Overview of Parameterizations for Short- to Medium-Range Coupled Forecasts...

Solutions in Play

- Scale-Aware Parameterization?
- Seamless Prediction?
- Unified Atmosphere-Ocean Parameterization?
- Stochastic Parameterizations for Ensembles?

Questions

- Coupled Model Errors--Differ by Timescale?
- Processes to parameterize: same or different, studied or new?
- Predictability & Computational Cost: payoff?
Air-Sea Errors vs. Data (L&Y 09) depend on timescale


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The Ocean is Vast and Diverse

CESM=NCAR Community Earth System Model

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Earth Age

10^16
10^11
10^6
10^1
10^0

Viscous Flow
Internal Gravity Waves
Salt Fingers
Finescale Turbulence
Capillary Waves

10^-2
10^0
10^2
10^4
10^8

Length (m)

Earth Circum.
Milankovitch

Boundary Currents
Baroclinic Rossby Waves
Barotropic Rossby Waves
MidLatitude Byres
Centennial Climate
Flushing times
ENSO
Tides

Submesoscale Fronts, Eddies
Ekman Layer
Langmuir Cells
Deep Convection Plumes

Tsunami
Poincare Waves
External Gravity Waves
The Ocean is Vast and Diverse
MRCF=Medium-Range Coupled Forecast

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The Ocean is Vast and Diverse

MRCF = Medium-Range Coupled Forecast

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Estimates of the Contribution of Wind-Waves in the Coupled Ocean-Atmosphere Climate System.

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Southern Ocean:
Wind too strong by about 5N/m²
AND
MLD too shallow by about 50%

< 10W/m²
net flux errors

Waves?
Southern Ocean Storm Belt Position is Sensitive to Roughness Parameterisation

Janssen and Viterbo (1996)
Sea-state dependent drag in Seasonal prediction model

Garfinkel et al. (2011)
Increased ocean roughness in GEOS-5 GCM improved SO wind bias.
Drag Coefficient vs Wind Speed (SOFS, 47S, 142E)

Total Heat Flux Mean

Momentum Flux Mean

\[ \tau_{\text{CORE}} = \rho C_{D,\text{CORE}} u^2 \]

Note:

S. Ocean wind effects in about the right size (0.03 N/m²)

Other basins O(5W/m²) flux effect

Parameterization dependent

NO STORM TRACK FEEDBACK HERE!

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2) Initialize with ARGO profile, run for 1 year with Large & Yeager (04) forcing (neglect oceanic flux divergence)

One example location shown at right, near OWS-PAPA
Percentage increase in MLD with introduction of SMC (E6=7) langmuir mixing ~180 days after Summer Solstice.

Zonal mean MLD after 180 days and after 365 days.

Many more wave-climate effects to come... stay tuned!


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Results

- Errors in climate model on annual to decadal timescales can be attributed (partly) to neglect of
  - Waves $\rightarrow$ Wind stresses, air-sea fluxes
  - Waves $\rightarrow$ Langmuir turbulence

These phenomena are the right size and active in the right places, but difficulties remain:

- Prognostic waves in Coupled Models needed
- Parameterizations need coding, evaluation, generalization

Along the way, we found negligible/erroneous effects with

- Whitecaps $\rightarrow$ radiation, PWP-based Langmuir and Babanin non-breaking wave turbulence

Hypothesis: Improving Seasonality will Improve Forecasts & Trends


CORE (Large and Yeager, 2004, 2009)
Standard air-sea flux dataset of WGOMD

Atmospheric Fields
- NCEP/NCAR
  - Near surface winds, U
  - Near surface atmospheric temperature, \( \theta \)
  - Near surface specific humidity, q

Radiation
- International Satellite Cloud Climatology Experiment
  - Short wave insolation, \( Q_i \)
  - Downwelling Long wave Radiation, QA

Precipitation
- GCGCS (Merged GPCP, CMAP, S-H-Y data)

SST
- Hadley Centre sea Ice and SST dataset version 1 (HadISST1)
Real World Forcing: Misaligned Wind & Waves


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How well do we know Stokes Drift?

Within a factor of 2.
Assuming full-development (e.g., McWilliams & Restrepo, 1999) is worse

Langmuir Mixing Estimate from WW3 & Projection

Underestimates WAVE IMPACT on MLD

Southern Ocean Mixed Layer Depth (m)
Percentage increase in MLD with introduction of SMC (E6=7) Langmuir mixing ~180 days after Summer.

Reduced to Kantha & Clayson Approximation $GV=GS=0$

Zonal mean MLD after 180 days and 365 days.
Global mean air-sea fluxes (Wm\(^{-2}\))

Corrected 2007 CORE data. C.f., Table 3 Large and Yeager, 2009, but note different masking area defined by wave model.

<table>
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<th>Flux</th>
<th>CORE</th>
<th>Charn</th>
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</table>

• 1 no consideration of whitecapping.
• 3 whitecapping parameterisation is sea-state dependent, following Zhao et al. 2003.
  • This is a function of \(u^*\), thus dependent on zo parameterisation.
• No wave dependent long-wave radiation flux is implemented. Note surface emissivity has a sea-state dependent component
• 4 rms (spatial) of annual mean relative to CORE calculation annual mean.