LIDAR SOUNDINGS OF GRAVITY WAVES IN THE MIDDLE ATMOSPHERE ABOVE SOUTH POLE

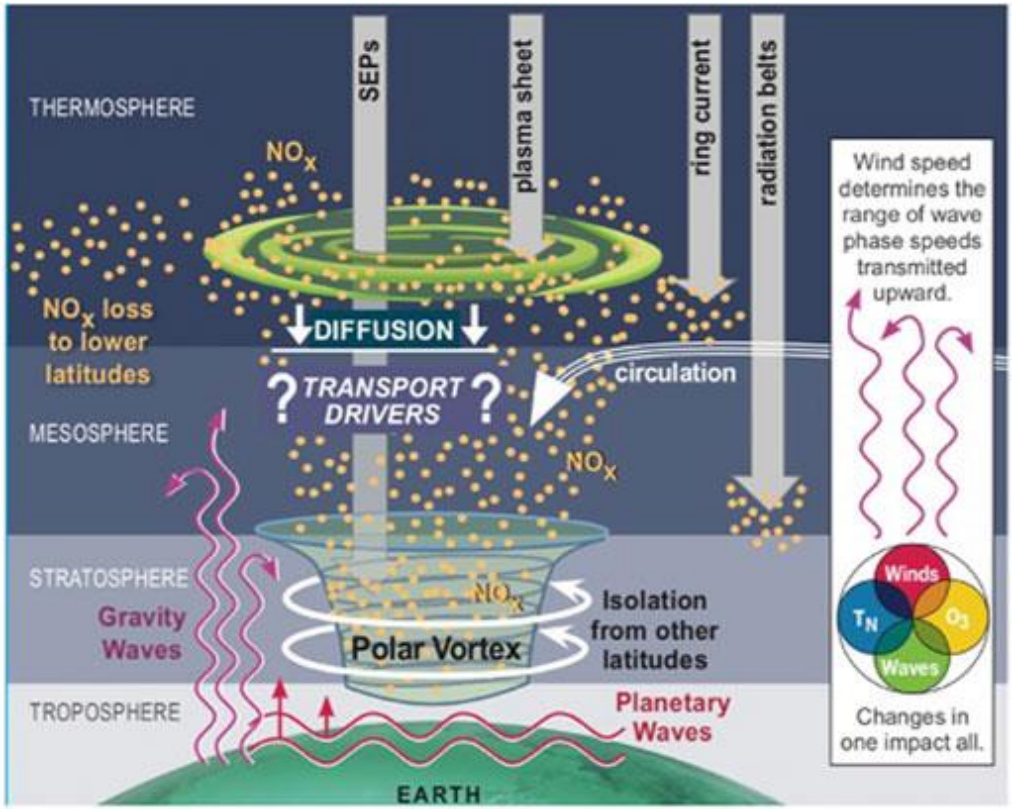
Natalie Kaifler and Bernd Kaifler

ANGWIN workshop

3-7 June 2024, Fredericton, Canada

DLR

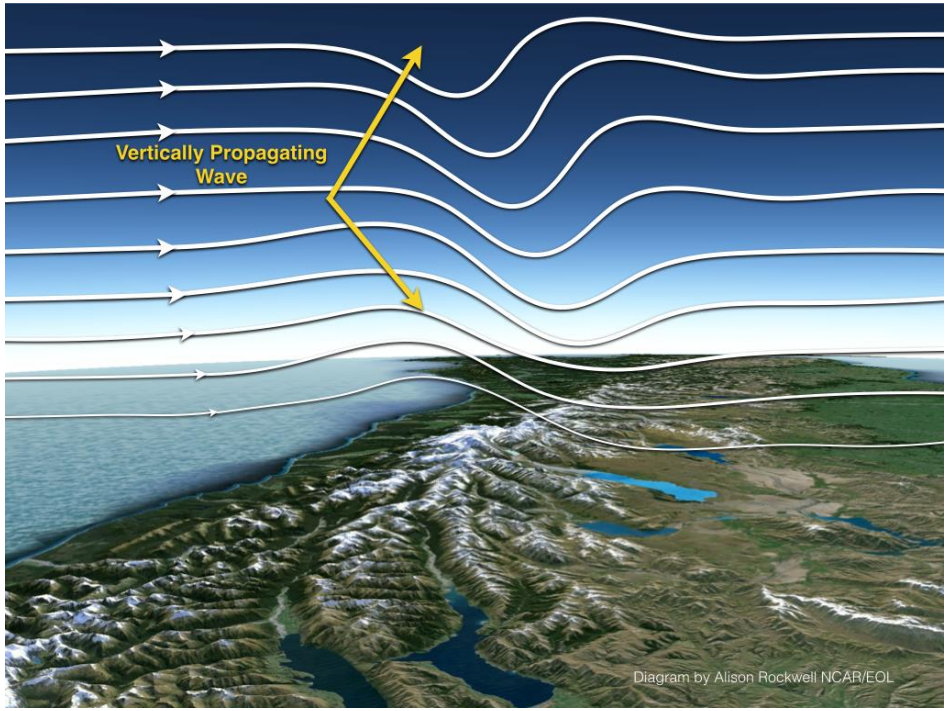
Gravity waves in the southern winter middle atmosphere



From Harvey et al., Front. Astron. Space Sci., 2022

The wave structure in these clouds over Mawson is caused by gravity waves in the Antarctic atmosphere Photo: Chris Wilson

