Ch. 4 Atmospheric Pressure and Wind

30 Sep. 2011

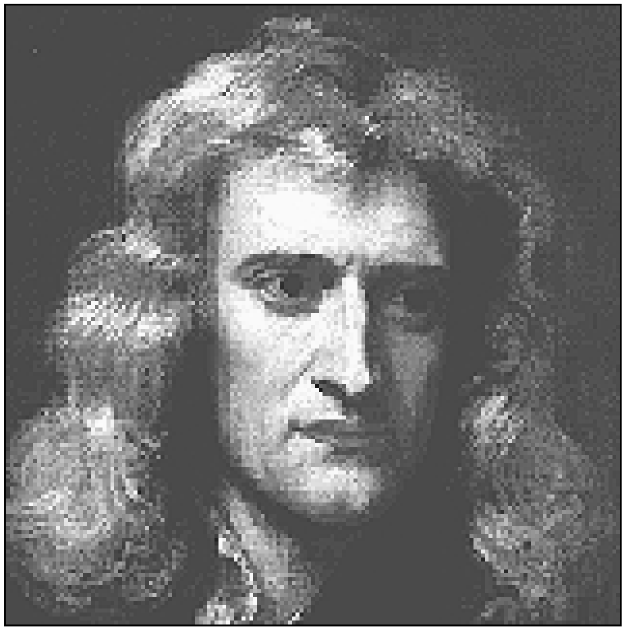
- hydrostatic pressure variation in the vertical

- *horizontal* pressure gradients – their relation to temperature gradients

- "height gradients" correspond to pressure gradients

- range of scales of atmospheric motion

- on the large scale, there exists a theoretical relationship between wind speed in the free atmosphere and the height gradient



Sir Isaac Newton
1642 - 1727

lec10.odp
JDWilson vers 29 Sep 2011

The hydrostatic equation (Sec. 4-3, p112)

Gives the change in pressure (Δp) associated with an increase (Δz) in height

$$\frac{\Delta p}{\Delta z} = -\rho g \quad \left[\mathrm{Pa\ m^{-1}} \right]$$

ρ = air density [kg m^{-3}] (approximately 1, near ground)
g = grav. accel'n = 9.81 [m s^{-2}] (approximately 10)

Thus: near ground, pressure increases by an amount Δp = - 10 Pa for each 1 m increase in height

