Parametrizing drifting snow sublimation in the saltation layer

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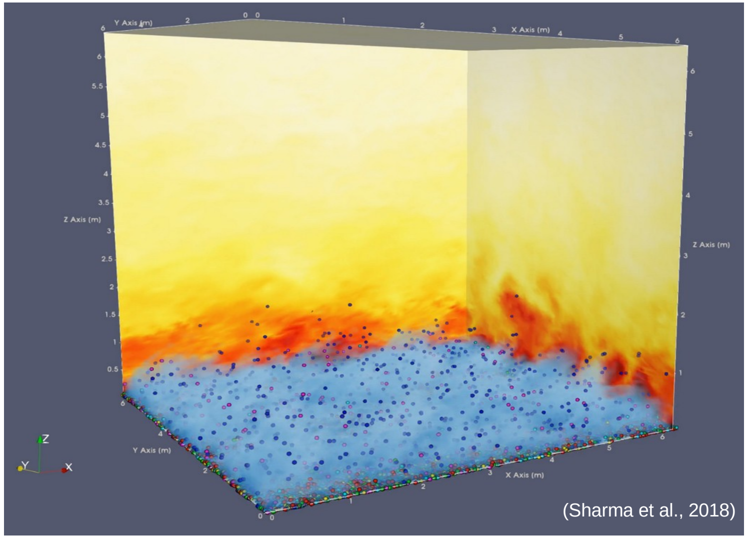
Image: https://www.wunderground.com/cat6/Taste-Traverse-How-Cross-Antarctica-without-Plane

Goals

- Propose and validate a parametrization for sublimation of saltating snow particles using Large-eddy simulations (LES) as reference
  - Evaluate the performance of the Thorpe-Mason (TM) formula and an alternative
  - Assess the importance of accurate near-surface humidity and temperature profiles



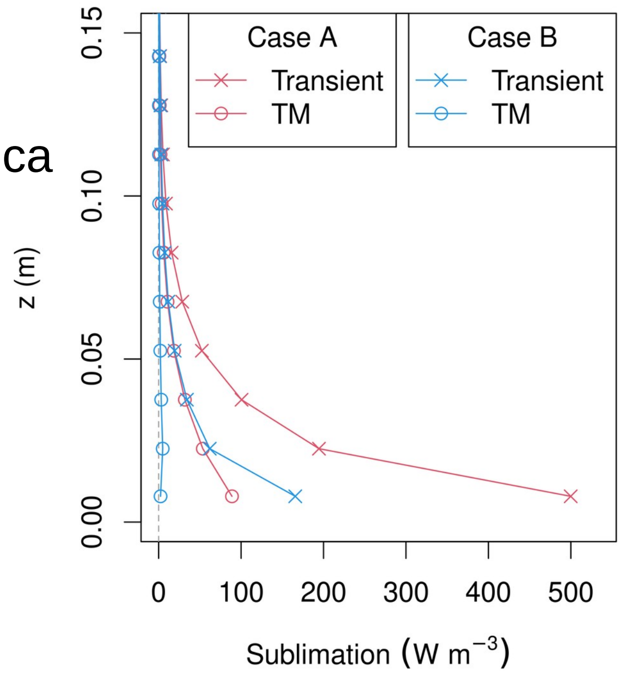
(Sharma et al., 2018)

Thorpe-Mason formula and alternative

- LES domain: 38 x 19 x 18 m^3
- Reproduce conditions (u, q, T) measured at S17, Antarctica
- Steady state profiles (400-s average)
- Lagrangian particles:
  - Vapour transfer: $$\frac{\mathrm{d}m_p}{\mathrm{d}t} = \pi D d_p \left(\rho_{w,\infty} - \rho_{w,p}\right) \mathrm{Sh}$$
  - Heat balance: $$\underbrace{c_i m_p \frac{\mathrm{d}T_p}{\mathrm{d}t}}_{\Delta\text{storage}} = \underbrace{L_s \frac{\mathrm{d}m_p}{\mathrm{d}t}}_{\text{Latent heat}} + \underbrace{\pi k d_p \left(T_{a,\infty} - T_p\right) \mathrm{Nu}}_{\text{Sensible heat}}$$

