The Arctic Middle Atmosphere in the Earth System: IPY Observations and Recent Model Results

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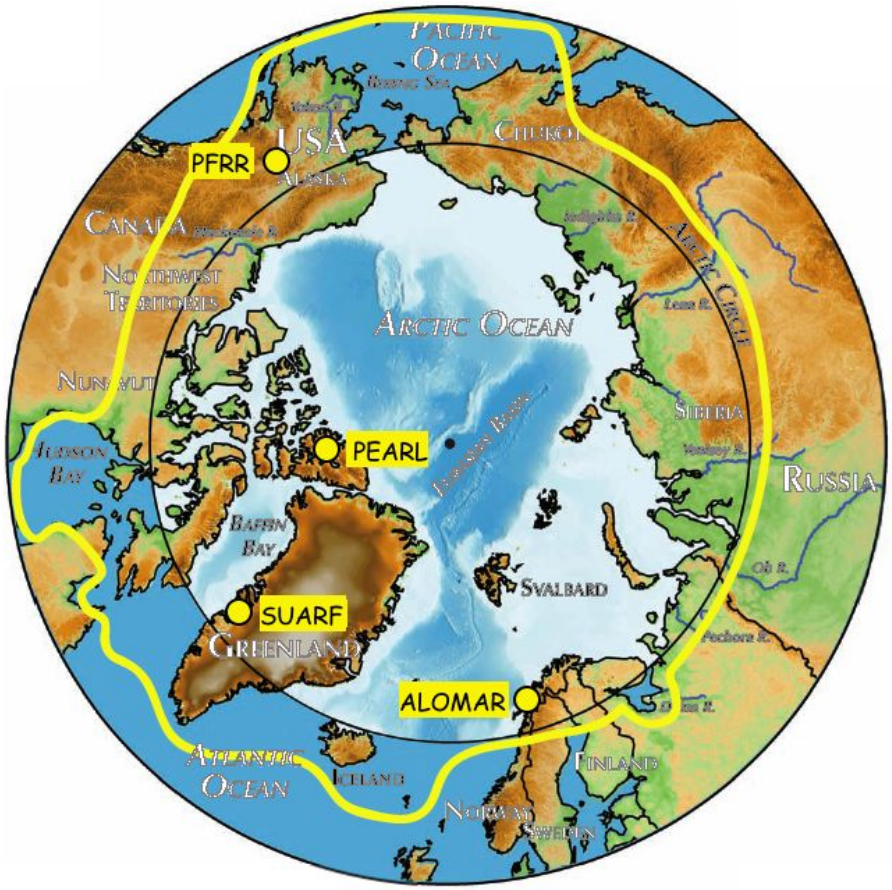


