UNIVERSITY - NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

RESEARCH VESSEL TECHNICAL ENHANCEMENT COMMITTEE

MEETING MINUTES

October 19-21, 1994

Rosenstiel School of Marine and Atmospheric Science
Miami, FL

Minutes of 1994 UNOLS/RVTEC Annual Meeting

The meeting was called to order by Chair Rich Findley at 0900 Wednesday, October 19, 1994 at the Rosenstiel School of Marine and Atmospheric Science, University of Miami. A list of the attendees and the agenda is included as Appendix 1.

Tom Wilson presented the report of the Database subcommittee. It was decided to continue the present effort of maintaining a database of the equipment held by each institution and of the capabilities of the technicians. At the present time the information is text format rather than a formal data base system and the consensus was that it is appropriate to continue this approach. Some concerns over privacy were expressed and Tom pointed out that submission of the information to him implies permission to publish it. Any one with reservations about the distribution of resume type information should not submit it. Tom will continue to examine methods for making this information available electronically and requested that updates be submitted to him at least annually, in March, to allow a new issue to be published in April of each year.

Steve Rabalais presented the report of the Technician Exchange and Training subcommittee. He pointed out the issue of technician exchange was completed at the last meeting and that sufficient ground work has been done to allow technician exchanges to take place as necessary with the details to be worked out on an ad hoc basis. Steve discussed the salinity workshop his committee had organized for the next day and reviewed the RVTEC policy statement on technician training. Steve then initiated a discussion of the UNOLS cruise assessment forms. Steve's premise was that if the forms were to be used as a management tool, to allow us to asses and improve our operations, there were several drawbacks to the existing forms. In the discussion that followed questions as to the actual purpose of the forms were raised. Jack Bash pointed out that the forms had been initiated at the request of UNOLS Council and the Council has said they are satisfied with the information the present forms are generating. It was suggested that more explicit instructions and definitions of some of the terms used might improve the uniformity of the responses. Rich Findley said that his group has developed forms which they ask the Chief Scientist to fill out in addition to the UNOLS form. The form currently in use for the R/V CALANUS is included as Appendix 2.

Editor's Note: This subject was also brought up at an RVOC workshop and many of the same concerns were addressed.

Marc Willis presented the report of the Data Interchange subcommittee. He remarked that there had been little feed back from his Interface article on NetCDF and made the following points:

a few institutions are already using NetCDF
it has been implemented on workstations and PC's, but not yet on Mac's
any standard we use should be performance based

Marc deferred further discussion of the technical aspects of NetCDF to the session scheduled for Thursday. Discussion of CD-ROM's followed and the consensus was that our group would continue to move in the direction of using ISO 9660 CD-ROM's as the media for data storage and distribution and NetCDF as the format for the data.

Jack Bash introduced the subject of the demise of OMNET and the alternatives available to us through the internet. In the subsequent discussion it was recognized that OMNET had been providing some unique services which will be difficult to replace but the basic needs of email, mailing lists, and ship schedule distribution can be implemented in the near future on the internet. Jack reported that the UNOLS office has established the procedures for posting ship schedules on OCEANIC, the WOCE data information unit maintained at the University of Delaware. Access instructions and a description of the types of information available on OCEANIC are included in Appendix 3.

The afternoon session was devoted to a tour of the General Oceanics facilities.

The Thursday, October 20, 1994 session began with a presentation by Russ Rew of the Unidata Program Center, University Corporation for Atmospheric Research (UCAR) titled "Models, Formats, and Interfaces for Scientific Data". The slides for this talk are included in Appendix 4. The URL for the NetCDF home page is http://www.unidata.ucar.edu/packages/netcdf/. In the discussion which followed there was a consensus that netCDF would definitely improve our handling of SAIL type data, but the benefits for CTD and ADCP data would be less immediate. There was strong opposition to a full set of rigid data "standards", but on the other hand there was agreement that we should handle commonly recorded parameters in a uniform manner. To this end, Marc Willis agreed to distribute the CDL files currently in use at OSU as a starting point for further discussion.

In conjunction with this discussion on data formats Don Moller raised the question of the transmission of data from the ship back to shore facilities. He said that they are seeing increasing demand for this, particularly with WOCE groups. He pointed out that this can be a major effort, both fiscally and operationally, and that although it is presently a project responsibility there will be increasing pressure for it to be handled by the ship. Lisa Rom commented that JOI's SEANET proposal addresses this problem.

The afternoon session began with a discussion of access to satellite imagery by Otis Brown, RSMAS. Copies of the slides which accompanied his presentation are included in Appendix 5. In the discussion which followed it was recognized that the cost, and to a lesser extent the technical problems, of the shore to ship transmission link is the limiting factor in making use of these images.

John Freitag discussed the latest generation of chirp sonar systems. URI had just taken delivery of an EG&G system for installation on the ENDEAVOR and Miami has installed a Datasonics system on the ISELIN. These systems realize additional gain both from the processing of the signal and from longer pulse lengths. The ENDEAVOR's system will initially work through their existing 3.5 kilohertz transducers and the ISELIN's system is dual frequency, using 3.5 and 12 kilohertz transducers.

Jack Bash then summarized the earlier discussion of possible alternatives to OMNET. UNOLS' current plan is to handle ship scheduling on OCEANIC, implement mailing lists on the internet as soon as possible, and then to work toward additional applications such as electronic distribution of newsletters and electronic submission 831 Ship Time Request forms.

Jack Bash asked the group to consider criteria for the construction of vans to be used aboard UNOLS vessels. A list summarizing the points brought out in the discussion which followed is included as Appendix 6.

Tim Pfeiffer raised the question of working with radioactive isotopes and the consensus of the group was that the procedures outlined in the UNOLS safety standards are working well and are not in need of revision.

Specific action plans for the various subcommittees were discussed. Tom Wilson will continue with the equipment data base, using a text format. Steve Rabalais will continue to develop training programs. Marc Willis will distribute his NetCDF CDL files as the next step in implementing NetCDF.

Rich Findley's term as chair expired with this meeting and the Vice Chair called for nominations for a new Chair. Joe Stennett nominated Rich Findley, the nomination was seconded by Don Moller, John Freitag moved that the nominations be closed, the motion was seconded by Tom Wilson, and carried unanimously. In accepting his second term, Rich said that he felt that there should be a two term limit for the Chair and Vice Chair of RVTEC.

The date and location for the 1995 meeting were discussed. It was decided that three days was an appropriate format for the meeting and that next year's meeting should be held on the West coast, during the week following the

Marine Technology Society meeting. Rich Muller agreed to look into the details of hosting the meeting in the Monterey area.

Don Moller initiated a discussion on CTD cable by asking if anyone was having problems with premature rusting of .322 cable. Marc Willis said that they had seen some, that the galvanizing on the interior of the wire appeared powdered, and the outer layer of armor was loose. Don said that there had been one production run of the .322 cable which had been contaminated in the galvanizing process. Don said that it might be necessary to go through another round of competitive bids on the next purchase of wire, in which case it would be necessary to review the specifications on which the bids would be based. Fiber optic cable is still an order of magnitude more expensive than copper.

Paul Ridout, Ocean Scientific International, began the Friday session with a presentation on salinity. He discussed the historical background of salinity measurements and the production of standard sea water, leading up to the present definition of salinity which is based solely on electrical conductivity. Paul provided reprints of two articles on salinity and standard sea water which are included in Appendix 7. A listing of UNESCO papers relevant to salinity is also included in Appendix 7. Subsequent discussion focused on the importance of proper technique in taking, storing, and handling salinity samples. Rich Findley provided the specification sheet for the salinity bottles and caps used on the ISELIN which is also in Appendix 7. Don Cucchiara, RSMAS, presented a demonstration of the software developed at RSMAS which leads an operator through the process of properly running a sample on the Autosal.

Appendix 1. Attendance List

Rich Findley RSMAS	RFindley@RSMAS.Miami.edu
Tim Pfeiffer Delaware	Pfeiffer@udel.edu
Barry Bjork Bermuda Biological Station	bbjork@BBSR.edu
Jim Sullivan Harbor Branch	Harbosul@class.org
Lane Mitcham Skidaway Inst.	Lane@skid.peachnet.edu
Lisa Rom National Science Foundation	erom@nsf.gov
Steve Harte Univ. of Alaska	Helix@iliamna.IMS.Alaska.edu
Robert Kluckhohn Antarctic Support Associates	Kluckhro.ASA@ASA.org
Don Moller WHOI	DMoller@WHOI.Edu
John Freitag URI-GSO	jfreitag@GSOSUN1.gso.uri.edu
Bobluke Wejinya Michigan	BobLuke.Wejinya@UMICH.cc.edu
Marc Willis OSU-COAS	willis@occ.orst.edu
Joe Ustach Duke	joeu@duncoc.duke.ml.edu

Woody Sutherland
SIO
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Steve Rabalais
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SRabalais@SMTPGW.Lumcon.edu

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Jack Bash
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UNOLS@GSOSUN1.GSO.URI.edu

Chip Maxwell RSMAS	CMaxwell@RSMAS.Miami.edu
Louis Davidson RSMAS	Davidson@RCF.RSMAS.Miami.Edu
Tom Wilson SUNY Stony Brook	Twilson@ccmarl.sunysb.edu
Jay Harris NOAA/AOML	Jharris@AOML.erl.gov
Annette DeSilva ONR	desilva@onrhq.onr.navy.mil

AGENDA

RESEARCH VESSEL TECHNICAL ENHANCEMENT COMMITTEE

OCTOBER 19, 20, 21, 1994

LIBRARY

ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE

MIAMI, FLORIDA

Wednesday

9:00 Meeting Called to Order

Introductory Remarks by Chair

9:15 Participant Introductions

9:30 Subcommittee Reports and Working Discussions (45 minutes each)

Catalog Mailing Lists/Database Services; Tom Wilson

10:15 **Break**

10:30 Technician Training/Technician Exchange; Steve Rabalias

11:15 Data Standards; Marc Willis

12:00 Depart for **Lunch** at Grove Isle Club hosted by General Oceanics

2:00 Depart for Tour of General Oceanics Facilities

Thursday

8:30 Meeting Called to Order

NetCDF Guest Speaker; Russ Rew UCAR-UNIDATA

Followed by NetCDF Round Table Discussions

10:15 **Break**

10:30 NetCDF Round Table Discussions (cont.)

