Ice Mushrooms of the Patagonian Andes

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Cerro Torre, Argentina

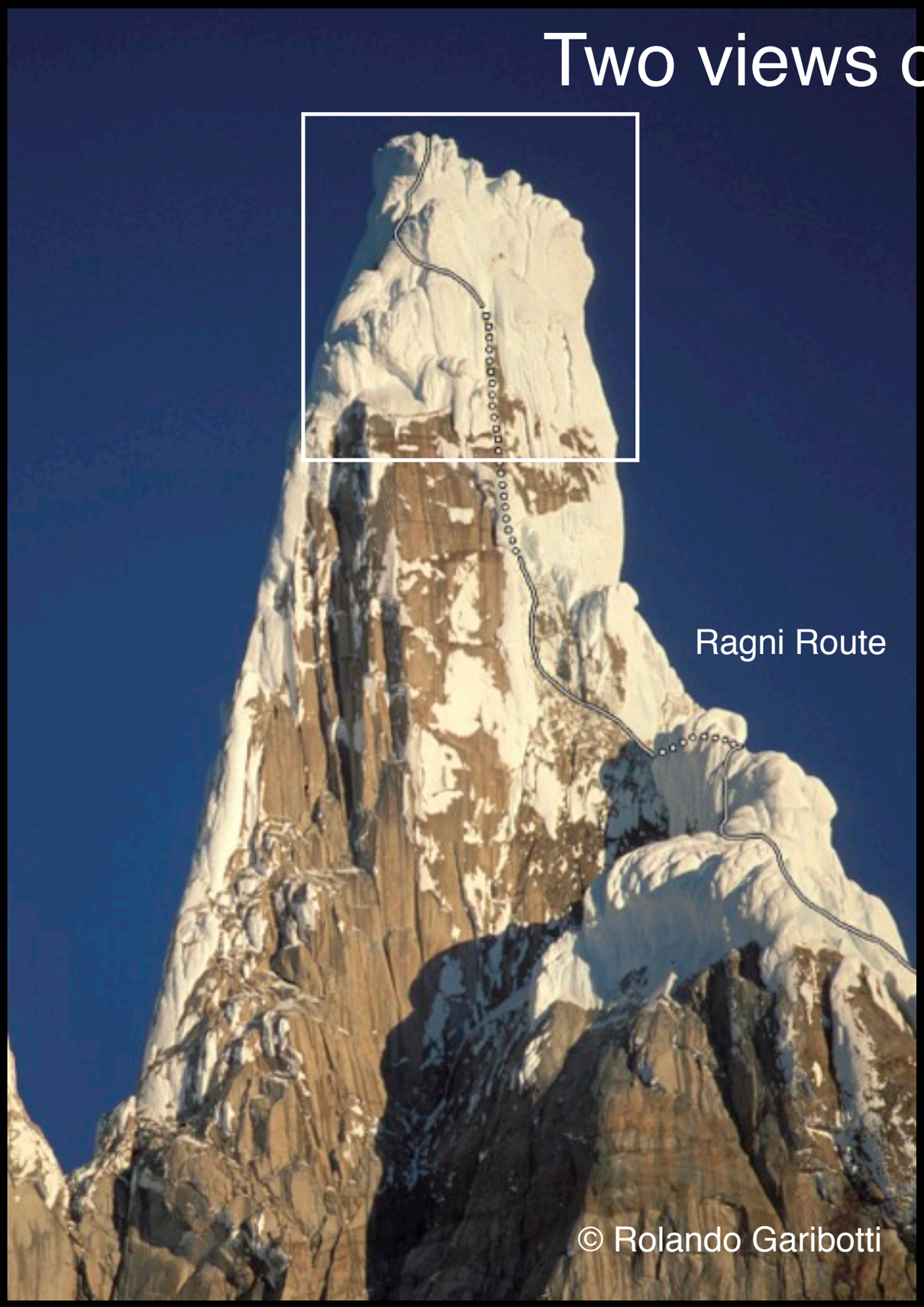
Cerro Torre massif

Torre Egger

Paine Grande SW

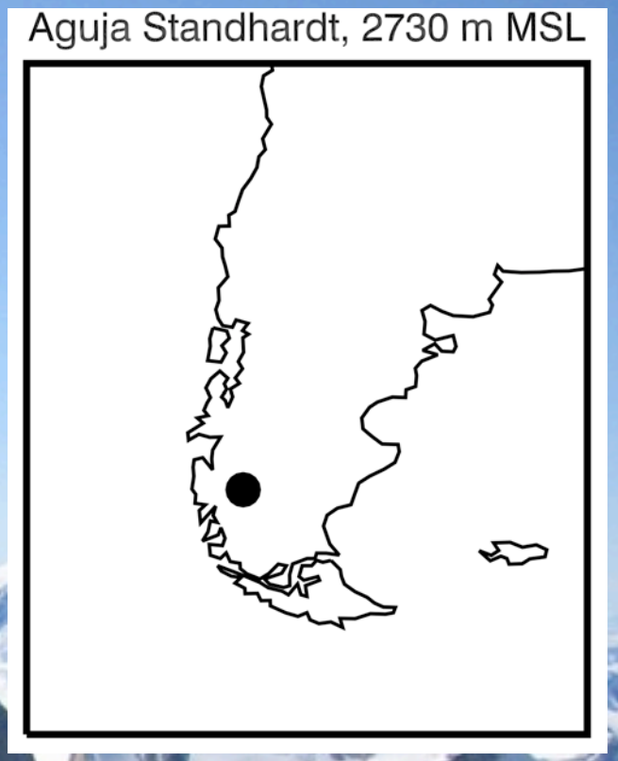
Rime mushrooms can present a significant impediment to mountain climbers.

Two views of Cerro Torre



Cerro Standhardt
N Ridge

30 m



Monte Sarmiento, Tierra del Fuego

Cerro San Lorenzo

In 2000 Toni Rohrer (Switzerland) and Santiago Batet (Argentina) lost their lives when the summit mushroom of Cerro San Lorenzo collapsed

© Ralf Gantzhorn

Monte Sarmiento, Tierra del Fuego

Punta Herron
W Ridge

Ice mushrooms form on this ridge. They grow and then break off.

Rime mushroom: A bulge, mound or mushroom-shaped projection of ice produced primarily by the accretion of hard rime on a surface-based obstacle such as a summit, ridge or mountain face, lasting more than one year, and constituting an obstacle to climbing.

