KYOTO FDEPS LECTURES 4-7 xi 2007 P.B. RHINES

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While there will not be time or energy to discuss all these topics, this the 'reservoir' from which I am drawing the lectures. *PBR*

1. BASIC ROTATING, STRATIFIED FLUIDS..OCEANS AND ATMOSPHERES

Stiffness - rotation

layering - buoyancy and geometry

fat bodies, thin sheets

textures - SeaWiFS ocean color video

AVHRR

energetics

solar source 1368 W m^{-2} => 342 W m^{-2} average solar radiation

flux, transformation, utilization, storage (ff) transportation

human utilization: 4×10^{20} j/yr,

IE + KE + PE α adiabatic perf gas

3DTurbulence: classical

vector tracer VORT α $D\boldsymbol{\omega}/Dt = (\boldsymbol{\omega}\cdot\nabla)\mathbf{u}$ tipping, bending of vortex lines

vector tracer cascade

energy dissipation $\varepsilon = \upsilon|\omega|^2$ plus boundary terms

stretching of conservable tracers…active, passive

stirring => mixing

vortex tube strength: α proof

topology of vortex lines: we need to see them Okhitani (U EA)

vorticity meters

hydrogen bubble visualization…MIT films

tornado vortex

rotational stiffnness

inertial waves , Taylor-Proudman columns video

internal wave eqn: α

waves & circ (linear): TC as low freq inertial wave

grav+Ω Kelvin waves …in gen'l edge modes arise from mixed b.c., two rest forces video

geostrophic adjustment

continuous stratification: N-venetian blind α

upper mixed layer

θ/S sorting…. compensation not univ Gregg, Ferrari

thermal wind…exact α

$\nabla \mathbf{p} \times \nabla \varrho$ solenoids, twisting horiz vorticity eqn… thermal wind imbalance forced by

fric,wind,convec

veloc spirals -- veering backing, heating

WBUC, 500mb/slp

add θ/S sorting

compensation is not universal..Gregg, Ferrari

results from general wave theory

rays geom. optics

sta phase or w.p.

•group vel Moiré

divergence of rays α

far field asymptotics: steady radn FT α MJL

impulsive generation (Dickinson Revs Geophys 1969)
(note rad'n condn = gradual switch-on or weak friction)
waveguide modes
rays vs modes energy flux.
Ocean : …do internal modes exist or does energy propagate downward and dissipate at depth?
constructing the wave pattern
Taylor column revisited
• refraction, dispersion Dk_i/Dt, Dx_i/Dt, ..
•WKBJ $p^{-1/4}\exp(i\int p^{1/2}\,dx)$ => wave action α
gen'l wave action $A = \xi_\alpha \cdot (u + \Omega \times \xi)$
why is it so general: RWS arg. flux of M = flux of E/c α
intro to form drag
ray example: grav waves on an adverse current. Shear and critical layers
trivial: look at undular bore KdV..only slightly nl

2. POTENTIAL VORTICITY, ROSSBY WAVES

Kelvin's theorem with rotation
Ertel/Rossby PV
QG PV
conservation, invertibility…………………Maxwell eqns atomic orbitals
cylind geos adj (fig) Hedstrom..
Prandtl ratio
Hidaka's Onions (fig)
Haynes-McIntyre eqn: PV locked to isentropic surfaces…mixed layers and PV
unnatural b.c. for PV (unless know MLD…)
boundary sheets
fpb, pbr, Schneider et al.
Eady prob: zero interior PV, sheets stripped into interior
non geostrophic PV: Elliasssen Sawyer eqn for symm circs
instability if PV < 0: PV = J(H,θ) where H= abs ang mom
…if density surfaces steeper than ang mom sfcs, unstable
mixing, convec along H surfaces
ageostrophic cases pull us away from geostrophic, hydrost, θ-wind balance
vorticity waves
inertial waves are vort waves (except for trivial inertial osc)
that's what holds them together: abs vortex lines bending, stretching
Cormac Ω wake
Rossby waves
DR: anisotropic, inverse, witch's hat
primitive vort arg suggests role of *vortex/PV rearrangement*
qbx runs
oceans:
Ocean-Green's function – 1 $\delta(x,y)\exp(-i\omega t)$ videos: GFDlab, altimeter-Chelton
Ocean-Green's function-2 β plume $\delta(x,y)$ do asymptotics carefully
western boundary by method of images
Ocean gyres: 2 layer wind-driven ocean Hallberg
RW set up, β plumes for compact PV forcing
boundary currents: active or passive? Modern numerical diagnosis Maximenko, Liu
atmospheres:
Atmosphere- Greens function-3 standing RW video
Lighthill blocking