12:00 **Lunch**

1:00 Satellite Imaging Display Guest Speaker; Otis Brown (RSMAS)

3:00 **Break**

3:15 Presentation on CHIRP Sonar Systems; John Freitag (URI)

5:00 Adjournment to Dean's Reception in Smith Commons

Friday

8:30 Meeting Called to Order

Salinity Guest Speaker; Paul Ridout

Followed by Salinity Round Table Discussion

and Demonstrations by Ken Bottom (TAMU) and Don Cucchiara (RSMAS)

10:00 **Break**

10:15 Salinity Round Table Discussions (cont.)

12:00 **Lunch**

1:00 Introduction of Studies Requested by UNOLS Council

Replacement for Telemail

Design Criteria and Use of 20 Foot Shipping Containers as Laboratories

3:00 **Break**

3:15 Updating of Action Plans

3:45 Election of Chairman

4:00 Scheduling of Next Meeting

4:15 New Business

5:00 Adjournment

Appendix 2. CALANUS Post Cruise Report

R / V CALANUS

Ship's Operation Report

UNIVERSITY OF Miami RSMAS MARINE OPERATIONS

CRUISE NO: ____________________ **DATE PREPARED:** ____________________

START DATE: ____________________ **END DATE:** ____________________

Chief Scientist: ____________________ Affiliation: ____________________

Senior Scientific Member: ____________________ Affiliation: ____________________

Instructions:

Senior Scientific Member for each cruise or leg should complete this report at the end of each cruise or leg. The report should be delivered to the Ships Master or Assistant Manager Marine Operations in the envelope provided.

Please evaluate each applicable item by checking the appropriate box or marking N/A for items that are not applicable. Items checked in the "COMMENT" column may be described in detail on the last page.

SECTION A. DECK MACHINERY

ITEM NO.	DESCRIPTION	SATISFACTORY	UNSATISFACTORY	COMMENT
A - 1	TRAWL WINCH			
A - 2	HYDRO WINCH			
A - 3	CONDUCTOR WINCH			
A - 4	ANCHOR SYSTEM			
A - 5	CRANES			
A - 6	CAPSTAINS			
A - 7	GALLOWS / A FRAME			
A - 8	WIRE, FAIRLEADS, BLOCKS			
A - 9	INSTRUMENTATION			
A -10	INTER-COMMUNICATIONS			
A -11	DECK LIGHTING			
A -12	OTHER			

SECTION B. LABORATORY (S)

B - 1	WORK BENCHES / STORAGE			
B - 2	ELECTRICAL UPS/OTHER			
B - 3	SERVICES / SINKS			
B - 4	REFRIGERATORS / FREEZERS			
B - 5	HEATING, VENTILATION AND A/C			
B - 6	LIGHTING			
B - 7	INTER-COMMUNICATIONS			
B - 8	OTHER			

SECTION C ELECTRONICS

ITEM NO.	DESCRIPTION	SATISFACTORY	UNSATISFACTORY	COMMENT
C - 1	GYRO SYSTEM			
C - 2	SPEED LOGS			
C - 3	RADARS			
C - 4	GLOBAL POSITIONING SYSTEM			
C - 5	SATNAV			
C - 6	LORAN			
C - 7	VHF			
C - 8	SSB			
C - 9	ATS			
C -10	OTHER			

SECTION D HABITIBILITY

D - 1	FOOD / SERVICE			
D - 2	LINENS / BEDDING			
D - 3	QUARTERS - SANITATION			
D - 4	QUARTERS - MAINTENANCE			
D - 5	LOUNGE AREA / ENTERTAINMENT			
D - 6	COOLING AND VENTILATION			
D - 7	LIGHTING			
D - 8	WATER			
D - 9	LAUNDRY			
D -10	OTHER			

SECTION E SAFETY / MEDICAL

E - 1	SAFETY EQUIPMENT			
E - 2	BRIEFING AND STATION DRILL			
E - 3	DRILLS, FIRE / MAN OVERBOARD			
E - 4	DECK OPERATIONS			
E - 5	MEDICAL SUPPLIES			
E - 6	MEDICAL ASSISTANCE			
E - 7	OTHER			

COMMENTS:

Instructions: Identify the following comments by the matching "ITEM NO.". Comments that include "problems" should, when possible, include "acceptable solutions". Evaluations of individual crew members should not be included in this report. (USC Title 46.239.d)

Appendix 3. Internet Access to Oceanic and Ship Schedules

The ship information and schedule databases on OCEANIC

The University of Delaware maintains several on-line databases related to US and foreign research ships. These are accessible on OCEANIC (OCEAN Network Information Center) through several systems, but primarily through the Internet.
We summarize our past and present thinking here to encourage a discussion of future options.

History

The original reasons for our involvement were twofold.

1. An interest by a consortium of International Ship Operators (ISOM), of which NSF was a major member, in having a single source for the cruise plans of the ships of their consortium. This would help them in using resources efficiently and help PIs to locate ships planning to work in areas in which they were interested.

2. Our perceived need for a searchable database of ship schedules world-wide that would help in planning expeditions, in particular the World Ocean Circulation Experiment (WOCE) for which we maintain the Data Information Unit.

We get the following information.

1. Ship schedules as posted on OMNET by UNOLS and by NOAA. We seek scheduling information from the US Agencies that do not post their cruises.

2. Updates on the cruise plans in other countries. We write to members of the ISOM group and others, about every half-year. Some operators now automatically provide us with new information as it appears.

3. A database of structural and operating characteristics of research and fisheries ships. We receive this annually from the Fisheries Industries Division of FAO. This database is the current equivalent to the old publication "Oceanographic Ships of the World" (without pictures) that some may remember from long ago. It also includes information previously published by the Naval Oceanographic Office as RP34- National Oceanographic Fleet Operating Schedules.

4. Deck plans, profiles, and photos of the ships. We usually collect these from operators.

What we make available on-line are:

1. ship schedule files to which we have added information to make them more easily searchable. In particular we add a "general ocean area" entry for which we use a small number of keywords. Examples are Equ Pacific or Caribbean, also a "discipline" such as Phys Oc. or Bio.

A search is possible on most fields. The result is a display of all cruises satisfying the search criteria. This search is at present carried out only on current and future cruises.

2. the annual schedules by ship name, agency, institution or country. This is much like what is available on OMNET.

3. sub-sets of the FAO ship characteristics data that are also searchable by name, agency, institution and country. A sample is in the appendix.

4. computer images of the pictures we have acquired.

5. an option to search for text strings in the files as supplied to us. We list the names of those in which matching text or image is found. There is the option then to read each file in detail.

We make the information accessible by

1. World Wide Web (WWW). This is a versatile and increasingly used part of the Internet that greatly simplifies the access to files on other computers. We have optimized our files for use by the widely available Mosaic Browser software on work-stations. We do check on the adequacy of the display by other browsers and other machines such as MACs and PCs.

2. Gopher. This is another system on the Internet developed before WWW that provides a simple menu search. It has some text search capability and there is the opportunity to download images for display off-line.

3. the "original" OCEANIC. This is a menu system developed in-house that has limited imaging capability but has a good text search for identifying cruises.

Recent Developments

The growth of the World Wide Web over the Internet has given us the ability to present information in different ways. Importantly, it gives us the opportunity to interact more readily with others. A few examples follow:

Several institutions now operate Web servers that contain sections on ships they operate. They often list the latest versions of the schedules they operate. We can link directly to that information and also incorporate the schedules in our database.

The Ocean Research Institute in Japan provides schedules for its ships thru' 1998. This is well beyond dates we have obtained by going to central contact points in different countries. The later cruises may be less certain in terms of funding or confirmation but their inclusion helps achieve an early goal of OCEANIC in assisting forward collaborative planning.

The UK Research Vessel Base has started a section on its WEB server that includes the cruise plans of current cruises. It also has twice weekly updates from the Masters of the ships on ships movements. OCEANIC provides direct links to this information.

The Future

Our aim of providing research scientists, ship operators, and program mangers with timely, accurate, and useful information on research ships worldwide gets more attainable day by day.
We plan to adapt to new resources. A user will find that parts of the system change daily. We will also maintain limited functionality for less sophisticated systems.

One of our data sources is from the schedules as posted on the OMNET bulletin boards. We get this information directly from those posting to the bulletin boards. The significantly decreased use of OMNET this year may pose some problems unless we are ready for them. The immediate fix would be to ensure that all postings currently sent to OMNET continue to come to us. Item 1 of the "**accessibility**" section above would then provide backup.

Queries and suggestions

1. Can the information and methods of access to it be augmented to make it more useful in the scheduling process?

This process itself is an interactive one between scientists, operators, and program managers. Sometimes it extends to barter arrangements with foreign operators. It would surprise us if there was not scope to organize the data in additional ways that will help this process.

2. Should we maintain a base of cruises actually carried out? If so, who has the information, and who wants it?

At present the concentration in OCEANIC is on future cruises and the planning process.

James Crease, Katherine Bouton
College of Marine Studies
University of Delaware

August 26, 1994

OCEANIC ACCESS INSTRUCTIONS:

If you would like to see the ship schedule information online you can access OCEANIC by three different methods over the Internet:.

A) % **telnet delocn.udel.edu** (or 128.175.24.1)
Username: **INFO**
Password: none required
Then choose menu item **5. Research SHIP SCHEDULES and Information**

For further information finger oceanic@delocn.udel.edu

B) If you have gopher available to you then
gopher diu.cms.udel.edu
and select menu item **5. Research SHIP SCHEDULES and Information**

For further information finger oceanic@diu.cms.udel.edu

C) If you have access to the World Wide Web (WWW) via Mosaic, Lynx, Cello etc:
open URL **http://www.cms.udel.edu/**
then choose **Research Ship Information and Cruise Schedules**

For further information finger oceanic@diu.cms.udel.edu

You can also access OCEANIC via Omnet (and pay the Omnet connect charge):

Type **Backdoor** at the *Where* prompt or at the *Command* prompt. Then choose the OCEANIC option and give your ID. No password is required.
Then choose menu item **5. Research SHIP SCHEDULES and Information**

From: "Katherine A. Bouton" <bouton@gertrude.cms.udel.edu>
To: pfeiffer@brahms.udel.edu
Subject: access text

Information about the status of the WOCE Field Program is ailablen-line from the WOCE Data Information Unit (DIU). If you have a computer connected to the Internet, you may access this system, called OCEANIC (for Ocean Information Center) at any time.

