EGU General Assembly 2022
Vienna | Austria | 23–27 May 2022

Investigating the mechanisms controlling elemental fractionation during pore closure in polar firn

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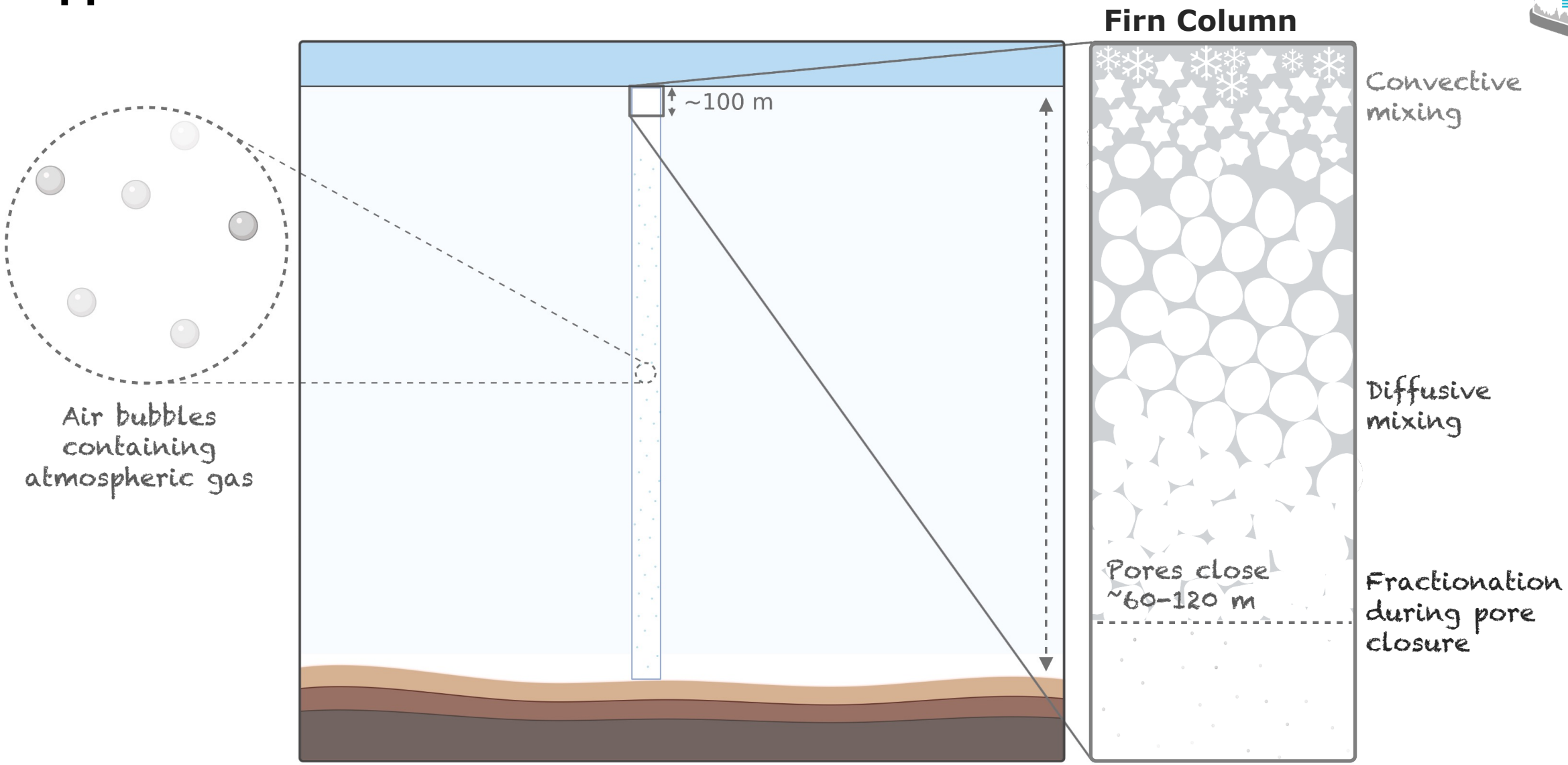
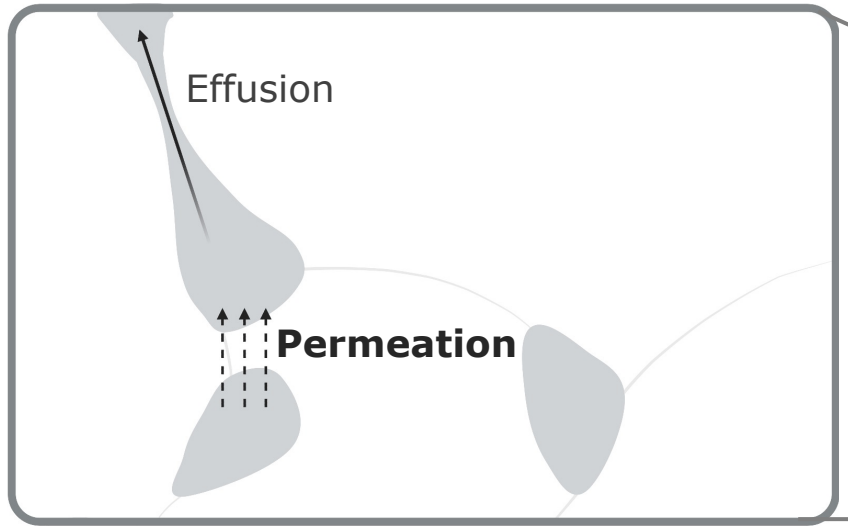
This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 955750