Australian Antarctic Magazine, Issue 28



DEEPWAVE campaign, New Zealand

Lidar principle

- Laser pulse transmitted at time t0
- Scattering at altitude

$$z = c\frac{t-t_0}{2}$$

proportional to air density

- Backscattered photon received at time t

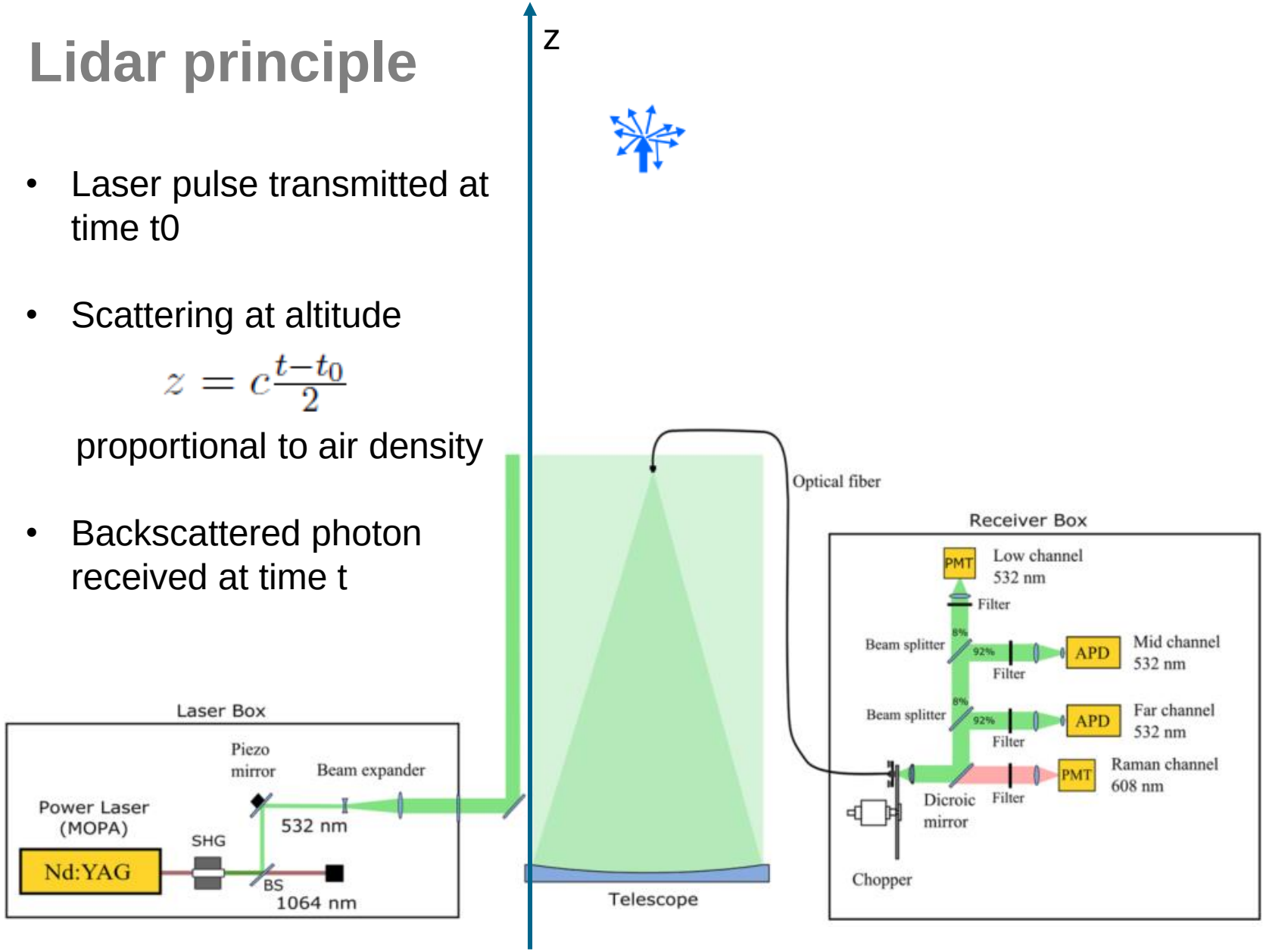


Figure 2. Schematics of the lidar instrument and optical paths. **B. Kaifler and N. Kaifler: Compact Rayleigh Autonomous Lidar**

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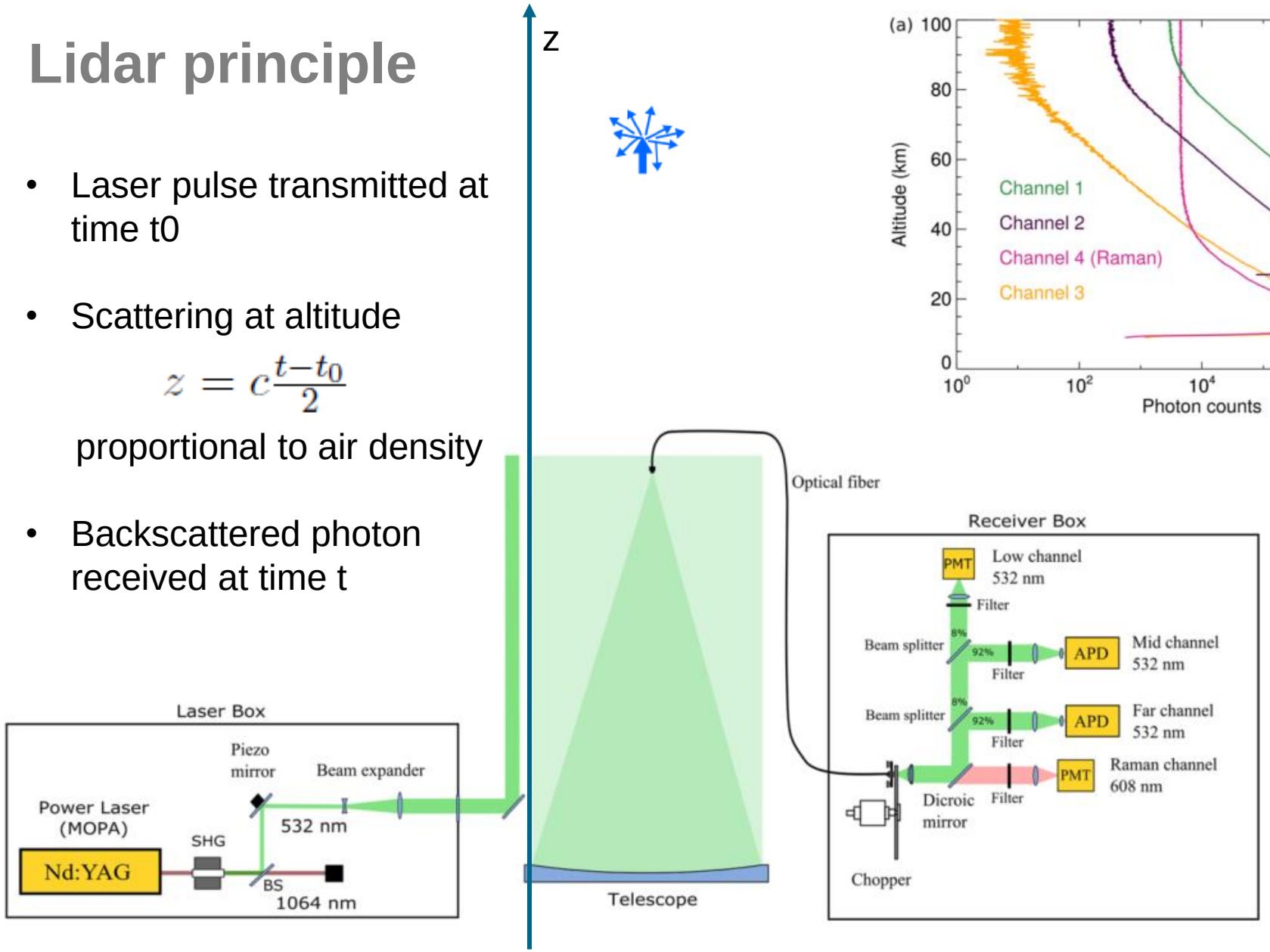
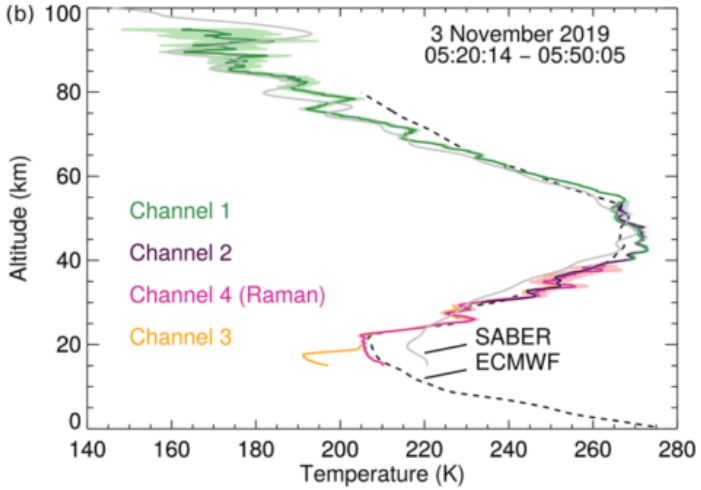


