# Water vapour fluxes above snow in conditions of drifting and blowing snow

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CATCH Open Science Workshop
May 10, 2022

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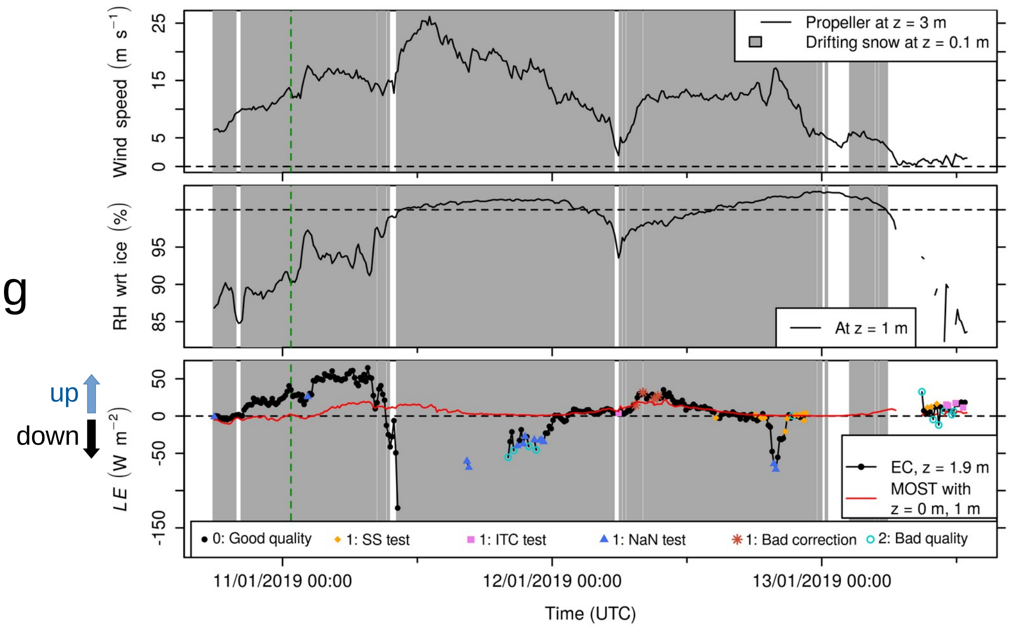
Image: https://www.wunderground.com/cat6/Taste-Traverse-How-Cross-Antarctica-without-Plane

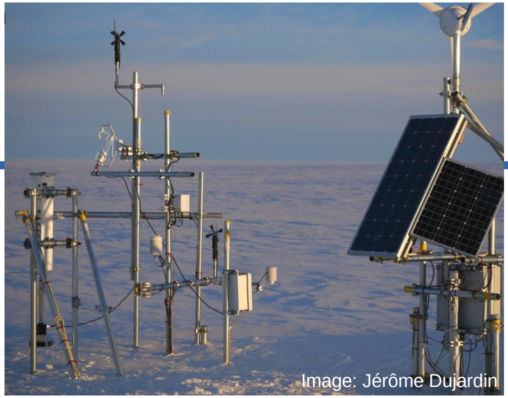
# Motivation

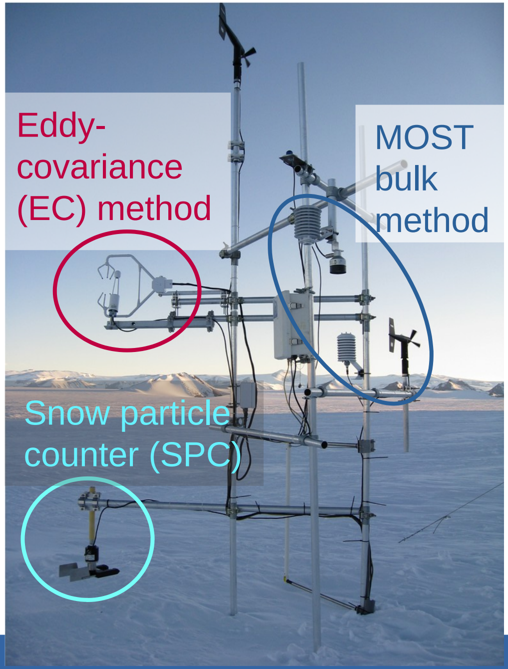
- Drifting and blowing snow can strongly enhance snow sublimation (water vapour flux)
- Relevant term in the mass balance of Antarctica?
- Vapour flux: Vertical turbulent transport (kg $m^{-2}$ $s^{-1}$ or W $m^{-2}$)
- Research questions:
  - **How reliable are measurements** of the water vapour flux in conditions of drifting and blowing snow?
  - **How to parametrize** sublimation of drifting and blowing snow in models?

