OLD DOMINION UNIVERSITY RESEARCH FOUNDATION

DEPARTMENT OF ELECTRICAL ENGINEERING
SCHOOL OF ENGINEERING
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA

PRELIMINARY STUDY OF (2-D) DIGITAL FILTERING FOR DEALIASING NOSS WIND DIRECTION DATA

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By

John W. Stoughton, Principal Investigator

Final Report
For the period ending August 31, 1980

Prepared for the
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia

Under
Research Grant NAS-1-15648
Task Authorization No. 38
Lyle C. Schroeder, Technical Monitor
FED-Antenna & Microwave Research Branch

January 1984

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Submitted by the
Old Dominion University Research Foundation
P.O. Box 6369
Norfolk, Virginia 23508

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PRELIMINARY STUDY OF (2-D) DIGITAL FILTERING FOR DEALIASING NOSS WIND DIRECTION DATA

By

John W. Stoughton*

SUMMARY

This report presents a summary of the study supported by NAS-1-15648, Task Authorization No. 38. The purpose of this study was to initiate an investigation into suitable two-dimensional (2-D) signal processing techniques for application to the ambiguity removal of NOSS-simulated scatterometer data. The study reviewed allied (2-D) methods as applied to image and geophysical data. Of particular interest were those methods which used filtering or pattern recognition for information extraction.

This study culminated in a proposal (see Appendix), for further study of a pattern recognition strategy. The proposal reflected a viable approach to solving the wind direction ambiguity problem as understood by this initial investigation. The proposal was subsequently awarded a grant by NASA, under research grant NAG1-111.

*Associate Professor, Department of Electrical Engineering, Old Dominion University, Norfolk, VA 23508.

APPENDIX

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ODURF NO. NASA-81-1154-403

A PROPOSAL TO THE

National Aeronautics and Space Administration
Langley Research Center
Office of Research Grants and University Affairs
Hampton, Virginia 23665

FROM THE

DEPARTMENT OF ELECTRICAL ENGINEERING

OLD DOMINION UNIVERSITY

FOR CONSIDERATION BY UNIT/DIVISION/PROGRAM	RFP/PROGRAM/SOLICITATION NO.
Flight Electronics Div - Electromagnetics Research Br	

TITLE

Investigation of a Pattern Classification Approach for Wind Streamline Direction Ambiguity Removal

PRINCIPAL INVESTIGATOR - NAME	DEPT.	PHONE
John W. Stoughton	Electrical Engineering	(804) 440-3741
ADDITIONAL INVESTIGATOR - NAME	DEPT.	PHONE
ADDITIONAL INVESTIGATOR - NAME	DEPT.	PHONE

AMOUNT REQUESTED	DURATION	DESIRED STARTING DATE
$35,250	10½ months	October 1, 1980

FOR RENEWAL OR CONTINUING AWARD REQUEST, LIST PREVIOUS AWARD NO.

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER AGENCY? Yes ___ No X IF YES, LIST ACRONYM(S).

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW.

- [ ] HUMAN SUBJECTS
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- [ ] PROPRIETARY AND PRIVILEGED INFORMATION

	PRINCIPAL INVESTIGATOR	DEPARTMENT CHAIR	DEAN
NAME	John W. Stoughton	Stanley R. Liberty	John A. Weese
SIGNATURE	J W Stoughton	Stanley R. Liberty	John A. Weese
DATE	8/18/80	8/18/80	8/18/80

	ASSOCIATE VICE PRESIDENT FOR RESEARCH AND SPONSORED PROGRAMS	EXECUTIVE DIRECTOR, OLD DOMINION UNIVERSITY RESEARCH FOUNDATION
NAME	Marvin E. Wyman	E.M. Maygarden
SIGNATURE	Marvin E Wyman	E M Maygarden
DATE	Aug 19, 1980	8/19/80

THIS PROPOSAL IS SUBMITTED THROUGH AND ANY RESULTING AWARD WILL BE ADMINISTERED BY THE

OLD DOMINION UNIVERSITY RESEARCH FOUNDATION
P.O. BOX 6369
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INVESTIGATION OF A PATTERN CLASSIFICATION APPROACH FOR WIND STREAMLINE DIRECTION AMBIGUITY REMOVAL

ABSTRACT

The proposed research will investigate a pattern classification approach to wind streamline direction ambiguity removal. The basic approach involves establishling an appropriate measurement of a characterizing vector of the streamline orientation angle parameter surface. Clustering and training techniques will be employed to distinguish major meteorological features from which directional information may be determined.

