Introduction to Catabatic winds

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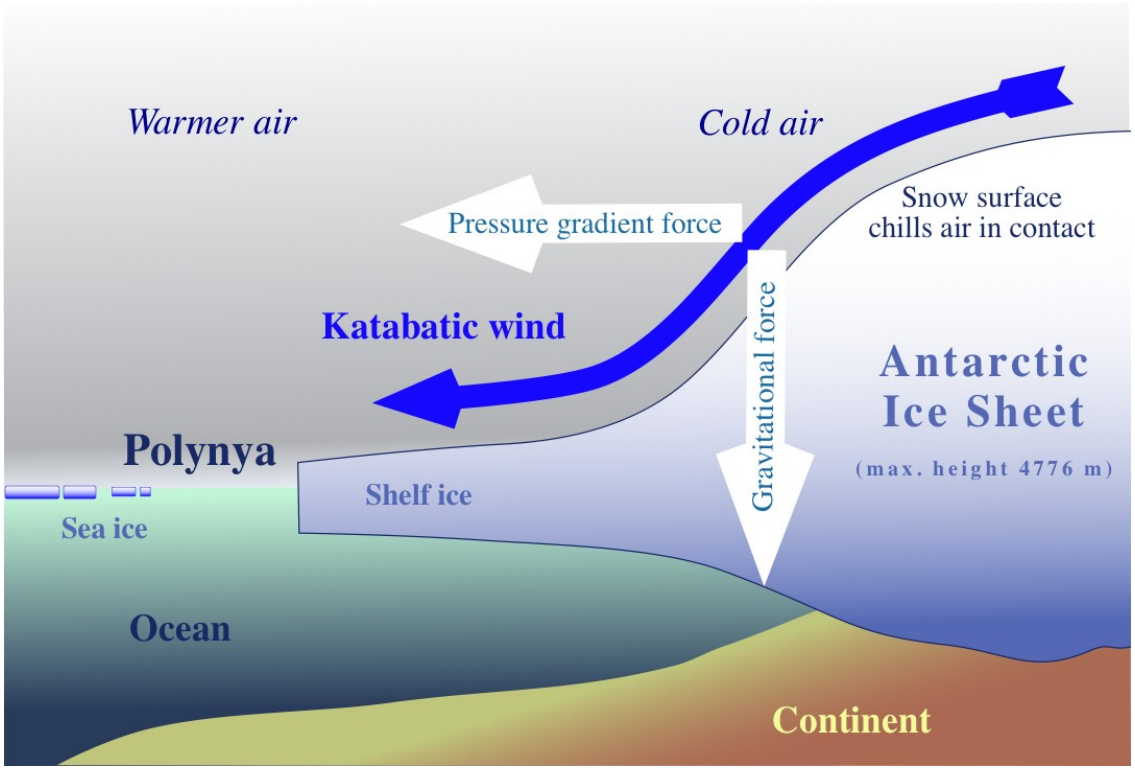
Definition Catabatic wind

Definition: ”Catabatic wind carries high density air from a higher elevation down a slope under the force of gravity” (wikipedia)

catabasis = decending in Greek

On ice sheets



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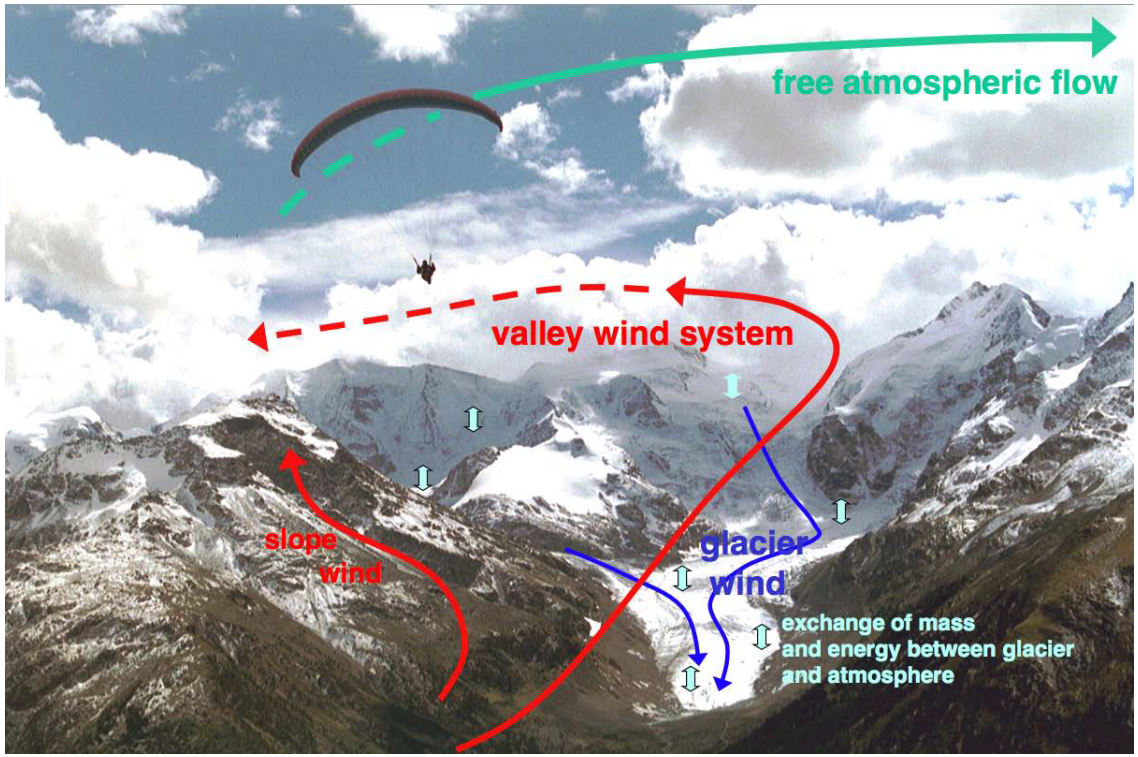
On glaciers



