# New Insights into the January 2016 West Antarctic Melt Event from the AWARE Campaign and Climate Model Simulations


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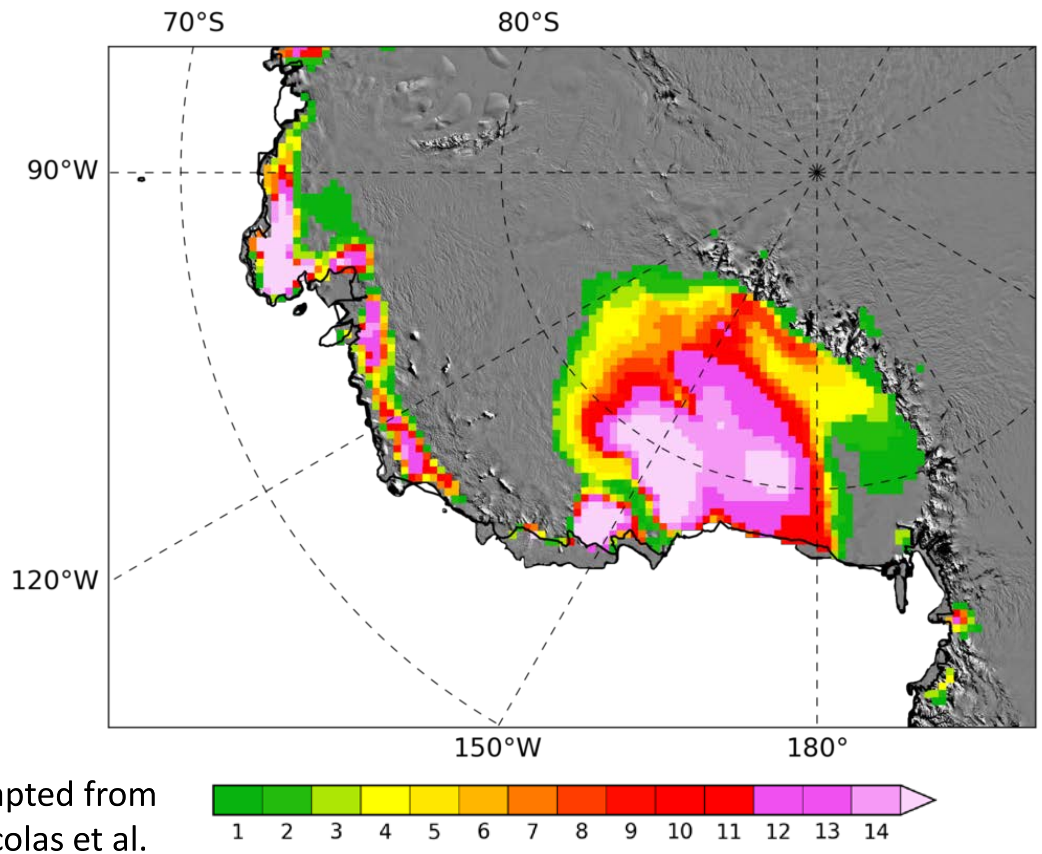
# Outline

- Recap of what happened in January 2016
- AWARE observations at WAIS Divide
- Large-scale atmospheric circulation
- Role of El Niño and the SAM
- Conclusions and implications for the future

# The melt event of January 2016

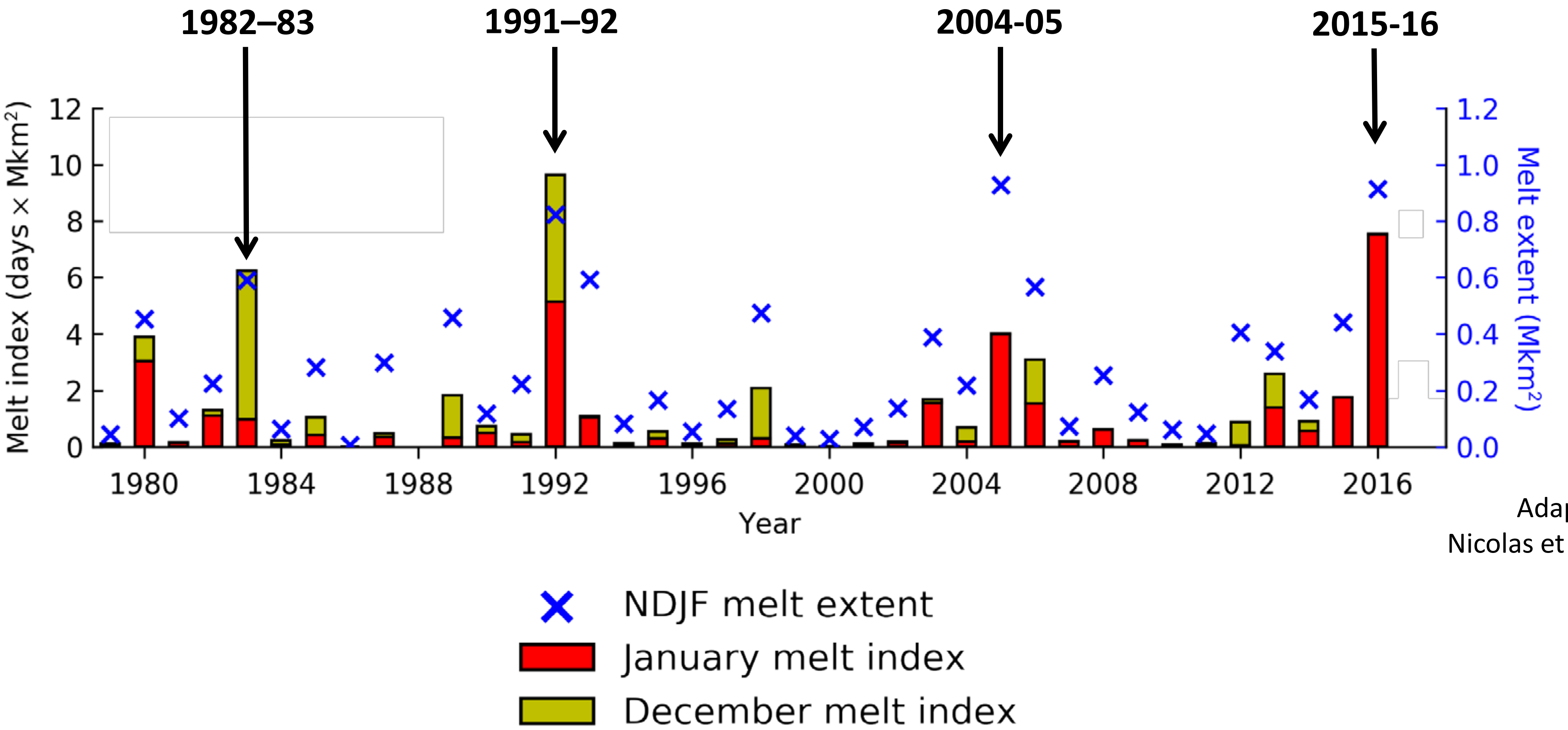



Adapted from Nicolas et al. (2017)