Physical processes in the firn column affect the composition of the air trapped in air bubbles in ice cores

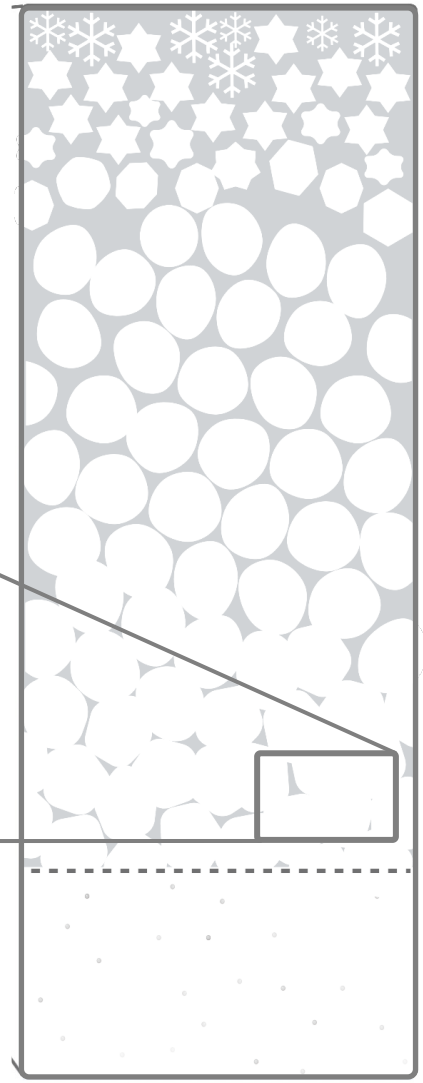


O_2 is preferentially excluded during pore closure via permeation through ice matrix

- Permeability is function of grain size
- O_2 fractionation depends on **firn microstructure** determined near surface
- Seasonal stratification also vital (Fujita et al., 2009)



