A numerical study of the effects of wind and upstream conditions on the Hawaiian circulation

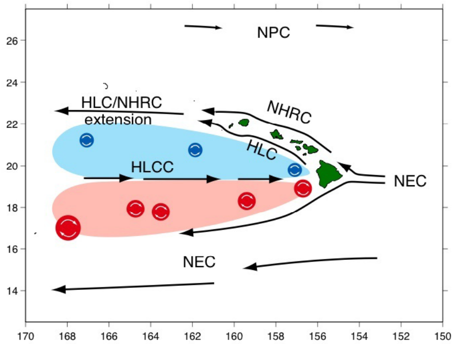
Andrei Natarov[1] Brian Powell[2]

[1]IPRC, University of Hawaii
[2]Dept. of Oceanography, University of Hawaii

2010 ROMS/TOMS User Workshop

- Present a high resolution, 4 km ($\sim 1/28^{\circ}$), regional ocean model for Hawaii that will be used for both operational purposes and scientific process studies
- Assess the sensitivity of the setup to atmospheric forcing and to operational, global boundary conditions

"Canonical" circulation around Hawaiian Islands
source: Lumpkin, 1998



Interesting questions

- The HLCC dynamics (Xie *et al*. 2002)
- Eddies in the lee of the Islands: their formation mechanism (Calil *et al*. 2008; Yoshida *et al*. 2010)

Modeling challenges

- Four open boundaries
- Large variations in bathimetry

ROMS setup

- The domain spans 164°W to 153°W in longitude and 17°N to 24°N in latitude.
- Volume conserved via Chapman condition on the free surface
- Flather condition for the 2D momentum
- Clamped conditions for the 3D momentum and tracers
- Nudging/sponge layer (80 km thick) along the boundaries
- Fourth order Akima horizontal advection scheme
- KPP vertical mixing
- The ocean surface heat flux is computed via the COARE algorithm of Fairall *et al.*, 1996

Forcing for the ROMS experiments

Lateral boundary conditions

- NCOM
- HYCOM

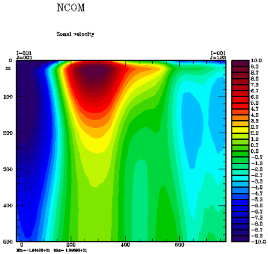
Experiments

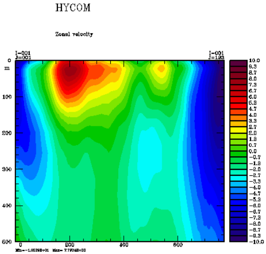
- NLo
- NHi
- HLo
- HHi

Atmospheric Forcing

- NCEP for swrad, lwrad, tair, pair, rain and qair.
- NCEP-CORA wind (Low 1/2° resolution)
- NCEP-CORA/MM5 blended wind (High 1/12° resolution)

Lateral boundary conditions
Mean zonal velocity at the western boundary

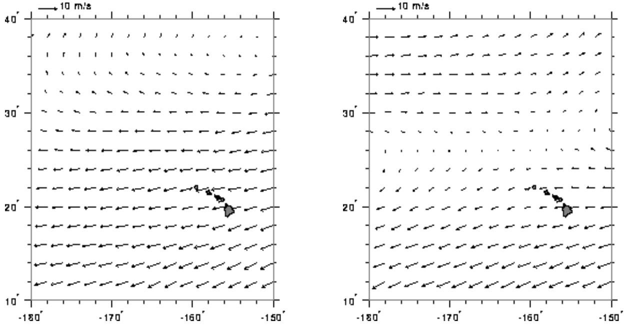




- Both NCOM and HYCOM assimilate SST and SSH satellite data
- However there are large differences between them
  - in transports associated with the major currents
  - in temporal variability (HYCOM has much more variance)

