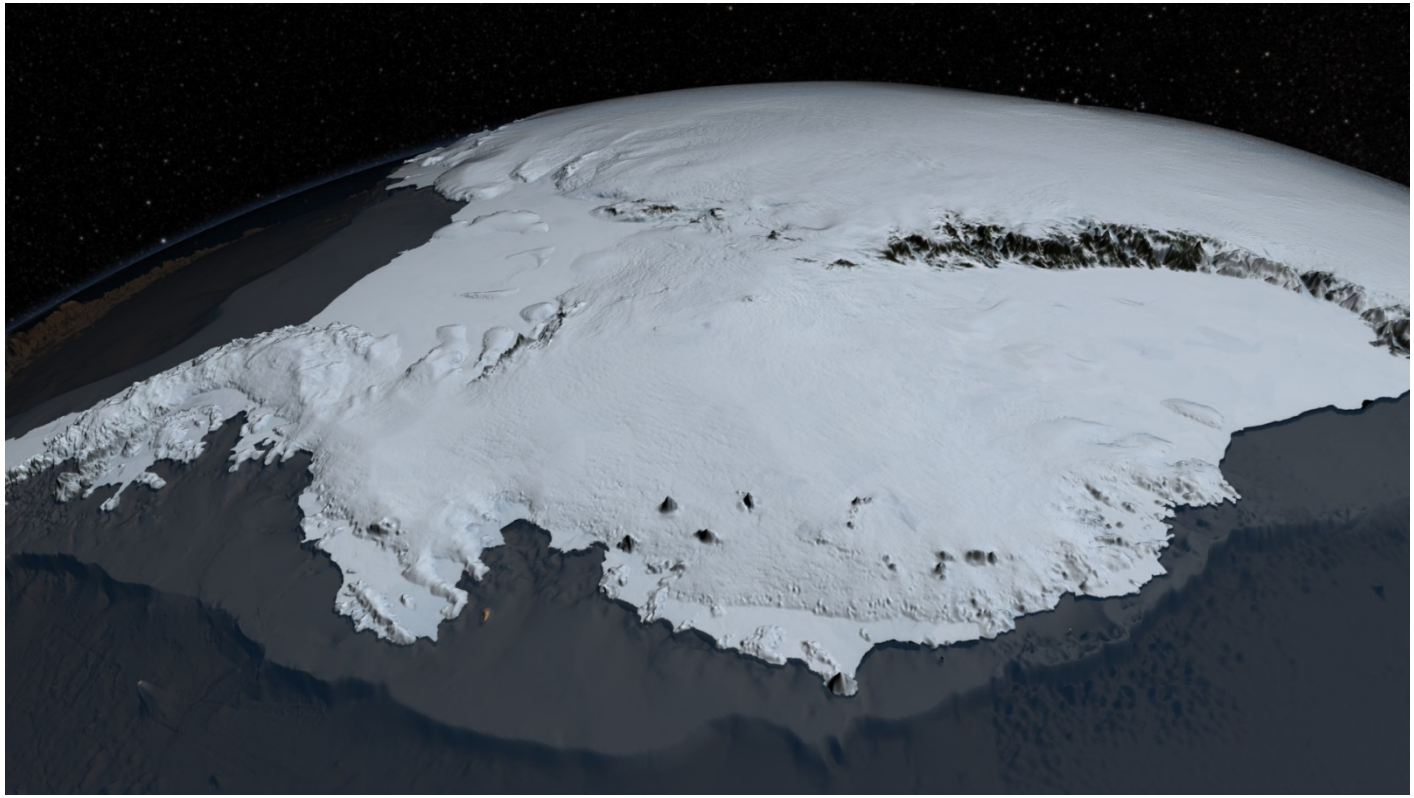
Ice Sheet Origins and Modern Climate

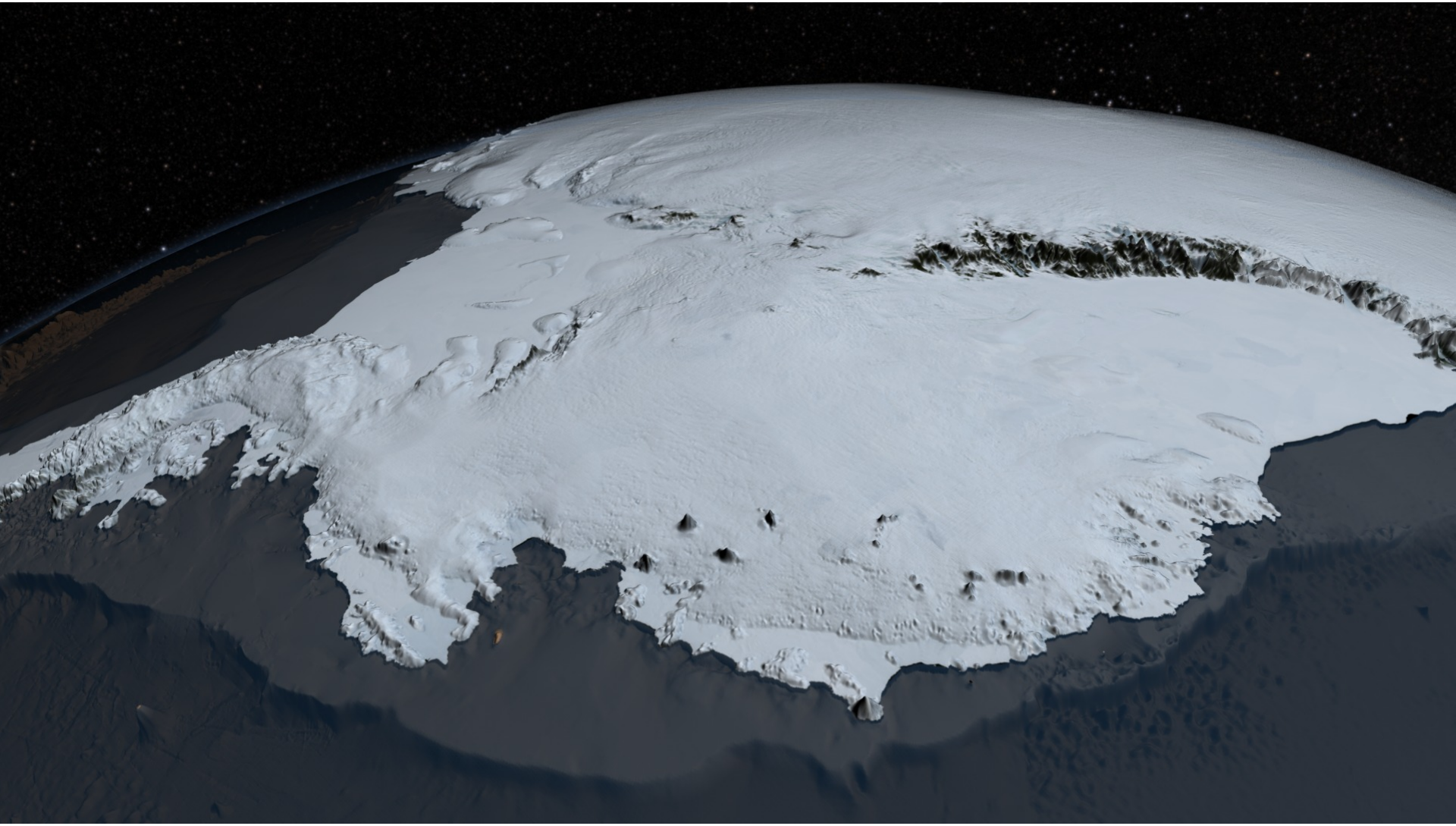
By 35 mya, the continents had shifted to their present positions

As the ice sheets over Antarctica began forming, it was not until ~14 mya when it reached its present size and dimensions

Sediment cores at the bottom of Prydz Bay have glacial boulders and pebbles carried by glaciers deposited there ~36-40 mya (Hambrey et al. 1991)

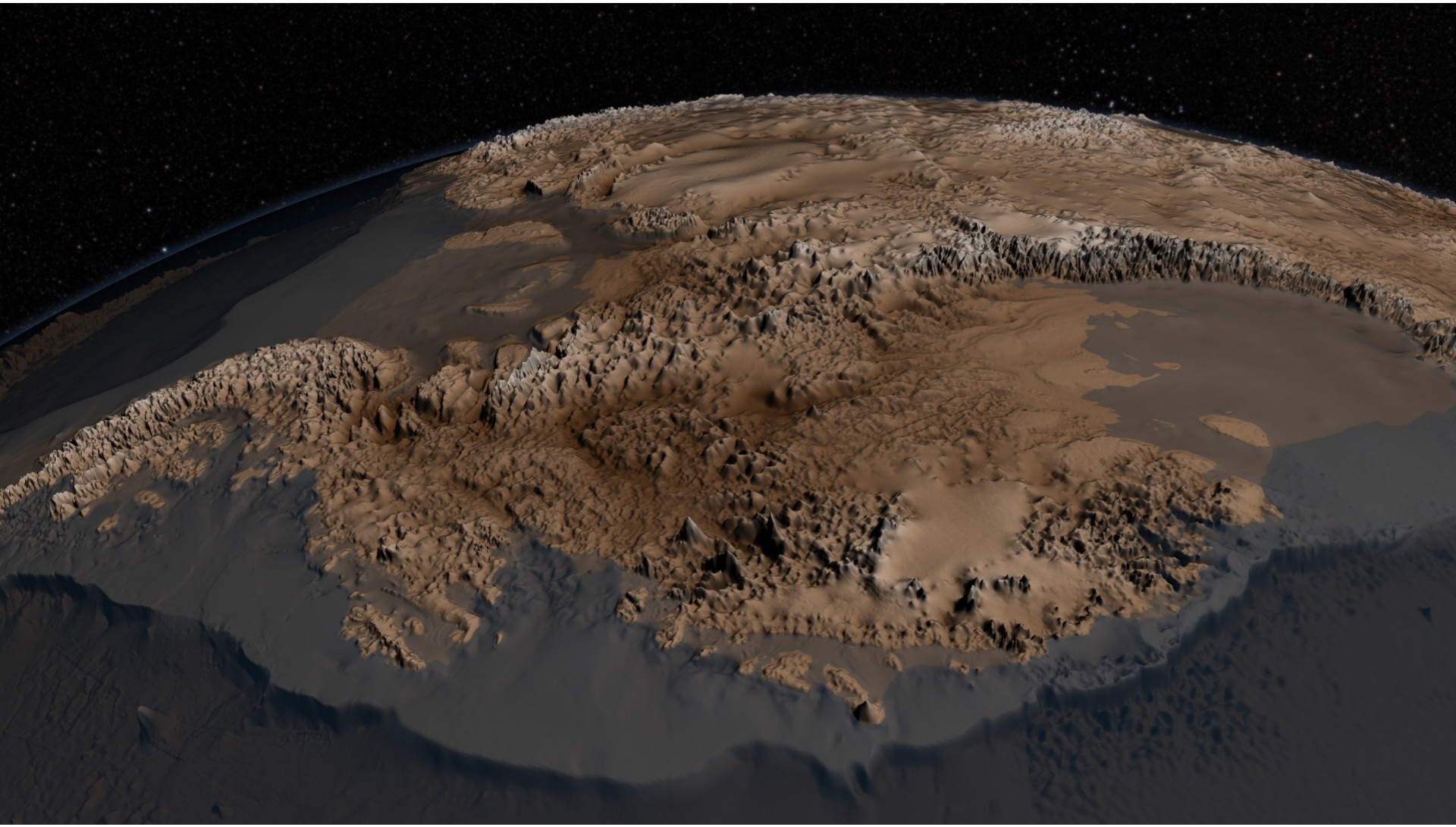


The ice sheet is over 4 km thick in places and covers 14 million km^2
It is the largest ice mass on earth and its weight actually pushes the Antarctic continent downward
When glaciers melt, there is isostatic uplift of the land as the weight is removed



http://www.nasa.gov/topics/earth/features/antarctic-map.html

The ice sheet represents 60-80% of fresh water on earth
If the ice melted, sea level would rise ~60-70 m



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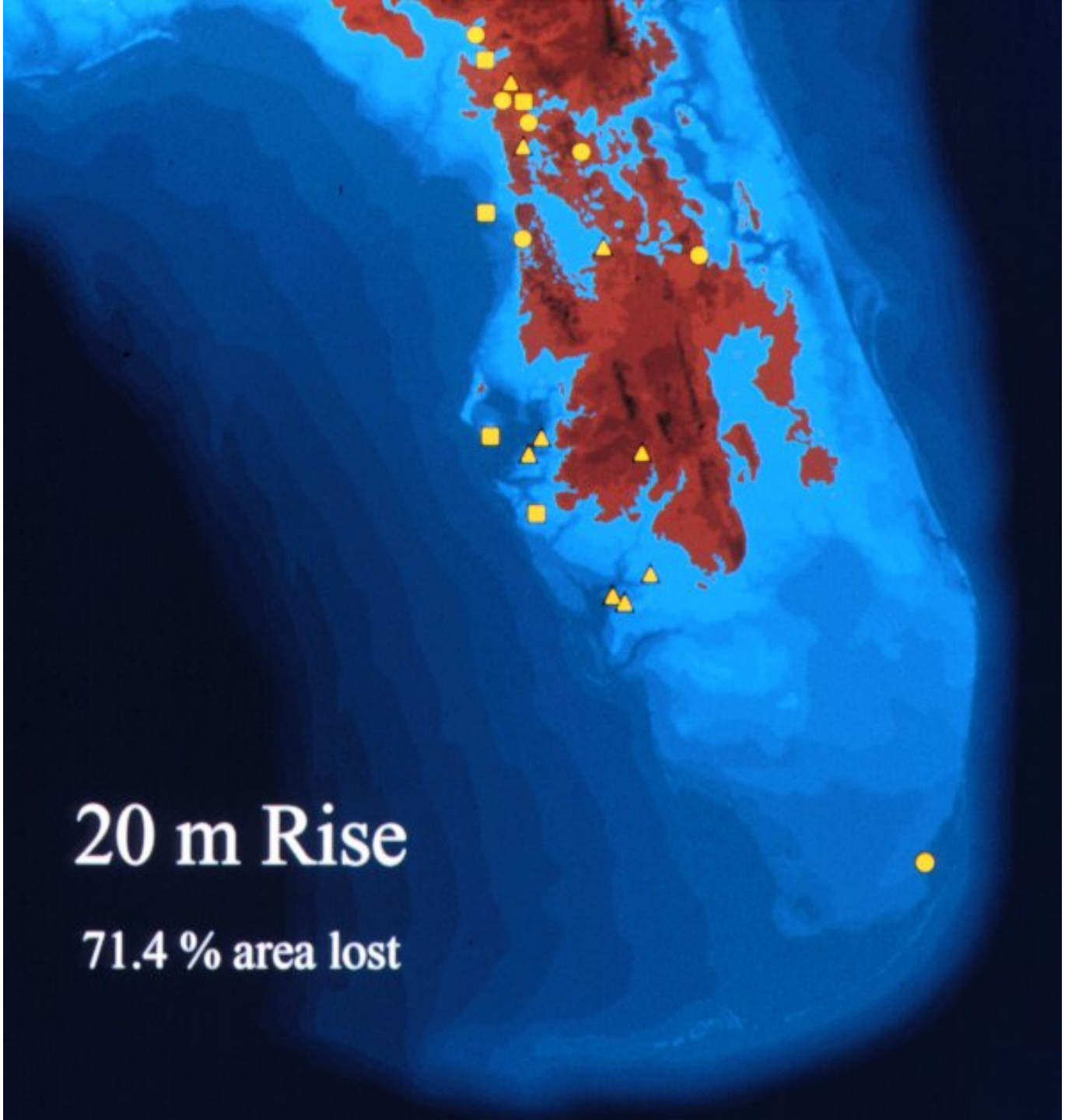
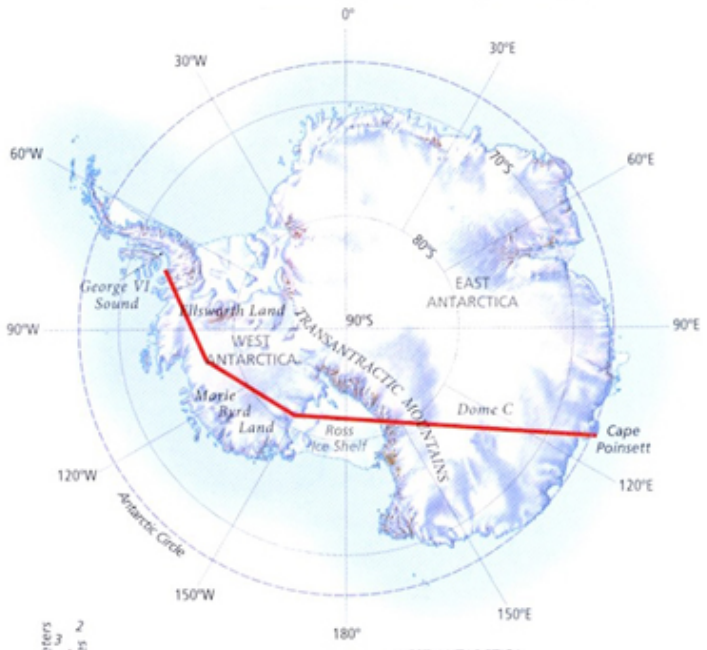
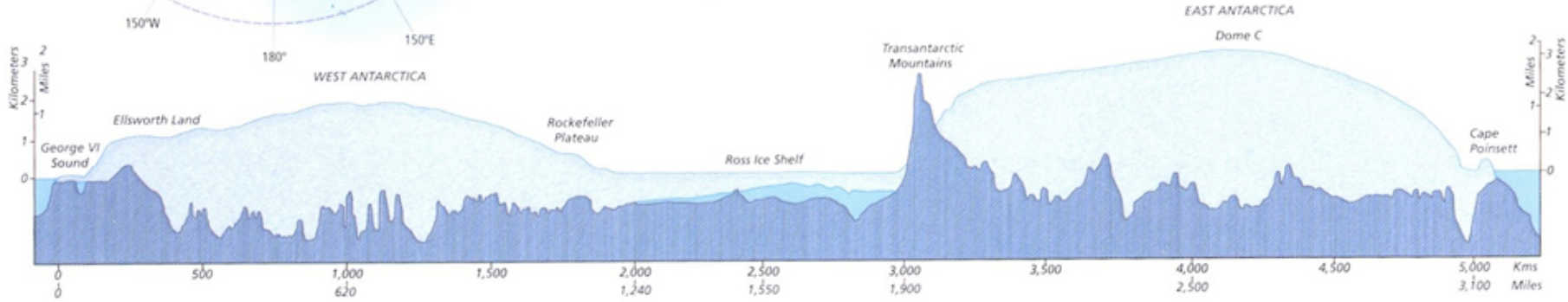

