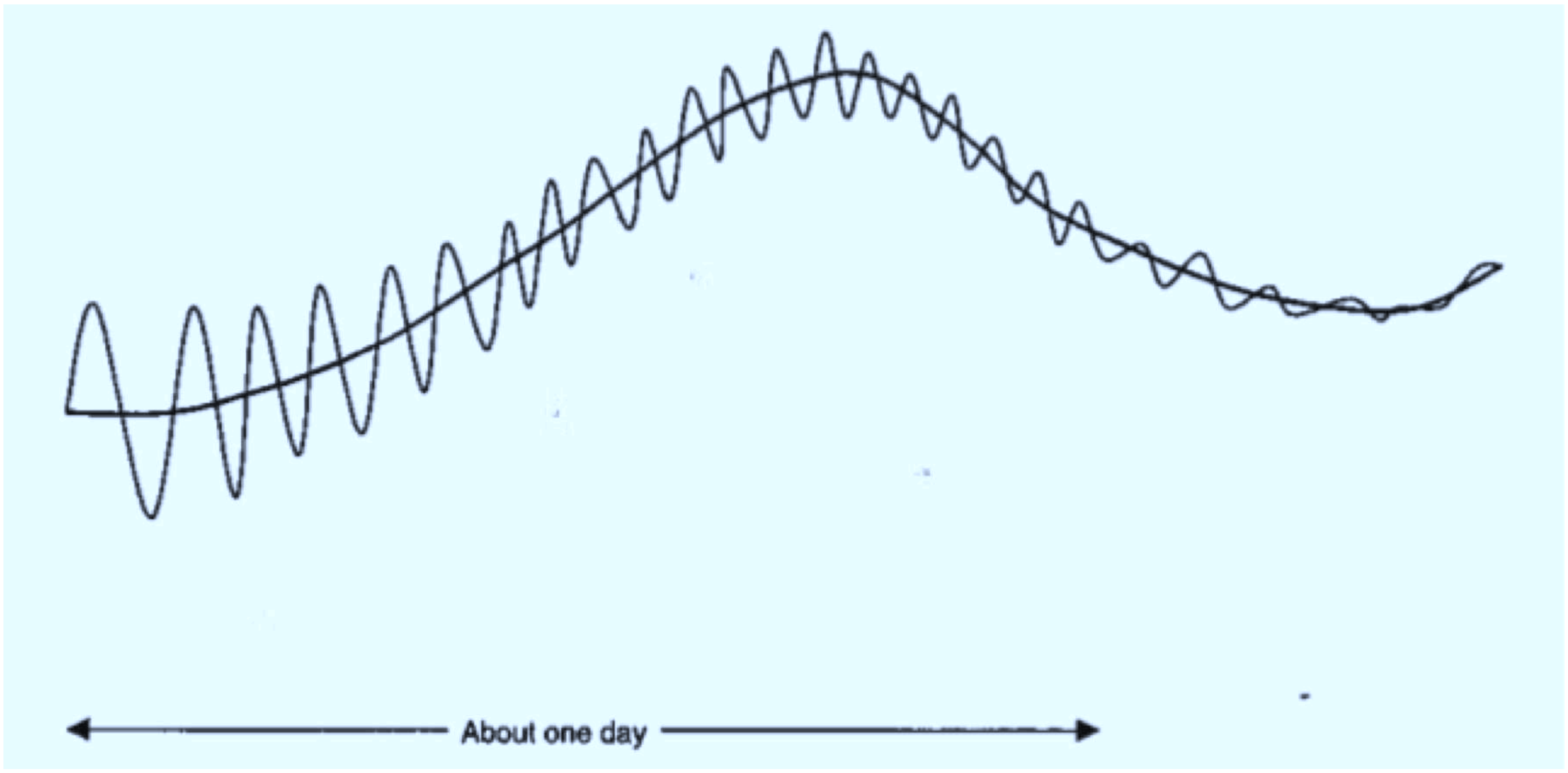
Slow weather-related variations with high-frequency sound or gravity wave superimposed. The derivative of the combination varies wildly and would require small time steps Δt to resolve



p 6 of handout on weather prediction

The Community Earth System Model (CESM), developed by the National Center for Atmospheric Research.

http://www.cesm.ucar.edu/

Includes:

- Community Atmosphere Model (CAM)
- Parallel Ocean Model (POP)
- Sea Ice Model (CICE)
- Community Land Model (CLM)
- Flux Coupler (CPL)

Most atmosphere models use terrain following coordinates called “sigma coordinates” near the surface

Pure pressure Region

Blend

$\sigma = P/P_s$
(sigma = pressure/ surface pressure)