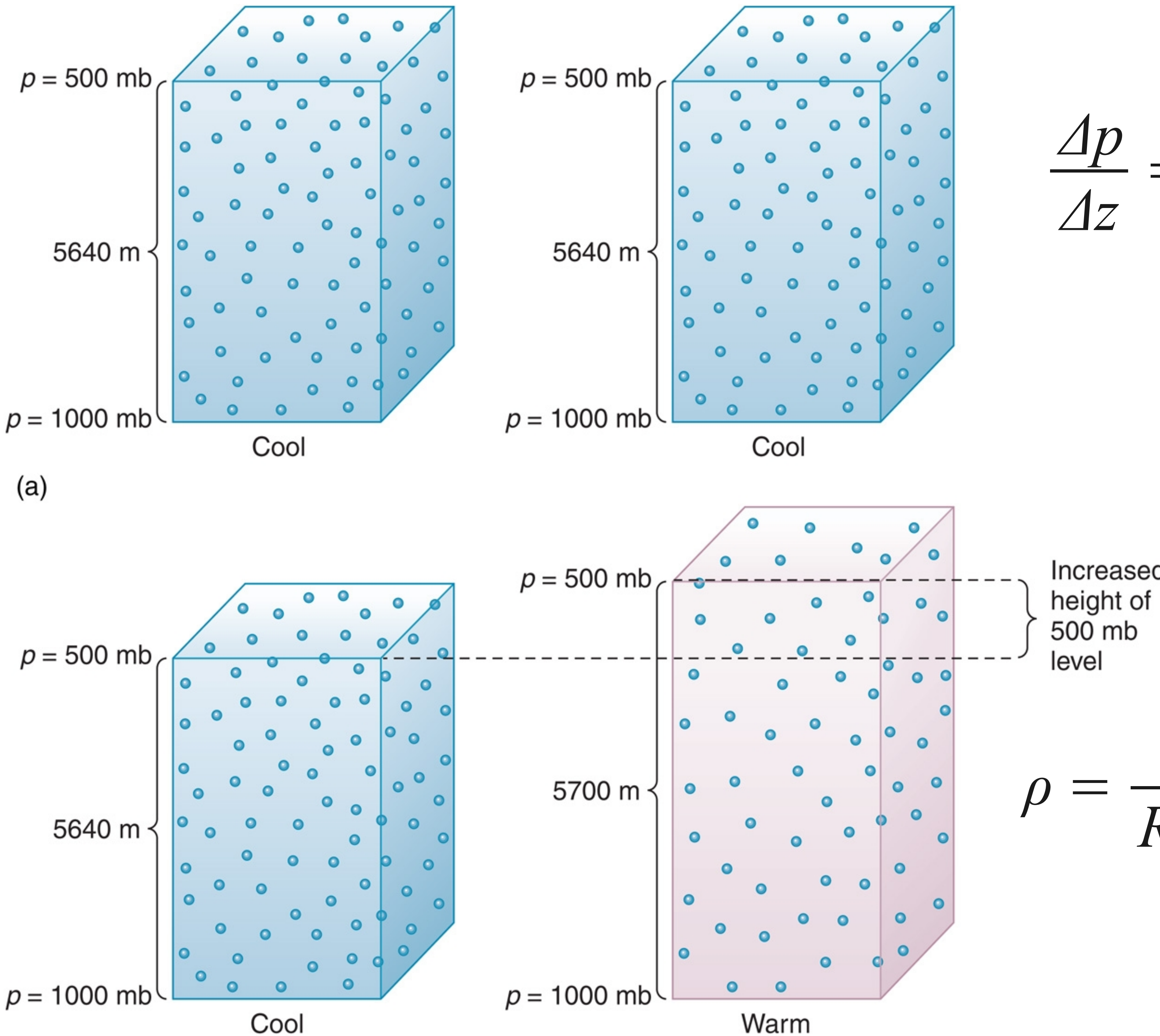
100 Pa (= 1 hPa) per 10m
100 hPa per 1 km

These paragliders, initially at 900 hPa where temperature is 25°C, descend 100 m. What is the pressure at their new flight level?