Melt days in January 2016
(based on SSMIS data from NSIDC)

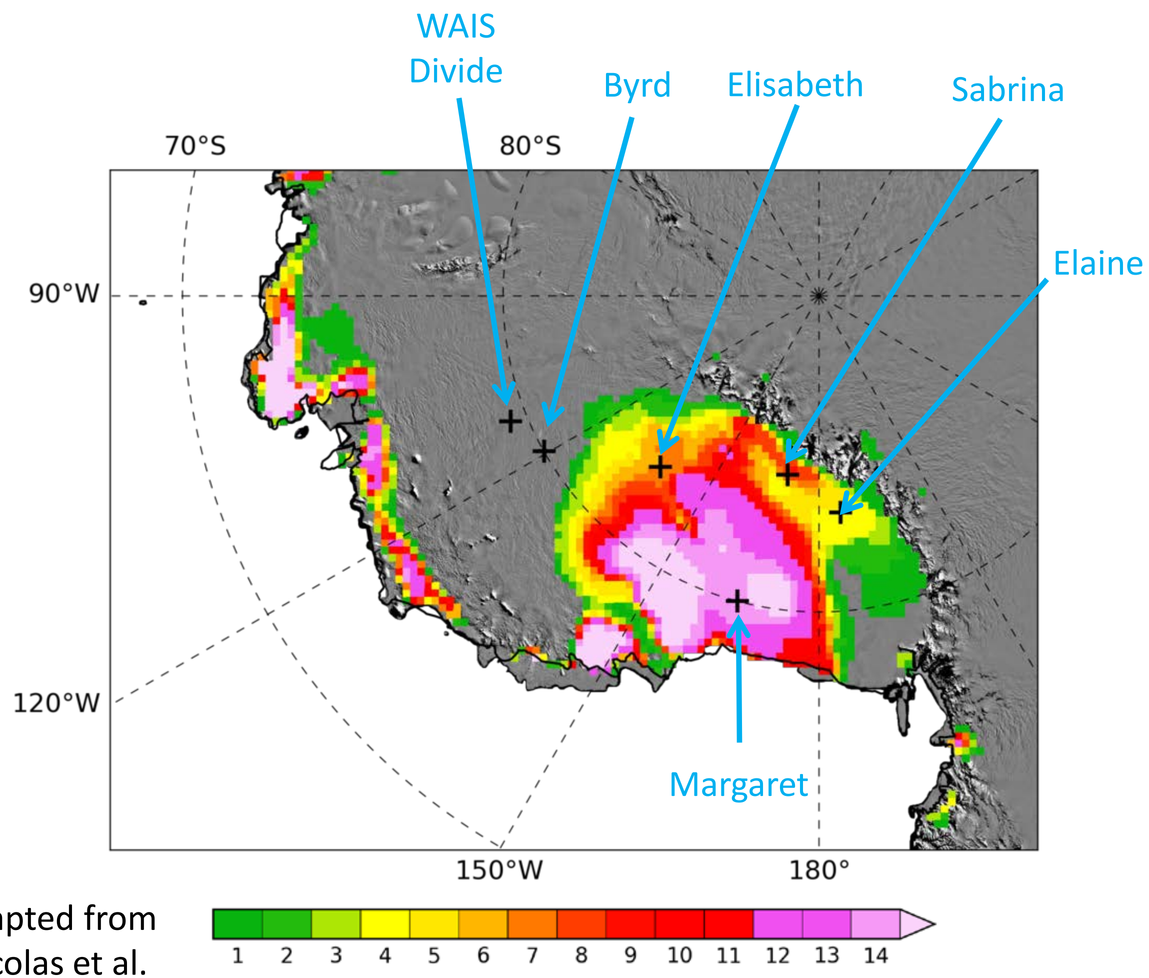
- Surface melting detected from PMW satellite data over large area of Ross Ice Shelf and Marie Byrd Land.
- Up to 15 days of surface melting in parts of the Ross Ice Shelf (January 10–25)
- One of the top 3 melt events in the Ross Sea sector of West Antarctica (in terms of melt duration and melt extent)

# Comparison with previous melt events




Adapted from
Nicolas et al. (2017)

# The melt event captured by AWSs

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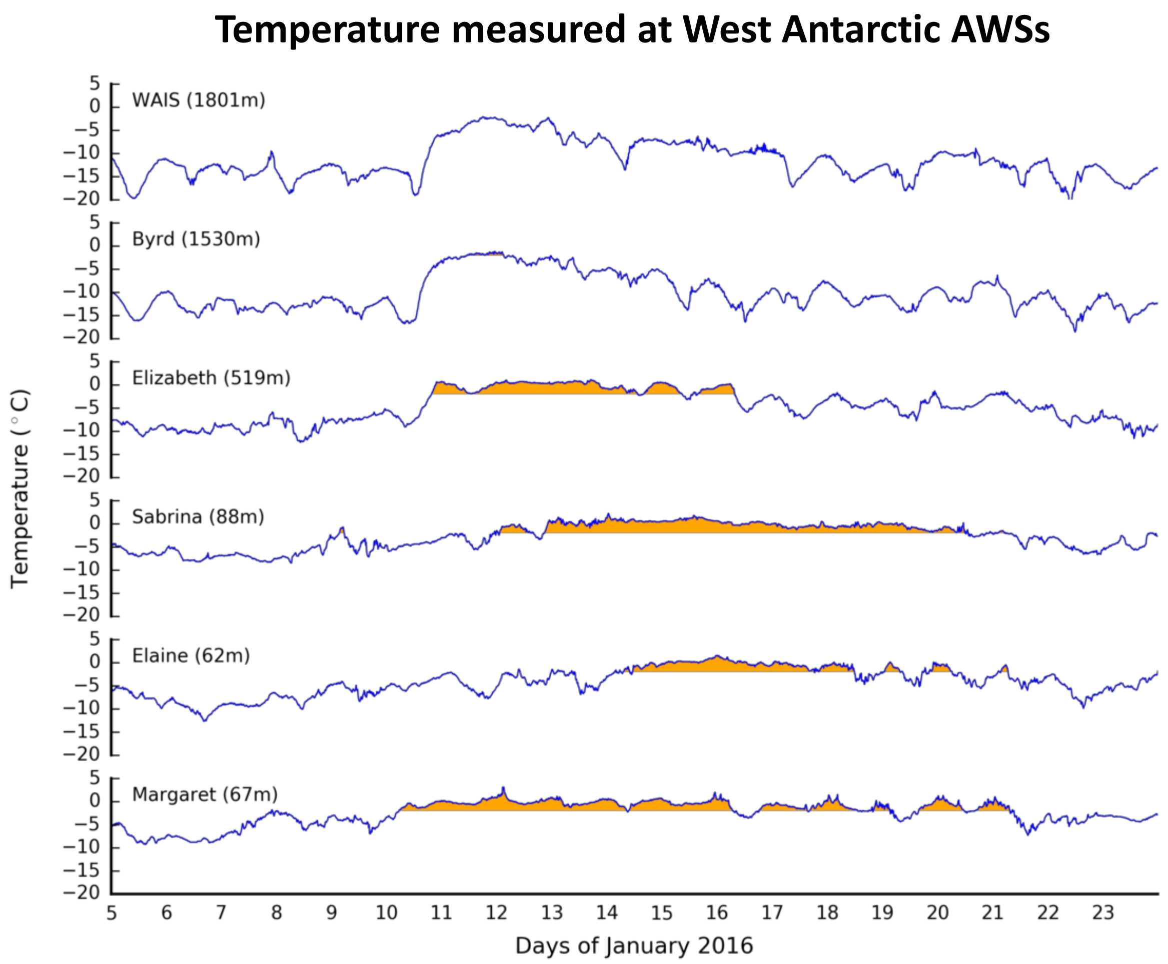