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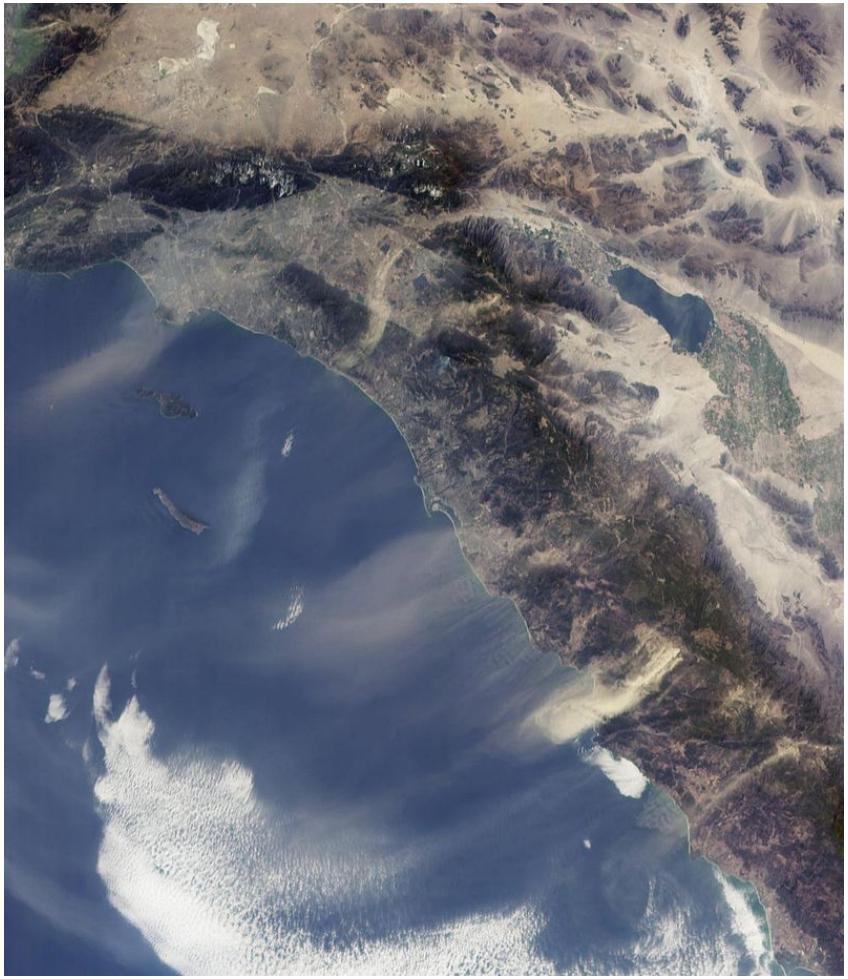
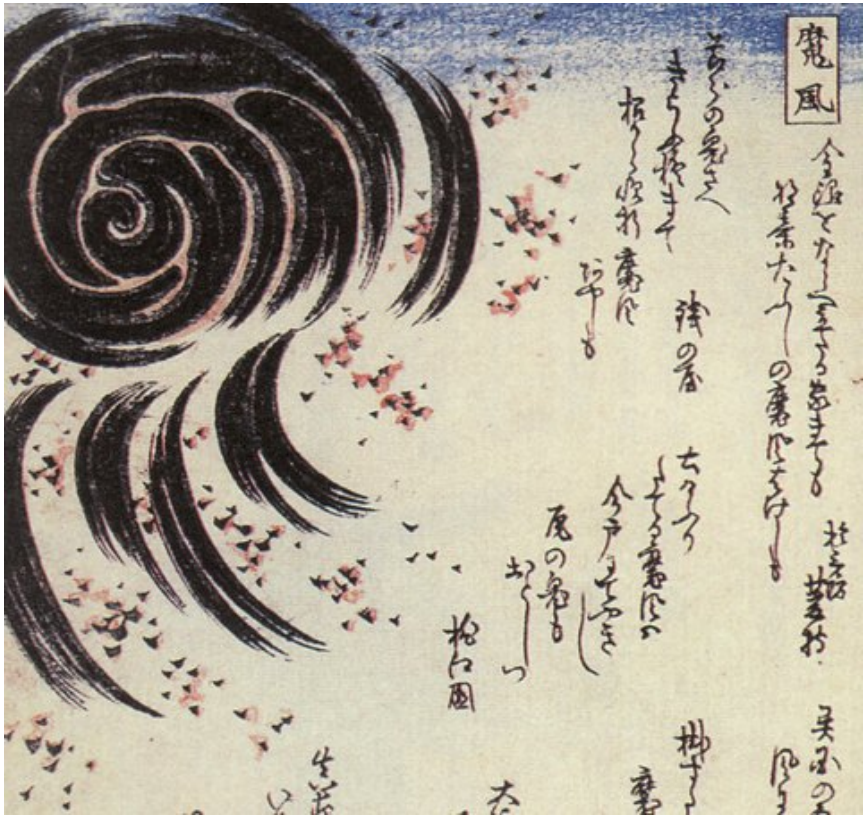
Overview:

- Examples:
  - Some non-ice related examples
  - Catabatic winds on glaciers and ice sheets
- Theoretical description
- Comparison with field observation

