
by

Jennifer Earles, University of Wisconsin
Lawrence Pratt, Woods Hole Oceanographic Institution
Peter Cornillon, University of Rhode Island
Jean-François Cayula, University of Rhode Island

November 1988

Technical Report

Funding was provided by the Office of Naval Research under contract Number N00014-87-K-0007 and by the National Science Foundation under grant Numbers OCE 87-00601 and OCE 85-10828.

Approved for public release; distribution unlimited.

by

Jennifer Earles
Department of Mathematics
University of Wisconsin
Madison, Wisconsin 53706

Lawrence Pratt
Department of Physical Oceanography
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

and

Peter Cornillon
Jean-François Cayula
Graduate School of Oceanography
University of Rhode Island
Narragansett, Rhode Island 02882

November 1988

Technical Report

Funding was provided by the Office of Naval Research through contract Number N00014-87-K-0007, and by the National Science Foundation under grant Numbers OCE 87-00601 and OCE 85-10828.

Reproduction in whole or in part is permitted for any purpose of the United States Government. This report should be cited as: Woods Hole Oceanog. Inst. Tech. Rept., WHOI-88-57.

Approved for publication; distribution unlimited.

Approved for Distribution:

Robert C. Beardsley, Chairman
Department of Physical Oceanography
Table of Contents

Abstract........................................................................................................................................................................ pg. 2
Acknowledgements........................................................................................................................................................ pg. 2
The Images and Digitized Plots (written summary).................................................................................................................. pgs. 2-3
Table of Included Images............................................................................................................................................... pg. 4
Digitized Plots........................................................................................................................................................................... pgs. A1-A89
Photographs of Original Images......................................................................................................................................... pgs. B1-B13
Abstract

Ninety plots of digitized temperature boundaries from infrared satellite images of the Gulf Stream along with corresponding image snapshots were compiled to determine stream width propagation speed. The satellite images are from the years 1982, 1983, and 1985 and are often of consecutive days. In this report, these images and digitized plots are presented.

Acknowledgements

The image-processing software was developed by R. Evans, O. Brown, J. Brown and A. Li at the University of Miami under Office of Naval Research funding. The continuing support of the Miami Group is gratefully acknowledged.

The Images and Digitized Plots

The ninety images used for this study were chosen from over twelve hundred images because they are cloud free in some region of the Gulf Stream and have a corresponding clear image within five days. Colors on the images range from violet for very cold (≈2 degrees Celsius) to red for very warm (≈30 degrees Celsius). The yellows of the Gulf Stream are in the mid 20s. Black areas are clouds. (Note that the converse is not true: all clouds were not detected by the cloud detection algorithm hence cloudy areas do appear in some of the imagery as anomalously cold regions as opposed to black regions; for example, the large violet area trending north-south in the center of the 12 May 1982 image.) The area covered by the 1985 color images is 32.624 to 44.376 degrees North and 64.123 to 75.877 degrees West. The area covered by the 1982 and 1983 images is 33.890 to 44.110 degrees North and 62.923 to 76.077 degrees West. Also superimposed on the color images are the edges located with the edge detection algorithm briefly described in the paragraph.

To locate the edges defining the Gulf Stream that were required for this study, an edge detection algorithm was passed over each image (Cayula, 1988). Although edge detection was the main focus, the first step was to remove the most obvious clouds from the image. To achieve this, a rough segmentation of the image between cloudy and non-cloudy areas was performed by thresholding the entire image with respect to the temperature and the gradient magnitude. The direction of the gradient vector in, and the shape of, each area classified as possibly cloudy were then examined to determine the validity of the classification. Next, the image was segmented into overlapping windows and the histogram associated with each window
was studied to detect any statistically significant edge. If an edge was detected, the temperature threshold determined through histogram analysis was used to segment the window under study into two populations. The temperature variability (a mix of variance and correlation) of each population was then examined to detect any remaining clouds. After all detected clouds were removed, the histogram analysis was performed again, this time to detect possible temperature fronts. When a statistically significant edge was detected, the cohesion of the two populations resulting from the histogram analysis was estimated to determine whether or not the histogram-based segmentation was spatially valid. The fronts detected at the window-level were subsequently completed and further validated at the local level by using a contour following algorithm. This algorithm performs better (lower standard deviation with respect to the inverted echo sounder determination of the edges) than other automated methods with the set of data used. Line drawings of the resulting edges were only produced for the region from 32 to 40 degrees North and 68 to 76 degrees West, the area of particular interest to this study. The program used to plot the sets of data points varied the types of lines representing the temperature boundaries. The reader is asked to ignore these differences.

