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Initial Measurements of Mesospheric Gravity Waves over McMurdo, Antarctica

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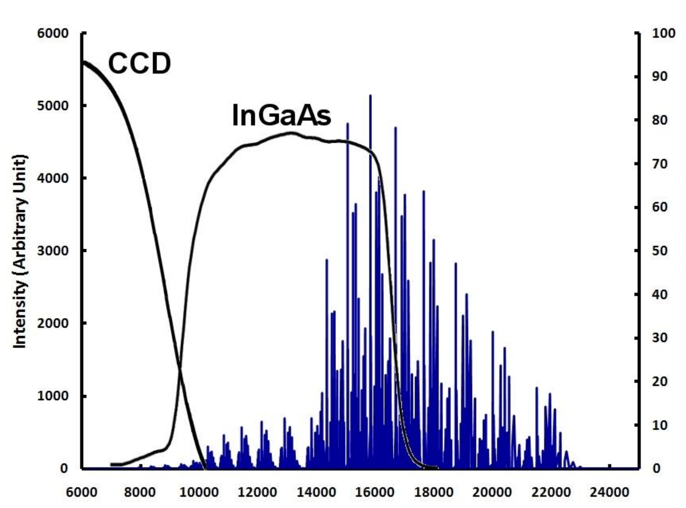
Introduction

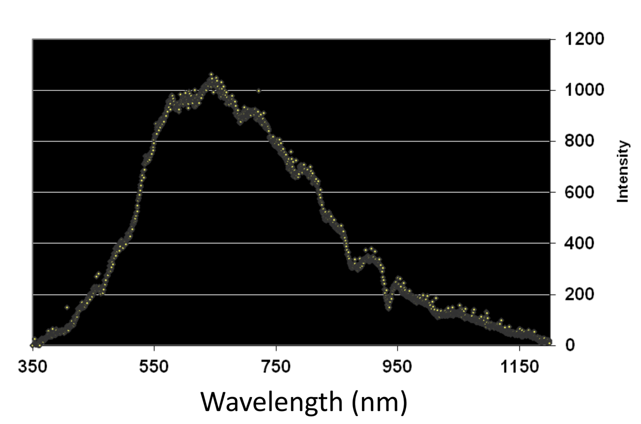
The ANtarctic Gravity Wave Instrument Network (ANGWIN) is an NSF sponsored international program designed to develop and utilize a network of gravity wave observatories using existing and new instrumentation operated at several established research stations around the continent. The primary goal is to better understand and quantify large-scale gravity wave climatology and their effects on the upper atmosphere over Antarctica. ANGWIN currently comprises research measurements from five nations (U.S., U.K., Australia, Japan, and Brazil) at seven international stations (see map). Utah State University's Atmospheric Imaging Lab operates all-sky infrared and CCD imagers and an Advanced Mesospheric Temperature Mapper (AMTM) imager at several research stations (Davis, Halley, Rothera, McMurdo, and South Pole). In this poster we present new measurements of short-period mesospheric gravity waves imaged from McMurdo Station (77°S, 166°E) on Ross Island. This camera has operated alongside the University of Colorado Fe Lidar during the past two winter seasons (March-September 2012, 2013). Here we present image results from the first year.

IR Imaging

All-sky InGaAs camera

Digital (CCD) imaging systems are regularly used to study gravity wave properties in the Mesosphere and Lower Thermosphere (MLT) region (~80-100 km) using well-defined nighttime airglow emission layers (e.g. Taylor, et al., 1997). However, moonlight and other sources of light pollution (e.g. aurora, street lights, etc.) can significantly limit the use of CCD imagers which are sensitive to light in the visible and near-infrared spectral range (< 1 µm). Therefore we use new infrared imaging systems to help mitigate these problems and to enable more detailed studies at high latitudes. As part of ANGWIN program all-sky observations of the OH emission (~87 km) were made from McMurdo using an infrared (0.9-1.7 µm) cooled InGaAs camera.