Rime

Type	Characteristics	Mode	Adhesion	T (°C)
Soft	Fragile rime consisting mainly of thin needles or scales of ice, density ~0.2 g cm^{-3}	Deposition of vapor in solid form from super-cooled fog, or air super-saturated with respect to ice. Fog not essential.	Easily detached	< -8
Hard	White granular structure with crystalline branches of ice grains more or less separated by entrapped air. Deposit grows upwind, density ~0.5 g cm^{-3}	Fog essential. Rapid freezing of super-cooled fog droplets, leaving interstices. Moderate or strong winds	Rather adhesive but can be scratched off	-2 to -10
Clear	Amorphous compact ice with alternate transparent and opaque (bubbles of air) layers, density ~0.8 g cm^{-3}	Slow freezing of fog drops with released heat hindering crystallization	Firmly adheres to surface	0 to -3

WMO (1975)

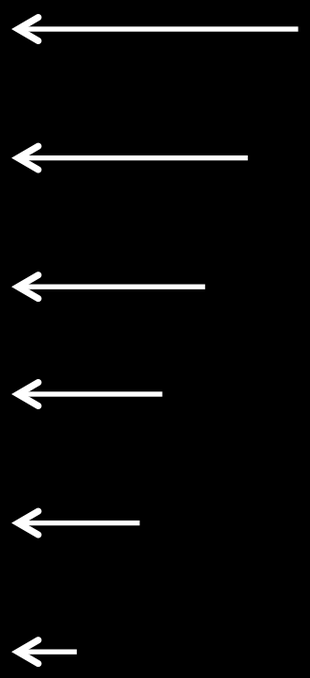
Compare glaze

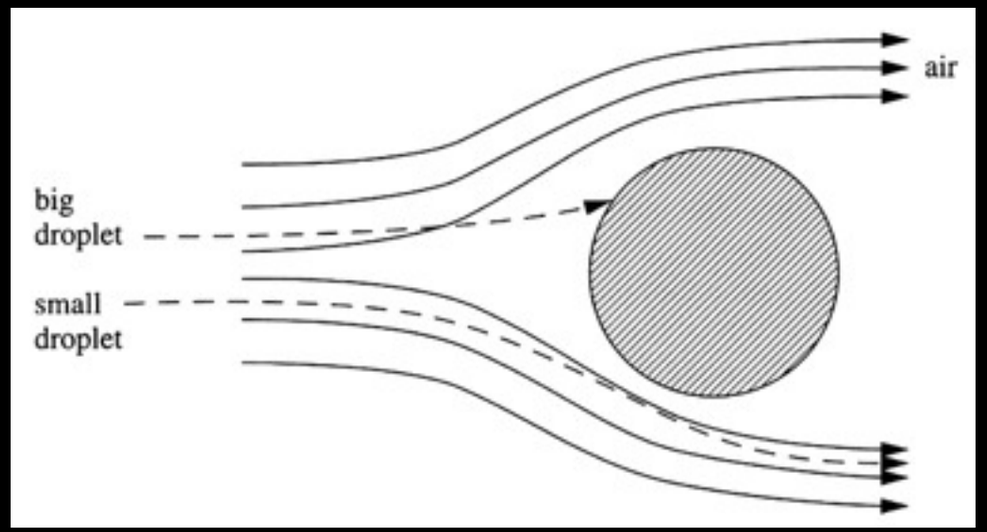
Hard rime

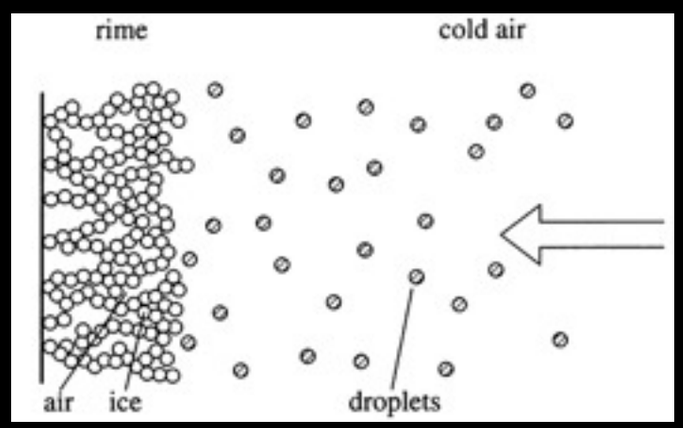
Hard rime: white ice that forms when super-cooled cloud droplets freeze on the windward side of sub-freezing ground-based obstacles, usually with high wind velocities and air temperatures between -2 and -10°C. WMO (1975)

note the 'overhang'

wind speed







Makkonen and Lozowski (2008)

Rate of accretion of super-cooled liquid water mass on a sub-freezing structure:

$$dM/dt = \alpha\ w\ U\ A \qquad [kg\ s^{-1}]$$

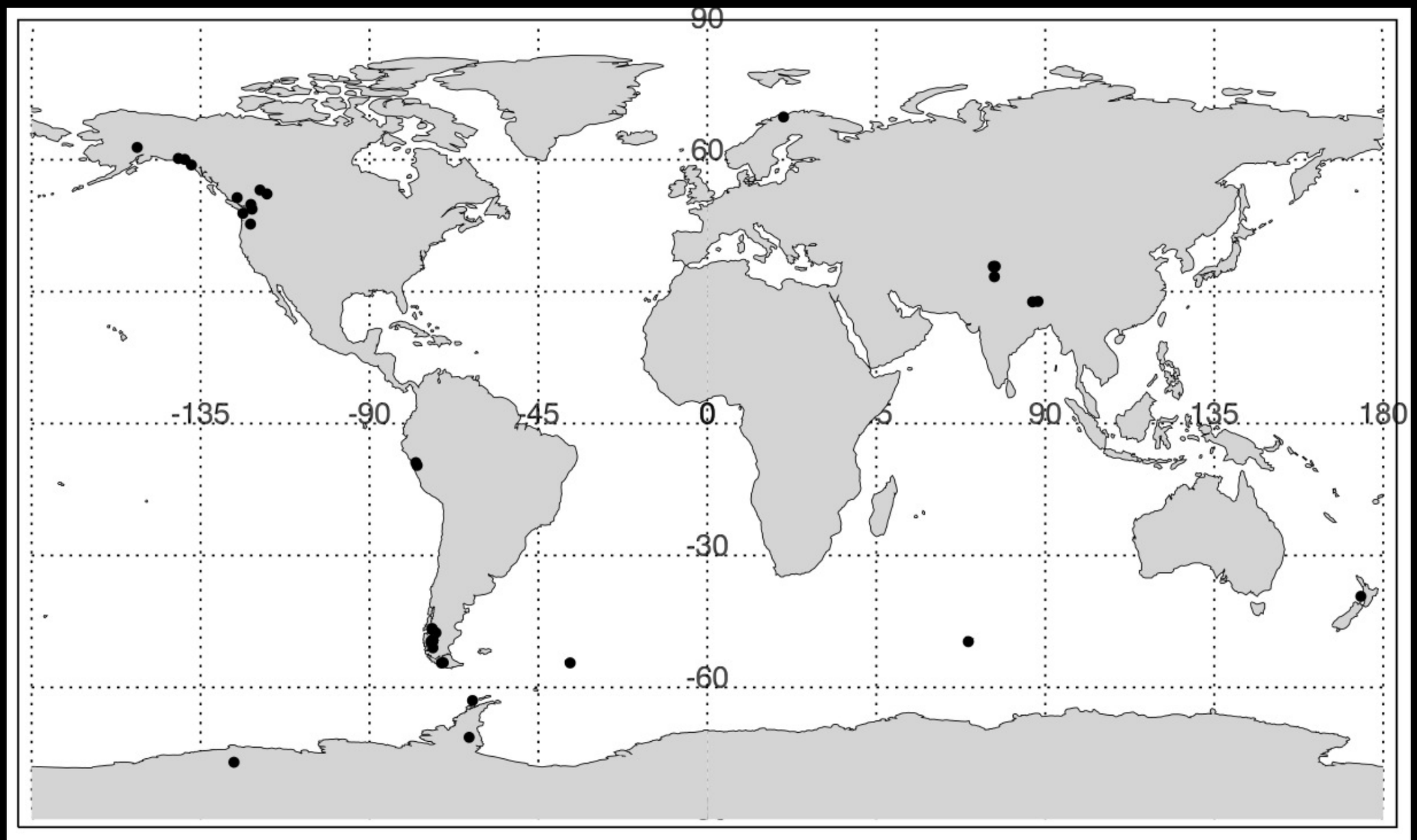
M = mass of accretion of S-C droplets
t = time
w = liquid water content
U = wind speed normal to surface
A = surface area
α = collision coefficient (0 - 1)