p_1, T_1 (known) $\rightarrow$ p_2, T_2

$$\rho_1 = \frac{p_1}{R \;\; T_1} =$$

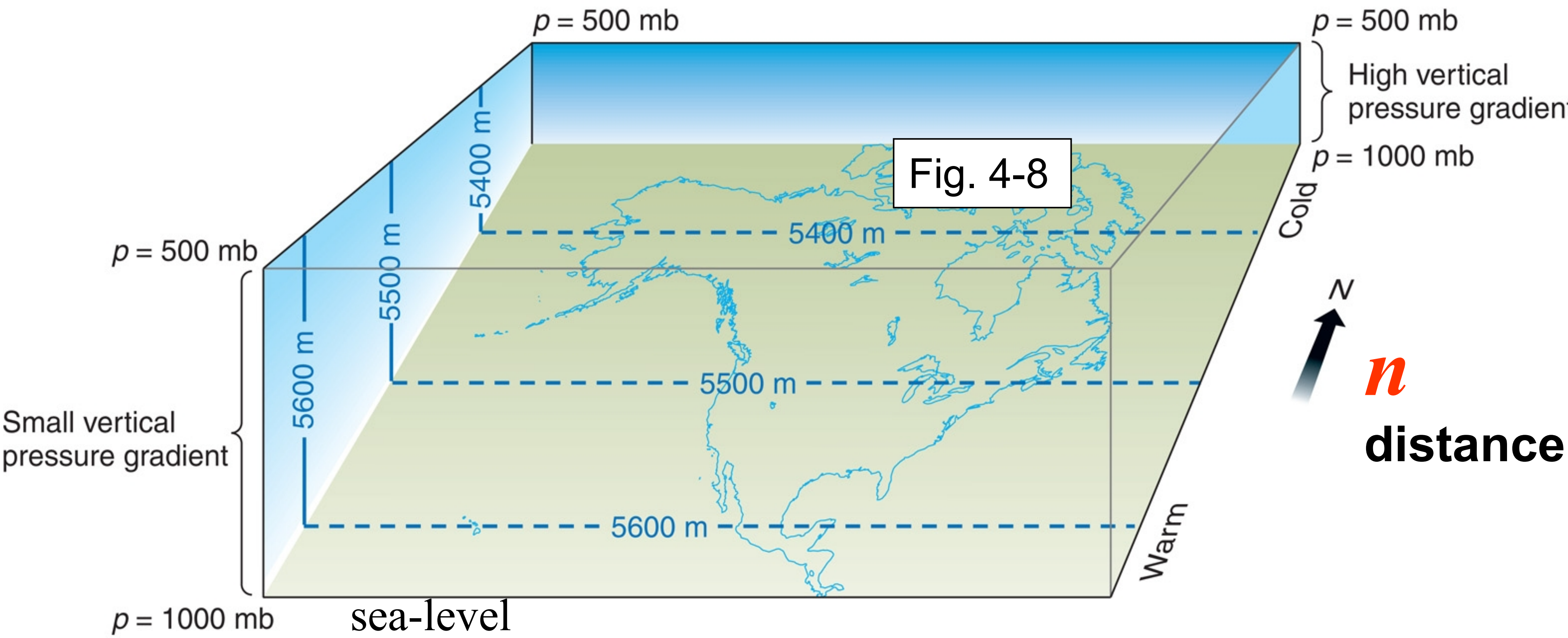
Temperature controls rate of vertical decay of pressure



$$\frac{\Delta p}{\Delta z} = -\rho g$$

$$\rho = \frac{p}{R T} \propto \frac{1}{T}$$

Idealized sloping 500 hPa surface: height (h) is lower in the colder, poleward air

