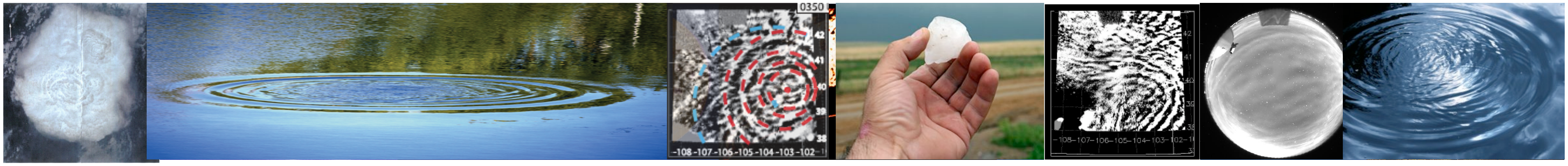

# Concentric gravity waves generated by deep convection on the Great Plains: Observation vs. Modeling


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NCAR

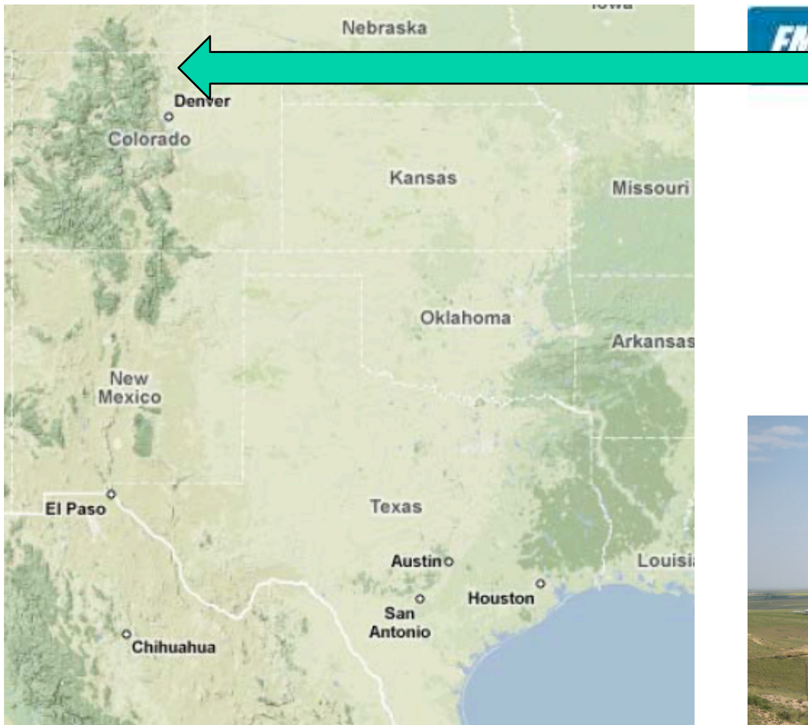

*The National Center for Atmospheric Research is sponsored by the National Science Foundation.*

# Outline

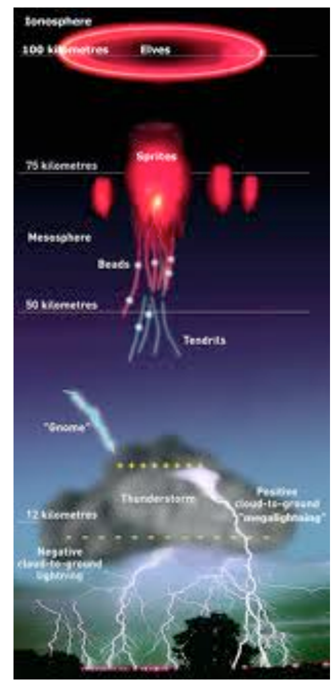
- all-sky airglow imager.
- Wave generation mechanism: updraft and tropopause overshooting.
- Concentric GW: simple case on 11 May 2004
- Concentric GW climatology in Colorado
- Concentric GW: complex case on 8 Sep 2005
- Ground-based observation vs. satellite:

Concentric GW on 03 Jun 2008

# Imager at Yucca Ridge, CO, USA
# A world-famous place to observe sprites

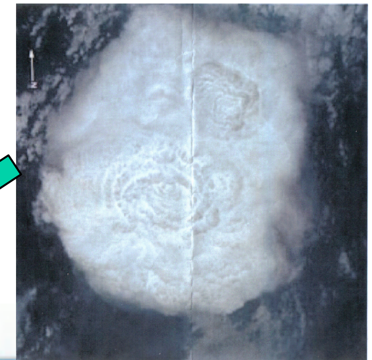






# Wave source: deep convection and overshooting at the tropopause

Air displacement in the stably stratosphere makes gravity waves



NASA

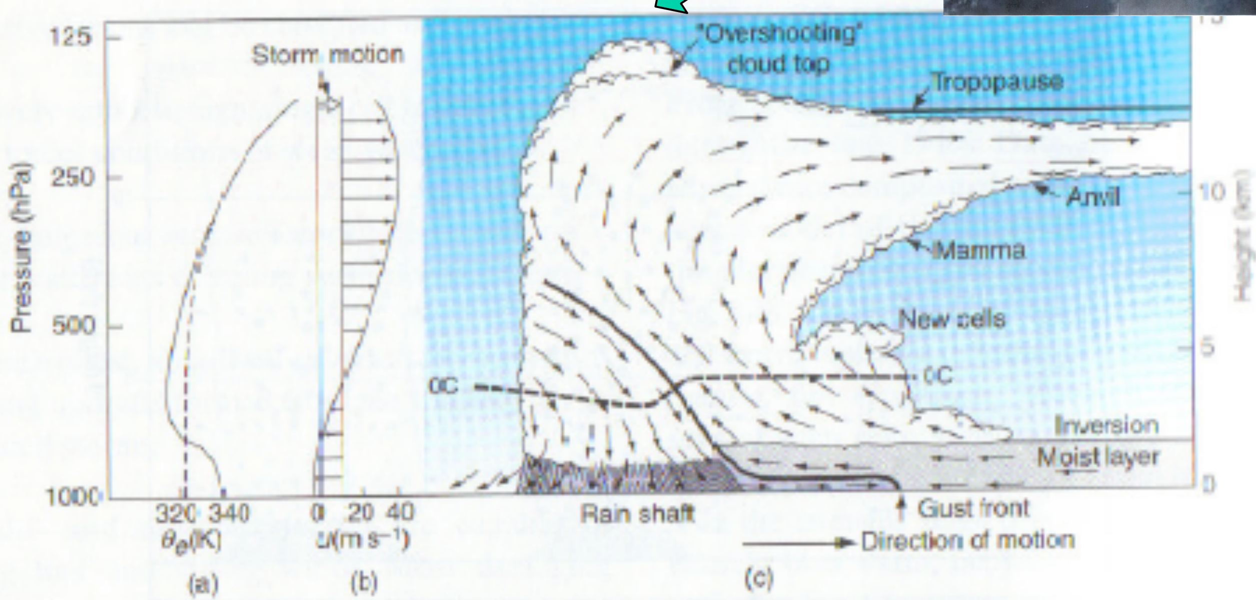
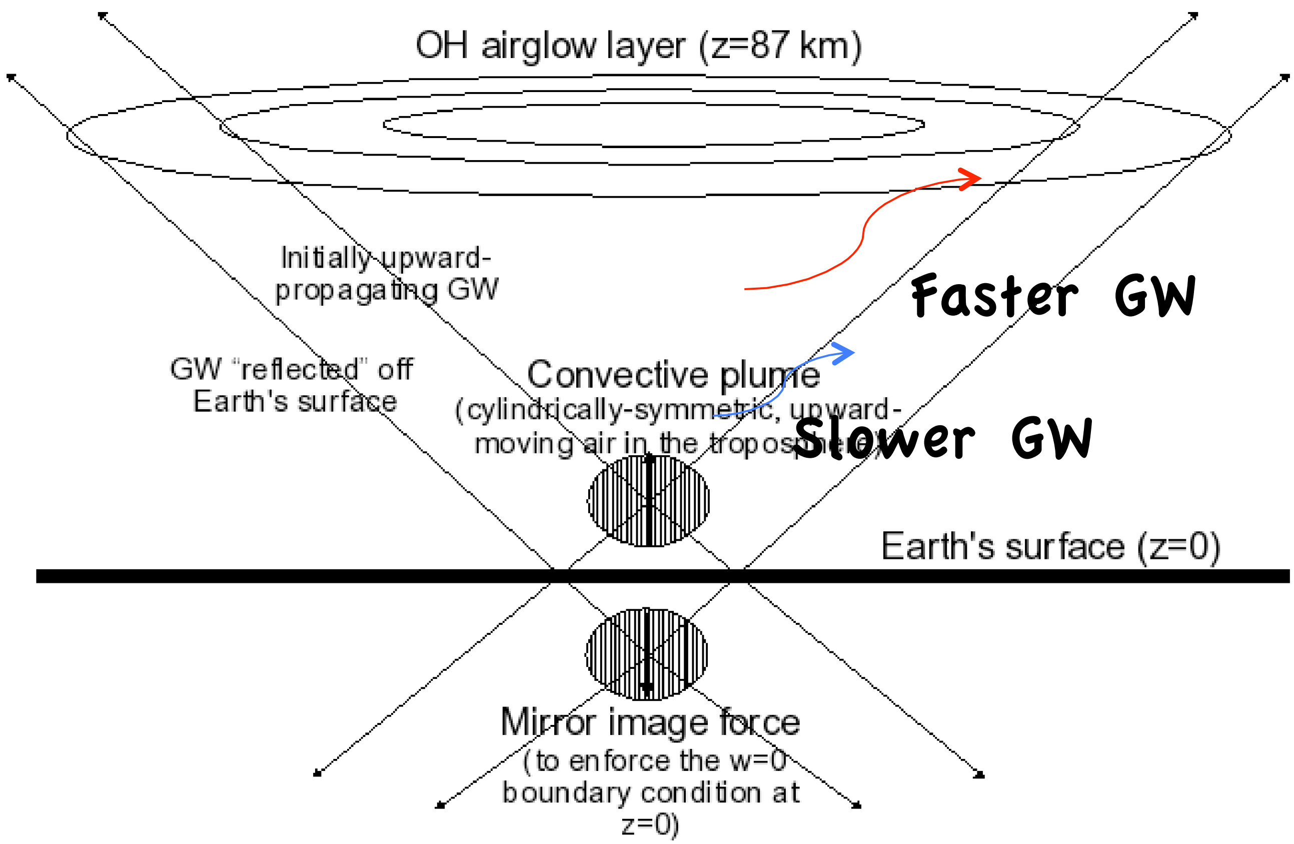



