Oceanography of the Mexican Pacific Ocean: An interactive region between north and south

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Objective

To show what are Oceanographic Mexican Institutions working (on PICES interest, i.e., Pacific Ocean!)
Outline

- Importance of the oceans for Mexico
- The Gulf of Mexico
- The Mexican Pacific: Transition zone
- Some Highlights from the Mexican Pacific
- Forthcoming goal (California Current Ecosystem)
Importance of the Oceans for Mexico

- Oil production
  (2015: about $2 \times 10^6$ barrels per day)

More than 80% from the ocean

Working on deep waters
Importance of the Oceans for Mexico

- Fisheries and aquaculture
  (2015: about $2 \times 10^6$ tons)

1990-2011
Importance of the Oceans for Mexico

* Registered Vessels
  - Civilian ~172,000
  - Military ~100
The Gulf of Mexico

* CIGoM:

Oceanographic observational network generating scenarios of possible contingencies related to the exploration and production of hydrocarbons in the Mexican EEZ Gulf of Mexico deep-water region

High-resolution numerical simulations performed with ROMS as part of CIGoM (also operational).
The Gulf of Mexico

- CIGoM: 5 lines of studies

1. System of oceanographic observation platforms (fixed and mobile),
2. Base line studies,
3. Circulation and biogeochemical numerical models with data assimilation,
4. Typify hydrocarbon natural degradation, and
5. Analysis of possible different spill scenarios
The Gulf of Mexico

- CIGoM: polygons for hydrographic stations
The Gulf of Mexico

CICESE with PEMEX: Measurements and analysis in deep water

Project duration 2007-2015
The Mexican Pacific: Transition Zone
The Mexican Pacific: Transition Zone (PICES-Equator)
Some Highlights from the Mexican Pacific

1. Research centers
2. Research Vessels
3. Transitional zones: Circulation and Water Masses
4. Transboundary fisheries and biological migrations
5. Marginal Sea and MPA (Gulf of California)
6. Boundary Upwelling Systems and BACs
7. Numerical modeling
8. Monitoring program IMECOCAL
Highlights of the Mexican Pacific
1 Research centers

CICESE
IIIO-UABC
CIBnor
CICIMAR-IPN
UNAM-Mazatlán
UdG
Highlights of the Mexican Pacific
2 Research Vessels

Alpha Helix 40m
CICESE

El Puma 49 m
UNAM

BIPO 59 m
INAPESCA
Highlights of the Mexican Pacific
3 Transitional zones: circulation and water masses

Transitional zones:

a) Mid latitude-Tropical-subtropical interactions

b) Climate signals multi-scale interactions (seasonal, El Niño, decadal, ...)

c) Biogeographic boundaries dynamics (dominated by currents)

d) Marine diversity responses to Climate Change (N-S migrations)

Schematic mean circulation off SW Mexico. Continuous lines indicate near-surface currents, and dashed line indicates the subsurface component of the Mexican Coastal Current. Gómez-Valdivia et al., CSR, 2015.

Highlights of the Mexican Pacific

3 Transitional zones: circulation and water masses

A cyclonic mesoscale eddy observed in the northeastern Pacific tropical-subtropical transition zone.

Formed at the coast, generated by coastal upwelling event with an equatorward flow. Traveled W ~ 1000 km in ~8 months.

Kurczyn et al., JGR-Oceans, 2013
Highlights of the Mexican Pacific
3 Transitional zones: circulation and water masses

Surface variance split in mesoscale, seasonal, and interannual scales.

Interannual component dominated by the ENSO, which induces in the gulf entrance an anticyclonic (cyclonic) circulation during El Niño (La Niña); this circulation includes a poleward flowing branch (during El Niño) parallel to the Pacific coast of the Baja California peninsula.

Seasonal: coastal (~300 km) connection MCC and equatoward CC.

The mesoscale variability is caused by intense eddy activity.

Godinez et al., JGR-Oceans, 2010
The seasonal signal of the sea level, which shows the interplay of the poleward Mexican Coastal Current and the equatorward branch of the California Current, can be explained by a long Rossby wave model forced by the annual wind and by radiation from the coast.

