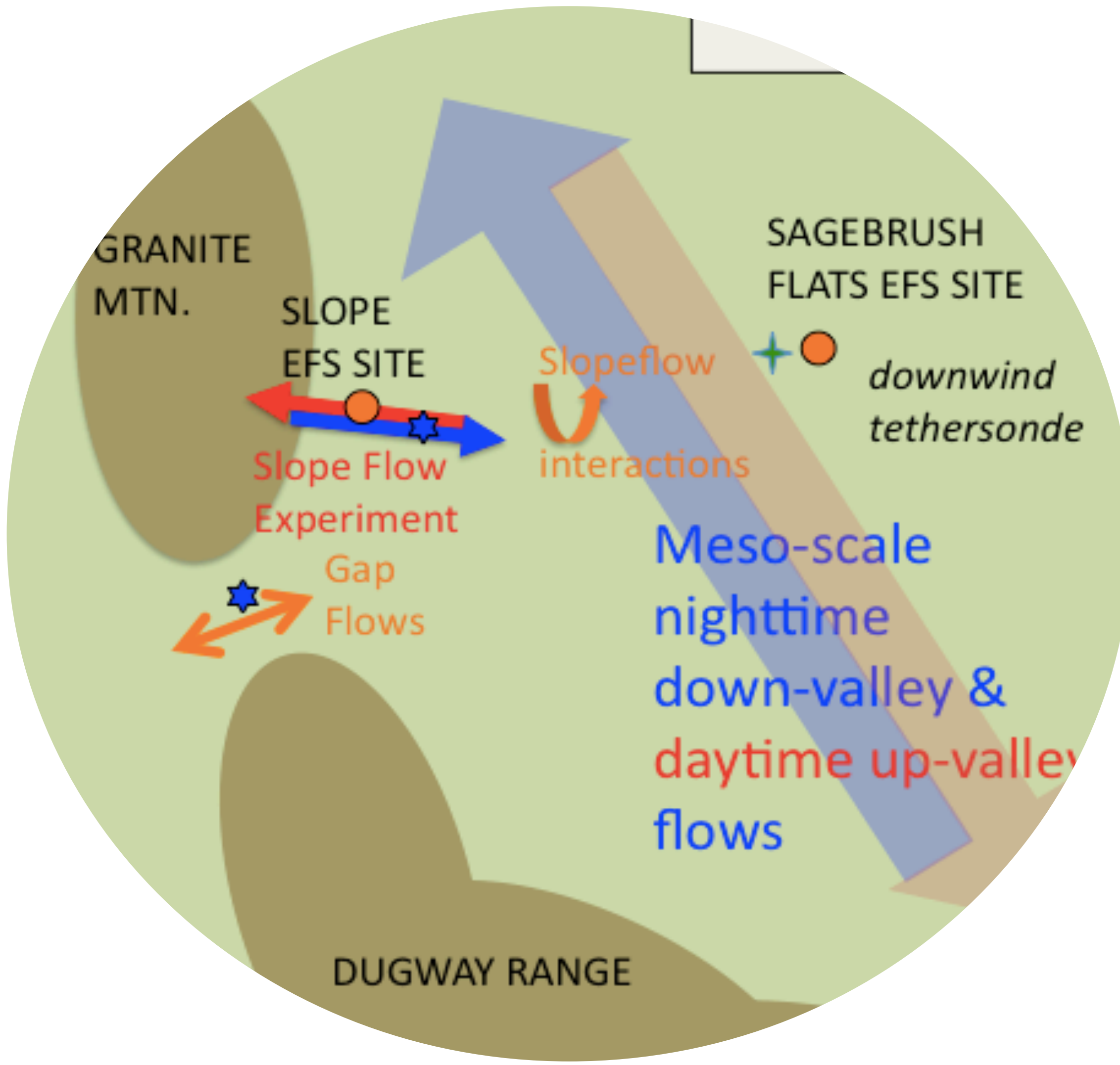
… lead to differences in boundary layer development.





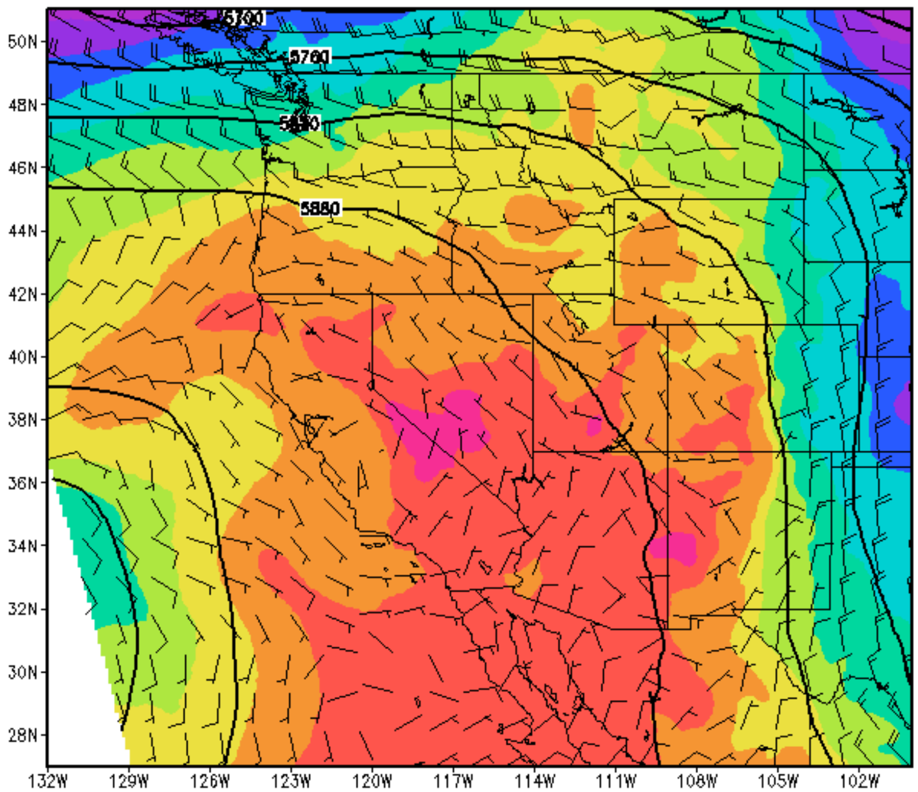
18 Oct. 2012 (IOP 8 MH-Fall)

Flow interactions – case study 1-2 October 2012 -- IOP-2

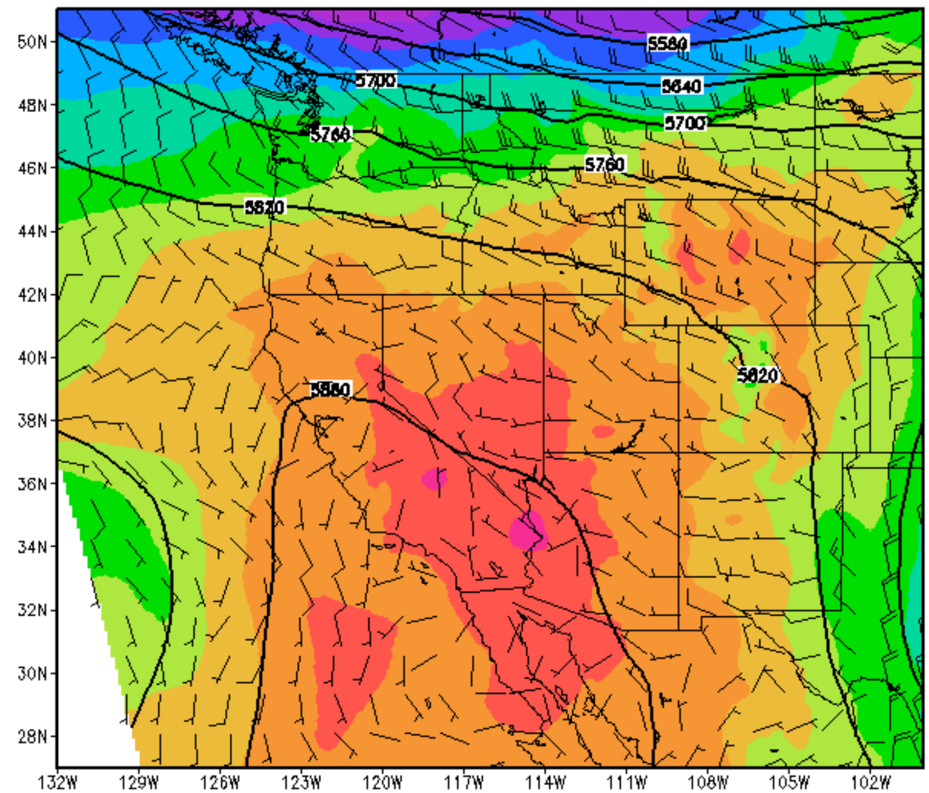


Synoptic setting

2 Oct 00 UTC (1 Oct 1700 MST)

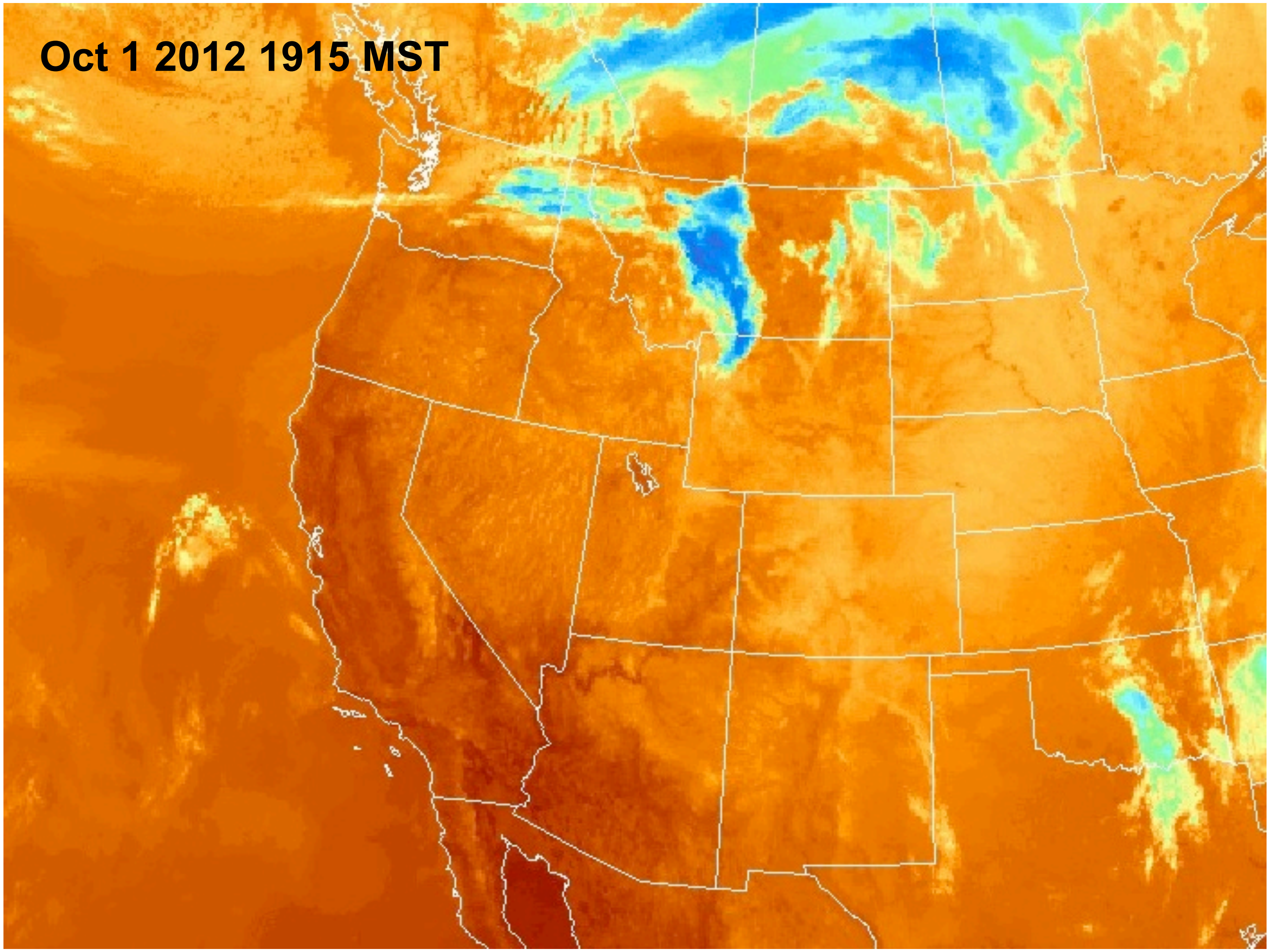


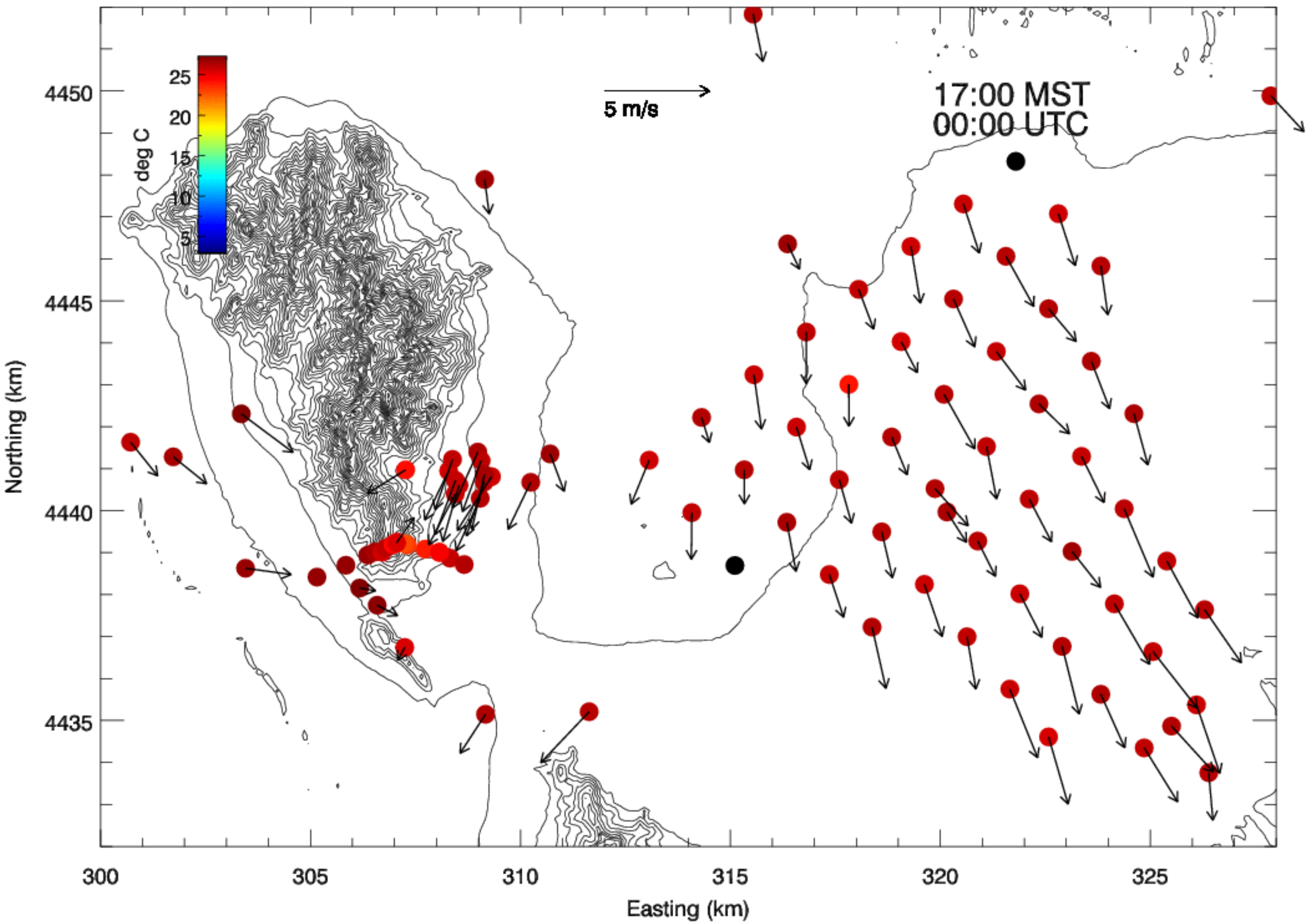
2 Oct 12UTC (2 Oct 0500 MST)



