

Dynamics and Waves in the Atmosphere and Ocean: Introduction

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M1 MOCIS

Global view

Dynamical actors:
jets, vortices and
waves

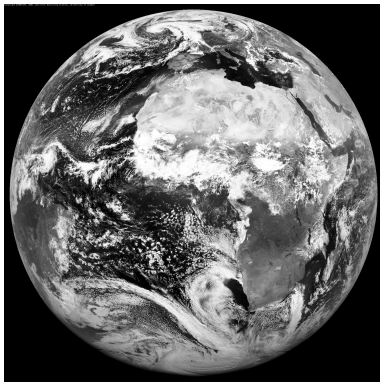
Atmospheric and oceanic
jets

Atmospheric and oceanic
vortices

Atmospheric and oceanic
inertia-gravity waves

Smaller-scale
oceanic waves

Atmosphere: space-view



Courtesy: NASA

Visible in clouds - (unperfect) tracers : extratropical depressions, equatorial easterly waves and emerging tropical storm, inertia-gravity waves

Ocean: similar, but not visible without tracers.

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Smaller-scale oceanic waves

General observations

Atmosphere and ocean: fluid-dynamics systems

- ▶ on the **rotating** (\sim) **sphere**
- ▶ with **stratification** due to gravity
- ▶ with non-trivial bottom (atmosphere, ocean) and lateral (ocean) **boundaries**
- ▶ with multiple phases and **phase transitions** (water vapor, liquid water, ice)

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Typical scales

Atmosphere:

- ▶ Planetary (general circulation $\mathcal{O}(10000 \text{ km})$)
- ▶ Synoptic (weather systems) $\mathcal{O}(1000 \text{ km})$
- ▶ Meso-scale (thunderstorms) $\mathcal{O}(10 \text{ km})$
- ▶ Micro-scale (weather at the airport) $\mathcal{O}(10 - 100 \text{ m})$

Ocean:

- ▶ Planetary (general circulation $\mathcal{O}(1000 - 10000 \text{ km})$)
- ▶ Meso-scale (Gulf-stream rings) $\mathcal{O}(100 \text{ km})$
- ▶ Sub-Mesoscale (coastal phenomena) $\mathcal{O}(1 - 10 \text{ km})$
- ▶ Small-scale (swell) $\mathcal{O}(10 - 100 \text{ m})$

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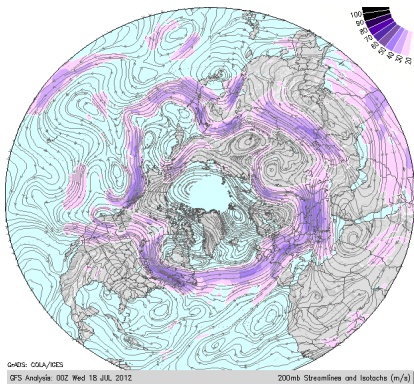
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Upper tropospheric jet



Courtesy: COLA/NOAA

Mid-latitude jet-stream in the Northern Hemisphere as follows from the analysis in a general circulation model. Streamlines and modulus of velocity (colors).

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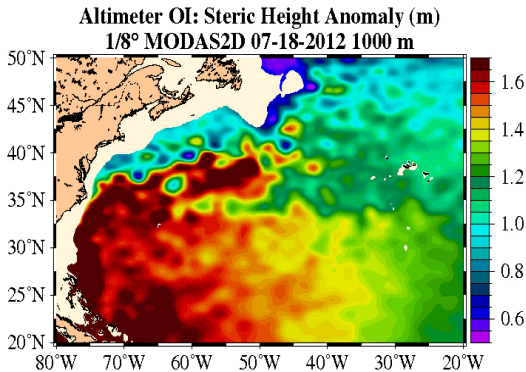
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Gulf-stream



Courtesy: US Navy

Gulf-stream as seen in the sea-surface height anomaly (colors) observed by satellite. See geostrophic balance in the main course for the relation between height and velocity.

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Jets on other planets



Courtesy: NASA

Alternating jet-streams in Jovial atmosphere as seen by Juno mission. As in previous images, eddies are produced by **instabilities** of the jets.

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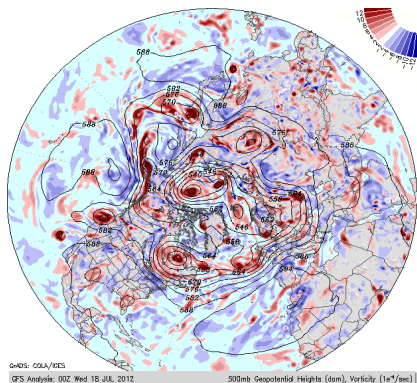
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Tropospheric vortices in data



Courtesy: COLA/NOAA

Tropospheric eddies in the Northern Hemisphere as follows from the analysis in a general circulation model at $500 \text{ mb} \approx 4.5 \text{ km}$ altitude. Colors: relative vorticity (curl of the horizontal velocity). *Red*: cyclones, *Blue*: anticyclones.

Global view

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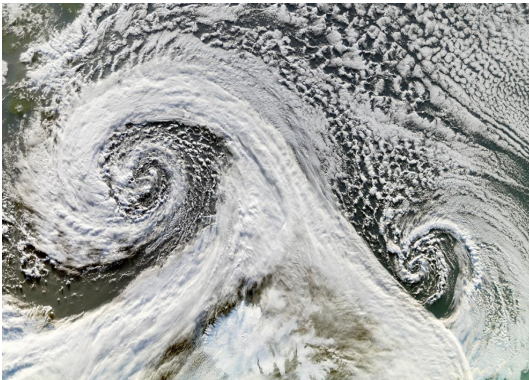
Atmospheric and oceanic jets

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Tropospheric vortices in satellite images



Courtesy: NASA

Double cyclone in the Northern hemisphere.