Examples

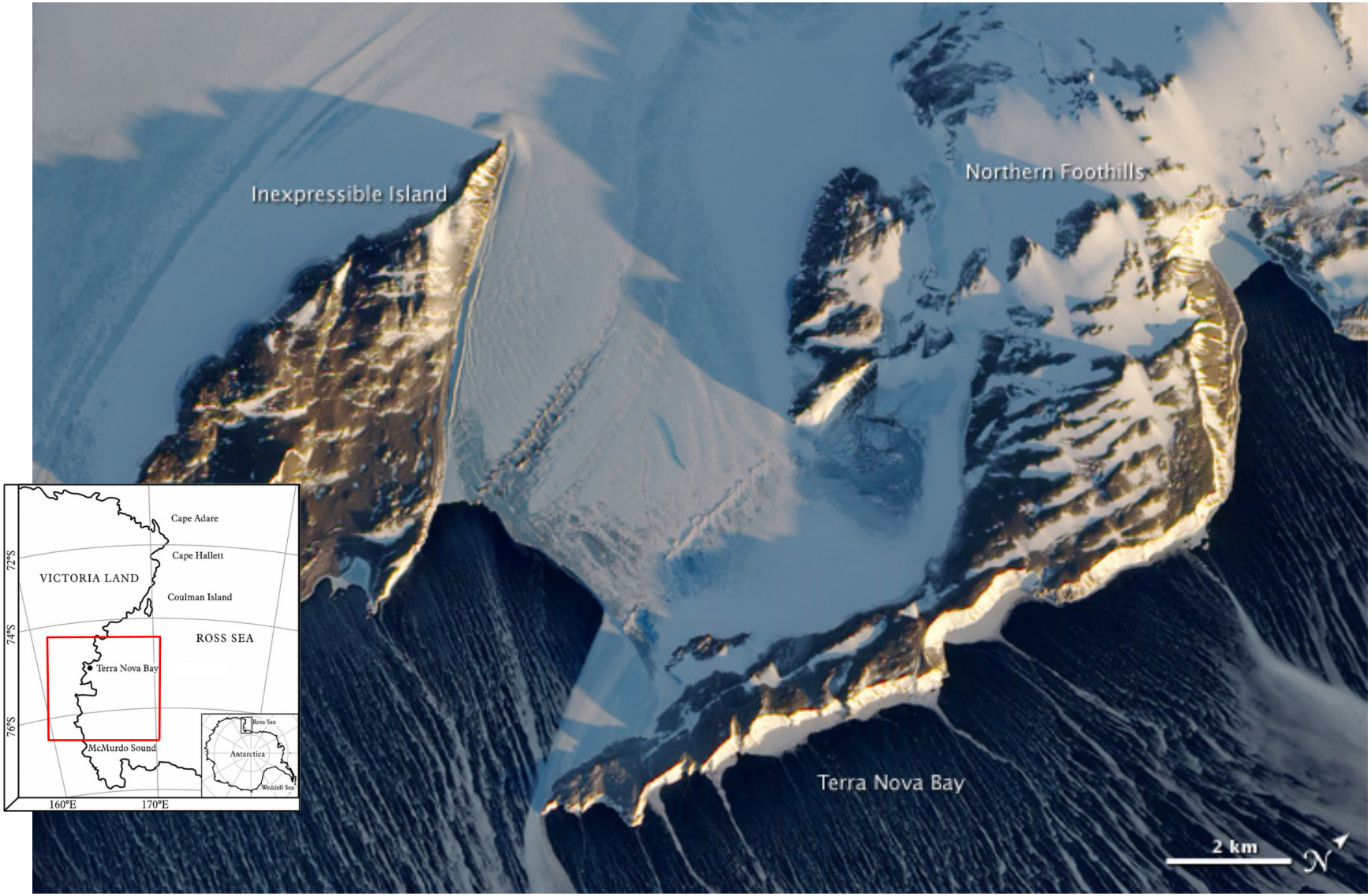


”Santa Ana” in Califonia



”Oroshi” in Japan – translates to ”wind which causes unpredictable damage” (Mafu, 1853)