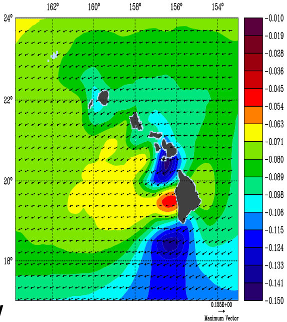
Mean wind

source: COADS; period: 1946-1993

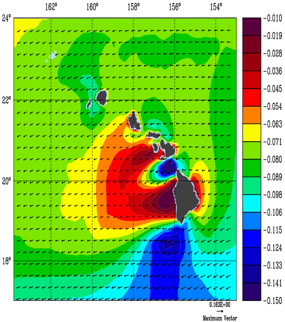


(c) summer (d) winter

- Trade winds are stronger and steadier in summer



Low



High

Distinguishing characteristics of Hi wind

- Much stronger curl
- Reduced magnitude in the lee of the Islands

Sea Surface Temperature bias

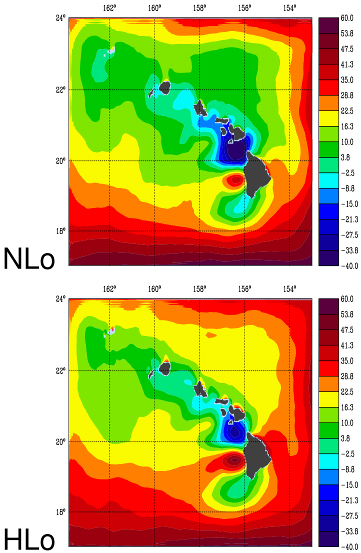
Mean SST

- JPL/NOAA Pathfinder V5 SST product: $25.44^{\circ} C$
- NLo: $25.82^{\circ} C$
- NHi: $25.92^{\circ} C$
- HLo: $25.76^{\circ} C$
- HHi: $25.85^{\circ} C$

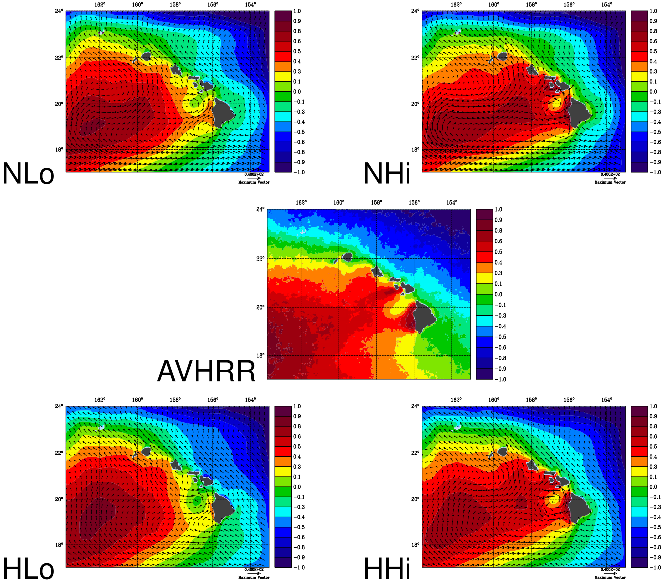
Possible reasons

- Both global NCOM and HYCOM already have a small bias for the region of Hawaii
- Thermodynamic imbalance between the state of the ocean and different (NCEP vs NOGAPS) atmospheric forcings

