

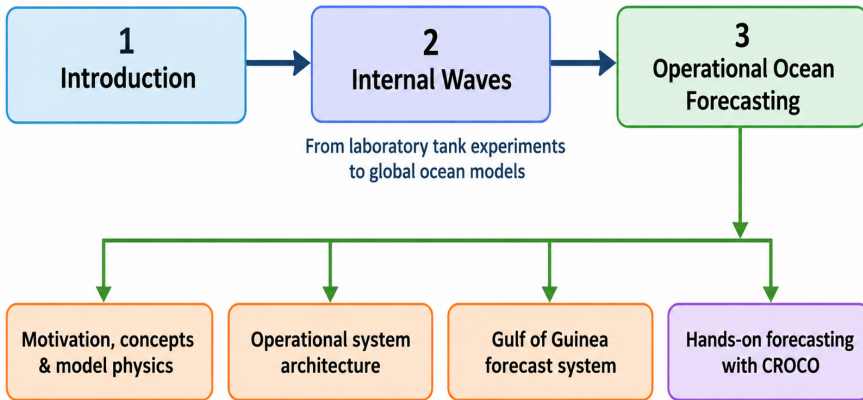
An Introduction to Operational Ocean Forecasting

Joseph K. Ansong
(jkansong@ug.edu.gh)

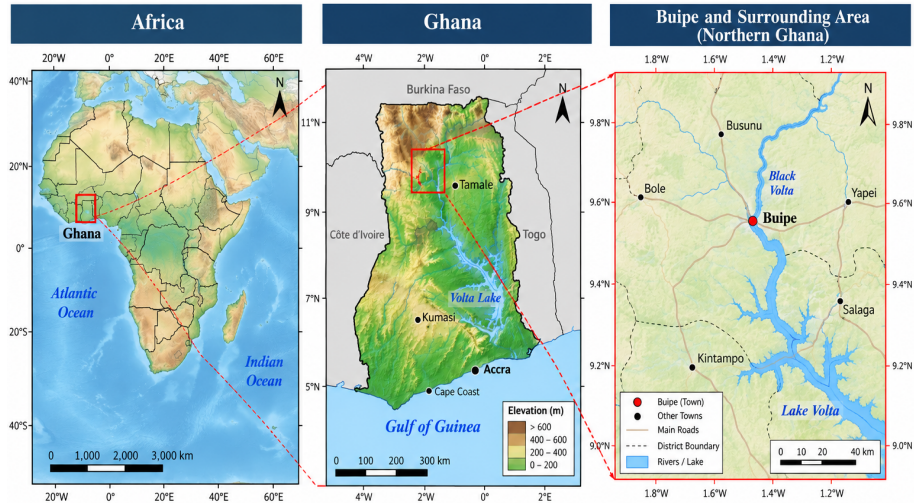
Department of Mathematics
University of Ghana

UNESCO/IOC-ODC Training Course on Ocean Dynamics and Ocean Models
1-11 September 2026, Qingdao, China
Host: The First Institute of Oceanography (FIO)

Outline



Introduction



Education and Training

University of Cape Coast (Ghana)

BSc. (Mathematics)

University of Twente (The Netherlands)

MSc. (Engineering Mathematics)

University of Alberta (Canada)

PhD (Applied Mathematics)

University of Michigan (USA)

Postdoctoral Fellow

Dr Joseph Kojo Ansong

Head of Department

Dear undergraduate and postgraduate students,

It is with great pleasure that I join with my colleagues in welcoming you to the Department of Mathematics at the University of Ghana. As the Head of the Department, I am honoured to lead a team of highly qualified faculty members and staff who are committed to providing you with an exceptional educational experience.

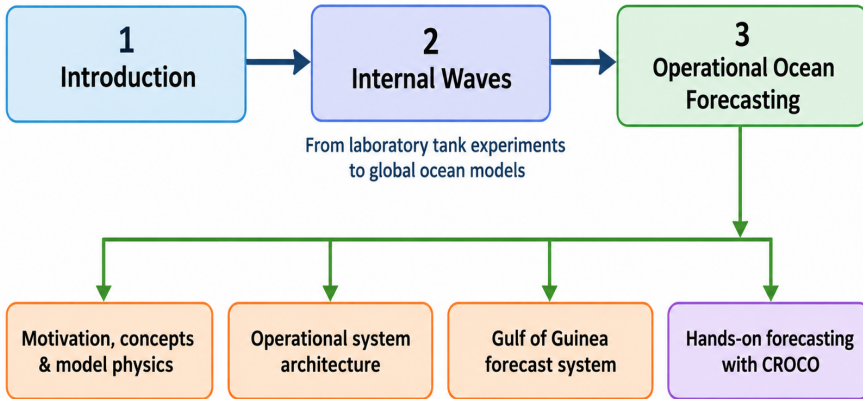
Whether you are an undergraduate or a postgraduate student, you have made an excellent choice by choosing to study mathematics at the oldest and premier University of Ghana. Our programme is designed to equip you with the necessary skills and knowledge to succeed in your future careers in academic or industrial work/research careers.

Our Department offers a diverse range of courses and research opportunities, with a particular focus on both pure and applied mathematics. We are proud to have a reputation for excellence in teaching and research, and we are dedicated to providing you with a stimulating and innovative learning environment that



<https://www.ug.edu.gh/mathematics/about/hod-message>

Outline



Internal Waves: From Laboratory Tank Experiments to Global Ocean Models

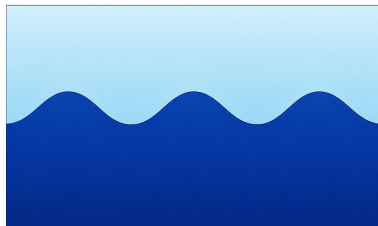
1. Introduction & Motivation
2. Internal waves generated in the laboratory
3. Internal tides in global ocean models:
 - ① Where do internal internal tides dissipate their energy?
 - ② How reliable are tidal energy fluxes in HYCOM?
4. Building scientific capacity in West Africa

INTERNAL GRAVITY WAVES

Introduction & Motivation

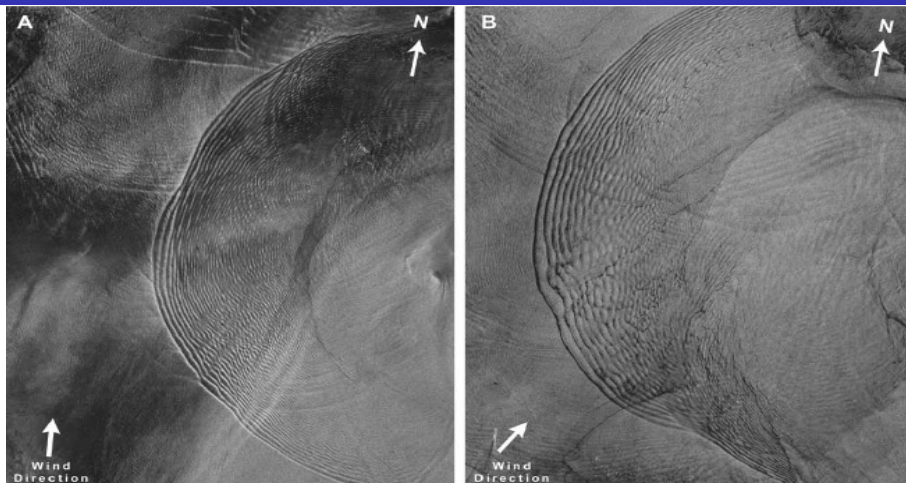


- Internal gravity waves exist any time you have a lighter fluid above a heavier fluid with a mechanism to set them in motion.



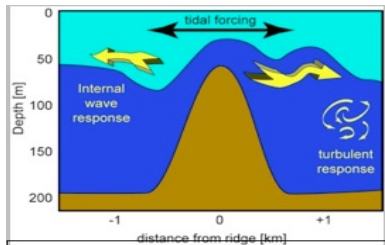
- They have much larger amplitudes than waves we see on beaches (surface waves). This is because the density differences within the ocean are much smaller than on the surface.
- Internal waves with tidal frequency are called internal tides.