2010 State of the Arctic Conference: Interactions between the Arctic and Earth System

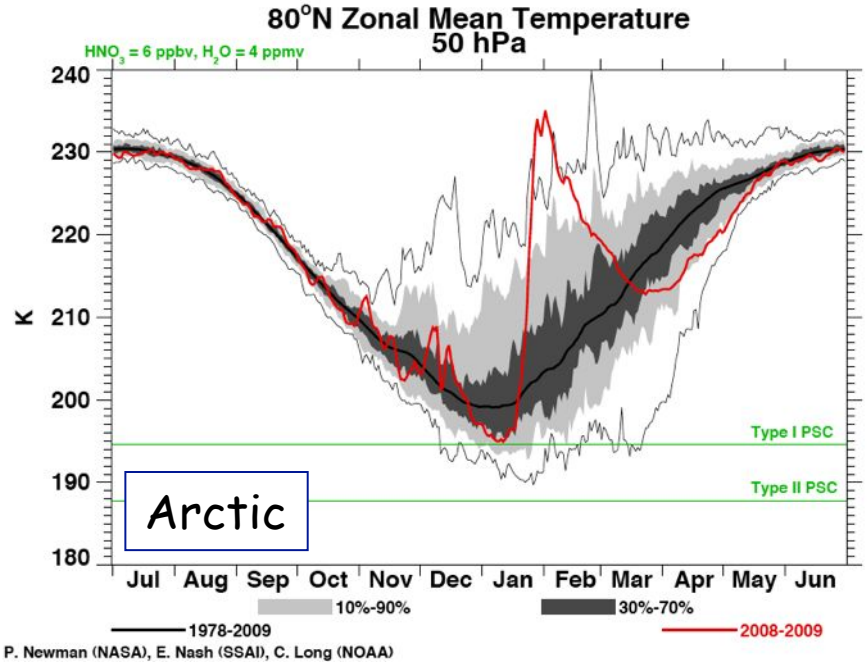
Miami, Florida

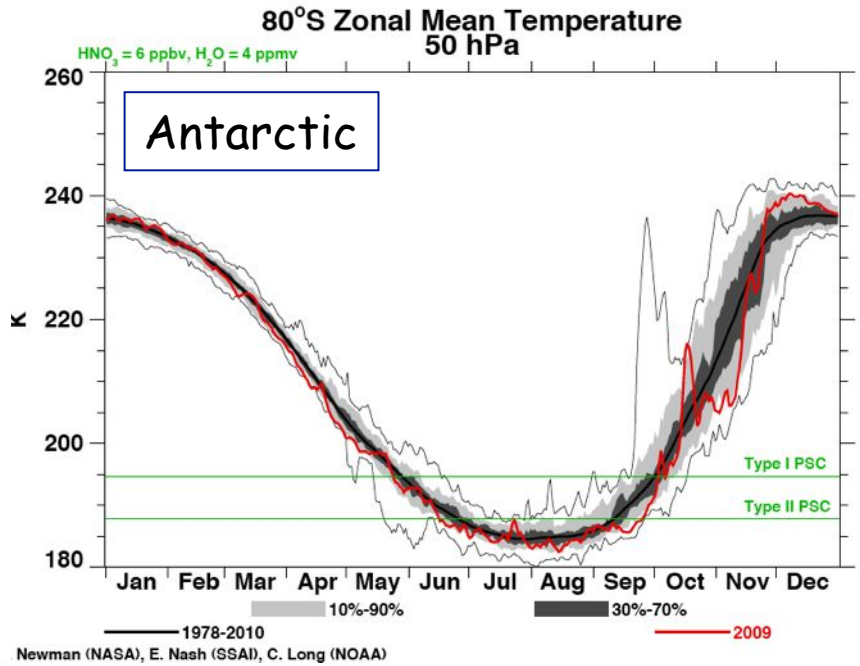
March 17, 2010

2007-2009 International Polar Year Alaska

University of Alaska Fairbanks

Circulation of the Polar Middle Atmosphere





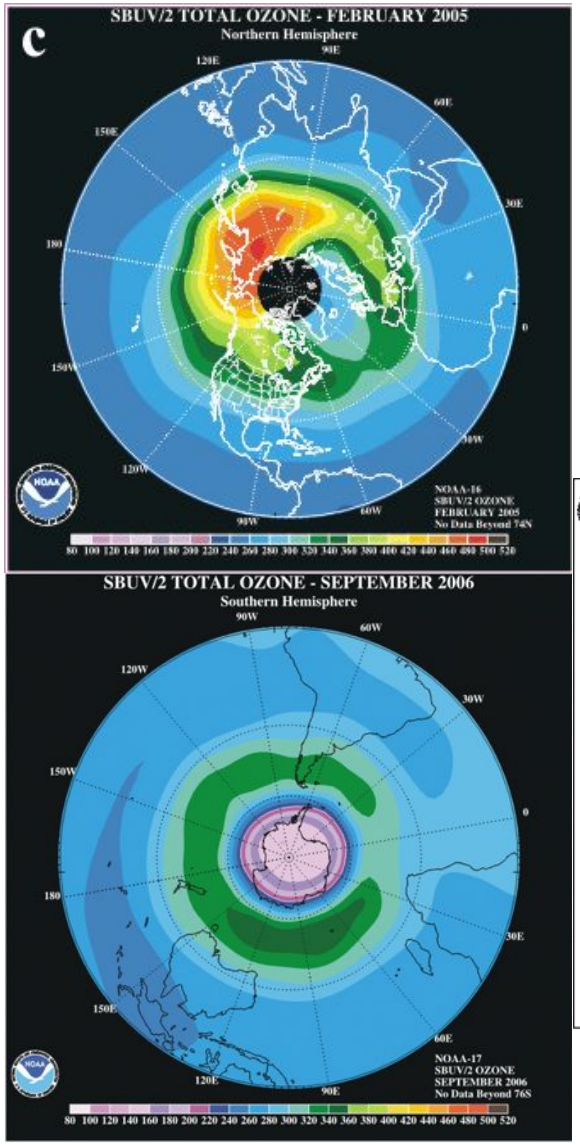
Studies of the polar middle atmosphere driven by studies of the stratospheric vortex and ozone depletion.

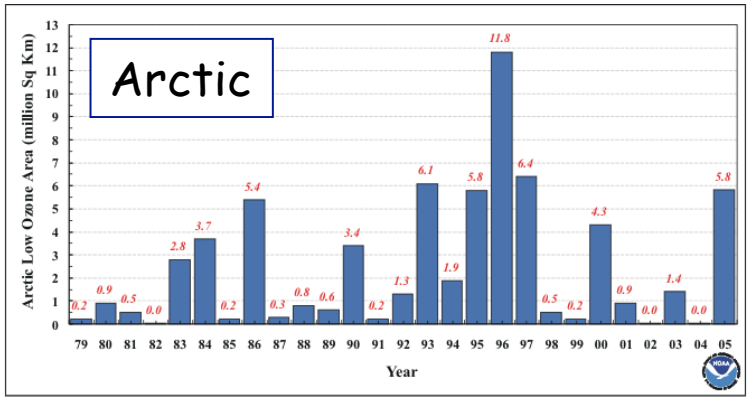
Vortex is more stable in the Antarctic than Arctic.

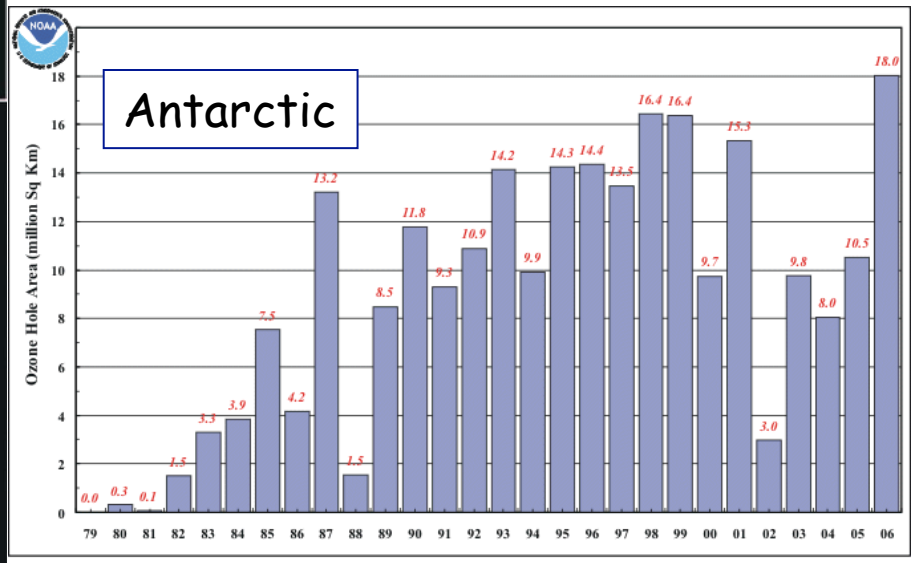
Arctic vortex disturbed by large-scale planetary waves that cause displacement and splitting of the vortex.

Arctic middle atmosphere temperatures warmer than Antarctic - less ozone depletion.