AWS data from AMRC/UW-Madison

# Near-melting conditions at WAIS Divide!

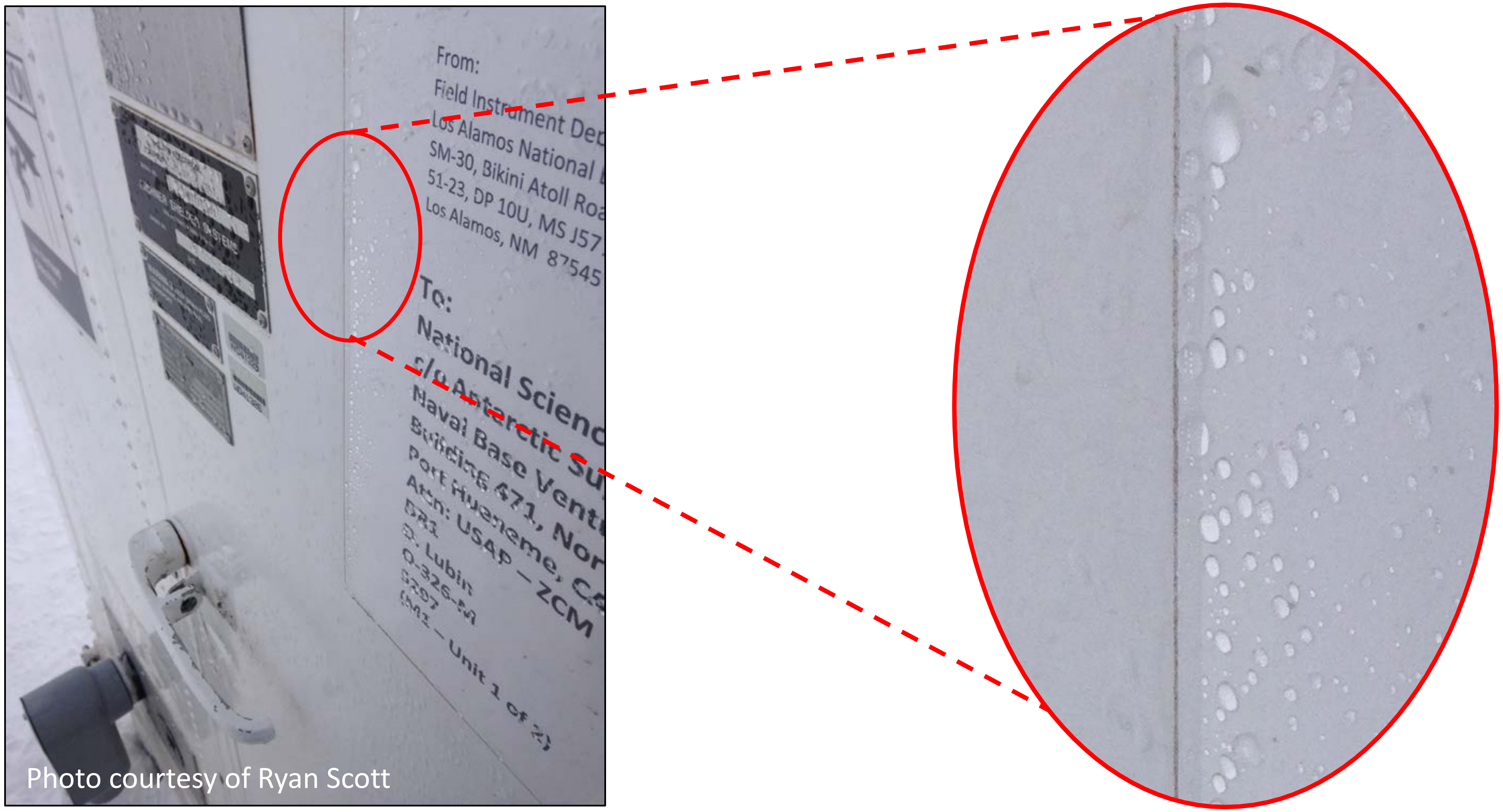
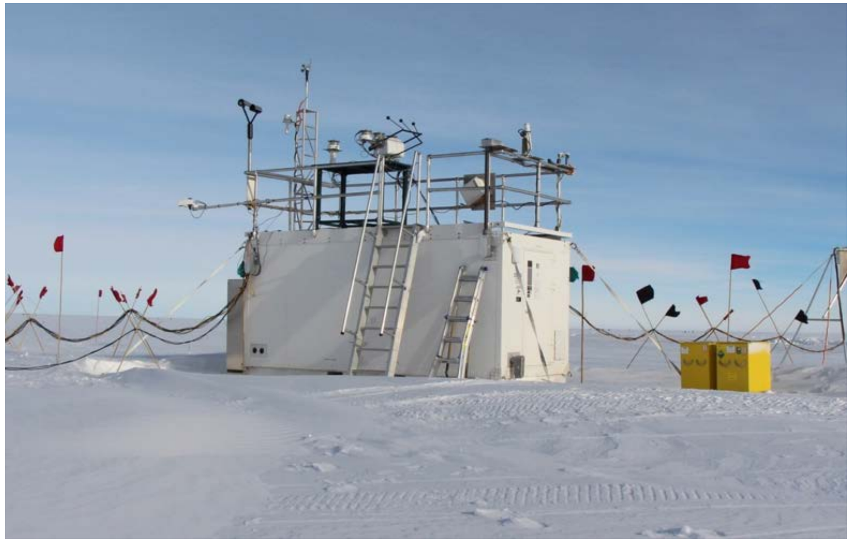