Fig. 8.49 Schematic of an idealized multicell storm developing in an environment with strong vertical shear in the direction of the vertically averaged wind. The vertical profile of equivalent potential temperature $\theta_e$ in the environment is shown at the left, together with the wind profile. Arrows in the right panel denote motion relative to the moving storm.

Wallace and Hobbs

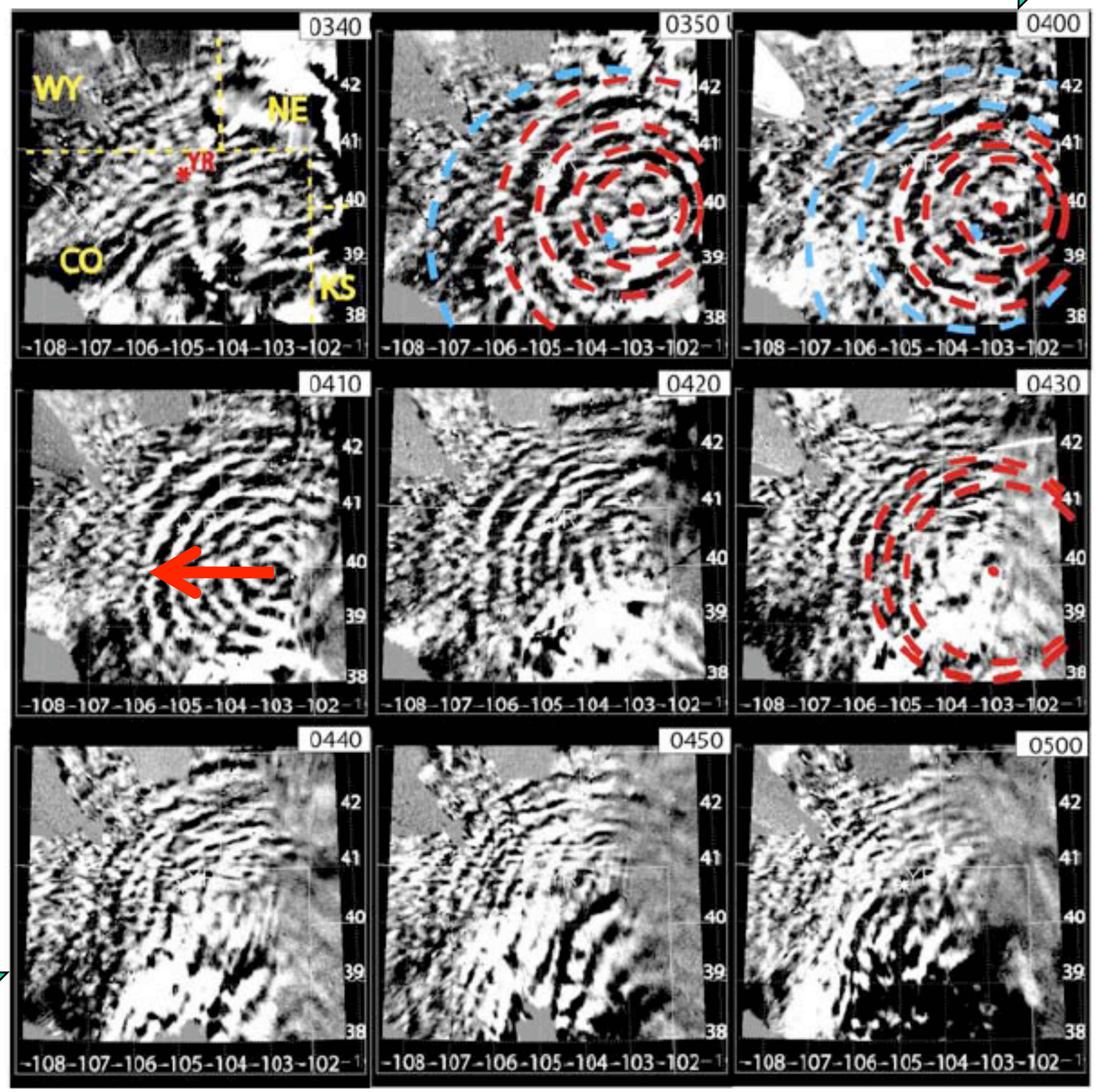
# Dispersive GWs:

- Instantaneous force leads to a broad spectrum of GWs
- Dispersive nature of GWs spreads out the waves in space and time as a function of period and wavelength