Collision efficiency
Skiing analogy

Collision efficiency = 1

Accounts of Ice or rime Mushrooms

- American Alpine Journal, 1929-present
- Personal accounts of climbers
- Web search

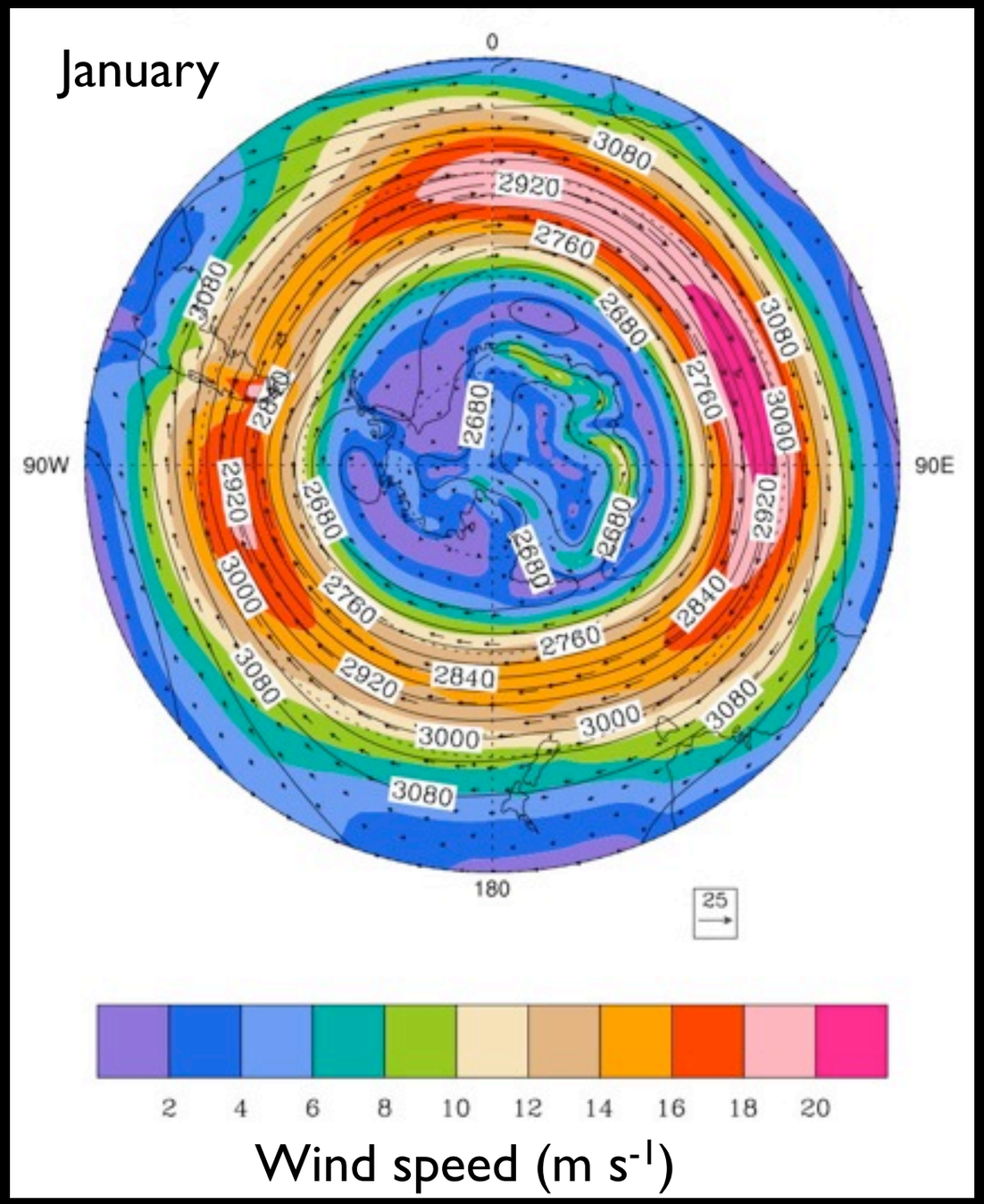