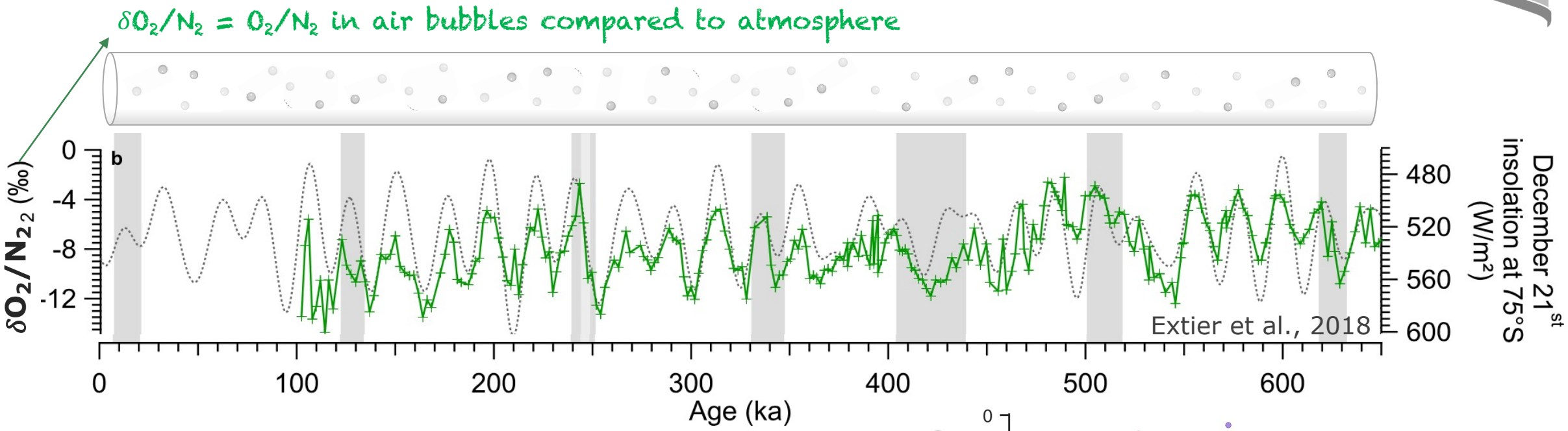
Adapted from Severinghaus et al., 2006



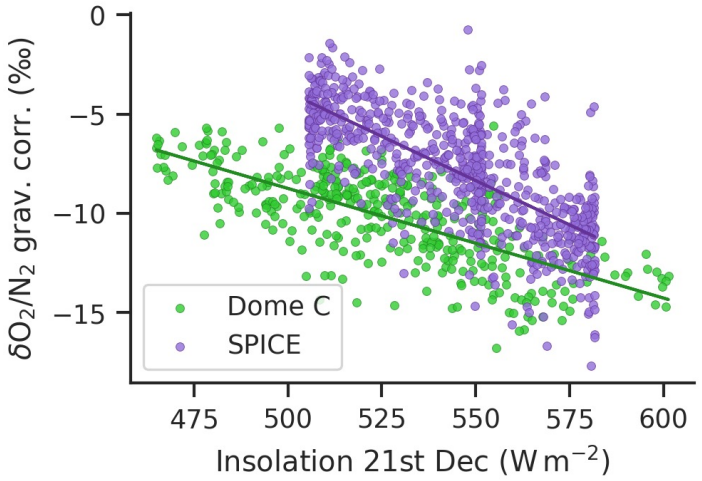
Fractionation during pore closure

Adapted from Blunier and Schwander, 2000

Insolation paced variability in $\delta O_2/N_2$ records linked to near-surface snow metamorphism but exact mechanisms not quantified



- Strong fractionation of O_2 with insolation
- Difference in variability between records
- Insolation cannot explain all of the variability
- Higher mean $\delta O_2/N_2$ at South Pole suggests dependence on an additional mechanism…



Insolation paced variability in $\delta O_2/N_2$ records linked to near-surface snow metamorphism but exact mechanisms not quantified

Insolation hypothesis:

High summer solstice insolation increases temperature gradients causing increased grain size and seasonal layering (Bender, 2002; Fujita et al., 2009)

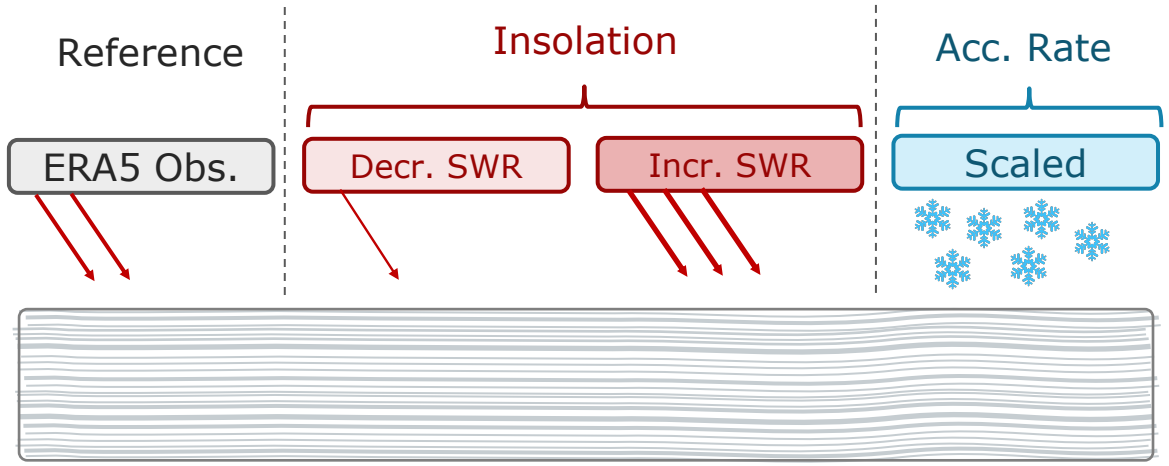
Accumulation rate hypothesis:

Increased accumulation rate will result in decreased grain size at a given depth given the more rapid burial of snow having less exposure to strong temperature gradients.

