Infrarødt kamera for deteksjon av gravitasjonsbølger

A search for the smallest scale waves that drive global circulation

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Background Picture from D. Fritts

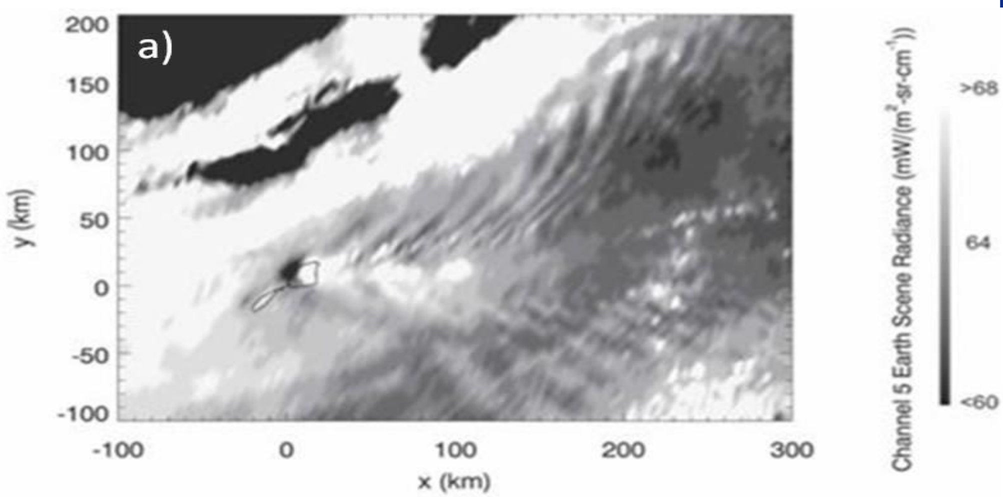
See gravity waves every day

- Gravity Waves: oscillations of air parcels
  - Restoring forces: gravity and buoyancy
- NOT General relativity: Gravitational Waves
  - Ripples in the curvature of spacetime

