Exam format:

word	symbol	nutshell meaning	longer explanation of meaning (concept) in question	Relevant sketch with arrows or little f(x) curve or whatever if appropriate
divergence				
	ρ			xxxxx

...
...

Pure math concepts/words to know

Sphere:
Latitude, longitude, altitude
Zonal, meridional, vertical.
Northward, northerly; eastward, westerly
upward, altitude, pressure level (know Earth's atmosphere layers in p coordinate)

Cartesian: x,y,z **i,j,k** u,v,w

scalar, vector; scalar field vs. vector field

Scalar functions: domain, coordinates, range, value, curve (1D), surface (2D), field (3D, 4D)

Derivatives: slope, curvature, gradient, Laplacian. Notations for differentiation. Math definition of derivative.

dot product, cross product. For a vector, for a vector *field*.

Dot/cross using del operator (nabla symbol):
- vergence (divergence, convergence)
- advection -V.del(T)
- Curl of vector field **V**(x,y,z,t)
  - (vorticity if **V** is a velocity field)
- Curl of gradient vanishes precisely - why?

Nondivergent vs. irrotational decomposition of a vector field
- (Sometimes called rotational and divergent)

Integral relationships (opposite of derivative) for gradient, div, curl

Stokes theorem, Gauss' theorem
vanishing of div(curl), vanishing of loop integral of gradient

Partial derivatives of a field f(x,y,z,t)
Local or Eulerian $\partial f/\partial t$
Total or Lagrangian df/dt, following a parcel at position $[x_p(t), y_p(t), z_p(t)]$
Write the relationship to the local derivative $\partial f/\partial t$ (chain rule)
Advection by $\mathbf{V} = [u,v,w] = d/dt\ [x_p(t), y_p(t), z_p(t)]$

Gradient of a scalar field
Vergence (divergence, convergence) of vector field **V**(x,y,z,t)
Laplacian (divergence of gradient of a scalar field): *curvature*

ODEs and solutions
exponential solutions to df/dt = -bf
sinusoidal solutions to $d^2f/dt^2 = -c^2f$
exp() with complex numbers combines both
need boundary or initial conditions (constant of integration)

stationary or steady-state solution, equilibrium.
df/dt = A - B. Make steady-state assumption. Is it still a diff-eq?

PDEs and solutions: terms and concepts (for our applications)
prognostic vs. diagnostic
boundary conditions, initial conditions
inverse of Laplacian (smoothed, reversed sign)

Physical concepts/words to know

Temperature, pressure, density, wind, humidity (symbols, units)
Basic units (m, K, s, kg) – how defined (originally) from Earth and Water?
Derived units: hPa, mb, J/kg, W/m^2, …

Mass, mass fractions (specific ____, mixing ratio of ____, concentration of ___)
Conservation of mass (*continuity* of mass flux)
Flux of mass, multiply by specific ___ to get flux of specific ___
Conservation of specific ___

TRANSPORT:
Flux of (anything): what are the units? Flux *convergence*.
Advection: what is the sense of it (and the math)?
how are *advection* vs. *flux convergence* treatments related?

PROGNOSTIC EQUATIONS:
Governing equation, budget, tendency, Eulerian (local), Lagrangian (total)
d/dt(something) = 0 + sources - sinks
∂/∂t(something) = flux convergence + sources - sinks
∂/∂t(something) = advection + sources - sinks

Conserved, tracer

Balance: neglect some time derivative relative to other tendencies
Adjustment ("fast" process leading to restoration of balance)

Kinematics: vorticity, divergence deformation. diffluence/confluence.
recipes: shear = vorticity + deformation
Streamlines, trajectories: know the difference

Diffusion (convergence of a flux that is proportional to a gradient)

Waves

frequency, period, wavelength, wavenumber, amplitude, phase
phase velocity, group velocity
growing, decaying *amplitude* (in space or time)
growing, shrinking *scale* (expressed as wavenumber or wavelength)

Vorticity equations: d/dt(vorticity) = 0 + complications

Relative vorticity ζ: eliminates PGF from momentum equations
Absolute vorticity ζ_a=(f+ζ) which RHS terms are moved to LHS?

Vortex interactions (e.g. for TC steering): 2D reasoning

1/r decay of "induced" wind: $V_{tan}\ \alpha$ (1/r) ζ_{rel}
ζ_{rel} is advected by that "induced" flow
Sketch how this plays out for 2 vortices of same/opposite sign

Equation of Motion / Newton's 2nd Law

Pressure gradient force (PGF): Enforcer of continuity
Coriolis force (as 'real' as still air on rotating Earth is 'motionless')
"Inertial forces" (advection of momentum by wind itself)
"Friction" (convergence of momentum flux by small-scale motions)

Scales of variation (m vs. km vs. 1000s of km; hours vs. days vs. months)

Running average (smoothing) isolates *large scales* (filter or grid scale)
Deviations from that are *small scales*: (subfilter, subgrid)

anomaly (in time), *eddy* (in space

Perturbations: someone/something perturbed something
(an experiment, impact, effect, cause-effect chain)

Beyond exam but current in course

Rossby waves:

- explain from $d/dt(\zeta_a)=0$ with $\beta = df/dy$
- Phase velocity $c=U - \beta/k^2$: westward relative to U, long waves faster
- Group velocity $c_g=U + \beta/k^2$: eastward relative to U, " " "
    - "downstream development" process
- For stationary waves, $c_g = 2U$