Recently, the DIU has added some new forms of presentation to OCEANIC and increased the options for access to it. There are three different forms of presentation. The original presentation of OCEANIC is an ASCII version accessible through a remote login over Internet. This basic system focuses on WOCE information and an international research ship schedule. Another version uses the Gopher client/server system to present the information above as well as information about the TOGA/COARE experiment. The third method uses the World Wide Web to provide direct links to other ocean data and information services. Both the Web and Gopher systems have expanded graphics capabilities.

So how can you sign onto OCEANIC?

GOPHER ACCESS

If you have gopher software on your machine, to access OCEANIC you type "gopher gopher.cms.udel.edu".

If you are using your local gopher browser to access OCEANIC, you type "gopher: /gopher.cms.udel.edu/."

> It is recommended that you run a local gopher client rather than accessing one of the public gopher clients. A local client can use features of your local machine (mouse, scroll bars, etc.) and should give better response time.

Gopher Access to Oceanic (for users without local gopher clients)

> If you do not have a local gopher client available, however, you may use the public gopher clients which are listed below. These may be somewhat restricted in function as compared to a local gopher client, but will provide you the basics. Each site's menu structure differs slightly, but most have a similar menu tree that will get you to OCEANIC at the University of Delaware. Look for a reference to "other gophers" or "other internet resources" and work your way through the geographic hierarchy (Gopher servers/North America/USA/Delaware) to link to OCEANIC.

> Telnet to the machine listed for your area, and use the login name specified. For example, if you live in the US, type 'telnet gopher.msu.edu', and at the login prompt, type 'gopher'. No password is required. See below for the sequences to use to get to the main menu of Oceanic.

Machine Name	Machine Number	Login	Area
a. gopher.msu.edu	35.8.2.61	gopher	North America

Menu tree to get to OCEANIC:
Network & Database Resources -> Internet Resources by Type -> Gopher Servers -> North America -> USA -> Delaware ->

OCEANIC

b. uxl.cso.uiuc.edu 128.174.5.59 gopher North America
   Menu tree to get to OCEANIC:
   Other Gopher and Information Servers -> USA -> Delaware -> OCEANIC

c. gopher.ebone.net 192.36.125.2 gopher Europe
   Menu tree to get to OCEANIC:
   Other Gopher and Information Servers -> USA -> Delaware -> OCEANIC

d. gopher.sunet.se 192.36.125.10 gopher Sweden
   Menu tree to get to OCEANIC:
   Other Gopher and Information Servers -> USA -> Delaware -> OCEANIC

e. info.anu.edu.au 150.203.84.20 info Australia
   Menu tree to get to OCEANIC:
   Worldwide Networked Information Servers -> Search for Gophers by Name or Internet Address: OCEANIC, Univ of Delaware OCEANIC

f. tolten.puc.cl 146.155.1.16 gopher South America
   Menu tree to get to OCEANIC:
   Otros servidores de Gopher en el mundo -> North America -> USA -> Delaware -> OCEANIC

g. gan.ncc.go.jp 160.190.10.1 gopher Japan
   Menu tree to get to OCEANIC:
   Other gophers etc. -> World wide gopher list (mirror) -> North America -> USA -> Delaware -> OCEANIC

2. World Wide Web version of Oceanic

Features:

- WOCE science and program information including:
  - Maps, cruise tracks, and cruise reports
  - Data assembly center information and data holdings
  - Searchable address directory of WOCE scientists
  - WOCE related data directories
- TOGA COARE information system
- Research Ship schedule and information database
  - Contains graphical deck layouts and photographs
- Direct links to other web and ftp sites containing oceanographic information
- Ability to download data and information
- Graphics type: .GIF files
- Requirements:
  - Internet access
  - World-Wide-Web browser (ie. Mosaic, Linx, etc.)

World Wide Web Access to Oceanic

OCEANIC is available through World-Wide-Web on www.cms.udel.edu. Use your local www browser to access http://www.cms.udel.edu/.

For example, if you are running Mosaic, type 'Mosaic http://www.cms.udel.edu/'

3. VAX ascii version of Oceanic

WOCE science and program information
- Maps, cruise tracks, and cruise reports
- Data assembly center information and data holdings
- Searchable address directory of WOCE scientists
- WOCE related data directories

Research Ship schedule and information database - no graphics
Graphics type: Textronix files
Requirements:
- Internet, SPAN, Omnet, or modem access

VAX Access to ASCII OCEANIC
telnet delocn.udel.edu (or 128.175.24.1)
Username: INFO
no password required

This version of OCEANIC is also accessible via Span, Omnet or Direct Dial.

Appendix 4. NetCDF

Models, Formats, and Interfaces for Scientific Data

Research Vessel Technical Enhancement Committee
Miami, FL 19-21 Oct 94

Russ Rew
Unidata Program Center
University Corp for Atmospheric Research

Unidata Program Center

Software & services empowering universities to acquire and use atmospheric & related data on their own computers, often in real time

Funded by

National Science Foundation

Managed by

University Corporation for Atmospheric Research

Program Center Functions

Serving 120 universities

- **Facilitating real-time data access**
- **Providing specialized software systems**
  - **Development**
  - **Maintenance & upgrades**
  - **Training, consultation, documentation...**
- **Fostering participation in Unidata as a community endeavor**

Two Software Categories

To meet community needs with no data center

- **Analysis & display applications**
  - **Meteorological emphasis**
  - **Developed in community; supported by Unidata**
- **Data Management**
  - **Developed *and* supported by Unidata staff**
  - **Underpinnings for (generic) applications**
  - **Emphasis on distributed functionality**

Data Management Emphases

- Local Data Manager (LDM)

  Real-time reception, multiple datastreams

  Tailored holdings; event-driven processing

- Internet Data Distribution (IDD)

  Nationwide distributed system of LDM sites

  Multiple data sources

- Network Common Data Form (netCDF)

  Access to named, multidimensional arrays

  Model, software, and portable data format

The Focus of this Talk

- Models

  What is a data model?

  Examples, including the netCDF data model

- Data formats

  Pitfalls of standardization

  Data hiding

- Software

  Issues of portability, APIs, efficiency...

  Examples, including the netCDF library

What Is a Data Model?

- An abstraction of a dataset or database
  - Types of data represented
  - Relationships among data elements
- Available operations
  - Definition
  - Storage
  - Modification
  - Query and Retrieval

Examples of Models

- Within common programming languages
  - Fortran read/write statements
  - C standard i/o functions
- Implemented via libraries
  - CDF
  - HDF
  - netCDF

Data Formats

Implies a data model

- **Data stored as sequence of bits or bytes**
- **Format is a mapping to specified data types**
- **Read/write operations**
    - **Sequential or direct (byte count)**
    - **Transfer blocks of bits or bytes**
    - **Conversion controlled by format**

Pitfalls of Standardization

Beware the standard format!

- **Difficult to ensure compliance**
- **Consumes programming effort**
- **Data access may be cumbersome**
- **Usually too static**
- *Solution: data hiding*

Data Hiding

Users need not know the format!

- **Define a data model**
  - **Types**
  - **Relationships**
  - **Operations**
- **Develop an Applications Programming Interface (API) that realizes all aspects of the model**
- **Perform all data access through the API**

Software Issues/Decisions

- **Support for users**
- **Portability across platforms**
- **Compatibility with**
  - **Programming languages**
  - **File systems**
- **Efficiency of**
  - **Data storage**
  - **Data access operations**

Unidata netCDF

• **Support:**	**On-line (e-mail list, WWW)**
• **Portability:**	**Most common platforms**
• **Compatibility with**	
Languages:	**Fortran, C, C++**
File systems:	**Portable binary data**
• **Efficiency of**	
Storage:	**Low overhead**
Access:	**Direct or record-oriented**

Goals of netCDF

- **Model for scientific data**

self describing:	**named multidimensional variables**
portable:	**machine-independent data**
appendable:	**datasets can grow**
direct access:	**to subsets of large dataset**

- **Interface insulating applications from data representation**

What is netCDF?

Key Aspects

- A Model for scientific data access
- Freely-available Software implementing the model
- A Format providing machine-independent representation for scientific data

netCDF: the Model

- a dataset has dimensions, variables, and attributes
- a dimension has a name and size
- a variable has a name, type, shape, values, and attributes
- an attribute has a name, type, and value(s)
- a variable's shape is specified by a list of dimensions
- a dimension may have an associated coordinate variable

Example netCDF Dataset

- Dimensions

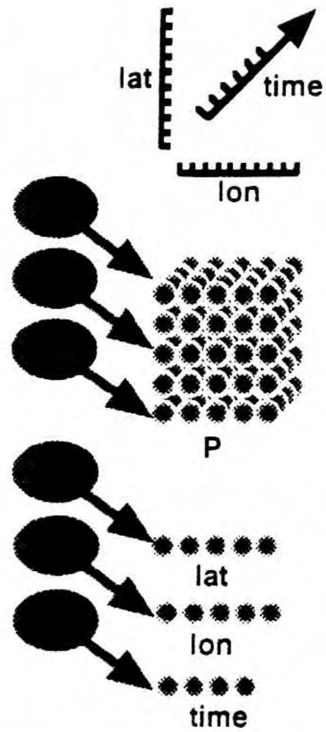
lat	73
lon	73
time	unlimited

- Variables

float	P (time, lat, lon)
float	lat (lat), lon (lon), time (time)

- Attributes

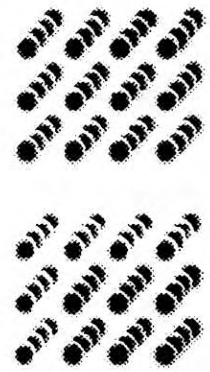
P:long_name	"mean sea level pressure"
P:units	"hectopascals"
P:valid_range	800., 1200.
lat:units	"degrees_north"
lon:units	"degrees_east"
time:units	"hours"