20 m Rise
71.4 % area lost

Most of the West Antarctic Ice Sheet rests on rock below sea level



A Cross-section of Antarctica

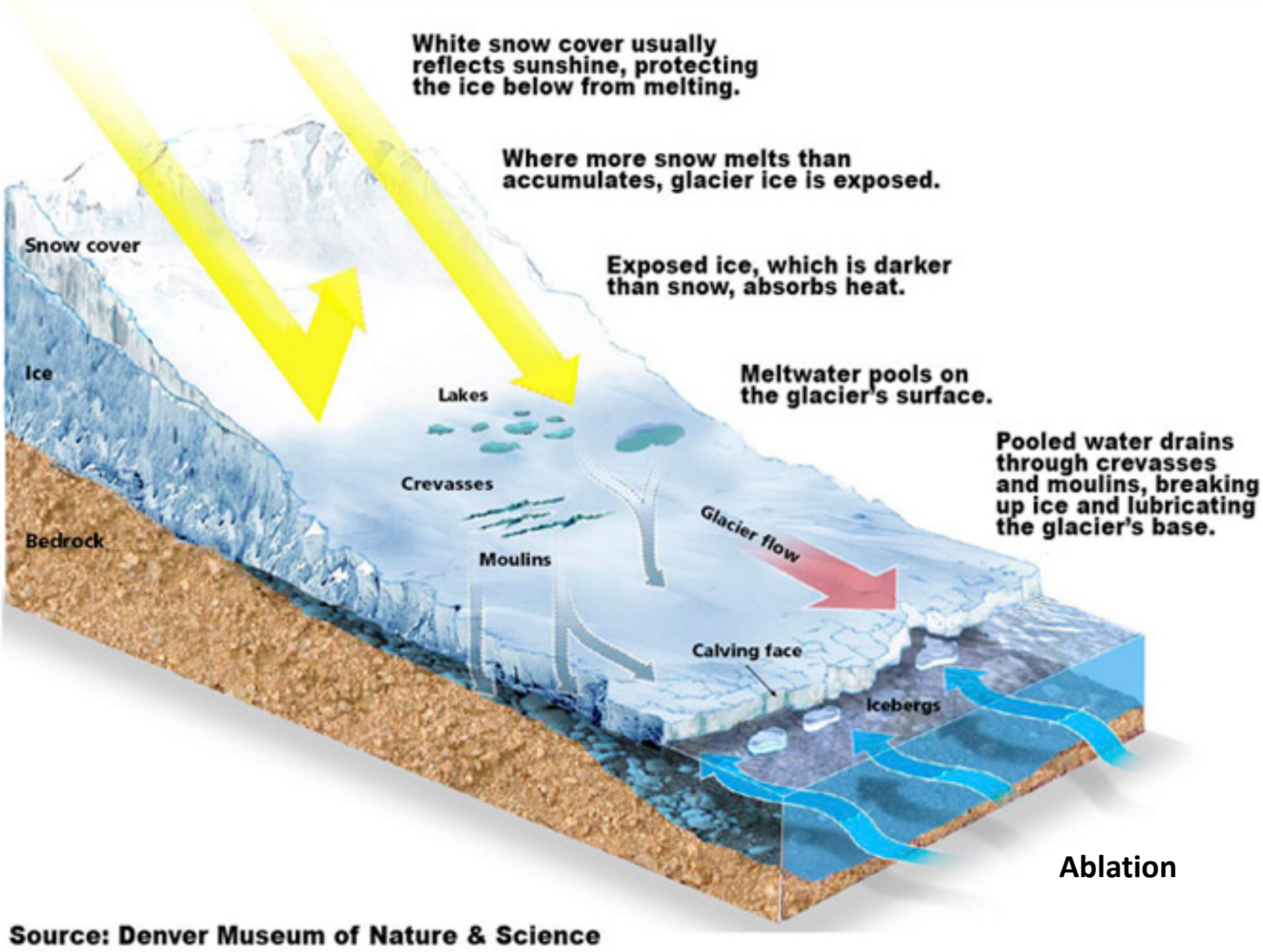
The shape of Antarctica, with the exception of the Transantarctic Mountains and a few locations around the coast, is lost under a blanket of ice. In some locations in East Antarctica, the ice is up to several miles thick.



Although inland Antarctica is a cold desert, the little snowfall that does occur is enough, over time, to build up into the ice sheets

Ice and glaciers move and flow, slowly over time, with gravity

Thus, the average age of ice in East Antarctica is 125,000 yrs, and only 45,000 years in West Antarctica


White snow cover usually reflects sunshine, protecting the ice below from melting.
Where more snow melts than accumulates, glacier ice is exposed.
Snow cover
Exposed ice, which is darker than snow, absorbs heat.
Ice
Meltwater pools on the glacier's surface.
Lakes
Pooled water drains through crevasses and moulins, breaking up ice and lubricating the glacier's base.
Crevasses
Bedrock
Glacier flow
Moulins
Calving face
Icebergs
Source: Denver Museum of Nature & Science

Ablation

Glaciers explained

Glacial Movement

Quiz

1. What features characterize or define a glacier?

2. What factors determine the speed at which a glacier moves?

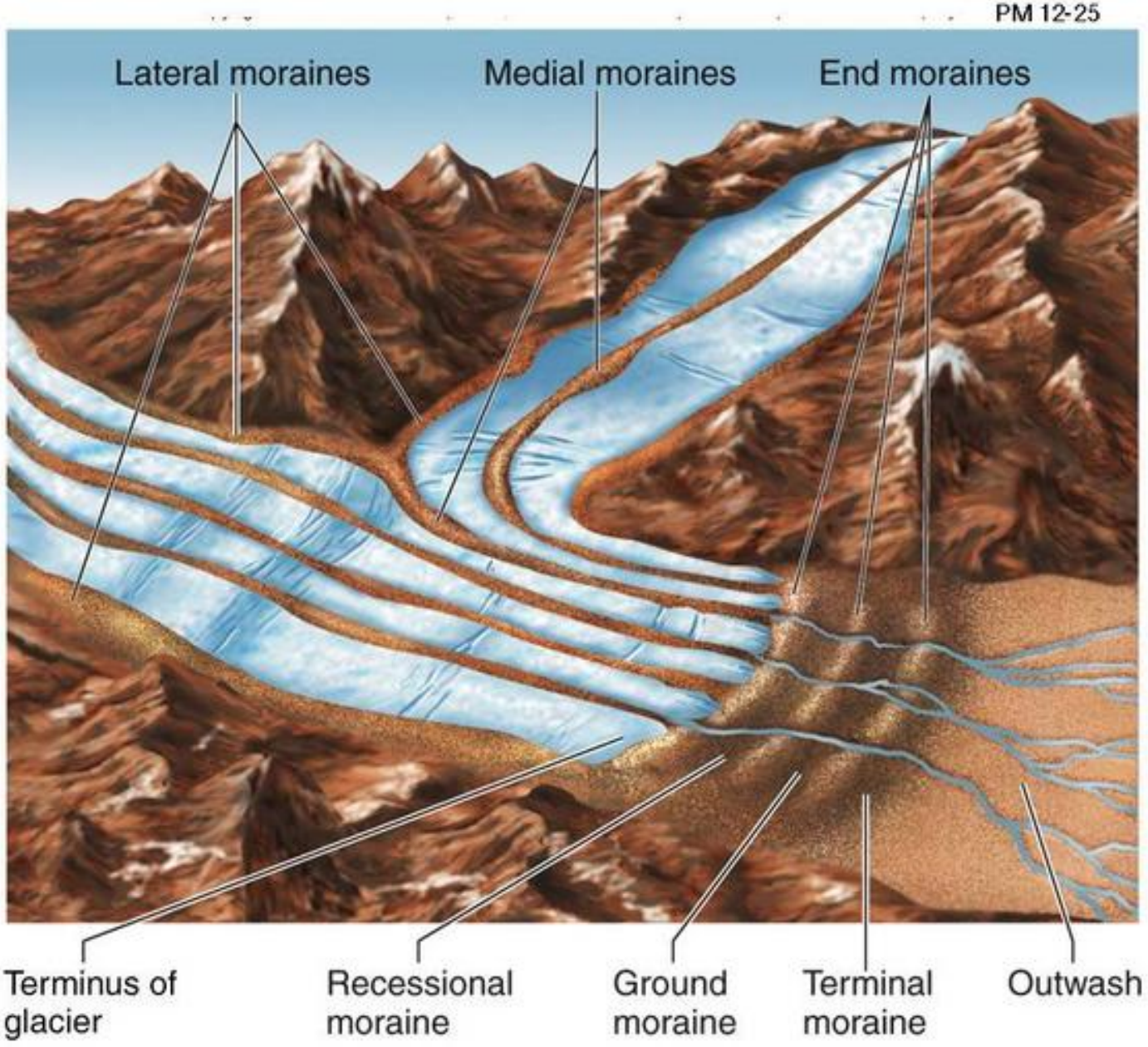
3. What causes blue ice?

4. What is isostatic uplift?

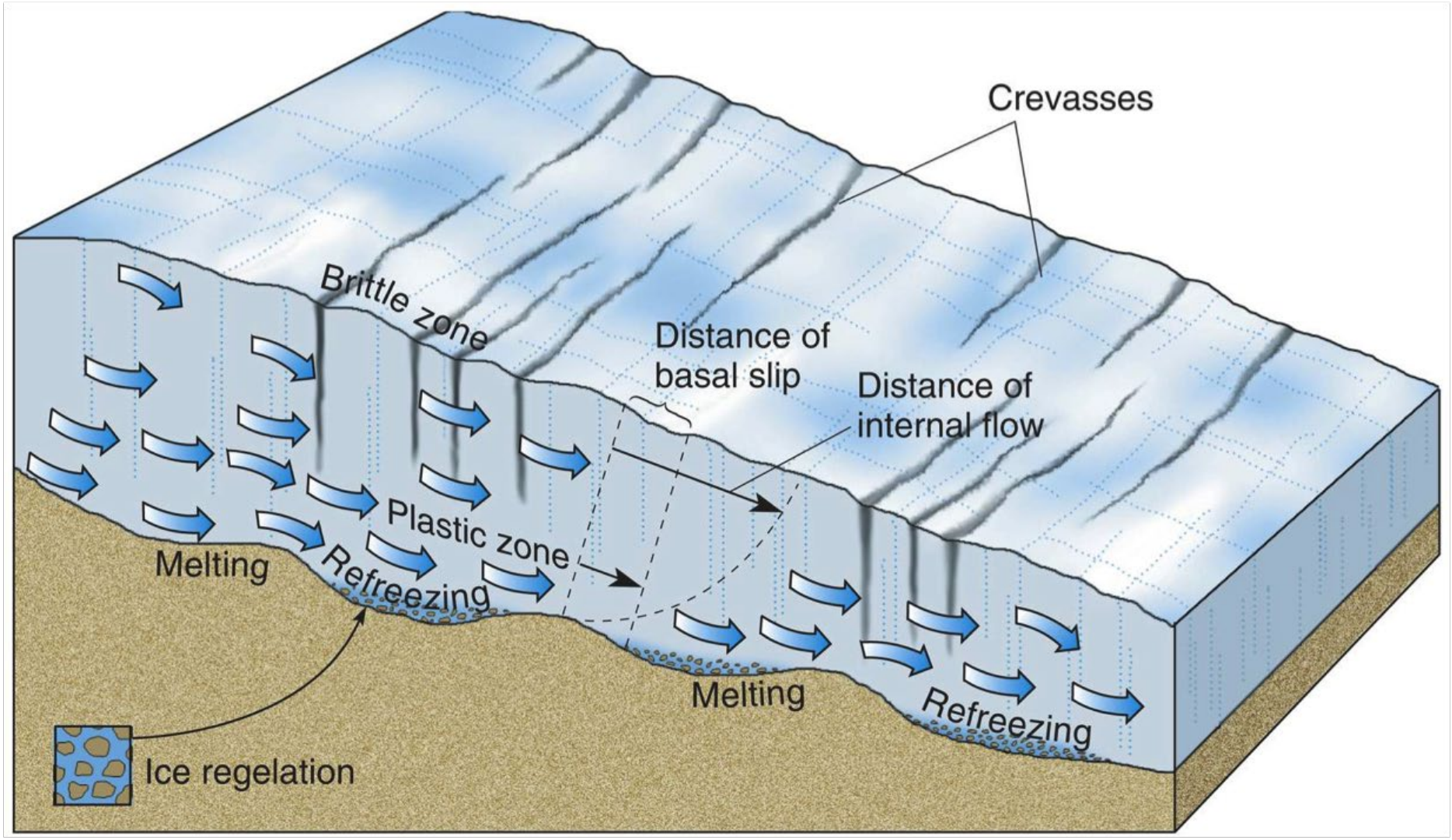
Geologic history is written on the landscape, you just need to know how to read it

Glaciers also can carry debris (boulders, pebbles) for hundreds of miles

https://onlinegeography.wikispaces.com/Glacial+Landforms

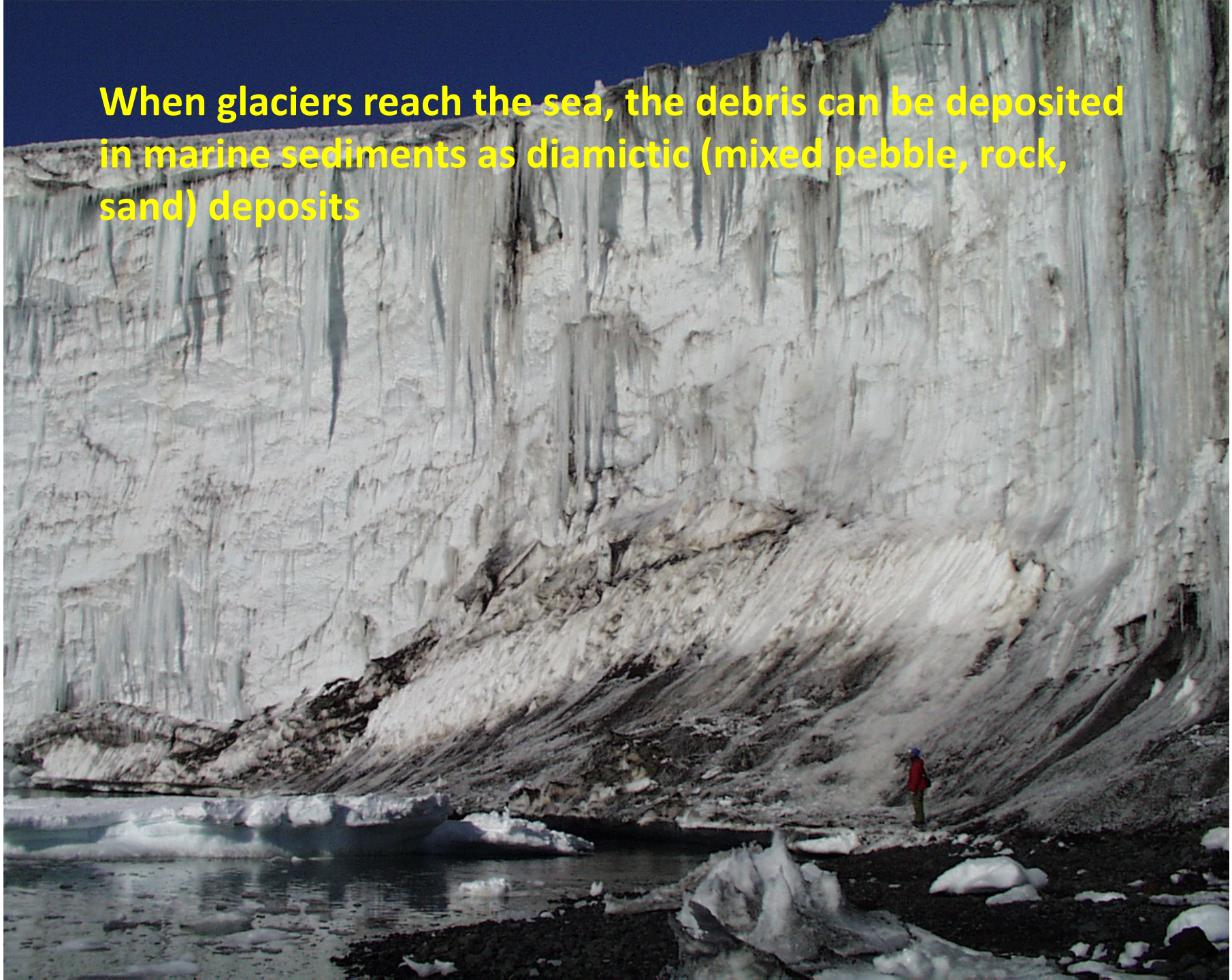



Glacial crevasses



www.studyblue.com

Glacial Erratics


When glaciers reach the sea, the debris can be deposited in marine sediments as diamictic (mixed pebble, rock, sand) deposits

Drill core data

Glacial diamictite

Diatomite overlain by glacial diamictite showing deformation in the diatomite and mixing of it into the diamictite, from 192.49-192.80mbsf.
Photo by ANDRILL
http://andrill.org/report/6.html

Interglacial diatomite

Well laminated diatomite with cream-colored monospecific diatom layer. Topmost diatomite is finely bioturbated and a lonestone occurs in the lower interval.
Photo by Ross Powell

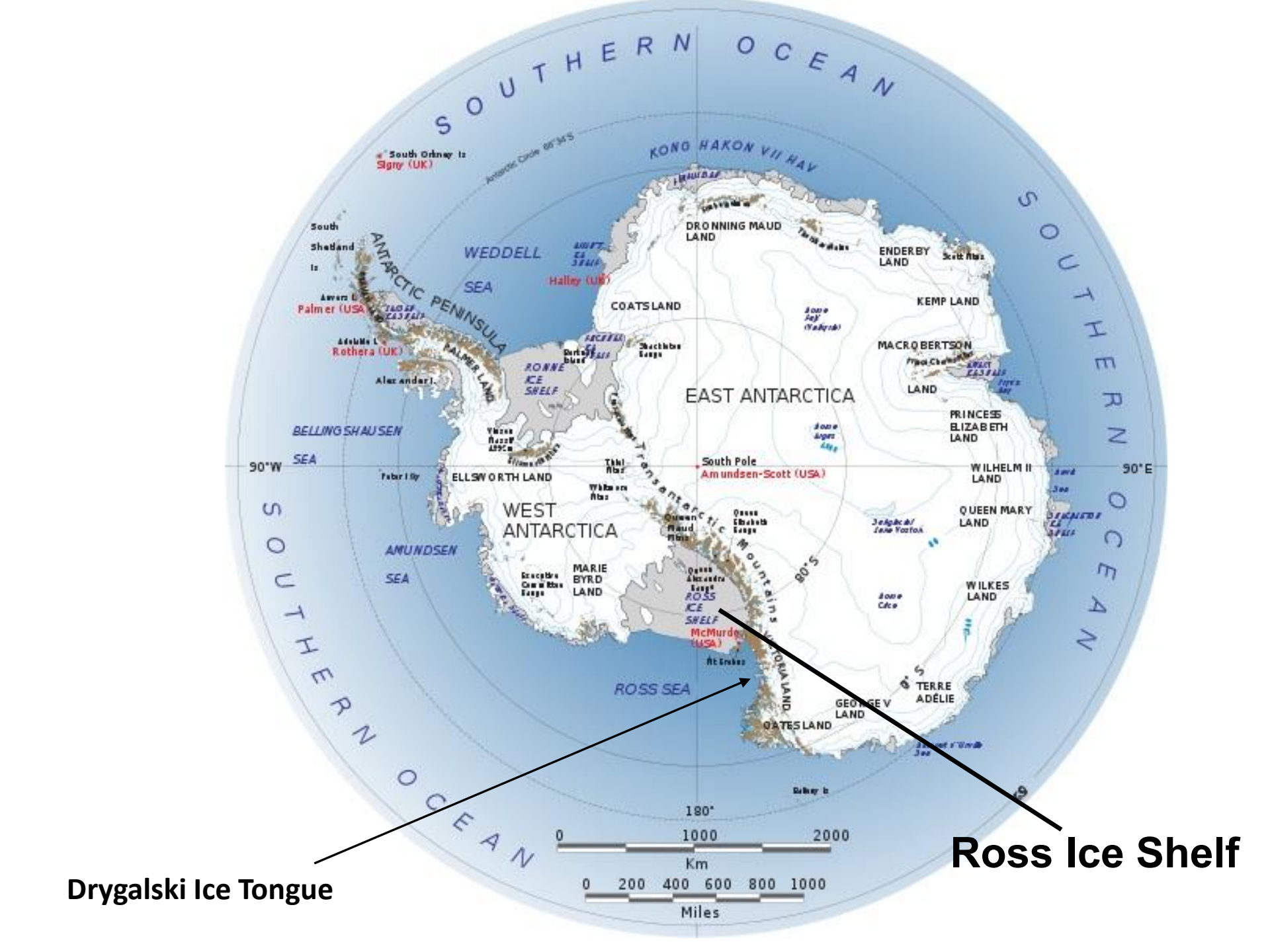
http://andrill.org/report/ - 12/2/06

Diamictic layers in marine sediment cores provide evidence for former glacial activity.