Introduction: internal gravity waves in the ocean

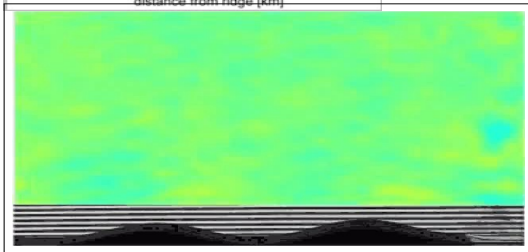


Satellite image of internal waves over the Gulf of Maine west of Cape Cod on June 23, 2008 [Jackson et. al. (2013); Oceanography]

Introduction: generation mechanisms of internal waves



Generation by stratified flow over topographic bumps.
(Prof. Jonathan Nash)

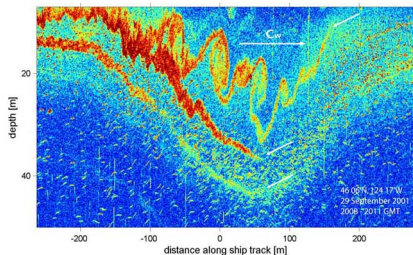


Generation in a laboratory tank by sinusoidal hills
(Prof. Bruce Sutherland)

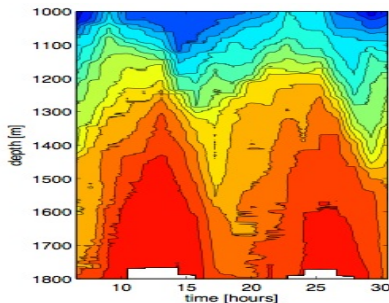
Play/Pause

Introduction: why do we care?

- Breaking internal gravity waves (IGW) mix the ocean; acting as a nutrient-supplier and also affect ocean's circulation.
- The spatial variability of mixing is important for accurate climate modeling.
- The Navy care about internal gravity waves; submarines don't want to get caught up in IGW.

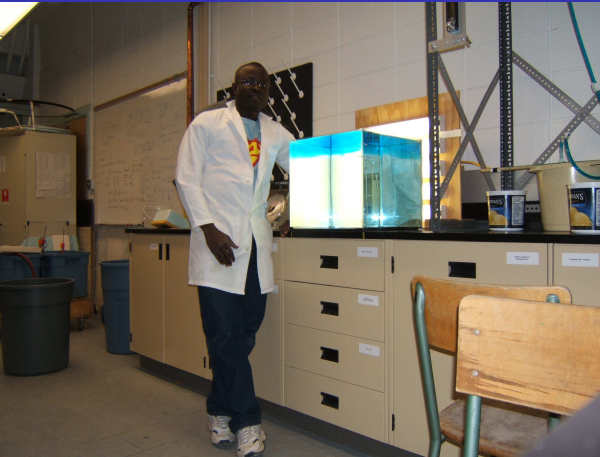


Courtesy: Jim Moum



Jonathan Nash (~600m tall; Luzon strait)

Summary of PhD research



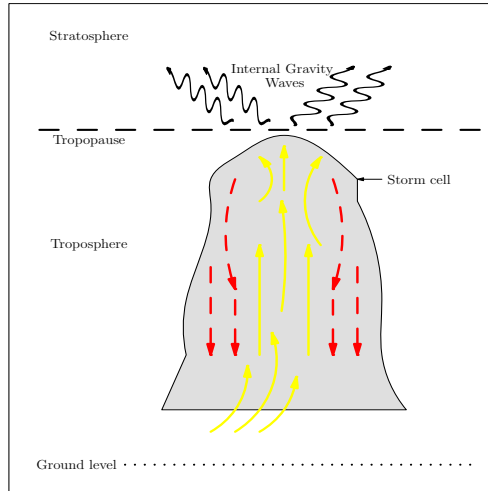
Sutherland et al. (2012),
Physics of Fluids, vol. 24



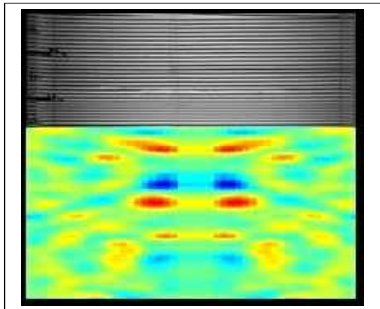
- Ansong et al. (2008), JFM, vol. 595
- Ansong & Sutherland (2010), JFM, vol. 648
- Ansong et al. (2011), JFM, vol. 689

Motivation: generation of atmospheric/oceanic waves by storms

- Generation by convective forcing:
- **mechanical oscillator effect**
- Vertical oscillations of updrafts about neutral buoyancy level generate waves



Internal gravity waves generated by plumes

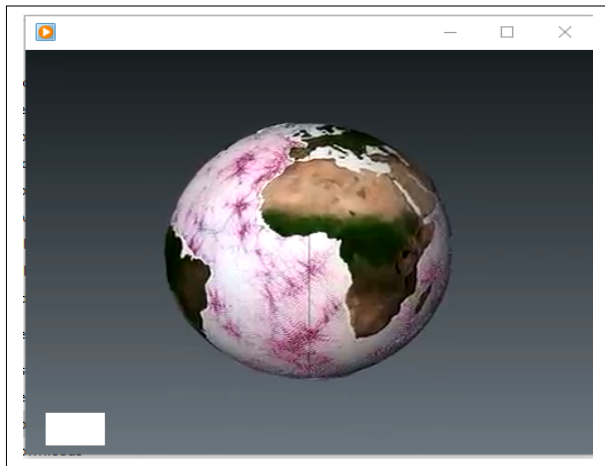
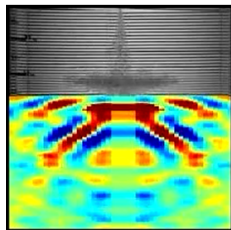


- Axisymmetric waves...
- Waves propagate down as conical beams
- The upshot:
 - amplitude of waves linearly related to penetration depth
 - about 4% of energy of plume (at interface) goes into waves

Play/Pause

Ansong & Sutherland (2010),
JFM, vol. 648

From laboratory tank experiments to global ocean models



Play/Pause

Courtesy: Max-Planck Institute for ocean modeling

Motivation: the big picture

- Vertical mixing by breaking internal waves has a strong influence on the stratification and general circulation in the ocean.
- The general circulation in turn determines the distribution of heat and vital nutrients and gases around the globe.
- General circulation models (GCMs) used for climate research often use over-simplified parameterizations to capture the impact of small scale processes like breaking internal waves because of limited resolution.
- GCMs do not generally include most of the spatial variability of mixing patterns.

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- GCMs do not generally include most of the spatial variability of mixing patterns.
- Formation of the Climate Process Team (CPT)

Climate Process Team:

improving representations of internal-wave driven mixing in global ocean models

<http://www.pord.ucsd.edu/~jen/cpt/>

“...created to develop, test, and implement dynamically appropriate parameterizations for diapycnal mixing due to internal-wave breaking for use in global climate models.”

- Dr. Jennifer MacKinnon



Rob Pinkel (SIO)
Kurt Polzin (WHOI)
Harper Simmons (UAF)
Lou St. Laurent (WHOI)

The CPT Team

Official CPT Post-docs

Joseph Ansong (U Michigan)
Angelique Melet (GFDL)
Oliver Sun (WHOI)
Amy Waterhouse (SIO)

PIs

Matthew Alford (UW/APL)
Brian Arbic (U Michigan)
Frank Bryan (NCAR)
Eric Chassignet (FSU)
Gokhan Danabasoglu (NCAR)
Peter Gent (NCAR)
Steve Griffies (GFDL)
Robert Hallberg (GFDL)
Steve Jayne (WHOI)
Markus Jochum (U. Copenhagen)
Jody Klymak (UVic)
Eric Kunze (UW/APL)
William Large (NCAR)
Sonya Legg (GFDL/Princeton)
Jennifer MacKinnon (SIO) **
Jonathan Nash (OSU)

CLIMATE PROCESS TEAM ON INTERNAL WAVE–DRIVEN OCEAN MIXING

JENNIFER A. MACKINNON, ZHONGXIANG ZHAO, CAITLIN B. WHALEN, AMY F. WATERHOUSE,
DAVID S. TROSSMAN, OLIVER M. SUN, LOUIS C. ST. LAURENT, HARPER L. SIMMONS, KURT POLZIN,
ROBERT PINKEL, ANDREW PICKERING, NANCY J. NORTON, JONATHAN D. NASH, RUTH MUSGRAVE,
LYNNE M. MERCHANT, ANGELIQUE V. MELET, BENJAMIN MATER, SONYA LEGG, WILLIAM G. LARGE, ERIC KUNZE,
JODY M. KLYMAK, MARKUS JOCHUM, STEVEN R. JAYNE, ROBERT W. HALLBERG, STEPHEN M. GRIFFIES,
STEVE DIGGS, GOKHAN DANABASOGLU, ERIC P. CHASSIGNET, MAARTEN C. BUIJSMAN, FRANK O. BRYAN,
BRUCE P. BRIEGLEB, ANDREW BARNA, BRIAN K. ARBIC, JOSEPH K. ANSONG, AND MATTHEW H. ALFORD

The study summarizes recent advances in our understanding of internal wave–driven turbulent mixing in the ocean interior and introduces new parameterizations for global climate ocean models and their climate impacts.