Gravity waves in clouds from the ground

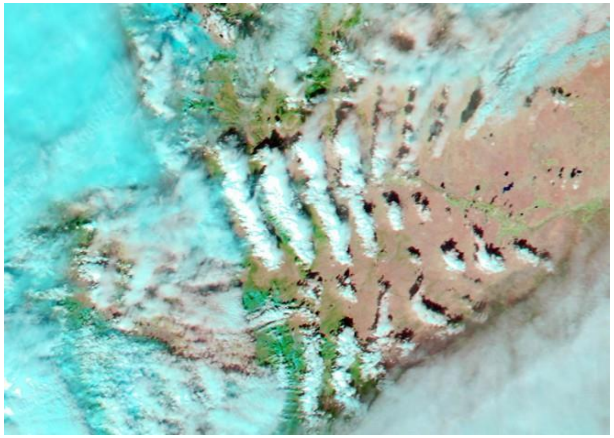
Photo by Marc Valero

Extensive gravity waves in clouds from Jan Mayen seen from weather satellite



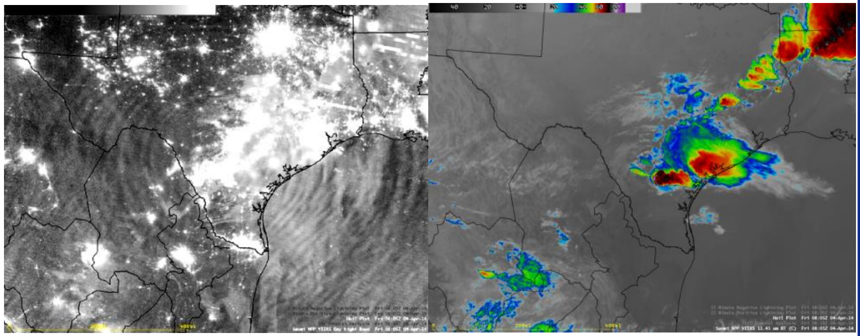
Sources

- Mountain Waves

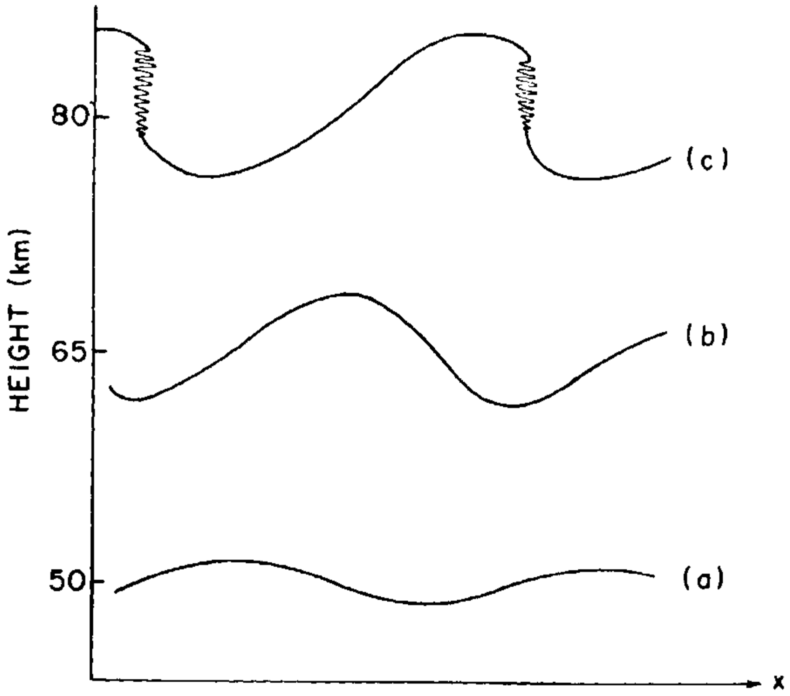


- Frontal systems

- Extreme weather
  - Thunder storms Tornadoes etc.



But the energy does not stop there



Waves continue to propagate upward

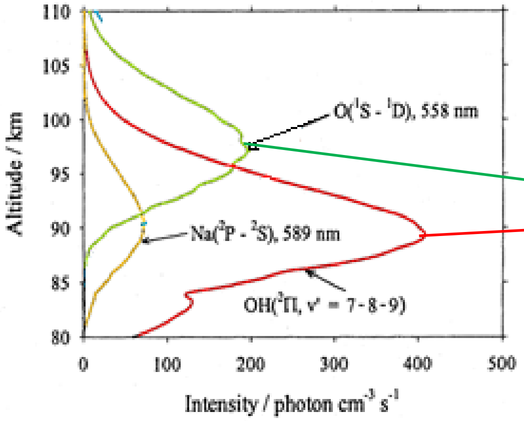
Grow in amplitude with height to conserve energy

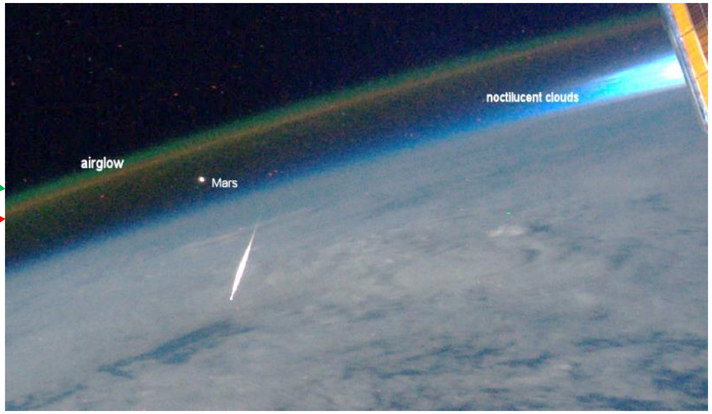
Become non-linear & unstable: sheds energy and momentum (whitecaps)

Overturns and deposits its energy and momentum locally near 90 km

Drives the global circulation of the upper atmosphere

That means we can observe them in the upper atmosphere



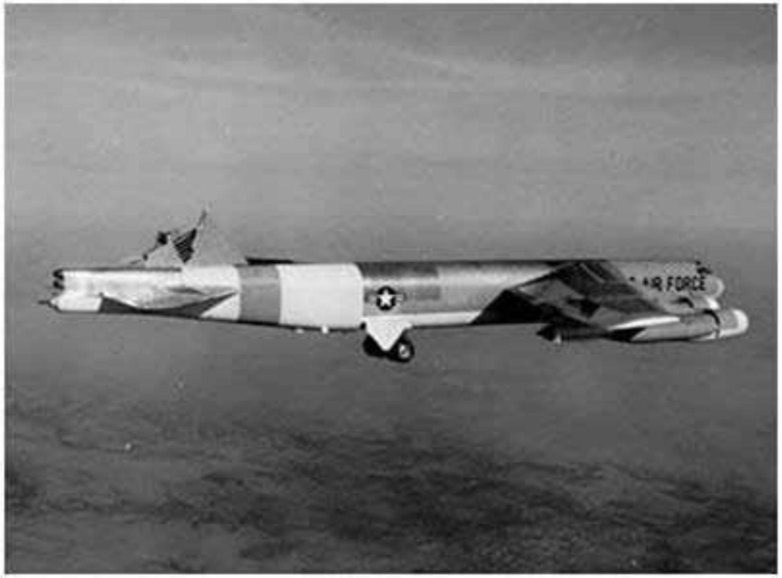


Observe them as they modulate the airglow

Observations from space don't have a cloud background

So What? Who Cares?

