	1031
	atistical dynamics Impacts that integrate
	 Land: Precip, Evap, hydrology ⊙ Ocean
	Wind stressFreshwater flux
\bigcirc	Maximum Covariance "modes" Rotated
	OrthogonalZonal mean and eddies
	Momentum flux [u*v*]Zonal PGF vanishes
\odot	Time mean and anomalies • Anomaly correlations v'T'
	partial_t vanishes (balance) atistics
\bigcirc	Joint PDFs Mutual information
	CovariancesMarginal, conditional PDFs
\bigcirc	PDF /histogram Shannon information
	MomentsSkewness
	variance (stdev is sqrt)Mean
	nenomena Features (coherent structures)
	intensitydurations in time
	scales in spaceconvective
	mesoscalefrontal
	synopticplanetary
	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 variablesTendencies
	 Integrated Budgets Statistics monthly or daily surface impacts https://
	 monthly or daily surface impacts https:// goldsmr4.gesdisc.eosdis.nasa.gov/dods/M2SDNXS- LV.info EXTREMES: https://disc.gsfc.nasa.gov/datasets/
	M2SMNXEDI_1/summary , https://goldsmr4.gesdis- c.eosdis.nasa.gov/dods/M2SMNXEDI Documentation https://gmao.gsfc.nasa.gov/pubs/docs/
 	Bosilovich785.pdf Pure obs (satellite, radar, in situ)
	spectral imagery interpretationsclouds/particles easiest to see
	hyperlocal values odel Outputs Foregoets / hindecets / referencets
•	(Re)Analyses (data assimilation)
⊗ Ni	Simulations umerical models: see MindMap Atmosphere.mm Regional (w/ peither virtuel)
• •	Regional (w/ neither virtue!) Globe-covering
	physicswater phase changessubgrid turbulence
	 subgrid turbulence surface interaction radiation
	radiationlongwaveshortwave
	shortwavedynamicsspectral
	gridpoint Process-resolving (LES, CRM)
	microphysicssubgrid turbulence
	resolutionboundary conditions
○ C○	onservation laws d/dt = 0!!! + sources-sinks ("tendencies") PV: conserved even w/ hordiv
	Huge in stratosphere (static stability part)Mainly matters in strat-trop exchanges
\bigcirc	Momentum Output Provided to the state of t
	Cartesian tangent planevort = v_y - u_x, eliminates PGF
	Absolute vort cons: Ro wavesPhase west, energy east, equal
	 Goes as wavelength squared Stationary: roughly continent scale wave-
	lengthRelative vort cons: vortex interactions, V goes as 1/r
	 aGeostrophic (non-gradient) wind Contains almost all of the divergent wind compo-
	onent Ooze to maintain balance (QG omega equation)
	warm advection —> ascentvorticity advection above —> up
	August 11
	gravity wavesconvection
	 convection Frictional down-gradient flow Governs change: dV/dt = fV_a x k "Gradient wind": along isobars (Thereby almost no divergence) Vertical diff: "Thermal Wind" V_T directed along
	 convection Frictional down-gradient flow Governs change: dV/dt = fV_a x k "Gradient wind": along isobars (Thereby almost no divergence) Vertical diff: "Thermal Wind" V_T directed along isotherms "equivalent barotropic" V_T parallel to isobars
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	 convection Frictional down-gradient flow Governs change: dV/dt = fV_a x k "Gradient wind": along isobars (Thereby almost no divergence) Vertical diff: "Thermal Wind" V_T directed along isotherms "equivalent barotropic" V_T parallel to isobars Vg turns with height: temperature advection 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
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	econvection Frictional down-gradient flow Governs change: dV/dt = fV_a x k "Gradient wind": along isobars (Thereby almost no divergence) Vertical diff: "Thermal Wind" V_T directed along isotherms "equivalent barotropic" V_T parallel to isobars Vg turns with height: temperature advection Gradient: neglect partial_t(V) Geostrophic: neglect d/dt(V) Spherical Vertical in atm. hypsometric equation relates thickness to T, p Use hyd. p as coordinate Full dw/dt equation Thermal buoyancy Dynamic pressure SD 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 voricity line or sheet rolls up into balls, rolls Navier-Stokes: Source = Force PGF: cop enforcing mass continuity Hydrostatic: fights divergence of Coriolis force Dynamic: fights divergence of Coriolis force Dynamic: fights divergence of (advection of momentum) Coriolis if coords rotating Gravity Thermo Stability & convection logic shear & tornadoes filigree skew-T, log-p plots (trad) moist conserved Liquid water SE: s - Lq_liq MSE: h = s + Lq_v dh/dt = Grad + Qmix Dry conserved Liquid water SE: s - Lq_liq MSE: h = s + Lq_v dh/dt = Grad + Qmix Enthalpy (heat content): C_p T Divide by T: entropy S, potential temperature theta Moist conserved: theta-e (for equivalent) or -w (wet bubls) Dry conserved wars as needed needed for density (thickness.buoyancy) ansport tendencies in d/dt
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\odot	
	■ Convertion ■ Frictional down-gradient flow ■ Governs change: dV/dt = IV_a x k □ "Gradient wind": along isobars (Thereby almost no divergence) □ Vertical diff: "Thermal Wind" V_T directed along isotherms ■ "equivalent barotropic" V. T parallel to isobars ■ Vg turns with height temperature advection □ Gradient: neglect partial. t(V) ■ Geostrophic: neglect d/dt(V) ■ Spherical □ Vertical in arm. □ 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 ■ 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 ■ shear & tornadoes filigree ■ skew-T, log-p plots (trad) ■ moist conserved thotal = Crad +
	• Convection • Frictional down-gradient flow • Governs change: dV/dt = IV_a x k • Gradient wind: along isothers (Thereby almost no divergence) • Vertical diff: "Thermal Wind" V_T directed along isotherms • "equivalent barotropic" V_T parallel to isobars • Vg turns with height: temperature advection • Gradient: neglect partial_t(V) • Geostrophic: neglect ddtt(V) • Spherical • Vertical in atm. • hydrostatic approx. • Hyssometric equation relates thickness to T, p • Use hyd. p as coordinate • Full ddw/dt equation • Thermal buoyancy • Dynamic pressure • SD 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 divergence of Coriolis force • Dynamic: fights divergence of Coriolis force • Stability & convection logic • shear & tomadoes filigree • skew-T, log-p plots (trad) • moist conserved: theta-e (for equivalent) or -w (wet buitb) • Dry conserved: theta-e (for equivalent) or -w (wet buitb) • Dry conserved: theta-e (for equivalent
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