3. INSTABILITY TO GEOS TURBULENCE - WAVES, JETS and GYRES

enstrophy cascade

contour stretching. dual cascade: in part due to local (in k) dynamics but globally (in k)

must be controlled by dissipation. Dissip of PV different from dissip of energy

spectra

hard-core vortices can resist the enstrophy cascade

rings from Kuroshio, GS, Meddies, LS eddies usually assoc with bc instab

jet-generation by random stirring video

PV rearrangement

importance of radiation

Welander's goldfish

Baroclinic instability as a pair of interacting Rossby waves Methven Hoskins

Haynes Scinocca Magnusdottir life cycles

stratified fluid…Phillips effect

PV staircases

jet stream waveguide

low lat critical layers reflecting/absorbing (Jung Rhines fig)

vertical structure: external mode α wave eqn

baroclinic life cycles

jet sharpening in classic BCI

barotropization

turbulent view: lateral expansion and barotropization pbr 77

still true?

downstream development Chang, Orlanski

dual cascade?? Thompson & Young

importance of energy sink: McWilliams: high resolution simulations

with free slip

mode-jumping as a product of barotropization

ocean gyres

Ocean- PV balance: sources and sinks (Breckenridge) Haynes/McIntyre, Marshall…

cold and warm subduction

rev of homog and ventilation

barotropization and form drag

Hallberg model: boundary PV injection

PV of gyres

Williams O'Dwyer bdry mixing, deep PV

boundary layers

boundary currents Ocean and Atmosphere

A lower bl

O upper mixed layer

Ferrari dual SGT model frontogenesis

Thomas: wind gen PV (by convec overturning: stronger than frontogenesis

in controlling PV, subduction bolus'). Elliassen-Sawyer equation

annular modes – storm tracks

Nakamura N Pacific

teleconnections—Pacific to Atlantic

ocean centers of action: Held: thermal versus orographic forcing

explosive cyclogenesis Reid, Hoskins, Bracegirdle

NAO, NAM, SAM EP analsysis: self-tuning waveguide

acceleration of the south polar vortex: due to human activity!

Limpasuvan, Hartmann, Lorenz

Atlantic storm track synoptics of storm tracks and ssw, vertical interaction

Greenland's effect on the storm track

model resolution: T1000 global simulations

between the meridional overturning circulation (MOC) and gyres: the ACC

wind stress and form drag

4.THE GLOBAL MOC: OVERTURNING CIRCULATIONS AND CLIMATE

the argument

Munk's abyssal recipes

Sandström's theorem

Paparella & Young: 'buoyancy driven MOC is non-turbulent'

fallacy of single energetic arguements

obviously mixing is required to lift the dense cold waters to the sfc

Gnanadesekin, Toggweiler, GFDL HIM-ACC

what is the MOC?

transport, transformation and exchange on the θ/S plane

the θ/S relation is the key descriptor of ocean buoyancy

and thermodynamics and halodynamics

what drives ocean / atmosphere thermodyamics?

meridional energy flux dry static $C_pT + gz \approx C_p\theta$

cumulus clouds over the Bering Sea: air-sea buoyancy flux: does the GS warm Europe,

does the Kuroshio warm Seattle?

two different air/sea flux maps: one for ocean, one for atmosphere

Bailey et al Clim Dyn 05

are climate models too sensitive to the atmosphere (Lab Sea)

where does the ocean upwell?

Nurser et al…Veronis effect

ACC/Southren Ocean Speer

convection in GFD

rotating convection.

mesoscale eddies and convective plumes

5. AN OCEANOGRAPHER'S EXPERIENCE IN TEACHING ABOUT THE GLOBAL ENVIRONMENT

We are well-prepared to do so: physics, chem., bio, geo

Arctic climate: polar amplification video

Arctic natives: Chukchi coast: Harald Sverdup

150,000 Inuit natives with a common language.

The first ethnologist of the Arctic, Knud Rasmussen

Lapland Scandanavia, Greenland, Canada, Alaska, Chukchi coast

Energy as an organizing theme for understanding the environment

Sun=>Earth=>climate and photosynthesis

human use of energy and its implications

the future of water

Gaia's revenge or the **Skeptical Environmentalist?**

6. SEMINAR

Exploring high-latitude ocean climate with Seagliders and satellites

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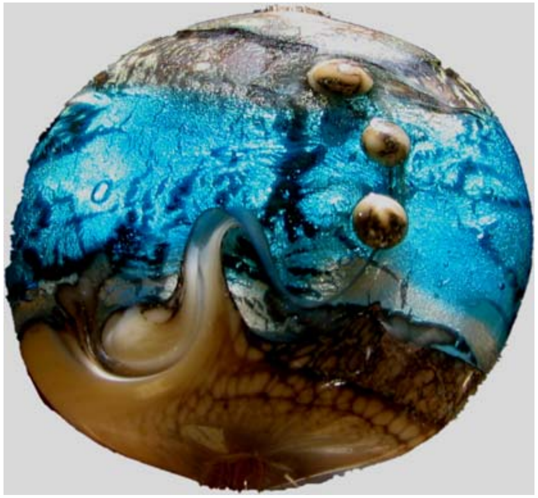


These lectures will address the dynamics of oceans and atmospheres, as seen through theory, laboratory simulation and field observation. We will look particularly at high latitudes and climate dynamics of the ocean circulation coupled to the atmospheric storm tracks. We will emphasize the dynamics that is difficult to represent in numerical circulation models. We will discuss properties of oceans and atmospheres that are both fundamental, unsolved questions of physics, and are also important, unsolved problems of global environmental change.

