Precipitation and atmospheric rivers from sub-Antarctic Chile to Antarctic Peninsula: transition between rain and snowfall

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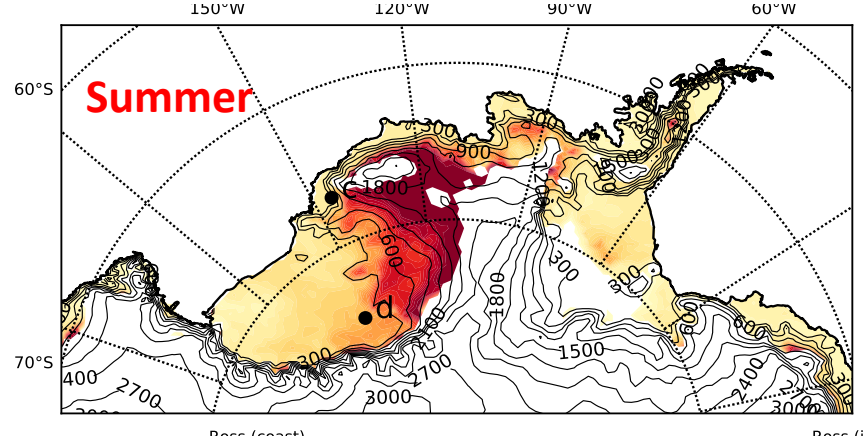
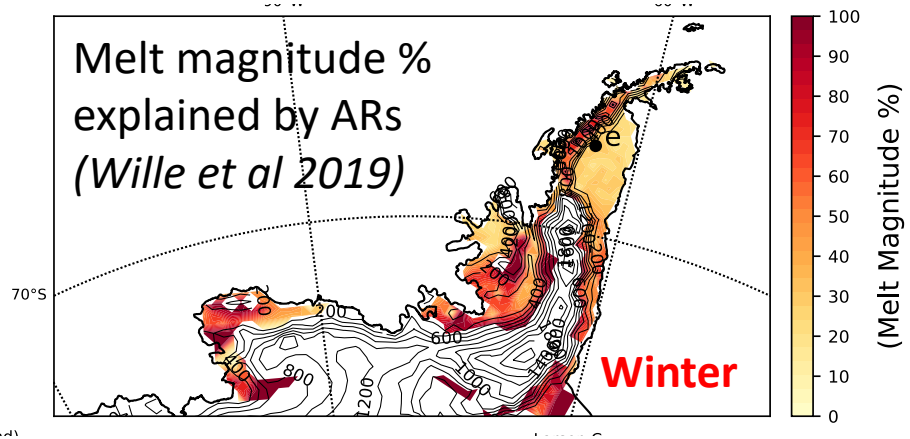
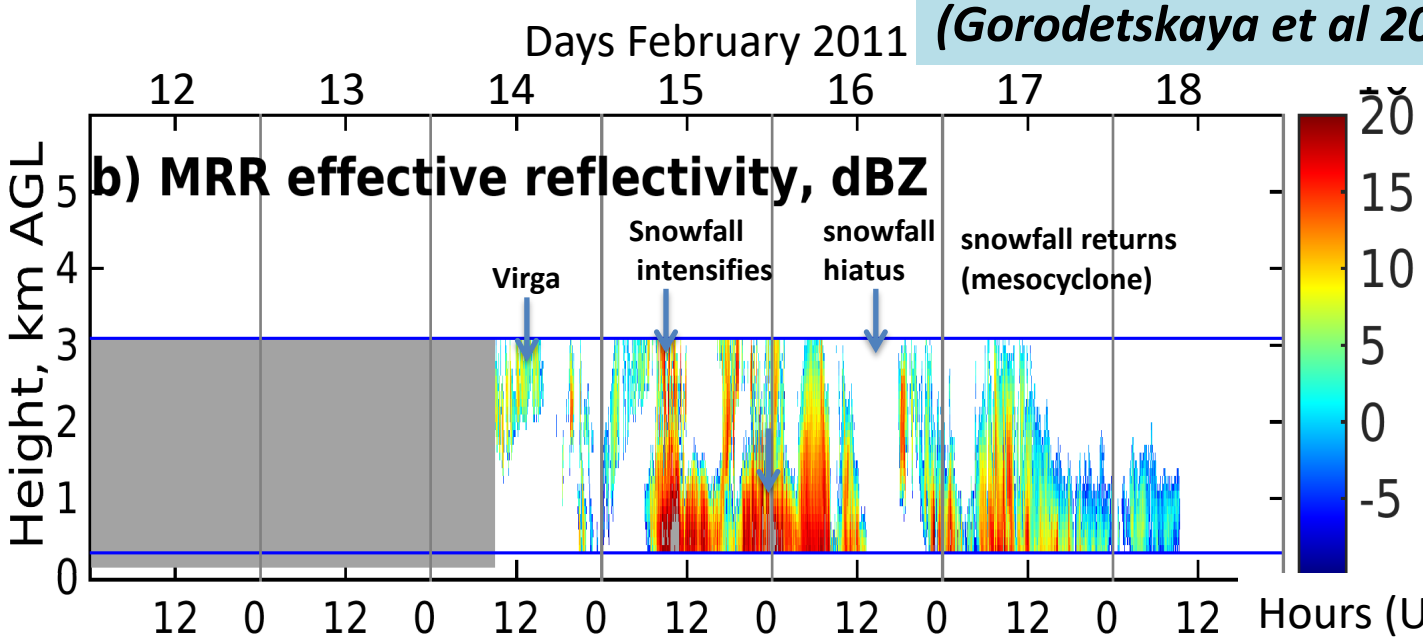
ARs in Antarctica