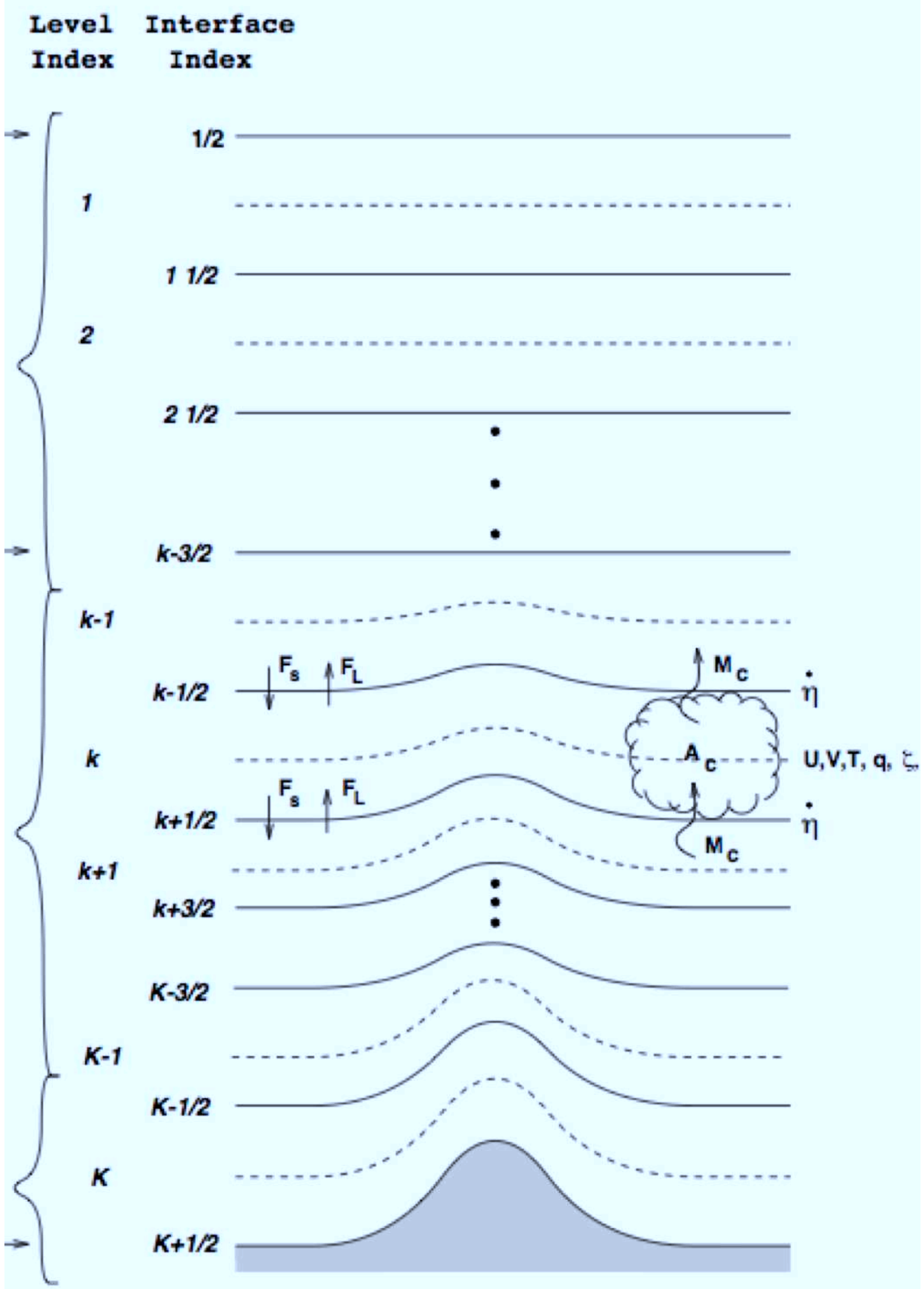


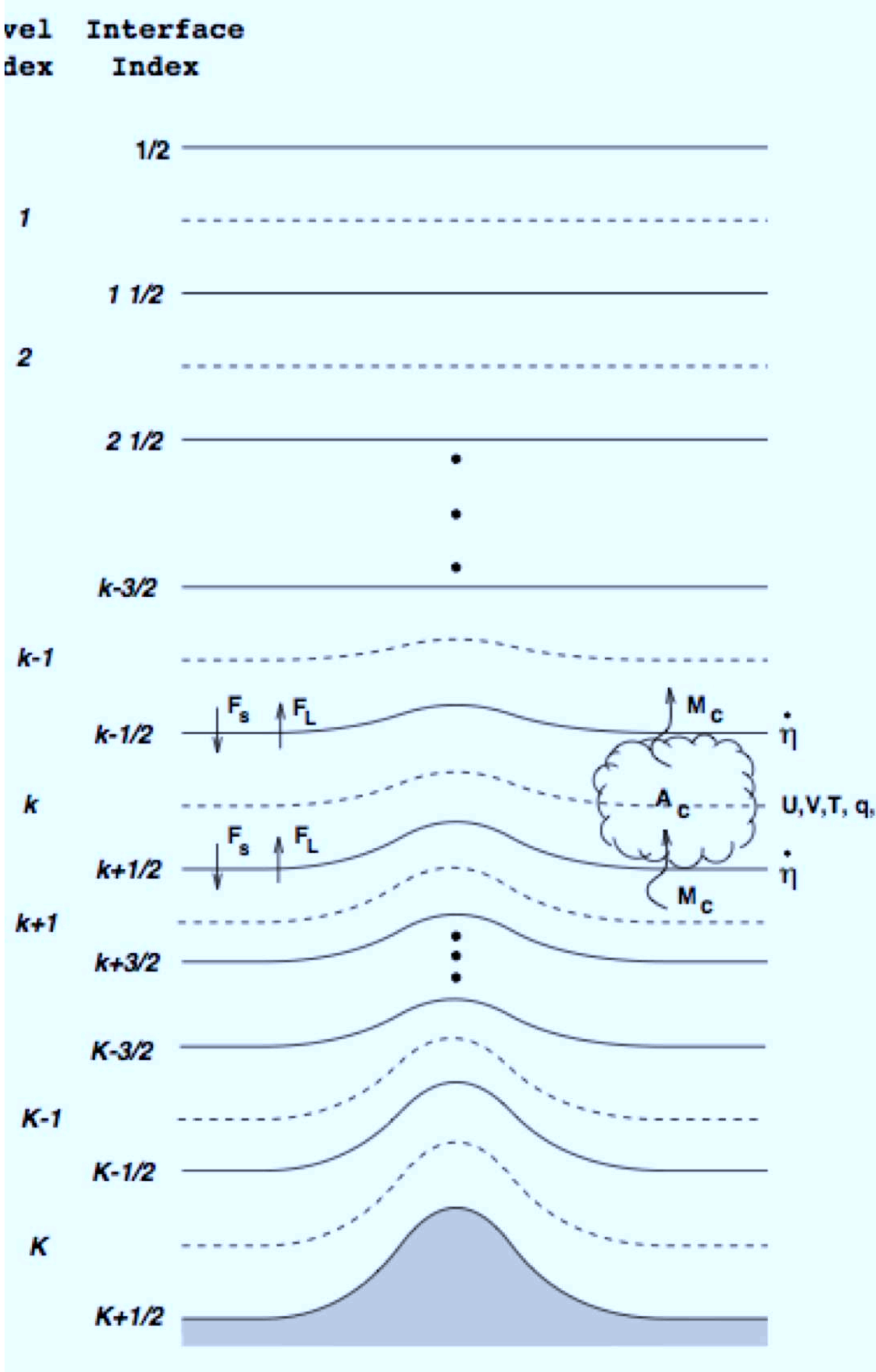
Figure 3.1: Vertical level structure of CAM 4.0