Godinez et al., JGR-Oceans, 2010
Highlights of the Mexican Pacific

3 Transitional zones: circulation and water masses

Surface Water Masses

winter

spring

summer

fall

Portela et al., JPO, 2016.
The shallow (50–100 m) salinity minimum originates with the California Current System and becomes saltier as it extends southeastward and mixes with tropical subsurface waters.

The surface salinity minimum extends farther north in the TPCM in summer and fall because of the northward advection of tropical surface waters.

Portela et al., JPO, 2016.
Transboundary fisheries:

- Pacific sardine, *Sardinops sagax*
- California Halibut, *Paralichthys californicus*

Large biological migrations:

a) Loggerhead turtles
b) Gray whale
c) Humpackwhale
d) Jumbo squid
e) Pacificsardine
f) White shark

Bloch et al.
Cetacean population densities. (Bayesian models)

a) Main features of low Absolute Dynamic Topography (ADT—pycnocline shoaling) in the California Current System (CCS), the Frontal System off Baja California (FSBC), the Gulf of California (GC), the North Equatorial Countercurrent thermocline ridge (NECCTR), the Costa Rica Dome (CRD), the Gulf of Panama and off Colombia (GPOC), the Equatorial Cold Tongue (ECT), and the Humboldt Current System (HCS).

a) Blue whale and short-beaked common dolphin sightings (dots colored), and survey effort (thin red lines), collected during July-December at from 1986–2009. Follow more productive physical structures.
Cetacean population densities.
(Hierarchical Bayesian models)

From Main features of low Absolute Dynamic Topography (ADT= pycnocline shoaling) in the California Current System (CCS), the Frontal System off Baja California (FSBC), the Gulf of California (GC), the North Equatorial Countercurrent thermocline ridge (NECCTR), the Costa Rica Dome (CRD), the Gulf of Panama and off Colombia (GPOC), the Equatorial Cold Tongue (ECT), and the Humboldt Current System (HCS).

Is possible to predict:
Blue whale and short-beaked common dolphin population density distributions (colorimetric scale) and interannual redistributions
Sightings (colored dots) and survey effort (thin gray lines), collected during July-December spanning 1986–2009. Follow more productive physical structures.

Highlights of the Mexican Pacific
4 Transboundary fisheries and biological migrations

Larval composition and abundance of species

Dendrograms of groups of sampling stations defined by the Bray-Curtis dissimilarity index.

Shaded White: Tropical
Gray: Coastal-and-Upwelling
Black: Transitional-CC

larval fish habitats

Leon-Chavez et al., JGR-Oceans, 2015
Marginal seas (Gulf of California):

a) Basin scale interactions

b) Semi-enclosed sea dynamics
Effects of Marine Protected Areas:

a) Fish stocks
b) Preserves genetic diversity
c) Larvaetransport and dispersal
d) Human dimensions

Soria et al., JMS, 2014.
Highlights of the Mexican Pacific
6 Boundary upwelling systems and BACs

Boundary upwelling systems and Biological Active Centers:

a) Primary productivity

b) Ocean-atmosphere interactions

c) Biogeochemical cycles

d) Long-term patterns

Processes involved in the variability of the CO2 system at the Gulf of Tehuantepec during Post-Tehuano conditions.

Red source
Blue sinks of CO2.
Highlights of the Mexican Pacific
7 Numerical modeling

Particle-tracking experiment.
(a) Color indicates time along the trajectory.
(b) Mean depth. Gray indicates one standard deviation.

Connectivity study between SC Bight and TS Bay with relation to harmful algal blooms.

3-D numerical simulation (see Rivas & Samelson, JPO, 2011)

Nitratos-Fitoplancton-Zooplancton-Detritus (NPZD; Powell et al., 2006),
Highlights of the Mexican Pacific

7 Numerical modeling

High-resolution numerical modeling is performed at CICESE (almost operational)

ROMS SST nested simulation (by A. Parés-Sierra)
Since October 1997

66 cruises (including one in February 2016)

Data partially online:

http://imecocal.cicese.mx/

Hydrographic data with CTD casts down to 1000 m. Biological sampling includes primary productivity, zooplankton, ichthyoplankton and continuous sampling of fish eggs.
Highlights of the Mexican Pacific
8 Monitoring program IMECOCAL