Vortex in Both Hemispheres





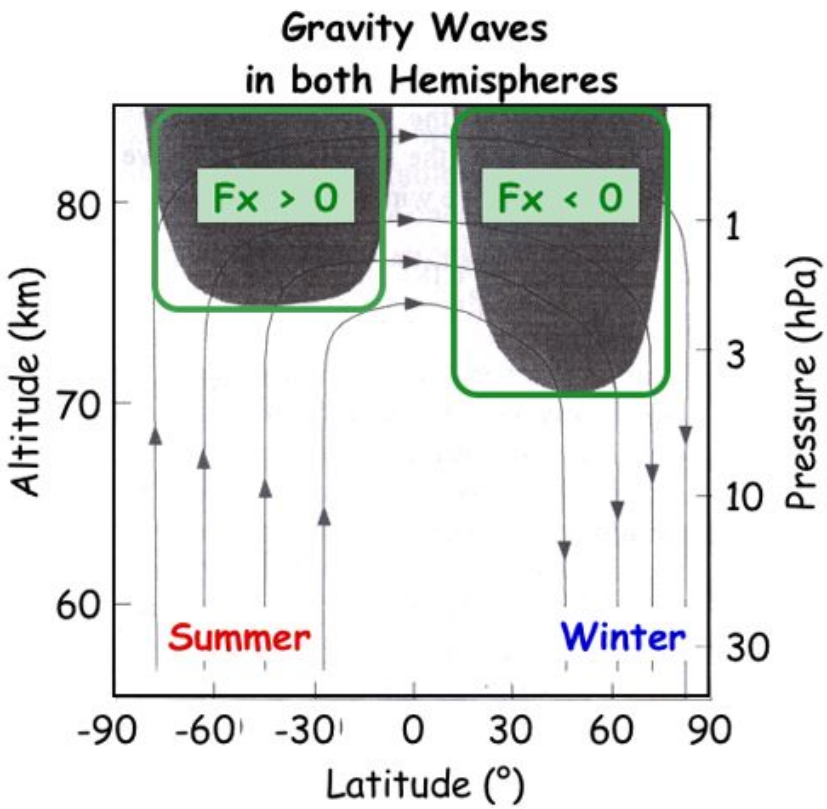


Arctic Vortex 2005 ~6 million km^2

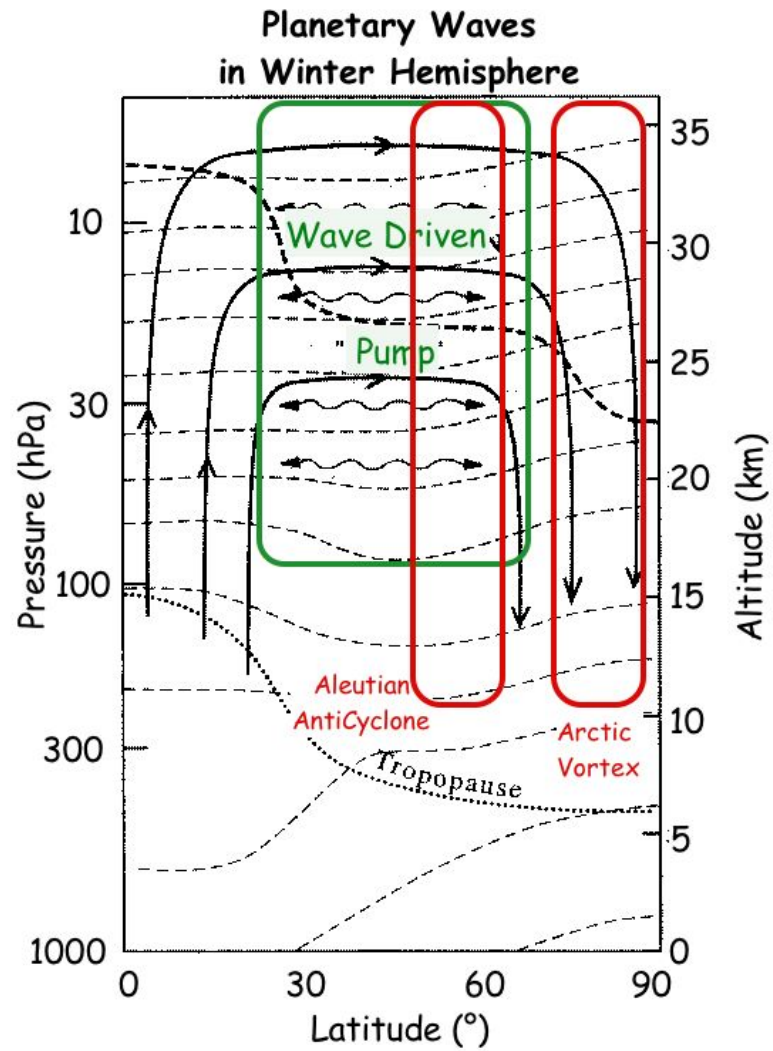
Antarctic Vortex 2006 ~18 million km^2.

2010 State of the Arctic Conference

Two Wave-Driven Circulations



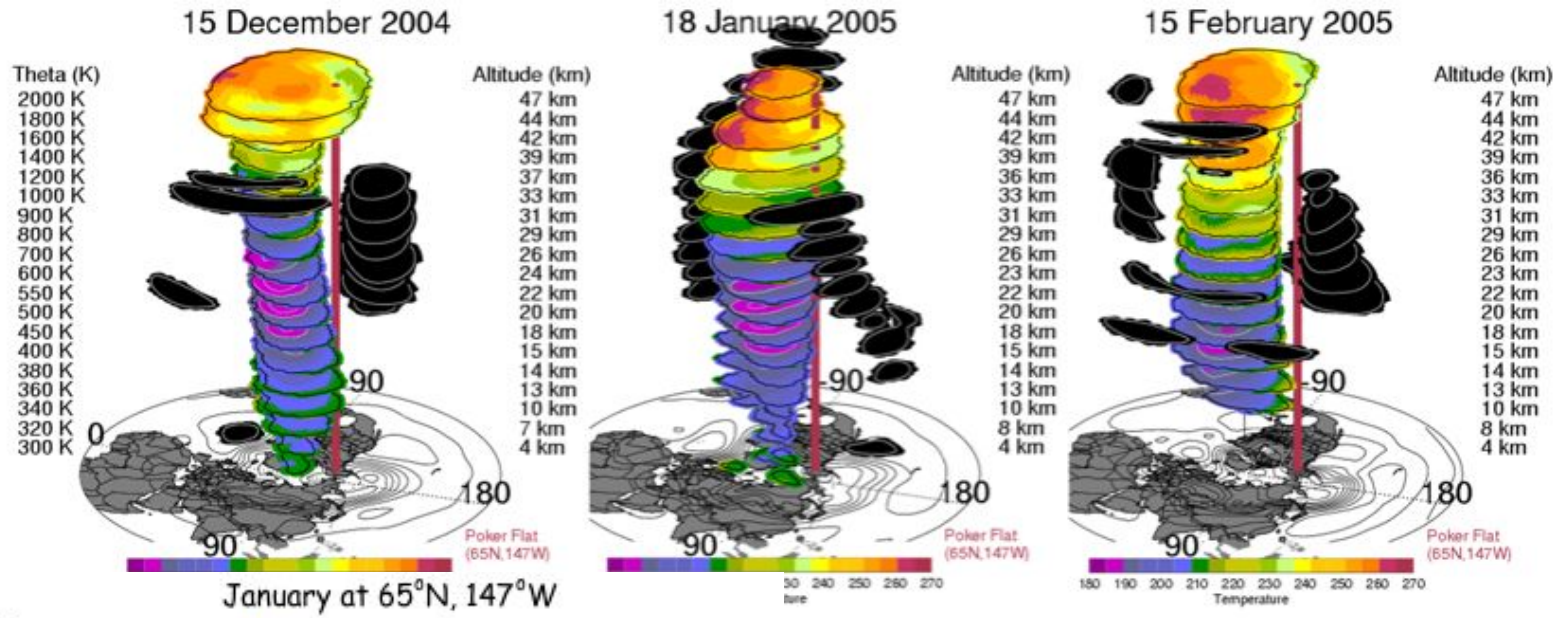
Adapted from Holton and Alexander (2000)

