On the colour of snow

Why does it matter ? [1]

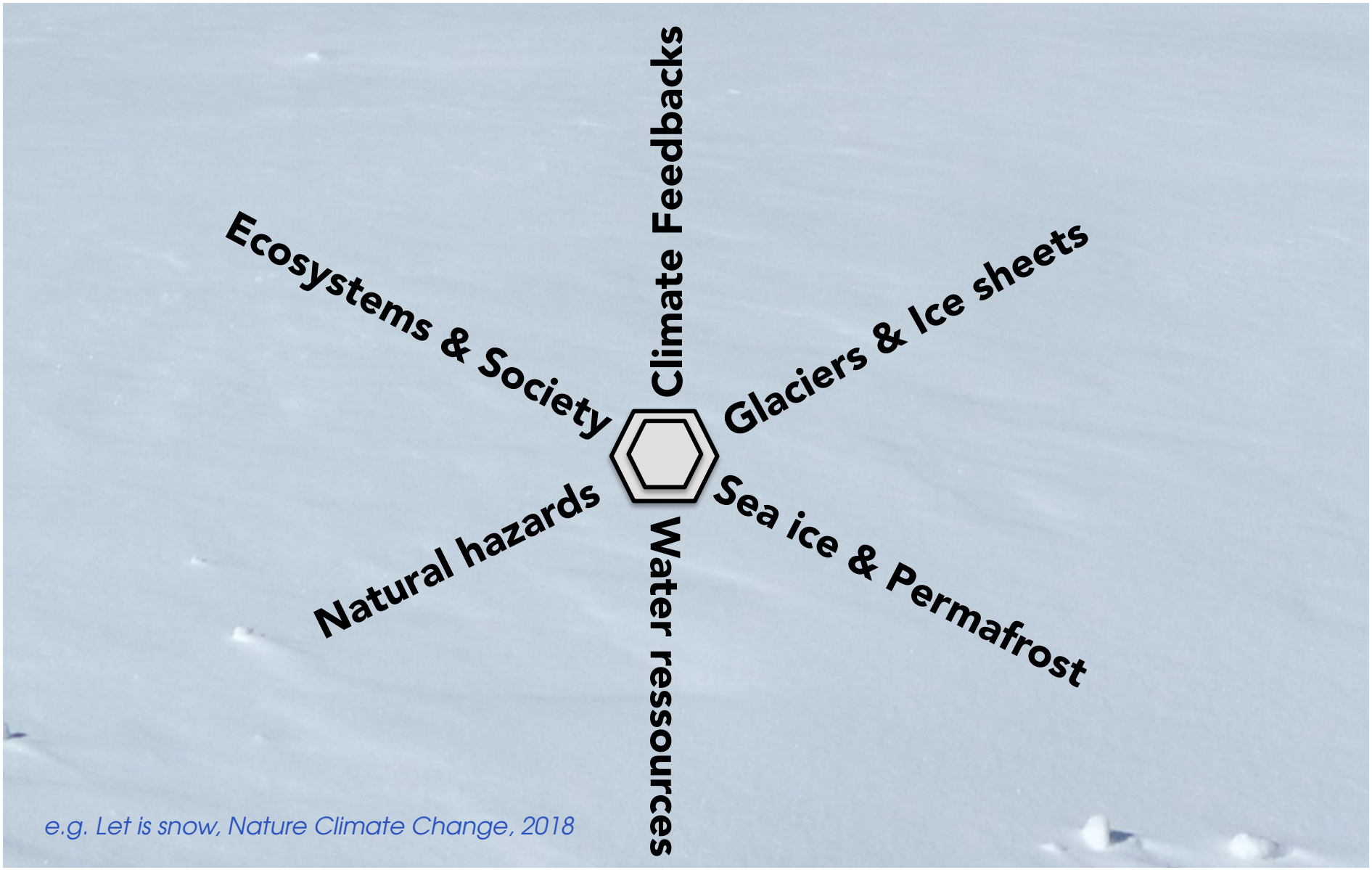
Marie Dumont

Météo-France - CNRS, CNRM/CEN, UMR 3589, Grenoble, France

EGU, Vienna, 2019

1. Inspired from Jeff Dozier

Snow in the Earth system



e.g. Let is snow, Nature Climate Change, 2018

Snow white

Picard et al., in review

Snow white

Pic

Disney

SNOW WHITE

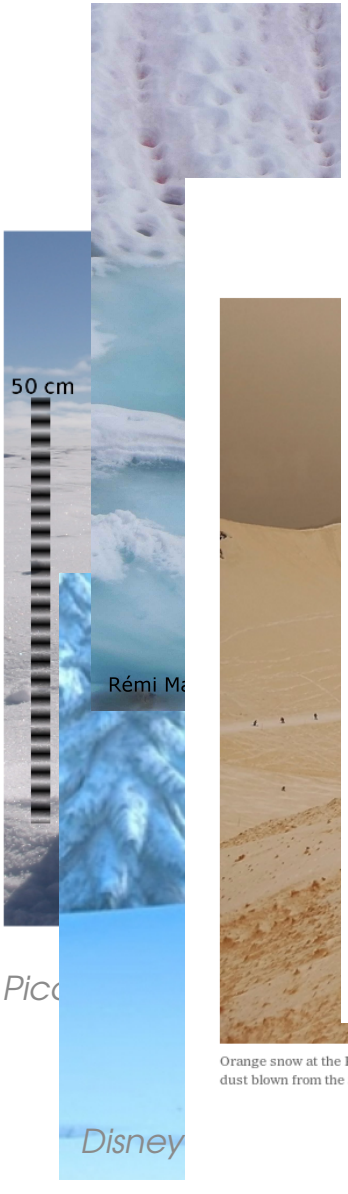
SNOW WHITE

Why the Snow in Parts of Europe Was Orange

Orange snow at the Rosa Khutor ski resort outside Sochi, Russia, on Thursday. Meteorologists say that snow from Siberia mixed with dust blown from the Sahara desert to create the colored snow. Margarita Alshina/ @margarita_alshina, via Associated Press

By Niraj Chokshi and Daniel Victor *The New York Times, March 2018*

SNOW WHITE



Eerie black snow falls over Siberian region triggering acute pollution concerns from locals

Siberian Times, February 2019

By The Siberian Times reporter

15 February 2019

Ghostly pictures of dark snowscapes - which should be pristine white - as blame pointed at failure to filter fumes at coal plant.

Eerie black snow. Picture: nataseife, Typical Kemerovo

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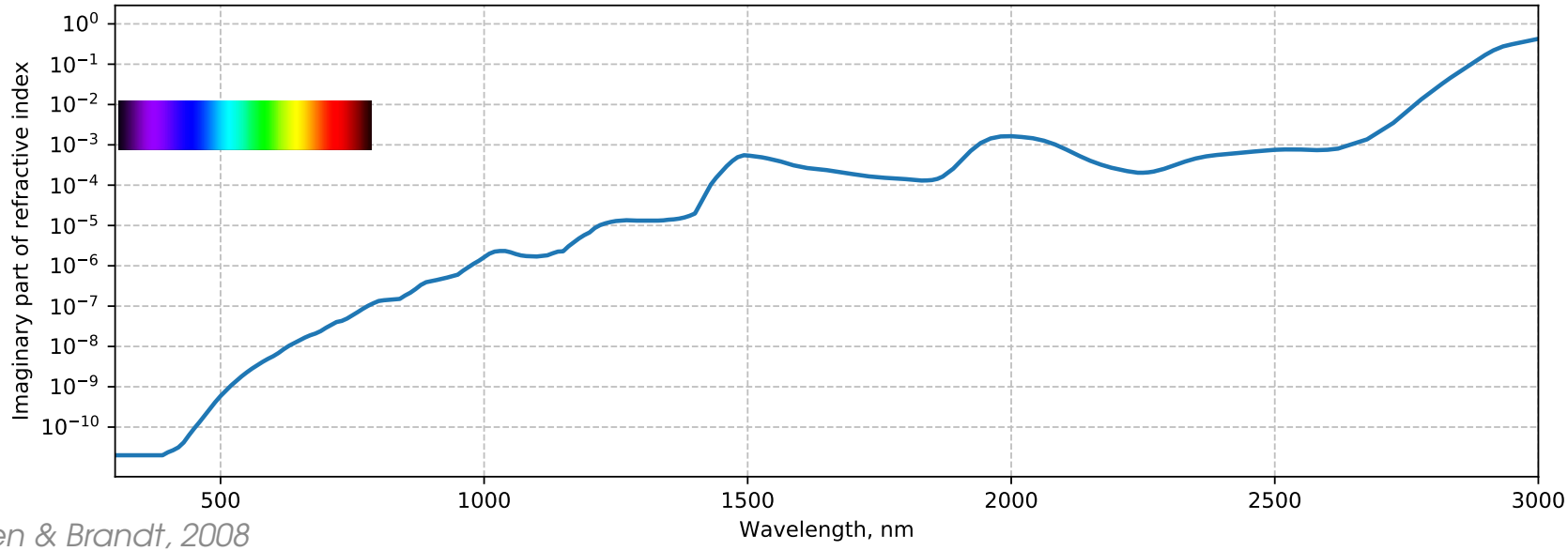
Eerie black sn

Chrome factory turns snow green in Russian town of Pervouralsk


The polluted ice is understood to have come from a factory
VLADISLAV ORESHKIN/THE SIBERIAN

The guardian, March 2019

SNOW IS MADE OF ICE



Warren & Brandt, 2008

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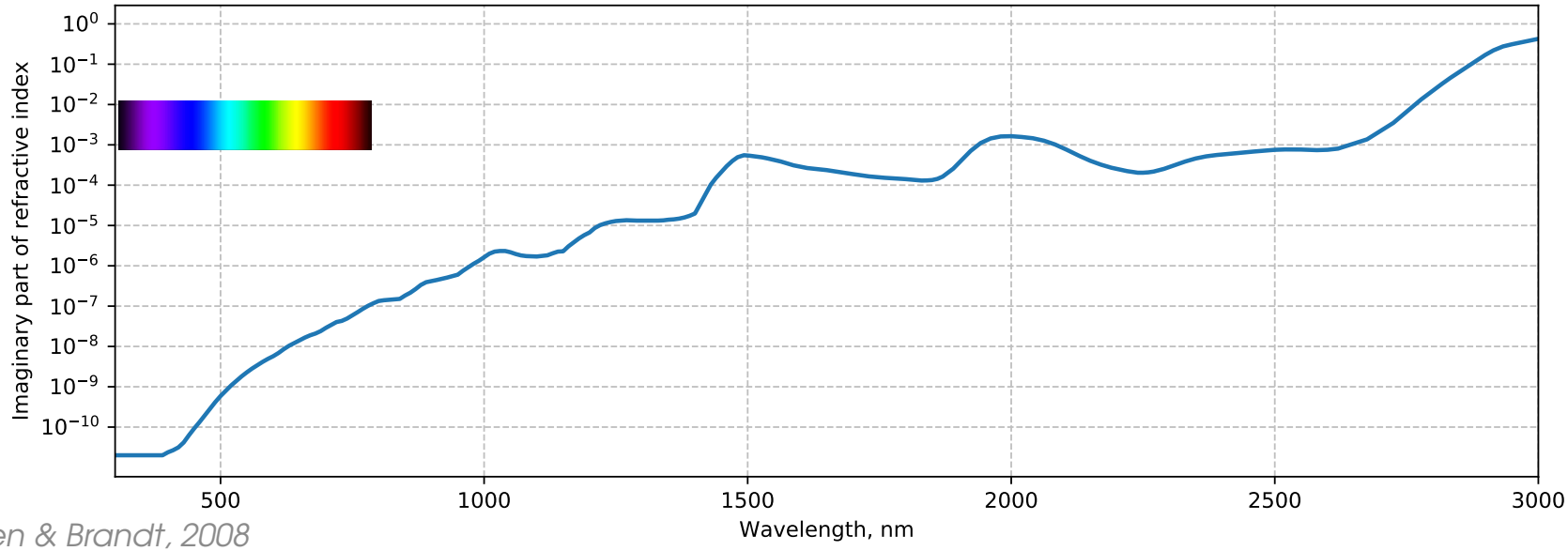

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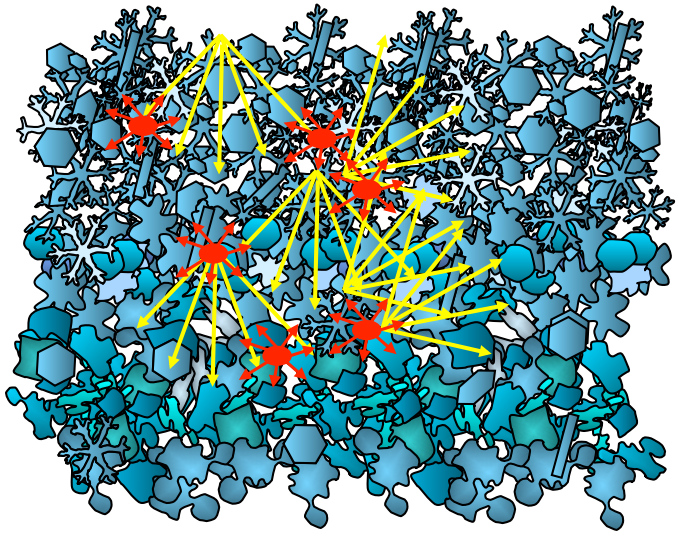

Courtesy of F. Domine

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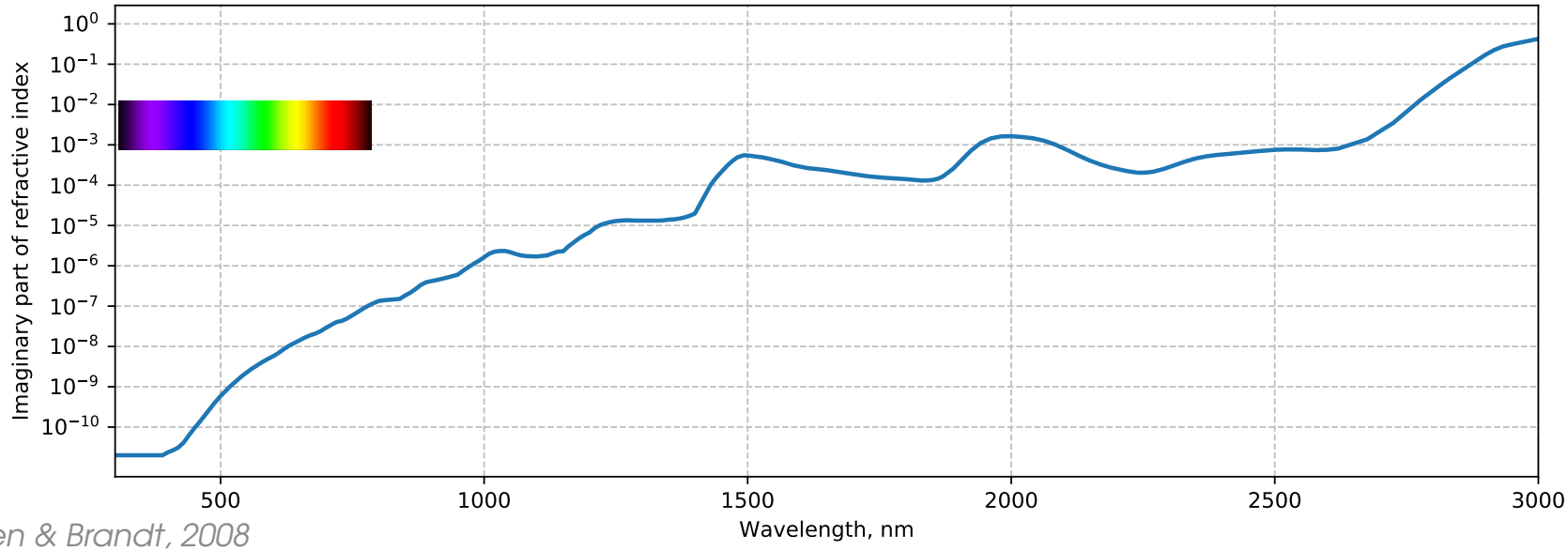

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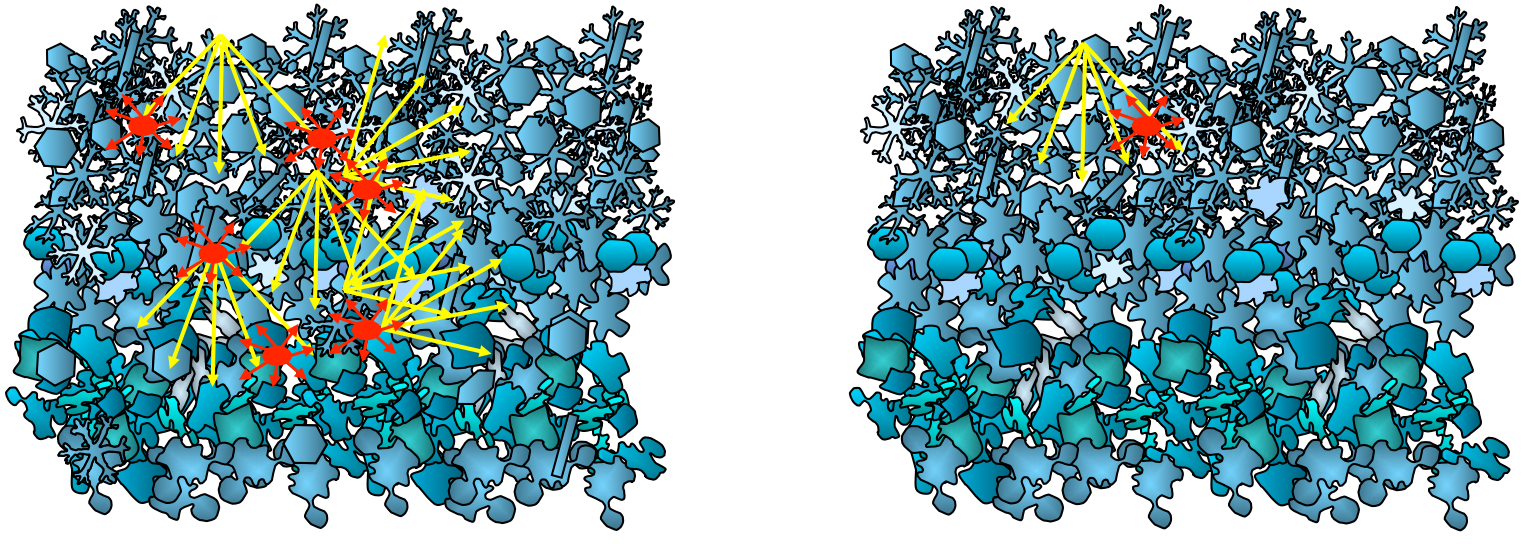

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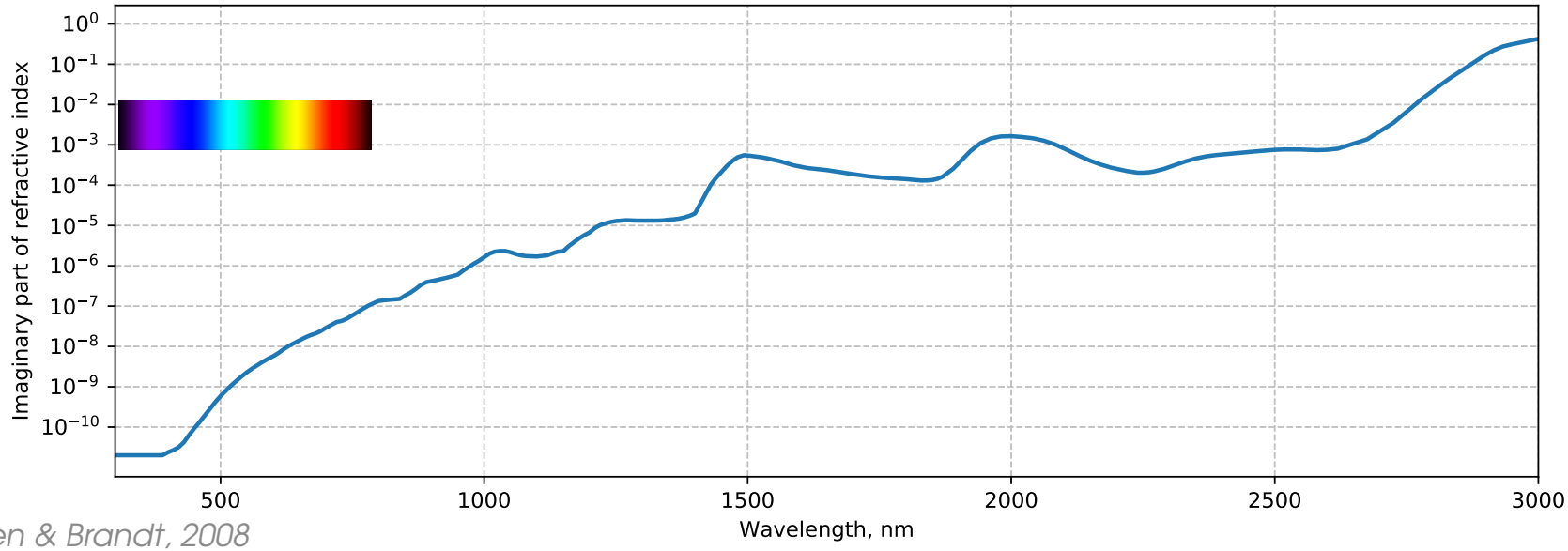

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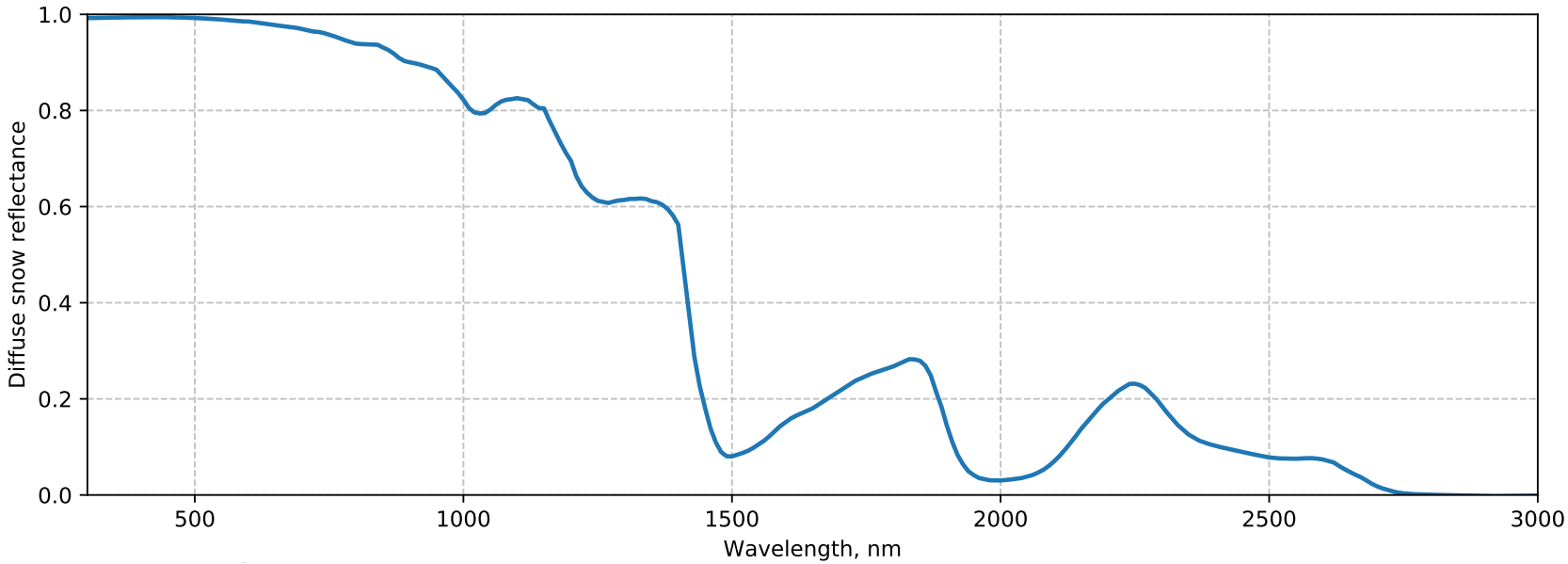
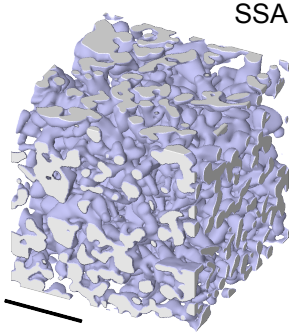
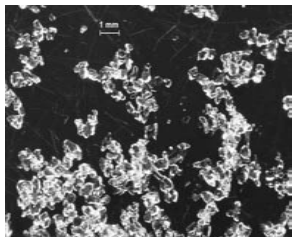


A THOUSAND SHADES OF WHITE

Snow reflectance and snow microstructure

SSA = 30 m^2 kg^{-1}





SSA = 4 m^2 kg^{-1}

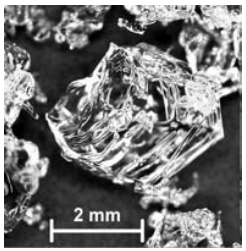
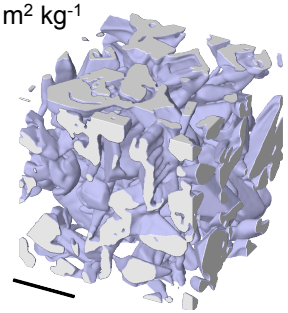