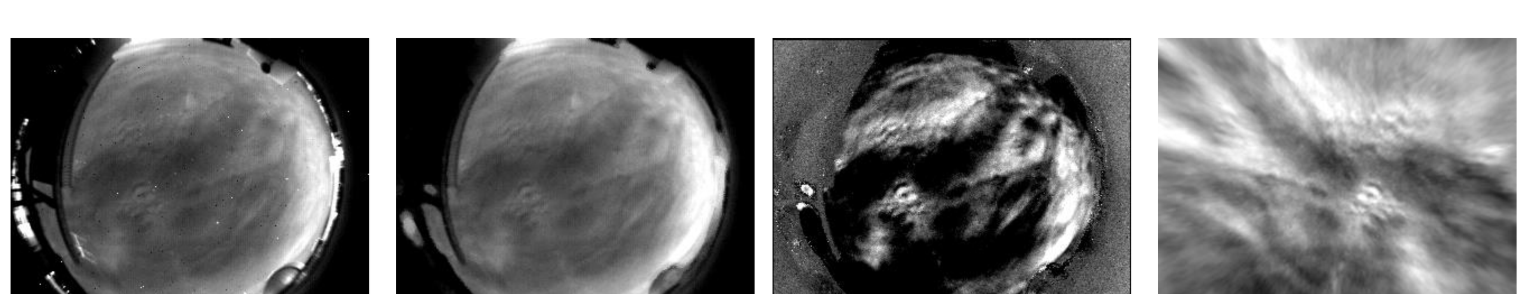




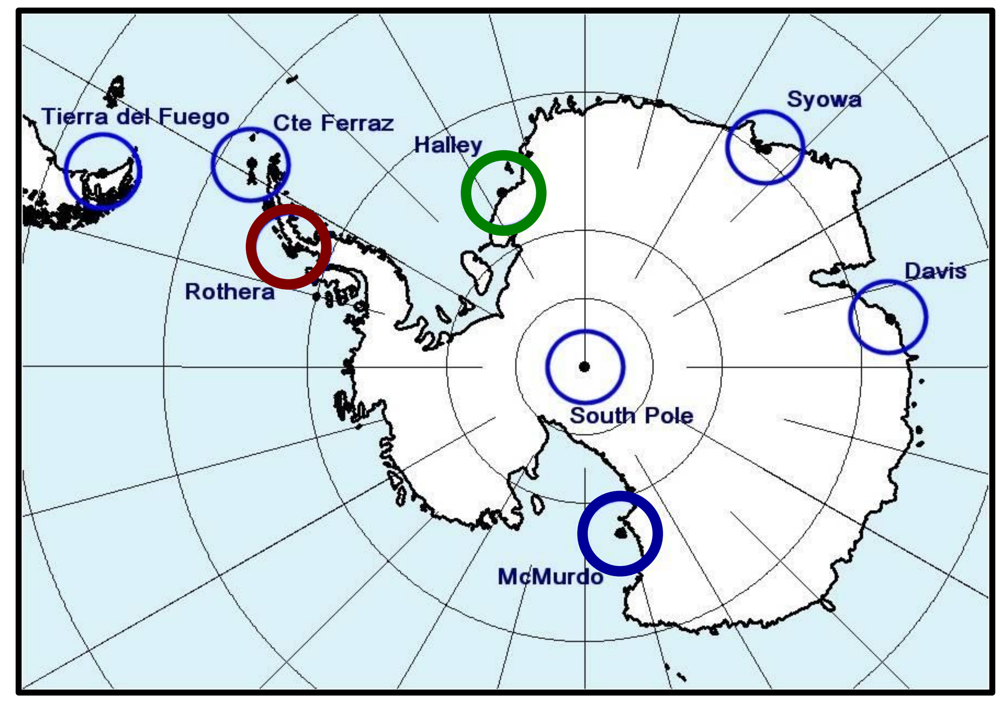
Moon Spectrum: Note that the intensity of scattered moonlight is much weaker in the IR region.

The OH airglow emissions extend from approximately 0.4-4 µm. The infrared emissions as shown in blue in the above figure are much stronger in the infrared region (>1 µm) are used by InGaAs cameras and enable high-quality short-exposure (a few seconds) imaging of gravity waves under auroral observing conditions. For example the infrared OH (3,1) band at 1.55 µm is ~70 times brighter than the OH (6,2) band which is a prominent component of submicron OH emission used for CCD measurements. Another major advantage of IR OH imaging is that the scattered moonlight spectrum is much weaker in the IR as shown in the right-hand figure.

Data Reduction Method



Raw images (a) were calibrated using the IR star field. The stars were then removed (b) and an average image known as a flat-field was created of the entire night and subtracted from the data images (c). The images were then unwarped and mapped onto a 350 x 320 km geographic grid as shown in figure (d).



Map showing ANGWIN sites. McMurdo is highlighted in bold blue. The comparison sites of Rothera and Halley are highlighted in red and green respectively.