NOTICE NUMBERING OF LAYERS STARTS FROM THE TOP

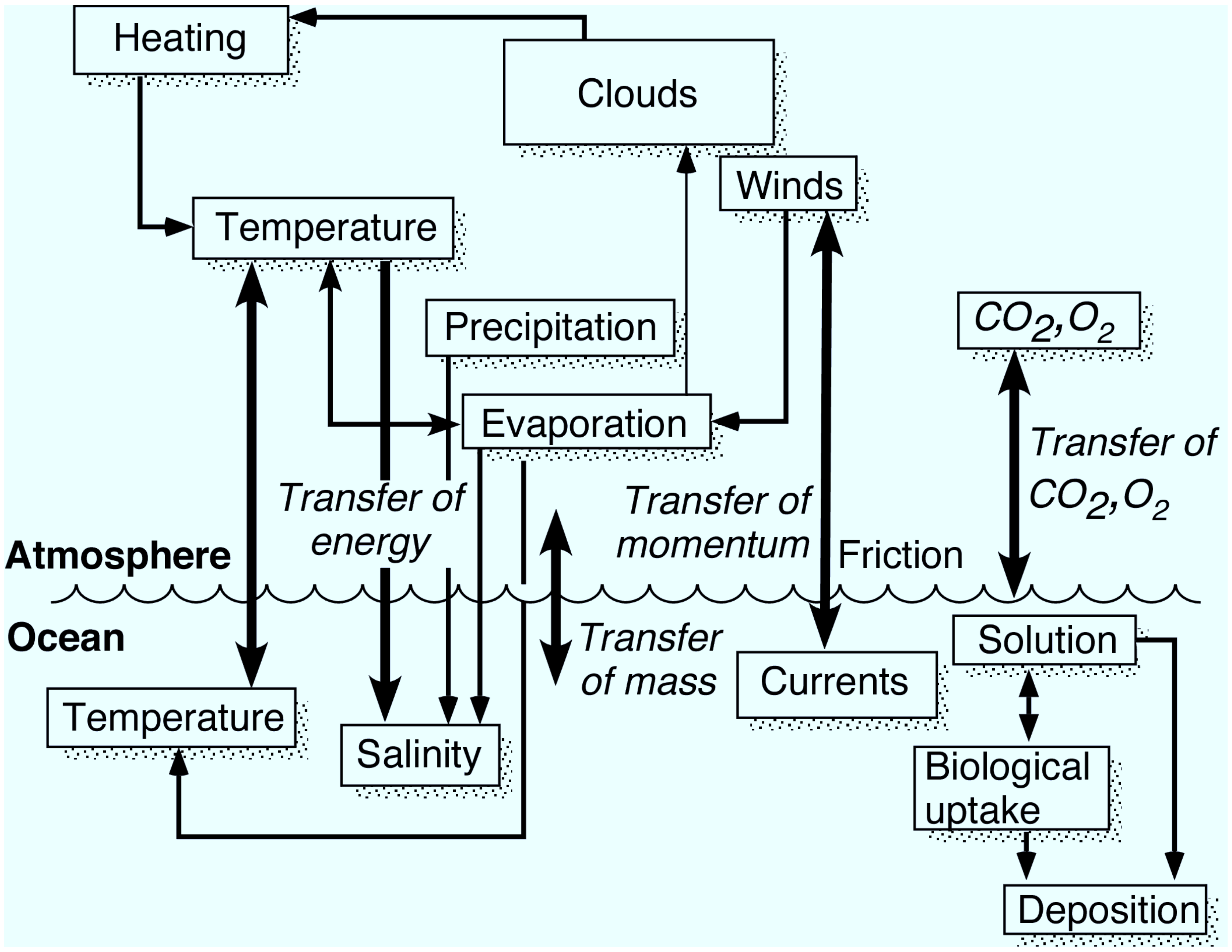
In addition there are “half” layers that are used for computing fluxes of heat and moisture into a layer.

