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MODELLING STUDIES IN SUPPORT OF OPEN-OCEAN CONVECTION FIELD PROGRAMS

I - RESEARCH GOALS

We have begun an inquiry into the process of open-ocean deep convection guided by the field observations collected in the western Mediterranean during the past winter (1991 - 1992) by the Kiel Group led by Professor Schott and Dr. Uwe Send. Our goals are to understand the role of planetary rotation in the sinking and spreading of cold water and test our understanding against field observations and laboratory models.

II - OBJECTIVES

(i) to understand and parametrize the convective scale in general circulation models.
(ii) to provide a context in which to design future observing programs for open-ocean deep convection.

III - APPROACH

Overturning on the scale of plumes is non-hydrostatic and so conventional primitive equation hydrostatic ocean models cannot be used to explicitly model it. Instead we employ a non-hydrostatic ocean circulation model. The model is capable of explicitly resolving, rather than parametrising, the overturning process; it can be run at sufficiently high horizontal resolution (~ 200 metres) that it can explicitly resolve structure on the cell-scale yet, at the same time, represent a population of plumes over the convection site and their effect on the large-scale. A description of the numerical model, based on the Boussinesq equations in the presence of rotation, and its use in the simulation of oceanic deep convection can be found in Brugge, Jones and Marshall (1991) and Jones and Marshall (1992). Both haline convection and overturning due to surface heat loss can be modelled.

IV - TASKS COMPLETED

A joint paper with Dr. Send is nearing completion which discusses the integral effects of a population of convective plumes. This study has direct relevance to the design of future field experiments and the role of tomography therein and the interpretation of the MEDOC 92.

Our studies of convection are being used to provide a context in which to design a future observing program of open-ocean deep convection in the field is being proposed by Dr. Fiaderio. A planning meeting is being held in San Francisco, this December.

V - SCIENTIFIC RESULTS

(1) We have demonstrated using vorticity conservation and model simulations that the convective activity in the interior of the cooling region does not generate significant average vertical velocities. Instead, the average sinking and circulation is concentrated in a thin band containing the rim current.

(2) If the vorticity is associated with the rim current as in our theory, it would be very difficult to detect this vorticity with a method like acoustic tomography since the sound would have to travel much of its path within this band to measure a significant circulation around the region. This has been a hope for the experiment that was conducted in the MEDOC region in the winter 1992/92, where area-averaged vorticity might be detectable with a tomographic array. The results are not available to date, but both within and far enough outside the convections patch one would not expect a vorticity signal based on the ideas presented here. Maybe the tomography can thus act as a test for our theory.

(3) We suggest that for events that are not too long, the deep water formation rate is given by the volume of mixed water above the normal level of the deep water. This water has been convectively generated from a mixture of surface, intermediate and deep waters with simultaneous cooling, and will eventually sink to its appropriate density level.

(4) We have argued that it may be sufficient in large-scale models to parametrize the convective process with an appropriate vertical adjustment scheme.

VI - ACCOMPLISHMENTS - IV and V above.

REFERENCES

Brugge, R., Jones, H.L. and J.C. Marshall
Non-hydrostatic ocean modelling for studies of open-ocean deep convection. In "Deep convection and deep water formation" edited by J-C Cascard
Elsevier Oceanography Series, 1991

Jones, H.L. and J.C. Marshall
Convection with rotation in a neutral ocean; a study of open-ocean deep convection. To appear in Journal of Phys. Oceanography.

PUBLICATIONS EMANATING FROM STUDY

P.I. Send, U and J.C. Marshall 1992
Integral effects of deep convection
to be submitted to Journal Physical Oceanography

STATISTICS

1) [0] Papers published, refereed journals.
2) [1] Papers submitted or in press, refereed journals.
3) [0] Books or chapters published, refereed journals.
4) [0] Books or chapters submitted, refereed journals.
5) [4] Invited presentations at scientific conferences.
6) [0] Contributed presentations.
7) [0] Technical reports and papers, non-refereed journals.
8) [0] Undergraduate students supported. *
9) [1] Graduate students supported. *
10) [0] Post-docs supported. *
11) [0] Other professional personnel supported. *

* supported means at least 25% support on this ONR grant

EEO/MINORITY SUPPORT:

12) [0] Female grad students
13) [0] Minority grad students
14) [0] Asian grad students
15) [0] Female post-docs
16) [0] Minority post-docs
17) [0] Asian post-docs

Minorities include Blacks, Aleuts, American Indians and Hispanics only

{Patents and awards}

Patents filed or granted and Awards, Honors and Prizes.

None

PLUMES

CONES

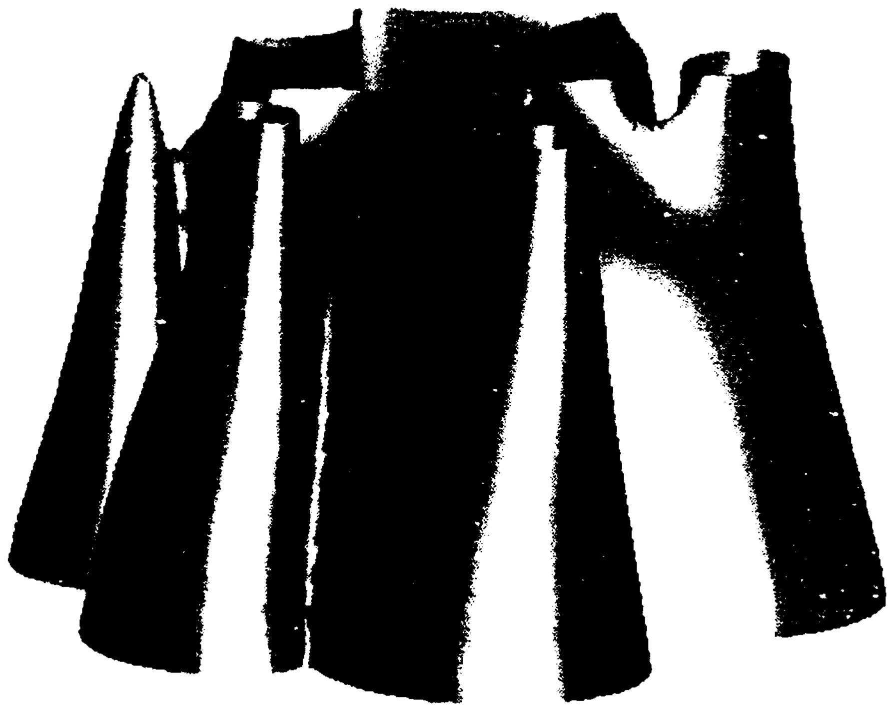

FIGURE CAPTION:

Plumes, the convective elements, and cones, the geostrophically adjusted end-state of the convective process,as seen in a high resolution numerical simulation of open-ocean deep convection. Plumes can be seen reaching down on a scale of approximately 1 km from the cooled sea surface. The dense water sinks under gravity and rotation and ends up in swirling cones of scale approximately 5 km on the periphery of the cooling region. The depth of the ocean is 2 km.