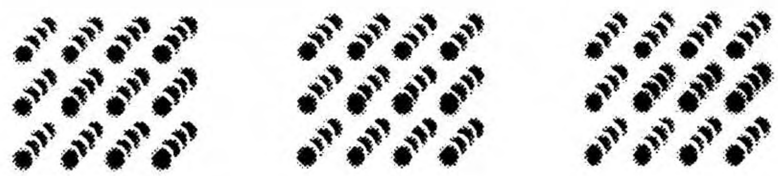
Datatypes and Operations

- **Direct access to data**
  - **netCDF file**
  - **variable name**
  - **desired indices**
- **Supports common scientific data types**
  - **bytes & characters**
  - **short & long integers**
  - **single & double precision floating-point**
- **Access to array sections**
- **Record-oriented access (unlimited dimension)**

Access to Array Sections

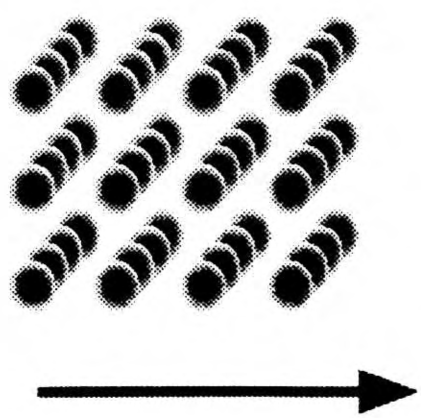


A single call accesses point values, vectors, planar cross-sections, volumes, or an entire variable



Unlimited Dimension

- **One dimension of each netCDF dataset may be unbounded**
- **Permits conventional record-oriented access**
- **Permits appending data to netCDF variables that use the unlimited dimension**



Limitations of netCDF Model

- Not a database system: no direct access to data by value
- No built-in support for nested data structures
- Only one unlimited dimension per dataset

netCDF: the Software

- Source freely available via anonymous FTP

  host: ftp.unidata.ucar.edu

  file: pub/netCDF/netcdf.tar.Z

- Ported to many platforms

  UNIX for Sun, IBM, DEC, CRAY, SGI, HP, ...

  MSDOS, OS/2 for PCs

  Mac (by others)

  ...

C and FORTRAN interfaces

- C interface
  - indices start at 0
  - right-most dimension varies fastest
- Fortran interface
  - indices start at 1
  - left-most dimension varies fastest

C++ Interface

- Provides functionality of C and Fortran interfaces
- Provides superior type safety
- Simpler to use than C and Fortran interfaces
- Code for types isolated, so adding new types easier
- Still experimental, undergoing slow changes

Example C calls

- **Open a netCDF file for read-only access**

```
ncid = ncopen ("mydata.nc", NC_NOWRITE);
```

- **Get the variable ID for a variable named "velocity"**

```
vid = ncvarid (ncid, "velocity");
```

- **Get n^th^ variable's name, type, shape, and # of attributes**

```
ncvarinq (ncid, n, name, &type, &ndims, dims, &natts);
```

- **Read a slab of values**

```
ncvarget (ncid, varid, start, count, vals);
```


Example FORTRAN Calls

- **Open a netCDF file for read-only access**

```
NCID = NCOPN ('data.nc', NCNOWRIT, IERR)
```

- **Get the variable ID for a variable named "velocity"**

```
VID = NCVID (NCID, 'velocity', IERR)
```

- **Get n^th^ variable's name, type, shape, and no. of attributes**

```
CALL NCVINQ (NCID, N, VNAME, VTYPE, VRANK, VDIMS,
    VATTS, IERR)
```

- **Read a slab of values**

```
CALL NCVGT (NCID, VID, START, COUNT, VALS, IERR )
```

netCDF: the Format

- You don't need to know about the format to write and read netCDF data.
- netCDF library uses XDR for all data structures and data values
- XDR (eXternal Data Representation) library

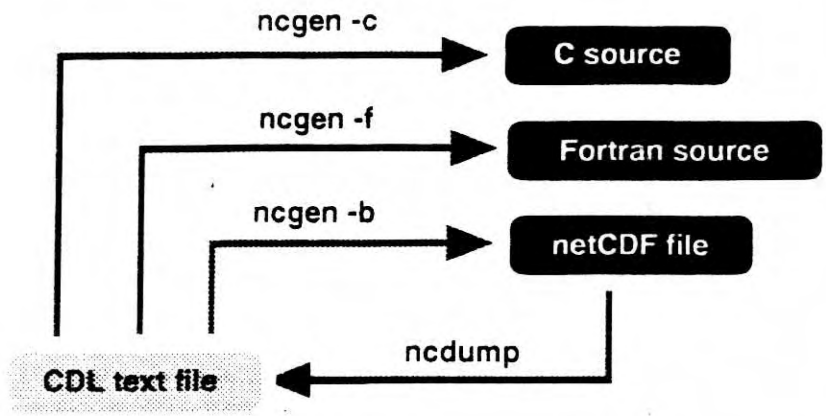
  a standard for machine-independent data

  nonproprietary, freely available

Limitations of netCDF Format

- No automatic packing or compression (yet)
- No built-in type for 1-bit values
- No support for wide characters or Unicode
- XDR conversion slow for floats on non-IEEE platforms

netCDF Utilities: ncdump and ncgen



CDL is an editable text version of binary netCDF

Example CDL File

```
netcdf example {     // a netCDF file with 3
variables
dimensions:
    lat = 10,   lon = 37,   level = 10,  time =
unlimited;
variables:
    float  T(time, level, lat, lon);
        T:long_name = "temperaure";
        T:units = "celsius";
        T:valid_range = -80.0, 60.0;
    float lat(lat);
        lat:long_name = "latitude";
        lat:units = "degrees North";
    float lon(lon);
        lon:long_name = "longitude";
        lon:units = "degrees East";
data:
    lat = 0, 10, 20, 30, 40, 50, 60, 70, 80, 90;
    lon = ...
}
```

Where is netCDF Used?

- Mailing list has 400 addresses in 16 countries
- Some research groups have adopted netCDF as a supported format: Unidata, Los Alamos, NOAA PMEL, Lamont-Doherty, NCAR RAF, TOGA-COARE, USGS, WHOI, Scripps, NOAA FSL, ...
- The netCDF interface is now incorporated in NCSA's HDF
- For details, point WWW browser (such as Mosaic) at: `http://www.unidata.ucar.edu/packages/netcdf/usage.html`

netCDF in Applications

- IDL (Research Systems, Inc.)
- SpyGlass Dicer (Spyglass, Inc.)
- IBM Visualization Data Explorer
- WXP (Purdue and Unidata)
- SIEVE (USGS)
- IVE (University of Washington)
- 25 other commercial and freely-available packages incorporating netCDF:
  `http://www.unidata.ucar.edu/packages/netcdf/`

The Future of netCDF

- Use is still growing
- C++ interface is getting more popular
- Unidata may resume development when Internet Data Distribution software is deployed
- Wider community use helps make programs interoperable and facilitates data exchange

More Information about netCDF

- World Wide Web netCDF Home Page: http://www.unidata.ucar.edu/packages/netcdf/
  - On-line hypertext netCDF User's Guide
  - Frequently Asked Questions list
  - Searchable email archives
- Subscription to mailing list for announcements, discussions: netcdfgroup-request@unidata.ucar.edu

Appendix 5. Satellite Imagery

SATELLITE IMAGERY

(ACCESS)