MacKinnon et. al. (2017)[Bulletin of the American Meteorological Society]

Research Questions

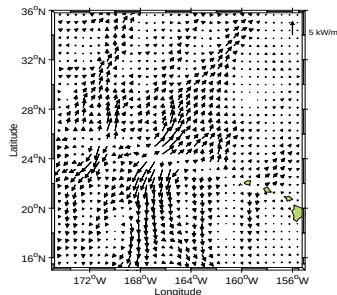
Some important questions for the physical oceanography community:

- Where do the low-mode internal waves seen crossing ocean basins dissipate?
- What are the dominant processes?
 - dissipation over topographic features?
 - dissipation over continental slopes?
 - wave-wave interactions?
(e.g. PSI= Parametric Subharmonic Instability)
- Is the dissipation primarily in the deep or upper ocean?
 - The geography of dissipation is very important for the large scale circulation in the ocean.

Summary of Some Research Projects

Use a high resolution global ocean model, HYCOM (www.hycom.org), to study

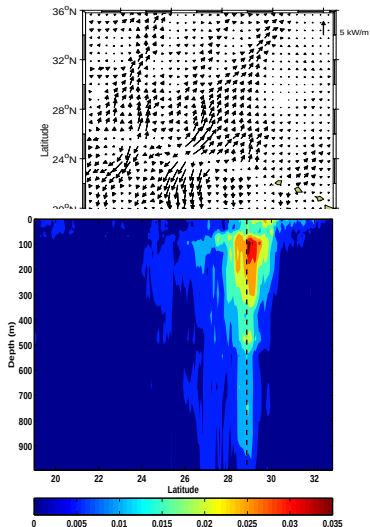
- Tidal energy fluxes:
 - Compare to observed energy fluxes
 - [Ansong et. al. \(2017\), JGR-Oceans](#)



Summary of Some Research Projects

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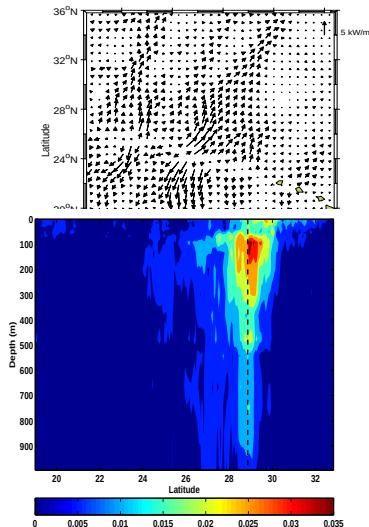
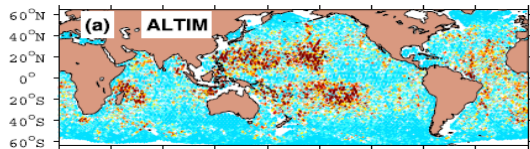
- Tidal energy fluxes:
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 - [Ansong et. al. \(2017\)](#), JGR-Oceans
- A wave-wave interaction mechanism (PSI)
 - Find PSI mostly along **critical latitudes**
 - [Ansong et. al. \(2018\)](#), JPO



Summary of Some Research Projects

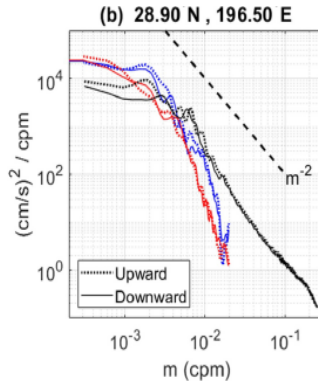
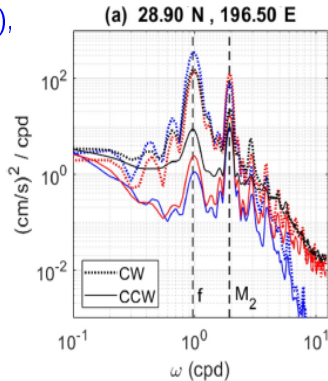
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- A wave-wave interaction mechanism (PSI)
 - Find PSI mostly along **critical latitudes**
 - [Ansong et. al. \(2018\)](#), JPO
- Where are the internal tides dissipating?
 - [Ansong et. al. \(2015\)](#), JGR-Oceans



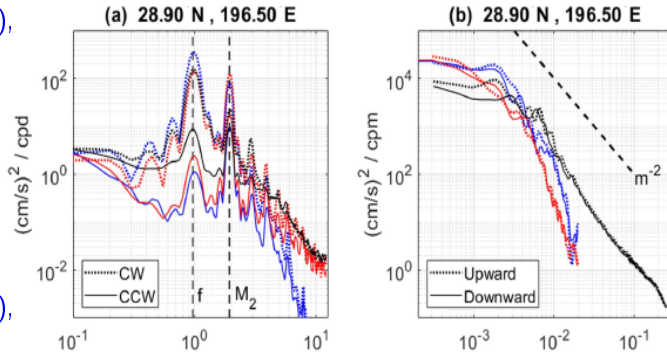
Summary of Some Research Projects

Ansong et. al. (2024),
JGR-Oceans



Summary of Some Research Projects

Ansong et. al. (2024),
JGR-Oceans



Ansong et. al. (2026),
[Under Review]

The accuracy of barotropic and baroclinic tides in global non-assimilative ocean general circulation models

Joseph K. Ansong^{1,2}, Brian K. Arbic², Romain Bourdalle-Badié³, Clément Bricaud³, Jérôme Chanut³, Dimitris Menemenlis⁴, Richard D. Ray⁵, Michael Schindelegger⁶, Alan J. Wallcraft⁷, He Wang^{2,8,9}, Alistair J. Adcroft¹⁰, Frédéric Briol¹¹, Maarten C. Buijsman¹², Loren Carrère¹¹, Eric P. Chassignet⁷, Gerald Dibarbouré¹³, Robert W. Hallberg⁸, Christopher N. Hill¹⁴, Ariane Koch-Larrouy¹⁵, Florent Lyard¹⁵, Matthew R. Mazloff¹⁶, An T. Nguyen¹⁷, Nicolas Picot¹³, Rui M. Ponte¹⁸, and Jay F. Shriver¹⁹

Parametric Subharmonic Instability (PSI) in HYCOM

What's the fate of mode 1 (large scale) internal waves that radiate away?