The debris is deposited either as glaciers calve and debris floats away, deposited when ice melts, (**Ice Rafted Debris**),

Or by **ice shelves**, when a glacier keeps growing into the sea, scouring the bottom as it moves forward.

Isotopic dating of marine sediments at Prydz Bay and in the Ross Sea suggest glaciers, and the East Antarctic Ice Sheet, were present ~35 mya



Drygalski Ice Tongue

Ross Ice Shelf


Ross Ice Shelf


OCEANWIDE
EXPEDITIONS
5

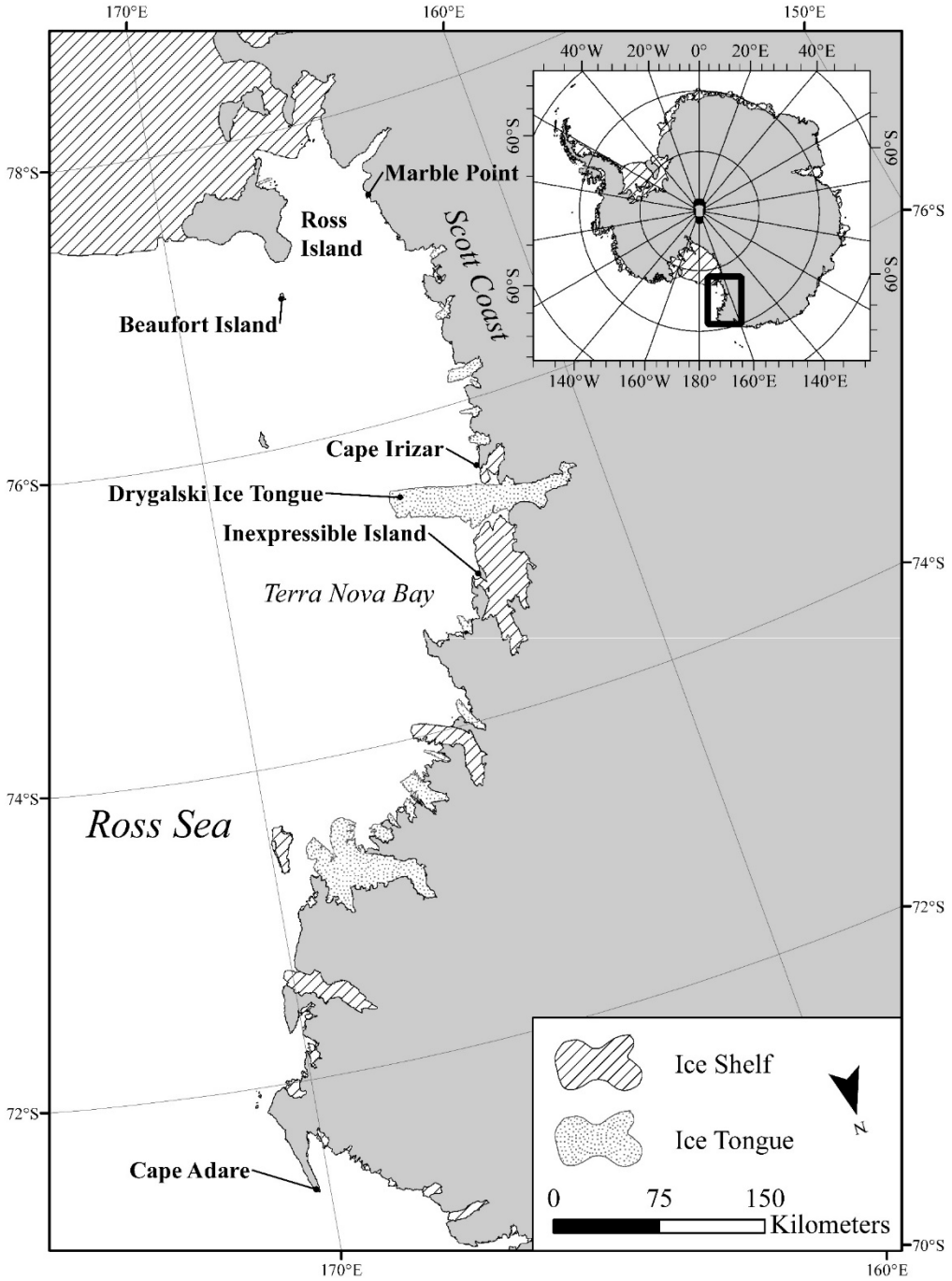

Alexander I.
ICE SHELF
EAST ANTA
SHAUSEN
Vinson Massif 4892m
Ellsworth Mtns
Thiel Mtns
South Pole
Amundsen-Scott (US
Peter I Øy
ELLSWORTH LAND
Whitmore Mtns
Transantarctic Mountains
WEST ANTARCTICA
Queen Maud Mtns
Queen Elizabeth Range
AMUNDSEN SEA
MARIE BYRD LAND
Executive Committee Range
Queen Alexandra Range
ROSS ICE SHELF
McMurdo (USA)
Mt Erebus
VICTORIA LAN
ROSS SEA

Rapid movement of a glacier into the ocean can form an *ice tongue*

Glacial ablation

Tabular iceberg from an ice shelf

As glaciers melt, old penguin breeding sites may be preserved below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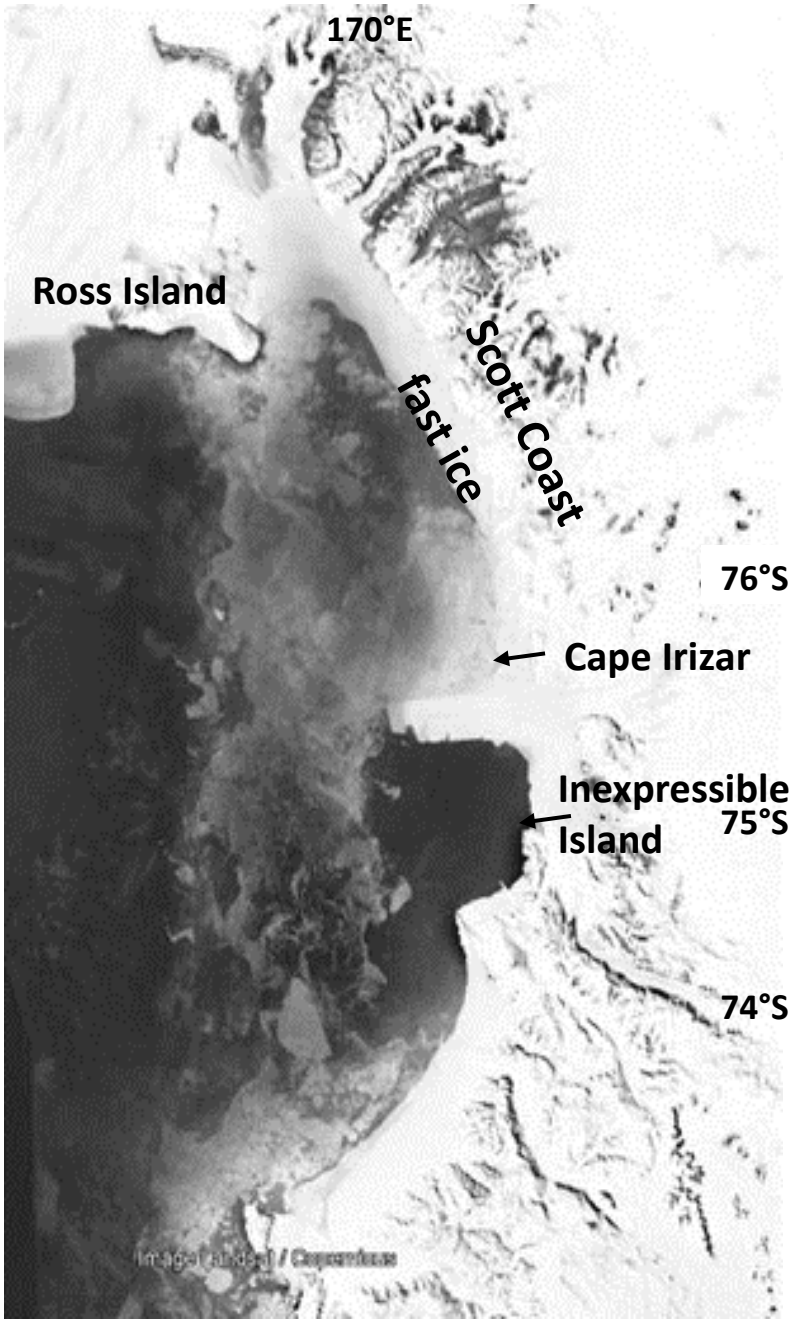
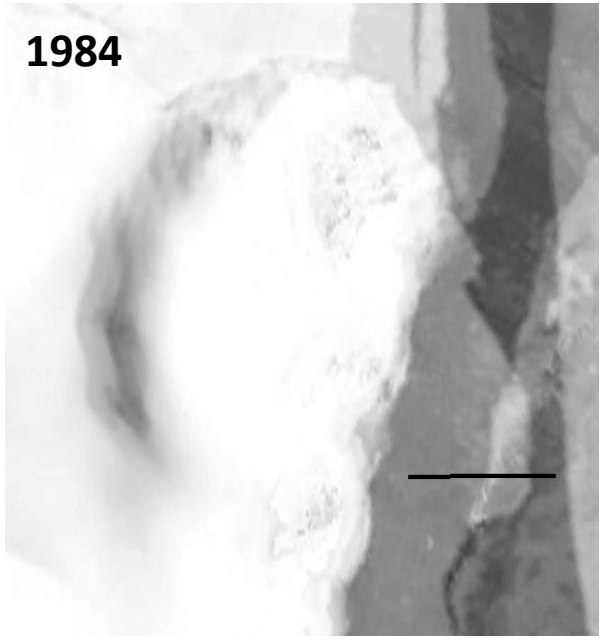
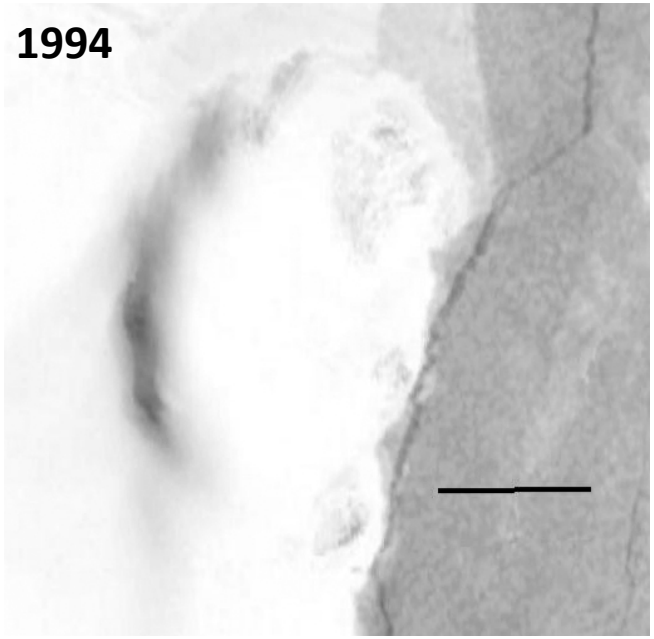
Marble Point
Ross Island
Scott Coast
Beaufort Island
Cape Irizar
Drygalski Ice Tongue
Inexpressible Island
Terra Nova Bay
Ross Sea
Cape Adare
40°W 20°W 0° 20°E 40°E
140°W 160°W 180° 160°E 140°E
60°S
Ice Shelf
Ice Tongue
N
0 75 150
Kilometers


170°E
Ross Island
Scott Coast
fast ice
76°S
Cape Irizar
Inexpressible Island
75°S
74°S


Cape Irizar, Ross Sea


1984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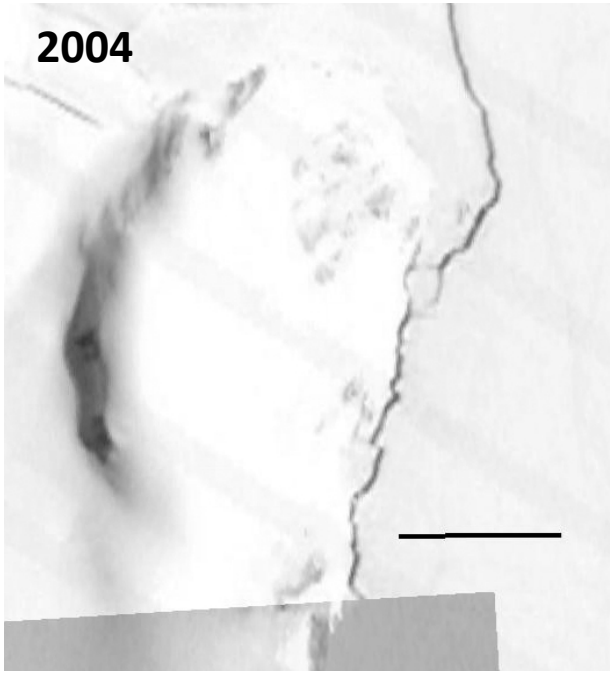
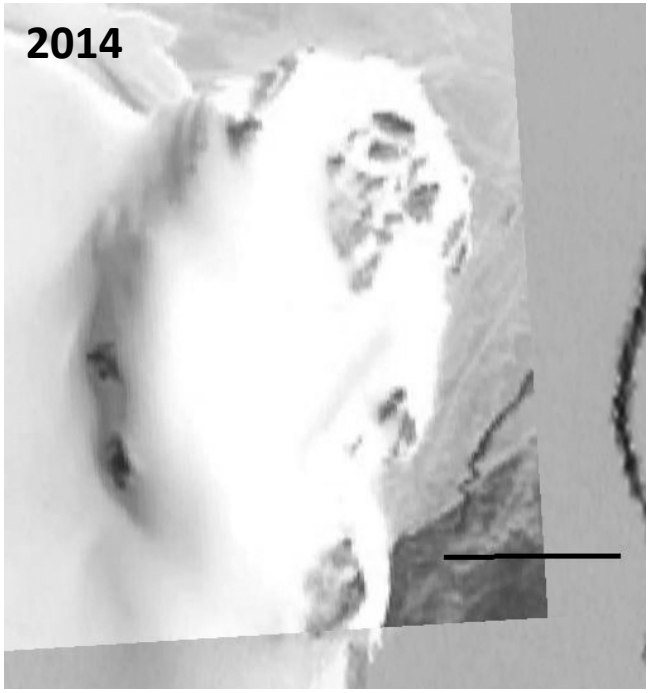

2004


2014

Quiz

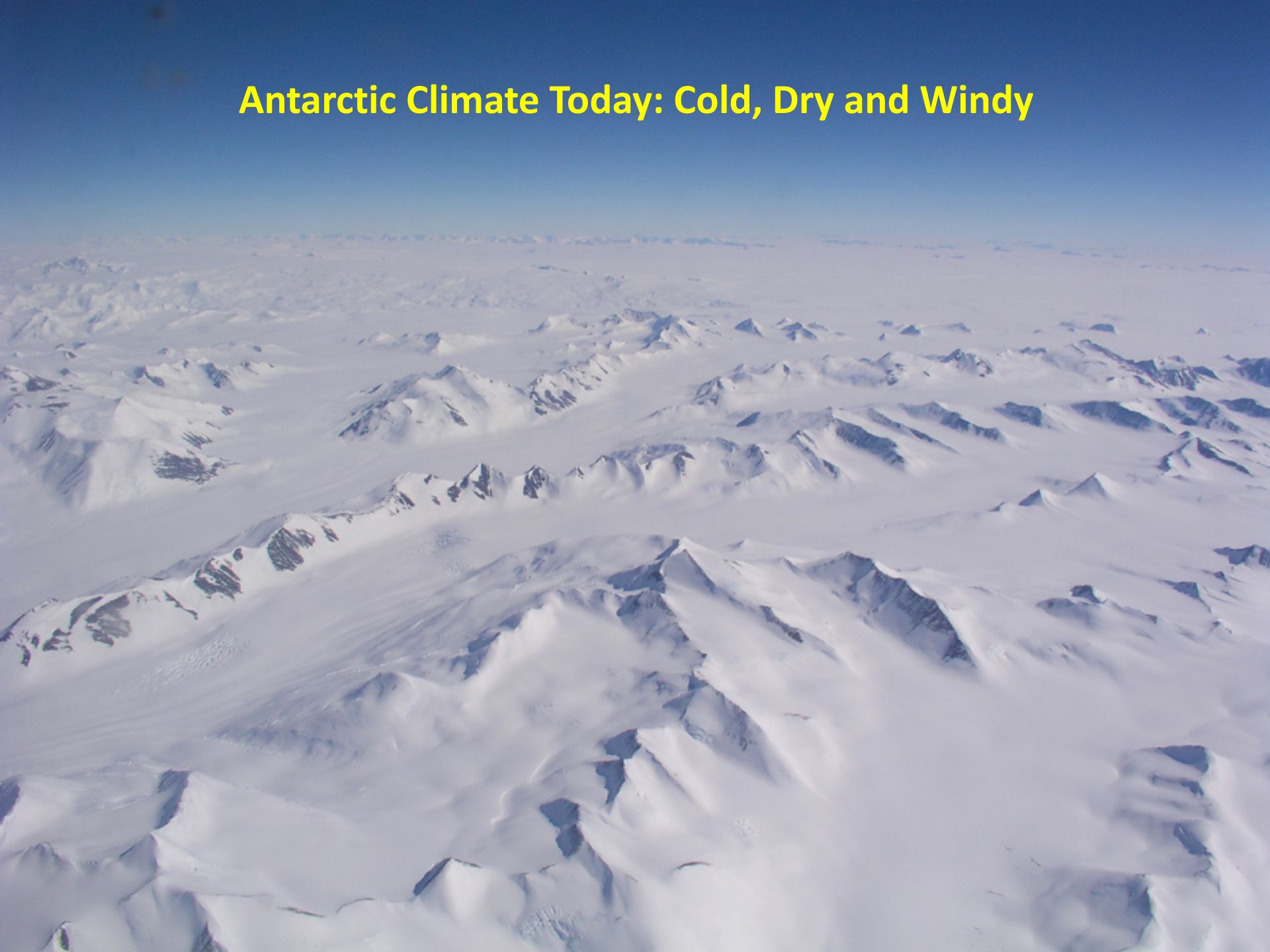
1. What are glacial moraines, erratics, and striations?