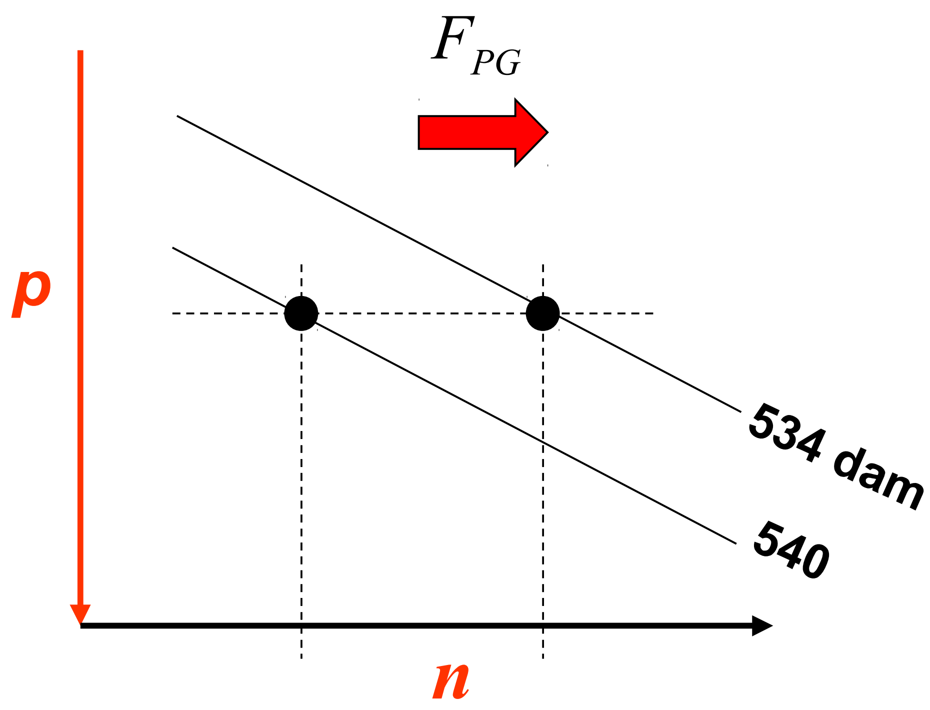


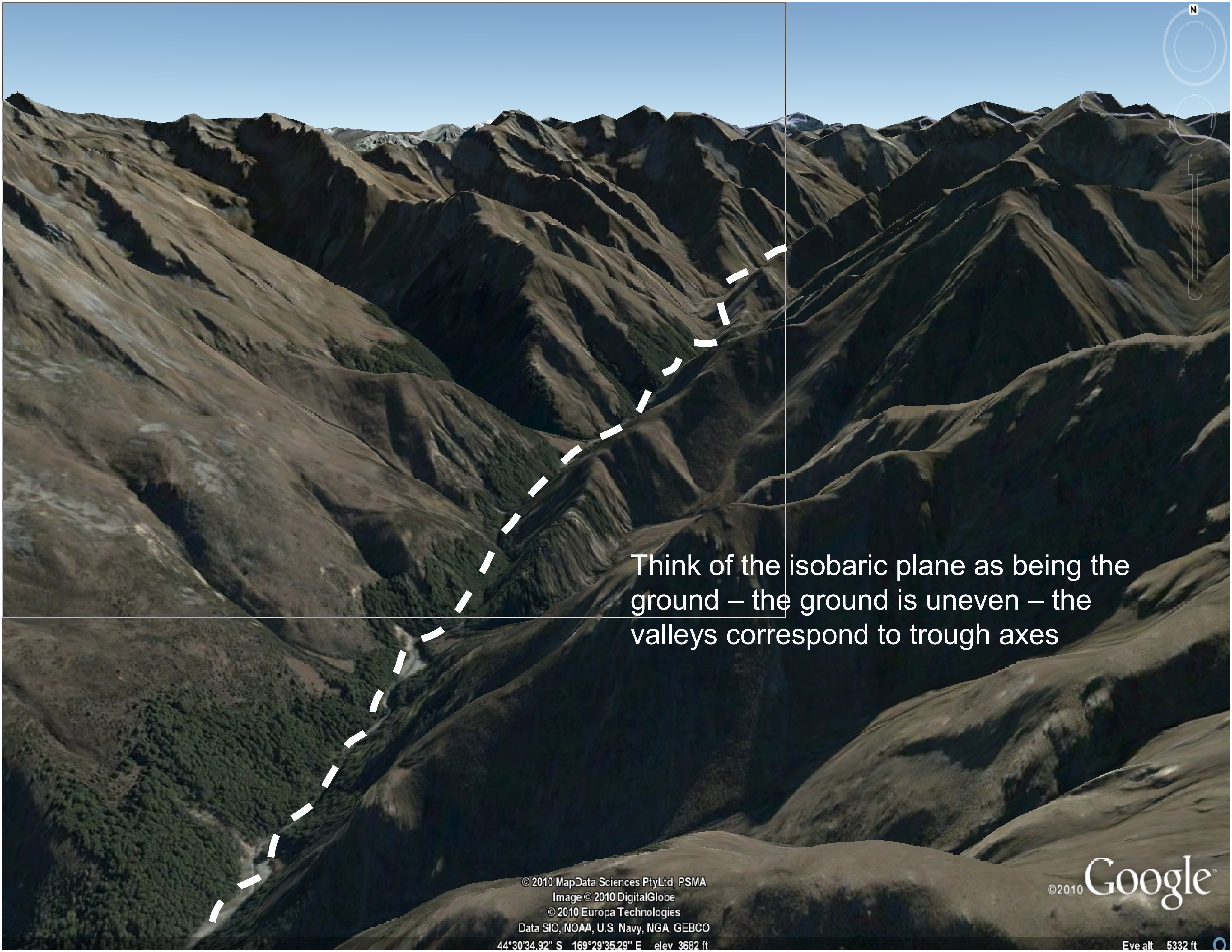
"Where a horizontal pressure gradient exists, there must also be a slope in the isobars**, with heights decreasing toward colder air. It so happens that the horizontal pressure gradient force is proportional to the slope of the isobars." (p112)