Catabatic winds at Antarctica



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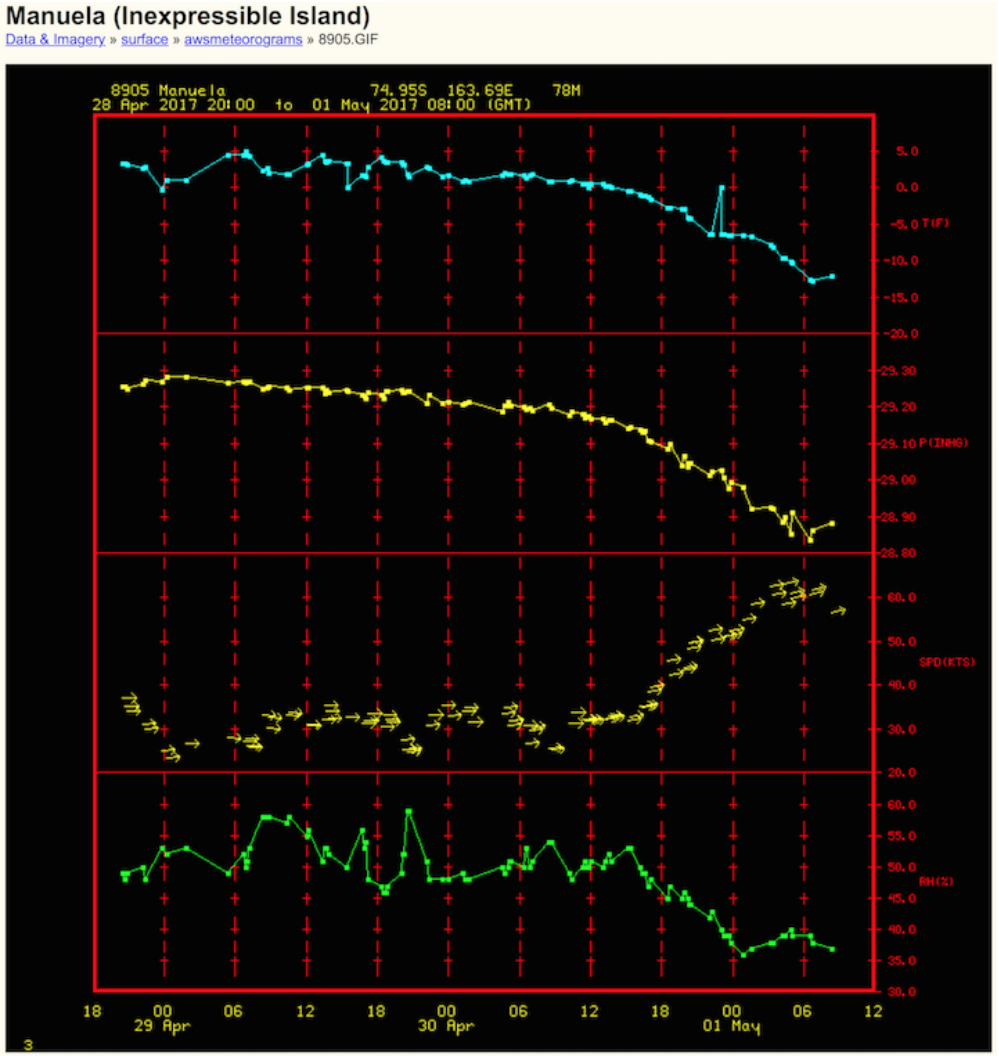
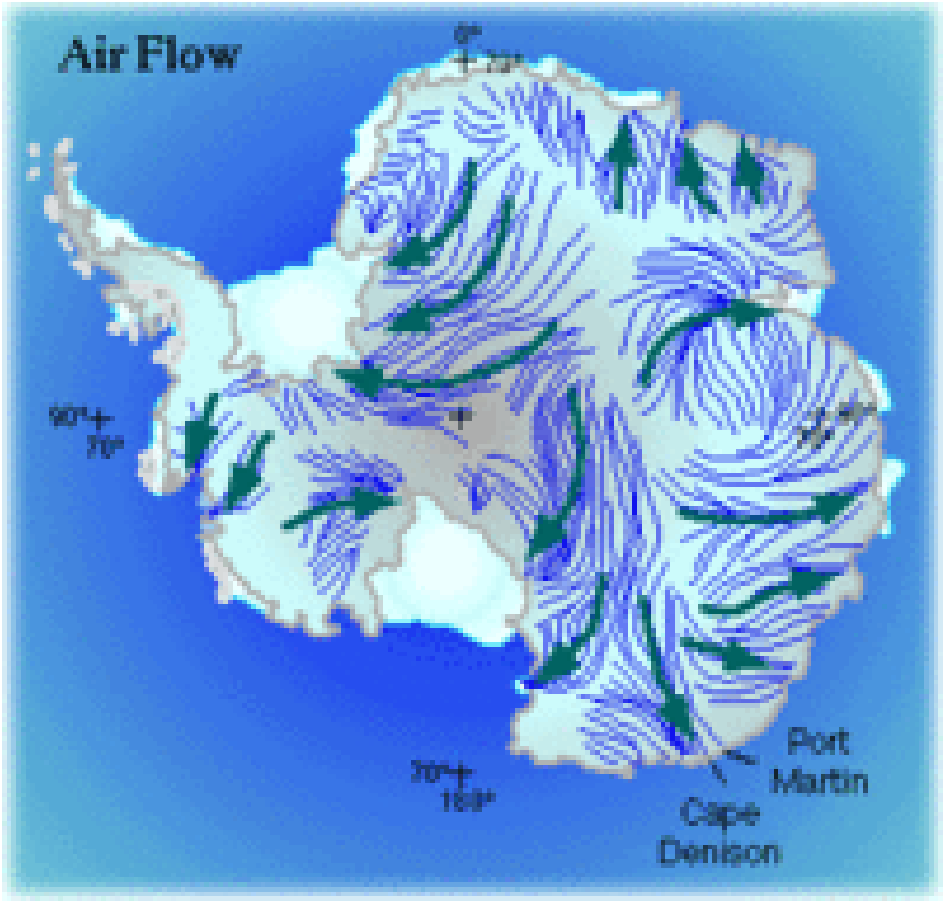


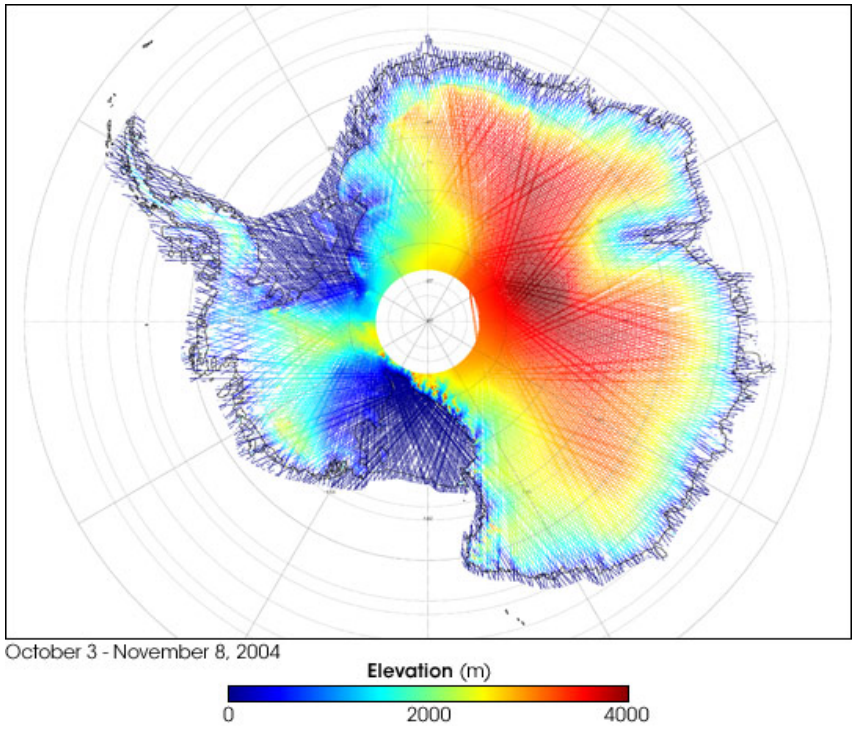
Data from 28 April 2017.