...ARs bring INCREASED TEMPERATURES and MELT, eg: T record at the Antarctic Peninsula (*Bozkurt et al 2015*) and major melt events in West Antarctica *(Wille et al 2019):*





...and ARs bring anomalous SNOWFALL...
(Gorodetskaya et al 2014):



One of anomalous precipitation events caused by an AR recorded by radar at Princess Elisabeth station 12-18 Feb 2011 (*Gorodetskaya et al 2015*)

- **ARs have strong signatures in the vertical atmospheric profiles**
- **Recent reanalyses struggle to reproduce the low-level jet, humidity increase and thus moisture transport**

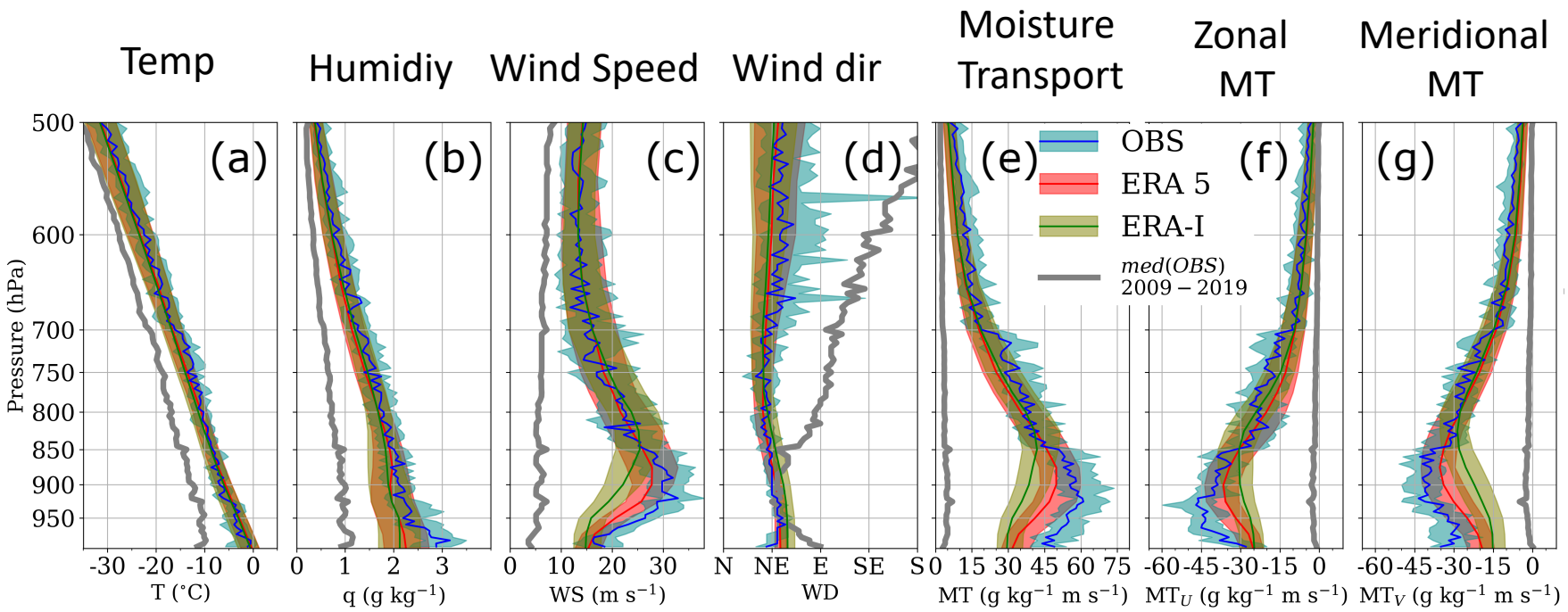


