REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 14, 1995	Final: 01 July 1993 - 31 July 1995

4. TITLE AND SUBTITLE
Sensitivity on Frontal Processes to the Assimilation of Remotely sensed Data

5. FUNDING NUMBERS
N00014-93-1-0572

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Department of the Navy
Office of Naval Research
Resident Representative
496 Summer St., Room 103
Boston, MA 02210-2109

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Final Report attached.

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12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The scientific objectives of this project were to gain a better understanding of how external forcing and eddy fluxes influence frontal properties such as the mean frontal structure, eddy variability, cross-front exchange, subduction, and biological productivity. During the past two yeas, this grant supported or partially supported the publication of 4 manuscripts in refereed journals, 2 articles in non-refereed journals, and 7 oral presentation. The common theme to each of these studies is improving our understanding of frontal dynamics and the role of fronts in the general circulation. The results (see attached) relating to how water is exchanged and subducted at both open ocean and near coastal fronts give insight into how fronts act as controlling factors in the exchange of water masses between different flow regimes. It has also been found here that even weak horizontal deformation fields can drastically alter the stability characteristics of strong frontal regions. Such frontogenesis mechanisms must be properly represented if one is to accurately predict frontal formation or evolution on time scales of days to years. Finally, a fundamental understanding of the physics that govern cross-frontal exchange processes is key to parameterizing their influences ion non-eddy resolving general circulation models, work towards this end has been started.

14. SUBJECT TERMS
Fronts, numerical modeling, baroclinic instability, subduction

15. NUMBER OF PAGES
2

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
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Final Report for Grant # N00014-93-1-0572

Sensitivity of frontal processes to the assimilation of remotely sensed data

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The scientific objectives of this project were to gain a better understanding of how external forcing and eddy fluxes influence frontal properties such as the mean frontal structure, eddy variability, cross-front exchange, subduction, and biological productivity. During the past two years, this grant supported or partially supported the publication of 4 manuscripts in refereed journals, 2 articles in a non-refereed journals, and 7 oral presentations.

The common theme to each of these studies is improving our understanding of frontal dynamics and the role of fronts in the general circulation. The results (described below) relating to how water is exchanged and subducted at both open ocean fronts (FASINEX) and near coastal fronts (Labrador Current) give insight into how fronts act as controling factors in the exchange of water masses between different flow regimes. Understanding and representing the details of frontal instabilities, and the resulting eddy formation and propagation, are essential to the development of high resolution regional models. It has also been found here that even weak horizontal deformation fields can drastically alter the stability characteristics of strong frontal regions. Such frontogenesis mechanisms must be properly represented if one is to accurately predict frontal formation or evolution on time scales of days to years. The coupled physical/biological studies have been initiated that demonstrate that frontal dynamics strongly influence the biological and optical properties in the upper ocean in frontal regions. Finally, a fundamental understanding of the physics that govern cross-frontal exchange processes is key to parameterizing their influences in non-eddy resolving general circulation models, work towards this end has been started.

Mechanisms of cross-frontal exchange and subduction at fronts were investigated in "Frontogenesis, subduction, and cross-front exchange at upper ocean fronts", by M. Spall (*J. Geophys. Res.,* **100:** 2543-2557, 1995). Analytic and nonlinear primtive equation models were used to demonstrate that localized frontogenesis driven by baroclinic wave growth can drive regions of subduction and result in the formation of energetic dipole vortex pairs. The total subduction rate driven by this frontogenesis mechanism is of O(20 m/yr), similar to that due to large scale atmospheric forcing.

Contributions due to large scale atmospheric forcing and small scale instabilities of the coastal Labrador Current towards the export of recently formed Labrador Sea Water are explored in "Mid-depth ventilation in the western boundary current system of the sub-polar gyre", by R. Pickart, M. Spall, and J. Lazier (submitted to *Deep Sea Res.*). It is found that instability of the baroclinic Labrador Current can form sub-mesoscale eddies that get entrained into the offshore barotropic deep Labrador Current, consistent with recent observations. The southern fringe of the Labrador Sea may also provide a region for formation and rapid export of Labrador Sea Water under extreme winter conditions.

The cross-front exchange of mass, and release of potential energy, resulting from baroclinic instability of a variety of fronts has been accurately reproduced in a two-dimensional model with space and time dependent mixing coefficients that are derived from the properties of the large scale flow ("On baroclinic eddy-flux parameterizations in the ocean: Evaluation of eddy transfer schemes using a 2D model", by M. Visbeck, J. Marshall, T. Haines, and M. Spall, submitted to *J. Phys. Oceanogr.*). This approach provides a means to calculate space and time dependent mixing coefficients for large scale models based on the model horizontal and vertical stratification.

Horizontal deformation fields (as provided, for example, by mesoscale eddies) are shown to produce mixed layer fronts consistent with those observed during the Frontal Air-Sea Interaction EXperiment (FASINEX) in "Baroclinic Jets in Confluent Flow", by M. Spall (to be submitted to *J. Phys. Oceanogr.*). The ageostrophic horizontal and vertical motions and vertical heat fluxes are consistent with that expected from scaling theory and found in FASINEX. The deformation field responsible for the frontal formations has been shown to stabilize the front relative to the spin-down case. Meandering fronts that oscillate about a mean state in a statistical equilibrium are produced for a wide range of model parameters. This result differs from the unforced frontal calculations, in which the front breaks down over a few instability cycles, but is consistent with the observations of long-lived fronts in the FASINEX. The theory of instabilities in time dependent flows (Bishop 1993, QJRMS) provides a useful tool for predicting which flows can reach this nonlinear, time dependent regime.