The Atmosphere Above the Antarctic Plateau

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Fellow Days - Arcetri - Oct 10 2007

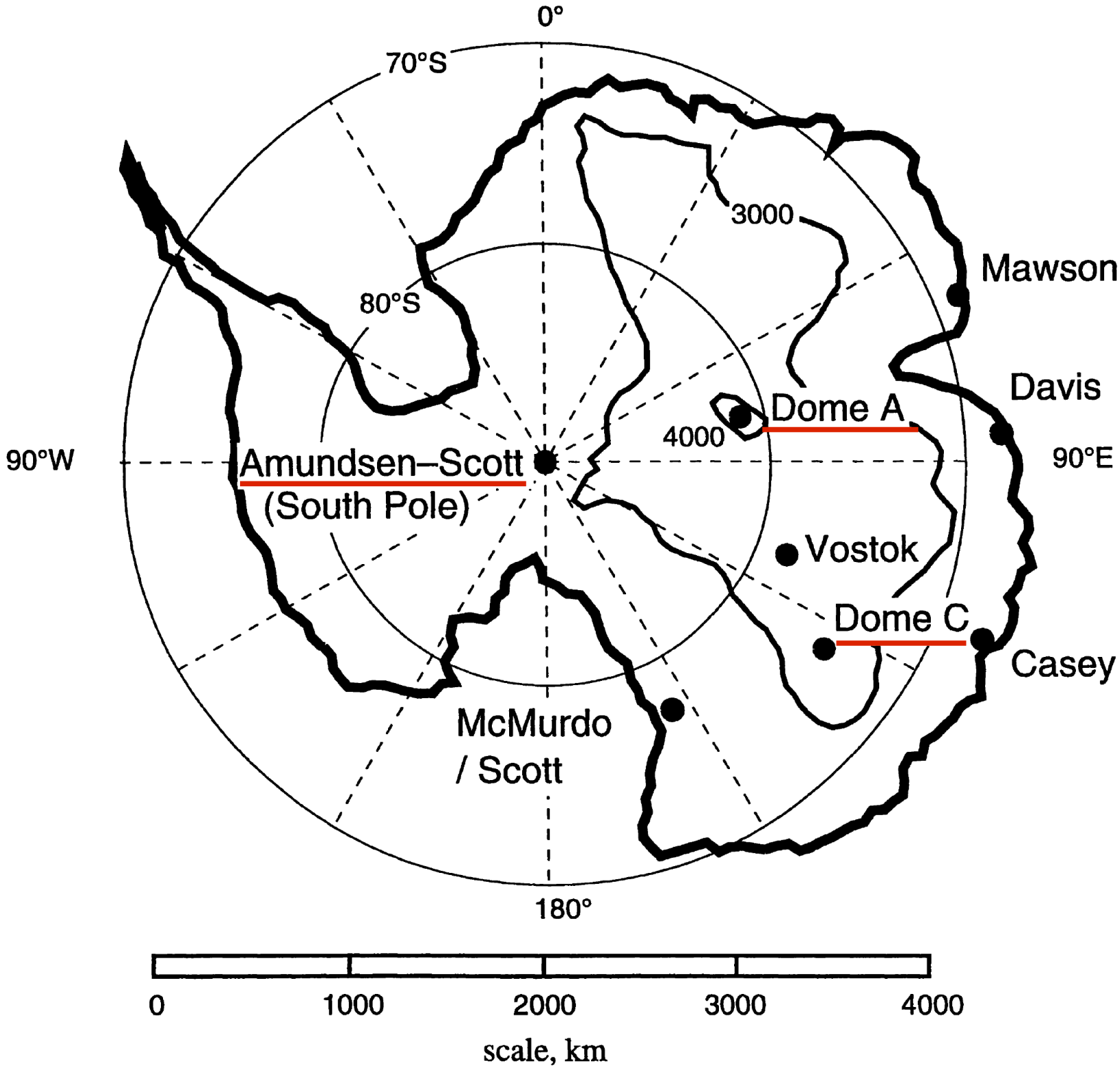
Why Antarctica?

- The antarctic atmosphere is:
  - Thin – Average altitude of the continent 2500 m
  - Cold – Average year-round temperature -50°C
  - Dry – PWV (Percipitable Water Vapour)

Florence	~20 mm
Mt Graham	2.9 mm
South Pole	0.4 mm

Why Antarctica?

- Stable atmosphere
- Most of the turbulence concentrated in a thin surface layer (a few tens of meters)
- Low wind speeds in the free atmosphere (?)
  - No jet streams, but there is the polar vortex
- Surface winds are generally weak above the Internal Antarctic Plateau


0°
70°S
80°S
3000
Mawson
Davis
Dome A
4000
90°W
90°E
Amundsen–Scott
(South Pole)
Vostok
Dome C
Casey
McMurdo
/ Scott
180°
0
1000
2000
3000
4000
scale, km

Measurements from the Plateau

- South Pole
  - Strong turbulence in a 200 m thick surface layer
  - Average seeing 1,73”
  - Average seeing above 300 m 0.37”

(Travouillon et al. 2003)

- Dome C
  - The surface layer is 36±10 m thick

(Agabi et al. 2006)

  - Measured seeing 0.27” median seeing above 30 m

(Lawrence et al. 2004)

Dome A better?