Reference

<table>
<thead>
<tr>
<th>1982</th>
<th>1983</th>
<th>1985</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 2, 19:47:25</td>
<td>April 22, 08:27:45</td>
<td>March 26, 18:41:24</td>
</tr>
<tr>
<td>April 12, 19:47:25</td>
<td>April 27, 18:50:52</td>
<td>March 29, 18:10:17</td>
</tr>
<tr>
<td>April 19, 18:05:55</td>
<td>April 29, 18:27:39</td>
<td>April 3, 18:56:17</td>
</tr>
<tr>
<td>May 1, 07:40:20</td>
<td>May 6, 07:17:50</td>
<td>April 4, 18:45:17</td>
</tr>
<tr>
<td>May 1, 19:03:44</td>
<td>May 6, 18:42:15</td>
<td>April 5, 07:09:23</td>
</tr>
<tr>
<td>May 6, 08:22:29</td>
<td>May 7, 18:30:36</td>
<td>April 7, 06:48:07</td>
</tr>
<tr>
<td>May 6, 18:06:15</td>
<td>May 8, 08:34:42</td>
<td>April 7, 18:14:33</td>
</tr>
<tr>
<td>May 12, 18:33:59</td>
<td>May 11, 07:57:22</td>
<td>April 17, 18:07:57</td>
</tr>
<tr>
<td>May 16, 19:29:01</td>
<td>May 13, 07:33:14</td>
<td>April 18, 06:31:51</td>
</tr>
<tr>
<td>May 18, 07:38:43</td>
<td>June 12, 08:09:43</td>
<td>April 18, 19:38:39</td>
</tr>
<tr>
<td>June 3, 07:49:15</td>
<td>June 23, 19:00:45</td>
<td>April 20, 07:51:49</td>
</tr>
<tr>
<td>July 3, 18:19:12</td>
<td>June 24, 07:24:39</td>
<td>April 21, 19:07:17</td>
</tr>
<tr>
<td>July 8, 07:35:27</td>
<td>June 24, 18:48:57</td>
<td>April 23, 18:44:31</td>
</tr>
<tr>
<td>July 8, 18:59:46</td>
<td>June 26, 08:41:56</td>
<td>April 26, 18:12:45</td>
</tr>
<tr>
<td></td>
<td>June 28, 08:15:46</td>
<td>April 27, 06:37:02</td>
</tr>
<tr>
<td></td>
<td>June 30, 19:16:46</td>
<td>April 28, 08:08:21</td>
</tr>
<tr>
<td></td>
<td>July 10, 18:54:51</td>
<td>April 28, 17:51:24</td>
</tr>
<tr>
<td></td>
<td>July 13, 20:00:37</td>
<td>April 30, 17:31:12</td>
</tr>
<tr>
<td></td>
<td>July 14, 19:48:25</td>
<td>May 1, 07:34:17</td>
</tr>
<tr>
<td></td>
<td>July 17, 19:10:30</td>
<td>May 5, 06:52:25</td>
</tr>
<tr>
<td></td>
<td>July 23, 08:12:47</td>
<td>May 6, 08:23:44</td>
</tr>
<tr>
<td></td>
<td>July 27, 18:48:59</td>
<td>May 6, 18:06:56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May 19, 19:10:57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May 20, 17:20:12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May 26, 08:12:11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May 26, 17:55:02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May 27, 08:00:52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May 27, 17:44:56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May 28, 07:49:27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May 28, 19:15:40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>June 2, 06:55:58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>June 2, 18:21:09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>June 4, 06:34:20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>June 9, 18:47:08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>June 10, 07:11:07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>June 15, 07:59:39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>June 17, 19:03:34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>June 21, 06:54:40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>June 22, 06:43:55</td>
</tr>
</tbody>
</table>

**Note:** Times are Greenwich Mean Time.
*20-May-85
17:20:12 GMT
09-Jun-85
18:47:08 GMT
10-Jun-85
07:11:07 GMT

A85
Attn: Stella Sanchez-Wade
Documents Section
Scripps Institution of Oceanography
Library, Mail Code C-075C
La Jolla, CA 92039

Hancock Library of Biology &
Oceanography
Alan Hancock Laboratory
University of Southern California
University Park
Los Angeles, CA 90089-0371

Gifts & Exchanges
Library
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, NS, B2Y 4A2, CANADA

Office of the International
Ice Patrol
c/o Coast Guard R & D Center
Avery Point
Groton, CT 06340

Library
Physical Oceanographic Laboratory
Nova University
8000 N. Ocean Drive
Dania, FL 33304

NOAA/EDIS Miami Library Center
4301 Rickenbacker Causeway
Miami, FL 33149

Library
Skidaway Institute of Oceanography
P.O. Box 13687
Savannah, GA 31416

Institute of Geophysics
University of Hawaii
Library Room 252
2525 Correa Road
Honolulu, HI 96822

Library
Chesapeake Bay Institute
4800 Atwell Road
Shady Side, MD 20876

MIT Libraries
Serial Journal Room 14E-210
Cambridge, MA 02139

Director, Ralph M. Parsons Laboratory
Room 48-311
MIT
Cambridge, MA 02139

Marine Resources Information Center
Building E38-320
MIT
Cambridge, MA 02139

Library
Lamont-Doherty Geological
Observatory
Colombia University
Palisades, NY 10964

Library
Serials Department
Oregon State University
Corvallis, OR 97331

Pell Marine Science Library
University of Rhode Island
Narragansett Bay Campus
Narragansett, RI 02882

Working Collection
Texas A&M University
Dept. of Oceanography
College Station, TX 77843

Library
Virginia Institute of Marine Science
Gloucester Point, VA 23062

Fisheries-Oceanography Library
151 Oceanography Teaching Bldg.
University of Washington
Seattle, WA 98195

Library
R.S.M.A.S.
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149

Maury Oceanographic Library
Naval Oceanographic Office
Bay St. Louis
NSTL, MS 39522-5001

Marine Sciences Collection
Mayaguez Campus Library
University of Puerto Rico
Mayagues, Puerto Rico 00708

Jennifer Earles, Lawrence Pratt, Peter Cornillon, Jean-François Cayula

The Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

The Office of Naval Research, Environmental Sciences
Directorate, Arlington, VA 22217
and by the National Science Foundation

This report should be cited as: Woods Hole Oceanog. Inst. Tech. Rept., WHOI-88-57.

Ninety plots of digitized temperature boundaries from infrared satellite images of the Gulf Stream along with corresponding image snapshots were compiled to determine stream width propagation speed. The satellite images are from the years 1982, 1983, and 1985 and are often of consecutive days. In this report, these images and digitized plots are presented.