The mean, trends and interannual variability in Mediterranean Air-Sea Interaction

Chris GARRETT and Richard OUTERBRIDGE

School of Earth and Ocean Sciences, University of VICTORIA **(Canada)**

The semi-enclosed nature of the Mediterranean Sea makes it an excellent place to test data sets and formulae, for air-sea interaction, that may be applied globally. In particular, we have used COADS (the Comprehensive Ocean Atmosphere Data Set) for 1946 to 1988, together with standard heat flux formulae, to examine the heat budget of the Mediterranean.

The initial estimate of the long term mean heat input is 36 W/m^2 higher than is compatible with the exchange through the Strait of Gibraltar; it is important to establish which component of the heat flux is responsible for this imbalance. An adjustment of the latent heat loss to make up the difference seems implausible as this would require a doubling of the rainfall over the Mediterranean to be compatible with the freshwater budget of the Sea. The heat imbalance may be partly due to an underestimate of the longwave back radiation, but it seems unlikely that all of the discrepancy can be accounted for in this way. Thus, as the sensible heat flux term is small anyway, we are reduced to ascribing most of the imbalance to an overestimate of the insolation, possibly due to the influence of marine haze. Direct measurements of insolation at sea are thus required, as well as improvement of the other terms in the heat and freshwater budgets.

An apparent trend in the COADS wind speed appears to be due to a change in observing practice (from sea state observations to anemometer measurements) which is difficult to allow for precisely. Thus any real trend in the total heat flux is difficult to establish, though COADS does show a downward trend in the insolation of about 5 W/m^2 over 40 years due to an increase of about 10% in the cloudiness.

COADS implies an interannual variability in the annual average total heat flux with a range of about 30 W/m^2, implying changes in the total heat content of the Mediterranean that might be detectable with historical hydrographic data. If these are not found the global application of COADS and standard formulae in variability studies will be further weakened. Much of the heat flux variability comes from changes in the latent heat flux term, with contributions due to variations in the humidity of the air and the saturation humidity at the sea surface temperature.

We have also examined the net buoyancy flux from the sea, finding that contributions from run-off and precipitation are important for the long-term mean, but insignificant for seasonal and interannual variability. In some years the net buoyancy flux is "estuarine" rather than "lagoonal", but a reversal of the average circulation would require larger changes in the heat or water budgets than seems plausible without major climate change.

We have extended our analyses of COADS to consider such things as interannual variability and spatial patterns of the fluxes and welcome further suggestions. In turn, we can help plan the future measurements and modelling studies that will improve our understanding of this fascinating sea.

Formation and Circulation of the Intermediate and the Deep Waters of the Mediterranean Sea

Jean-Claude GASCARD

Laboratoire d'Océanographie Dynamique et de Climatologie, Université Pierre et Marie Curie, PARIS **(France)**

Formation and circulation of intermediate and deep waters in the Mediterranean Sea is a broad topic implying many complex dynamical and thermodynamical processes, most of them being unknown up to now.

During the last ten years, a major discovery regarding these problems, has been undoubtedly the recognition of ubiquitous mesoscale eddy features in all the basins of the Mediterranean Sea:

- cyclonic and anticyclonic eddies associated with the Algerian and the Ligurian currents (MILLOT, 1991)
- complex patterns of circulation in the eastern Mediterranean Sea (ROBINSON *et al.*, 1991)
- cyclonic eddies around the Alboran anticyclonic gyre (TINTORE *et al.*, 1991)

to name a few. This is not too peculiar to the Mediterranean Sea since similar features had also been discovered 20 years ago in other oceans like the Atlantic Ocean for instance.

Obviously these widespread and intense mesoscale eddy features in the Mediterranean Sea must be clearly understood in order to make progress regarding formation and circulation of water masses such as Levantine Intermediate Water and Western and Eastern Mediterranean Deep Waters.

