1 Rapid Response 98

Rapid Response 98 (RR98) is a Military Oceanography (MILOC) survey for Rapid Environmental Assessment (REA) in the Gulf of Cadiz and the adjacent NE Atlantic in support of the NATO exercise Strong Resolve 98 (SR-98). Archive search, remote sensing, surveillance by aircraft and *in situ* measurements from survey ships will be combined with state of the art numerical modeling. The RR98 survey phase will be prior to SR-98. Delivery of RR98 REA products for anti-submarine, mine and amphibious warfare will continue for the period of SR-98.

2 The Gulf of Cadiz

2.1 Definition and structure

For our purpose we define the Gulf of Cadiz as to be the area east of 9°W and north of 35°N. In the north and east it is bounded by the Portuguese, Spanish and African coast. The western and southern boundaries are open; another open boundary exists in the east by means of the Strait of Gibraltar. The west–east extention is about 270 km, in north–south direction it extends over about 250 km. Maximum water depth is about 3000 m in the southwest corner. Topography slopes are gentle.

2.2 Driving forces

Large scale circulation

The Gulf of Cadiz is incorporated in the eastern recirculation regime of the North Atlantic subtropical gyre. It is located in the transition area between the Portugal Current and the Canary Current. A small fraction of the North Atlantic thermocline transport flows into the Strait of Gibraltar. Towards the southeast the area is connected to the north-west African upwelling regime.

Strait of Gibraltar inflow/outflow

The sill depth of the Strait of Gibraltar is about 300 m at the Camarinal Sill (5°45'W). The circulation in the Strait is characterized by a near surface inflow of low salinity Atlantic Water into the Mediterranean and an outflow of salty Mediterranean Water (MW) below. Mean transport rates of both flow components are on the order of 1 Sv, mean velocities are on the order of 1 m/s. After having passed the Camarinal sill, the high density MW slides down the continental slope and progresses further to the west while leaning against the Spanish/Portuguese continental slope. During these stages the MW is subject to strong mixing. The main spreading paths are confined to two warm salinity "veins" at about 600 m and 1100 m depth, typical velocities within these veins are 50 cm/s or even more.

Atmospheric fluxes

The Gulf of Cadiz circulation is influenced by wind forcing and surface heat and water fluxes. In wintertime, the area lies close to the main storm tracks of the northern hemisphere, hence wind forcing may play a dominant role.

Tides

The mean inflow/outflow situation in the Strait of Gibraltar is superimposed by strong tidal currents, the magnitude of which is on the same order as the mean flow. Hence, within a tidal cycle, inflow/outflow may be reversed. Strong tidal flow on the order of several knots prevails also in the Gulf of Cadiz, at least in the nearshore regions.

2.3 Internal dynamics

Special features of the internal dynamics of the region involve the external effects of internal waves and hydraulic jumps occurring in the the Strait of Gibraltar within a tidal cycle, the slope convection of MW west of the Camarinal Sill and the instability of the MW veins causing generation and detachment of meddies.

3 Scientific and technical objectives

1. To carry out nowcasts and forecasts of physical fields for the Gulf of Cadiz, to determine flow dependencies upon and sensitivities to the various driving forces (Mediterranean outflow, North Atlantic circulation, atmospheric fluxes and tides), and to evaluate their utility for REA;
2. To demonstrate the real-time capability of HOPS forecasts via Error Subspace Statistical Estimation (ESSE) and to utilize ESSE forecast error fields for the objective adaptive sampling design of AXBT flights;
3. To carry out demonstration of concept real-time coupled biological/physical nowcasts and forecasts, with a simple HOPS NPZ(etc.) model;
4. To provide a demonstration of concept tactical biological product via a couple empirical bioluminescence model.

4 Model setup and parameters

4.1 Model domains

Large domain

The large domain will cover the ASW area. In east–west direction it will extend from $\sim$ 8°30'W to 5°30'W over about 270 km, and in north–south direction from $\sim$ 35°00'N to 37°15'N over 250 km. The first choice for the horizontal resolution will be 3 km, which yields roughly $90 \times 85 = 7650$ grid points. In the vertical, 20 σ-layers will be used.