# Simple GW event: 11 May 2004 (Yue et al. [2009])

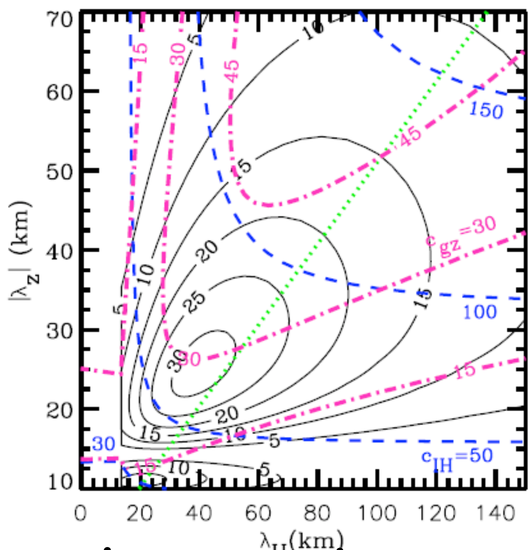
0340 UT
2140 LT




0500 UT
2300 LT

# Dispersion of GWs when propagating

At source



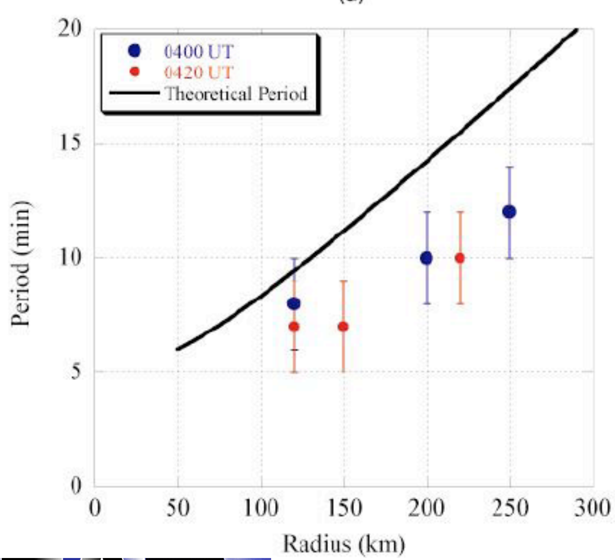

Vadas et al., 2009

$$\omega^2 = \frac{N^2 k_h^2}{k_h^2 + m^2} = N^2 \cos^2 \alpha,$$

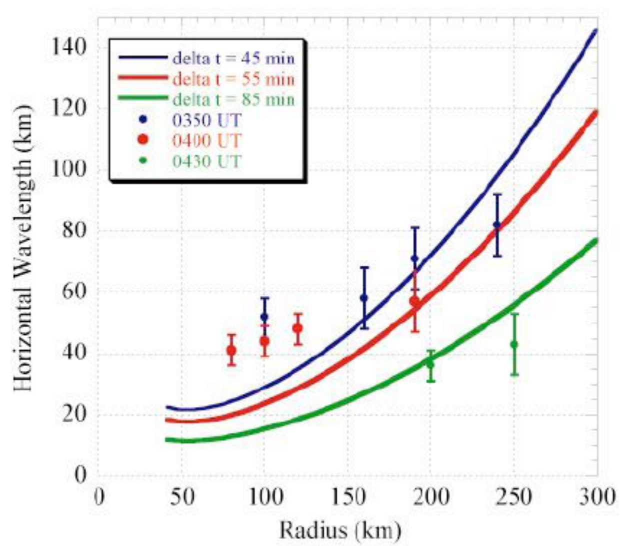
Small period = small angle

Small wavelength = slower velocity = longer propagating time

(a)



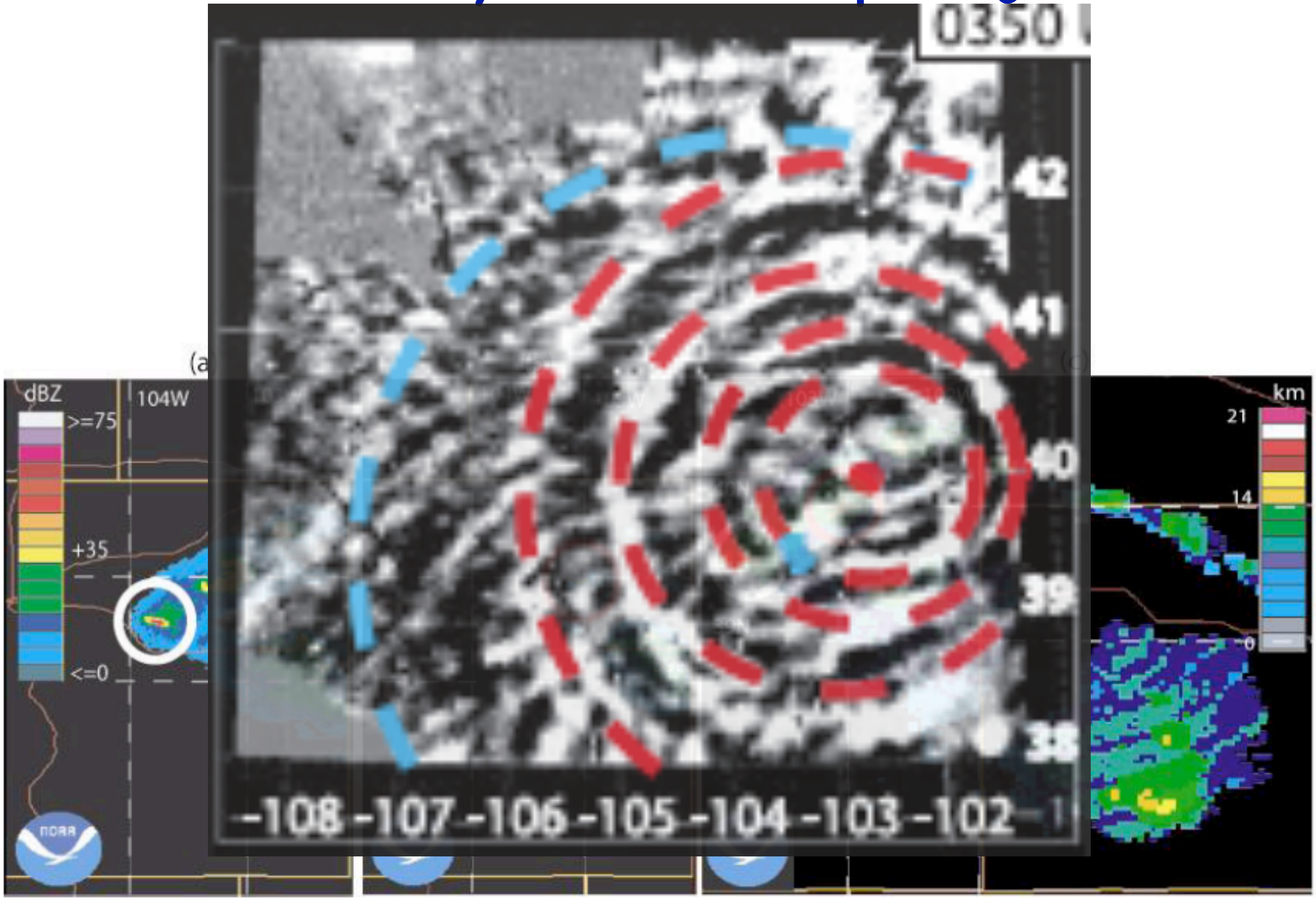

(b)




Yue et al., 2009

At OH layer

# Determination of GW sources: NEXRAD radar reflectivity and echo top height

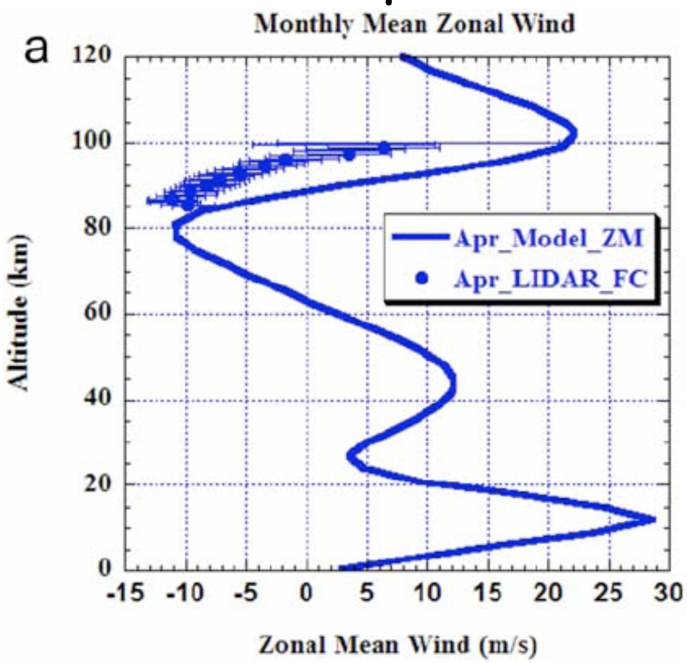


## Modeling vs. Observation: round 1

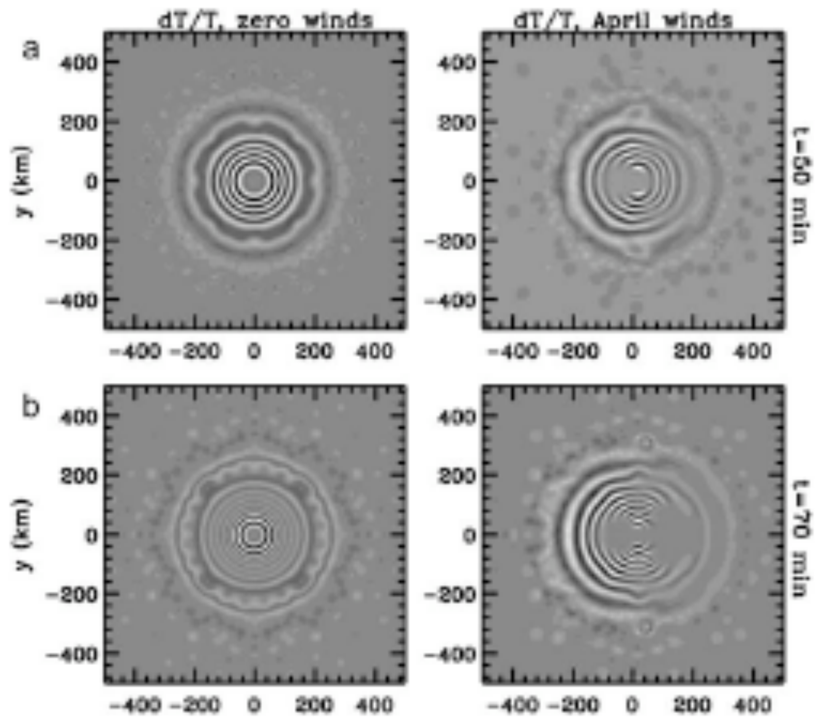
- Convective plume model: Gaussian body force
- Ray trace model: 2 million GWs excited for each plume;
- Background temperature and wind from GCM HAMMONIA near equinox.
- GW phase calcuated
- Temperature perturbation converted to airglow intensity perturbation by Krassovsky parameter