← Binnen photon counts

- Hydrostatic integration: temperature



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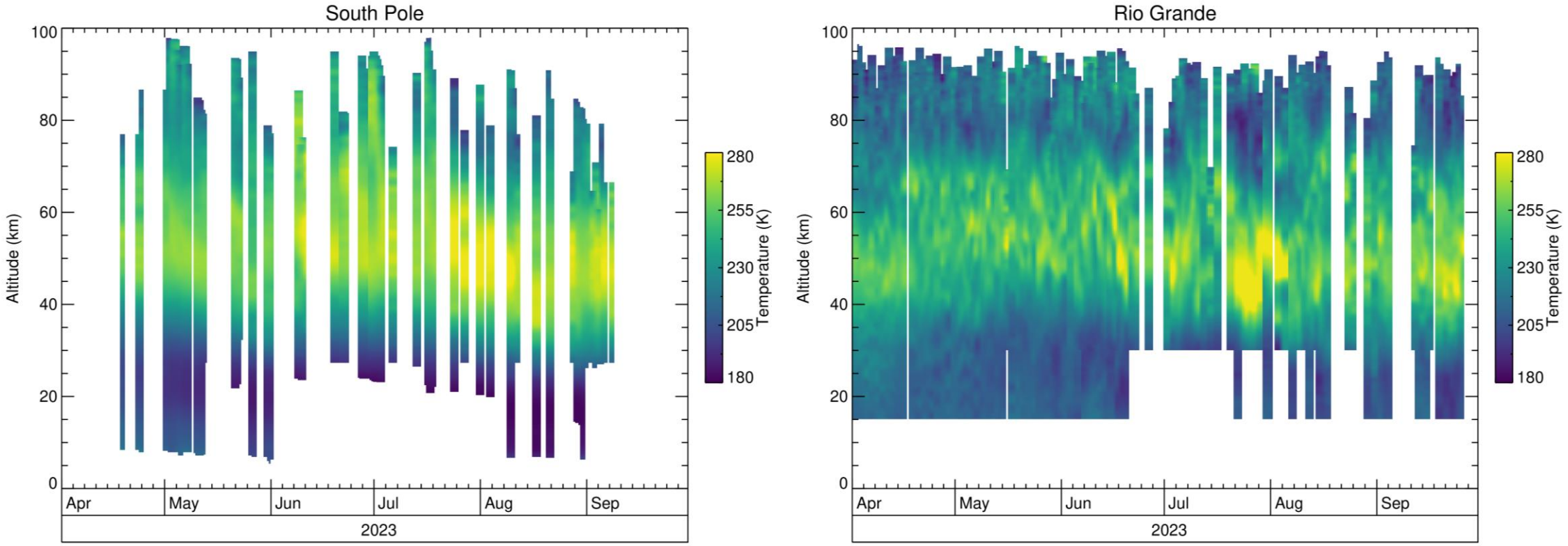
Temperature at South Pole and Rio Grande

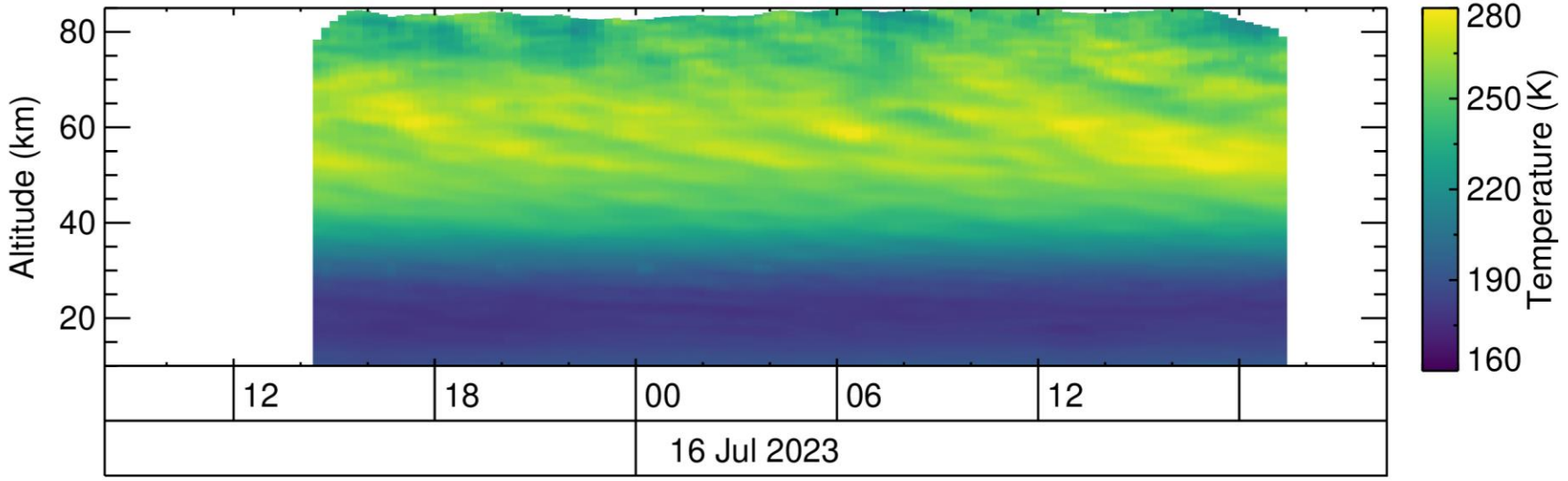


→ Nightly mean temperature profiles at South Pole and Rio Grande
→ Comparable; but variability is higher at Rio Grande

