

Studying the hydrological cycle in Antarctica: using ground-based remote sensing and regional climate models within the project HYDRANT

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Antarctic surface mass balance:

$$\text{SMB} = S \pm \text{SUs} - \text{SUds} \pm \text{TR} - \text{MR}$$

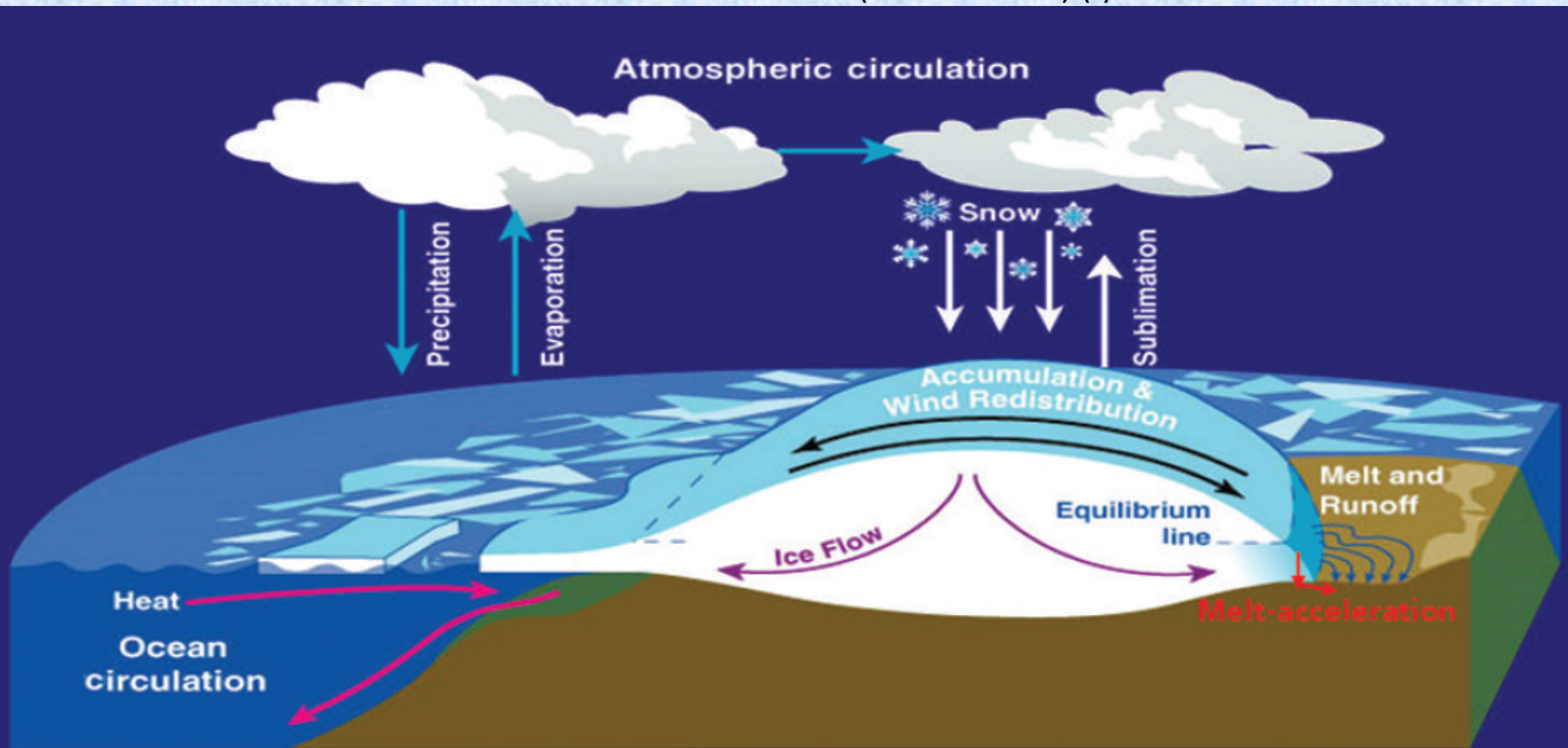
S = snowfall (+)

SUs = surface sublimation/deposition (+/-)

SUds = drifting snow sublimation (-)

TR = erosion or deposition of snow due to the wind-driven transport (+/-)

MR = melt and runoff (coastal areas) (-)