2. What is ice rafted debris and diamictic sediment and how do they relate to glacial history?

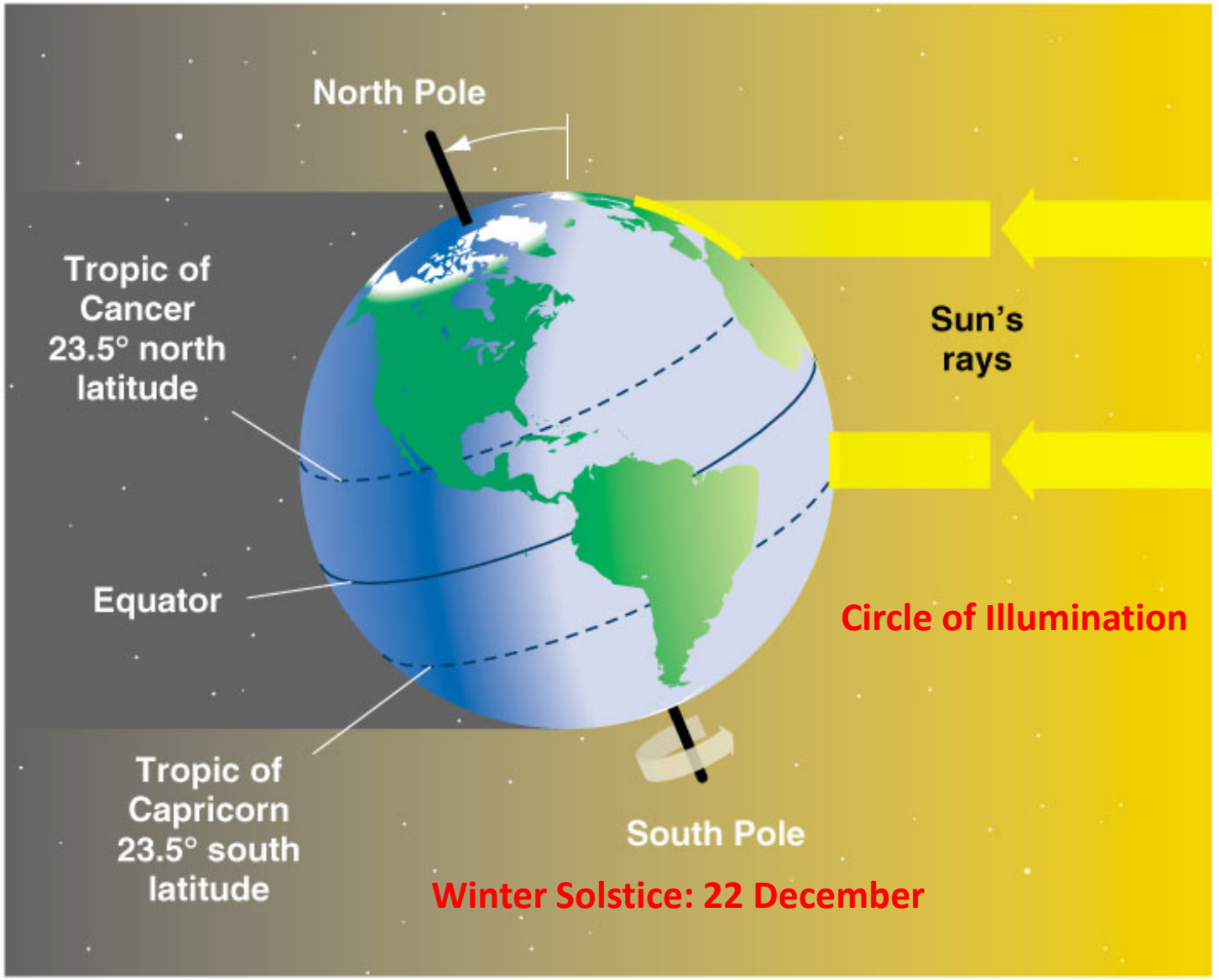
3. What is the difference between an ice shelf and sea ice? An ice tongue?

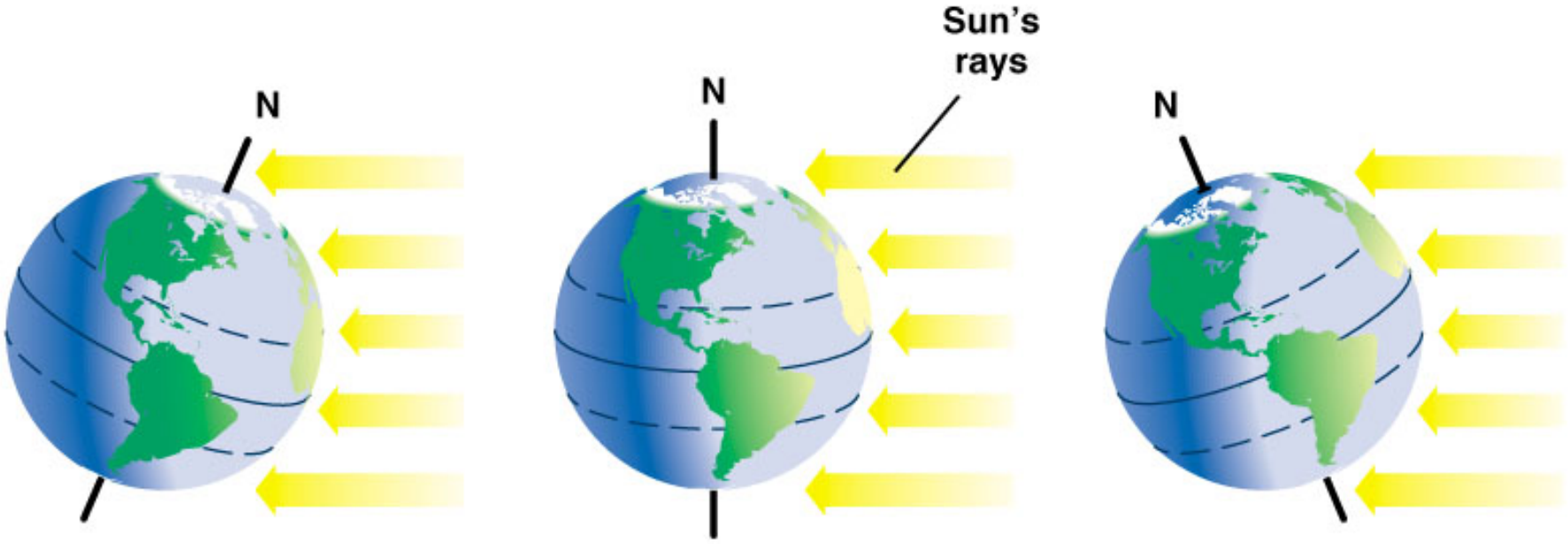
4. What is a tabular ice berg?

Antarctic Climate Today: Cold, Dry and Windy

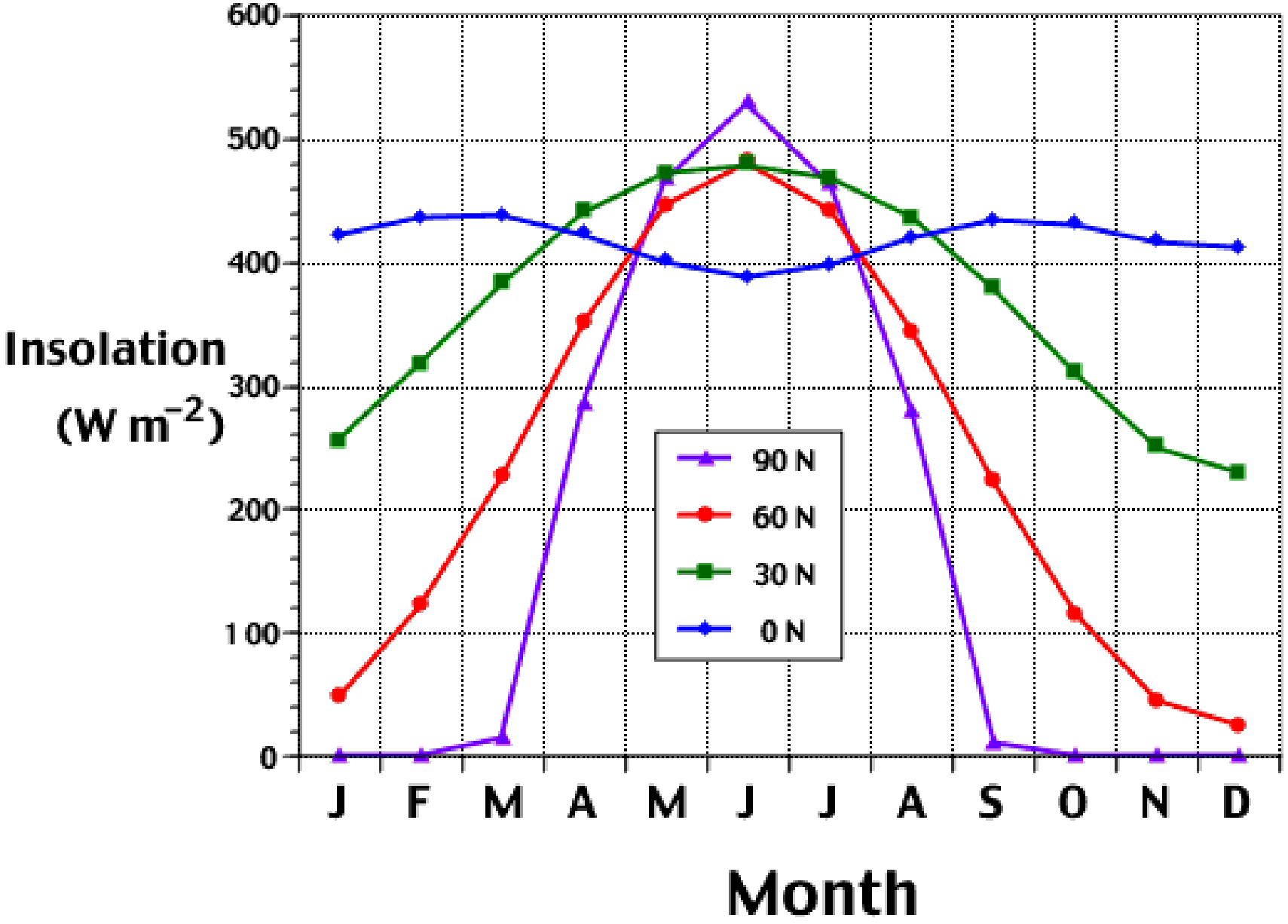


Coldest temperatures: solar radiation and albedo





21 March and 22 Sept.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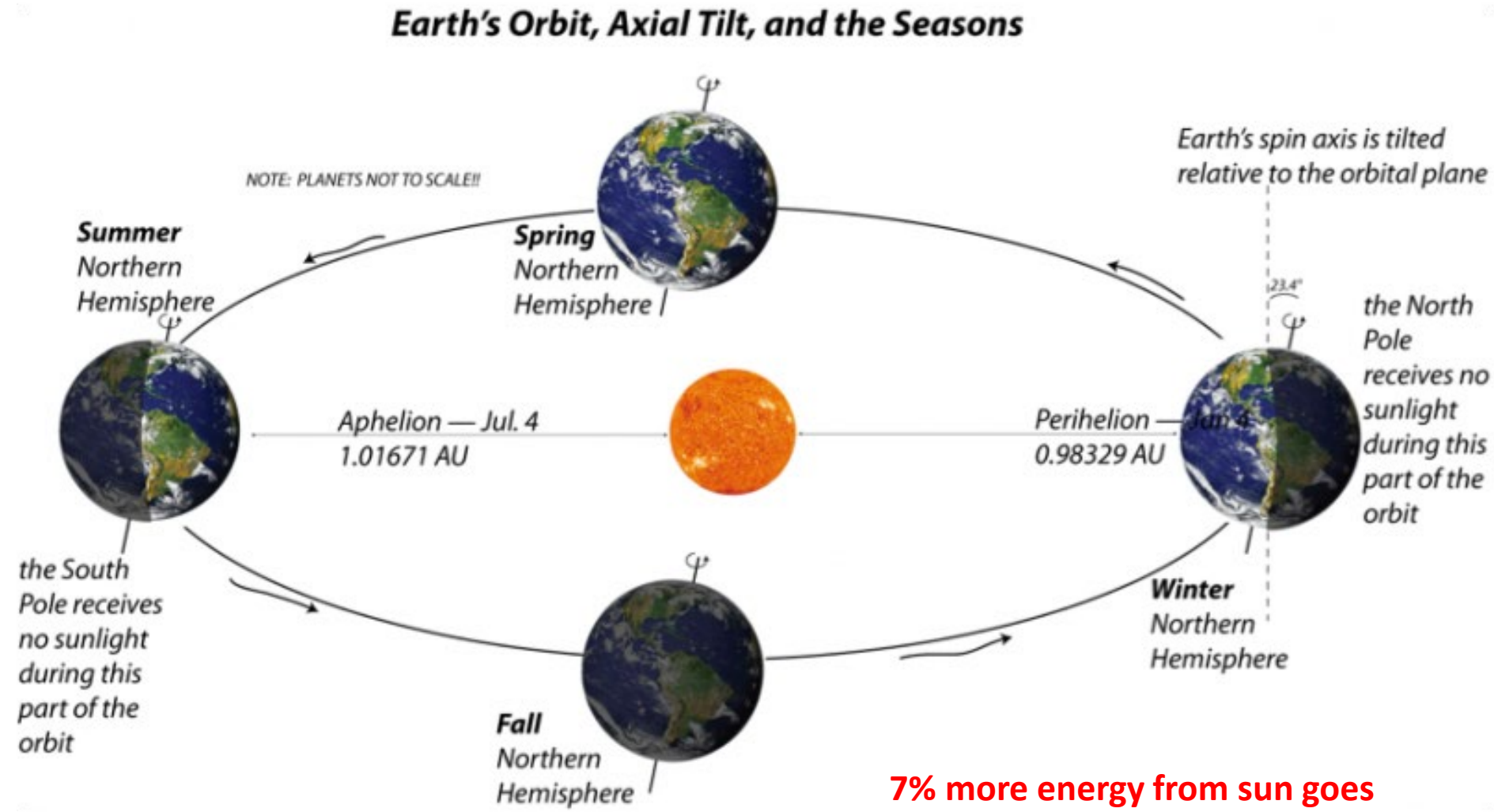
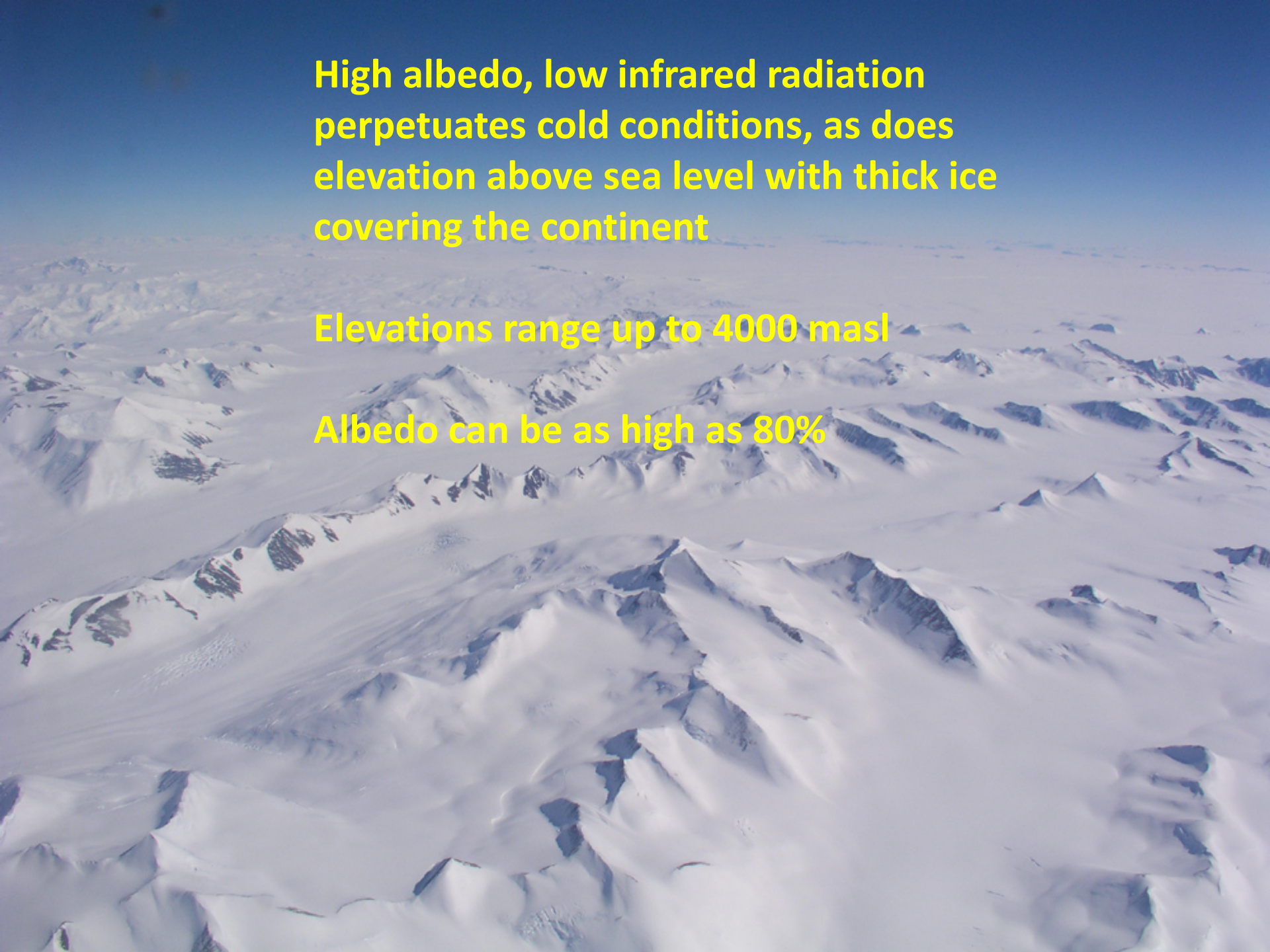


7% more energy from sun goes to the Antarctic than the Arctic



High albedo, low infrared radiation perpetuates cold conditions, as does elevation above sea level with thick ice covering the continent