700 mbar winds (5 m/s full barb) and 700 mbar temperatures, 500 mbar heights

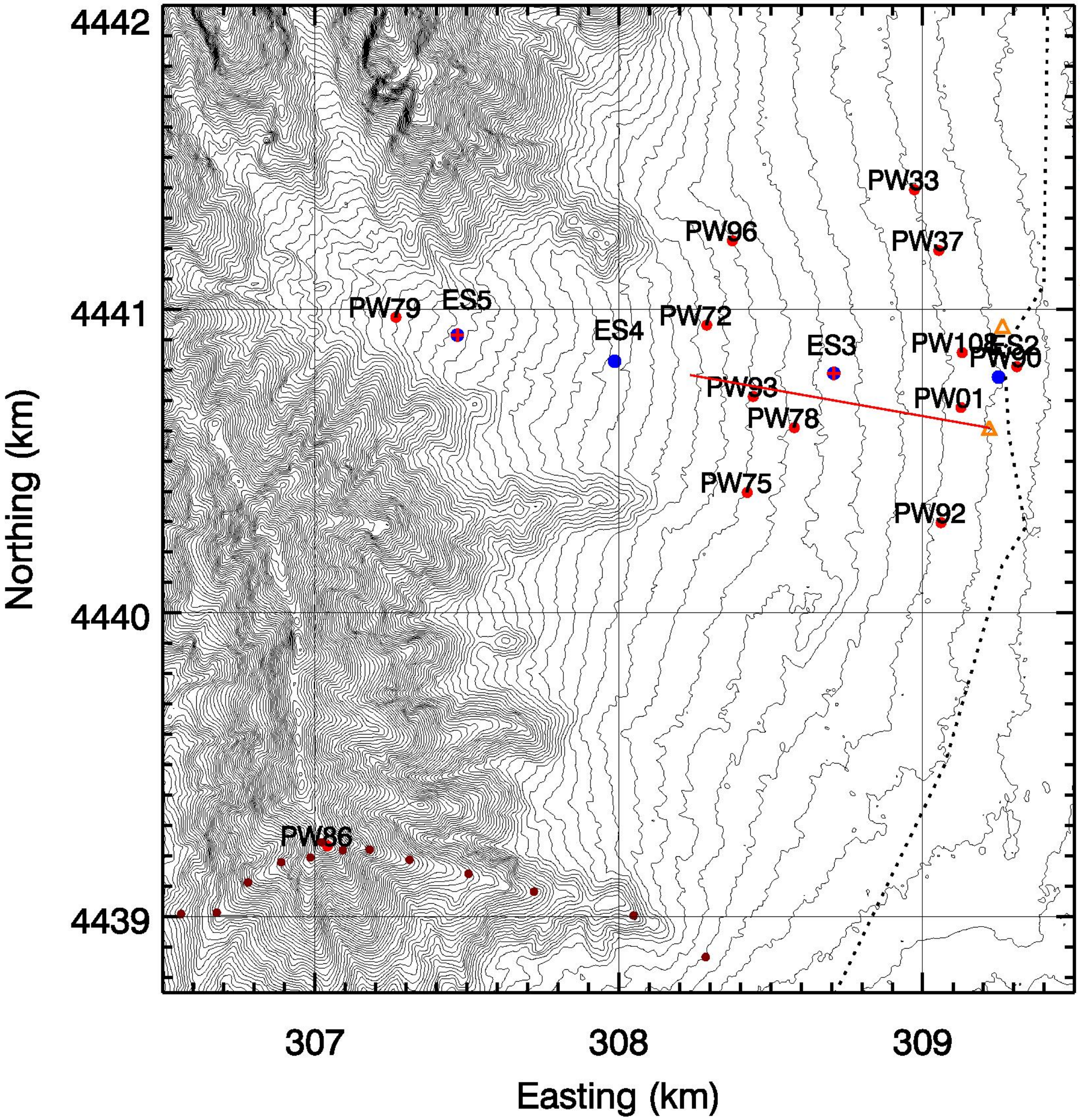
Thermal satellite imagery & cloud cover

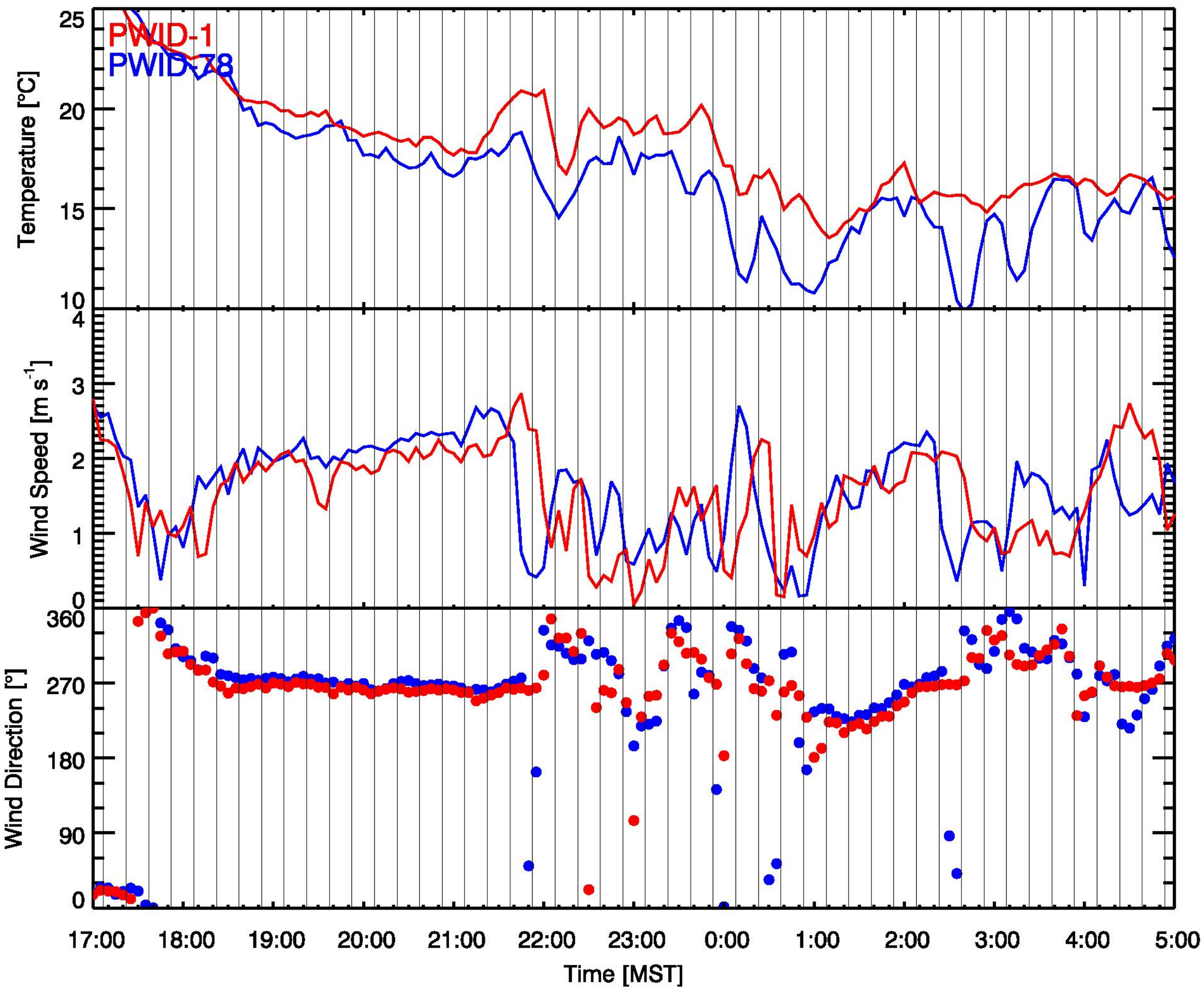




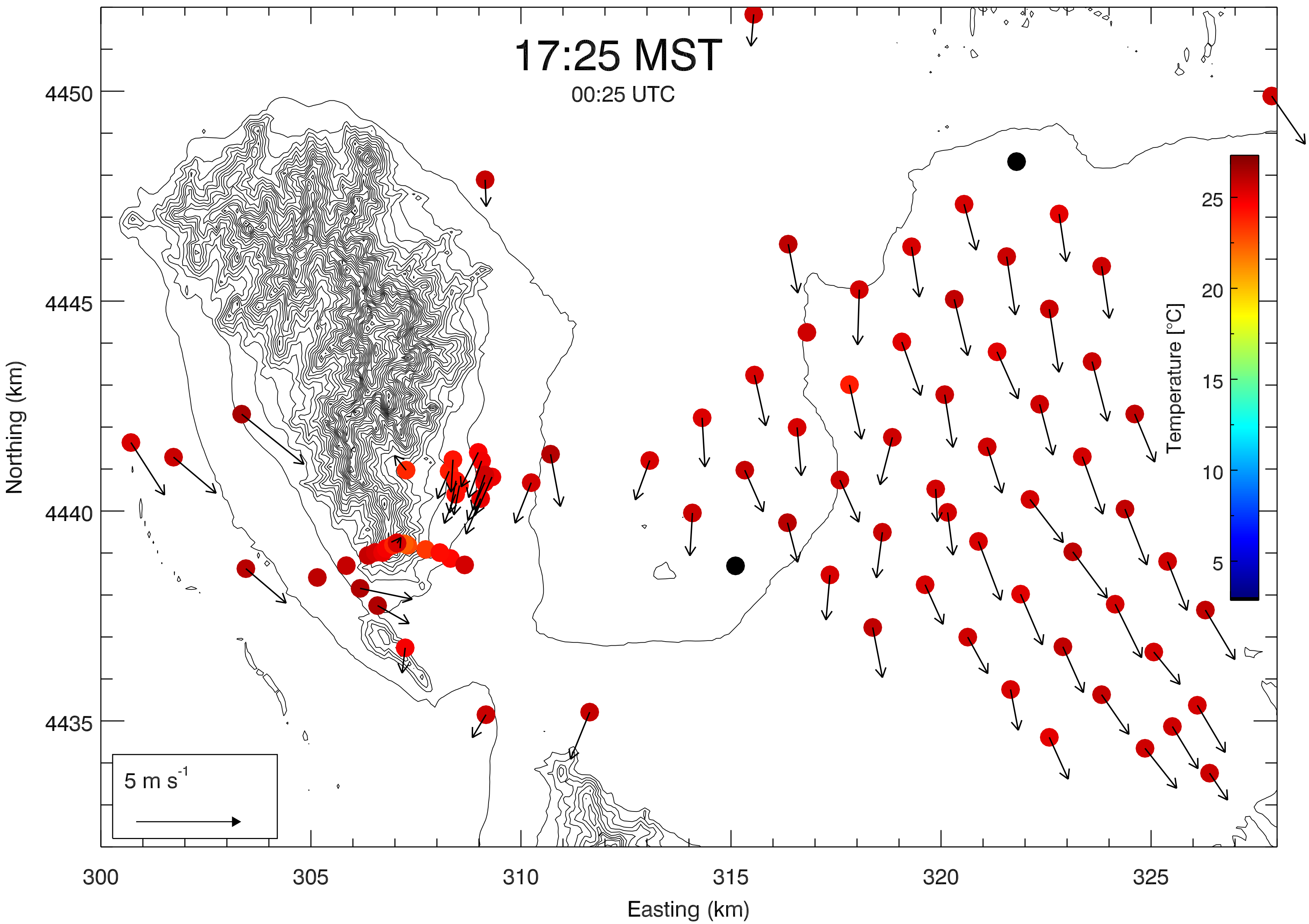
17:00 MST
00:00 UTC
5 m/s
deg C
25
20
15
10
5
Northing (km)
4450
4445
4440
4435
Easting (km)
300
305
310
315
320
325

East Slope of Granite Peak

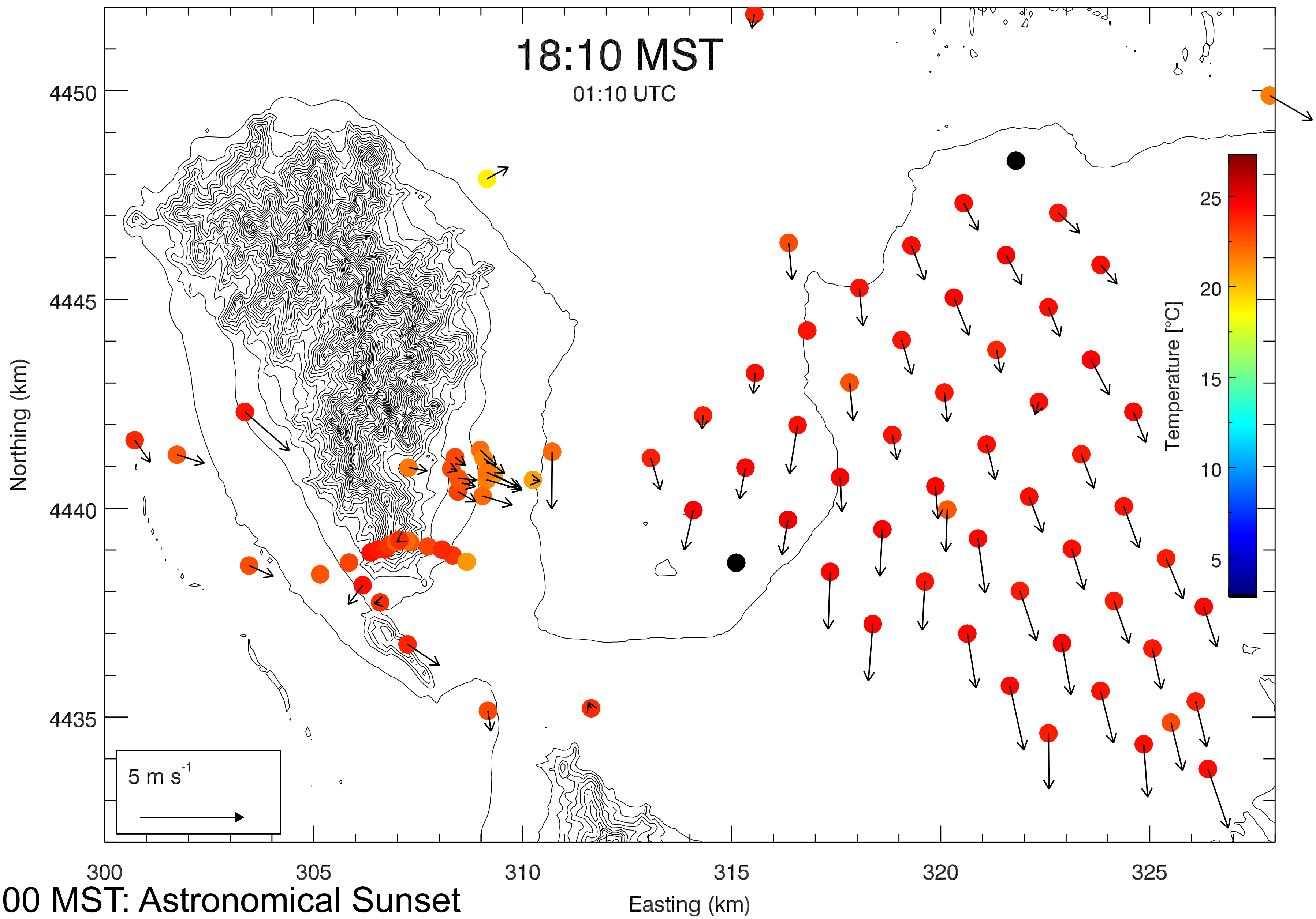




PWID-1
PWID-78
Temperature [°C]
Wind Speed [m s-1]
Wind Direction [°]
25
20
15
10
4
3
2
1
0
360
270
180
90
0
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
Time [MST]