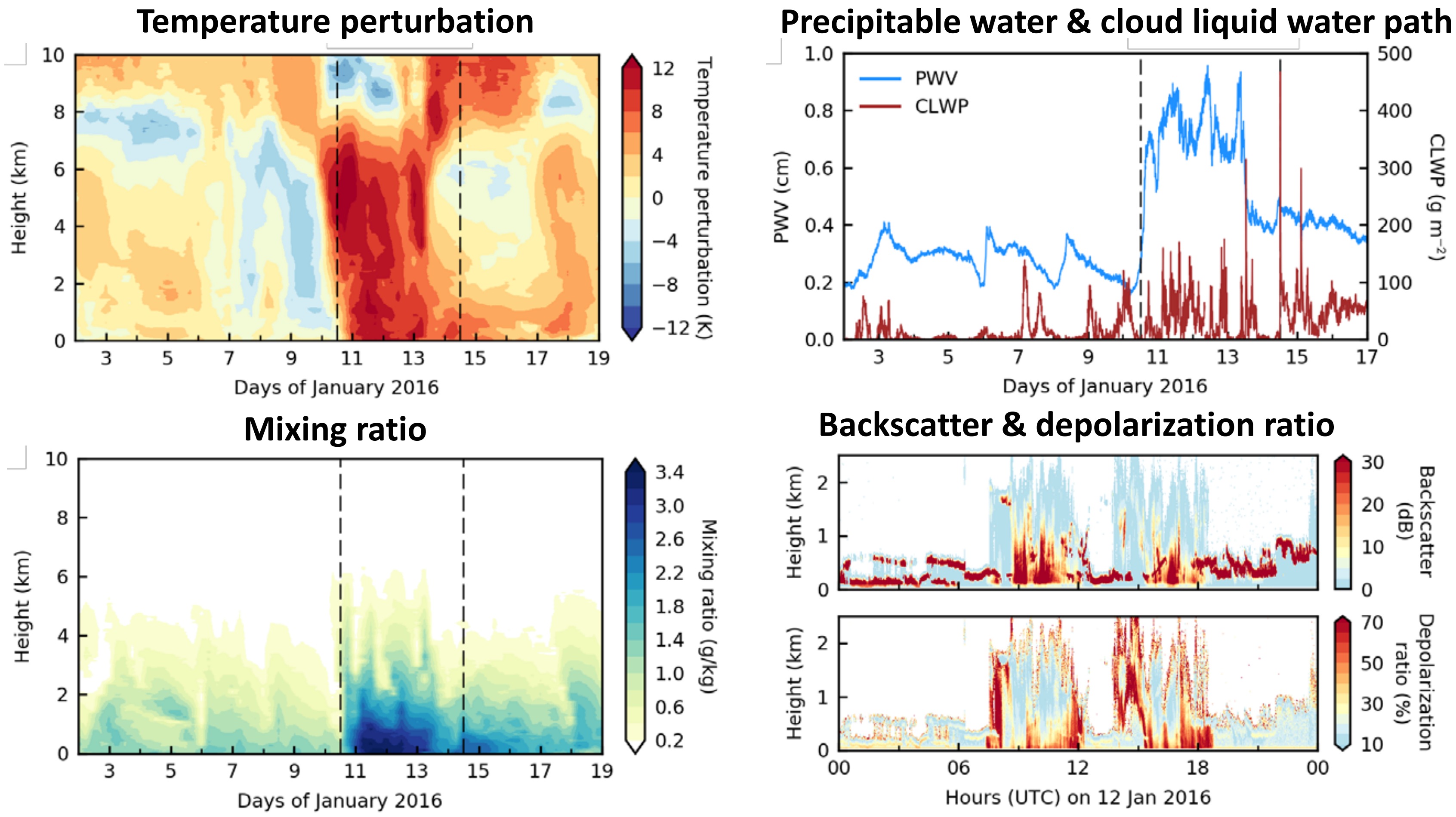

Photo courtesy of Ryan Scott

# AWARE observations at WAIS Divide



- **ARM West Antarctic Radiation Experiment (AWARE)** campaign at WAIS Divide from 4 Dec 2015 through 18 Jan 2016.
- Comprehensive cloud and radiation measurements from ARM Mobile Facility.
- Radiosonde launches every 6 hours (first upper-air observations from central West Antarctica since 1967!)

# AWARE observations at WAIS Divide




Nicolas et al. (2017)

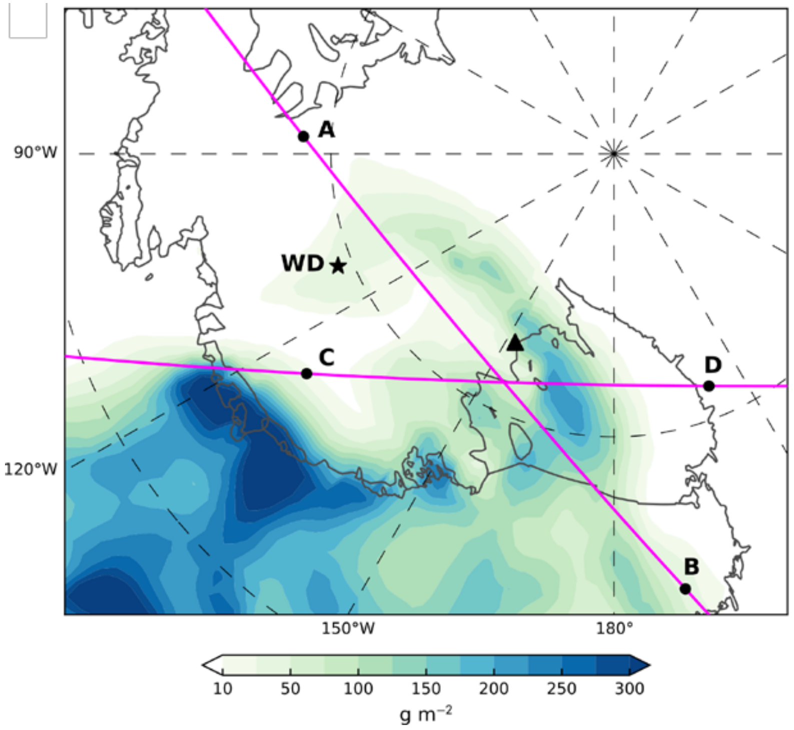
Sample of the observations collected by AWARE at WAIS Divide showing:

- ➢ Large, deep temperature and moisture perturbations associated with the warm marine air intrusion.
- ➢ Abundance of liquid water clouds.