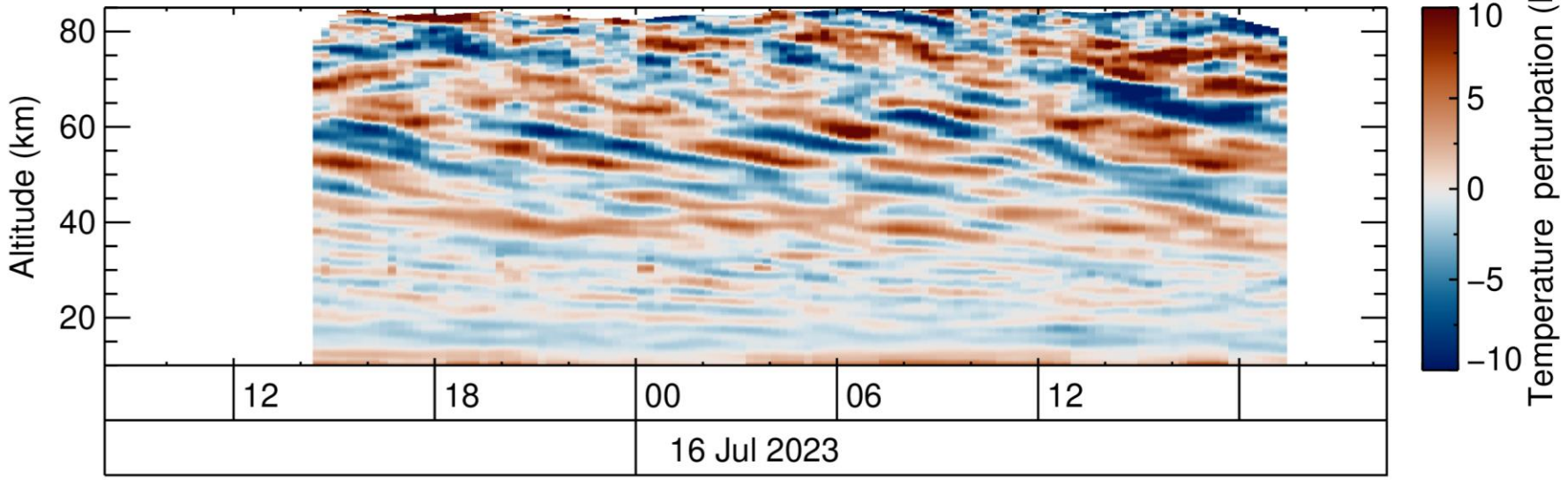
Gravity waves from temperature perturbations

TELMA lidar at South Pole

- Temperature at different resolutions
- Here 60 min

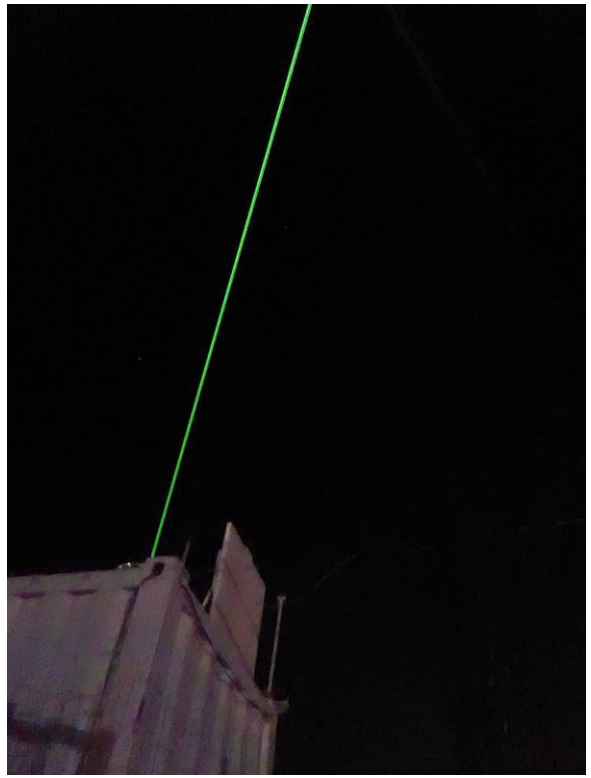


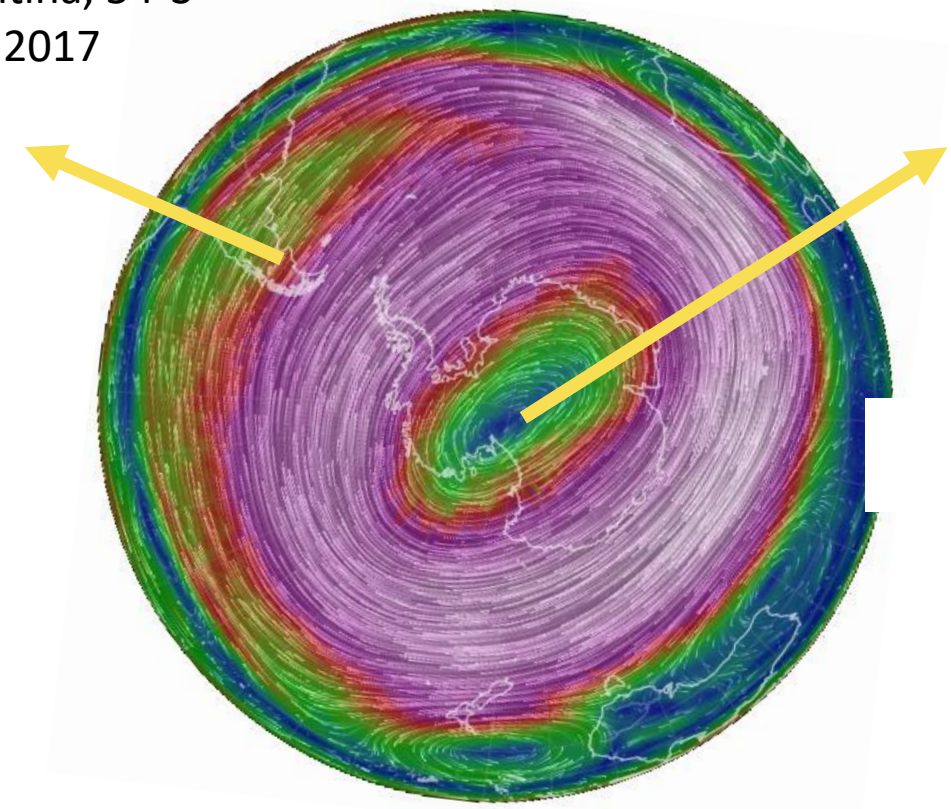
- 20 km vertical Butterworth filter for gravity waves



