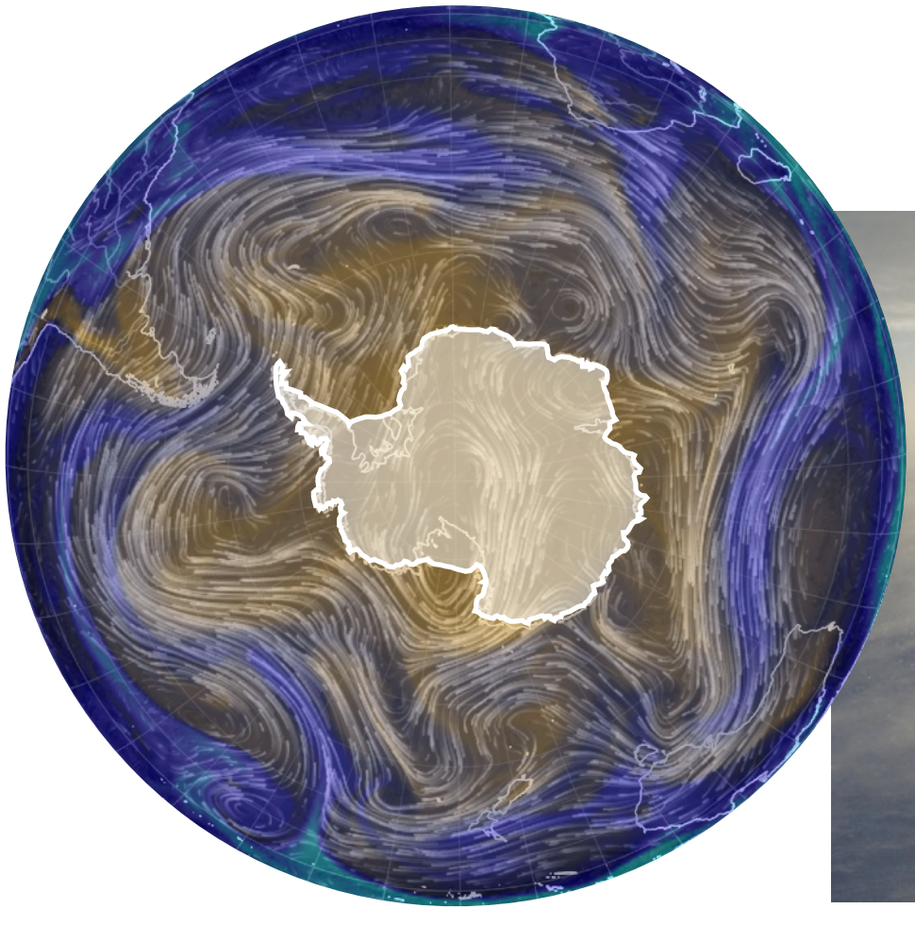
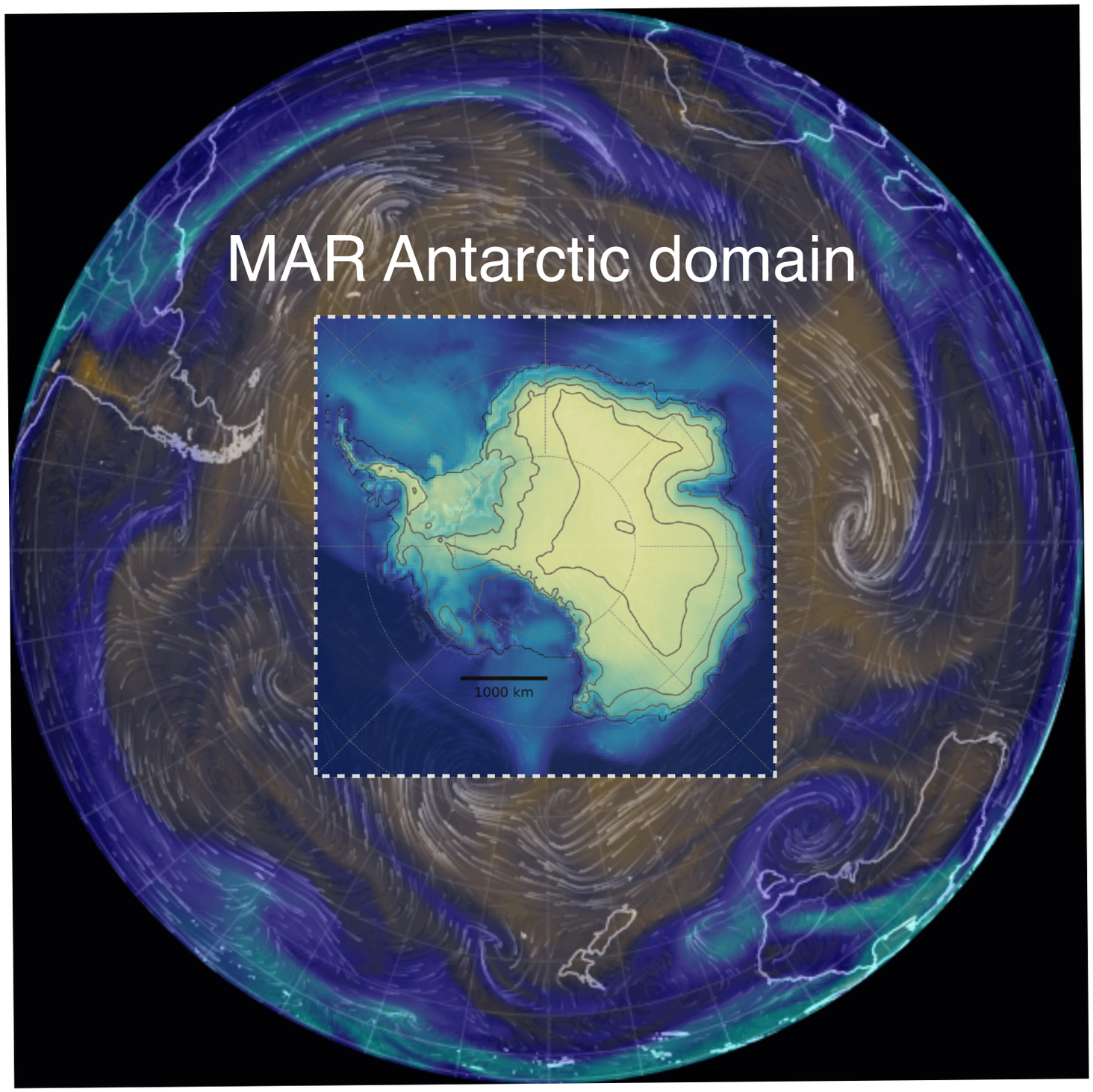
Highlights on key polar processes driving the Antarctic surface mass balance

Cécile AGOSTA

Christoph Kittel, Charles Amory, Xavier Fettweis



MAR: a regional climate model dedicated to polar studies



Cécile AGOSTA – AGU100 – C34A

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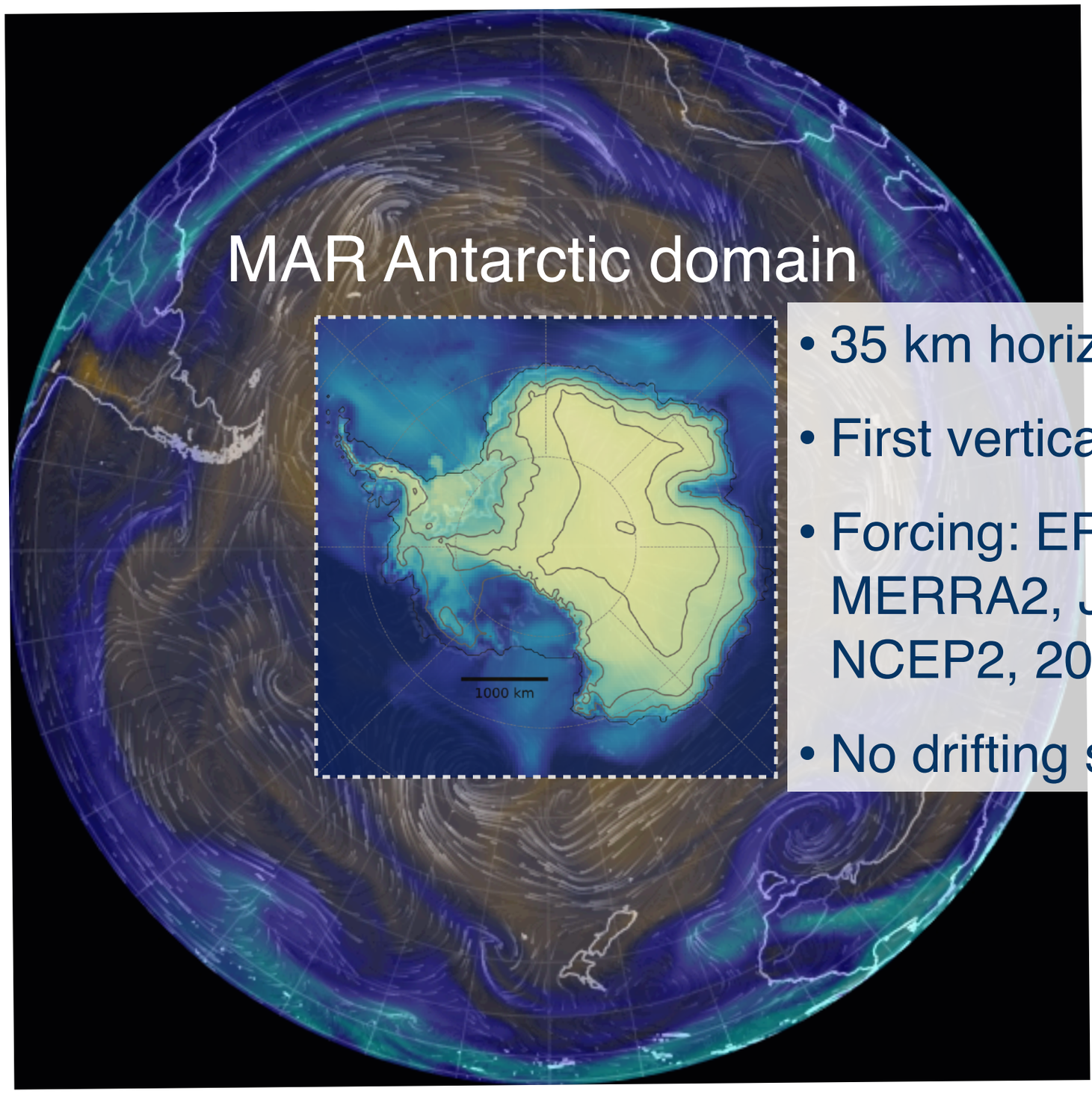
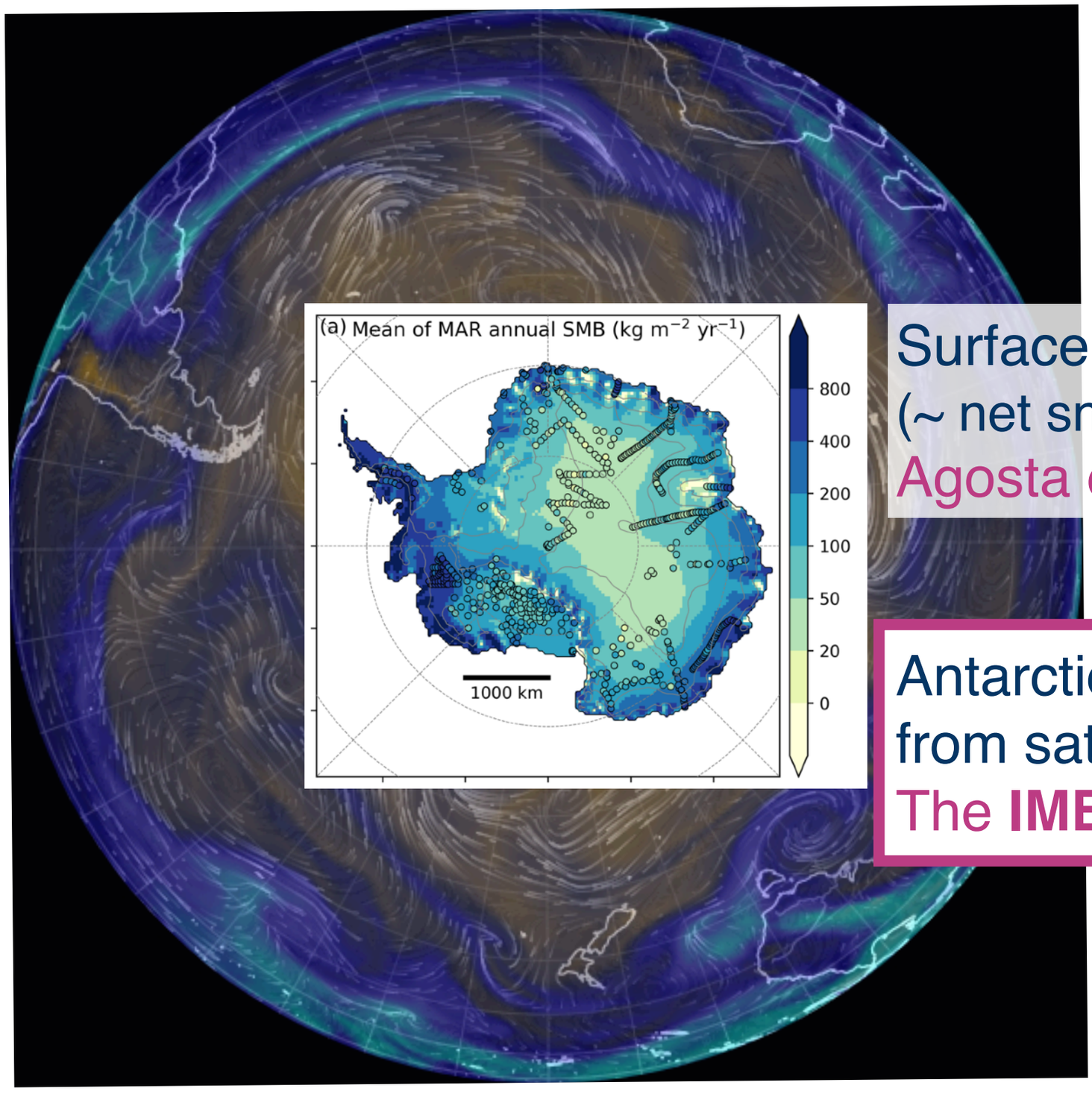


- 35 km horizontal resolution
- First vertical level: 2 m
- Forcing: ERA5, ERA-Interim, MERRA2, JRA-55, NCEP1, NCEP2, 20CRv2
- No drifting snow

MAR: a regional climate model dedicated to polar studies

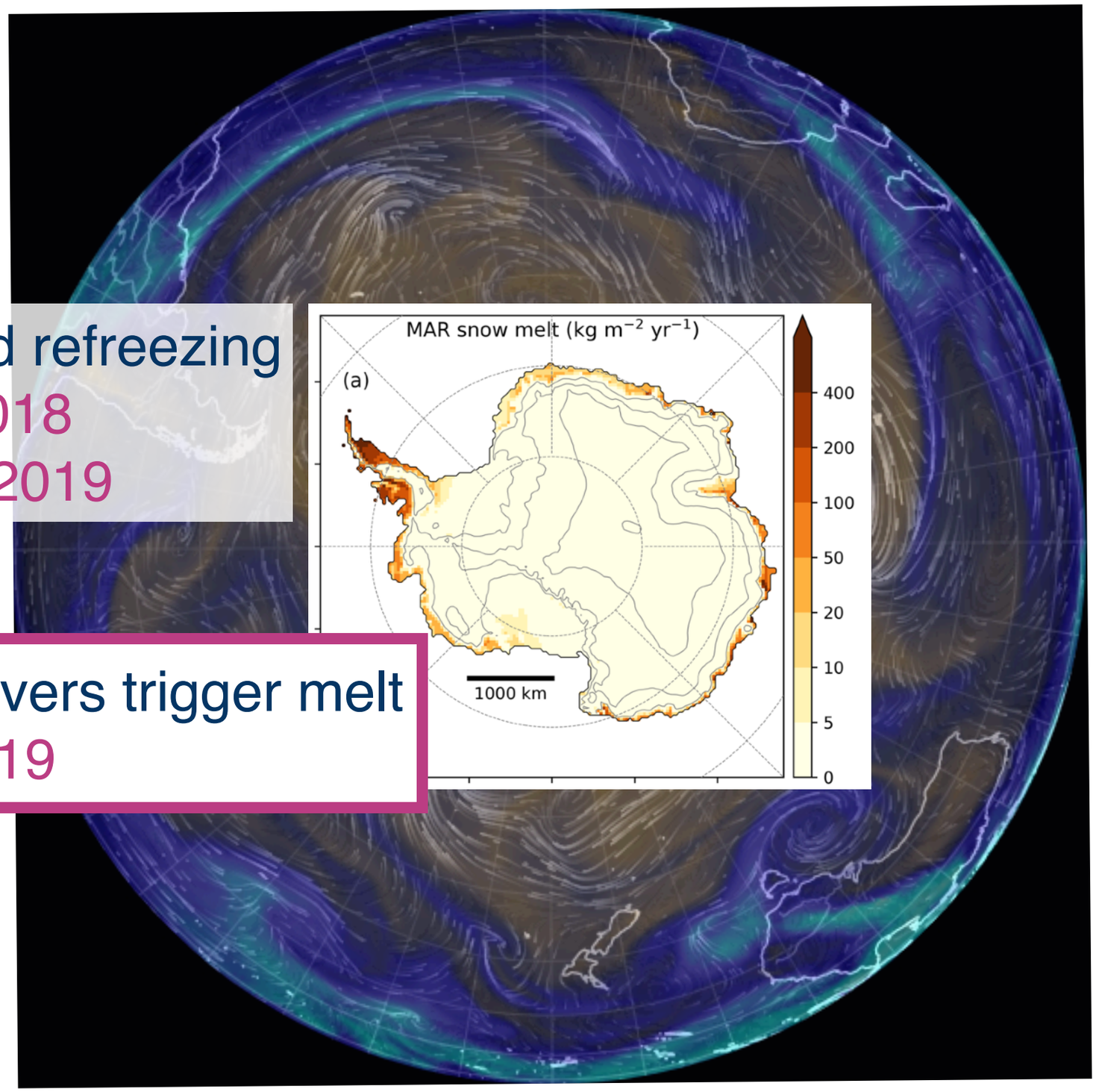


Surface mass balance
(~ net snow accumulation)
Agosta et al., 2019

Antarctic mass balance
from satellite
The **IMBIE** Team, 2018

RACMO2
SMB

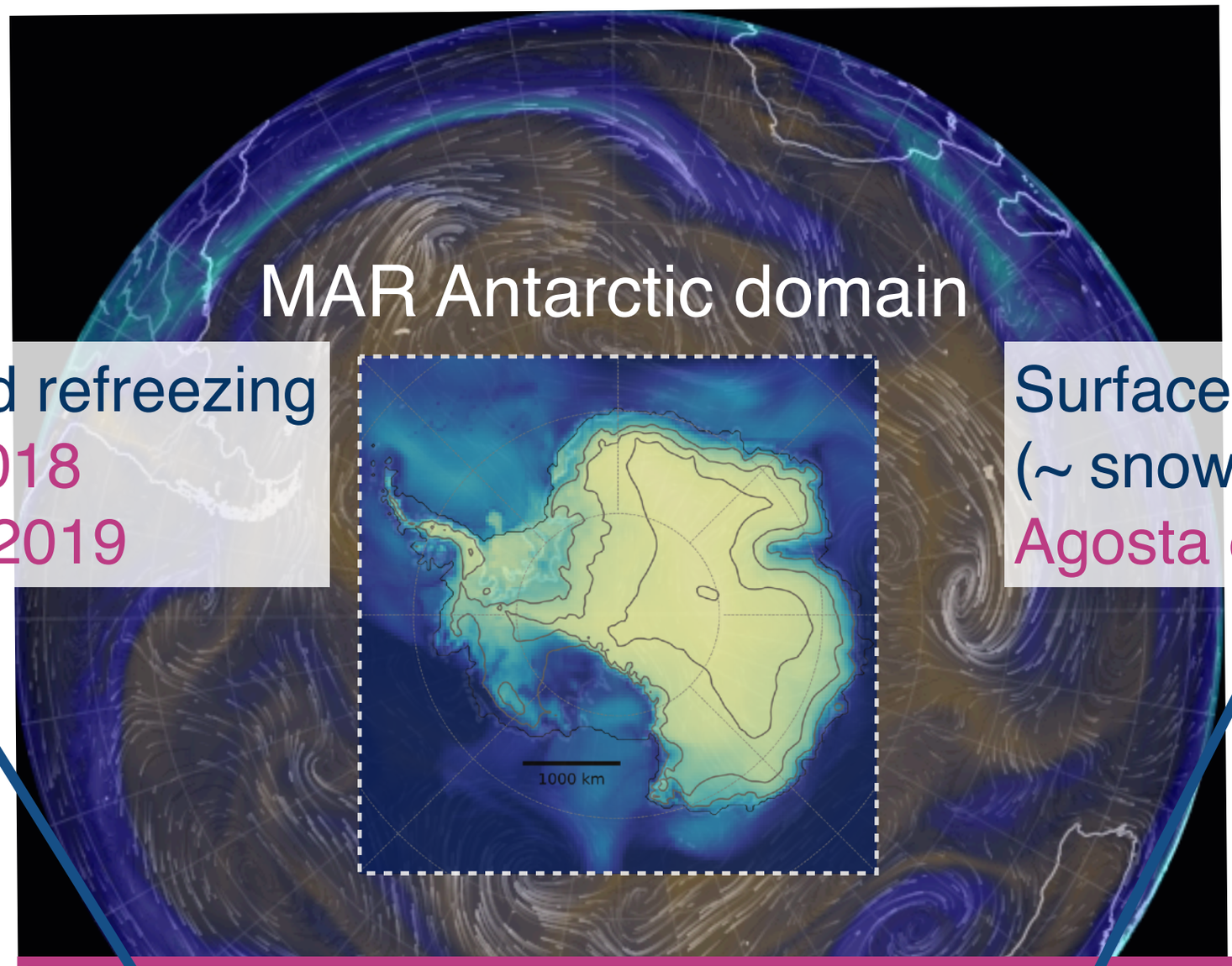
MAR: a regional climate model dedicated to polar studies



Snow melt and refreezing
Datta et al., 2018
Agosta et al., 2019

Atmospheric rivers trigger melt
Wille et al., 2019

MAR: a regional climate model dedicated to polar studies



Snow melt and refreezing
Datta et al., 2018
Agosta et al., 2019

Surface mass balance
(~ snow accumulation)
Agosta et al., 2019

Forcing of ice sheet models
Polar CORDEX
Barthel et al., 2019; Hansen et al. (in prep.)