This is known as a “staggered” grid

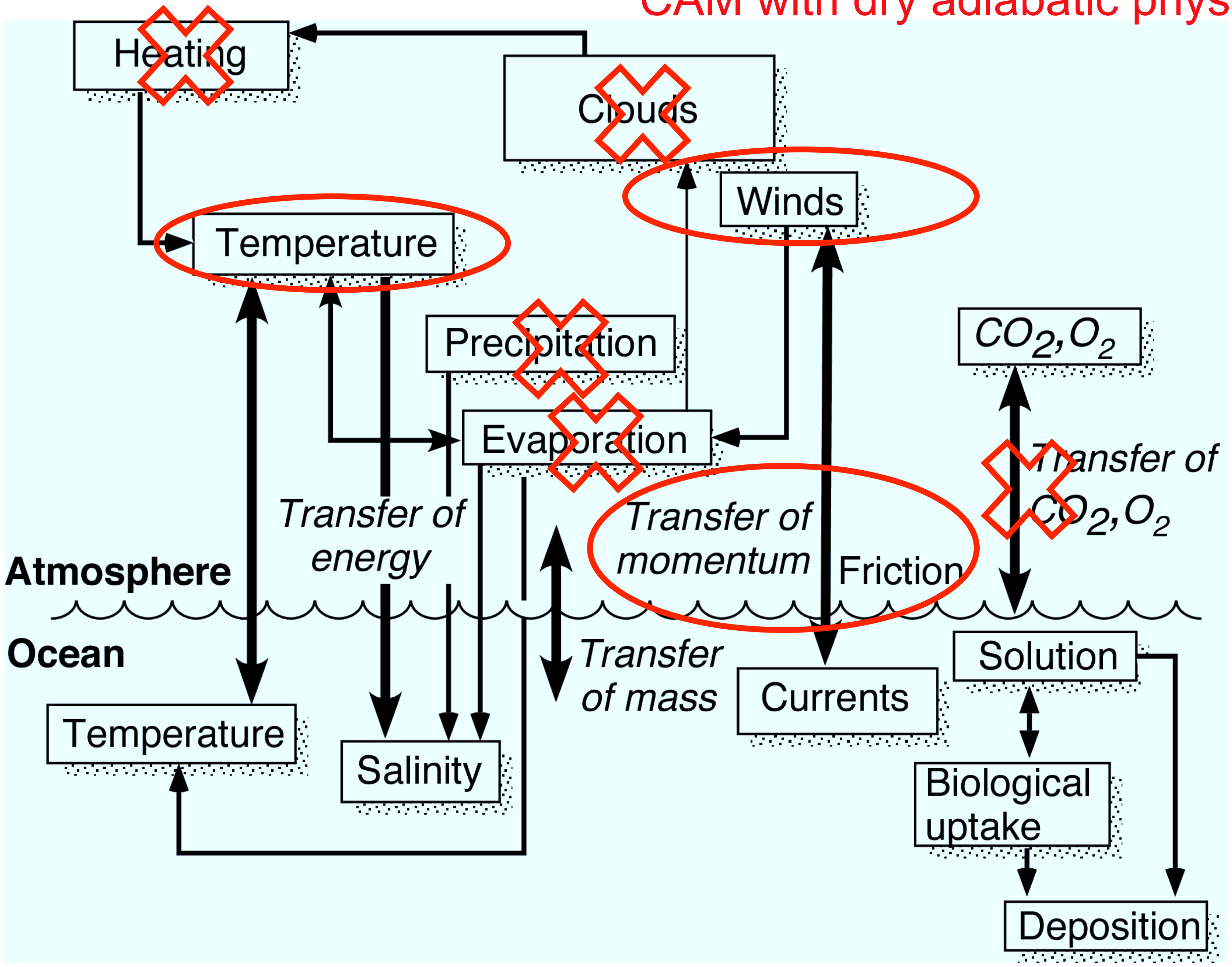
(The horizontal grid is also staggered)



re 3.1: Vertical level structure of CAM 4.0


Heating
Clouds
Winds
Temperature
Precipitation
Evaporation
CO_2,O_2
Transfer of CO_2,O_2
Transfer of energy
Transfer of momentum
Friction
Atmosphere
Ocean
Transfer of mass
Solution
Currents
Temperature
Salinity
Biological uptake
Deposition

CAM with dry adiabatic physics



CAM with dry adiabatic physics

Still based on conservation of momentum, heat, mass and gas law, but without diabatic heating in thermo eq. and no cloud equations

Momentum Eq in latitude and longitude

acceleration on Earth following parcel = Coriolis force + pressure gradient force + friction

Momentum Eq in vertical or “hydrostatic balance” (vertical acceleration is neglected)

pressure gradient force = gravity

Thermodynamic Energy Eq

temperature rate of change following parcel = adiabatic heating/cooling from vertical motion

Continuity Eq (mass conservation)

convergence of horizontal flow = vertical gradient accounting for compressibility of atmosphere

Initial Conditions (ICs) – need these to start the model

$T(\theta,\phi,z)$ 3 Dimensional Atmospheric Temperature

$\mathbf{V}(\theta,\phi,z)$ 2 Dimensional wind

$P_S(\theta,\phi)$ Surface Pressure

(the following are not needed for a dry atmosphere)
$q(\theta,\phi,z)$ 3 Dimensional water vapor
$C_W(\theta,\phi,z)$ 3 Dimensional cloud water
$C_I(\theta,\phi,z)$ 3 Dimensional cloud ice