DC-8 Cargo plane encountered clear-air turbulence from mountain wave
Left engine and 6m wing ripped off

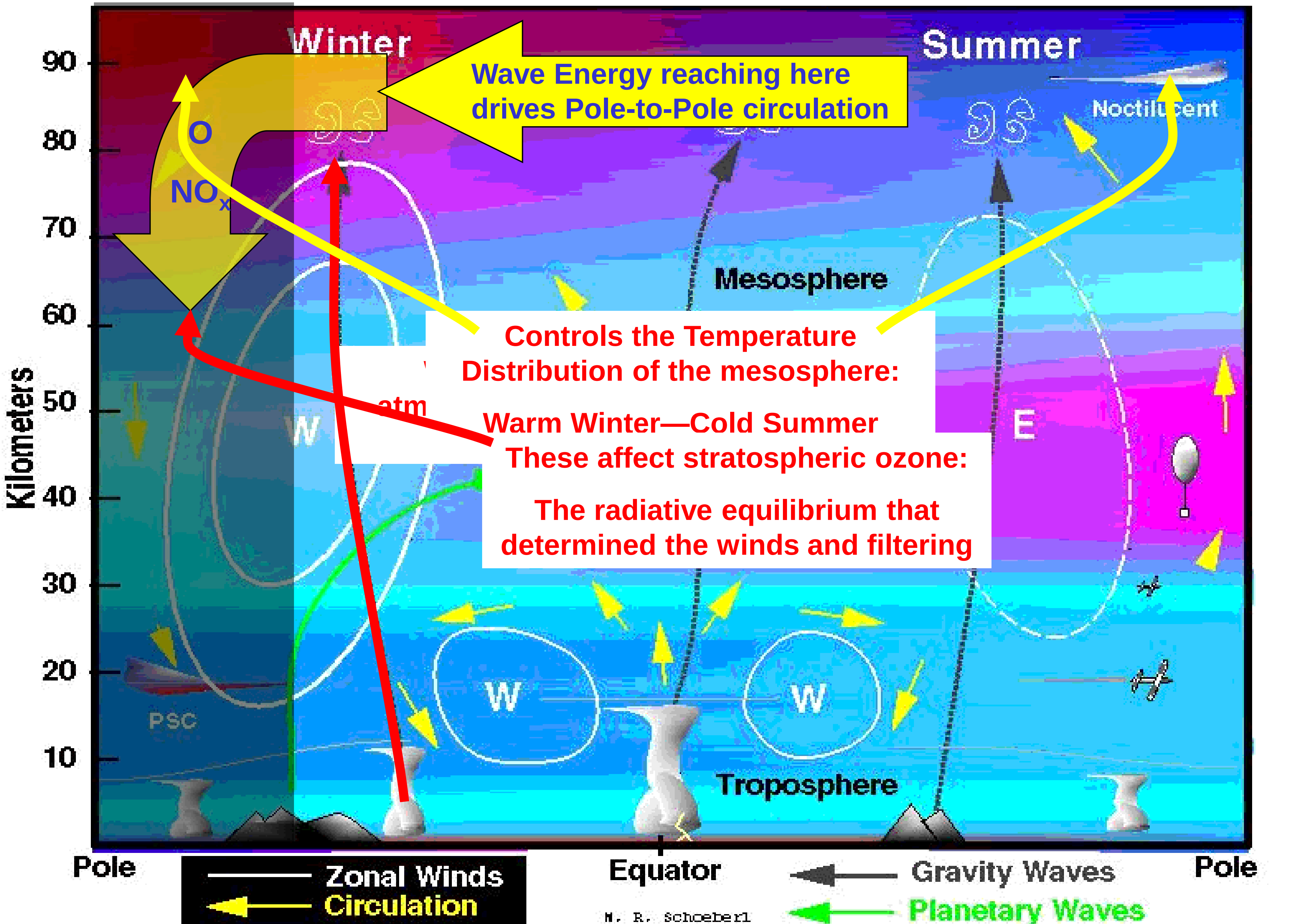


B-52H encountered clear-air mountain wave and lost vertical stabilizer

Obvious civilian and military need for better mountain wave forecasting

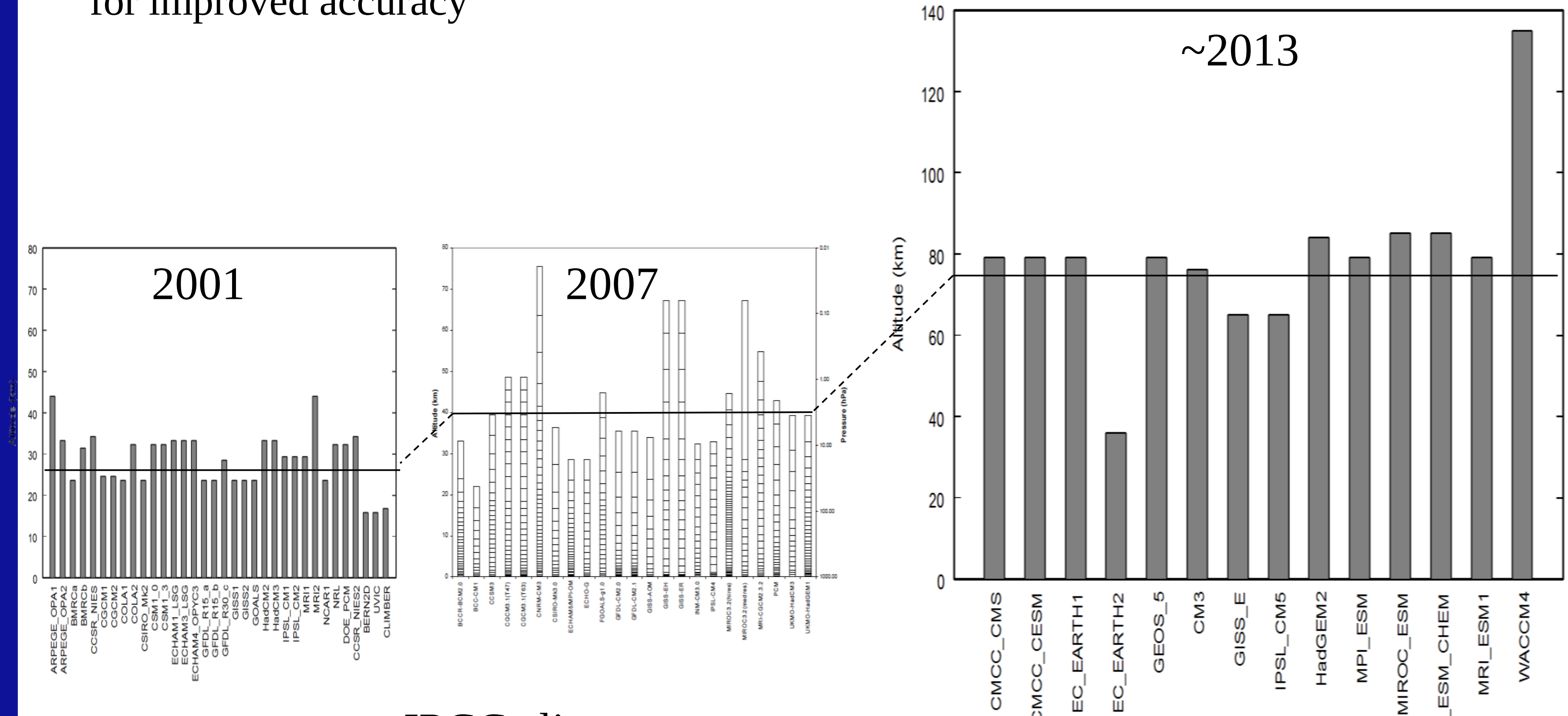
But also a critical need for wave observations for climate and weather models

Pole-to-Pole & Vertical Circulation



Weather/Climate models know this

- Atmospheric models required to predict future weather & climate
- Tele-connection mechanisms occur through the upper atmosphere
  - These upper atmospheric signals appear in troposphere but with timescales of days to years
- Long-term climate & weather forecasting must include upper-atmospheric processes for improved accuracy