Photo : Fierz et al., 2009



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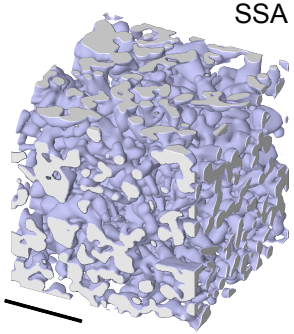

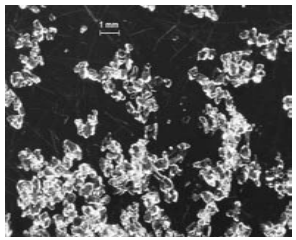

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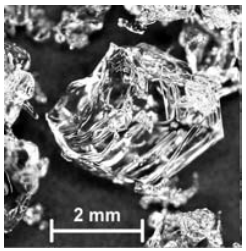

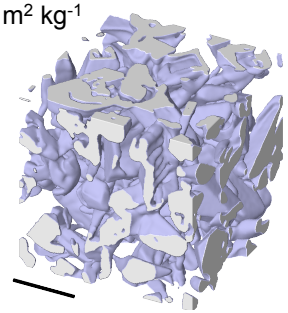

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Specific Surface Area

$$SSA = \frac{S}{\rho_{ice} V} \approx \frac{scattering}{absorption}$$

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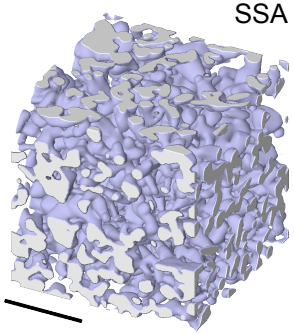

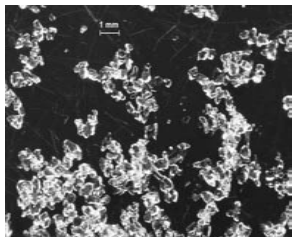

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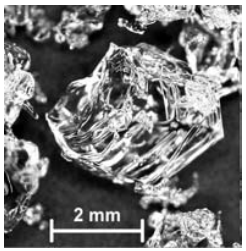

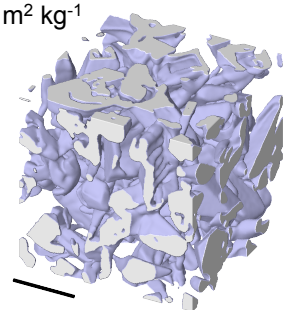

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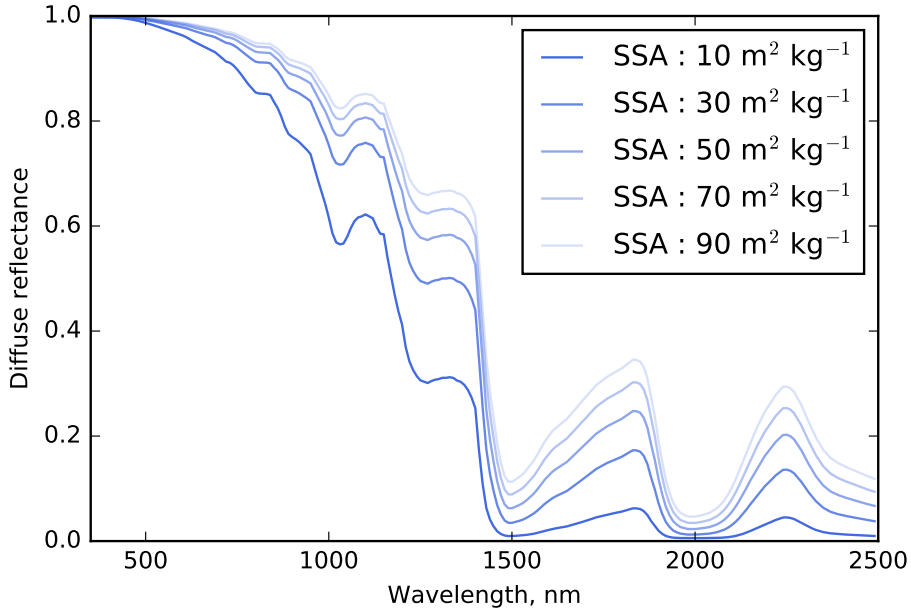

Two stream Analytical Radiative TransfEr in Snow (TARTES), Libois et al., 2013 ; AART, Kokhanovsky and Zege, 2004

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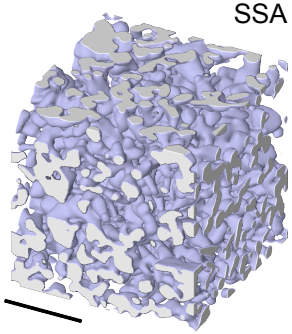

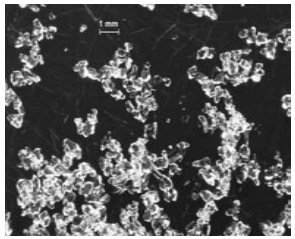

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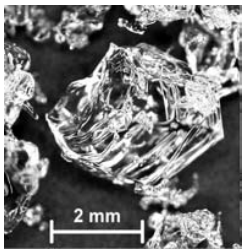

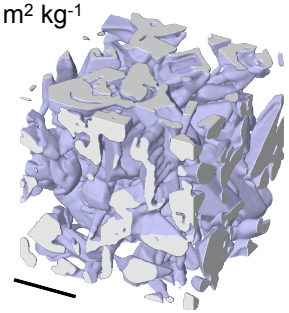

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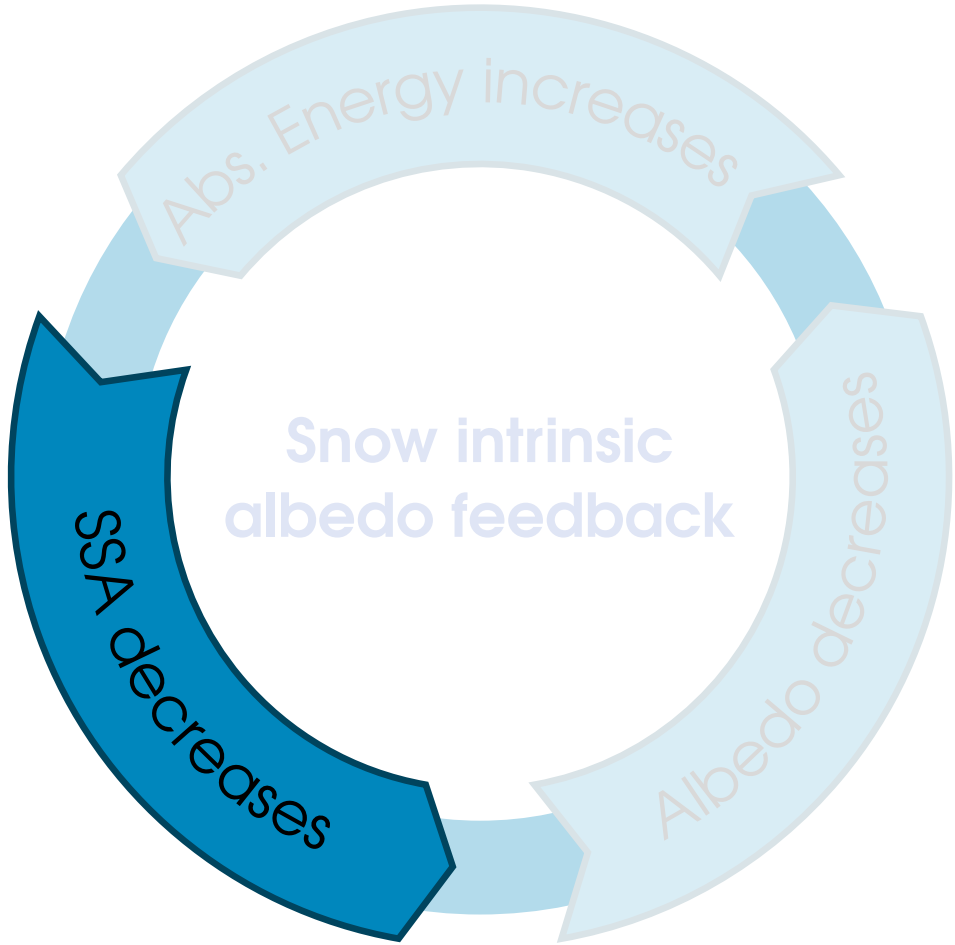

e.g., Flanner & Zender, 2006

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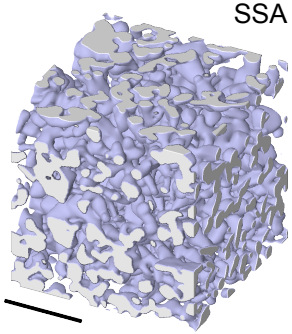

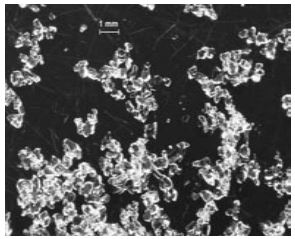

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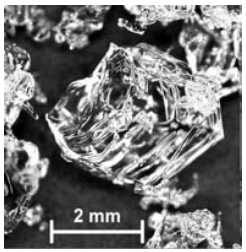

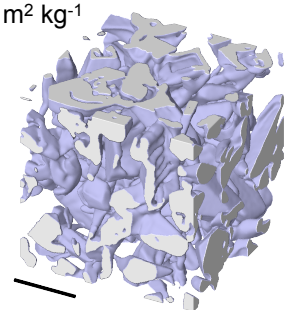

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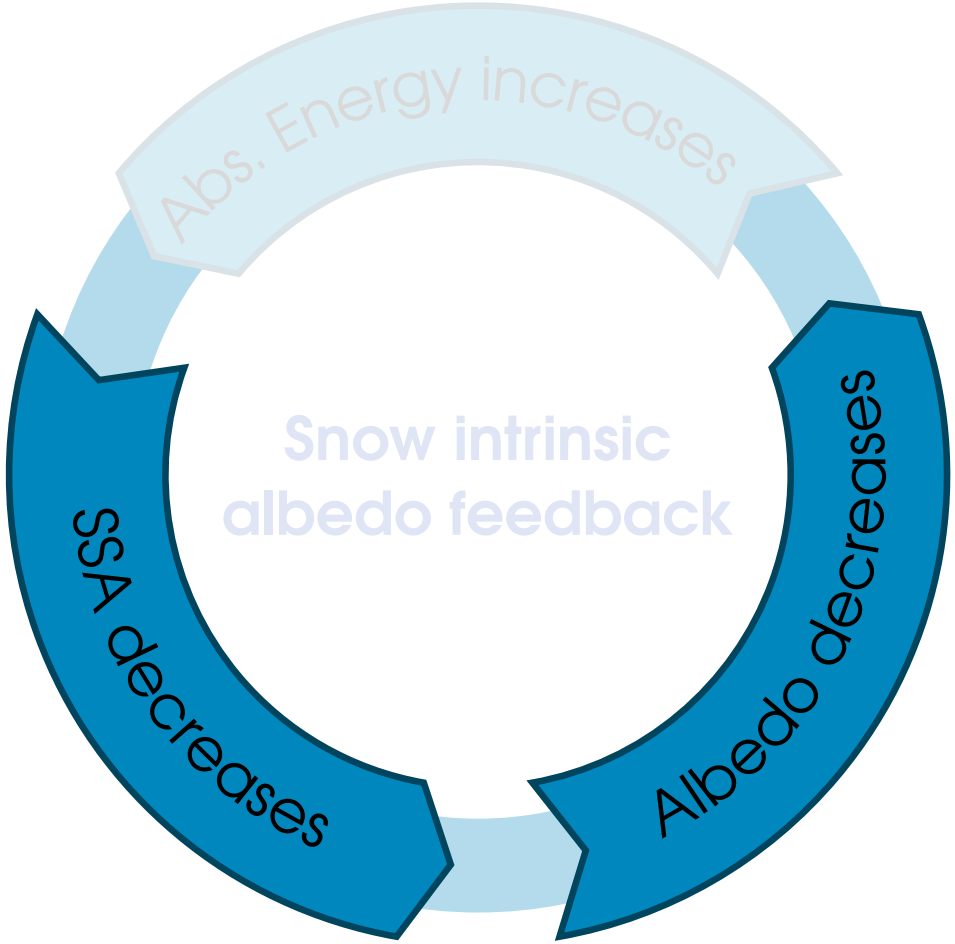

e.g., Flanner & Zender, 2006

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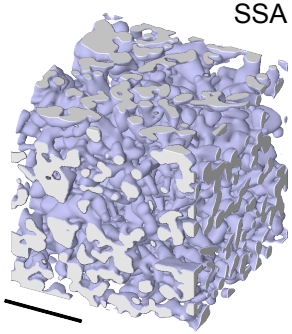

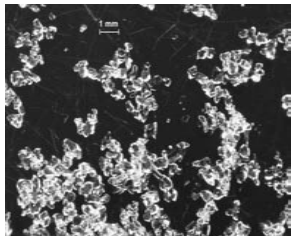

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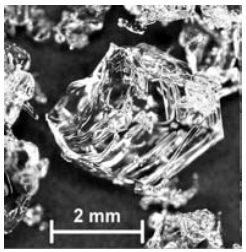

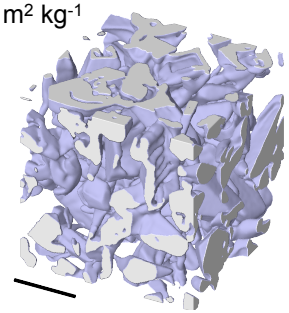

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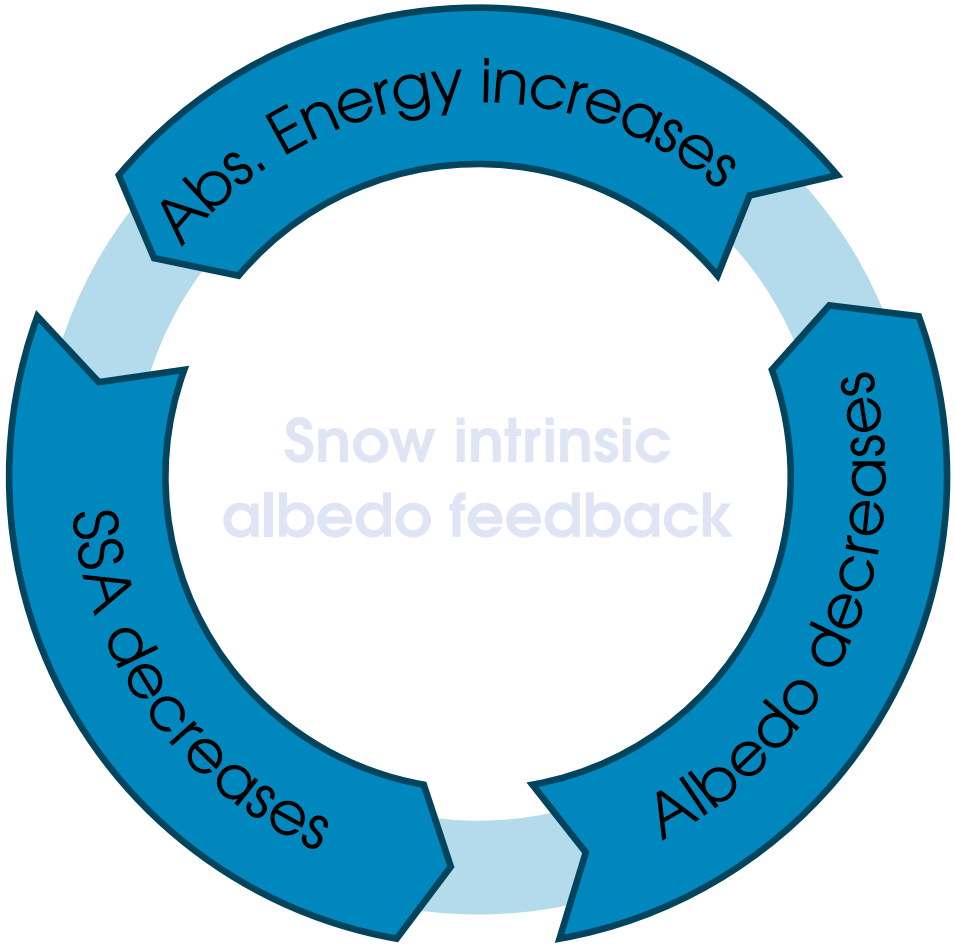

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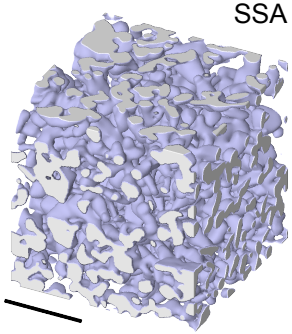

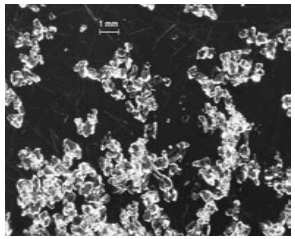

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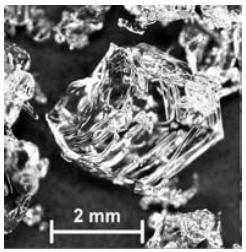

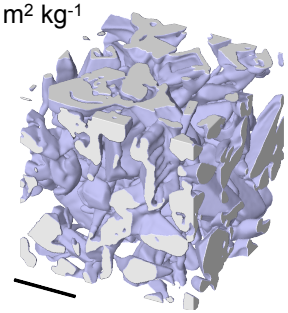

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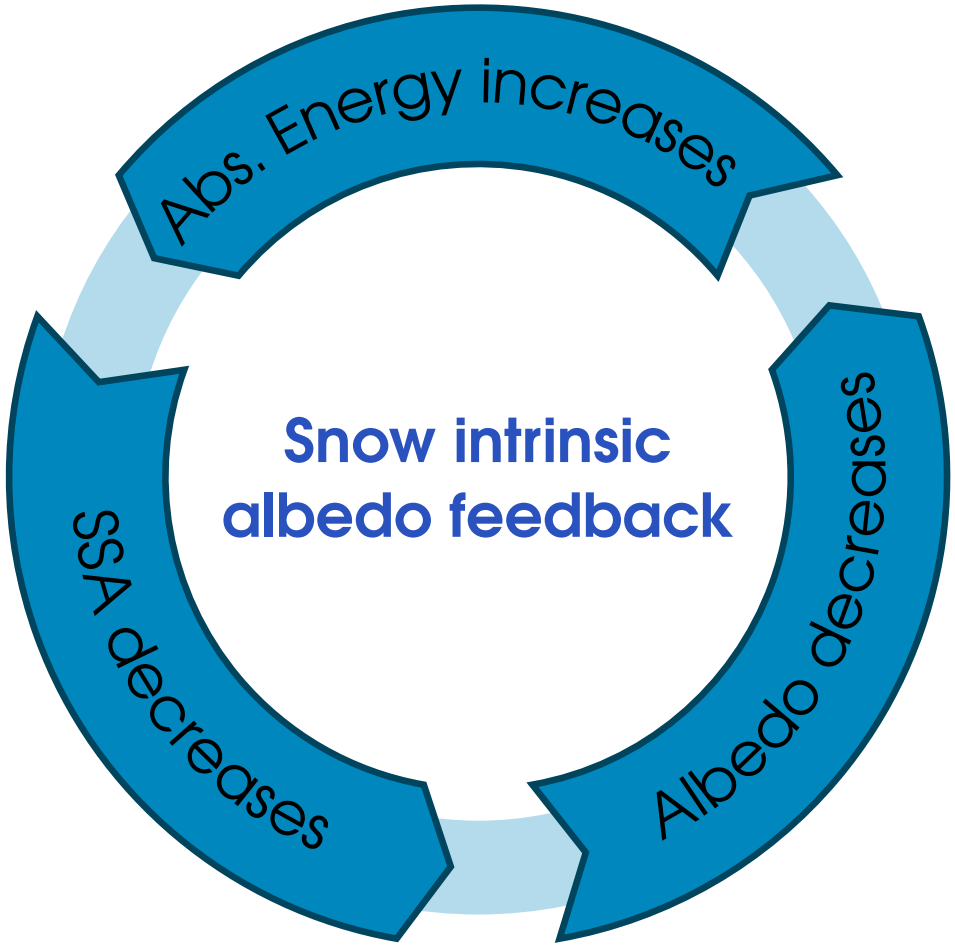

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DIRTY SNOW

Snow reflectance and light absorbing particles (LAPs)

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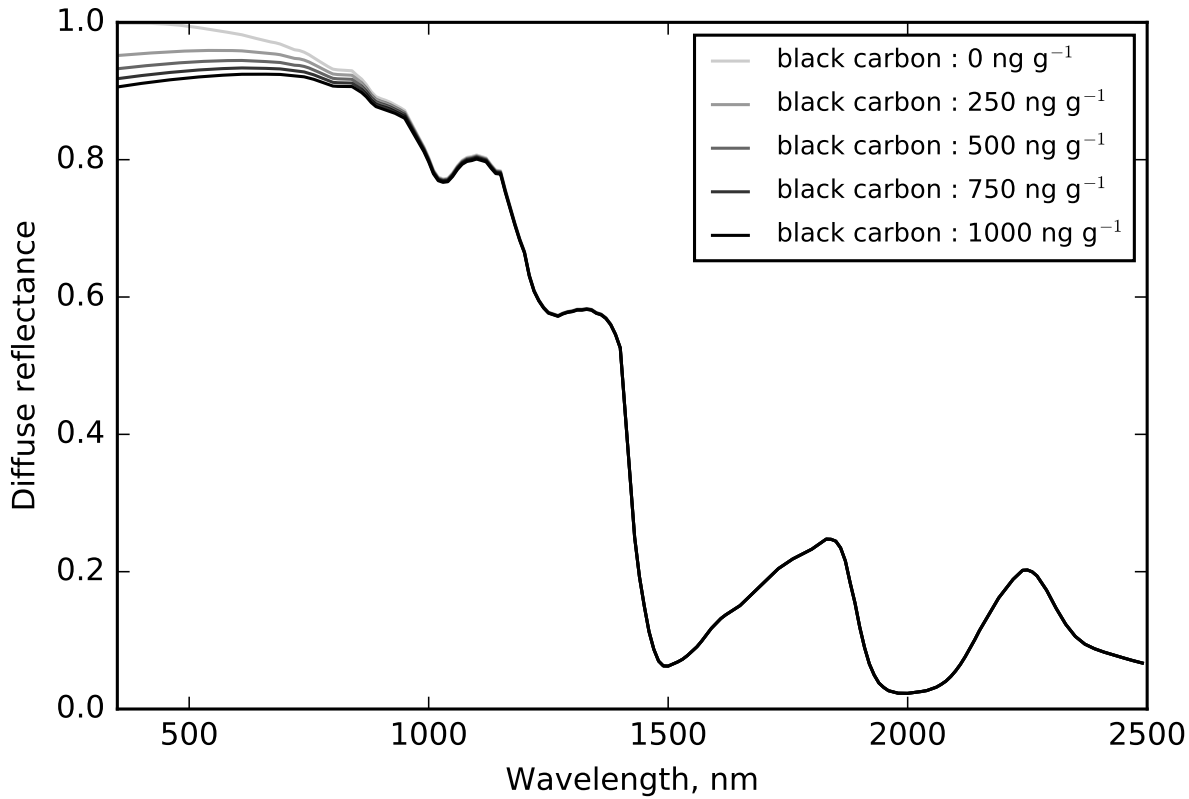

TARTES, Libois et al., 2013

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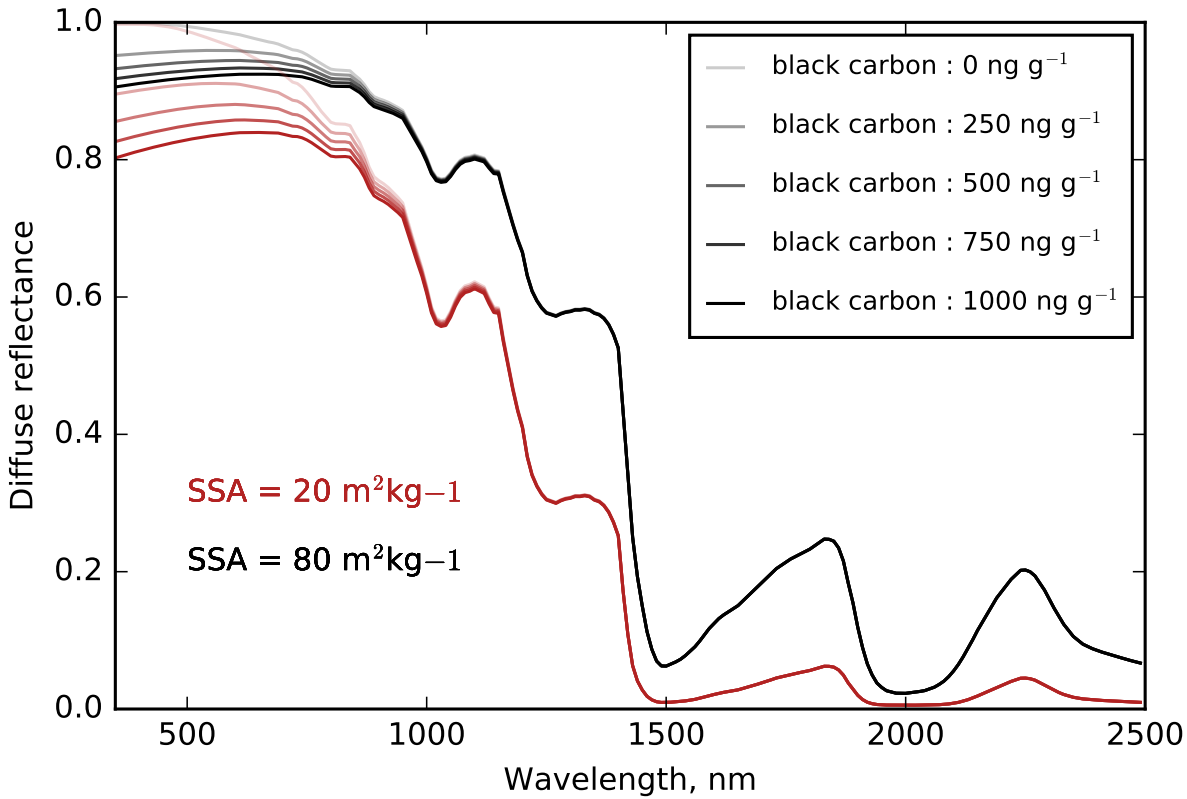

