# General Circulation assignment
# (Overturning circulation lecture)

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1-5): Figure 1 illustrates the overturning stream functions for the atmosphere and the ocean as well as the ocean transport of heat and salt, and the atmospheric transport of latent heat.

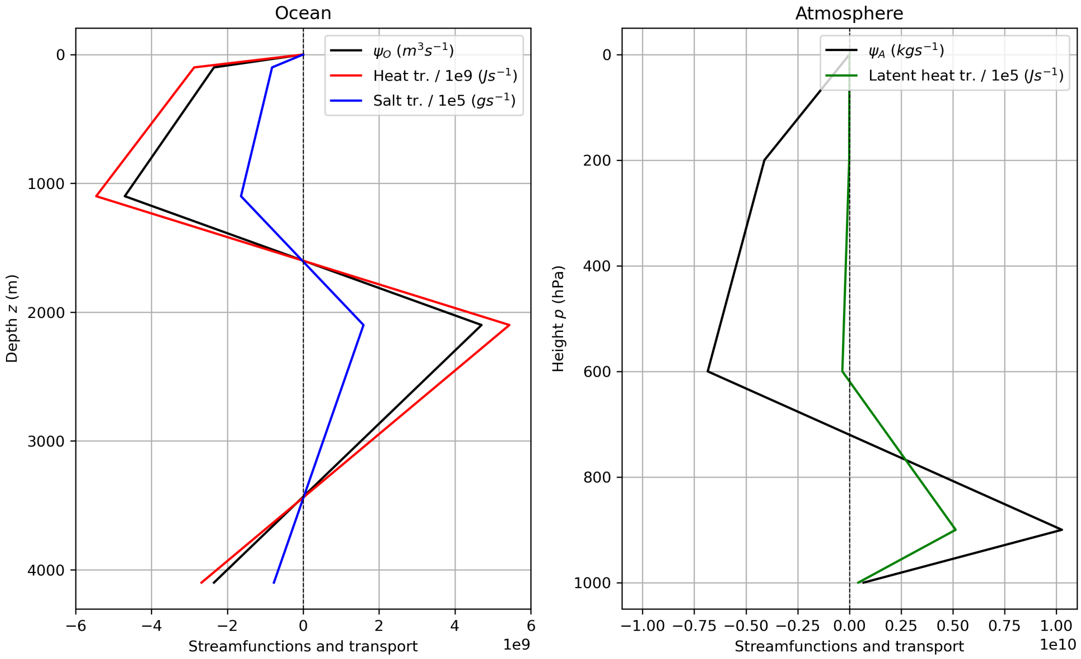


Figure 1: Overturning stream functions for the ocean (left) and the atmosphere (right), and transport of heat and salt (left) and latent heat (right). The transport values have been scaled to fit on the same figure.

The stream functions were computed by integrating vertically (along the height or depth) and horizontally along 10°of latitude ($Rx = R_{Earth} \cdot \cos(10°)$), taking into account the assumption of the ocean covering 70% of the land.

In particular,

$$\psi_{atm} = \frac{1}{g} \int_{1000}^{0} \int_{0}^{2\pi R_x} v(p) dx dp \quad [kg/s]; \tag{1}$$

$$\psi_{oce} = \int_{-4100}^{0} \int_{0}^{2\pi R_x \cdot 0.7} v(z) dx dz \quad [m^3/s]. \tag{2}$$

The transport variables were instead obtained from the stream functions as follows:

$$H_{atm}^{latent} = \frac{L}{g} \int_{1000}^{0} \int_{0}^{2\pi R_x} v(p) \cdot q(p) dx dp \quad [J/s]; \tag{3}$$

$$H_{oce}^{heat} = \rho C_p \int_{-4100}^{0} \int_{0}^{2\pi R_x \cdot 0.7} v(z) \cdot T(z) dx dz \quad [J/s]; \tag{4}$$

$$H_{oce}^{salt} = \rho \int_{-4100}^{0} \int_{0}^{2\pi R_x \cdot 0.7} v(z) \cdot s(z) dx dz \quad [g/s]; \tag{5}$$

6): In order to make the computation more accurate, one can relax some of the assumptions used in the exercise:

- Zonally constant properties:
  This is a major simplification (large heat and salt fluxes due to currents, differences between western and eastern boundary flow, zonal asymmetry in wind forcing...). Using gridded data could highly improve the "model" under this perspective.
- Ocean coverage:
  70% is just a global average but a land-sea mask could improve the prediction more.
- Convection ignored:
  We assume that the atmospheric is in "hydrostatic balance", but moist convection is very relevant at those latitudes and it is non-hydrostatic.
- Simplified data overall:
  Overall, there are several things that are oversimplified in the exercise: we only have a couple of data points, there isn't really a air-ocean interface, there is nothing that characterises eddies and turbulence, the vertical resolution is incredibly coarse...

All of this issues could be (at least partially) resolved by using real data (e.g. coming from ERA5).

7): I work with LES simulations of the atmospheric boundary layer and with passive scalar transport. I think streamfunctions could be very useful in understanding how passive scalars organise into structures in the convective boundary layer, which is characterised by non-local transport and convective structures rather than "ordered", down-gradient turbulence (I am up for advice on whether this could be a good way to proceed in my research). They can also be useful to compute scalar and/or mass transport in the boundary layer and how these change under different forcings.

The code is on GitHub.