Figure: **composites of the AR profiles for SYOWA station, 2009-2019**: observations (radiosondes) vs ERA5 and ERA-Interim reanalyses

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https://doi.org/10.1007/s00376-020-9221-8

Here we show a special case:

- **AR affecting both sub-Antarctic South America and Antarctic Peninsula**
- **AR signatures in radiosonde profiles**
- **Impacts of ARs in southern S America: increased IWV and cloud liquid**
- **Impacts of ARs at AP: thick clouds (liquid-containing) -> surface warming (night) and cooling (day) + precipitation as RAIN and SNOW**

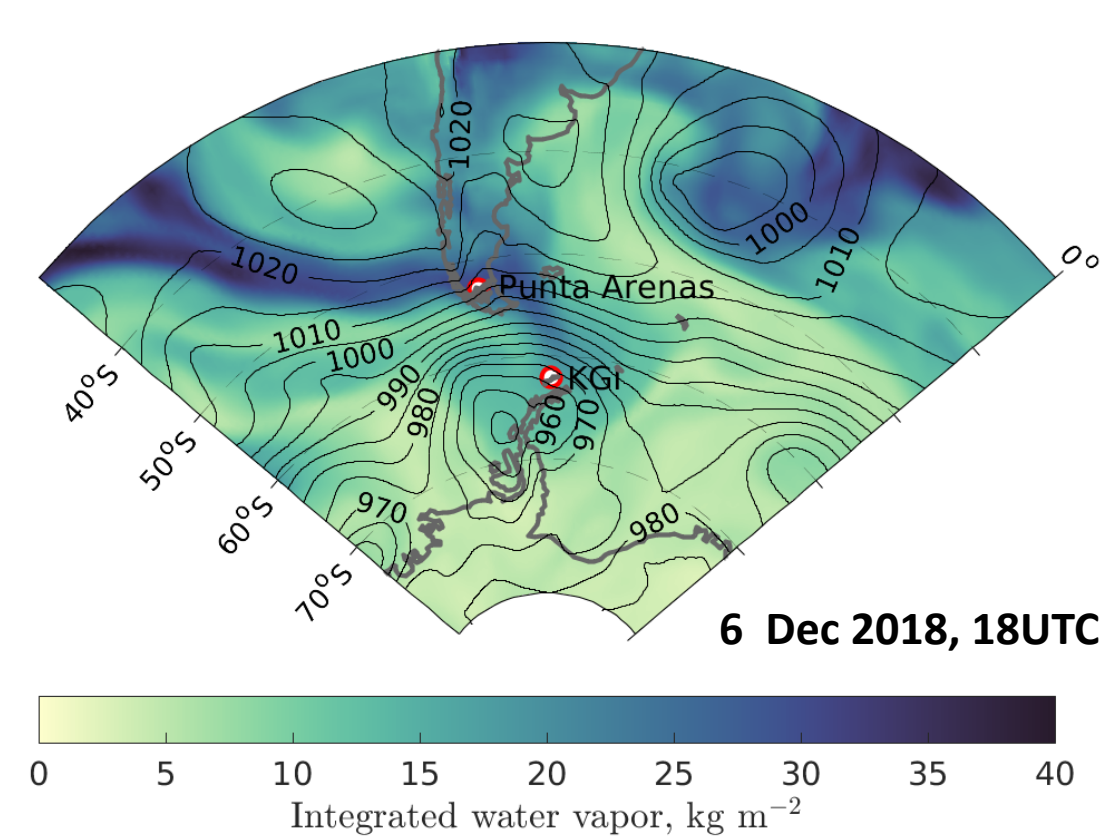


Fig. 11a/section 5 in Bromwich et al YOPP review (2020, ©BAMS)
https://doi.org/10.1175/BAMS-D-19-0255.1