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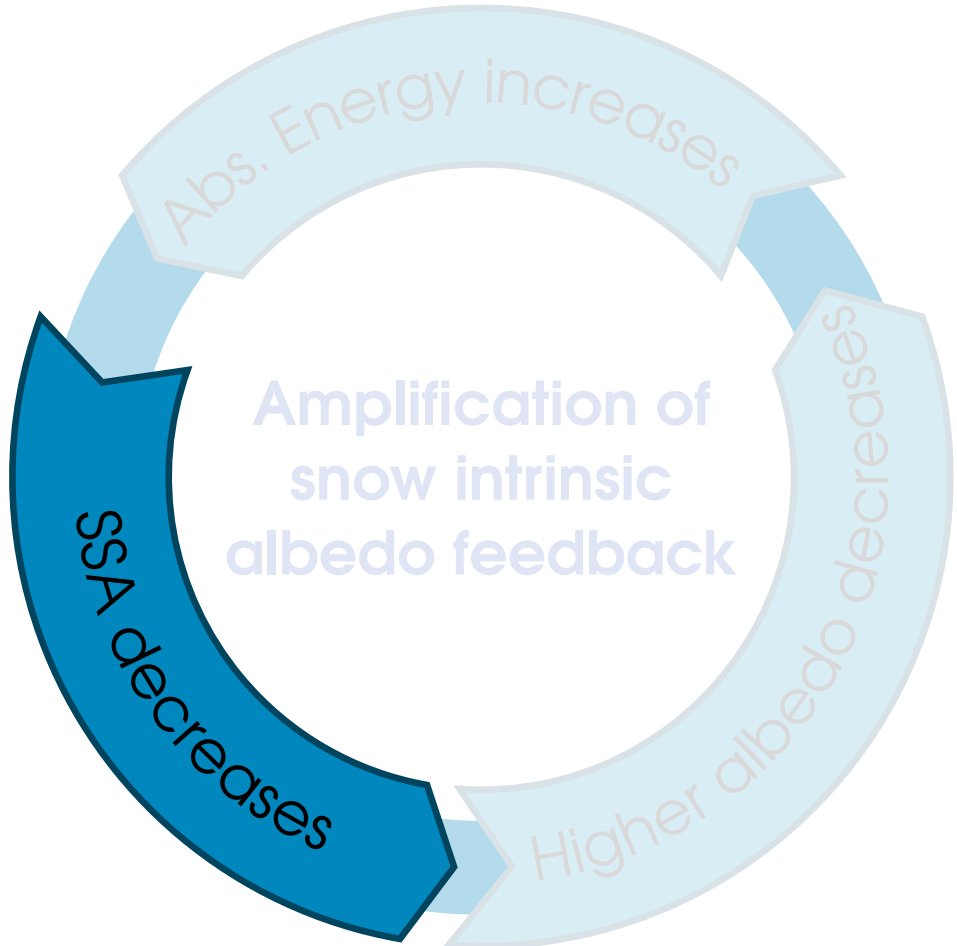

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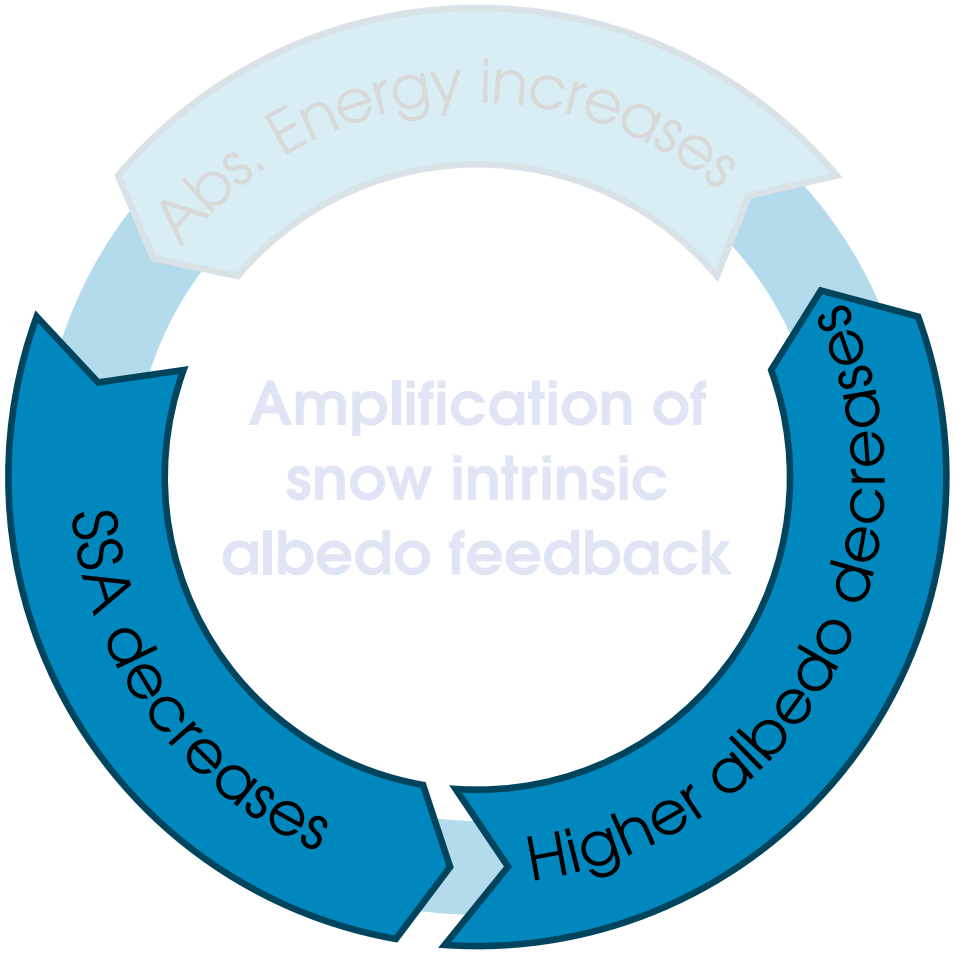

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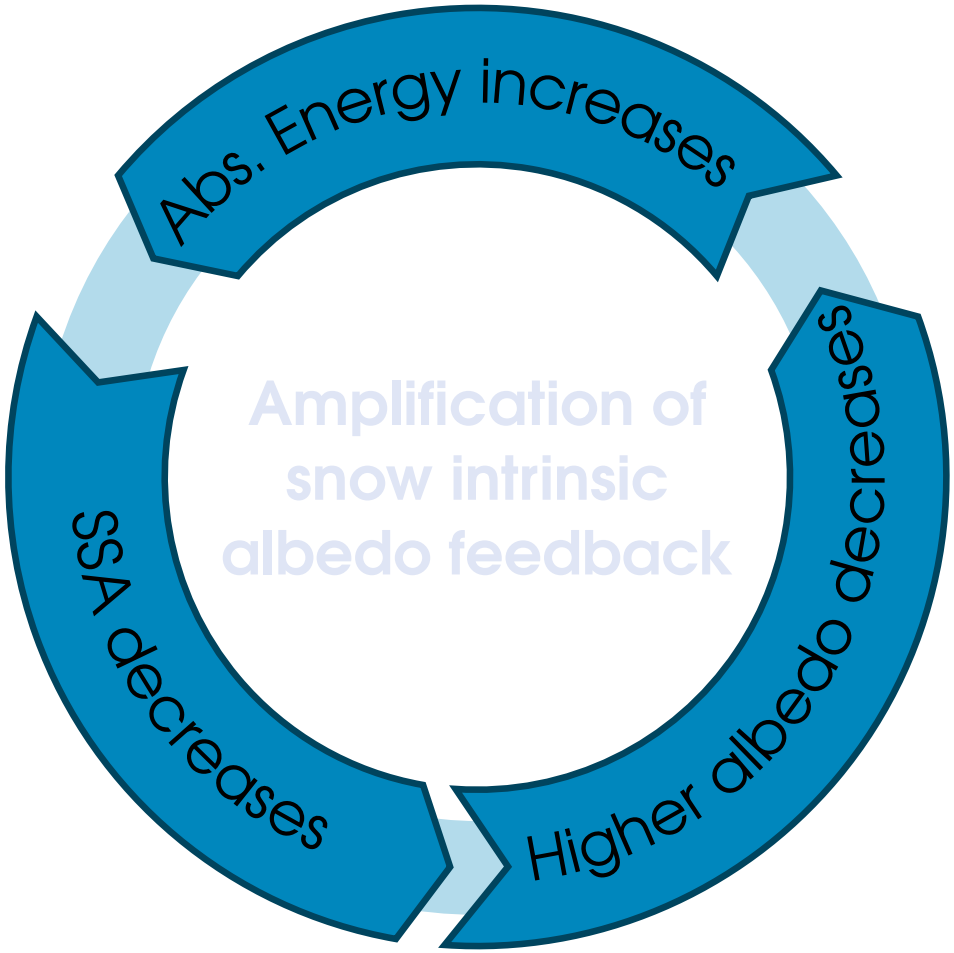

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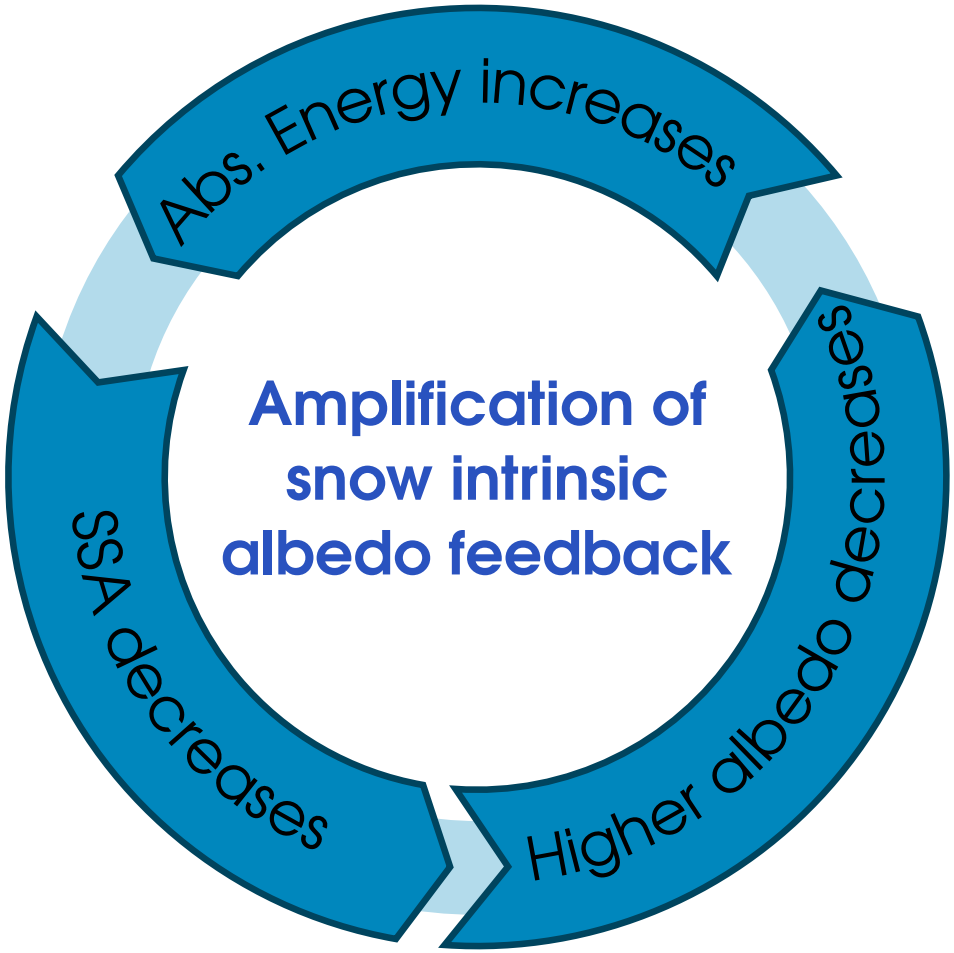

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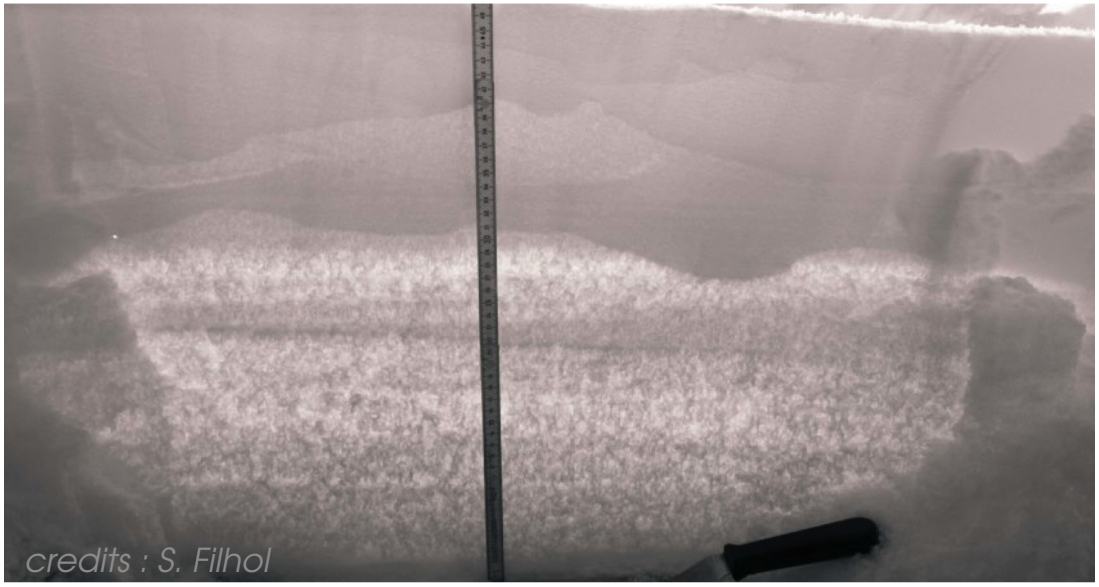
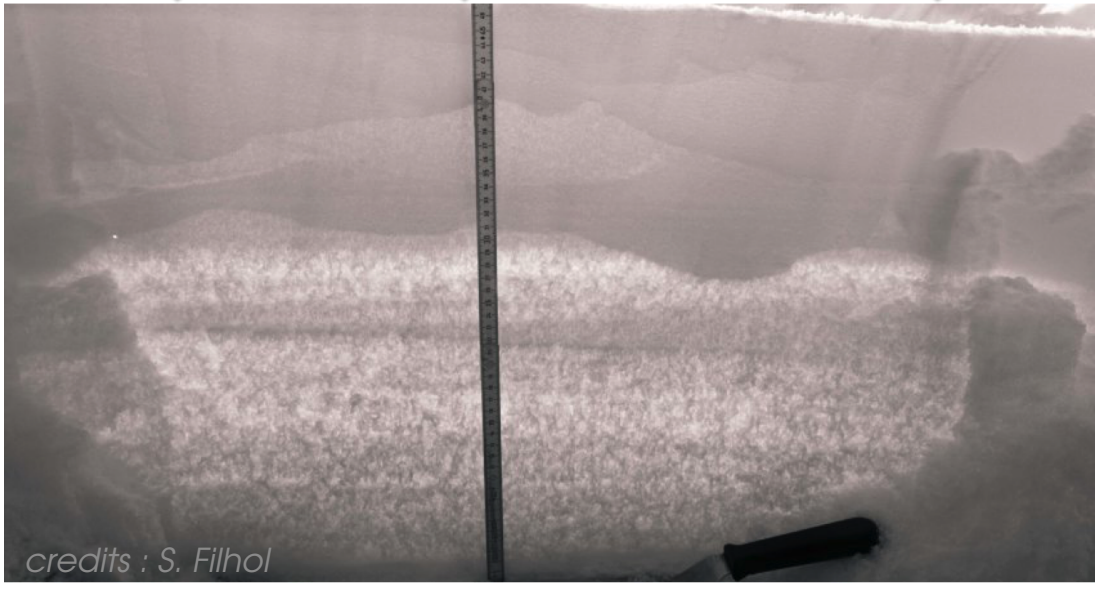
SNOWPACK EVOLUTION



SNOWPACK EVOLUTION

Atmosphere

Mass and energy fluxes



SNOWPACK EVOLUTION

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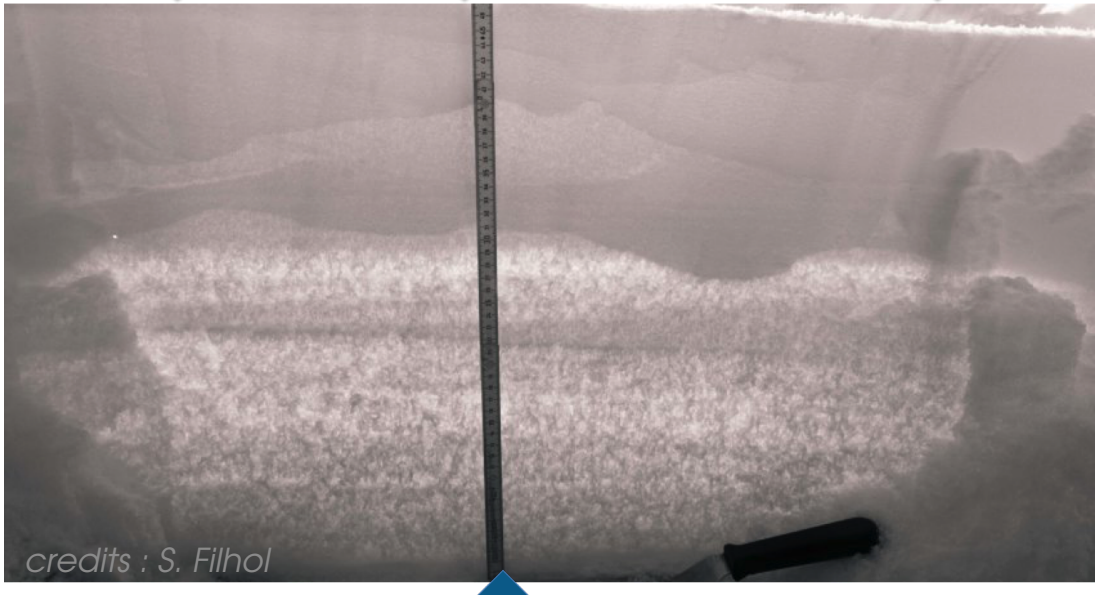
SW_{net} LW_{net} **H, LE**

Rain, snow



Soil, ice, ...

Mass and energy fluxes

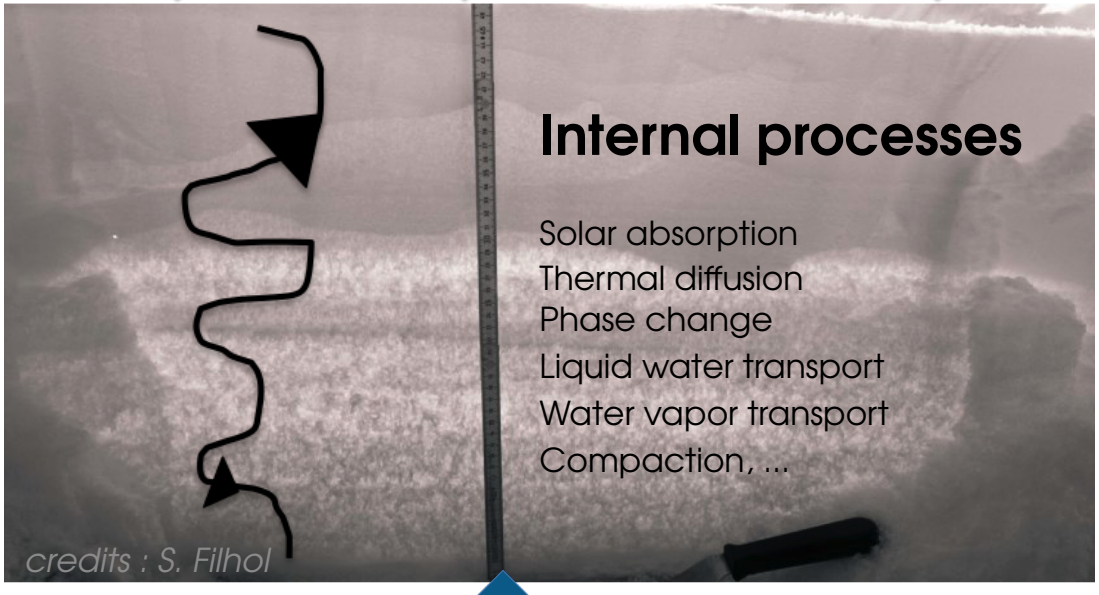
SNOWPACK EVOLUTION

Atmosphere

Mass and energy fluxes

SW_{net} LW_{net} **H, LE**

Rain, snow



Soil, ice, ...

Mass and energy fluxes

SNOWPACK EVOLUTION

Atmosphere

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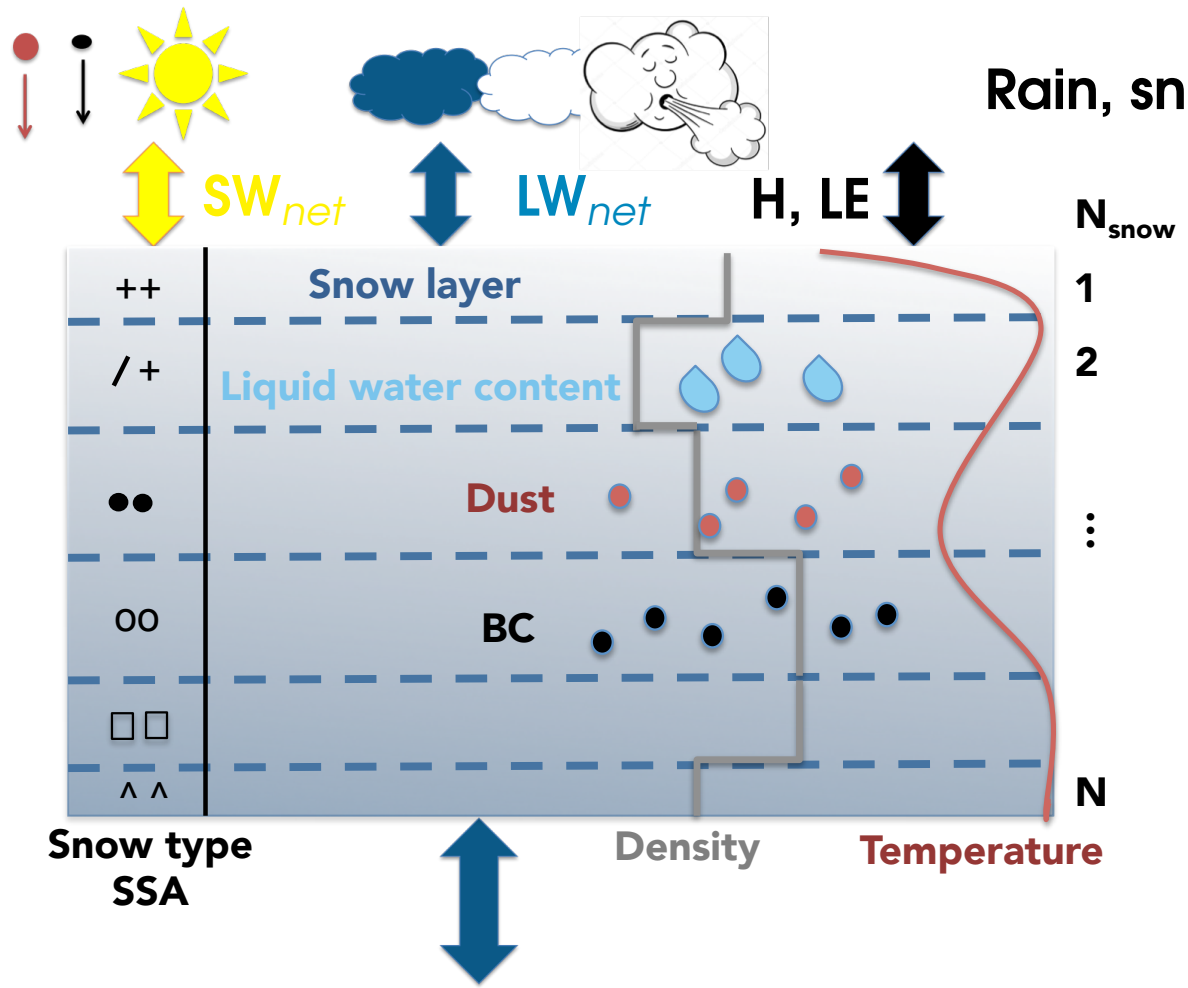
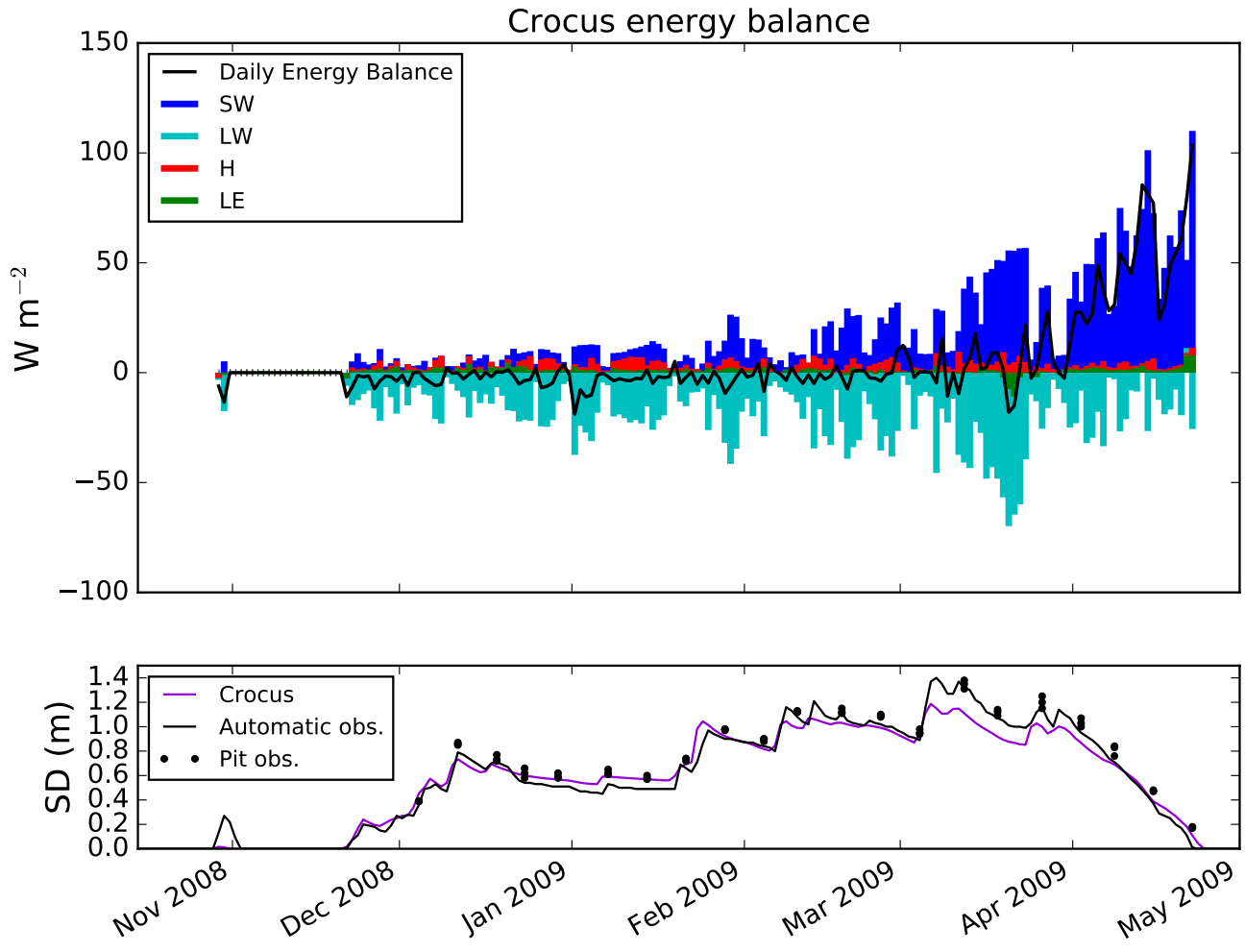


e.g. Crocus : Brun et al., 1992 ; Vionnet et al., 2012, SNOWPACK : Bartelt and Lehning, 2002 ; Lehning et al., 2002