# Widespread liquid water clouds

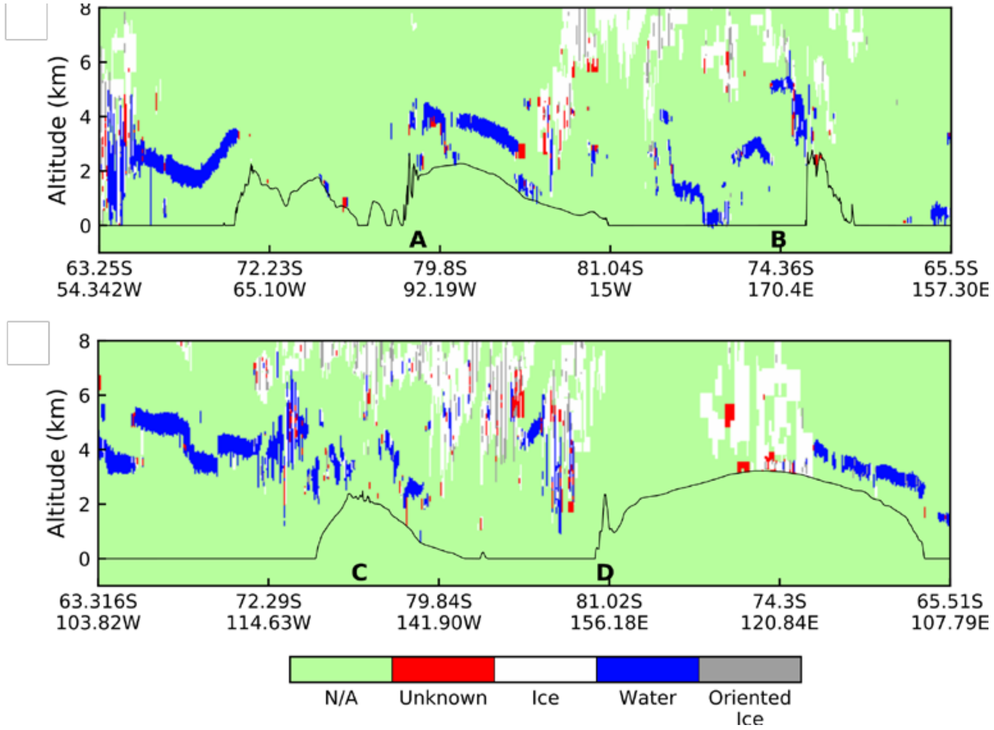
**ERA-Interim Cloud Liquid Water Path**

12 Jan 2016 @ 06 UTC




**CALIPSO Lidar Retrievals of Cloud Phase**

12 Jan 2016 @ 0415 UTC (top) and 0730 UTC (bott)



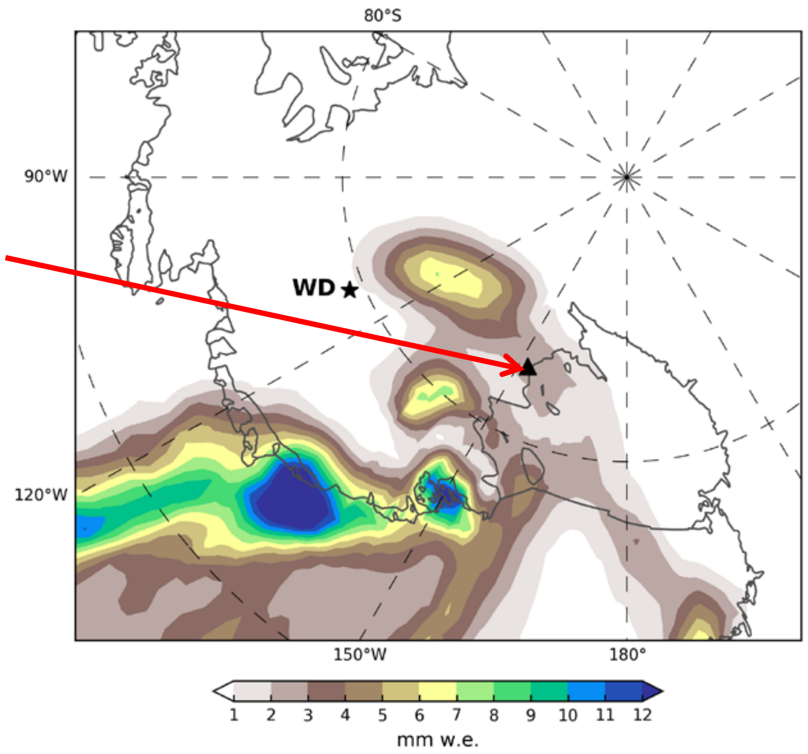

Nicolas et al. (2017)

- Widespread liquid water clouds based on ERA-Interim and CALIPSO.
- Consistent with AWARE measurements at WAIS Divide