# Mean wind effect

HAMMONIA monthly wind in April

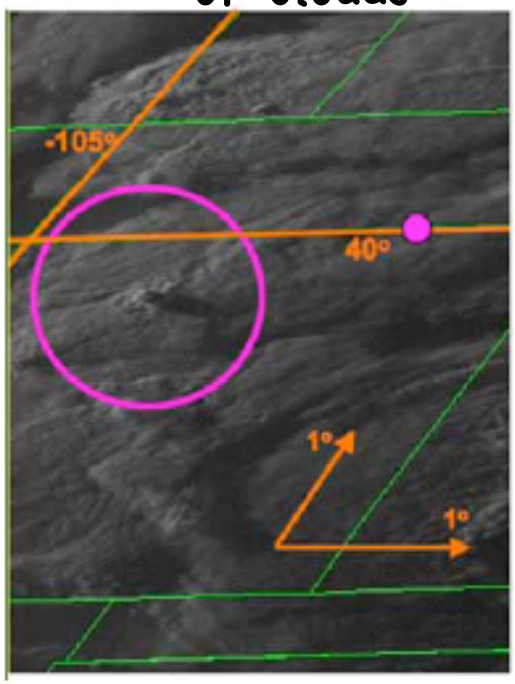



Zero wind  April wind

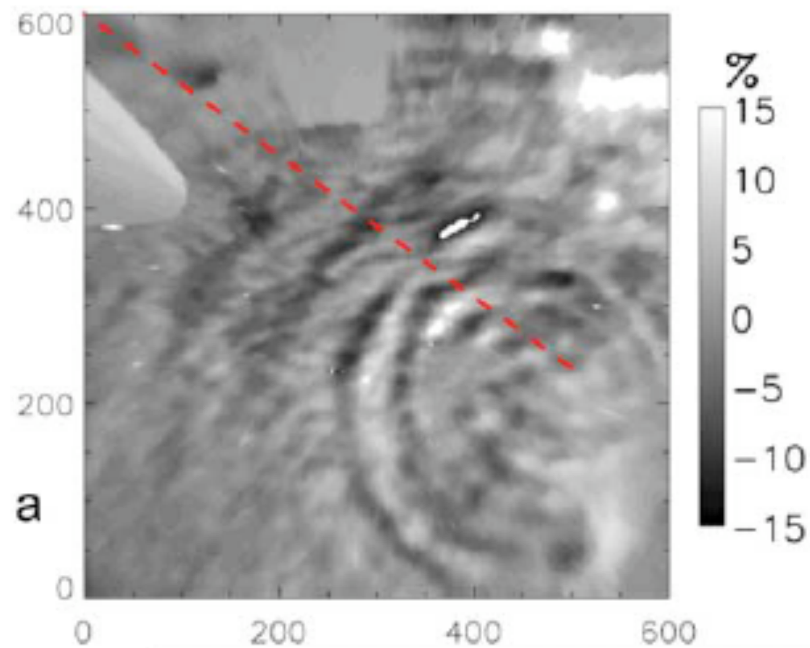


# Comparison between the observed and modeled GW

Overshooting on the top of clouds




Airglow intensity perturbation



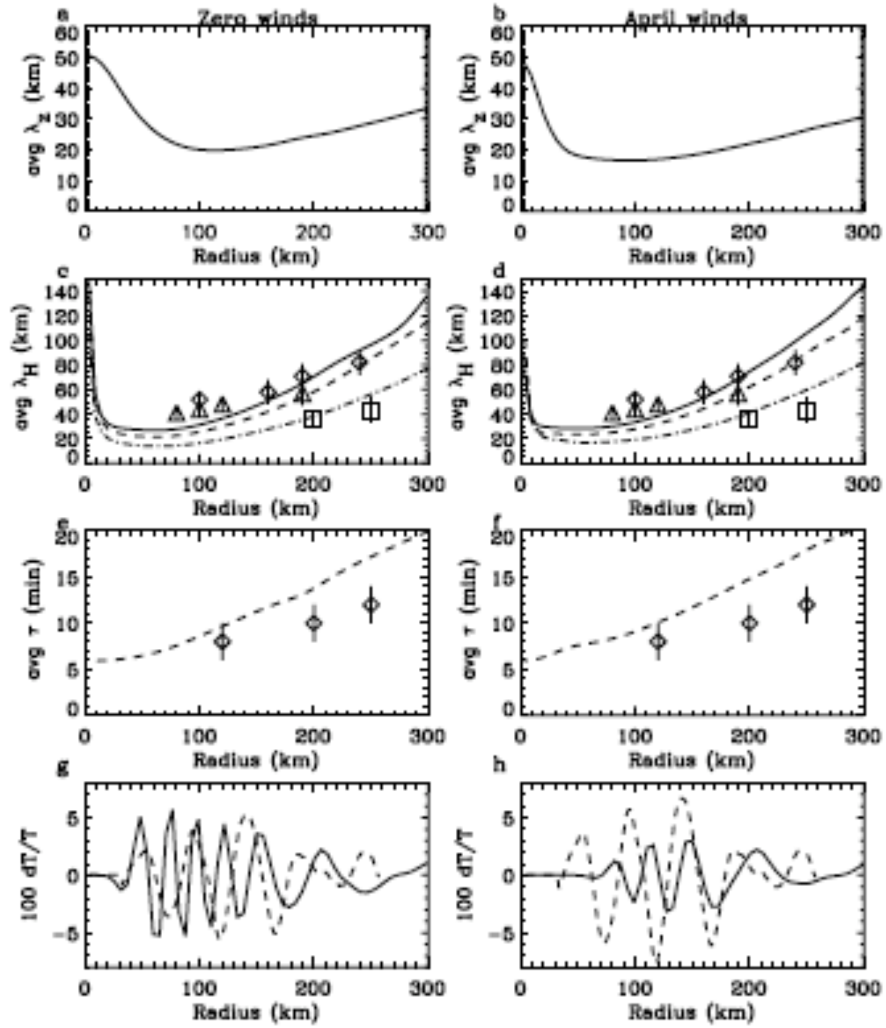
# Vertical and horizontal wavelength, period, and phase

