Introduction to Mesoscale Meteorology: Part I

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Overview

Hello. I'm Dr. Jeremy Gibbs.

- All too often, students are intimidated by instructors and are timid about approaching them or asking questions.

Don't be intimidated.

About me

- Completed my Ph.D. in Dec. 2012 from SoM
- My advisor was Evgeni Fedorovich
- I study boundary layer flows, turbulence, numerical modeling
- I currently work as a postdoc on a the PECAN project
- Now that you know my degree and job, save some time talking and just call me Jeremy.

Instructors

Jeremy

- Up until spring break
- gibbz@ou.edu, NWC 5648, TR 12:45 pm-1:30 pm

Dr. Ming Xue

- After spring break
- mxue@ou.edu, NWC 2502, TBA

Ms. Rachel Miller

- Grader
- rlmiller93@yahoo.com, NWC 5110

Websites

- Desire2Learn
- http://twister.ou.edu/MM2015

Textbooks

- Required: Markowski, P. and Y. Richardson: Mesoscale Meteorology in Midlatitudes. Wiley-Blackwell, 430pp.
- Optional: Ray, P. S. (Editor): Mesoscale Meteorology and Forecasting. American Meteorological Soc., 793 pp.
- Optional: Lin, Y.-L.: Mesoscale Dynamics. Cambridge University Press, 646 pp.

Notes

- I will provide detailed notes.
- Are you okay if I simply post them online (that's a lot of paper to print)?
- Do you prefer to have them prior to class?
- I'll post them both D2L and the course website.

Content

This course is designed for you to understand, by applying atmospheric dynamics and physical analysis techniques, mesoscale and convective-scale phenomena.

Topics include mesoscale convective systems, severe thunderstorms, tornadoes, drylines, low-level jets, mountain waves and orographic precipitation, land/sea breezes, boundary layer rolls, and hurricanes.

Grading

- Homework sets (2 or 3): 10%
- In-class exams (2): 30%
- Term project: 30%
- Comprehensive final exam: 30%

Homework

Homework is due by the end of class on the required submission date. You will be assessed a 20% penalty per day for late work.

Work will not be accepted 2 days beyond the announced due date.

You are encouraged to discuss homework problems with one another; however, solutions submitted under your name must express your own descriptions and calculations and be written by you - not copied in whole or in part from someone elses work or from a common work session on the chalkboard. Cheating is strictly forbidden and could result in suspension or expulsion from the University. Dont even think about doing it! It is your responsibility to read and understand the Student Code and policies on Academic Integrity

Exams

Two in-class examinations will be given during the regular lecture period (dates TBD). Make-up exams will be given only under exceptional circumstances.

The final examination is comprehensive and will be held in NWC 5600 on Thursday May 7, 2015 from 10:30 am - 12:30 pm. A make-up final exam will be given only under exceptional circumstances.

How to succeed

You are encouraged to visit Dr. Gibbs, Dr. Xue during office hours, or to make special appointments. The best way to reach us is via e-mail. Please take advantage of office hours!

Do not wait until the final exam to begin studying. The best way to ensure success is to keep up with the course material and to ask questions. Students who actively participate in lectures and avail themselves of office hours typically learn and retain the material at a much higher level.

Attendance and etiquette

You are all adults paying to be here. I have no desire to take attendance. It is up to you decide if you attend lectures. I think you might benefit from attending regularly, and I highly recommend doing so.

I realize lectures can sometimes become boring. If you decide to play Angry Birds or post embarrassing photos of your instructor to Twitter, make sure your sound is turned off.

This class time is awful. If you want to bring your lunch, feel free. Just don't make someone else clean up after you.

Have fun

Finally, HAVE FUN! In this course, we will try to understand many of the mesoscale phenomena that we encounter in real life. They are very relevant to your career as a meteorologist! Most weather that we see occur on the mesoscales!

What does Mesoscale cover?

In this class, we will try to understand many of the mesoscale phenomena that we encounter in real life.

- mountain waves
- density currents
- gravity waves
- land/sea breezes
- heat island circulations
- clear air turbulence
- low-level jets
- fronts
- mesoscale convective complexes
- squall lines
- supercells
- **tornadoes**
- hurricanes

The goal

We will focus on the physical understanding of these phenomena, and use dynamic equations to explain their development and evolution.

First, we must define **mesoscale**.

We tend to classify weather systems according to their intrinsic or characteristic time and space scales. Often, theoretical considerations can determine the definition.

There are two commonly used approaches for defining the scales: dynamical and scale-analysis.

Dynamical

The dynamical approach asks questions such as the following:

- What controls the time and space scales of certain atmospheric motion?
- Why are thunderstorms a particular size?
- Why is the planetary boundary layer (PBL) not 10 km deep?
- Why are raindrops not the size of baseball?
- Why most cyclones have diameters of a few thousand kilometers not a few hundred of km?
- Tornado and hurricanes are both rotating vortices, what determine their vastly different sizes?

There are theoretical reasons for them! There are many different scales in the atmospheric motion. Let's look at a couple of examples.