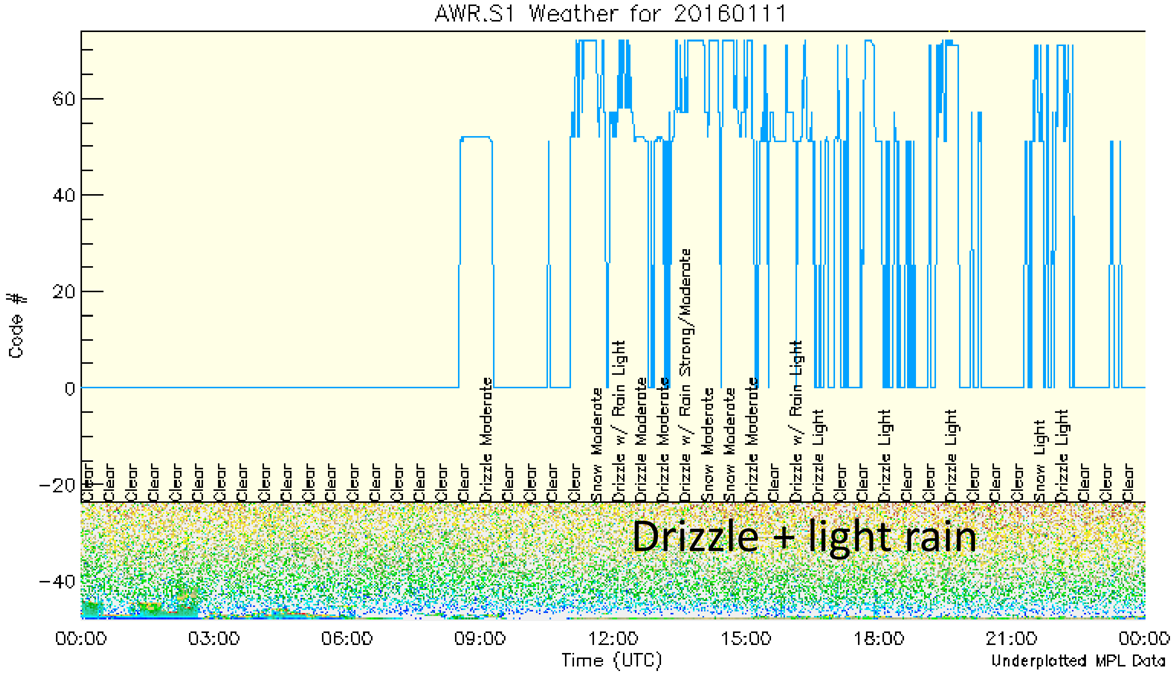
# Rain on the ice

Rain witnessed by field party on Kamb IS

**ERA-Interim Accumulated Rain**

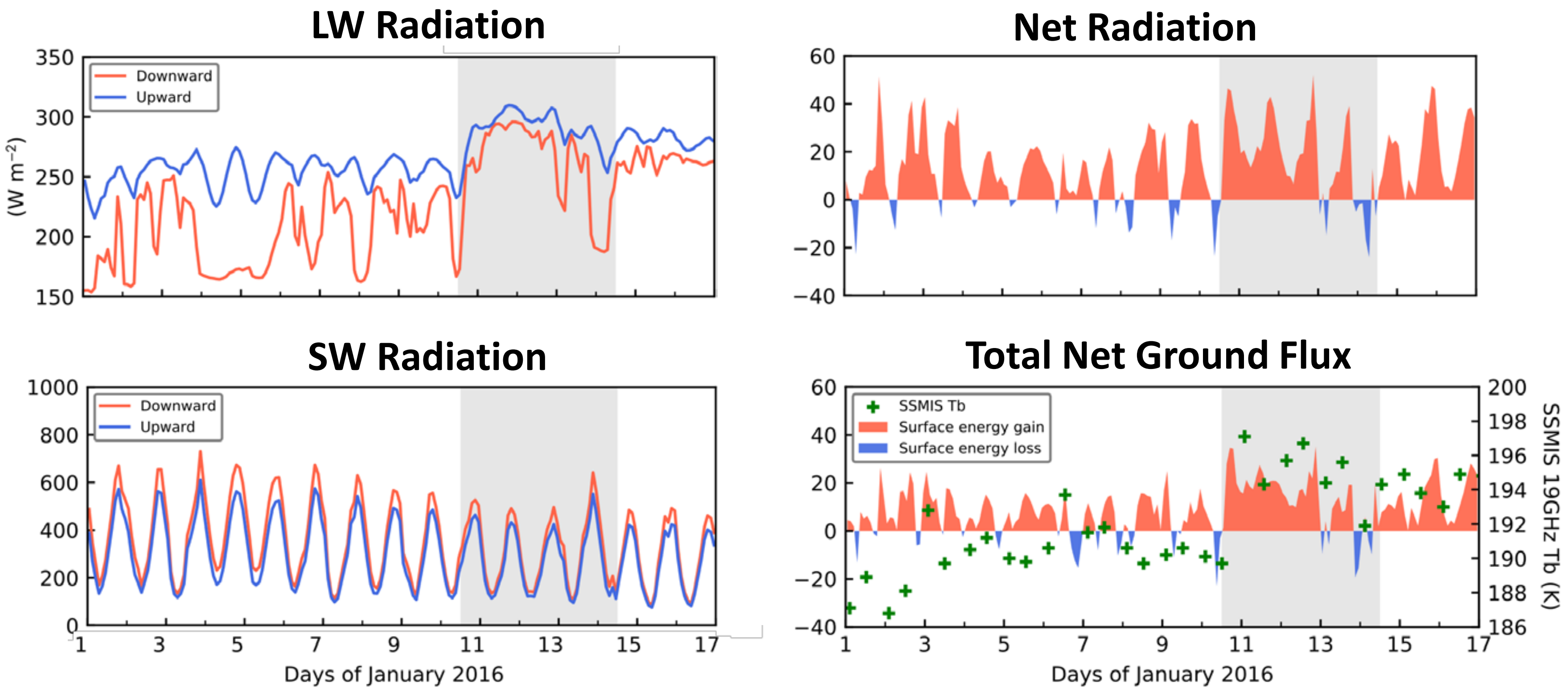



**Observations from WAIS Divide**




- Rain also simulated by ERA-Interim over West Antarctica early during the melt event.
- Corroborated by observations at WAIS Divide and field party on Ross Ice Shelf.

# Surface energy budget at WAIS Divide




Nicolas et al. (2017)

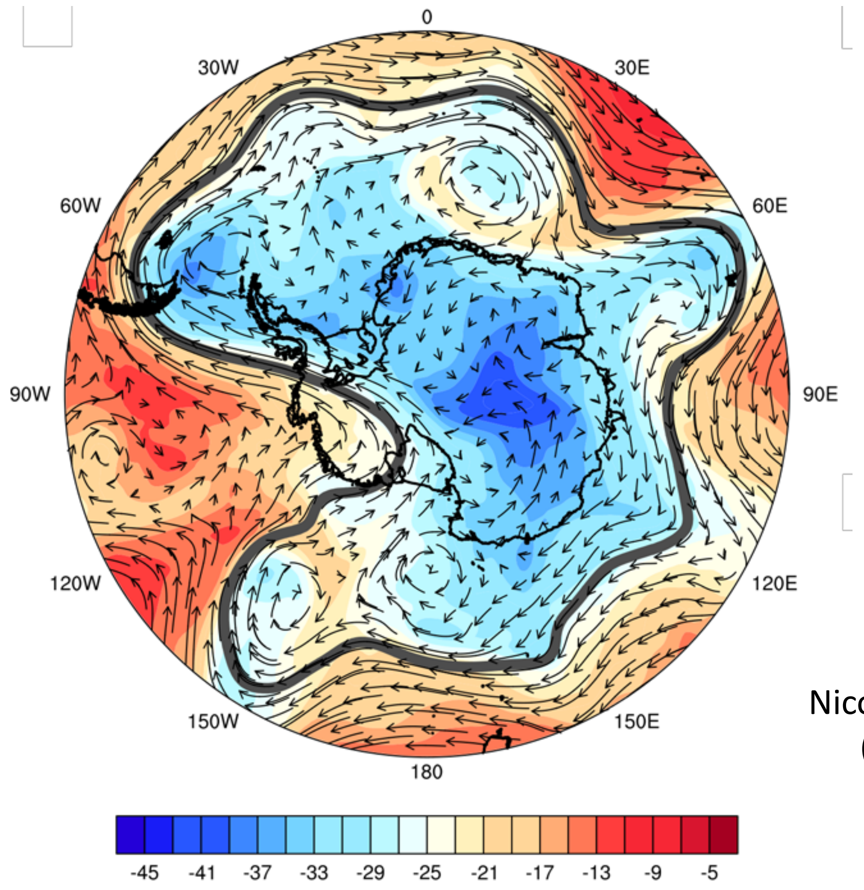
- Marked increase in the net energy input into the snowpack, mainly due to enhanced downwelling LW radiation.
- PMW satellite data are consistent with the surface observations

# Large-scale atmospheric circulation

- Prominent pressure ridge created dent in circumpolar westerly flow.
- Strong warm advection toward Marie Byrd Land and Ross Ice Shelf.
- Ridge and warm air advection strongest at the beginning of the melt event (first 3–4 days).