- break on topographic features, break on continental shelves, wave-wave interactions, ...
[Johnston et al (2003), Legg (2013), Kelly et al (2013), ...]
- **PSI (Parametric Subharmonic Instability) is a culprit**

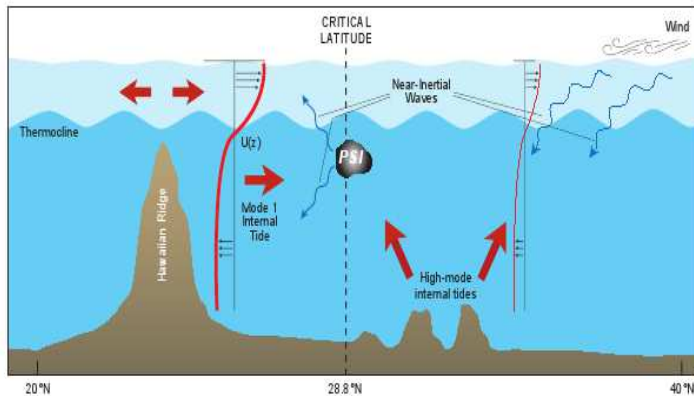
$$\omega_0 = \omega_1 + \omega_2, \quad \omega_1, \omega_2 \approx \omega_0/2$$

$(\omega_1, \omega_2) \rightarrow$ small vertical scales $\implies$ Mixing

McComas & Bretherton (1977), Hibiya et al.(1998, 2002), MacKinnon & Winters (2005), MacKinnon et al. (2011, 2012), Furuichi et al.(2005), Alford(2008), Hazewinkel & Winters (2011), Simmons(2008), Sun (2010), Sun & Pinkel (2013), ...

Motivation

e.g. $M_2/2 = f = 2\Omega \sin \phi$, $\phi = \sin^{-1}(M_2/4\Omega) \Rightarrow \phi \approx 28.8^\circ$



From:
Dr. Jennifer
MacKinnon

FIG. 10. Cartoon of PSI in the North Pacific. A combination of internal tides from remote (mode 1) and local (higher mode) generation leads to generation of near-inertial waves through PSI near a critical latitude of 28.8°N. These waves propagate both upwards and downwards as they travel equatorwards. At other latitudes, high-mode near-inertial internal waves are generally wind-generated and are constrained to propagate downwards from the ocean surface.

$x(t)$ = zero-mean signal

X = complex Fourier transform of $x(t)$

Bispectrum (Kim & Powers, 1979)

$$B(\omega_1, \omega_2) = E[X(\omega_1)X(\omega_2)X^*(\omega_1 + \omega_2)]$$

Implications: $B(\omega_1, \omega_2) = 0$ unless

- ω_1, ω_2 and $\omega_3 = \omega_1 + \omega_2$ are present
- phase coherence is present in waves

Bicoherence: normalized bispectrum

A quantitative measure is **bicoherence**:

$$b^2(k, l) = \frac{|B(\omega_1, \omega_2)|^2}{E[|X_{\omega_1} X_{\omega_2}|^2] E[|X_{\omega_1 + \omega_2}|^2]}$$

with $0 \leq b(\omega_1, \omega_2) \leq 1$.

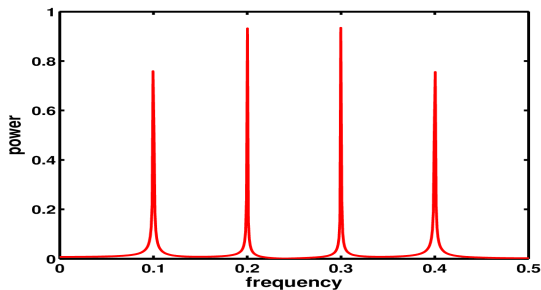
Significance levels: of b (Elgar & Guza, 1988)

$$95\% \equiv \sqrt{6/n_{dof}}; \quad 99\% \equiv \sqrt{9/n_{dof}}$$

where n_{dof} = number of degrees of freedom

(Carter & Gregg 2006, Sun & Pinkel 2010, MacKinnon et al. 2011)

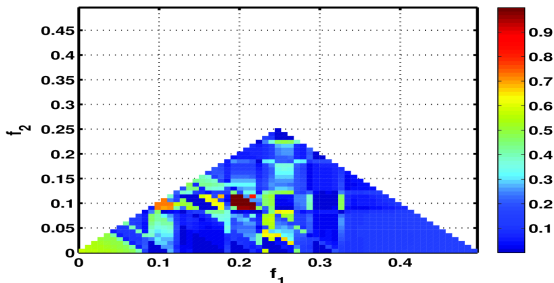
Illustrative Example



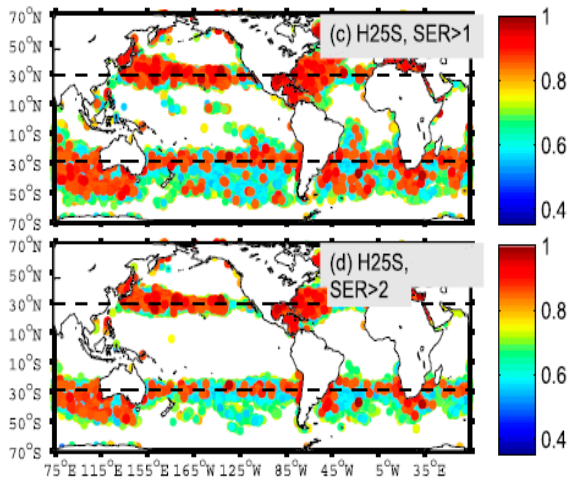
- $y = \cos(2\pi f_1 t + \phi_1) + \cos(2\pi f_2 t + \phi_2) + \cos(2\pi f_3 t + \phi_3) + \cos(2\pi f_4 t + \phi_4)$

- $f_1 + f_2 = f_3 \quad \phi_1 + \phi_2 = \phi_3$

- $f_1 = 0.2, f_2 = 0.1, f_4 = 0.4$



Bicoherence Results



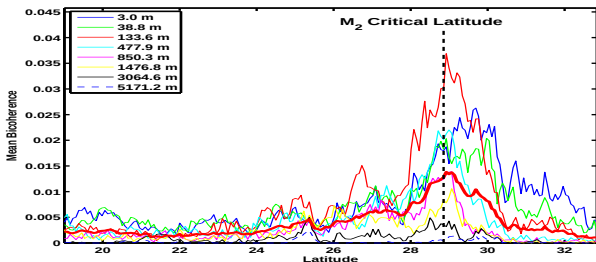
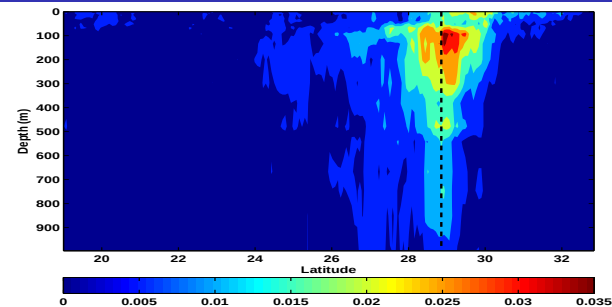
Semidiurnal tides

Significant bicoherence values localized around critical latitudes.

Subharmonic Energy Ratio (SER) is used to eliminate weaker signals.

FIG. 8. Global distribution of vertically averaged bicoherence for (a) HYCOM12S (SER > 1), (b) HYCOM12S (SER > 2), (c) HYCOM25S (SER > 1), and (d) HYCOM25S (SER > 2). The plots display significant bicoherence values at the 95% significance level ($b_{95\%} = 0.35$ for HYCOM12S and 0.50 for HYCOM25S), and every sixth grid point is plotted.

Depth vs Zonally-averaged bicoherence



Semidiurnals

Variation in depth of
zonally-averaged bicoherence

Only showing 0 – 1000m

Surface intensified

[Hazewinkel & Winters, 2011]

Highest bicoherences
centered on M_2 Critical
Latitude

Intensity falls around $\sim 3^\circ$

[Furuichi et al. 2005]

Rates of energy transfer...

QUESTION: How much energy flux $\rightarrow$ subharmonics?

CHALLENGE:

- How to separate subharmonics & Wind-generated NIO...

Following McKinnon et al (2013):

- Rate of energy transfer to 'daughter' waves:

$$E_t = -\frac{3}{2}ik_0 U_1^* U_2^* u_0 e^{2\theta_0 i} + c.c \quad (1)$$

$U^* = (u + iv)^*$ and (u, v) = East-North velocities

θ_0 = horizontal propagation direction of tide.

Compute (1) at locations of significant bicoherence...