Figure shows an AR stretching from the Pacific Ocean via southern South America and continuing to the Atlantic/Southern ocean ending at the northern tip of of the Antarctic Peninsula

Punta Arenas (southern Chile) *and* King George Island (KGI, north of Antarctic Peninsula) are the locations where observations were made

...The Year of Polar Prediction Special Observing Period (15 Nov 2018 – 15 Feb 2019): unprecedented measurements allowed us to study in detail Atmospheric Rivers vertical structure and impacts

Measurements from three YOPP projects are used:

1) **CAALC (Escudero station, King George Island, AP):** "Characterization of the Antarctic Atmosphere and Low Clouds" (Chile/USA)

2) **National Antarctic Program YOPP project at King Sejong station (King George Island, AP)** (South Korea)

3) **DACAPO-PESO (Punta Arenas, Chile):** "Dynamics, Aerosol, Cloud, And Precipitation Observations in the Pristine Environment of the Southern OCEAN" (TROPOS/U. Leipzig, Germany/U Magallanes, Chile)

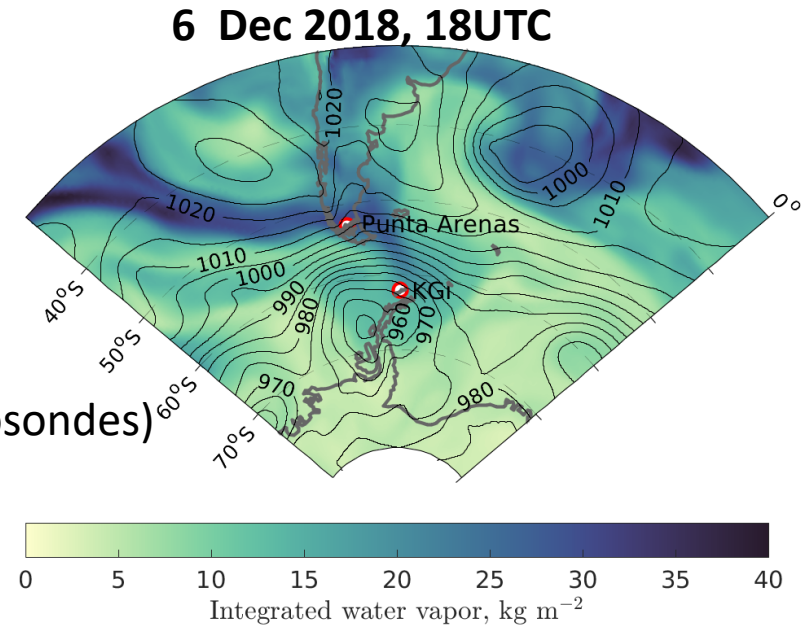
ARs are accompanied by strong winds and intense snowfall… making measurements difficult or impossible

Video of radiosonde launch at Syowa.
©Credit: Shogo Tanaka, Japan Meteorological Agency

See the video at: https://twitter.com/IrinaGorodets/status/1257582996116340736

or https://twitter.com/polarprediction/status/1257549685415346176

AR affecting Punta Arenas (southern Chile) *and* King George Island (KGI, north of Antarctic Peninsula)



- Strong increase in integrated water vapor measured at Punta Arenas (microwave radiometer/radiosondes) and KGI (radiosondes)
- Cloud liquid water path peaks at Punta Arenas
- Thick low-level liquid-containing clouds at KGI
- Strong cloud radiative forcing at both Punta Arenas and at Escudero station (KGI) (next slide)