**500-hPa Temperature and Wind**

00 UTC 12 Jan 2016

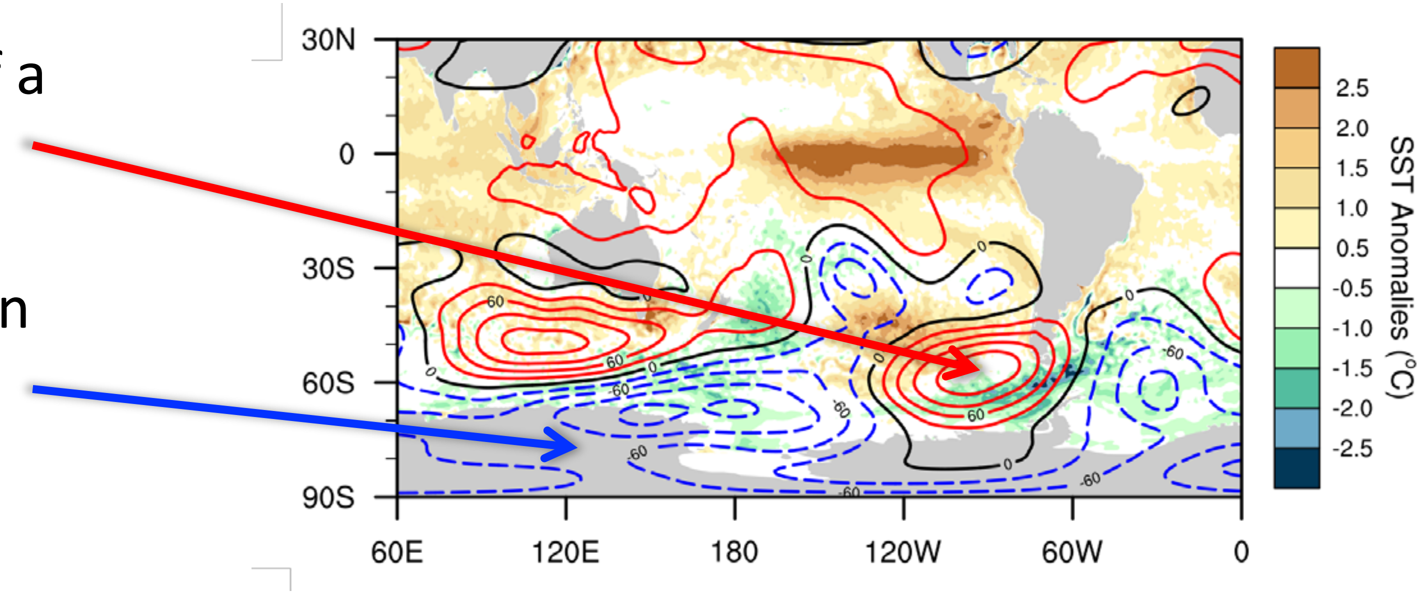



Nicolas et al. (2017)

# Large-scale atmospheric circulation

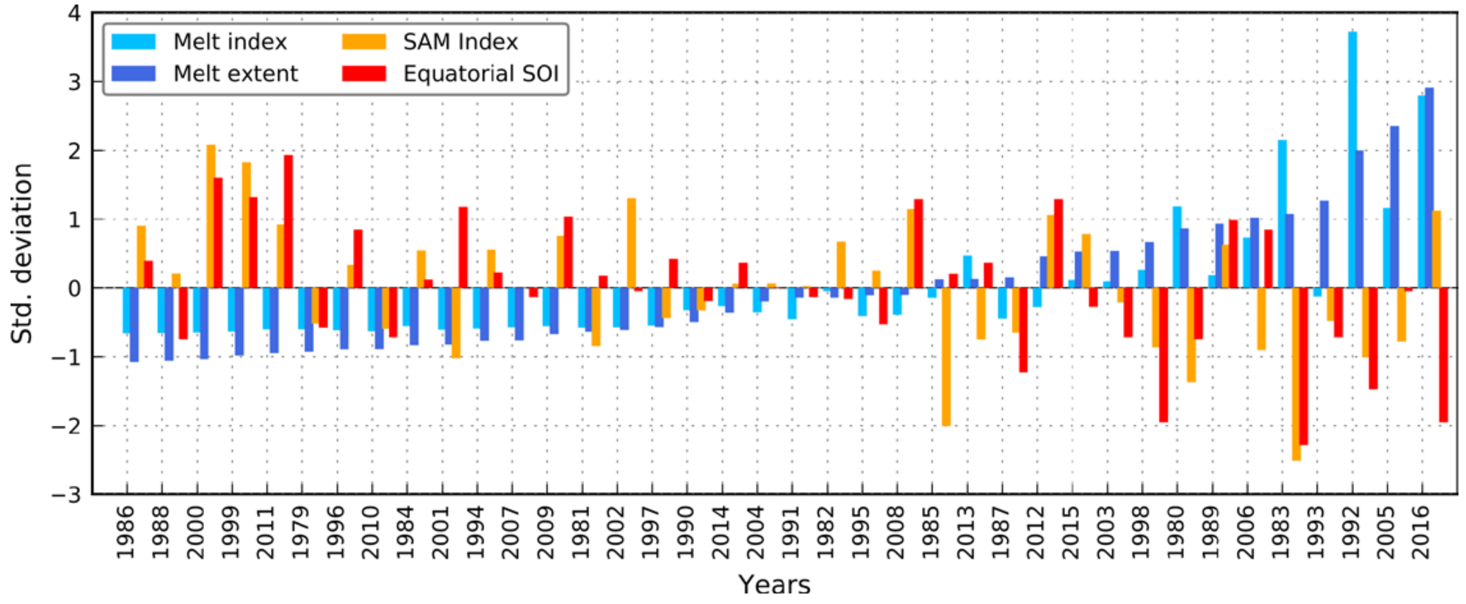
- Strong 2015–16 El Niño event near peak intensity in Jan 2016.
- The pressure ridge was part of a typical El Niño teleconnection pattern in the South Pacific.
- At the same time, the Southern Annular Mode (SAM) was in a strongly positive phase.