Dynamical

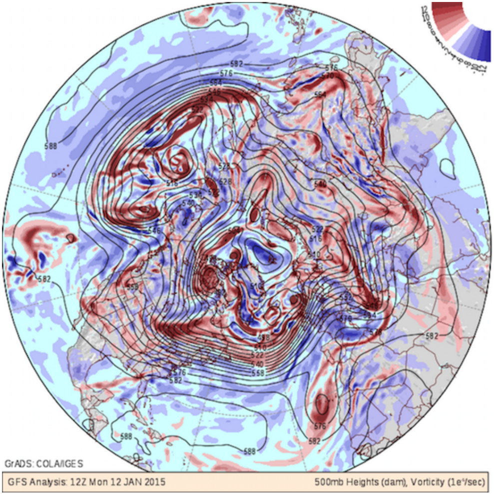


Figure: Hemispherical plot of 500mb height (contour) and vorticity (color) showing planetary scale waves.

Dynamical

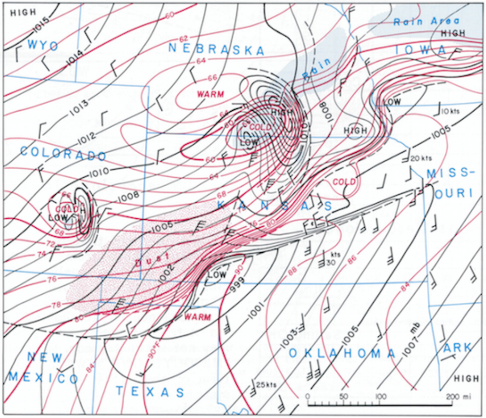


Figure: Sea level pressure (black contours) and temperature (red contours) analysis at 0200 CST 25 June 1953. A squall line was in progress at the time in northern Kansas, eastern Nebraska, and Iowa. [From Markowski]

Atmospheric Energy Spectrum

- Atmospheric motions exist continually across space and time scales.
- Spatial scales range from $\sim 0.1\ \mu\mathrm{m}$ (mean free path of molecules) to $\sim 40,000\ \mathrm{km}$ (circumference of Earth), while temporal scales range from sub-second (small-scale turbulence) to multi-week (planetary-scale Rossby waves).
- The ratio of horizontal space and time scales is approximately the same order of magnitude ($\sim 10\ \mathrm{ms}^{-1}$) for these features.

Atmospheric Energy Spectrum

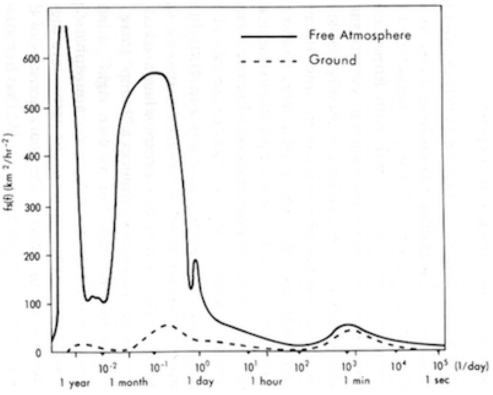
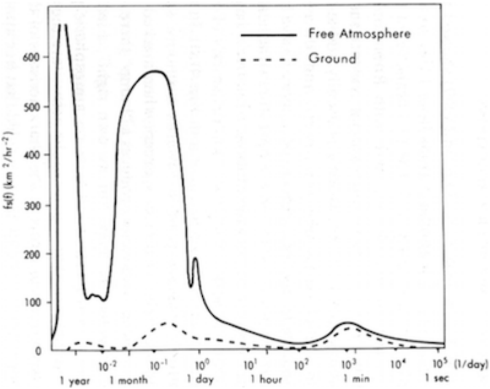


Figure: Average kinetic energy of west-east wind component in the free atmosphere (solid line) and near the ground (dashed line). (After Vinnichenko, 1970; see also Atkinson, 1981)

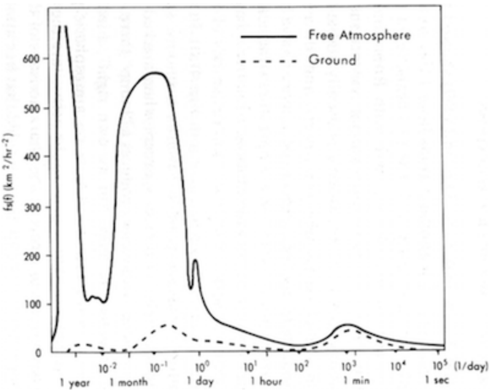
- There are a few dominant time scales in the atmosphere when looking at the kinetic energy spectrum plotted as a function of time.
- The figure also shows that the *energy spectrum* of the atmospheric motion is actually *continuous*!

