End of Lecture 3:

** hand written notes: thetae conservation is moist static energy conservation as well.

Deep convection: Common in tropics, but not only. Deep Cb clouds.

T16: Photo of Cu field

T17: Photo of Cu field

Tops reach tropopause and form anvils. $w \approx O(10m/sec)$, $\Delta T \approx O(1K)$, $H \approx O(10^4 W)$, but these numbers are for a single cloud and they are intermittent in space and time. Main form of vertical heat transport in tropics.

Unlike for Cu clouds, there is very little mixing of the rising parcels with the surroundings, and the vertical velocity anomalies are much stronger than the horizontal ones. Thus, $\Delta KE/\rho \approx 1/2w^2 = \Delta PE/\rho \approx g\ \Delta T/T\ \Delta z$ and $w \approx (2g\Delta T/T\ \Delta z)^{1/2} \approx 26m/sec$ for $\Delta T=1K$ and $\Delta z=10km$. This value is typical of observed. This is enough to suspend hail stones till they grow to large sizes.

This estimate is a gross estimate of a quantity called CAPE:

**se hand written notes.

The dynamics are also affected by the background flow, since these clouds are so deep. **T18: Schematic of Cu flow.**

Where does convection occur?

Deep convection is more common in tropical regions of warm SST, and less over the subtropical deserts. Can view it by looking at maps of OLR. LR depends on temperature.

T19: OLR map polar regions and a few tropical spots have similar low values. Low polar clear- low T, but why low tropical OLR? Shows T or emitting layer, which is at cloud top. The higher the cloud top the lower the OLR.

T20: Schematic of OLR

Convection forms when surface is heated afternoon convection, common In the tropics. Also- when upper air is cooled, as in cold front in midlatitudes.

Radiative convective equilibrium: observed to hold everywhere. In tropics it is clear, in midlatitudes less clear that convection sets vertical laps rate.

HW: Marshall and Plumb chapter 4 ex: 1,2,7,10,12

Lecture 4:

T1: sun's heating of tilted earth: cause of season's. length of day affects the amount of radiation hitting each latitude over a day- max at summer pole in solstice.

T2: radiation distribution

T3: Earth's orbit NH summer when farthest, and NH winter when closest. But only tiny effect cause orbit is almost circular. Exaggerated in schematic. Mention Milankovich cycles as source of climate changes on very long time scales.

T4: latitudinal radiation budget IR flatter- implied heat flux

T5: latitudinal heat flux from radiation budget. Seemless heat flux- interesting htat a few processes do it between equator and pole but it's a total smooth function. Has to be.

T6-10: seasonal maps of radiation balance warmest

Albedo: Global average ~0.3. Reflects the properties of the surface and the cloud distribution and brightness. Over the oceans albedo is a function of the Sun's zenith angle (deviation from the perpendicular) - the larger the angle the larger is the albedo. Large polar values : low-clouds+ice+snowcover and the low angle of the Sun over the oceans. High over desert and low in forrest regions (but those often have deep clouds). Tropical albedo follows dep convection structure.

T11: Annual mean T lat-height map warmest at poles, decreases with height in tps. Pole-equator difference of around 40 degrees C.

[3]The zonal average of a quantity X is conventionally written $\overline{X}$ (with an overbar) where:

$$\overline{X}(\varphi, z) = \frac{1}{2\pi}\int_0^{2\pi} X(\lambda, \varphi, z)\, d\lambda$$

(λ, φ) being (longitude, latitude).

T12: annual, DJF and JJA potential temperature. Increases with height and decreases with latitude. More bunched up in strat

T13: Annual mean equivalent potential temperature roughly constant in tropics.

T14: climatological solstice temperature. Note equatorial tpp cold, strat summer pole warmest (Radiative equilibrium). Note mesosphere – circulation. Come to MAD… tpp break – easy mixing since horizontal isentropes cross it. Jet stream location.

T15: geometry of pressure surface low pressure region is also a low height

T16: Jan mean 500mb pole is low pressure. Due to cold

Recall hypsometric relation:

$z_\phi(p_2) - z_\phi(p_1) = \dfrac{R}{g_o}\displaystyle\int_{p_2}^{p_1} T(p)\frac{dp}{p}$ so can estimate height of 500mb surface with z(1000mb)=0.

T17: annual mean geopotential height anomaly (from horizontal mean- removes increase with height) highest in tropical region.

To estimate slope of geopotential height surface: if T varies only horizontally, not vertically:

$$\Delta z_{\text{cold}}^{\text{warm}} = \frac{R\Delta T_{\text{cold}}^{\text{warm}}}{g}\ln\left(\frac{p_s}{p}\right),$$

For T diff of 40C, get Zdiff of 811m, which is similar to T15-T16

T18: Thermal wind schematic warmer region has wider layers, and slope has to increase with height- zonal wind increases with height

T19: schematic Hadley's speculated global mean meridional circulation: The

T20: zonal mean wind: subtropical winter jet and midlatitude summe jet which his weaker.

T21: zonal mean U and T- shows thermal wind balance

T22: observed snapshot of daily 300 mb U Quite noisy though jet stream evident.

T23: observed Jan and July mean 300 mb U much smoothers. Zonal asymmetries in NH.

T24: observed MMC Hadely, and Ferrel cells.
T25: observed Jan and July mean surface U Jet evident but much weaker at surface than higher up. Also meridional flow strong- trade winds. Fits obs but not Hadley's idealized picture.

T26: schematic of global circulation: The atmosphere is warmer in the equatorial belt than over the polar caps. These horizontal temperature gradients induce, by hydrostatic balance, a horizontal pressure gradient force ‘‘P’’ that drive rings of air poleward. Conservation of angular momentum induces the rings to accelerate eastwards until Coriolis forces acting on them, ‘‘C,’’ are sufficient to balance the pressure gradient force ‘‘P
T27: June 21 2003 500 mb geopotential height. Eddies, but overall pressure lower at pole
T28: annual zonal mean specific humidity: Largest at equatorial surface, decreases upwards and polewards
T29: annual zonal mean saturation specific humidity: Similar to specific humidity suggesting T controls.
T30: annual zonal mean relative humidity: Large but not 100%- around 70-80% at surface at all lats, with min in subtropics in regions of strongest descent ,and at poles. But decreases with height. Why? Because of descent regions which get included in average. Ascent dries by precipitation so above have less moisture to be averaged over entire plane- upward and downward regions. Rain effect on decrease in moisture stronger than the decrease in T for RH.
T31: schematic of convection drying effect.