- Highest summit of the plateau
- Weaker surface winds
  - The strength of the surface wind speed of the Antarctic Plateau is proportional to the steepness of the slope

=> thinner surface layer

- No measurements available yet

Method

- Data extracted from the GCM of the ECMWF (General Circulation Model of the European Centre for Medium-Range Weather Forecasts)
- Every 6h the model gives an analysis of the present state of the atmosphere globally and several forecasts.
- Using the analyses to compare Dome A, Dome C and the South Pole
- Particularly the first 150 m

Method

- Data extracted for all of 2005 at 00:00 UTC
- The monthly median of several meteorological parameters
  - Wind speed
  - The gradient of the potential temperature
  - Richardson number

Reliability of the Analyses

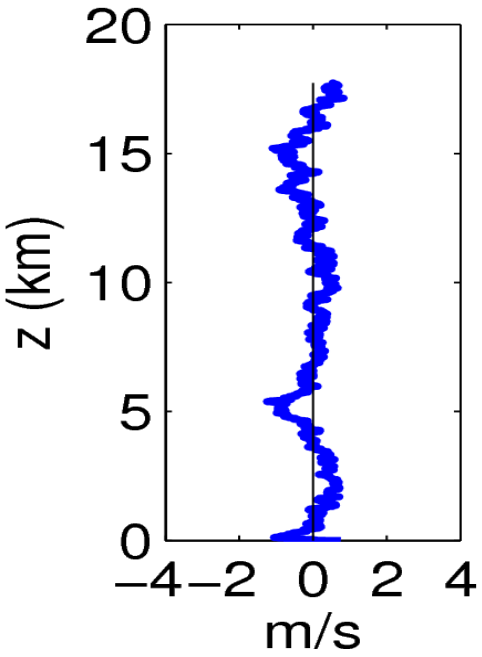
- GCM describes the circulation of the entire planet
- Horizontal resolution 0.5° x 0.5°
- Orography is smoothed
- Largest effect near the surface
- Analyses compared with radiosoundings

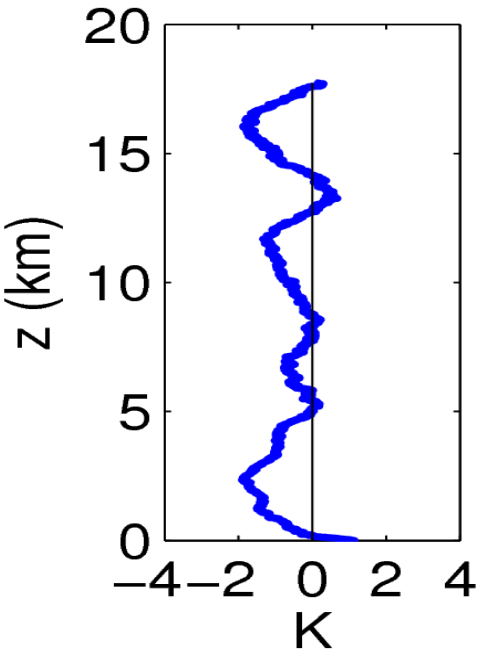
Mean of the Difference

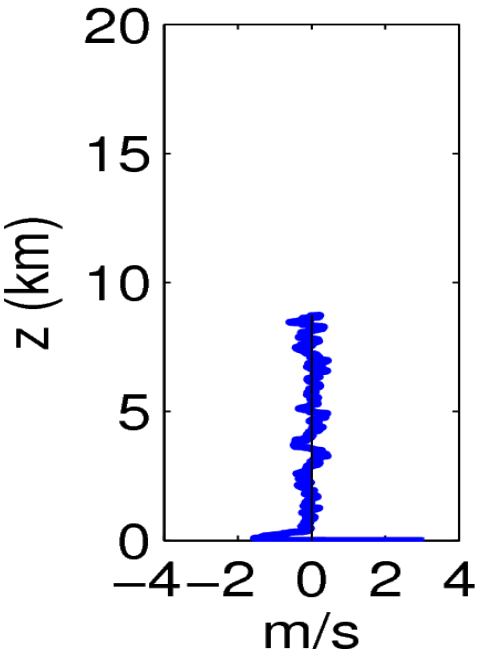
Dome C

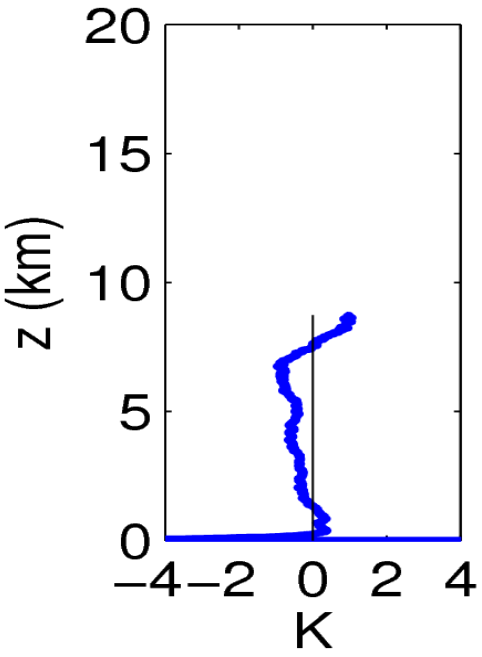
Summer
(Dec, Jan, Feb)