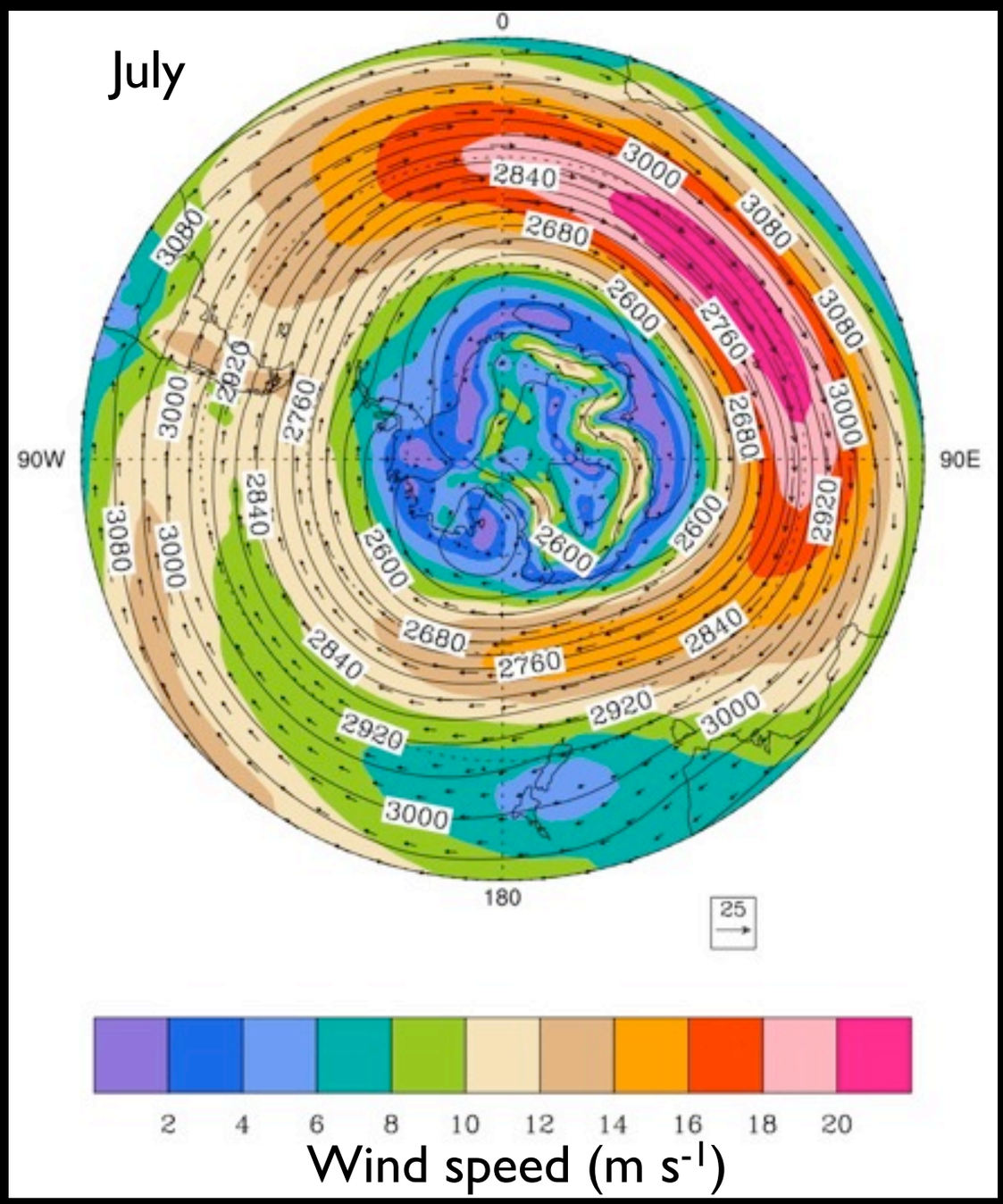
Reports of permanent rime mushrooms

AAJ, 1929-present, “funghi di ghiaccio” 1959; eispilzen; Hongo de hielo

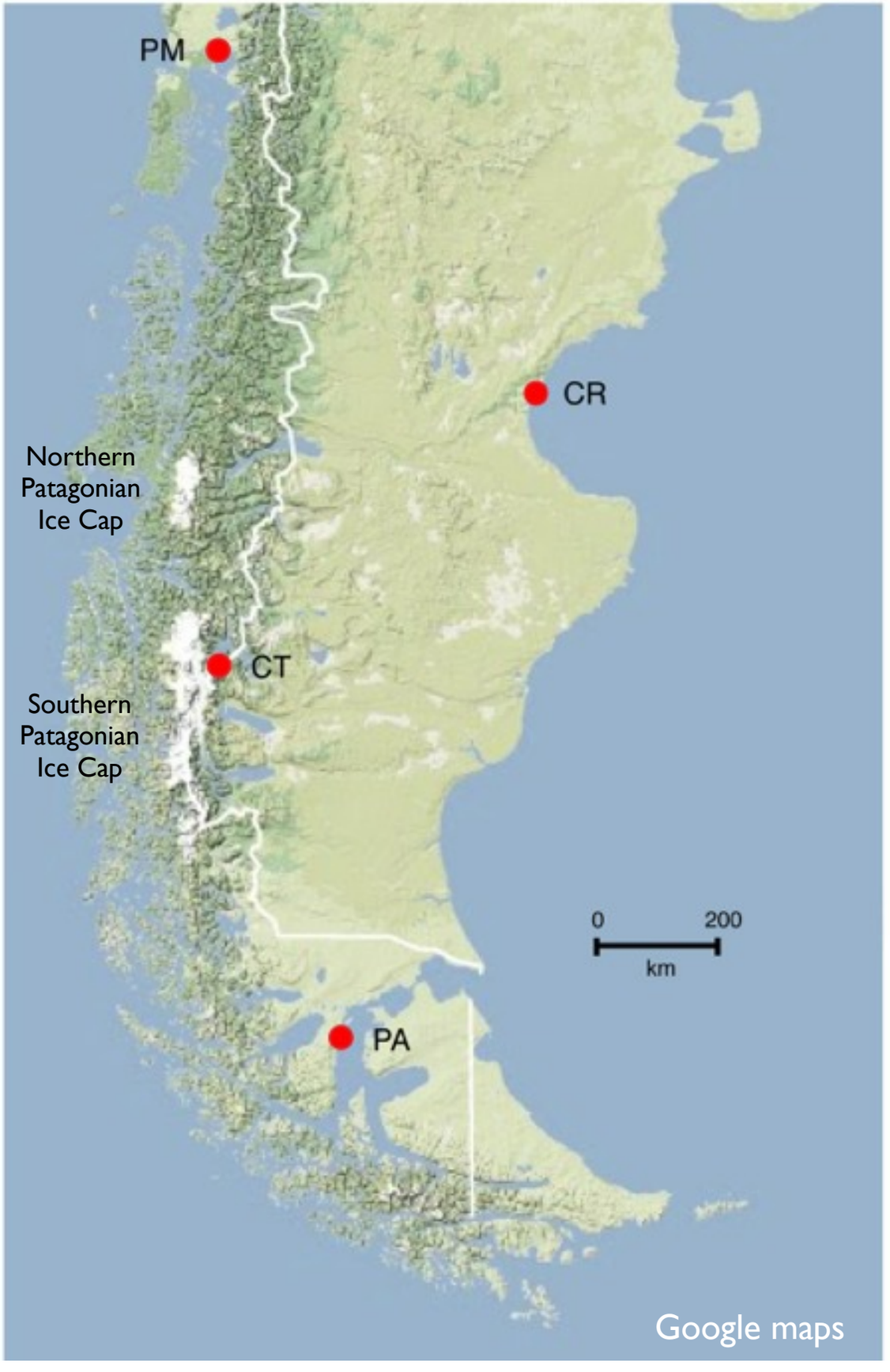
Meteorology of Rime Mushrooms - Patagonia