Vertical wavelength

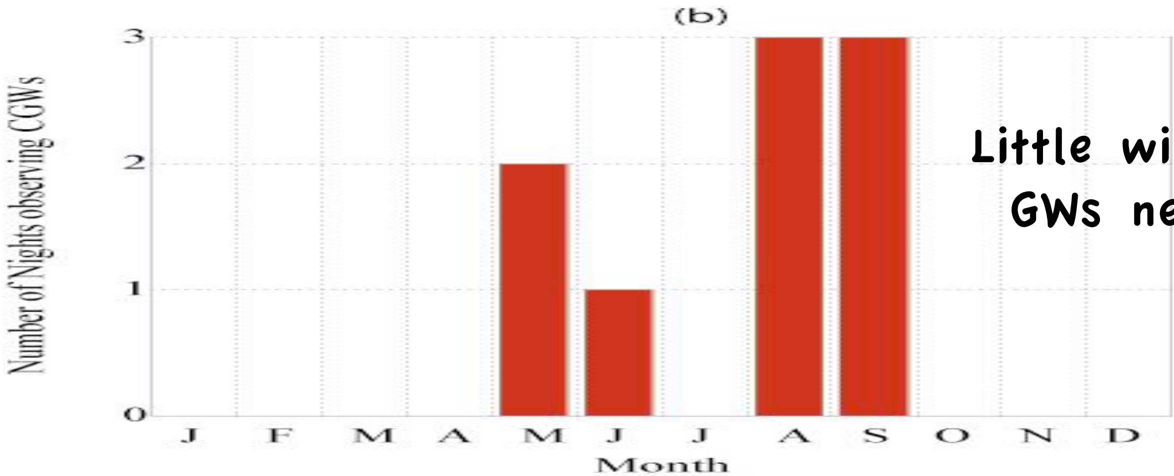
horizontal wavelength

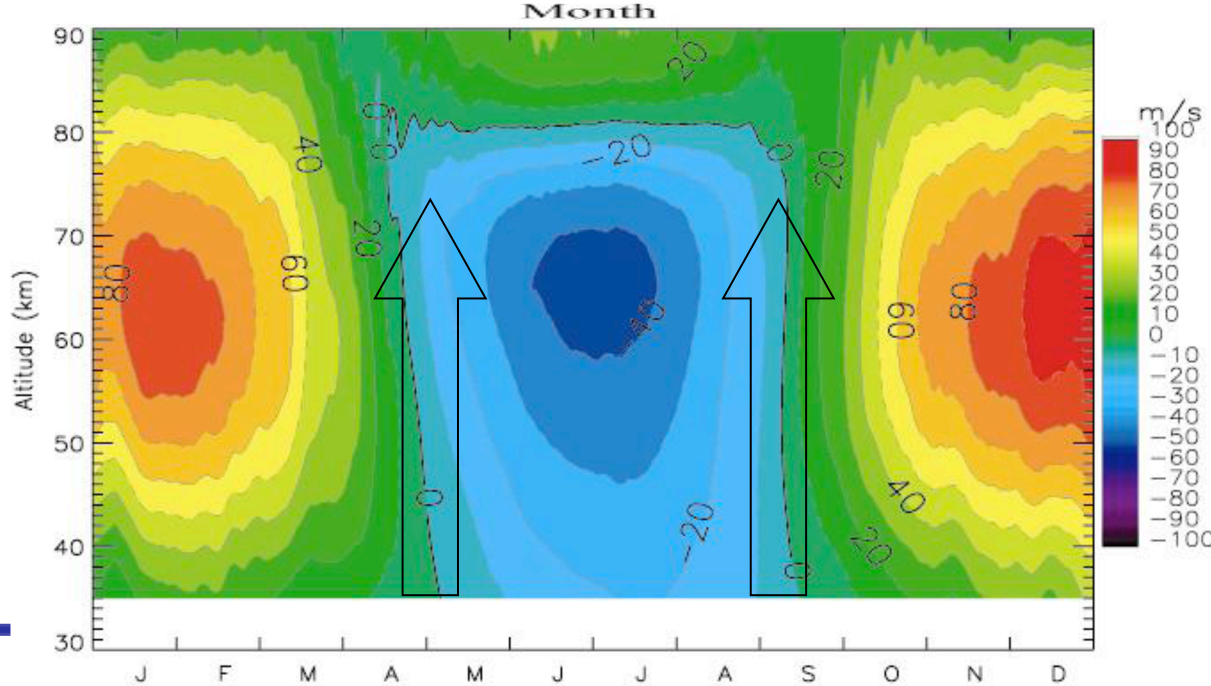
period

Temperature perturbation



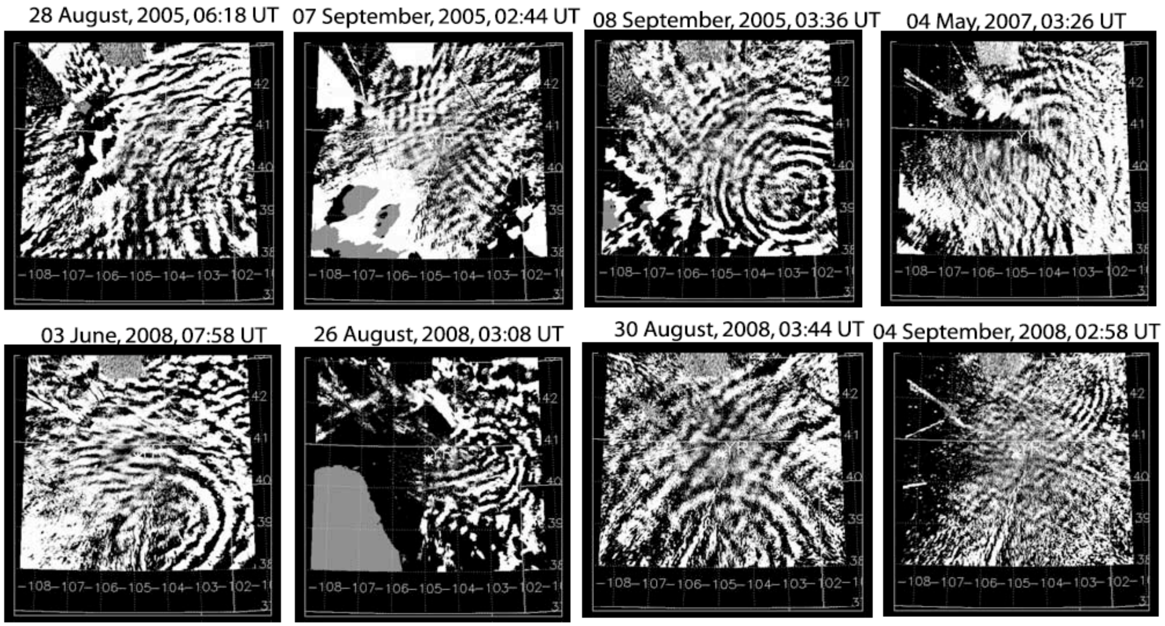
# Climatology of concentric GWs in 2003-2008: 9 nights out of 800 clear nights