Atmospheric Energy Spectrum



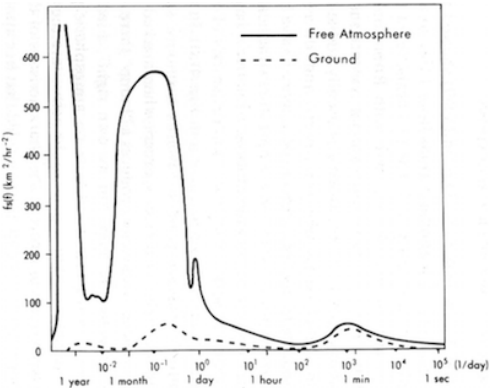
There is a local peak around one day (associated with the diurnal cycle of solar heating), and a large peak near one year (associated with the annual cycle due to the change in the earth's rotation axis relative to the sun). These time scales are mainly determined by forcing external to the atmosphere.

Atmospheric Energy Spectrum



There is also a peak in the a few days up to about one month range. Synoptic scale cyclones up to planetary-scale waves. There isnt really any external forcing that is dominant at a period of a few days. Thus, this peak must be related to the something internal to the atmosphere. It is actually the scale of the most unstable atmospheric motion.

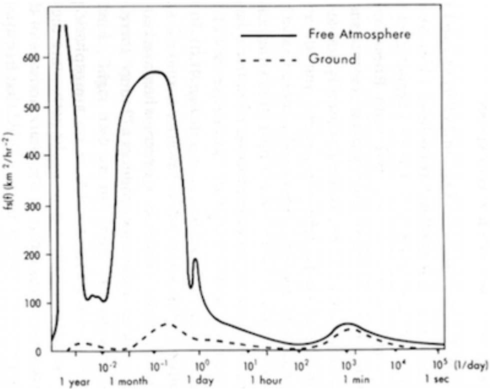
Atmospheric Energy Spectrum



There is another peak around one minute. This appears to be associated with small-scale turbulent motions, including those found in convective storms and the PBL.

There appears to be a 'gap' between several hours to $\sim$ 30 minutes. This 'gap' actually corresponds to the *mesoscale*, the subject of our class.

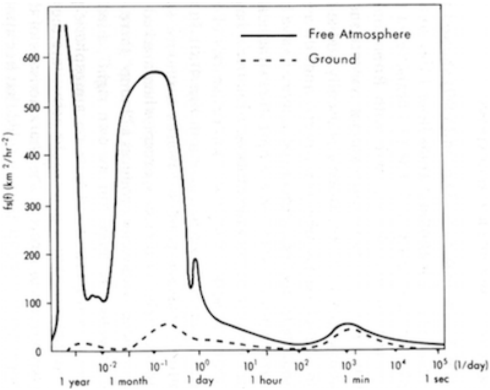
Atmospheric Energy Spectrum



We know that many weather phenomena occur on the *mesoscale*, although they tend to be intermittent in both time and space. The intermittency may be the reason for the 'gap'.

Mesoscale is believed to play an important role in transferring energy from large scales down to the small scales.

Atmospheric Energy Spectrum



While intermittent, we can not do without it. Otherwise, the heat and moisture will accumulate near the ground and we will not be able live at the surface of the earth!

Energy Cascade

- As scales decrease, we see finer and finer structures.
- Many of these structures are due to certain types of instabilities that inherently limit the size and duration of the phenomena.
- Also, there exists the exchange of energy, heat, moisture, and momentum among all scales.

Energy Cascade

- Most of the energy transfer in the atmosphere is downscale starting from differential heating with latitude and land-sea contrast on the planetary scales.
- Energy in the atmosphere can also transfer upscale, however. We call the energy transfer among scales *energy cascade*

Dynamical

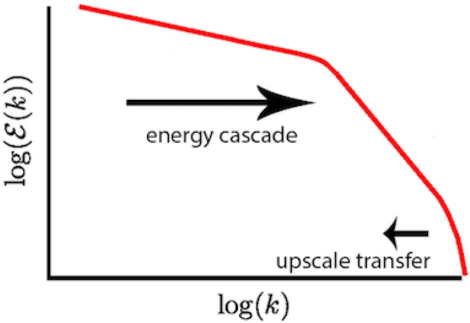


Figure: Energy cascade

Energy Cascade

Example: A thunderstorm feeds off convective instabilities (as measured by CAPE) created by e.g., synoptic-scale cyclones. A thunderstorm can also derive part of its kinetic energy from the mean flow. The thunderstorm in turn can produce tornadoes by concentrating vorticity into small regions. Strong winds in the tornado creates turbulent eddies which then dissipate and eventually turn the kinetic energy into heat. Convective activities can also feed back into the large scale and enhancing synoptic scale cyclones.

Energy Cascade

What does this have to do with the *mesoscale*?

It turns out that the definition of the mesoscale is not easy. Historically, the mesoscale was first introduced by Ligda (1951) in an article reviewing the use of weather radar. It was described as the scale between the visually observable convective storm scale (a few kilometers or less) and the limit of resolvability of a synoptic observation network i.e., it was a scale that could not be observed. The mesoscale was, in early 1950's, anticipated to be observed by weather radars.

The End