Physical Oceanographic Context of Seamounts

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Seamounts: definitions

- submarine topographic high,
- > 1000 m above seafloor,
- $20^\circ<\Phi<100\text{km}$,
- complex geometry: terraces, canyon, calderas, craters

*from ISA 2007*
Seamounts: geographical repartition
Seamounts effects on circulation and tracers

- Large scale currents deflection, wakes and meandering occasionally leading to eddy formation downstream,

- because they constitute anomalous topographic features embedded in geophysical flows, they are often characterized by their own “isolated” dynamics, which in turn affect the distribution of physical and geochemical tracers and biology:
  - Taylor column,
  - trapped waves,
  - enhanced kinetic energy,
  - enhanced mixing.

isolated physics, tracer isolation
Main sources of energy at intermediate depth in the ocean

- large scale “wind driven” flows:
  1 m/s at the surface but 1 to 10 cm/s at 1000 m depth,

- mesoscale variability, eddies:
  1-10 cm/s at 2000 m depth,

- tides:
  barotropic: generally weak,
  baroclinic or internal tides: 10 cm/s,

- internal swell (wind generated internal waves):
  up to 10 cm/s on the flank of some topographic features
Large scale flow interaction with seamounts

- current deflection,
- wake,
- eddy formation in the lee,
- potential impact on ocean circulation,
- potential impact on global climate via air-sea interaction.
Seamount specific phenomena: Taylor column

→ G. I. Taylor (1886-1975): steady, linear, inviscid flow follows isobath,
→ anticyclonic circulation above seamount and isolation from surrounding,

→ the ocean is unsteady, non-linear and viscous, but the general pattern holds so that the name of “Taylor caps” is used for general geometries.
Seamount specific phenomena: trapped waves and resonance

- steady flow generate upwelling upstream, downwelling downstream,
- giving a “butterfly” pattern,
- which in turn create a potential vorticity waves,
- subinertial coastal waves rotate anticyclonically around the seamount if friction allows,
- rectified flow is an anticyclone with doming isopycnals just above the seamount
- this phenomenon is trapped to the bottom

- if forcing is in phase with the coastal wave, then resonance happens, leading to high amplitudes.

from A. Beckmann, ISA 2004
Tides

→ Impact through:
  → trapped waves and resonance,
  → strong mixing via conversion to internal tides.

Outgoing internal wave

Incoming internal wave

• from J. Aucan, personal communication
• animation from M. Merrifield et al.
Internal tide mixing repartition

• only the coherent part!

• from M. Alford, Nature 2003, using D. Egbert TPX0.5
Internal swell

- same mechanism than internal tide: breaking on the flank of topographic features,
- source repartition:

- these waves can travel long distances!

from M. Alford, Nature 2003
Yet another source of mixing

• Simply from turbulence resulting as strong flow pass through narrow topographic passages (St Laurent and Thurnherr, Nature 2007)
Global effects of topography related mixing

- mixing is a driver of the “great conveyor belt”,
- topography related mixing is one important component of it.
Mesoscale variability

- mesoscale waves and eddies can be seen as storms for the deep ocean
Implications for geochemistry and biology

- Upwelling and vertical mixing above the seamount can increase nutrient concentrations,

- trapping of water above a seamount?
  - No for weak steady flow,
  - Maybe for strong steady flow,
  - Maybe for oscillating flows. through trapped waves

- wind events, eddies, intermittent strong currents can flush the area above a seamount
Implications for sediments

- strong currents, less sediments on top of seamounts,
- strong slope and enhanced turbulence increase potentiality for down slope turbidity current
Summary: physical parameters of importance

- height, diameter,
- steepness,
- degree of symmetry,
- smoothness of topography,
- stratification,
- mean current strength,
- oscillating current strength and frequency of oscillation,
- direction of the current if seamount is not symmetric.