Subsurface anticyclone  October 2009

Geostrophic Velocity from ADCP at 40 m

- Observed in summer and autumn off San Quintin
- Diameter ~70 km
- Center with California subsurface counter current.
- Formation related to separation of counter current from continental slope
- Eroded after passing submarine mount Mariano Matamores

Gomez-Valdes, Torres, and Wang (2016), JGR
Summers in North Baja California (30-32°N)
July–August

Euphausiids biomass

Not present in 1998 and 2015

Assemblages of euphausiid species

Highlights of the Mexican Pacific
8 Monitoring program IMECOCAL
Highlights of the Mexican Pacific
8 Monitoring program IMECOCAL

CalCOFI + IMECOCAL CUFES databases sardine spawning

Distribution and abundance of spring spawning (centered on April) of sardine eggs in the CALCOFI and the IMECOCAL regions from 2000 through 2013.

Track lines of ships shown in green.
Scale expanded for IMECOCAL region showing the % of total eggs for IMECOCAL.
Highlights of the Mexican Pacific
8 Monitoring program IMECOCAL

Mean autumn alongshore geostrophic flows

Continuos poleward flow could be connected to Davidson current
Highlights of the Mexican Pacific
8 Monitoring program IMECOCAL

30 m temperature anomalies

Blob and El Niño

Temperature anomalies for the North and South Pacific from 1995 to 2015.
Highlights of the Mexican Pacific
8 Monitoring program IMECOCAL
The Mexican Pacific is an area where:
- currents with water masses and properties and
- marine life from the tropical and mid latitude areas meet and interacts.

The above gets a local signature also due to local forcing.
Forthcoming Goal
(Nevertheless it requires swift actions)

To establish a tri-national (Canada-USA-Mexico) observational and physical-biological modeling program to study the California Current Ecosystem, in order to provide information for the management and conservation of marine resources.
Forthcoming Goal
(California Current Ecosystem)

- Where diverse environments, communities and species concur.

- Where physical forcing goes from days to decades.

- Where populations (e.g. sardines, anchovies, squid, salmon) respond to this forcing.
CCE from BC a BC:

Winter storms frequent and strong
Seasonal wind stress reversals
Significant freshwater input
Relatively smooth coastline
Winds mostly upwelling favorable
Strongest coastal upwelling
Strong coastal jets, filaments
Minor freshwater input
Major coastal promontories
Fewer storms
Weaker winds
Weak local upwelling
Stable stratification
Negligible freshwater input
Primary productivity strongly seasonal
Copepods commonly overwinter at depth
Major estuaries/nursery grounds
Species boundary (Subarctic level)
Zooplankton biomass strongly seasonal
Latitudinal minimum in spawning by epipelagic fishes
Latitudinal maximum in spawning by epipelagic fishes
Latitudinal minimum in spawning by epipelagic fishes
Latitudinal maximum in spawning by epipelagic fishes
Major water mass mixing
Continuous reproduction by some copepods
Damped seasonality in primary productivity
Damped seasonality in zooplankton biomass

(Courtesy of C. Werner)
California Current Ecosystem
(Example of integrated observing system)

Much is already in place
- ship surveys:
  - regular quarterly surveys
  - regular 1-day surveys
  - NOAA stock assessment surveys
  - NOAA OA surveys
- 3 glider lines:
  - CORC
- 3 ecosystem moorings:
  - CCE-1/2
  - MBARI moorings
- coming OOI glider sections and moorings

Need only small increment to complete a comprehensive system (example in yellow):
- 2-3 glider lines
- 4-5 ecosystem moorings

(Courtesy of C. Werner)
What is next?

• Particularly
  o Establish a tri-national (Canada-USA-Mexico) observational and physical-biological modeling program to study the California Current Ecosystem, in order to provide information for the management and conservation of marine resources

• In general
  o Invest in human resources training for the different areas of oceanography
  o Link early and comprehensively the human dimension and development for the country
  o Have oceanographic infrastructure and state of the art technology
  o Promote interaction among science-industry-government sectors
  o Promote high level research on priority resources and themes of economical interest, promoting the development of new technologies and the innovations of tools that allow us to solve the challenges of the different fields
  o Recognise the importance of long term studies relevant to predictive models of regional and global scales
  o Generate open data bases
  o Promote collaboration among the different institutions
Thank you

http://www.cicese.edu.mx