** or isobaric planes, which are the constant pressure surfaces

Idealized sloping 500 hPa surface: height (*h*) of the isobaric surface is lower in the colder, poleward air

Note: direction of increase of p-axis




Think of the isobaric plane as being the ground – the ground is uneven – the valleys correspond to trough axes
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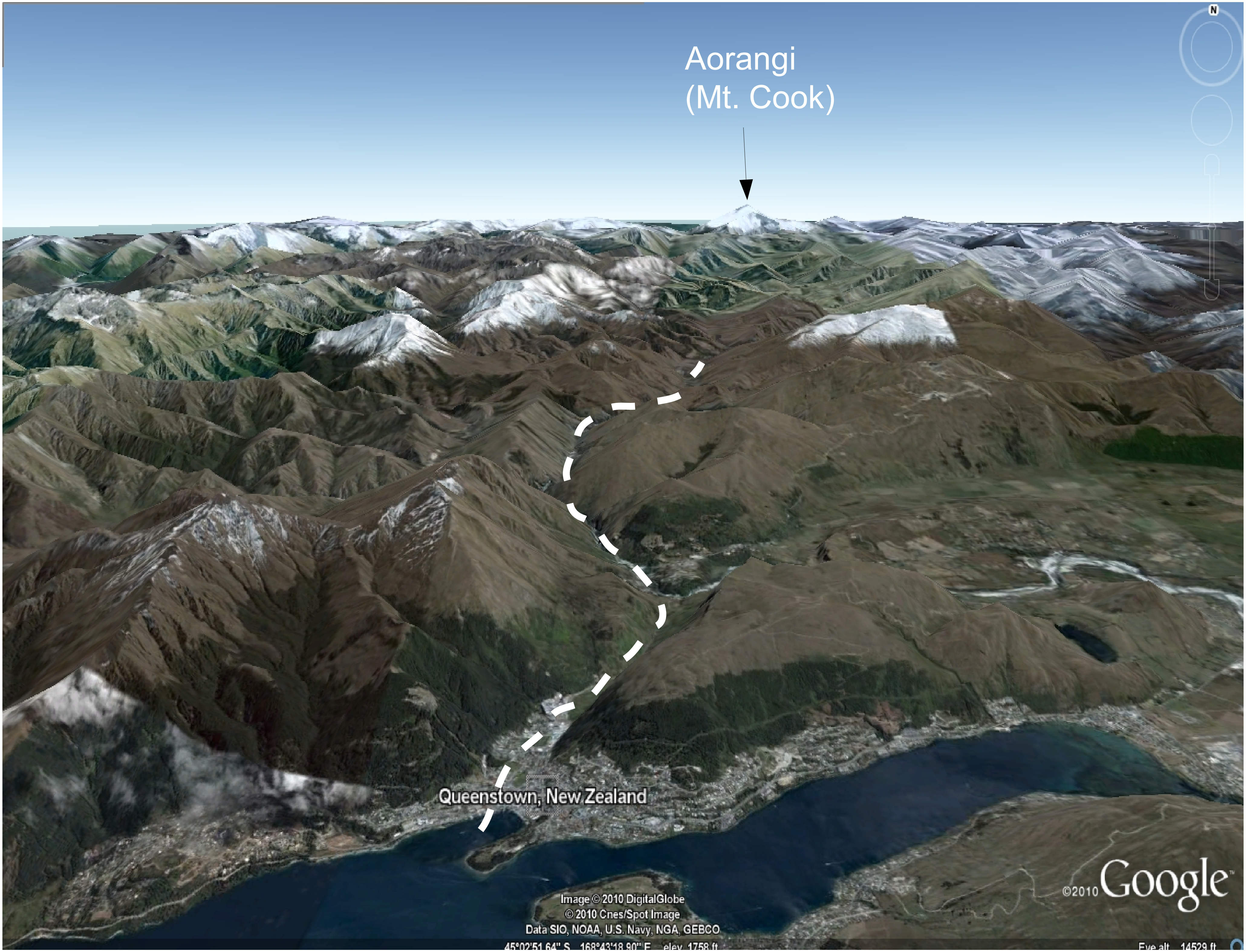
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
44°30'34.92" S 169°29'35.29" E elev 3682 ft
©2010 Google
Eye alt 5332 ft