Global **distribution of PSI** in high resolution HYCOM show

- PSI around critical latitude (CL) of tides via bicoherence calculations
- Intense semi-diurnal PSI in upper ocean [Hazewinkel & Winters 2011]
- Intensity falls within 3° of CL [Furuichi et al. (2005)]
- Estimates of energy flux into subharmonics around Hawaii $O(0.4 - 23 \%)$
[consistent with IWAP estimates around Hawai'i: $O(10 - 20 \%)$]

Global **distribution of PSI** in high resolution HYCOM show

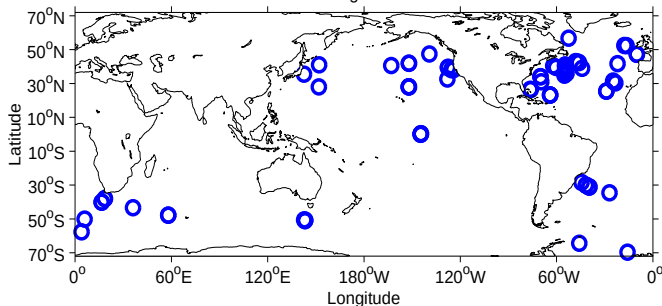
- Energy transfers in a few patchy spots around CL and along wave beams
- Globally integrated rates are very small compared to net conversion...

Comparing modeled tidal energy fluxes to observations

Comparison of modeled internal tide energy fluxes to observations in HYCOM

Comparing modeled tidal energy fluxes to observations

Mooring locations



Mooring data

From 78 locations...

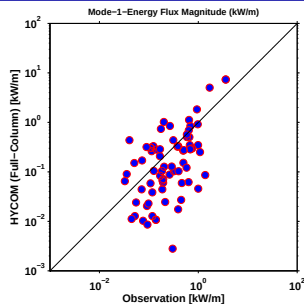
(Moored instruments
sampled at few vertical
locations)

Alford & Zhao (2007)

Will only show semidiurnal, mode 1 results

- Full-column HYCOM vs observed magnitude of fluxes
- Subsampled HYCOM vs observed magnitude of fluxes
- Global map of fluxes

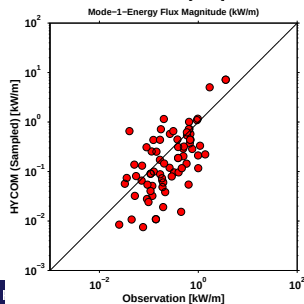
HYCOM vs Observations: Mode 1



Full-column fluxes

Correlation is good ~ 0.88 , but...

HYCOM fluxes are generally weaker.

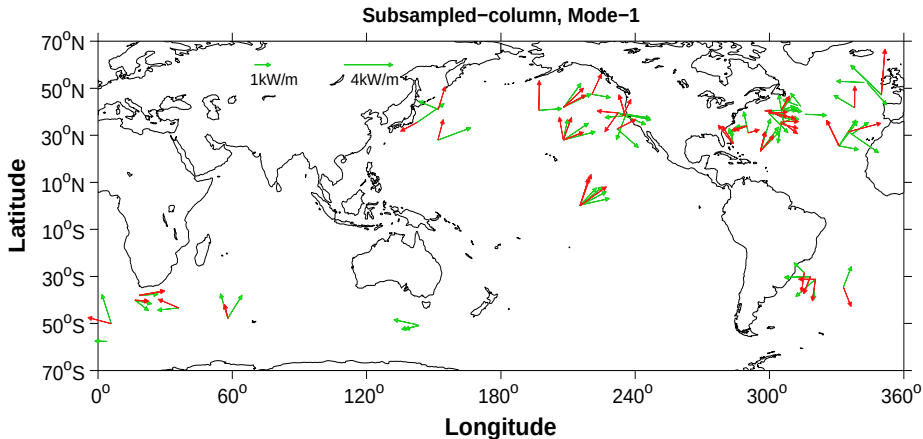


Subsampled fluxes

Correlation is good ~ 0.89 , but...

HYCOM fluxes are generally weaker.

HYCOM vs Observations: Mode 1



- Averaged over all locations, HYCOM agrees to within a factor of about two with observed fluxes.
- New simulations with longer time series records,...Draft paper ready

Where are the tides dissipating?

What's the fate of mode 1 (large scale) waves that radiate away?



Hypothesis:

- cascade to turbulence at source
(Legg & Klymak 2008; Buijsman et al. 2012)
- scatter off bottom topography (Dunphy & Lamb 2014; Kerry et al. 2014)
- wave-wave interactions (Muller et al. 1986; Eden & Olbers 2012)
- break on remote continental shelves (Nash et al. 2004; Kelly et al. 2013)

NOTE: These scenarios manifest as a drag on internal tides

Test a couple scenarios...

Method & Wave Drag Scenarios

By comparing HYCOM tides to altimeter observations, we can determine which drag scenarios are plausible and which are not.

We will:

- apply it on the total bottom flow (“Bottom wave drag”)
- apply it on only the barotropic (depth-averaged) component (“Barotropic wave drag”)
- remove the wave drag
- increase the bottom drag along the continental shelves
- apply it in the upper ocean to mimic wave-wave interactions (to be done with a simpler model from GFDL-Princeton)

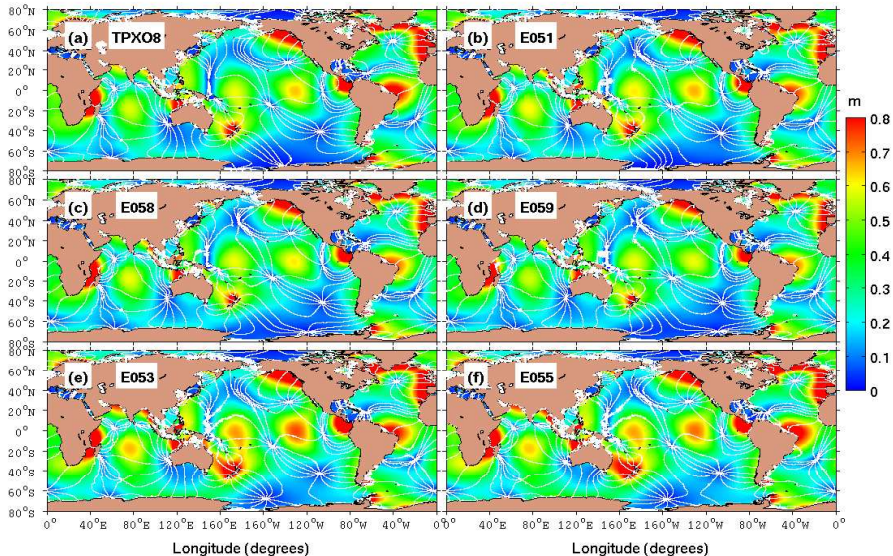
Wave Drag Scenarios

Table 1. Description of the Different Simulations and the Strength of the Applied Wave Drag and Quadratic Bottom Friction^a

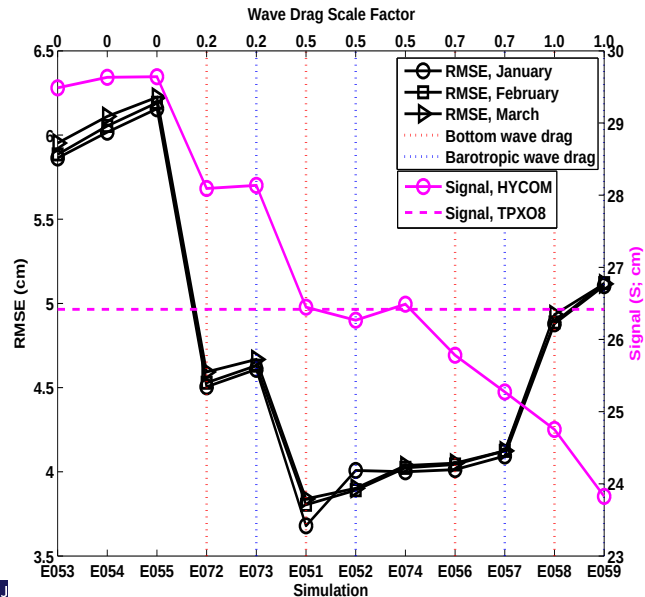
Simulation	Description	Drag Scale Factor
E053	No-wave drag	0.0
E054	Increased bottom friction ($\times 25$) along shelves	0.0
E055	Increased bottom friction ($\times 100$) along shelves	0.0
E072	Wave drag on bottom flow	0.2
E073	Wave drag on barotropic flow	0.2
E051	Wave drag on bottom flow	0.5
E052	Wave drag on barotropic flow	0.5
E074	Wave drag on barotropic flow and increased bottom friction ($\times 100$) along shelves	0.5
E056	Wave drag on bottom flow	0.7
E057	Wave drag on barotropic flow	0.7
E058	Wave drag on bottom flow	1.0
E059	Wave drag on barotropic flow	1.0

^aIn E054, E055, and E074, the bottom friction (C_d) along the shelves (depths < 2500 m) is increased by about 25 and 100 times, respectively, above the value in the deep ocean ($C_d = 0.0025$) (see text for additional explanation).