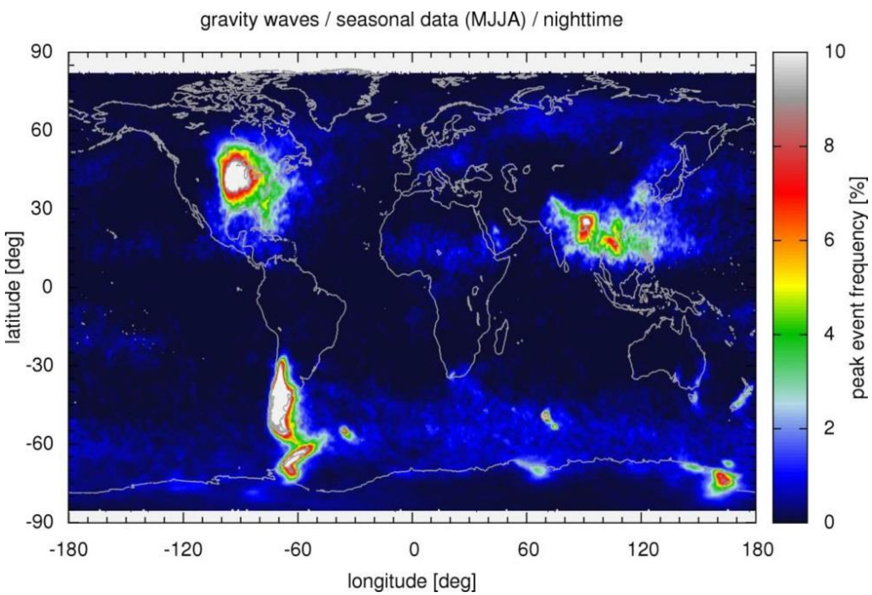
IPCC climate assessments

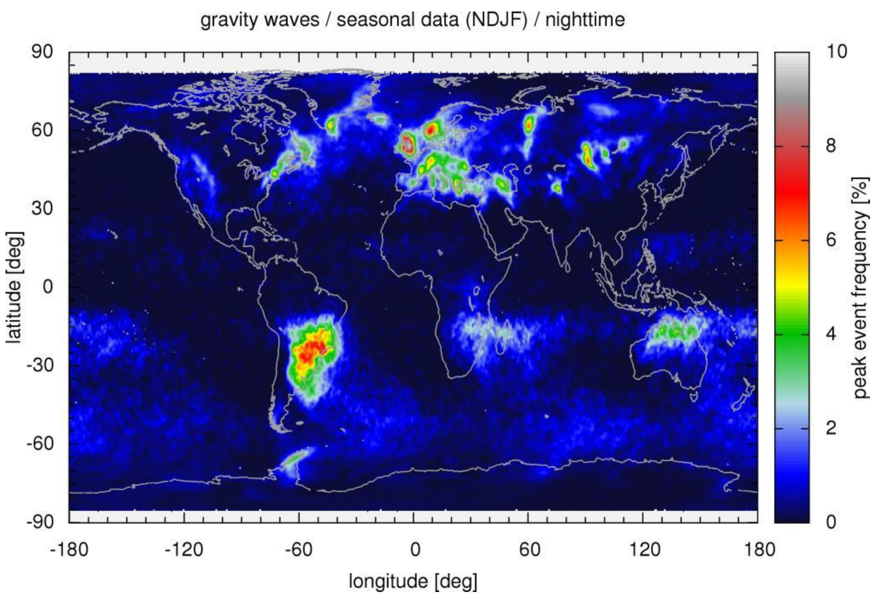
Gravity-Wave Momentum Flux

- Circulation and thermal balance between 60 and 100 km forced by "*sub-grid-scale*" gravity waves
- Bulk of the energy and momentum is carried by waves with period < 30 min.
- GCM's, weather forecast and climate models require parameterization of gravity waves with spatial and temporal variations

What we need to know

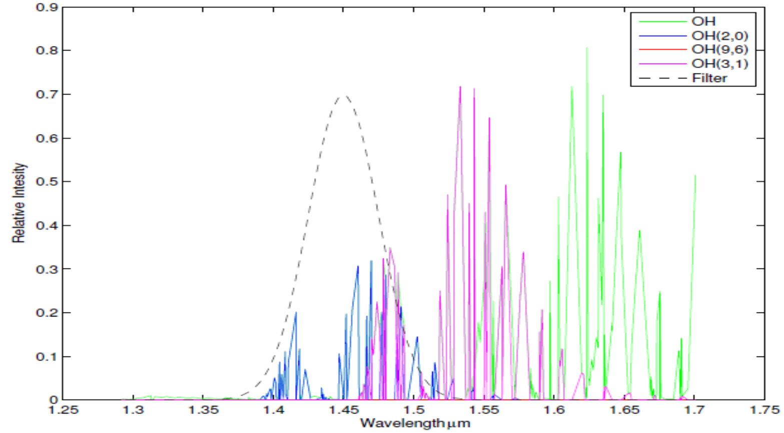
- The wave sources and their seasonal climatology
- Wavelength, direction and speed are the critical parameters