Wind speed up to 110 km/h.

Catabatic winds at Antarctica

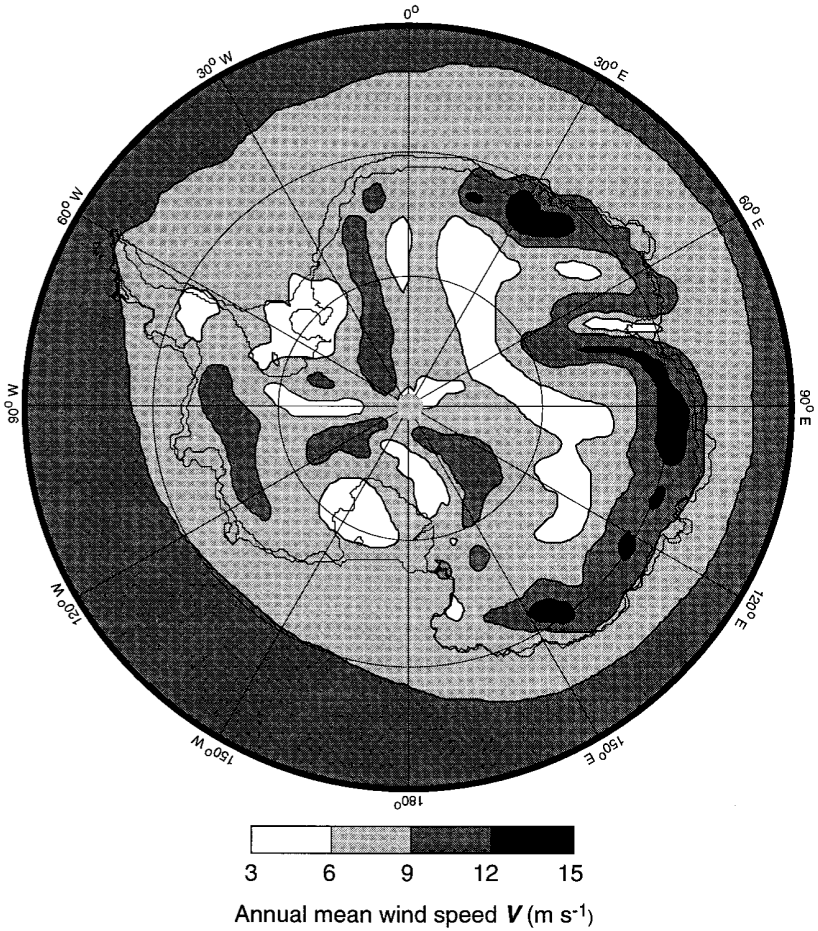
Significant snow redistributed by Catabatic wind