HYCOM barotropic tides vs TPX08



HYCOM barotropic tides vs TPX08



RMSE=

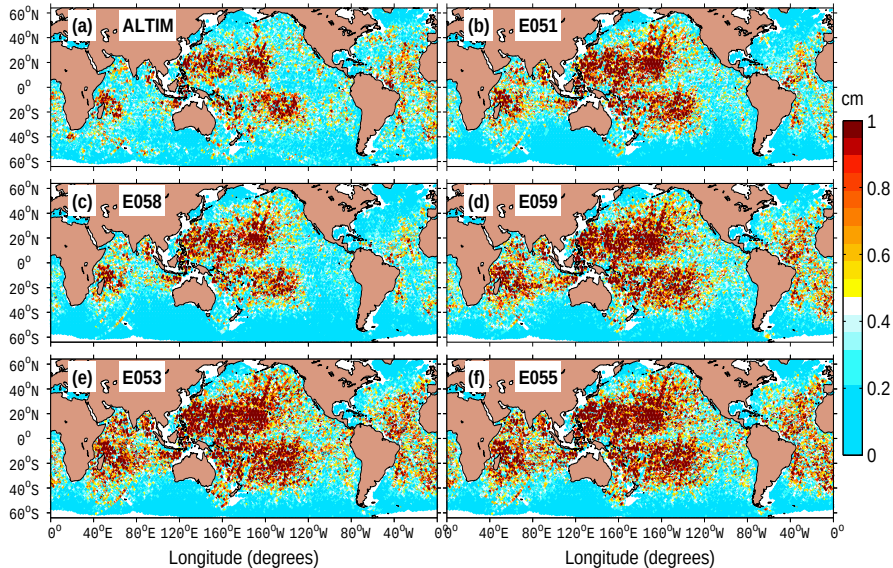
$$\sqrt{\frac{\int \int \langle [\eta_m(t) - \eta_0(t)]^2 \rangle dA}{\int \int dA}}$$

Signal=

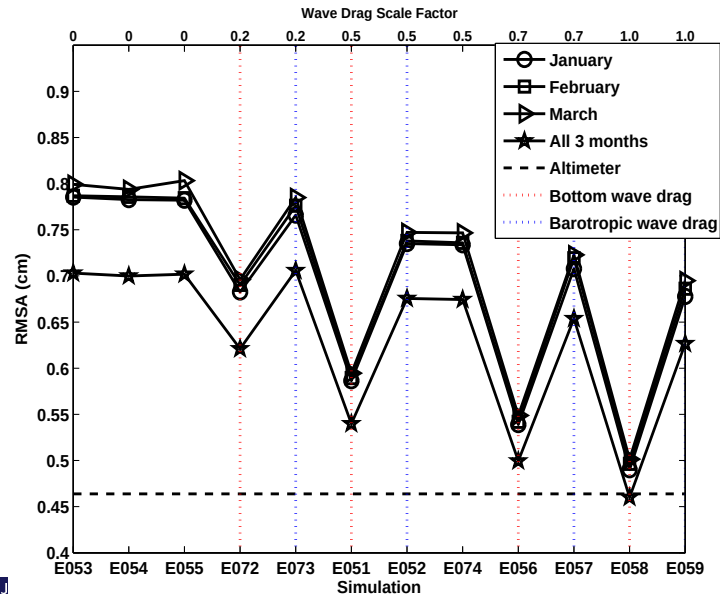
$$\sqrt{\frac{\int \int A_m^2 dA}{\int \int dA}}$$

- Bottom wave drag better than Barotropic wave drag
- No wave drag is worst
- Minimal monthly variance

HYCOM Internal tides vs ALTIMETER



HYCOM Internal tides vs ALTIMETER



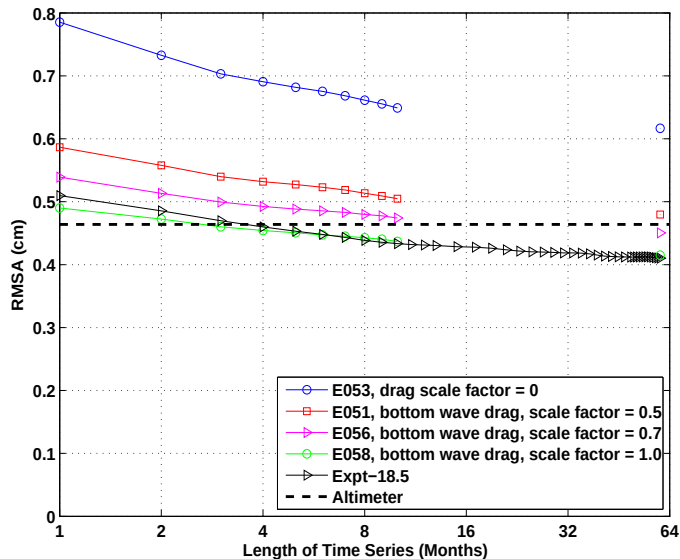
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Barotropic wave
drag

No wave drag is
worst

Minimal monthly
variance

3-months analysis
gives better results

HYCOM Internal tides vs ALTIMETER



Internal tide amplitudes
require ~ 4 years to
converge!

Duration of model
output plus damping
strength affects
comparison to altimetry.

Summary & Conclusions

Simulations were conducted in a high resolution global ocean circulation model (HYCOM) to examine the plausibility of various limiting cases of damping scenarios. We found that

- application of a damping scheme on the total bottom flow resulted in the most accurate barotropic and baroclinic tides.
- all other scenarios which do not utilize a bottom wave drag resulted in more energy barotropic and baroclinic tides that propagate too far from their generation sources.
- the duration of model output as well as the damping strength affects comparison to altimeter. – internal tides require about 3 – 4 years to converge!

Could the problem be coming from HYCOM? Let's investigate...

Importance of damping in many hydrodynamical models

We now consider realistic global simulations of several hydrodynamical models:

- **HYCOM** –Hybrid Coordinate Ocean Model ($1/12^\circ$)
- **MITgcm** – Massachussettes Institute of Technology general circulation Model ($1/12^\circ$ & $1/48^\circ$)
- **NEMO** – Nucleus for European Modelling of the Ocean ($1/12^\circ$)
- **MOM6** – Modular Ocean Model Version 6 ($1/12^\circ$)

Apart from HYCOM and MOM6, these other models have no explicit damping mechanism, and they have different numerical implementations compared to HYCOM.

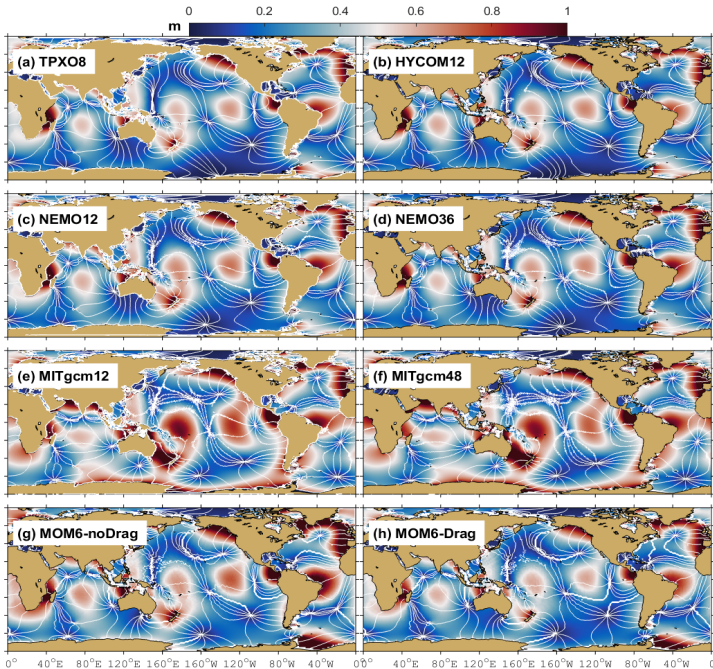
Importance of damping in many hydrodynamical models

QUESTIONS:

- Are the barotropic & baroclinic tides affected in these other models without extra explicit damping?
- Does the length of model output affect the comparison to satellite altimetry, as in HYCOM?