Highlights on key polar processes driving the Antarctic surface mass balance

Study questions

What are the processes controlling the Antarctic SMB?

What are the differences between MAR and other models?

What are the processes correctly or incorrectly simulated?

Method

Regional modeling: MAR forced by 7 reanalyses

Model-Observation comparison

Model intercomparison: MAR vs RACMO, MAR vs reanalyses

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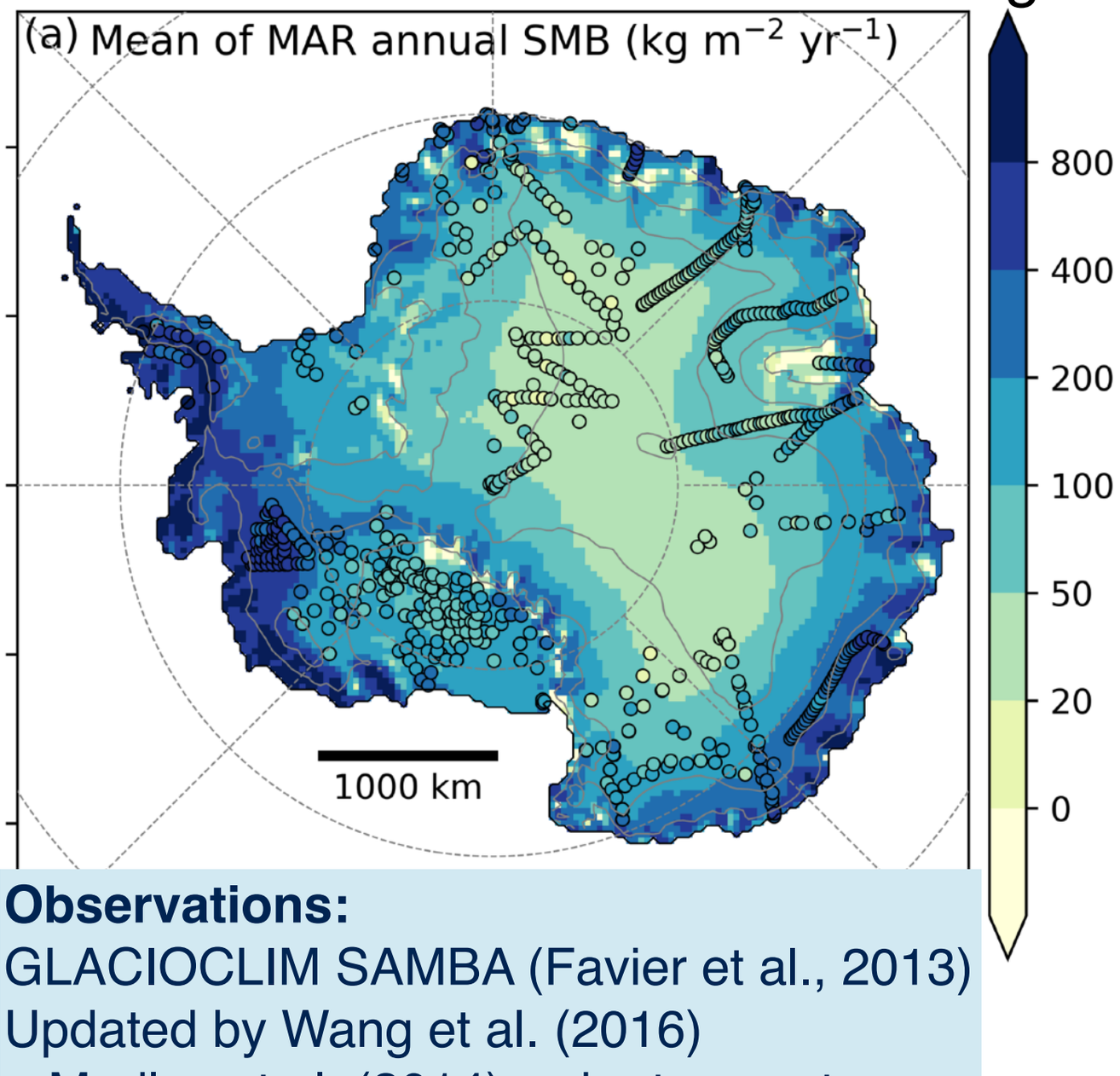
Agosta et al. (2019), The Cryosphere

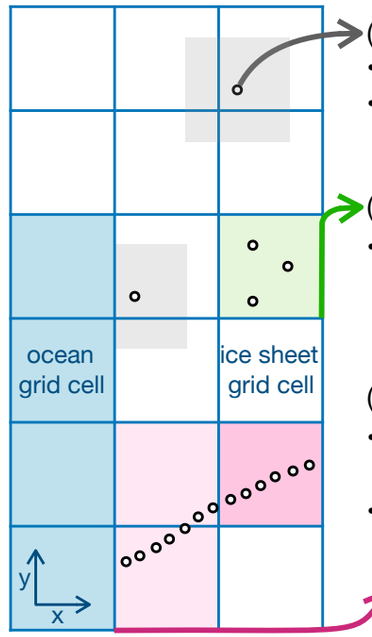
Modeling the Antarctic surface mass balance with MAR

Resolution + Snowpack + Boundary layer + Microphysics ⟹ SMB

MAR and observed SMB



Observations:
GLACIOCLIM SAMBA (Favier et al., 2013)
Updated by Wang et al. (2016)
+ Medley et al. (2014) radar transects



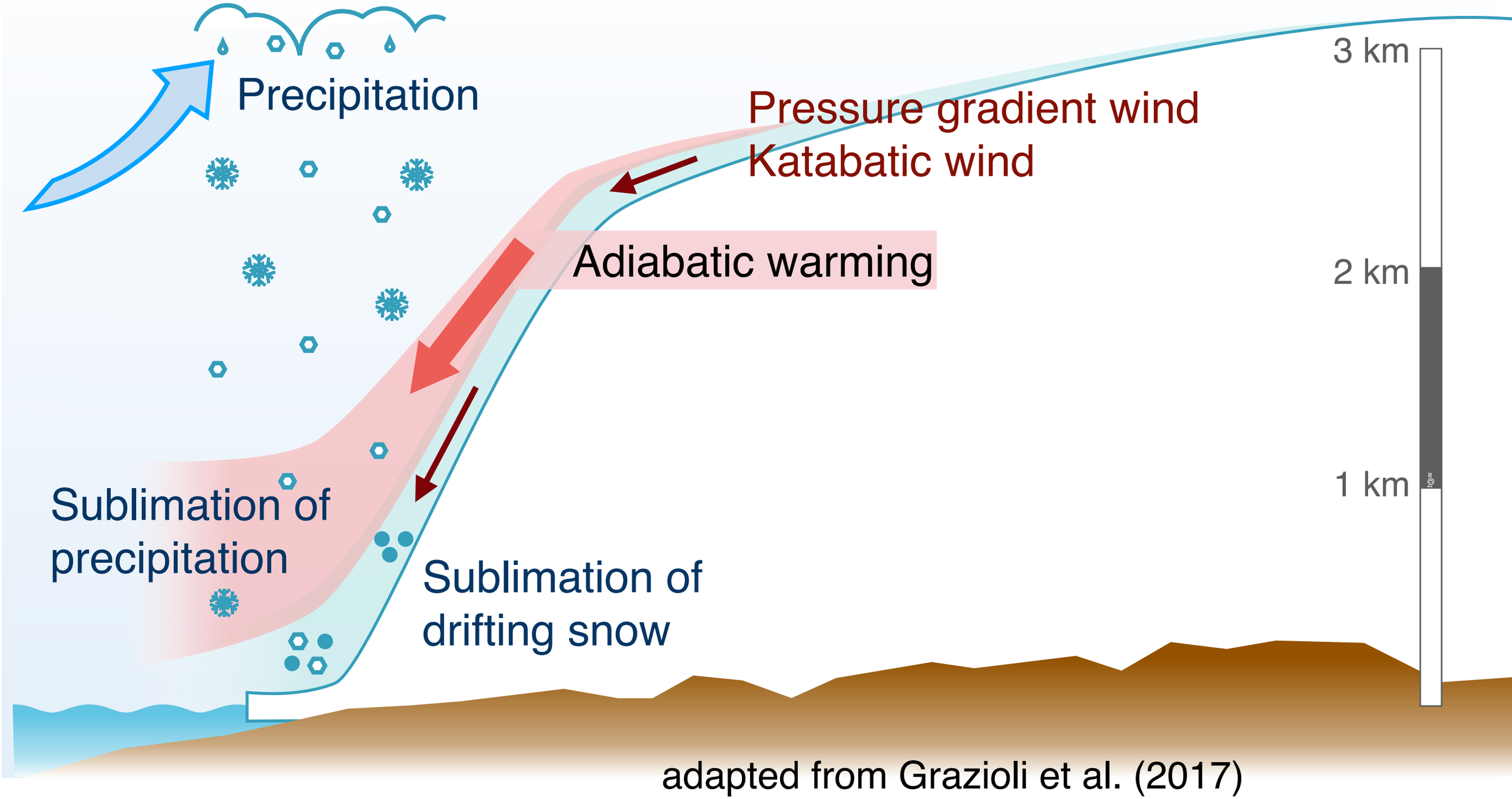
(1) At each observation location:
- observed SMB over time span
- bi-linear interpolation of modelled SMB (mean on same time span as observation)

(2) For each grid cell containing observation:
- average of observed and interpolated modelled values weighted by the observations time span

(3) For transects:
- choice of a direction (x or y of the stereographic grid)
- average of grid cells orthogonally to this direction, weighted by the sum of observations time span

Agosta et al. (2019), The Cryosphere

Snowfall sublimation in surface layers: a large mass sink

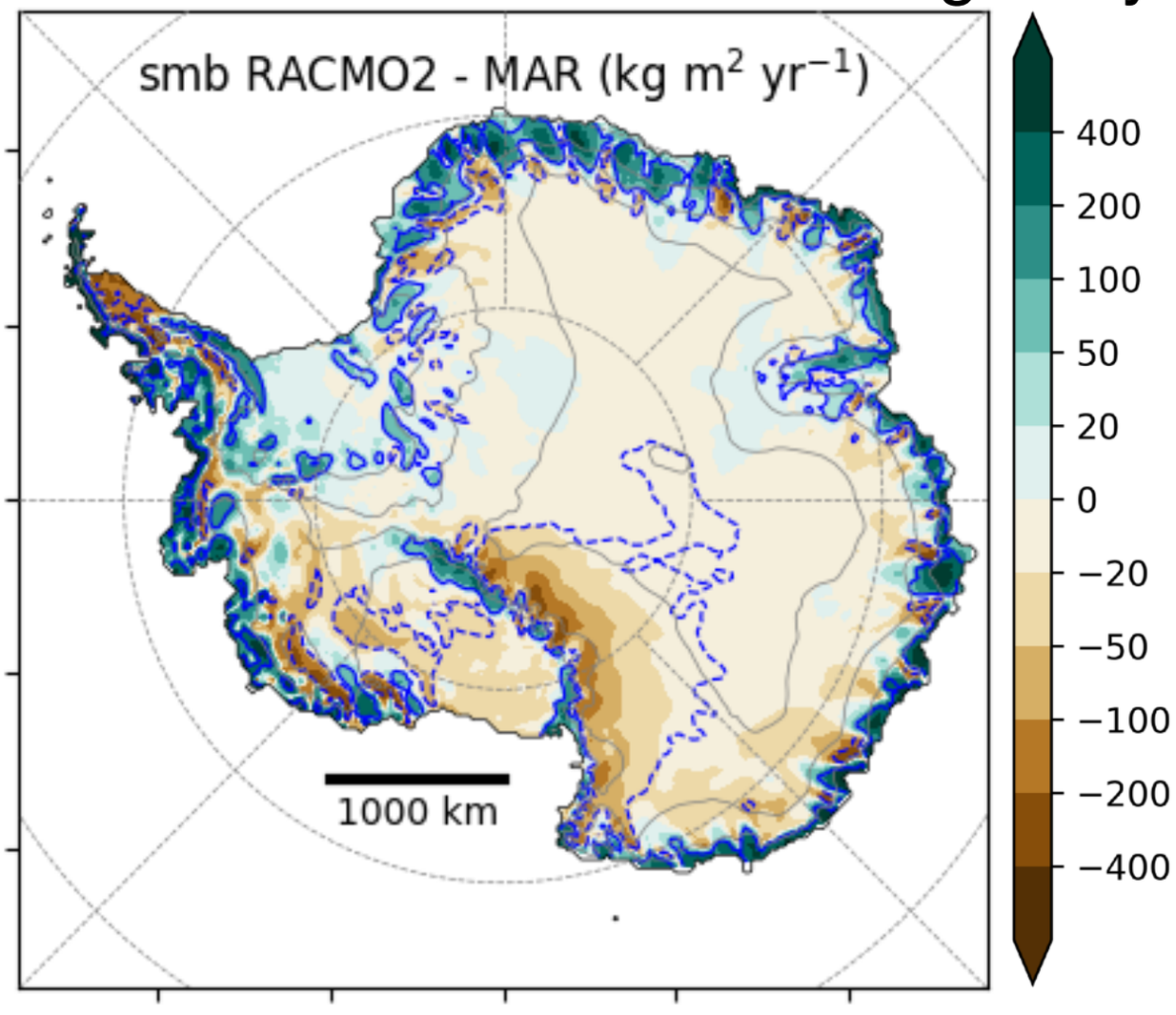


adapted from Grazioli et al. (2017)

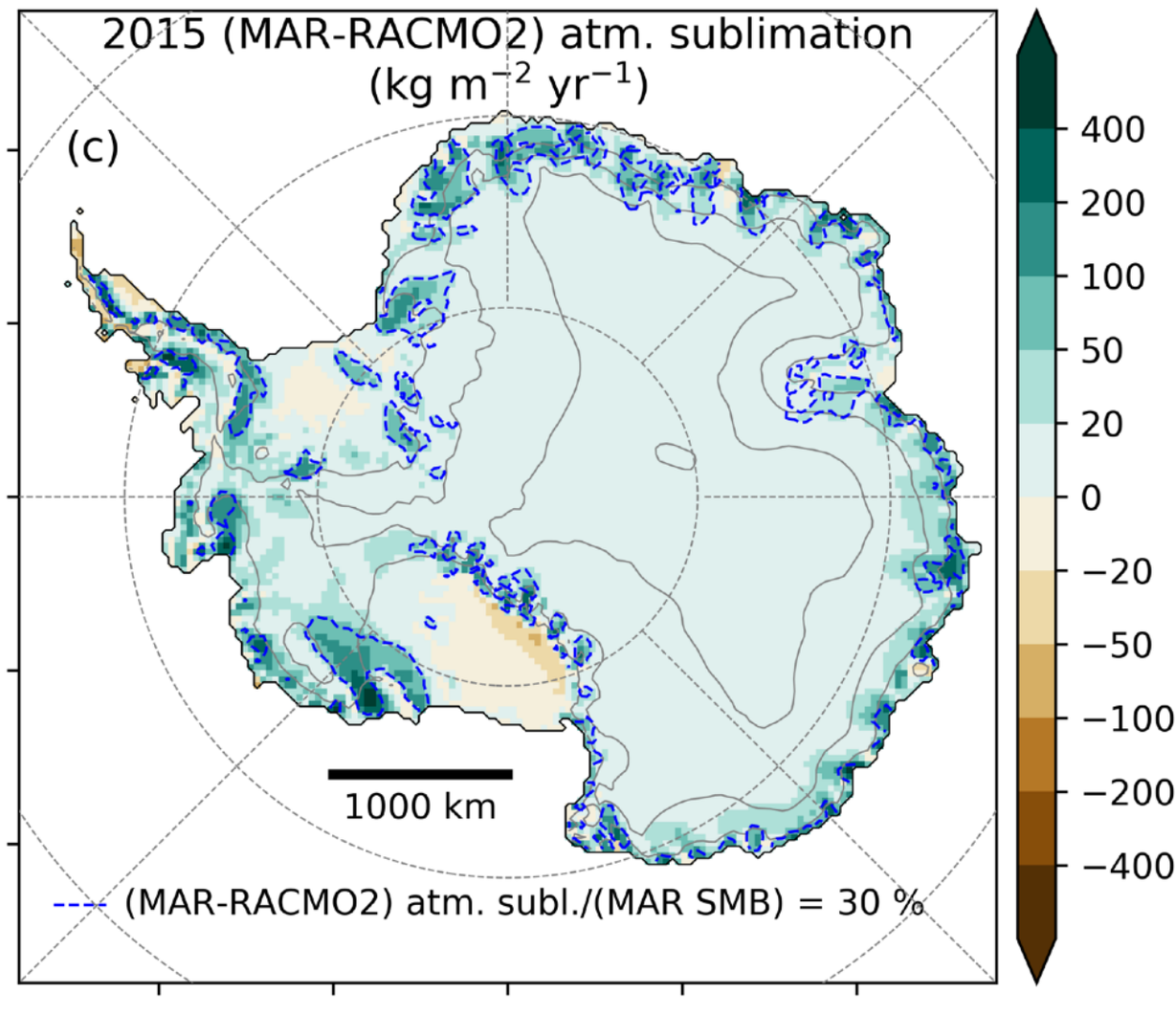
Grazioli et al. (2017): **300 Gt/yr** for 2015

Snowfall sublimation in surface layers: a large mass sink

(RACMO2-MAR) SMB



Difference in atmospheric sublimation between MAR and RACMO2



Grounded ice sheet atmospheric sublimation for 2015:

Grazioli et al. (2017): 300 Gt/yr vs. **MAR: 360 Gt/yr** vs. RACMO2 130 Gt/yr

Highlights on key polar processes driving the Antarctic surface mass balance

Study questions

What are the processes controlling the Antarctic SMB?

Are reanalyses SMB simulations reliable?

Are climate models SMB simulations reliable?

Method

Regional modeling: MAR forced by 7 reanalyses

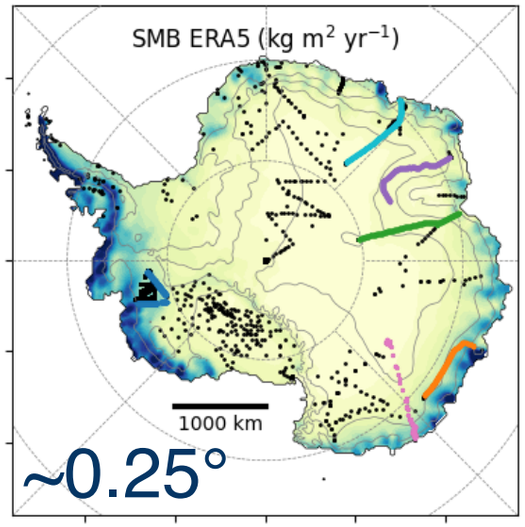
Model-Observation comparison

Model intercomparison: MAR vs RACMO, MAR vs reanalyses

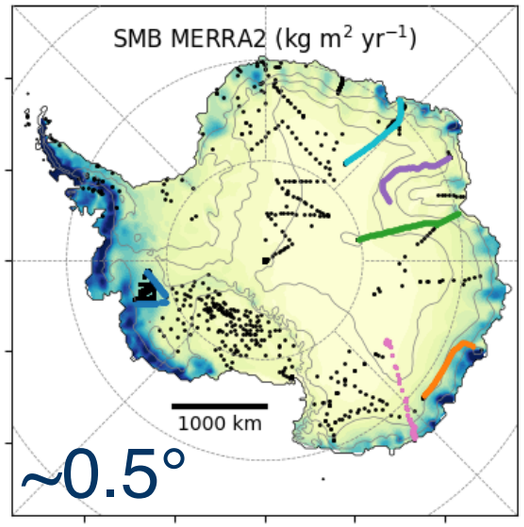
Reanalyses (1979-2017)