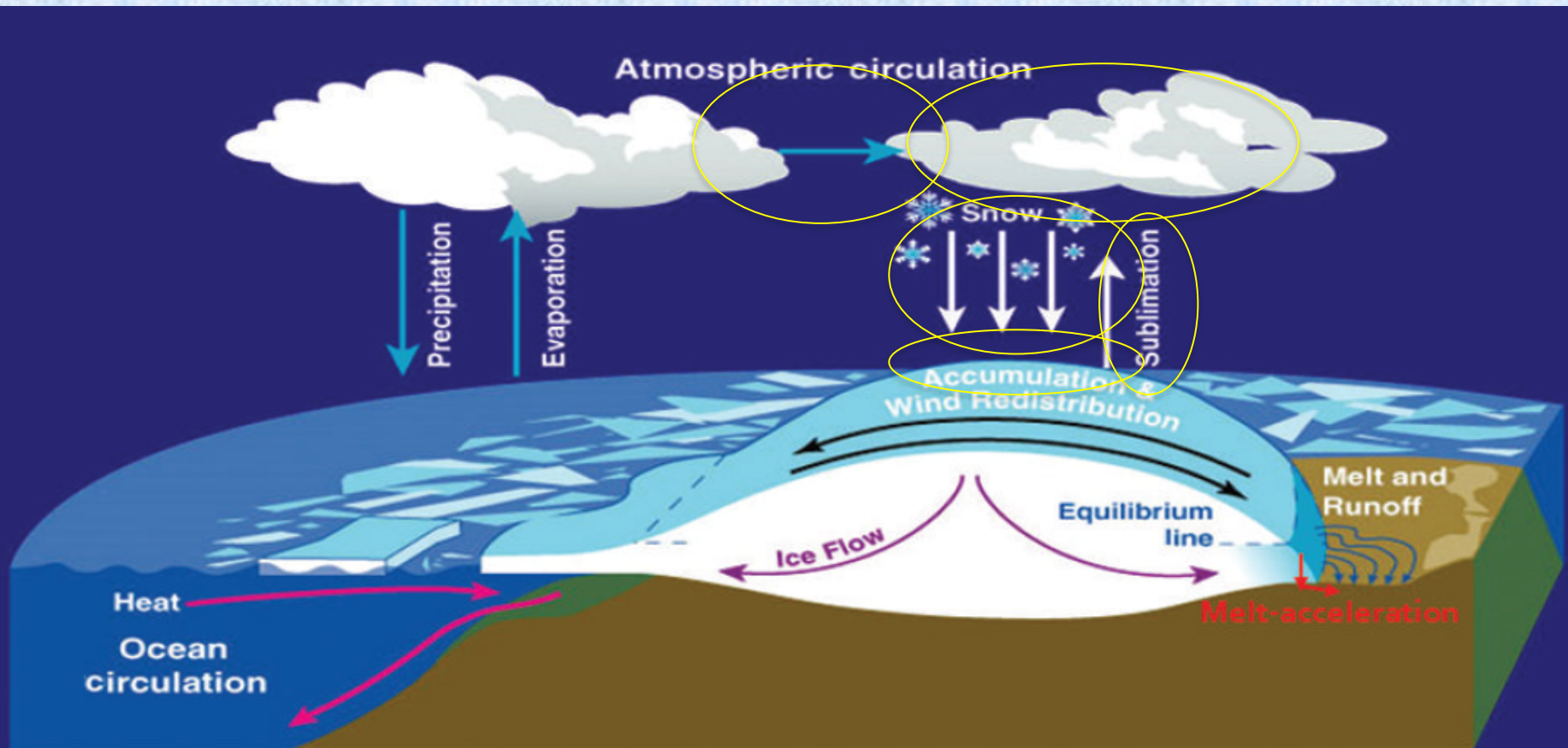


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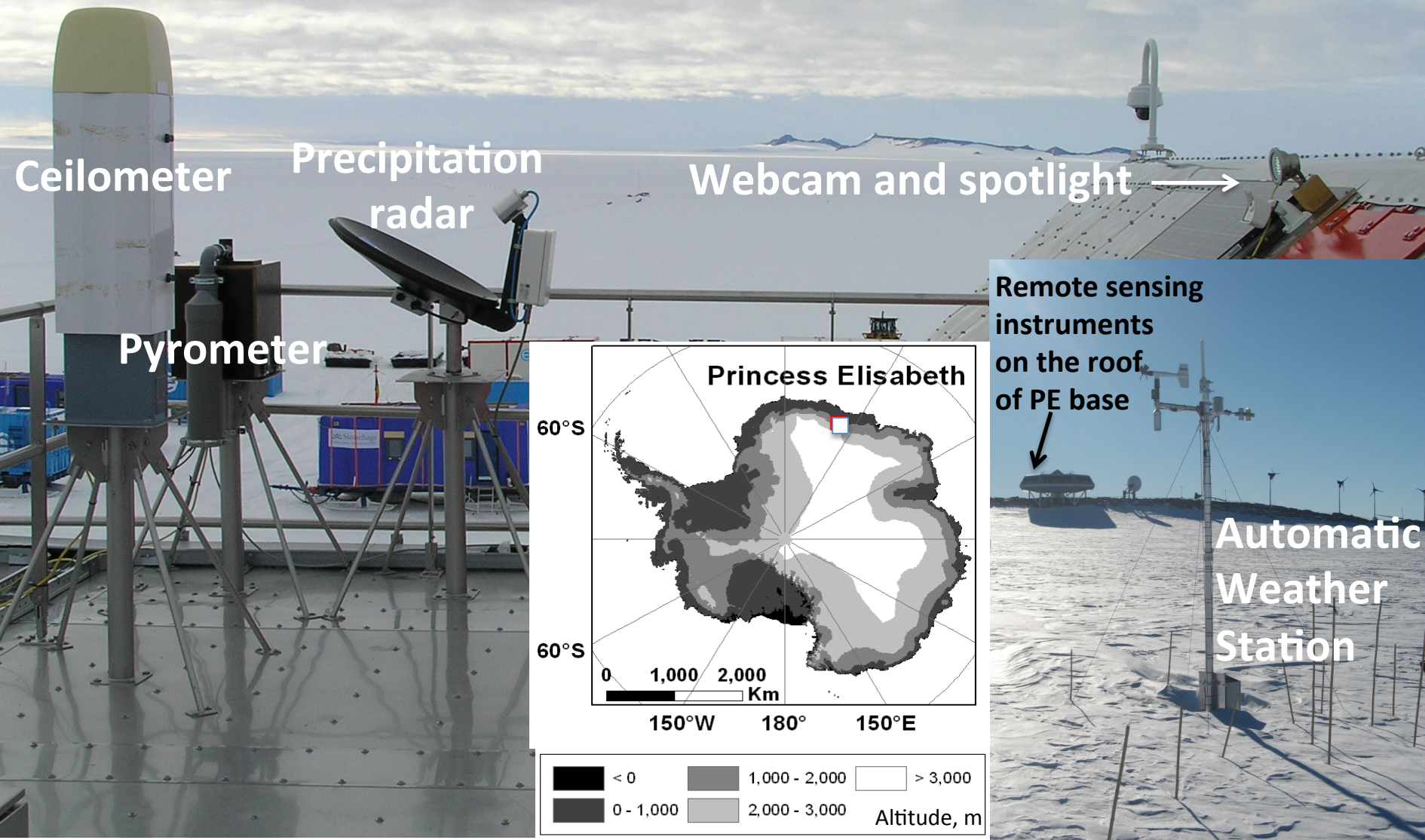
Project HYDRANT

The atmospheric branch of the hydrological cycle in Antarctica
funded by the Belgian Science Policy



Meteorology-cloud-precipitation observatory at Princess Elisabeth base in Dronning Maud Land, East Antarctica

installed within the HYDRANT project



HYDRANT project results and applications

- **Gorodetskaya, I. V.,** Kneifel, S., Maahn, M., Van Tricht, K., Thiery, W., Schween, J. H., Mangold, A., Crewell, S., and Van Lipzig, N. P. M. : **Cloud and precipitation properties from ground-based remote sensing instruments in East Antarctica**, *Cryosphere* (2015).
- **Gorodetskaya, I.,** M. Tsukernik, K. Claes, F. M. Ralph, W. D. Neff, and N. P. M. Van Lipzig **The role of atmospheric rivers in anomalous snow accumulation in East Antarctica**, *GRL* (2014)
- Van Tricht, K., **Gorodetskaya, I. V.,** Lhermitte, S., Turner, D. D., Schween, J. H., and N. P. M Van Lipzig : **An improved algorithm for polar cloud-base detection by ceilometer over the ice sheets**, *Atmos. Meas. Tech* (2014)
- Maahn M., C. Burgard, S. Crewell, **I. V. Gorodetskaya,** S. Kneifel, S. Lhermitte, K. Van Tricht, and N. Van Lipzig: **How does the space-borne radar blind-zone affect derived surface snowfall statistics in polar regions?** *J. Geophys. Res.* (2014)
- Jan T. M. Lenaerts, J. Brown, M. R. Van Den Broeke, K. Matsuoka, R. Drews, D. Callens, M. Phillipe, **I. V. Gorodetskaya,** E. Van Meijgaard, C. H. Reijmer, F. Pattyn, N. P. M. Van Lipzig, **High variability of climate and surface mass balance induced by Antarctic ice rises**, *J Glaciology* (2014)
- **Gorodetskaya, I. V.,** Van Lipzig, N. P. M., van den Broeke, M. R., Mangold, A., Boot, W., Reijmer, C. H. (2013). **Meteorological regimes and accumulation patterns at Utsteinen, Dronning Maud Land, East Antarctica: Analysis of two contrasting years**, *J. Geophys. Res.* (2013)
- Thiery, W., **Gorodetskaya, I. V.,** Bintanja, R., van den Broeke, M. R., Reijmer, C. H., Kuipers Munneke, P., Van Lipzig, N. P. M. (2012). **Surface and snowdrift sublimation at Princess Elisabeth station, East Antarctica**, *Cryosphere* (2012)
- Bromwich, D., Nicolas, J., Hines, K., Kay, J., Key, E., Lazzara, M., Lubin, D., McFarquhar, D., **Gorodetskaya, I. V.,** Grosvenor, D., Lachlan-Cope, T., Van Lipzig, N. P. M. (2012). **Tropospheric clouds in Antarctica**, *Rev. Geophysics* (2012)