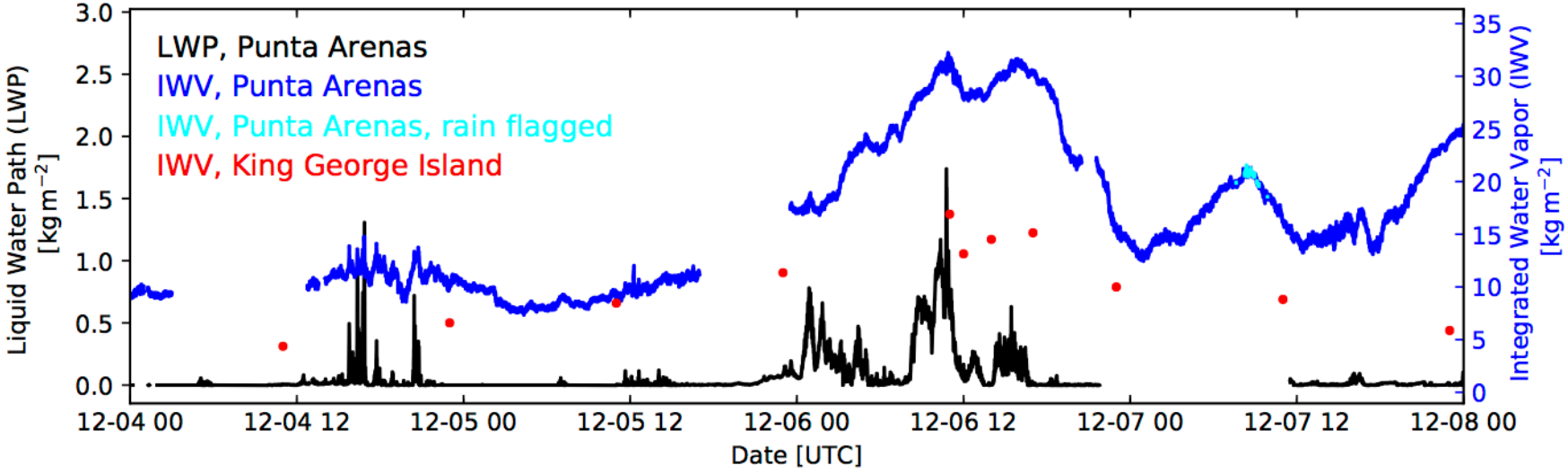
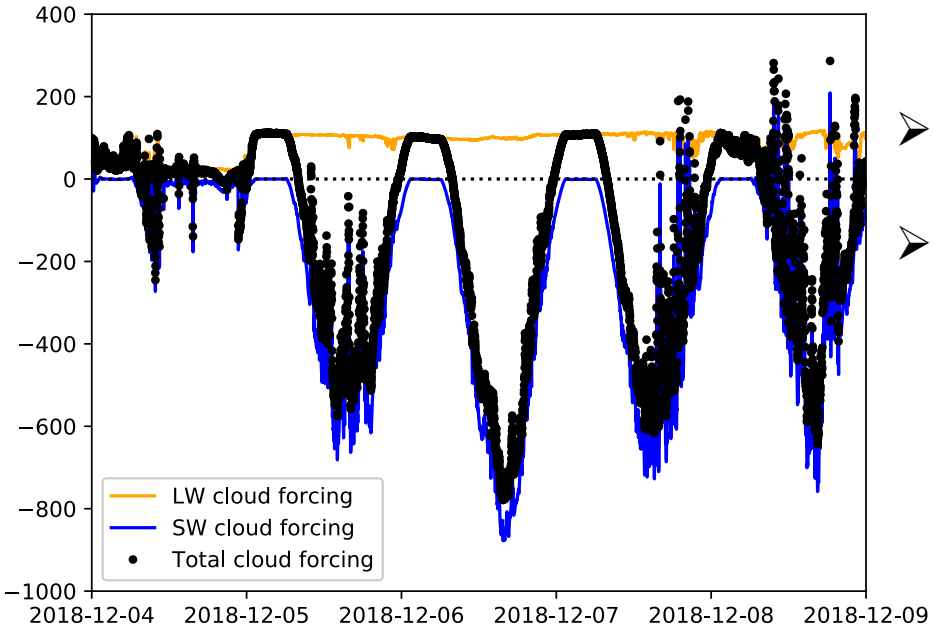