SMB Reanalyses = Precipitation - Evaporation

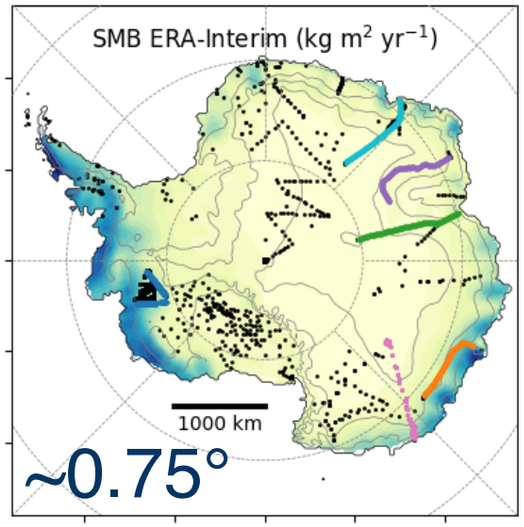
ERA5



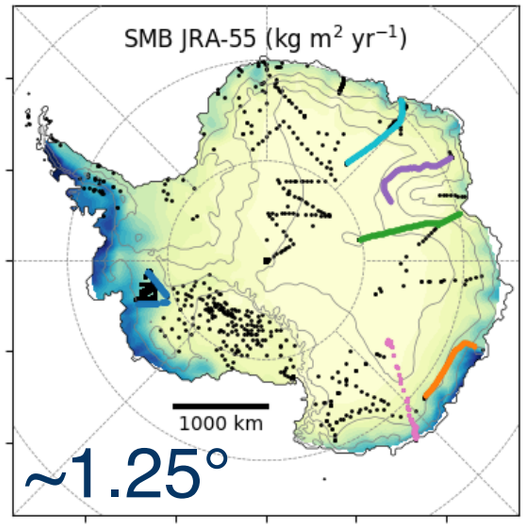
MERRA2



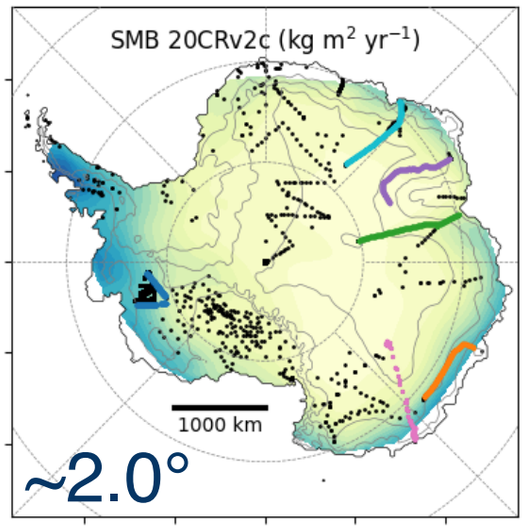
ERA-Interim



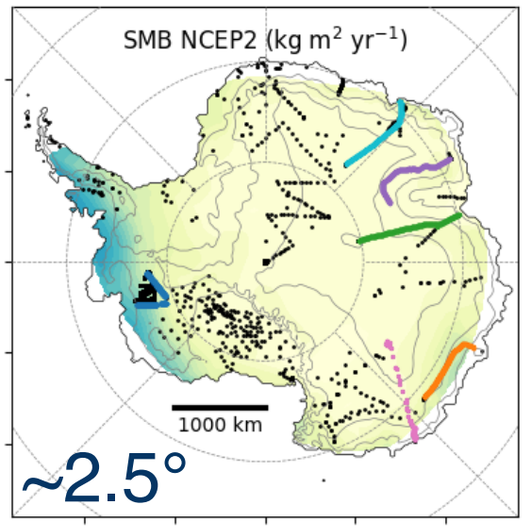
JRA-55



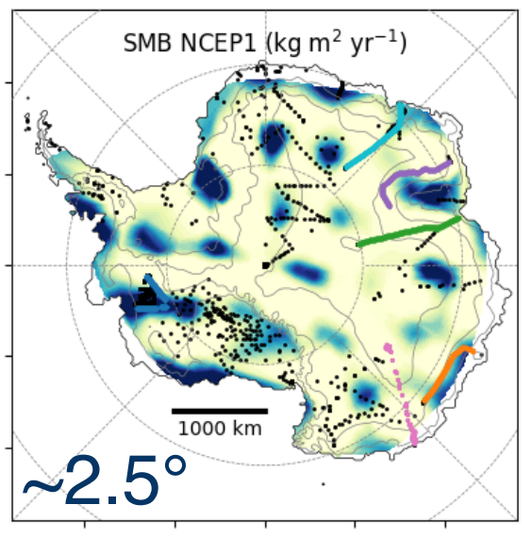
20CRv2

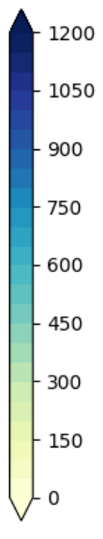


NCEP2

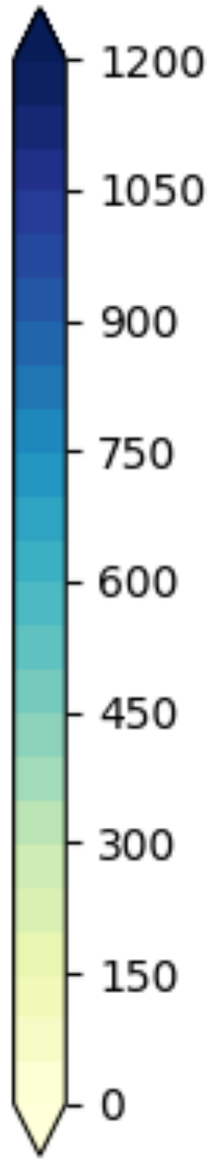


NCEP1





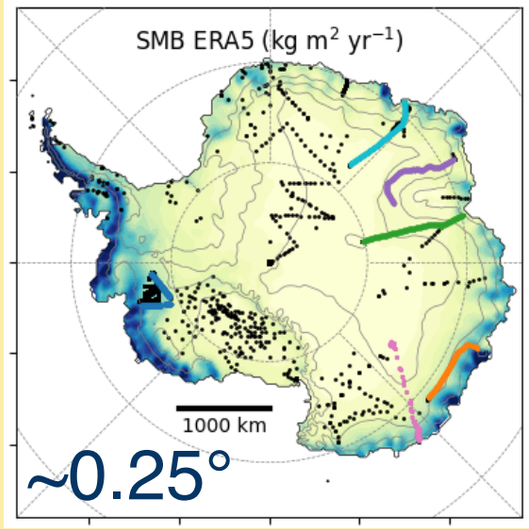
SMB
kg m^{-2} yr^{-1}



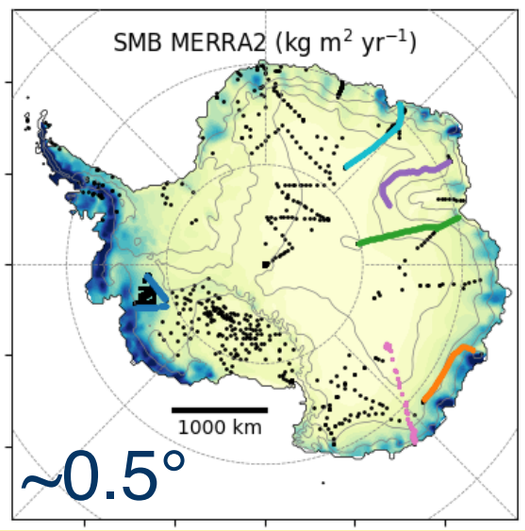
Reanalyses (1979-2017)

SMB Reanalyses = Precipitation - Evaporation

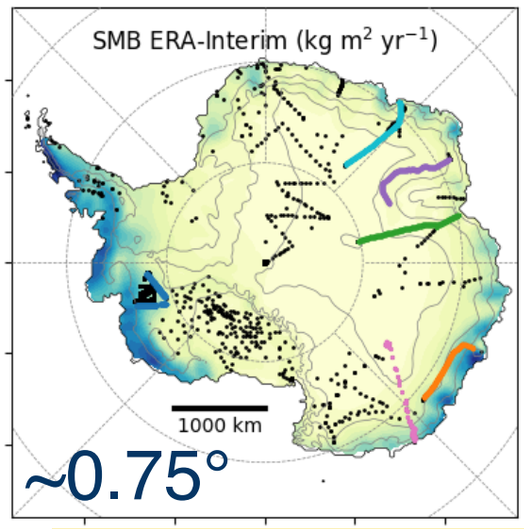
ERA5



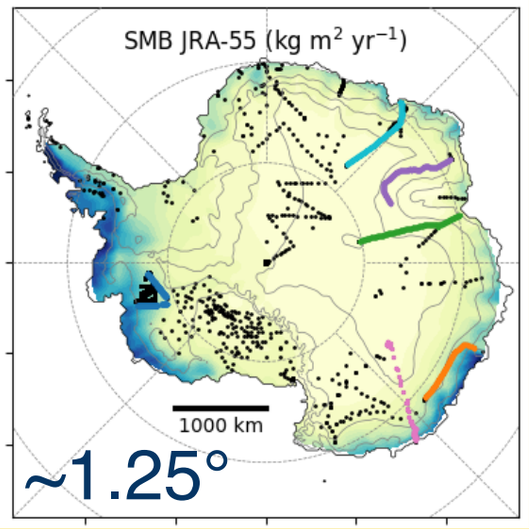
MERRA2



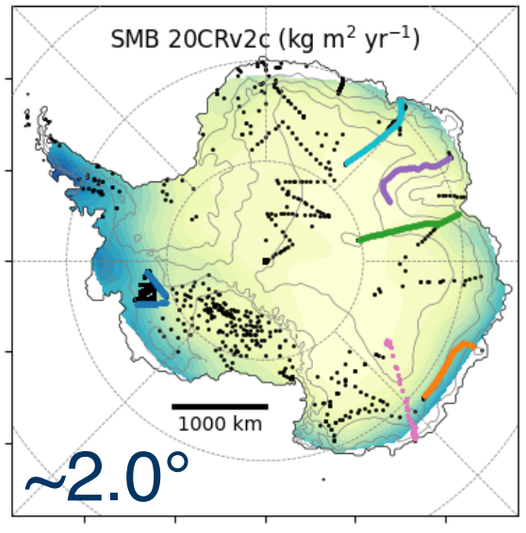
ERA-Interim



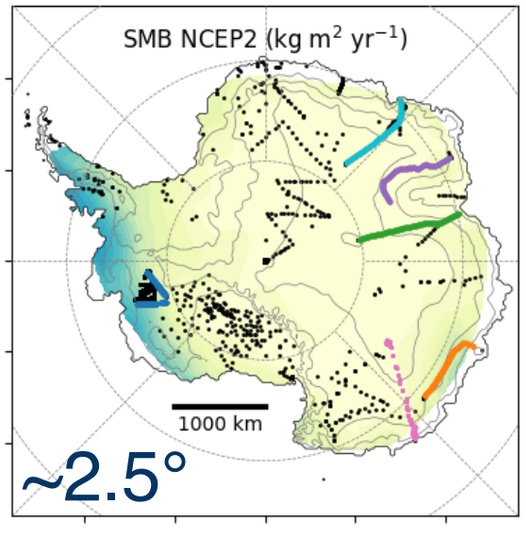
JRA-55



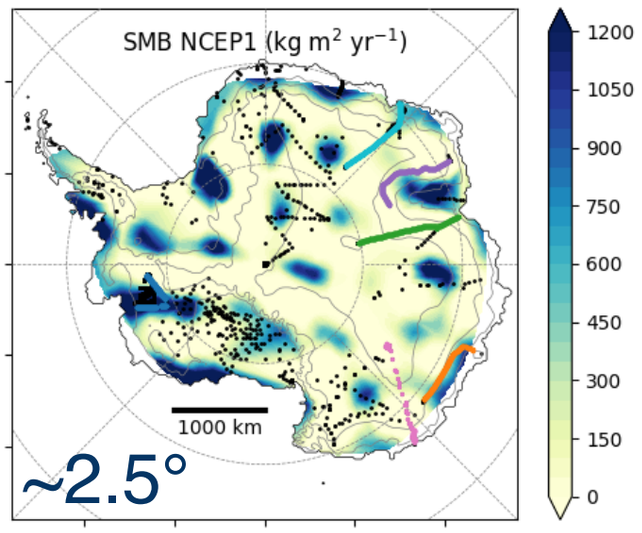
20CRv2



NCEP2



NCEP1



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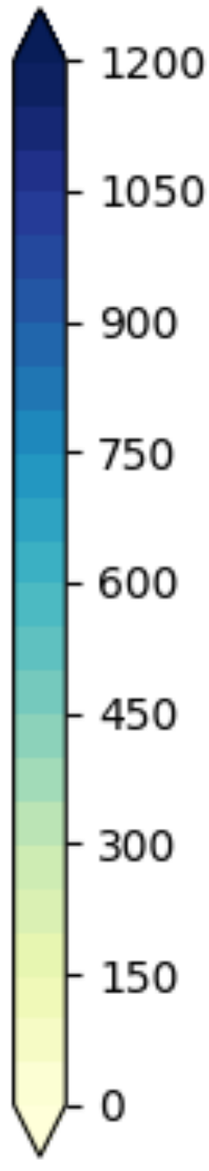
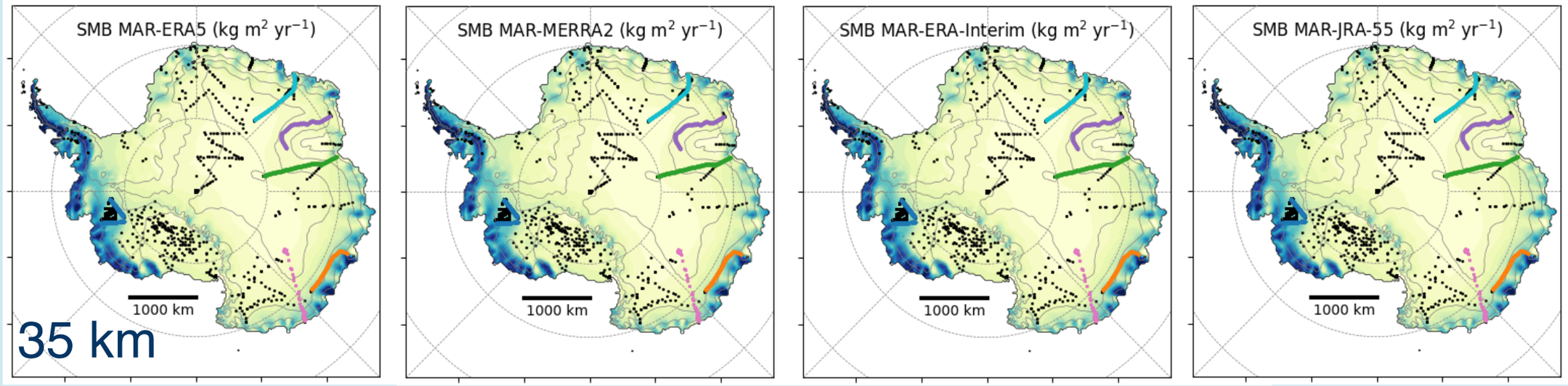


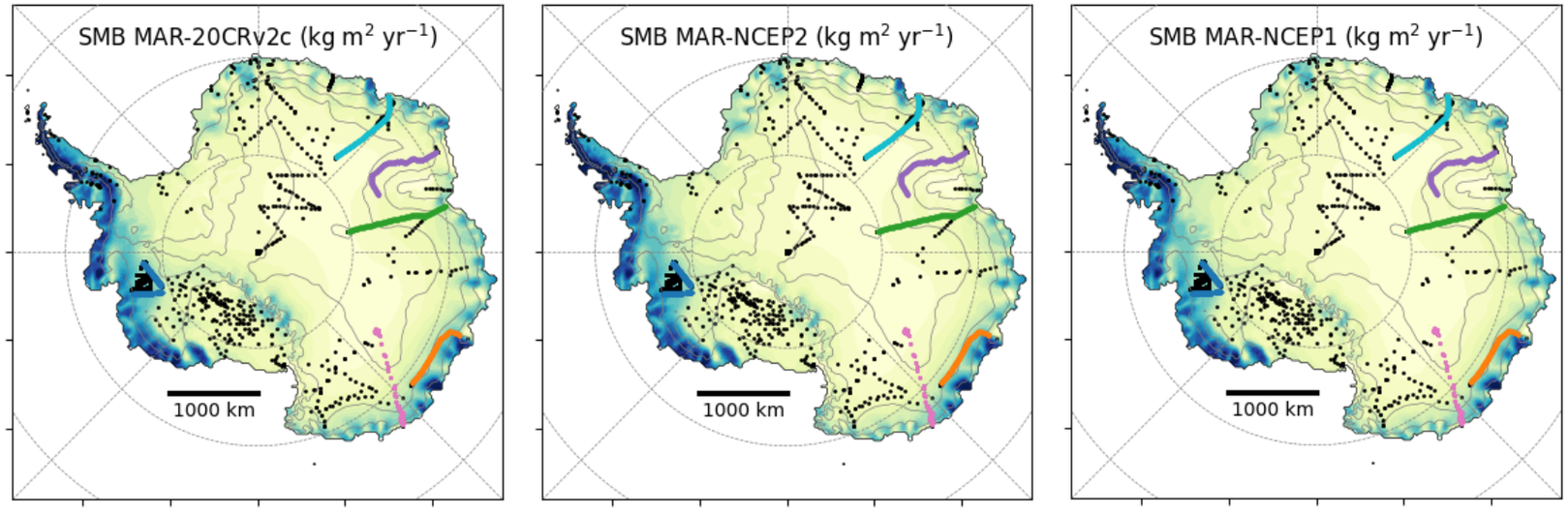
Multi-reanalyses forcing of MAR (1979-2017)

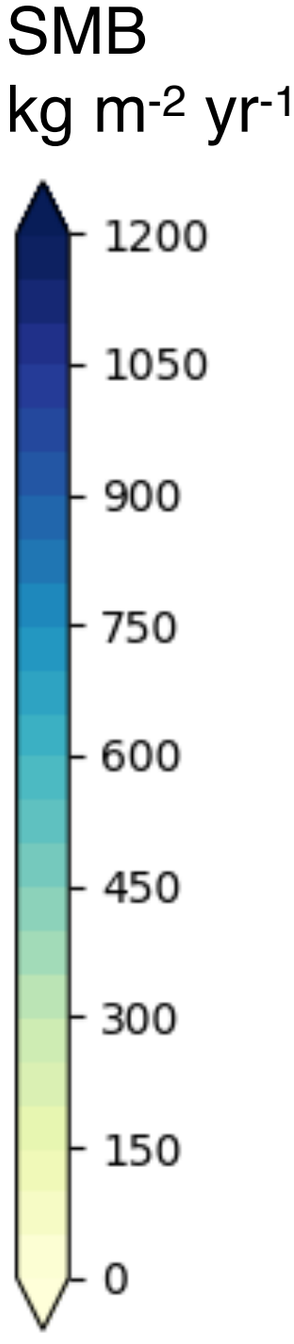
SMB MAR(Reanalyses) = Precipitation - Evaporation - Runoff

MAR(ERA5) MAR(MERRA2) MAR(ERA-Interim) MAR(JRA-55)



MAR(20CRv2) MAR(NCEP2) MAR(NCEP1)



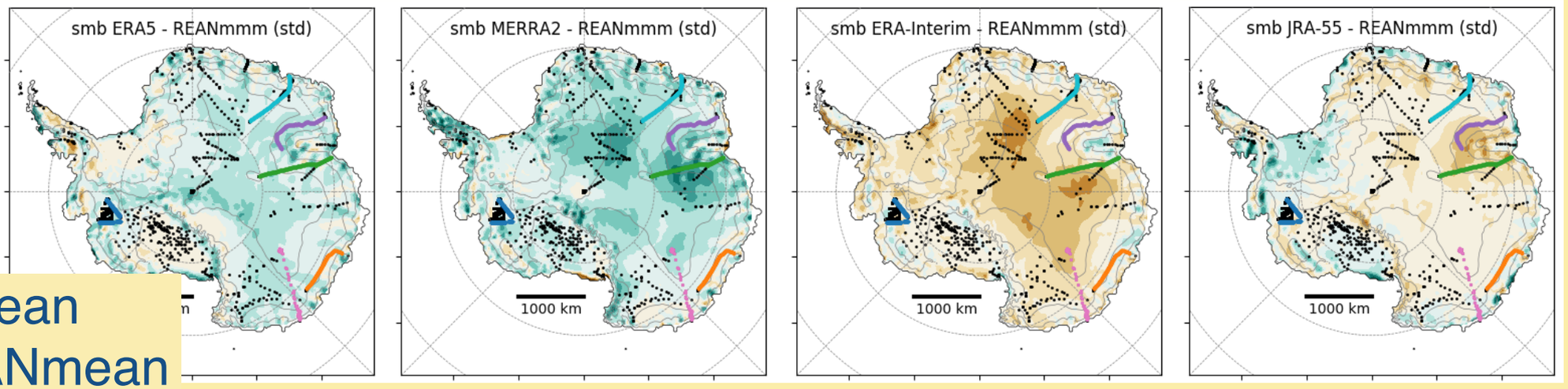


➡ NCEP and 20CR large scale circulation sufficiently reliable for regional downscaling

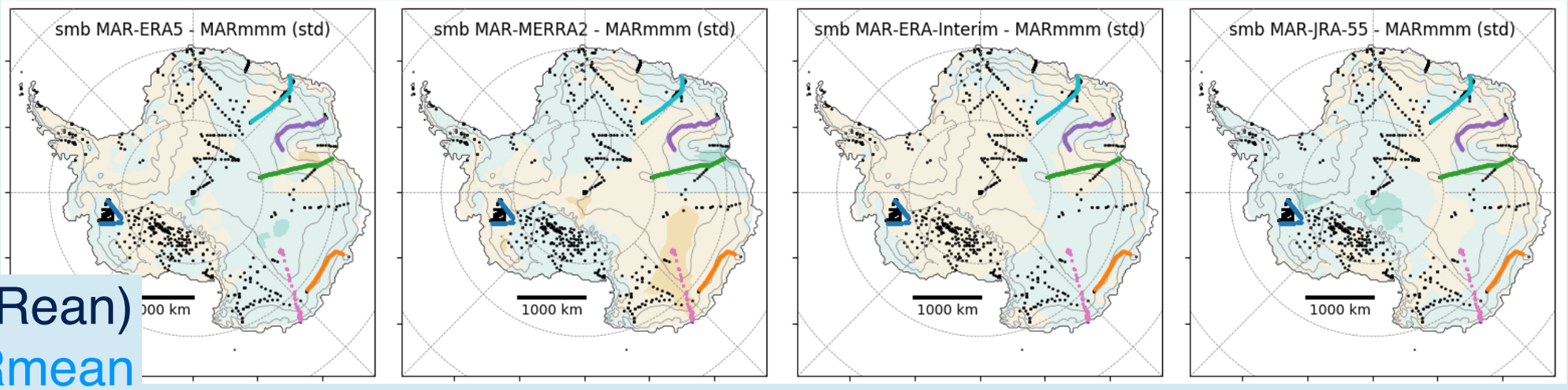
MAR vs Reanalyses for SMB (1979-2017)

