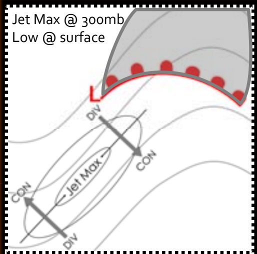
Idealized Modeling of the Role of Stability and Shear on Mesoscale Gravity Wave Evolution

* Michelle Pitcel * Brian Jewett * Bob Rauber * Greg McFarquhar *

UIUC ATMOSPHERIC SCIENCES

What is a Mesoscale Gravity Wave (MGW)

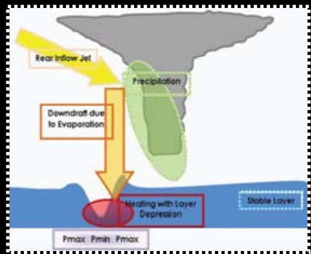
* Correlated pressure-wind perturbations often found behind a Mesoscale Convective System (MCS)
* MGWs can cause damaging winds and intense precipitation
* MGWs can be very long lived and travel several hundred kilometers



MGW Synoptic Environment

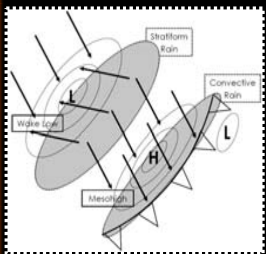
* Black arrows denote acceleration
* Form in grey area behind MCSs
* Form with a strong stable layer present at the surface

(Koch & O'Handley 1997)



Characteristics of a MGW with a MCS

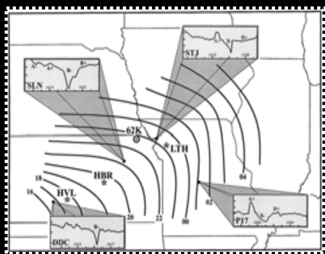
* Period: 0.5-4h
* Wavelength: 30-250km
* Amplitudes can exceed several mb
* Pressure min below depressed stable layer



Mesohigh-Wake Low Couplet

* Black arrows are wind direction
* Grey shading shows precipitation
* Pressure-wind configuration similar to that in a MGW

(Johnson & Hamilton 1988)



MGW Movement Over Time

* MGWs can move over several hundred km
* Black lines are isochrones of low pressure
* Isochrones show movement of one MGW

(Trexler and Koch, 2000 MWR)

Goals

* Explore the relationship between the following variables
  - Lapse rate within the stable layer
  - Temperature of the imposed cooling aloft
  - Vertical U-wind speed shear

  To the following characteristics of MGW intensity
  - High and positive correlation between U-wind perturbation (U') and pressure perturbation (P')
  - Increased temperature immediately following lower pressure
  - Strength of surface winds in vicinity of large pressure changes

Forcing Mechanism

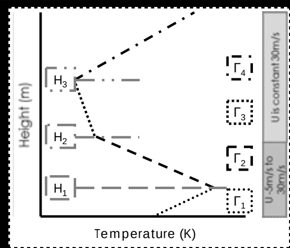
* Evaporative cooling that occurs behind the convective line in the stratiform region of an elevated MCS
  - Downdraft depresses inversion/stable layer
  - Causes pressure falls and MGW genesis

Acknowledgements

* NSF Grant ATM-0413824
* The National Center for Supercomputing Applications (NCSA) at U of I
* The Department of Atmospheric Sciences at U of I

