

Module I: How Geophysical Flows Form Structures

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i.) *Models and Basics*

- Rossby number, geostrophic balance, potential vorticity and PV conservation
- 2D fluid, QG equation, beta plane model
- 2D turbulence, dual cascade
- Inverse cascade → the end state

ii.) *Jets / Zonal Flows*

- Rossby waves, zonal flows
- Heuristics of jet formation
- PV mixing, Taylor identity, Charney-Drazin Theorem
- Jets and cascades – Rhines mechanism

iii./iv.) *Routes to Relaxation*

- On basic principles of mixing relaxation, etc. → origin of irreversibility
- The Approaches:
 - 1.) Batchelor → PV Homogenization
→ Prandtl–Batchelor theorem, proof, time scales, implication
 - 2.) Bretherton and Haidvogel → Minimum Enstrophy Relaxation
→ from dual cascade to variational principle end-state configuration, implications
 - 3.) Lynden-Bell, et al. → Most Probable States
→ entropy for local phase space density conservation; memory
→ relaxed states and their properties
→ toward turbulence with self-bound structures
- What it all means ... (open-ended)

N.B.: Connections to physics of magnetized plasmas will be discussed (time permitting) and developed in homework problems.