OPTICAL PROPERTIES AND THE ENERGY BUDGET

Snow reflectance is both a cause and an effect of the surface energy balance



Lafaysse et al., 2017

OPTICAL PROPERTIES AND THE ENERGY BUDGET

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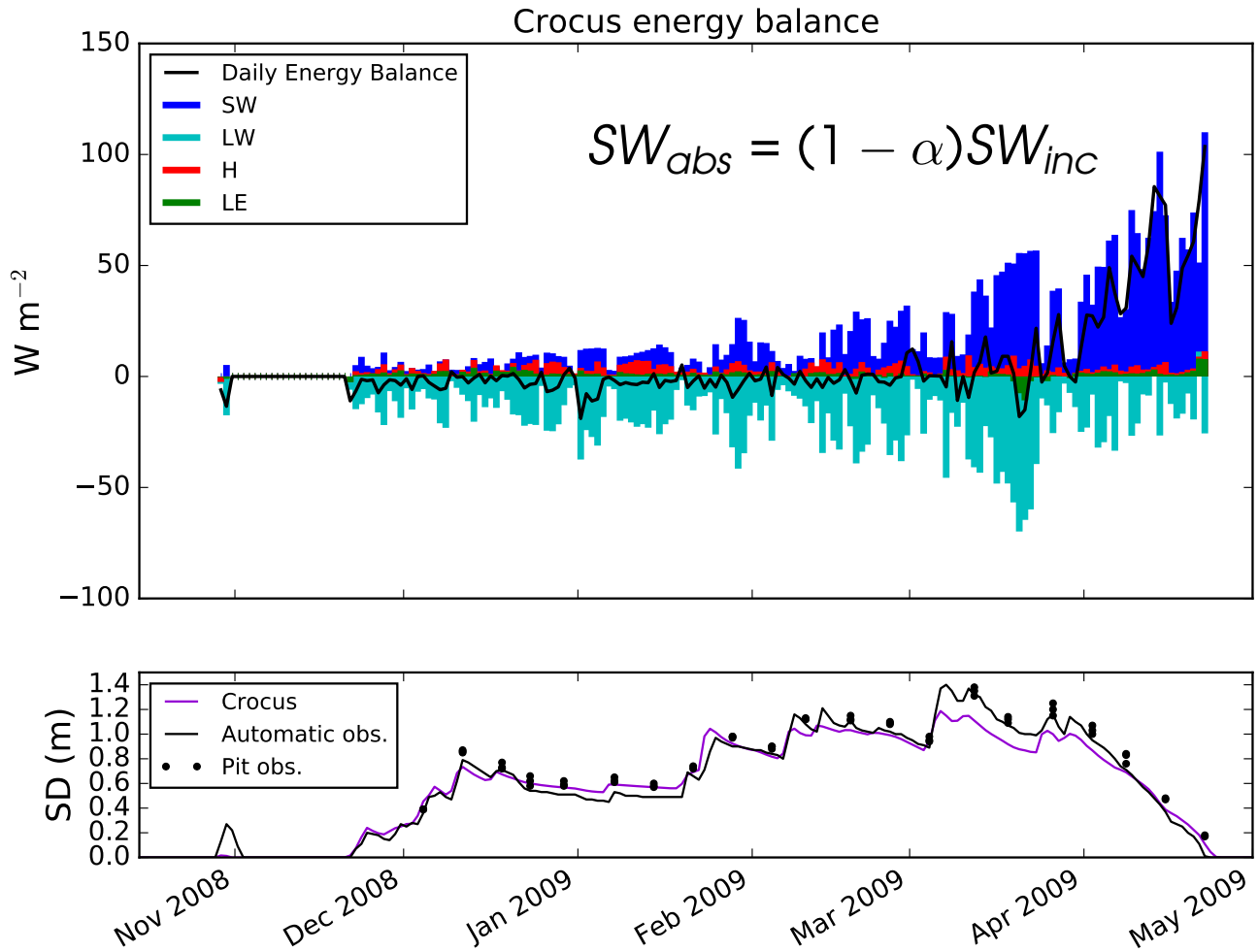
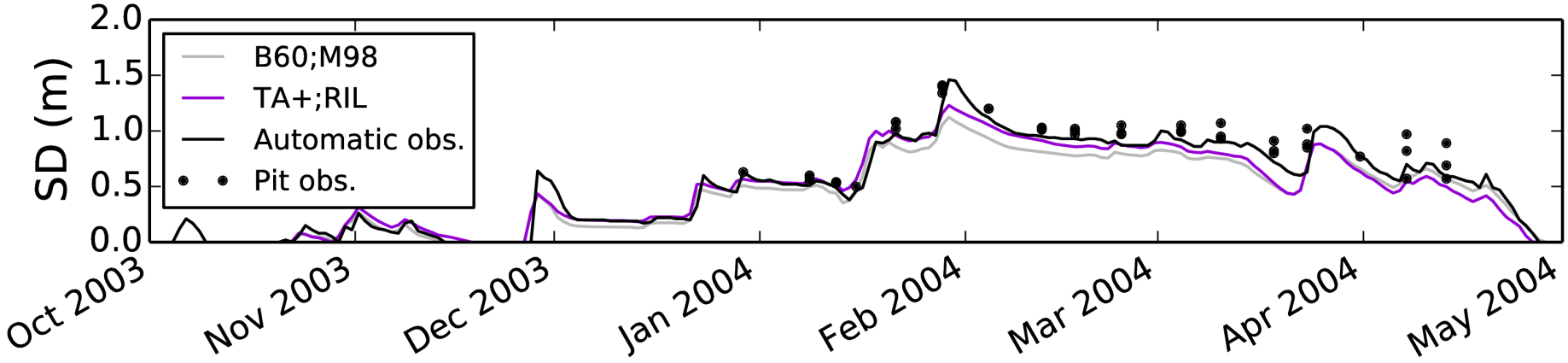


Lafaysse et al., 2017

EQUIFINALITY IN SNOW MODELLING

Energy balance models



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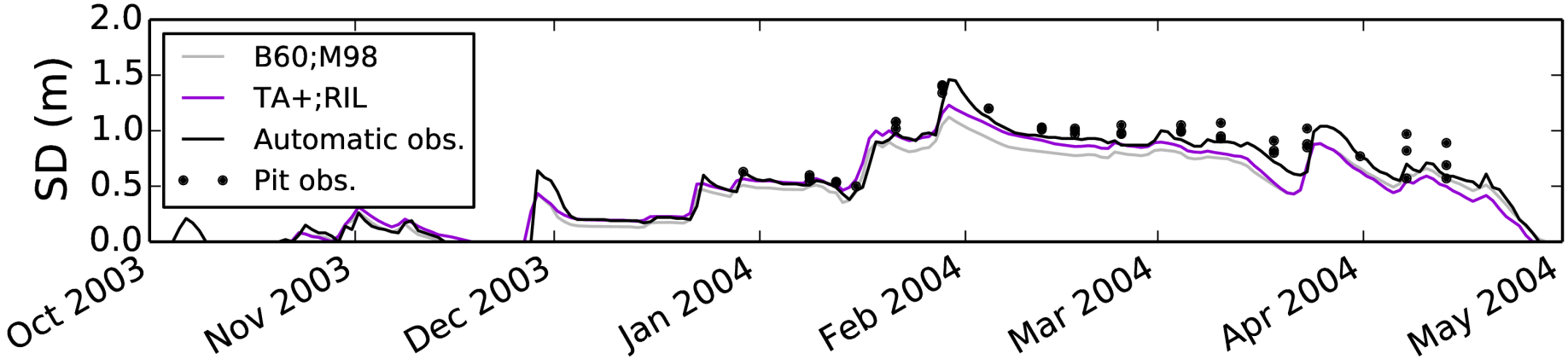
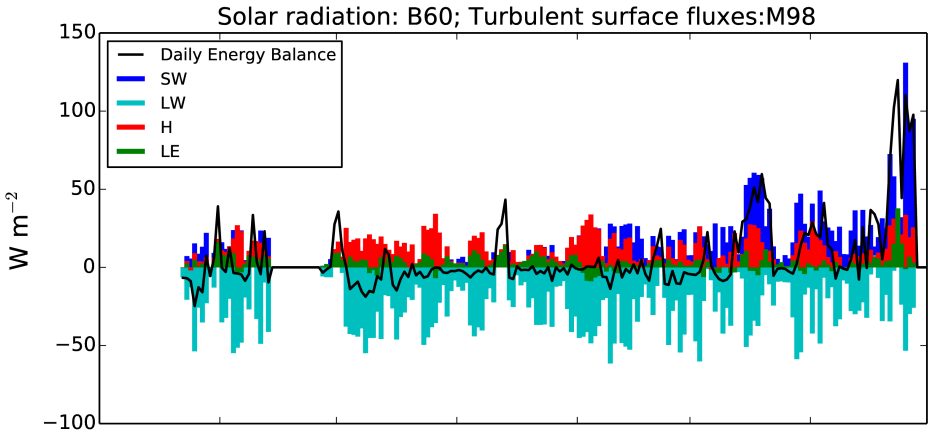
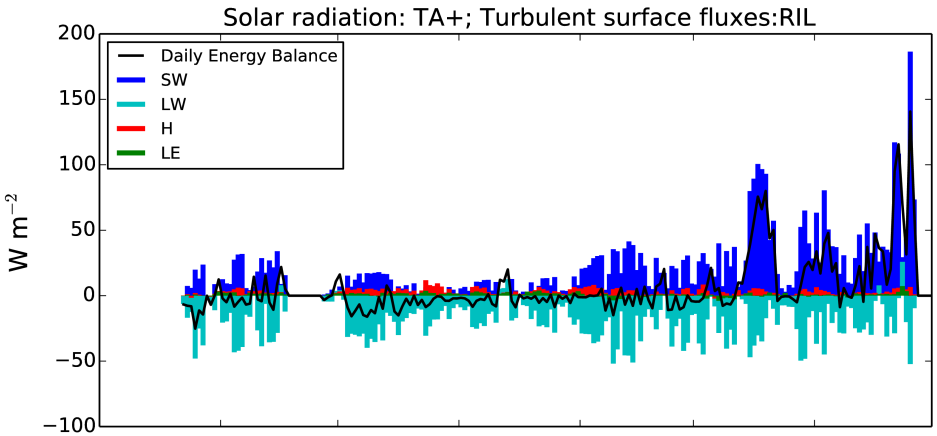


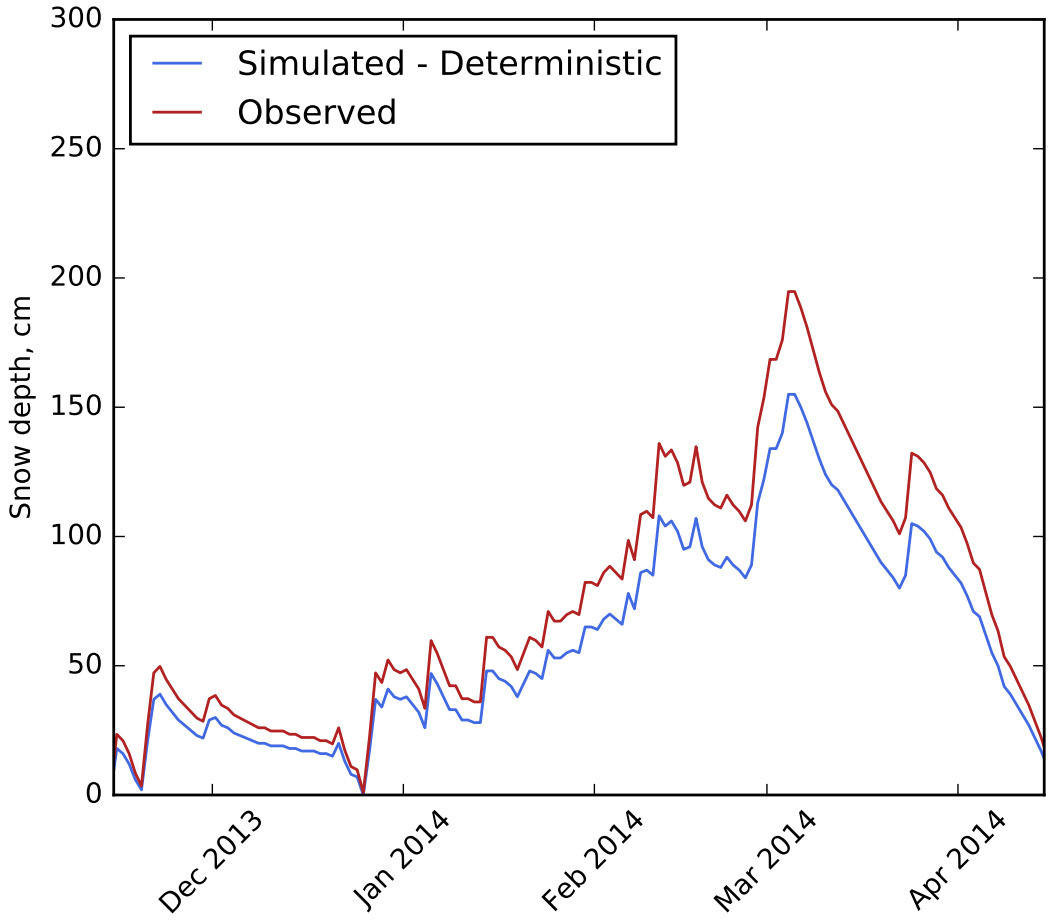




Lafaysse et al., 2017 ; Essery et al., 2013

Ensemble simulations, Why have just one!

Uncertainties in snow modelling



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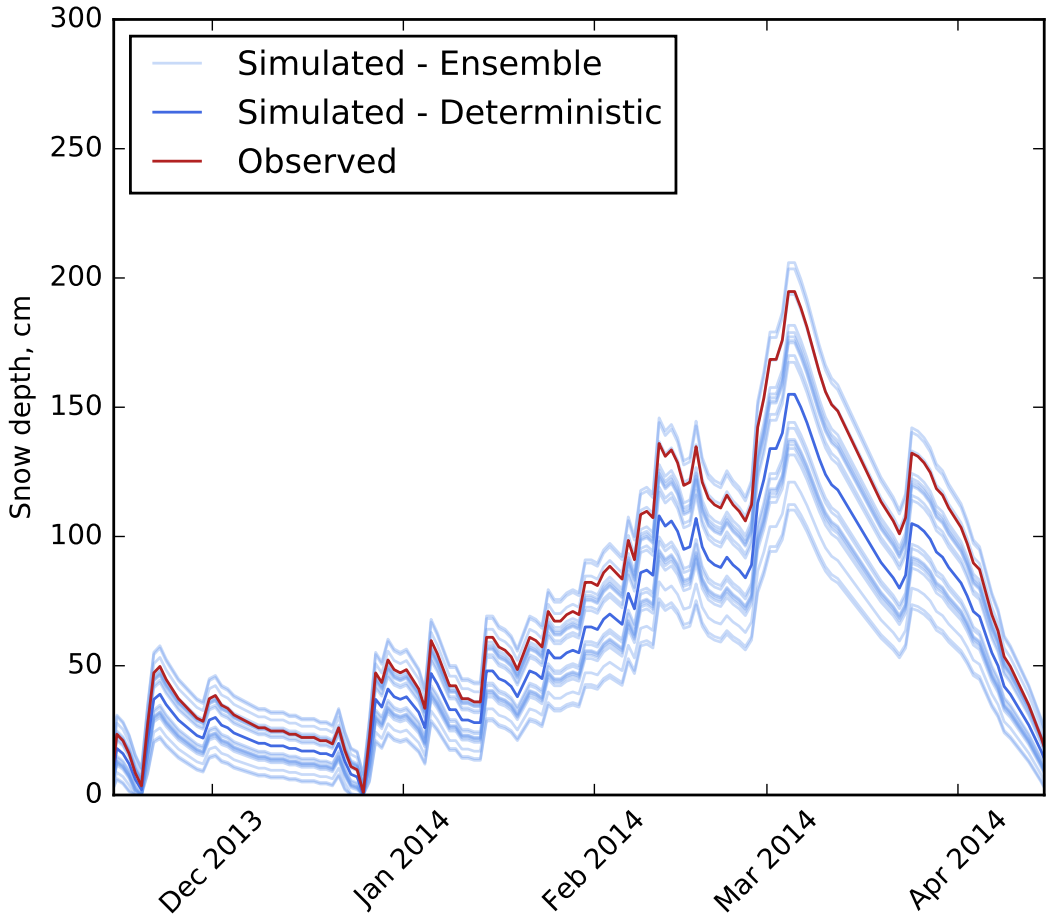

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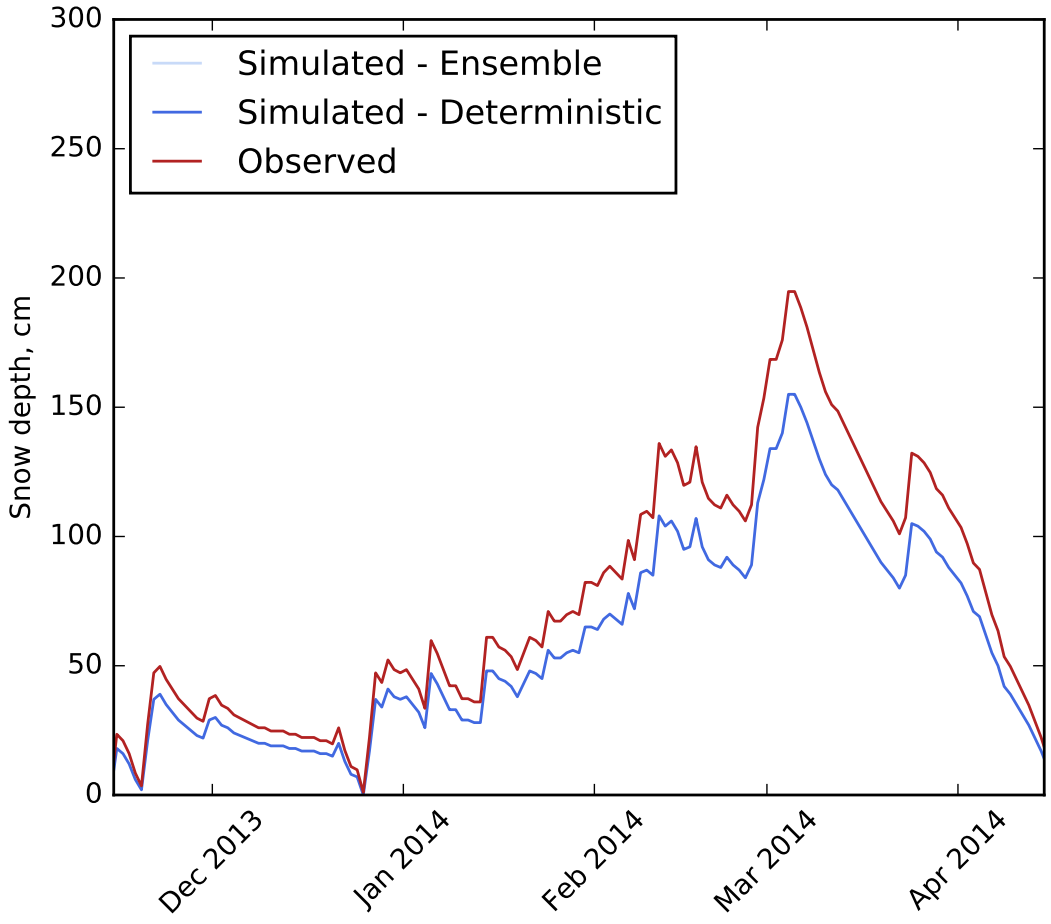