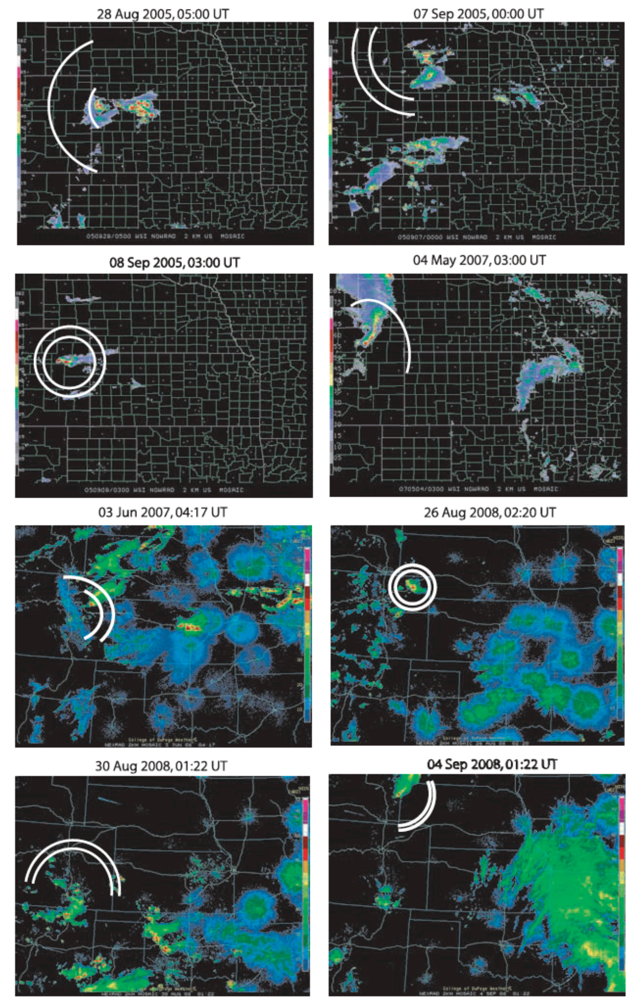



Little wind filtering of GWs near equinoxes

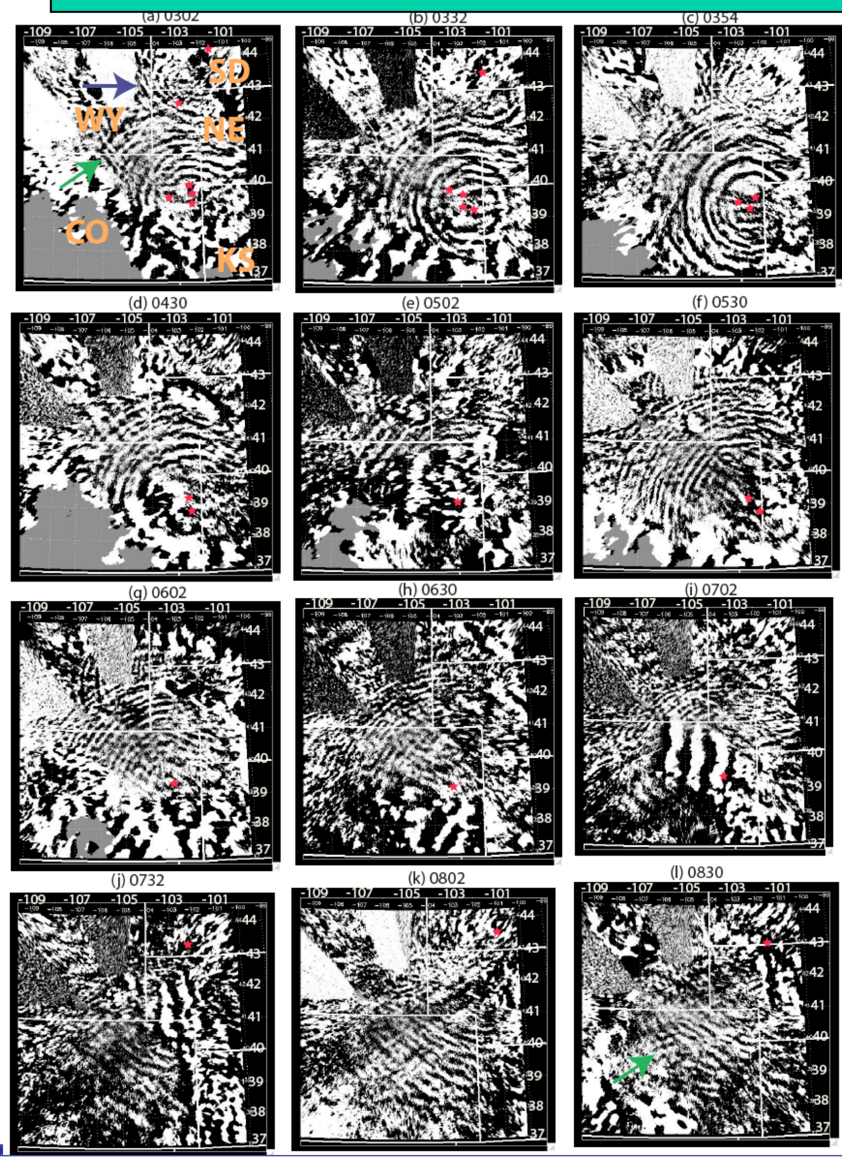
# Strong convection located at the center of each concentric GWs ~1 hour before weak wind found in the radiosonde