Optical site at Arrival Heights, McMurdo Station

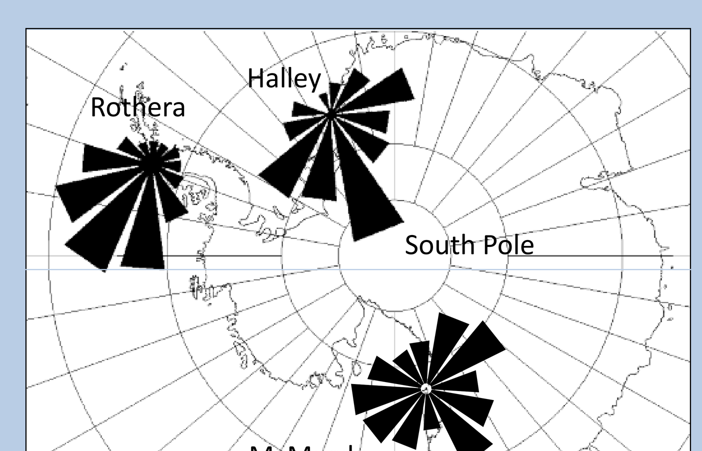
McMurdo Station (77° S)

All-sky image data were recorded every 10 s with a XX s exposure at McMurdo Station enabling detailed measurements of individual gravity wave events in the infrared OH emission layer (~87 km). During the 2012 observing period (March-September, nighttime hours) at McMurdo over 300 short period (<1 hr) gravity wave events were observed. Gravity waves were analyzed using well developed Fourier analysis techniques to determine direction of propagation, horizontal wavelength, and observed horizontal phase speed. The gravity wave characteristics observed at McMurdo (blue) are contrasted with 3 years of wave measurements (1100+ wave events) from other sites around the continent: Rothera station (67° S) in red, and Halley Station (76° S) in green.

Summary and Future Work

We have analyzed one year of data to date from McMurdo Station, Antarctica. The results are the following:

- A large number (300+) of short-period gravity waves observed over McMurdo, Antarctica enabling the climatology to be investigated.
- Similar magnitude horizontal wave characteristics (wavelength, phase speed) observed annually at each site although McMurdo does exhibit a large spread of phase speeds.
- The sources of the wave events observed from McMurdo are probably associated with strong weather systems outside Antarctica (over the Weddell and Ross Seas), with another source perhaps being the polar vortex.
- Dominant poleward wave propagation observed at Halley Station with strong year to year consistency. The source of the waves may be similar to those observed at McMurdo, from convection in the South Atlantic. Evidence for a rotation of the direction of propagation during the winter season [Nielsen, et al., 2009, 2012].
- Dominant westward wave propagation observed at Rothera Station with strong intra-annual consistency and no variation during the winter season shows signatures of mountain waves being created off of the Antarctic Peninsula.
- New measurements have recently been initiated from the South Pole Station and in combination with other ANGWIN sites will be used to investigate pan-Antarctic anisotropy and wave parameters.
- Ongoing analysis of McMurdo data from 2013 and soon to be available 2014 data will further clarify the asymmetries in the wave propagation at this key site for understanding the climatology of gravity waves observed at McMurdo.



Sketch illustrating different wave anisotropy from McMurdo, Halley and Rothera.

References

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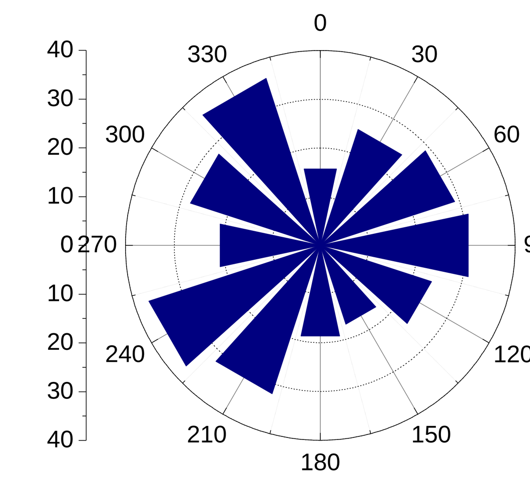
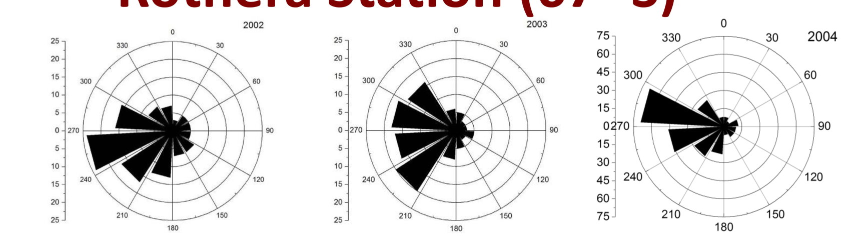
Direction of Propagation