DISCUSSION:

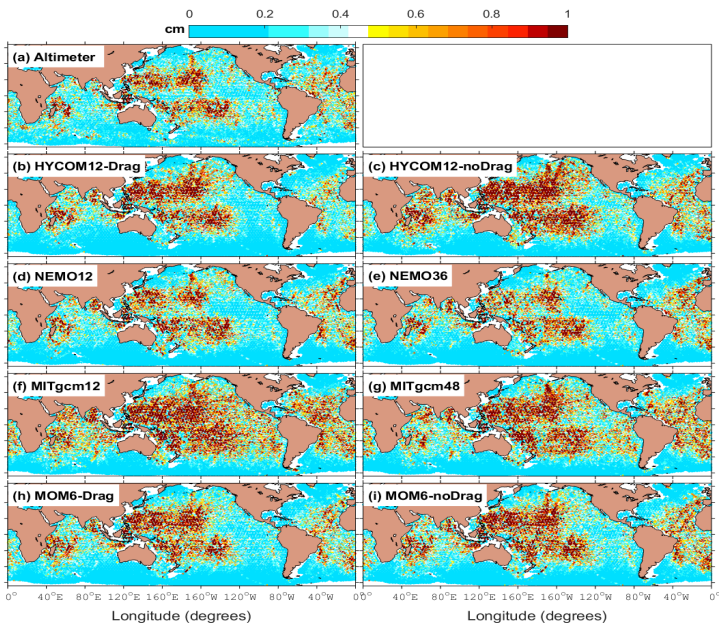
- Discussion of some mishaps in the implementation of the tidal forcing in this particular MITgcm runs that affect the accuracies of the modeled tides. We suggest a mitigating correction to the tidal output before the “next big run”.



Barotropic tides from five global simulations compared to TPX08.

HYCOM (with wave drag) and NEMO (no explicit damping) compare well to TPX08. Why is NEMO different?

Other simulations have more energetic barotropic tides.

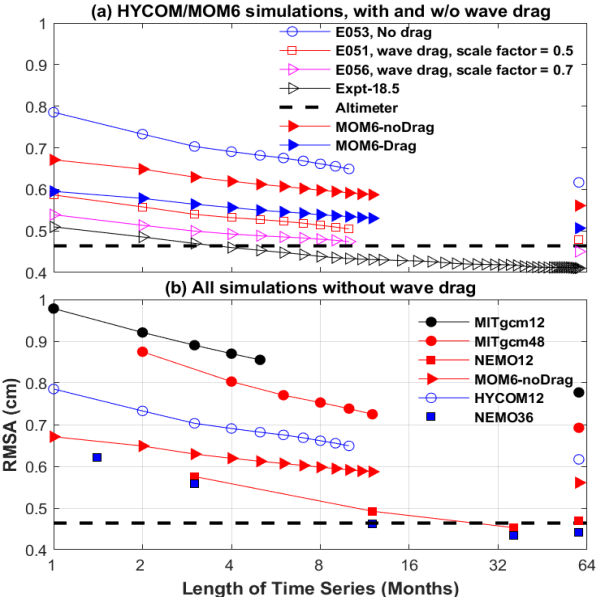


Modeled baroclinic tides vs.
one from along-track altimeter.

HYCOM (with wave drag) and
NEMO (no explicit damping)
compare well to altimeter
internal tides.

Others are more energetic,
similar to HYCOM without
wave drag (*Ansong et al.*
2015).

Importance of model output duration: Baroclinic Tides



Results from $1/12^\circ$
HYCOM (Ansong et al.
2015)

Output from other global
models, besides HYCOM,
also show importance of
model output duration in
comparison to altimeter.

Why the large amplitudes in
 $1/48^\circ$ MITgcm?

Why the large amplitudes in this MITgcm simulations?

The momentum equation intended to be solved is

$$\frac{d\mathbf{u}}{dt} + OT = -g\nabla(\eta - \eta_{EQ} - \eta_{SAL})$$

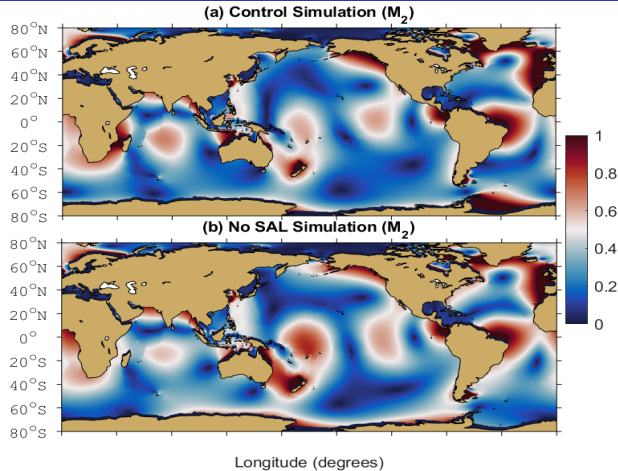
where $\mathbf{u}$ =horizontal velocity, OT =other terms in momentum equation, g =gravitational acceleration, η =perturbation sea surface height, η_{EQ} =equilibrium tide, and η_{SAL} =self-attraction and loading term (Hendershott 1972; Ray 1998).

The intent was to apply a “scalar approximation” such that $\eta_{SAL} = 0.1121 \times \eta$. Due to some miscommunication amongst the implementers, what was actually solved was

$$\frac{d\mathbf{u}}{dt} + OT = -g\nabla(\eta - 1.1121\eta_{EQ}).$$

Astronomical tidal forcing was inadvertently too large by a factor of 1.1121, and the SAL term was mistakenly omitted.

Estimate of impact of mistakes in MITgcm simulations



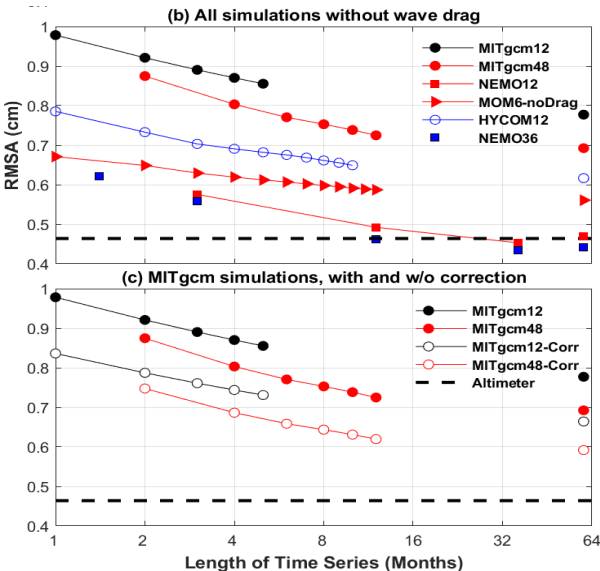
Results from a shallow-water
barotropic tide model
(*Schindelegger et al. 2018*)

“No-SAL” simulation
qualitatively captures spatial
distribution of amplitudes in
barotropic MITgcm runs.

$$\frac{KE_{\text{no-SAL}}}{KE_{\text{control}}} = 1.44$$

Upshot: Amplitudes of MITgcm internal tides could be reduced by an
estimated correction factor of $\sqrt{1.44} = 1.20$

Importance of model output duration: Baroclinic Tides

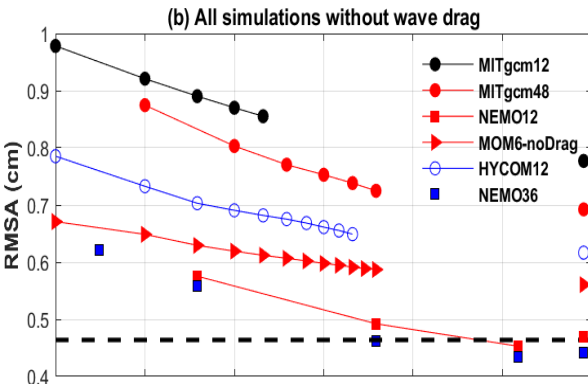


Results from all simulations without wave drag (or any extra explicit damping).