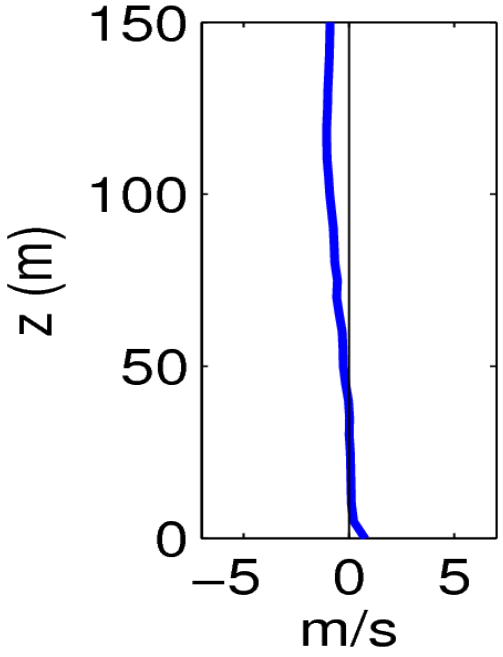
Winter
(Jun, Jul, Aug)

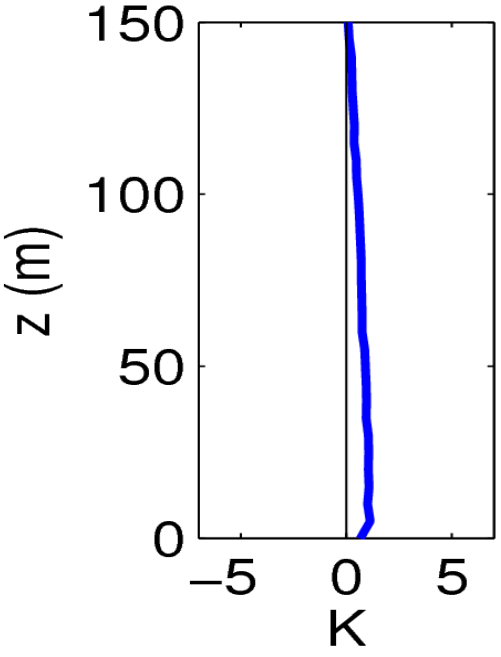


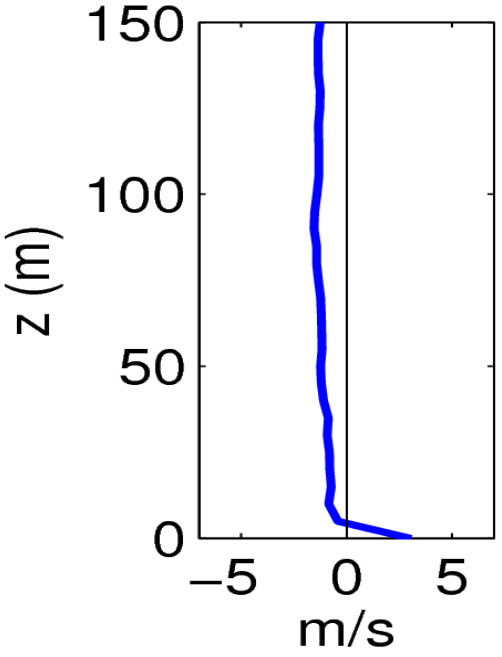


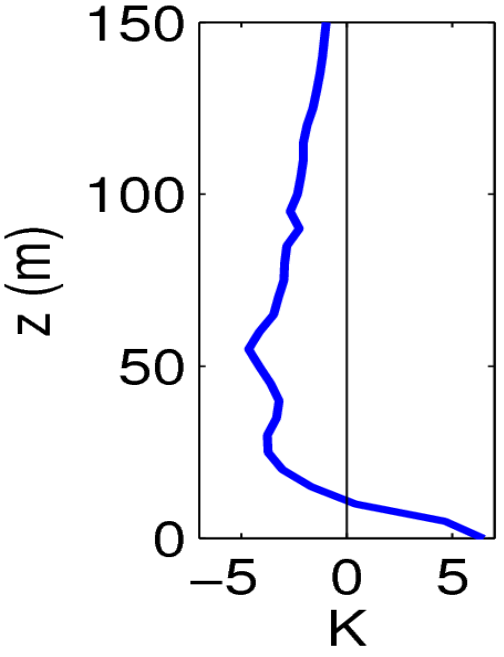






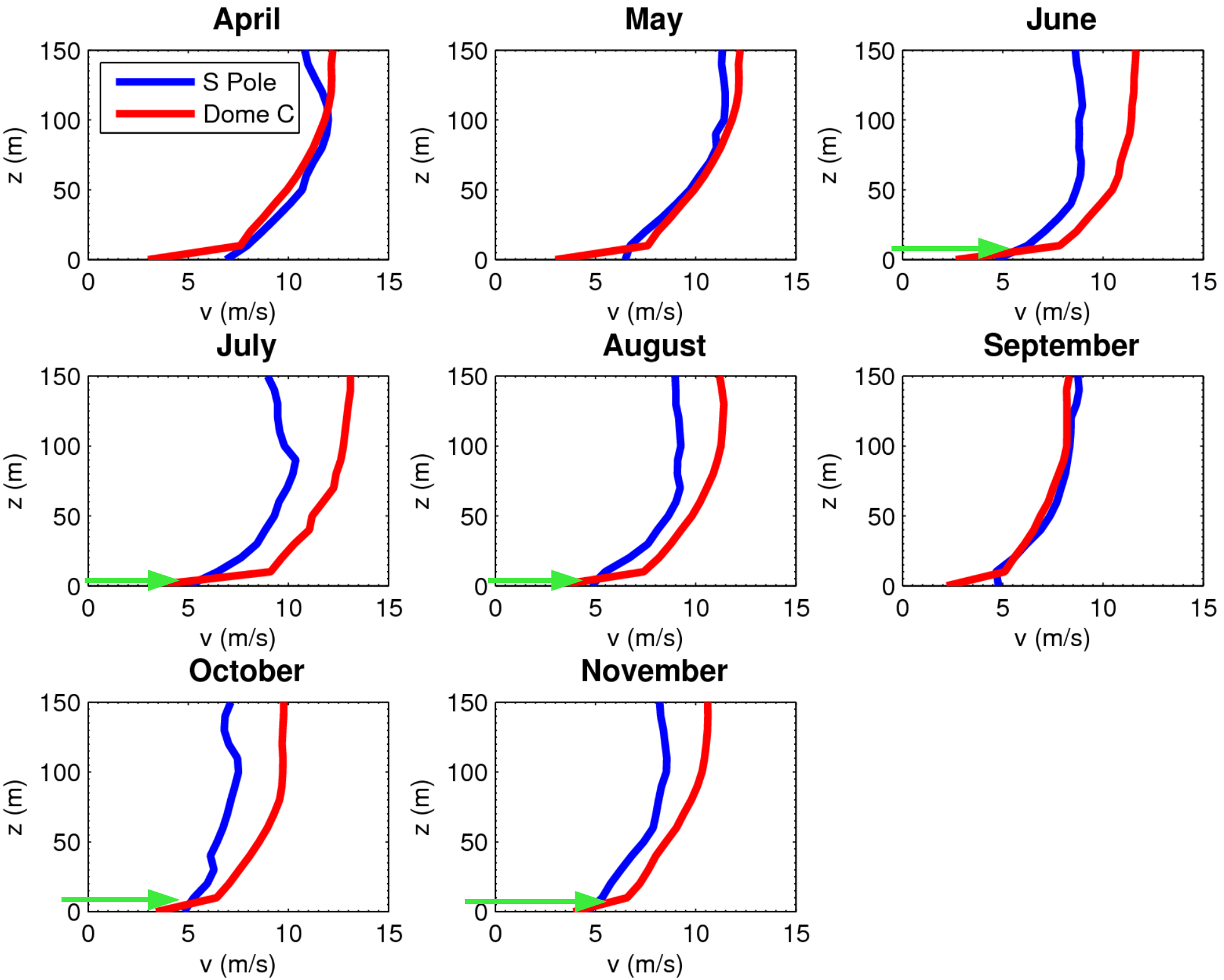






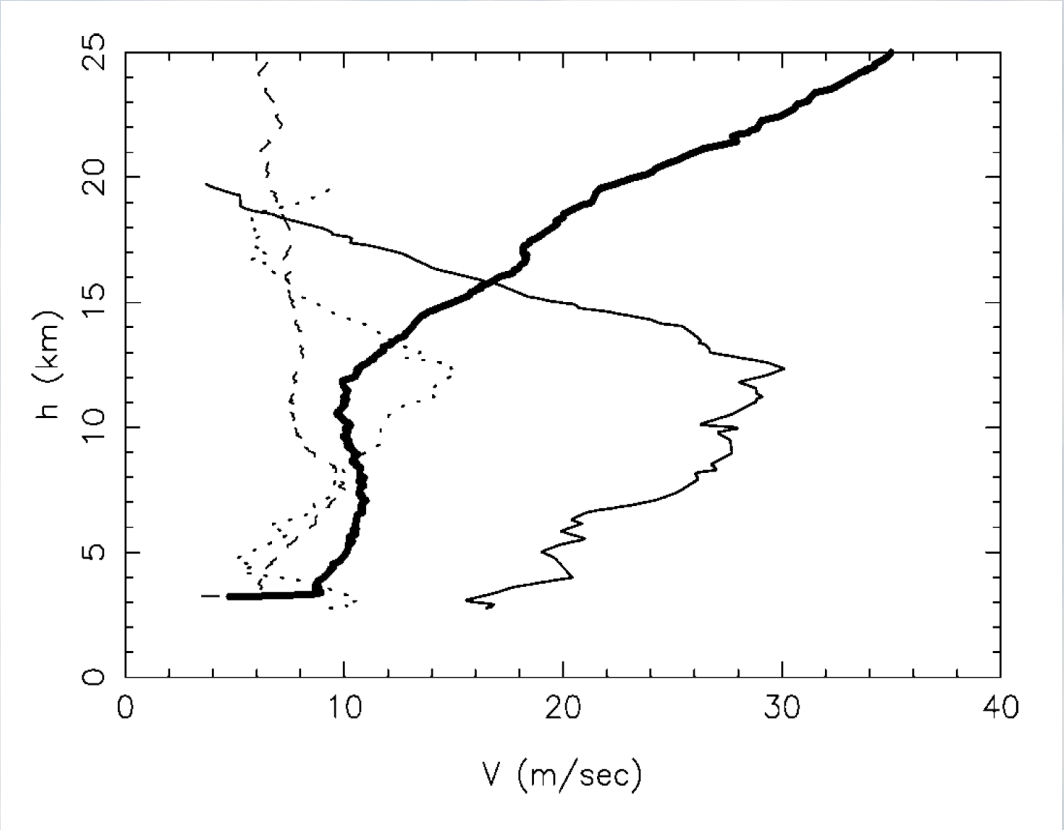
Wind Speed Near the Surface

- Near the surface the resolution of the analyses data is too low to be able to discriminate between the sites
- The surface wind speed should be weaker at the summits than at the slopes
- Radiosoundings from the South Pole (slope) and Dome C (summit) give a slightly different picture

