A high-resolution numerical study at the Canary Islands off Northwest Africa

Evan Mason¹, Francois Colas², Jeroen Molemaker³, Pablo Sangrà⁴, Ananda Pascual⁵, James C. McWilliams⁶

¹IMEDEA (CSIC-UIB), Esopes, Illes Balears, Spain; ²OCEAN, CNRS/IRD/LUMIP/CNHN, Université Pierre et Marie Curie, Paris, France; ³CESA, University of California Los Angeles, Los Angeles, USA; ⁴ULPGC, Tafira, Las Palmas de Gran Canaria, Spain

Seven deep water islands located near the Canary upwelling offshore of Morocco in the subtropical northeast Atlantic (Fig. 1).

Figure 1: (left) Map showing Canary Island topography. From west to east the islands are El Hierro (EH), La Palma (LP), La Gomera (LG), Tenerife (Te), Gran Canaria (GC), Fuerteventura (Fu) and Lanzarote (La). night MODIS 4 km SST on 12 May 2007 at the Canary Islands. SST anomalies downsteam of Gran Canaria and Tenerife indicate topographic eddy generation.

- Islands exposed to the equatorward Canary Current
- Elevated levels of mesoscale energy
- Topographically generated eddies
- Wind stress shear
- Baroclinal instability at upwelling front

Figure 2: Nested snapshots SST in August of model year 38. Dashed white lines demarcate the L1 (outer) and L2 (inner) boundaries. SST from L2 (L1) is superimposed upon that of L1 (L2).

- Climatological surface and boundary forcing
  - Winds from monthly Scatterometer Climatology of Ocean Winds (SCOW; 0.25°) and daily PSYUCAR Mesoscale Model (MMS, 6 km)
- See Mason et al. (2011) for further details and validation of 50 year L0 solution

Figure 3: Time evolution of surface and volume averaged kinetic energy (KE) from L1, L2, and three L2 MMS forced runs. Years correspond to the L1 period of the L0 parent solution (not shown).

Eddy energy

Eddy kinetic energy (EKE)

- EKE from AVISO altimetry and ROMS L0 (Fig. 4).
- High EKE associated with island wake
- Expected seasonal cycle

Energy conversion and instability

Figure 4: Winter and summer geostrophic and eddy kinetic energy at the Canary Islands from AVISO DT14 (left) and ROMS L0 (right).

- Focus on L0 barotropic and baroclinic conversion terms (e.g., Marchesiello et al., 2003) in Fig. 5.
- Relevant to generation of EKE by model
- Volume integrated energy budget equations:
  - Mean KE to eddy KE: K - P (barotropic)
  - Mean potential energy (PE) to eddy KE: PE - P (baroclinic)
- Caveat: Wind work is missing here

Drag and lift forces

Figure 5: Winter (upper panels) and summer (lower panels) barotropic K - K and baroclinic PE - P energy conversion at the Canary Islands. Integration depth range 0-110 m. Bar plots show alongshore averages between black lines in maps.

- Wake asymmetry contributes to horizontal forces on islands. For a variable incident flow, bottom pressure anomalies (BPA) can be used to compute timeseries of the total force (e.g., Molemaker et al. 2015)
- Figure 6 shows L2 drag and lift forces on Gran Canaria
  - Drag acts in the direction of the incident flow
  - Lift acts perpendicular to the incident flow
  - Gran Canaria incident flow generally SE to SW
  - Consistent with observations.
- Caveat: computation of BPA ignores contribution to form stress near land mask

Eddies at Gran Canaria

Figure 6: Time series of (a) drag and (c) lift forces normalised by the Bernoulli head L2/DH with U = 1 m s⁻¹, 20-50 km, H=300 m at Gran Canaria from L2. Colours correspond to the directions of the respective forces. Surface fields of (b) normalised relative vorticity (σ 1) and (d) bottom pressure anomaly (σ 2) on day 639 which is the day with maximum drag force in (a).

- Barotropic conversion important in summer at Gran Canaria
  - A wind forced anticyclonic eddy develops in the lee of Gran Canaria
  - Relevant to generation of EKE by model
  - Expected seasonal cycle
  - High EKE associated with island wake

The Canary Island archipelago

Eddy shedding period identified in light brown in drag timeseries (Fig. 6):

- Period with southward incident current
  - BPA shows positive anomalies along northern coast
  - Snapshots in Fig. 7 of relative vorticity show generation and spinoff of anticyclonic eddy

Figure 7: Sequence of normalised surface L2 vorticity snapshots at Gran Canaria corresponding to maximum drag force on day 639.

Response to MMS wind forcing

Figure 8: L2 August wind stress curl from (a) SCOW and (b) modified MMS. Vectors show the wind speed and direction. The zero wind stress curl is contoured in black.

- Seasonal EKE cycle in agreement with altimetric estimates
- Barotropic instability is important for the island wake
- In agreement with Dong et al. (2007)

Conclusions

- Mesoscale eddy activity at the Canary Islands described using outputs from ROMS simulations
- Seasonal EKE cycle in agreement with altimetric estimates
- Barotropic instability is important for the island wake
- In agreement with Dong et al. (2007)
- Drag and lift timeseries at Gran Canaria correspond to Canary Current
  - Eddy generation and shedding coincide with large drag and oscillating lift
- Use of higher resolution wind leads to increased KE

References


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