MITgcm ($1/48^\circ$) gets closer to observed value after dividing by mitigating correction factor.

Recent global MITgcm runs have effected the correction.

More interesting questions...

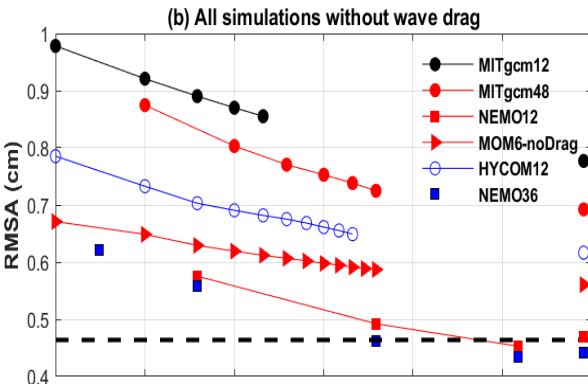


Why the attenuation in energy with length of time series?

...It's not due to model spin-up! Tests done with NEMO...

Hypothesis: "...dependence on the details of sea level spectra in the tidal bands, particularly the magnitudes and shapes of tidal cusps, and on the inherent spectral resolution of each time series."-Richard Ray

More interesting questions...



Does the attenuation in energy vary in space?

YES!

Maarten Buijsman has submitted a paper where he looks at the spatial variability in the variance decay in HYCOM (*Buijsman et al., 2020*).

Summary & Conclusions

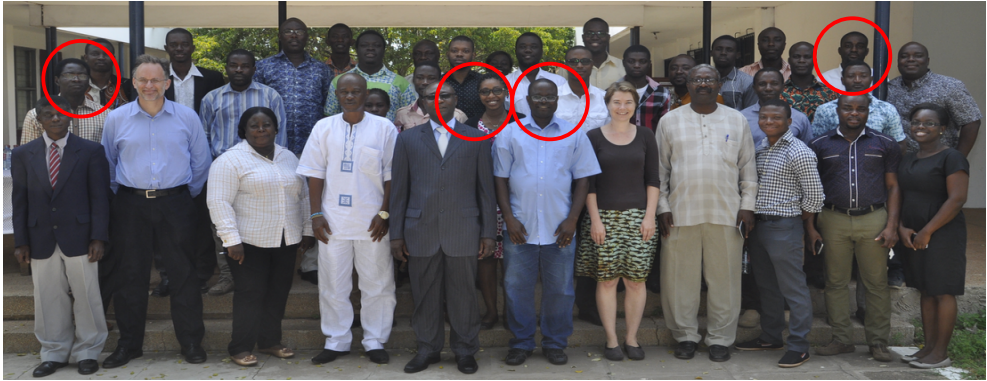
- In general, models without a wave drag results in internal tides that are too large and travel too far from their sources. It is important to insert some damping mechanism to obtain better agreement with altimetry.
- Record duration strongly affects the comparison of modeled internal tides to observations, as in *Ansong et al. 2015*. Needs further investigation to unravel the reasons for this.
- These particular MITgcm runs (LLC4320) had some mistakes in the astronomical tidal forcing that can be fixed in the “next round”. In the mean time, we have estimated some rough mitigating correction factors.

BUILDING SCIENTIFIC CAPACITY IN WEST AFRICA

Educational projects: building scientific capacity in West Africa

- Organizing summer schools in Ghana & Nigeria with Prof. Brian Arbic (University of Michigan)
- GOAL: To collaborate with faculty and to teach and motivate students to study oceanography, fluid dynamics, modeling, applied mathematics, etc.
- Marine issues of great importance to Ghana (coastal nation):
 - oil drilling, pollution, fisheries
- In 2014, Brian and I took a first 'scouting trip' to Ghana to see which institutions will be interested in oceanography summer schools.

Oceanography Summer School in Ghana: 2015



- At Regional Maritime University (RMU, ~35 participants)
- Lectures on ocean modeling (internal waves), satellite oceanography, chemical oceanography, basic topics in physical oceanography

Presenting certificates of participation: 2015



Positive feedback and great suggestions for improvement:

- both lectures and hands-on labs
- the physics and biogeochemistry of coastal ocean environment
- the tools scientists use to describe/understand the ocean



The 2023 School was a big success!

After a great online school (July 31 – August 4), with an array of lectures, a panel on Women in STEM, and an extensive Python and git/GitHub curriculum, the in-person school kicked off at the University of Ghana (August 14 – 18). The first day featured the opening ceremony, a handful of lightning talks, and then we split into 4 project tracks.

- Biogeochemistry
- Fisheries
- Physical Oceanography, Climate Modeling, and Python Computing
- Science and Policy of Plastics

Previous Schools

2024 School

2024

2022 School (in Nigeria)

2022

Coessing 2021

2021

2020 School + 2021 Mini-School
(virtual)

2020

2019 School at RMU

2019

Coessing 2019

2019

2018 School at U. Ghana

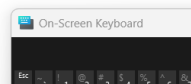
2018

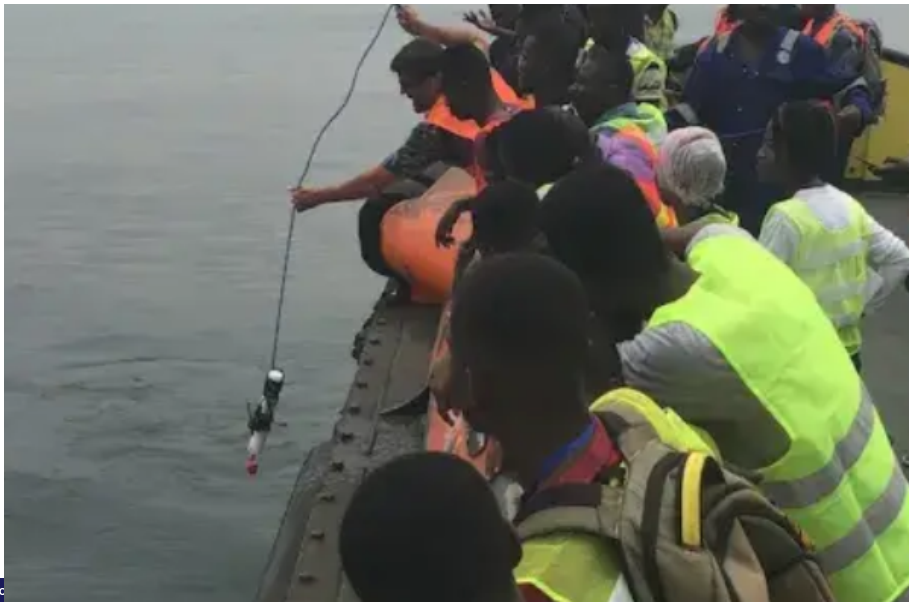
2017 School at RMU

2017

2016 School at U. Ghana

2016





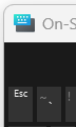
Biogeochemistry Fieldtrip



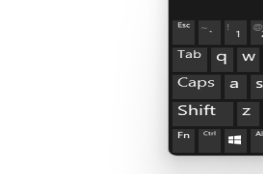
Fisheries Fieldtrip to Makoko



Plastics Fieldtrip to Lekki Beaches



Python Research Group



Strengthening Ocean Science Capacity in Africa

Africa's coasts and oceans are vital for livelihoods, climate resilience, and sustainable development.

By training the next generation of ocean scientists, COESSING empowers young leaders to tackle regional challenges with global collaboration and local insights.

10 +
years

of ocean science education and
research

100+
students

empowered to become the best

20+
communities

engaged in ocean science
education and research

United
Nations

endorsed initiative

THANK YOU.