70 kPa





ERA interim reanalysis



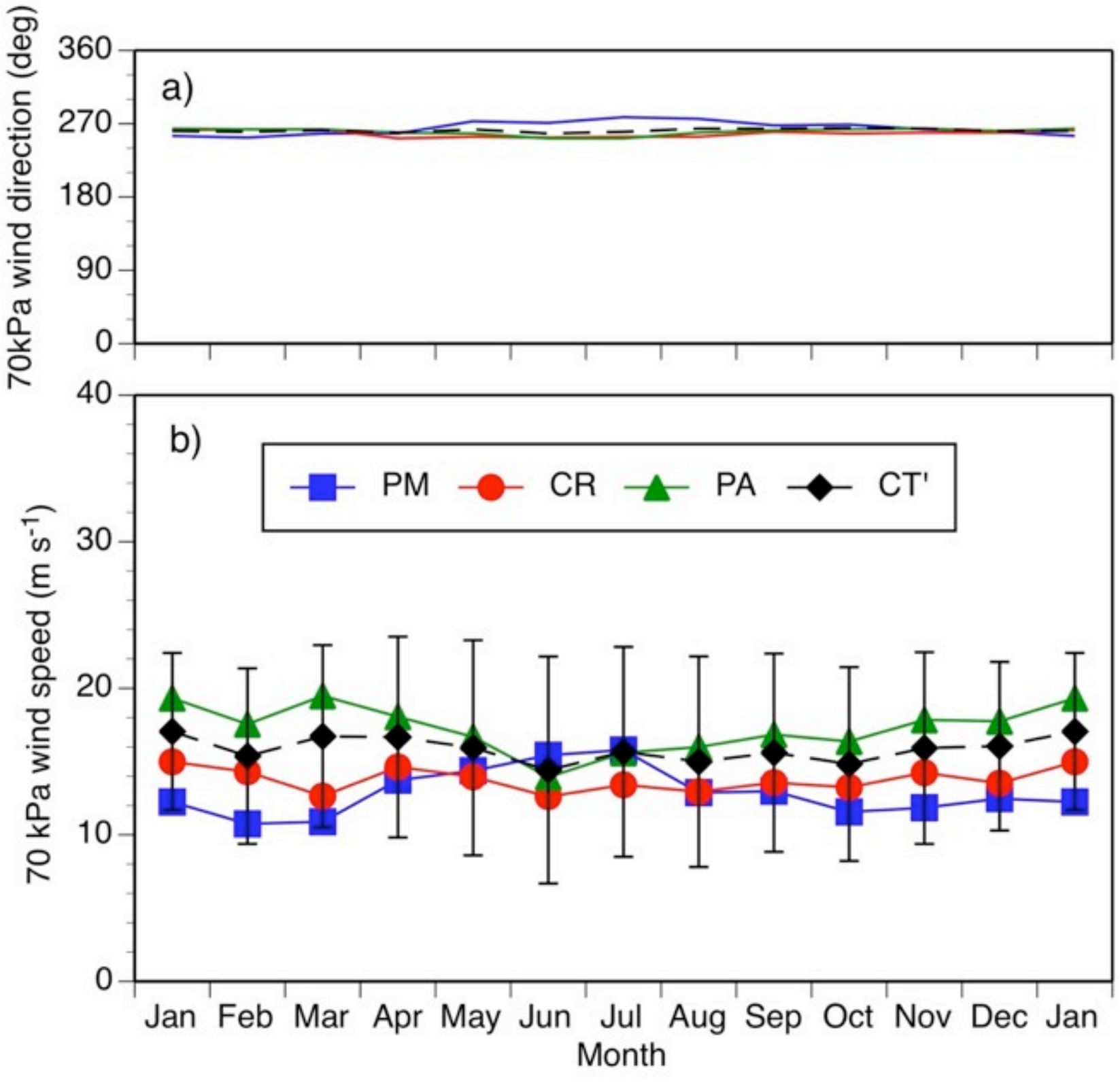
PM = Puerto Montt
CR = Comodoro Rivadavia
CT = Cerro Torre
PA = Punta Arenas