Aorangi
(Mt. Cook)
Queenstown, New Zealand
Image © 2010 DigitalGlobe
© 2010 Cnes/Spot Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
45°02'51.64" S 168°43'18.90" E elev 1758 ft
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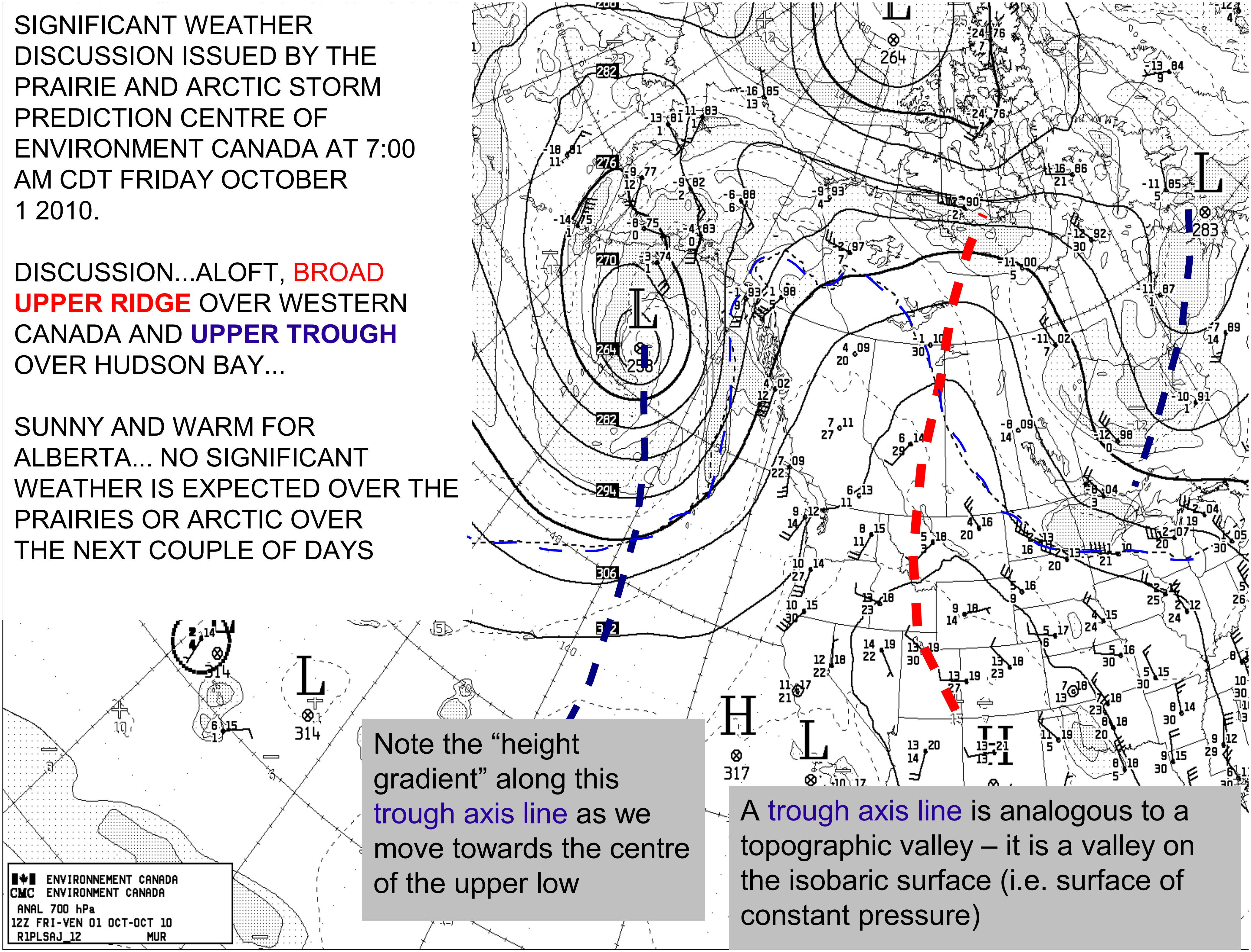
Eye alt 14529 ft

SIGNIFICANT WEATHER DISCUSSION ISSUED BY THE PRAIRIE AND ARCTIC STORM PREDICTION CENTRE OF ENVIRONMENT CANADA AT 7:00 AM CDT FRIDAY OCTOBER 1 2010.

