What is GFD?

ATM S 509/OCEAN 512

Geophysical Fluid Dynamics I

1-4-17

Key aspects of geophysical flows

- Rotation
- Stratification

Also:

- Topography/bathymetry/ inhomogeneous surface
- Latent heating/other diabatic terms

The GFD Toolkit

- Development of equations for the atmosphere and ocean
  - Fluid properties of air and water
  - Ways to talk about stratification
  - Mathematical formulation of rotating reference frame

The GFD Toolkit

- Conservation equations
  - Energy
  - Vorticity
  - Potential vorticity

The GFD Toolkit

- Scaling arguments
  - To rule out particular terms and find dominant balances
  - Deriving simplified equations
  - Sometimes based on order of magnitudes
  - Sometimes formal asymptotic expansions in small nondimensional parameters

The GFD Toolkit

- Examination of transient and steady response to forcing
  - Waves
    - Linear theory, Fourier analysis

The GFD Toolkit

- Instabilities
  - Convective
  - Barotropic, baroclinic, inertial

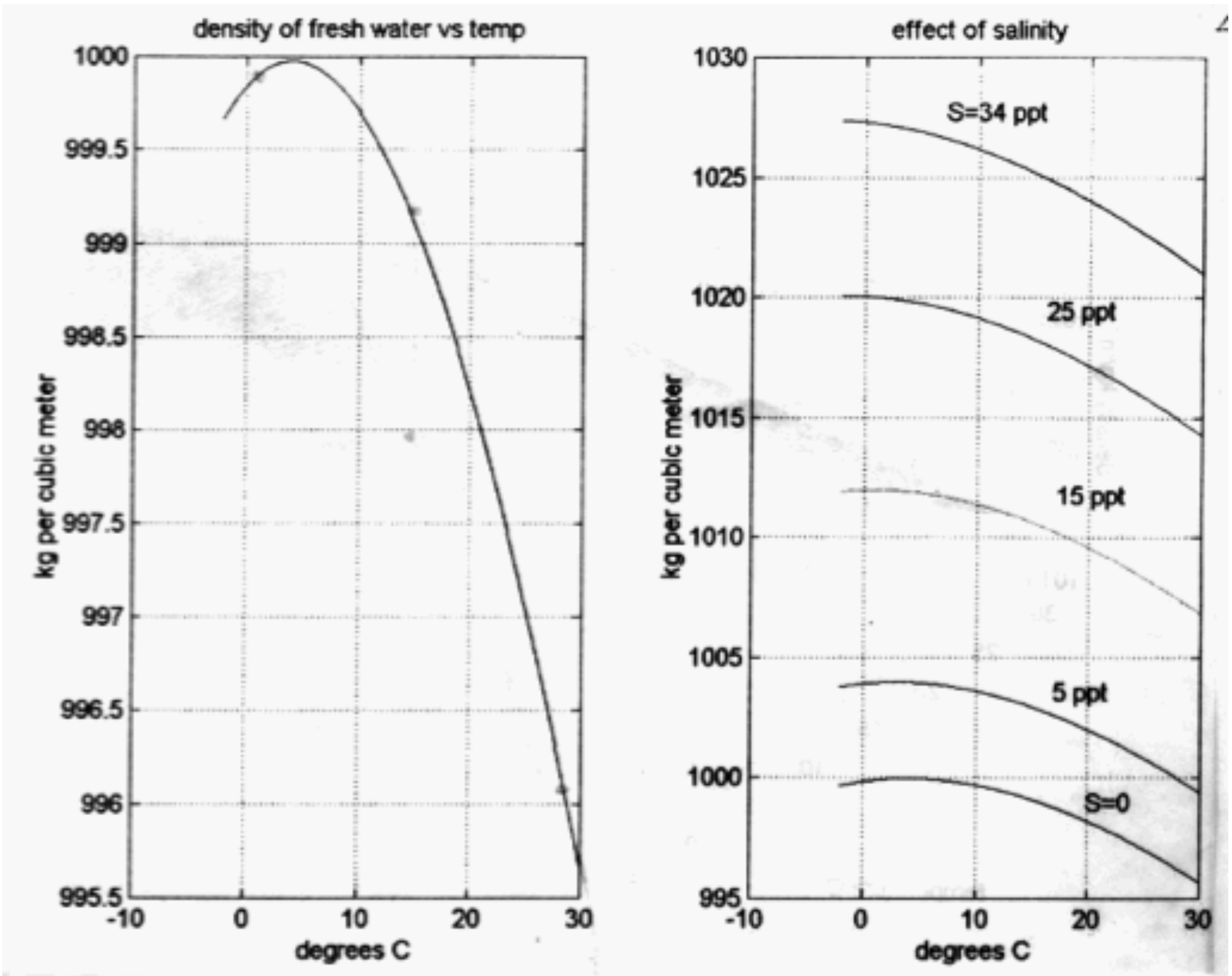
The GFD Toolkit

- Idealized physical systems
  - To illustrate phenomena most succinctly and elegantly
- Lab experiments/numerical experiments

Equations of Motion

- Conserved tracer
- Momentum equation
- Mass equation
- Equation of state

Equation of state for seawater



Equation of state for seawater

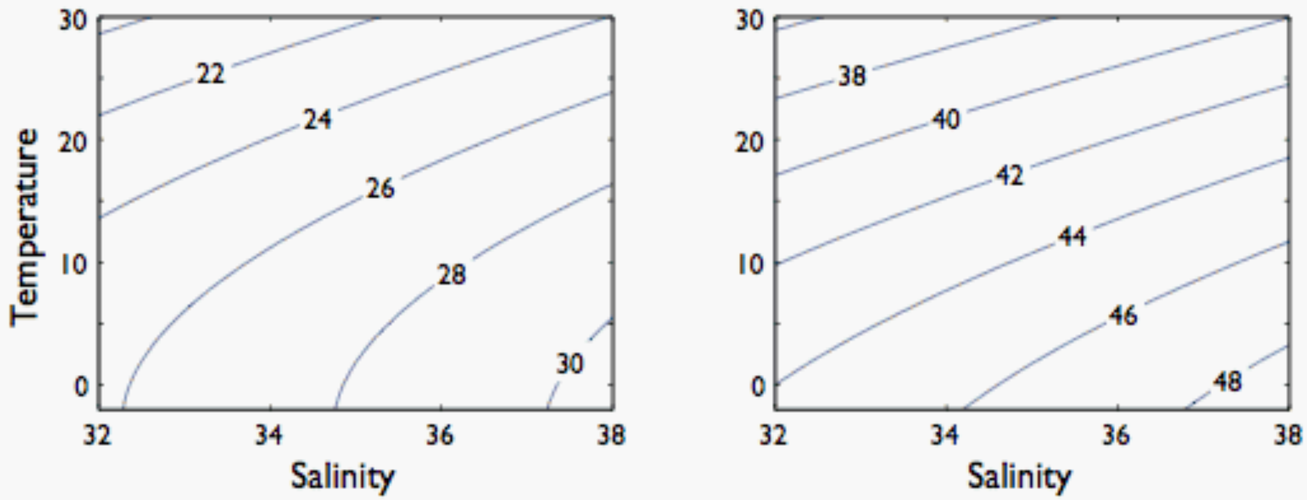


Fig. 1.3 A temperature–salinity diagram for seawater, calculated using an accurate empirical equation of state. Contours are (density $-$ 1000) kg m^{-3}, and the temperature is potential temperature, which in the deep ocean may be less than *in situ* temperature by a degree or so (see Fig. 1.4). Left panel: at sea-level ($p = 10^5$ Pa $= 1000$ mb). Right panel: at $p = 4 \times 10^7$ Pa, a depth of about 4 km. Note that in both cases the contours are slightly convex.