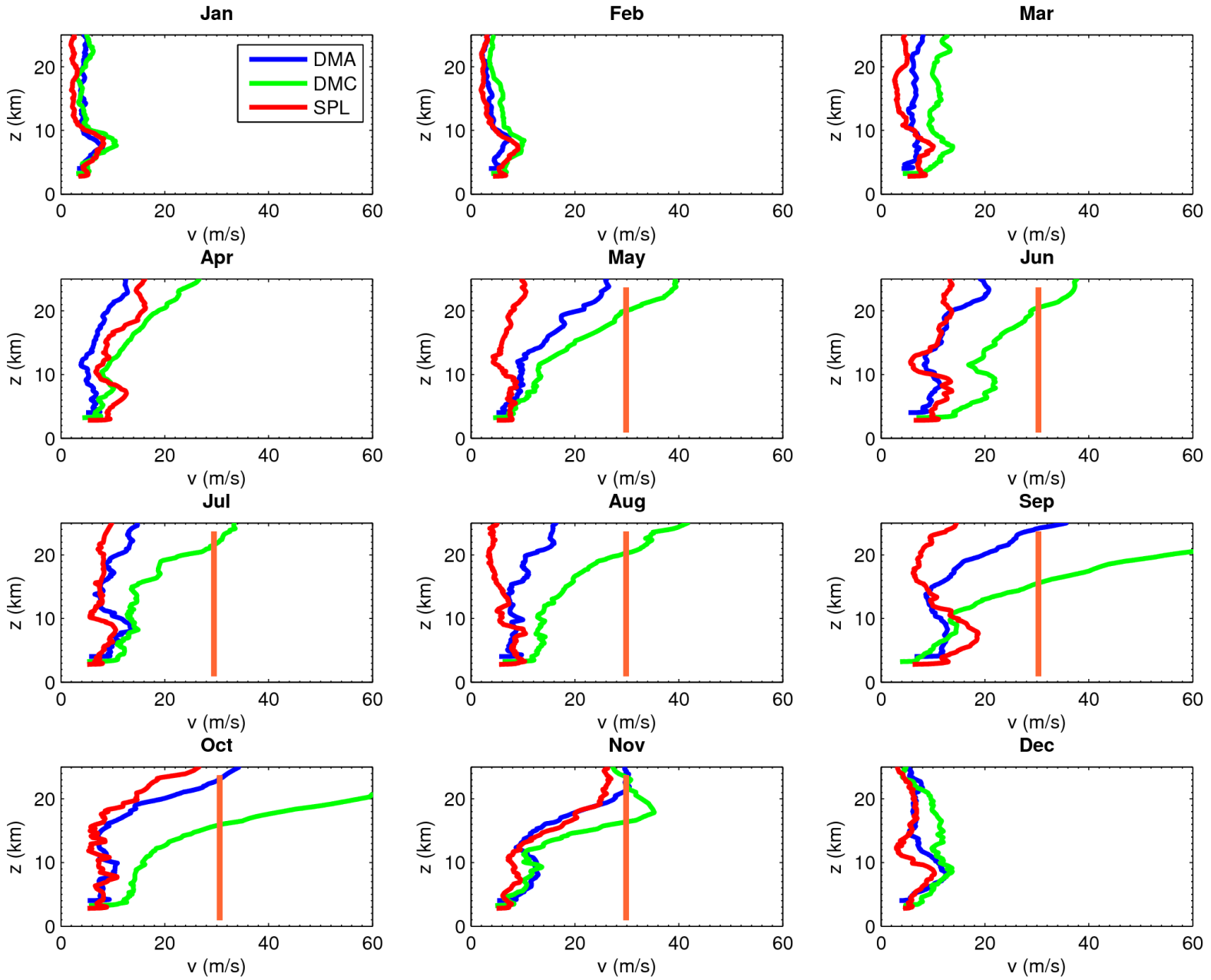

April
May
June
July
August
September
October
November
S Pole
Dome C
z (m)
v (m/s)
0
50
100
150
0
5
10
15

Wind Speed in the Free Atmosphere

- At mid-latitudes the wind speed profile has a peak at the jet stream, 300 hPa (≈10 km)
- Over Antarctica high altitude winds are dominated by the polar vortex