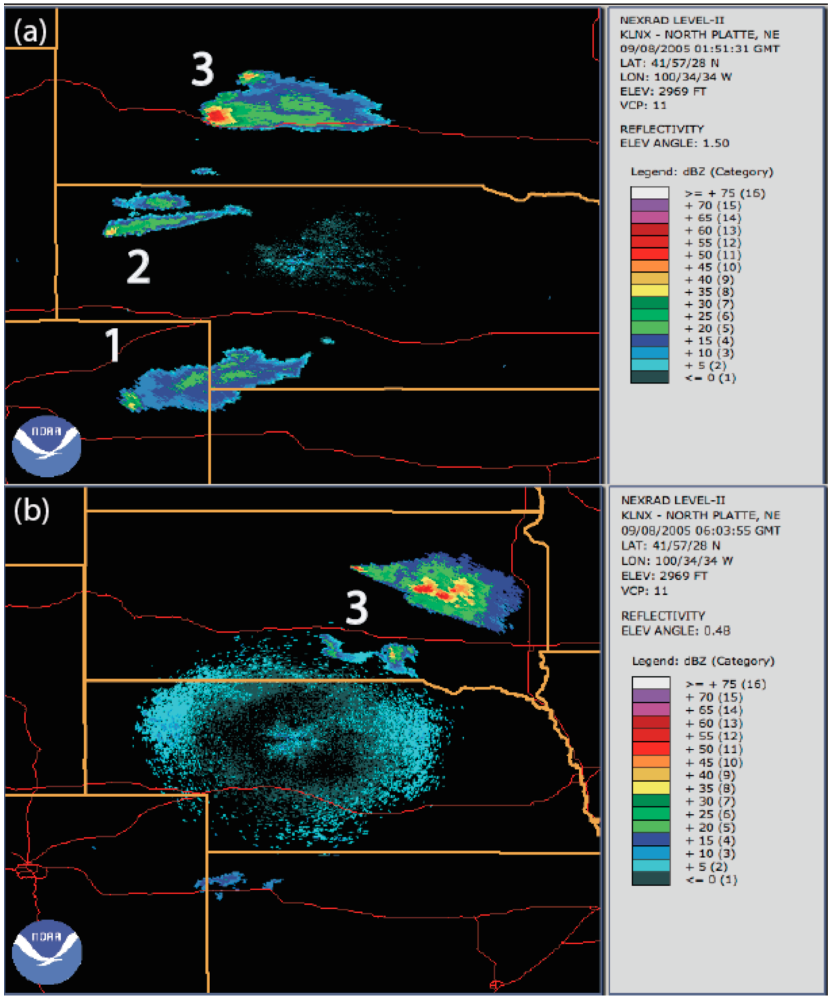
# Complex GW event: 08 Sep 2005

0300 UT
2100 LT

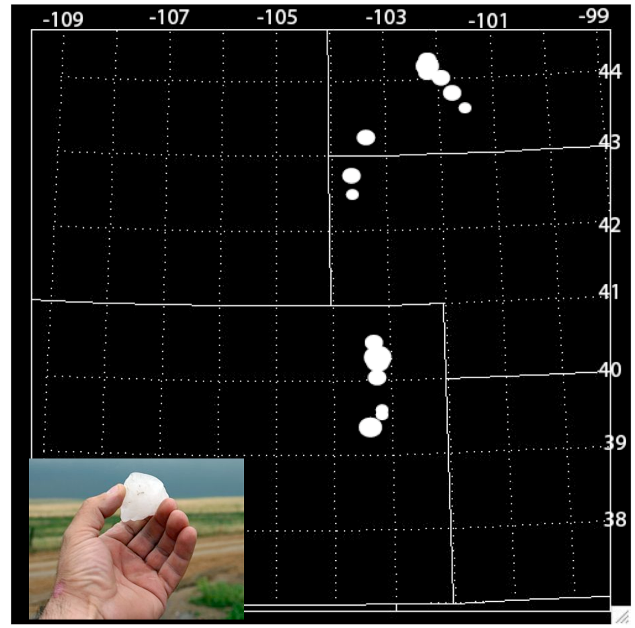



0900 UT
0300 LT

# GW sources: a number of thunderstorms on the Great Plains



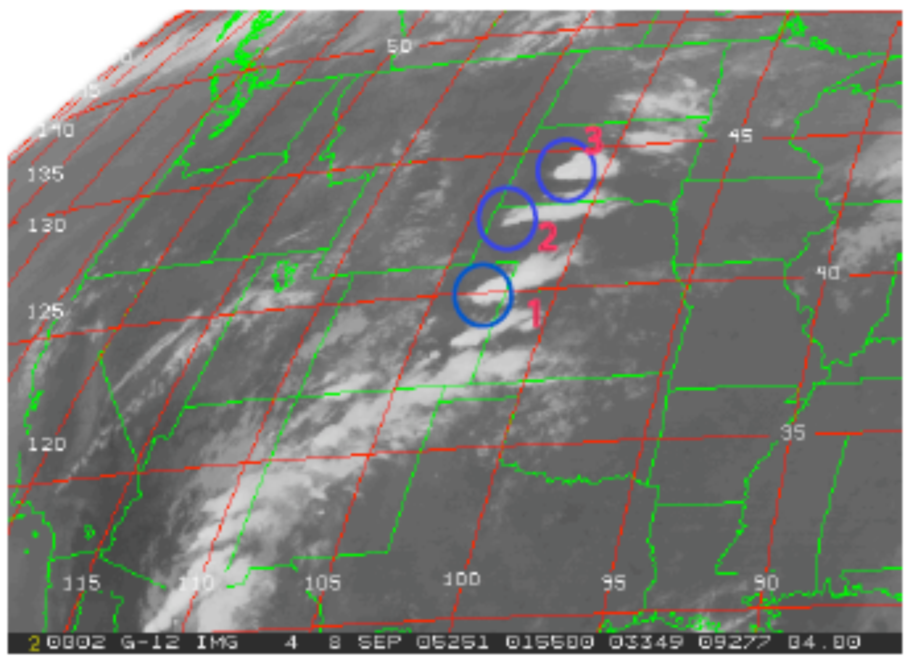

## Hail distribution (0.75”-3”)




Both hail and concentric GW are the products of strong updraft in a thunderstorm

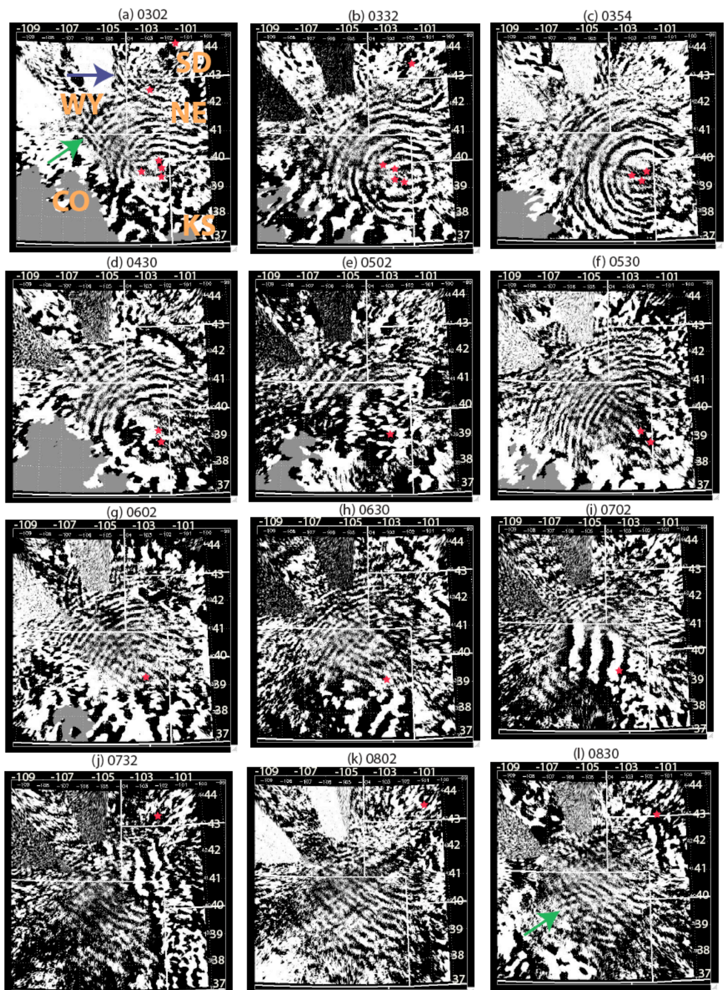
## Modeling vs. Observation: round 2

- Implement multiple plumes (~ 100) in 3000 km*3000km area
- Lindzen type saturation scheme
- Hourly temperature and wind profiles from the TIME-GCM + radiosonde