Equation of state for seawater

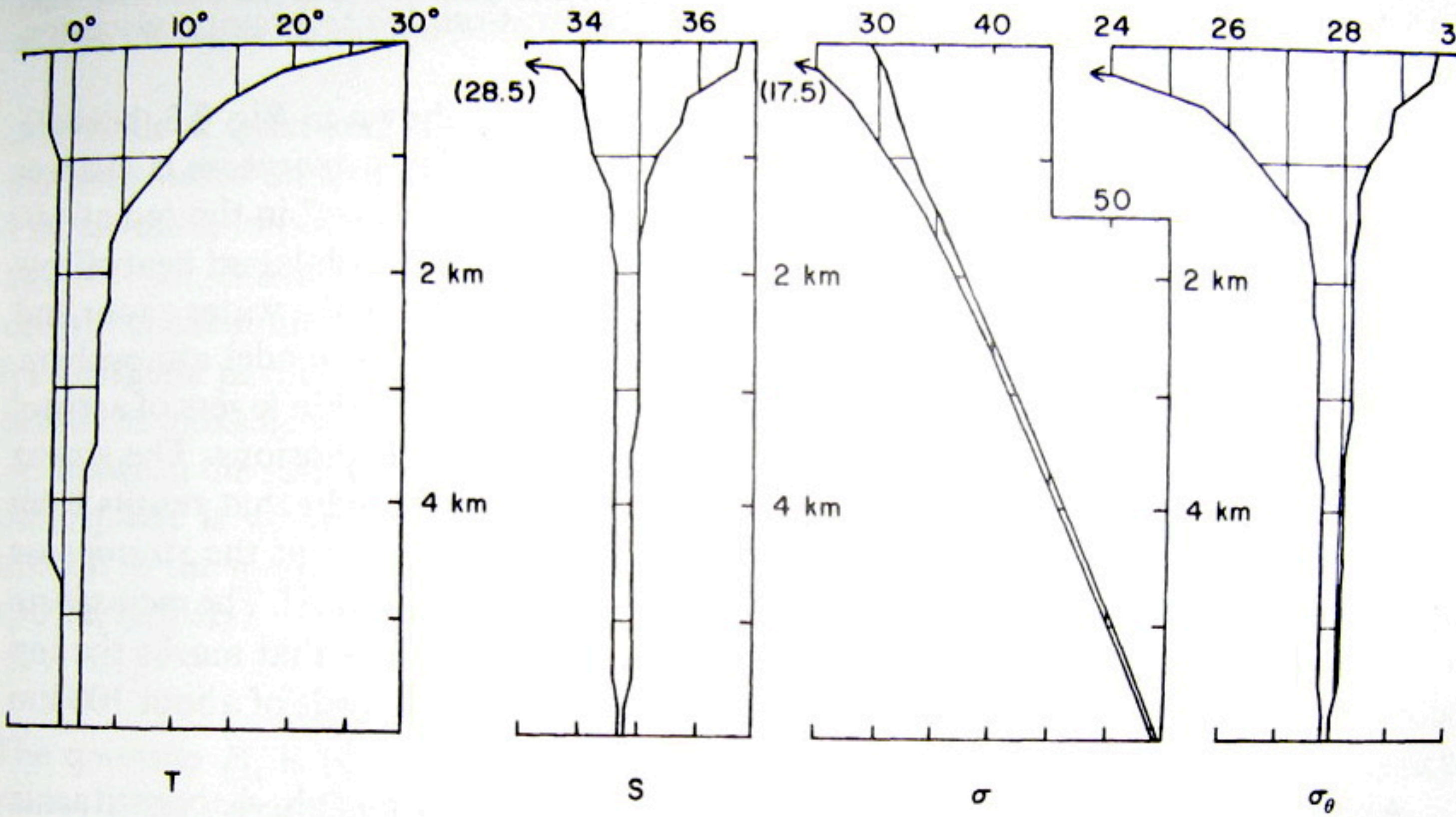