Concerning the deep convection and formation of Western Mediterranean Deep Water, the importance of the mesoscale had already been recognized a long time ago during the Medoc experiments (GASCARD, 1978), (KILLWORTH, 1979). More recently attention has been focused on three aspects all related to deep and bottom water formation:

- θ/S variability in bottom water characteristics (LACOMBE *et al.*, 1985)
- Small scale phenomenom ($u = v = w = 10$ cm/s; $x = y = z = 1$ km) influenced by atmospheric forcing (SCHOTT and LEAMAN, 1991)
- large scale barotropic circulation strongly influenced by bottom topography (MADEC *et al.*, 1991).

These three aspects should now be integrated in order to progress in our complete understanding of deep and bottom water formation processes. As noticed by (LACOMBE *et al.*, 1985), the phenomenom of variable bottom water and the processes which produce it, may be relevant to our understanding of water formation.

Last but not least, significant progress has been made during the past ten years in strait dynamics mainly in the strait of Gibraltar (ARMI and FARMER, 1988), (FARMER and ARMI, 1988) but also in the strait of Sicily. The importance of these straits for the general circulation of water masses and their formation in the Western and Eastern Mediterranean Seas, is now better understood (BRYDEN and STOMMEL, 1984). The variability in transport through the strait of Sicily compared with the much more stable transport through the strait of Gibraltar is quite intriguing.

Most of these new discoveries are resulting from observations, but in some cases they are also confirmed by numerical modelling. In this presentation we will try to review these new aspects thoroughly. Based on past observations, high resolution 3D numerical models, and advanced technology, we will also indicate new perspectives in the monitoring of the Mediterranean sea that should allow us to envision the construction of an operationnal model by year 2000.

REFERENCES

ARMI L. & FARMER D.M., 1988.- The Flow of Mediterranean Water Through the Strait of Gibraltar. *Progress in Oceanography,* 21, 1-105.

BRYDEN H.L. & STOMMEL H.M., 1984.- Limiting processes that determine basic features of the circulation in the Mediterranean Sea. *Oceanologica Acta* 7, 289-296

FARMER D.M. & ARMI L., 1988.- The Flow of Atlantic Water Through the Strait of Gibraltar. *Progress in Oceanography,* 21, 1-105.

GASCARD J.-C., 1978.- Mediterranean deep water formation, baroclinic instability and oceanic eddies. *Oceanologica Acta,* 1, 3, 315-330.

KILLWORTH P.D., 1979.- On "Chimney" formations in the ocean. *Journal of physical Oceanography,* 9, 3, 531-554.

LACOMBE H., TCHERNIA P. & GAMBERONI L., 1985.- Variable Bottom Water in the Western Mediterranean Basin. *Progress in Oceanography,* 14, 319-338

MADEC G., CHARTIER M., DELECLUSE P. & CREPON M., 1991.- A Three-Dimensional Numerical Study of Deep-Water Formation in the Norwestern Mediterranean Sea. *Journal of Physical Oceanography,* 21, 9, 1349-1371

MILLOT C.,1991.- Mesoscale and seasonal variabilities of the circulation in the western Mediterranean. *Dynamics of Atmosphere and Oceans,* 15, 3-5, 179-214

ROBINSON A.R., GOLNARAGHI M., LESLIE W.G., ARTEGIANI A., HECHT A., LAZZONI E., MICHELATO A., SANSONE E., THEOCHARIS A. & UNLUATA U., 1991.- The eastern Mediterranean general circulation: features, structure and variability. *Dynamics of Atmosphere and Oceans,* 15, 3-5, 215-240.

SCHOTT F. & LEAMAN K.D., 1991.- Observations with moored Acoustic Doppler Current Profilers in the Convection Regime in the Golfe du Lion. *Journal of Physical Oceanography,* 21, 4, 558-574.

TINTORE J., GOMIS D., ALONSO S. & PARILLA G., 1991.- Mesoscale Dynamics and Vertical Motion in the Alboran Sea. *Journal of Physical Oceanography,* 21, 6, 811-823.

Rapp. Comm. int. Mer Médit., **33,** (1992).