ERA5 ~0.25° | MERRA2 ~0.5° | ERA-Interim ~0.75° | JRA-55 ~1.25°

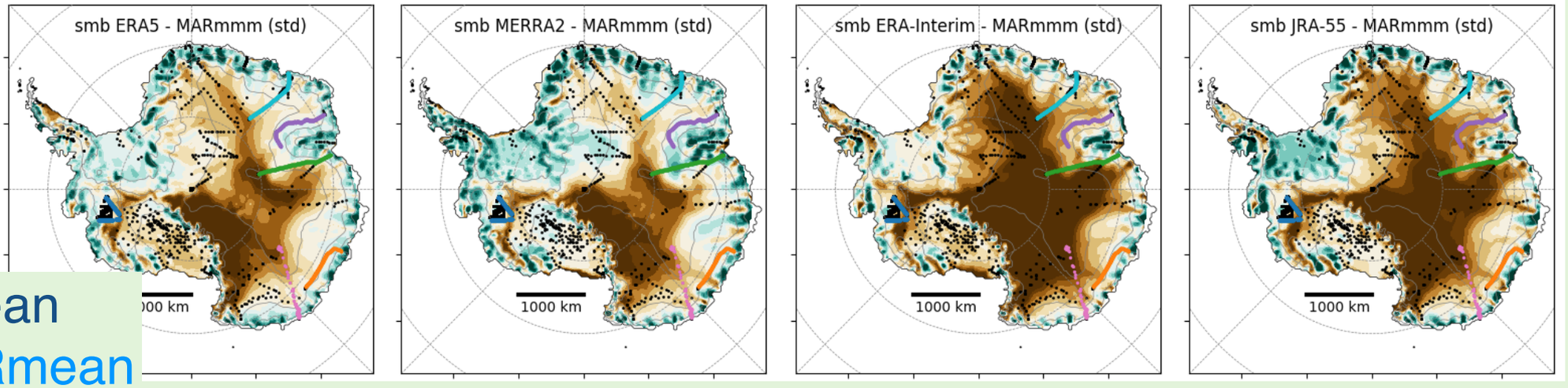
Rean –REANmean

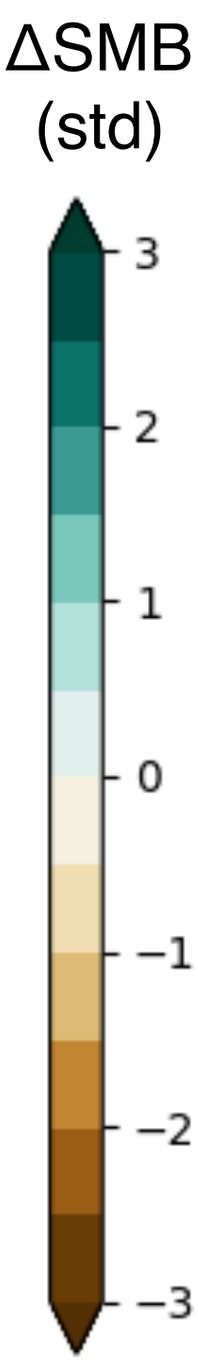


MAR(Rean) –MARmean



Rean –MARmean





MAR vs Reanalyses for SMB (1979-2017)

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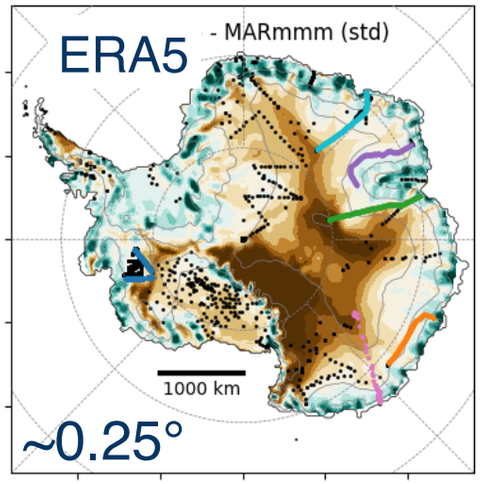
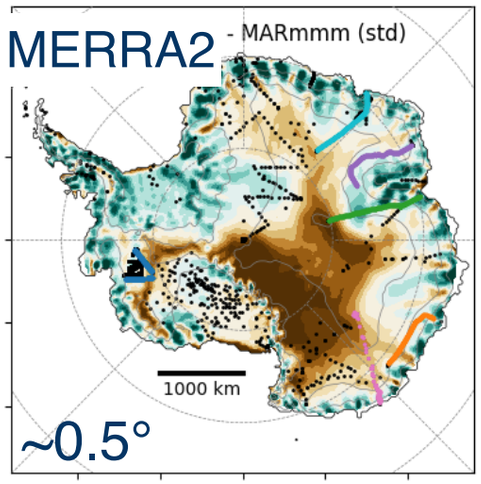
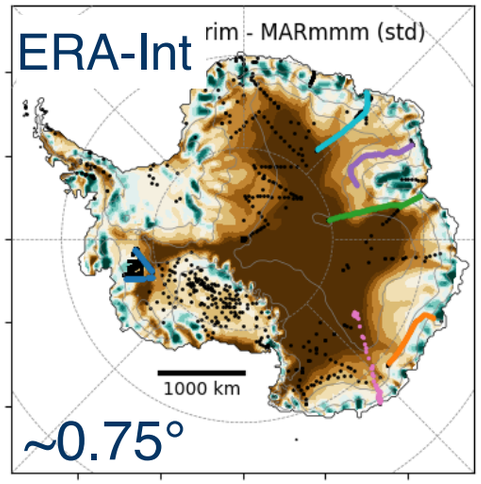
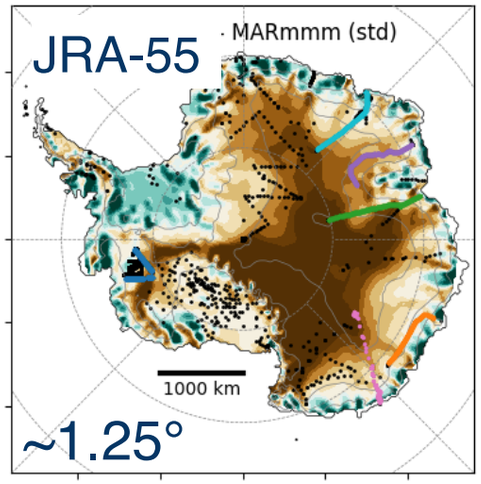
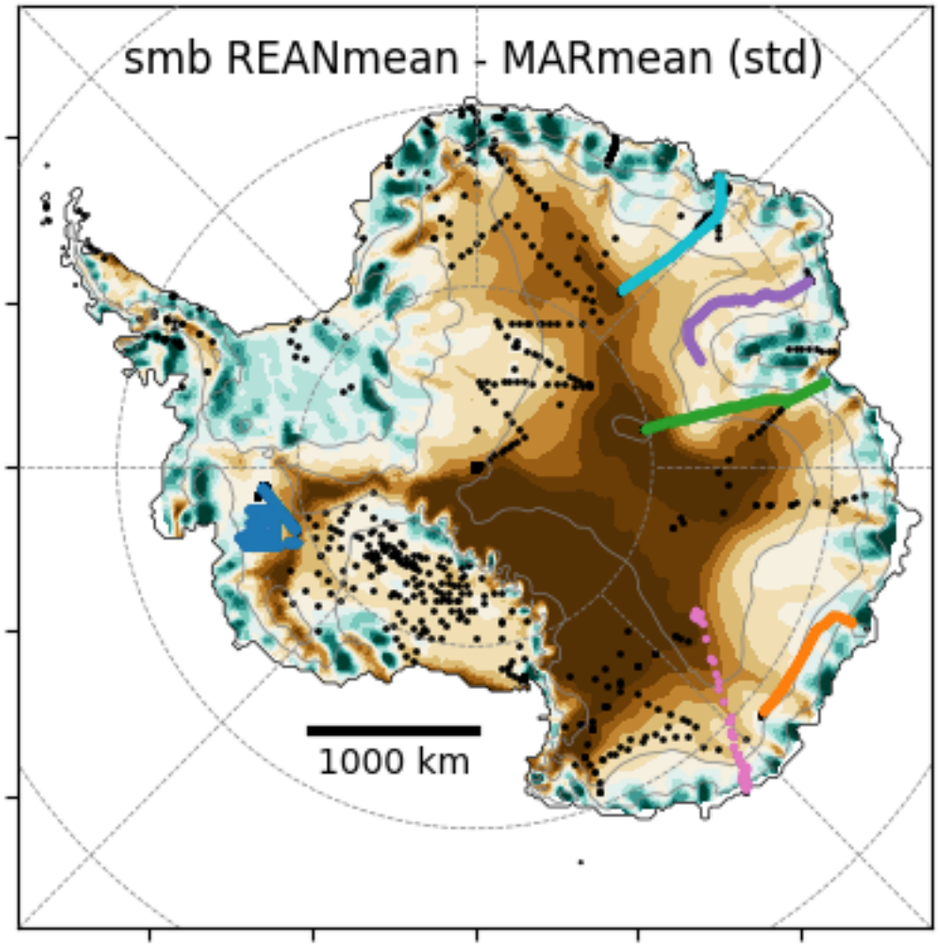


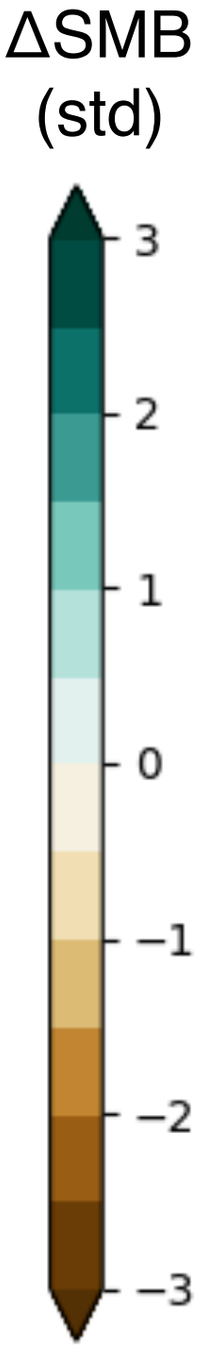






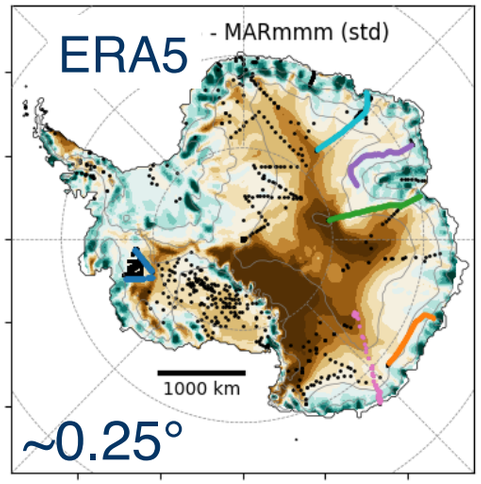
REANmean – MARmean

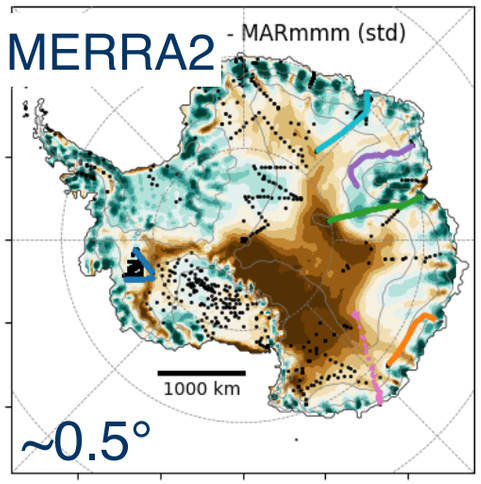


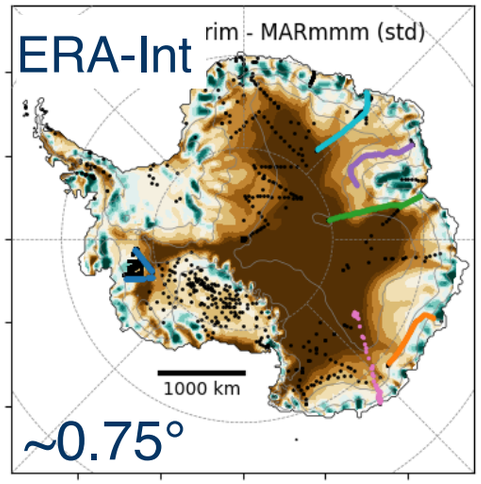


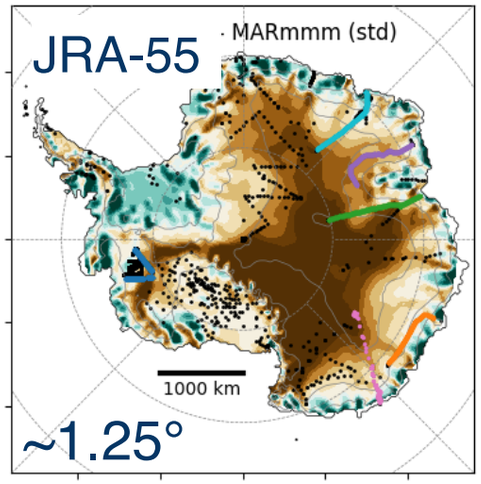
MAR vs Reanalyses for SMB (1979-2017)