Polar Plot Showing Distribution of Wave Headings: 2012

Wave motion is prominent in three directions, from the Antarctic continent (polar vortex), from the Ross Sea, and from the Weddell Sea (which is the dominant direction observed at Halley).

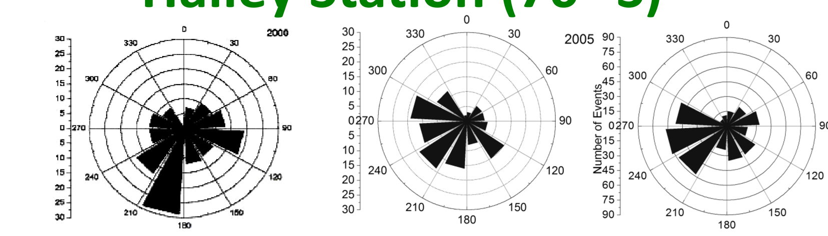
Rothera Station (67° S)



Polar Plots Showing Distribution of Wave Headings: 2002-2004

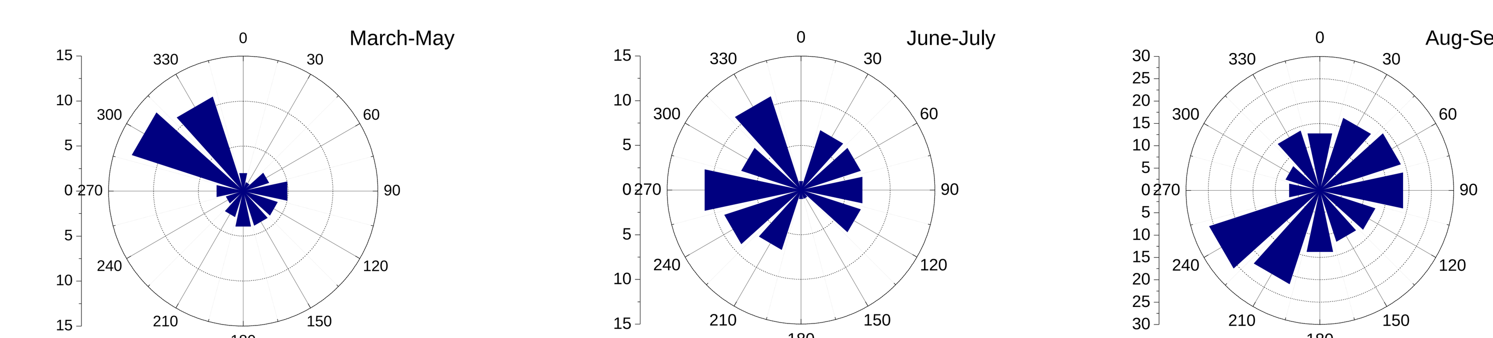
Note the strong and consistent westward wave motions observed each year from Rothera.

Halley Station (76° S)