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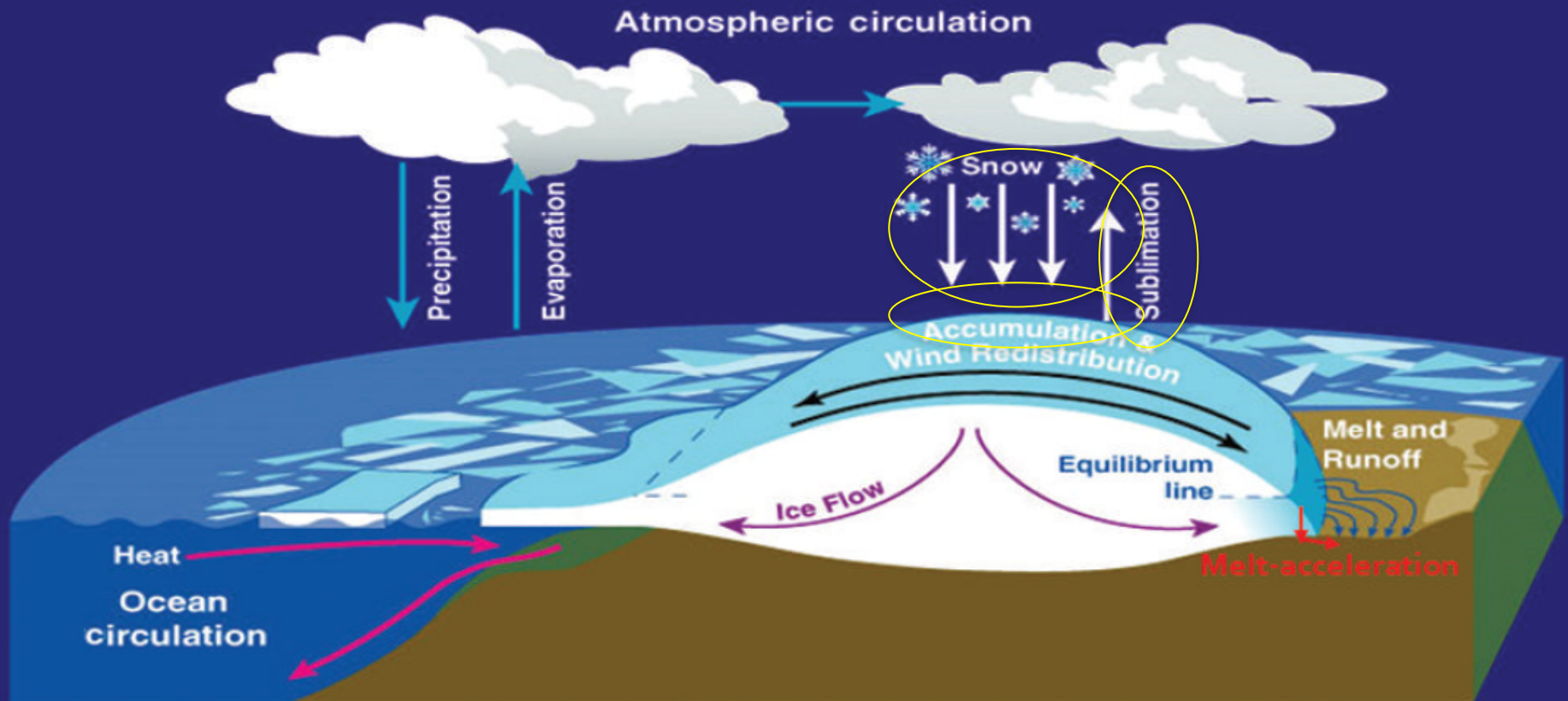
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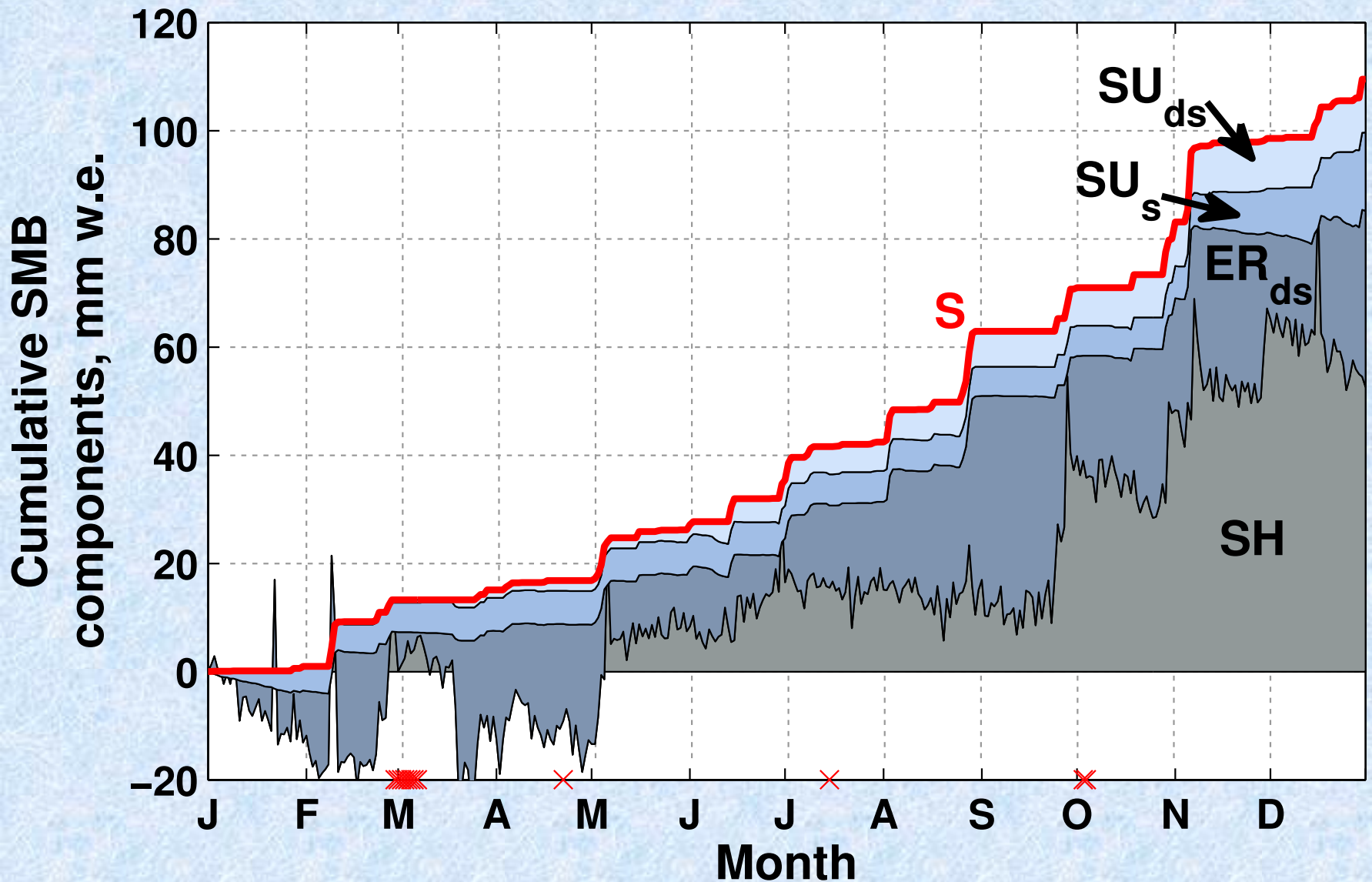
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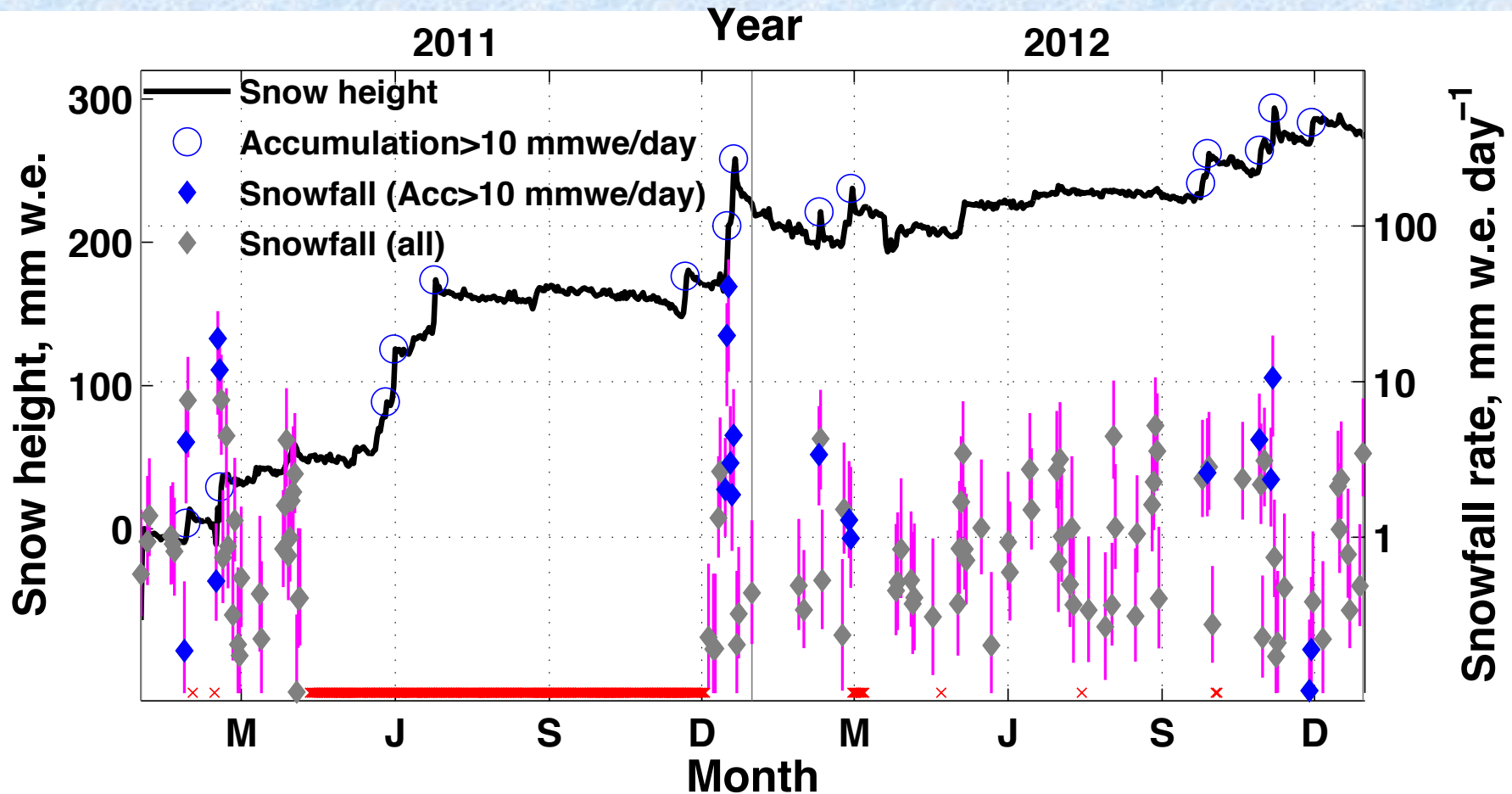


Surface mass balance

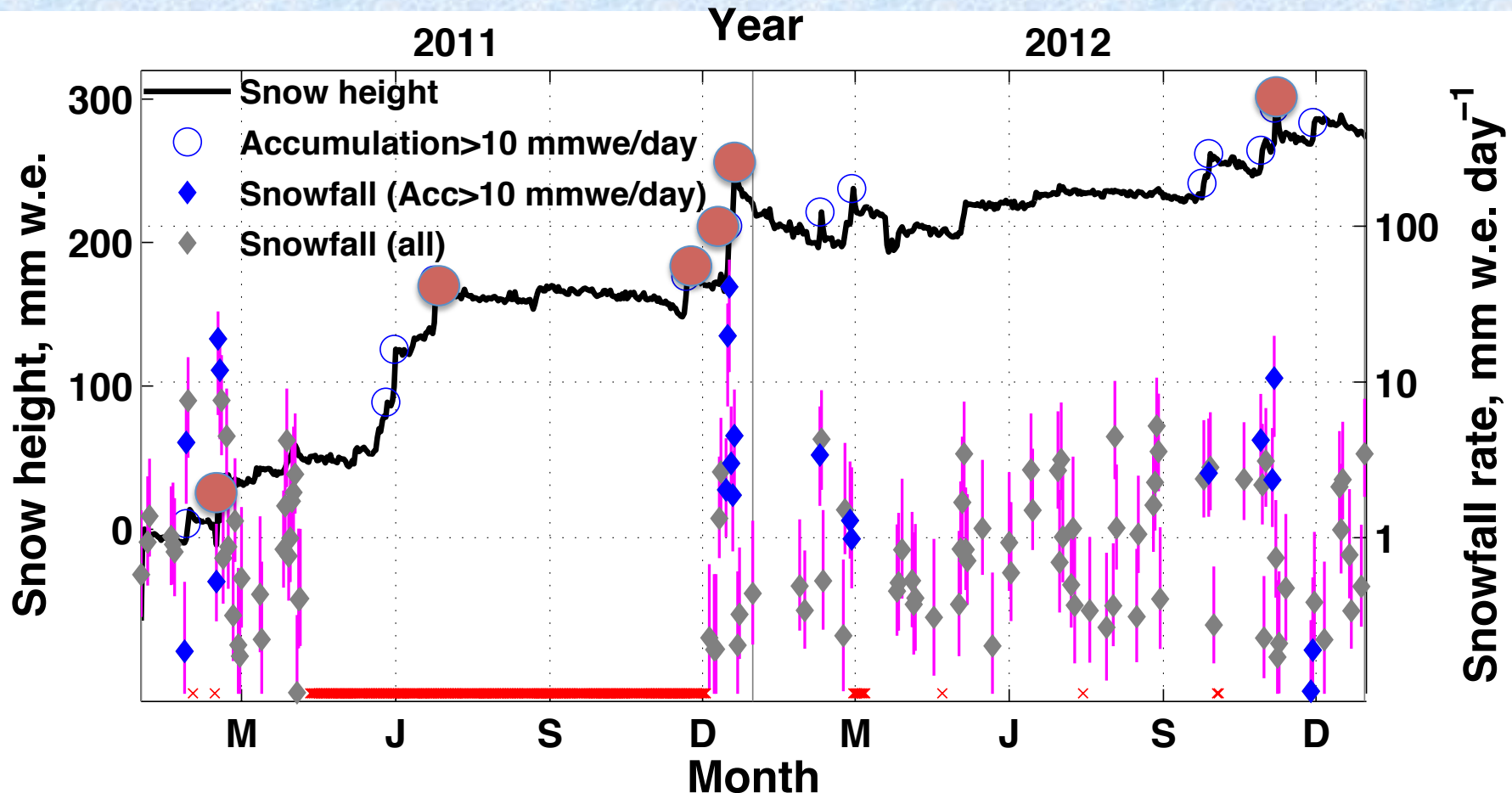


- Gorodetskaya et al "Cloud and precipitation properties from ground-based remote sensing instruments in East Antarctica", *Cryosphere* 2015
- Thiery et al "Surface and snowdrift sublimation at Princess Elisabeth station, East Antarctica, *Cryosphere* (2012)