# Measured fluxes at S17, Antarctica

- Homogeneous, nearly flat snow surface, 15 km from coast
- 10 min averaging interval

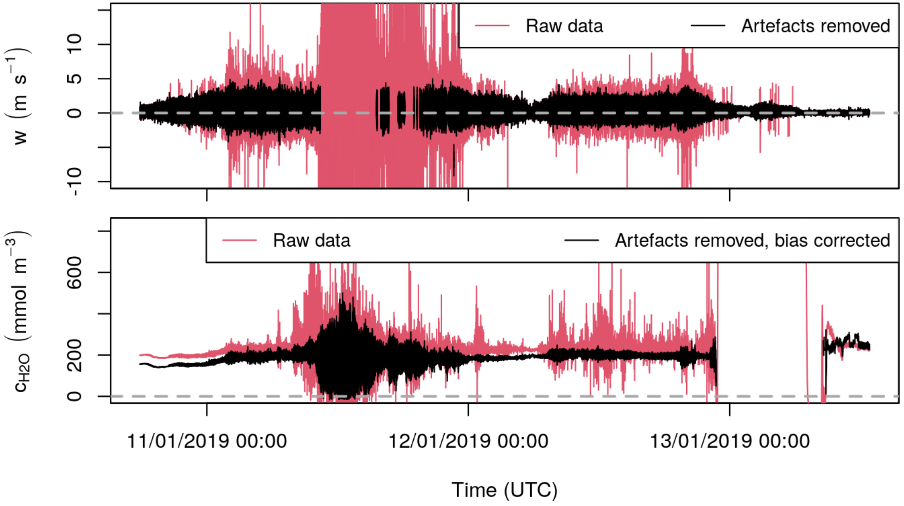


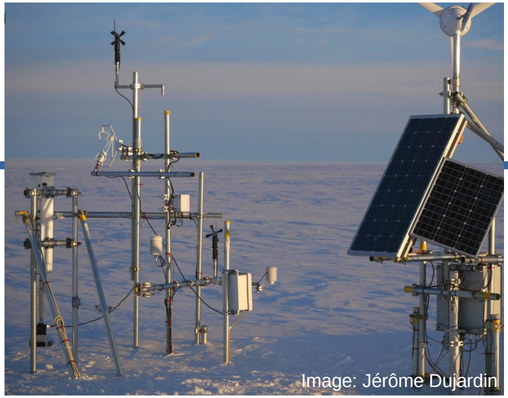



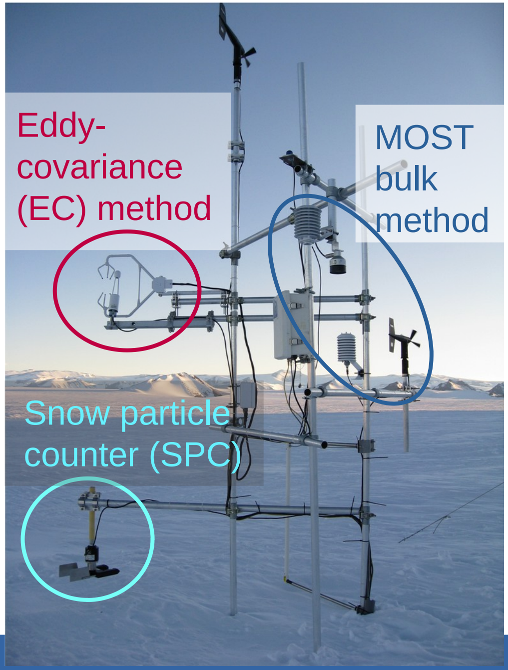



# Measured fluxes at S17, Antarctica

- Homogeneous, nearly flat snow surface, 15 km from coast
- 10 min averaging interval
- Artifacts and spikes in 20-Hz EC data
- Snow particles = vapour sources or sinks violating MOST assumption