Elevations range up to 4000 masl

Albedo can be as high as 80%

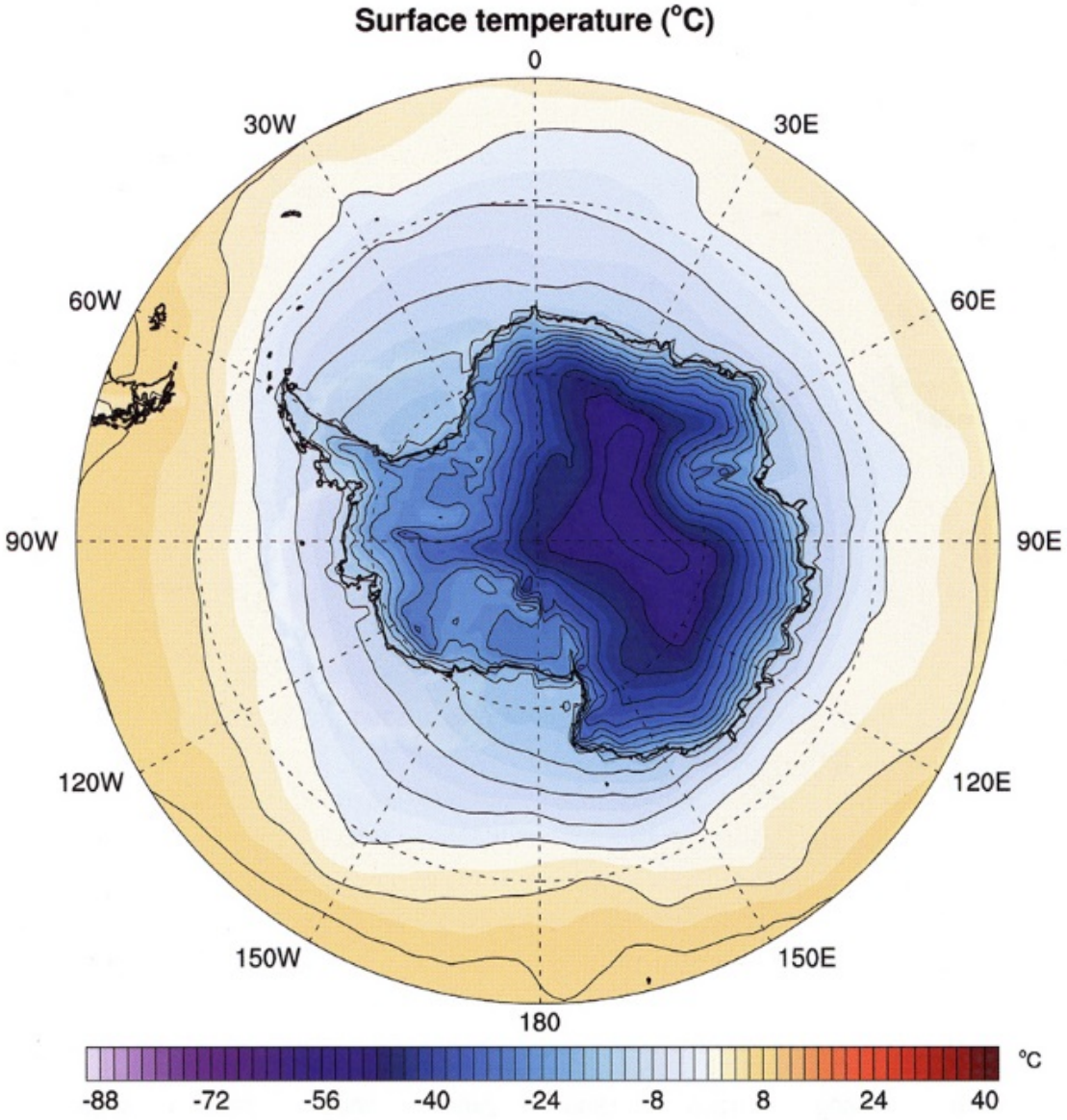


Figure 4.8 Map of average annual surface temperature in Antarctic. (Credit: Matthew Higgins, Cooperative Institute for Research in Environmental Sciences, University of Colorado)

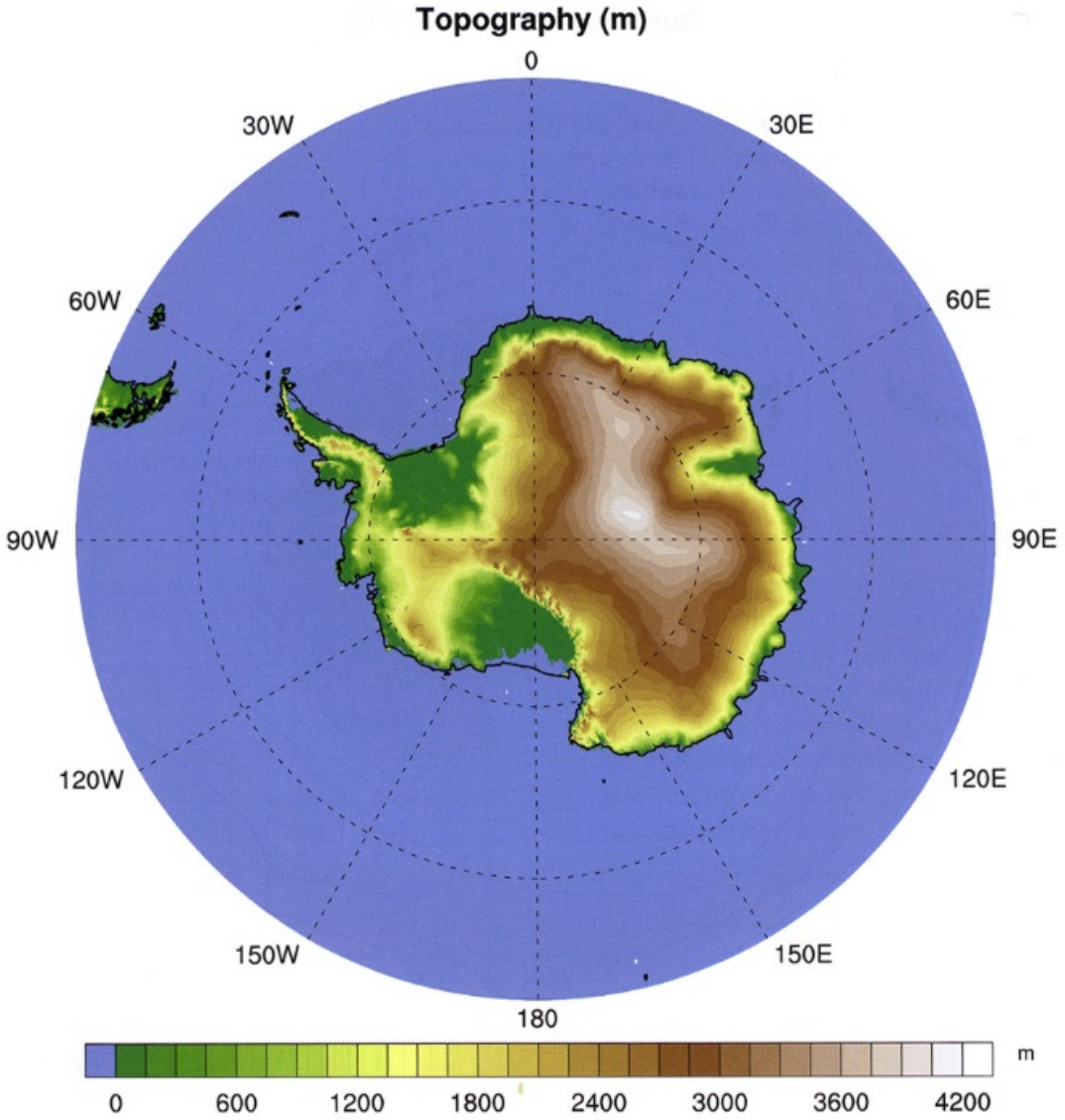
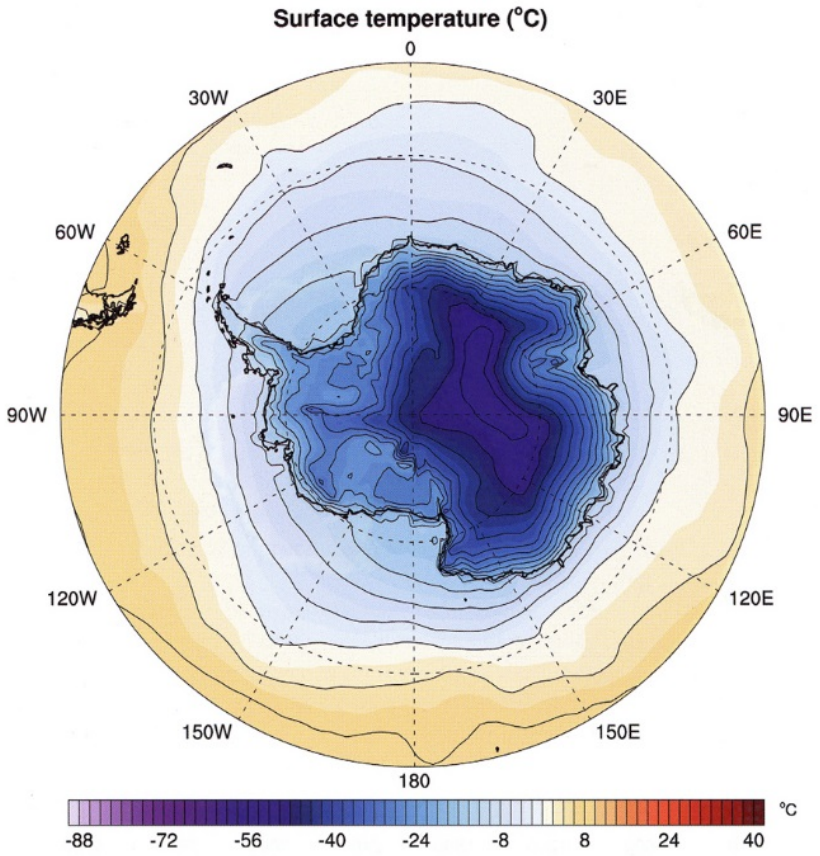


Figure 4.9 Map of Antarctic topography showing the high East Antarctic plateau and lower West Antarctic ice sheet. Both regions slope steeply down to the coast. (Credit: Matthew Higgins, Cooperative Institute for Research in Environmental Sciences, University of Colorado)



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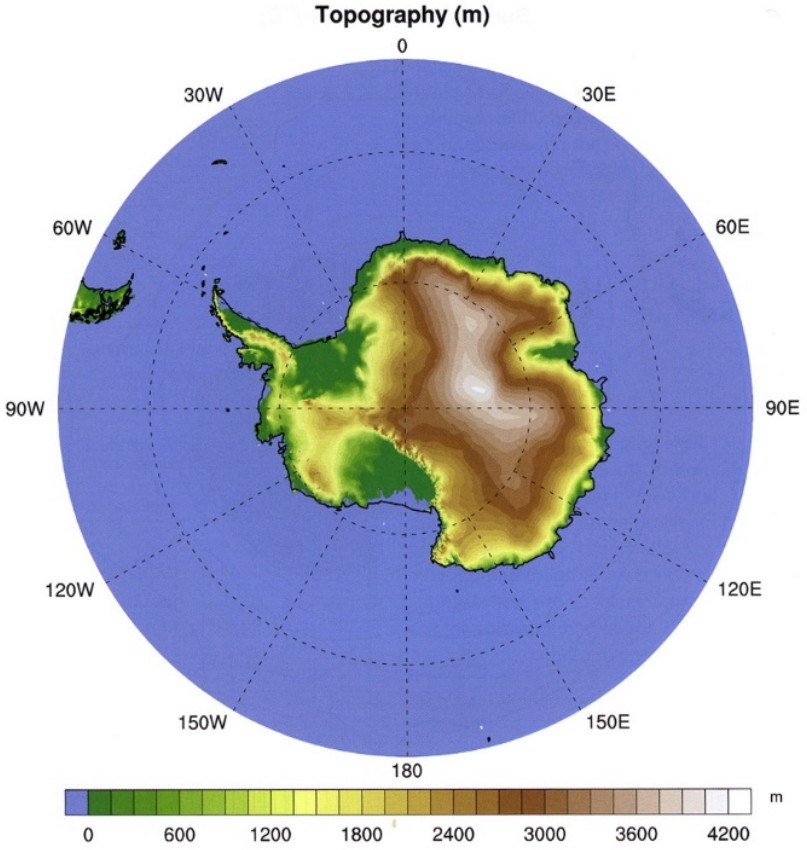
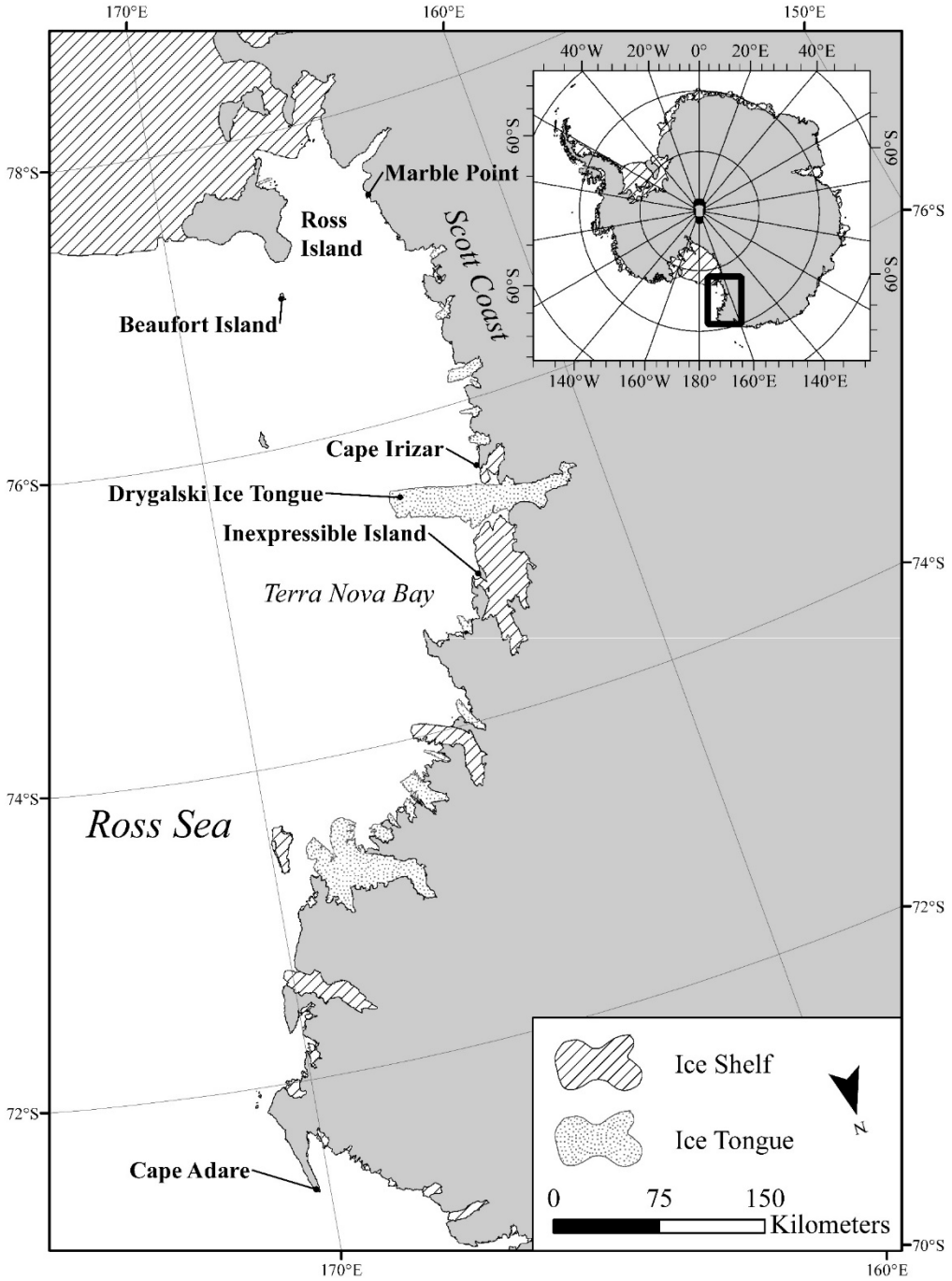


Figure 4.9 Map of Antarctic topography showing the high East Antarctic plateau and lower West Antarctic ice sheet. Both regions slope steeply down to the coast. (Credit: Matthew Higgins, Cooperative Institute for Research in Environmental Sciences, University of Colorado)


