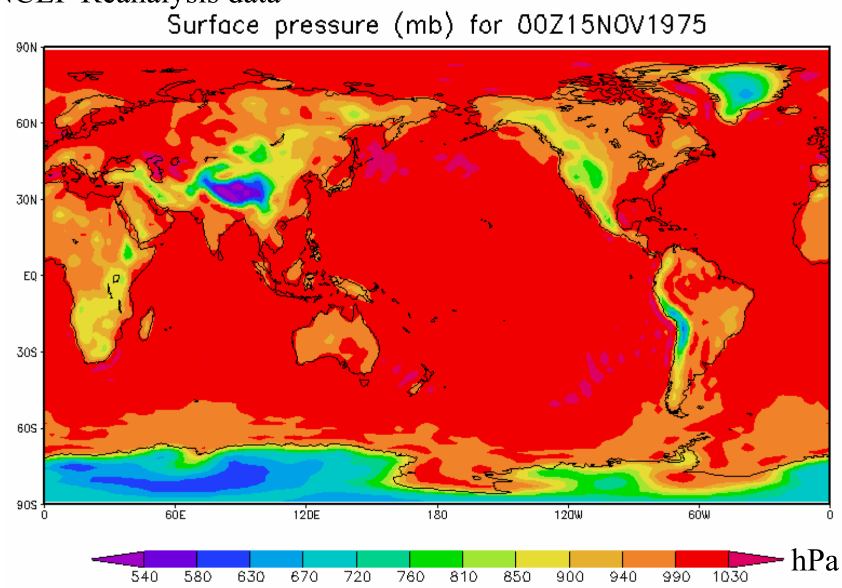
Review of basic eqlationships

Key concepts for today

- Define coordinate systems
- Thermodynamic equation
- Lapse rate - define
- Definition of potential temperature
- Scale analysis – (homework revision, and more next week)
- ***Geostrophic and thermal wind balance***

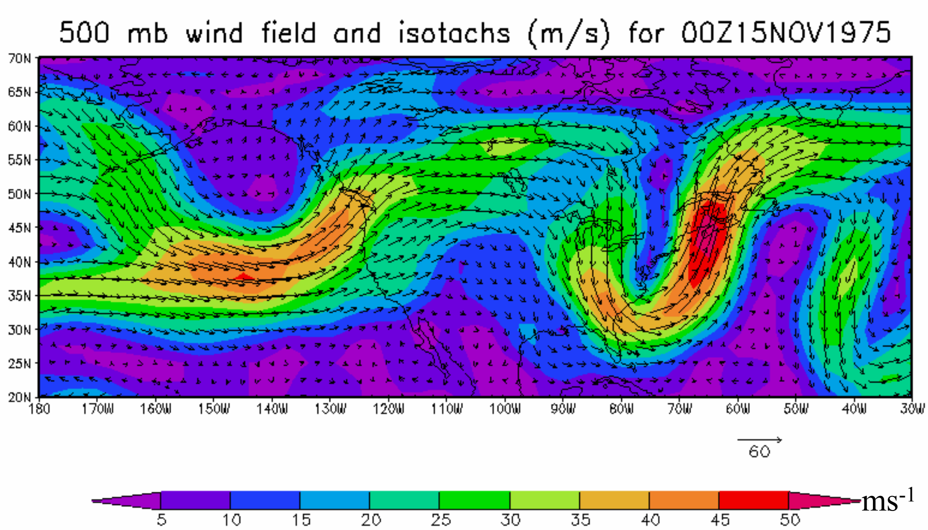
- Keep your eye on the quantity "RT" which we will see again and again
- Notice quantity "g/c_p" which we will see again and again

NCEP Reanalysis data



Christopher Godfrey's NCEP Reanalysis Page
http://weather.ou.edu/~cgodfrey/reanalysis/