I. INTRODUCTION

1. Background

In the area of two-dimensional (2-D) signal processing, much effort has been applied to spatial "signals" such as imaging and geophysical data. The signal processing methods typically employ filtering strategies or pattern recognition techniques for information extraction.

Of interest is a particular class of 2-D information which involves streamlines such as found in flow phenomena or fingerprint patterns. One member of this class is wind stream patterns which result from remotely sensed (satellite scatterometer based) data (ref. 1), which is processed (ref. 2) to yield wind vectors with directional ambiguity on a grid of points along a path on the ocean's surface. Efforts to deal with these patterns for the purpose of removal of the directional ambiguities have been recently reported (ref. 3). Additional efforts have been reported which define an improved scatterometer configuration which promotes a bidirectional ambiguity instead of a quad-directional ambiguity (ref. 4).

2. Proposal Direction

It is the purpose of the proposal to suggest a pattern recognition approach which will be suitable for characterizing streamline patterns. Additionally, the investigation should provide an extension of the pattern classification problem to wind streamline direction ambiguity removal.

II. THEORY OF APPROACH

1. Background

The basic approaches to streamline pattern classification are twofold. The first approach is syntactical in nature as evidenced by a recent report on fingerprint classification (ref. 5). The second approach involves the basic clustering techniques (ref. 6). In this technique a feature is identified if a specific measurement vector lives in a particular region of the measurement space designed for a particular attribute of the streamline pattern. However, the appropriateness of a particular measurement scheme becomes important in establishing separability of the feature clusters in the measurement space.

2. Streamline Modeling

Of immediate interest is a class of sampled functions $\underline{V}$ $(m\Delta x, n\Delta y)$ (or more simply $\underline{V}_{mn}$) where $\underline{V}$ is a complex variable of magnitude s and angle θ with 180-degree uncertainty. For simplicity, we assume equiprobable uncertainty. Thus, on a sampling grid, V_{nm} could be represented by a bidirectional vector with lengths as shown in figure 1.

The directional quality of a region in this sampled space is characterized by the general orientation of the vectors. This perspective provides a sense of orientation to streamline characteristics when viewed in the x-y plane.

The grid of points $\underline{V}_{mn}$ may now be represented by two sampled-parameter collections. The first, a magnitude of S-surface; and the second, an angle or θ-surface. That is, each $S_{mn} = |V_{mn}|$ and

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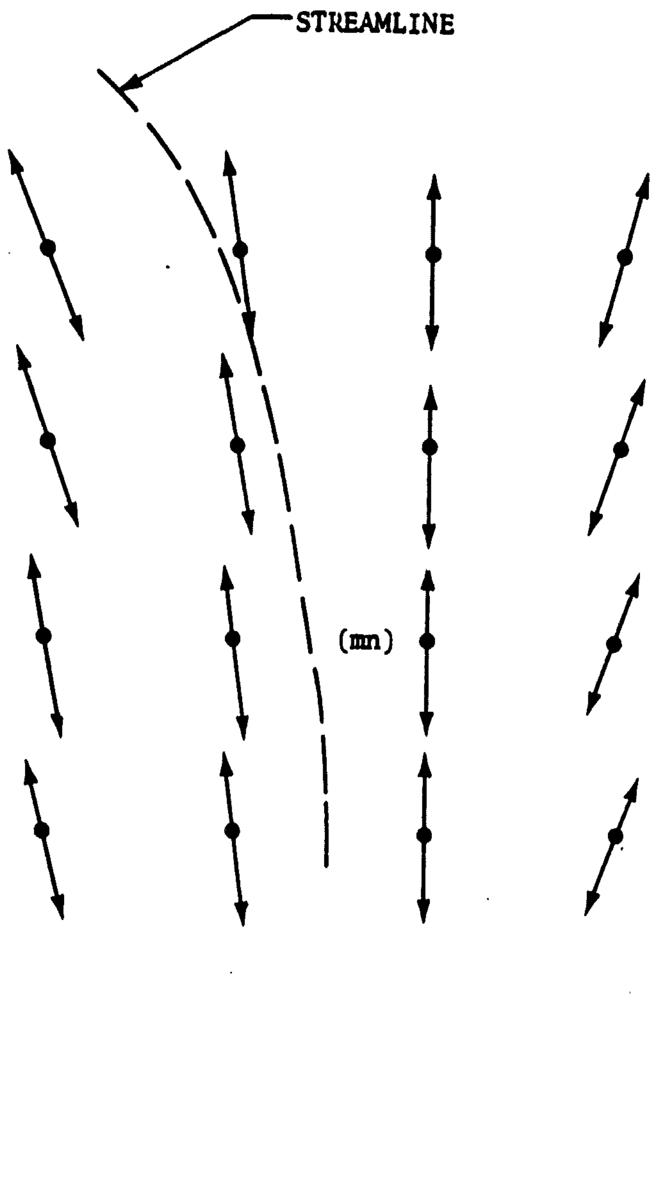