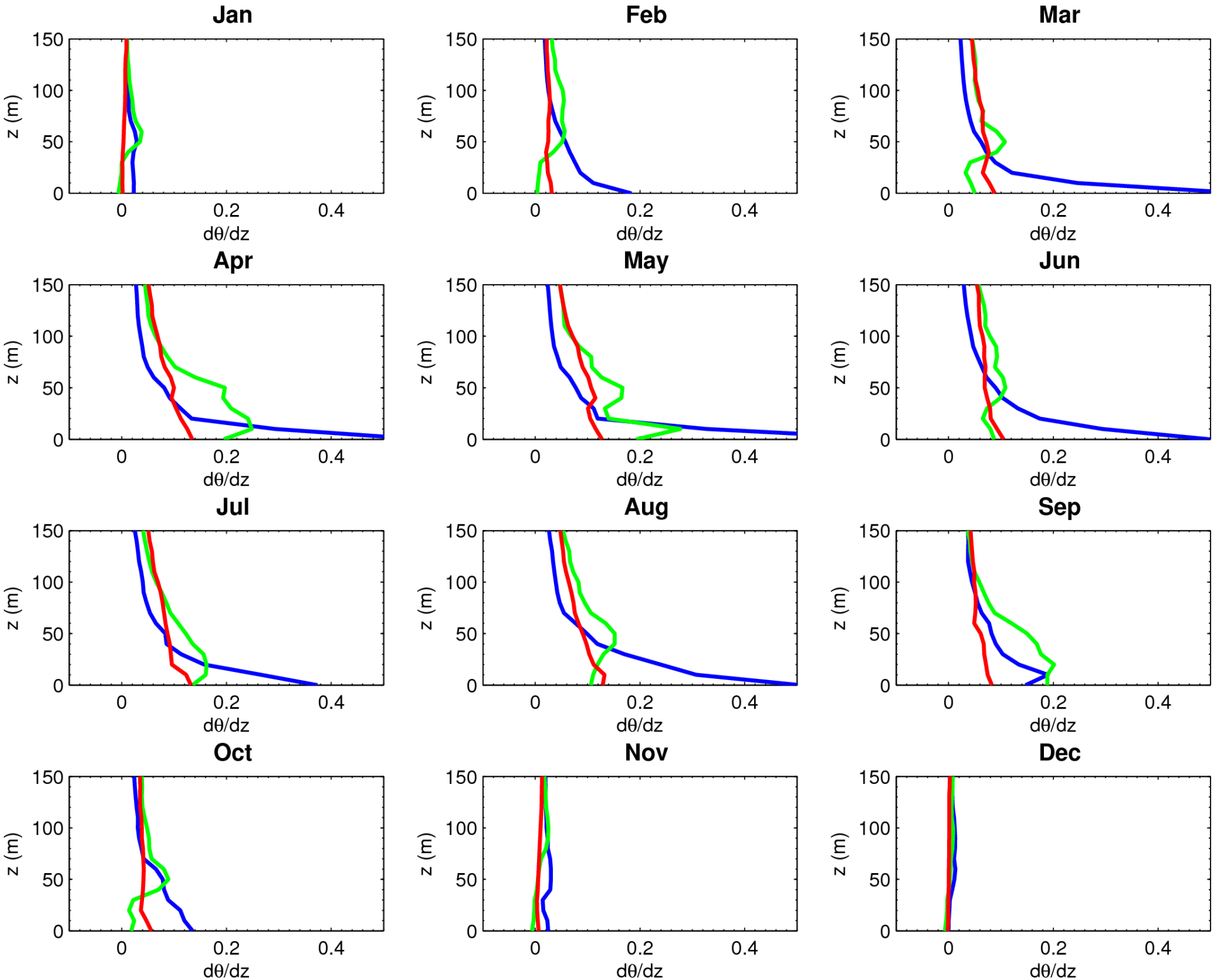


Geissler & Masciadri (2006)


Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
DMA
DMC
SPL
z (km)
v (m/s)
0
10
20
0
20
40
60

Potential Temperature

- The temperature an air parcel would have if it was brought down adiabatically to 1000 hPa.
- During the absence of sun light the radiative cooling of the ice surface makes it colder then the air above
- If the temperature increases with height the stratification is thermally stable and vertical motion of the air is supressed


Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
z (m)
dθ/dz
0
50
100
150
0.2
0.4