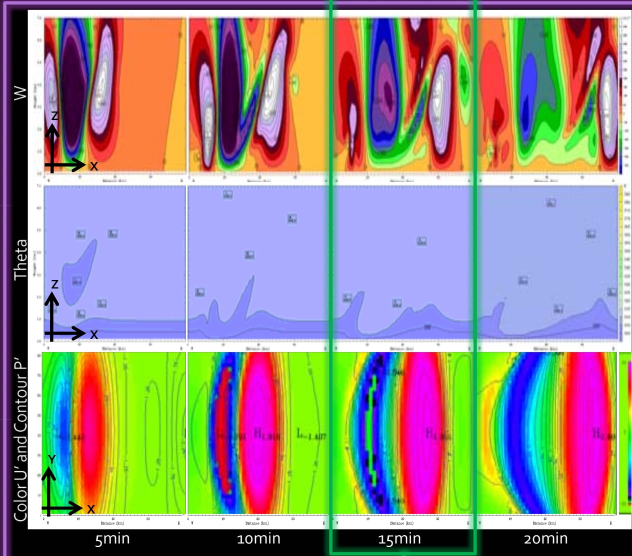
Modeling MGWs

* Using WRF version 2.2.1 and NCSA/LEAD workflow broker system
* Evaporative cooling is simulated using an imposed cold thermal
* Model domain is (x*y*z)=(83*83*7km)
* In the model example images
  - Cold thermal is falling at 5min
  - Wave is at max activity at 15min



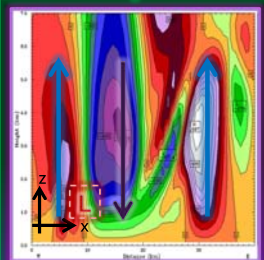
Sounding configuration for simulations

* Each run uses a model-generated sounding
* $\Gamma = \partial\theta/\partial z$
* Γ_1 and Γ_2 range from 0-12 K/km
* H_1 = 0-1800m; H_2 = H_1-7000m



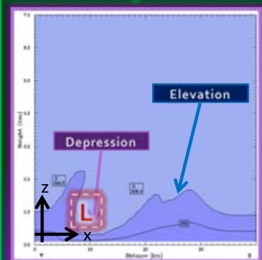
Lifecycle of a MGW

Green outline denotes time of greatest MGW activity



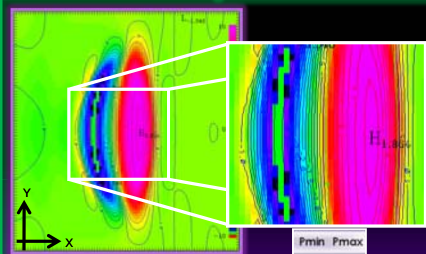
Vertical Wind Profile

* Cross-section
* Depression of stable layer (L)
* Max downdraft leads min P



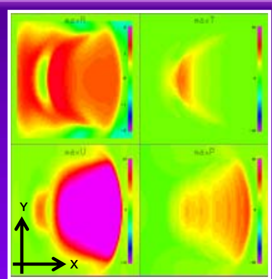
Theta Cross-Section

* Cross-section
* Depression of stable layer (L)
* Theta shows stable layer



Wind with Pressure Maximum and Minimum

* Wind is shaded; Pressure is contoured
* Pattern similar to Mesohigh-Wake Low Couplet
* Strong correlation between U' and P'



Correlation Coefficient

* Max variables at each point over all time
* R is correlation of U' and P' over all time
* R implies MGW activity as wind speed should change as pressure changes

Summary of Current and Future Work

* Current Work
  - 500 runs completed
  - Analysis code written to process data and results from each WRF simulation
  - What we know now about variable dependence for strong MGW cases
    - -10°C thermal combined with larger H_1 and Γ_1 and a smaller H_2 and Γ_2
    - Results in larger negative U' and P'
    - Thermal appears to be the most important, followed by the lapse rates and heights

MGW	Thermal	H_1	Γ_1	H_2	Γ_2	r	min u'	min p'
Strong	-10	1750	12	2750	4	0.901	-7.436	-4.080
Weak	-2	250	0	3750	8	0.948	-0.899	-0.683

* Future Work
  - Complete all runs
  - Create Regime Diagrams to relate shear, stability, and cooling with MGW activity
  - Substitute a constant cold source for the cold thermal
  - Examine MGW response for the thermal versus a constant cold source