**Monthly mean SST and Z500 anomalies in Jan 2016**




Nicolas et al. (2017)

# El Niño, SAM, and West Antarctic melt

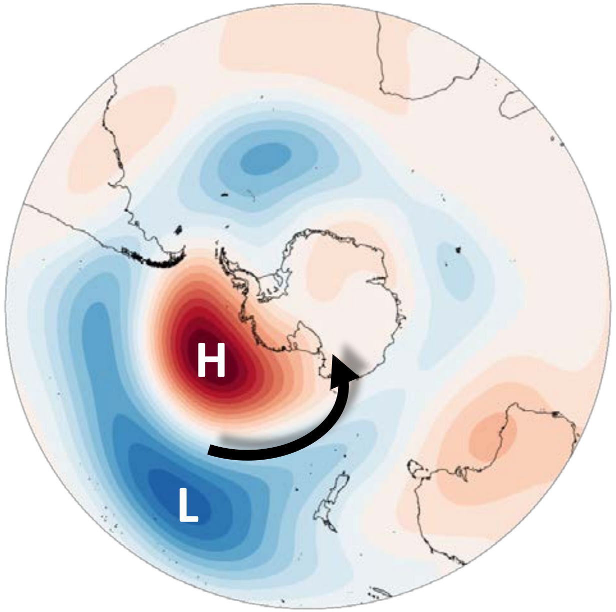



Nicolas et al. (2017)

- In the figure, the years are ranked by order of increasing West Antarctic melt extent.
- In general, less melt during La Niña-like conditions (SOI>0) and positive SAM, and more melt during El Niño-like conditions (SOI<0) and negative SAM.
- However, there are a number of exceptions to the rule (Jan 2016 being one of them).

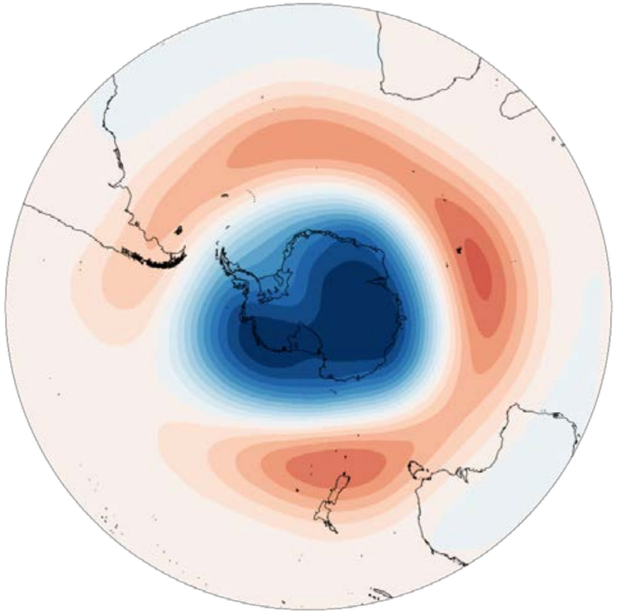
# Hypotheses

**El Niño teleconnection**




El Niño conditions are favorable to West Antarctic melt, therefore the strong El Niño contributed to the Jan 2016 melt event

**Positive SAM**



Positive SAM conditions hamper warm air advection to the Ross Ice Shelf, therefore the positive SAM mitigated the magnitude of the melt event

# Modeling experiment

- Our hypotheses are supported by a relatively large body of literature, but we had to do more to convince the reviewers!
- We conducted a series of idealized simulations with the CAM4 model forced with tropical SSTs reflective of strong eastern-Pacific El Niño events for a total of 45 years.
- Model results:
  - More warm events occur overall, consistent with the impact of El Niño teleconnection pattern on West Antarctic temperatures.
  - Warm events are rarely associated with a positive SAM.
  - Cold events are rarely associated with a negative SAM.

| | Temperature anomaly | | Row totals |
|---|---|---|---|
| | Warm | Cold | |
| +SAM | 3 | 8 | 11 |
| Neutral SAM | 14 | 5 | 19 |
| –SAM | 15 | 0 | 15 |
| Column totals | 32 | 13 | 45 |

"Warm" and "cold" refer to averaged Dec-Jan temperature anomalies over Marie Byrd Land

# Conclusions

- The Jan 2016 melt event in West Antarctica was one of the 2–3 most prominent in close to 40 years.
- There is strong evidence that:
  - The strong 2015–16 El Niño event contributed to the melt event.
  - The positive SAM before/during the melt event mitigated the magnitude of the melting (extent, duration)
- In other words, without the positive SAM, the melt event may have been more prolonged/extensive and thus an all-time record.
- Accurate projections of future West Antarctic melt events will require model improvements in a number of areas, such as:
  - Tropical teleconnections to Antarctica.
  - Microphysical cloud properties and their impacts on radiative fluxes.

# Implications for the future

- More frequent extreme El Niños projected for the future (Cai et al., 2014).
- Future changes in the SAM in DJF influenced by competing effects of stratospheric ozone recovery and increasing GHG concentrations.
- More El Niños-driven melt events could occur regardless of changes in the SAM.
- The melt event occurred in a critical area with a large potential for retreat (DeConto and Pollard, 2016).

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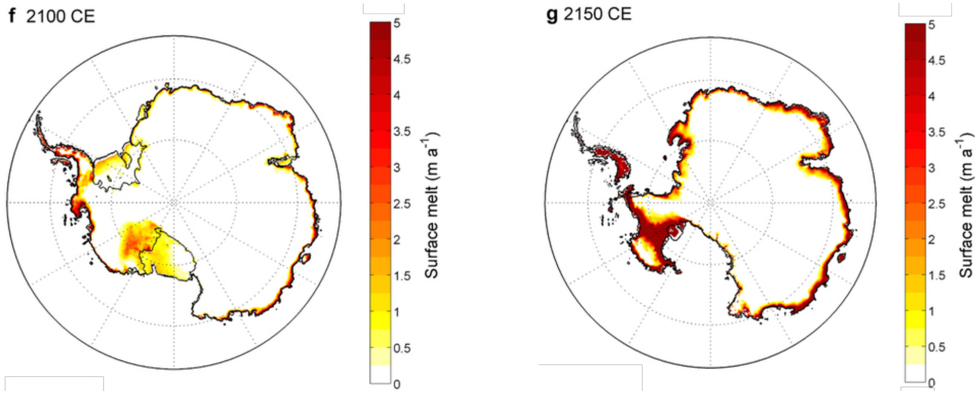
**Increasing frequency of extreme El Niño events due to greenhouse warming**

Wenju Cai[1,2]*, Simon Borlace[1], Matthieu Lengaigne[3], Peter van Rensch[1], Mat Collins[4], Gabriel Vecchi[5], Axel Timmermann[6], Agus Santoso[7], Michael J. McPhaden[8], Lixin Wu[2], Matthew H. England[7], Guojian Wang[1,2], Eric Guilyardi[3,9] and Fei-Fei Jin[10]

**Projections of Antarctic surface melt and coastlines under RCP8.5 emission scenario**




DeConto and Pollard (2016)