Daily snowfall and snow height



Daily snowfall and snow height: extreme events = atmospheric rivers



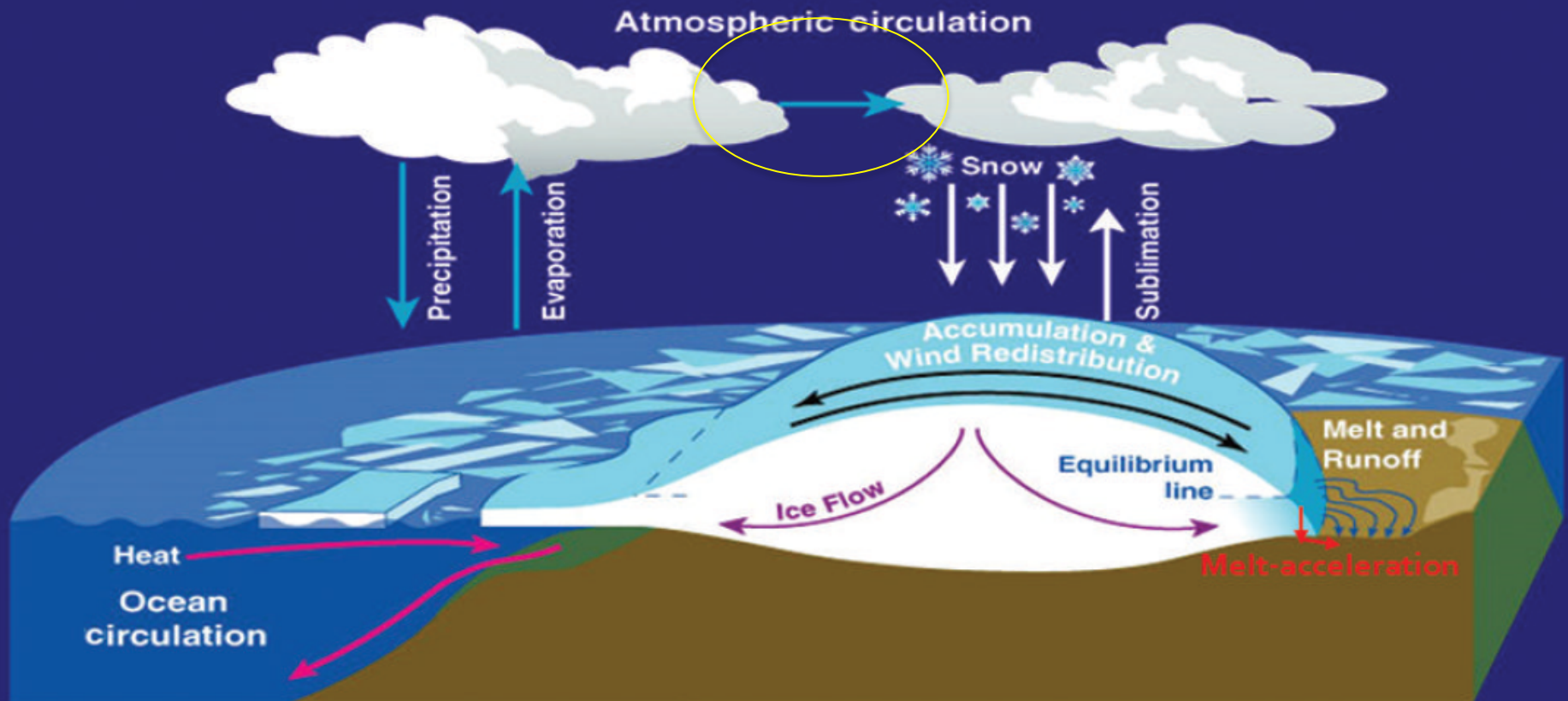
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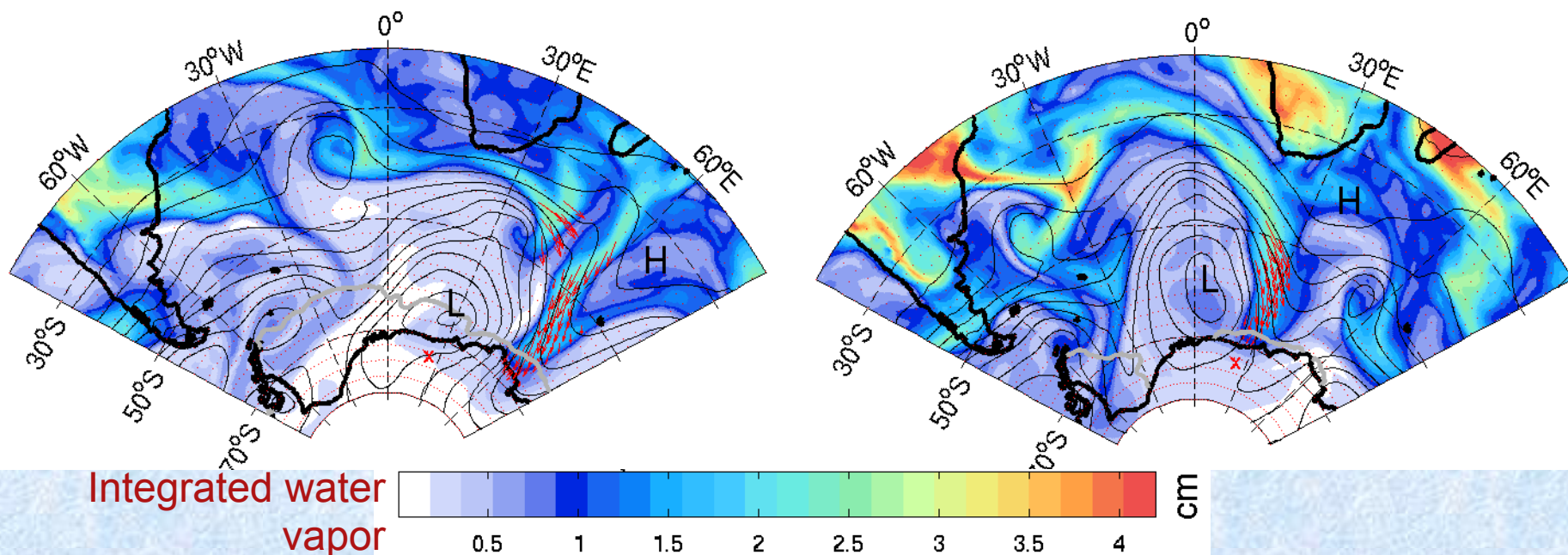


Major components of the Antarctic mass balance (credit: NASA)

Atmospheric rivers identified using a new definition adapted for Antarctica

19 May 2009

15 Feb 2011



Colors = integrated (900-300hPa) water vapour

Red arrows = total integrated moisture transport within ARs

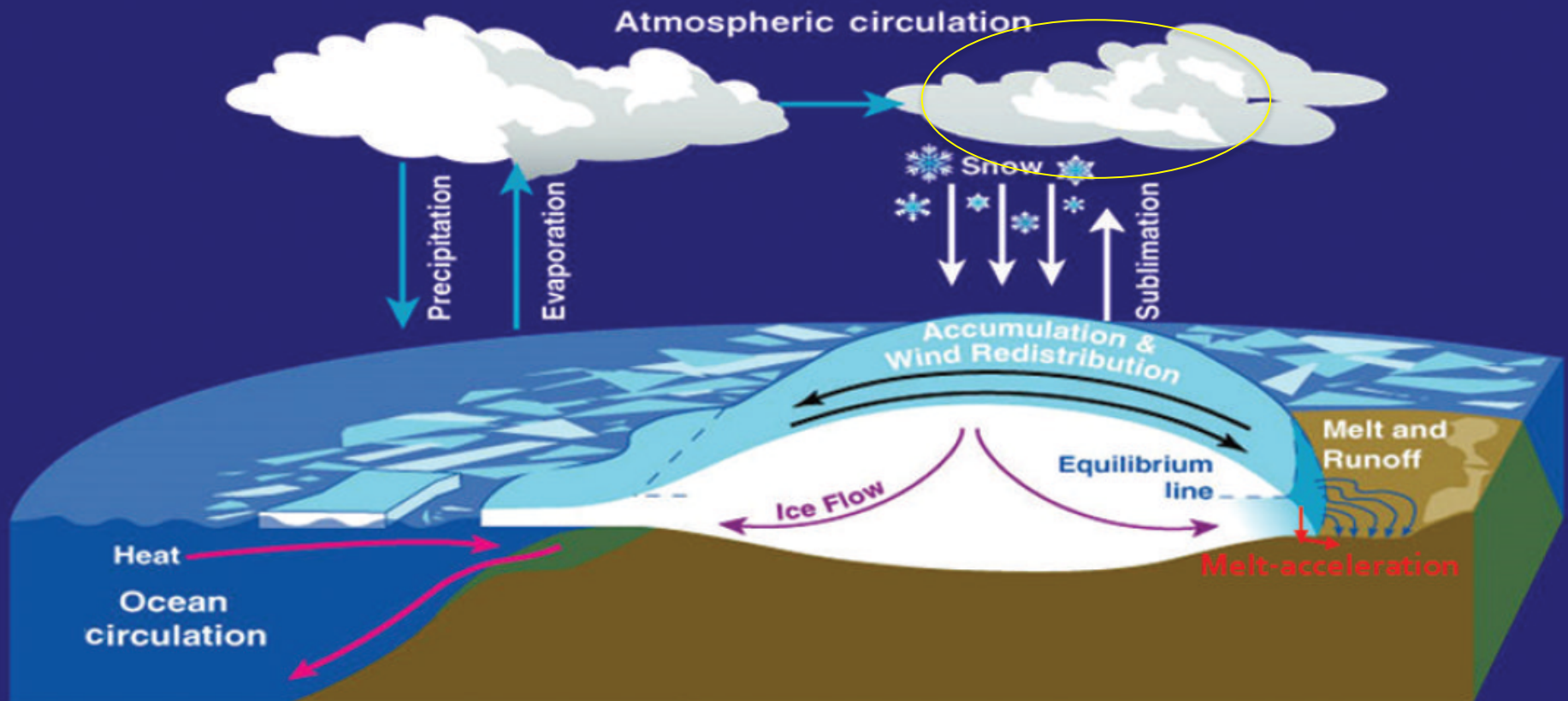
black contours = 500 hPa geopotential height