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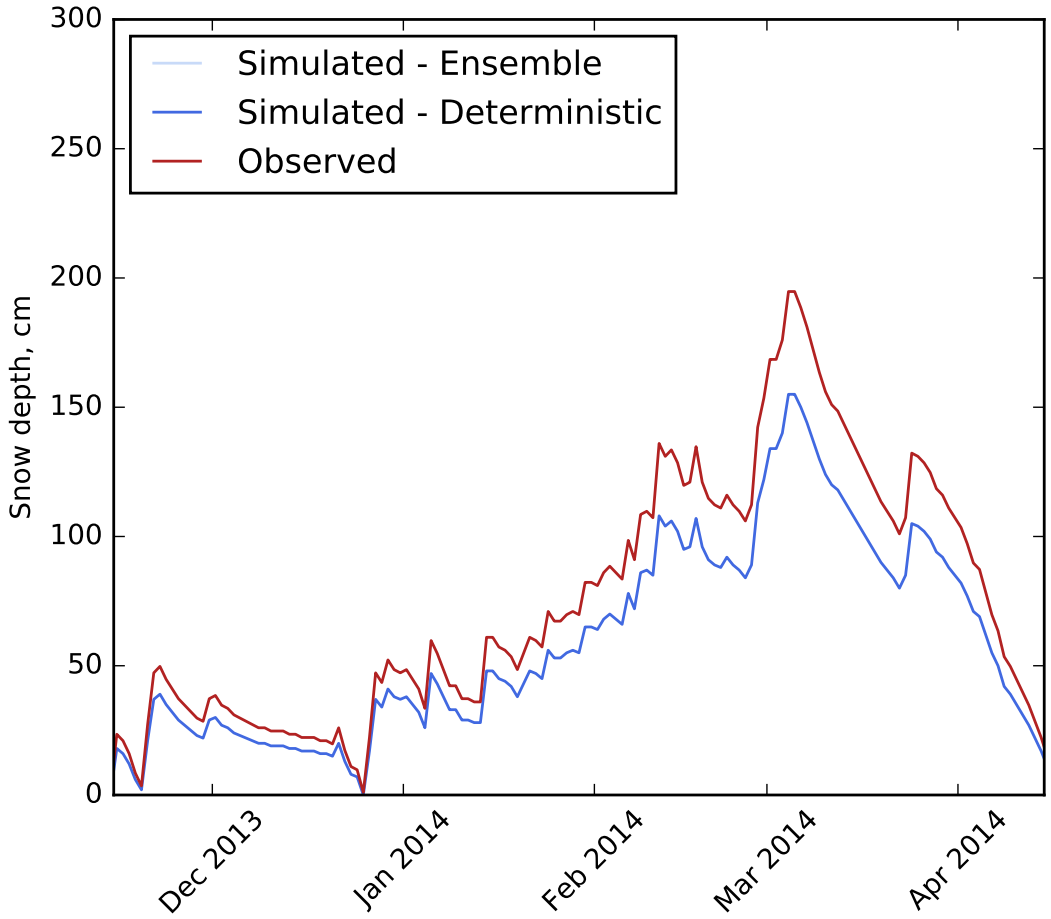
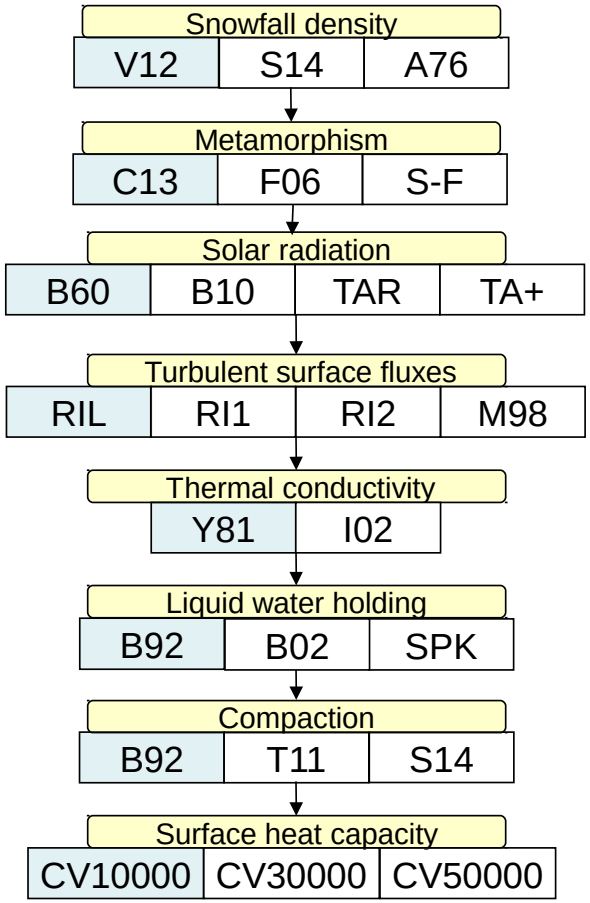
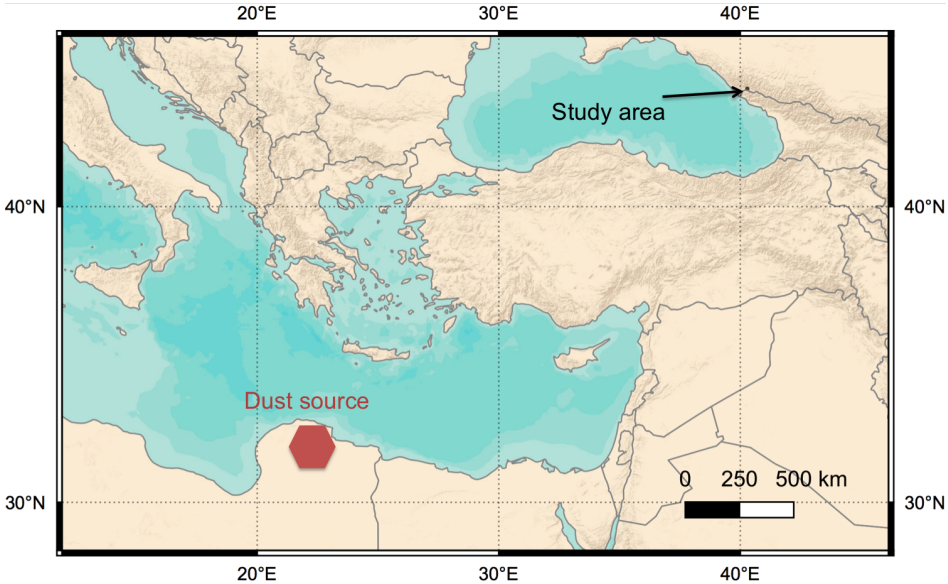
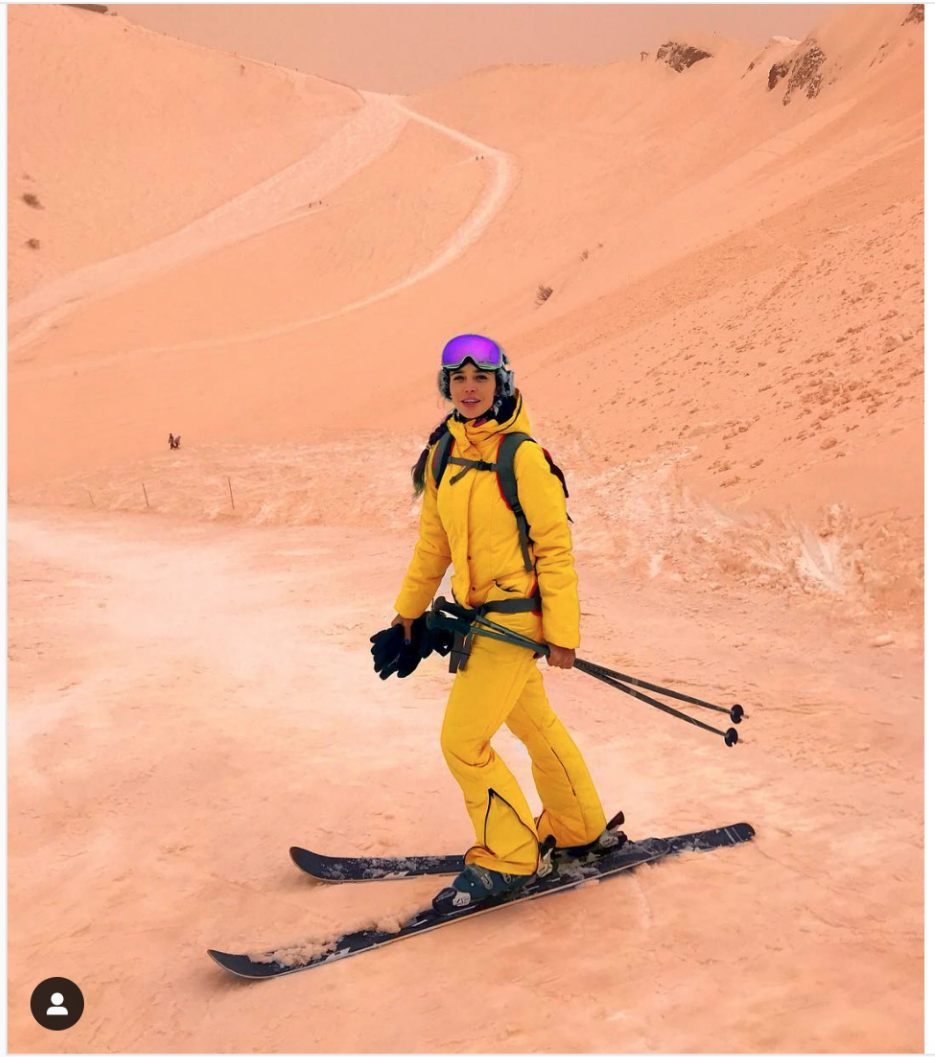




Lafaysse et al., 2017

ORANGE IS THE NEW WHITE

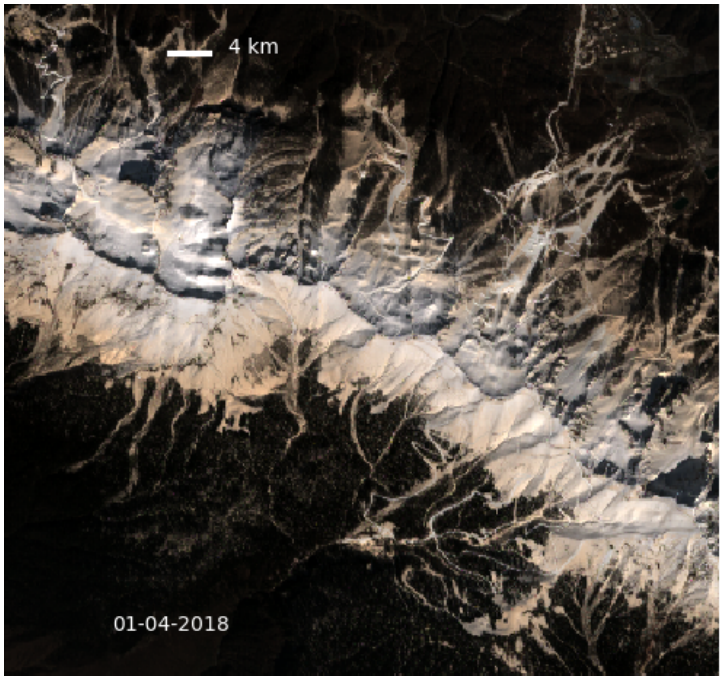




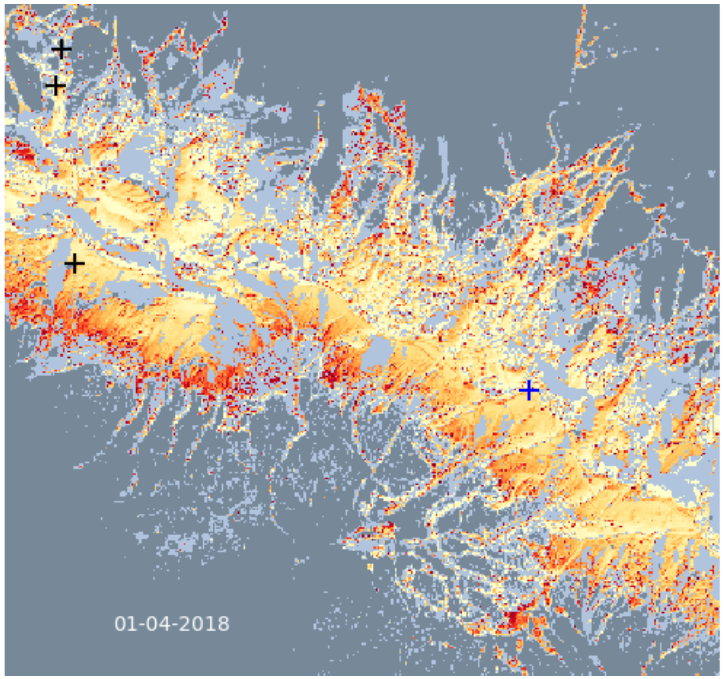
Instagram, March 2018 ; *Gascoin, Dumont and Picard, 2018, EGU news*

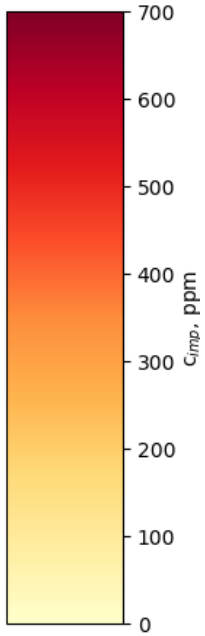
Dust content evolution from Sentinel-2

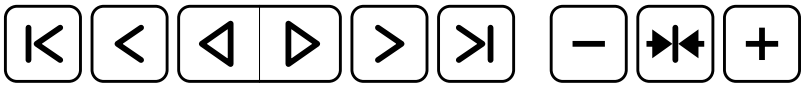
RGB composite



Surface dust content

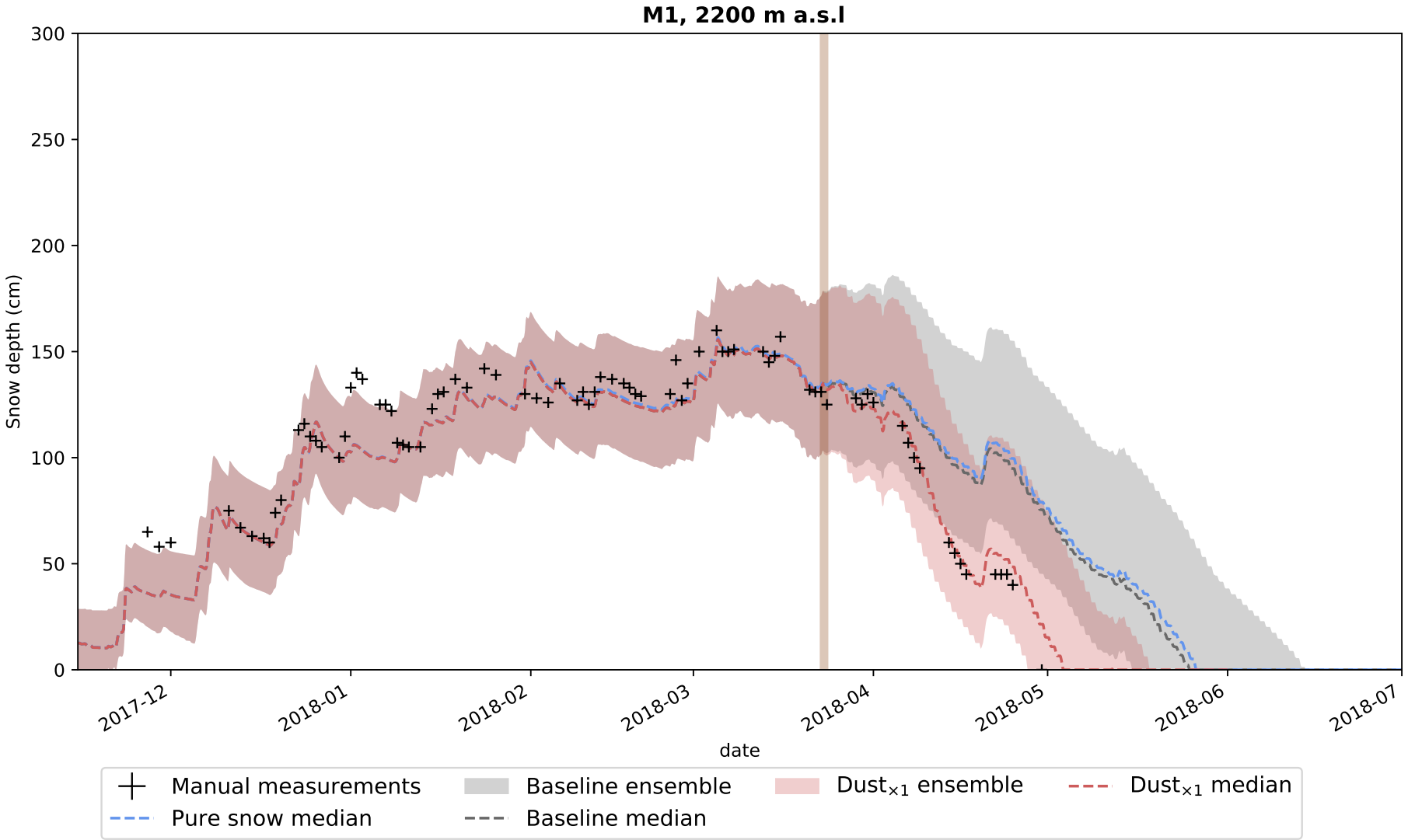






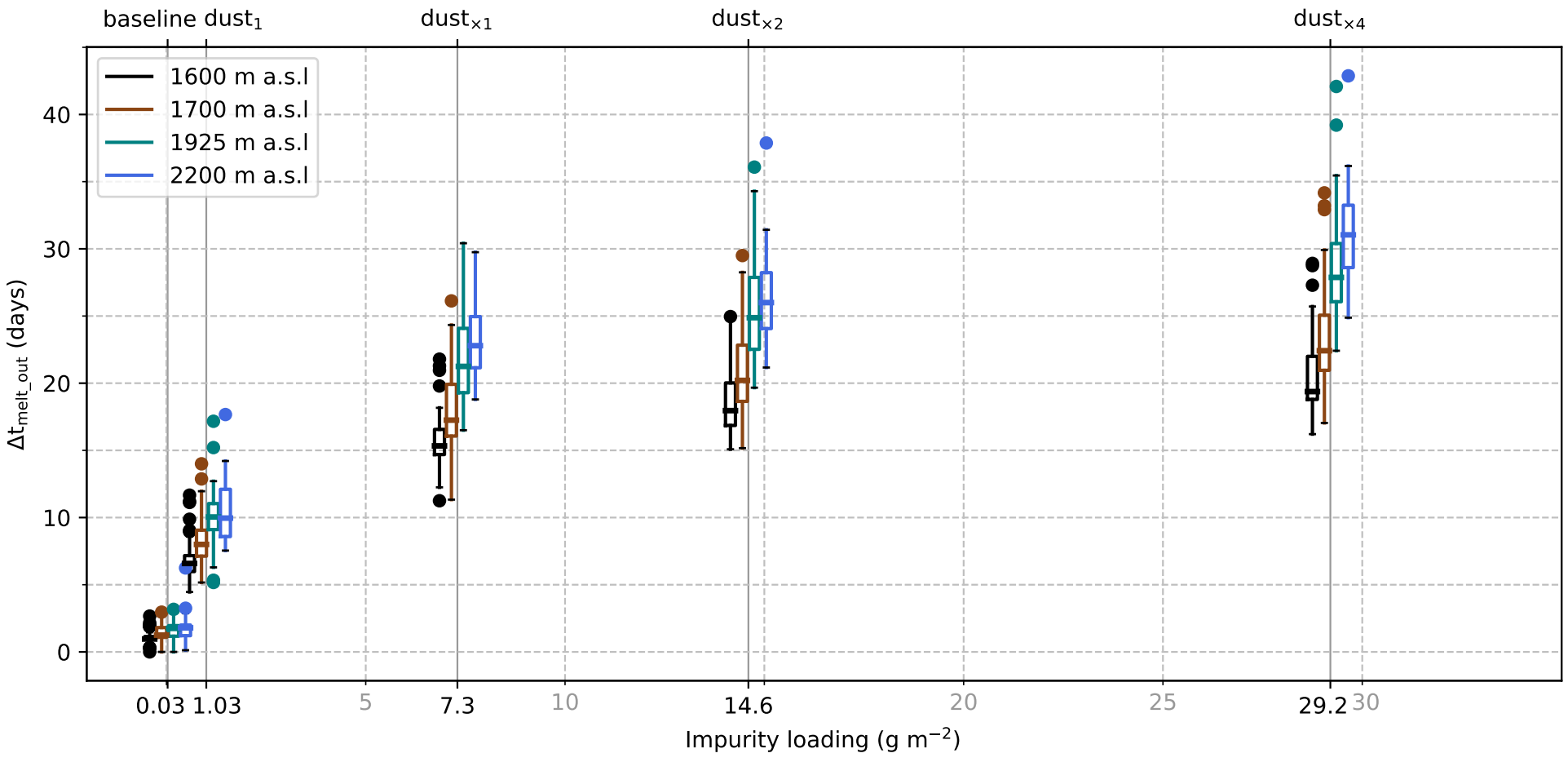
Dumont, Tuzet, et al., in prep

DUST IMPACT ON SNOWPACK EVOLUTION



Dumont, Tuzet, et al., in prep ;

SHORTENING OF THE SNOW SEASON



Dumont, Tuzet, et al., in prep

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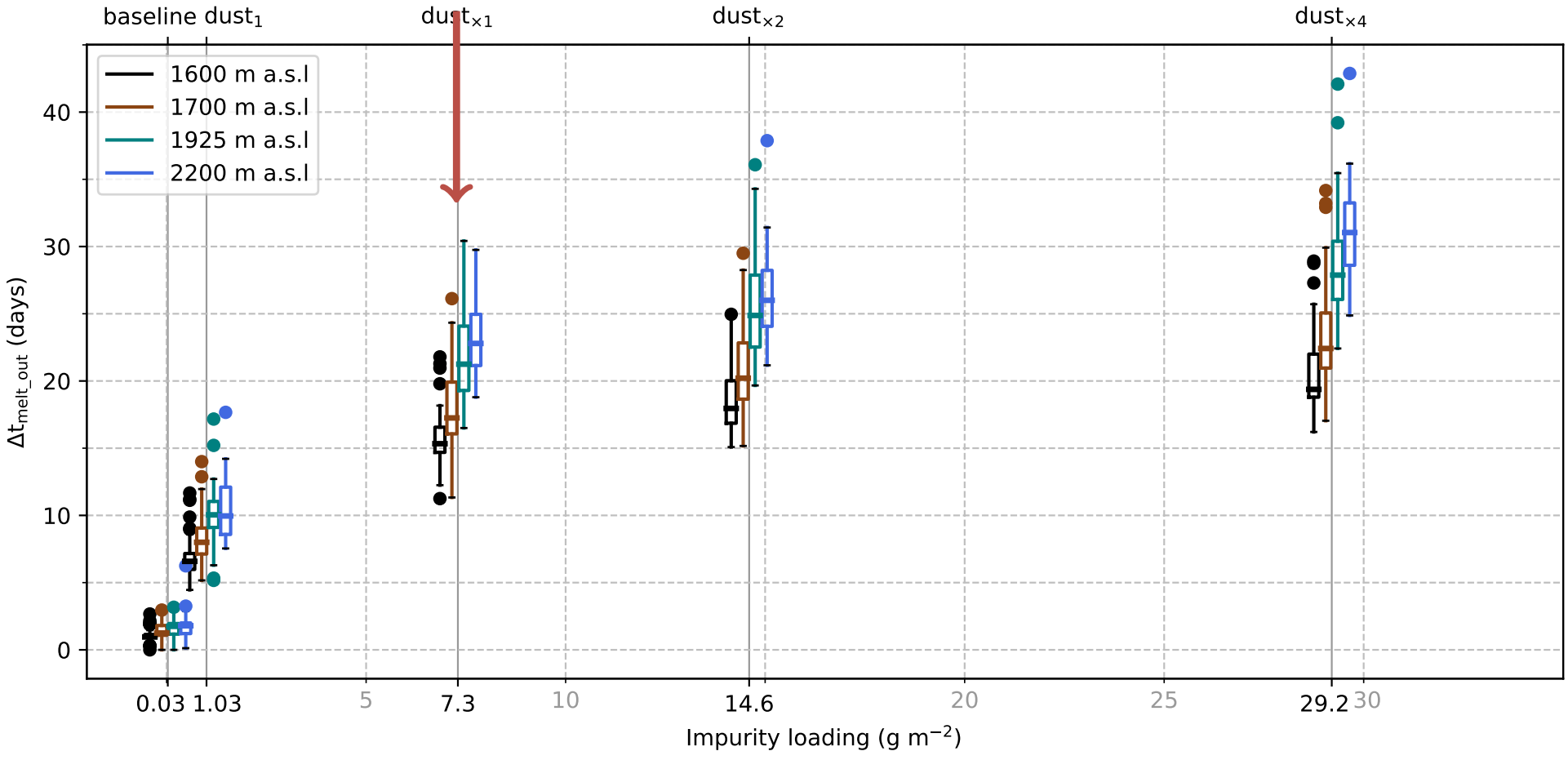

Dumont, Tuzet, et al., in prep

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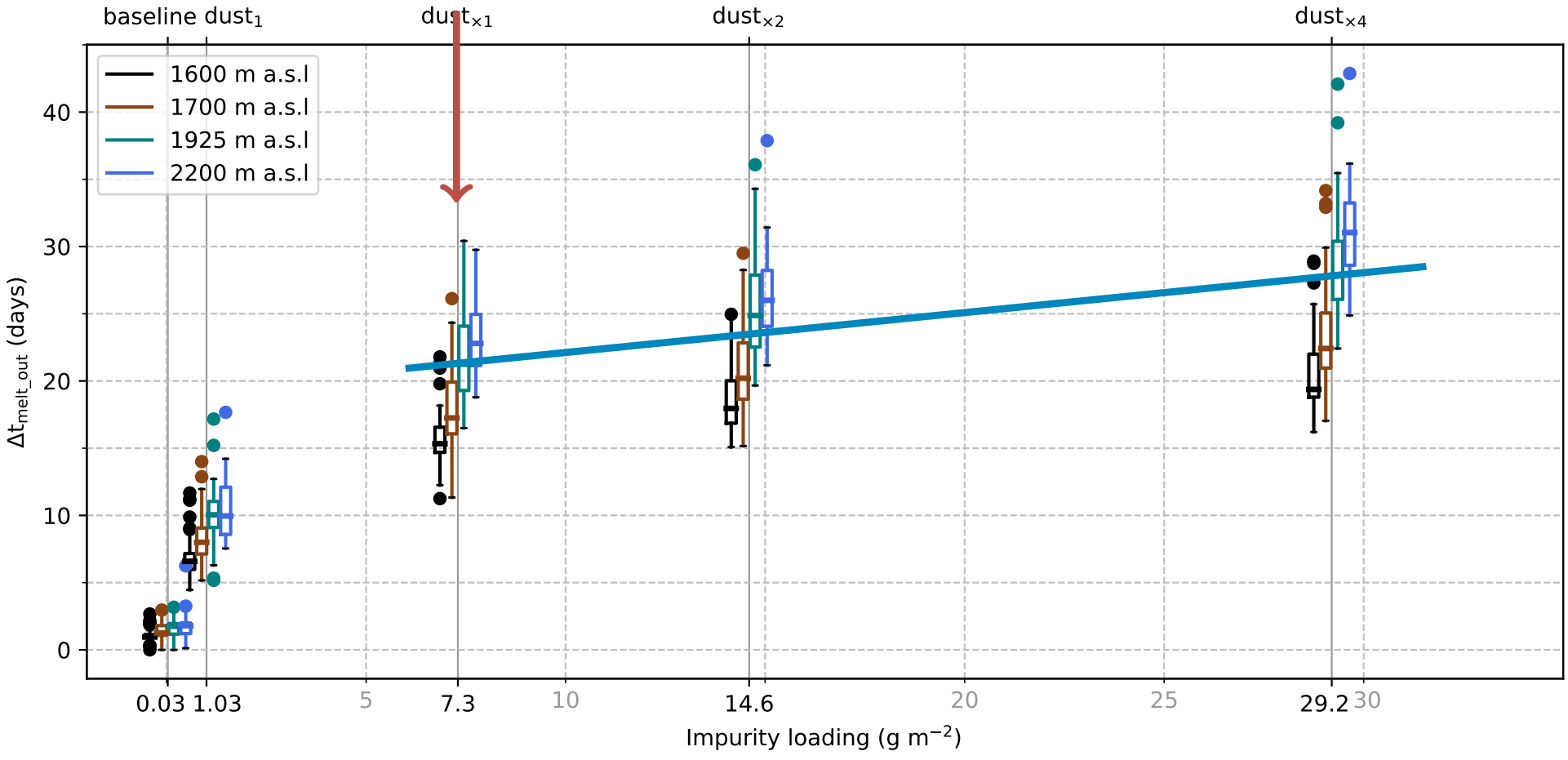