TM: 0 = Δstorage

(Details on method: Sigmund et al., 2021)



Case	u_{3m} (m s^{-1})	RH_{1m} (%)	$T_{1m} - T_0$ (K)	$\frac{S_{TM}}{S_{Trans}}$ (%)
A	12	98.7	-0.7	25
B	16	99.9	-0.2	6

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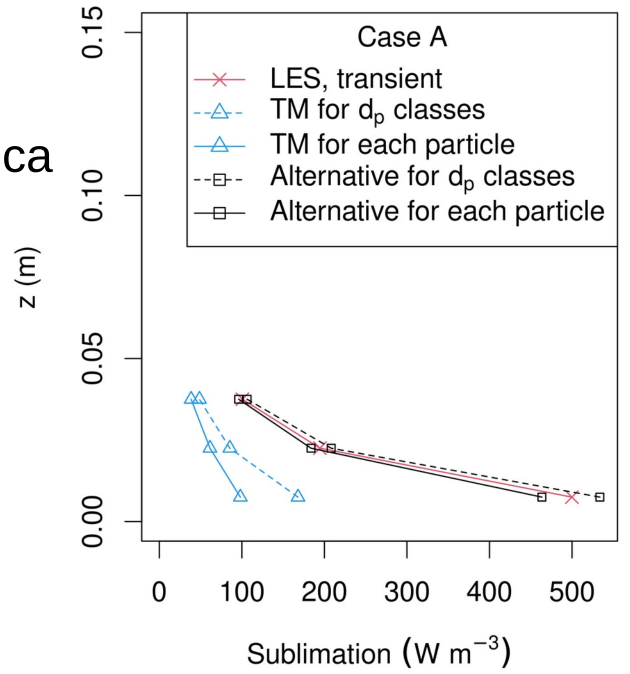

- Alternative to TM:
  - Estimate empirically $\frac{dT_p}{dt} = f(T_a\text{-}T_0, d_p, z, u_*)$

    based on LES output averaged per d_p class and height

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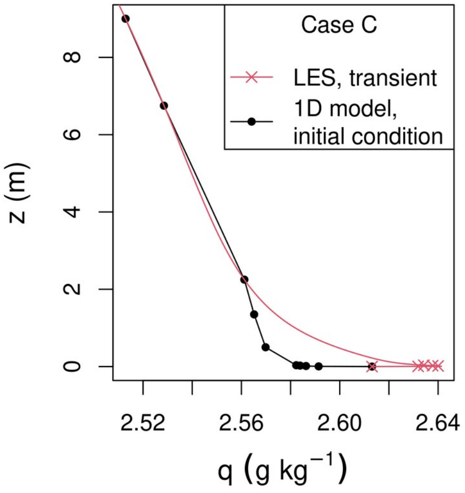
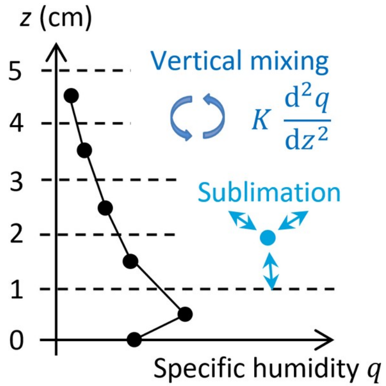
1D model for humidity and temperature

- Particle concentration
  - Assume known profile (from LES)
- *T* and *q* boundary conditions (0 m, 9 m)
  - Dirichlet type
- Fluxes at surface
  - Monin-Obukhov (MOST) bulk method
- *T* and *q* initial conditions:
  - z ≥ 2.25 m: From LES
  - z < 2.25 m: MOST profiles
- Simulate until steady state, so far with TM formula

  a) z ≥ 2.25 m: Prognostically
     z < 2.25 m: MOST profiles

  b) All z: Prognostically





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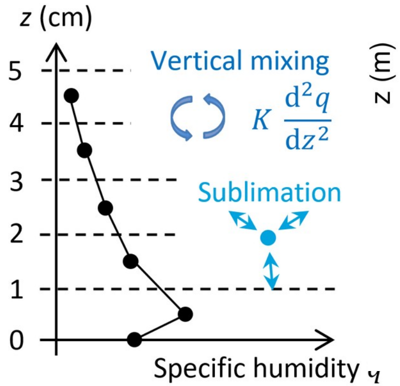

