Association of the atmospheric rivers over Southern Ocean/Antarctica with warm conveyor belts

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Workshop Warm Conveyor Belts – A Challenge to Forecasting, 10-12 March 2020, ECMWF, UK

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Introduction

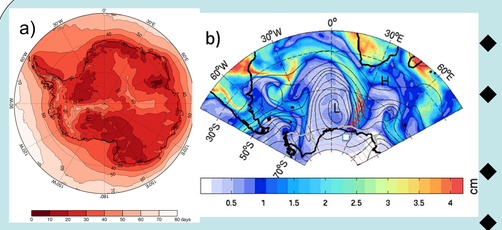

Figure 1: a) # of days of extreme precip resulting in 50% of total annual (Turner et al 2019); b) IWV during AR event responsible for extreme precipitation on 15 February 2011 (Gorodetskaya et al 2014)

- Intense snowfalls over the Antarctic ice sheet contribute the majority of its surface mass balance (Schlosser et al 2010; Gorodetskaya et al 2014; Turner et al 2019)
- Precipitation over the Southern Ocean and Antarctic is mainly brought by the extratropical cyclones and fronts (Catto et al 2013; 2015; Sinclaire and Dacre 2019), with the strongest events being driven by the atmospheric rivers (ARs, Gorodetskaya et al 2014)
- ARs are long, narrow and transient corridors of enhanced horizontal vapor transport typically within the cyclones' warm conveyor belt (WCB), ahead of the cold front (Ralph et al 2004)
- ARs and their association with WCBs has to be correctly represented in models/reanalyses and there is a lack of observations for their evaluation especially in Antarctica
- Intense observational campaigns, such as during Year of Polar Prediction Special Observing Period in the Southern Hemisphere (YOPP-SOP-SH), provide new data for model evaluation

Figure 2: Radiosonde launch at Neumayer

Data and Methodology

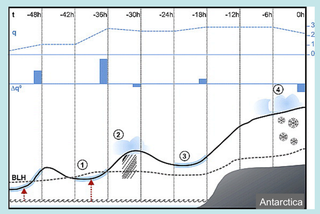

Figure 3: Schematic of moisture source diagnostics (Sodemann et al 2008)

- Frequent (3-4 per day) radiosonde measurements during YOPP-SOP-SH at Neumayer and Syowa stations (DML – Dronning Maud Land, East Antarctica)
- Regular radiosonde data from IGRA2 archive during 2009-2019
- ECMWF reanalyses (ERA-Interim and ERA5) fields are evaluated using radiosonde observations and applied for large-scale analysis
- LAGRANTO trajectories with WaterSip moisture source analysis (Sodemann et al 2008; 2020)

Atmospheric rivers at Syowa

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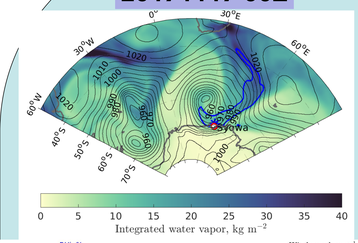