NCEP Reanalysis data



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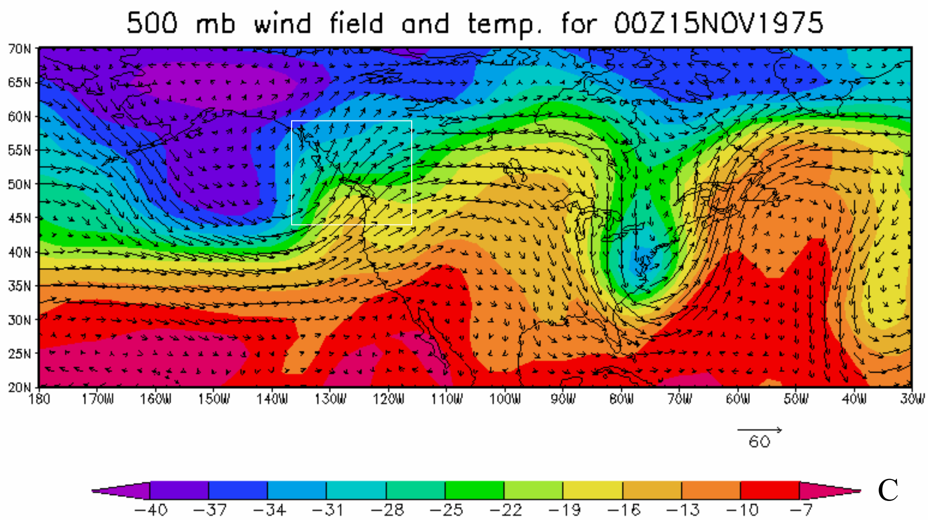
NCEP Reanalysis data

V~50m/s, ∇T~ (30-15)/10deg



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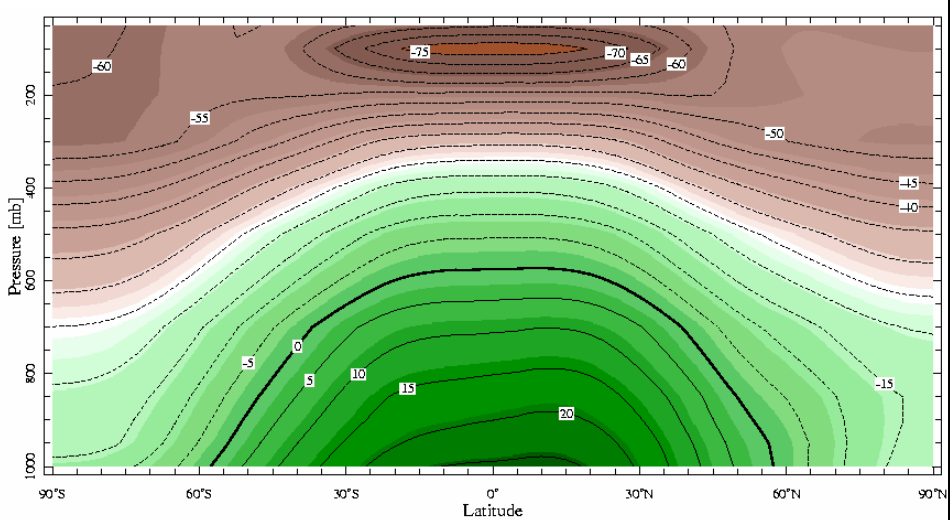
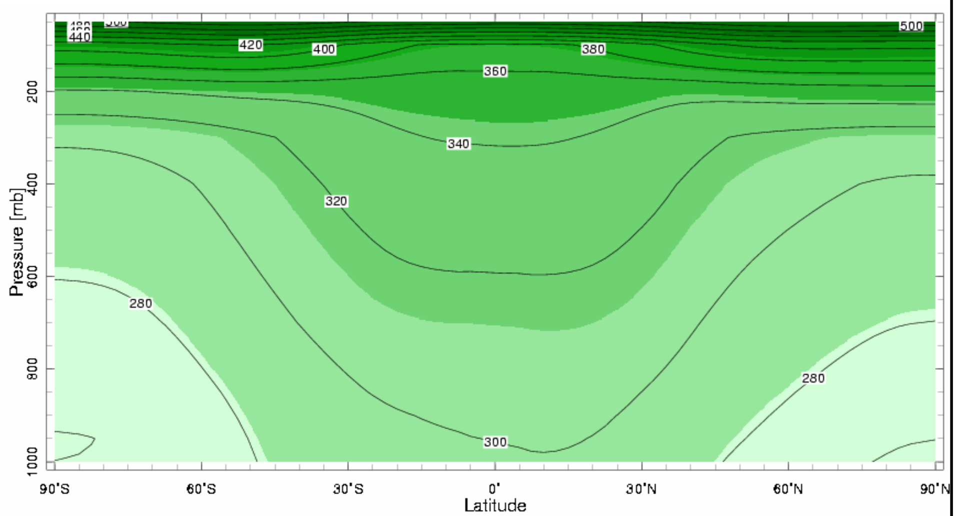
Zonal mean temperature