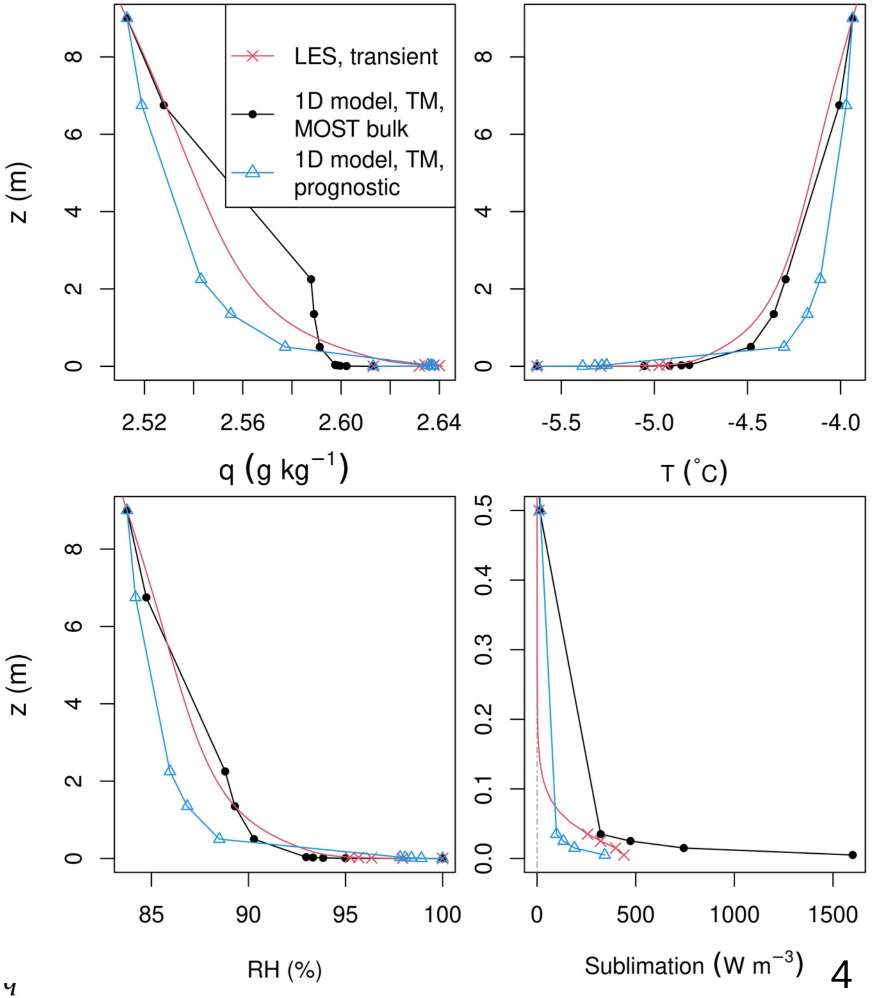

Conclusions

A parametrization of sublimation in the saltation layer should ...

… account for an (empirical) expression for $\frac{dT_p}{dt}$ (to be derived from LES)