Some areas of Antarctica are colder than others,
depending on local topography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Scott Coast
Beaufort Island
Cape Irizar
Drygalski Ice Tongue
Inexpressible Island
Terra Nova Bay
Ross Sea
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Ice Shelf
Ice Tongue
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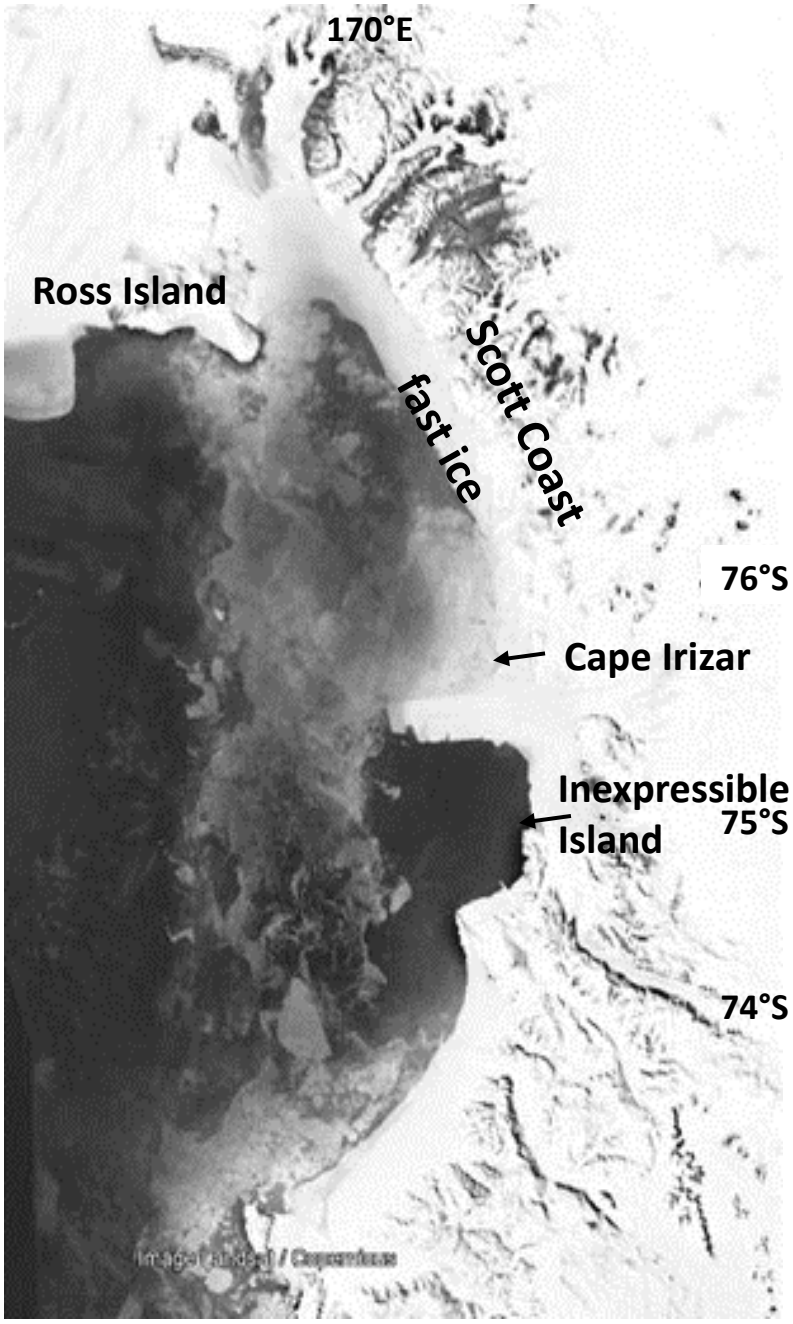
Kilometers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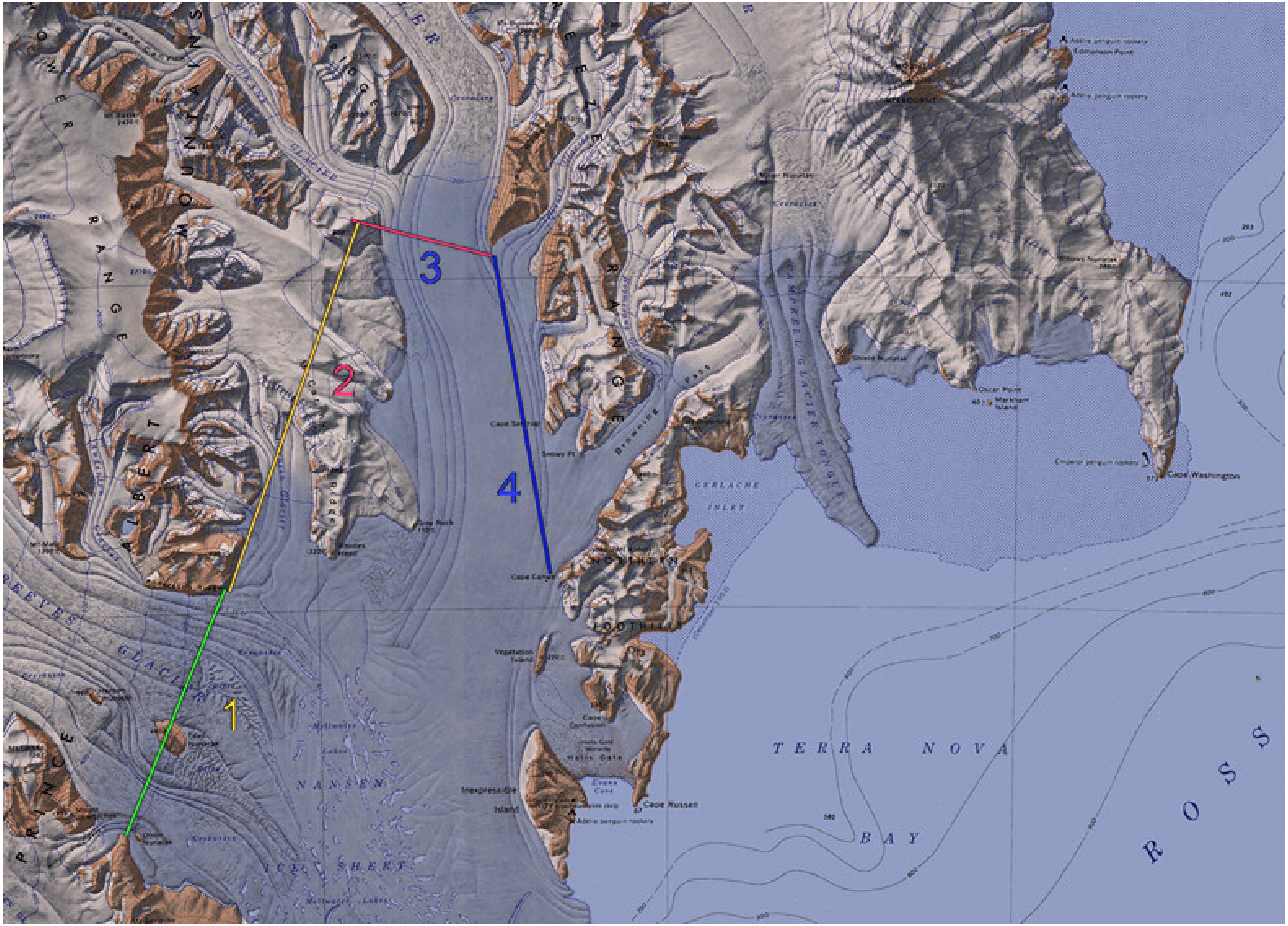
75°S
74°S



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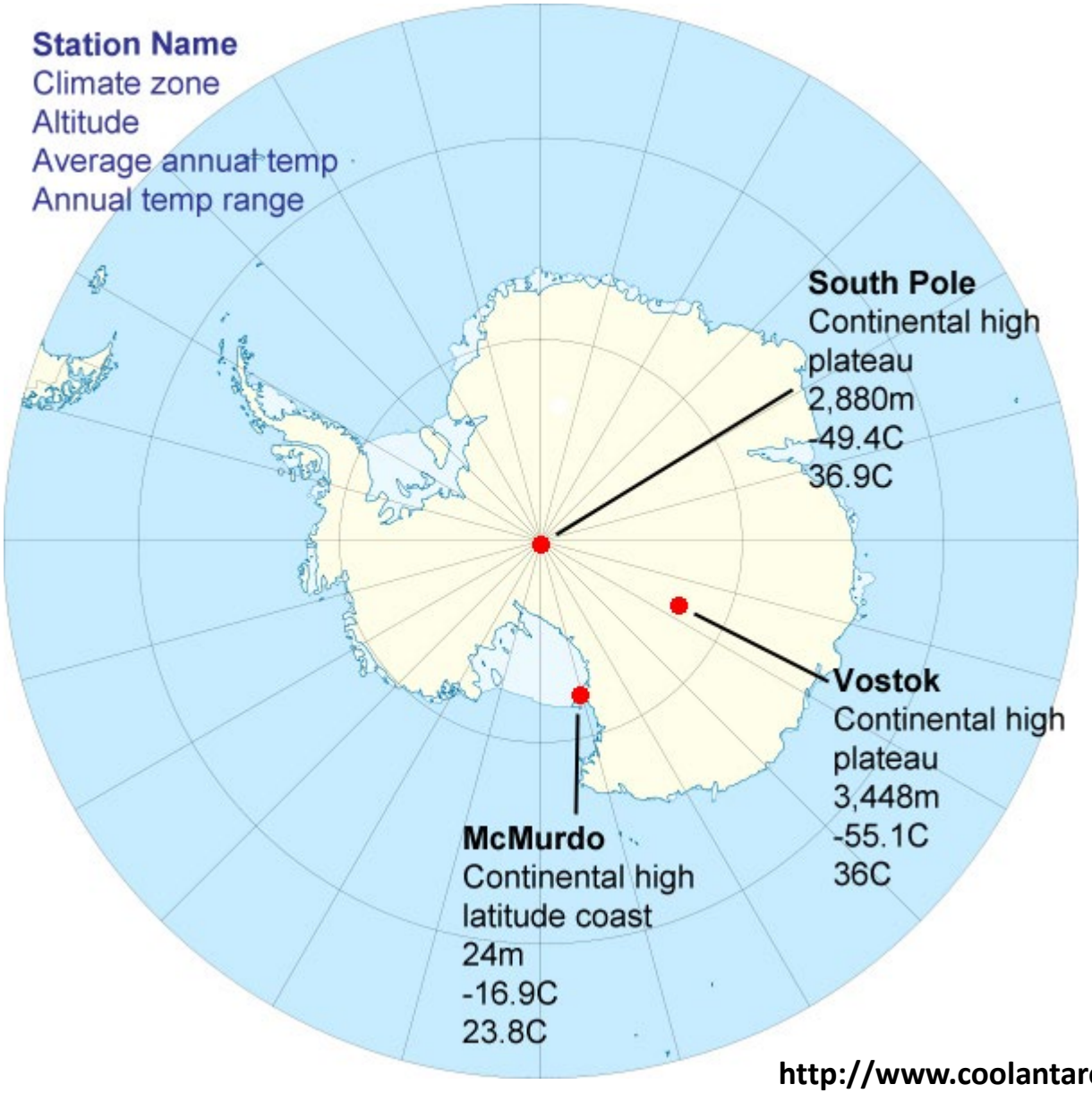
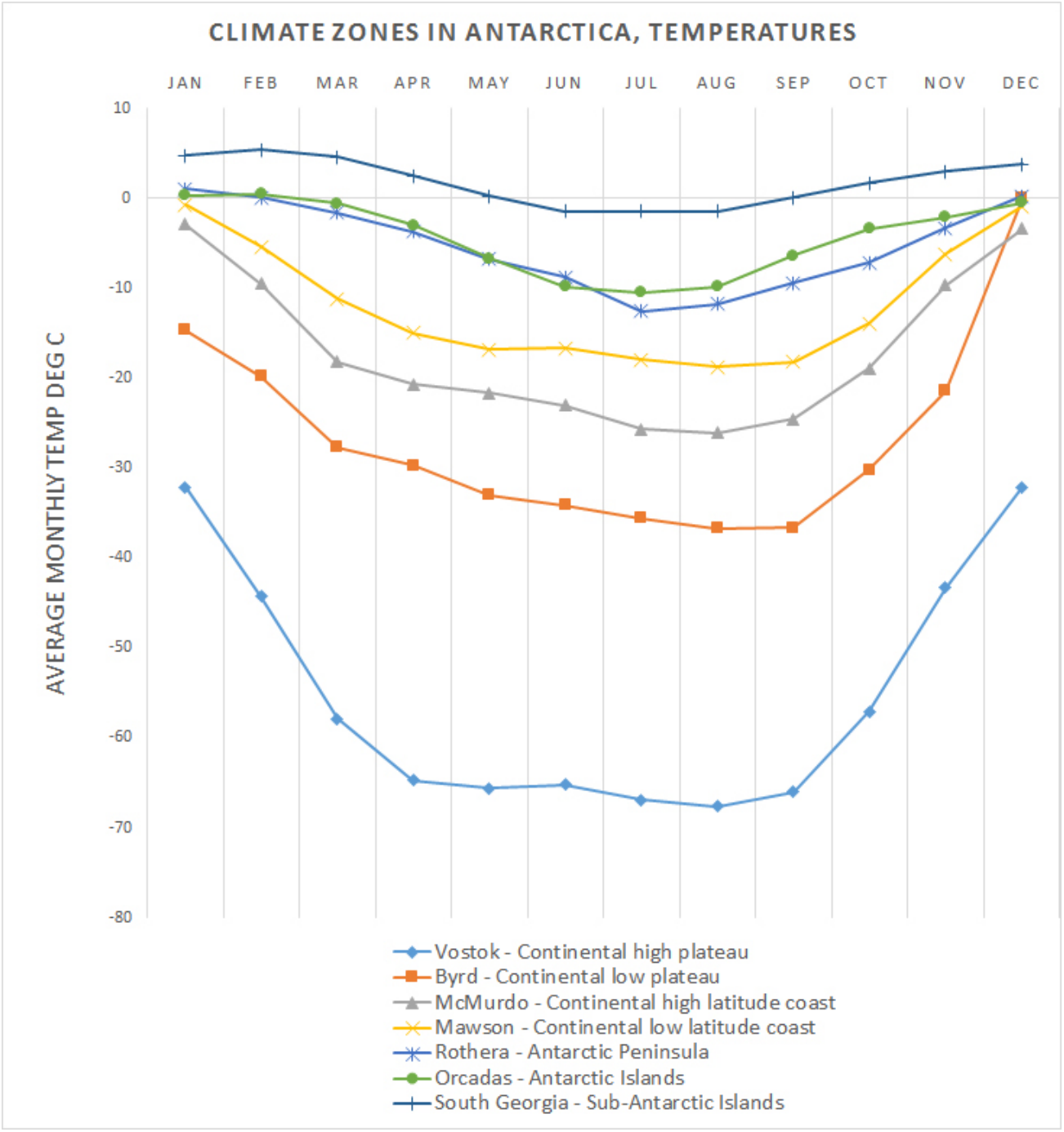
GERLACHE
INLET
Cape Washington
Inexpressible
Island
Cape Russell
Vegetation
Island



http://www.coolantarctica.com


CLIMATE ZONES IN ANTARCTICA, TEMPERATURES
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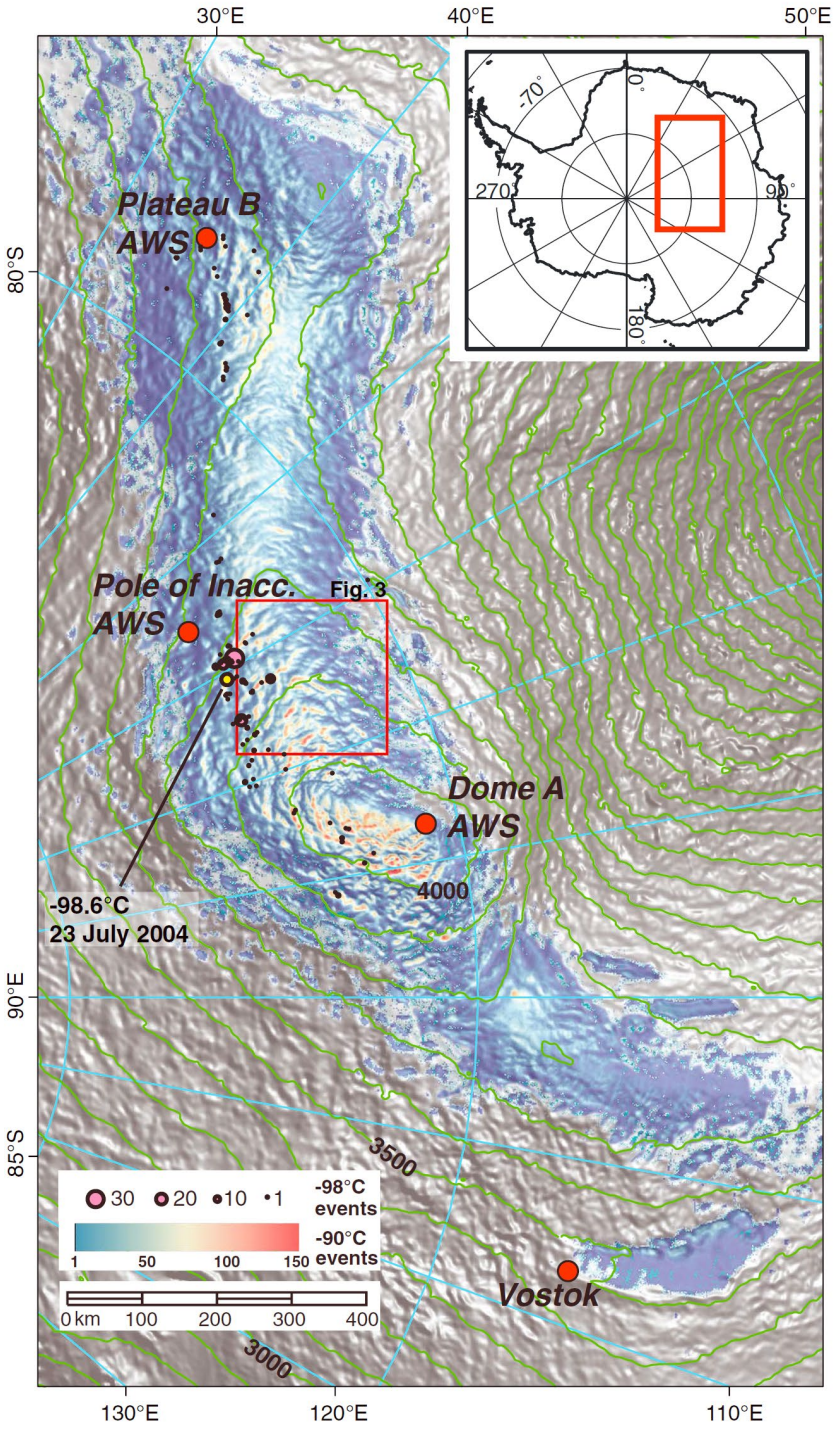
Vostok - Continental high plateau
Byrd - Continental low plateau
McMurdo - Continental high latitude coast
Mawson - Continental low latitude coast
Rothera - Antarctic Peninsula
Orcadas - Antarctic Islands
South Georgia - Sub-Antarctic Islands



Ultracold Antarctica

While Vostok Station recorded the coldest known temperature on Earth in 1983 (-89.2°C or -129°F), new analysis of satellite data using a spectroradiometer indicate that shallow topographic basins at higher elevations get as cold as -94°C

These 'ultracold' conditions are the lowest possible temperatures that can occur on Earth, based on dynamics between cold snow surface, solar radiation, and winds

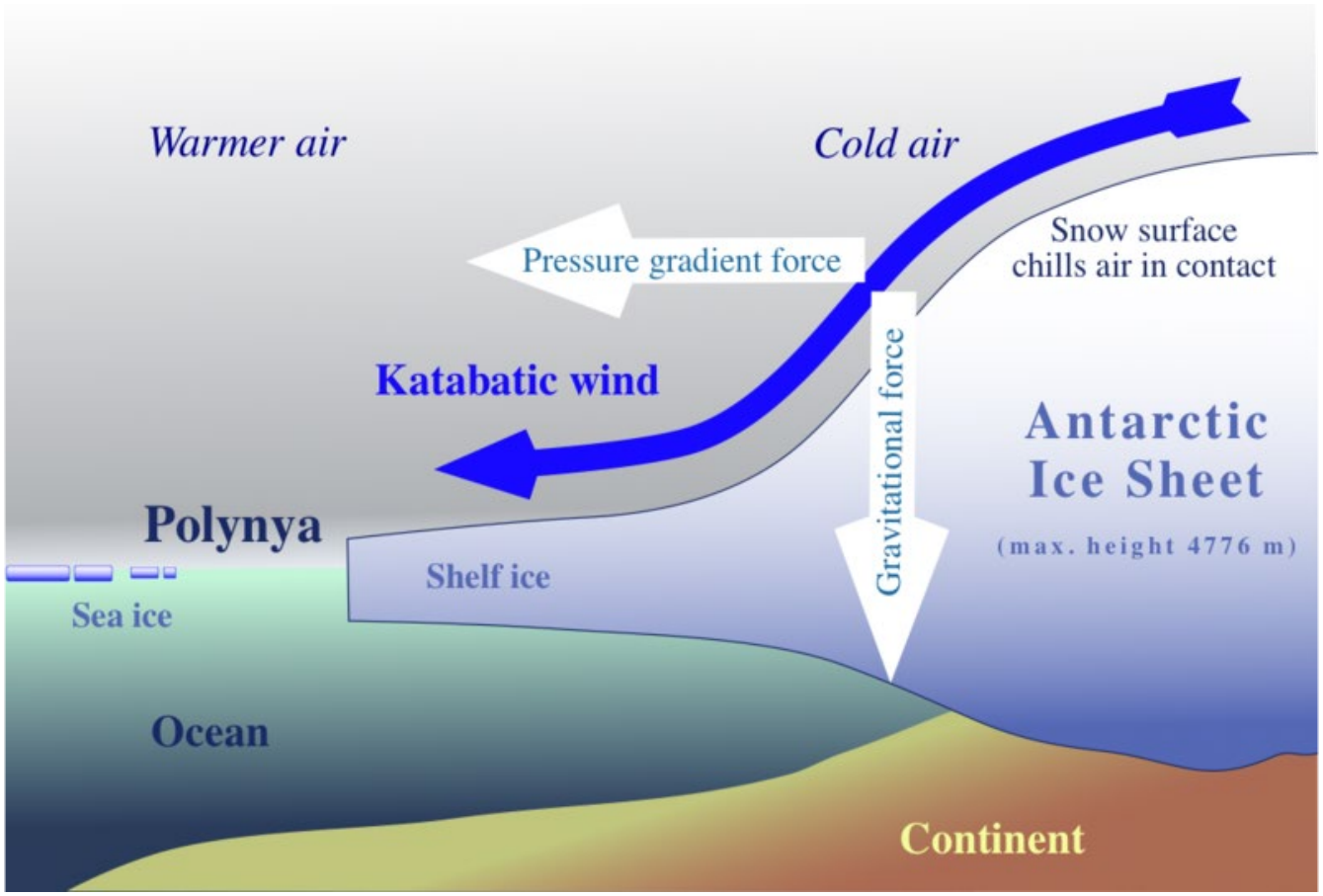
This temperature is colder than the surface of Mars!