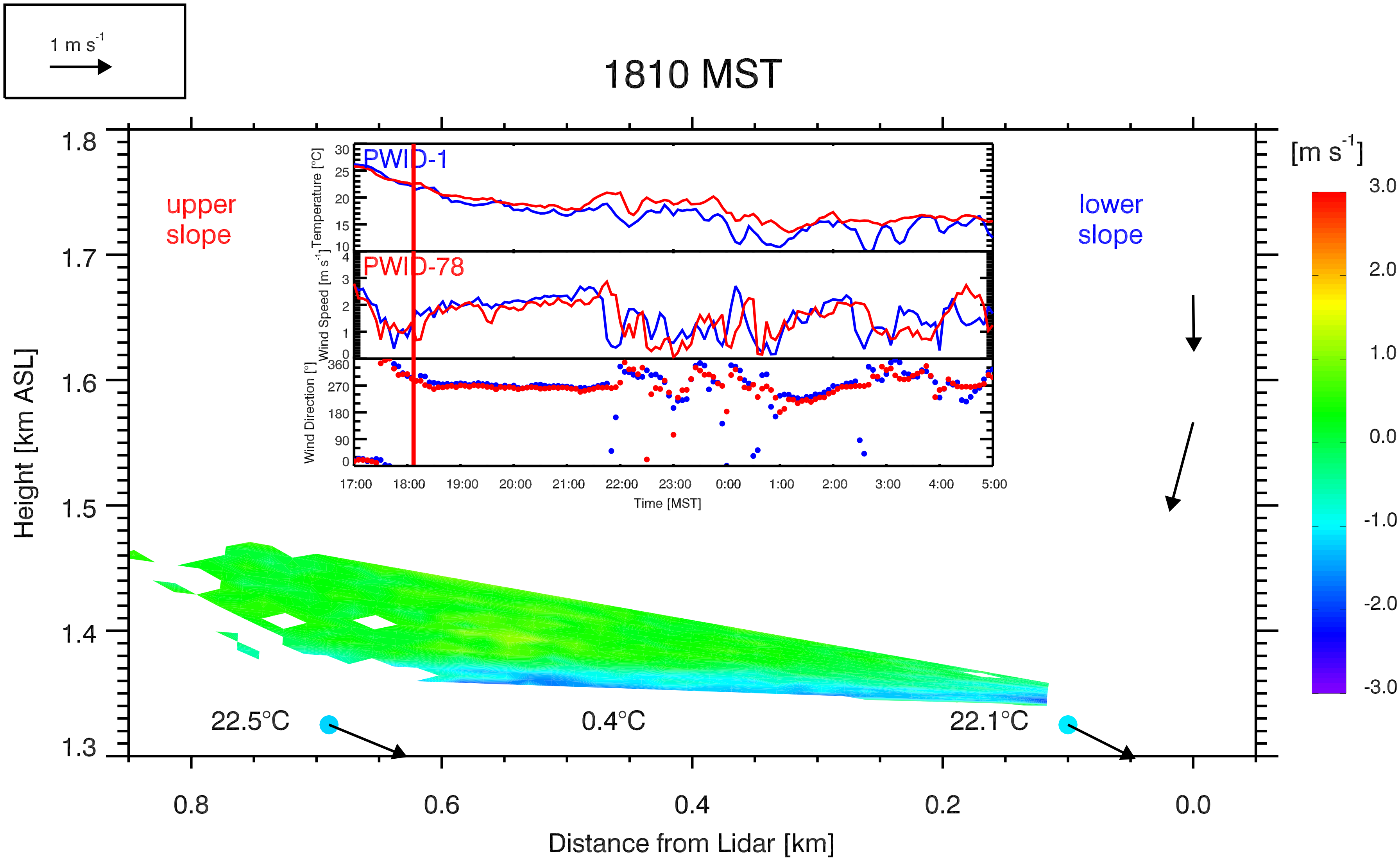


1725 MST: Sunset on Slope. Fully developed up-valley flow.

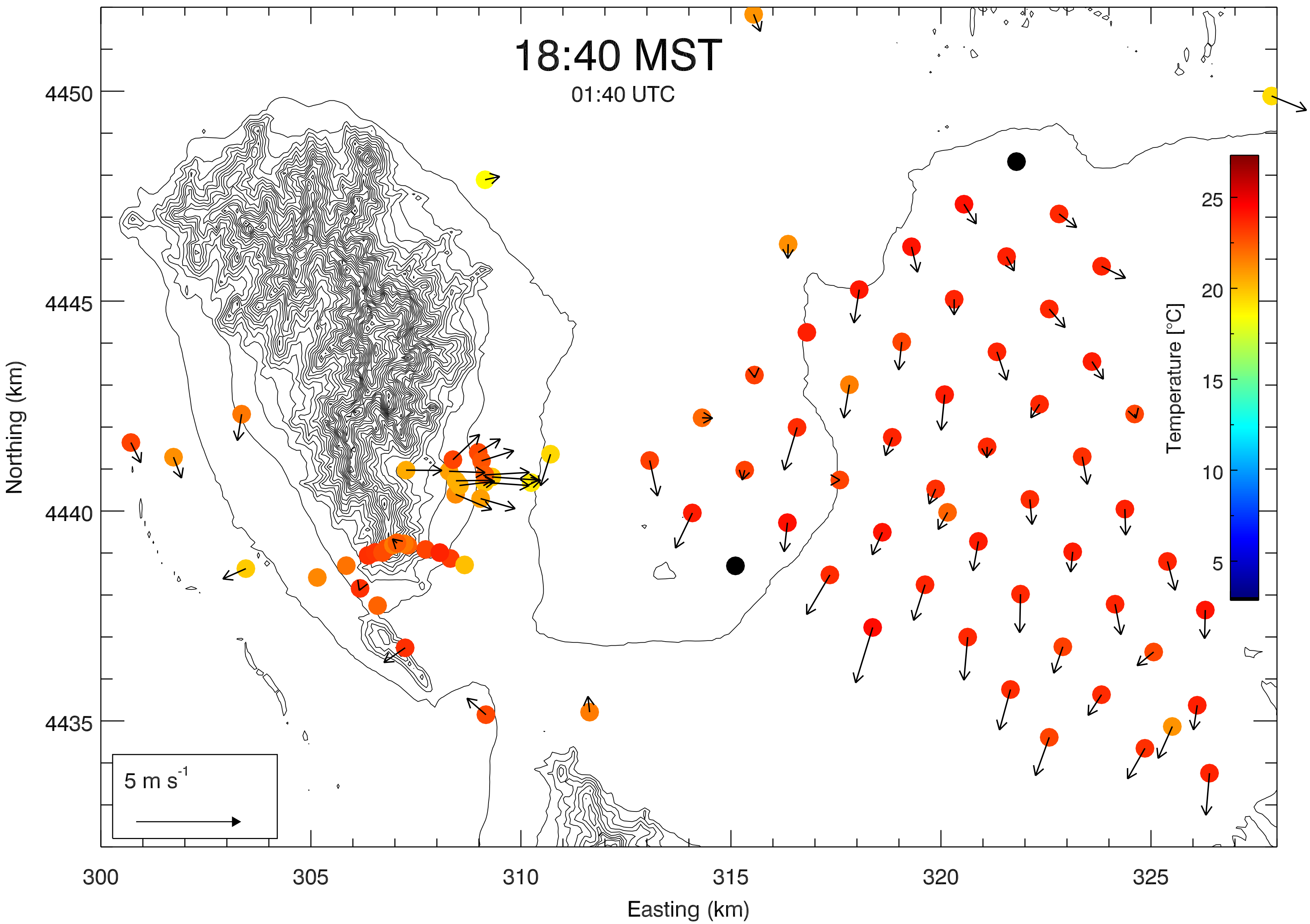


1800 MST: Astronomical Sunset

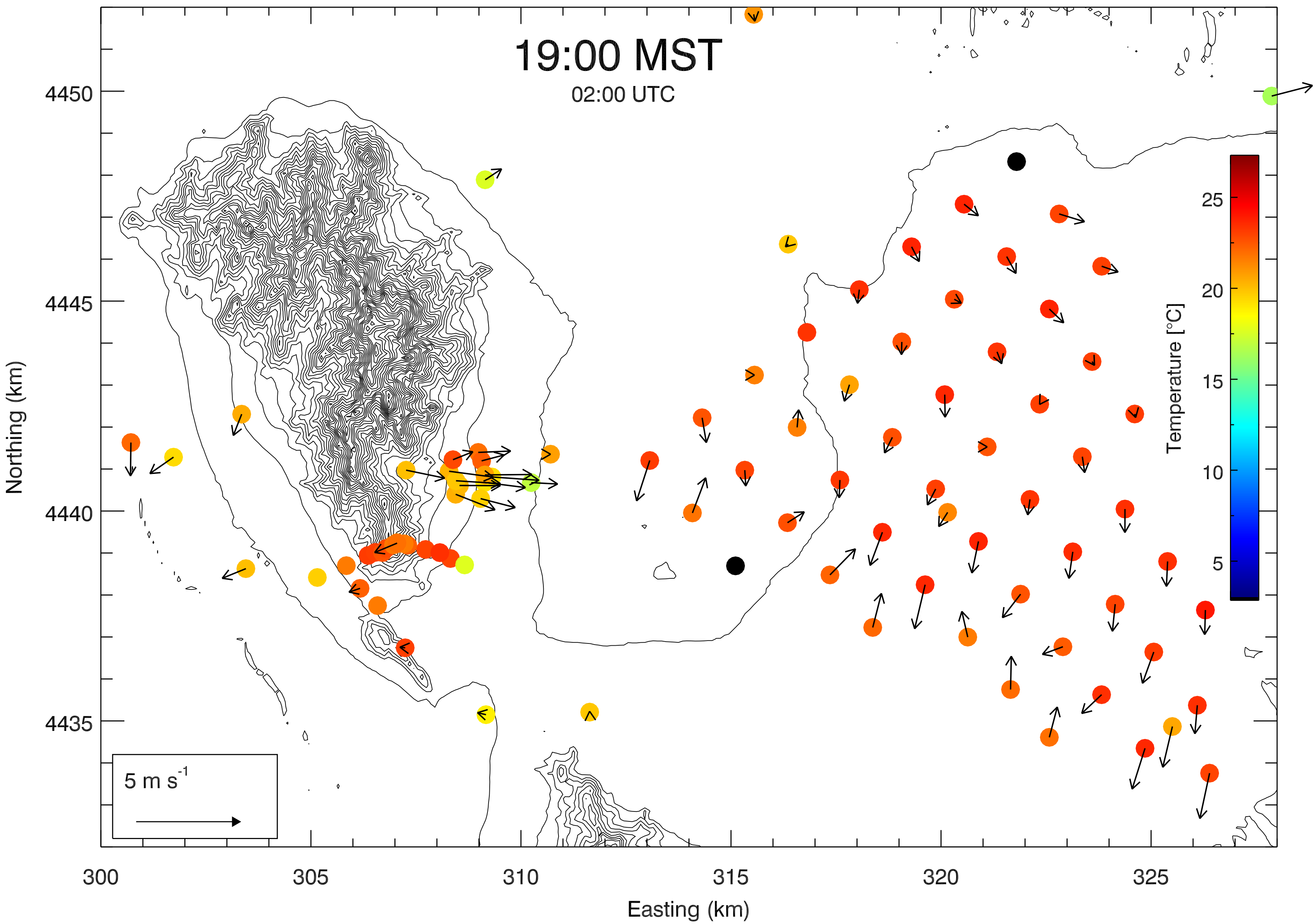
1805-1810 MST: Onset of slope flows on East Slope of Granite Peak. Up-valley flow in main basin persists.



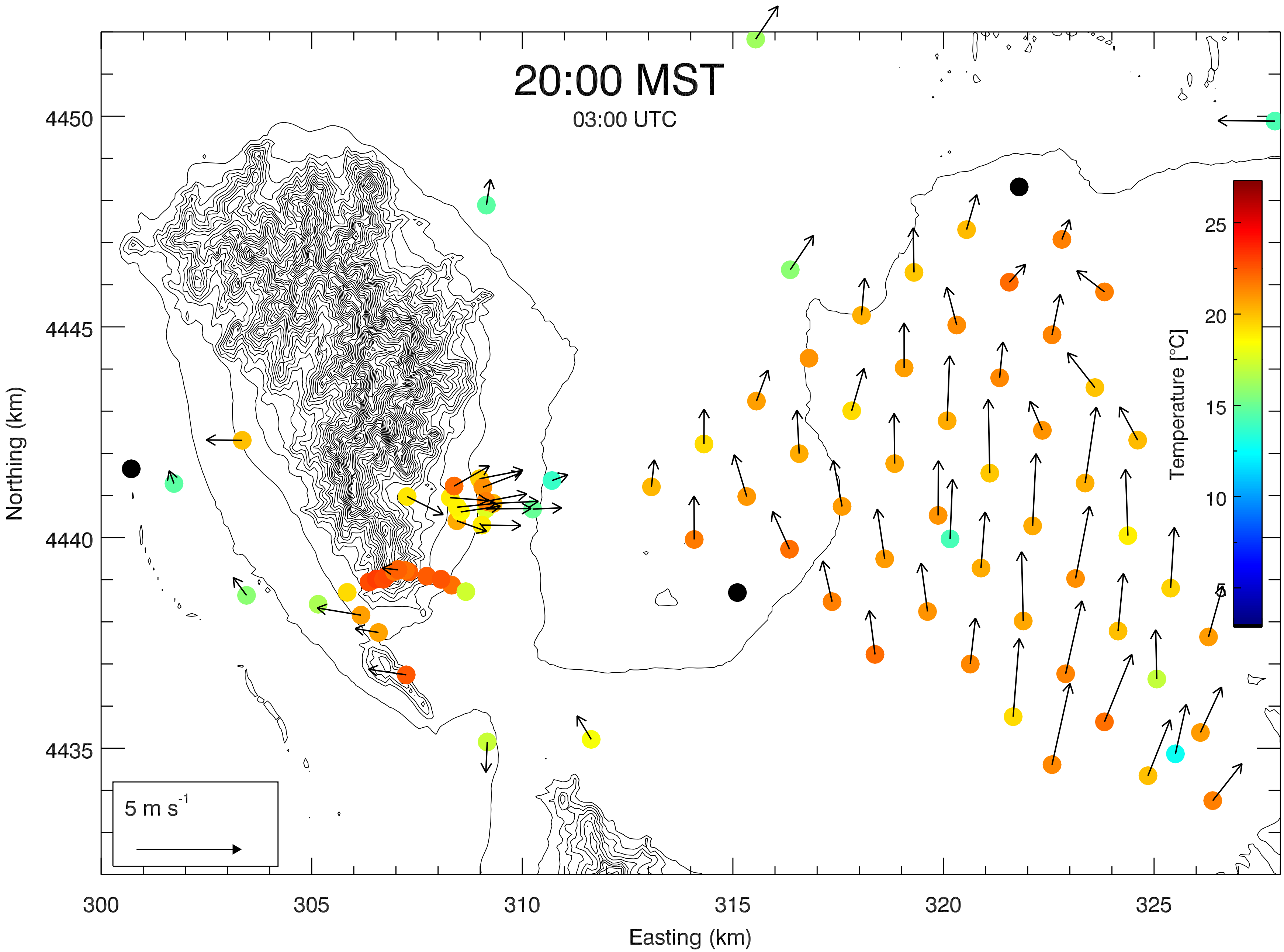
1 m s-1
1810 MST
upper slope
lower slope
PWID-1
PWID-78
Temperature [°C]
Wind Speed [m s-1]
Wind Direction [°]
Time [MST]
[m s-1]
22.5°C
0.4°C
22.1°C
Height [km ASL]
Distance from Lidar [km]



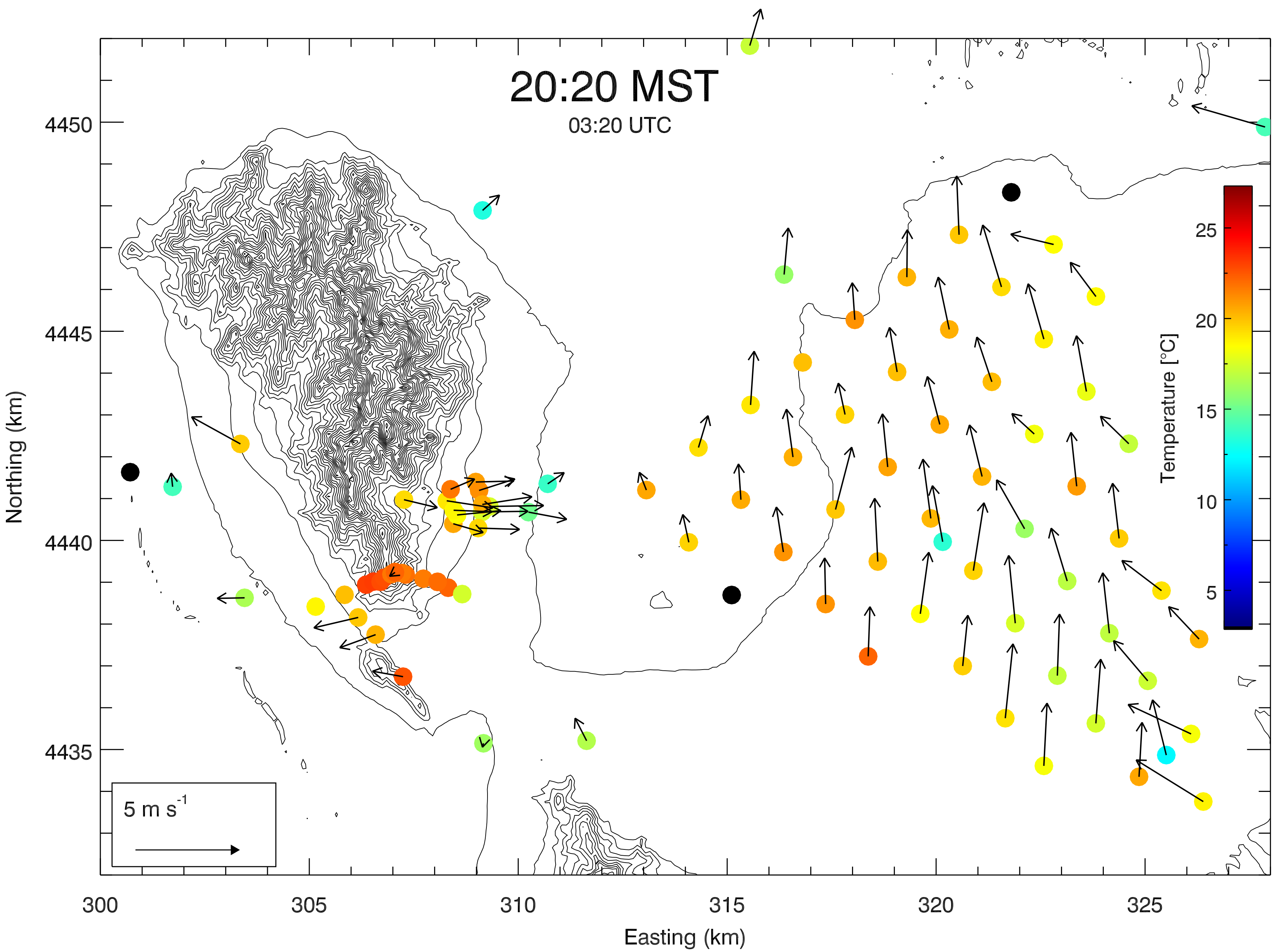
1840 MST: Slope flow on alluvial fan: Up-valley circulations deteriorating.



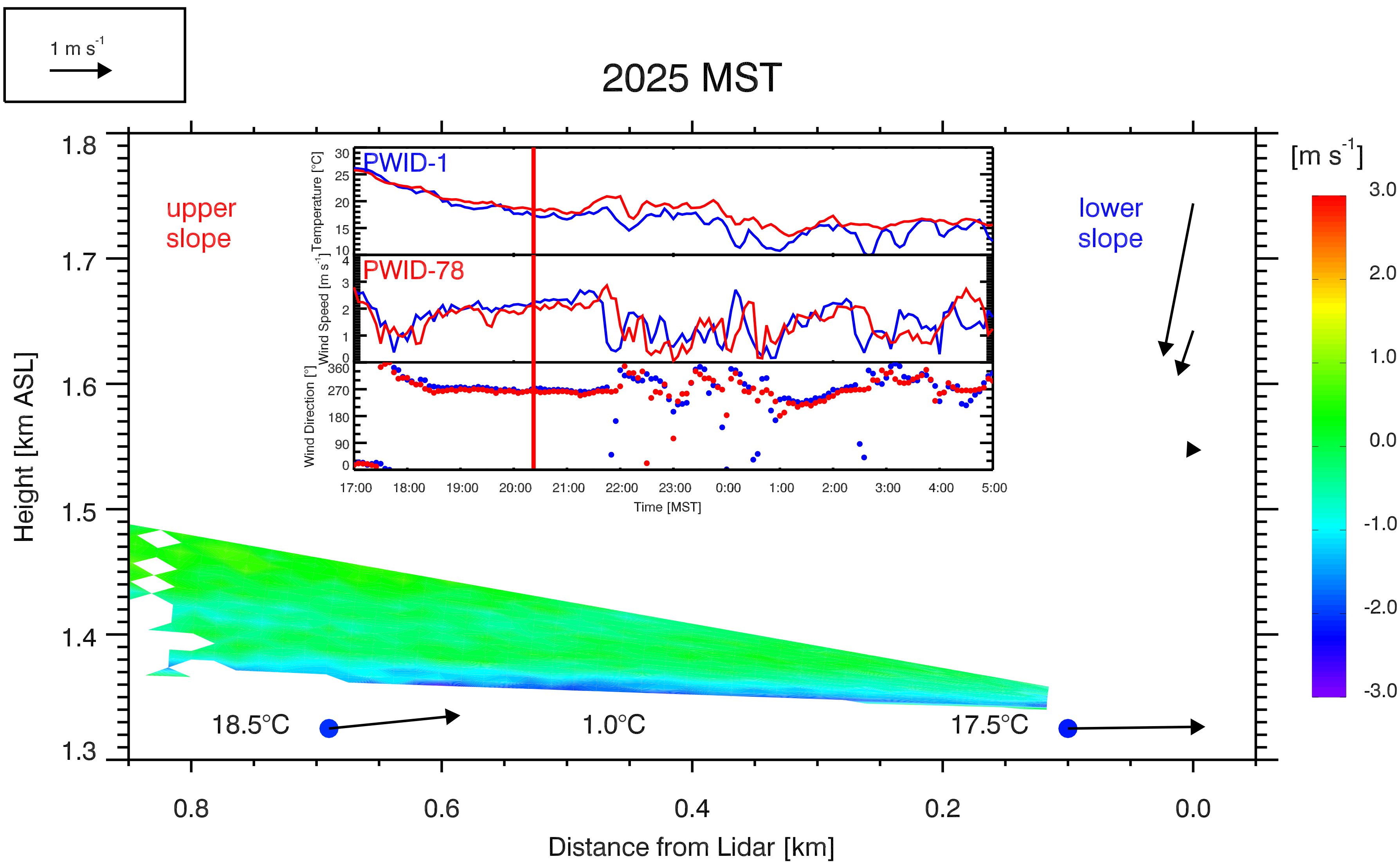
1900 MST: Calm or opposing flows on miniSAMS grid. Arrival of slope flows off Dugway Range slopes.



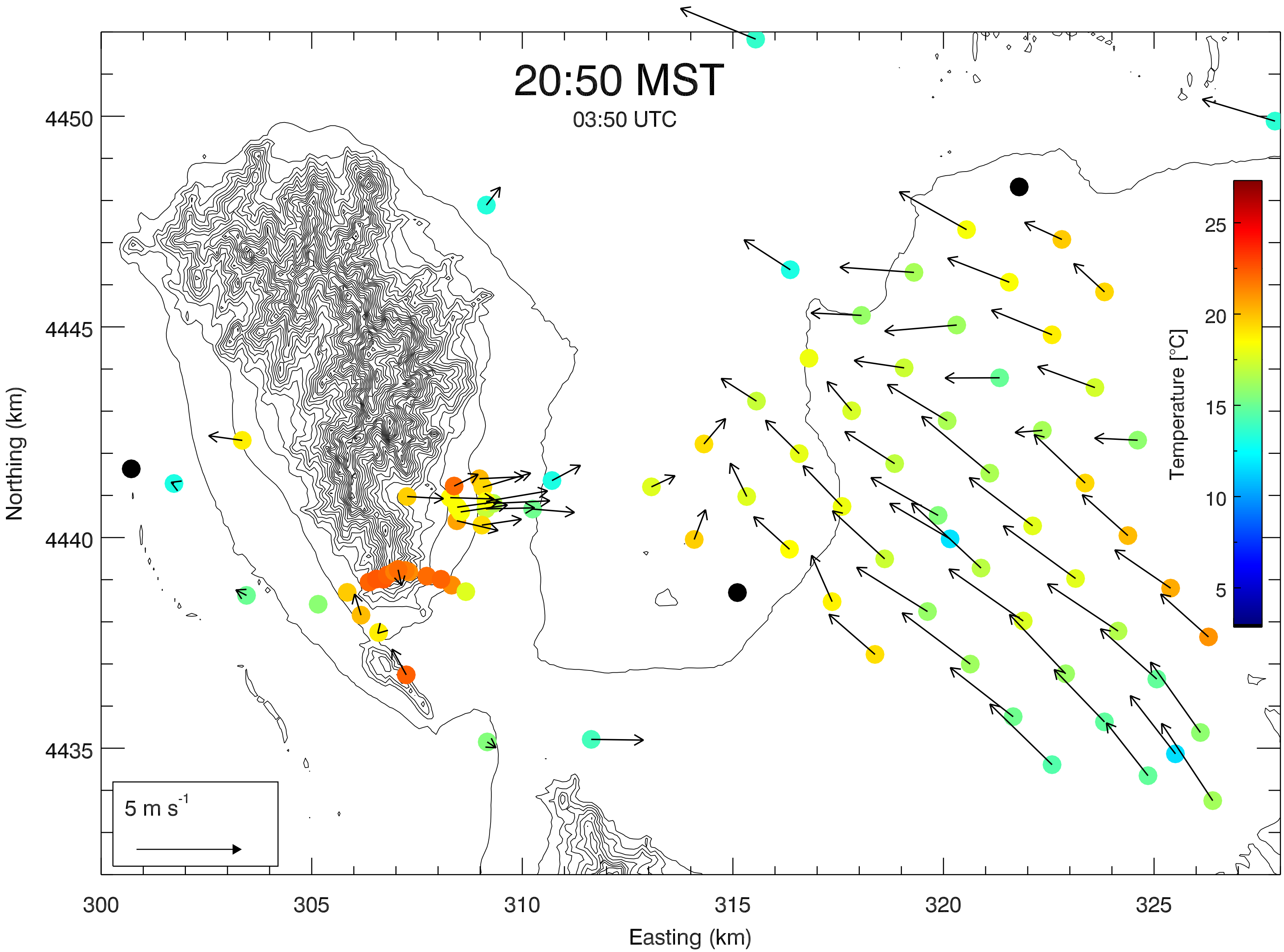
2000 MST: Basin dominated by southerly down-slope flow off Dugway Range slopes.