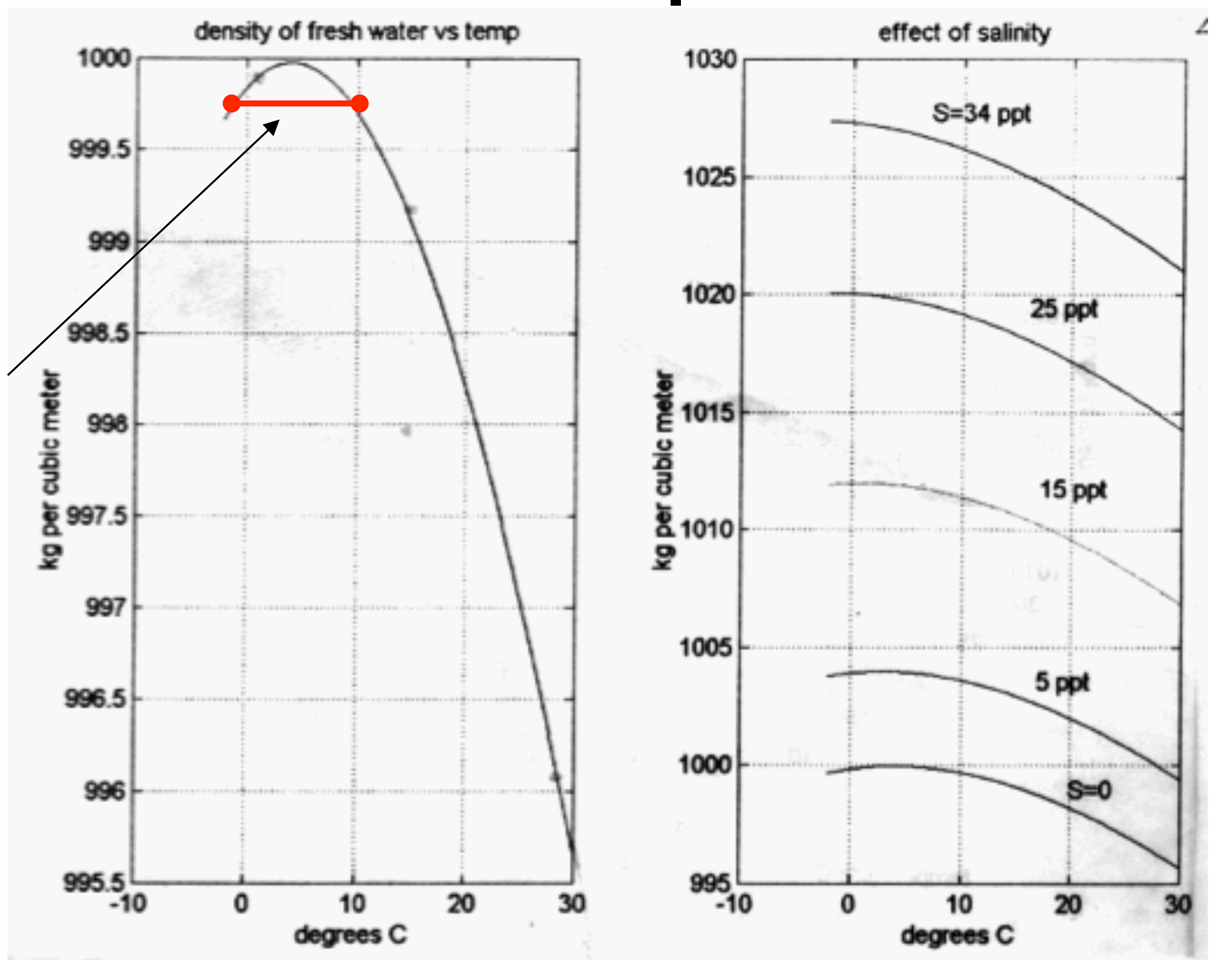