South Pole and Rio Grande

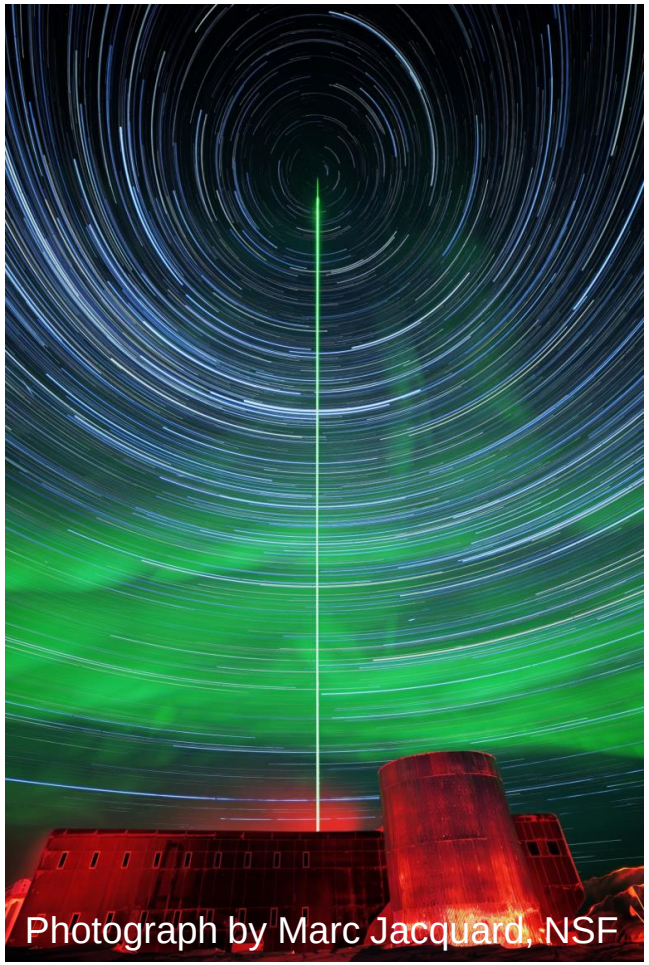
Rio Grande, Argentina, 54°S
CORAL lidar since 2017





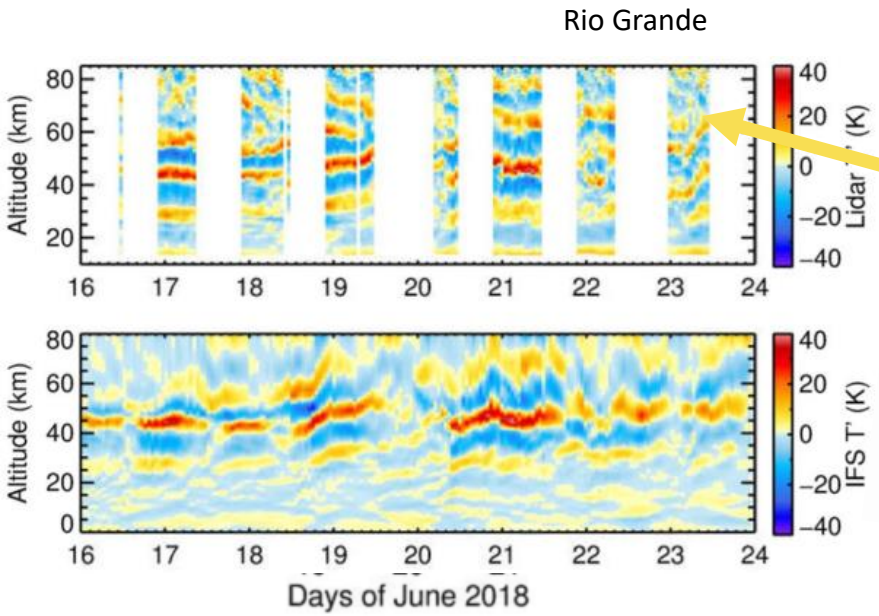
Wind at 10 hPa, 15 June 2023
GFS / NCEP / US National Weather Service

South Pole
TELMA lidar

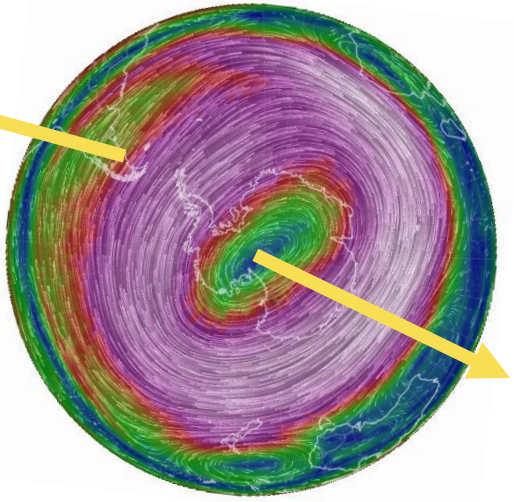


Gravity waves at South Pole and Rio Grande

- Orographic with high potential energy densities dominate at Rio Grande
- Gravity waves with shorter wavelengths and less amplitude at South Pole



Kaifler et al., Lidar observations of large-amplitude mountain waves …, Scientific Reports, 2020