Dumont, Tuzet, et al., in prep

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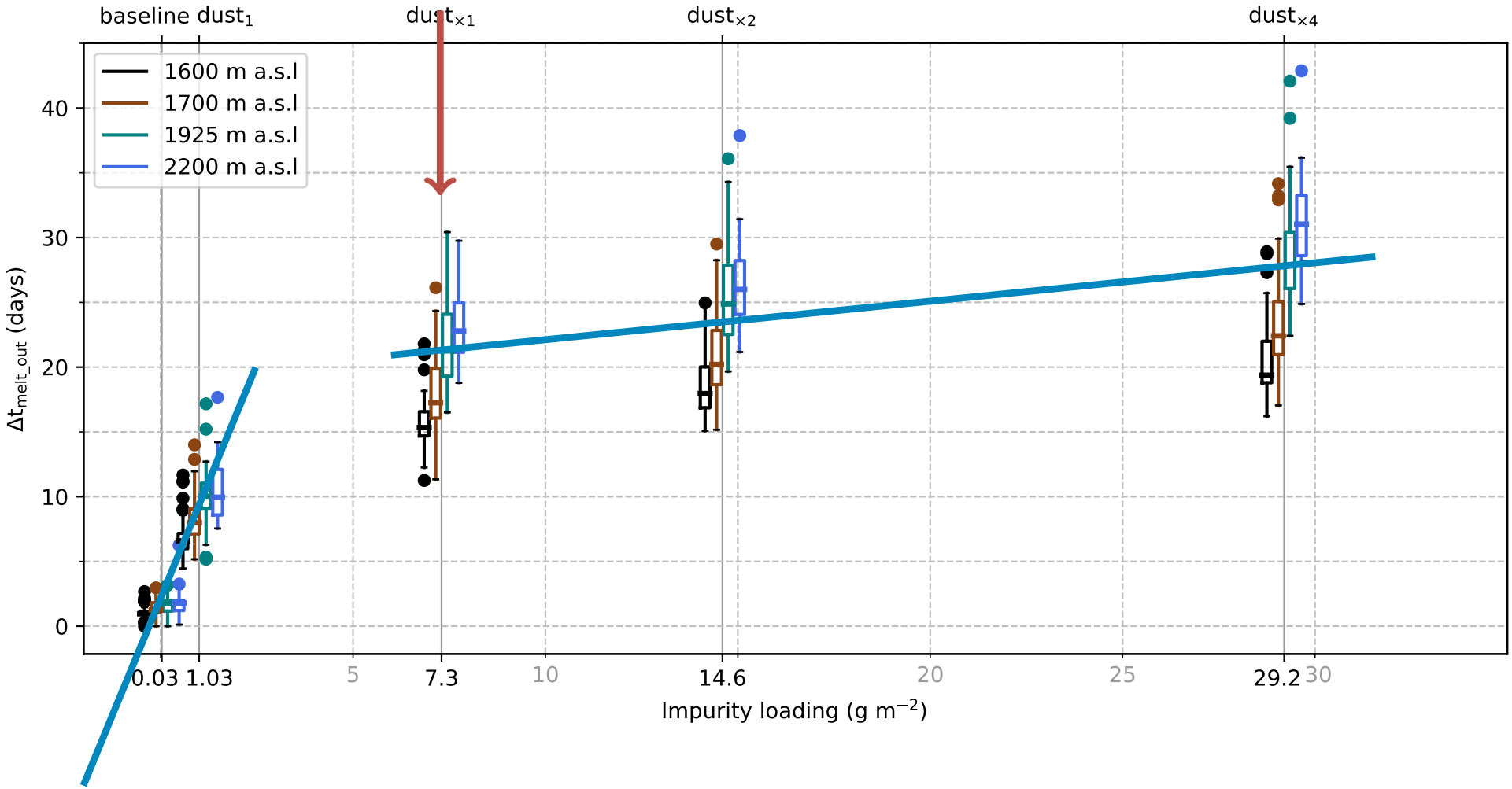

Dumont, Tuzet, et al., in prep

SLOWER SNOW MELT IN A WARMER WORLD

(Musselman et al., 2017), Here at Col de Porte, France

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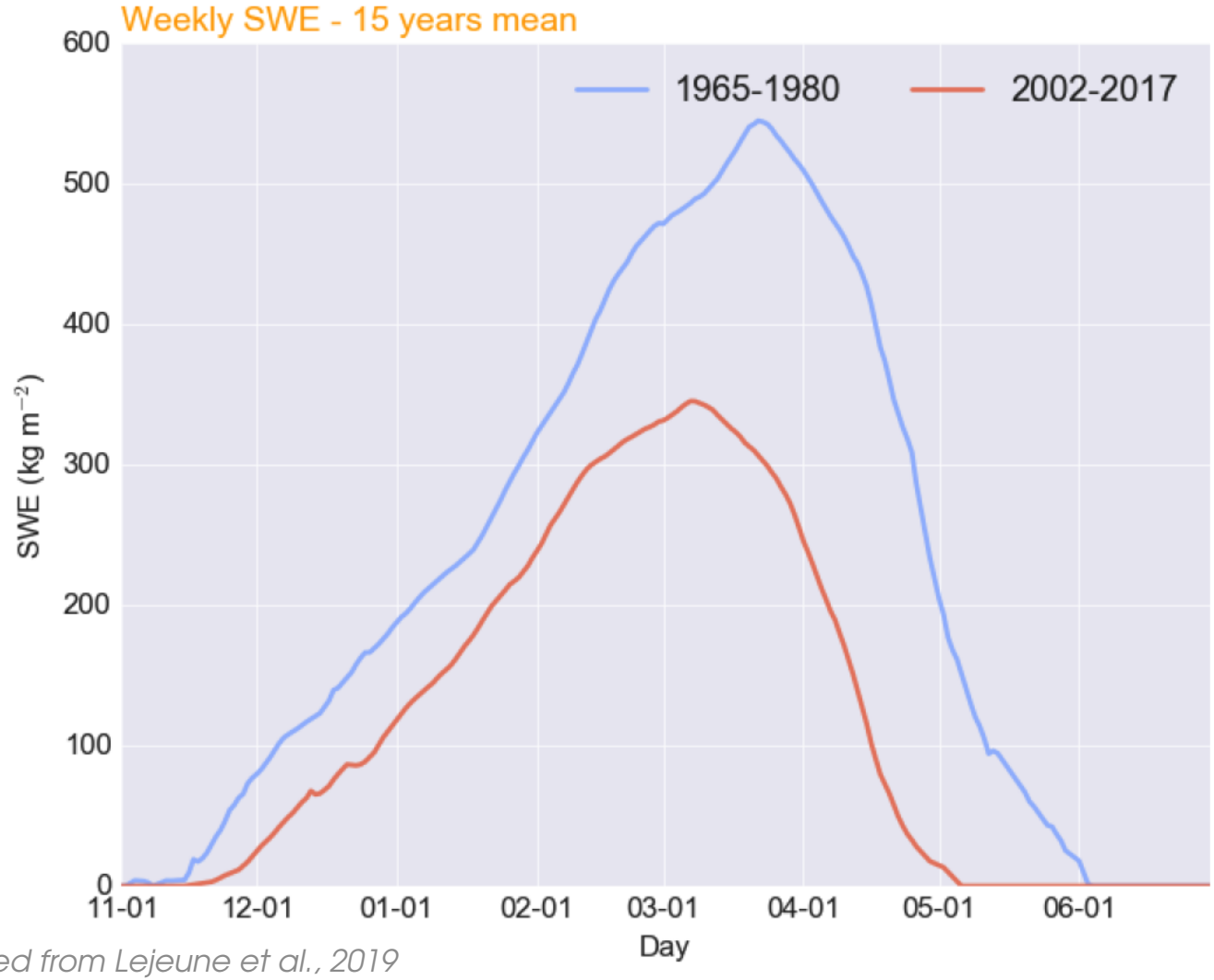

M. Fructus, adapted from Lejeune et al., 2019

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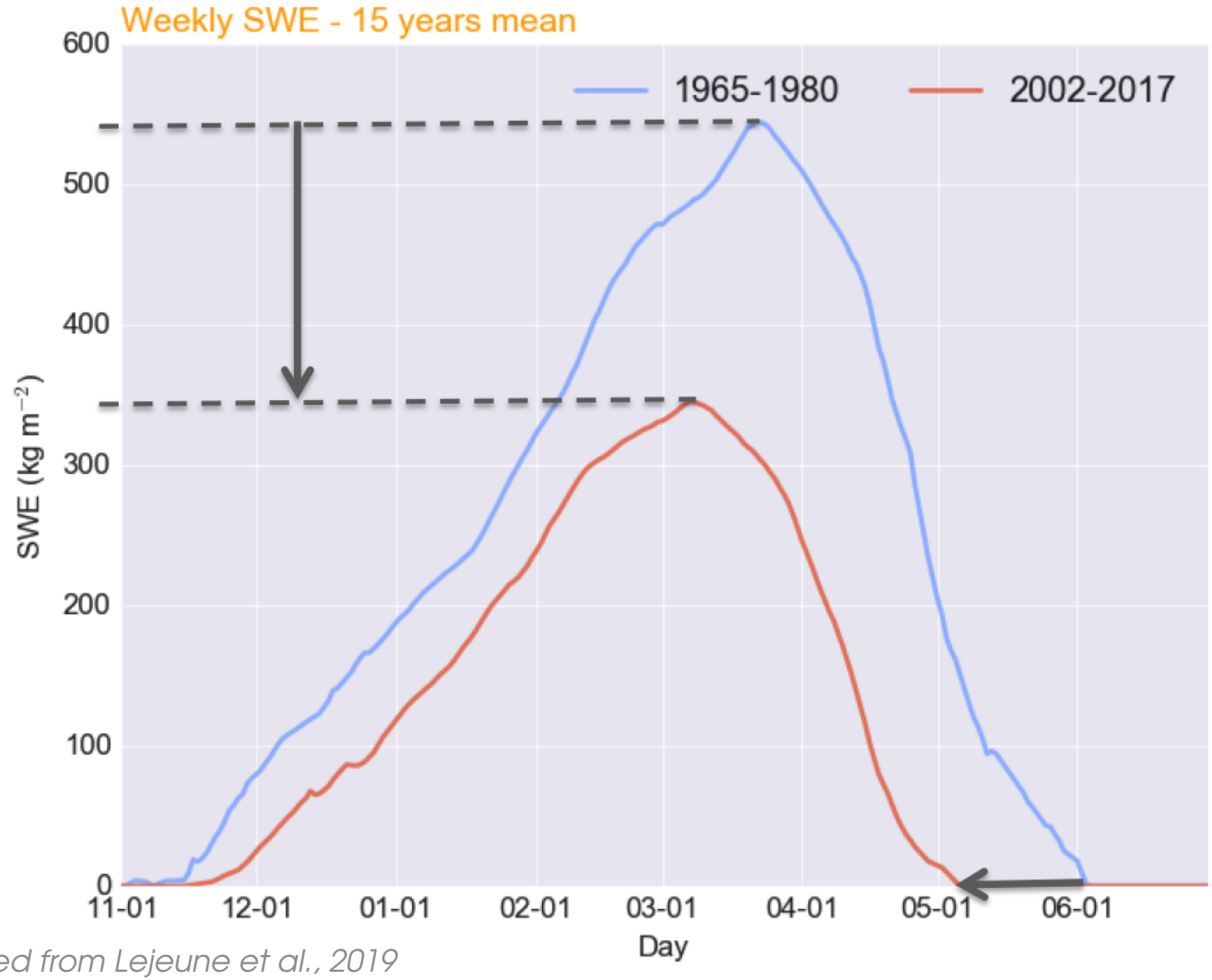

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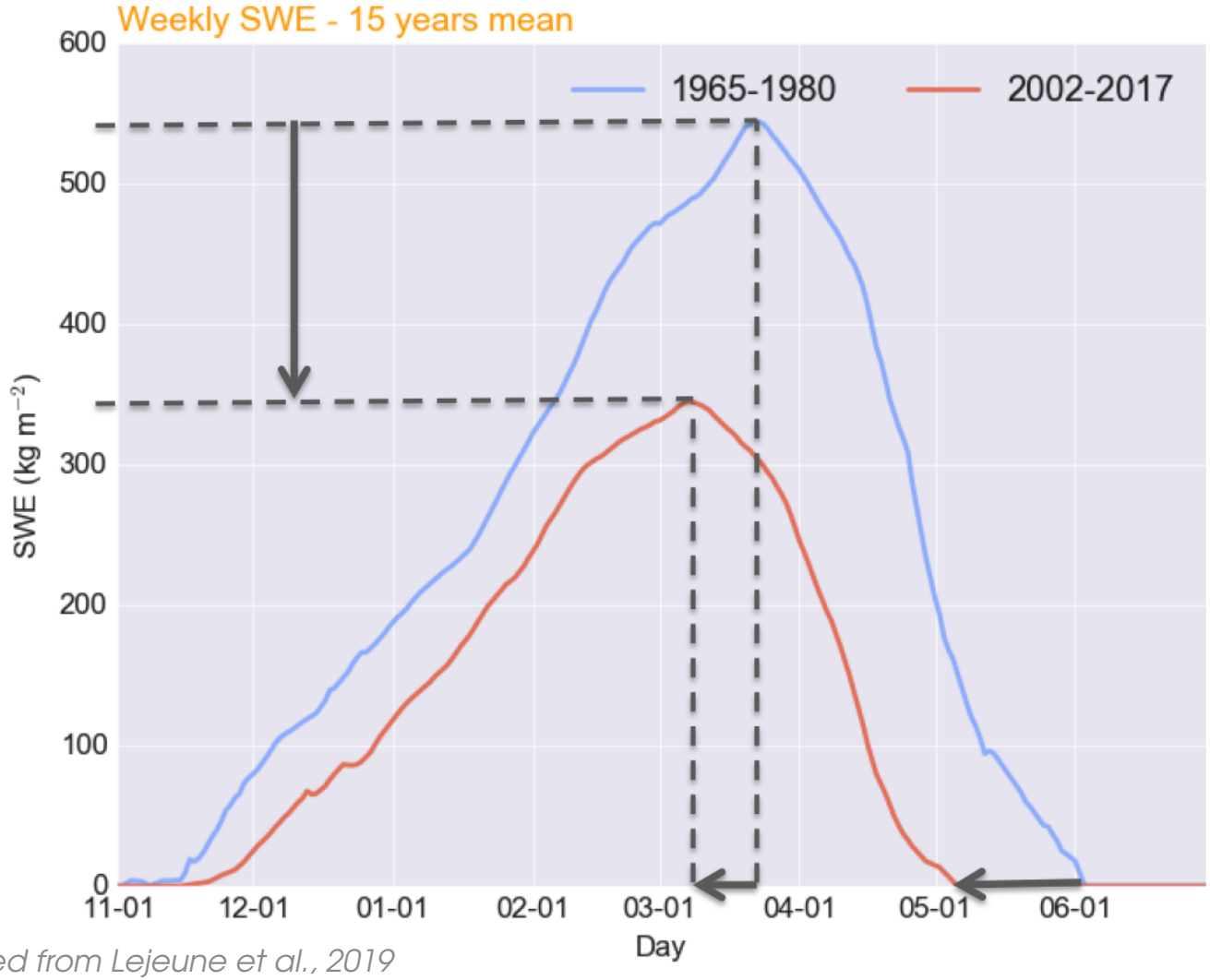

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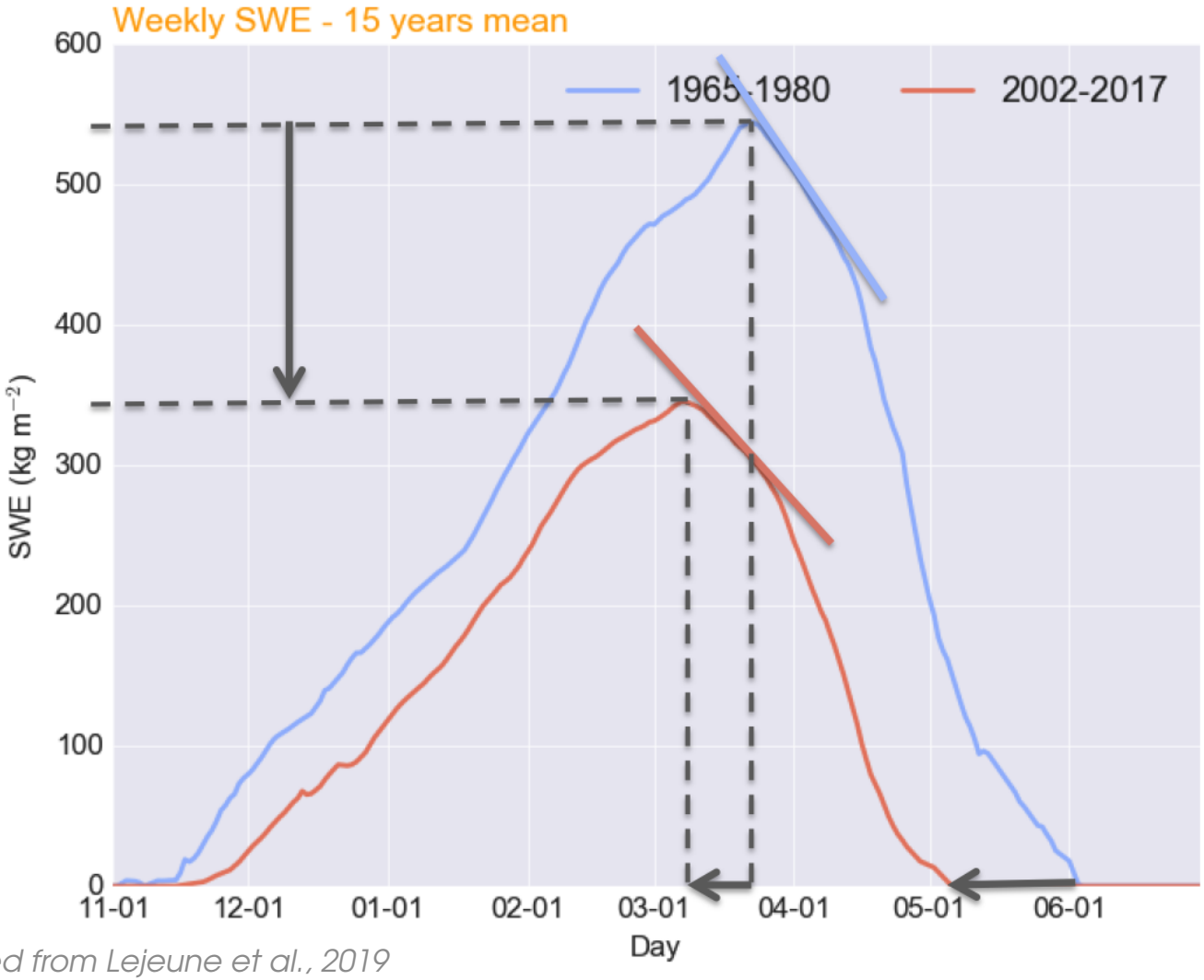

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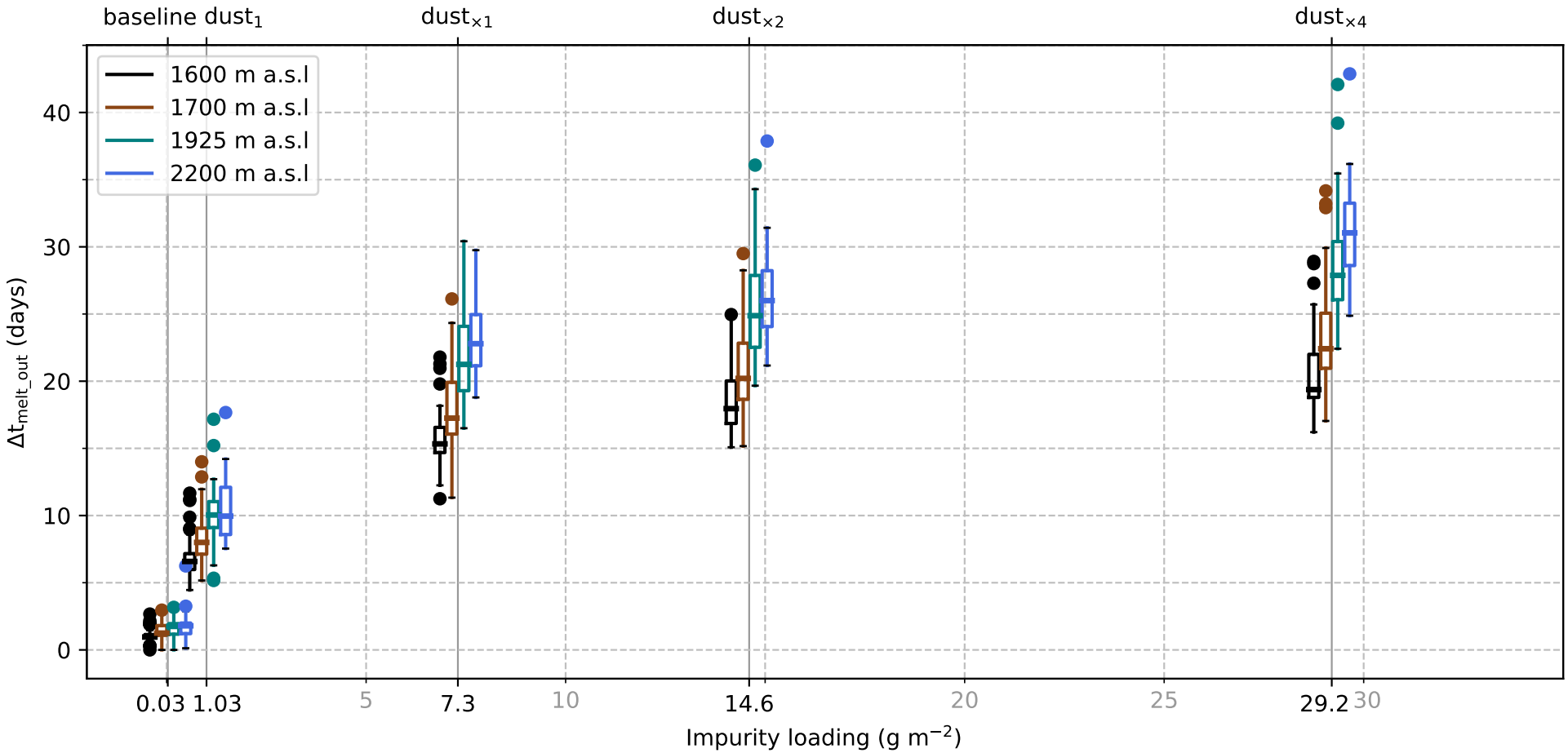
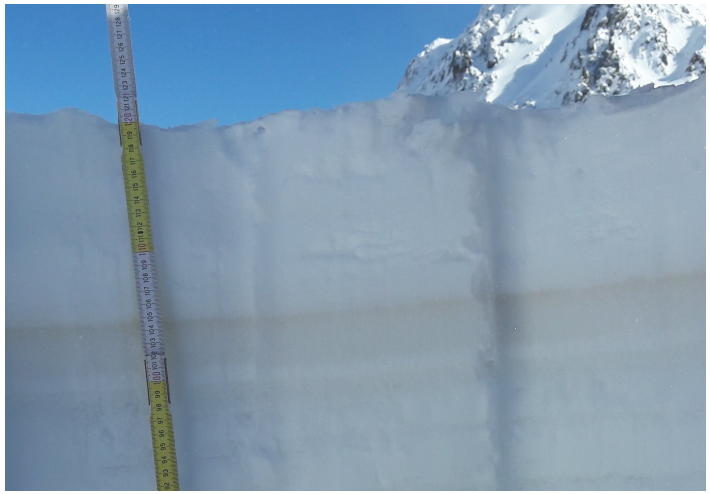
Lower impact of LAPs in a warmer world ?

also see Flanner et al., 2008

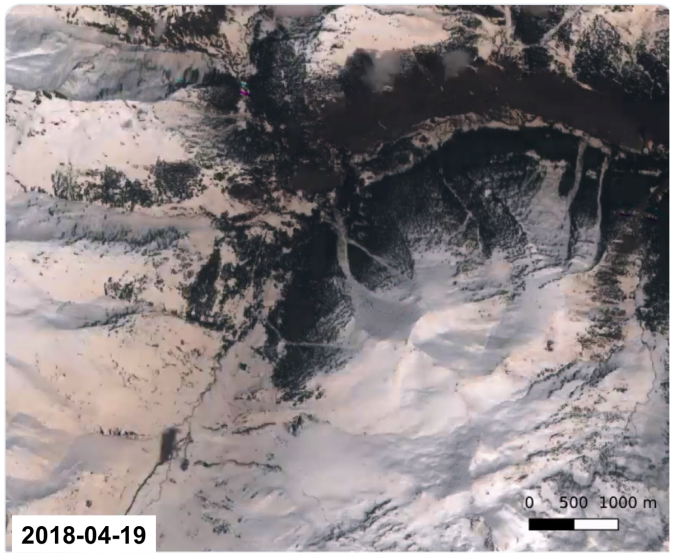


Dumont, Tuzet, et al., in prep

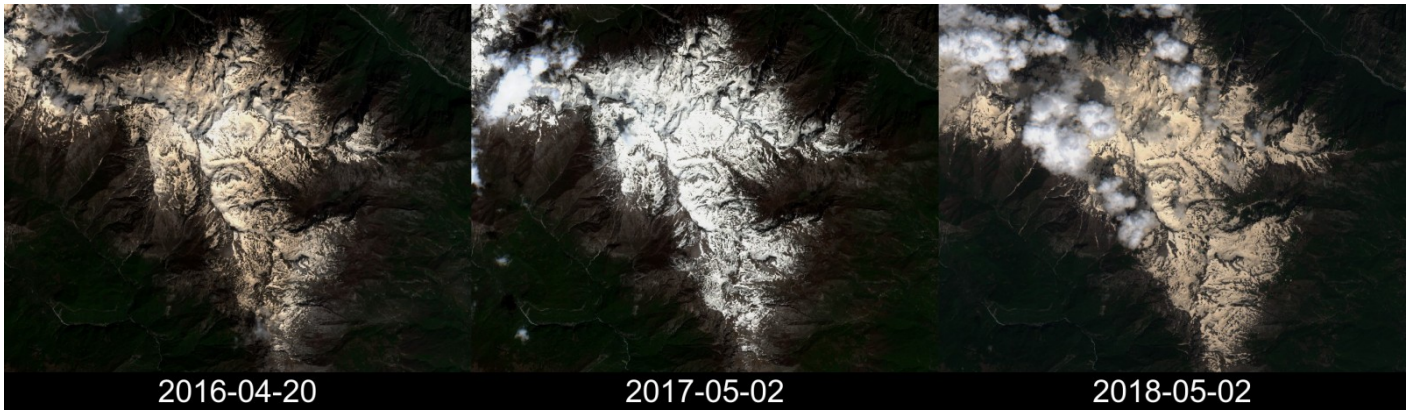
SNOW IN OTHER LOCATIONS ?