Boundary Conditions (BCs)

$\Phi_S(\theta,\phi)$ Surface Geopotential, which is equal to topography height times gravity (units are m^2/s^2)

Other "Boundary" Conditions for non-dry atmosphere

$T_S(\theta,\phi,t)$ Surface Temperature

$F_{Solar}(\theta,\phi,t)$ Solar Flux at top of atmosphere (TOA)

$F_x(\theta,\phi,t)$ Latent, sensible, net radiation fluxes at surface

$MCO_2(t)$ mixing ratio (mol of CO2 per mol of air)

$MO_3(t)$ mixing ratio

other gas mixing ratios

aerosol mixing ratios

These are BCs because they are "external" to the atmosphere model

ICs defined in the initial conditions file for HW2: cami_baroclinic_wave_0.9x1.25_L26_c101231.nc

variable name in file is far left, variable symbol is next

T	$T(\theta,\phi,z)$	3 Dimensional Atmospheric Temperature
US,VS	$\mathbf{V}(\theta,\phi,z)$	2 Dimensional wind (S=on staggered grid)
PS	$P_S(\theta,\phi)$	Surface Pressure

I included the boundary conditions in this file for convenience

PHIS	$\Phi_S(\theta,\phi)$	Surface geopotential (g x h)

Note the extension “nc”
cami_baroclinic_wave_0.9x1.25_L26_c101231.nc

This stands for NetCDF

Binary (can’t bring it into a text editor)

Need special libraries to read in matlab

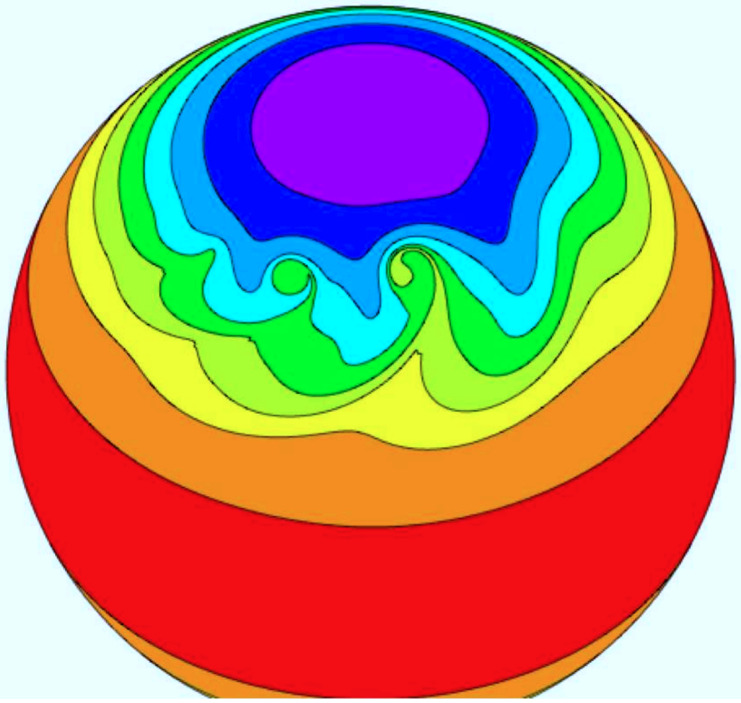
“self describing” because they have “meta data”

You can convert to text on unix command line with “ncdump” command. Beware it will scroll the whole file to screen too fast to see and it could take hours. Kill the window if this happens. Use the “-h” flag to see just the “header” or meta-data.

```
% ncdump -h /home/disk/eos11/bitz/inputdata/atm/cam/inic/fv/

cami_baroclinic_wave_0.9x1.25_L26_c101231.nc
netcdf cami_baroclinic_wave_0.9x1.25_L26_c101231 {
dimensions:
        time = UNLIMITED ; // (1 currently)
        lat = 192 ;
        lon = 288 ;
        lev = 26 ;
        slon = 288 ;
        ilev = 27 ;
        slat = 191 ;
variables:

        etc.

        double US(time, lev, slat, lon) ;
        double T(time, lev, lat, lon) ;
        double VS(time, lev, lat, slon) ;

        etc.
```

Idea for HW2 from Jablonowski and Williamsom, 2006 NCAR Tech Note title:

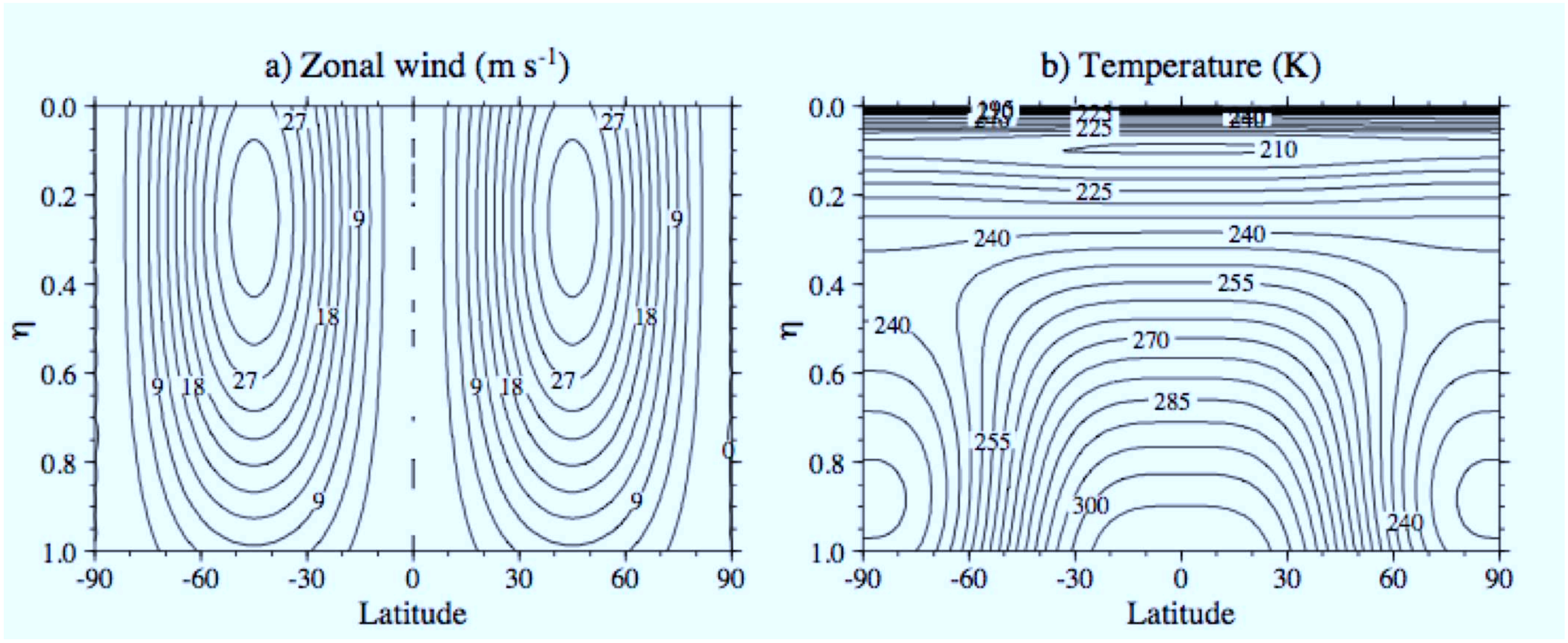
A Baroclinic Wave Test Case for Dynamical Cores of General Circulation Models: Model Intercomparisons



posted on class web

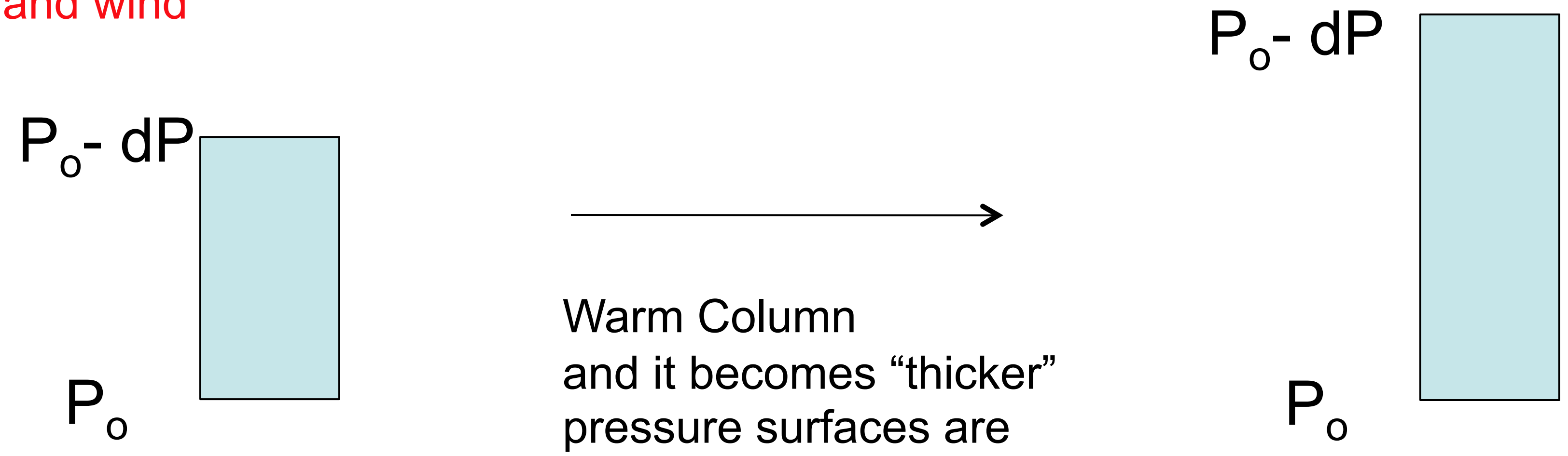
ICs are from Jablonowski and Williamsom, 2006

Perfect balance of forces in momentum equation (geostrophic balance)
and
Temperature and winds are in balance (thermal wind balance)
-> Hence, the atmosphere is in steady state!