Rean – MARmean

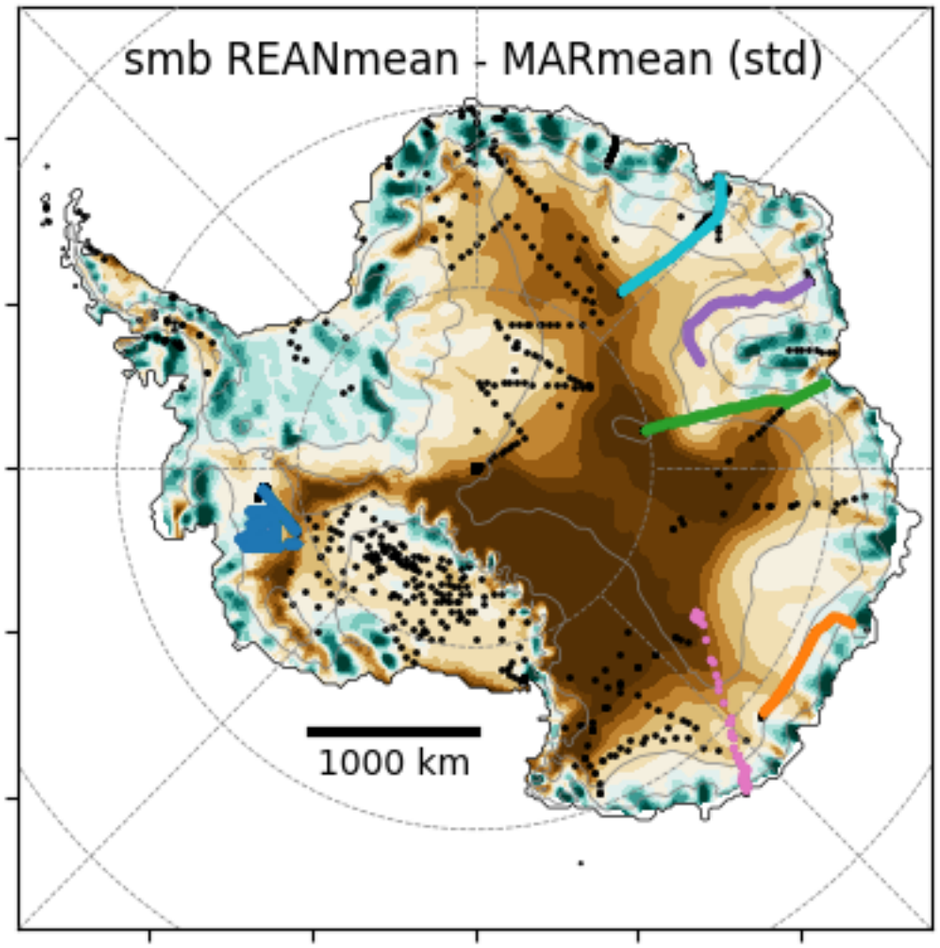




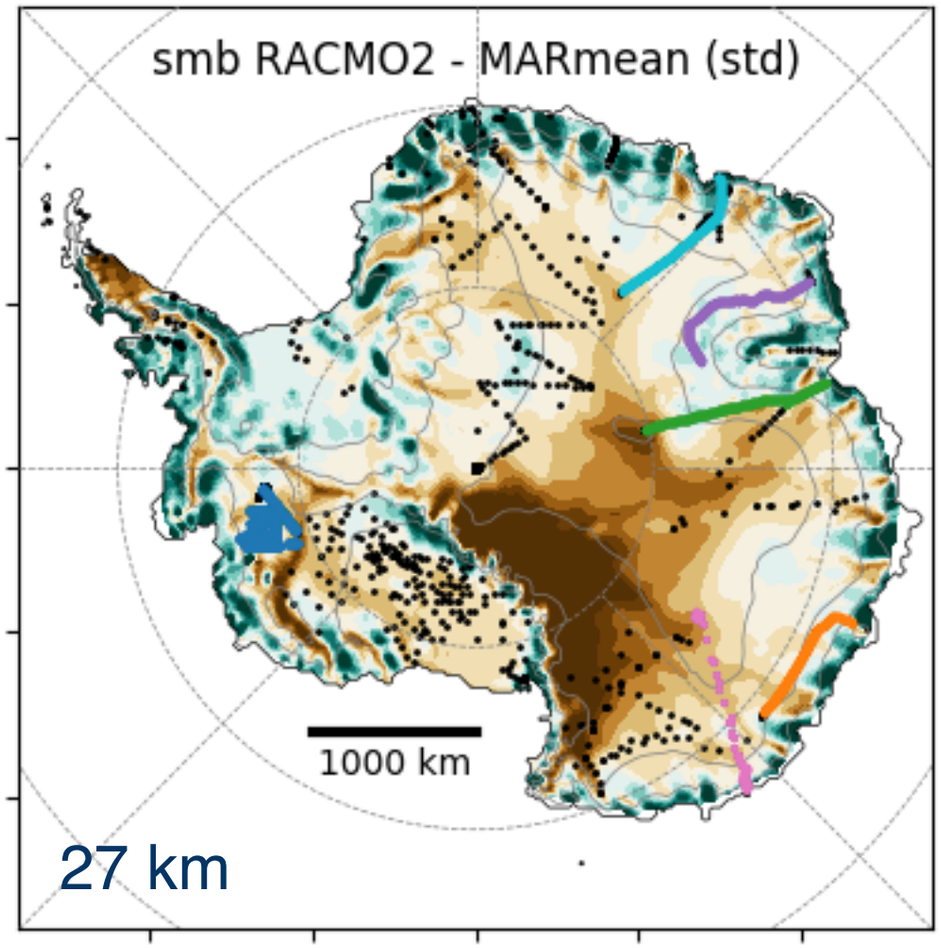


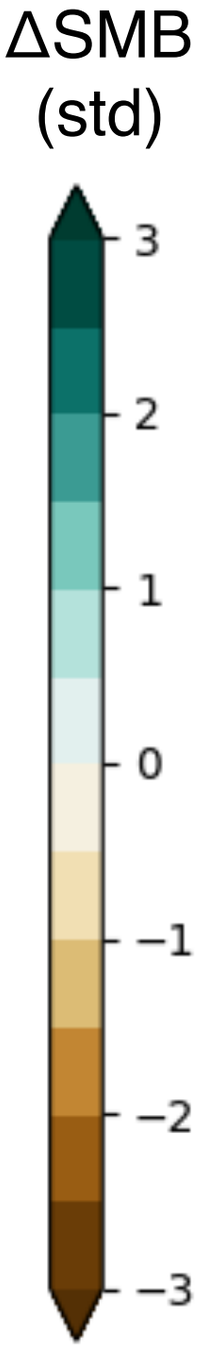


REANmean – MARmean



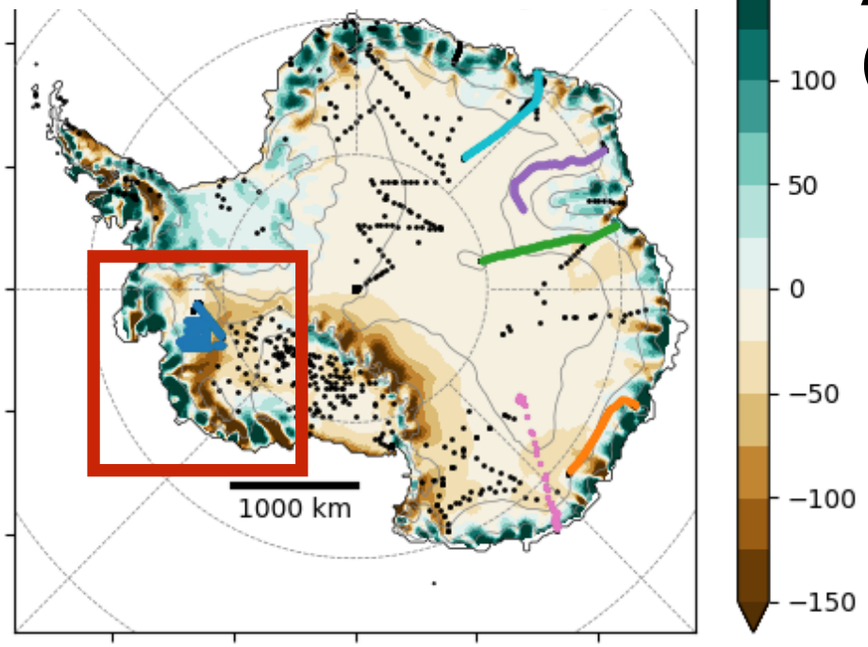
RACMO2 – MARmean



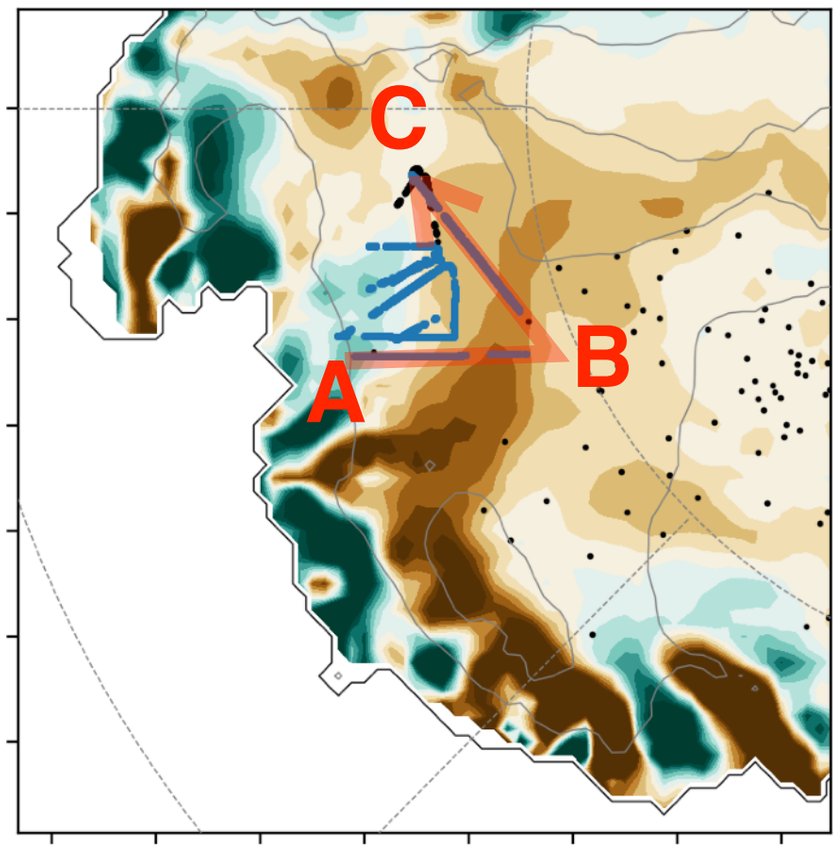


MAR vs. reanalyses: comparison to observations

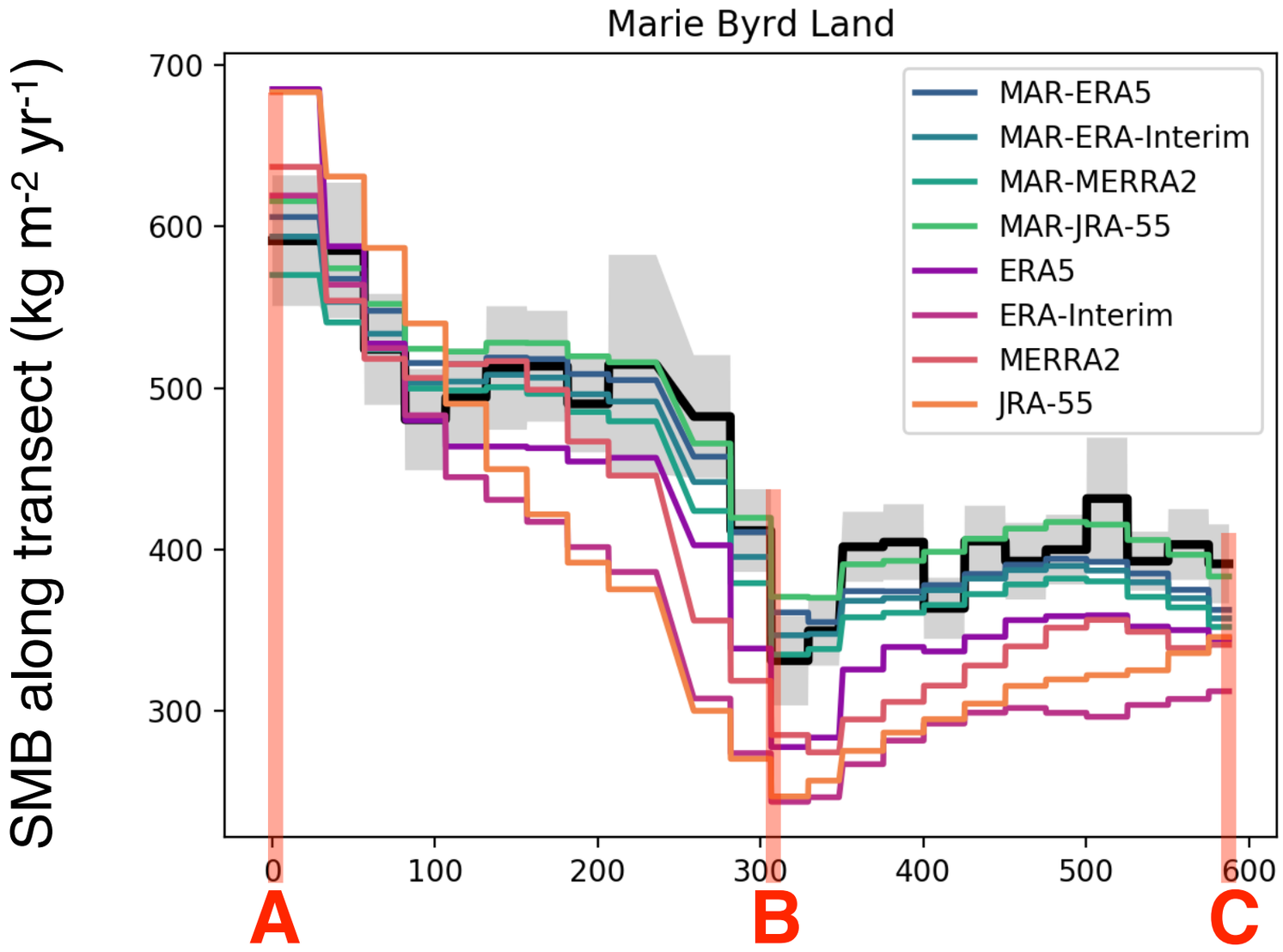
REANmean – MARmean



ΔSMB
(kg m^{-2} yr^{-1})

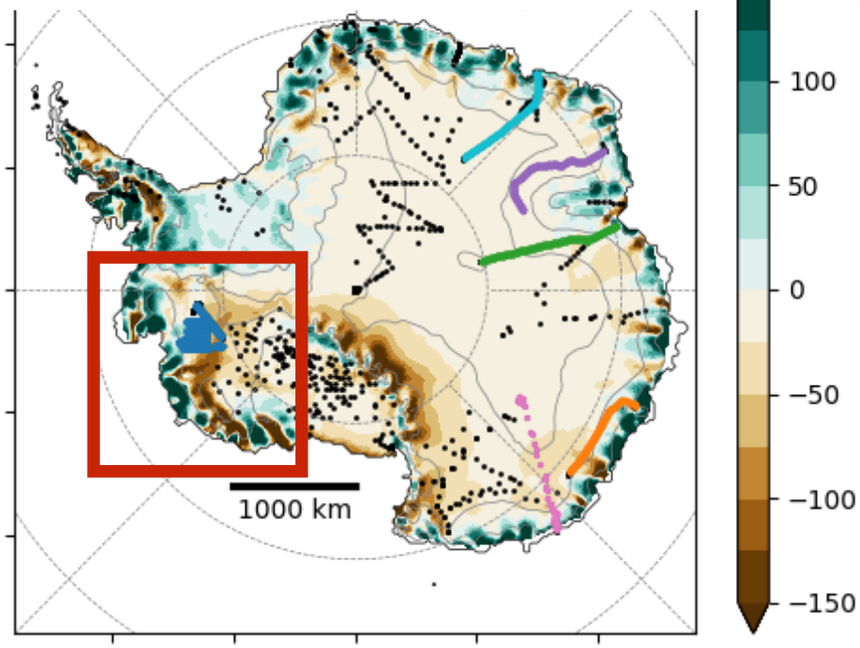


Medley et al. (2014) radar transects

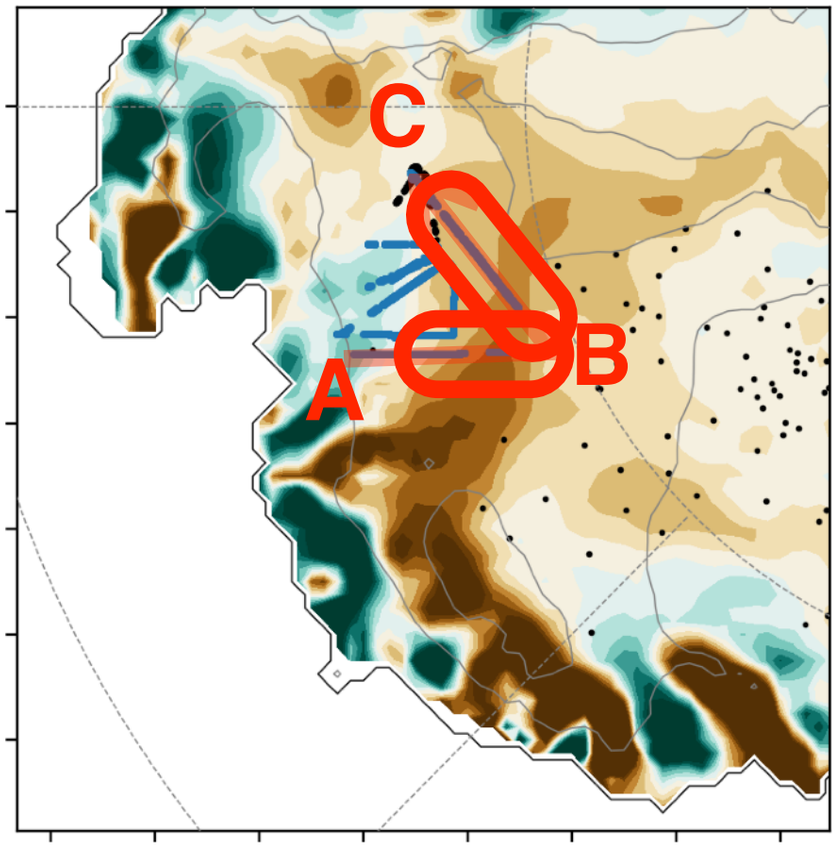


MAR vs. reanalyses: comparison to observations

REANmean – MARmean



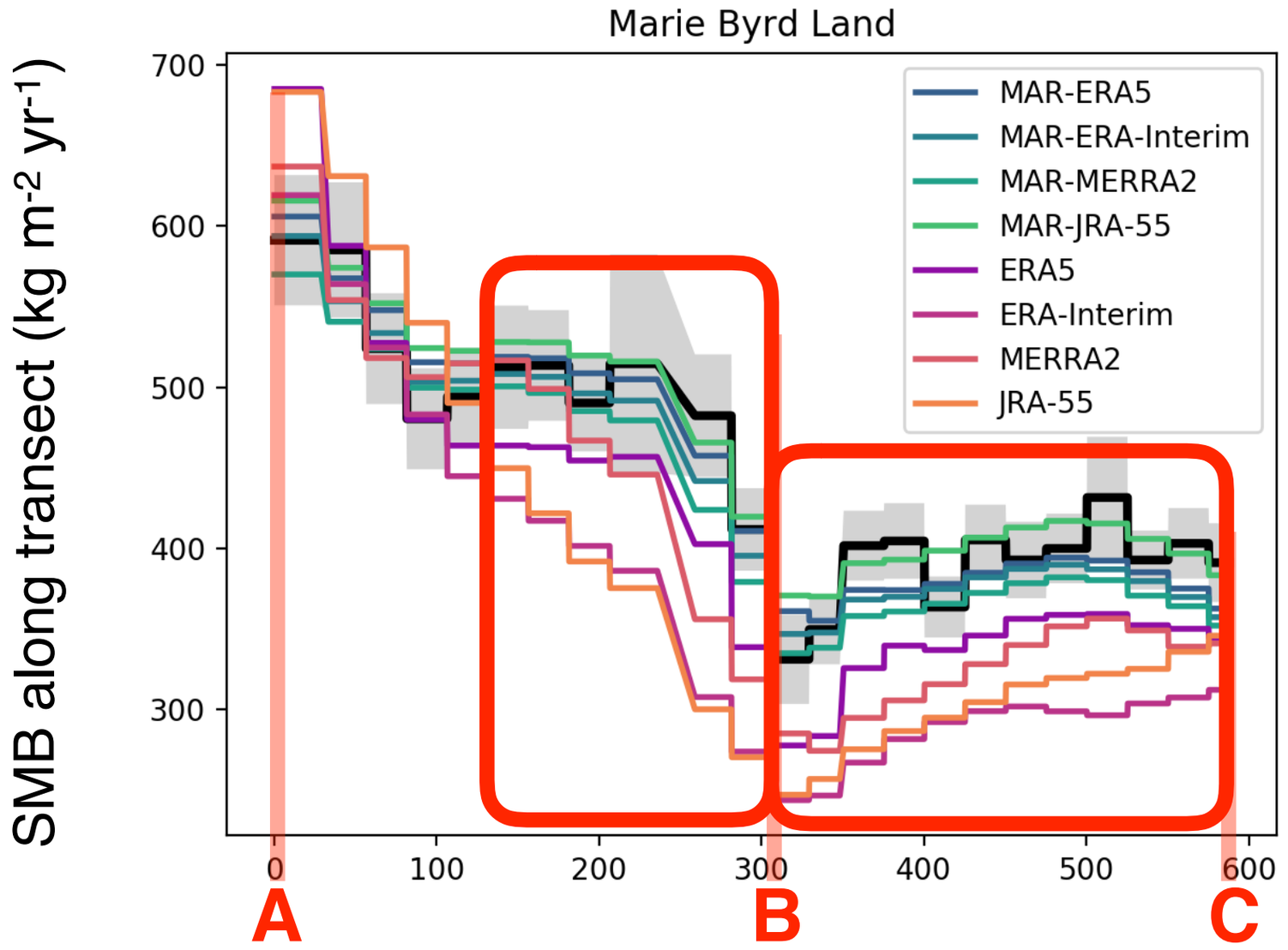
ΔSMB
(kg m^{-2} yr^{-1})



Medley et al. (2014) radar transects

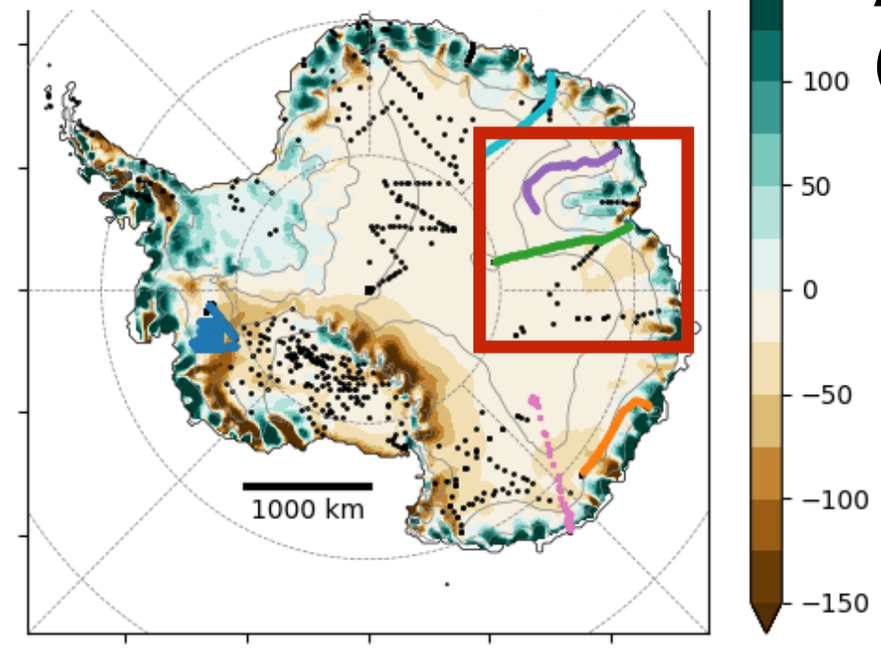
MAR advects precipitation further inland

- Clouds-precipitation conversion
- Precipitation fall speed

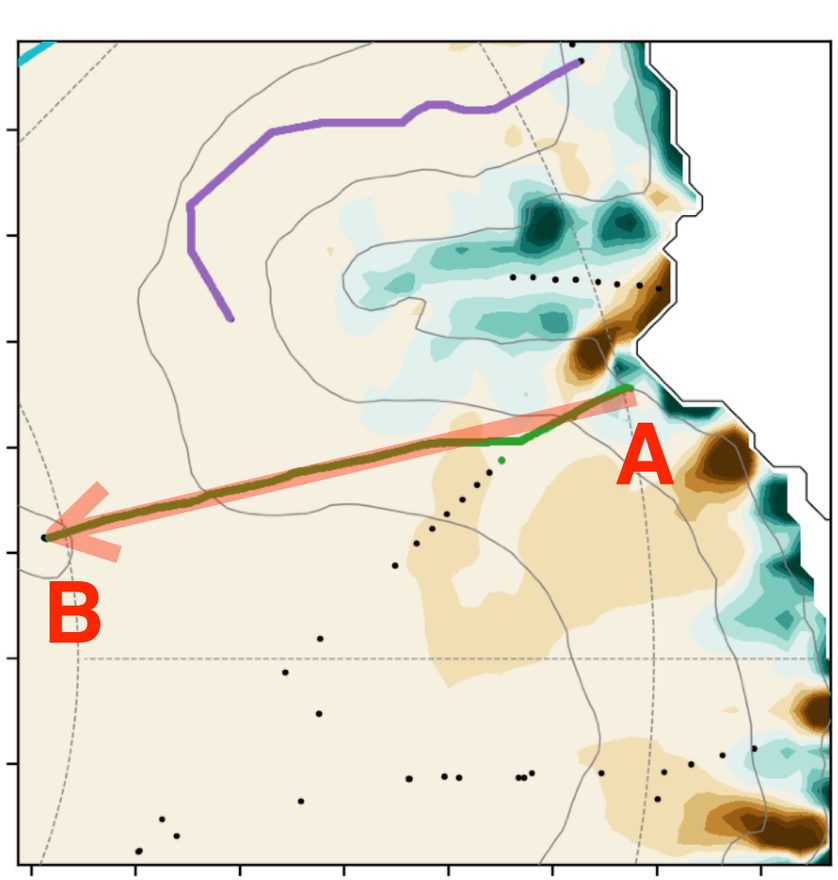


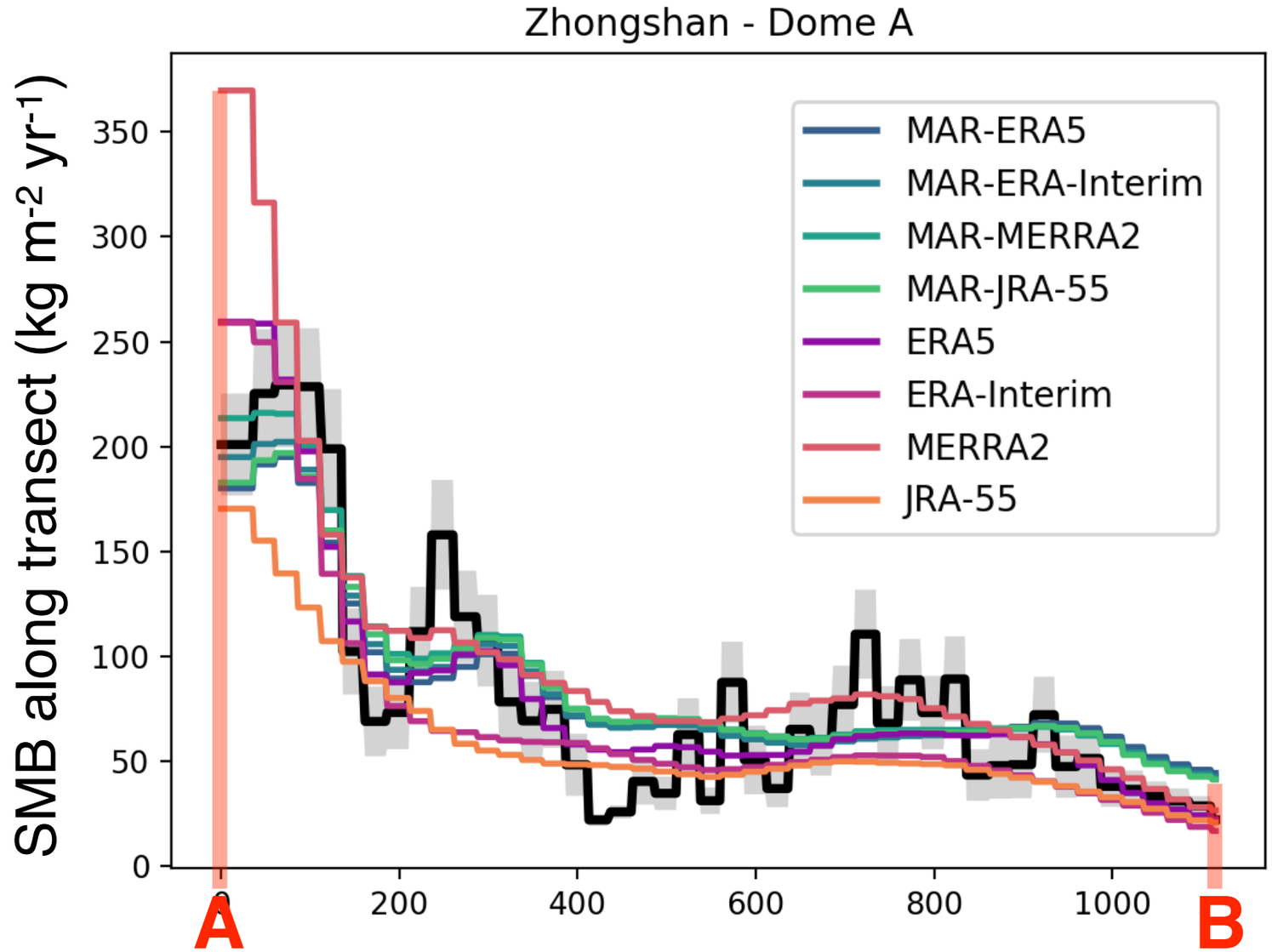
MAR vs. reanalyses: comparison to observations

REANmean – MARmean



ΔSMB
(kg m^{-2} yr^{-1})





CHINARE, Ding et al. (2011), Wang et al. (2016)