by

OTIS B. BROWN

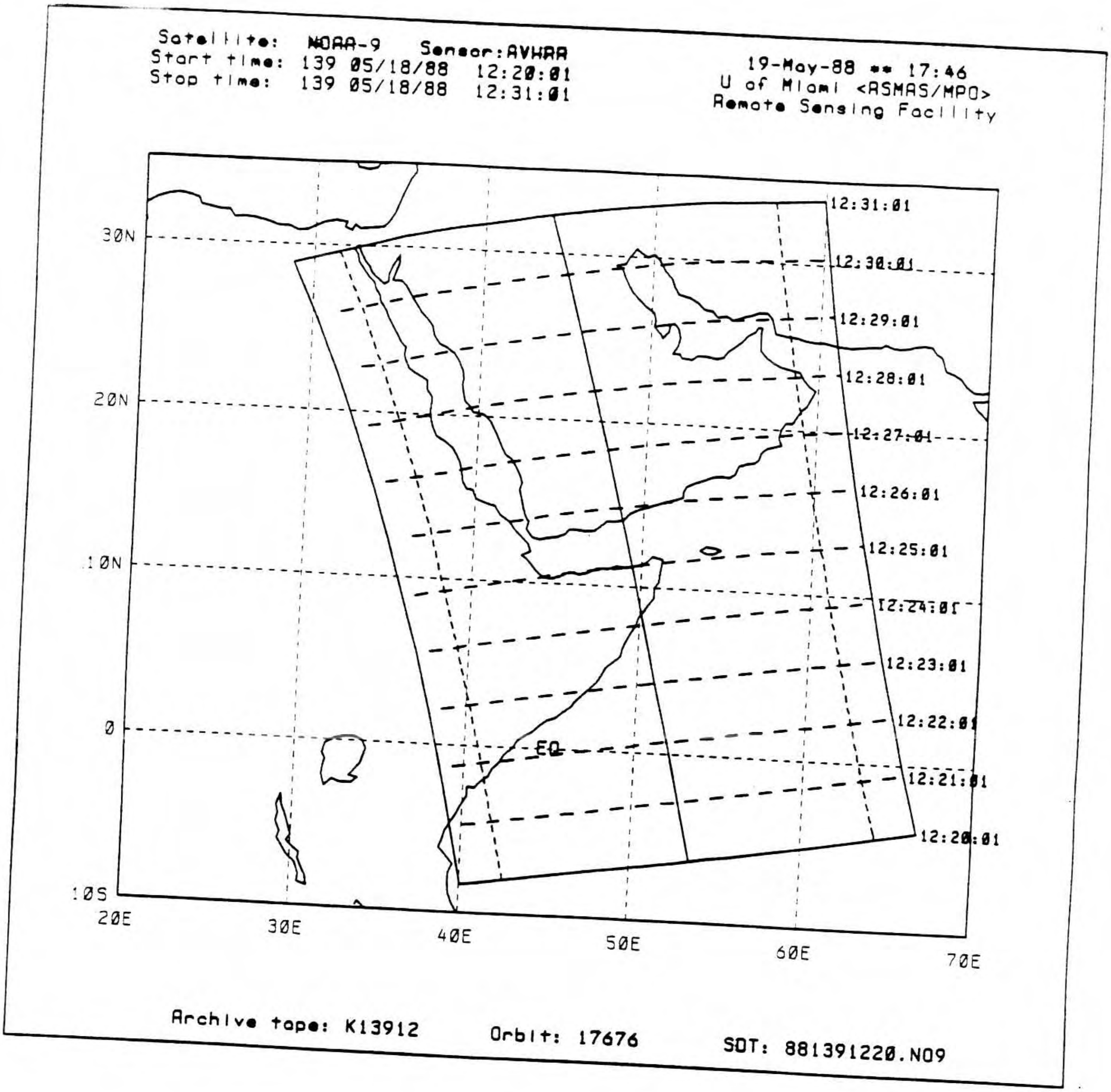
OVERVIEW

- Rationale
- Product Description
- Access Mechanisms
- Access Protocols

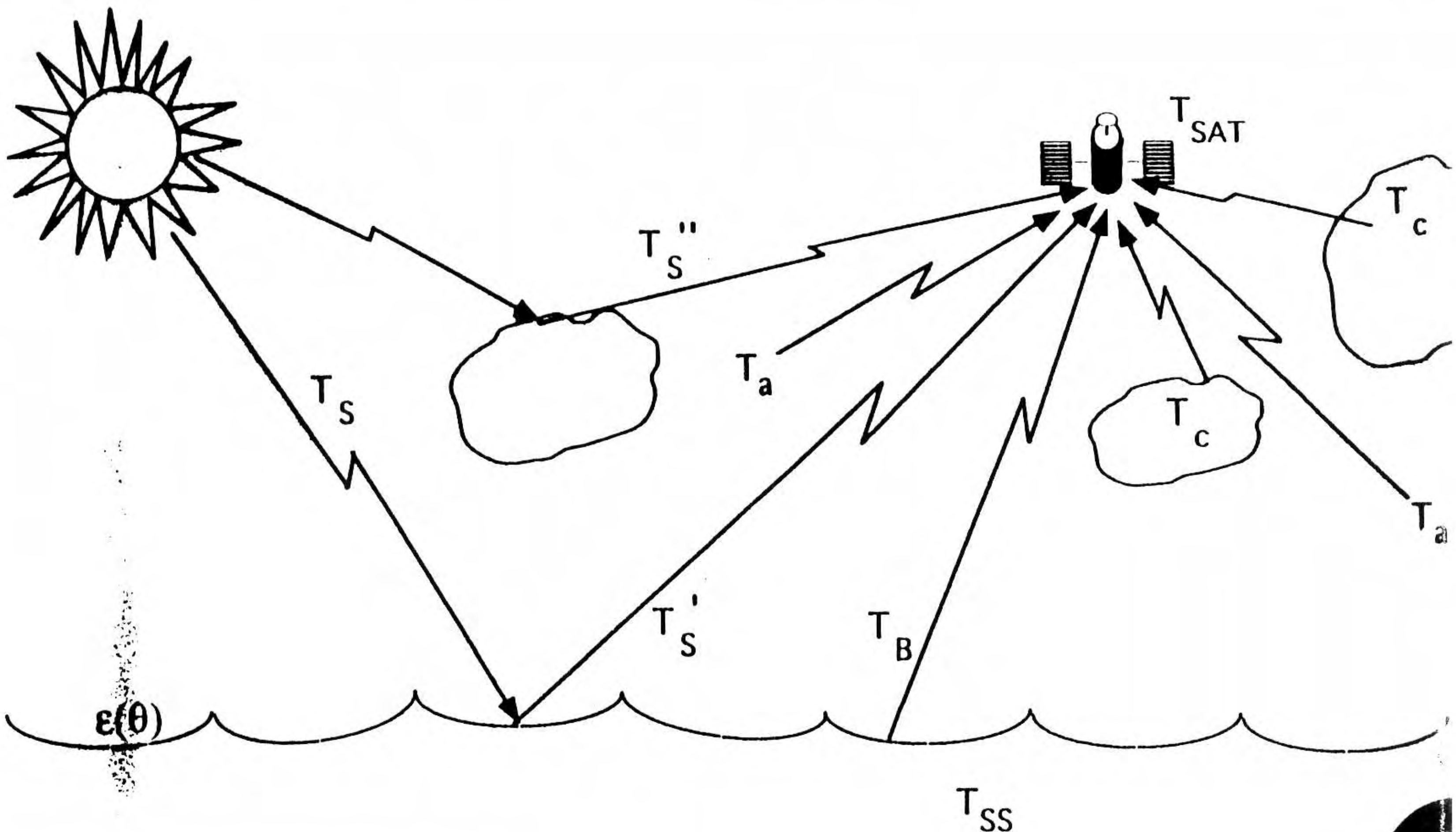
HSMAS

PRODUCT DESCRIPTION (1)

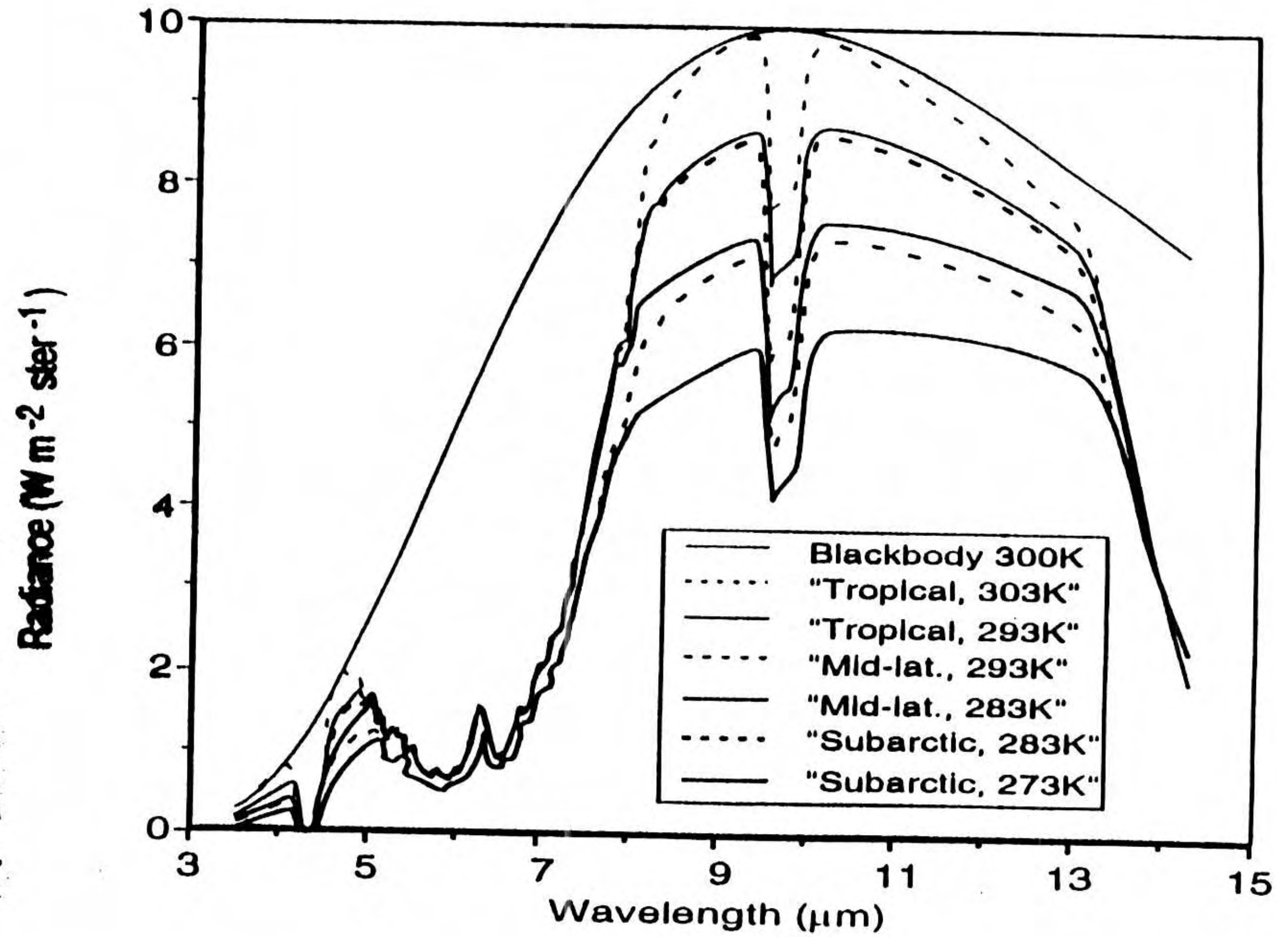
- Visible and Infrared Imagery
  (NOAA/AVHRR, DMSP/OLS, ERS-1/ATSR
- Microwave Passive Imagery
  (DMSP/SSMI)
- Microwave Active Imagery
  (ERS-1/AMI)
- Altimetry
  (ERS-1/TOPEX)


Satellite: NOAA-9 Sensor:AVHRR
Start time: 139 05/18/88 12:20:01
Stop time: 139 05/18/88 12:31:01
19-May-88 ** 17:46
U of Miami <RSMAS/MPO>
Remote Sensing Facility
12:31:01
12:30:01
12:29:01
12:28:01
12:27:01
12:26:01
12:25:01
12:24:01
12:23:01
12:22:01
12:21:01
12:20:01
30N
20N
10N
0
10S
EQ
20E
30E
40E
50E
60E
70E
Archive tape: K13912
Orbit: 17676
SDT: 881391220.N09

Radiative Transfer Schematic L_{SAT}



Atmospheric Transmissivity



Infrared Correction Approaches

- Single-Channel (to 1981)
- Multi-Channel (1981)
  - MCSST 1981 - ...
  - CPSST 1990 - 1992
  - NLSST 1992 - ...
- ESA/ATSR
  - Dual Look 1992 - ...