Fig. 3.2. The ranges of temperature T (in °C) and salinity S for 98% of the ocean as a function of depth [From Bryan and Cox (1972)], and the corresponding ranges of density σ and potential density σ_θ (see Appendix 3).

More on nonlinear eqn of state

Mix these
two parcels



More on nonlinear eqn of state

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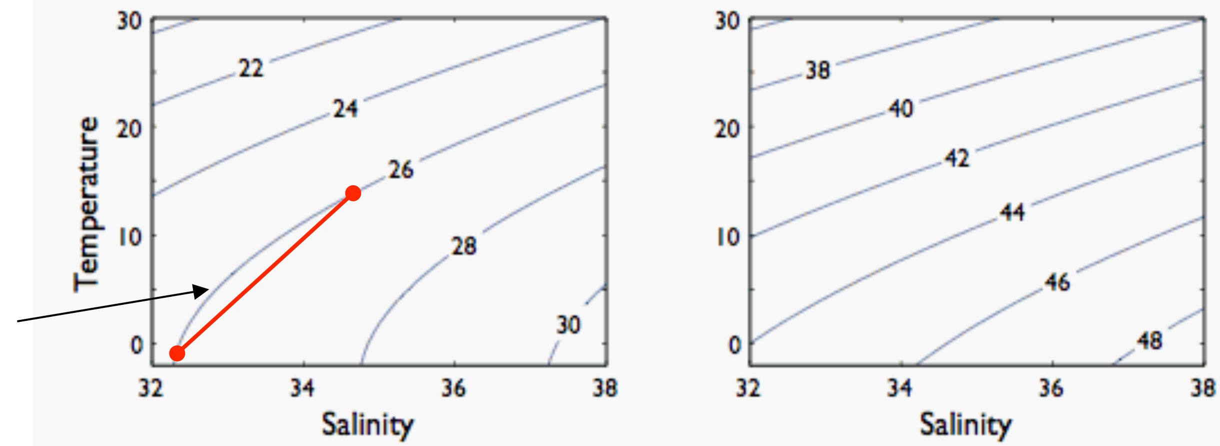