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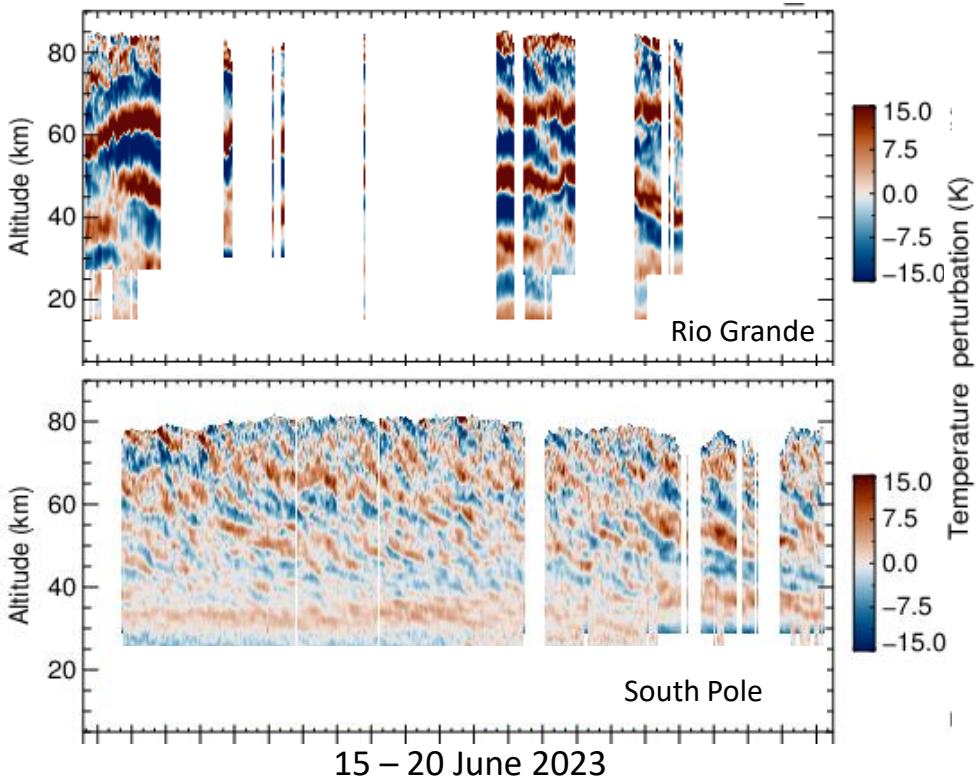
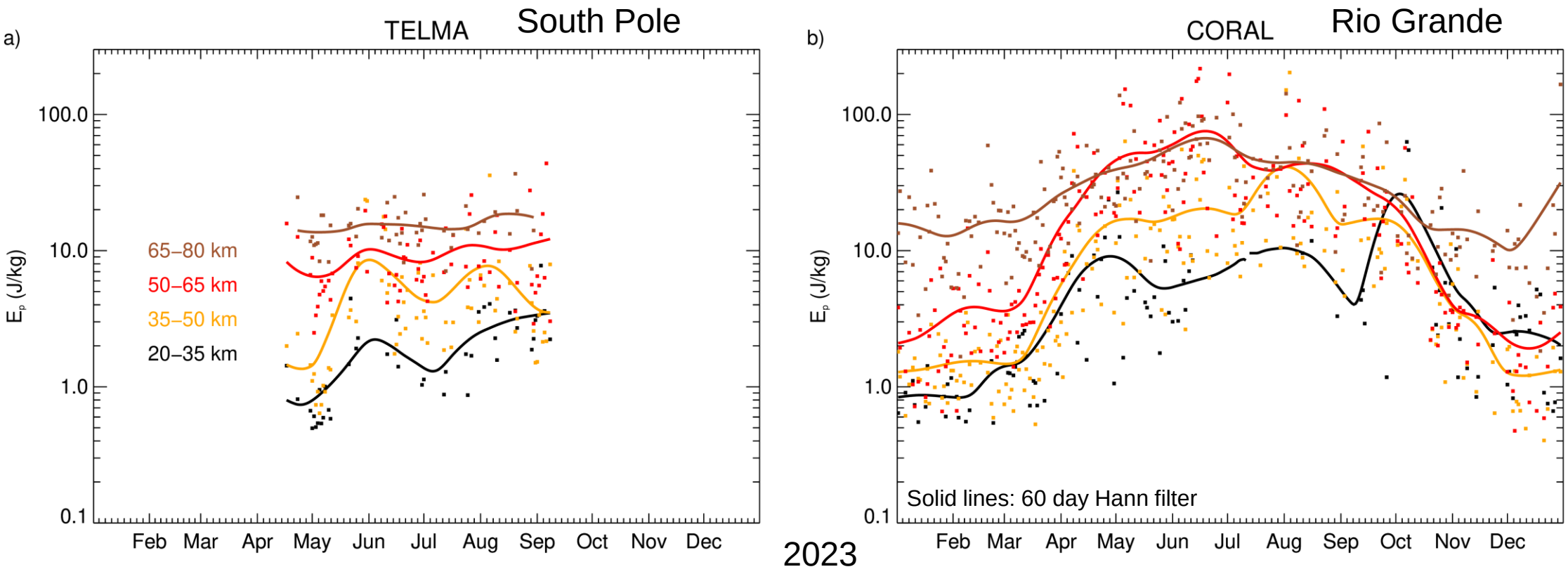


→ Gravity waves at center and edge of polar vortex are different
→ Origin of gravity waves at South Pole?

Evolution of potential energy density

$$F_{ph} = \frac{1}{2}\varrho\frac{k_h}{m}\left(\frac{g}{N}\right)^2\left(\frac{\hat{T}}{T}\right)^2 = \frac{k_h}{m}E_{pot}$$

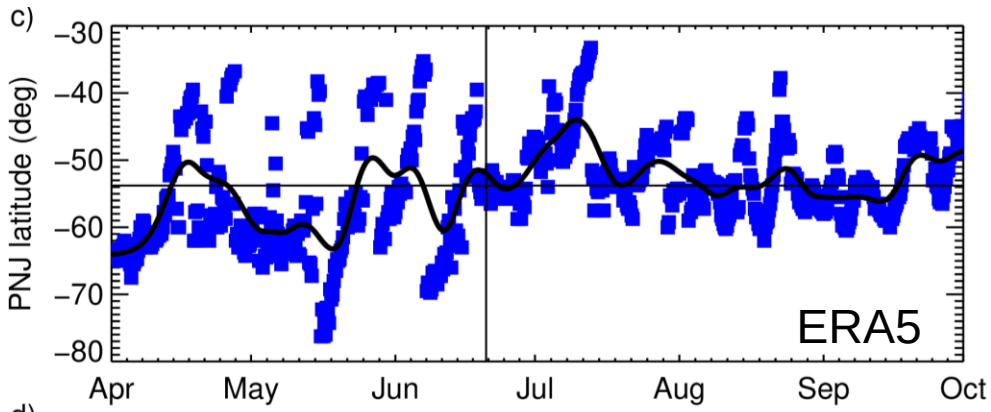
Ern et al. (2004)



→ Increase with altitude at South Pole
→ Lower at South Pole compared to Rio Grande, but above winter values