η (eta) times surface pressure = pressure

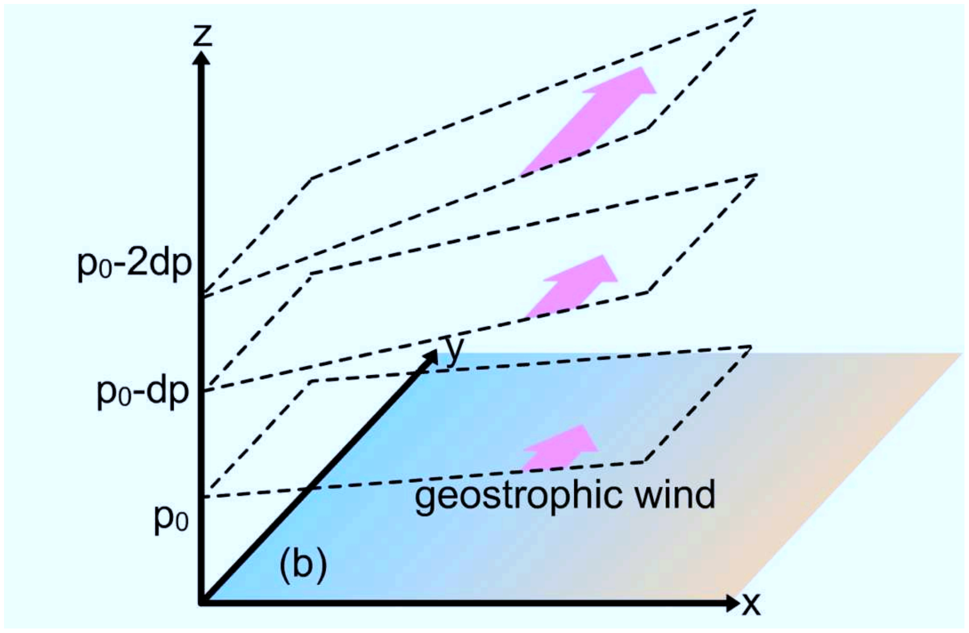
Thermal wind balance is a relationship between T and wind



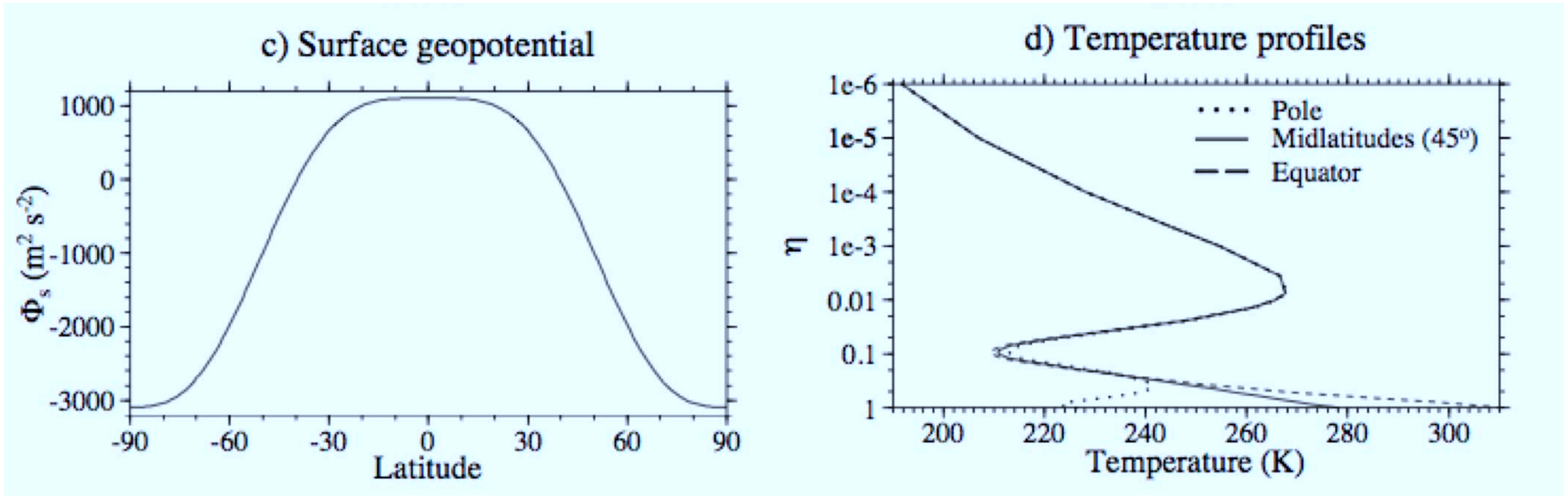
Warm Column
and it becomes “thicker”
pressure surfaces are
further apart

The colors on the base
extend through the atmosphere

Pressure gradient increases with height due to integrated temperature change below it. Thus winds increase with height.