Figure 1. Sampled wind stream pattern with ambiguity.

$\theta_{mn} = \underline{V}_{mn}$ (with ambiguity). It is the θ-surface which is representative of the streamline behavior. Examples of a streamline characteristic and corresponding θ-surface are illustrated in figure 2.

3. θ-Surface Representation

The first step in streamline classification is to represent the θ-surface by some two-dimensional function $\phi(xy)$. One candidate is for $\phi(xy)$ to be a 2-D polynomial where

$$\phi(xy) = \sum_{k=0}^{M} \sum_{l=0}^{N} a_{kl}\, x^k\, y^l \tag{1}$$

Further, let $\phi_{mn}(xy)$ be defined in a least-mean-square sense to a region of $P \times Q$ points minimizing

$$e^2_{mn} = \sum_{\substack{i = -(M-1) \\ j = -(N-1)}}^{0} \sum^{0} \left(\theta_{m+i,n+j} - \sum_{(k,l)}\sum a_{kl}\, x^k_{m+i}\, y^l_{n+j}\right)^2 \tag{2}$$

relative to $a_{kl}(mn)$.

Thus, at each indice (m,n) there will be generated a measurement or characterizing vector $\underline{a}(mn)$ consisting of the polynomial coefficient $a_{ij}(mn)$. An efficient algorithm for the one-dimensional case has recently been suggested by the author (ref. 7).

4. Feature Space

For a given type of contour or shape of the θ-surface, there should exist distinct regions in the $\underline{a}$ vector space in which the particular $\underline{a}(mn)$ may be found. These regions may be determined by clustering sets of $\underline{a}(mn)$ vector from training pattern sets (ref. 6). In the case of the θ-surface which is generated by windstream phenomena, it is of interest to identify and classify the meteorological feature which is typically

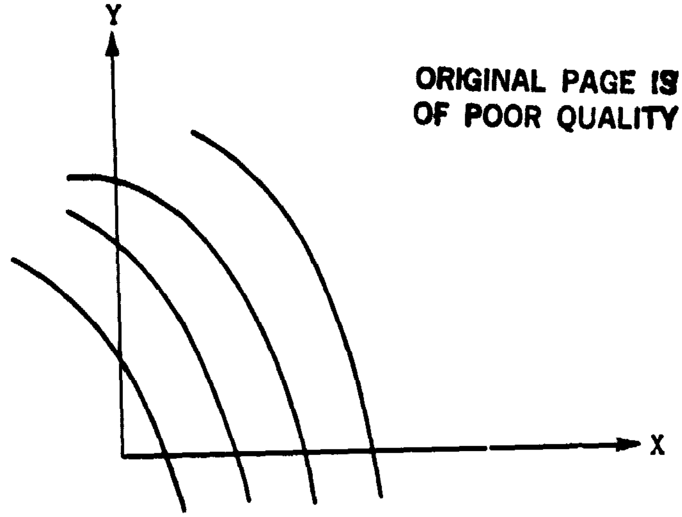

Figure 2a. Streamline.