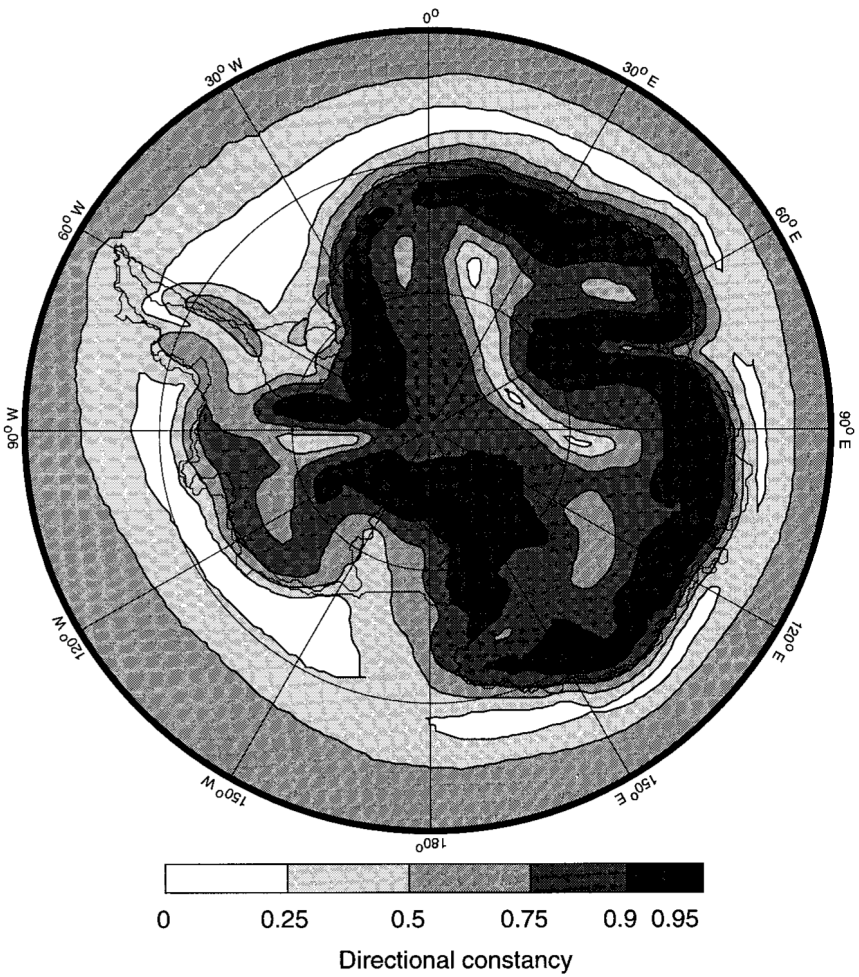




ICESat, Nasa

Catabatic winds at Antarctica

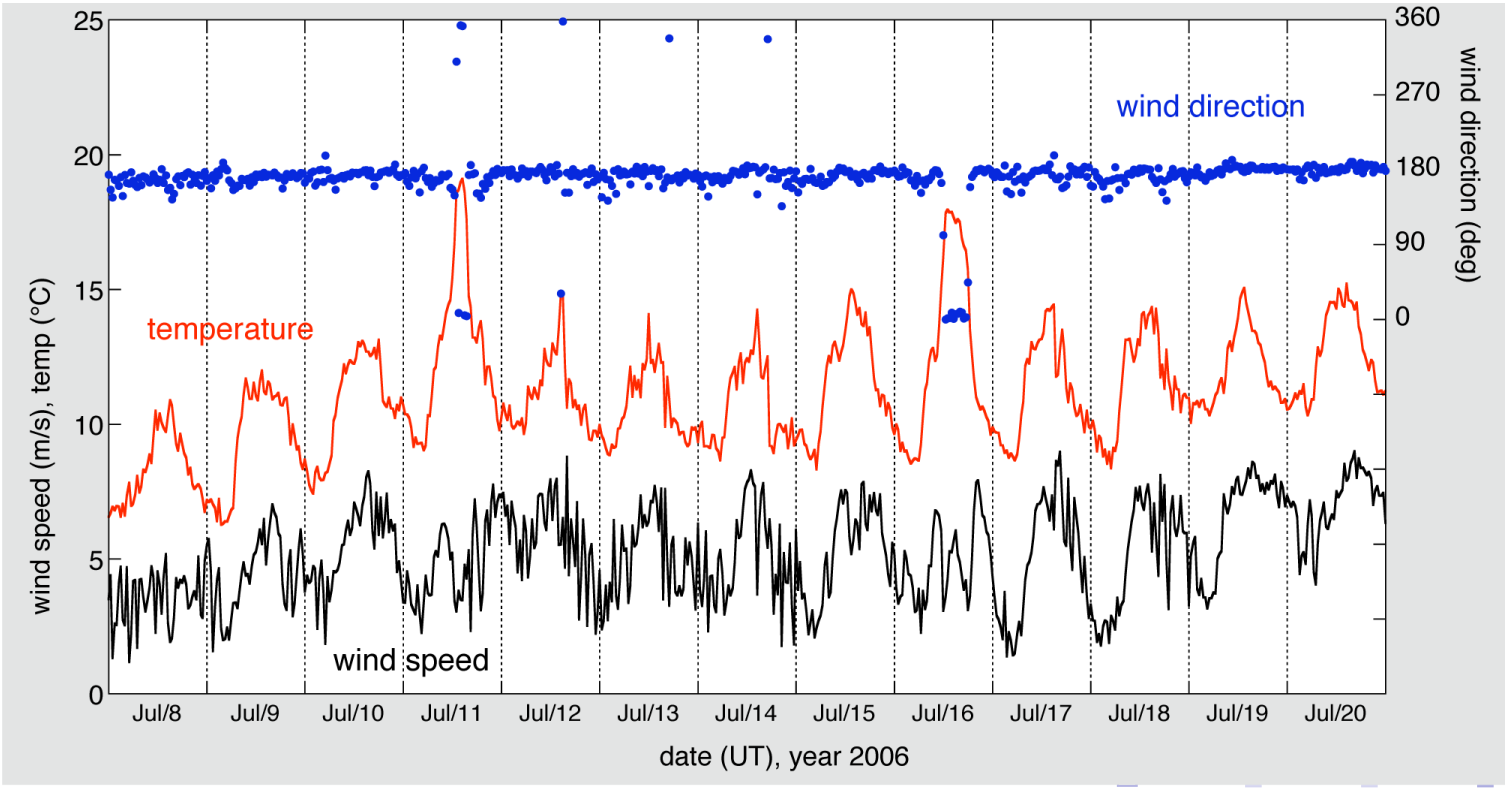




Van den Broeke et al, 1997, AMS

Katabatic wind on glaciers

Field observation at Morteratschgletsjer



Governing equation

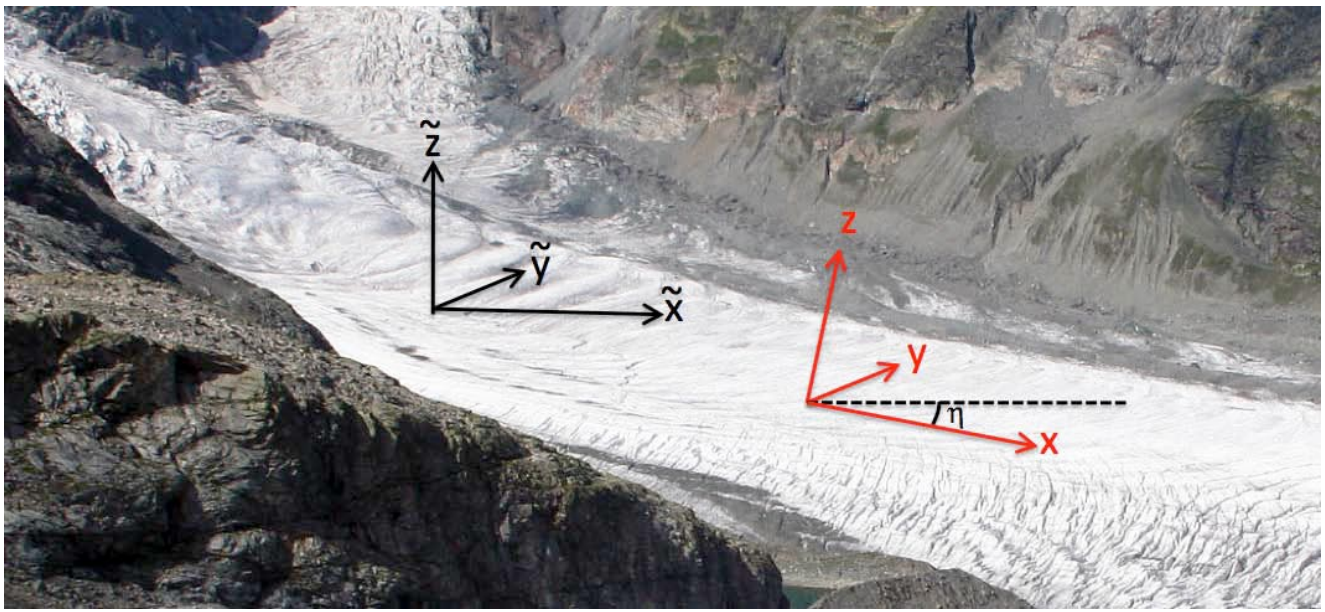
Based on ”Microclimate of Valley Glaciers” (138 pp, free online download)
by Hans Oerlemans (Utrecht University)