MAR vs. reanalyses: comparison to observations

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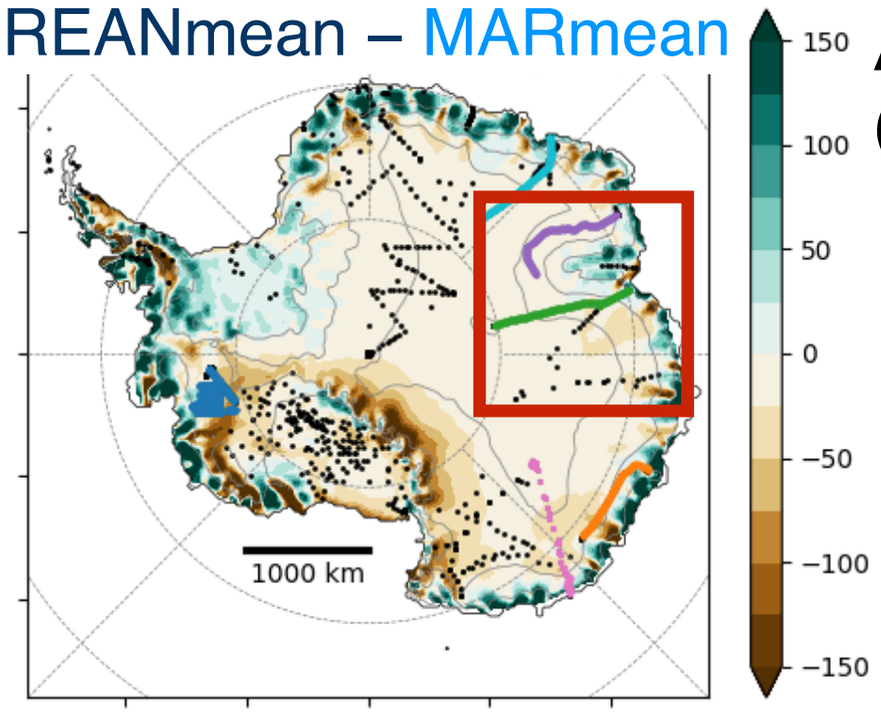
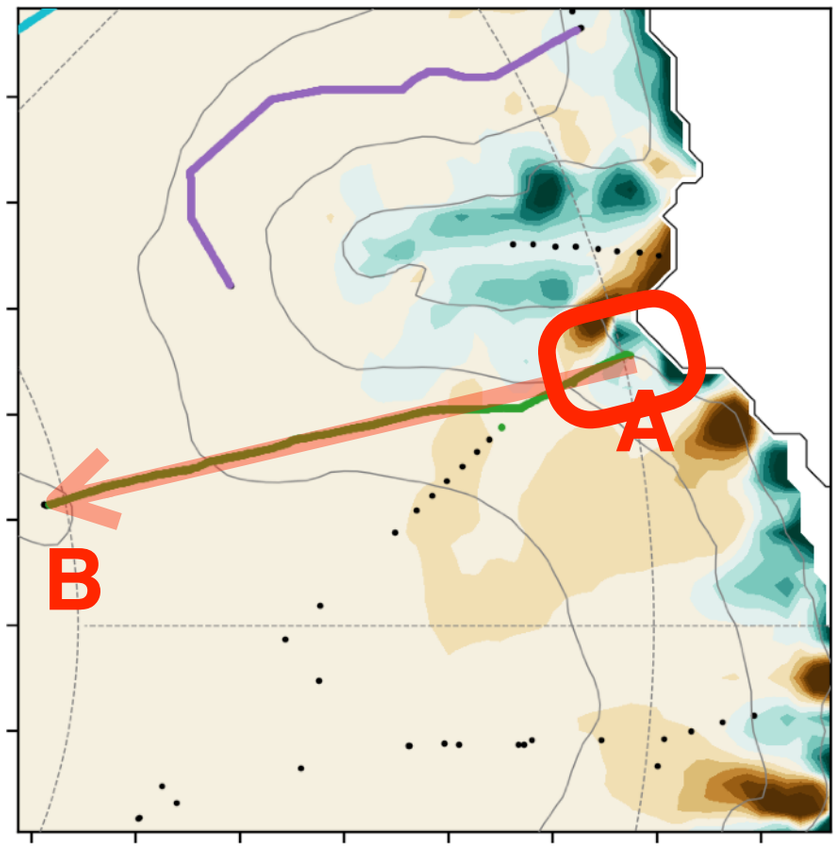
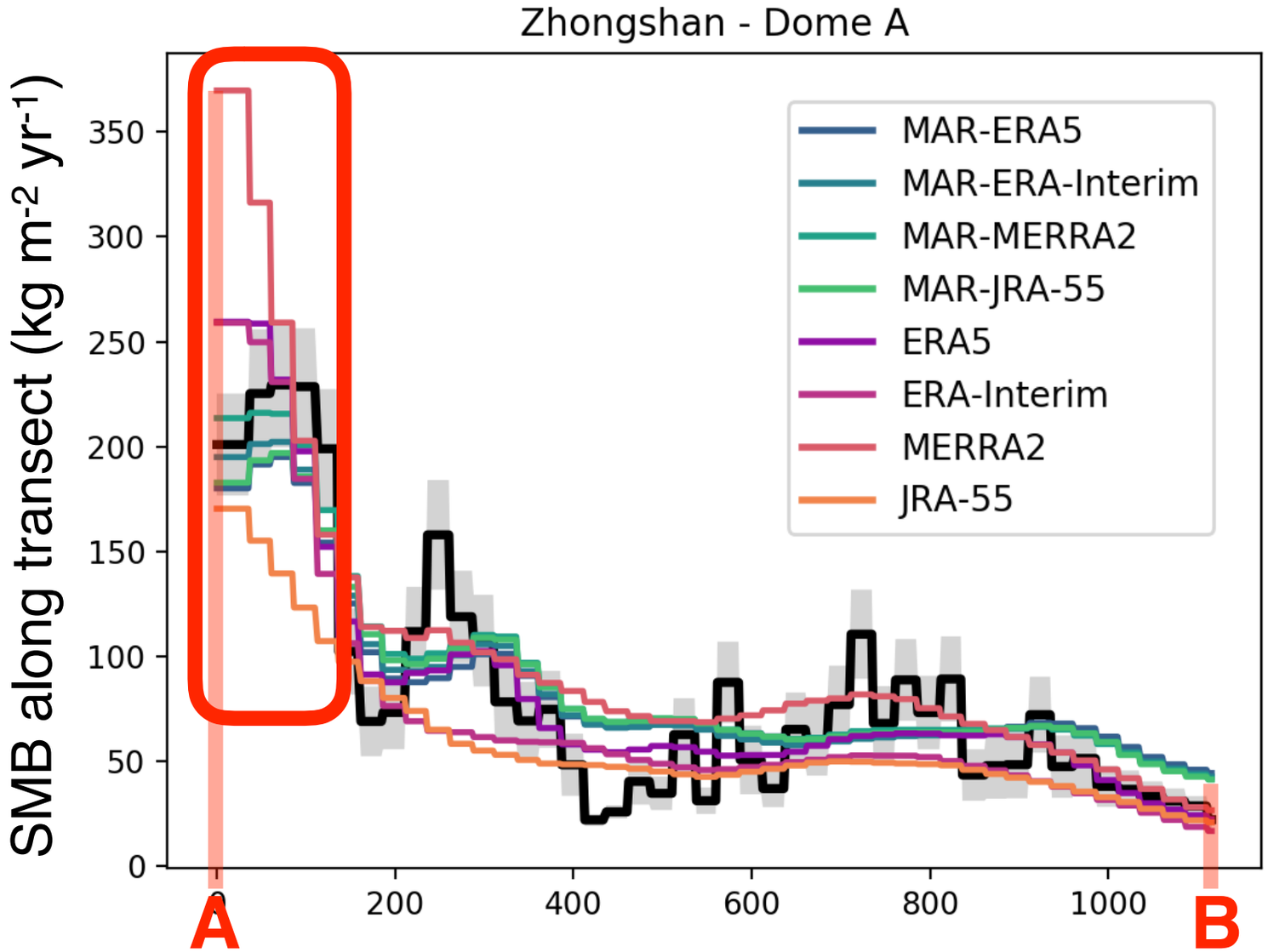




CHINARE, Ding et al. (2011), Wang et al. (2016)

MAR sublimates precipitation in atmospheric layers (~ –300 Gt/yr)

- Underestimated in reanalyses?



MAR vs. reanalyses: comparison to observations

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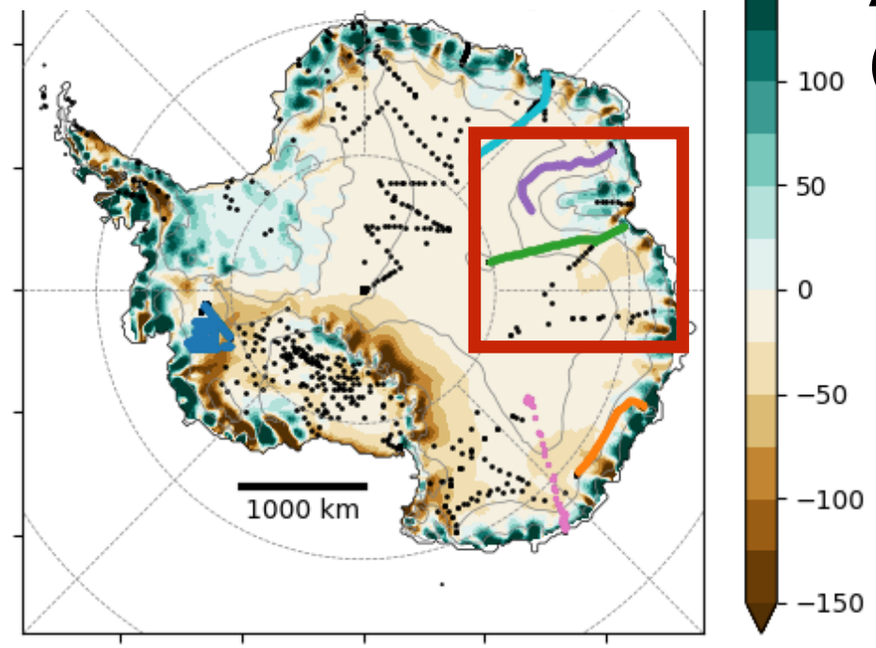
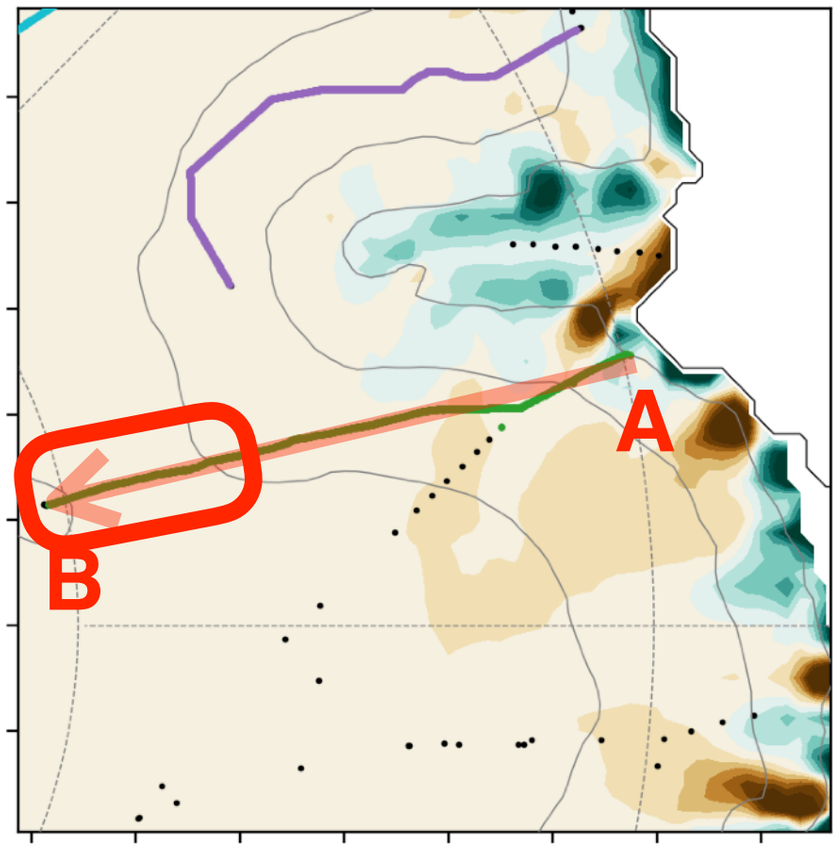
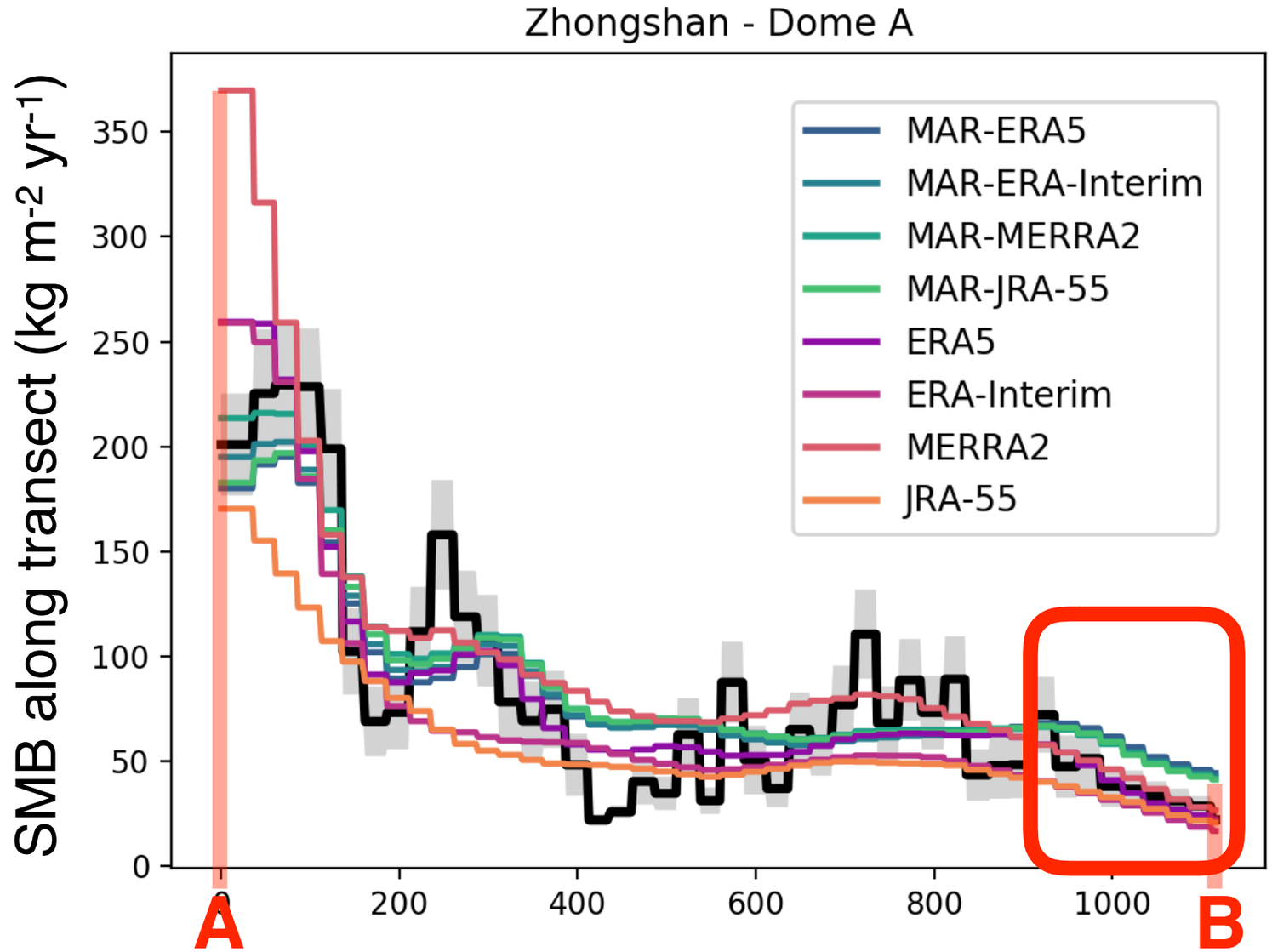


ΔSMB
(kg m^{-2} yr^{-1})

Too much accumulation in MAR at elevation > 3000 m (~ +50 Gt/yr)



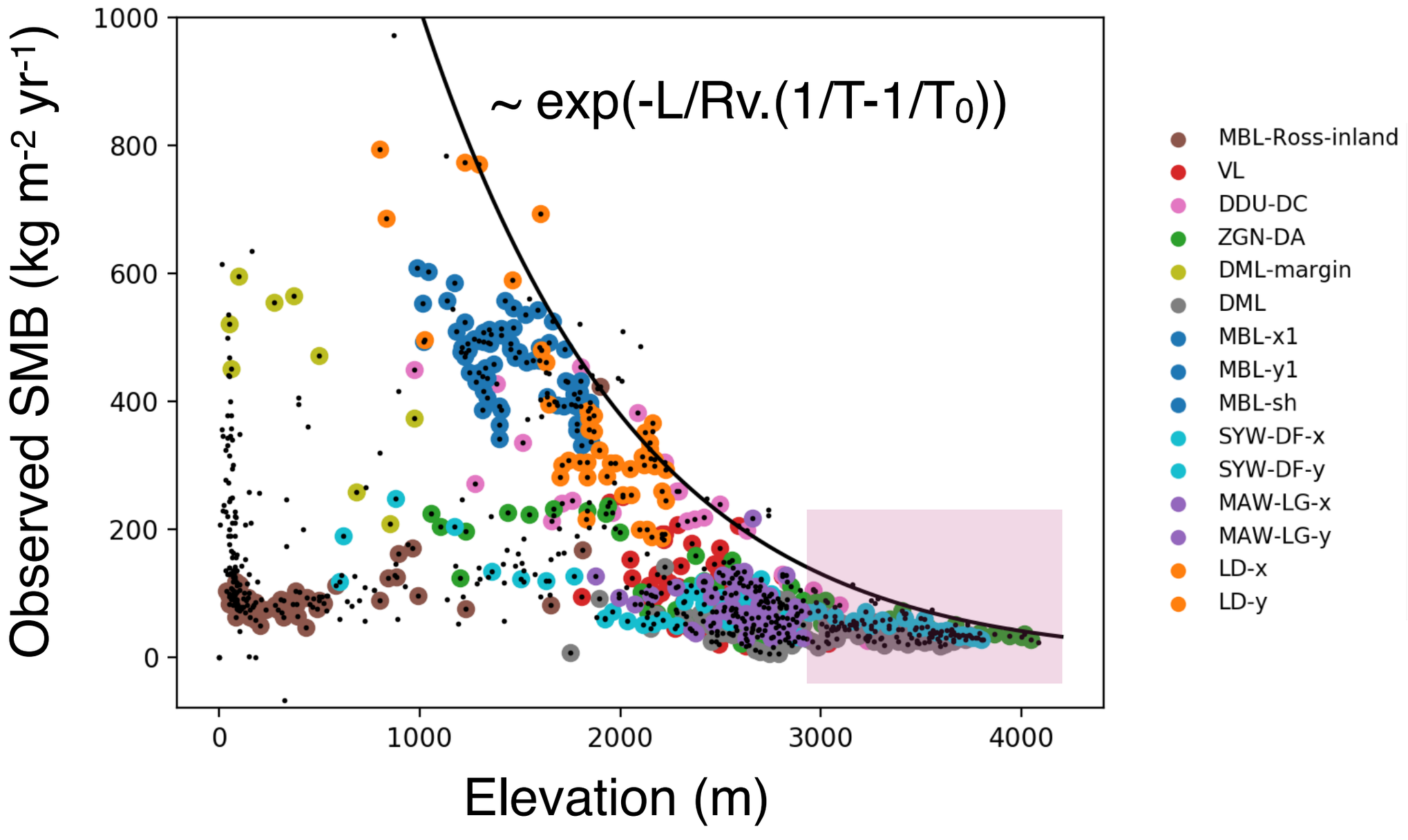


CHINARE, Ding et al. (2011), Wang et al. (2016)

MAR vs. reanalyses: comparison to observations

Too much accumulation in MAR at elevation > 3000 m

- High elevation SMB is controlled by Clausius-Clapeyron
  - ➡ **Overestimated supersaturation**? (Genthon et al. 2017)



Conclusions

- MARv3.6 correctly model the coast-to-inland SMB gradient, independently of the reanalysis forcing.
- **Cloud/precipitation conversion and fall speed** have large impact on the surface mass balance pattern.
- **Sublimation of precipitation,** ~360 Gt yr^{-1} in MAR, is probably underestimated in reanalyses.
- **Supersaturation to be improved**
- **Drifting snow sublimation still to be quantified**

Agosta et al. (2019), The Cryosphere

Estimation of the Antarctic surface mass balance using the regional climate model MAR (1979–2015) and identification of dominant processes

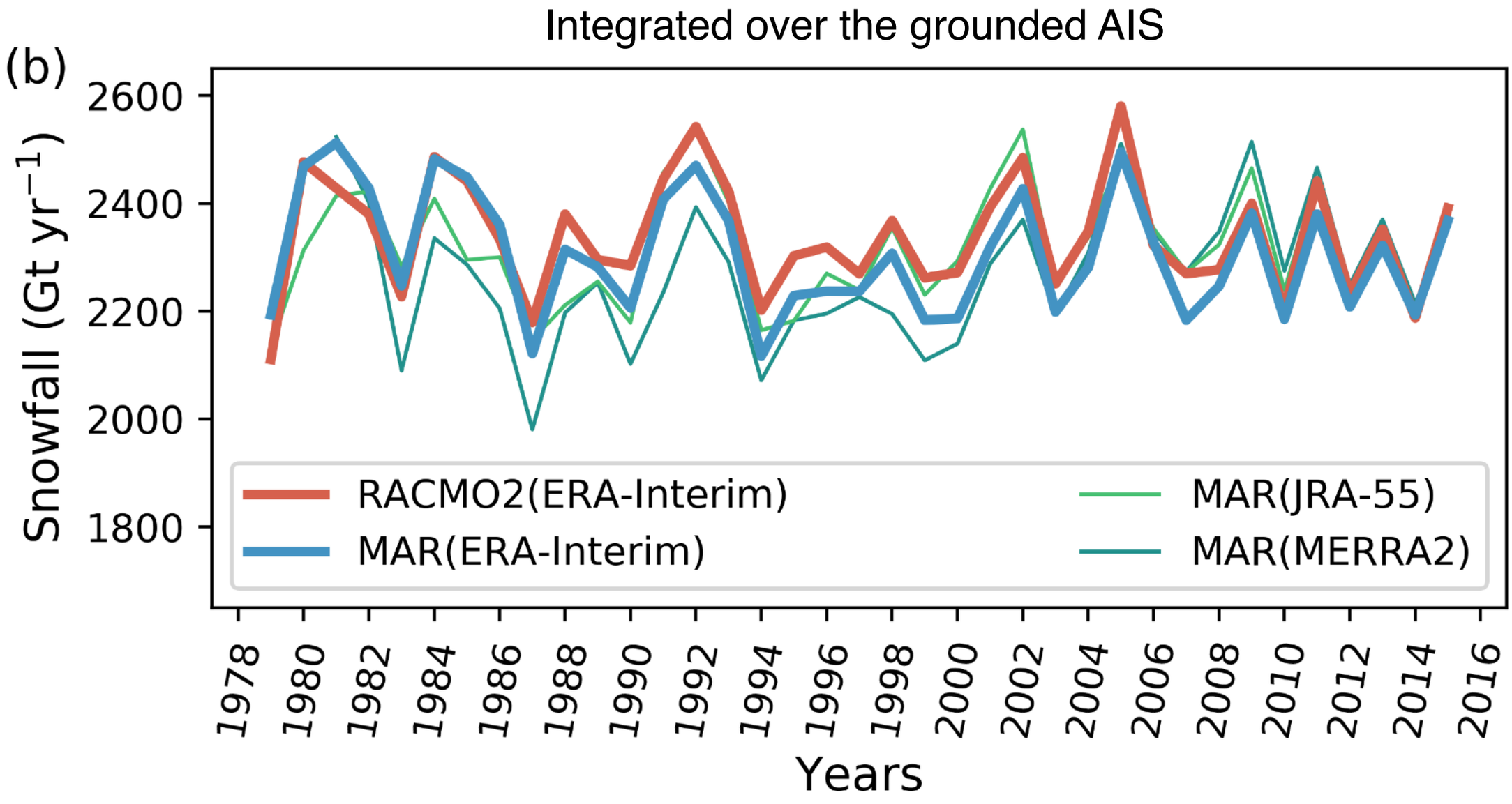
Cécile Agosta[1,2,3], Charles Amory[1], Christoph Kittel[1], Anais Orsi[2], Vincent Favier[3], Hubert Gallée[3], Michiel R. van den Broeke[4], Jan T. M. Lenaerts[4,5], Jan Melchior van Wessem[4], Willem Jan van de Berg[4], and Xavier Fettweis[1]

