

Modelling of geophysical vortices

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Modelling of Geophysical Vortices

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Abstract

The large-scale vortex structures that are commonly observed both in the oceans (e.g. Gulf Stream rings) and in the atmosphere (hurricanes, cyclones, Jupiter's Great Red Spot) are in good approximation two-dimensional (2D), due to the combined effects of geometrical confinement (essentially, the oceans and atmosphere are thin fluid shells), density stratification, and planetary rotation. Their dynamics is governed by conservation of potential vorticity, which is here defined as $PV=(f+\omega)/H$, with f the Coriolis parameter ($=2\Omega\sin\phi$, with Ω the planetary rotation speed, ϕ the geographical latitude), ω the local relative vorticity, and H the local layer depth (column height).

The latitudinal gradient in f provides a self-propelling mechanism to the vortices: cyclonic vortices show a drift in NW direction, while anticyclonic vortex structures have a tendency to drift to the SW. This is e.g. nicely observed in the NW-drifting vortices that are shed from the retroflecting Agulhas Current, south of Africa.

Gradients in the Coriolis parameter f can be mimicked in a rotating fluid tank by applying a suitably chosen bottom topography, e.g. a linearly sloping bottom. Laboratory experiments in such rotating tank configurations have provided useful insight in the drift properties of coherent vortices.

A remarkable property of 2D turbulent flows is the inverse energy cascade, which leads to so-called 'selforganisation', as observed in the emergence of larger vortices. During this evolution one frequently observes different types of interactions between vortices, e.g. merging of like-signed vortex structures, and the tearing of a vortex in the strain field induced by its neighbours. These types of interactions have been studied both by numerical simulations and in laboratory experiments.

Another aspect that will be addressed in the lecture concerns the transport and mixing properties of vortices. This is in particular relevant for a better understanding of large-distance tracer transport in the ocean and the mechanism of the transport barrier in the atmospheric polar vortices. In the latter case, the limited mixing at the vortex edge prevents the filling up of the ozone-depleted vortex core (the 'ozone hole') by ozone from moderate latitudes. Numerical simulations – based on the contour dynamics method – have provided important insight in the dynamics of the polar vortices and their mixing properties.

Over de spreker

GertJan van Heijst studeerde in Twente (aan de toenmalige Technische Hogeschool) en voerde daar ook zijn promotieonderzoek uit. Nadat hij zijn proefschrift "On the flow in a rotating cylinder with bottom topography" in 1981 verdedigd had, vertrok hij naar Cambridge (UK) om aan het Department of Applied Mathematics and Theoretical Physics van de universiteit gedurende een jaar als postdoc te werken. Na dat jaar kreeg hij een baan als UD (en later UHD) bij het Instituut voor Meteorologie en Oceanografie aan de Faculteit Natuur- en Sterrenkunde van de Universiteit Utrecht. Zijn onderzoek betrof onderwerpen uit de fysische oceanografie, zoals twee-lagen stromingen, frontdynamica en coherente wervelstructuren. In 1990 werd hij benoemd als gewoon hoogleraar aan de Faculteit Technische Natuurkunde van de TU Eindhoven, met als leeropdracht 'stromingsleer'. Hij leidt de groep 'Werveldynamica en Turbulentie', welke zich richt op onderzoek aan fundamentele aspecten van turbulentie, stromingen met achtergrondrotatie en –stratificatie, de dynamica van wervelstructuren en chaotisch transport in al dan niet turbulente stromingen. De geofysische toepassingen spelen een belangrijke motiverende rol in deze onderzoekslijn.