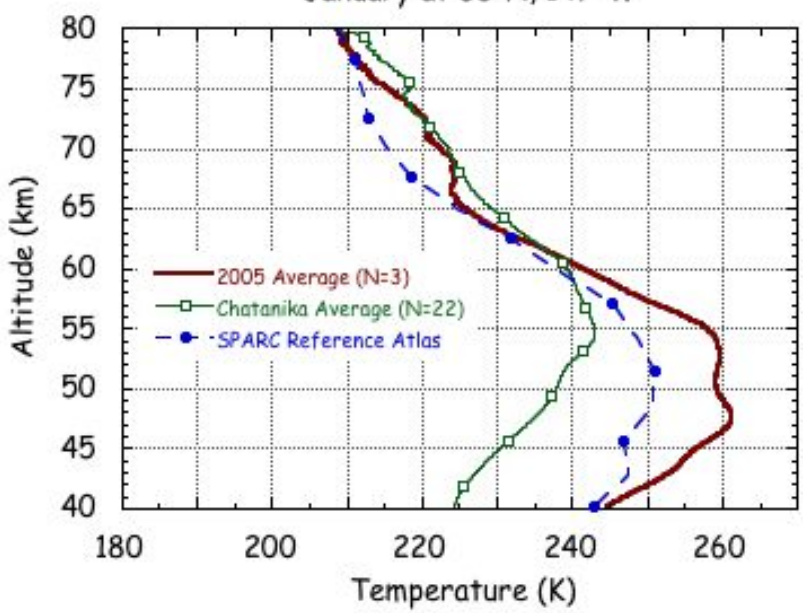


Small-scale gravity wave driven circulation is "embedded" in large-scale planetary wave circulation.

Both circulations impact mean flow → Nonlinear Feedbacks

Synoptic View during 2004-2005

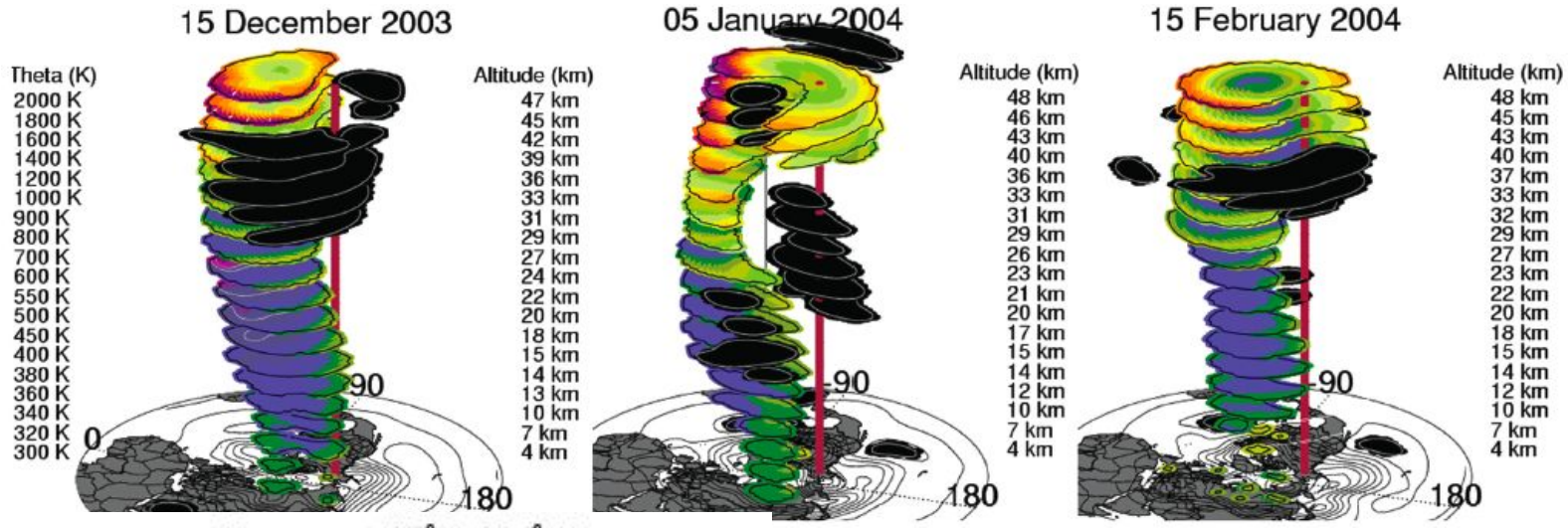


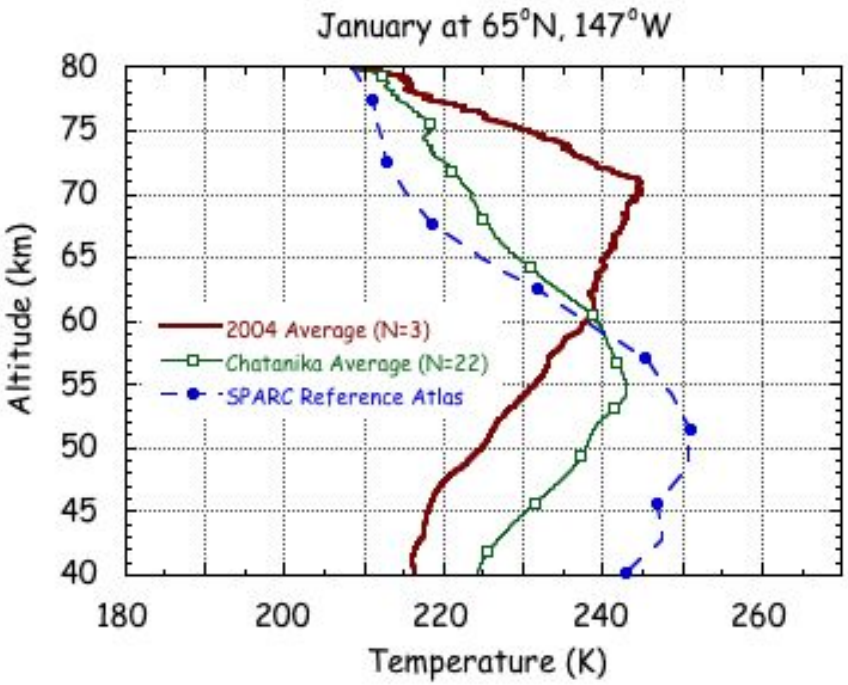


The Arctic vortex in 2005 was highly stable and supported significant ozone depletion.

Single site lidar temperature soundings show WARM stratosphere.