Governing equation

Momentum equation for down-slope wind

$$\frac{\partial u}{\partial t} = \underbrace{-u\frac{\partial u}{\partial x} - w\frac{\partial u}{\partial z}}_{advection} \quad \underbrace{-\frac{\partial F_u}{\partial z}}_{turbulence} \quad \underbrace{+\frac{g(\sin\eta)}{T_0}\theta}_{katabatic\ forcing} \quad \underbrace{+\frac{g(\cos\eta)}{T_0}\frac{\partial \overline{\Theta}}{\partial x}}_{thermal\ wind} \quad \underbrace{+f(\cos\eta)(v - v_g)}_{Coriolis\ acceleration} \ ,$$

Potential temperature $\theta = \Theta - \Theta_{ref}(\tilde{x},\tilde{z}) = \Theta - \{\Theta_0(\tilde{x}) + \gamma_\theta \tilde{z}\}$



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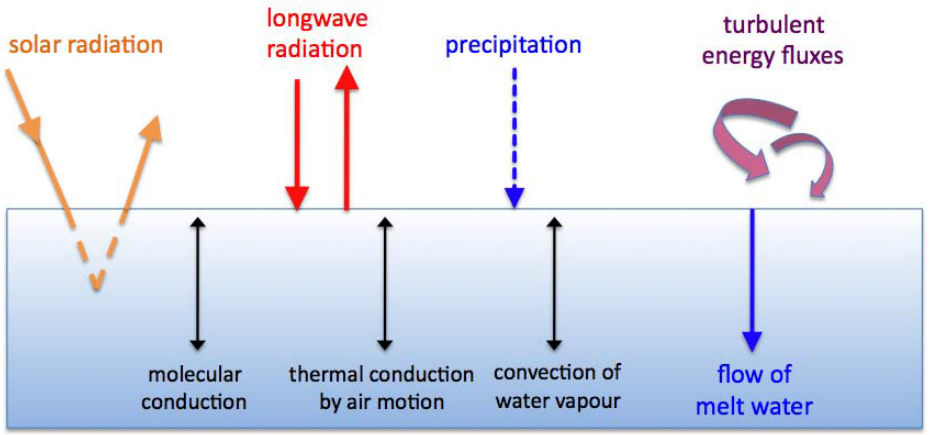

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Katabatic wind balance:

$$\frac{g(\sin\eta)}{T_0}\theta - \frac{\partial F_u}{\partial z} = 0 \ ,$$

$$-\gamma_\theta(\sin\eta)u - \frac{\partial F_\theta}{\partial z} = 0 \ .$$

with

$$F_u = -K_m\frac{\mathrm{d}u}{\mathrm{d}z} \ , \quad F_\theta = -K_h\frac{\mathrm{d}\theta}{\mathrm{d}z} \ .$$

Comparison catabatic wind with field observations

$$\frac{g\,(\sin\eta)}{T_0}\theta - \frac{\partial F_u}{\partial z} = 0 \ ,$$

Analytical solution to

$$-\gamma_\theta(\sin\eta)u - \frac{\partial F_\theta}{\partial z} = 0 \ .$$

$$\theta(z) = C\,e^{-z/\lambda}\cos(z/\lambda) \ ,$$

$$u(z) = C\mu\,e^{-z/\lambda}\sin(z/\lambda) \ ,$$

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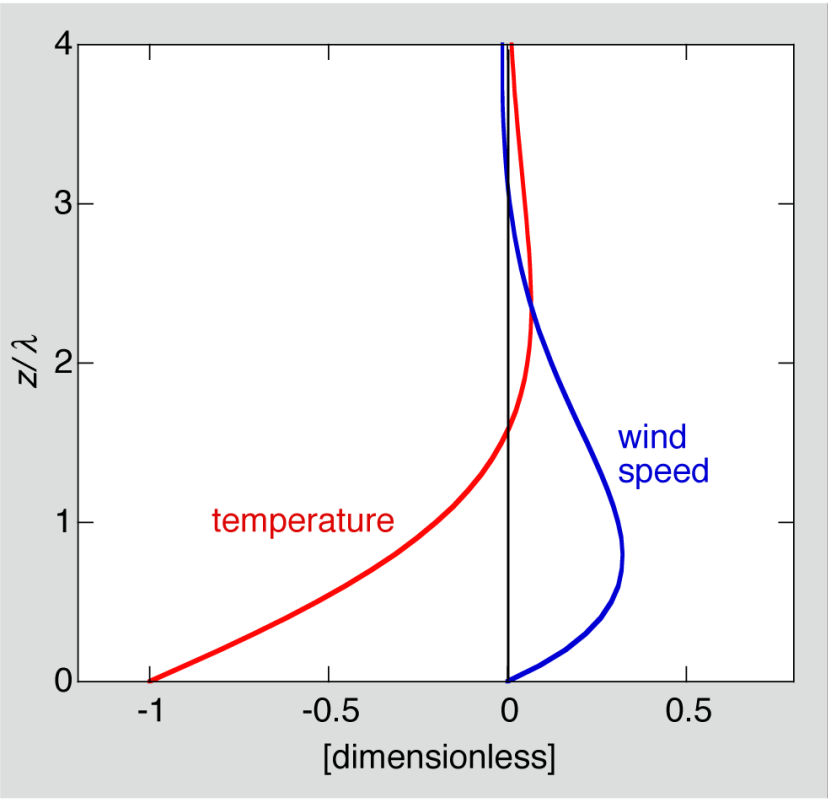