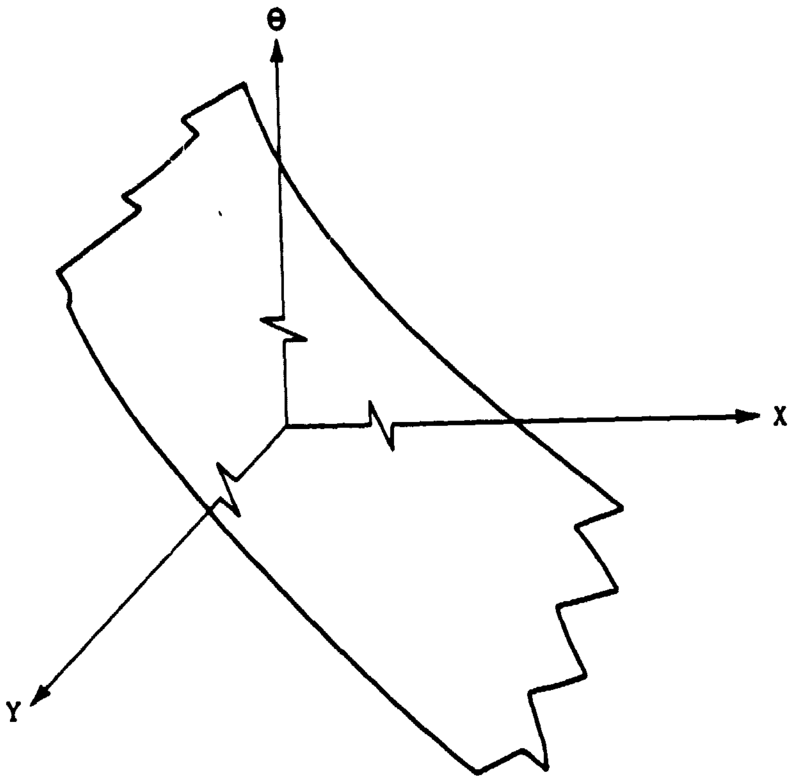

Figure 2b. θ-surface.

a source, sink, or boundary of the windstream contour. These features include cyclones, anticyclones, fronts, etc. These large-scale features might be observed as having distinctive attributes relative to the surface of the corresponding region. For example, a front may be viewed as a near-step discontinuity in the θ-surface. Windstreams which are sufficiently far from a major meteorological feature will have θ-surfaces which appear flat or which change slowly.

5. General Classification

In terms of characteristics of the θ-surface the windstream pattern should fall into two major groups. The first group, Group I, would consist of high-activity regions associated with strong or major meteorological features. The second group, Group II, is identified with streamline regions surrounding or in between high-activity Group I regions. An example of this regionalization is shown in figure 3.

6. Windstream Direction Ambiguity Removal

To this point, a pattern recognition approach has been suggested which will yield a classification of meteorological regions. In the case of windstream lines, it is of specific interest to determine the streamline pattern in each region.

The approach to the direction ambiguity removal is an extension of the pattern classification approach just described. Once a Group I region has been identified, and the particular meteorological feature identified (front, etc.), then basic meteorological rules can be applied to make a decision as to the wind direction. Most likely, peripheral information such as hemisphere, water vapor, and wind speed (from S-surface) may be brought in to increase the dimensionality of the basic measurement space or to define a smaller dimensioned feature space. Once streamline directions have been resolved in the Group I regions, then by continuity arguments, the directional attributes may be extended to remove the directional ambiguities in the Group II regions. Most likely, a Group III category should be assigned to those small regions involving