Synoptic View during 2003-2004

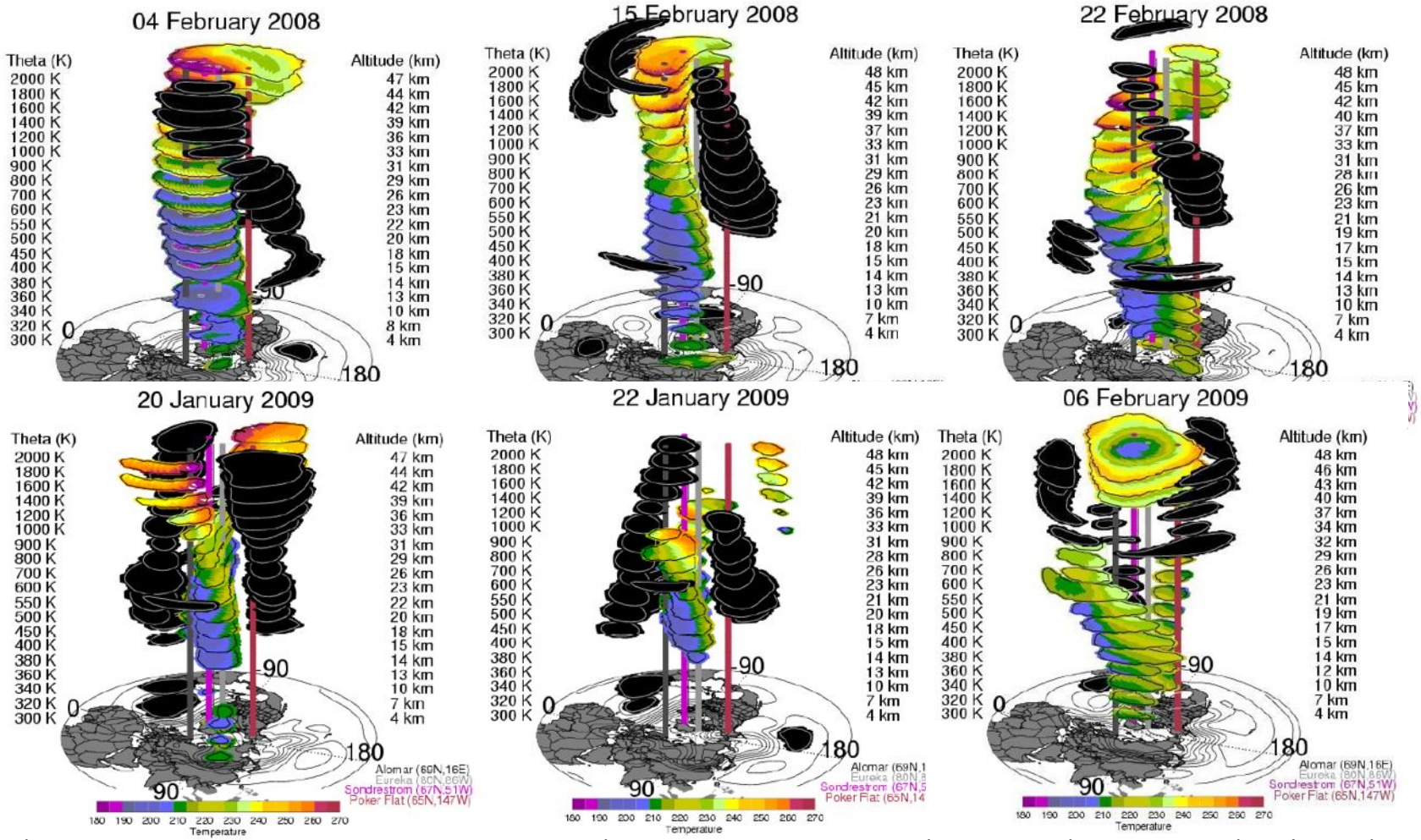




The Arctic vortex in 2004 was highly disturbed and supported little ozone depletion.

Single site lidar temperature soundings show UNUSUAL stratosphere.

Synoptic View during IPY



The Arctic vortex in 2007-2008 and 2008-2009 were disturbed. Vortex displaced with repeated pulses of planetary wave activity or warming events in 2008. Vortex split in 2009 during large stratospheric warming.

Synoptic View during IPY

Snapshot of daily conditions at 800 K (~30 km, 10 hPa).

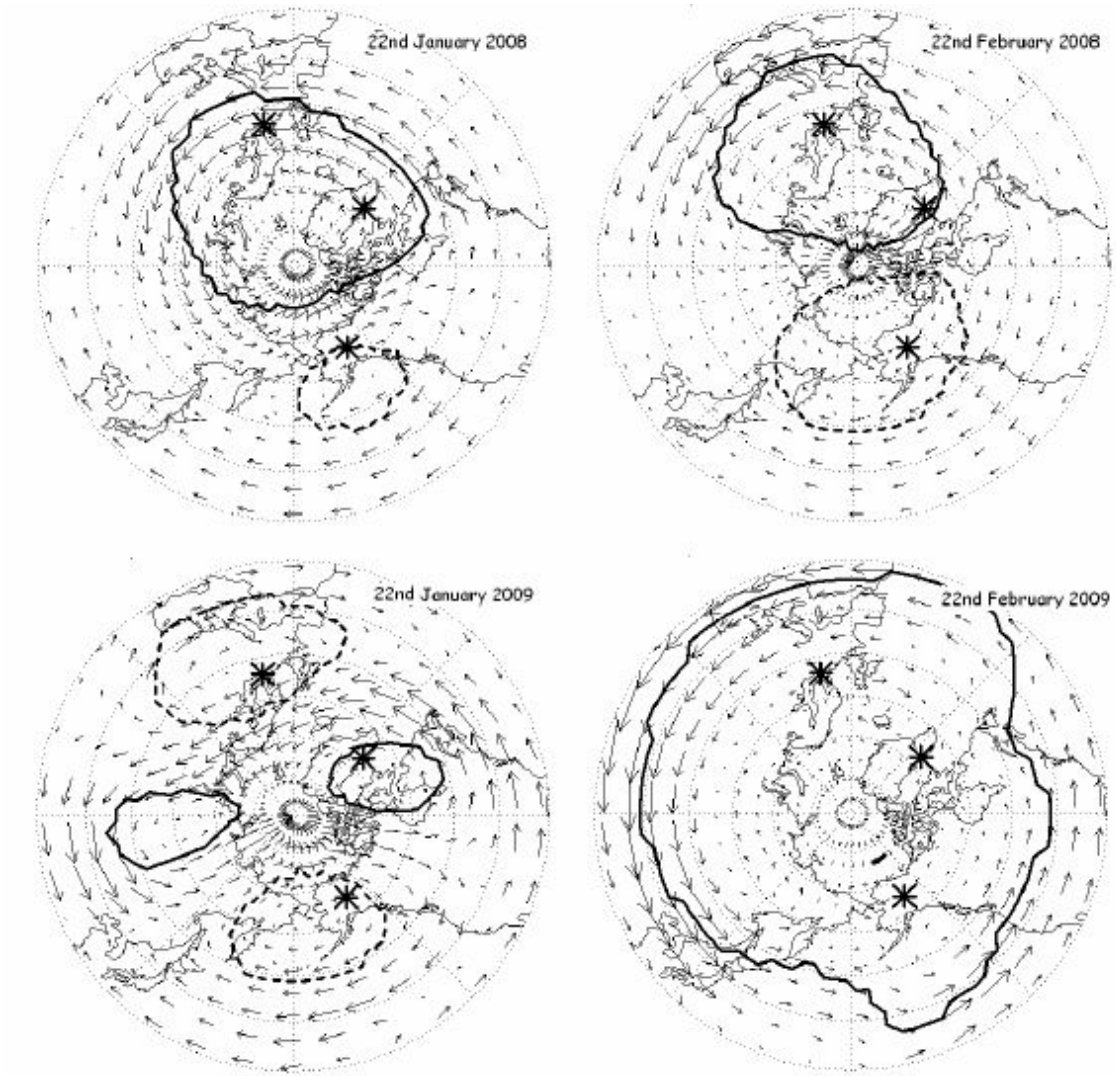
Different sites under different flow conditions.