Radiosondes
1975 -Apr 2012

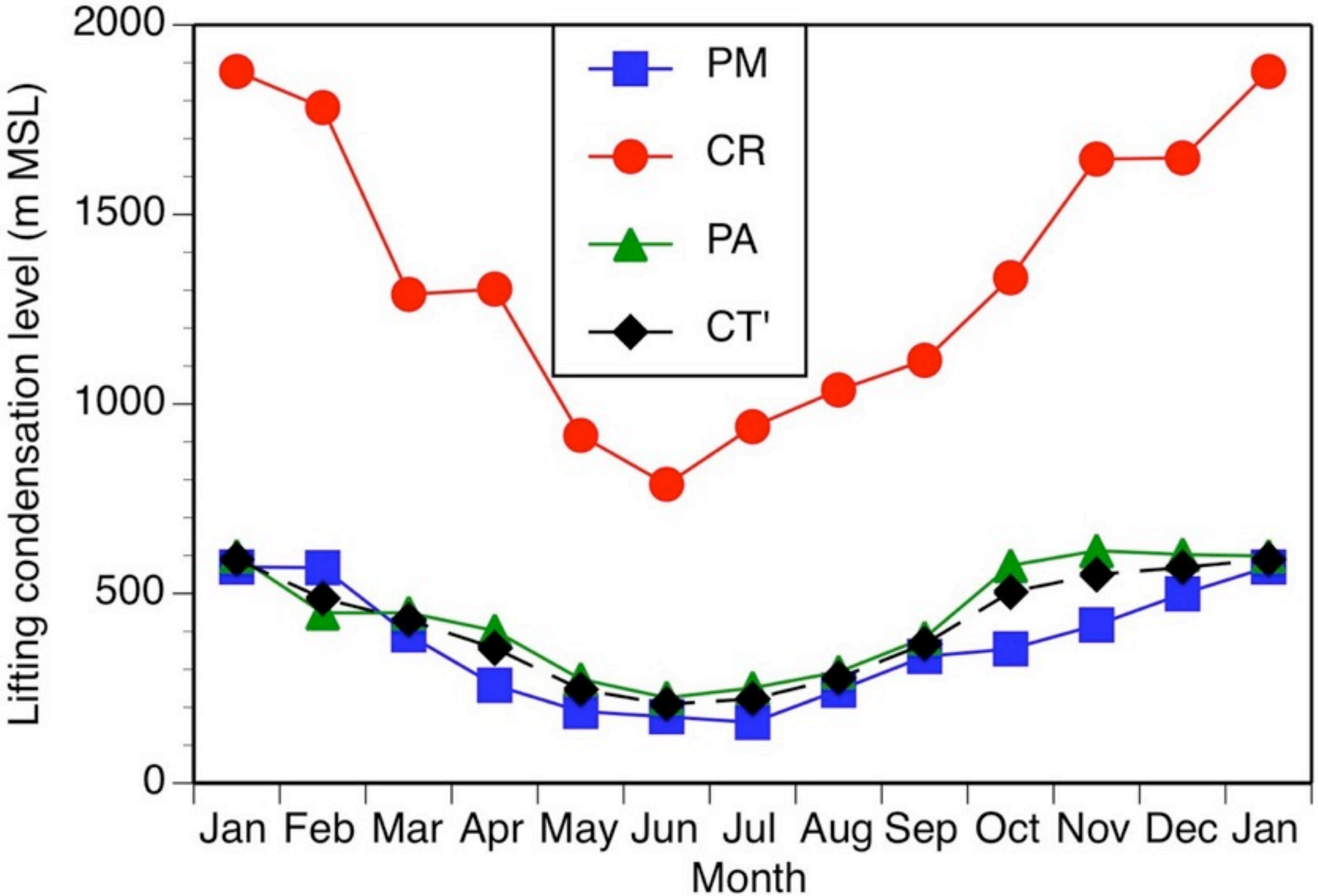
Cerro Torre is in the Monte FitzRoy Massif

NCDC: Global radosonde archive

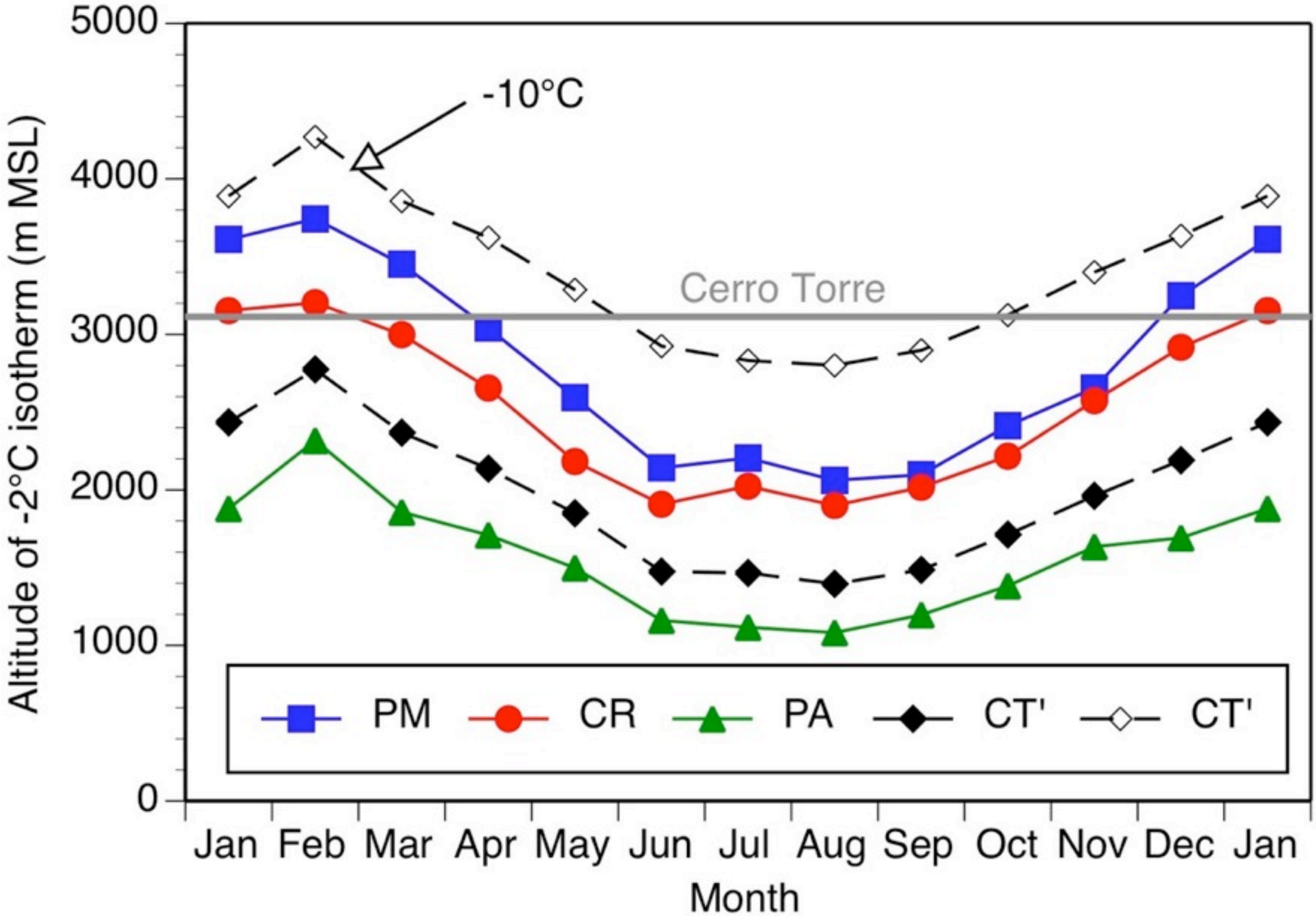
70 kPa winds


70kPa wind direction (deg)
360
270
180
90
0
a)
40
30
20
10
0
b)
PM
CR
PA
CT'
70 kPa wind speed (m s-1)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Month