Small domain

The small domain will cover the AW area extending west–east from $\sim$ 6°10'W to 5°45'W over about 40 km, and north–south from $\sim$ 36°00'N to 36°12'N over less than 25 km. A first choice horizontal resolution of 1 km is equivalent to $40 \times 25 = 1000$ grid points. The

CPU time will be $\sim 3 \times 1000/7650 \sim 0.4$ times that of the large domain using the same amount of vertical levels. A higher horizontal resolution of 0.5 km is optional. The large and small domains will interact at least via one-way nesting; two-way nesting has to be tested.

4.2 Topography

NAVOCEANO bathymetric data (perhaps 1' horizontal resolution) are to be used.

4.3 Forcing functions

FNOC products are to be used for the surface wind and heat flux forcing. It has to be decided, whether the freshwater flux of two rivers will be included. Inflow/outflow conditions and possibly a heat/salt source have to be specified in the Strait of Gibraltar. The large scale forcing of the North Atlantic circulation will be modeled from early hydrographic measurements of PLANET and AXBT flights. Climatological data from the MED4 data set (it extends possibly up to 10°W) and/or the UK Hydrographic Office will serve as background fields. The best reference level for the objective analysis has to be determined. The tidal forcing will be gained from the best available tidal model.

4.4 Assimilated fields

The following field types will be assimilated into the model:

- Temperature and salinity from CTD/XBT/XCTD of survey ships and aircrafts,
- Tides from tidal model
- Altimeter data from TOPEX/ERS-2
- SST and color from NOAA-AVHRR (?)
- Bioluminescence from PATHFINDER (tentative)

5 Products

The primary HOPS products will be as before: maps of temperature, salinity and velocity for the ASW and AW regions, and maps of surface and bottom velocity for the MW region. Potential new products include: ESSE fields and error fields which will indicate suggested sampling regions and maps of bioluminescence or bioluminescence vs N,P,Z as potential research operational products.

6 Logistics and time line

All nowcasts and forecasts for Harvard needs will be produced at Harvard. Reiner Onken will visit Harvard for the period 15 February - 6 March. Harvard will provide a suitable workstation. The set-up and preliminary work necessary for modeling will begin immediately. Historical data will be gathered from the NODC CD-ROM and the SACLANTCEN web site. Climatological temperature and salinity fields will be created from MED-4. A suitable tidal model or tidal data is a necessity but has yet to be discovered. Meteorological forcings will be from NODC. The bottom topography will be from NAVOCEANO.

Some items which remain to be determined: the date of the military brief, dates of AXBT flights during Strong Resolve, regions for vessels to survey after 20 February.

Operational (real-time) data will be acquired from the RR98 web site. Data flow will likely begin ~8 February with CTD data from the Planet. The ships will gather for a briefing in Cadiz on 9 February. Significant data gathering begins 10 February with an intensive survey 10-19 February and AXBT flights scheduled for 12, 14, 16, 18, 19 and 20(2) February. A second meeting of ships will again take place in Cadiz on 20 February.

The *first* operational product is to be produced for 21 February. ESSE error fields are to be used to design the track for the AXBT flight on 23 Feb. Products will be uploaded to the RR98 web site immediately after their completion.

The *best* operational product is to be delivered in sufficient time to be included in the presail brief for the military vessels involved in SR-98. The present target date is 1 March. The product is to include data from the ships which are sampling after 21 February. ESSE error fields are to be used to design the track for the AXBT flight on 3 March.

The first operational product update will be delivered on 8 March, the beginning of SR-98). The update will be used to design AXBT flights to be flown during Strong Resolve. Their exact schedule is not yet known.

The second operational product update will be delivered on 15 March. This update will be used to design all remaining AXBT flights. SR-98 concludes on 22 March.

7 Critical dates

- Feb. 06 - Data gathering begins - Planet
- Feb. 09 - Briefing in Cadiz
- Feb. 10-19 - Intensive Survey
- Feb. 12 - AXBT flight
- Feb. 14 - AXBT flight
- Feb. 16 - AXBT flight
- Feb. 18 - AXBT flight
- Feb. 19 - AXBT flight
- Feb. 20 - 2 AXBT flights
- Feb. 20 - Briefing in Cadiz
- Feb. 21 - Operational Product 1 - *first*
- Feb. 23 - AXBT flight

- Mar. 01 - AXBT flight
- Mar. 01 - Operational Product 2 - *best*
- Mar. 03 - AXBT flight
- Mar. 08 - Operational Product 3 - *first update*
- Mar. 15 - Operational Product 4 - *second update*

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