Conditions at;

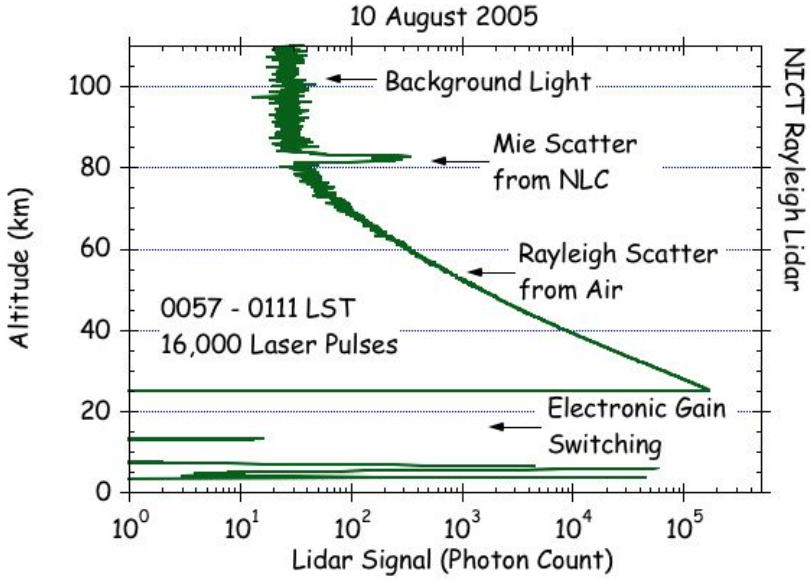
Chatanika, Alaska (65°N, 147°W)

Kangerlussuaq, Greenland (67°N, 51°W)

Kühlungsborn, Germany (54°N, 12°E).



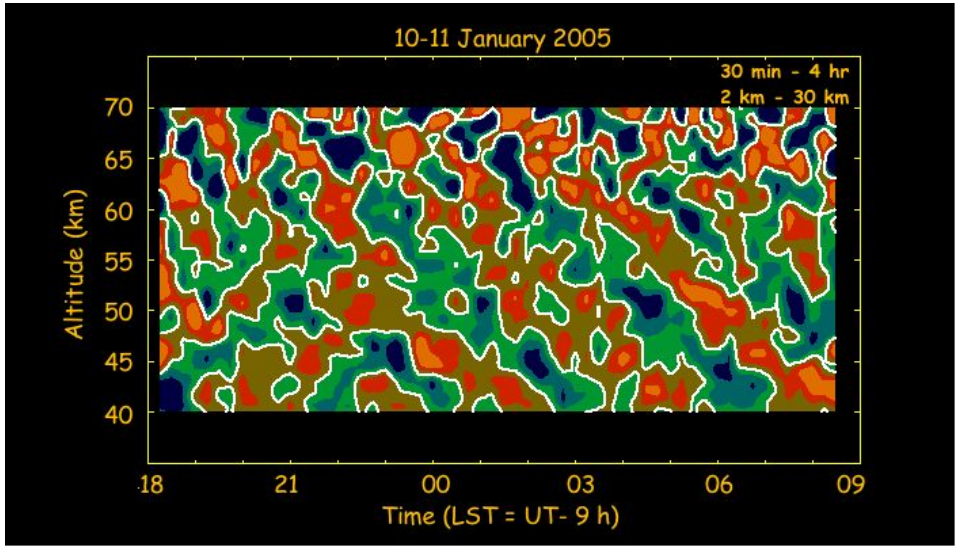
Lidar Measurements of Gravity Waves



Lidar (Laser radar) systems make precise measurements of atmospheric density at high resolution.

Lidar density profiles also yield temperature profiles.

Use 15-min and nightly average profile to quantify wave activity in the middle atmosphere.