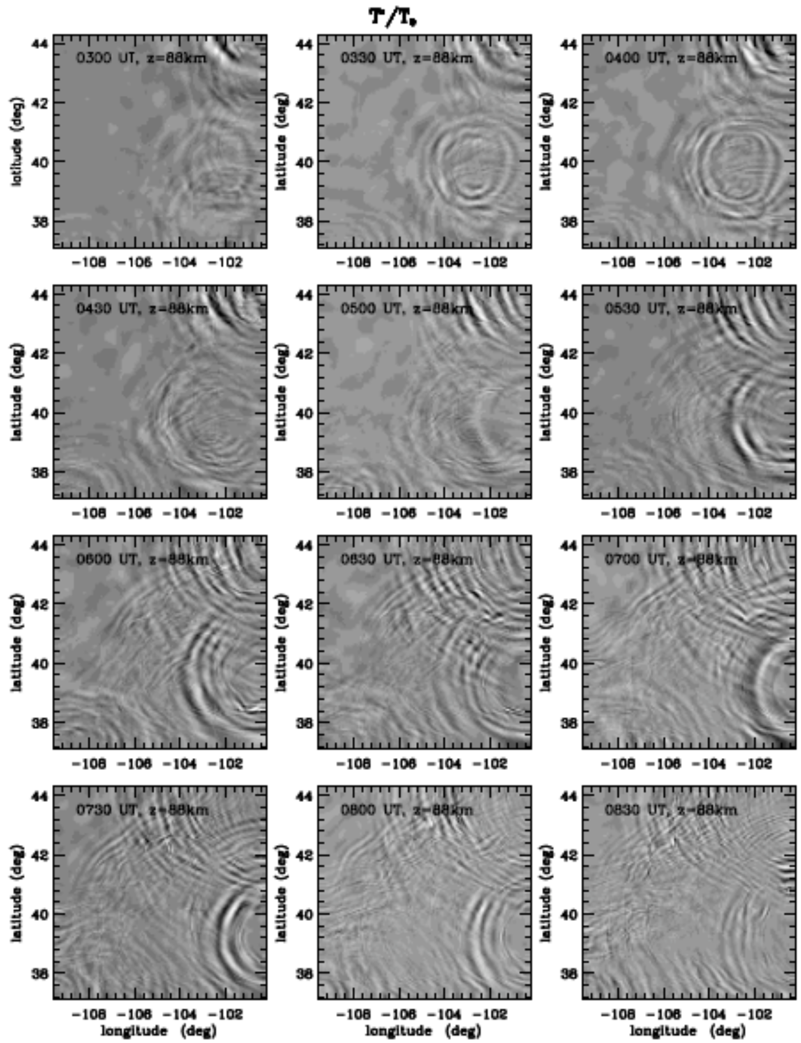


# Saturation considered

## Observation: airglow perturbation



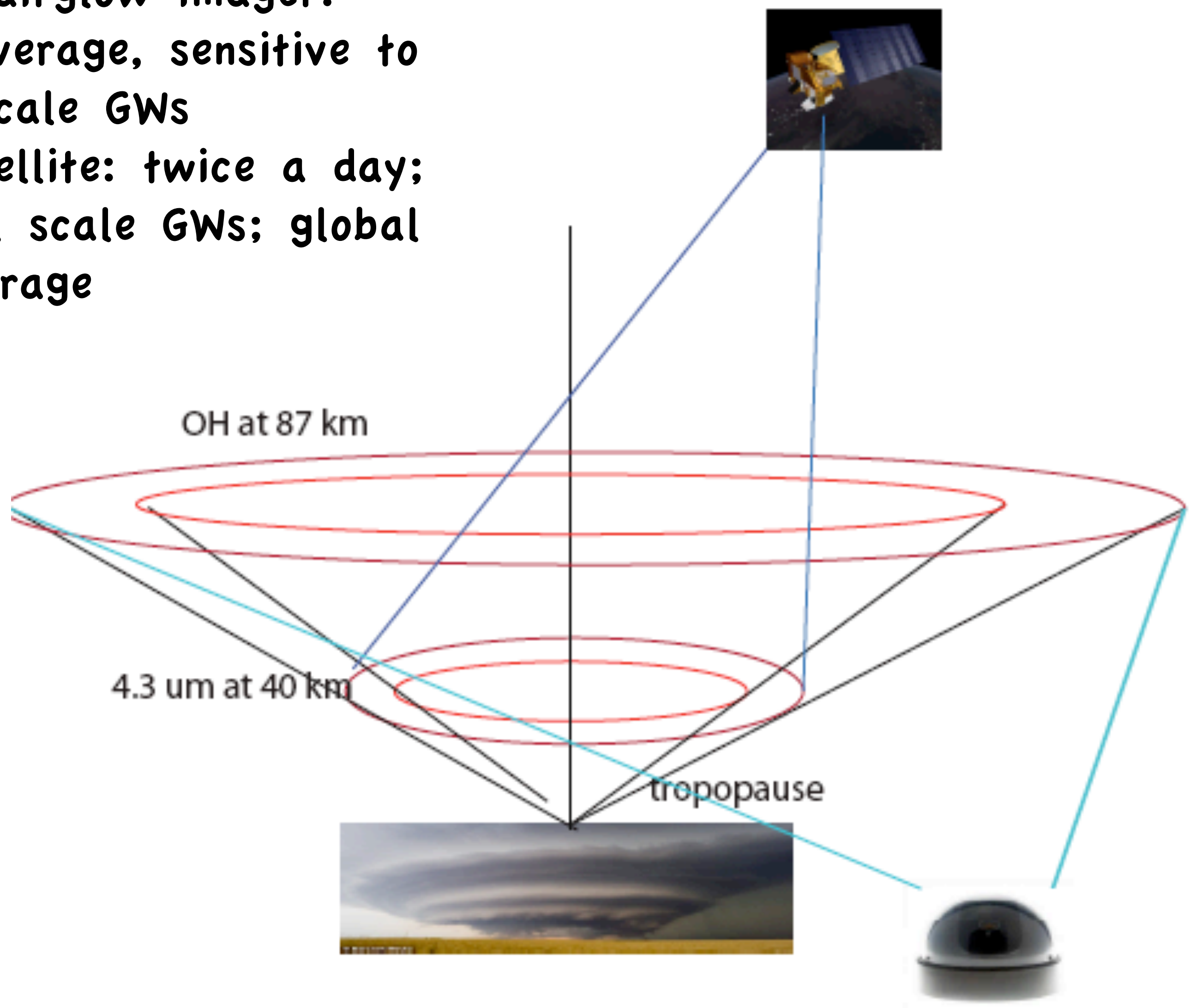

## Model: Temp perturbation



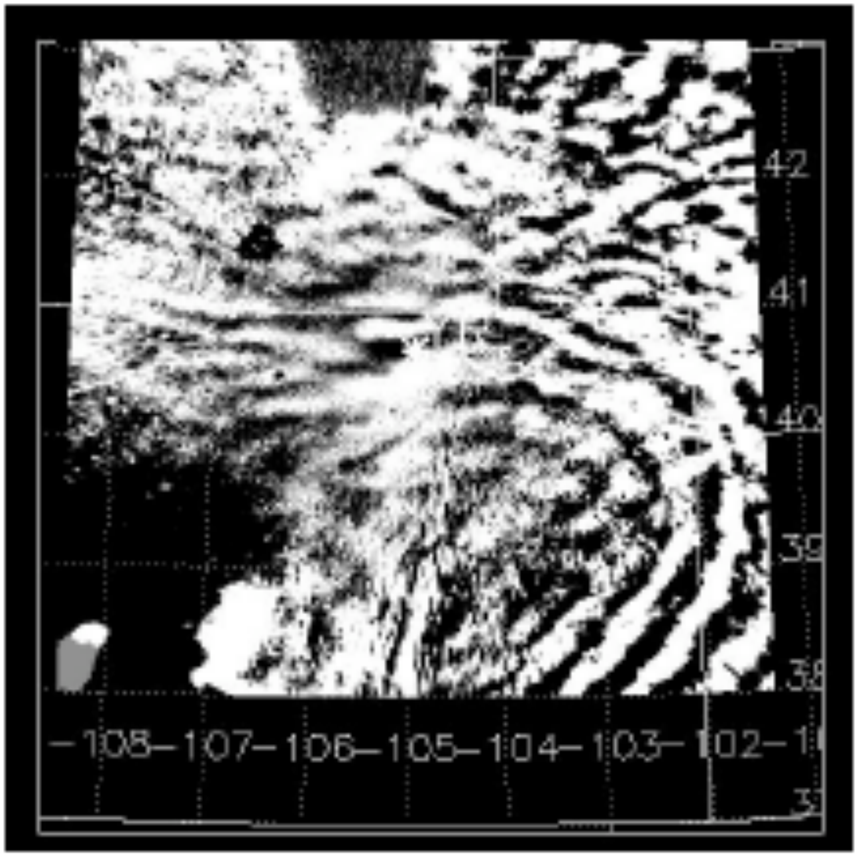
# Concentric GWs observed simultaneously from ground and space

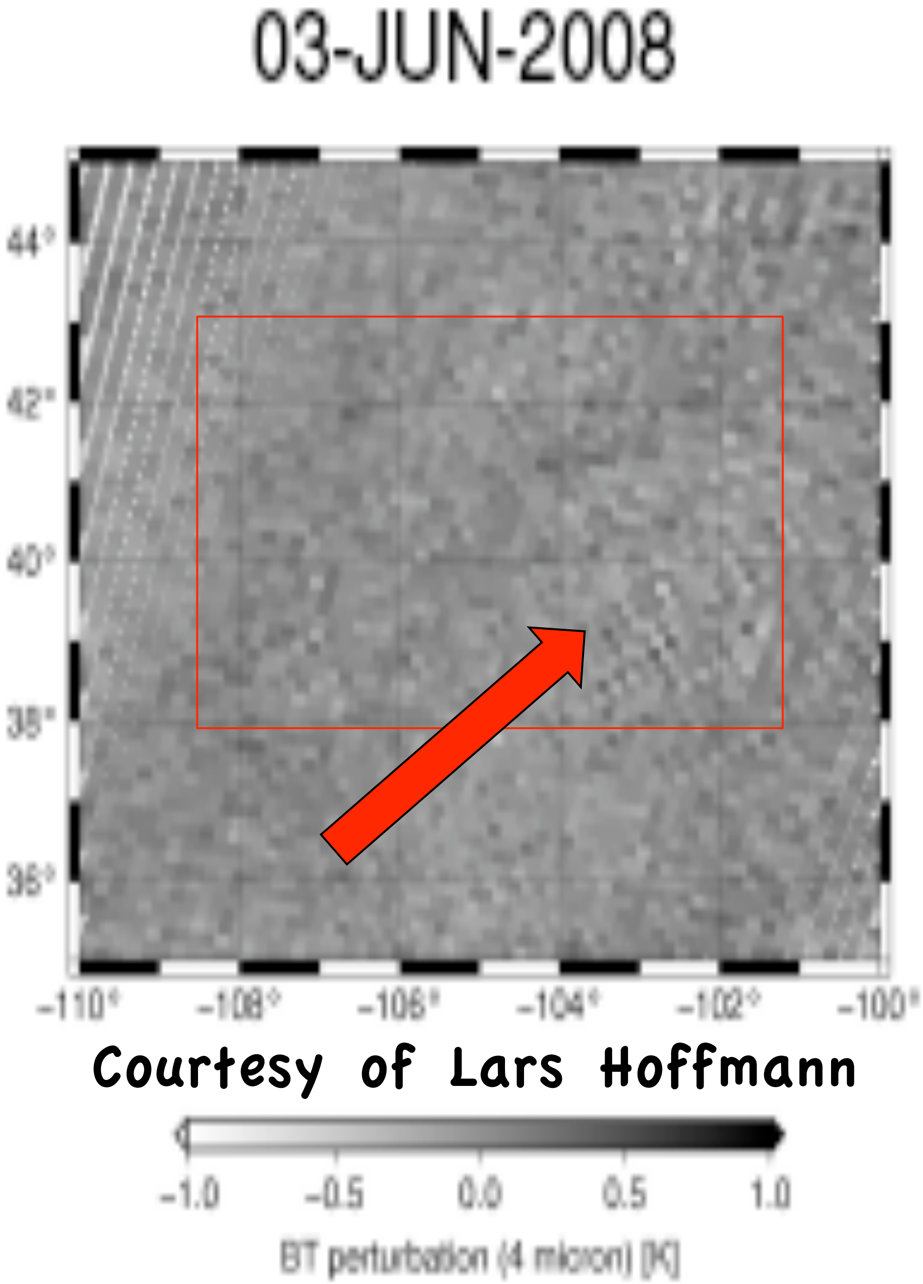
•Ground-based airglow imager: continuous time coverage, sensitive to small scale GWs

•AIRS on Aqua Satellite: twice a day; insensitive to small scale GWs; global coverage



03 June 2008, 08 UT, 02 LT
Aqua satellite descending orbits




Courtesy of Lars Hoffmann

# Conclusions and future work

- The great Plains are ideal place to observe concentric GWs from deep convection.
- GW dispersion relation tested; compare spectrum in model.
- Ray trace model validated.
- Require better background wind and temperature hour-to-hour variation in GCM.
- No wave-wave nonlinear interaction included in the ray trace model.
- Look for GWs signature in the thermosphere/ ionosphere

# Thank you and enjoy the movie!

Dance in the rain