RSMAS

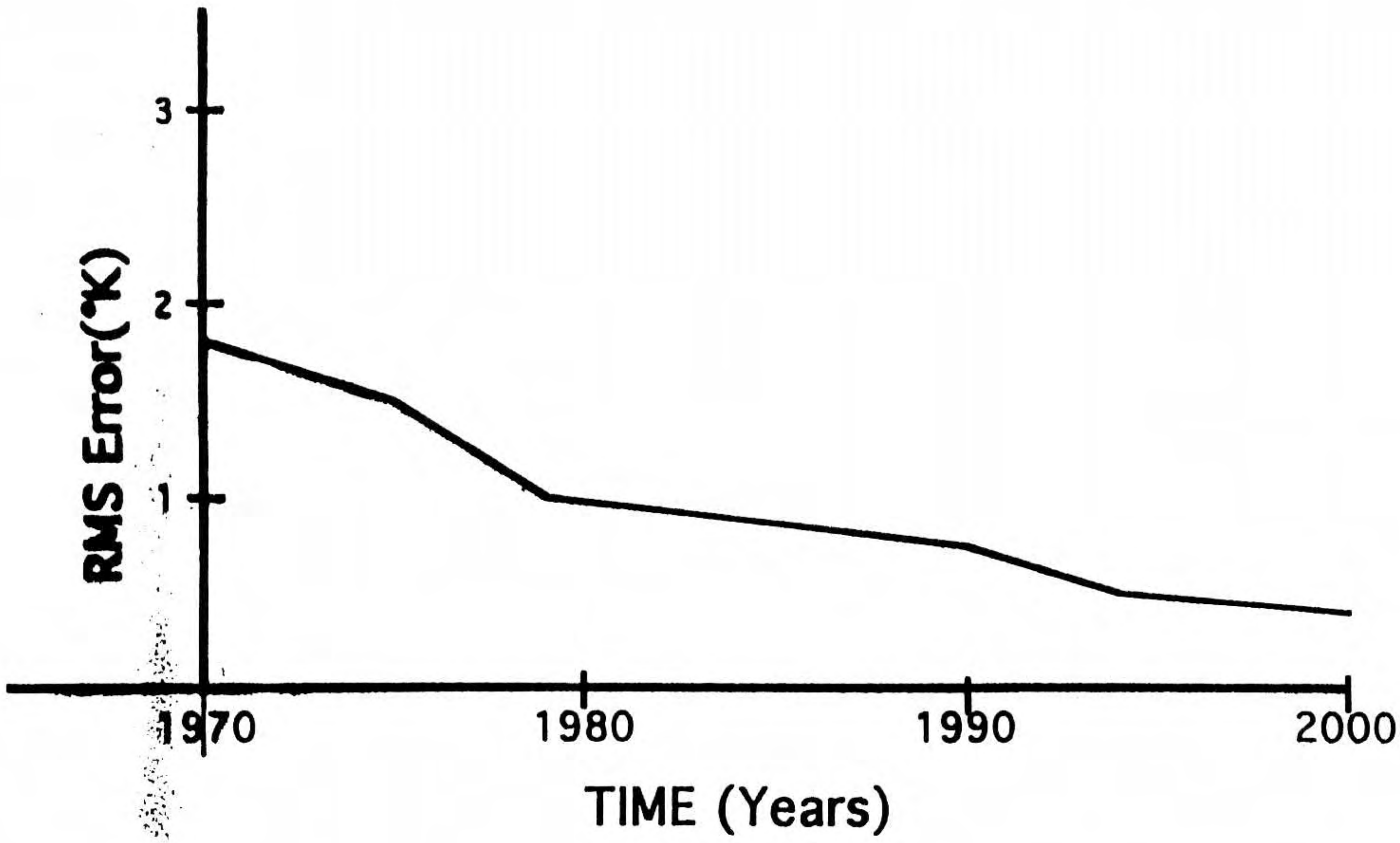
Algorithm Structure

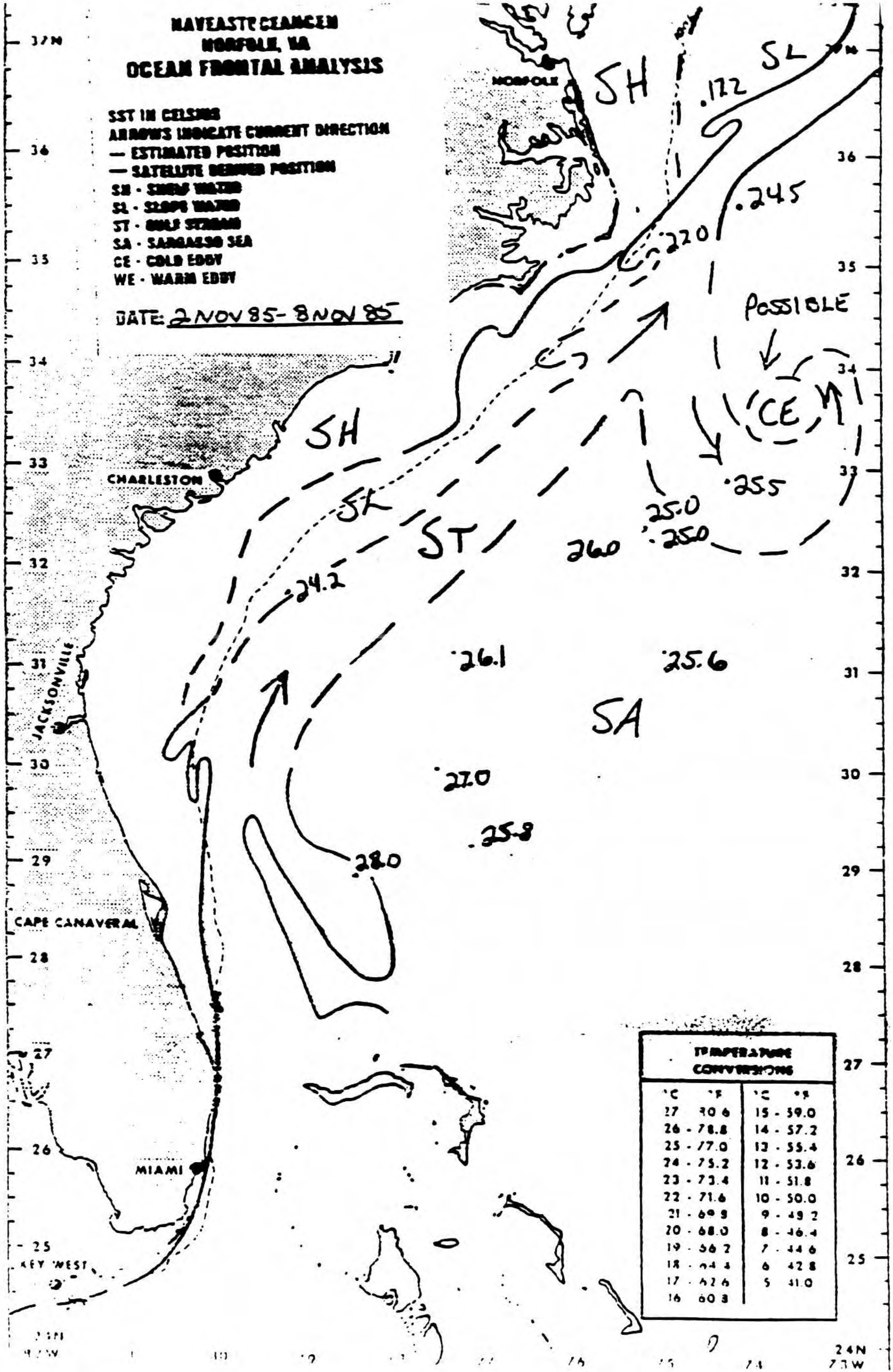
$$MCSST = a_o + a_1 T_1 + a_2 T_2$$

$$CPSST = (a_o - a_1 T_4) / (a_2 + a_3 T_5 - a_6 T_4) \times (a_7 + T_4 - T_4) + a_8 T_5$$

$$NLSST = a_0 + a_1 T_4 + a_2 (T_4 - T_5) T_c + d_3 (\sec \vartheta - 1)(T_4 - T_5)$$

Retrieved SST RMS Error





NORFOLK, VA
OCEAN FRONTAL ANALYSIS
SST IN CELSIUS
ESTIMATED POSITION
SA - SARGASSO SEA
CE - COLD EDDY
WE - WARM EDDY
DATE: 2 NOV 85 - 8 NOV 85
NORFOLK
CHARLESTON
JACKSONVILLE
CAPE CANAVERAL
MIAMI
KEY WEST
SH
SL
ST
SA
CE
POSSIBLE
.122
.245
22.0
25.5
25.0
26.0
25.0
24.2
26.1
25.6
27.0
25.8
28.0
TEMPERATURE CONVERSIONS
°C °F
26 - 78.8
25 - 77.0
24 - 75.2
23 - 73.4
22 - 71.6
20 - 68.0
16 60.8
°C °F
15 - 59.0
14 - 57.2
13 - 55.4
12 - 53.6
11 - 51.8
10 - 50.0
8 - 46.4
7 - 44.6
6 42.8
5 41.0
37N
36
35
34
33
32
31
30
29
28
27
26
25
24N
73W

PRODUCT DESCRIPTION (2)

- Imagery:
  - Typically a 512 x 512 frame with each pixel is a byte (8 bits) ≡ 1 megabit/frame
  - Should have navigation and calibration embedded in the image