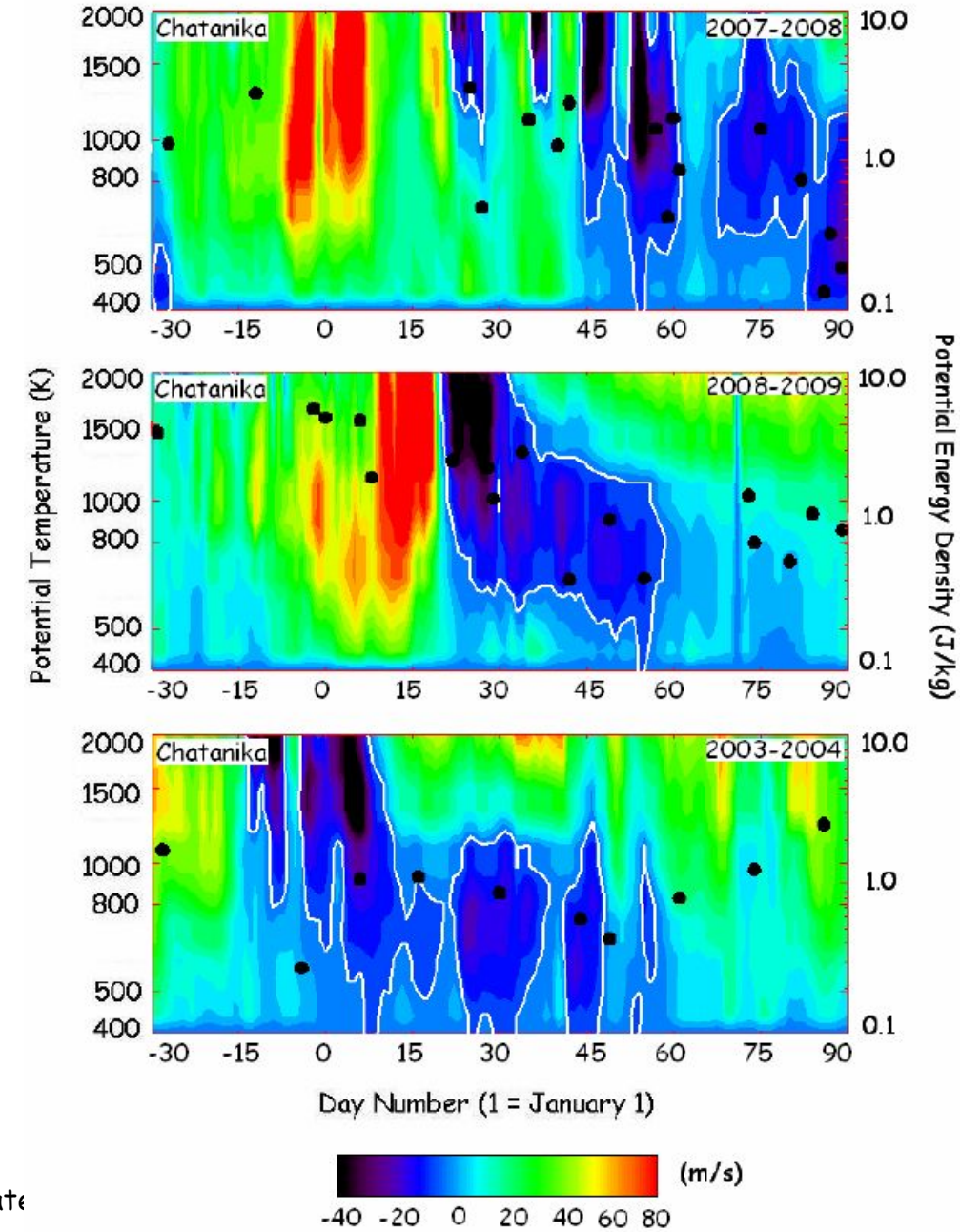


Interannual Variations in Wind and Waves at Chatanika

Measurements at Chatanika are correlated with wind fields. Reversal of zonal winds yields reduction in gravity wave activity.

Low gravity wave energies correlate with weak winds.

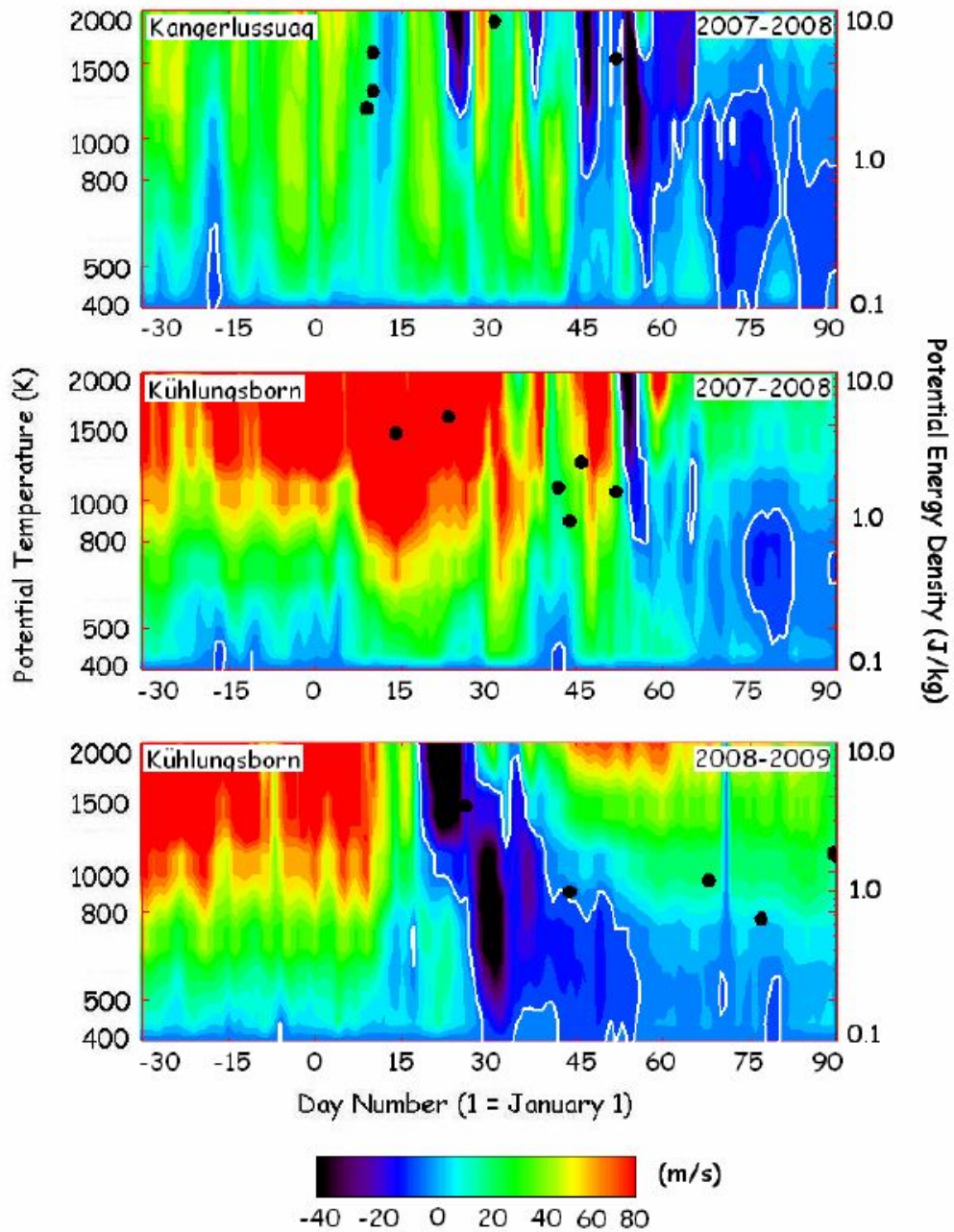
Blocking of upward flux of small-scale waves by large-scale wind structure.



Interannual Variations in Wind and Waves at Kangarlussuaq and Kühlungsborn

Again low gravity wave energies correlate with weak winds.

Highest energies at Kangerlussuaq and lowest at Chatanika (JF 2008) and similar energies at Kühlungsborn and Chatanika (FM 2009).

