GEOGRAPHY 5941
SYNOPTIC ANALYSIS AND WEATHER FORECASTING
AUTUMN SEMESTER 2021

Instructor: Jeff Rogers, Professor Emeritus Office: Derby Hall 1085
Office Hours: just before class, by appointment, or by e-mail: rogers.21@osu.edu
Class times: T, Th 11:10 – 12:30 p.m. DB140
Prerequisites: Geography 5900, Geography 5940, Math 1152, Physics 1251.
Course Website: http://carmen.osu.edu for syllabus, lecture pdf's, assignments & announcements

Course Objectives: The primary objective of this course is to serve as an introduction to the fundamentals of, and techniques involved in, synoptic-scale analysis of winter storms and the forecasting of their weather. Discussion of the fundamentals of weather forecasting includes understanding the physical models available to analyze synoptic-scale weather patterns, evaluation of the physical processes that create temperature change, vertical motions, precipitation, and those processes that lead to cyclones and fronts, causing them to evolve and produce weather. Techniques of synoptic weather analysis revolve around weather maps and methods used to analyze them to predict horizontal and vertical motions and make weather forecasts. Analysis of forecast output will be evaluated to compare precipitation and vertical motion forecasts among different models.

Upon successful completion of the course, students will be able to use synoptic weather charts and numerical forecasting products in order to acquire skills needed to make competitive weather forecasts of temperature, precipitation and other meteorological conditions for 1-2 days in advance. You will have a good understanding of the conceptual models of wave cyclones, including those of their structure and evolution, and you will be able to explain the role of various physical processes, such as PVA, thermal advection, atmospheric stability, and diabatic heating, in the development and evolution of mid-latitude wave cyclones.

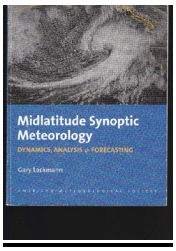
Your total grade (100%) will be determined as follows:
Mid-term exam: 30% Final exam: 30% Assignments: 40%

The assignment grade will include:
1. Take-home assignments.
2. Small point value in-class analyses, assigned and due at the end of each class (no make-ups)
3. Ongoing assignment involving weather forecasts submitted this semester to the University of Oklahoma National Weather Forecast Contest. This will account for 15% of your total grade and therefore about 40% of your assignment grade. We follow Oklahoma's rules (with a couple of exceptions described later) and I grade the results as an assignment. Student grades will range from A to C- (lower with extensive failure-to-participate). The contest/assignment requires electronic submission of a forecast every Monday through Thursday from late September onward by 8:00 p.m. EDST (later 7:00 p.m. EST). Participation is mandatory and will cost $3.

Assignment grading may be optional sometimes, although I will always provide answers and consider using similar assignment concepts on the exams. Assignments must be done

individually unless it is announced that the assignment is a group effort. Proof of a medical problem is necessary to excuse an absence on an exam day.

Important Dates: There is no class on Thursdays October 14 and November 11. The final day of this class is Tuesday December 7. University Official Final Exam dates are December 10-16.



Recommended book:
by Gary Lackmann, not required, but the best synoptic book in decades

Final Examination scheduled: Monday December 13, 2021; Noon - 1:45 p.m. in Derby 140. This final exam date and time may or may not be observed, as described above.

Geog. / Atmos. Sci. 5941: Synoptic Meteorology Course Topics Outline

Lecture #. Title, followed by subsections

1. History of Meteorology & Weather Forecasting
    - Ancient Meteorology
    - Nineteenth Century Meteorology
    - Thermal theory
    - Bergen School: the model, members and legacy
1. Physical Geography factors in No. Am. weather
2. Atmospheric Heat Transfer & the Mean State of the atmosphere
    - Energy types and earth response to solar & IR
        - TPE, ZAPE, EAPE
    - Atmos Heat Transport tropics & mid-Lats
        - APE to Kinetic energy conversion in the tropics & mid-lats
        - Baroclinic instability & mid-latitude heat transfer
    - Mean State of the upper atmosphere: standing waves
        - Standing wave “centers of action” at the surface
3. Air Masses
    - Air Mass types and stability
    - Air Mass Modification
    - Air mass parcel trajectories
3. Upper Air Rossby waves
    - Long Waves, streamlines
    - Short (transient) Waves, stable & unstable
4. Equations of Motion & Gradient wind
    - Wind in Cartesian & Natural Coordinates
    - (Momentum) Equations of motion
    - Gradient and Geostrophic winds
    - Ageostrophic winds and vertical motion
        - Gravity waves and geostrophy
    - Atmospheric scales of motion
        - Synoptic scale and mesoscale-alpha
    - Quasi-geostrophic theory premise and benefits
5. Hypsometric Equation and Thickness

- 3rd eq motion and hydrostatic equilibrium
  - Geopotential and geopotential meters
- Equation of state & virtual temperature
- Hypsometric equation
- Tropospheric thickness
  - Thickness on weather charts
  - Four basic vertical structures