From Scambos et al. 2018

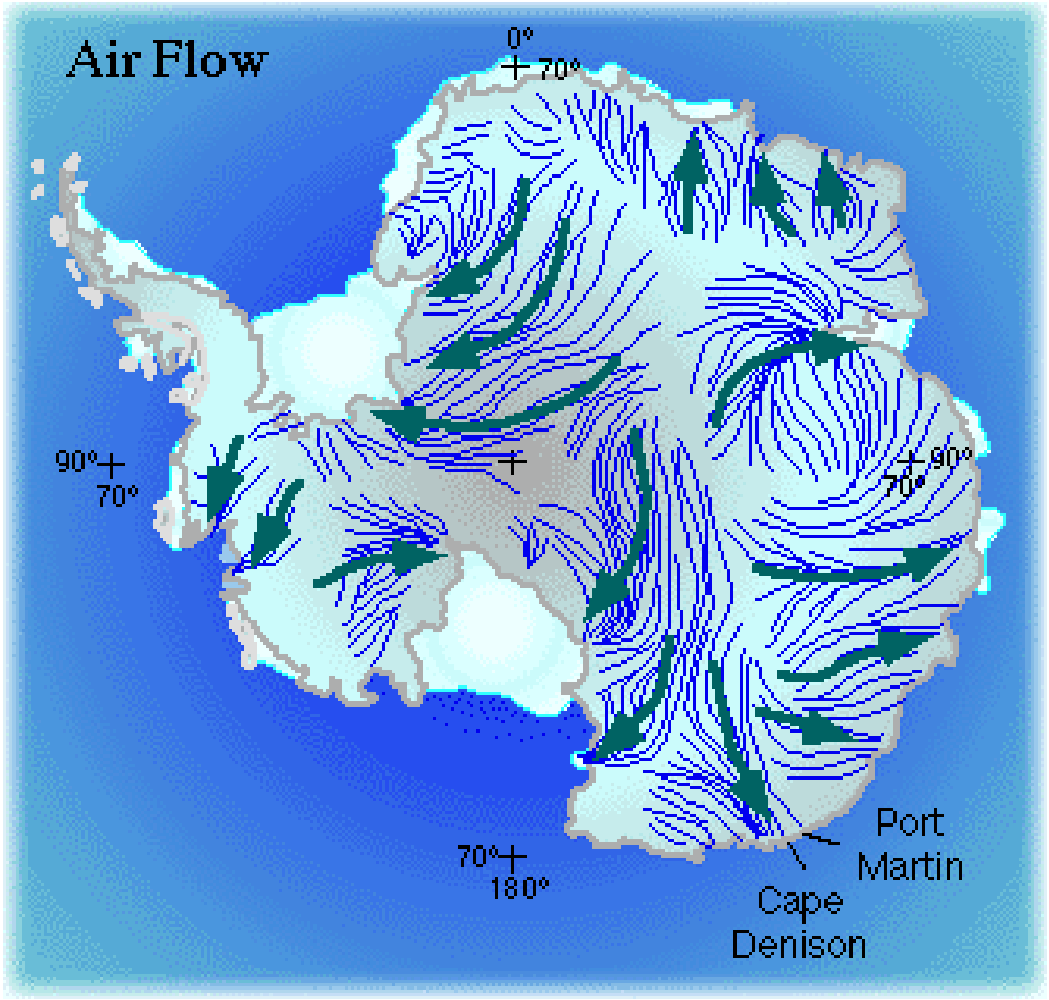

30 January 2012
Temperature: -36 C
Wind: light
Windchill: -50 C
Geographic South Pole
Roald Amundsen
December 14, 1911
"So we arrived and were able to plant our flag at the geographical South Pole."

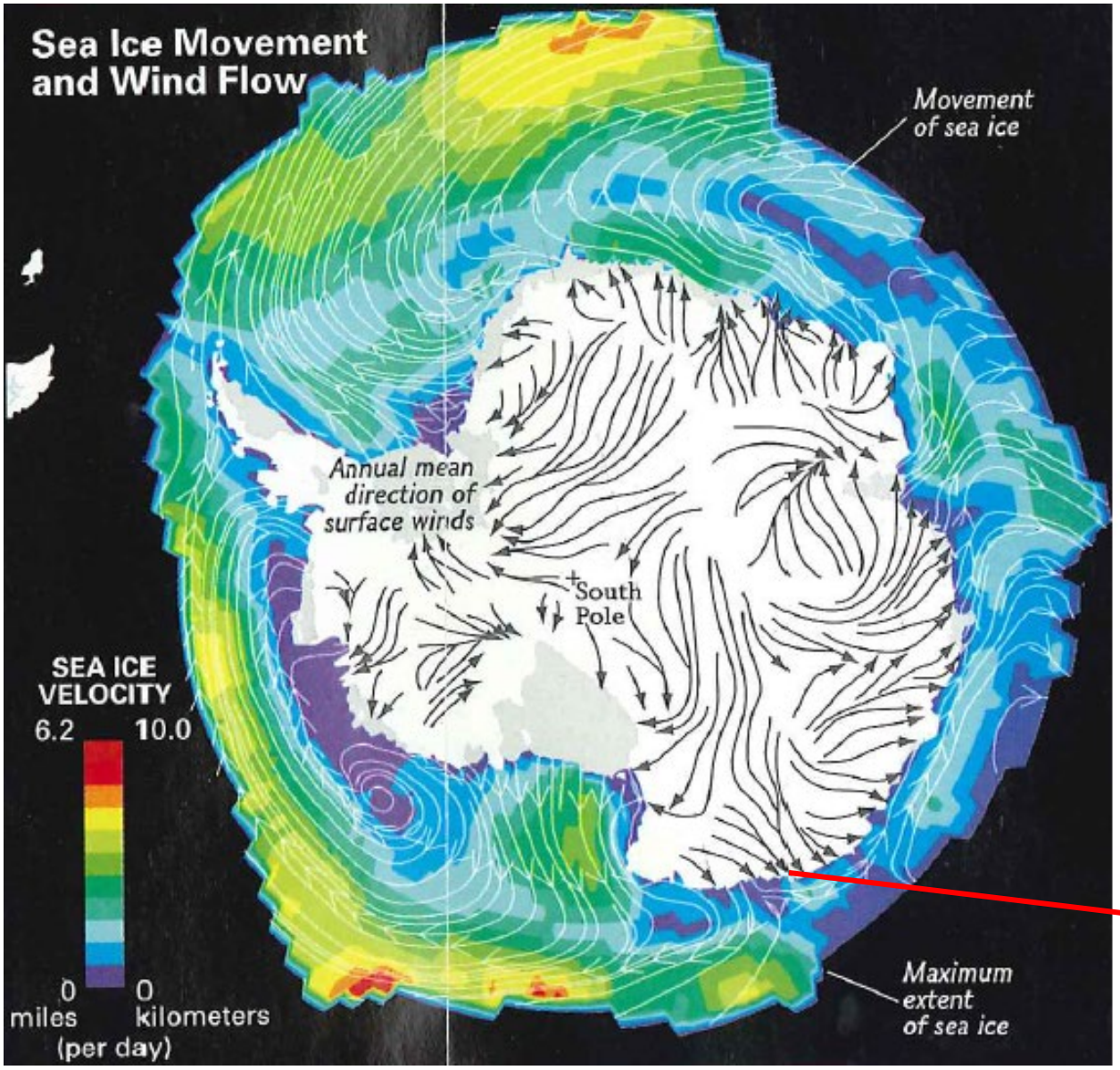
Antarctic Winds: Effects of air density, ice, topography

Katabatic Winds



Air flows downward all around the continent, channeled by valleys and bends left with coriolis





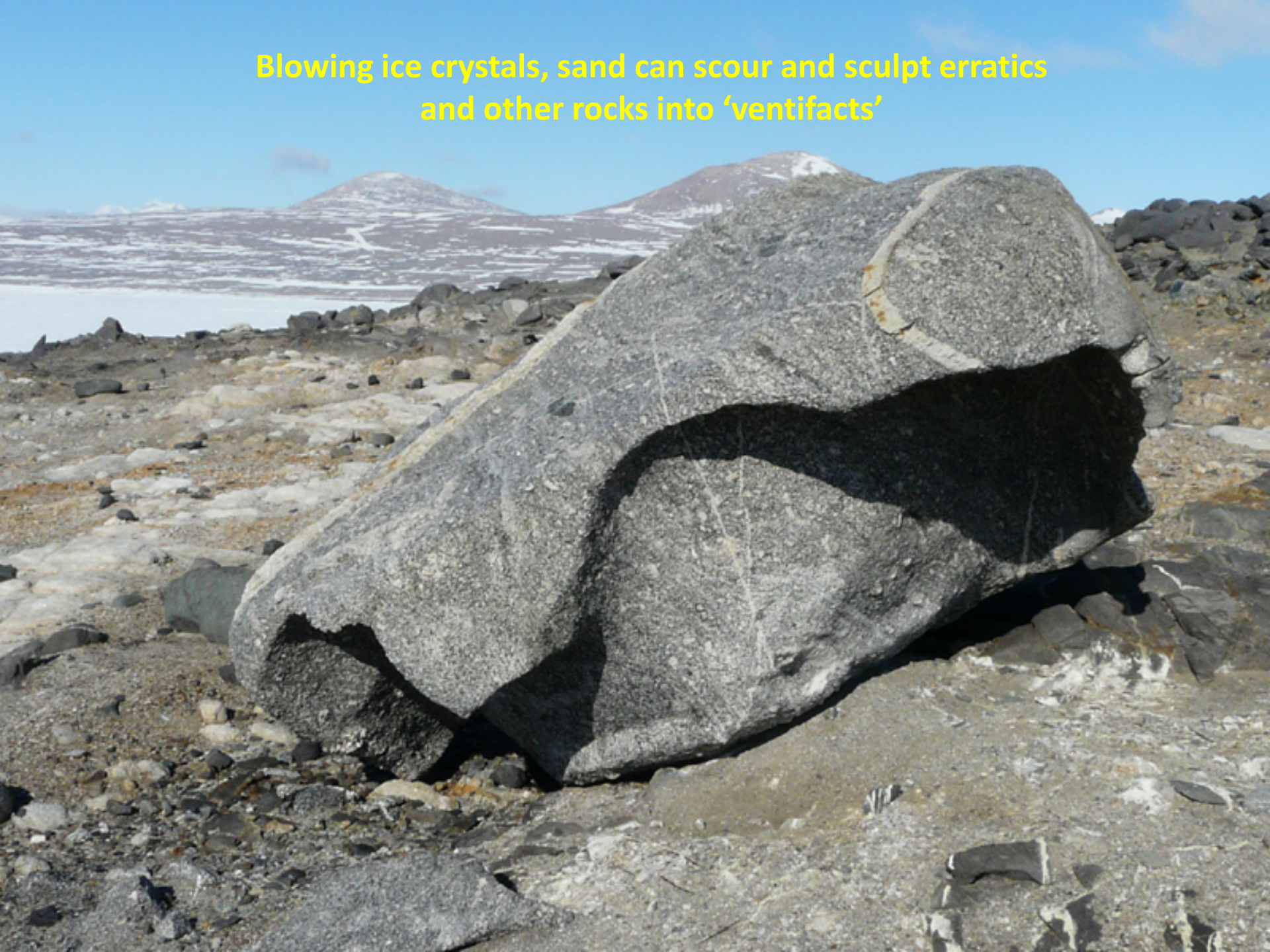
Winds in turn affect local climate, sea ice formation and movement, erosion, and even penguin behavior

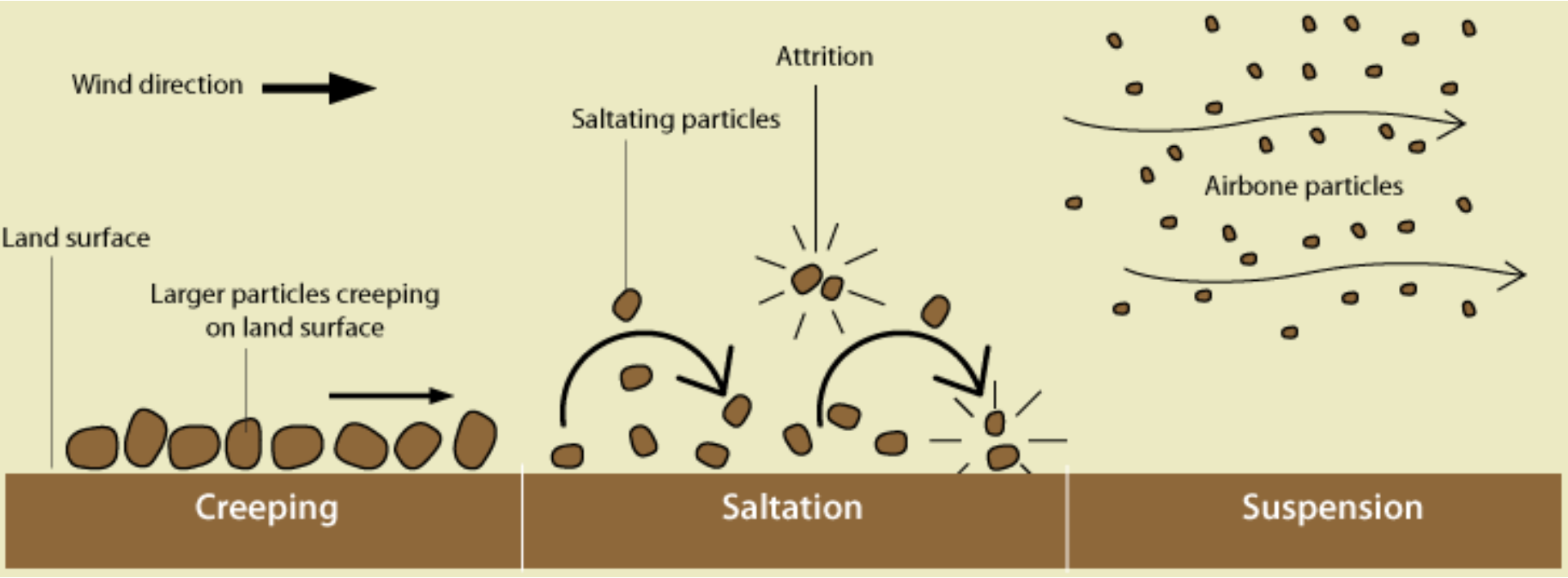
Cape Denison: Home of the Blizzard, Douglas Mawson

Cape Denison

Katabatic winds in this 1912 photo at Cape Denison

You can’t see wind, but you can see the effect of katabatic wind on snow

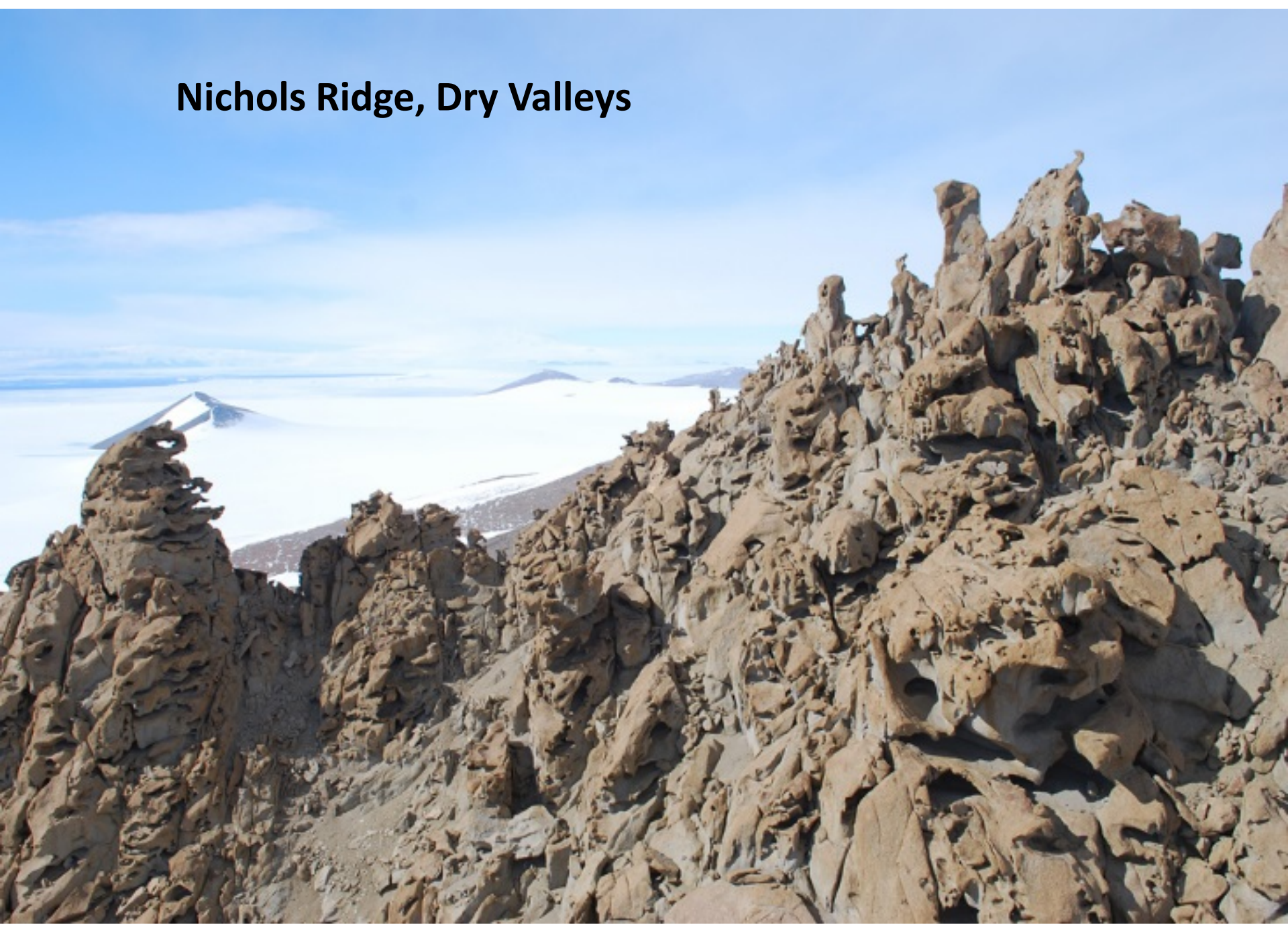

Blowing ice crystals, sand can scour and sculpt erratics
and other rocks into ‘ventifacts’