The Richardson Number

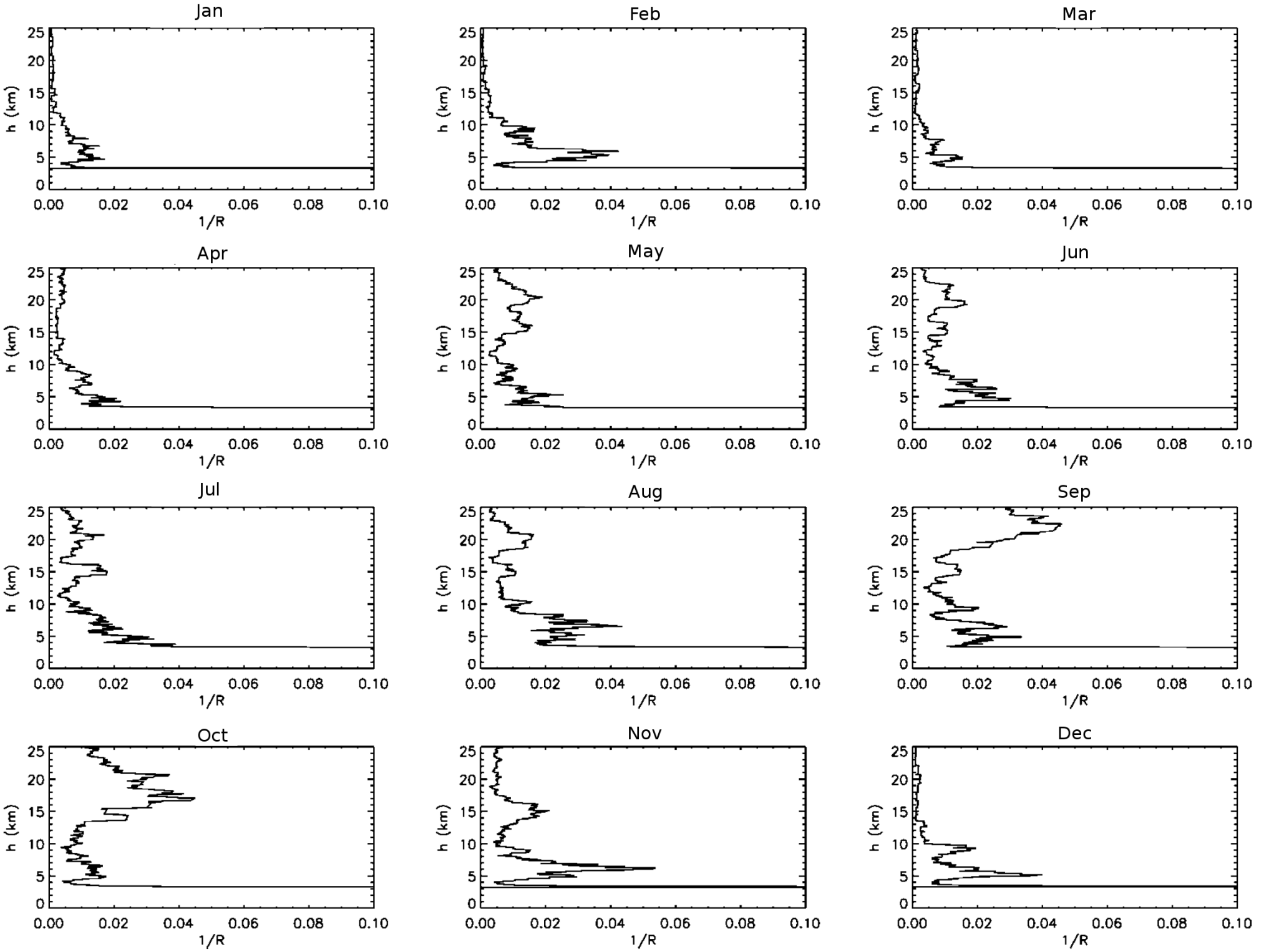
- Indicates the stability of the atmosphere

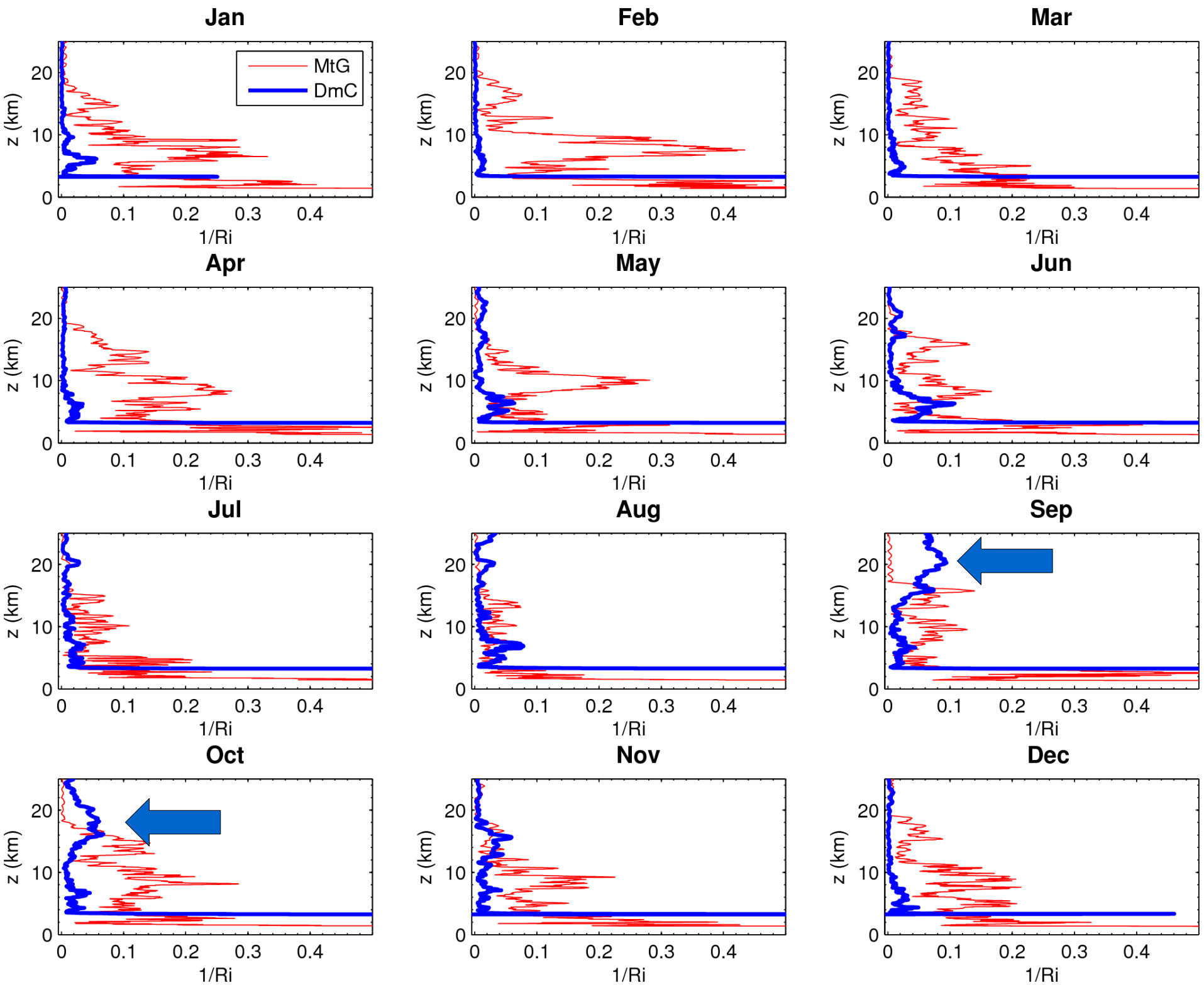
$$Ri = \frac{g}{\theta} \frac{\partial \theta / \partial z}{(\partial v / \partial z)^2}$$