F. Tuzet, Lautaret, France



Venμs, S. Gascoin, Pyrenees, France



Sentinel-2, S. Gascoin, Sierra Nevada, US

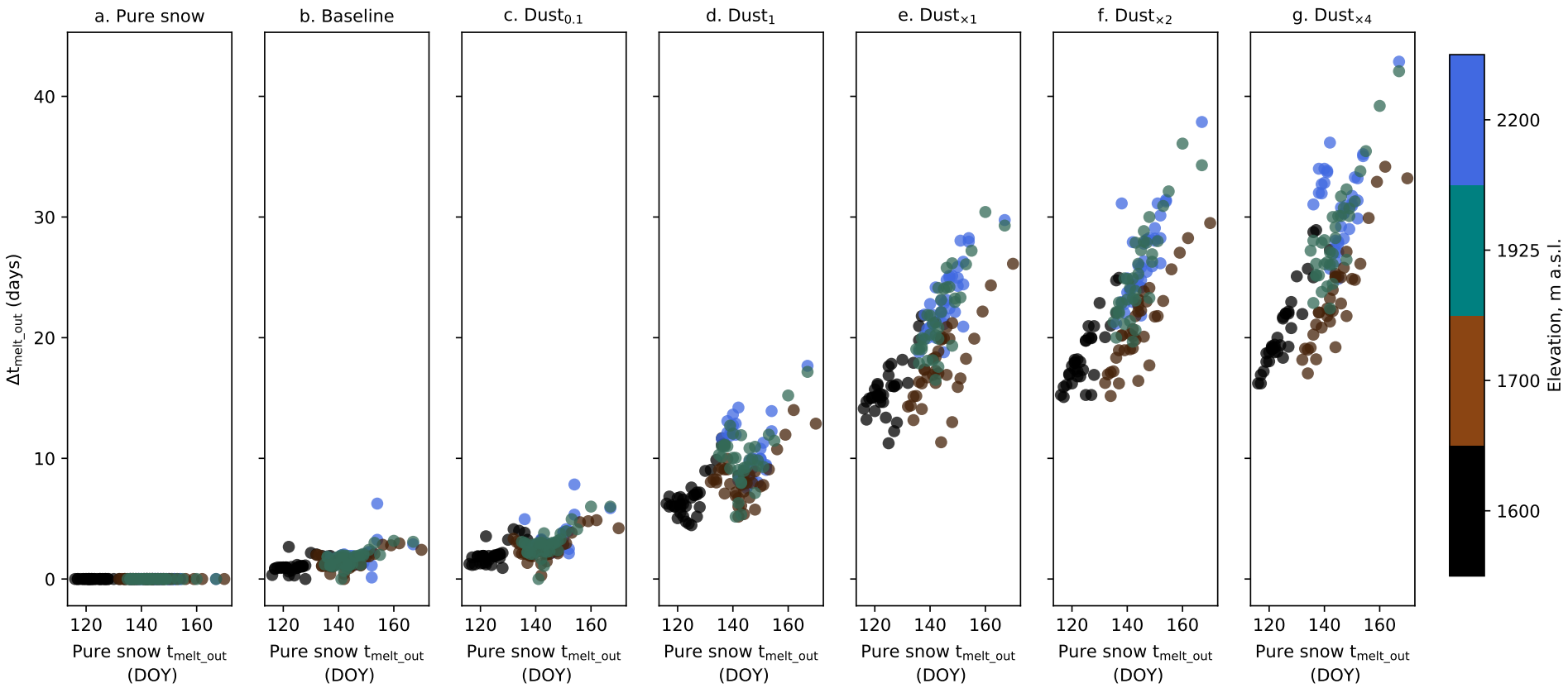
KEY MESSAGES

- Snow is white, but different shades of **white**.
- Snow optical properties are both a **result** and a **cause** of the snowpack evolution.
- Snow optical properties trigger effective **feedbacks** for the snow evolution that must be accounted for.
- Combining optical satellite data and physically-based snow modelling reduces uncertainties in predictions.

MERCI

LESS DUST IMPACT IN A WARMER WORLD ?

Dust load

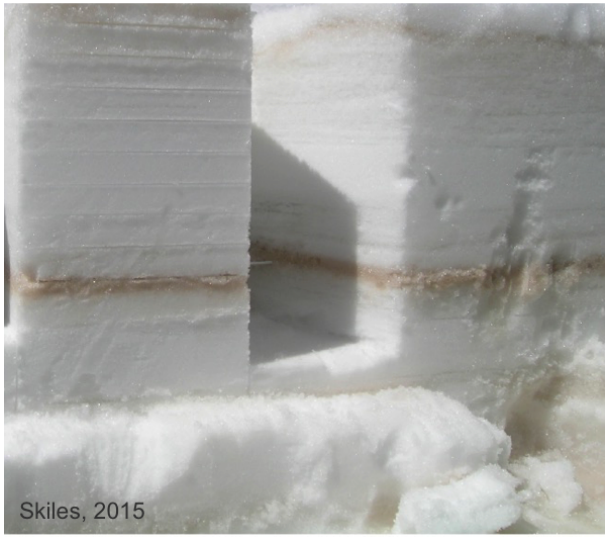


Shortening

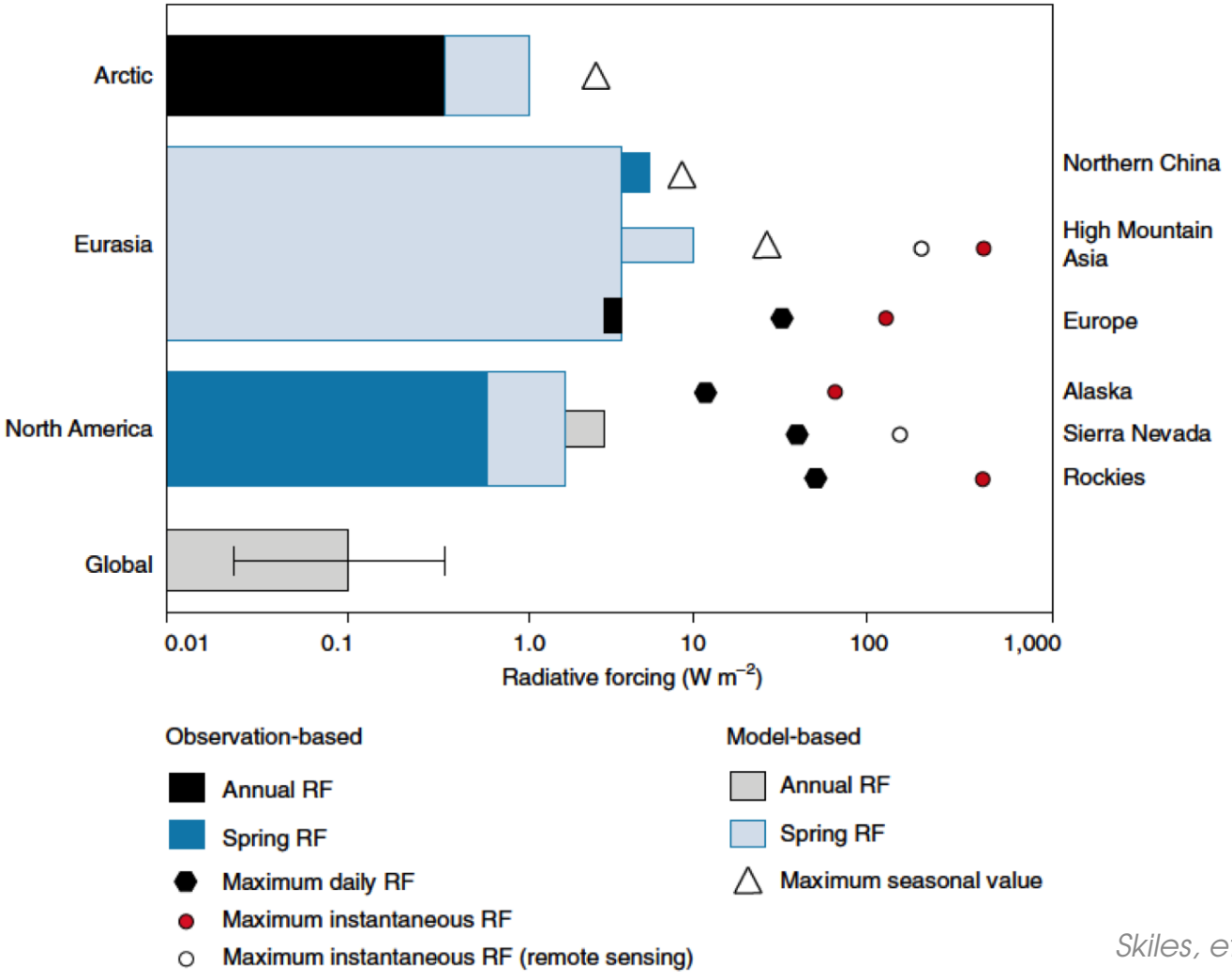
Dumont, Tuzet, et al., in prep

KEY POINTS

- Such events shorten the snow season by up to **one month**.
- The complex feedbacks require a **physically-based** snowpack model and the choice of the model configuration is crucial.
- The shortening of the snow season for a given dust mass is driven by the snow season duration, itself controlled by **peak SWE and elevation**.

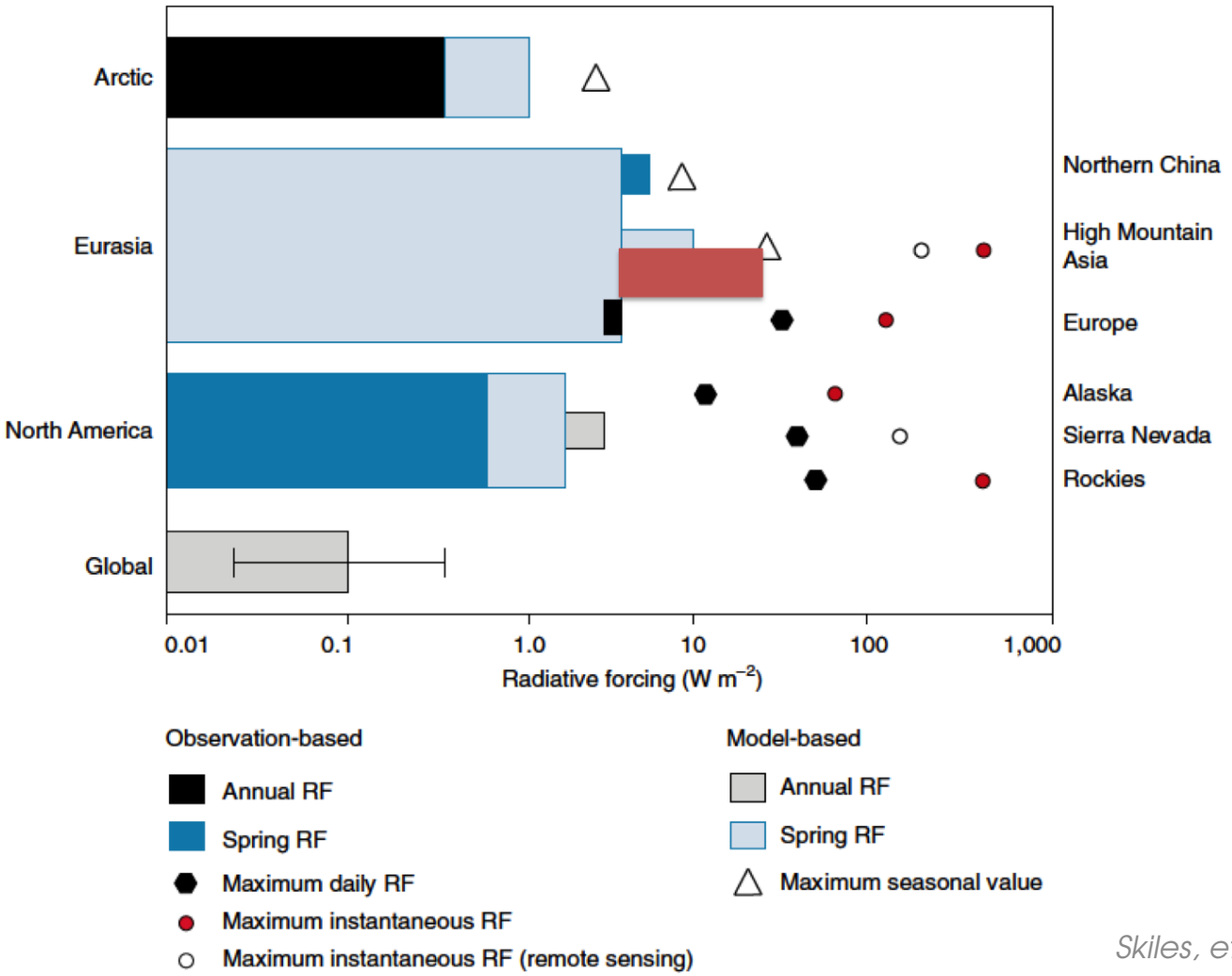


Dust radiative forcing



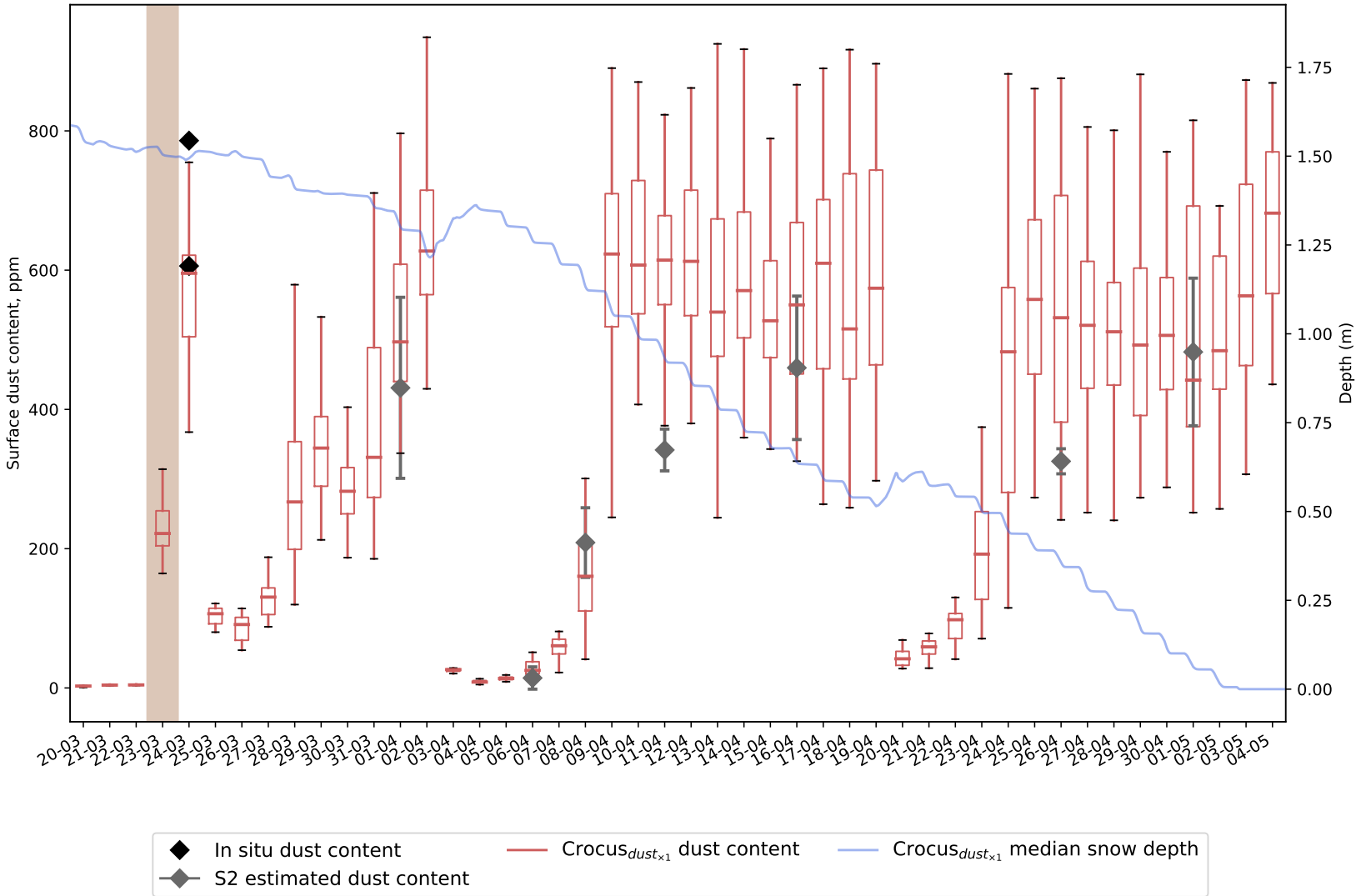
Skiles, et al., 2018

Dust radiative forcing



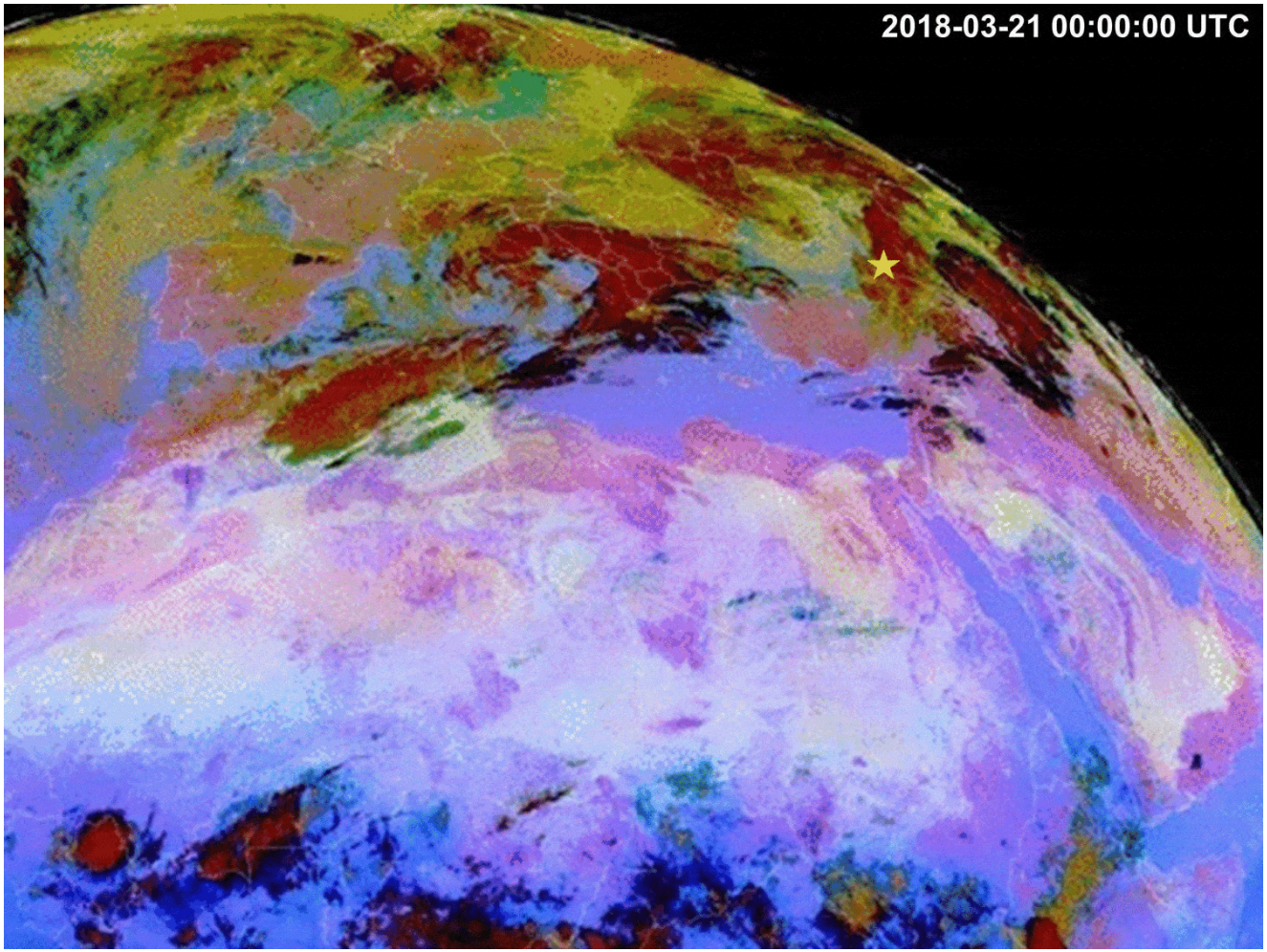
Skiles, et al., 2018

DUST CONTENT EVOLUTION



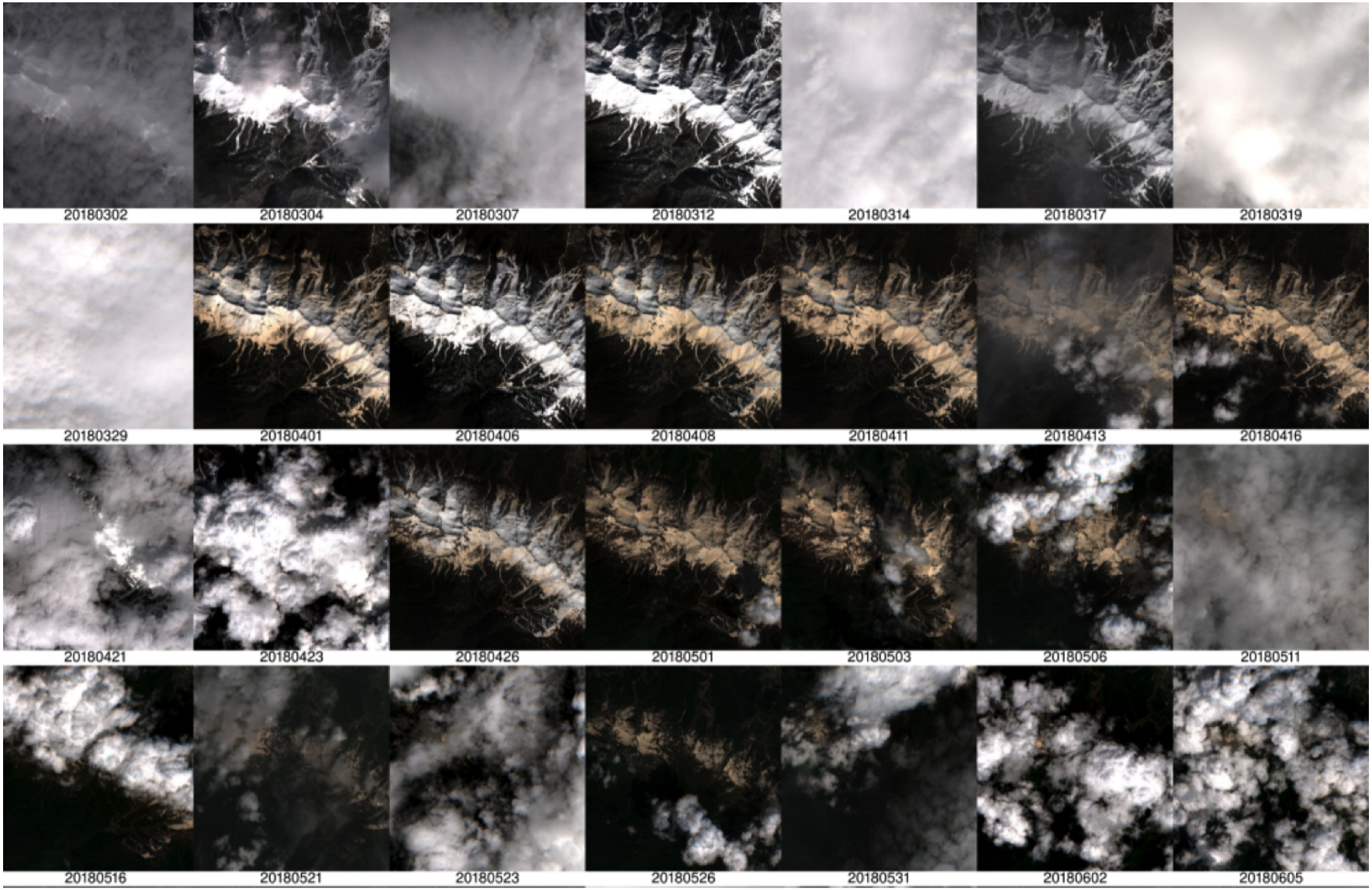
Dumont, Tuzet, et al., in prep

SAHARAN DUST DEPOSITION



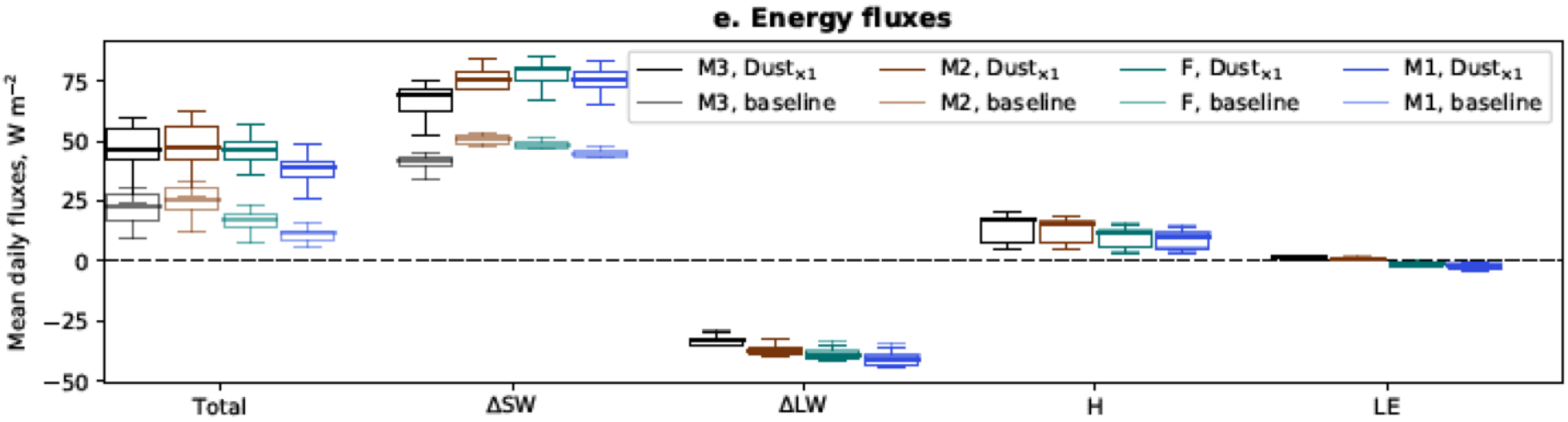
SEVIRI images, S. Kutuzov, https ://www.eumetsat.int/website/home/Images/ImageLibrary/DAT_3902461.html