http://iridl.ldeo.columbia.edu/

Zonal mean potential temperature



http://iridl.ldeo.columbia.edu/

Homework

Three questions

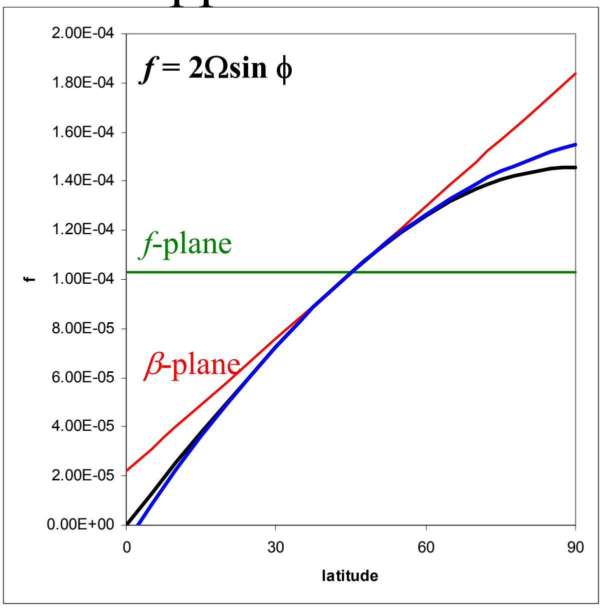
1. Approximating the role of earth's rotation
   (To go over in class)
2. Review of partial derivatives, potential temperature and coordinates
   Especially, review "advection"
3. Review of scale analysis
   (a theme in the first few weeks)

(i.e., read chapter 1, 2 and 3 of the text book)

Homework assignment

- Baseline road in Boulder is exactly 40 N. Perform a Taylor expansion of the Coriolis parameter *f*. Retain the first (linear) term to estimate the value of the Coriolis parameter at 45N based on a reference latitude of 40 N. Determine the size of the error in the approximation (as a percentage).

Approximate forms of *f*



Zeroth order approx (f-plane) is "OK" but not great

First order approx. Is not bad! Works over reasonably large range of latitudes
(say +/- 10 degrees?)

Second order getting quite close, but seems like a lot of work for just the midlatitudes.

We will see the first term ("beta") is often enough.

Homework exercise (for next class)

1. Show that the horizontal pressure gradient force in height coordinates can be rewritten in isentropic coordinates as: $$\frac{1}{\rho}\left(\frac{\partial p}{\partial x}\right)_z = \left(\frac{\partial M}{\partial x}\right)_\theta$$

2. Do a scale analysis to show that an approximate form of the thermodynamic equation tells us that temperature changes are mostly due to imbalance between temperature advection and work done by expansion or compression

3. Read Hadley's paper from 1735, and figure out what physical principle he is relying on.

PDF file of assignment, with details, on class web site.