6. Thermal wind and Jet Streams
   - Thermal wind, its vector representation and thermal advection
     - Thermal wind vectors and thermal heat advection
       - Veering, backing winds
   - Baroclinic and Barotropic Atmospheres
   - Jet streams in the upper air westerlies
     - Jet Stream seasonality and geographic variation
     - African easterly jet
     - Climate change and jet streams
   - Forecasting Issues and jet streams
     - Mid-latitude air
     - Do jet streams cause the weather
7. The First Law & Air Temperature Forecasting
   - First Law of Thermodynamics & the Thermodynamic Energy Equation
   - Advection, adiabatic and Diabatic processes in temperature forecasting
   - Modifying MOS temperature forecasts
8. Divergence, Vorticity and Vertical Motions
   - Equation of mass continuity leading to divergence
   - 3 Causes of Ageostrophic motions
     - Friction, curvature, df/dy
   - Ageostrophic motions
   - Relative and Absolute vorticity definitions
   - Vorticity (tendency) equation and relation to divergence
   - CAV trajectories (why Rossby waves exist at all)
   - Rossby wavelength and divergence strength
9. QG Vertical Motions on Synoptic Weather Charts
   - QG Omega equation
   - Analysis of Thermal advection & vertical motion
     - Thermal Advection vectors and TA solenoids
   - Divergence, linking Rossby waves & surface systems
     - Divergence analyses on weather maps
   - Vorticity Advection Analysis on weather charts
     - PVA, NVA, and DPVA
10. QG diagnostics of Synoptic weather systems
    - Pressure Tendency Equation
      - Derivation & interpretation of constituent terms
      - Surface system deepening, weakening, and motion
        - Lists: factors causing pressure falls; vertical motion proxies; divergence
    - QG Omega Equation and DPVA
    - Diagnostics of wx systems with QG Height tendency equation
      - PVA, height falls, vertical motions & adiabatic heating/cooling
        - Surface cyclogenesis in baroclinic zones and PVA
        - Digging, Lifting troughs aloft
        - Differential thermal advection & height tendency
11. Equivalent Barotropic & Baroclinic wx systems
    - Barotropic atmospheres
    - Equivalent Barotropic systems and their wind vectors

- Features: occlusions, cut-off low, polar lows, warm-core lows
  - Blocking high, cut-off Highs, plateau high, warm-core Highs
- Baroclinic atmosphere
  - Baroclinic wx system features
  - Baroclinic Highs

12. Baroclinic Instability & Self-development of cyclones
- Baroclinic Lows: their structure and weather
- Brief overview Norwegian cyclone model
- Baroclinic Instability Process
  - Minimum requirements for Baroclinic Instability
  - Changes in wave tilt, amplitude, length, & jet stream
- Self-development of cyclones
  - Feedback between thermal advection and vorticity advection
  - What stops Instability/self-development?

13. Conservation of potential vorticity
- Static stability and vorticity change
- Lee trough cyclogenesis
- Polar outbreaks and air mass evolution

13. Jet Streaks
- Jet Streak PVA centers and ageostrophic motions
- Jet entrance region dynamics and stability changes
- Satellite observed transverse cloud bands due to jet streaks

14. Diabatic heating and instability in U.S. East Coast & Clipper storms
- Role of vertical lift of stable & unstable air
  - Latent heat release and meteorological bombs
- Role of diabatic heating
- Examples of cyclogenesis over North America
  - East Coast storms
    - Cold air damming & coastal fronts
    - Jet streak interaction in east coast snowstorms
  - Rocky Mtn lee storms, panhandle hook & Alberta Clipper

15. Fronts and Frontal Characteristics
- Introduction, Density differences across fronts
- 7 major Frontal Characteristics
  - Frontal slope importance and how to determine it
- Surface Cold fronts
  - Warm conveyor belt and baroclinic cirrus shield
  - Anafronts and anafrontal weather
- Warm Fronts and mechanisms of warm frontal weather

16. Winter Precipitation, Fog & Wind Forecasting
- Heavy snow forecasting
- Precipitation type (mixed precip.) forecasting
- Fog types & Fog forecasting
- Wind forecasting and causes of turbulence

17. Frontogenesis, overview and math
- Frontal Intensification, thermal wind, and ageostrophic motions
- 5 processes leading to frontogenesis
  - Pressure field deformation zones & frontogenesis
- Horizontal deformation zone cloud bands & winter weather
    - Cold conveyor and the deformation zone under warm fronts

18. Upper and Coastal Fronts and Comma Clouds
- The Dry Conveyor belt and its descending air
- The Cold Front Aloft (CFA) and its descending unstable dry air
  - Baroclinic instability and the dry slot

- The Kata- cold front or split front
- The Elevated Mixed Layer on the southwestern desert plateau
  - EML passage in the U.S. and placement relative to the CFA
- Coastal Fronts and cold air damming
- MesoscaleVorticity Comma clouds and their causes
- Large-scale comma clouds
  - Large-scale commas linked by BCS & DZ cloud bands

19. The Shapiro Keyser Cyclone Model
    - Norwegian cyclone model final stages
      - The seclusion, seclusions over Ohio
      - The cold are warm types occlusions
      - Bergen Cyclone model critical problems
    - The Shapiro-Keyser cyclone component features
      - Frontal fracture and T-bone bent-back warm fronts
      - The warm air seclusion, revisited
      - The Sting Jet and synoptic-scale weather catastrophes
      - Occlusion, revisited
20. The Great Plains (Cyclone) Blizzard
    - Blizzard Climatology
    - Blizzard Development and Features
    - Component features of the Great Plains Cyclone
    - Precipitation Features of the Storm; cyclone variants; how to identify a CFA
21. Heat Waves;
    - Causes of Heat Waves
    - The types and causes of droughts
    - Human and agricultural impacts of heat waves and droughts.