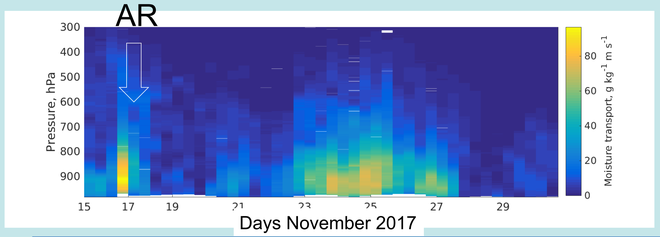

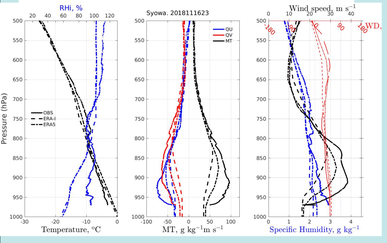

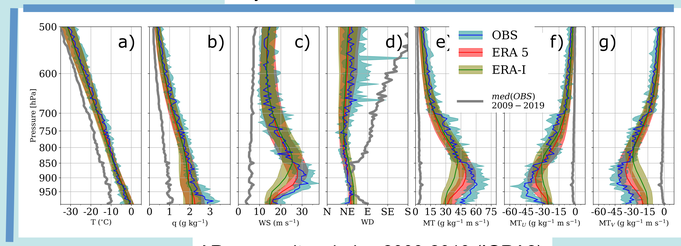

AR composites during 2009-2019 (IGRA2)

Key features during YOPP Nov 2017 AR event:

- Near-surface moisture maximum and LLJ higher 900 hPa
- Different from 15 Feb 2011 case when maximum moisture flux was at higher levels
- Both ERA5 and ERA-Interim underestimating moisture flux maximum

10-year AR composites:

- **ARs are extreme state compared to median profiles**
- both ERA5 and ERAI underestimate humidity and wind speed maxima

Atmospheric rivers at Neumayer

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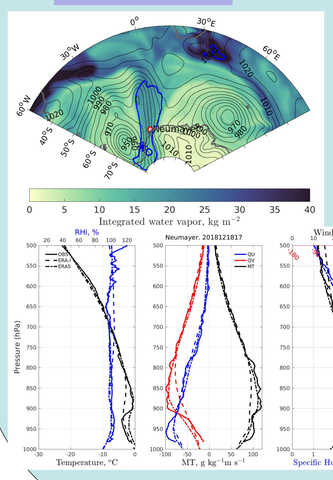
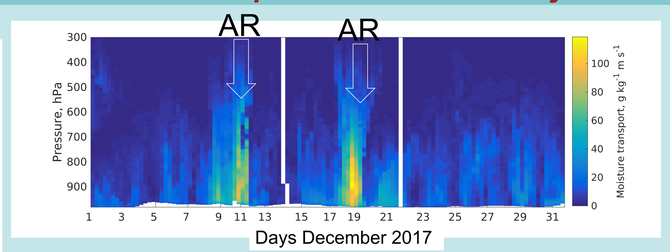
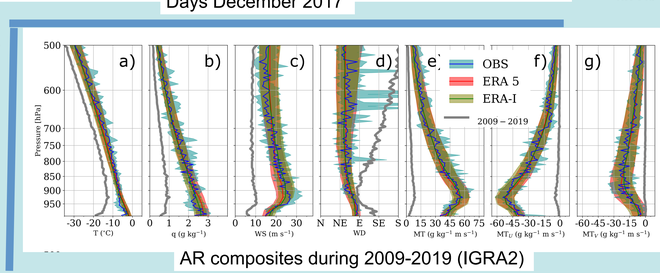






AR composites during 2009-2019 (IGRA2)

Key features during YOPP Dec 2017 AR events:

- Strong elevated moisture inversion above LLJ
- Similar to the 15 Feb 2011 case
- ERA5 is better than ERA-Interim in representing humidity inversion and moisture flux maximum

10-year AR composites: good representation of MT profile composite by both reanalyses... Compensation of biases: underestimated LLJ and overestimated humidity inversion