Winter stratopause

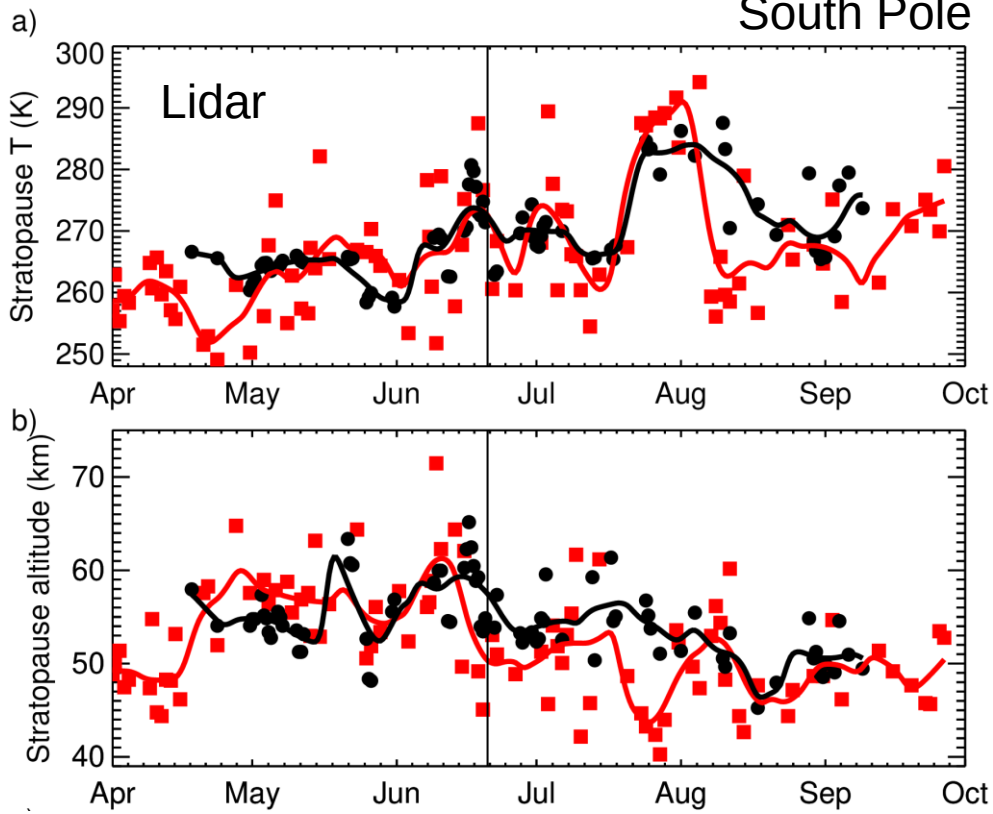
Winds



Temperature

Rio Grande

South Pole



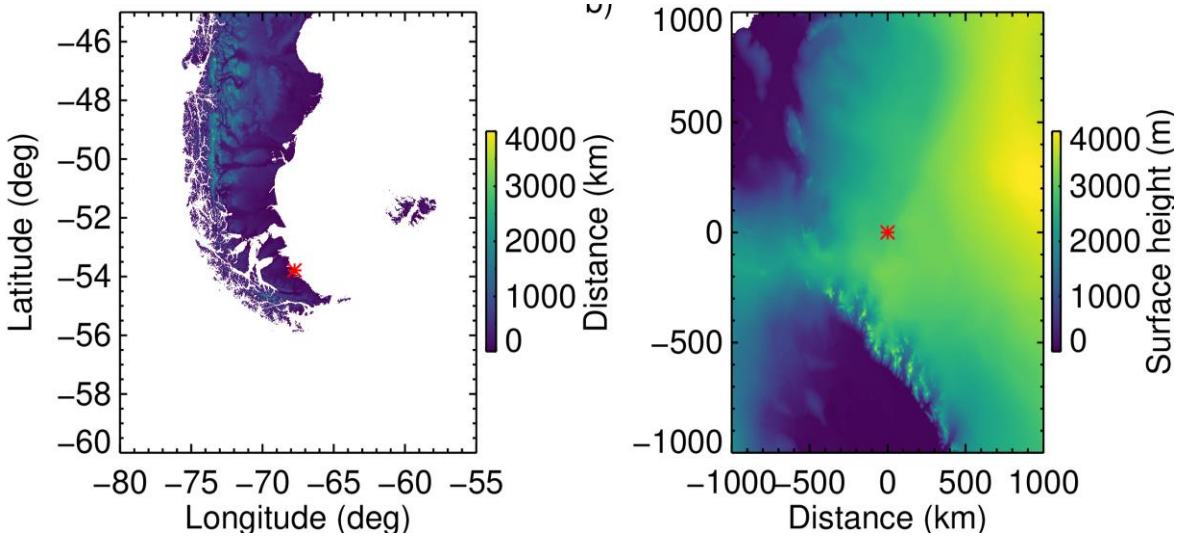
→ Polar vortex edge above Rio Grande
→ Vortex fully developed after solstice

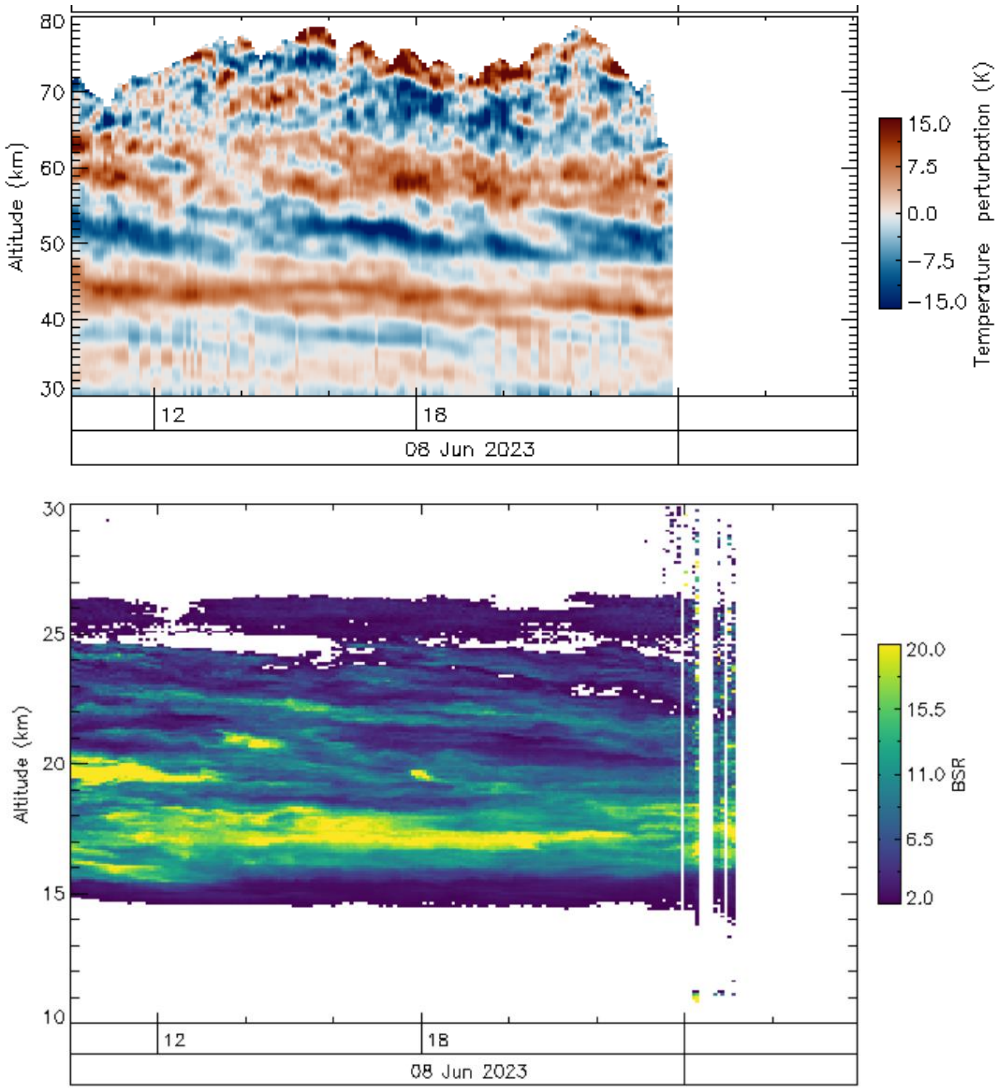
→ Comparable stratopause T;
higher at South Pole in August
→ Comparable stratopause altitude