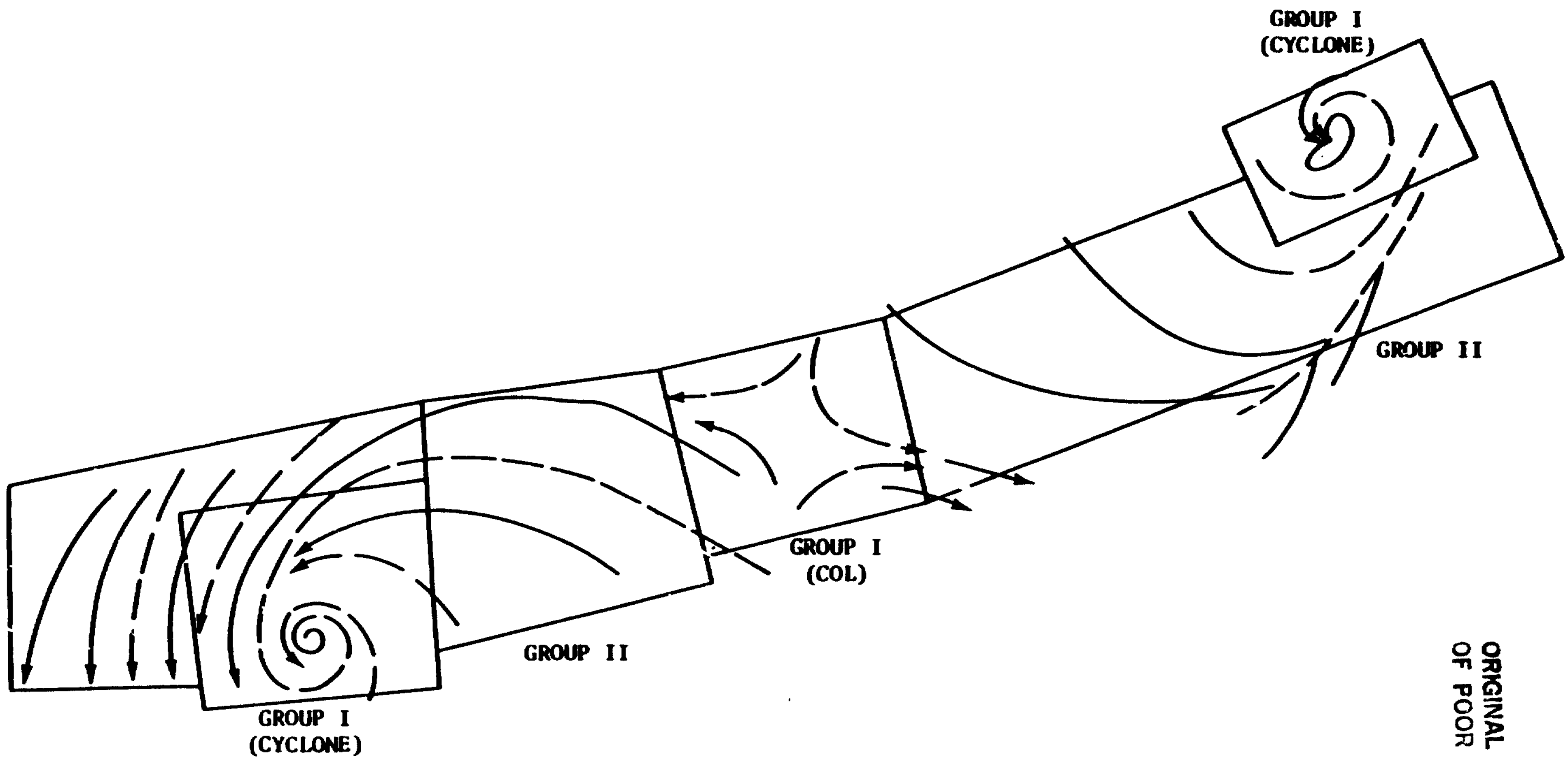

Figure 3. Group I and Group II streamline features.

low wind speeds and far from Group I regions which make impossible deterministic decision making on the direction ambiguity removal.

III. PROPOSED RESEARCH

The objective of the proposed research is to investigate a pattern classification approach to the identification and direction ambiguity removal of wind streamline patterns. The approach followed in this research would incorporate the following:

1. Determination of the suitability of the characterizing surface function, ϕ, where ϕ is defined as in equation (1). Of interest is minimizing the dimensionality of the 2-D surface polynomial with respect to providing adequate characterization of the streamline θ-surface.

2. Determination of a strategy for positioning or "sliding" ϕ through the sampled wind vector data V_{mn}. Efficient computational processes for resolving the $\underline{a}(mn)$ should be explored.

3. Establishment of a suitable training method for determining the classification region in the $\underline{a}$ measurement space.

4. Determination of an unambiguous decision basis for determining wind direction in a Group I meteorological region.

5. Demonstration of the applicability of approach to synthesized NOSS wind stream data.

In this research effort it is expected that appropriate wind vector data will be supplied by NASA/Langley Research Center. Further, it is expected that computational facilities will be made available at Langley Research Center via remote hookup for support of this research. Terminals and graphic terminal will be made available by Old Dominion University.

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