RSMAS

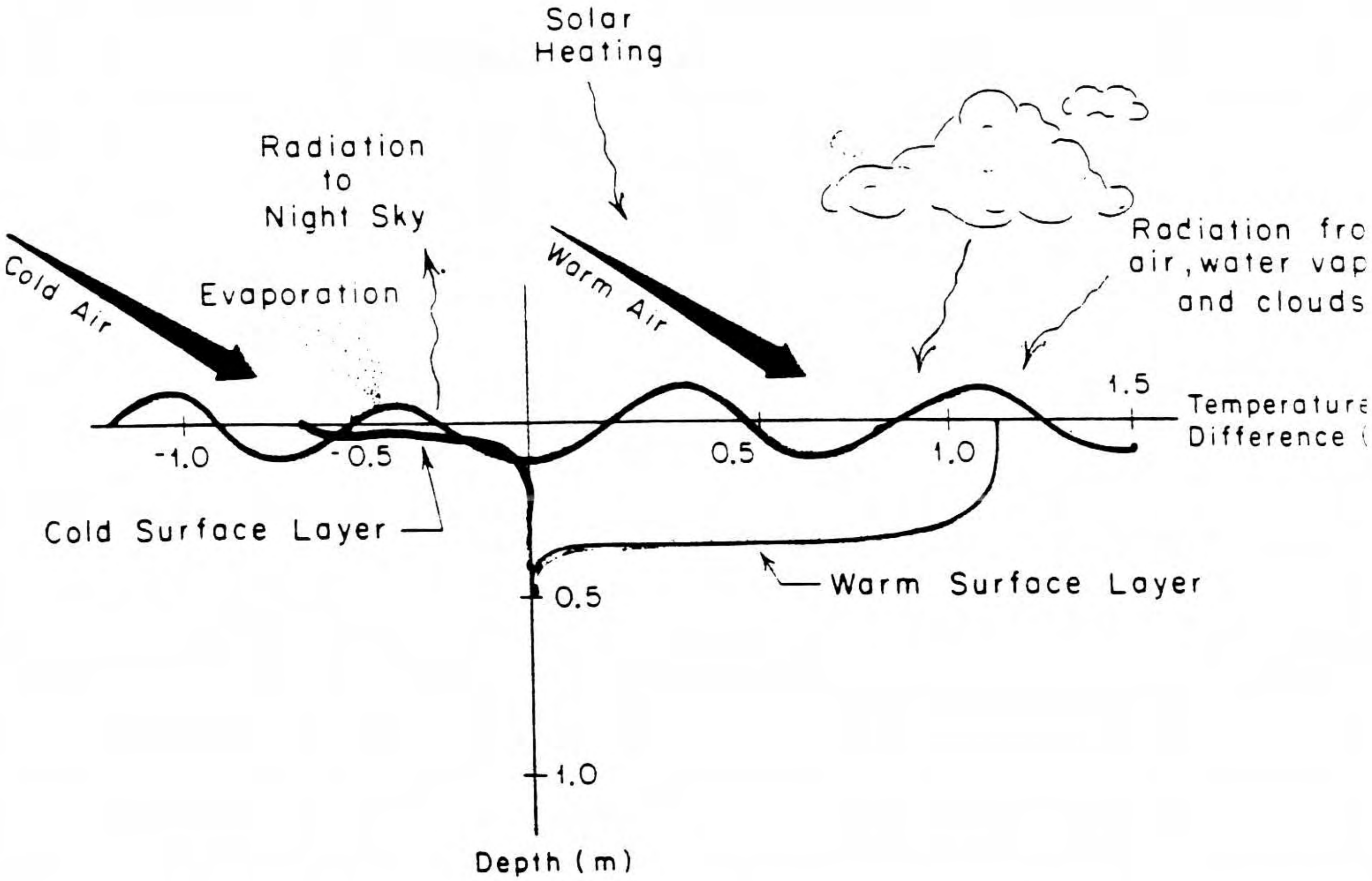


Figure 8.7 Processes influencing the temperature of the skin of the ocean. The skin temp ture is measured by infrared radiometers, and it may not be representative of temperature slightly greater depths.

ACCESS MECHANISMS

- Cellular Phone
- Satellite VHF (ATS)
- Satellite L/C Band (GOES)
- Inmarsat (A, B)
- Future Systems

RSMA

CELLULAR COMMUNICATIONS

- Cellular Phone + Comm. Jack (e.g. Motorola
- Cellular Modem (e.g. Cellblazer, Zyxel)
- PC, MAC or Workstation (BLAST/SLIP/PPP
- Viewer (mosaic, netscape, xv, ...)

VHF/UHF COMMUNICATIONS

- Full Duplex Transceiver (ATS/LES)
- Modem (asychronous, synchronous)
- PC, MAC or Workstation (BLAST/SLIP/PPP)
- Viewer (mosaic, netscape, xv, ...)

RSM

SATELLITE L/C BAND (GOES)

- **Full Duplex Transceiver**
- **Modem (asychronous, synchronous)**
- **PC, MAC or Workstation (BLAST/SLIP/PPP)**
- **Viewer (mosaic, netscape, xv, ...)**

RSMAS

INMARSAT (A,B)

- **Full Duplex Transceiver**
- **Modem (A-asychronous, B-synchronous)**
- **PC, MAC or Workstation (BLAST/SLIP/PPP)**
- **Viewer (mosaic, netscape, xv, ...)**

HSMAS

FUTURE SYSTEMS

- **Full Duplex Transceiver (phone?)**
- **Modem (asychronous)**
- **PC, MAC or Workstation (BLAST/SLIP/PPP)**
- **Viewer (mosaic, netscape, xv, ...)**

RSMAS

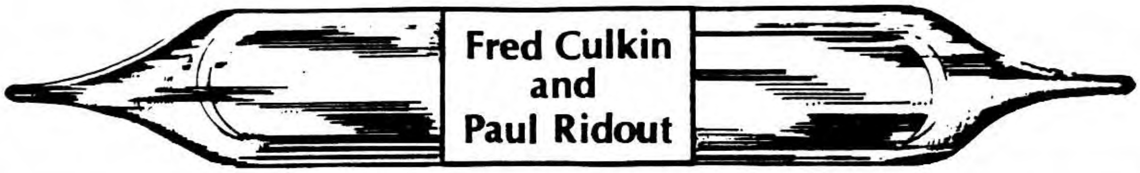
Appendix 6. Shipboard Vans

Desirable features for vans to be used aboard UNOLS vessels:

1. 20' ISO container
2. All exterior fittings should be recessed
3. Escape hatch
4. Floor drain
5. Outward opening doors
6. Active air replenishment
7. water cooled air conditioner
8. stackable while in use
9. uninterruptible power supply
10. unistruts
11. windows or ports
12. emergency lighting

Appendix 7. Salinity

THE IAPSO STANDARD SEAWATER SERVICE



Fred Culkin
and
Paul Ridout

In oceanography it was recognized very early that precision, accuracy and comparability between measurements on the same water mass by different laboratories could best be achieved if all measurements were based on the same standard. This recognition led to the formation of what is now known as the IAPSO Standard Seawater Service, the function of which is to provide scientists with a certified standard seawater for determination of salinity.

History

For the origins of the Service and the reasons for its formation we have to go back to the last century when studies of ocean circulation using salinity were started. Direct determination of salinity by evaporating a sample and weighing the residue was recognized as imprecise and impractical. The most widely adopted technique was the determination of chlorinity *Cl*, the concentration of chloride plus bromide (see below), and the use of relationships of the form:
salinity = $a.Cl + b$ where a and b are constants.

With the growth of hydrographical investigations it became obvious that this method of determining salinity, when used by different laboratories, was not satisfactory. One reason was probably that several forms of the salinity/chlorinity equation were in use so that a given chlorinity could produce different values of salinity according to which relationship was used.

Another, more fundamental, reason for differences between results obtained by different laboratories lay in the actual chlorinity determination. To determine the chlorinity of seawater the usual method has always been to use titration: a silver nitrate solution of known concentration is added to a known volume or weight of sample, until all the chloride (plus the small amount of bromide which is also present) has been precipitated, as shown by various indicators.

Unfortunately, silver nitrate is not what a chemist would call a good primary standard: it is not possible to prepare a silver nitrate solution of accurately known concentration by simply dissolving a weighed amount of the solid in a given volume of water, because solid silver nitrate cannot be dried without decomposing. The usual practice is therefore to prepare a solution of approximately the required concentration and to standardize this against a primary standard such as potassium chloride which can be obtained in a pure form. With each laboratory preparing its own standards, and no agreement on which salinity/chlorinity relationship to adopt, it is perhaps not surprising that salinity determinations were unsatisfactory at the turn of the century.

In 1899, the Danish hydrographer Martin Knudsen (1871–1949) suggested that greater accuracy, which was necessary to distinguish between water masses, could be obtained if all salinity determinations were carried out relative to the same standard. For his own hydrographic work, Knudsen had prepared sealed glass ampoules of seawater, on a number of which he determined the chlorinity by a very accurate method. Then, each time he prepared a fresh silver nitrate solution he simply determined its concentration by titrating it against the standard ampoule of seawater, thus eliminating the need to dry and weigh out potassium chloride each time.

This was obviously much quicker and more reliable than the existing practice and Knudsen went on to distribute ampoules of this certified standard to other laboratories for use in their own chlorinity titrations. As a result, greater uniformity was obtained because all laboratories were basing their chlorinities on one standardization, and this was the start of what later became the Standard Seawater Service.

On the basis of his own experience, Knudsen proposed to an International Commission that an institution be set up with the responsibility for producing sealed ampoules of seawater which would be certified in chlorinity and made available to other laboratories for the standardization of their silver nitrate solutions. This proposal was accepted, and a new Central Laboratory, with responsibility for the preparation and distribution of the standard, was set up in Oslo in 1902 under the directorship of Fridtjof Nansen. When the Central Laboratory closed down in 1908 the International Council for the Exploration of the Sea (ICES) handed over responsibility for the standard to Knudsen and he fulfilled this task until shortly before his death in 1949. Thus, the Standard Seawater Service was established in Copenhagen where it remained for 67 years.