Major AR event causing extreme snowfall in DML on 15-16 Feb 2011

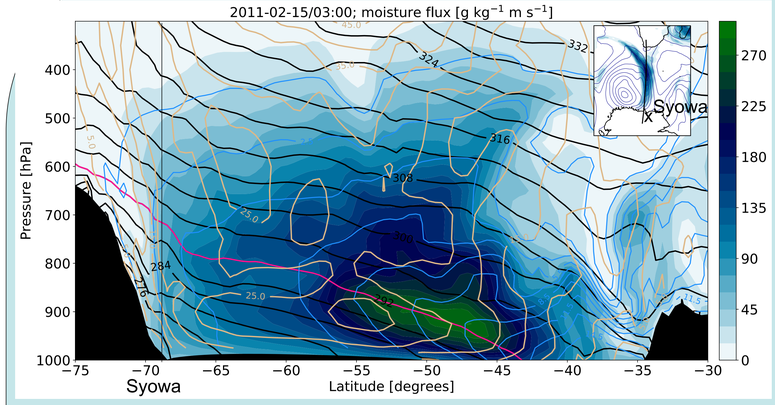
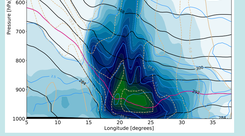
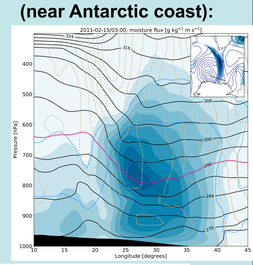


***Figure 4a:* Vertical cross-section through the warm sector of the cyclone:** moisture flux (shading, g kg m s^{-1}), potential temperature (black lines, K, pink-line=292K, wind speed (yellow lines, m s^{-1}), and specific humidity (blue lines, g kg^{-1}).

(4b) Cross-section at 42-48ºS (near moisture source):



(4c) Cross-section at 65ºS (near Antarctic coast):



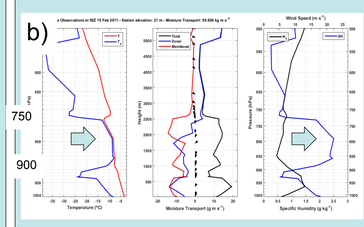


Figure 5: Syowa radiosonde profiles

- Isentropic upgliding with maximum moisture flux along 292K isentrope from nearly the moisture source ~40ºS to Antarctic coast
- Moist advection is at higher layers and decoupled from the low-level jet
- Loss of moisture by precipitation
- Near the surface: warm air over cold ocean surface; no evaporation => limited moisture in the boundary layer

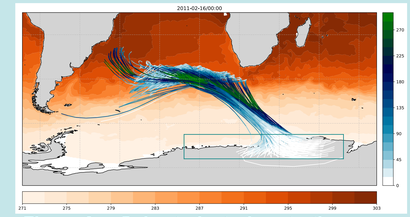


Figure 6a: 5-day trajectories starting on 16 February 2011 at 00:00UTC in DML (only for MT>250 g kg^{-1} m s^{-1})

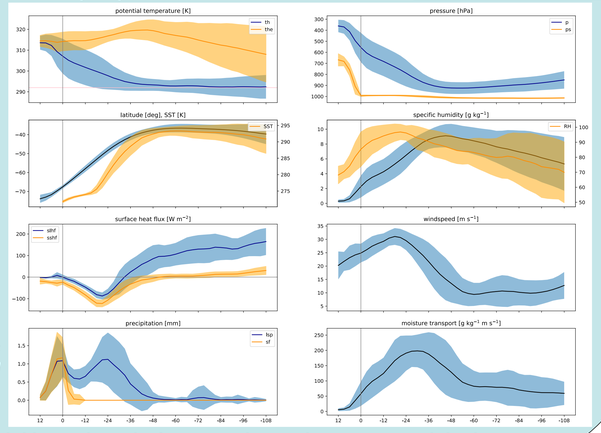


Figure 6b: Properties along the trajectories (Fig.6a) showing mean values (lines) and standard deviation (shading).

Gorodetskaya, Silva, Schmithüsen, Hirasawa, 2020: Atmospheric river signatures in radiosonde profiles and reanalyses at the Dronning Maud Land coast, East Antarctica, Adv Atm Sci, in press, doi: 10.1007/s00376-020-9221-8

Terpstra, Gorodetskaya, Sodemann: Linking subtropical evaporation and extreme precipitation over East Antarctic: An atmospheric river ase study. To be submitted to JGR, AR special issue