http://www.eschooltoday.com


thedryvalleys.com

Nichols Ridge, Dry Valleys

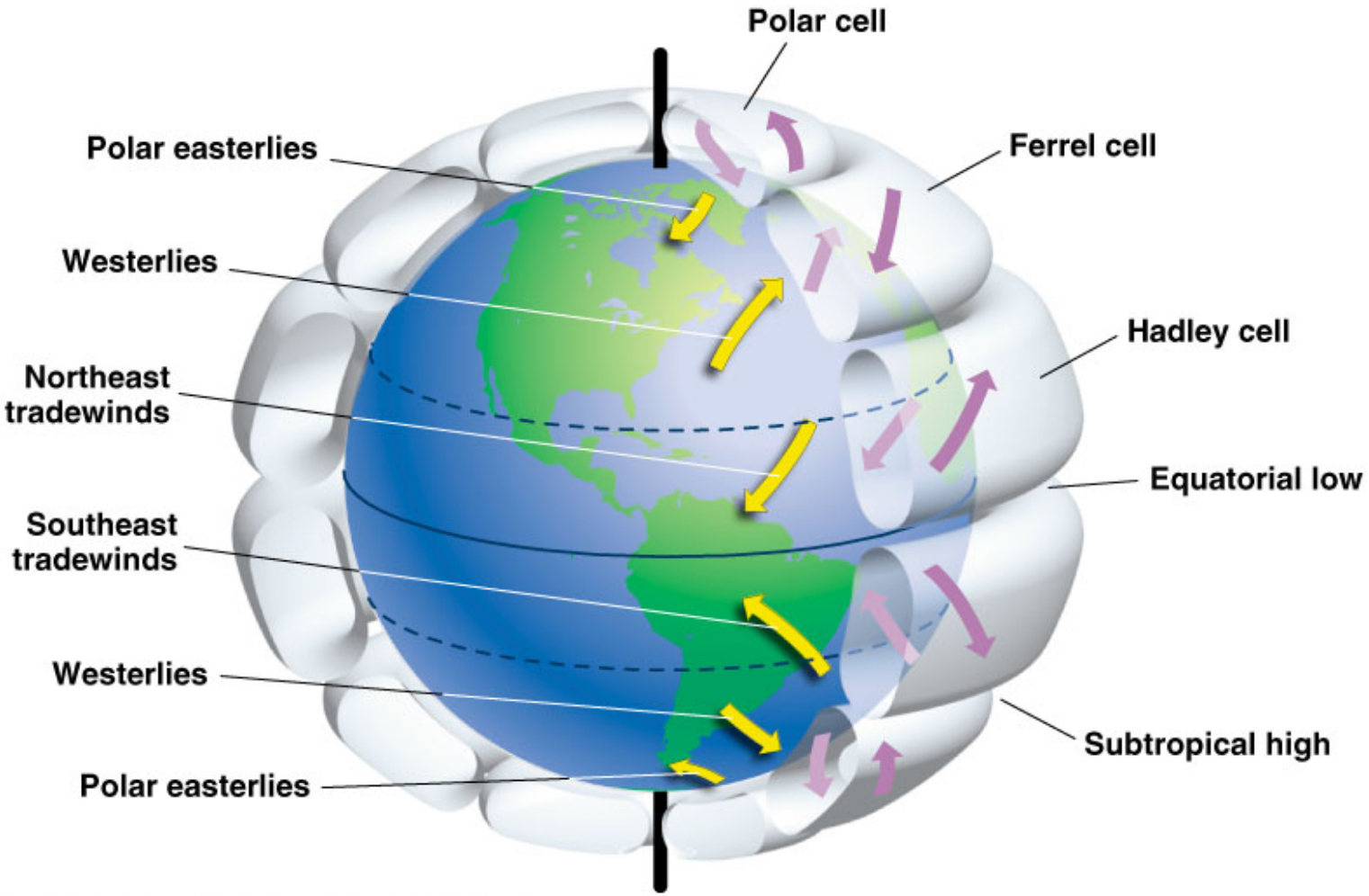



Pitting is caused by saltation of sand particles by wind

Sastrugi also form from constant wind direction
Parallel to wind, caused by erosion and saltation

Antarctica as the Driest Continent

Partly due to high pressure zone from Polar Cell
Also, colder air holds less water, so little precipitation



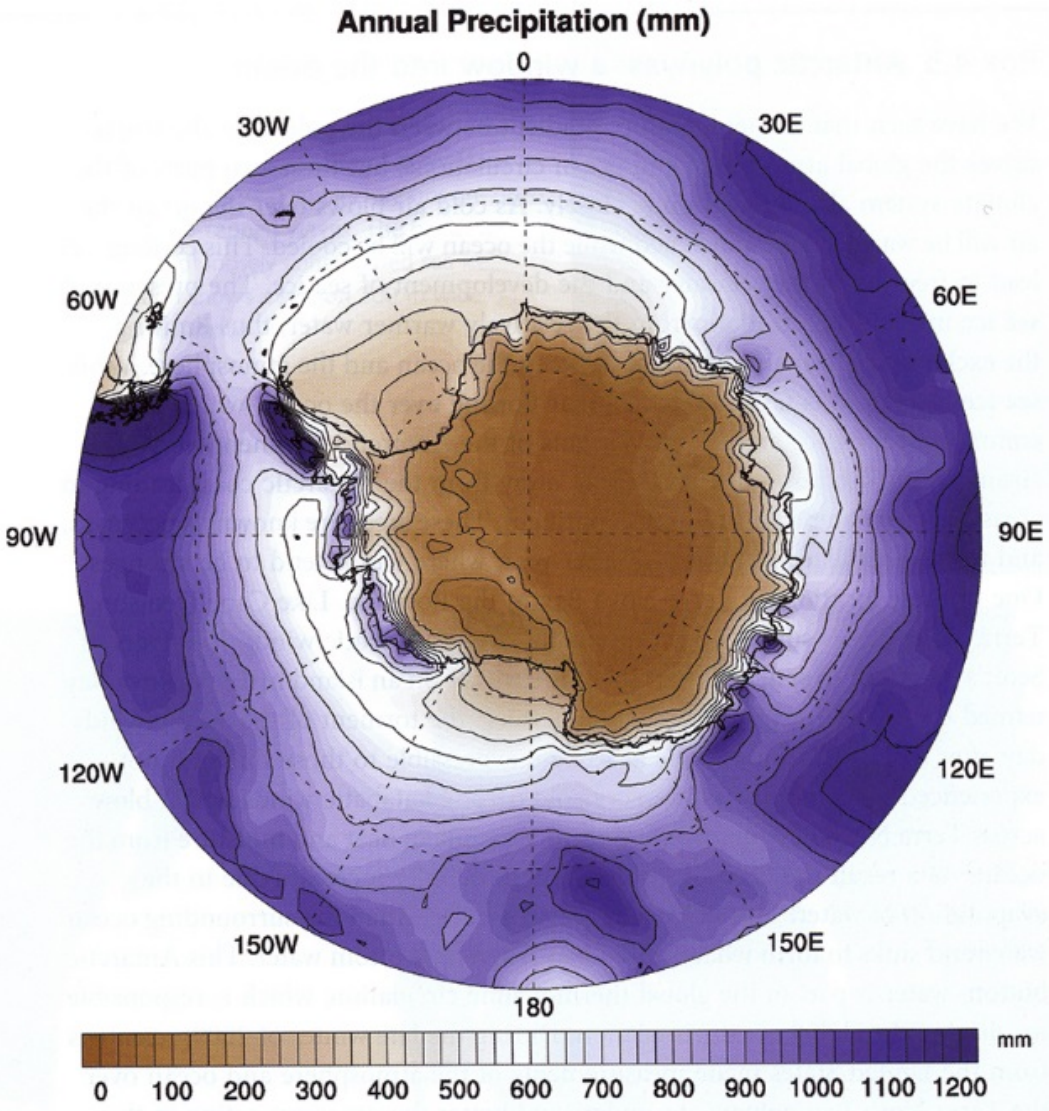
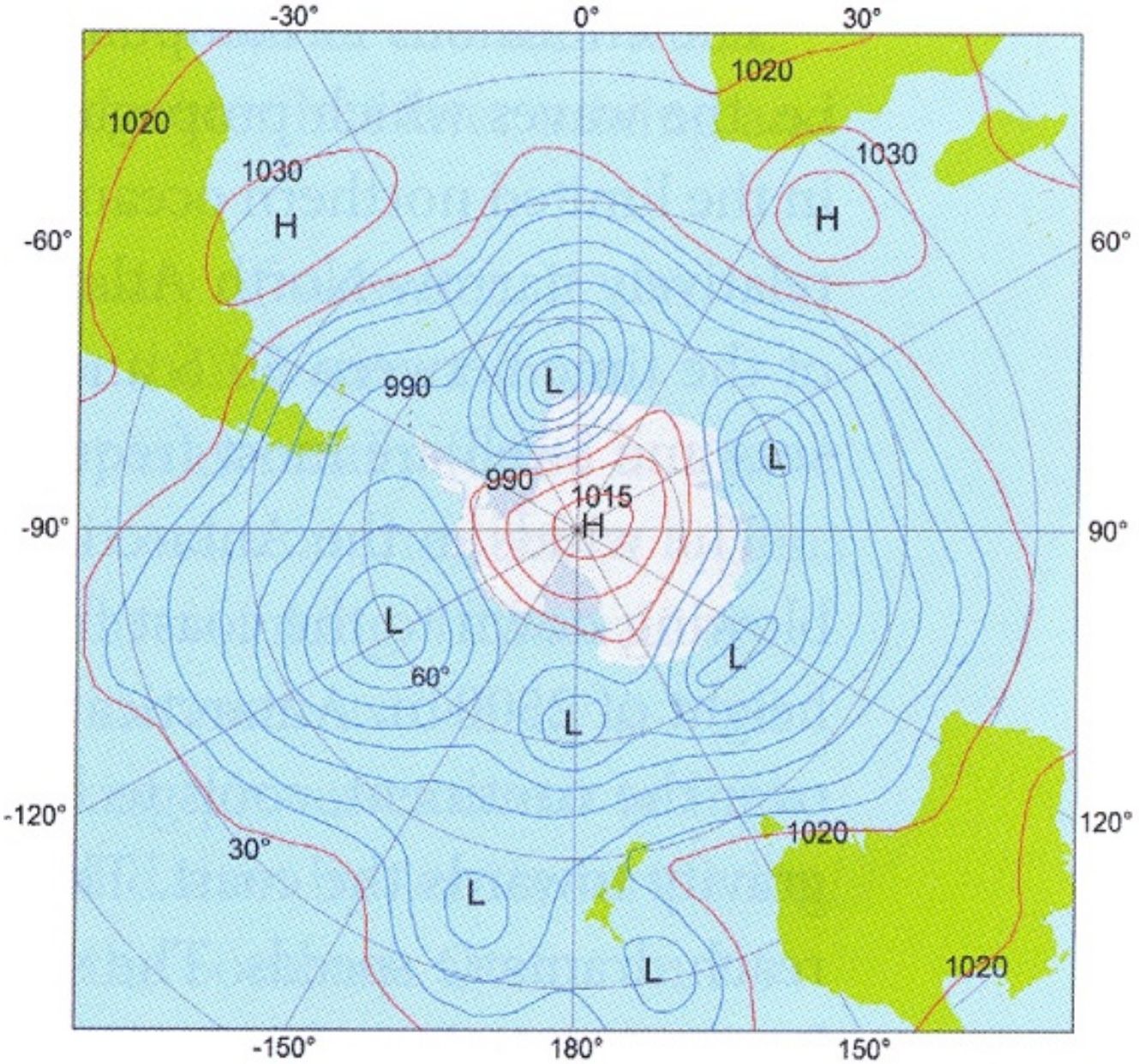
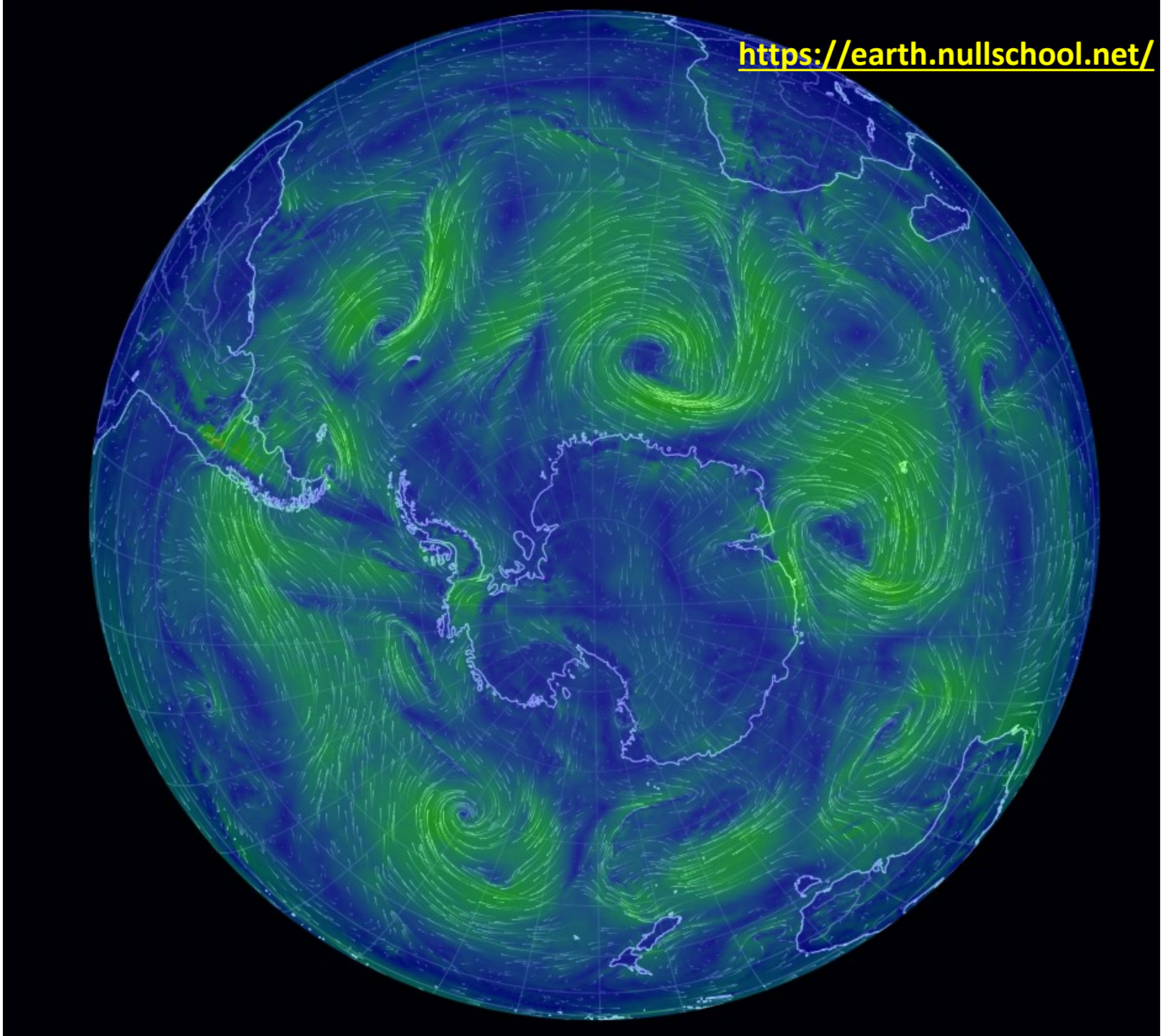


Figure 4.17 Map of Antarctic precipitation distribution. (Credit: Matthew Higgins, Cooperative Institute for Research in Environmental Sciences, University of Colorado)

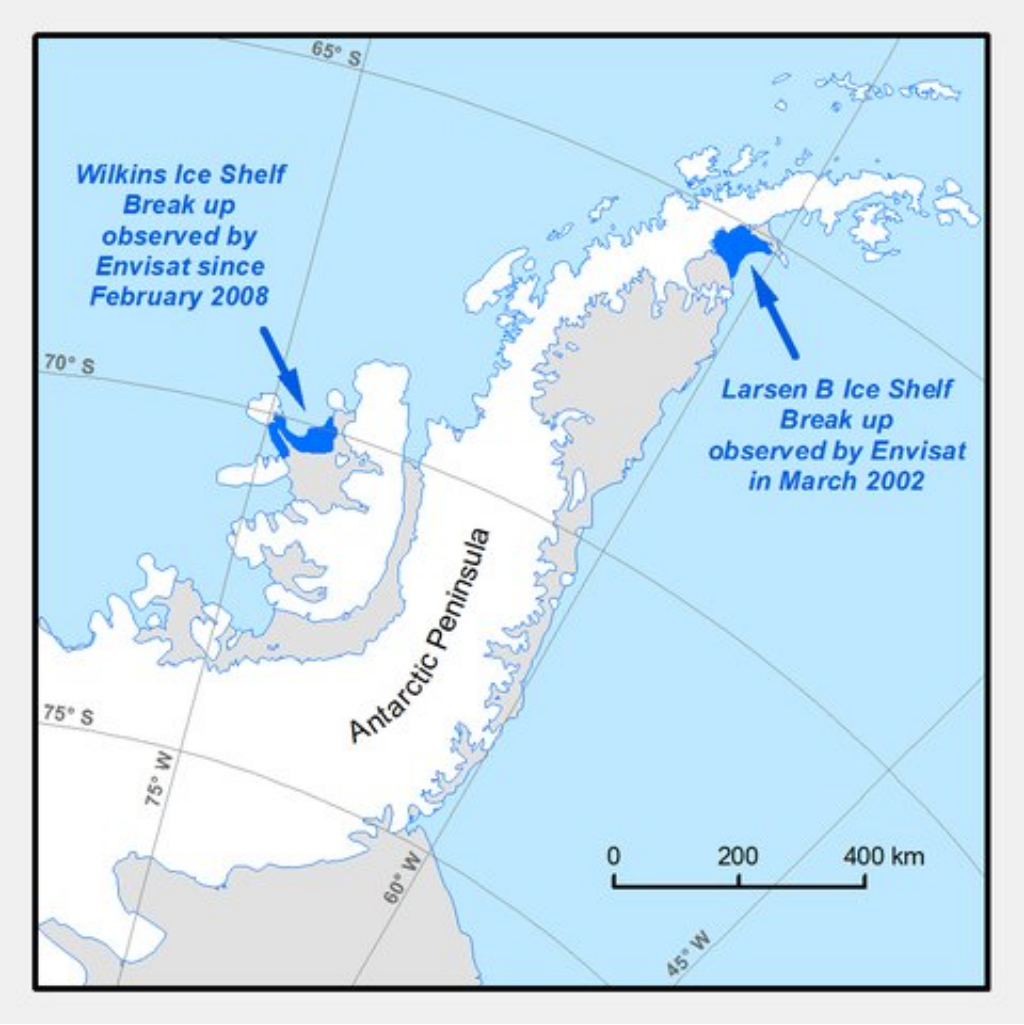


See current winds at: https://earth.nullschool.net/

Fig. 5.2 in Walton (2013)


https://earth.nullschool.net/

Why is the Antarctic Peninsula so Moist?



Receives 35-50 cm precipitation per year, mostly as rain

Most northerly part of Antarctica

Colder on east side, receives warm air currents from west

Temperatures 1-2 °C in January

Climate warming has had greatest impact here

Only two flowering plants in Antarctica and both are located in northern AP

Quiz

1. **Why is Antarctica so dry?**

2. **What is meant by solar insolation?**

3. **Why is Antarctica so windy?**

4. **How do katabatic winds form? What is wind force and fetch?**

5. **What are ventifacts, sastrugi, and saltation?**