Orographic waves from Transantarctic Mountains

Rio Grande:
- 18 m elevation
- rugged topography
- strong winds

South Pole:
- 2800 m elevation
- flat surrounding
- Transantarctic Mountains at 400 km distance



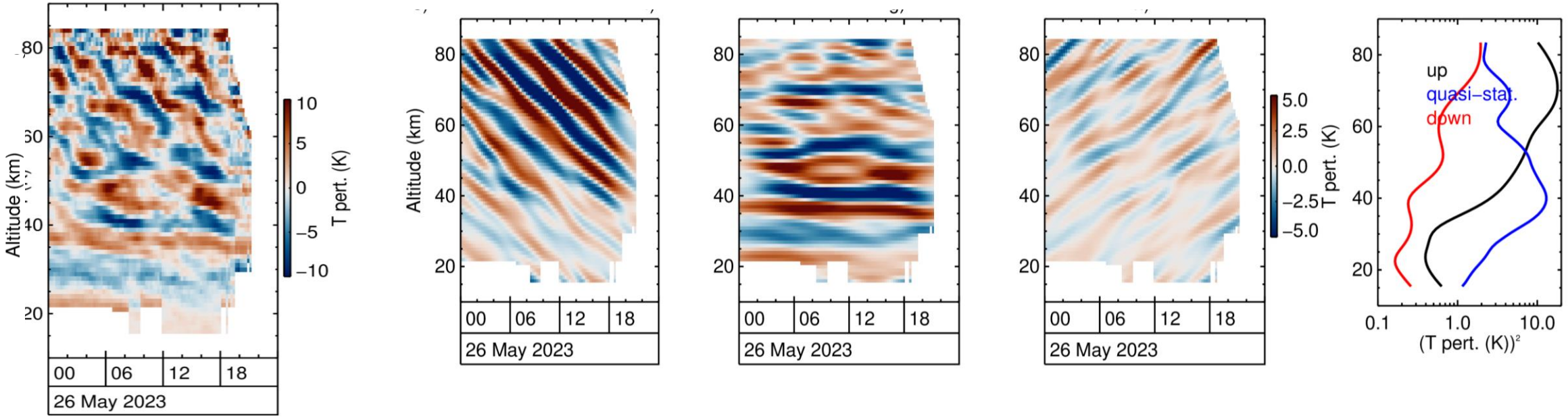


- Observation of polar stratospheric clouds at South Pole
- Possibly form in cold phases of orographic waves

Upward-, quasi-stationary- and downward propagating waves

Spectral decomposition with
2d wavelets

T squared



- Decompose wave field and quantify contributions

→ Upward propagating waves dominate in mesosphere

→ Quasi-stationary waves dominate in stratosphere

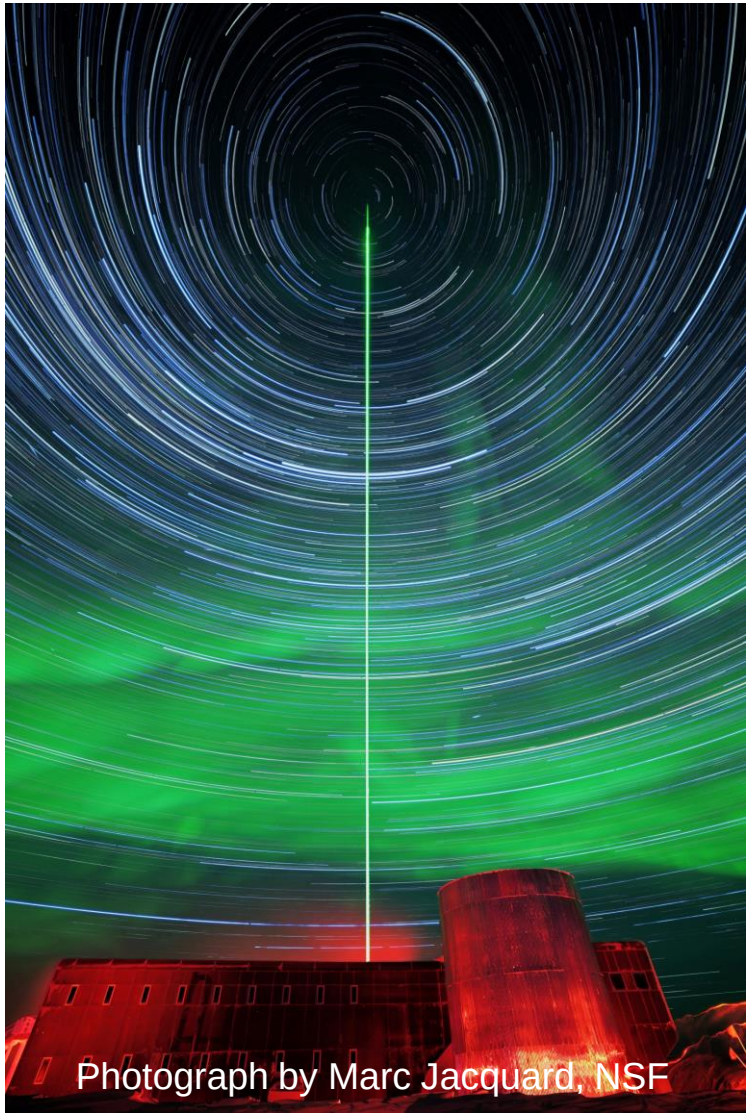
Conclusion

- More than 600 h of lidar observations at South Pole in winter 2023
- Also operating now (winter 2024)
- Temperature up to 90 km
- Observation of gravity waves up to the mesopause region
- Lower amplitudes and potential energy density than at polar vortex edge
- Investigation of two possible sources
  - Polar vortex dynamics and
  - Orographic waves from nearby Transantarctic Mountains

Thank you for listening!

Thanks to Dominique, Yucheng, Mike, Christopher and South Pole staff

Bernd Kaifler, installation of TELMA, Jan 2023


Photograph by Marc Jacquard, NSF