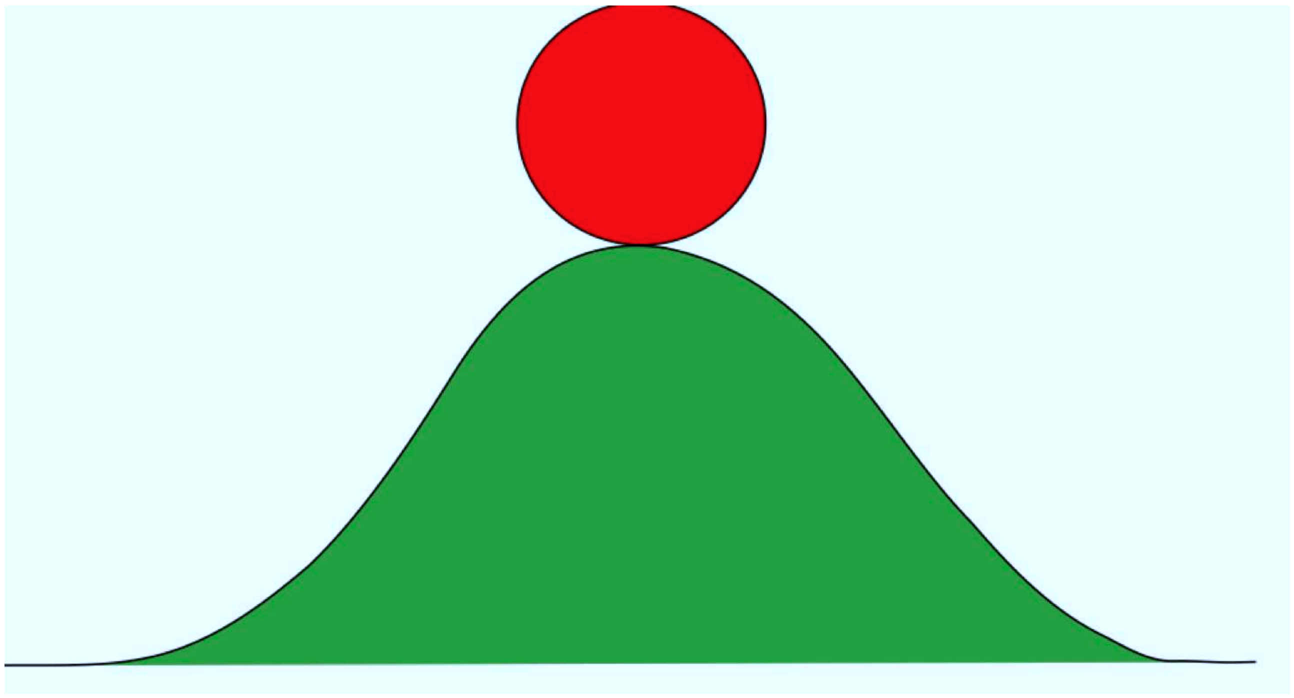
More on ICs


c) Surface geopotential
Φ_s (m^2 s^{-2})
1000
0
-1000
-2000
-3000
-90
-60
-30
0
30
60
90
Latitude
d) Temperature profiles
η
1e-6
1e-5
1e-4
1e-3
0.01
0.1
1
200
220
240
260
280
300
Temperature (K)
Pole
Midlatitudes (45°)
Equator

This is a steady state but an unstable one

It is “baroclinically” unstable

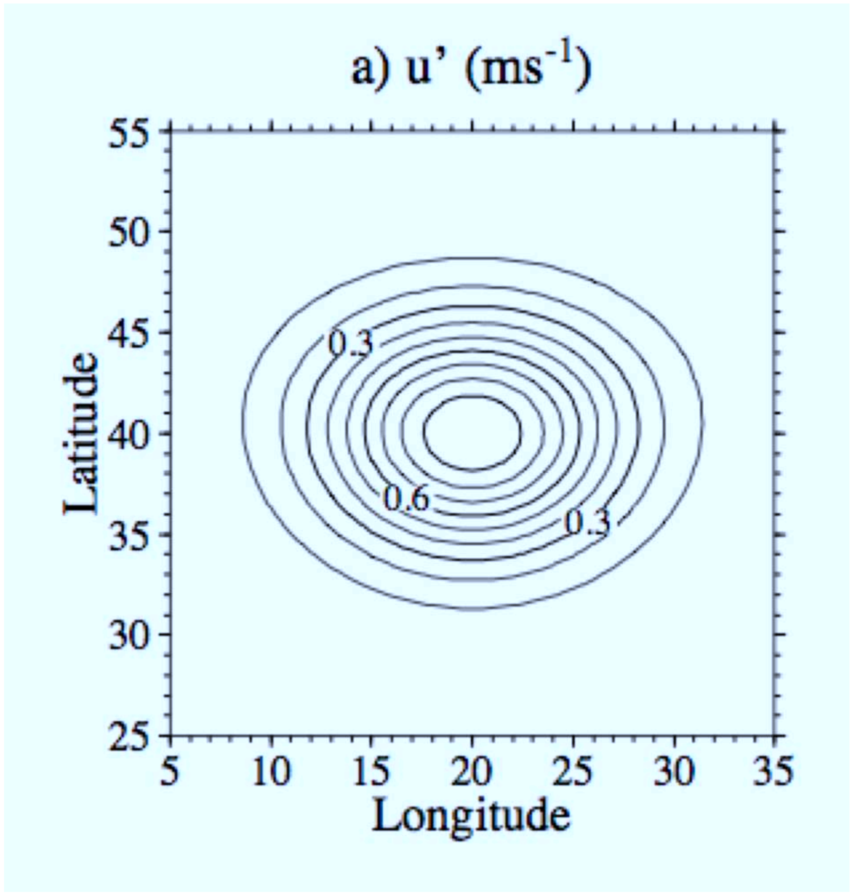
A small perturbation will grow (that is what unstable means). Analogous to:



The instability does not grow spontaneously in CAM (I tried it)

It does grow with this perturbation, which is not in geostrophic or thermal wind balance:

Without any perturbation, one might imagine numerical roundoff errors in the model would be sufficient to cause growth. But they did not. Hence it is possible the hill top in that last picture is very broad or possibly there is a small dimple (owing to numerics) that holds the ball on top for tiny perturbations. I do not know yet how big the perturbation must be to cause growth.



The Exercise on Friday will have you run one script on the unix command line.

It will compile the model (~3 min)

Create some files called “namelists” that feed the model information like run length and timestep (stuff you can change without recompiling)

Create a “run” script that you submit to run the model. You will be instructed to submit it using the “queue” system

It will run in 40 minutes (from the time it starts)