Lecture 1:

Is the ocean circulation important to global climate ? Does dense water drive the global conveyor circulation? Fundamental questions about oceans and atmospheres that are currently under debate.

The field theory for buoyancy and potential vorticit
Basic propagators: Rossby waves and geostrophic adjustment.
Potential vorticity: inversion and flux.

Lecture 2:

How do waves and eddies shape the general circulation, gyres and jet streams?
Almost invisible overturning circulations.
Lessons from Jupiter and Saturn.
The peculiar role of mountains, seamounts and continental-slope topography.

Lecture 3:

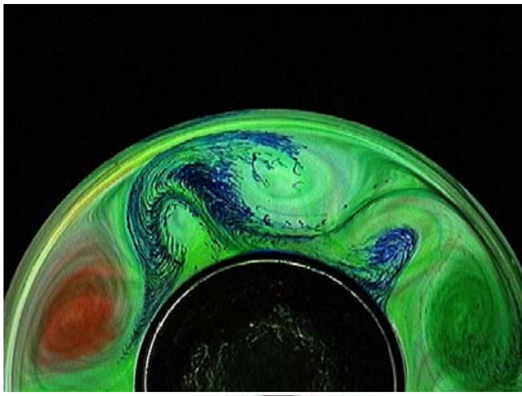
Dynamics of ocean gyres and their relation with the global conveyor circulation.
Water-mass transport, transformation and air-sea exchange of heat and fresh water.
Ocean overflows and their mixing.
Decadal trends in the global ocean circulation.

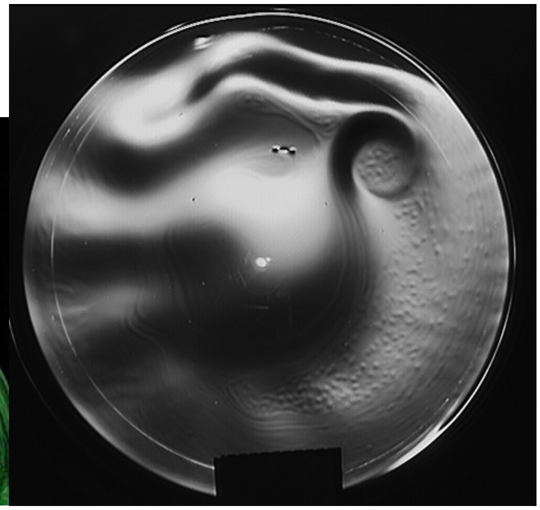
Lecture 4:

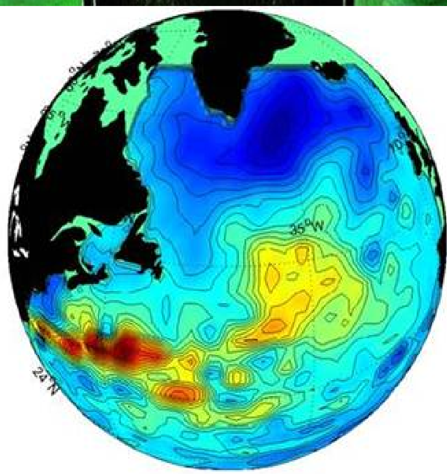
Heat, fresh-water, ice: convection in oceans and atmospheres and the texture of geophysical fluids.

Lecture 5:

Teaching young students about the global environment using the GFD laboratory: science meets energy and environment in the lives of Arctic natives



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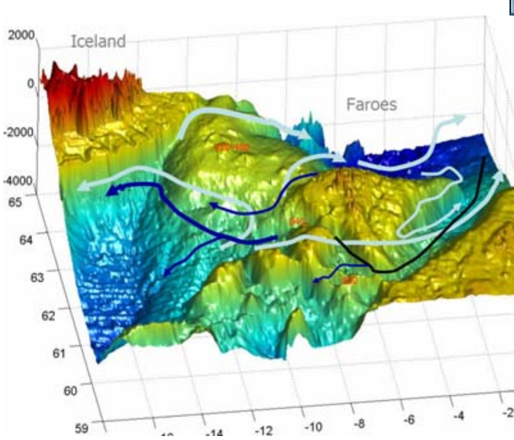
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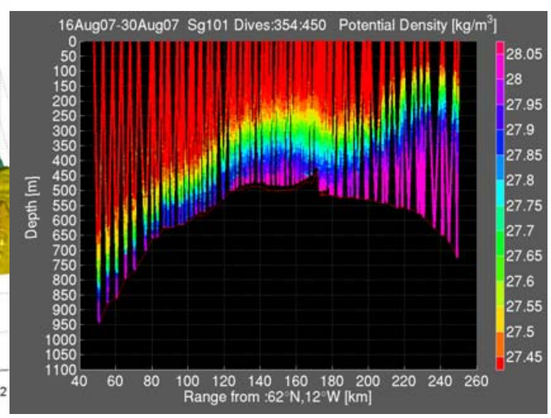
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