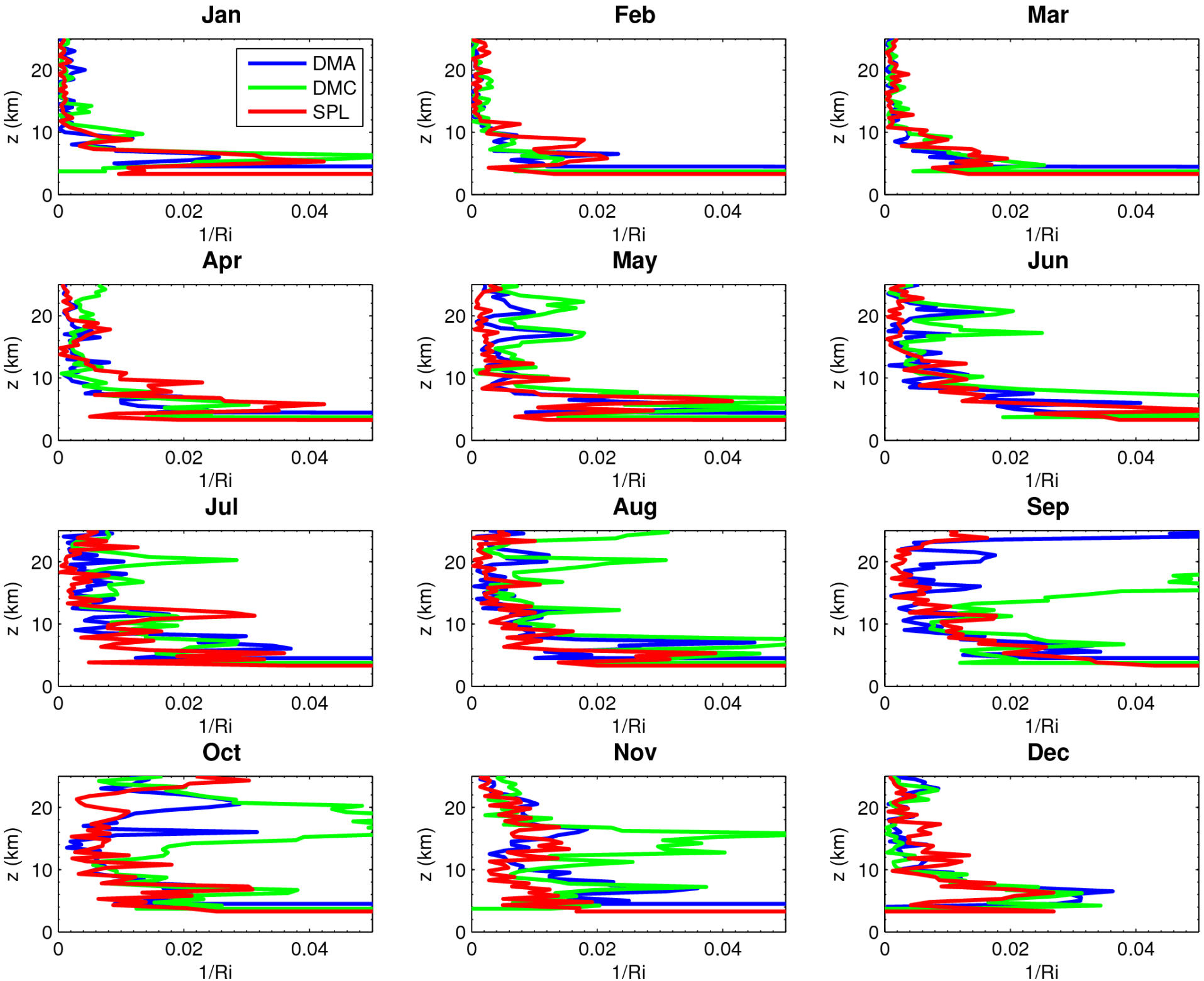
- The less stable the atmosphere is, the higher is the probability of triggering turbulence

The Richardson Number

- Pressumably the atmosphere over Antarctica should be more stable than over a mid-latitude site
- But, is it...


Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
h (km)
1/R
0
5
10
15
20
25
0.00
0.02
0.04
0.06
0.08
0.10


Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
MtG
DmC
z (km)
1/Ri
0
10
20
0.1
0.2
0.3
0.4


Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
DMA
DMC
SPL
z (km)
1/Ri
0
10
20
0.02
0.04

Conclusions

- These analyses have a resolution that is too low to be able to determine the height of the surface layer
- In the free atmosphere the most stable site is the South Pole
- Dome A and especially Dome C are influenced by the Polar Vortex

Conclusions

- The analyses data can only give a relative estimate of the difference between the sites
- To better understand which is the better site
  - measurements
  - a mesoscale model with a higher resolution,

    e.g. Méso-NH