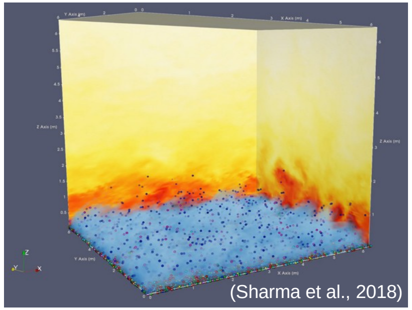


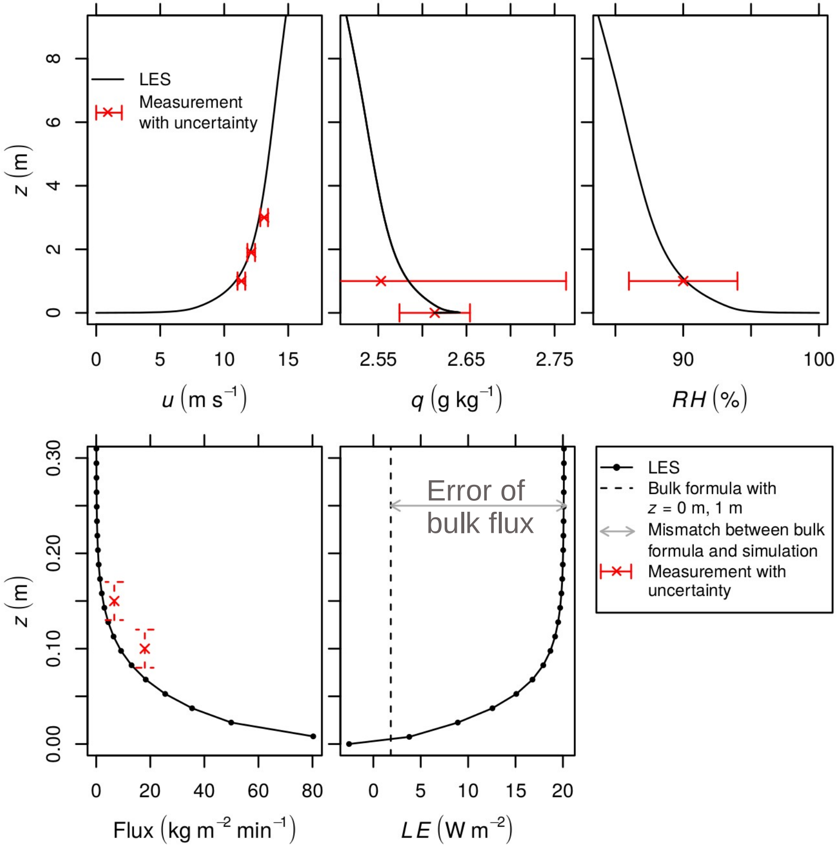



# Large-eddy simulation (LES)

- Domain: 38 x 19 x 18 $m^3$
- Reproduce 10 min steady state
- Lagrangian particles:
  - Vapour transfer: $$\frac{dm_p}{dt} = \pi D d_p \left(\rho_{w,\infty} - \rho_{w,p}\right) \mathrm{Sh}$$
  - Heat balance: $$\underbrace{c_i m_p \frac{dT_p}{dt}}_{\Delta\text{storage}} = \underbrace{L_s \frac{dm_p}{dt}}_{\text{Latent heat}} + \underbrace{\pi k d_p \left(T_{a,\infty} - T_p\right) \mathrm{Nu}}_{\text{Sensible heat}}$$
- MOST bulk flux strongly underestimates the water vapour flux