MAR website: mar.cnrs.fr

MAR vs. reanalyses: added value of a polar RCM

The interannual variability is reanalyse-dependent

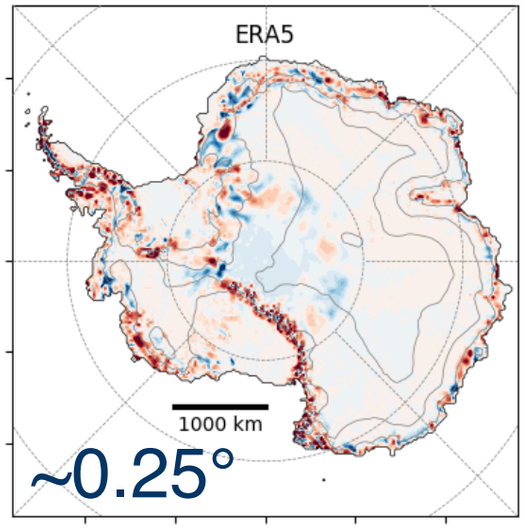
Interannual variability of precipitation (MAR 1979-2015)



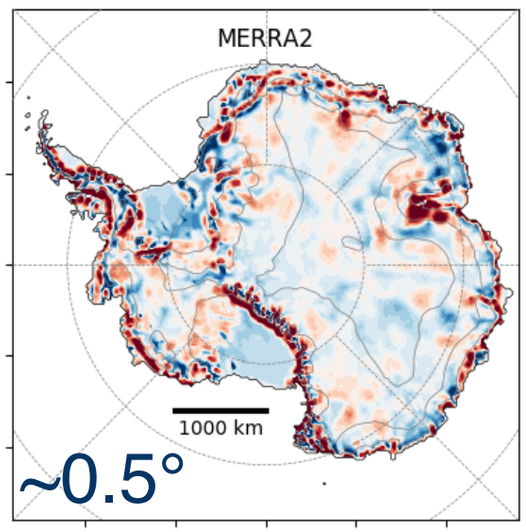
Reanalyses (1979-2017)

ΔSurface height: Reanalyses – bedmap2

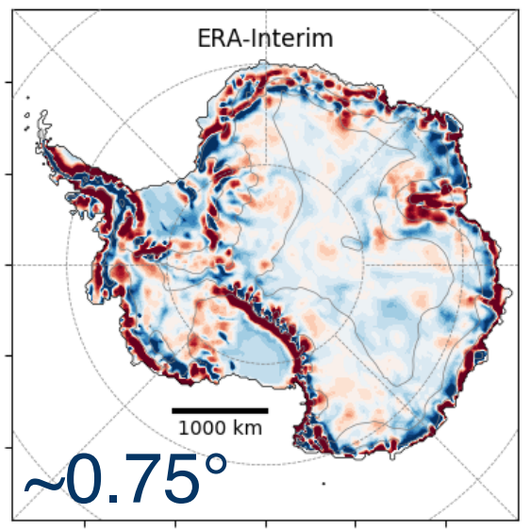
ERA5



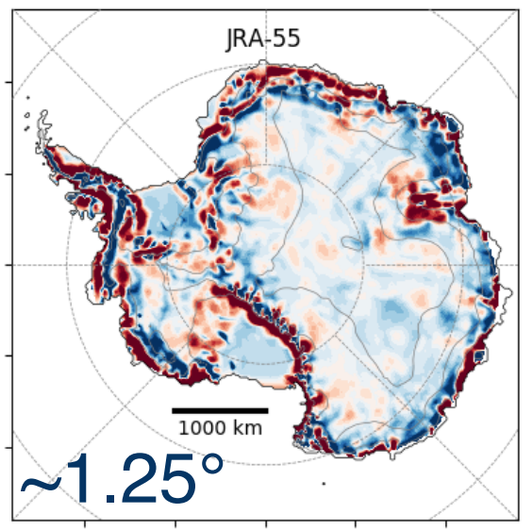
MERRA2



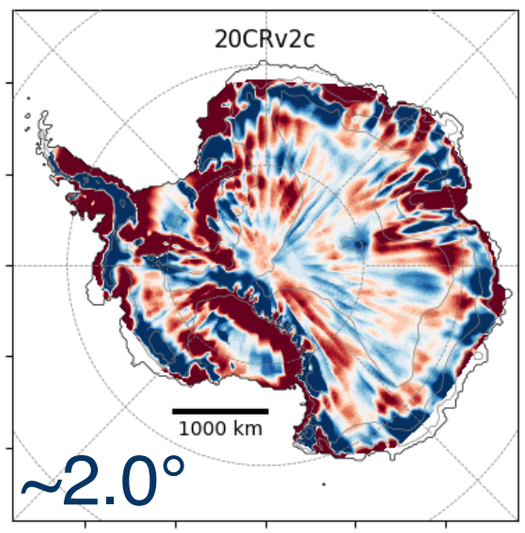
ERA-Interim



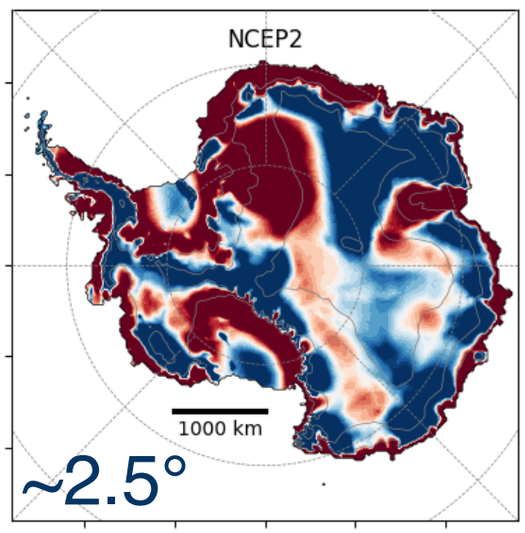
JRA-55



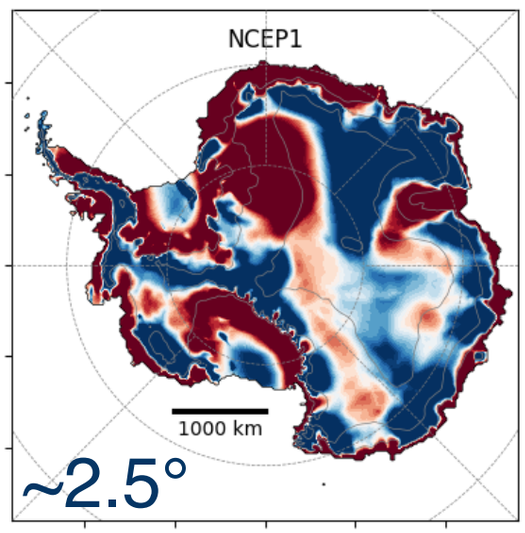
20CRv2



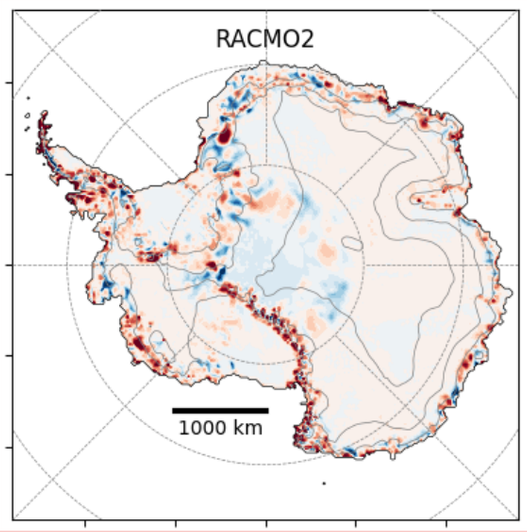
NCEP2

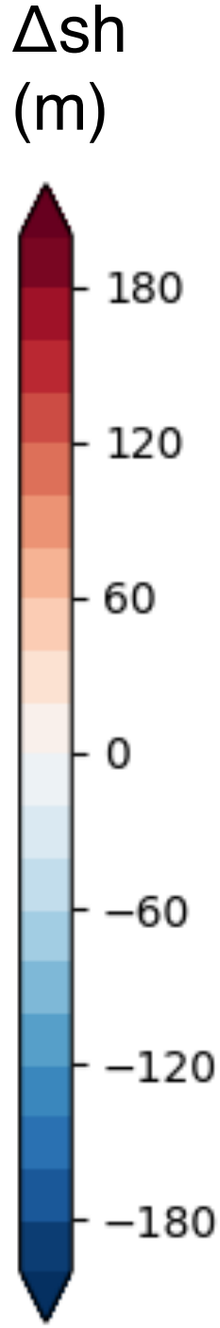


NCEP1



RACMO2





MAR vs. reanalyses: comparison to observations

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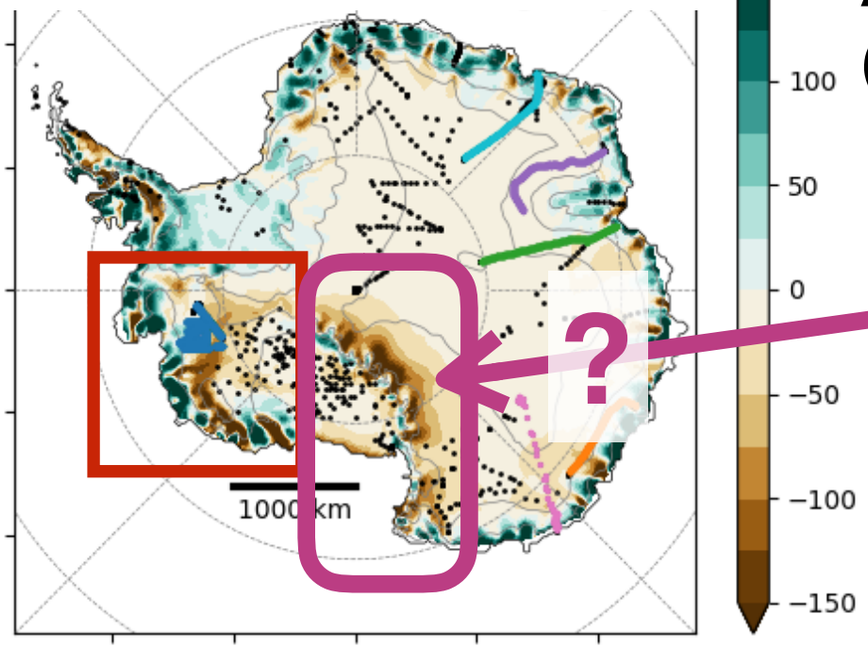
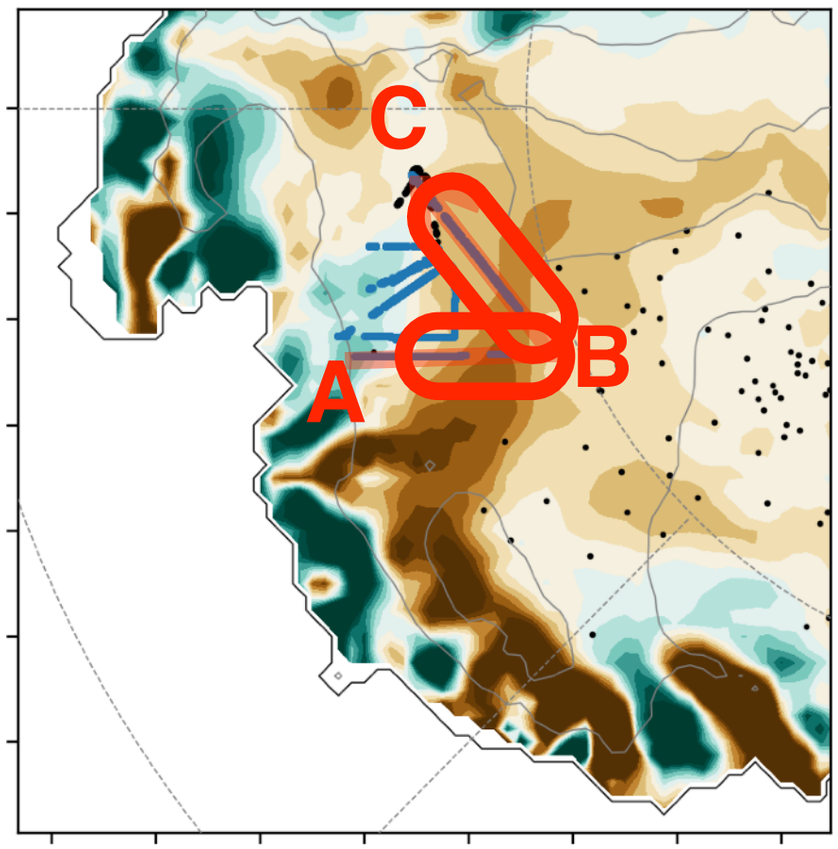


ΔSMB
(kg m^{-2} yr^{-1})

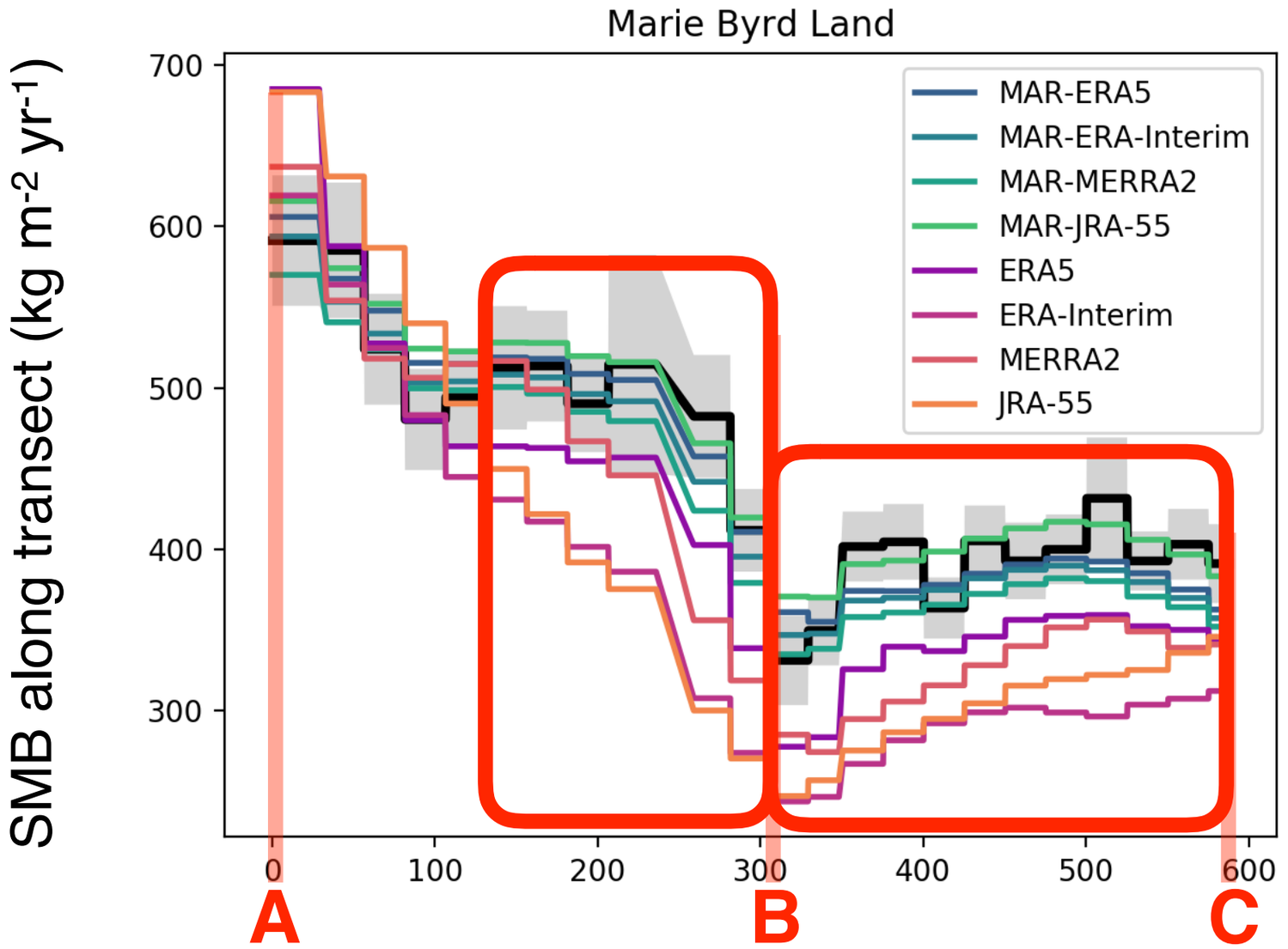
?

MAR advects precipitation further inland

- Clouds-precipitation conversion
- Precipitation fall speed



Medley et al. (2014) radar transects



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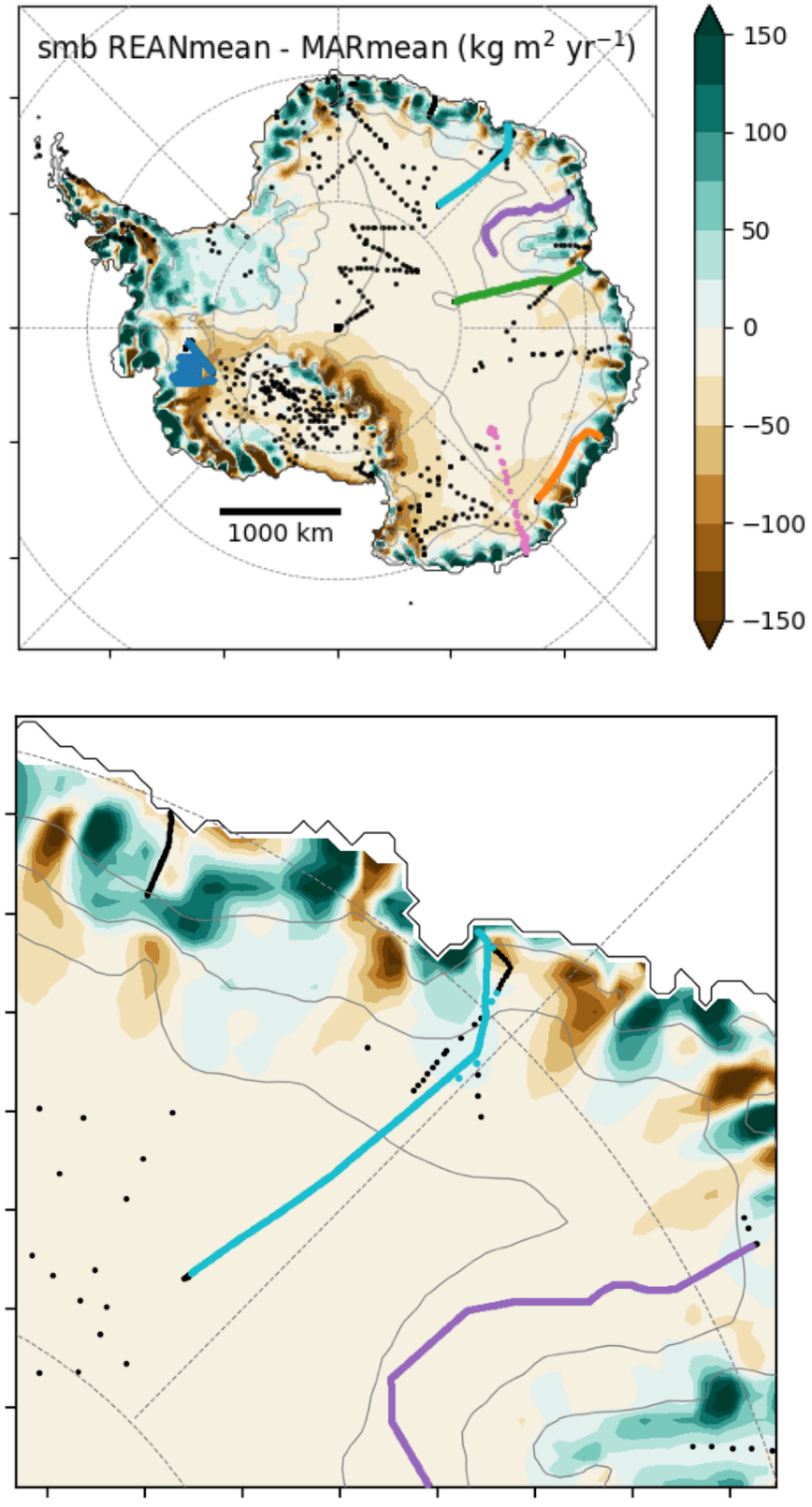