Polar Plots Showing Distribution of Wave Headings: 2000, 05-06

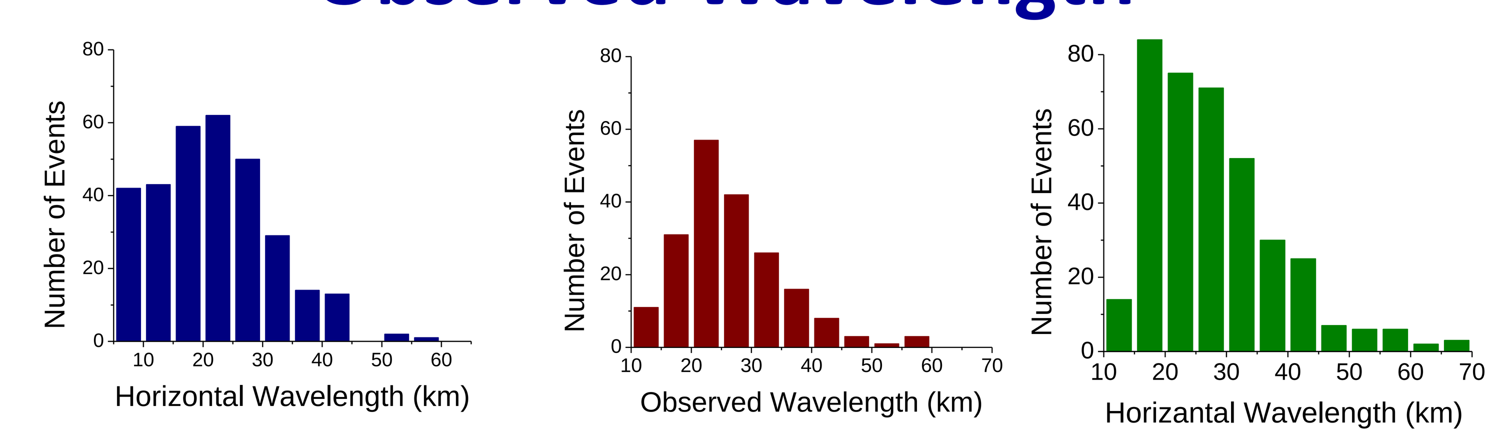
Note the strong and consistent ~poleward wave motions observed each year from Halley [Nielsen et al, 2009].



Month by Month Variability In Wave Propagation Headings 2012

A clear change from NW focused propagation during the fall expanding to more isotropic motions during the winter and later becoming anisotropic with dominant SW motion in the spring can be seen at McMurdo Station during the 2012 observation season. The strong spring and fall asymmetries both with westward components of motion strongly suggests localized sources.

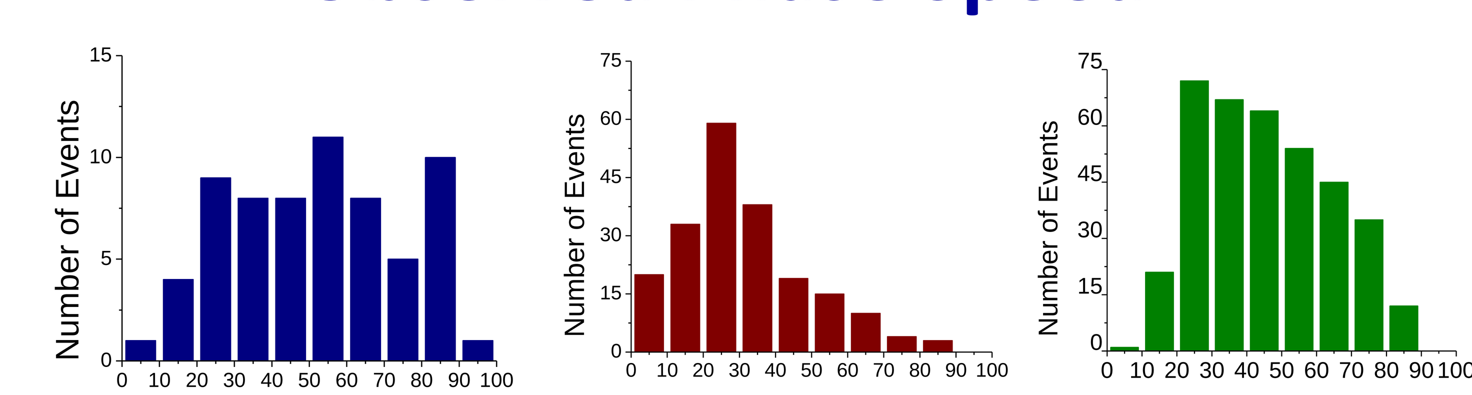
Observed Wavelength



Distributions of Observed Horizontal Wavelengths

At McMurdo, during the 2012 season the average horizontal wavelength is 22 km with a range of ±10.5 km (blue). At Rothera, 2006 the average was measured to be 27.6 (range ± 12.3) km (red). At Halley, 2005 the average was measured to be 27.8 (range ± 10.3) km (green). McMurdo shows a stronger tendency for waves of shorter wavelength.

Observed Phase Speed



Distributions of Wave Parameters

At McMurdo, during the 2012 season the average measured phase speed is 53.3 m/s with a range of ±24.0 m/s (blue). At Rothera the average was 31.7 m/s with a range of ±19.3 m/s (red). At Halley, the average was observed to be 45.5 m/s with a range of ±18.6 m/s (green).