Lifting condensation level

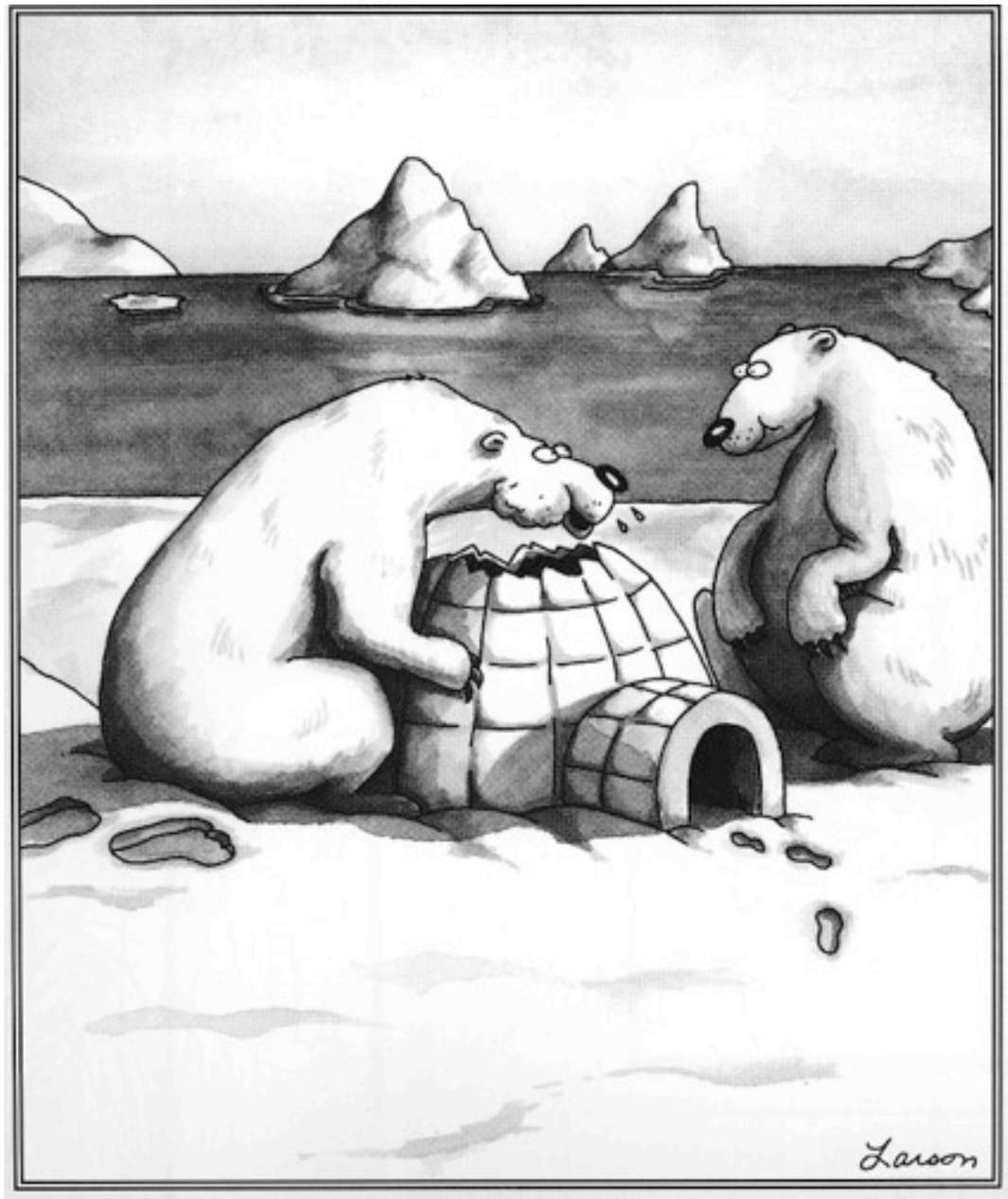


Height of -2° and -10°C isotherms



Climbing Ice Mushrooms

anchorage, surface characteristics and internal cohesion



“Oh, hey! I just love these things! … Crunchy on the outside and soft on the inside!”


