ATM 651

- Statistical dynamics
  - Maximum Covariance "modes"
    - Rotated
    - Orthogonal
  - Impacts that integrate
    - Land: Precip, Evap, hydrology
    - Ocean
      - Wind stress
      - Freshwater flux
  - Zonal mean and eddies
    - Momentum flux [u*v*] drives
    - Zonal PGF vanishes
  - Time mean and anomalies (or 'transients')
    - Anomaly covariance [w'T'] is eddy or transient heat flux
    - partial_t = conv(flux) or =0 if you assume balance
- Statistics
  - Joint PDFs
    - Mutual information
    - Covariances
    - Marginal, conditional PDFs
  - PDF /histogram
    - Shannon information
    - Moments
      - Skewness
      - variance (stdev is sqrt)
      - Mean
- Phenomena
  - Features (coherent structures)
    - intensity
    - durations in time
    - scales in space
      - convective
      - mesoscale
      - frontal
      - synoptic
      - planetary
    - boundaries? "systems"?
  - Maps/grids (MERRA2)
    - Data collections: hourly, monthly, diurnal. 3D https://goldsmr5.gesdisc.eosdis.nasa.gov/dods/, 2D https://goldsmr4.gesdisc.eosdis.nasa.gov/dods/
      - State variables
      - Tendencies
      - Integrated Budgets
      - Statistics
        - monthly or daily surface impacts https://goldsmr4.gesdisc.eosdis.nasa.gov/dods/M2SDNXSLV.info
        - EXTREMES: https://disc.gsfc.nasa.gov/datasets/M2SMNXEDI_1/summary , https://goldsmr4.gesdisc.eosdis.nasa.gov/dods/M2SMNXEDI
    - Documentation https://gmao.gsfc.nasa.gov/pubs/docs/Bosilovich785.pdf
  - Pure obs (satellite, radar, in situ)
    - spectral imagery interpretations
    - clouds/particles easiest to see
    - hyperlocal values
- Model Outputs
  - Forecasts/ hindcasts/ reforecasts
  - (Re)Analyses (data assimilation)
  - Simulations
- Numerical models: see MindMap Atmosphere.mm
  - Regional (w/ neither virtue!)
  - Globe-covering
    - physics
      - water phase changes
      - subgrid turbulence
      - surface interaction
      - radiation
        - longwave
        - shortwave
    - dynamics
      - spectral
      - gridpoint
  - Process-resolving (LES, CRM)
    - microphysics
    - subgrid turbulence
    - resolution
    - boundary conditions
- THE GAP (explicit models help)
- Logic: stability, waves, balance maintenance
  - Ageostrophic in QG theory
  - Momentum (vort) instabilities
  - Stratification and lifted-parcel instability
    - Conserved moist variable (h, theta-e) lifted from PBL
    - Comparison to environment's saturated value of that indicates sign of T_parcel - T_env
    - For linearly-mixing variable, entrainment pulls parcel toward env as it rises
- Conservation laws d/dt = 0 + sources-sinks ("tendencies")
  - PV: conserved even w/ hor.div.
    - Huge in stratosphere (due to static stability part)
    - Mainly matters in strato-tropo sphere interactions
    - Source and sink terms:
1. curl(Friction).grad(theta)
2. 3Dvor.d(heating)/dz
      - Curl friction of course
      - Heating acts as a **downward flux** of PV, like how an upper cool-core cyclone spawns or strengthens a surface of warm-core cyclone with latent heat release. "PV substance" is globally conserved!
  - Momentum
    - Horizontal
      - Cartesian tangent plane
        - vort = v_y - u_x, eliminates PGF
          - Absolute vort cons: Ro waves
            - Phase west, energy east, equal
            - Goes as wavelength squared
            - Stationary: roughly continent scale wavelength
          - Relative vort cons: vortex interactions, V goes as 1/r
        - aGeostrophic (or non-gradient) wind
          - Contains almost all of the divergent wind component
            - Ooze to maintain balance (QG omega equation)
              - vorticity advection above level —> ascent at level
              - warm advection —> ascent
            - gravity waves
            - convection
            - Frictional down-gradient flow
          - Governs change: dV/dt = fV_a x k
        - "Gradient wind": along isobars (Thereby almost no divergence)
          - Vertical deriv. of geostrophic/gradient balance: "Thermal Wind" VT: a shear (wind difference with height) directed along isotherms
            - Vg turns with height: implies warm/cold T advection
            - Cold or warm core vortices (in lower troposphere)
              - cyclones
              - anticyclones
          - Gradient: neglect partial_t(V)
          - Geostrophic: neglect d/dt(V)
      - Spherical
    - Vertical in atm.
      - hydrostatic approx.
        - Hypsometric equation relates thickness to T, p
        - Use hyd. p as coordinate
      - Full dw/dt equation
        - Thermal buoyancy
        - Dynamic pressure
    - 3D in atm.
      - KE: V dot dV/dt eliminates Cor
        - Source: V.PGF
        - Transport
          - Advective
          - Nonadvective
        - Sink: V.Fri
      - Curl(V): turbulence, tornadoes
    - solutions (e.g. instabilities)
      - counterweight: stability (KH)
      - internal vorticity line or sheet rolls up into balls, rolls
    - Navier-Stokes: Source = Force
      - PGF: cop enforcing mass continuity
        - Hydrostatic: fights gravity, prevents collapse on sfc
        - Geostrophic: fights divergence of Coriolis force
        - Dynamic: fights divergence of (advection of momentum)
      - Coriolis if coords rotating
      - Gravity
  - Thermo
    - Stability & convection logic
      - moist conserved plots (logical!)
      - skew-T, log-p plots (trad)
      - shear & tornadoes filigree
    - Moist conserved
      - MSE: h = s + Lq_v dh/dt = Qrad + Qmix
      - theta-e ('equivalent') or theta-w ('wet bulb') potential temp.
      - Liquid water SE: s - Lq_liq
    - Dry conserved
      - hydrostatic z(p): static energies
        - s = C_p T + gz

ds/dt = 0
+ L dq/dt + Qrad + Qmix
        - Enthalpy (heat content): C_p T
      - Divide by T: entropy S, or potential temperatures (theta)
        - theta = T(1000 hPa /p)^(R/C_p)
    - Temperature
      - Has adiabatic compression term, clearer to convert from conserved vars as needed
      - needed for density (thickness,buoyancy)
- Transport tendencies in d/dt
  - Advection -V.del( )
    - separate: vertical, horizontal,…
    - (equals LS flux convergence, in 3D)
  - Convergence of flux
    - flux by Large-Scale (LS) flow
    - flux by small scales (down gradient: diffusion, viscosity)
    - Area average = flux into perimeter, *zero for globe*
- Continuity of mass in space-time
  - rho_t = -div(rho*V)
  - rho_t partial derivative =0 in Anelastic and Boussinesq sets
- Vector calculus
  - 2D: area <--> perimeter
    - Circulation theorem
    - Divergence theorem
  - 3D Del operator
    - Curl of vector field: only in 3D
    - Divergence of vector field
    - Gradient of scalar field
  - *fields* of scalars and vectors
  - Vectors: mag (w/units),direction
- Partial and total derivatives
  - total d/dt in moving coordinate
  - partials of T(x,y,z,t), T(x,y,p,t)
- Quantities and Units
  - Special honorifics (N, J, W, Pa)
  - MKS: Earth, water, 10fingers