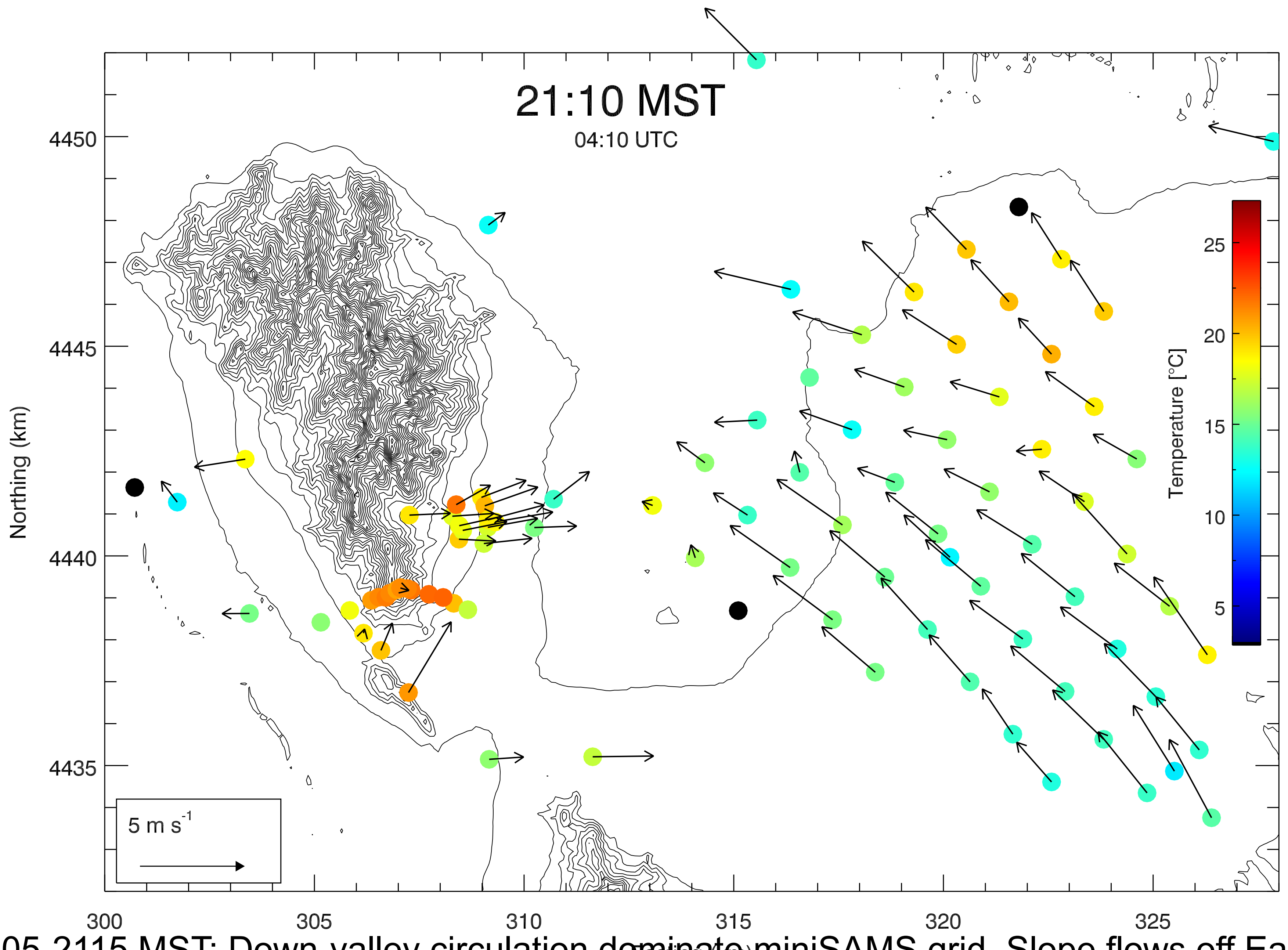
2010 MST: Slope flows from Dugway Valley / Slopes of Simpson Mountains influence eastern part of miniSAMS grid (climatological feature).



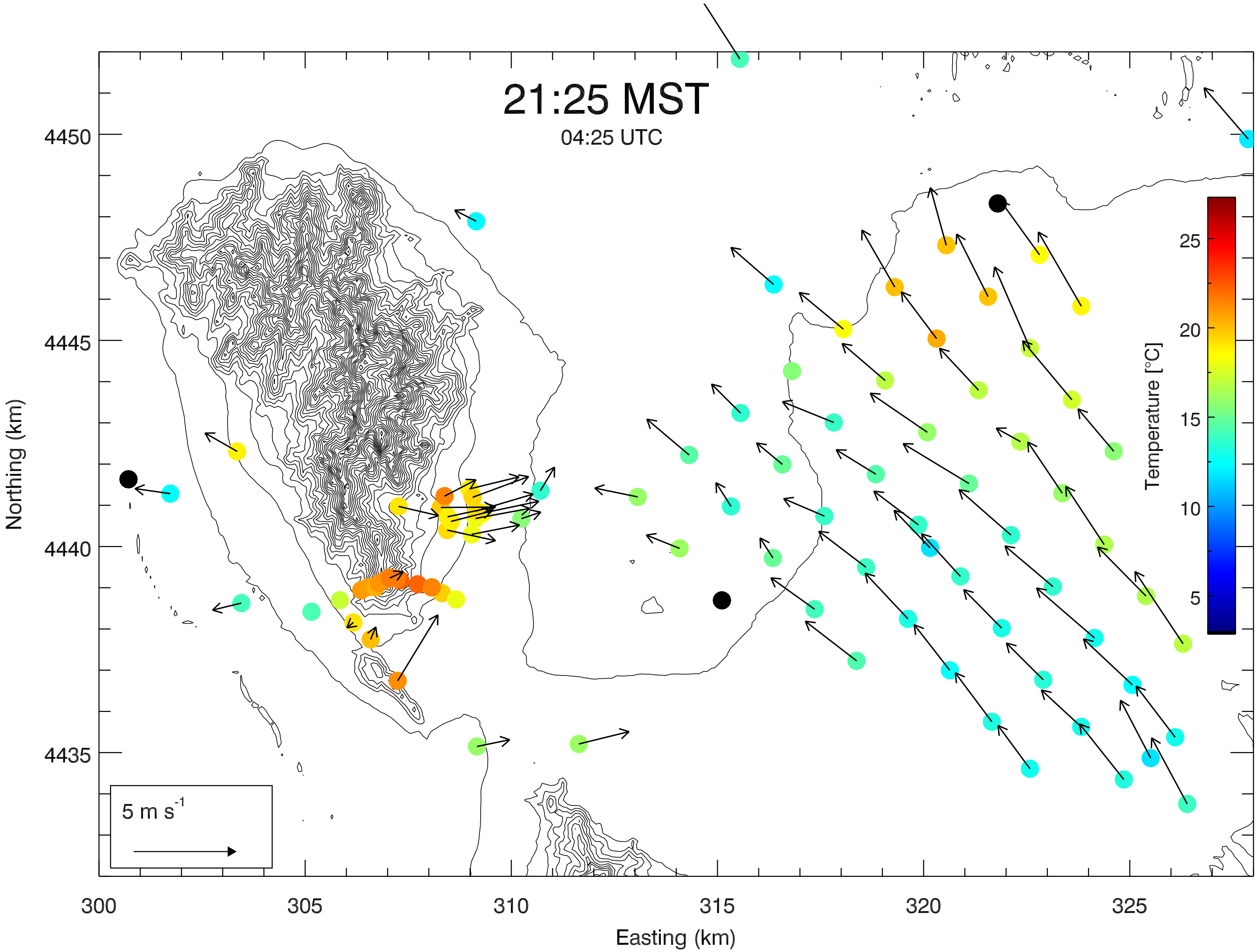
1 m s-1
2025 MST
upper slope
lower slope
PWID-1
PWID-78
Temperature [°C]
Wind Speed [m s-1]
Wind Direction [°]
Time [MST]
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
18.5°C
1.0°C
17.5°C
Height [km ASL]
Distance from Lidar [km]
[m s-1]



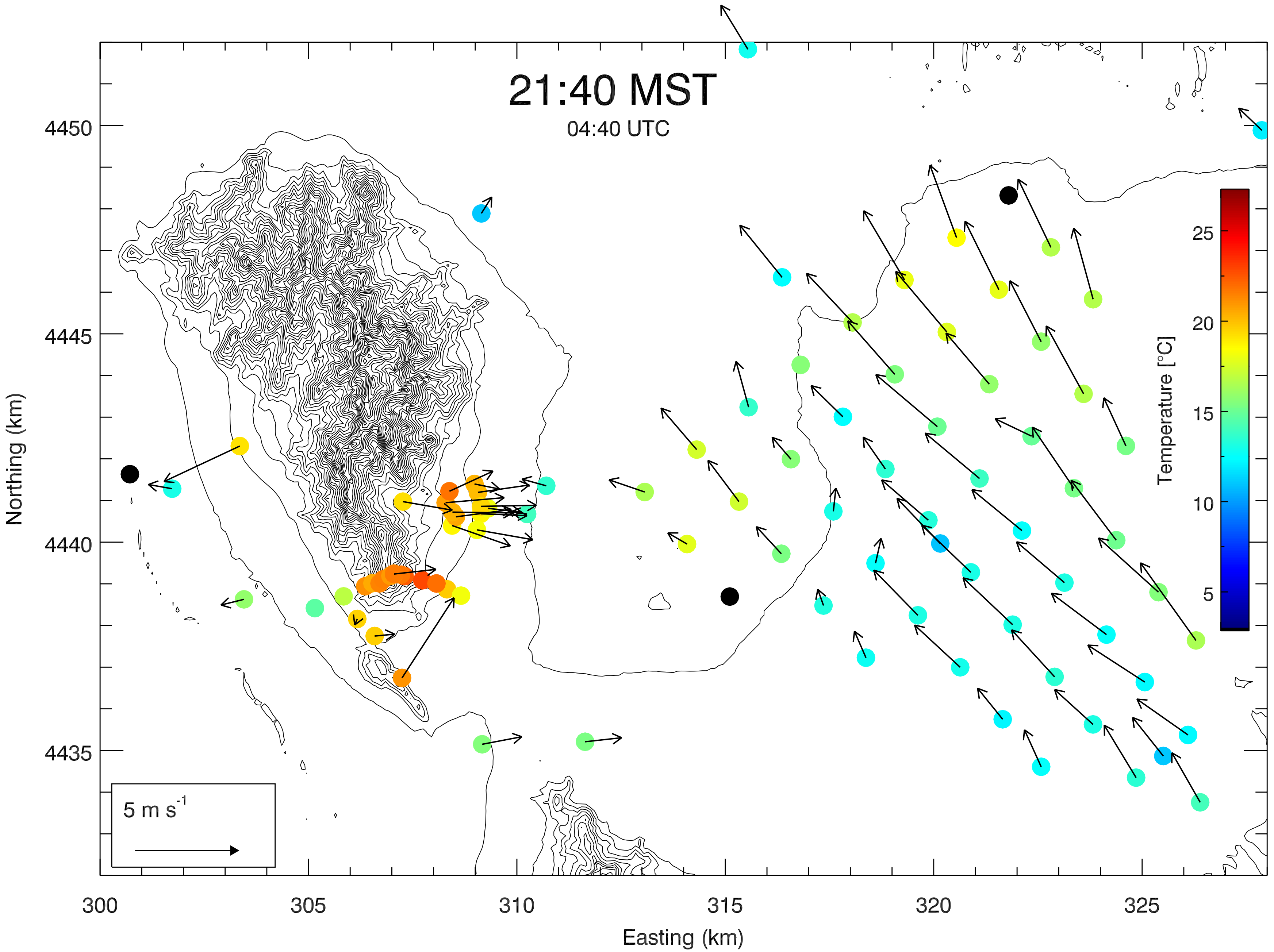
2050 -2100 MST: Slope flows from East Slope of Granite Peak reach and influence miniSAMS grid.



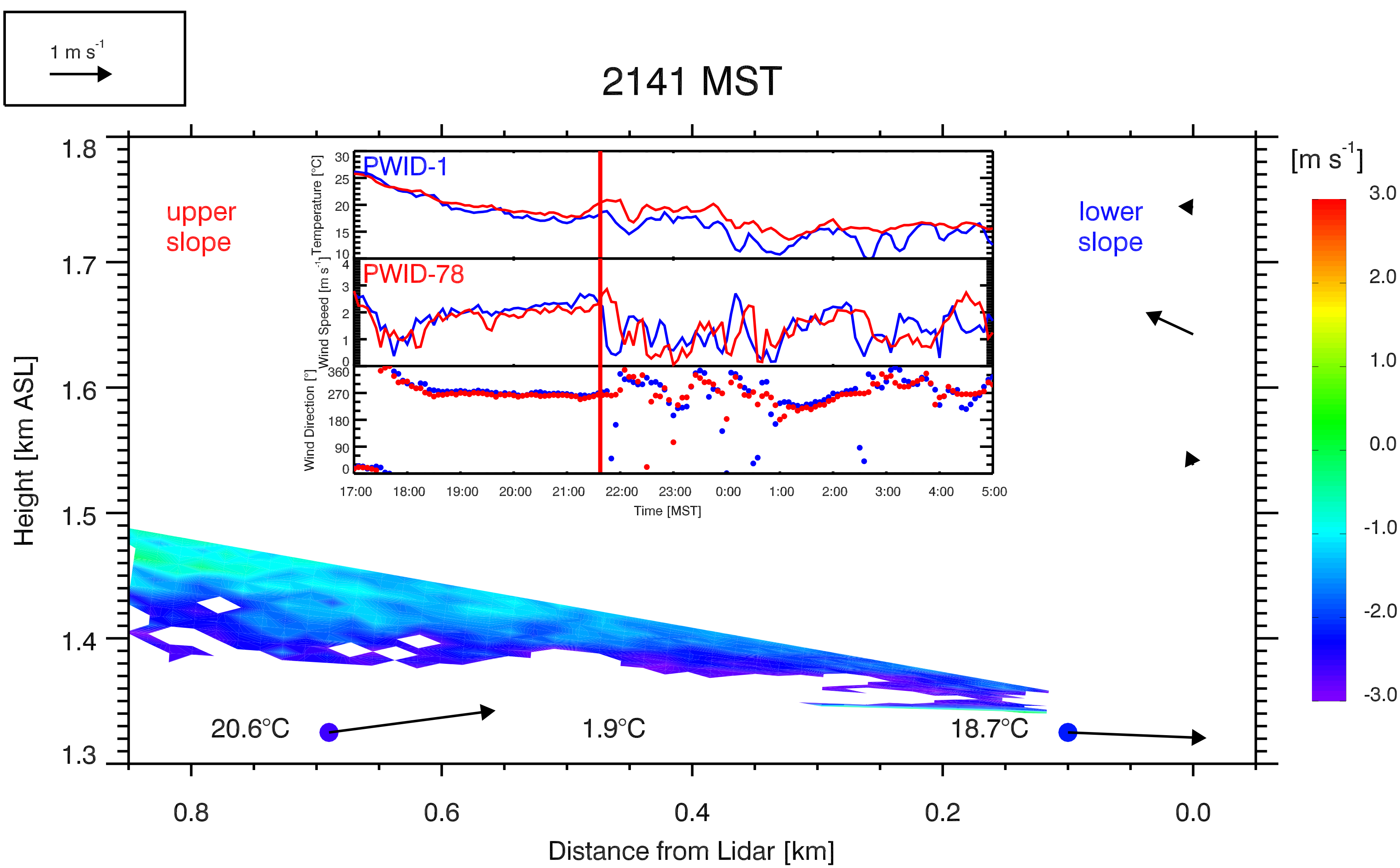
2105-2115 MST: Down-valley circulation dominate miniSAMS grid. Slope flows off East Slope of Granite Peak turn north and temperatures increase by ~2 K over the next hour. Corresponds to increasing SSW flow on Sapphire Mountain.



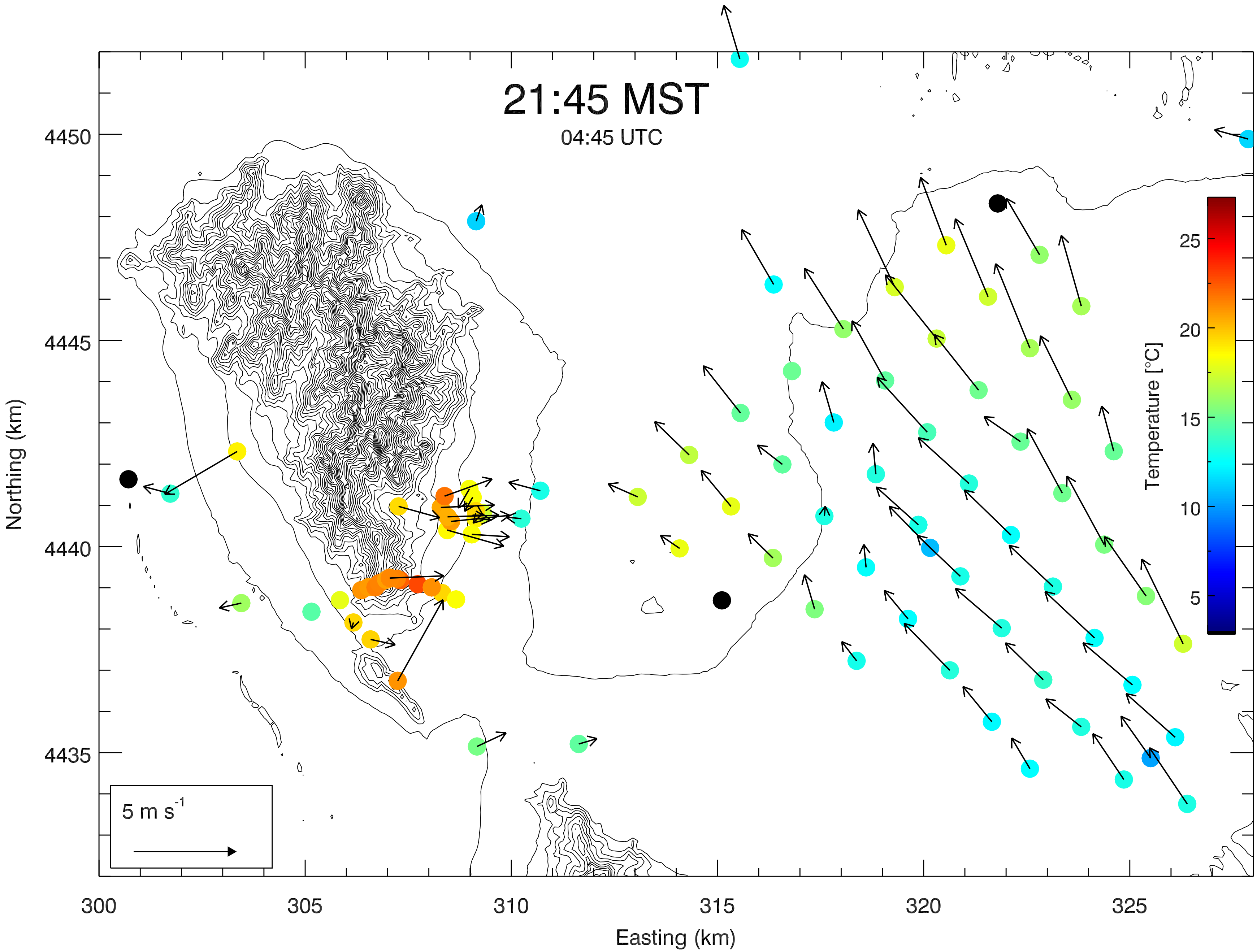
2125 MST: confluence of valley flow and slope flow - deflection to the North. Fully developed down-valley flow.