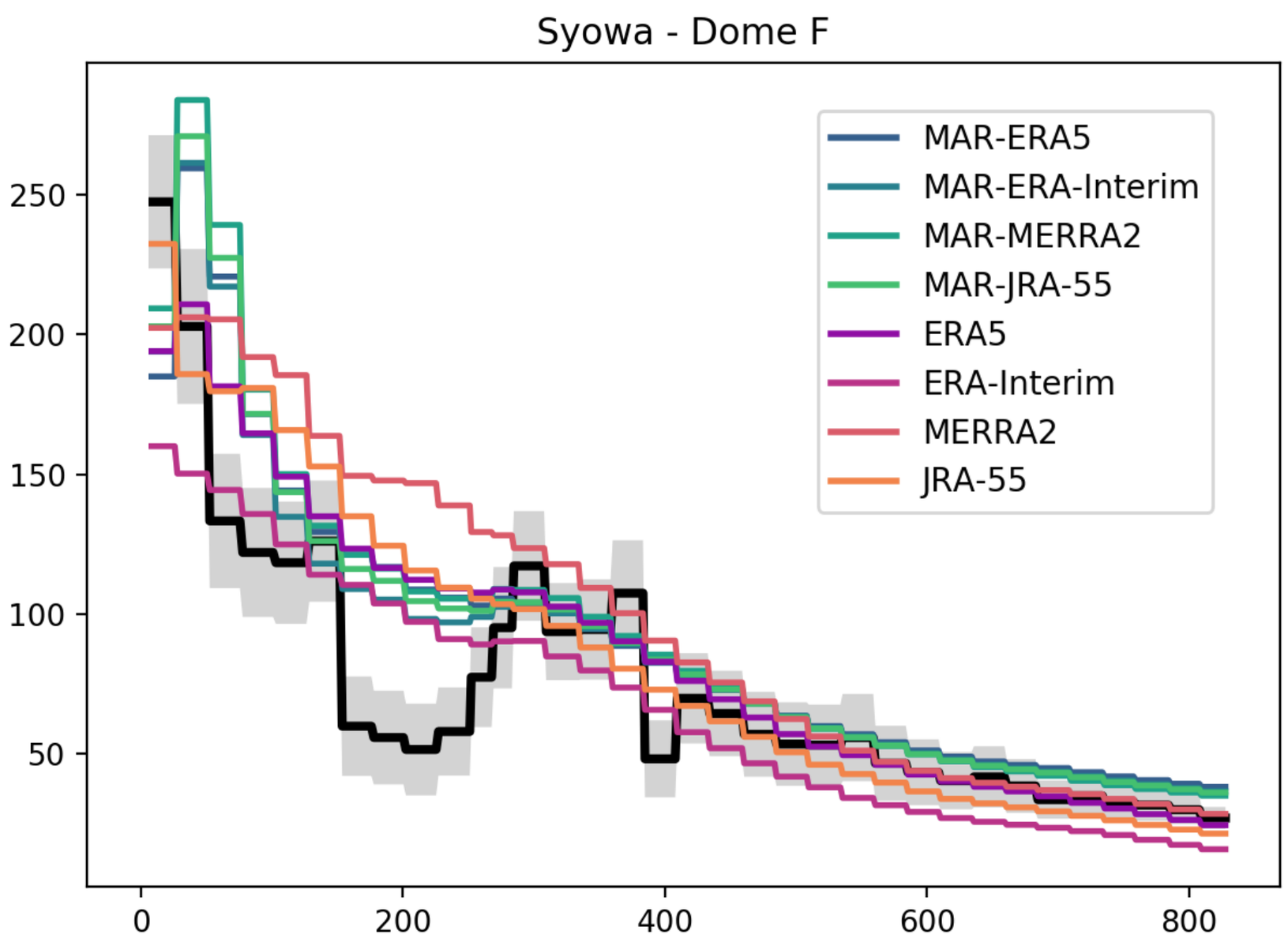

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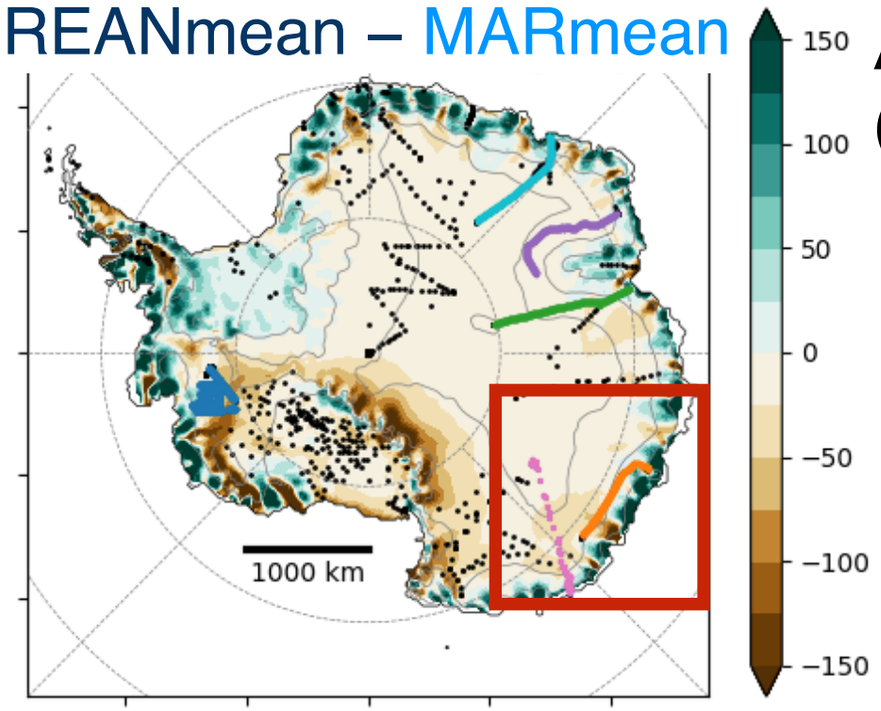
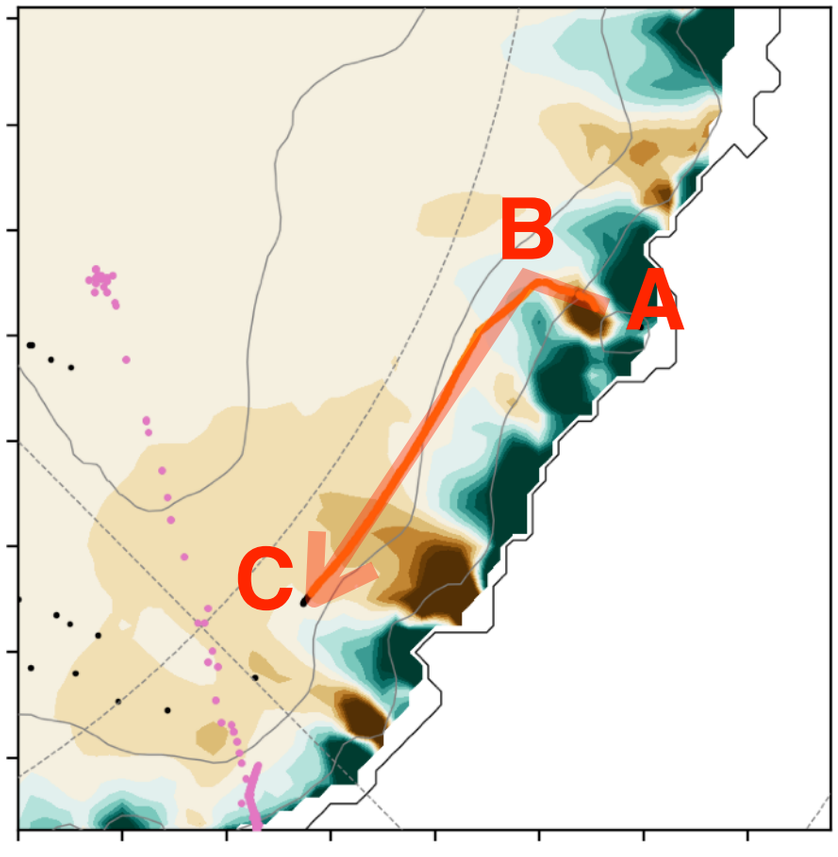
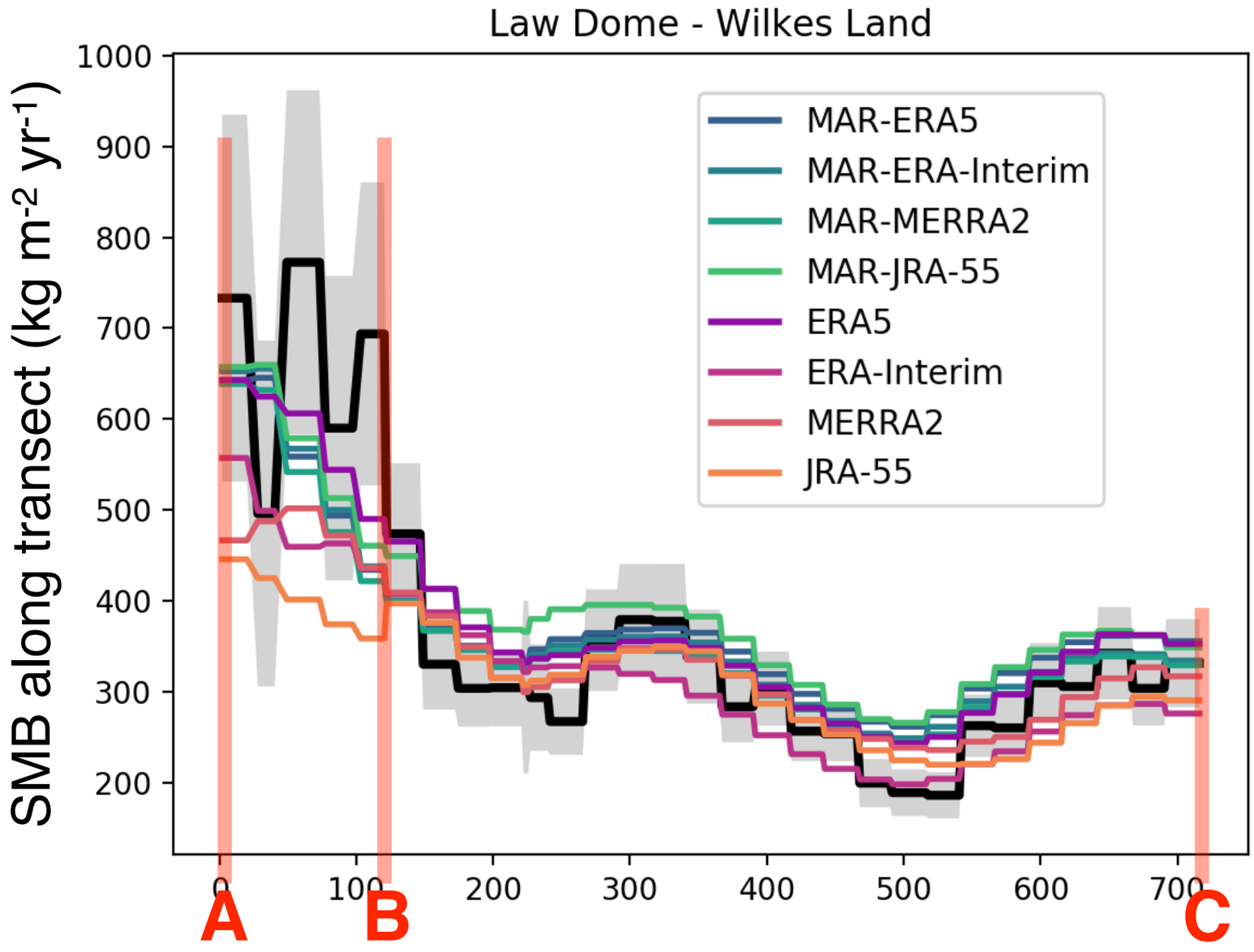


ΔSMB
(kg m^{-2} yr^{-1})





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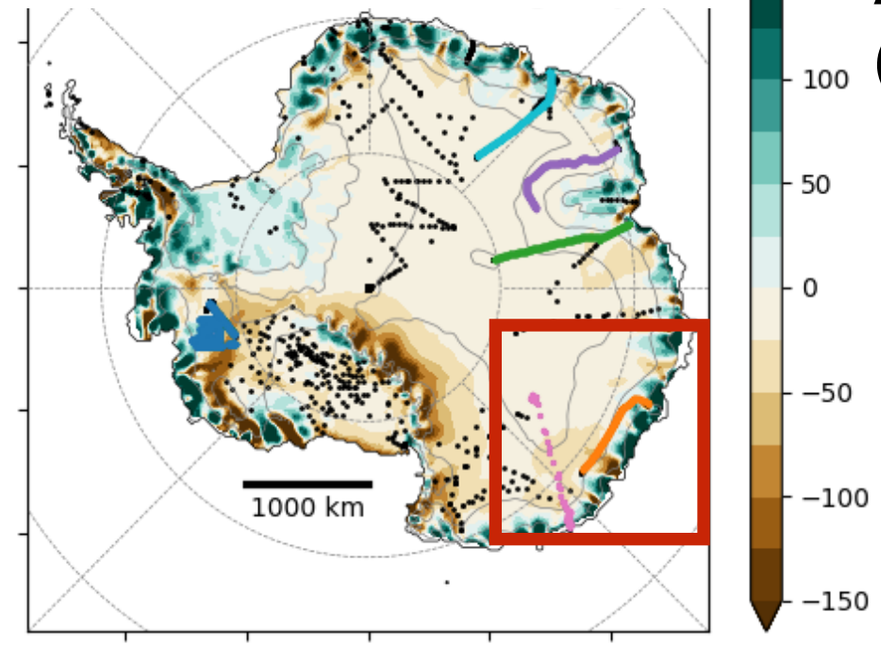

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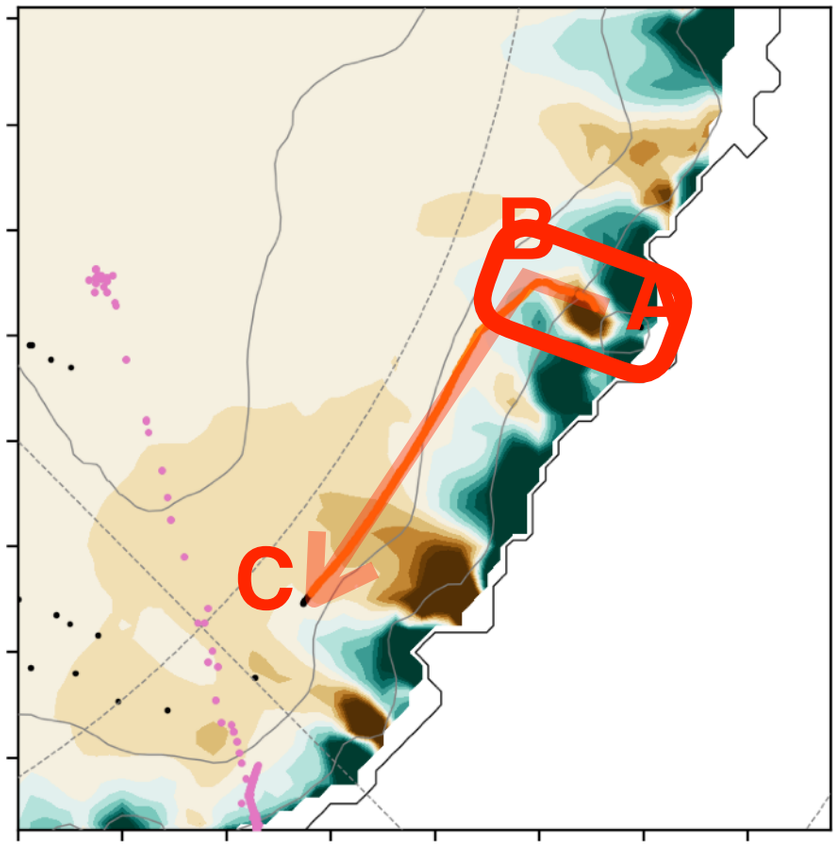
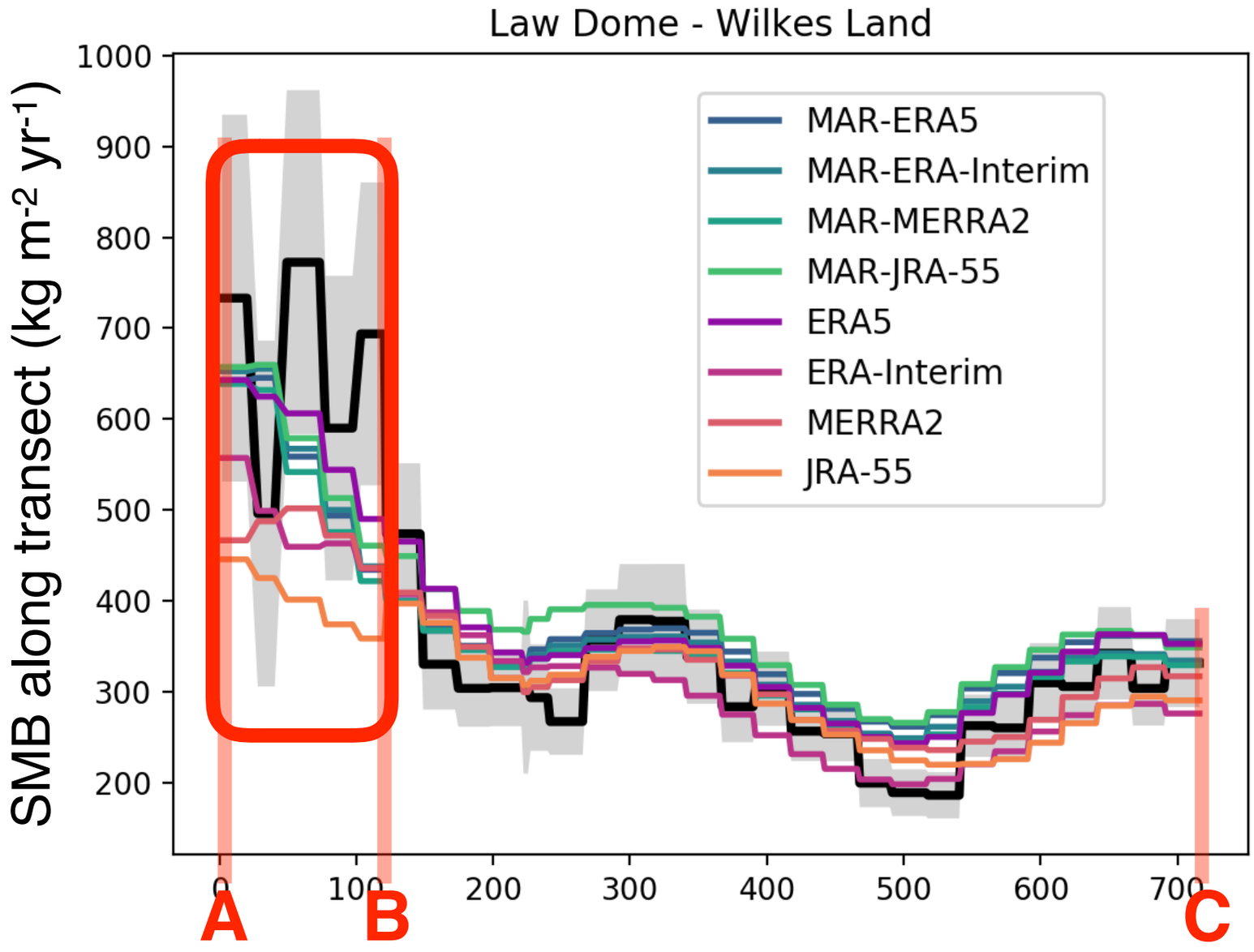


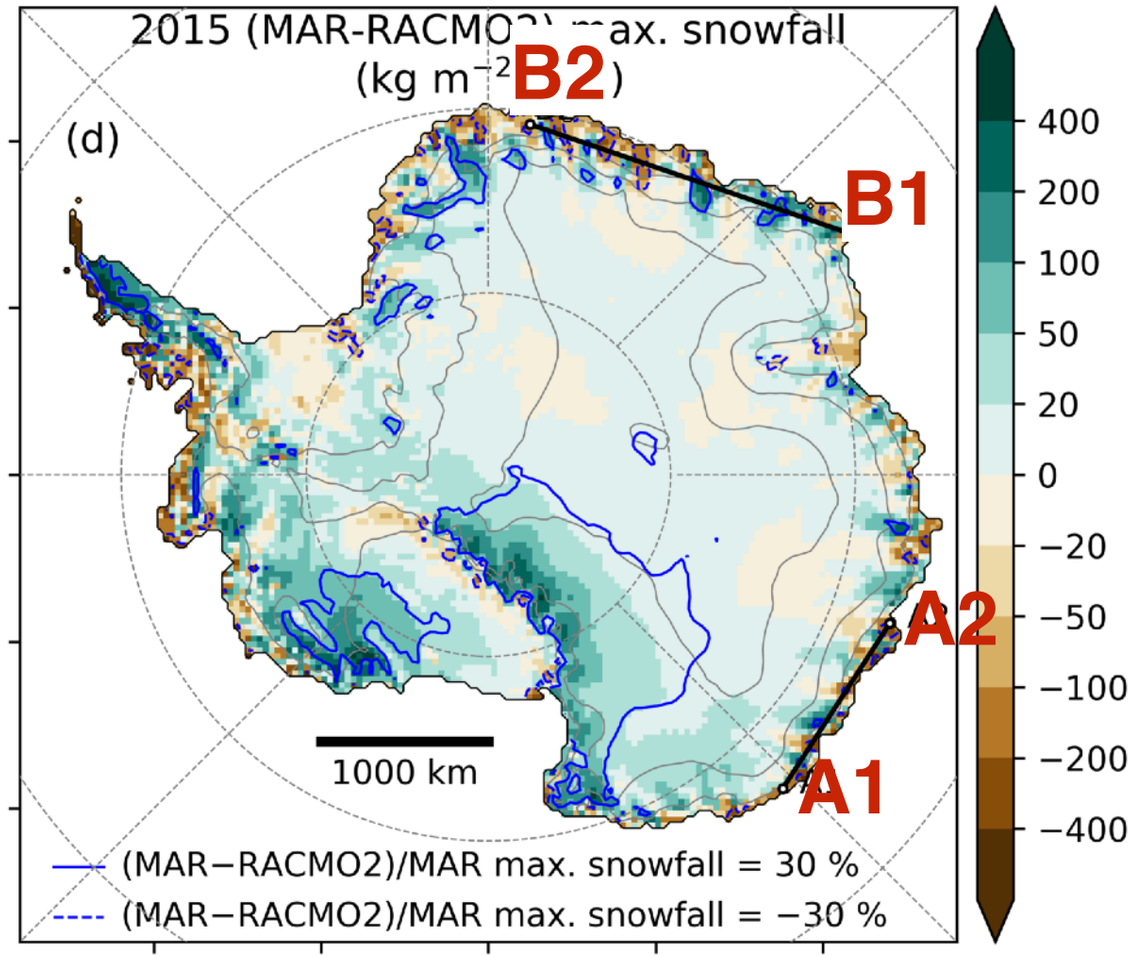
Effect of elevation on precipitation

- Clausius-Clapeyron



Snowfall pattern: cloud/precipitation conversion and precipitation advection

(MAR-RACMO2) max. snowfall before sublimation in the atmosphere



Agosta et al. (2019), The Crysophere

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(MAR-RACMO2) max. snowfall before sublimation in the atmosphere