Fig. 11b/section 5 in Bromwich et al YOPP review (2020, ©BAMS)

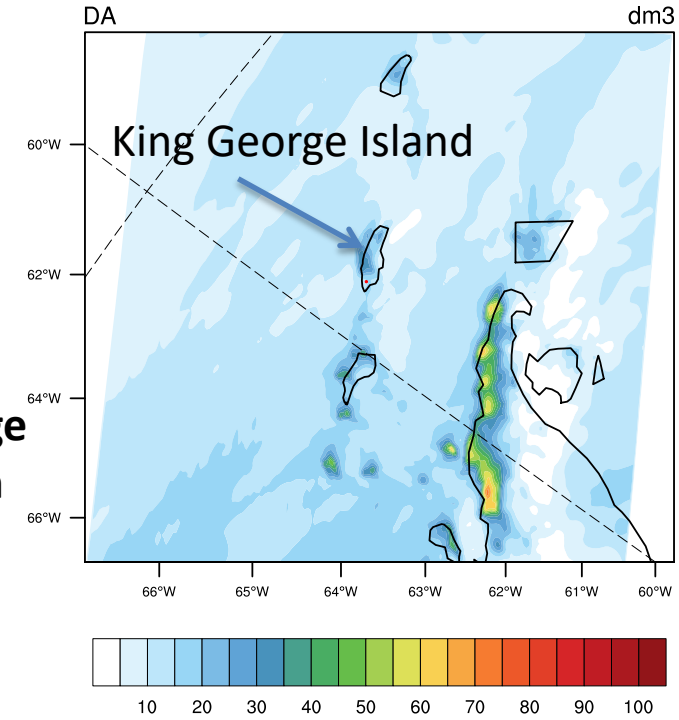
Clouds and precipitation at KGI, north of Antarctic Peninsula

5-7 Dec 2018



- **Persistent thick low-level liquid-containing clouds observed at Escudero**
- **Cloud forcing:**
  Night: warming the surface
  Day: cooling the surface >> warming

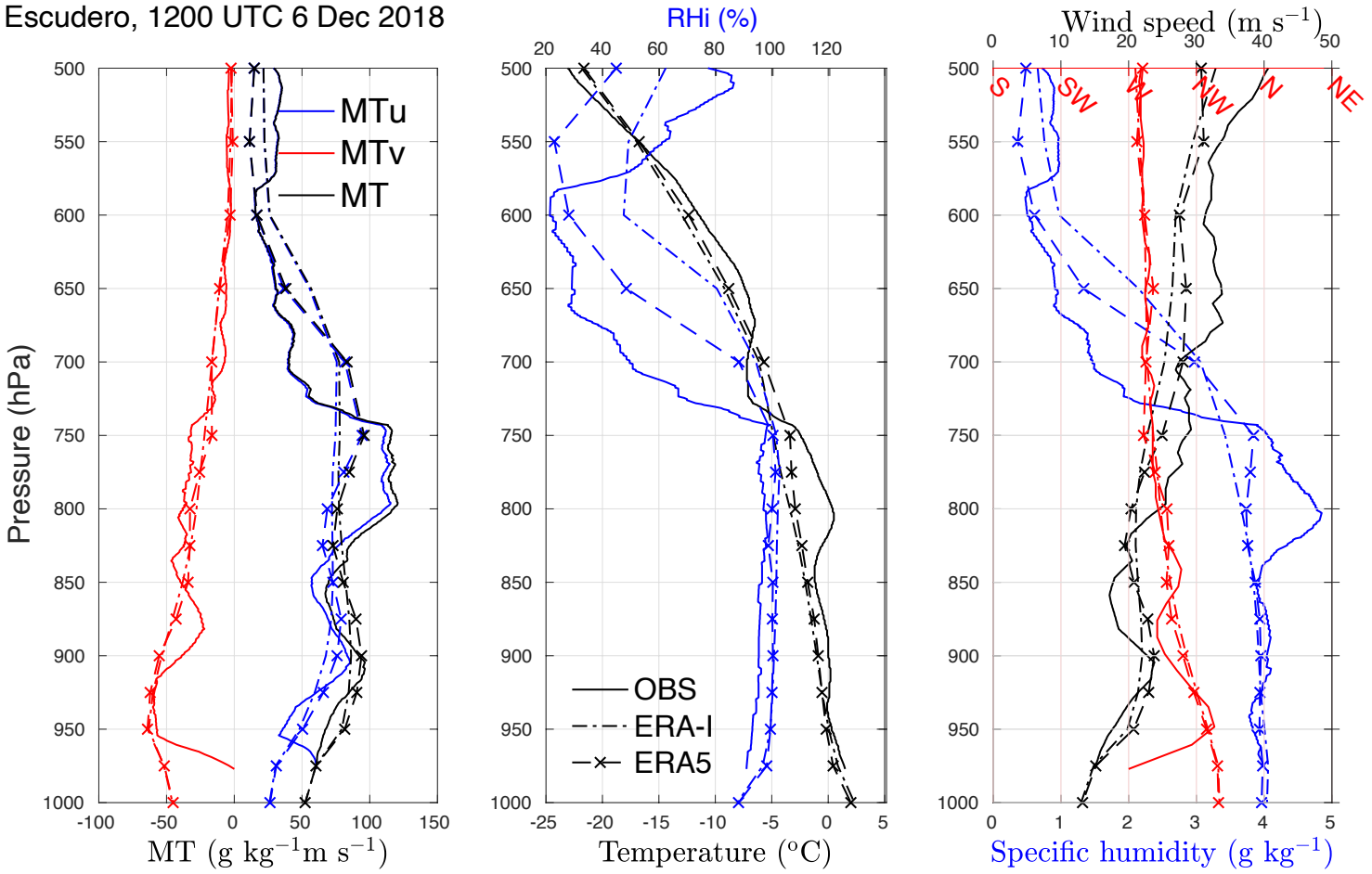
Accumulated Rain (mm) from 2018120512 to 2018120812