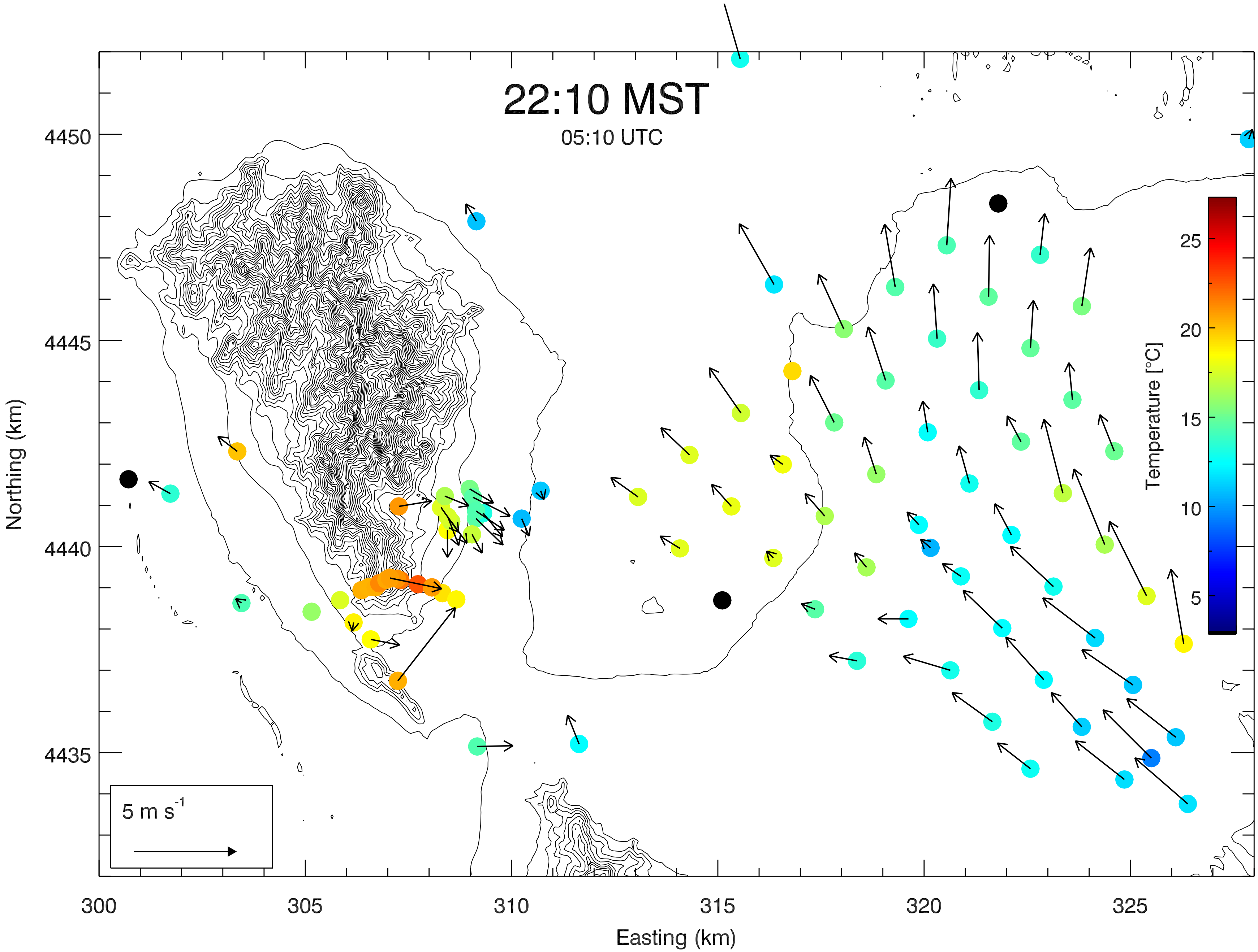
2140 MST: cold air arrives on the lower East Slope of Granite Peak, resulting in a 5 K temperature drop



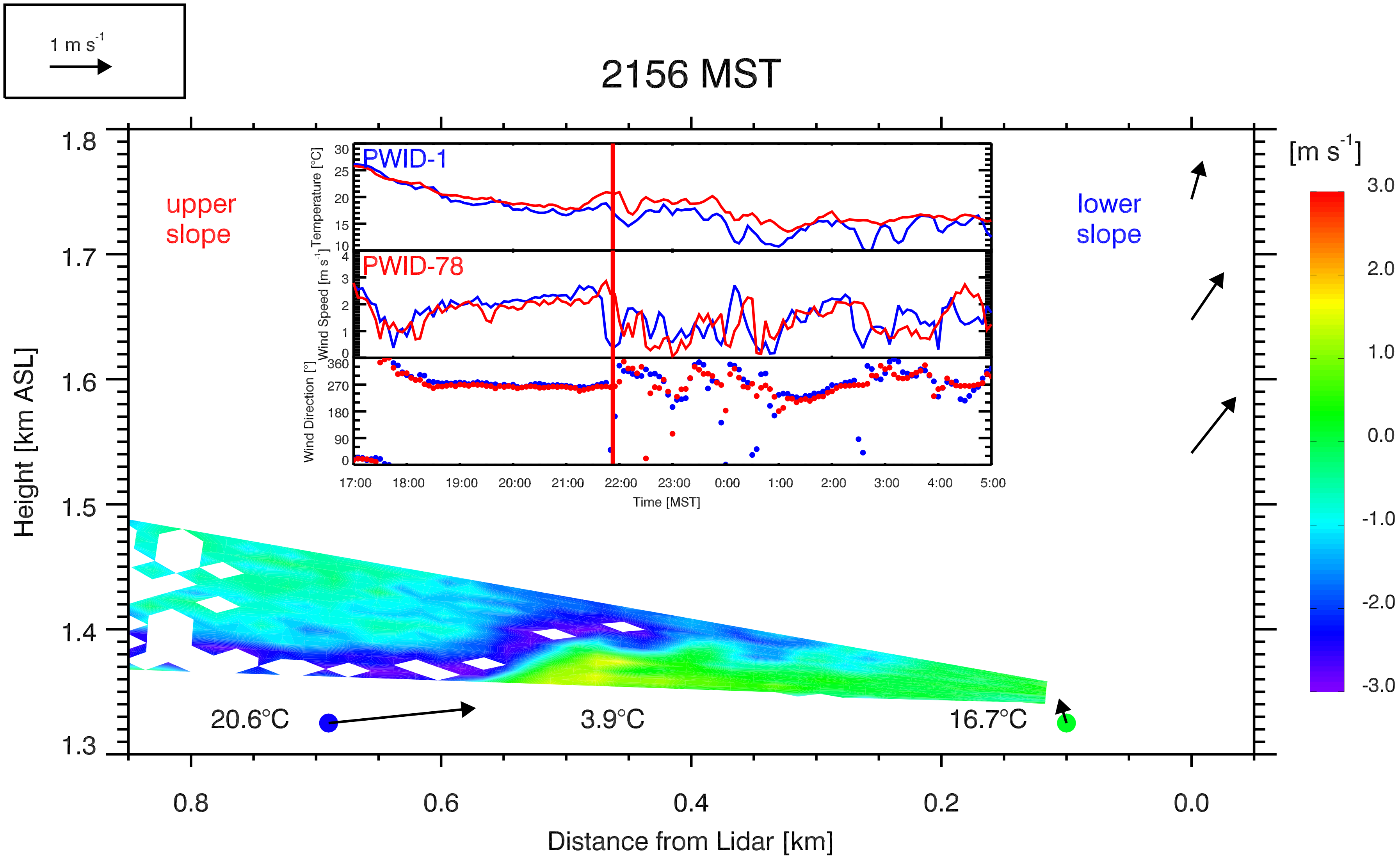
1 m s-1
2141 MST
upper slope
lower slope
PWID-1
PWID-78
Temperature [°C]
Wind Speed [m s-1]
Wind Direction [°]
Time [MST]
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
20.6°C
1.9°C
18.7°C
Height [km ASL]
Distance from Lidar [km]
[m s-1]
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0



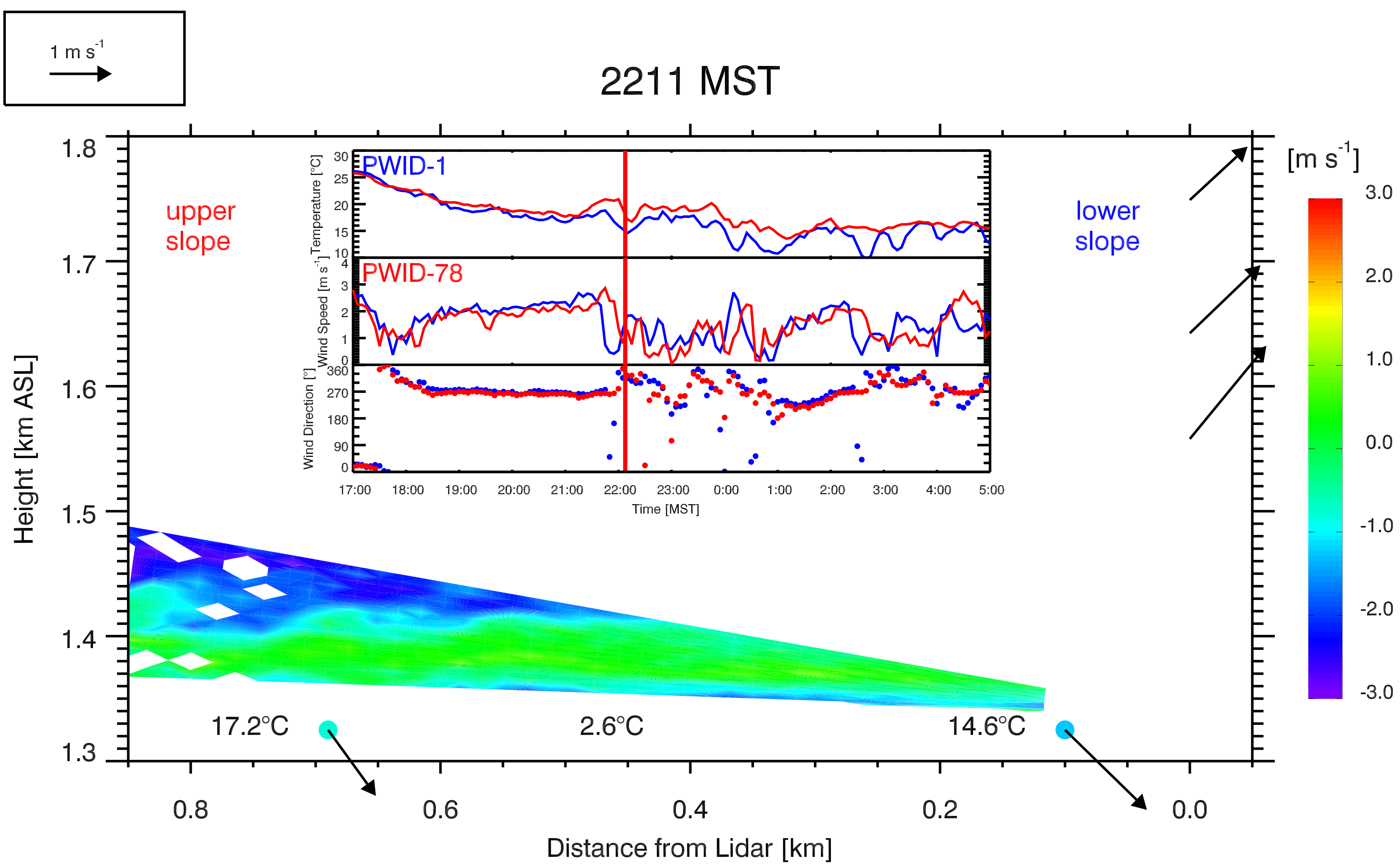
2145 MST: Cold air 'washes up' the slope from the E and NE.

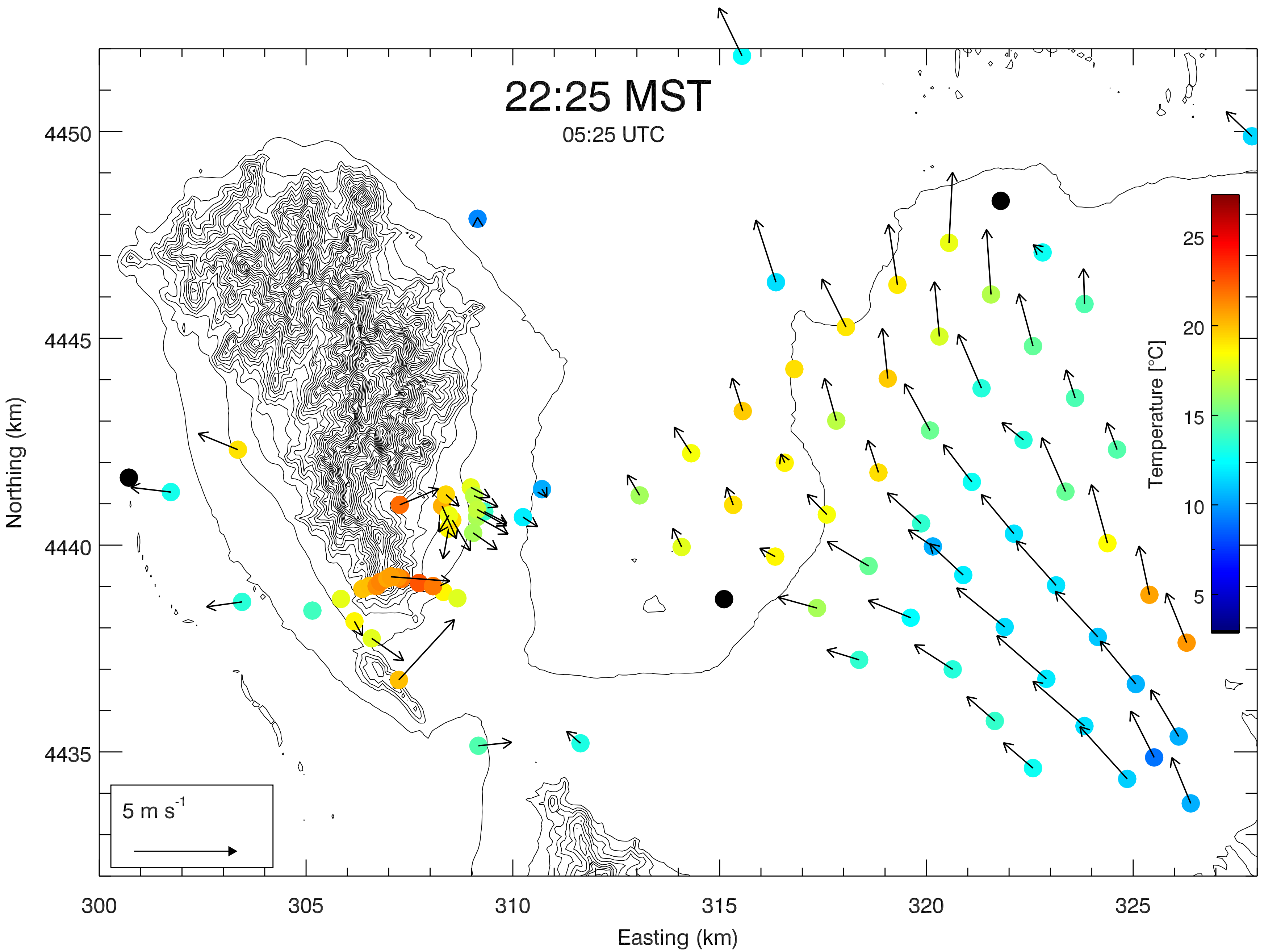


2210 MST: Cold air on East Slope drains back down the slope. Target R area is now now under weak northerly flow (but no flow through gap yet).

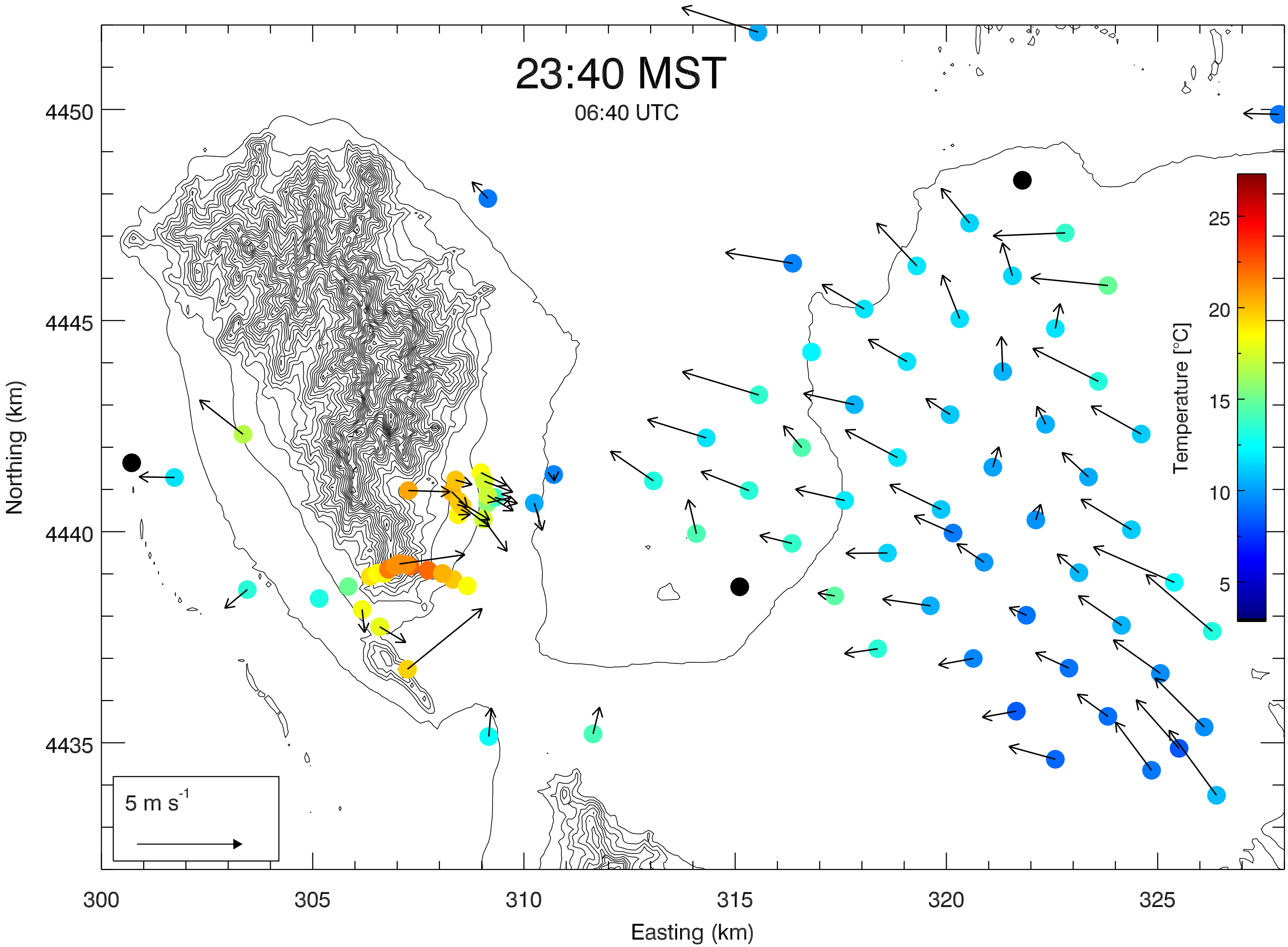


1 m s-1
2156 MST
upper slope
lower slope
PWID-1
PWID-78
Temperature [°C]
Wind Speed [m s-1]
Wind Direction [°]
Time [MST]
20.6°C
3.9°C
16.7°C
Height [km ASL]
Distance from Lidar [km]
[m s-1]

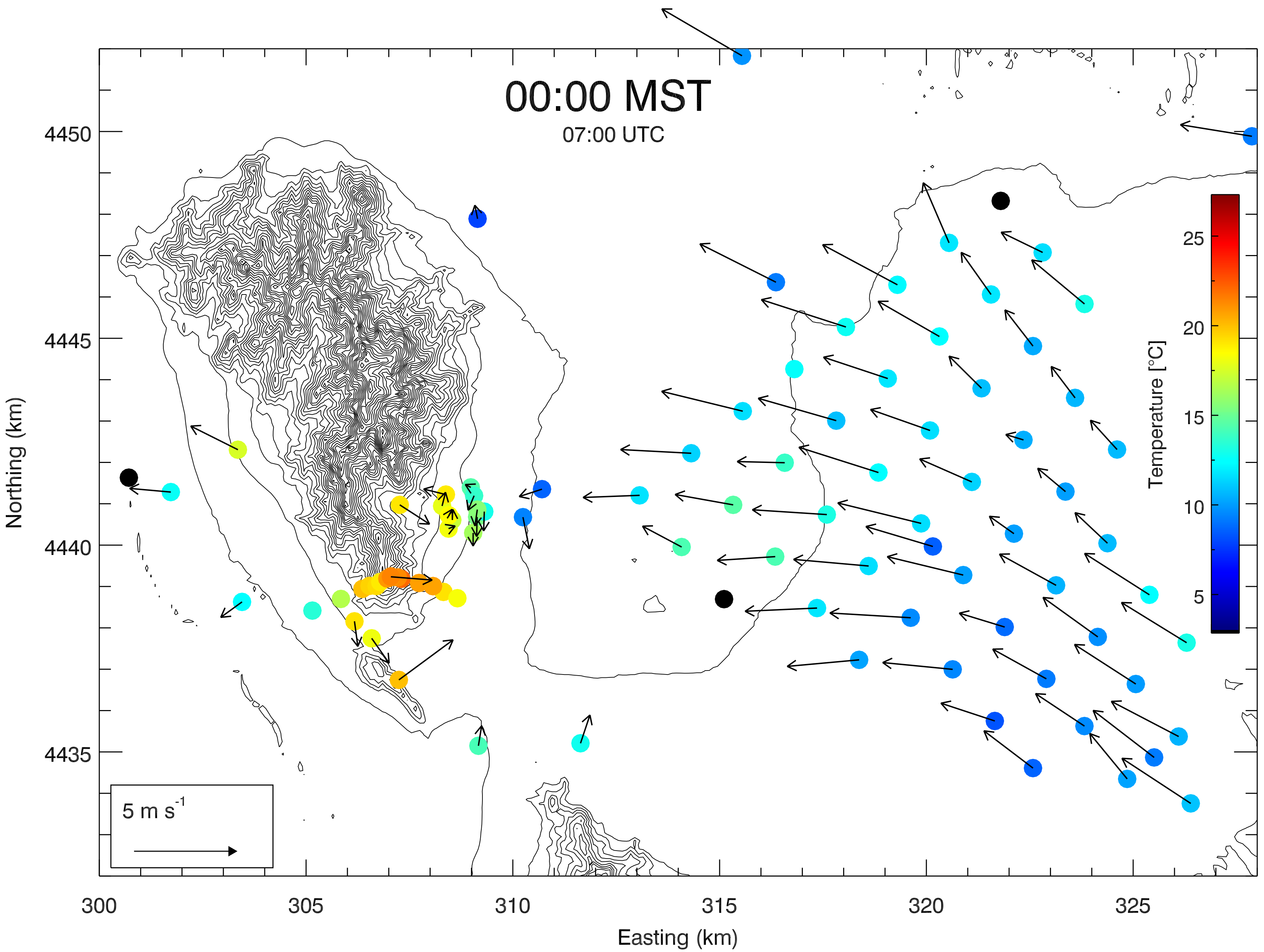

1 m s-1
2211 MST
upper slope
lower slope
PWID-1
PWID-78
Temperature [°C]
Wind Speed [m s-1]
Wind Direction [°]
Time [MST]
17.2°C
2.6°C
14.6°C
Height [km ASL]
Distance from Lidar [km]
[m s-1]