DISCUSSION...ALOFT, BROAD UPPER RIDGE OVER WESTERN CANADA AND UPPER TROUGH OVER HUDSON BAY...

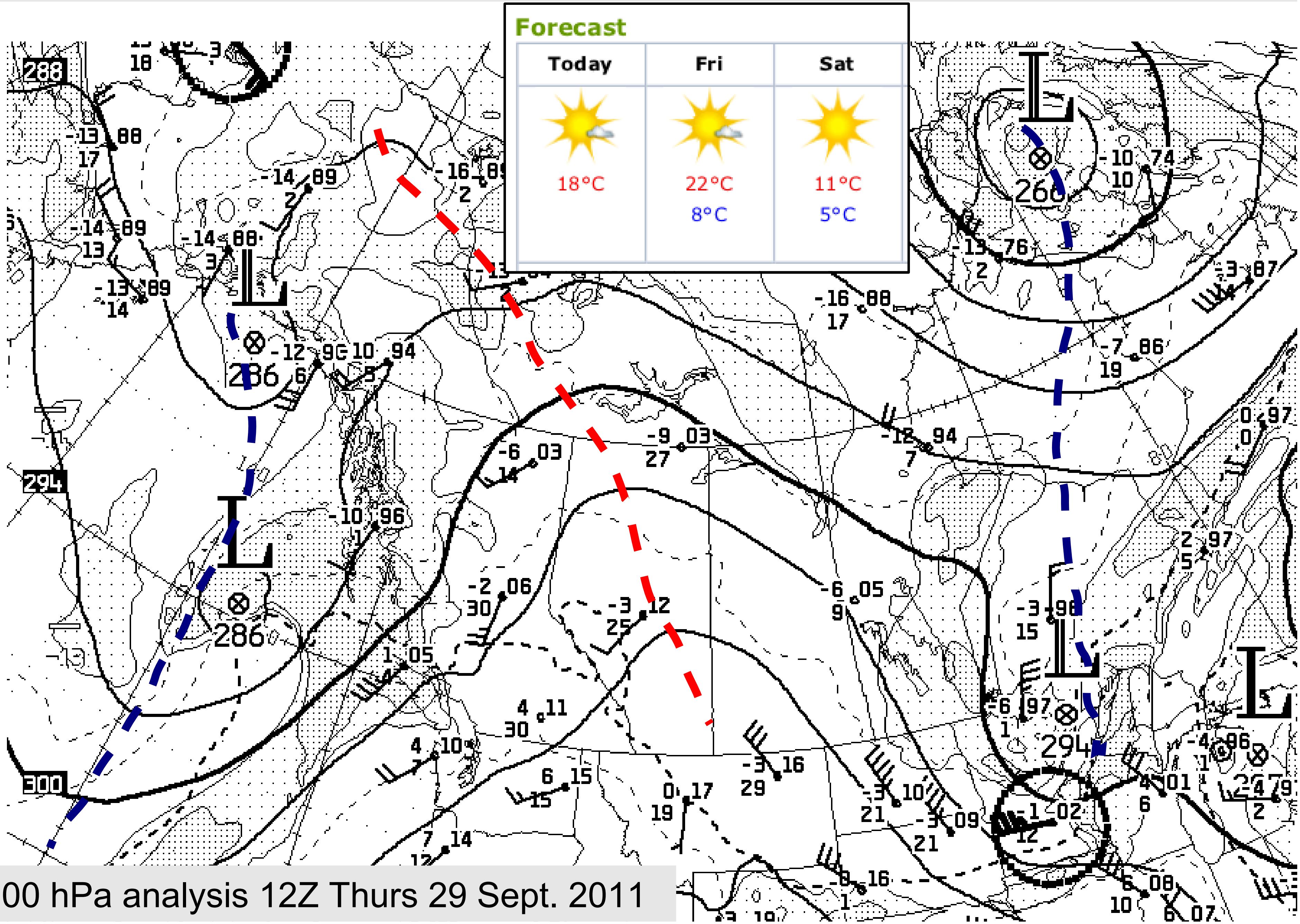
SUNNY AND WARM FOR ALBERTA... NO SIGNIFICANT WEATHER IS EXPECTED OVER THE PRAIRIES OR ARCTIC OVER THE NEXT COUPLE OF DAYS