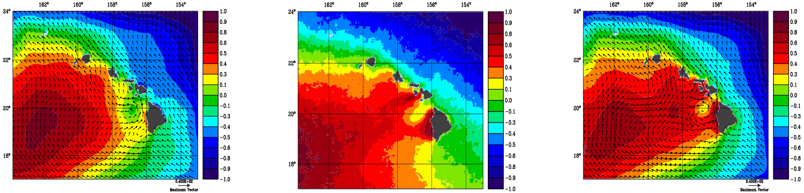
Surface heat flux



Time mean SST anomaly and surface velocity

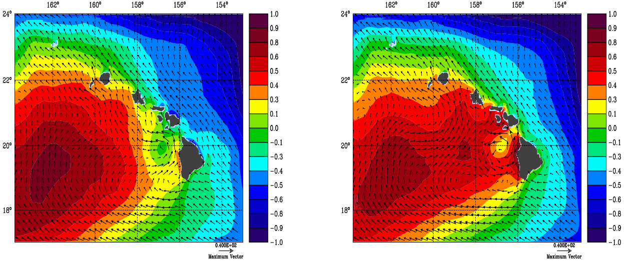


Time mean SST anomaly and surface velocity
HLo, AVHRR & HHi



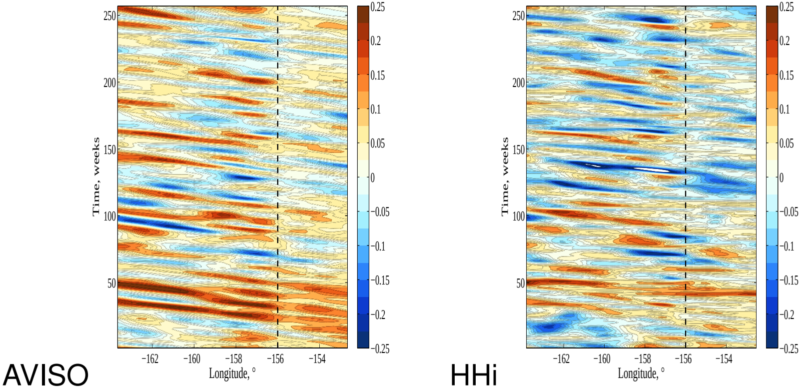
- The currents are considerably stronger in the HHi experiment
- AVHRR and HHi warm tongues are extended further east through advection by the HLCC
- HLo warm tongue is more Gaussian
- HHi successfully captures the meandering of the northern flank of the tongue

Surface velocity
HLo, AVHRR & HHi



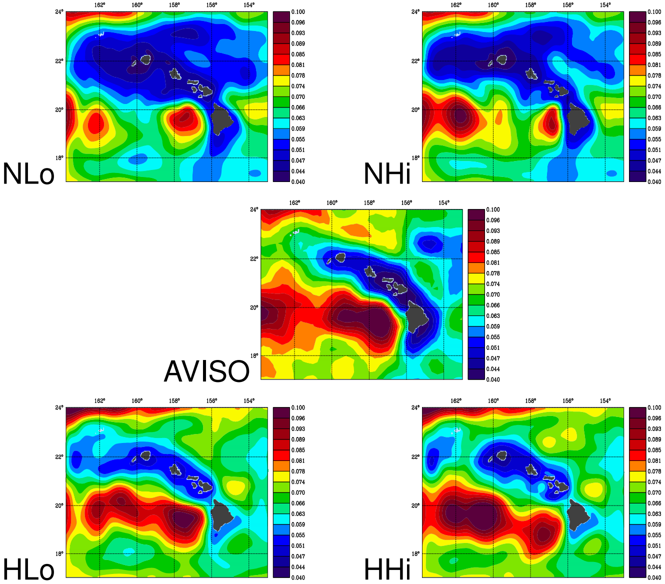
- The "canonical" current system is identifiable in the HLo graph
- The HHi current system is different from the canonical:
  - Four bifurcation branches for the HLCC
  - More meandering
  - Recirculating gyre

Eddy propagation along 19°N

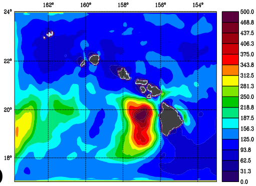


In observations and HHi there are regions with a different eddy propagation velocities. In the HLo this distinction is missing

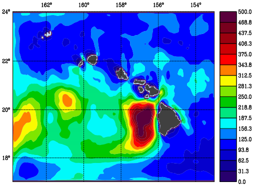
RMS SSHA


NLo
NHi
AVISO
HLo
HHi
162° 160° 158° 156° 154°
24° 22° 20° 18°
0.100 0.096 0.093 0.089 0.085 0.081 0.078 0.074 0.070 0.066 0.063 0.059 0.055 0.051 0.047 0.044 0.040