- **Precipitation by Polar WRF with YOPP measurements data assimilation experiment**
- **Moderate increase of precipitation at King George Island and orographically enhanced precipitation in the western Antarctic Peninsula** (figure shows output from PolarWRF with assimilated YOPP radiosondes)

Figs. 11d,d/section 5 in Bromwich et al YOPP review (2020, ©BAMS)

Profiles at Escudero during the transition from snow to rain: Radiosondes vs reanayses (ERA5 and ERA-Interim)

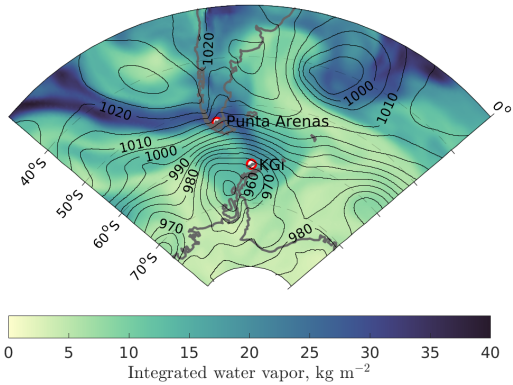


2018/12/06 1148 UT: Snow changes to rain with significant increase in temperature and humidity in the lower troposphere from 00UTC (snowfall) to 12 UTC (rain)

2018/12/06 1243 UT: Visibility reduced to 500 m, **mix light rain and snow.**

©Gorodetskaya, Rowe et al, in prep

Conclusions from the AR case affecting southern Chile and Antarctic Peninsula:



- On the **Antarctic Peninsula**, the surface mass balance can be especially sensitive to AR events during summer, when **surface temperatures vary around zero** and frequent **transitions occur between snow and rainfall**

- High precipitable water, presence of liquid-containing clouds and only light rainfall observed at Punta Arenas during AR**: the lack of moisture loss via precipitation over southern Chile** allowed the enhanced IWV to reach and strongly affect Antarctic Peninsula weather and surface radiation

- **Transition from snowfall to rain and mixed-phase precipitation** during the AR event associated with a **significant warming and moistening of the lower troposphere** (underestimated by reanalyses)

- **AR conditions** (strong wind, low clouds, precipitation) have important consequences for air, ship and station operations around the Antarctic Peninsula but **forecast is challenging**: **improved rainfall and wind using YOPP data-assimilated experiments** with Polar WRF

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