Our approach: sensitivity tests using Crocus snowpack model

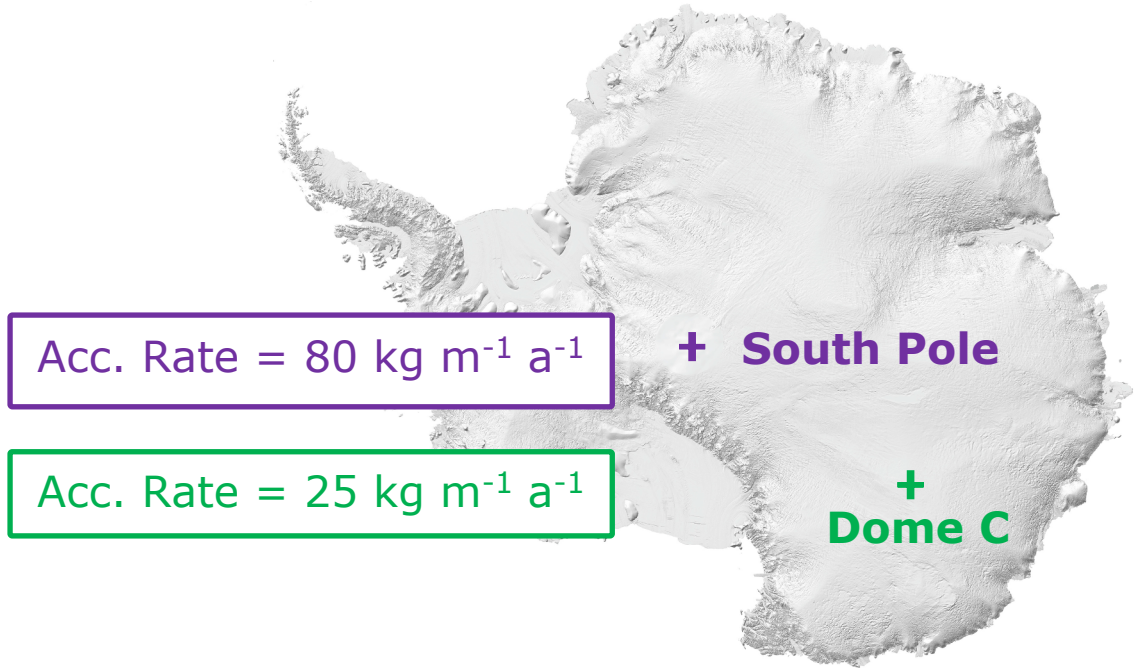
INPUTS

Modelling snowpack sensitivity to:



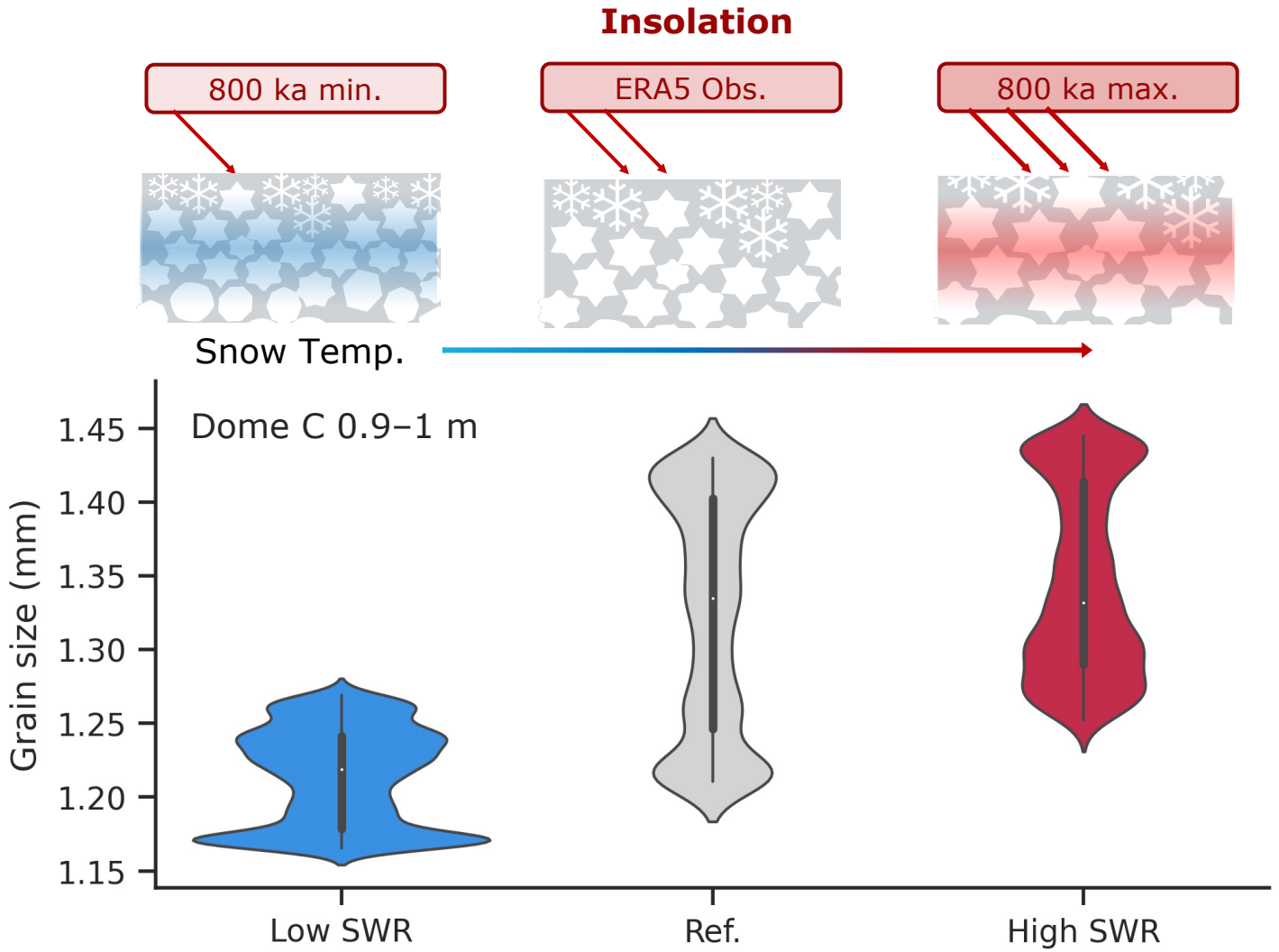
Force model with:

1. ERA5 reanalysis data
2. Observed snow profiles from sites
3. Modified insolation (SWR)
4. Modified accumulation rate



Crocus Model

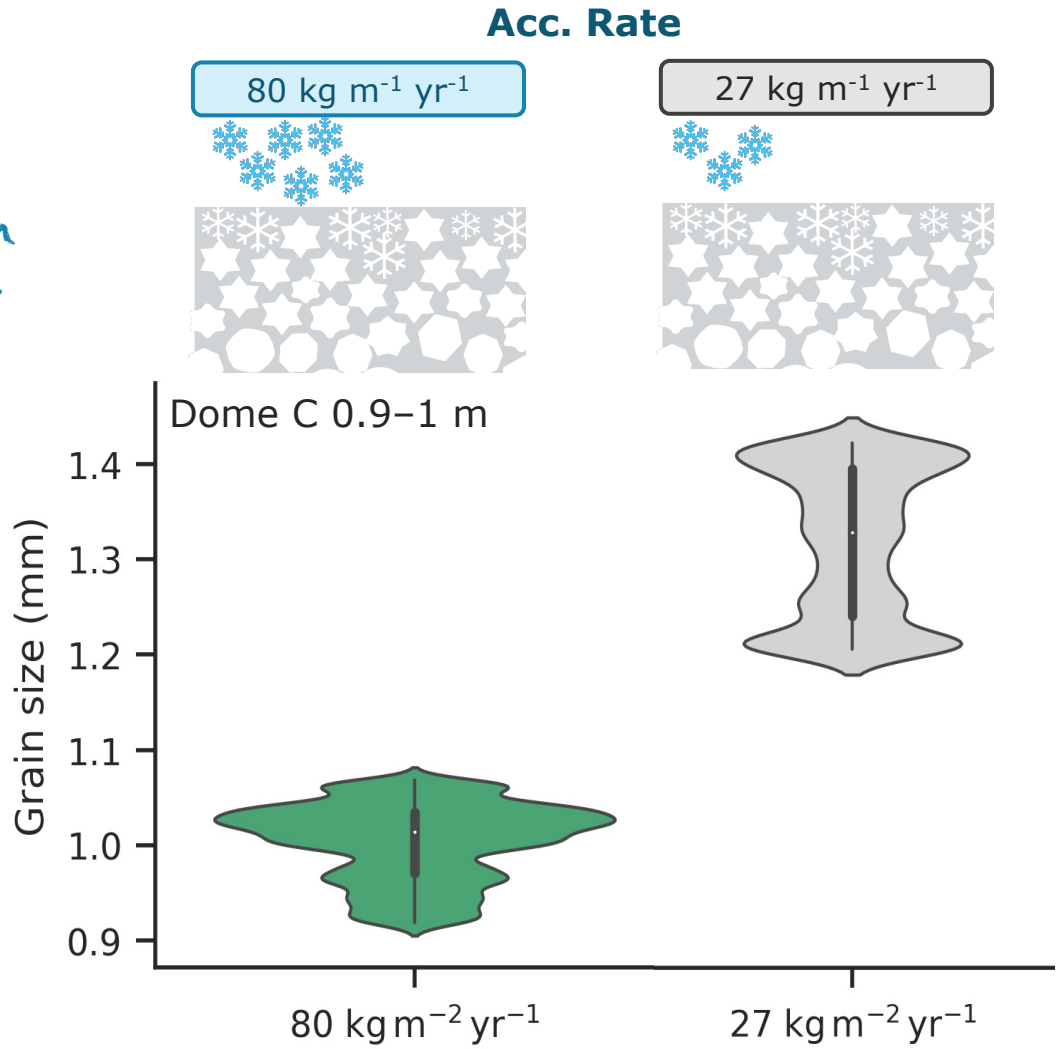
Grain size increases with insolation due to increased snow temperatures and macroscale temperature gradients



Supports observation of increased O_2 fractionation during high summer solstice insolation

Grain size decreases with increased accumulation rate due to less time exposed to strong temperature gradients

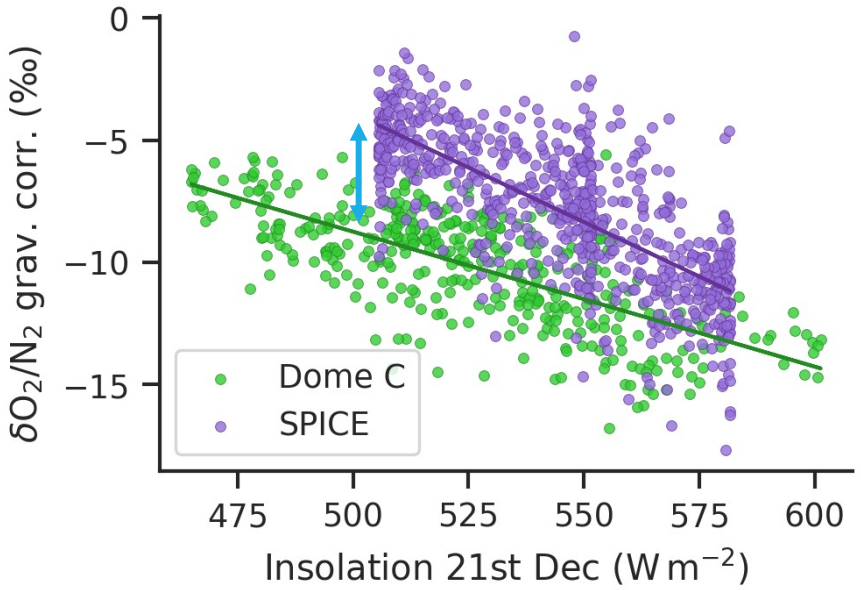
We swap the accumulation rate between Dome C and South Pole



Can explain increased mean $\delta O_2/N_2$ at high accumulation sites South Pole compared to Dome C

Conclusions

- Grain size increases with insolation at both sites
- Supports hypothesis of increased grain size causing stronger fractionation via permeability
- Grain size is decreased with increased accumulation rate
- Potentially explains the increased mean $\delta O_2/N_2$ at high accumulation sites South Pole compared to Dome C



Ongoing work:

- Identify influence of stratification vs. near-surface snow microstructure
- Quantify relative influence of accumulation rate and insolation
- Implement in firn densification models