Antarctic surface mass balance:

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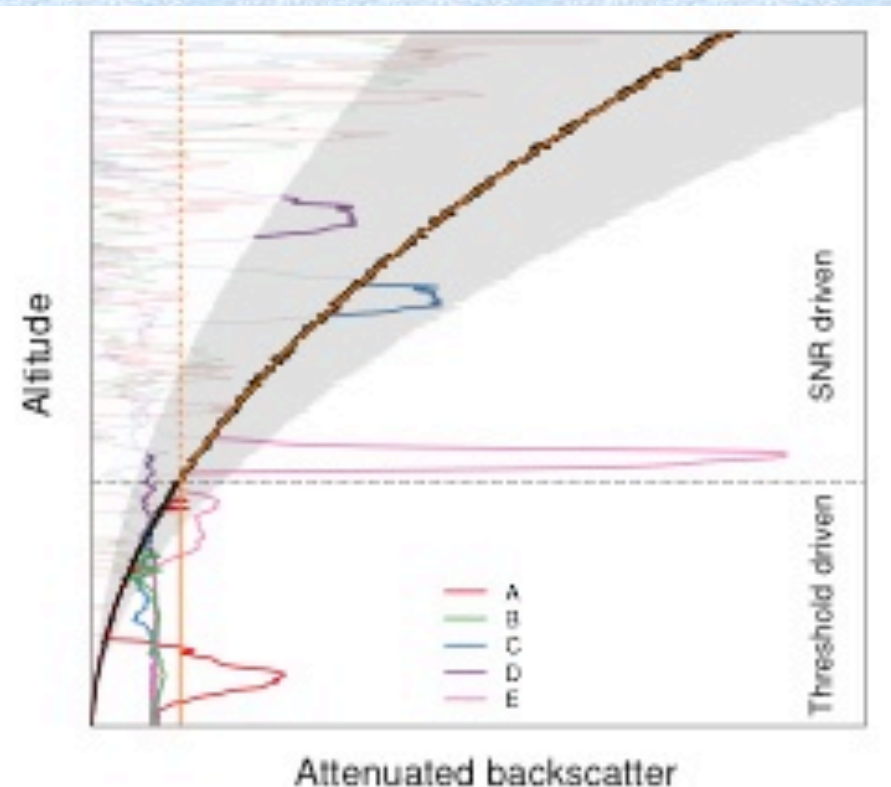
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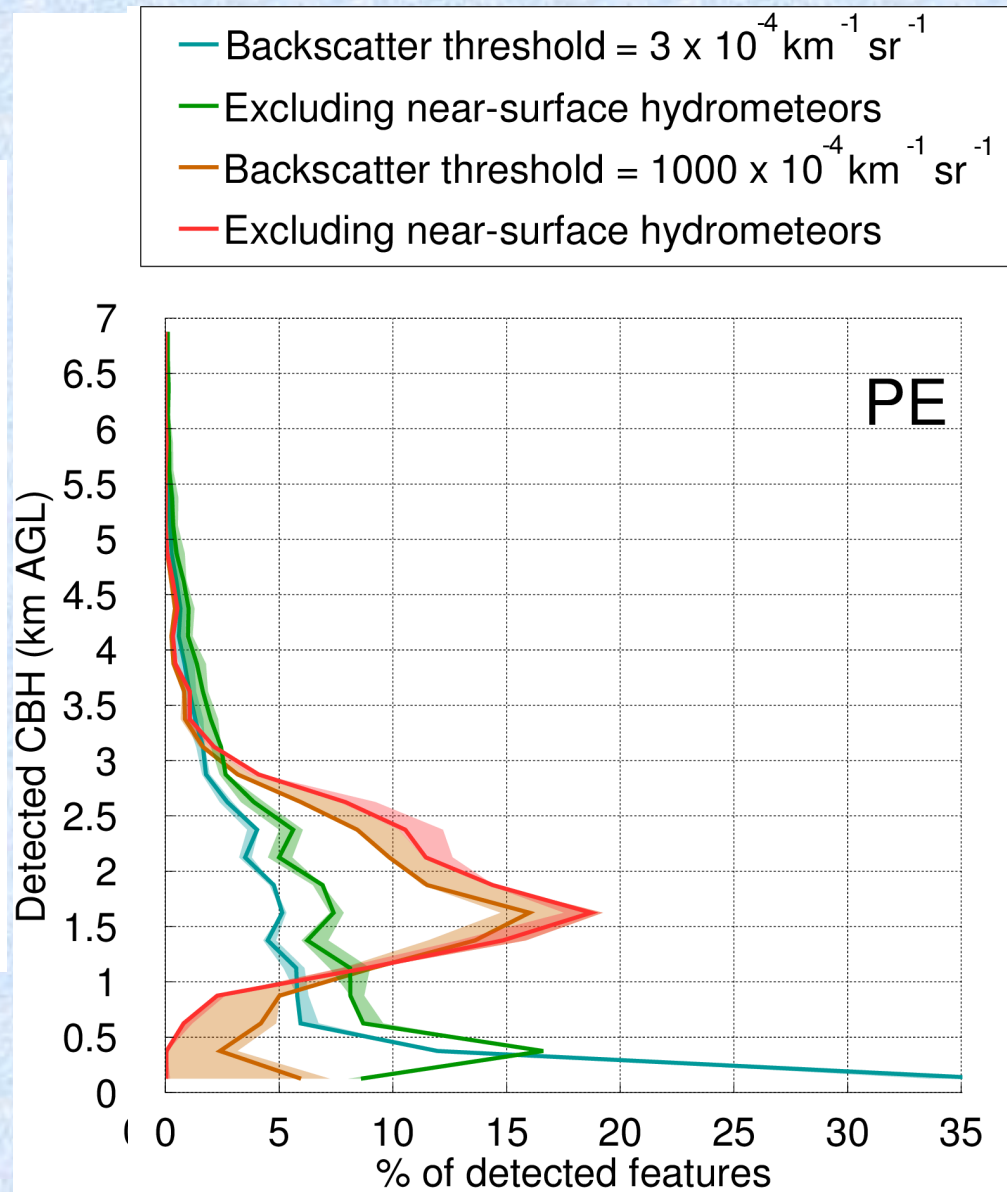


Major components of the Antarctic mass balance (credit: NASA)

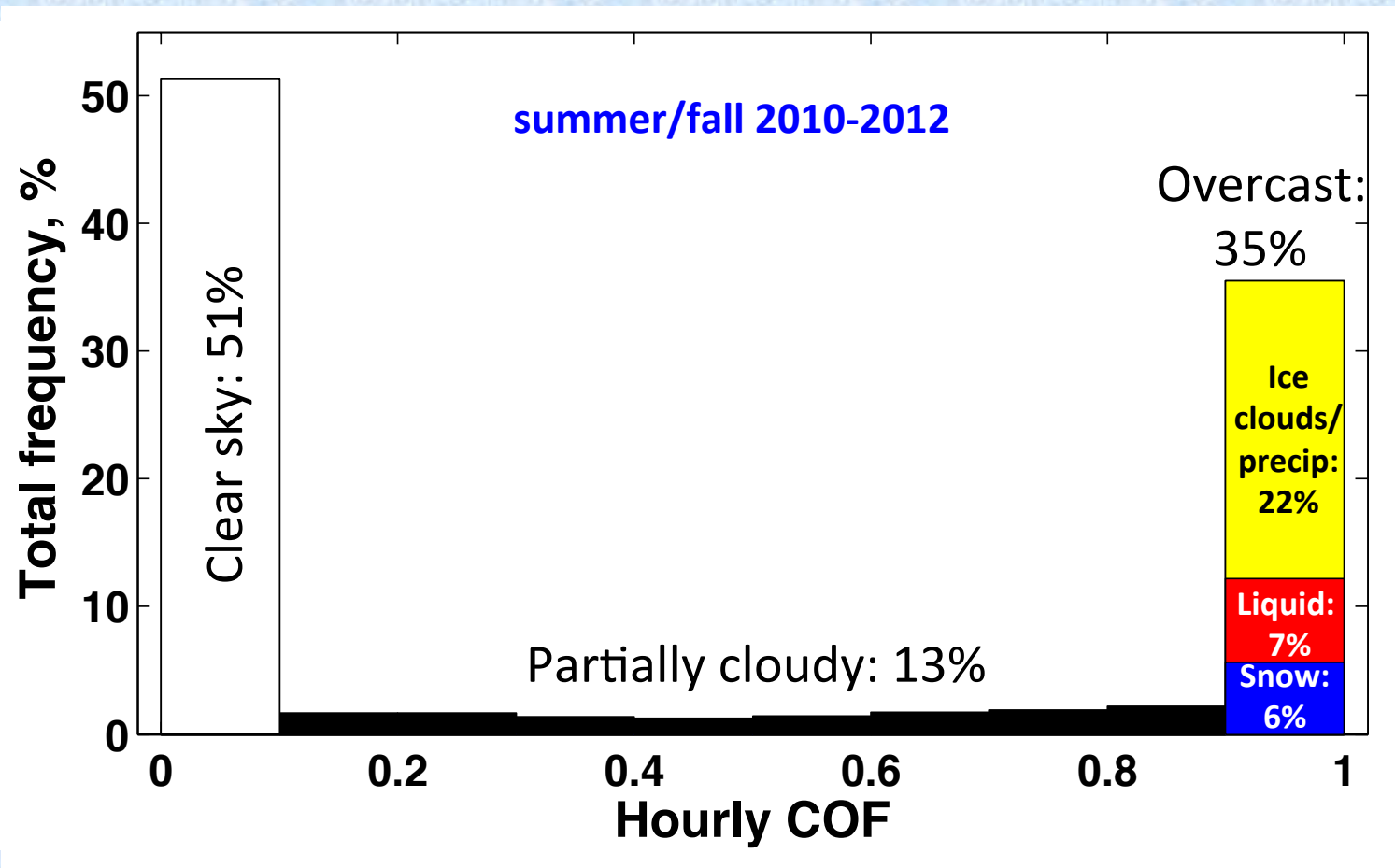
Cloud/precipitation base heights for all and liquid-containing layers:



Theoretical working of the Polar Threshold algorithm for detecting cloud base height



Cloud occurrence frequency (COF) for each cloud type and snowfall



- Gorodetskaya et al "Cloud and precipitation properties from ground-based remote sensing instruments in East Antarctica", Cryosphere 2015



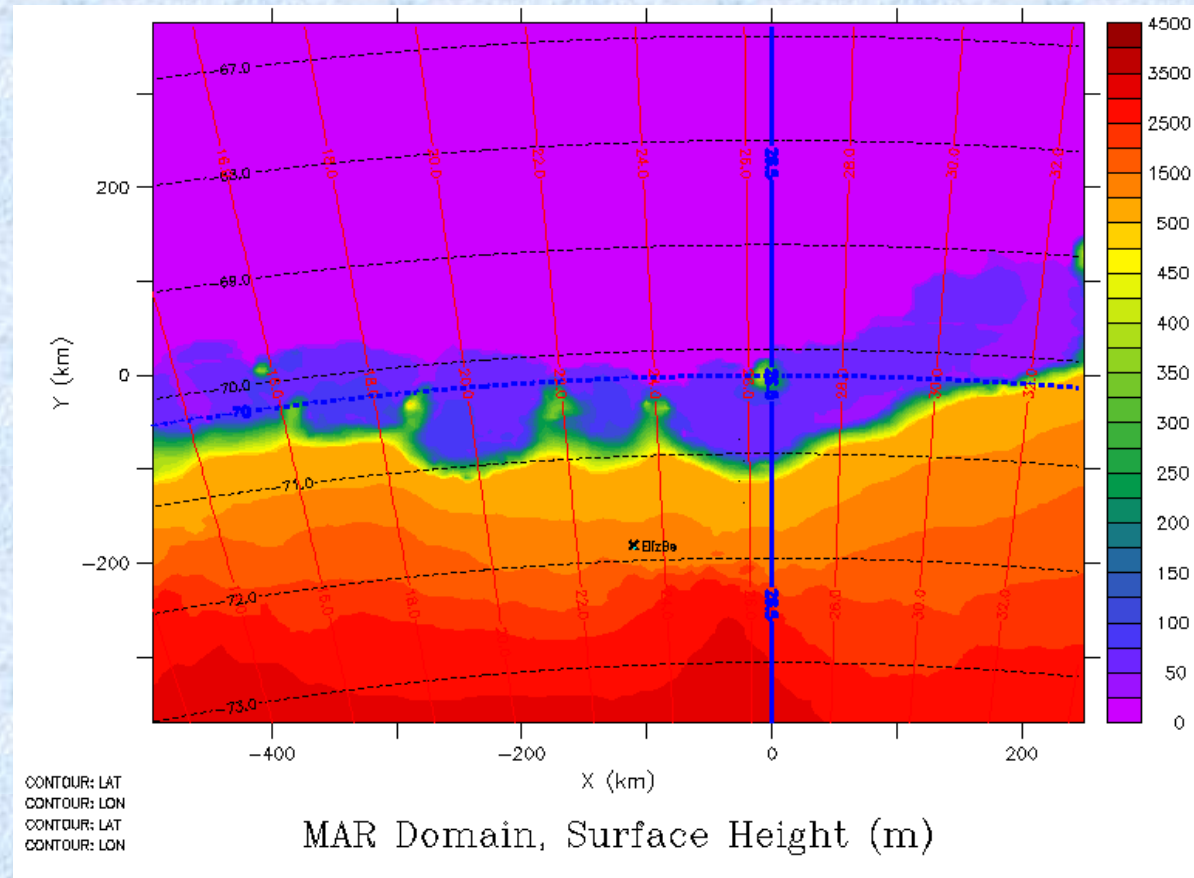
...in regional climate models

Regional climate model RACMO2.3-ANT

- **New model version RACMO2.3**, simulation over Dronning Maud Land 5.5x5.5 km horiz rez
- **Updates in this model version** (*Van Wessem et al. TC 2013*):
 - cloud ice super-saturation (Tompkins and Gierens 2007)
 - precipitation formation (increase in auto-conversion coeff)
 - radiative flux scheme (McRad, Morcrette et al. 2008)
 - turbulent flux scheme (EDMF, Siebesma et al. 2007)

Modèle Atmosphérique Régional (MAR)

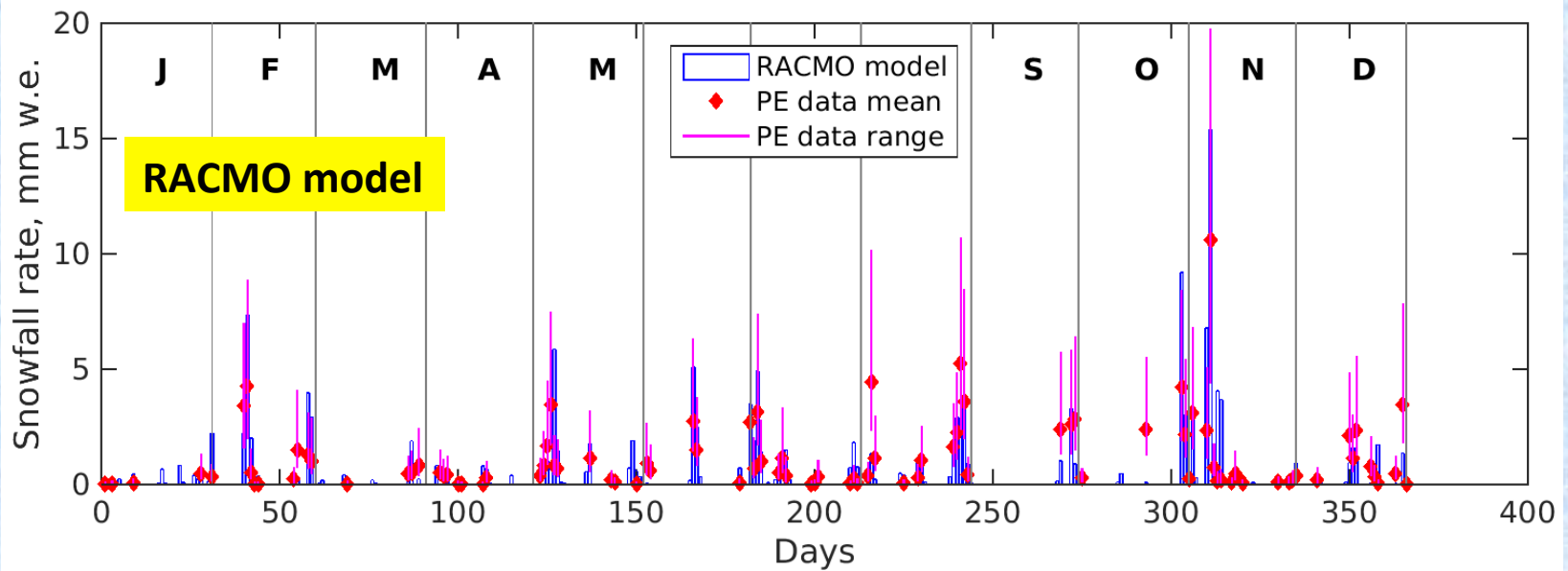
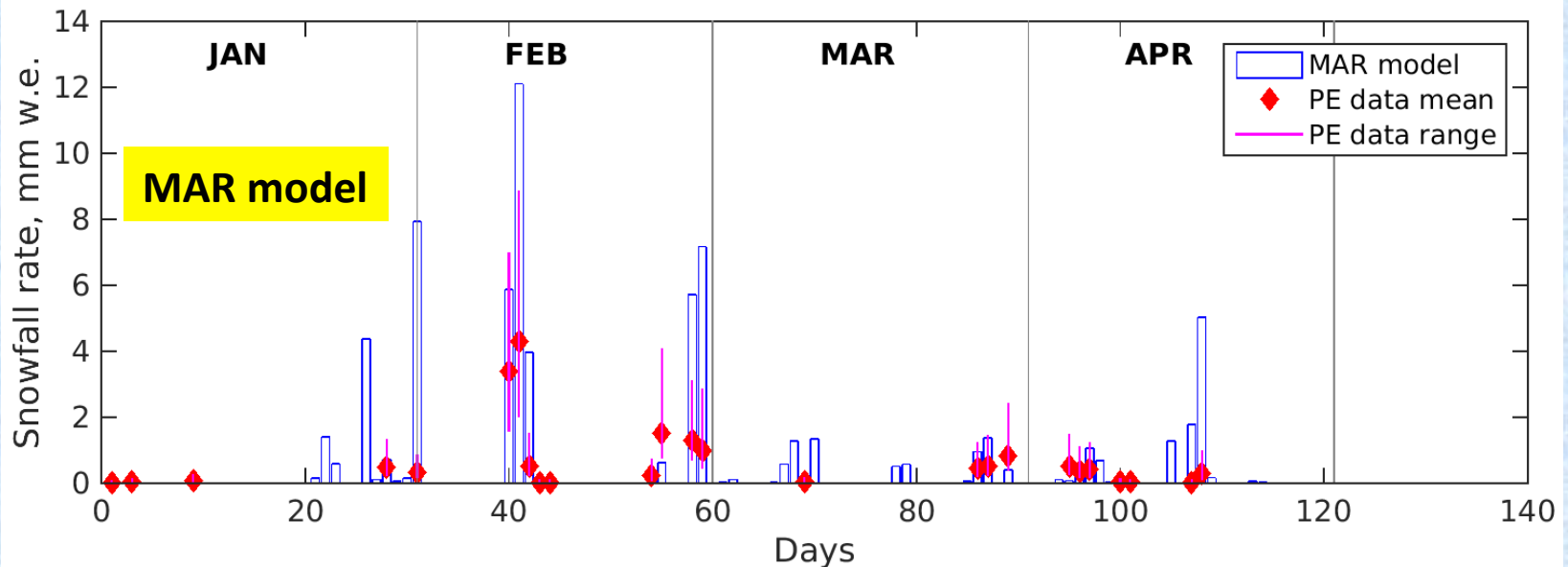
- Simulation over Dronning Maud Land centered over Derwael Ice rise, 5 km horiz rez