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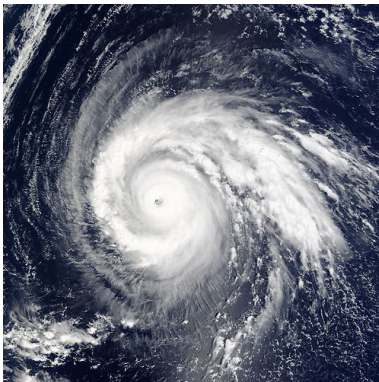
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Tropical cyclones



Courtesy: NOAA

Tropical cyclone - intense sub-synoptic scale tropospheric vortex.

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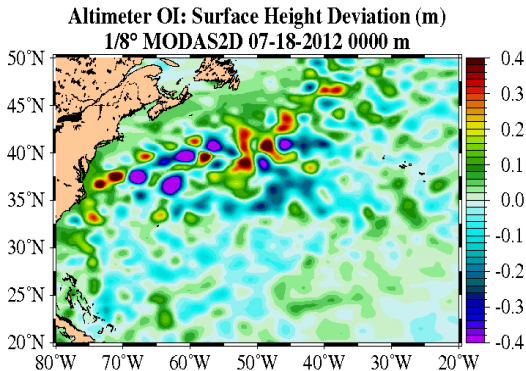
Atmospheric and oceanic
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Gulf-stream rings



Courtesy: US Navy

Gulf-stream vortices as seen in the sea-surface height anomaly deviation (colors) observed by satellite. See geostrophic balance in the main course for the relation between height and velocity.

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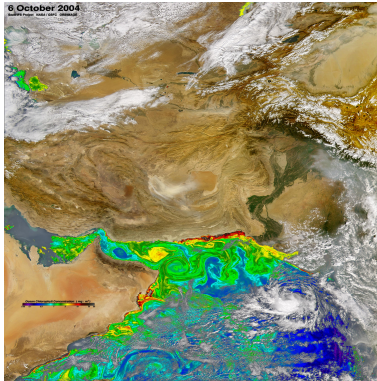
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Vortices in Arabian see



Courtesy: US Navy

Vortices in Arabian see as seen in the plankton bloom (false colors).

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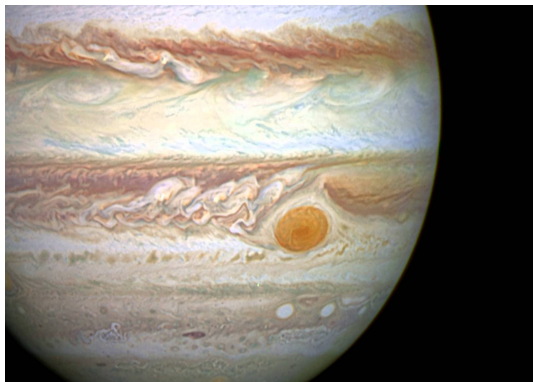
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Smaller-scale
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Vortices in the the atmospheres of other planets



Courtesy: NASA

Great Red Spot in Jovial atmosphere - a quasi-stationary anticyclonic vortex, as seen by Juno mission.

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Atmospheric and oceanic jets

Atmospheric and oceanic vortices

Atmospheric and oceanic inertia-gravity waves

Smaller-scale oceanic waves

Internal inertia-gravity wave in the Andaman sea



Courtesy: NOAA

Large-scale internal wave as seen in the satellite image.

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Internal inertia-gravity wave in Mediterranean



Courtesy: NASA

Large-scale internal wave produced by a tide in the Gibraltar straight as seen in the satellite image.

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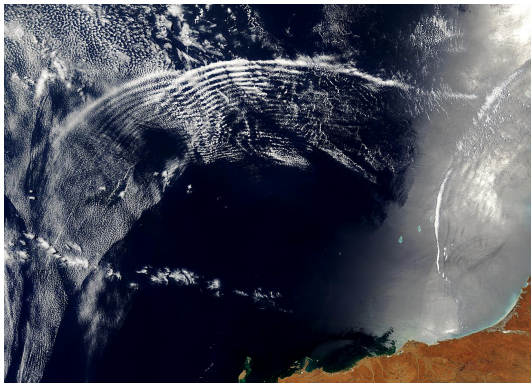
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Smaller-scale
oceanic waves

Atmospheric inertia-gravity waves near Australian coast



Courtesy: NASA

Traces of inertia-gravity waves in clouds.

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“Morning glory” in Northern Australia



Courtesy: R. Grimshaw

A close view of the internal gravity wave in the atmosphere.

Global view

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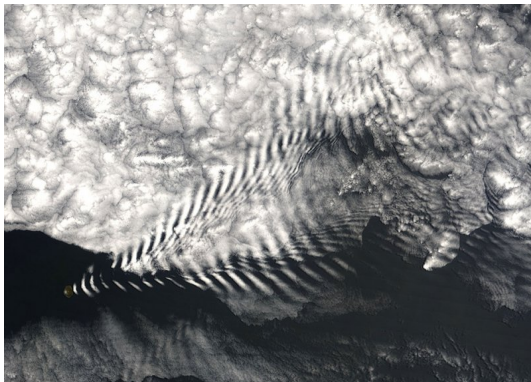
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Atmospheric lee wave behind an island



Courtesy: NOAA

Lee wave as seen in the clouds behind an island.

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Ocean swell



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**Smaller-scale
oceanic waves**

Breaking swell wave



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**Smaller-scale
oceanic waves**