SENTINEL-2 RECORD



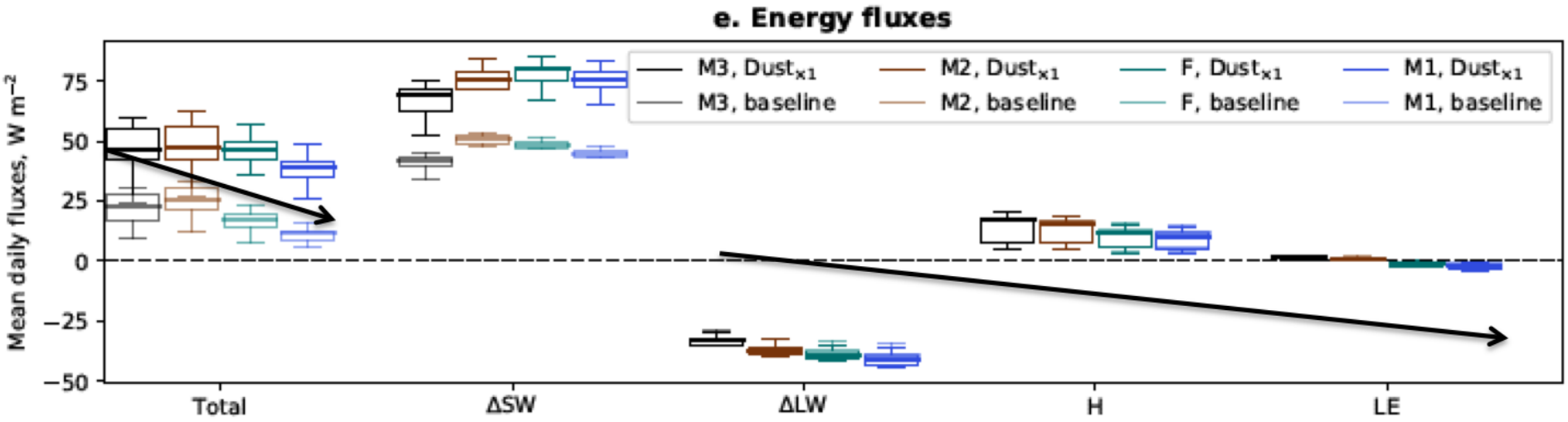
S. Gascoin

CHANGES WITH ELEVATION



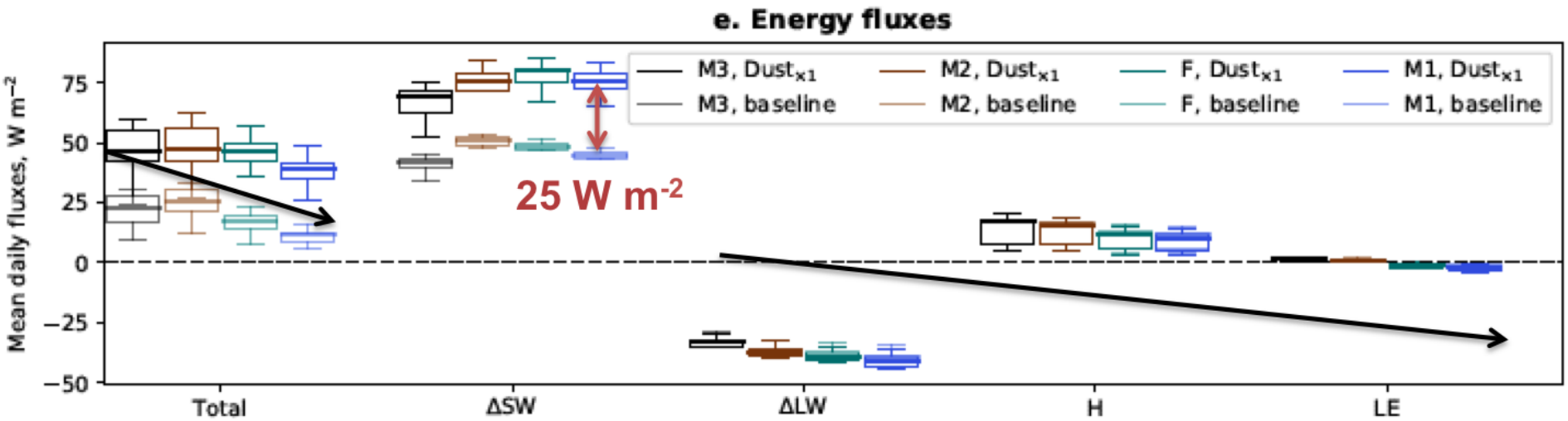
Dumont, Tuzet, et al., in prep

CHANGES WITH ELEVATION



Dumont, Tuzet, et al., in prep

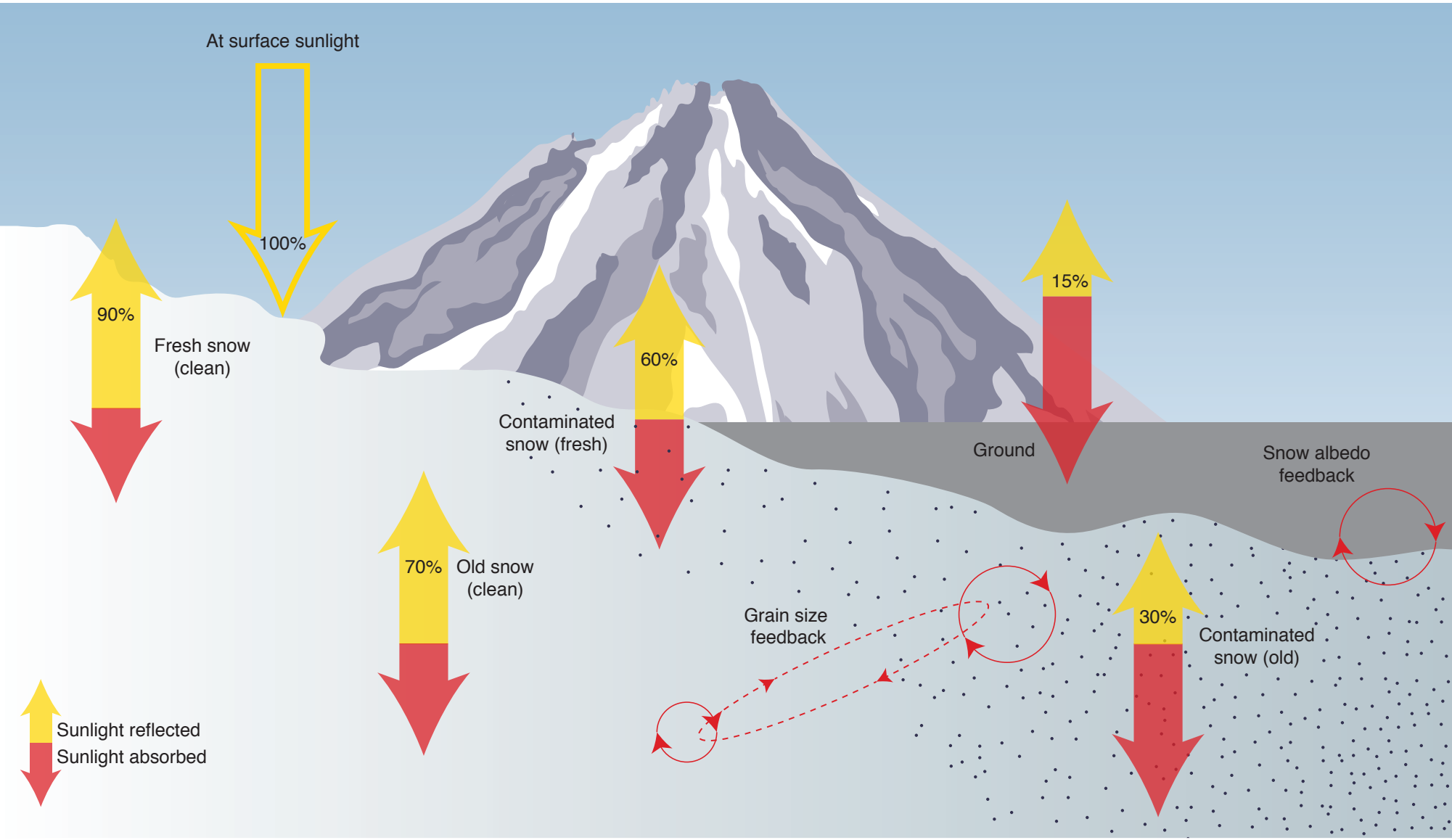
CHANGES WITH ELEVATION



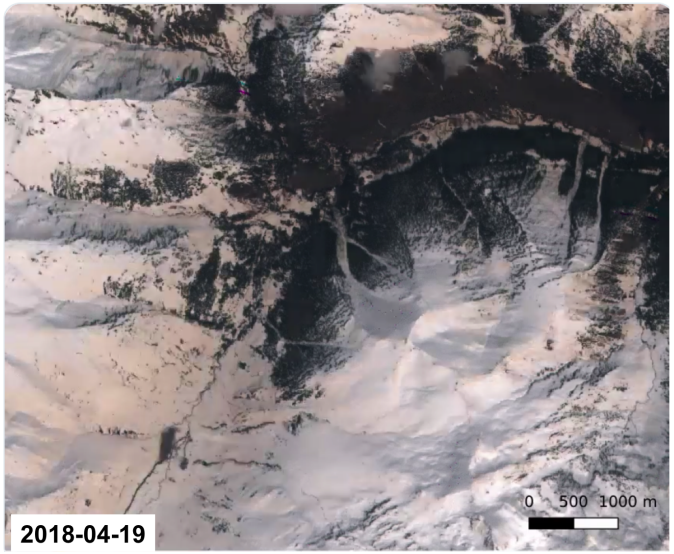
Dumont, Tuzet, et al., in prep

DIRTY SNOW

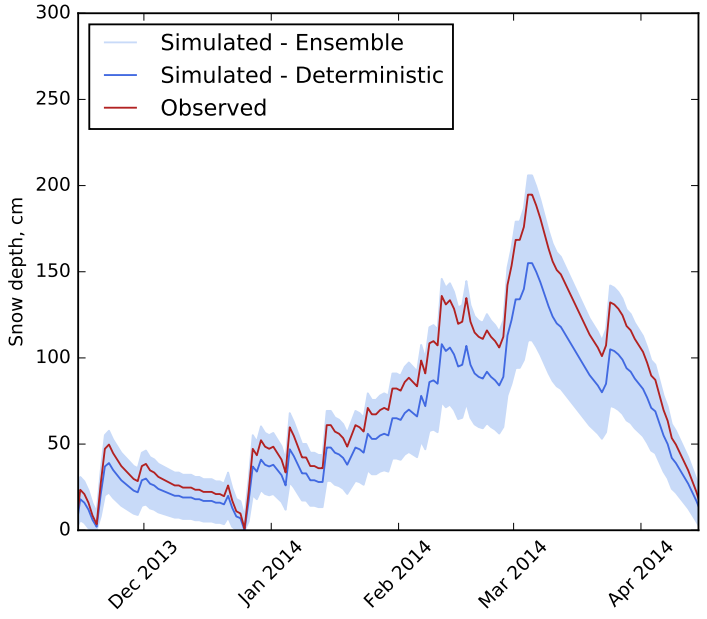
Skiles et al., 2018



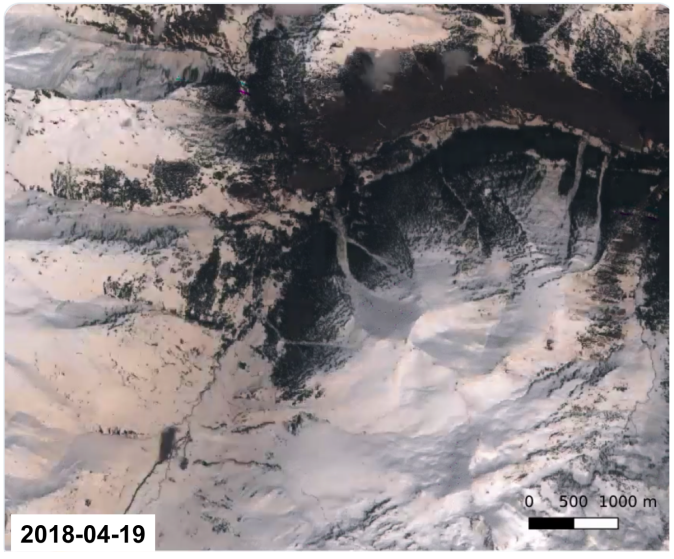
Data Assimilation



Venμs, S. Gascoin, Pyrenees, France



Data Assimilation



Venμs, S. Gascoin, Pyrenees, France

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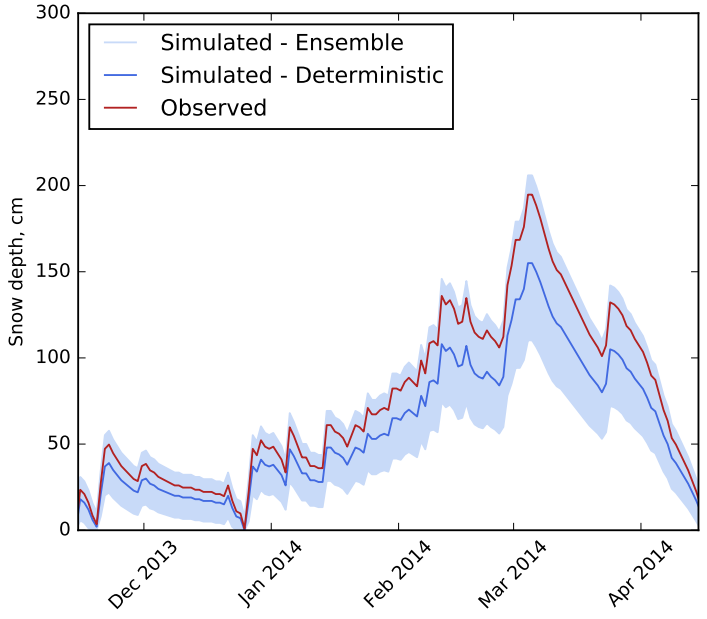

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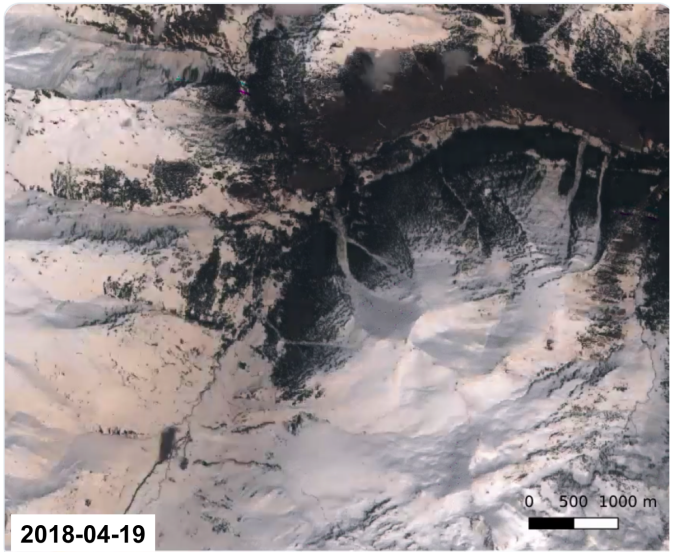

Venμs, S. Gascoin, Pyrenees, France

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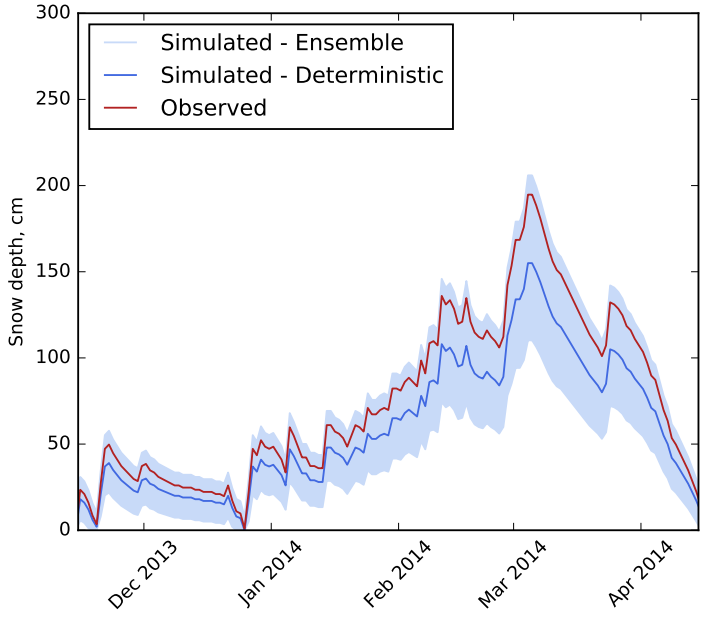

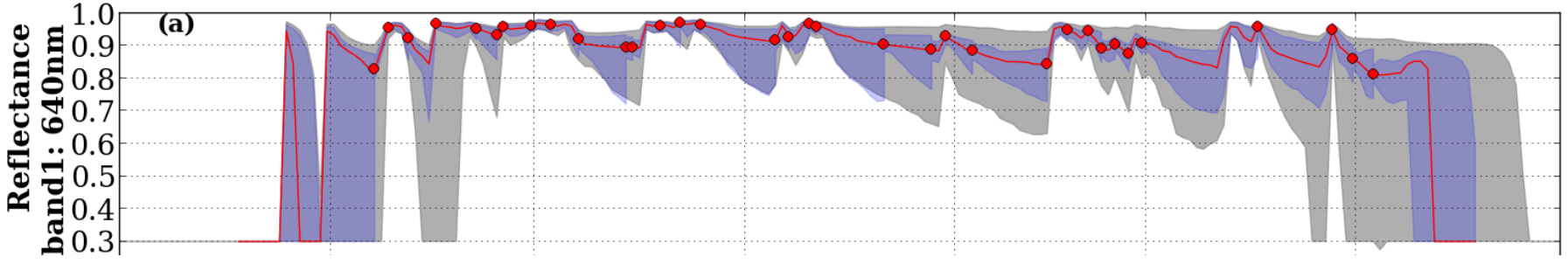

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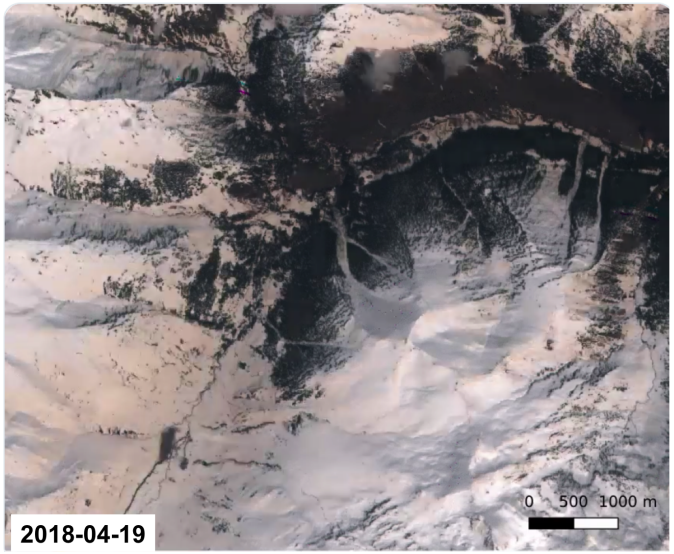
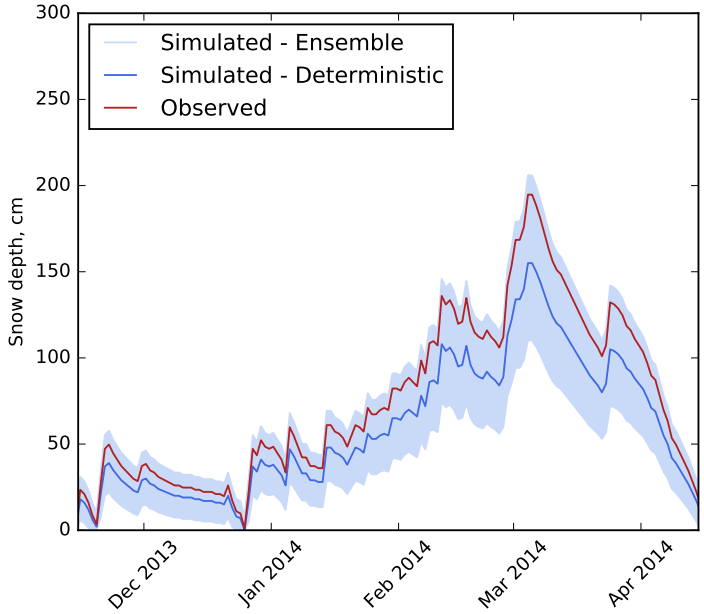
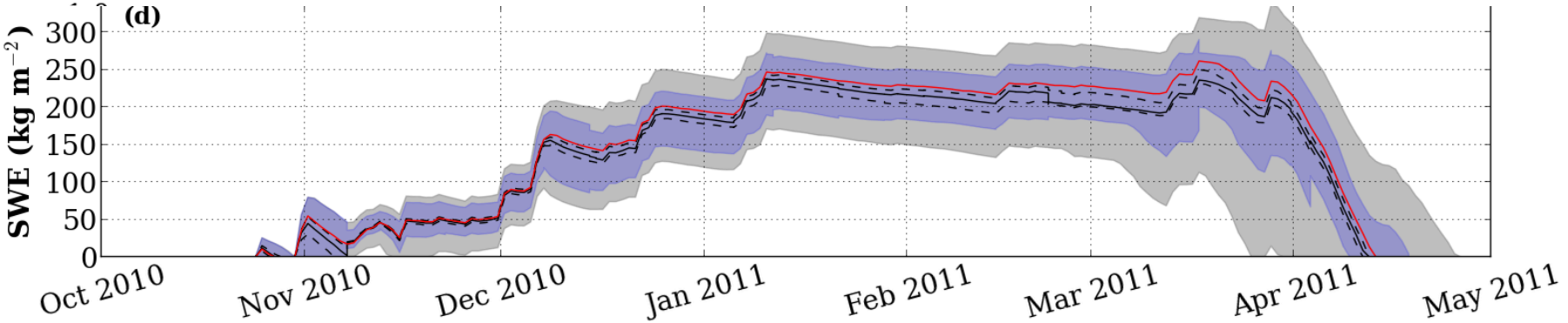


Venμs, S. Gascoin, Pyrenees, France

Assimilation





e.g. Dumont et al., 2012, Charrois et al., 2016, Cluzet et al., in review