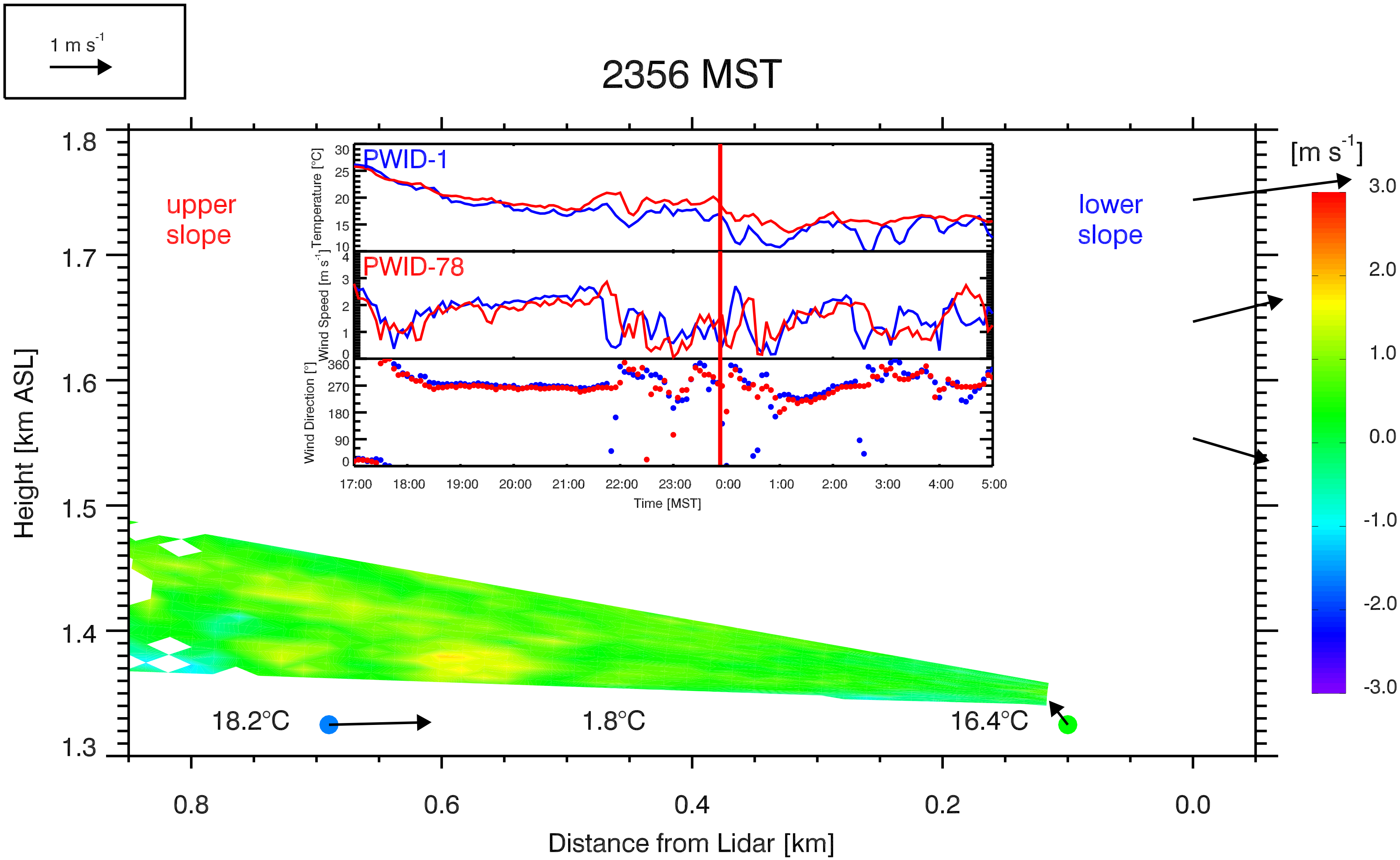
2225 MST: N-NW flow on East Slope. Cold air arriving from Simpson Springs slopes

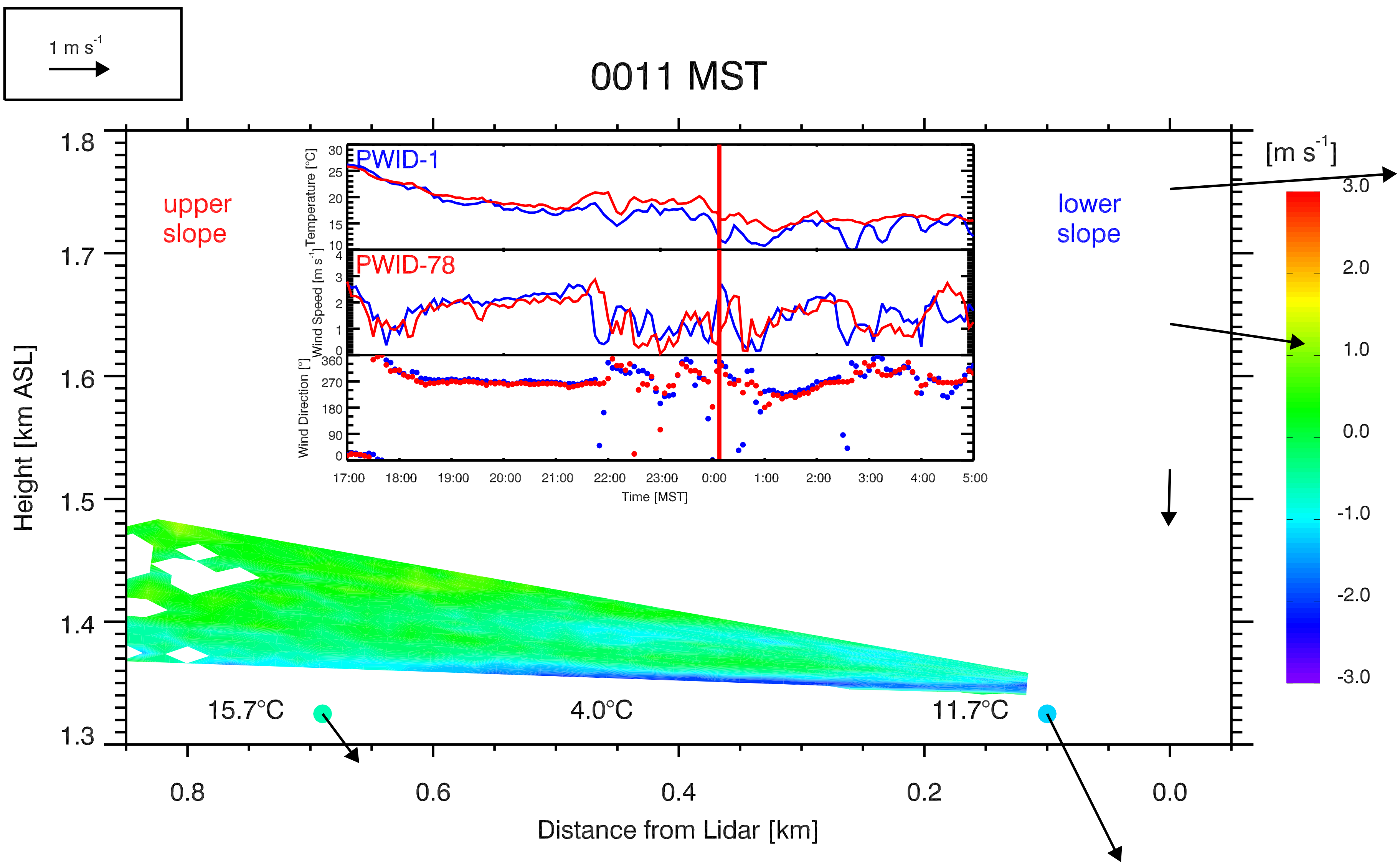


2340 MST: Down-valley circulation becomes more easterly

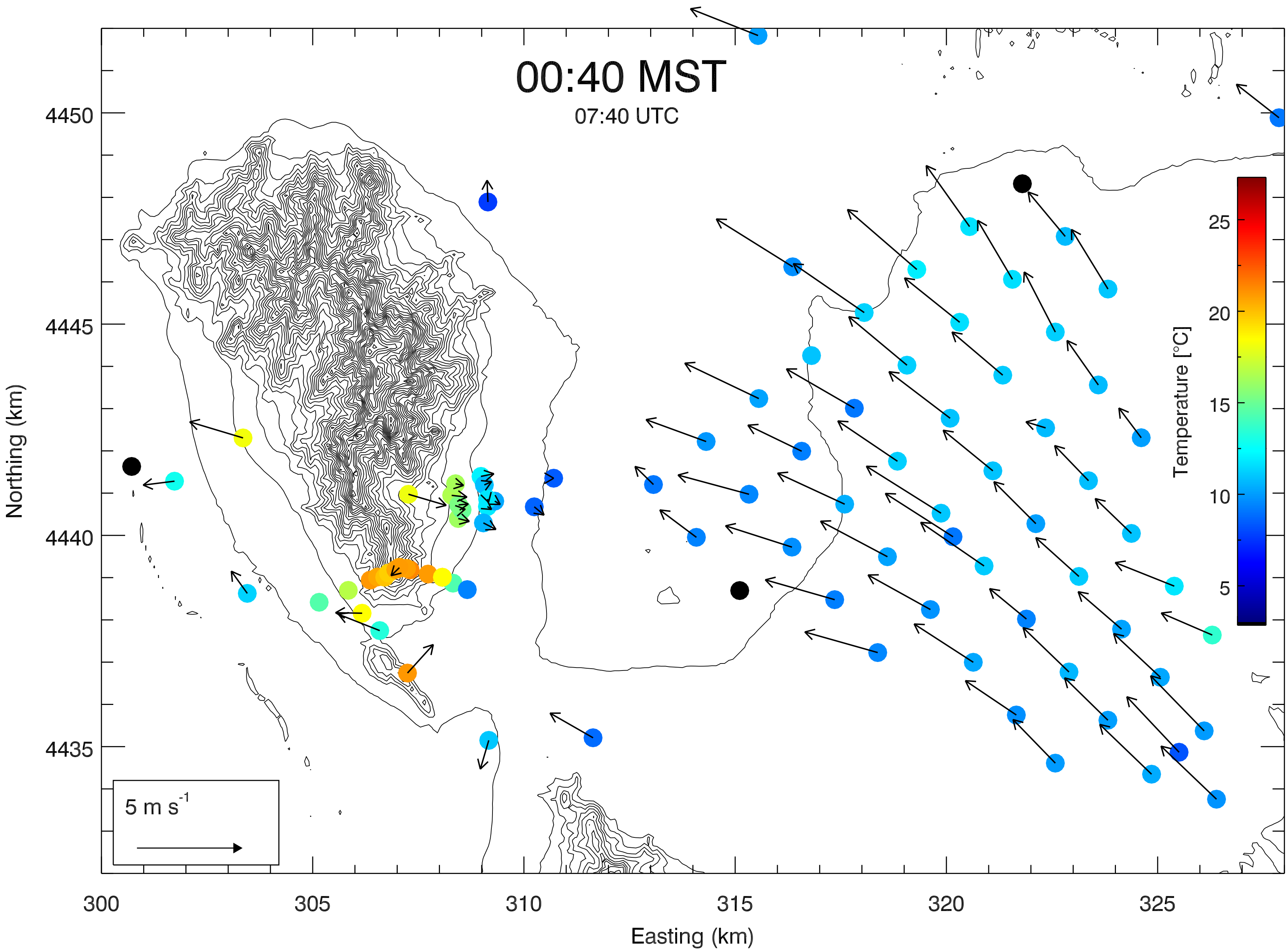


0000 MST: A new push of cold air from basin 'washes up' the East Slope -- and drains towards south. Temperatures drops by 5 K.

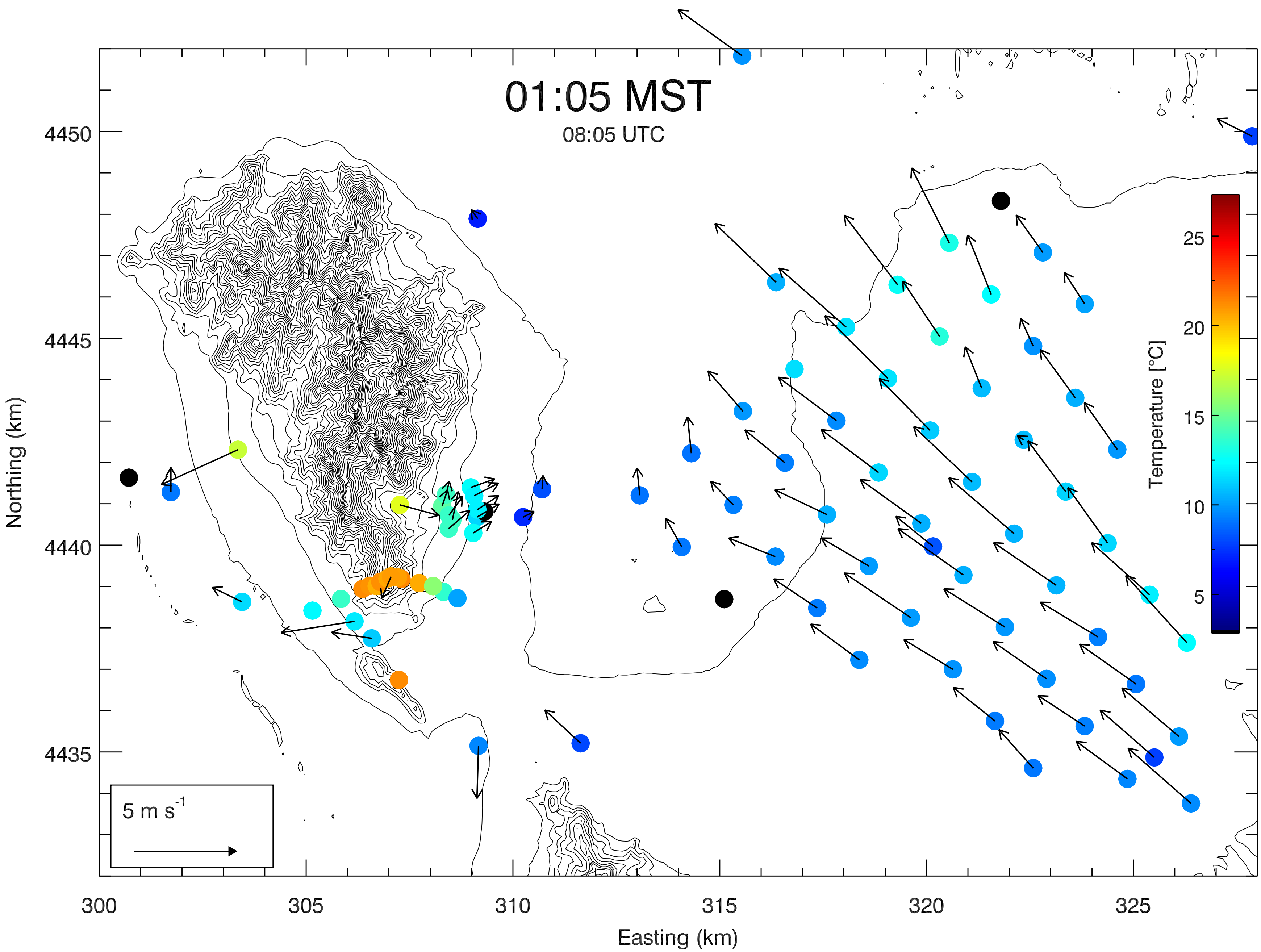

1 m s-1
2356 MST
upper slope
lower slope
PWID-1
PWID-78
Temperature [°C]
Wind Speed [m s-1]
Wind Direction [°]
Time [MST]
[m s-1]
18.2°C
1.8°C
16.4°C
Height [km ASL]
Distance from Lidar [km]



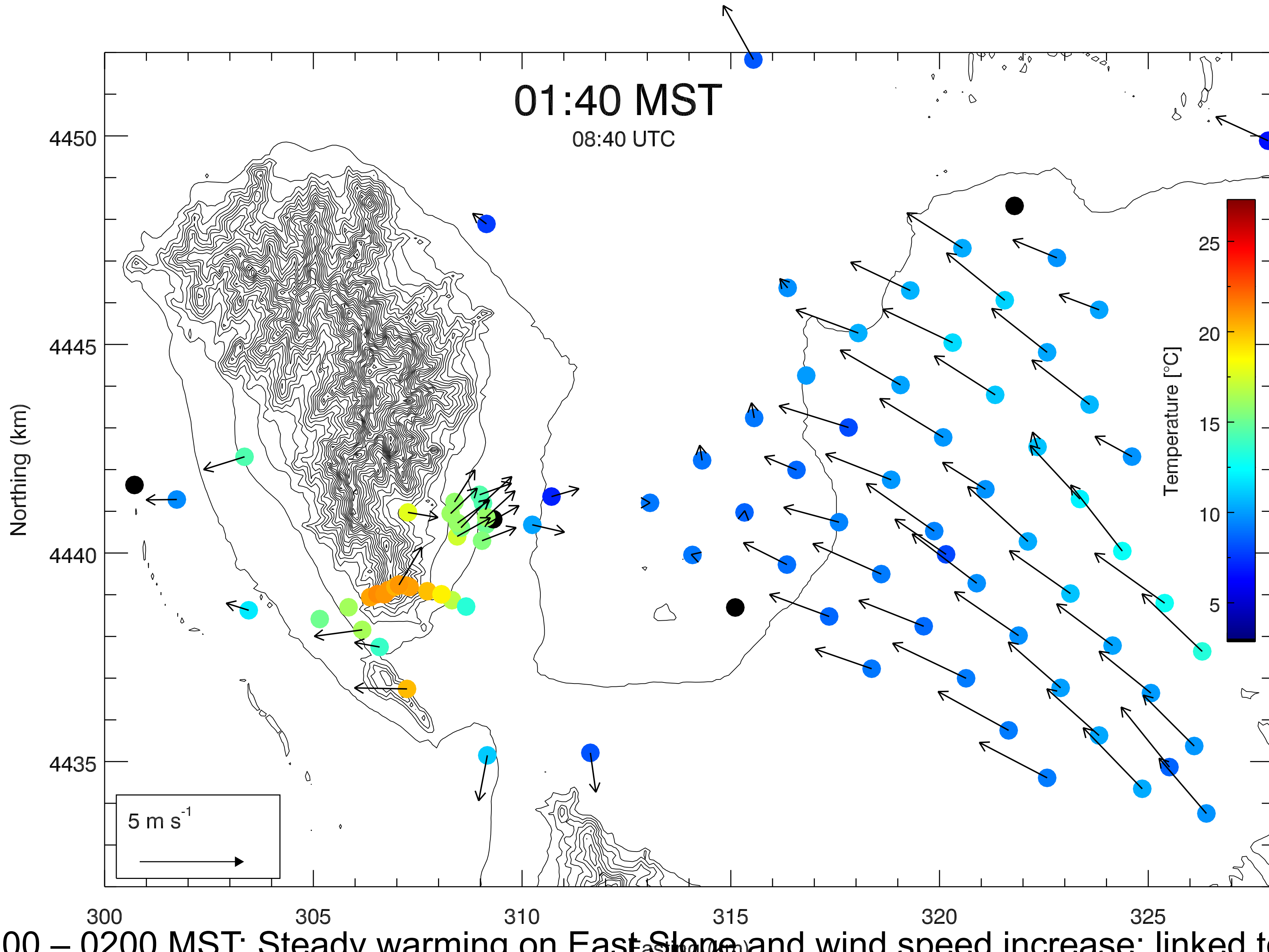
1 m s-1
0011 MST
upper slope
lower slope
PWID-1
PWID-78
Temperature [°C]
Wind Speed [m s-1]
Wind Direction [°]
Time [MST]
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
[m s-1]
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Height [km ASL]
1.8
1.7
1.6
1.5
1.4
1.3
15.7°C
4.0°C
11.7°C
0.8
0.6
0.4
0.2
0.0
Distance from Lidar [km]