… solve prognostically for T and q at a few levels

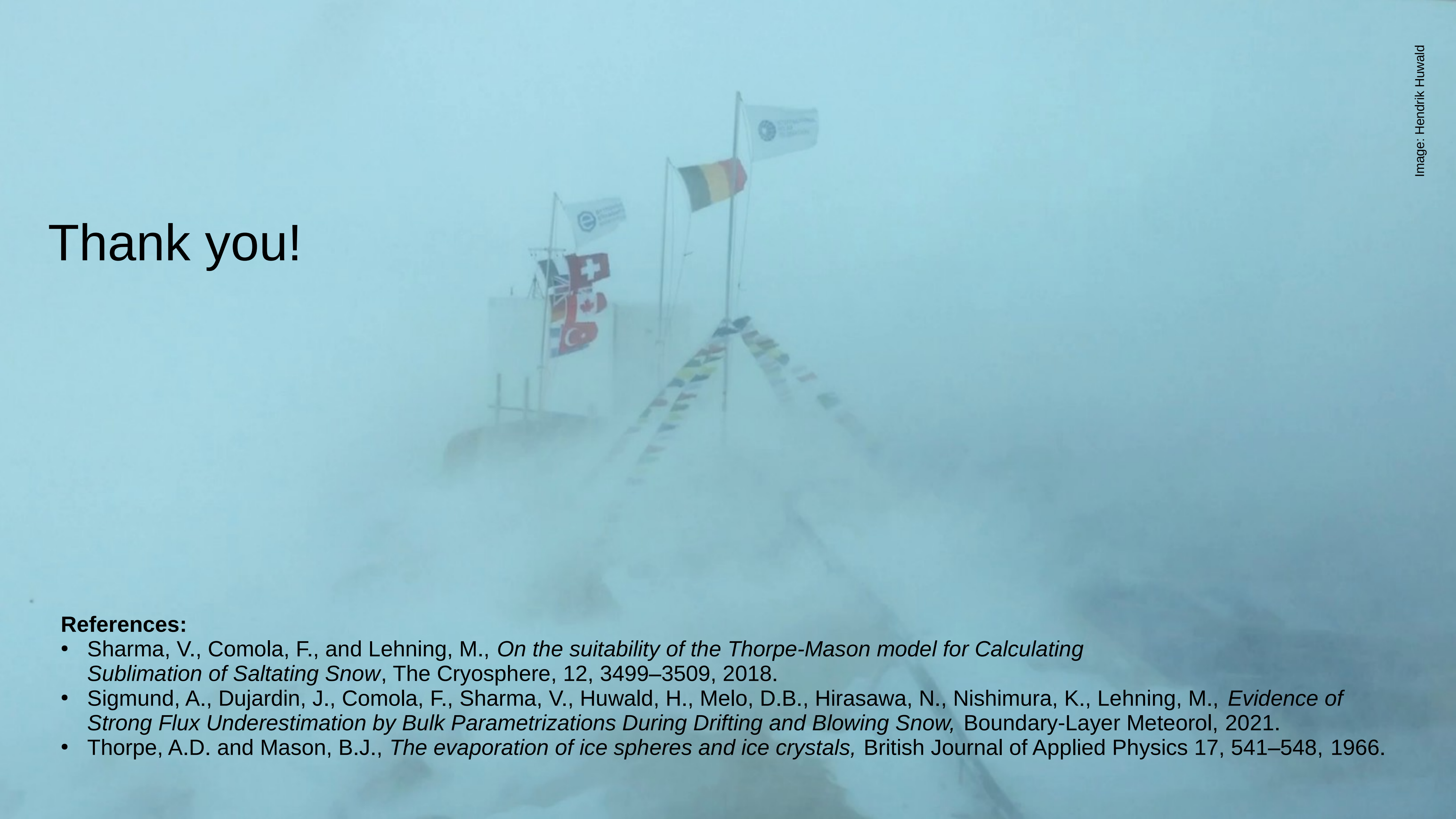

Image: Hendrik Huwald

Thank you!

References:

- Sharma, V., Comola, F., and Lehning, M., *On the suitability of the Thorpe-Mason model for Calculating Sublimation of Saltating Snow*, The Cryosphere, 12, 3499–3509, 2018.
- Sigmund, A., Dujardin, J., Comola, F., Sharma, V., Huwald, H., Melo, D.B., Hirasawa, N., Nishimura, K., Lehning, M., *Evidence of Strong Flux Underestimation by Bulk Parametrizations During Drifting and Blowing Snow,* Boundary-Layer Meteorol, 2021.
- Thorpe, A.D. and Mason, B.J., *The evaporation of ice spheres and ice crystals,* British Journal of Applied Physics 17, 541–548, 1966.