(Sharma et al., 2018)



# Parametrization in large-scale models (CRYOWRF)

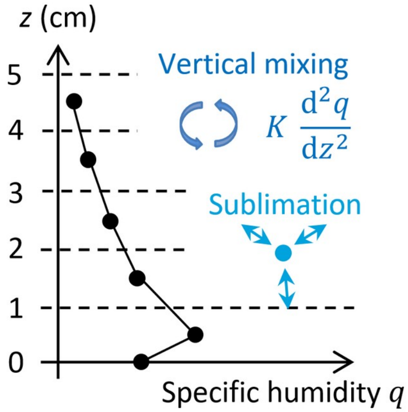
- Current approach
  - Based on Thorpe and Mason (1966)
  - Gamma distribution for $d_p$
  - Saltation layer not resolved

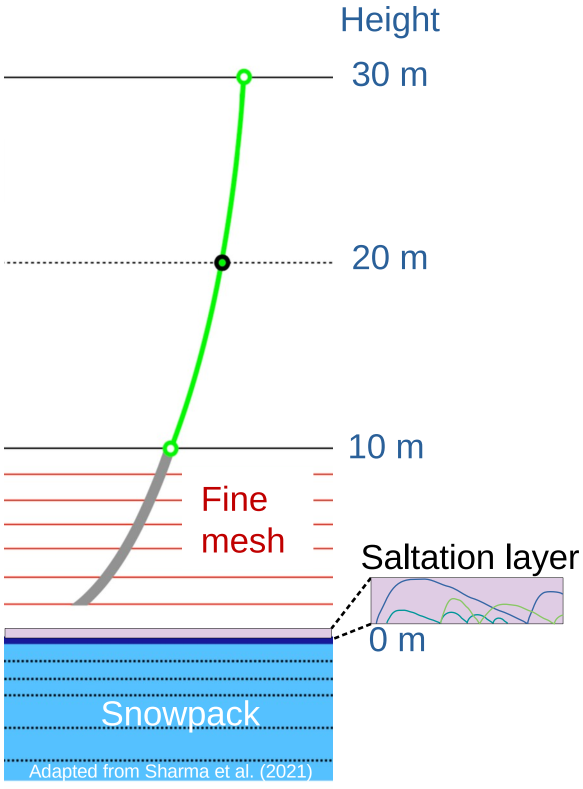
$$\frac{\mathrm{d}m_p}{\mathrm{d}t} = \pi D d_p \left(\rho_{w,\infty} - \rho_{w,p}\right) \mathrm{Sh}$$

$$\underbrace{c_i m_p \frac{\mathrm{d}T_p}{\mathrm{d}t}}_{=0} = \underbrace{L_s \frac{\mathrm{d}m_p}{\mathrm{d}t}}_{\text{Latent heat}} + \underbrace{\pi k d_p \left(T_{a,\infty} - T_p\right) \mathrm{Nu}}_{\text{Sensible heat}}$$

- Planned: Sublimation in saltation layer
  - Particle concentration: Exponential profile
  - $T$, $q$: Prognostic profiles
  - Account for transient particle temperature?

$$\frac{\mathrm{d}T_p}{\mathrm{d}t} = f(T_s - T_a, d_p, z)$$



# Conclusions

- MOST bulk method can be affected by a significant theory-related error during drifting and blowing snow
- EC measurements are more reliable as long as few blowing snow particles reach the sensor height
- To parametrize sublimation in the saltation layer, it may be crucial to
  - Solve for $T$ and $q$ prognostically
  - Estimate the imbalance between latent and sensible heat exchange

Image: Hendrik Huwald

# Thank you!


**References:**

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- Sharma, V., Gerber, F., Lehning, M., *Introducing CRYOWRF v1.0: Multiscale atmospheric flow simulations with advanced snow cover modelling,* The Cryosphere. 2021, in review.
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