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Density of Air vs Ocean

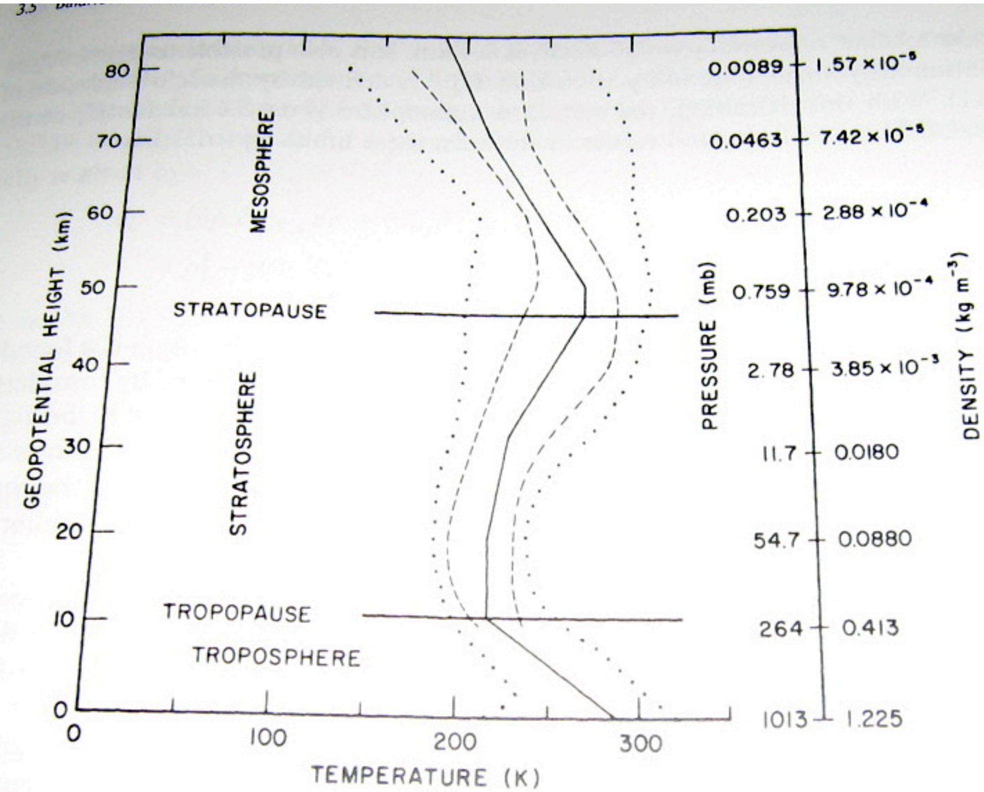

Fig. 3.3. Temperature variation with geopotential height for the U.S. Standard Atmosphere (solid line). This consists of straight-line segments with breaks at 11, 20, 32, 47, 51, and 71 km. The surface temperature is 15°C and the gradients, starting from the surface, are −6.5, 0. 1.0, 2.8, 0, −2.8, and −2.0 K km^{-1}. The dashed line shows the lowest and highest monthly mean temperatures obtained for any location between equator and pole, whereas the dotted line shows estimates of the 1% maximum and minimum temperatures that occur during the warmest and coldest months, respectively, in the most extreme locations. The scale at the right gives pressures and densities at 10-km intervals for the standard profile. [From NOAA/NASA/USAF, 1976.]

Air is much less dense than water (3 orders of mag or more)

Also air density changes much more than sea water (orders of mag vs 2%)