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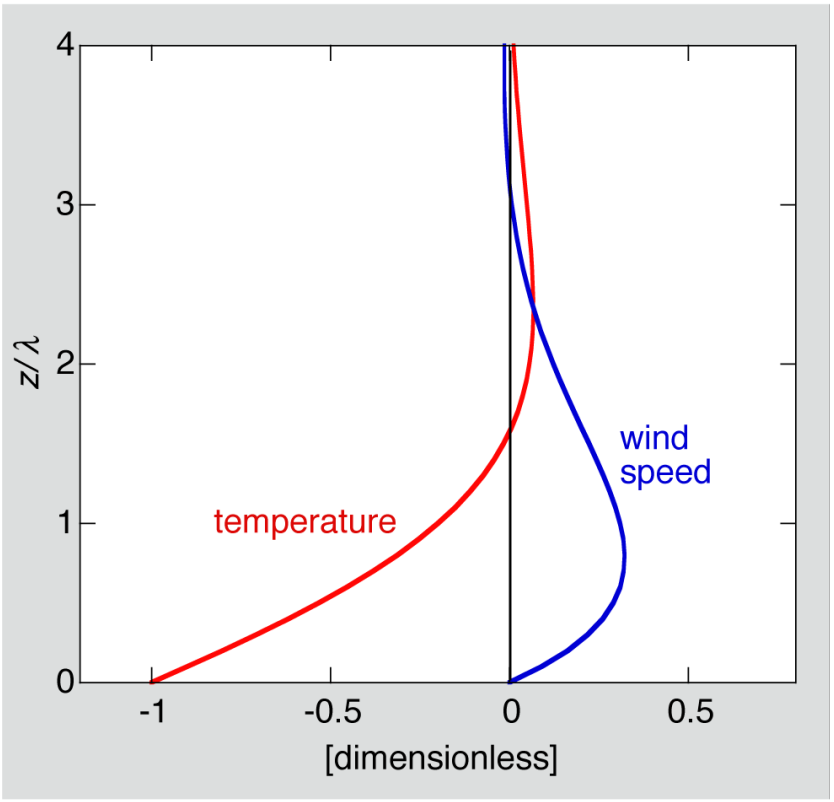

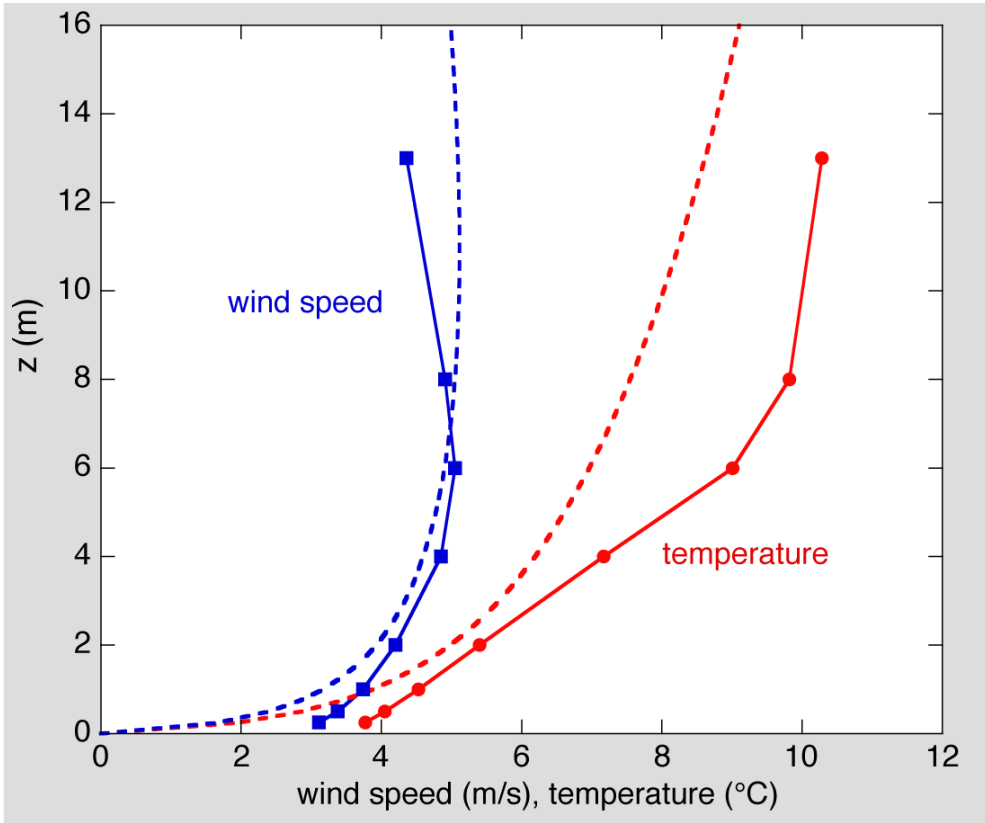

Summary

Catabatic winds:

- Turbulent bouyancy-driven boundary layer current
- Relevant for glacier and ice sheet energy budget