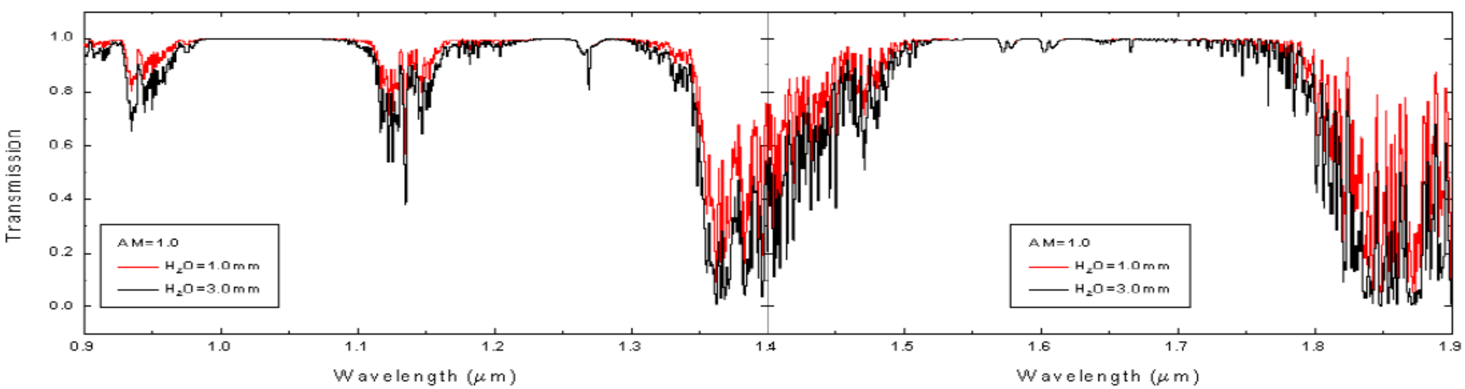




Observations of OH airglow

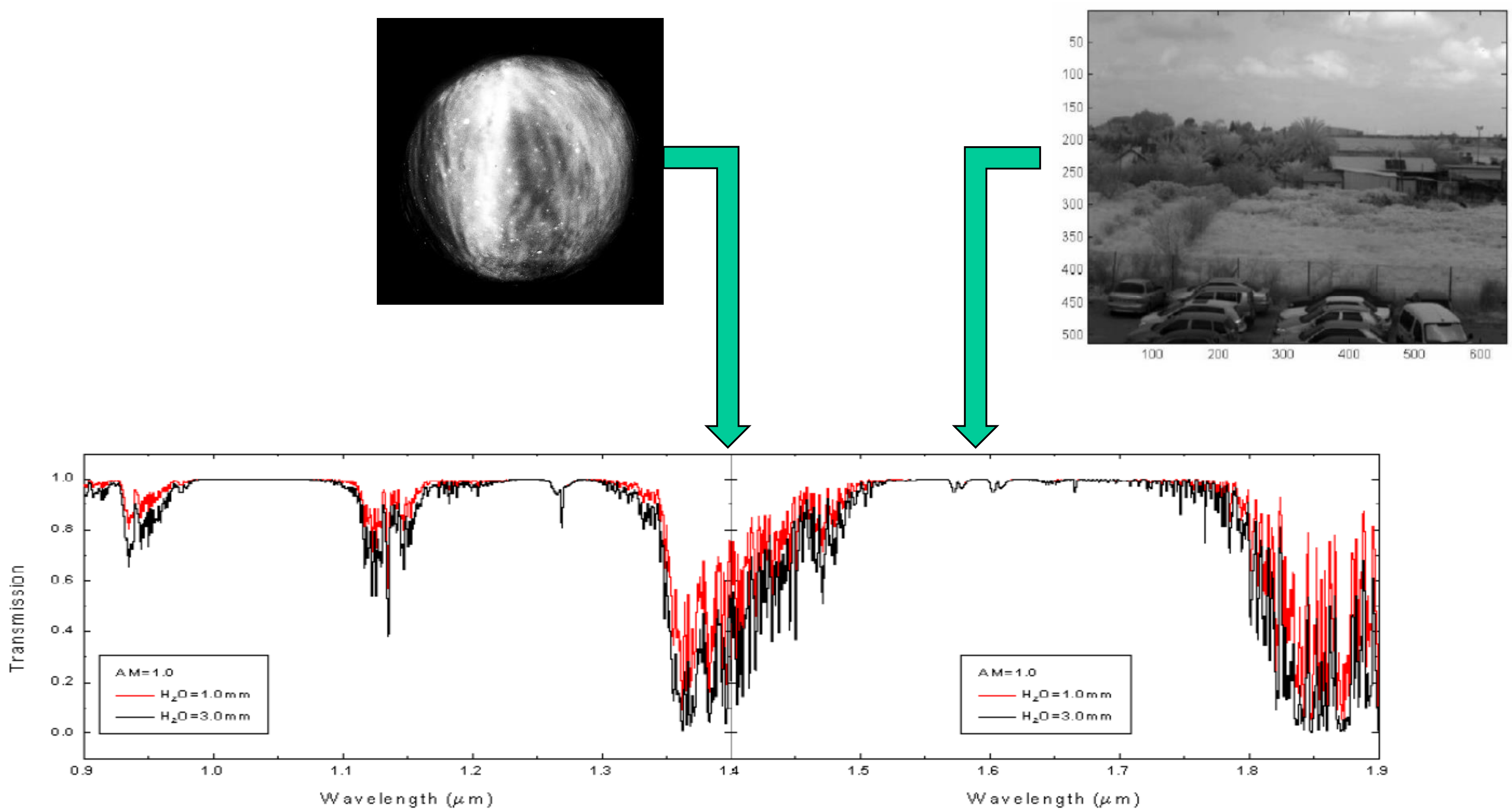
- OH band at 1.4 μm sits in a water vapour absorption