Anchorage
Torre Egger
© Bjørn-Eivind Årtun

Punta Herron

FitzRoy Massif in background

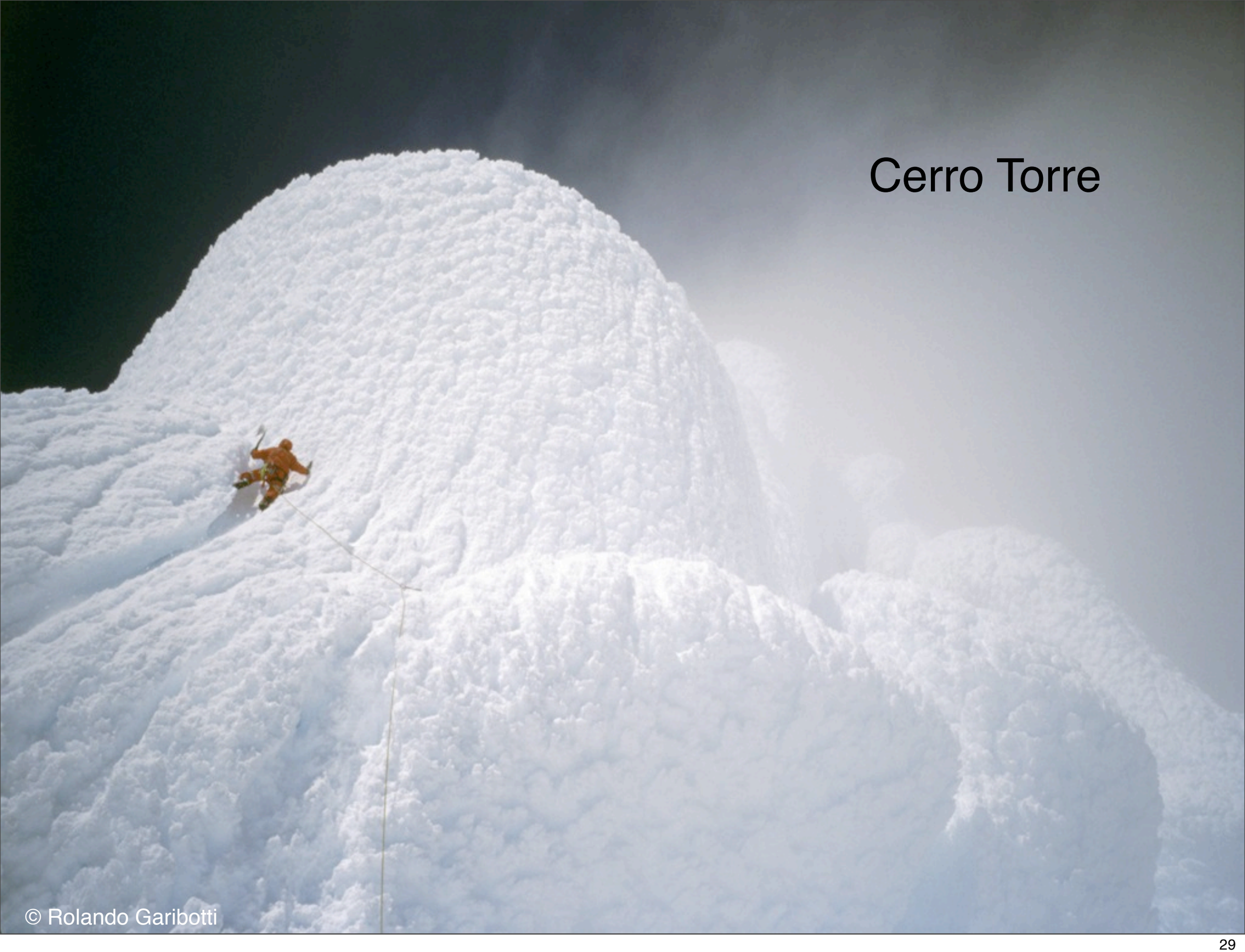
© Hayden Kennedy

Surface characteristics

© Ralf Gantzhorn

Monte Sarmiento

Cerro Torre



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Natural tunnels

Cerro Torre W Face

W Face Cerro Torre natural tunnel was climbable 2005-2008+. Absent in 2011. Reports of such tunnels date back to mid-1980s.

Colin Haley entering 50-m long natural tunnel

W face Cerro Torre

This tunnel climbable from 2005 through at least 2008. No longer present in 2011-2012.

50 m long natural mushroom tunnel

A similar tunnel was climbed on Torre Egger in 1993 by Jay Smith and partners

Internal cohesion

© Rolando Garibotti

2008, Colin Haley digging tunnel, 4 hours for 30 m.

2008, Colin Haley finishing tunnel

© Rolando Garibotti

Cerro Torre
Summit mushroom

Cerro Torre

Jorge Ackermann digging upper part of a tunnel/half pipe in CT's last mushroom

© Rolando Garibotti

© Cullen Kirk

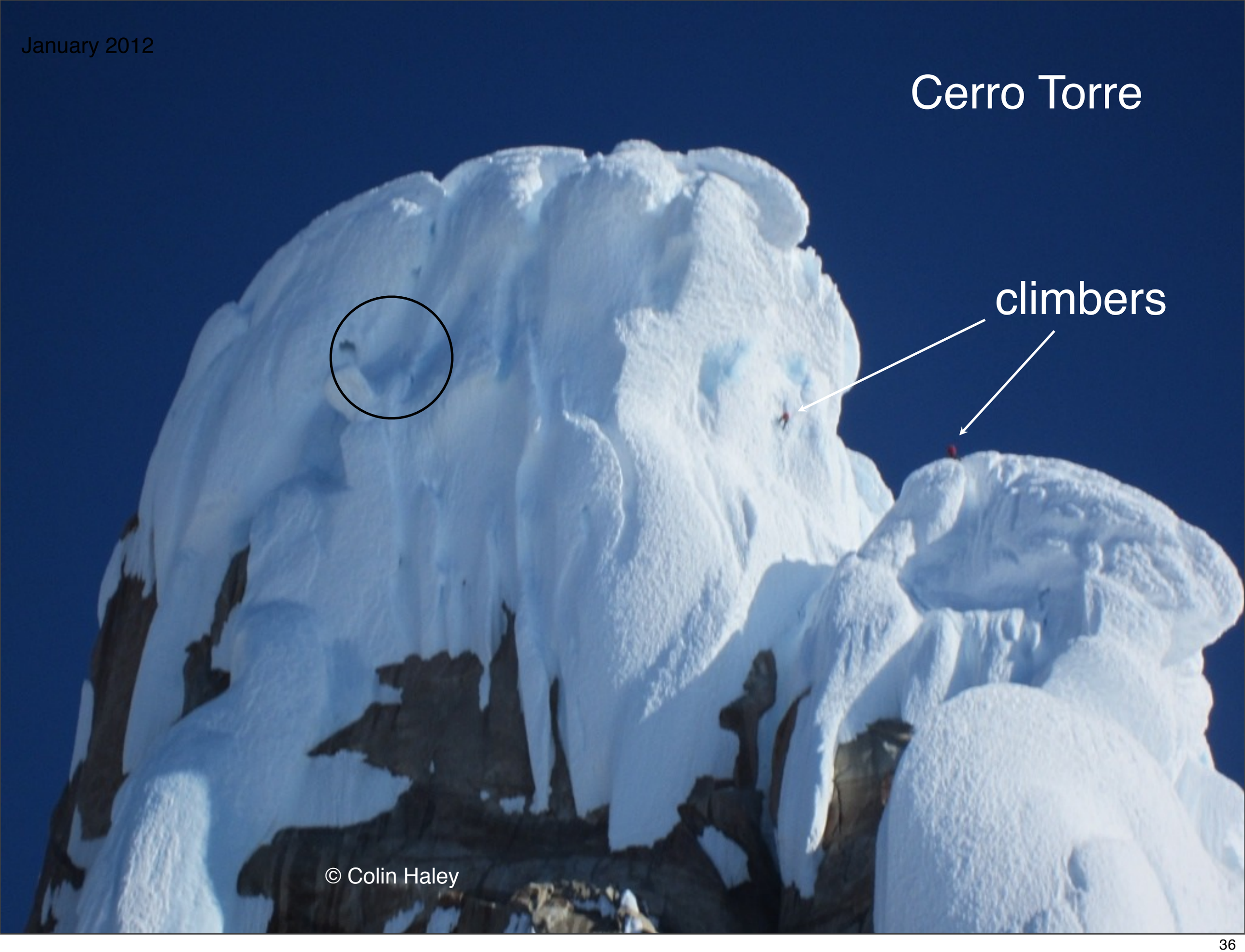
Hazards

Torre Egger

January 2012

Cerro Torre

climbers



ice mushrooms

internal

ice metamorphism

external

crusts
phase changes
collapses

synoptic, seasonal and interannual effects

firmament-attachment
topology -ridges, summits
isolated peaks
terrain channels
terrain relief
SST
distance to ocean

topography

phase changes
other hydrometeors
hard rime
droplet size distribution
cloud formation
aerosol spectrum

cloud microphysics

tunnel formation
wind channeling
turbulence
wakes
windward accretion
local vertical motions
large-scale vertical motions

airflow dynamics

Why grow upwind? overhang? grow vertically?

Summary

- Rime mushroom examples and definition
- Physics: super-cooled cloud droplets and strong winds
- Global locations of reports
- S. Patagonia - a favored location for rime mushrooms
  - Extremely strong, consistently westerly winds
  - High frequency of clouds with low bases
  - High frequency of super-cooled cloud droplets
- Examples of obstacles to mountain climbing
  - Texture, internal cohesion and anchorage
  - Half-pipes and natural tunnels

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