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 |  |  |  |  |
|  |  |  |  | xxxxx |

...

...

Domains and coordinates and fields as functions of them:

Latitude, longitude, altitude

Zonal, meridional, vertical.

Northward vs. northerly; eastward vs. westerly

upward, altitude, pressure level (know Earth's atmosphere layers, p coordinate)

troposphere, stratosphere, planetary boundary layer (PBL)

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

scalar, vector; scalar field vs. vector field All Have Units!

vectors have 2 *properties* (in 2D or 3D): magnitude and direction

even though they involve a set of 3 components (numbers) in 3D

dot product, cross product. For a vector; same at every point for a vector *field*.

Scalar functions. Domain (coordinate or argument) vs. value (range)

curve (1D), surface (2D), field (3D, 4D)

Derivatives:

first derivative: slope (1D) or gradient (2D, 3D)

second deriv: curvature or Laplacian (flips sign, for sin/cos)

Del operator (nabla symbol):

gradient (of a scalar function) like temperature gradient

vergence (divergence, convergence) div(**V**) = "del dot **V" =**

advection **"minus V dot del**(T)" or "minus V dot grad T)

note negative sign

Curl of vector field **V**,

Only in 3D! Right hand rule

(vector vorticity, if **V** is a 3D velocity field)

we use only its *vertical component,*  = vy - ux

(where subscript indicated partial derivative)

Curl of gradient vanishes precisely - why?

Scale of variation (m vs. km vs. 1000s of km; hours vs. days vs. months): notice these are logarithmic (power of 10) distinctions, not just "size" (like 10m vs. 5m)

Running average (smoothing) isolates *large scales* (filter scale)

Deviations from that are *small scales*: (subfilter)

*anomaly* (deviation from time average)

*eddy* (deviation from space average)

*perturbation*: someone/something *perturbed* something

away from some control case

(an experiment, isolating cause and effect)

Partial derivatives of a field f(x,y,z,t)

Local or Eulerian **∂**f/**∂**t

Total or Lagrangian df/dt, following a parcel at position [xp(t), yp(t), zp(t)]

Write the relationship to the local derivative **∂**f/**∂**t (chain rule): it gives

advection by **V** = [u,v,w] = d/dt [xp(t), yp(t), zp(t)]

Nondivergent vs. irrotational decomposition of a vector field

(rotational and divergent) "components"

different meaning than vector *components in the axis directions*

streamline, streamfunction, streamwise

trajectory (different from streamline)

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

Stokes theorem (circulation), Gauss' theorem (for divergence)

vanishing of div(curl), vanishing of loop integral of gradient

ODEs and solutions

exponential solutions to df/dt = -bf

sinusoidal solutions to d2f/dt2 = -c2f

exp() with complex numbers combines both

need boundary or initial conditions (constant of integration) to solve

stationary or steady-state solution; equilibrium or "balance"

df/dt = A - B. Make steady-state assumption. Is it still a diff-eq? NO!

PDEs and solutions: terms and concepts (for our applications)

prognostic vs. diagnostic

boundary conditions, initial conditions

inverse of Laplacian (smoothed, reversed sign)

PROGNOSTIC EQUATIONS:

Governing equation, budget, tendency

Eulerian (local) vs. Lagrangian (total) derivatives

d/dt(something) = 0 + sources - sinks

**∂**/**∂**t(something) = flux convergence + sources - sinks

**∂**/**∂**t(something) = advection + sources - sinks

Conserved tracer special case: *sources-sinks negligible*

*Balance* special case: *neglect time derivative relative to other tendencies*

Adjustment ("fast" process leads to restoration/maintenance of balance)

"Kinematics": spatial gradients of velocity

vorticity, divergence, deformation. diffluence/confluence.

recipes: shear = vorticity + deformation

Streamlines, trajectories: know the difference

Waves: terms and concepts

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)

Physical concepts/words to know

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? Stuff per second per square meter (in 3D)

Flux *convergence* is the effect of the flux (*transport's* "drop-off")

Advection: what is the sense of it (upstream coming at ya) and the math ( -**V.del** )?

how are *advection* vs. *flux convergence* treatments related?

(equal, because of mass continuity as in homework 3).

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

PHYSICAL LAWS

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)

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

Relative vorticity : eliminates PGF from momentum equations

Absolute vorticity a=(f+) moves v df/dy = v\*beta term to LHS

Potential vorticity PV eliminates adiv(**V**) "stretching" term from RHS

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

1/r decay of “induced” rotational wind from vorticity element

Vtan  (1/r) rel

rel is advected by that “induced” flow

Sketch how this plays out for 2 vortices of same/opposite sign

Rossby waves: includes advection of planetary vorticity (or conservation of absolute)

explain from d/dt(a)=0 with  =df/dy

Phase velocity c=U - k2 : westward relative to U, long waves faster

Group velocity cg=U +  k2: eastward relative to U, " " "

"downstream development" process

For stationary waves, cg = 2U

First Law of Thermodynamics (conservation of microscopic energy)

heat energy added to gas = change in internal energy + work done by gas (p dV/dt)

Per unit mass: Q = Cv dT/dt + p da/dt

Ideal gas law: pa = RT

Plug in: Q = Cp dT/dt - a dp/dt

where Cp = Cv + R

Mass continuity

Hydrostatic pressure (mass) coordinate makes it especially clean

omega = dp/dt is vertical velocity, but also "pressure drop" at the surface for instance

Primitive Equations: write them like a sonnet (perfectly), as in HW3

see attached exam prep doc