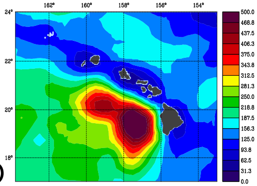
Mean surface EKE



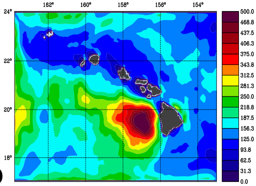
NLo



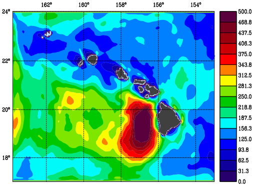
NHi



AVISO



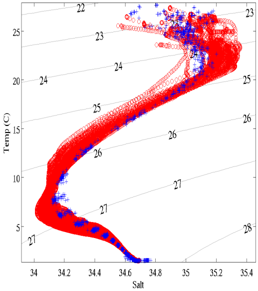
HLo



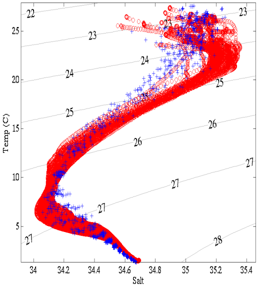
HHi

Comparison with station ALOHA data (Karl & Lukas, 1996)

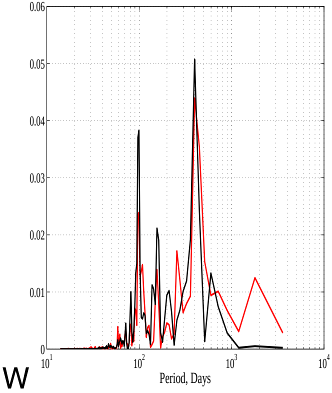
NHi



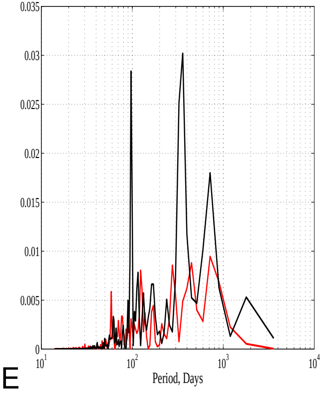
HHi



- NCOM contains little variabiliy
- HYCOM captures variability but not the salinity structure below the thermocline
- Comparison with ARGO floats yields similar results



0.06
0.05
0.04
0.03
0.02
0.01
0
10^1
10^2
10^3
10^4
Period, Days
W



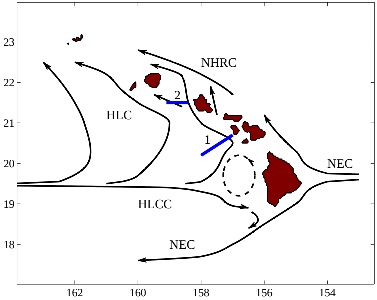
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
10^1
10^2
10^3
10^4
Period, Days
E

RMS SSHA spectra

Comparison with Yoshida *et al.* 2010

- AVISO: peaks at 98-day period in both W and E; and 62-day period in E (black line)
- All four runs perform well in region W. HHi produces the closest to AVISO estimate.
- In region E the 98-day maximum is missing from all four ROMS experiments.
- The 62-day peak is absent from NLo and NHi, and is dominated by a stronger peak at 58 days in HLo and HHi. Boundary conditions appear to be very important for the 62-day peak.

Summary



- The mean circulation is considerably different from "canonical" in NHi and HHi experiments
- Higher resolution wind drives stronger HLCC directly and stronger NEC through a mismatch in boundary condtions
- Boundary conditions are resonsible for time variances
- Surface heat flux issues at the boundaries need to be resolved

Summary

- The mean circulation is considerably different from "canonical" in NHi and HHi experiments
- Higher resolution wind drives stronger HLCC directly and stronger NEC through a mismatch in boundary condtions
- Temporal variances are more sensitive to boundary conditions than to the wind forcing
- Surface heat flux issues at the boundaries need to be resolved