- 2-moment cloud scheme for ice clouds (ice nucleation parameterization following Meyers et al 1992; Prenni et al. 2007)
- 1-moment cloud scheme for other hydrometeors (cloud droplets, rain drops and snow particles)

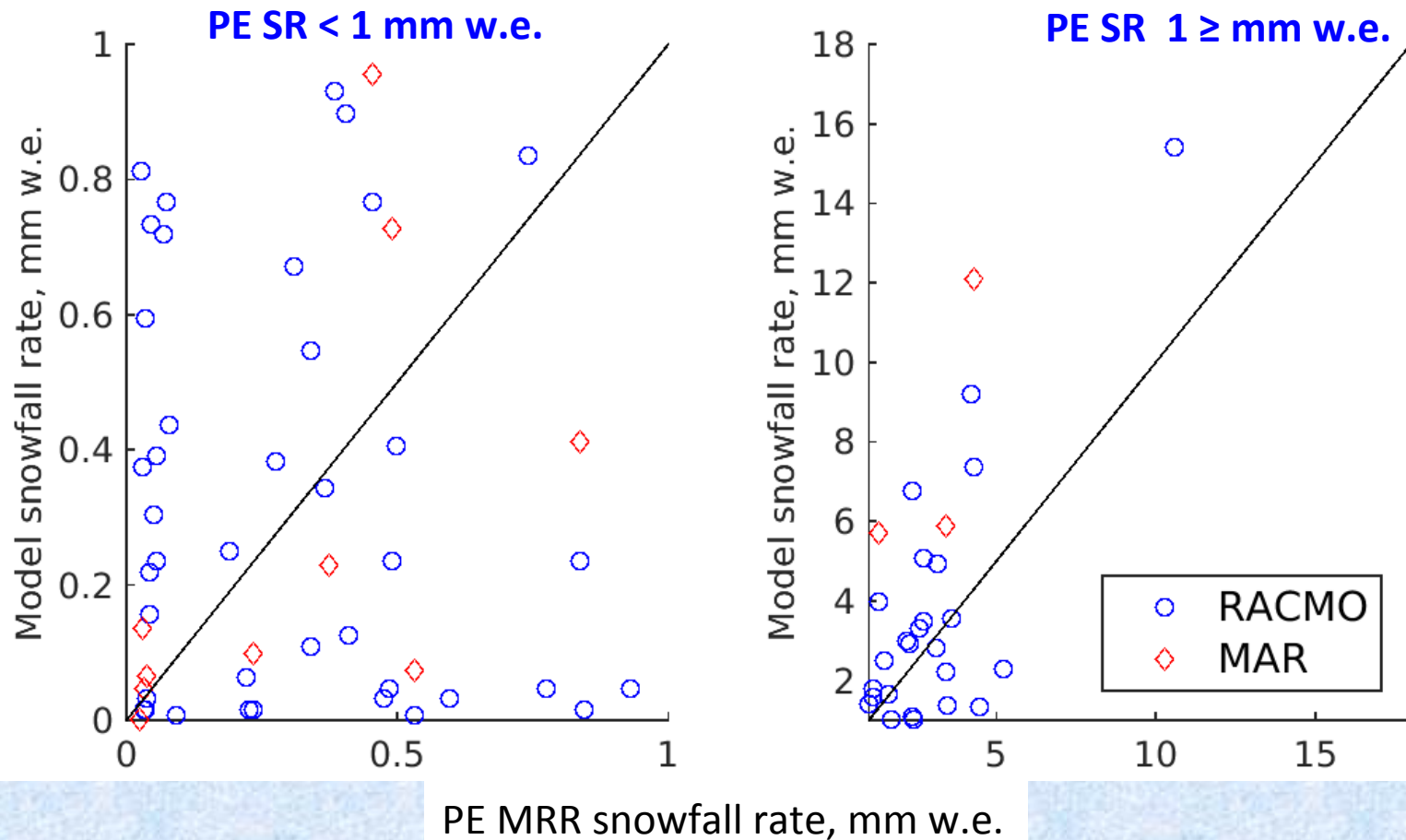
Snowfall evaluation

1. observations-to-model approach: comparing SR

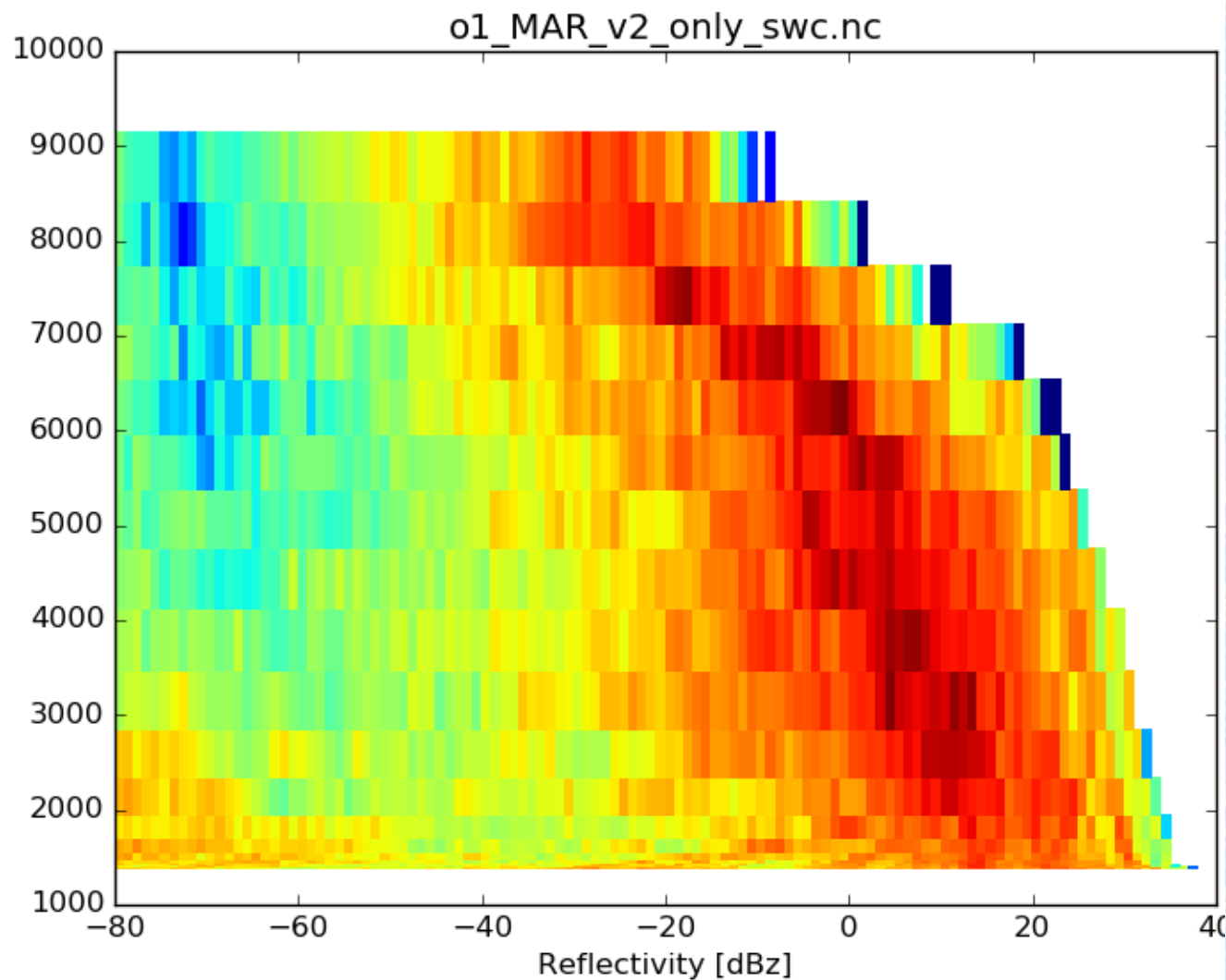


Snowfall evaluation

1. observations-to-model approach: comparing SR



Snowfall evaluation: model-to-observations approach: comparing Ze



Forward model

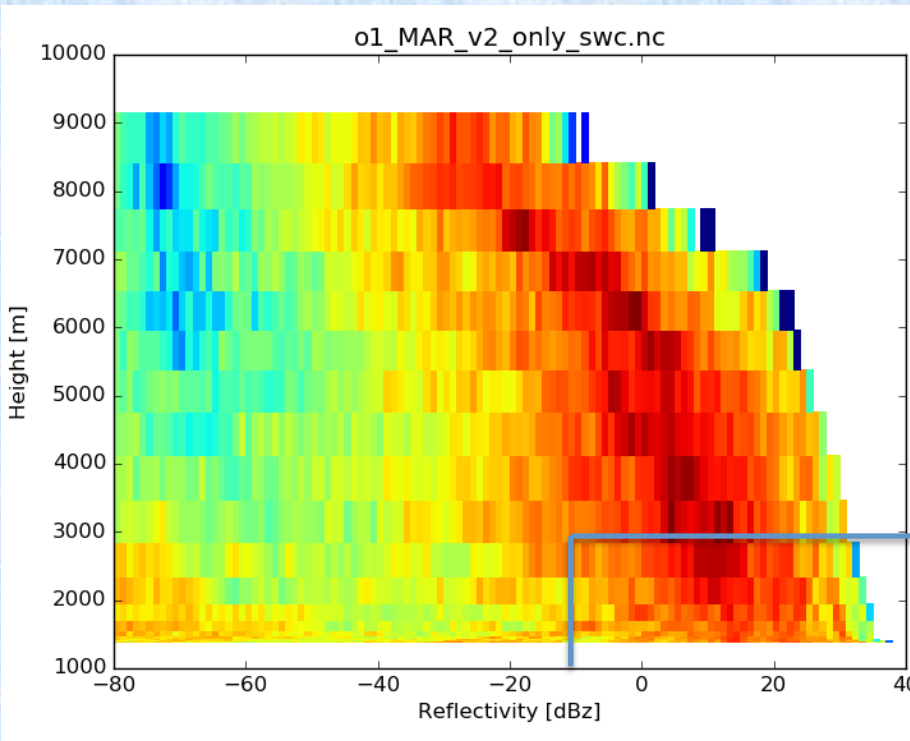
PAMTRA – Passive and Active Microwave radiative transfer model

➤ Used to synthesize Ze at 24 GHz (MRR) for MAR model

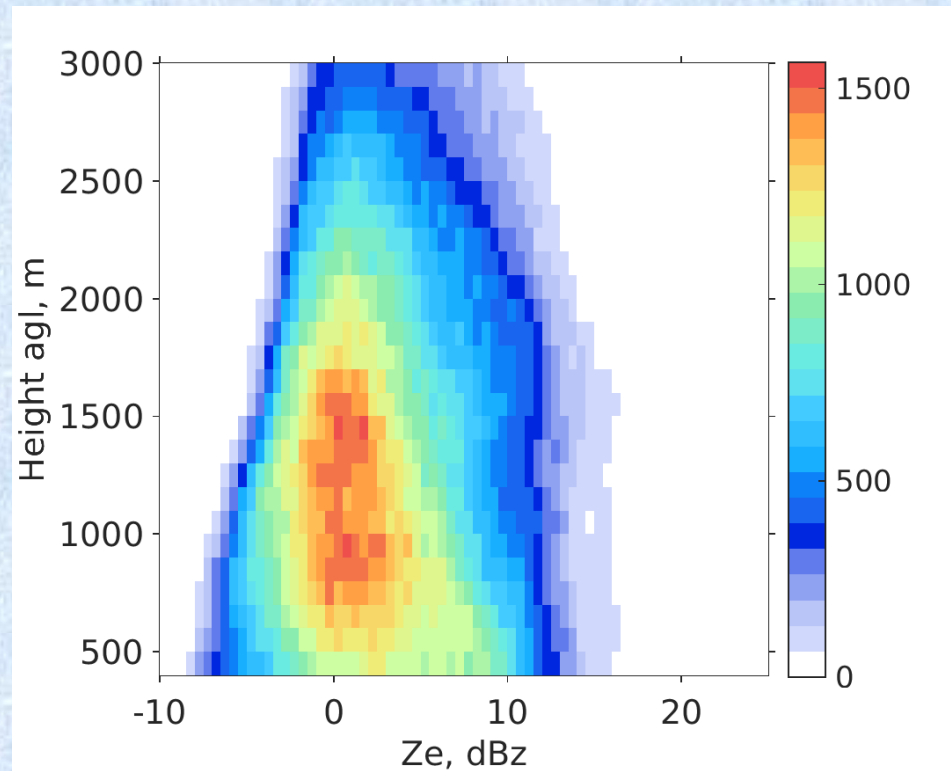
MAR parameters used:

- $V(D)$ for snow based on graupel-like snow of hexagonal type from Locatelli&Hobbs (1974)
- $m(D)$: fixed snow density = 100 kg m^{-3}
- Snowfall $N(D)$: exp (Marshall-Palmer)

Snowfall evaluation: model-to-observations approach: comparing Ze



**Ze forward-modeled using PAMTRA for
MAR RCM snowfall (full model range)**



**PE MRR Ze on 1-min scale during 2012
(from Gorodetskaya et al, Cryosphere 2015)**

Conclusions

- **Antarctic surface mass balance** is dependent on many processes => integrated measurements and analysis are needed for model evaluation and process understanding
