Linear versus non-Linear dynamics

Increasing the forcing rate leads to the instability of the westward jet configuration: many eddies grow inside the zonal central jet, propagate towards the west and then get dissipated as they enter the western boundary currents, causing exchange of tracer between the two gyres.

\[
\frac{U}{U_0} = 0.3 \quad \frac{U}{U_0} = 0.4 \quad \frac{U}{U_0} = 0.5 \quad \frac{U}{U_0} = 0.7
\]

Sensitivity to the distance separating the source/sink

The instability of the westward jet configuration can be inhibited by increasing the distance between the source and the sink (here F=100 ml/min).

Non dimensional vorticity equation

\[
\frac{\partial \zeta}{\partial t} + (u \cdot \nabla)\zeta + \nu \nabla^2 \zeta = -\frac{\partial}{\partial x}(\delta x - x_{source}) - \frac{\partial}{\partial x}(x - x_{sink})
\]

Origin of the instability

The spatial origin of the instability may either be in the westward boundary current, in the region near the source and sink, or in the westward jet. Counter mean potential vorticity gradient eddy fluxes suggest that the instability grows within the westward jet.

Mechanism of the instability

The Charney-Stern criteria for barotropic instability proves to be verified within the westward zonal jet of our unstable circulations: \(U_y - \beta \) changes sign.

Conclusions

In our simulations, no instability occurred in the western boundary layers, although western boundary currents played a major role in the exchange of tracer between the two gyres. Having distributed sources and sinks would certainly better mimic the ocean circulation. Nevertheless, a prerequisite to rationalize the much more complex eddy wind driven gyres or abyssal circulation is to understand the dynamics of such simple systems.