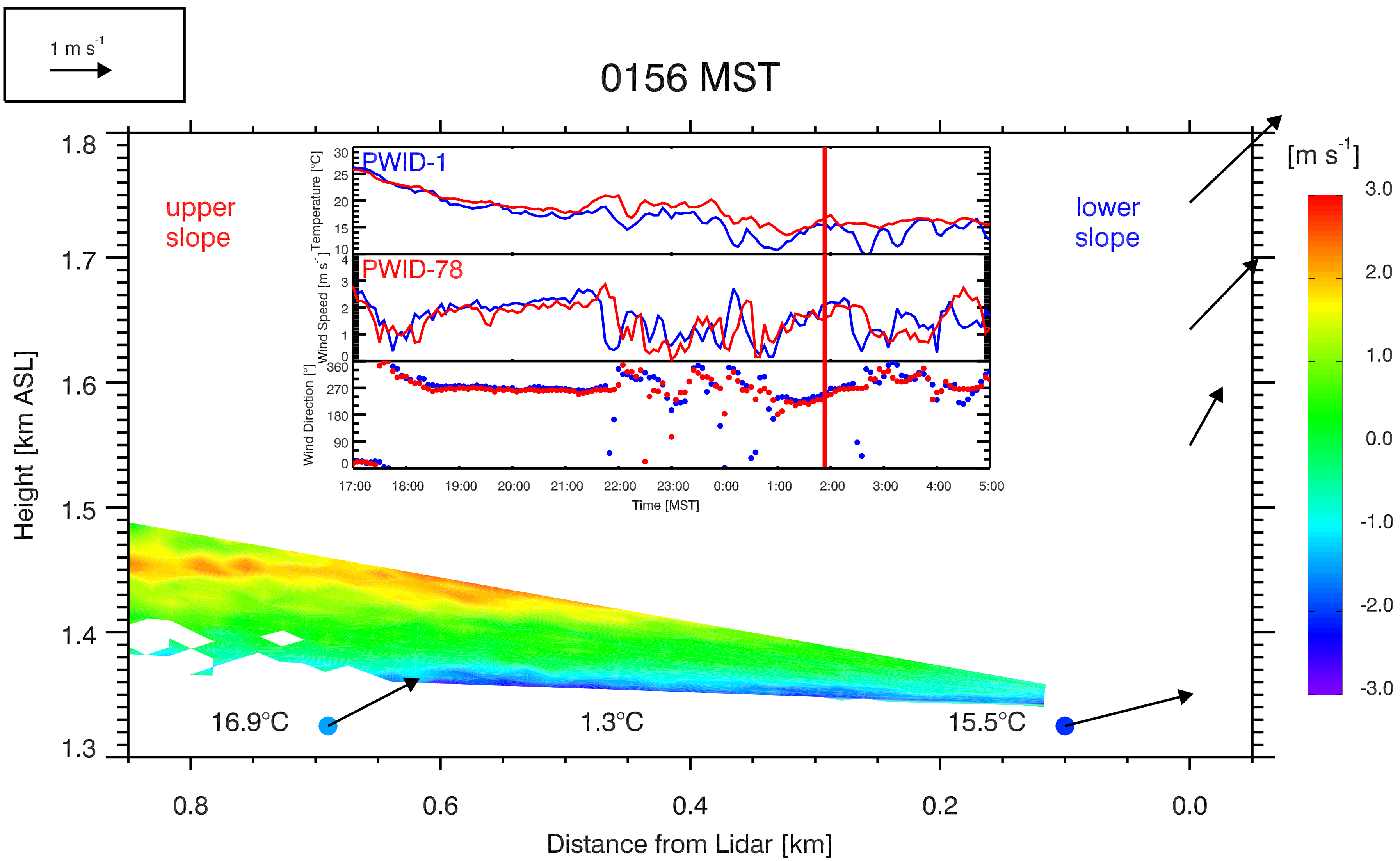
0040-0100 MST: Cold pool fully set up on slope and basin -- stagnation at Target R -- drain through gaps to SW has started.



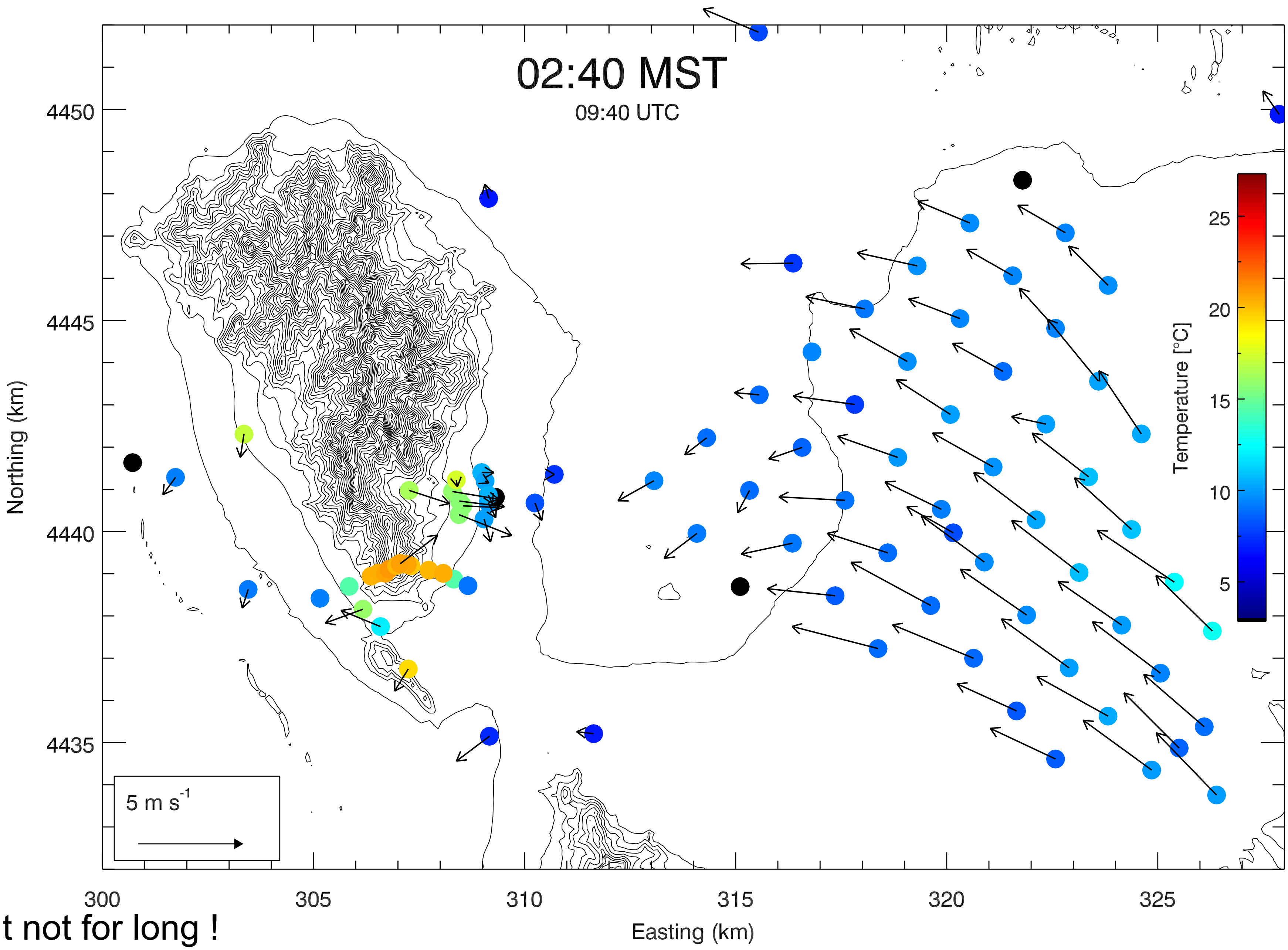
0105 MST: Down-valley flow now dominating Target R area, draining to the NW, deflecting slope flows on the East Slope to the North.



0100 – 0200 MST: Steady warming on East Slope and wind speed increase; linked to wind speed increase at Granite Ridge? Cold air is pushed back East; stagnation. Climatological feature: stagnation on western miniSAMS grid.

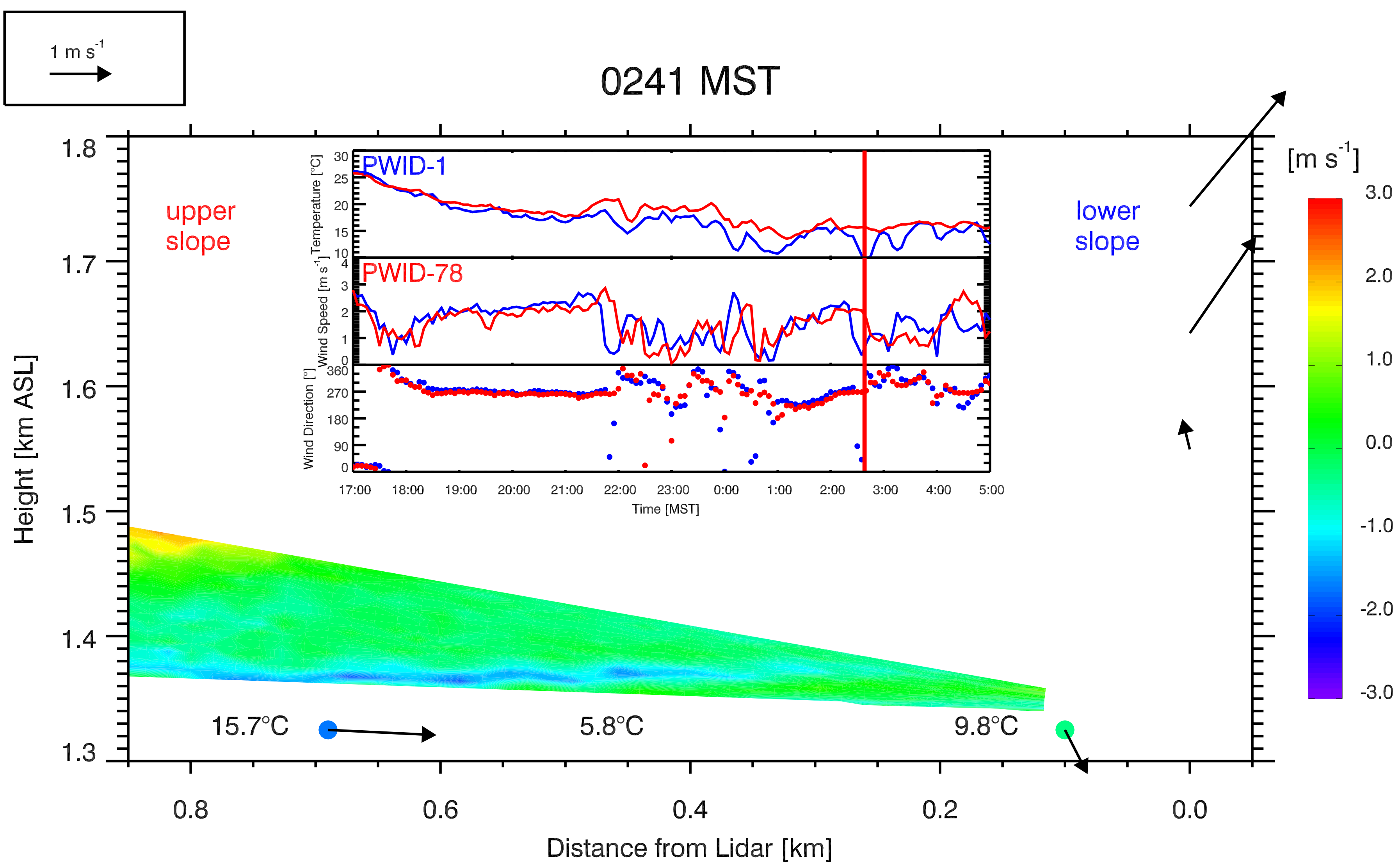


1 m s-1
0156 MST
upper slope
lower slope
PWID-1
PWID-78
Temperature [°C]
Wind Speed [m s-1]
Wind Direction [°]
Time [MST]
16.9°C
1.3°C
15.5°C
Height [km ASL]
Distance from Lidar [km]
[m s-1]

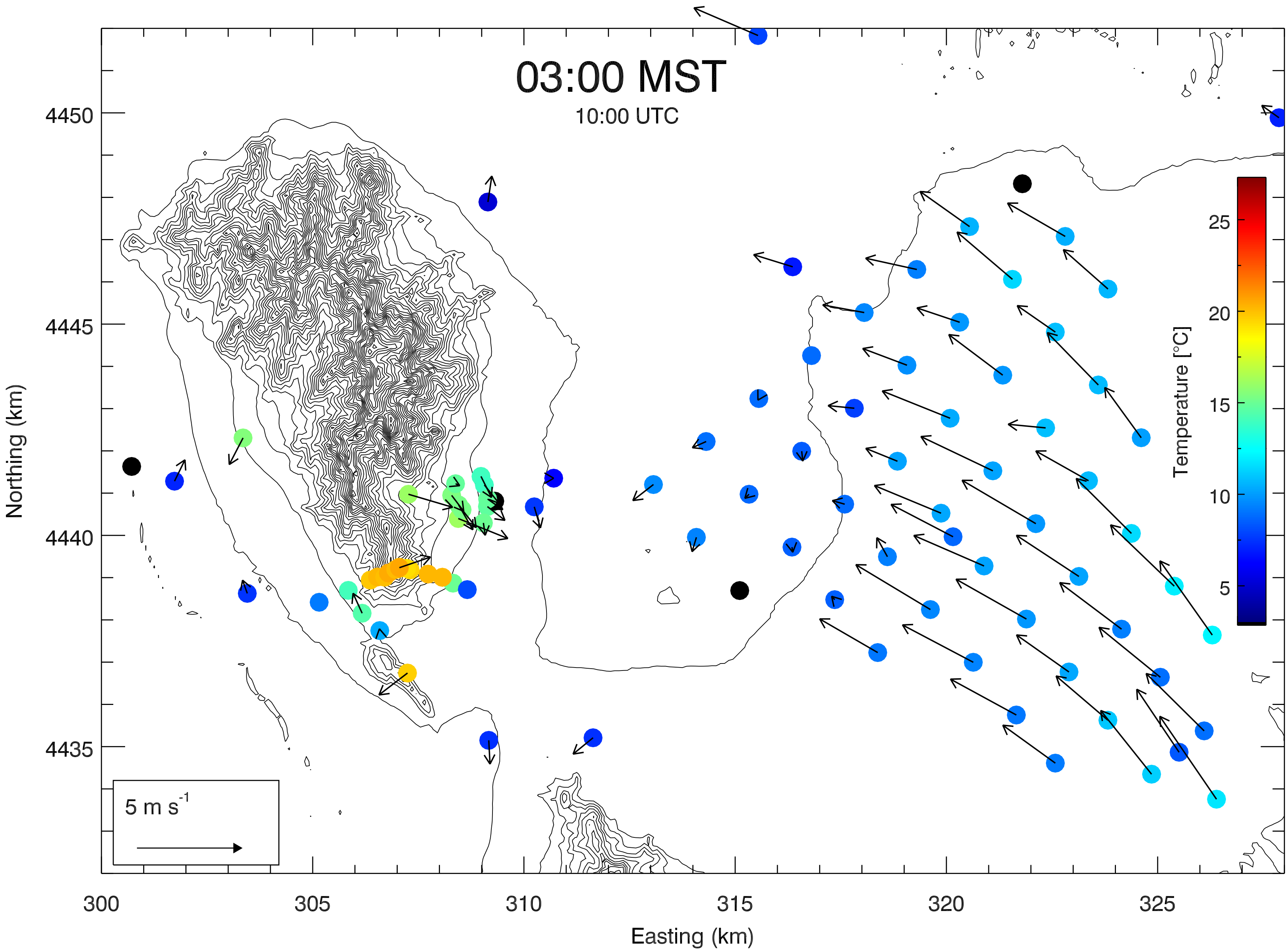


But not for long !

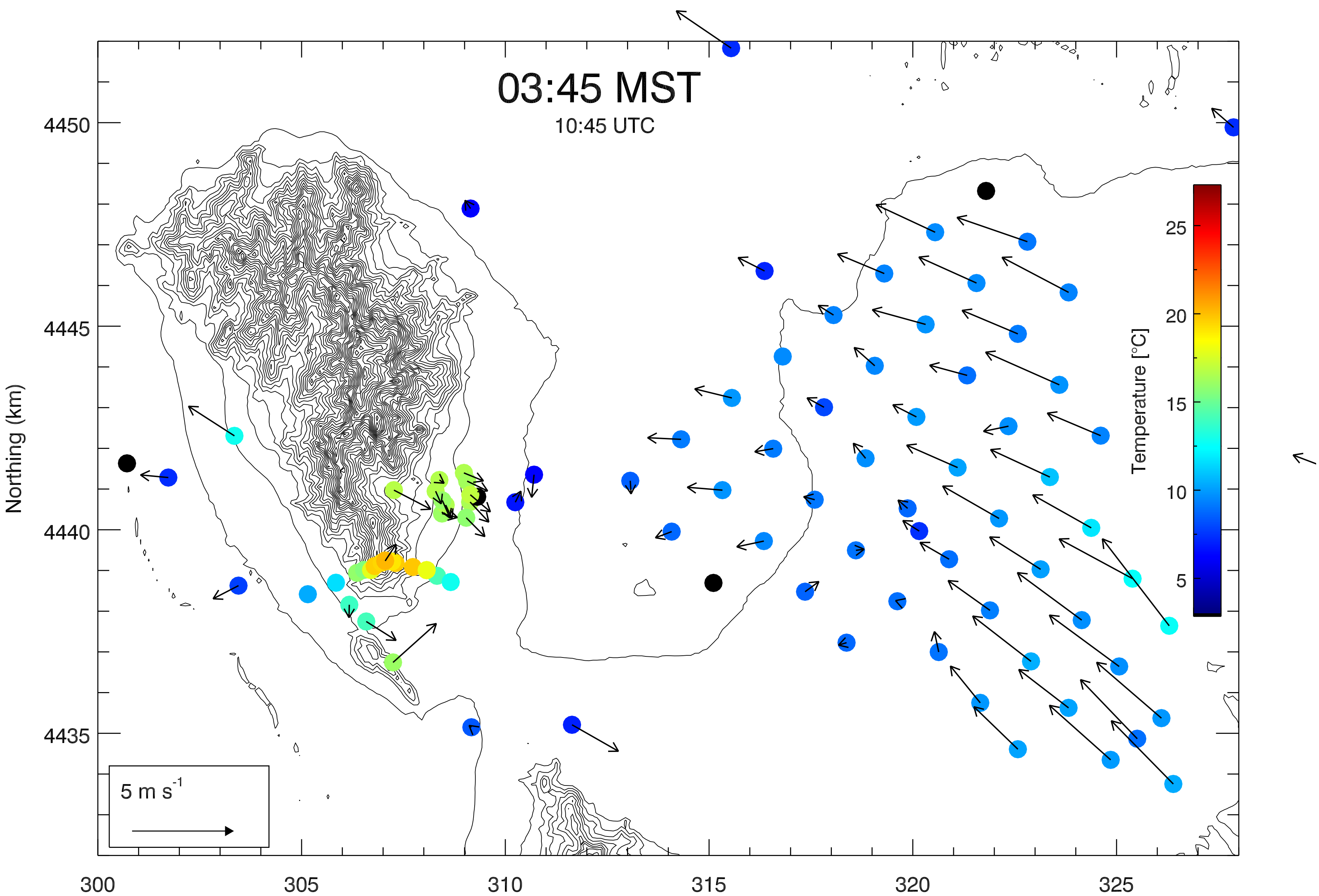
0240 MST: New pulse of cold air ‘washes up’ the lower East Slope, draining to the South. The flow on western miniSAMS grid now flowing south towards Big Gap.