- **New observatory installed within HYDRANT project in East Antarctica** provides ground-based remote sensing of clouds and precipitation, + meteorological parameters, snow accumulation and radiative fluxes
- **Derived parameters include:**
 - Cloud/precipitation base height
 - Cloud types (ice clouds and virga, mixed-phase clouds)
 - Snowfall rate
 - SMB components (sublimation – sfc and drifting; wind erosion)
- **MRR measurements** => high-resolution estimates of snowfall rate and relationship to SMB + direct comparison using forward modeling (avoids uncertainties in SR estimates)
- **Regional climate models** tend to overestimate intense snowfall events => need for parameterization improvements

Work continued...

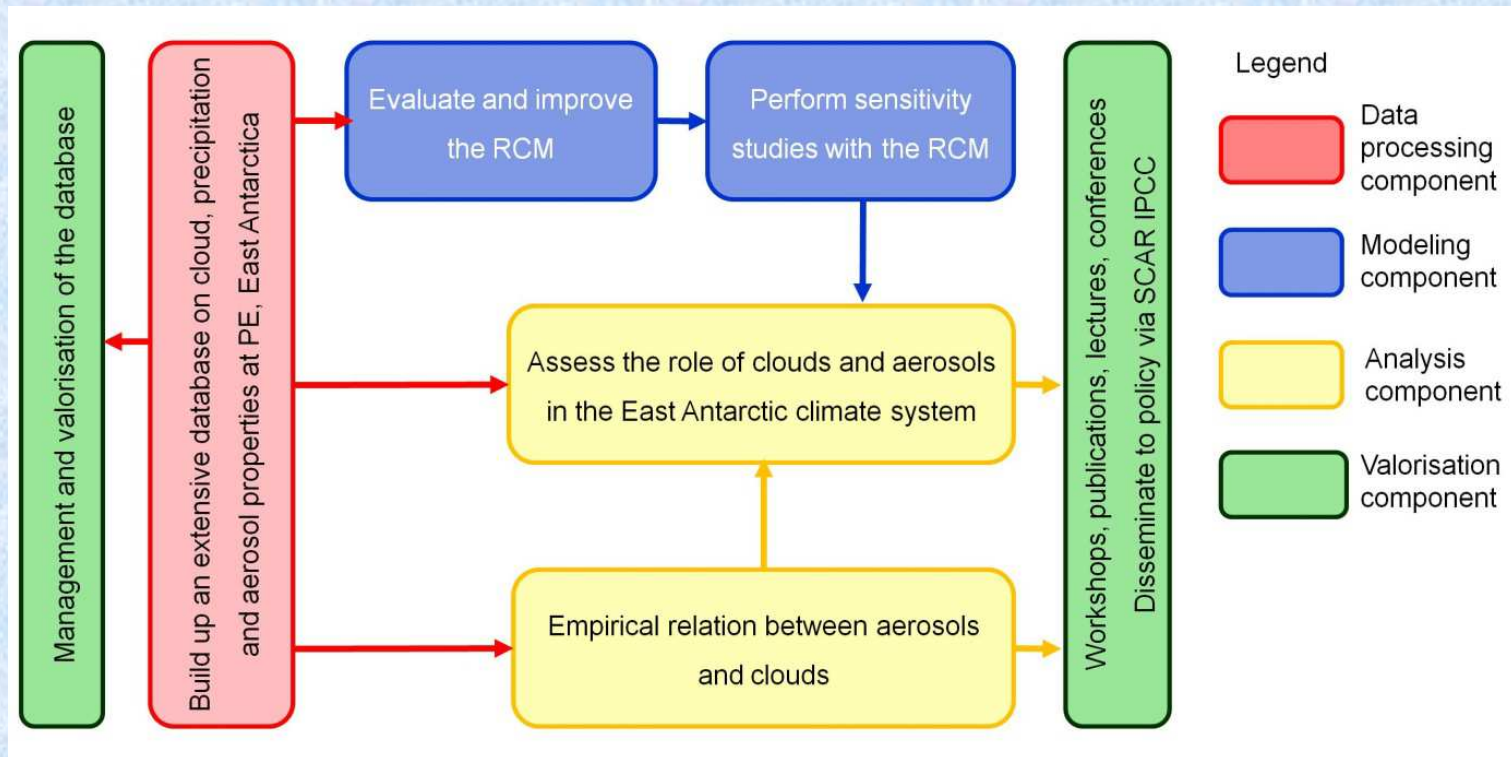
AEROCLOUD: How do aerosols and clouds affect East Antarctic climate?

Collaborative project lead by KU Leuven (PI: Nicole Van Lipzig)

Collaboration on snowfall products: IGMK, U Cologne

Belgian partners: Royal Meteorological Observatory
and Belgian Institute for Space Aeronomy

KU Leuven: Alexandra Gossart and Niels Souverijns (PhD students)





Thank you for your attention! Questions?

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