Atmosphere conserves

- Energy (mechanical, heat, …)
- Mass (of air, and other gases)
- Momentum (and angular momentum)

To describe motion, we can make use of:

- Newton's 2nd law ($\sum F = ma$)
- First Law of Thermodynamics
- We need to account for fact that earth is rotating, spherical and there is gravity

Primitive equations (basic building blocks)

- Momentum (horizontal)
- Hydrostatic (vertical)
- Continuity
- Thermodynamic
- (and equation of state: ideal gas)

$$\frac{du}{dt} = fv - \frac{1}{\rho}\frac{\partial p}{\partial x}$$

$$\frac{dv}{dt} = -fv - \frac{1}{\rho}\frac{\partial p}{\partial y}$$

$$\frac{\partial p}{\partial z} = -\rho g$$

$$\frac{1}{\rho}\frac{d\rho}{dt} = -\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}\right)$$

$$c_p \frac{dT}{dt} - \alpha \frac{dp}{dt} = J$$

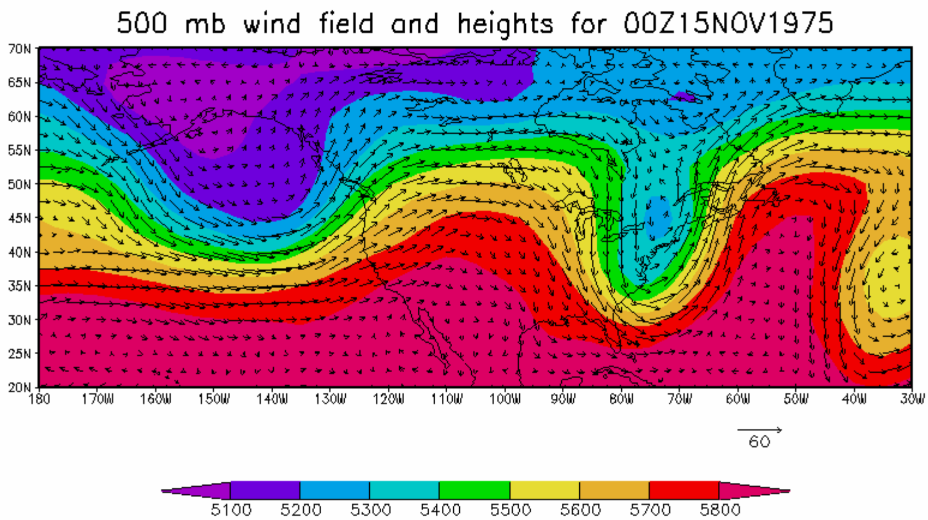
$$p = \rho R T$$

Boundary layers add an extra force for momentum equations, and contributes to J in thermodynamic equation

Otherwise, a closed set of PDEs

See Holton Ch2 for full derivation

NCEP Reanalysis data



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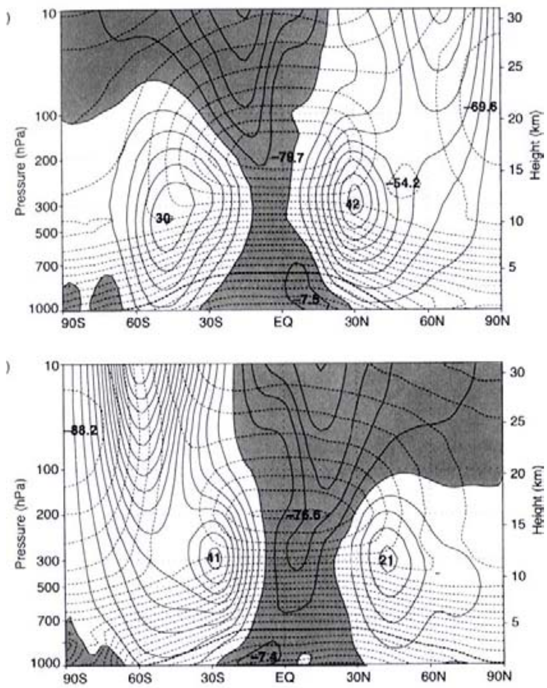
Some assumptions

- Atmosphere is thin so distance from center is about the same as the earths radius.
- Gravity is constant
- Given these, also neglect horizontal component of rotation ensures momentum equations conserve momentum.

- *These are called the "traditional approximation"*



Westerly wind and temperature

Temperature and wind field related
(thermal wind balance)

i.e., $\partial u/\partial p \sim \partial T/\partial y$

- Knowing temperature gradient, estimate jet.
- Knowing jet, estimate gradient.