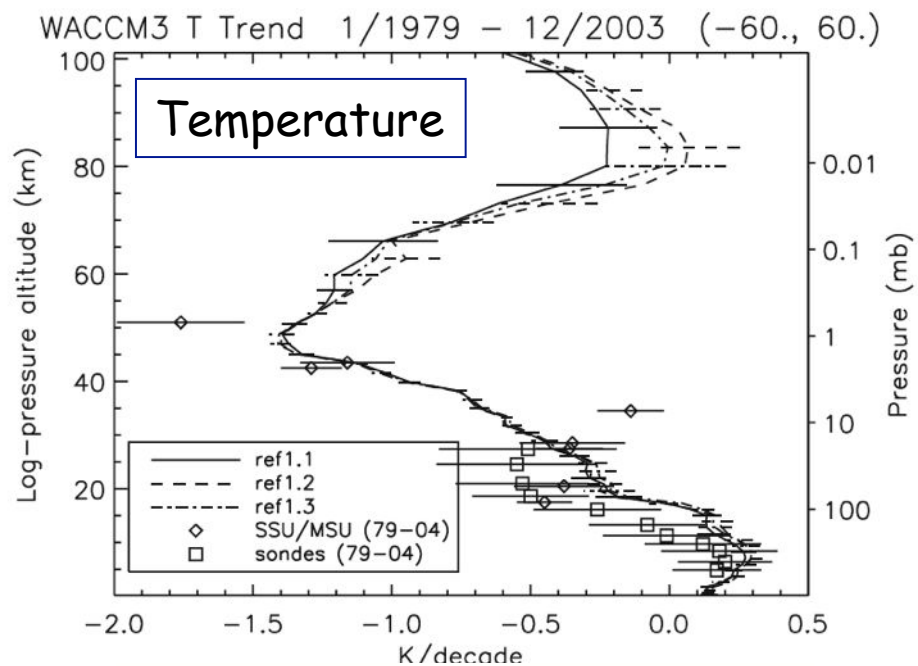


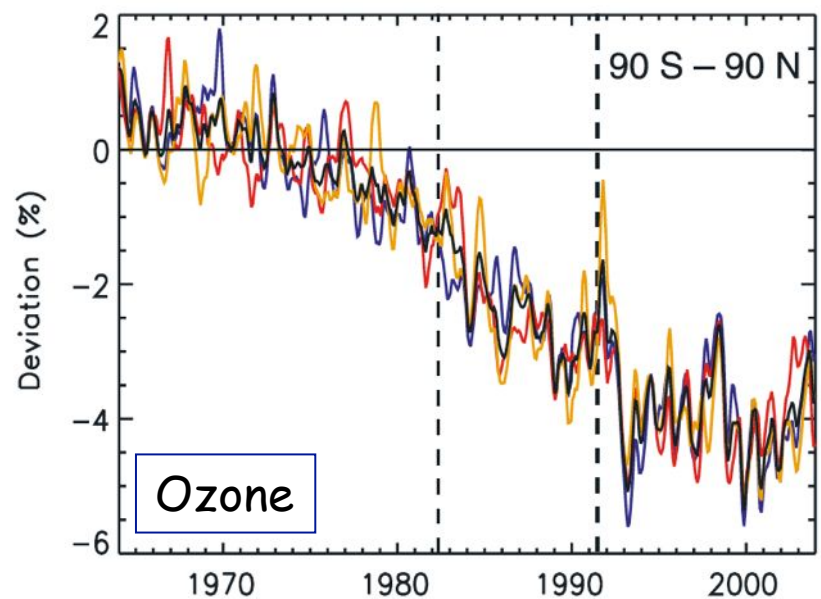
Whole Atmosphere Community Climate Model (WACCM)

Contemporary chemical-climate model that has been used to simulate 1950-2003 to investigate secular trends.

WACCM successfully simulates cooling trends that have been observed in middle atmosphere.

WACCM simulates secular secular trend in globally averaged column and shows variability due to volcanic aerosol (post Mt. Pinatubo) and variations in planetary wave activity (model year 1991).





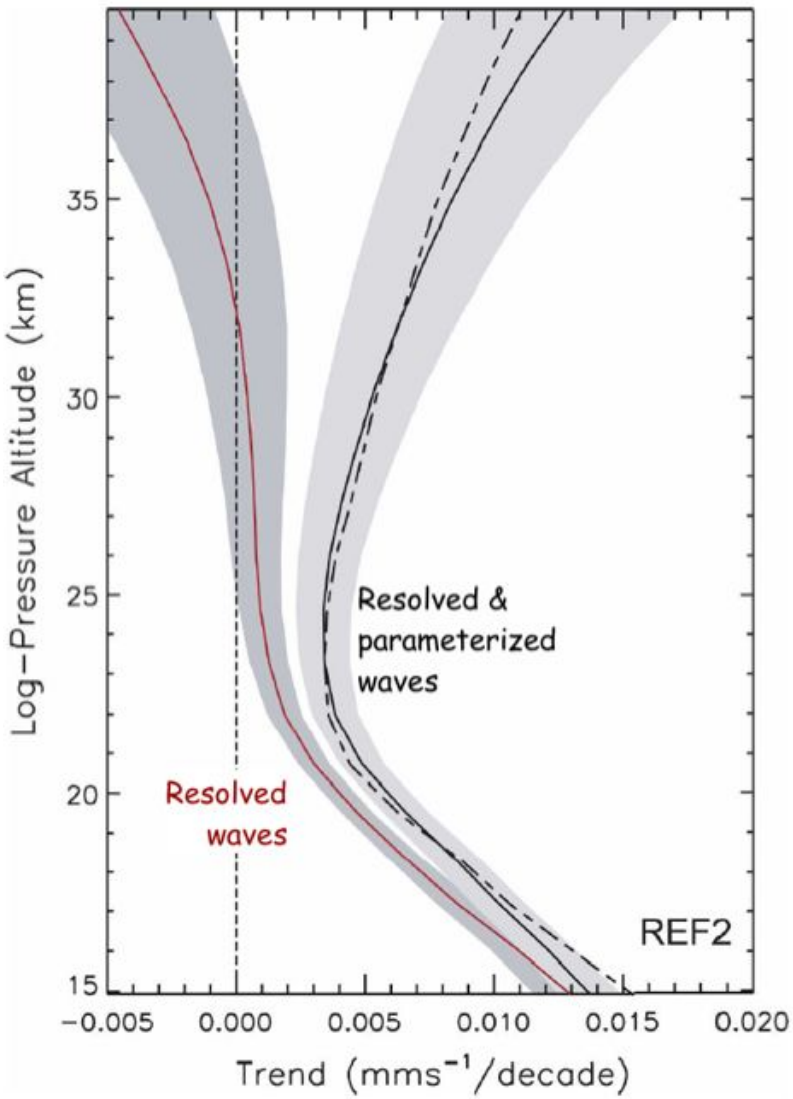
WACCM Circulation Trends

WACCM simulations for 1980-2050 (using IPCC scenario 1b).

Model shows acceleration of the Brewer-Dobson circulation due to both planetary-scale waves (resolved) and mesoscale gravity waves (parameterized).

Model shows increase NOT due to wave sources but due to changes in wind filtering by zonal winds that increase as the meridional temperature gradients increase.

A more variable middle atmosphere?



WACCM-IPY Studies

Recent Arctic winters show significant interannual variability in both planetary and gravity wave activity.

Modulation of wave activity by winds is a significant source of variability in the general circulation.

Current studies show that differences between model and observations are related to gravity wave parameterization.

Goal is to use recent Arctic winters as benchmark for studying gravity wave parameterizations in WACCM.

Acknowledgements

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2007-2009 INTERNATIONAL POLAR YEAR ALASKA

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