Note the “height gradient” along this trough axis line as we move towards the centre of the upper low

A trough axis line is analogous to a topographic valley – it is a valley on the isobaric surface (i.e. surface of constant pressure)

PRAIRIE AND ARCTIC STORM PREDICTION CENTRE 7:00 AM CDT THURS SEPT 29 2011...
OVERVIEW... UPPER LOW OVER WESTERN BAFFIN ISLAND WITH TROF SSWWD THRU MANITOBA. WEAK RIDGE OVER BC LEAVING PRAIRIE IN WNWLY FLOW... NO SIGNIFICANT WEATHER OVER EASTERN AND WESTERN PRAIRIES



MSC 700 hPa analysis 12Z Thurs 29 Sept. 2011

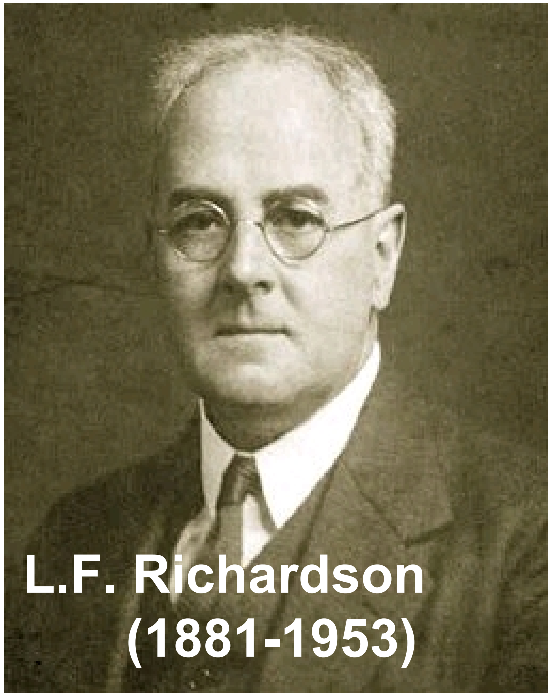
A vast and continuous range of scales of motion (p246)

- Global scale
  Rossby waves…
- Synoptic scale (persist on timescale days-weeks)
  Highs & Lows, Monsoon, Foehn wind…
- Mesoscale (timescale hours)
  sea breeze, valley breeze…
- Microscale (timescale seconds-minutes)
  dust devils, thermals…
- and we don't give specific names to "turbulent eddies" whose scale spans (roughly) 100 m – 0.001 m (minutes to milliseconds)

- largest scales of motion are "quasi two-dimensional," meaning that ($W << U,V$), due to thinness of troposphere (p5)

- smallest scales are three-dimensional and turbulent

A vast and continuous range of scales of motion (p246)



"Big whorls have little whorls,
Which feed on their velocity;
And little whorls have lesser whorls,
And so on to viscosity."

- L.F. Richardson, 1922
(parody of poem** by Johnathon Swift, 1732)

"Great fleas have little fleas upon their backs to bite 'em, And little fleas have lesser fleas, and so *ad infinitum*."

- ambulance driver, WW1 France
- in off-duty time, embarked on test of his mathematical weather forecasting method. Had with him in France observations for 7 a.m., 20 May 1910
- by 1916, had written *Weather Prediction by Arithmetic Finite Differences*…

This poem hints at the interaction and mutual interdependence of distinct scales of motion. Our focus for now is the synoptic scale horizontal wind