Observations of OH airglow

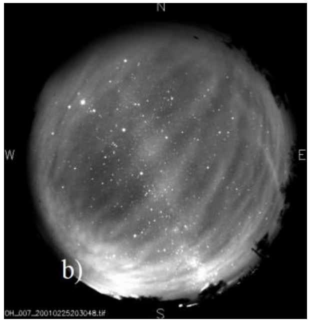
- Observe at 1.4 μm, see OH airglow and not the ground
- Observe at 1.6 μm, see the ground illuminated by airglow



Observing waves in airglow from space

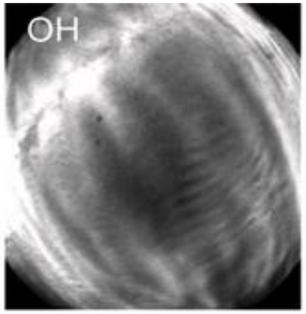
- Like early weather forecasting, we have several ground-based observation stations
- Cannot give us what we need, but can constrain the observation criteria

44ºN



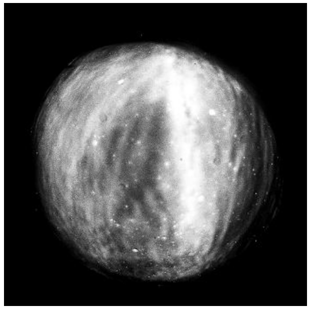
Pictures from Taylor et al. 2007

7 ºS

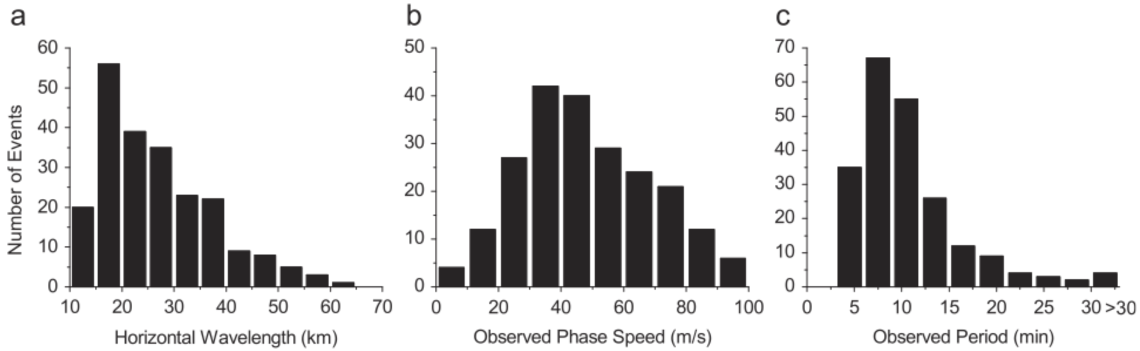


Pictures from Medeirosr et al. 2007

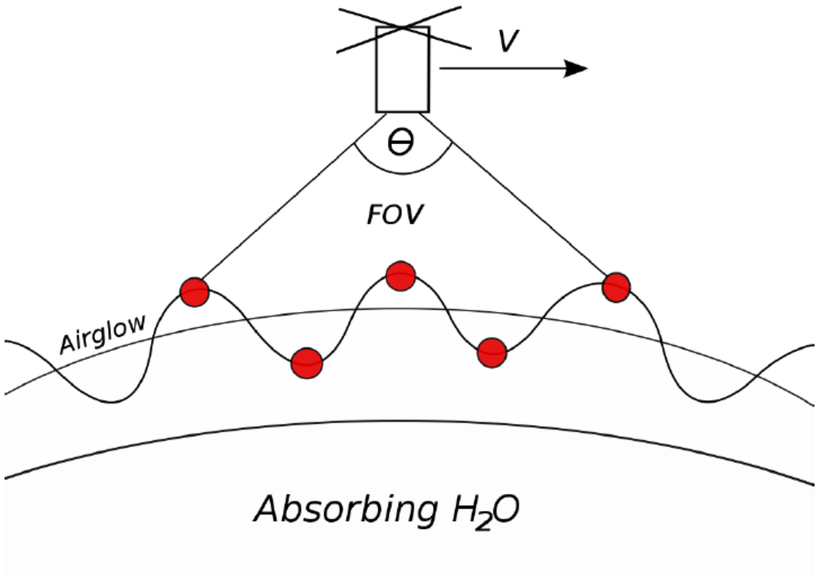
76ºS



Pictures from Espy et al. 2003



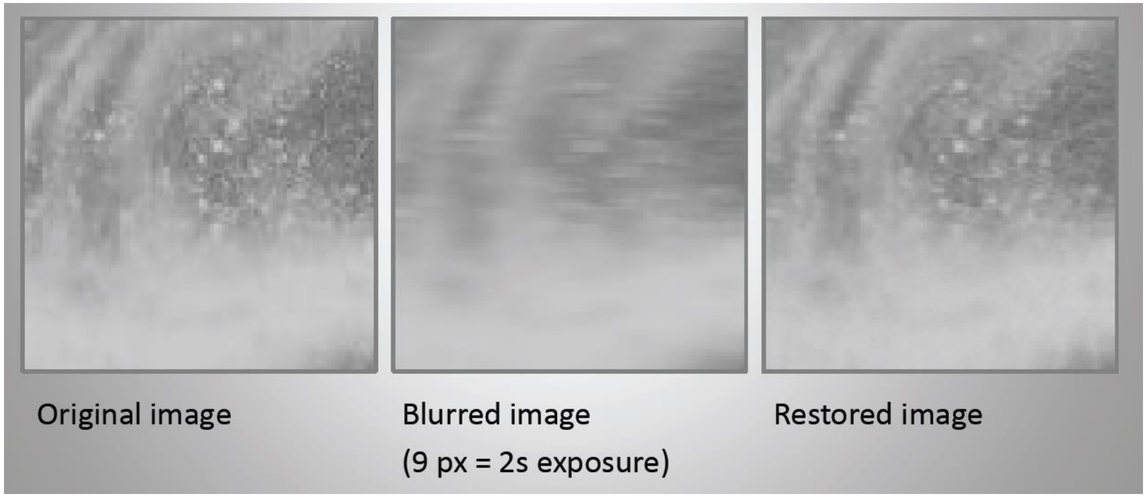
Optimizing the observations

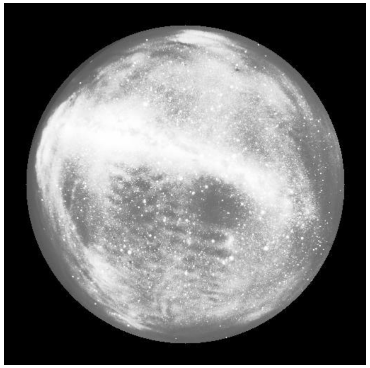


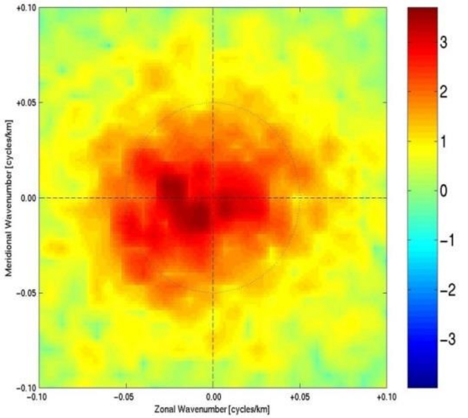
Parameter	Result
Focal length	16 mm
F-number	1.4
GSD	2 km
Resolution	160×160
Binning factor	4
B_{max}	13
FOV	34°
Ground segment one image	320 km
Blurred wavelengths	≤15 km
Integration time	3 s
ΔSNR for one image	1.6
Effective FOV	200 km
N_{images}	11
Δ $SNR_{average}$	5.5

- Interplay of wavelengths to be observed, spatial sampling and total field of view with satellite altitude and velocity
- Snorre Rønning at NTNU has developed a tool to input these parameters and output the detector size and focal length required.

Data compression/restoration testing







- Blur restoration from moving satellite
- Fourier techniques can be employed to transmit only wavelength, direction and speed of waves

Dual use technology

- Ground transmission band used for surveillance
  - Smoke/haze penetration
  - Forest fire detection
  - Ship/aircraft heat plume detection
- Night capability (illumination from airglow)

Goals

- Science:
  - Global identification of gravity wave generation mechanisms
    - Mountains, frontal systems, extreme weather
  - Source efficiency
  - Seasonal variability
  - Momentum carried from troposphere to mesosphere by waves.
- Security/Safety
  - Night surveillance capability
  - Heat plume detection
  - Fire detection
  - Early warming of mountain wave events

Results/benefits

- Allow realistic parameterizations to be developed for today's weather/climate models
- Allow future high-resolution models to incorporate the actual mechanisms
- Ultimately improved forecast and climate models
- Provide an important visual counterpart to ship identification
- Provide identification of fire hot spots
- Provide identification of mountain wave conditions from space

Indeed they are waves!

Movie from Daryl Herzmann