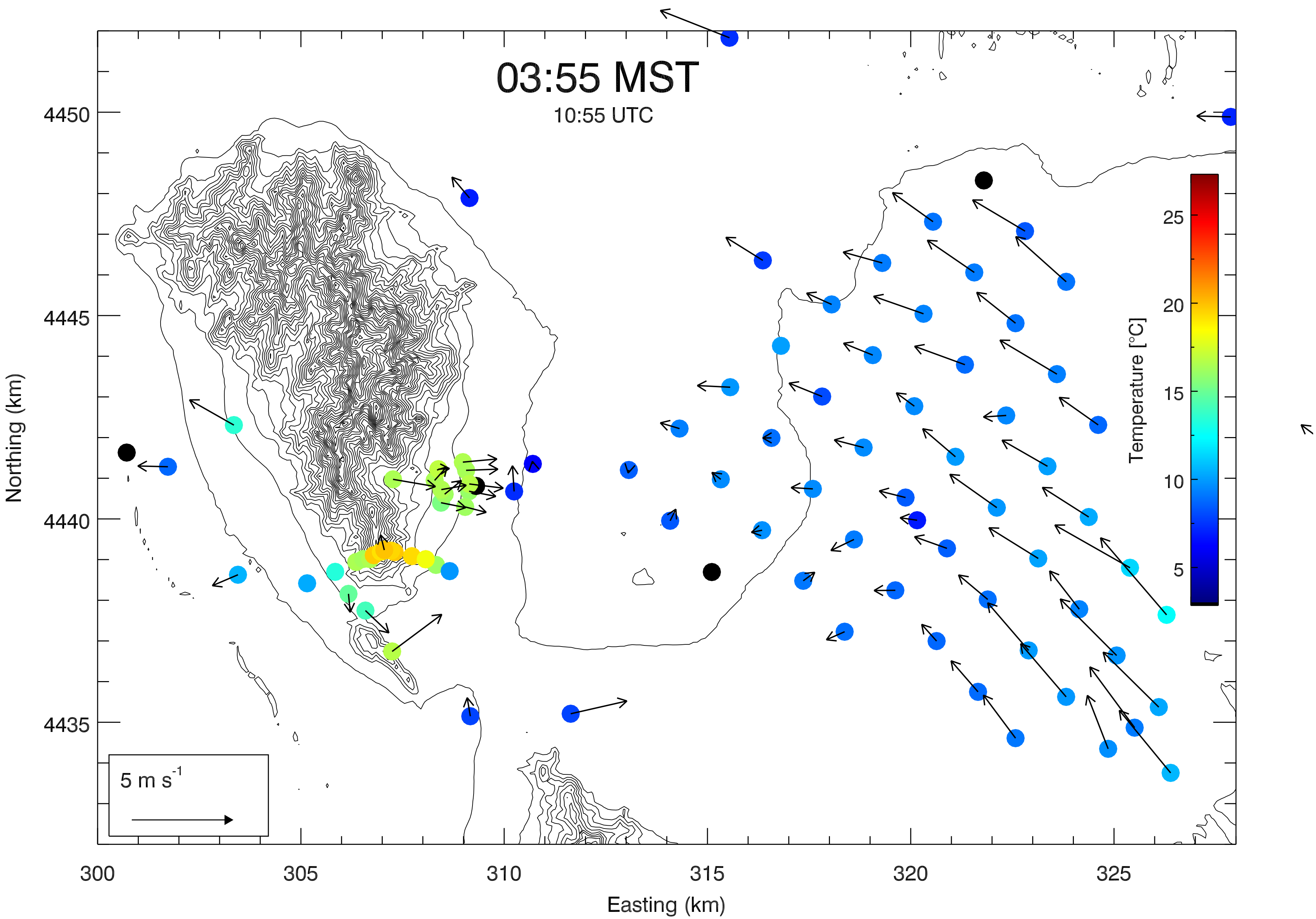
1 m s-1
0241 MST
upper slope
lower slope
PWID-1
PWID-78
Temperature [°C]
Wind Speed [m s-1]
Wind Direction [°]
Time [MST]
15.7°C
5.8°C
9.8°C
Height [km ASL]
Distance from Lidar [km]
[m s-1]



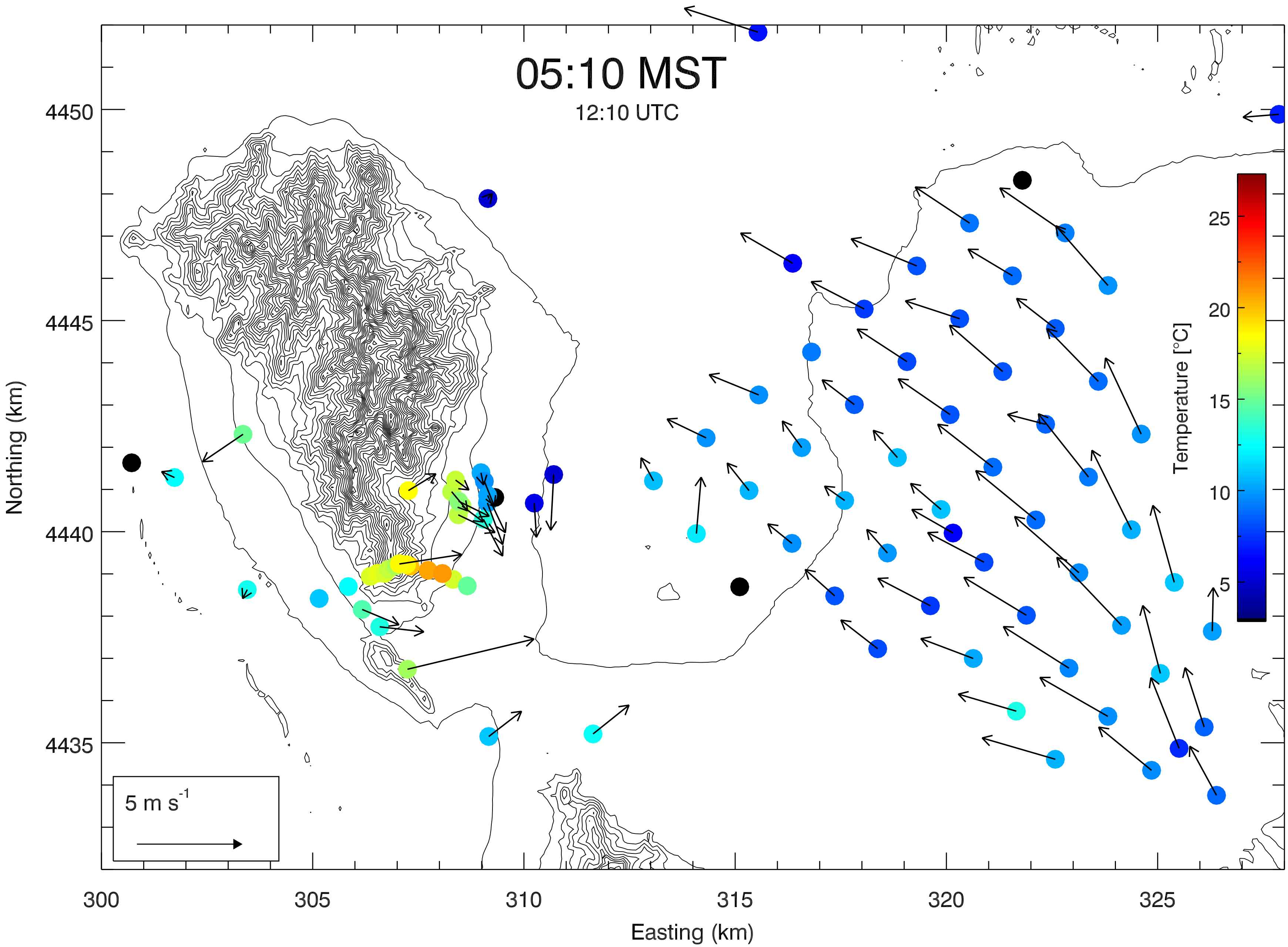
0300 MST: Calming of winds in eastern miniSAMS grind. Cold air retreating and stagnating. Valley circulation flowing over the colder air?



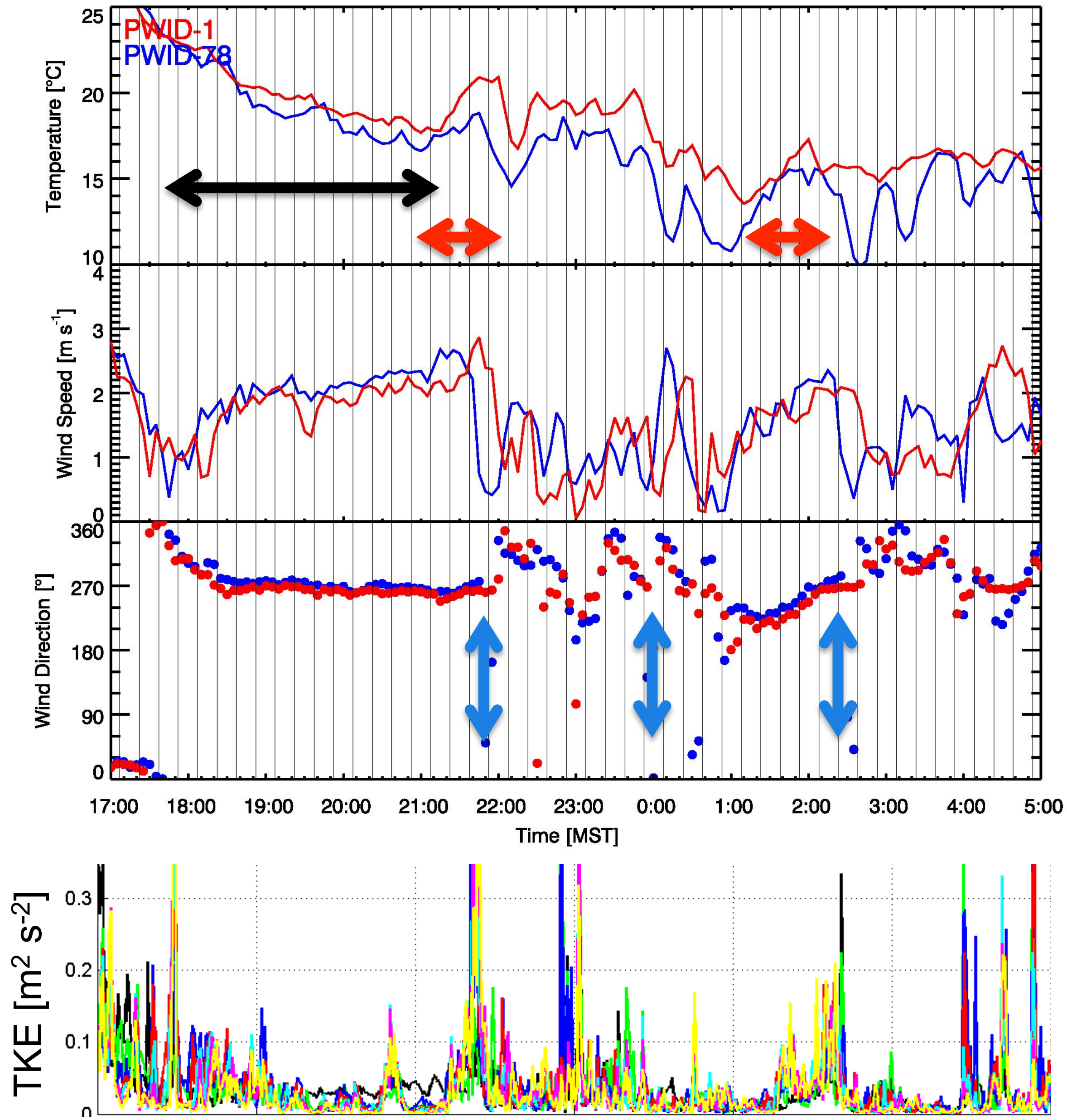
0345 MST: Southerly winds pick up at Sapphire Mountain -- Slope flow on East Slope deflection from towards south to towards north. Gap Flows reverse as well. Warming in Gap.



03:55 MST
10:55 UTC
5 m s^{-1}
Temperature [°C]
25
20
15
10
5
Northing (km)
4450
4445
4440
4435
Easting (km)
300
305
310
315
320
325



0500-0600 MST: Eddy-like circulation sets up NE of the 'Big Gap'. Fairly strong flow seen across Sapphire Mountain. Cold air on slope.

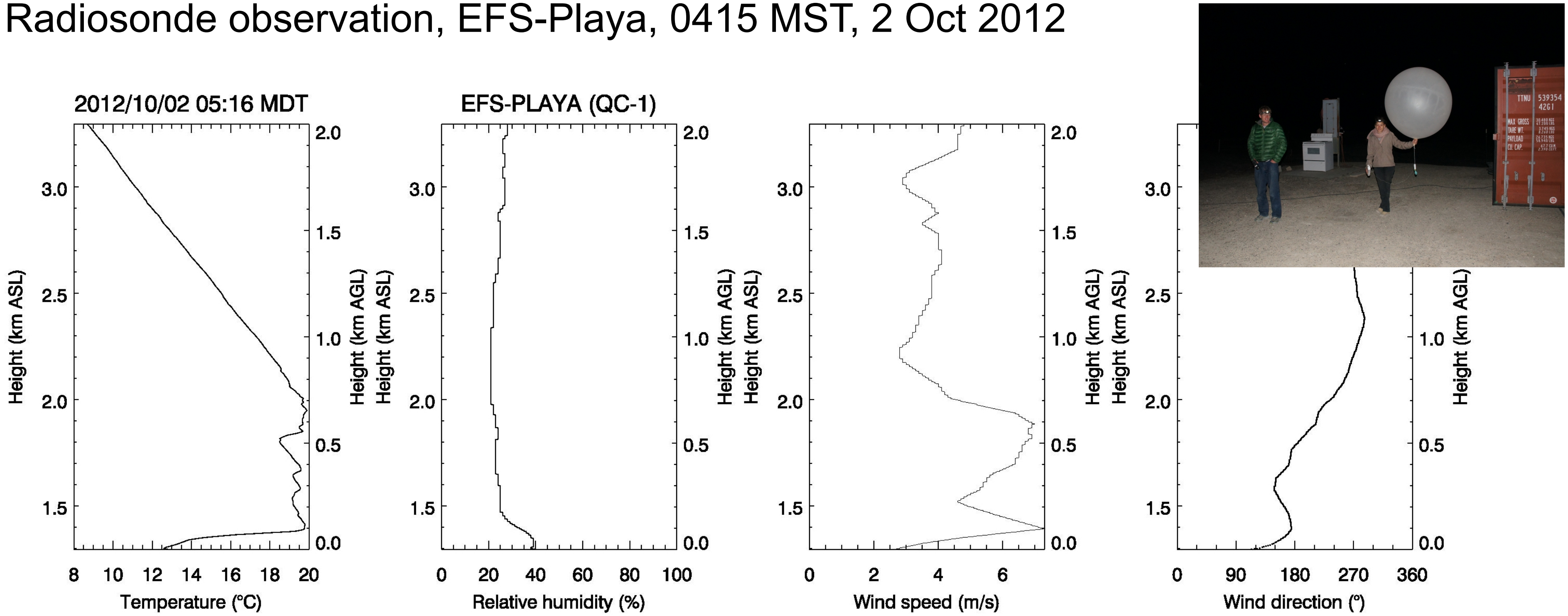


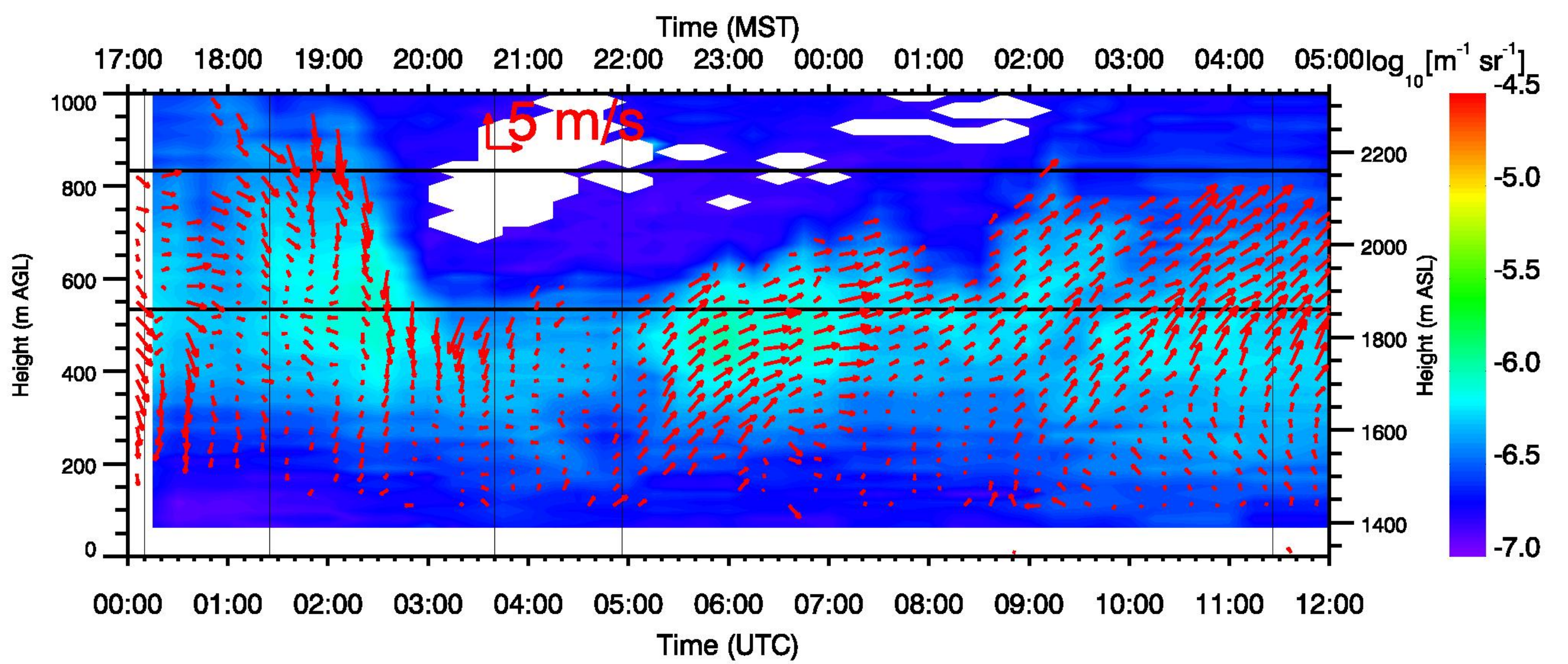
Downslope flow regime

Cold air surges, 'sloshing'

Warming phases

Radiosonde observation, EFS-Playa, 0415 MST, 2 Oct 2012





VAD retrieval
UU LiDAR
East Slope

Summary & Conclusions

- MATERHORN data has surface and upper air observations of unprecedented density – allows the visualization and analysis of complex flow interactions.
- Slope scale, basin scale, regional scale, and synoptic scale (or lack thereof) flows are observed.
- The temporal and spatial variability of flows is much larger than anticipated – even under no synoptic forcing.
- Regional scale nocturnal jets of (yet) unknown origin considerable modify the thermally driven surface flows in the complex terrain of DPG.
- Small terrain features are very important.
- This dataset should be resolved enough to provide challenging test material for of-state-of-the-science models and will lead to new model development.

Acknowledgements

- **Office of Naval Research ONR**
- Dugway Proving Grounds
- All MATERHORN participants