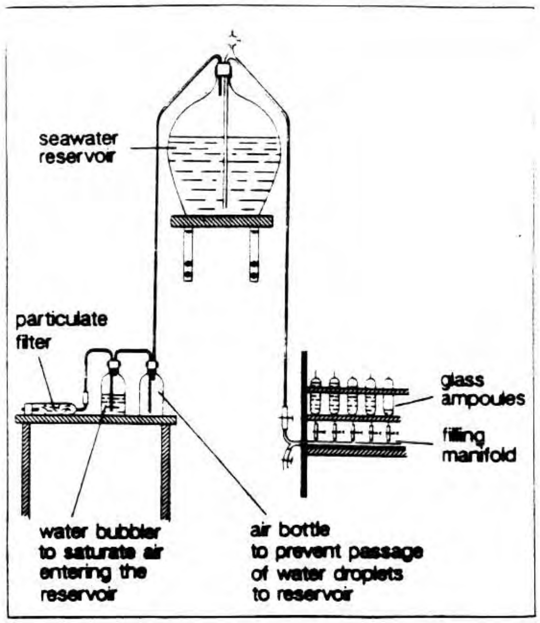
In its earlier years, the Service received financial support from ICES, but in 1914 Knudsen took overall charge in a personal capacity to relieve ICES of financial responsibility. When Knudsen retired from the directorship in 1948 the International Association for Physical Oceanography (now the International Association for the Physical Sciences of the Ocean, IAPSO) took over the responsibility for operating the Service at Knudsen's suggestion. At this time, two of Knudsen's colleagues at the Danish Commission for Marine Research, Copenhagen, operated the Service, with Helge Thomsen in charge of administration and Frede Hermann continuing to prepare and analyse the standard as he had done for some time under Knudsen. In 1960 Hermann succeeded Thomsen as Director of the Service, a post which he held for 15 years.

The long association with Copenhagen finally ended in 1975 when, in preparation for his retirement, Hermann handed over the responsibility to Fred Culkin at the Institute of Oceanographic Sciences, Wormley and the equipment was transferred to England. A further change took place in 1989 when Culkin was succeeded as Director of the Service by a former colleague at IOS, Paul Ridout, who formed Ocean Scientific International Limited. The company operates the Service from premises alongside IOS at Wormley, and also provides training courses, CTD calibration, instrument sales and servicing, and consultancy.

A remarkable feature of the Standard Seawater Service is the continuity which has been maintained over its 90 years of operation. After six years in Oslo, the Service operated until 1975 from four addresses in the Copenhagen area, under only three Directors in 67 years. This undoubtedly was responsible for the consistency and reliability of the standard over a period when production expanded from laboratory scale in Knudsen's time to production of more than 30000 ampoules in peak years. With the increasing use of *in situ* instruments, the demand for Standard Seawater has diminished in recent years but it is still in the 12000–15000 ampoules per year range. In addition, there is a lower but steady demand for secondary standards of salinities *c*.10, 30 and 38 which are available for checking salinometer offsets at other points on the salinity scale.

Preparation of Standard Seawater

The preparation of standard seawater has changed little in principle over the years, though obviously the scale has increased. The

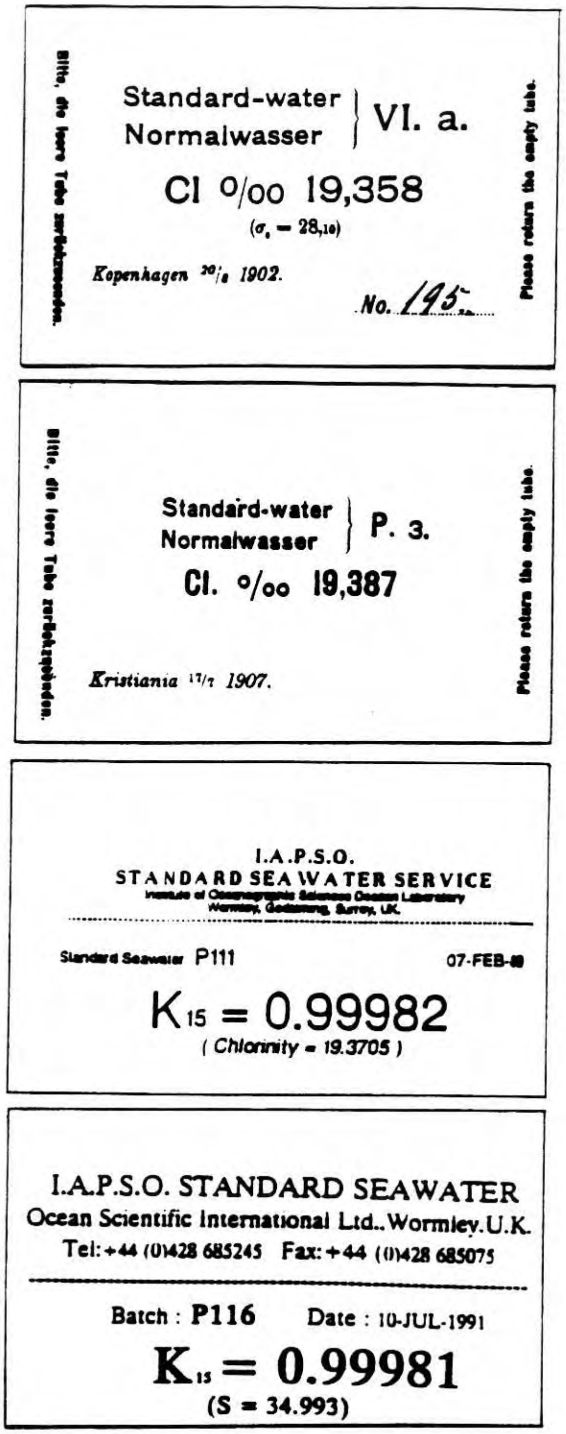


Early equipment for preparing Standard Seawater

seawater (*c*.5000 litres a time) is collected at the surface in the North Atlantic and transported in polythene containers to Wormley where it is immediately pumped through coarse filters to remove most of the particulate material. It is then stored until a batch of standard is required, when it is pumped through fine-membrane filters into a 5000-litre storage tank lined with PVC. It is then circulated continuously through the filters for two to three weeks to remove all particulate material and to mix it thoroughly. During this time the salinity (which is usually higher than 35) is measured by conductivity and the calculated amount of distilled water is added gradually to reduce the salinity to just below 35. For transferring the seawater to glass ampoules the method used today is a scaled up version of the method used by Knudsen (see figure) but, whereas he fed the seawater by gravity from a 50-litre container, a powerful pump and a 5000-litre tank are now necessary. The seawater is pumped from the storage tank to a horizontal glass tube on the filling table. This tube has several outlets to each of which is fitted one (open) end of a clean, dry ampoule. The seawater is allowed to fill the ampoule to within 2–3 cm of the top (~ 275 ml) and then the rubber tubing is closed by means of a clip and the upper tip is sealed by drawing off in an acetylene/air flame. After cooling, the ampoule is inverted, the seawater in the other tip is allowed to drain and then this tip is sealed. By operating two filling benches, each handling 48 ampoules at a time, it is possible to produce about 7000 ampoules in a day.

Certification of Seawater

Until fairly recently, all batches of Standard Seawater were calibrated in chlorinity by a high precision, combined gravimetric/potentiometric technique, using very high purity silver metal as the primary standard. In the last 20–30 years, however, the chlorinity titration has been



Examples of Standard Seawater labels

almost completely replaced in hydrographic work by the measurement of electrical conductivity and this has led to redefinitions of salinity and the need for a standard seawater certified in electrical conductivity.

The most recent developments took place in 1978 when the link between chlorinity and salinity was abandoned, with chlorinity to be regarded henceforth only as a descriptive parameter of seawater with no defined relationship to salinity. At the same time, the Practical Salinity Scale was adopted in which the salinity of a seawater sample was defined in terms of its electrical conductivity ratio at 15°C relative to a defined and reproducible potassium chloride solution. In accordance with the Practical Salinity Scale, the conductivity ratio (K_{15}) of each batch of standard seawater is compared with that of the defined potassium chloride solution, at 15°C, to give a certified value of K_{15}. Preparation of this primary standard requires the use of the highest purity potassium chloride and involves measurements of extremely high accuracy, so this work is carried out *only* by the Standard Seawater Service. For the calibration of laboratory salinometers it is only necessary to fill the cell with standard seawater and either adjust the instrument to read the certified value of K_{15} or note the correction to be applied to subsequent readings. In this way, all salinity data are traceable to the defined potassium chloride solution.

It is probable that salinity was, and continues to be, the most frequently measured parameter of seawater. Determinations, both by the old chlorinity titration method and by electrical conductivity, run into millions and are still increasing rapidly with the widespread use of *in situ* instruments. The comparability of these data depends to a large degree on the use of IAPSO Standard Seawater for calibration.

Frederick Culkin is a marine chemistry consultant under contract to Ocean Scientific International. Prior to this, he was a Principal Scientific Officer and group leader in marine chemistry at the Institute of Oceanographic Sciences. He was also director of the IAPSO Standard Seawater Service from 1975 to 1989 and is a member of the Joint Panel on Oceanographic Tables and Standards.

Paul Ridout is Managing Director of Ocean Scientific International and Director of the IAPSO Standard Seawater Service. Previously, he worked for 11 years in the Marine Chemistry Department at the IOS Deacon Laboratory. His work there – apart from management of the IAPSO Standard Seawater Service – included research in several aspects of chemical oceanography, and his journal publications include studies of pigments in marine systems, porewater chemistry and trace metals in marine organisms and sediments.

Salinity: Definitions, Determinations, & Standards

Importance of Salinity Distribution Leads to Need for a Single Standard in all Salinity Determinations

By Dr. Frederick Culkin
Marine Chemistry Consultant

and

Paul Ridout
Managing Director
Ocean Scientific International Ltd.

Unquestionably salinity is one of the most important and frequently studied parameters of seawater. Data centers today contain the results of millions of salinity determinations obtained by workers over a long period of time. Such data are used by physicists, chemists, biologists, and engineers in a variety of applications. A knowledge of salinity distribution is important in studies of circulation and mixing in both oceanic and estuarine regions, in meteorology, in acoustic measurements, and in pollution.

In the past 90 years, considerable thought has been given to the concept of salinity and, as a result, its definition has undergone several changes. Recent developments have been due to the deliberations of, and fundamental work encouraged by, the Joint Panel on Oceanographic Tables & Standards (JPOTS), and have been adequately brought to the notice of deep sea oceanographers.

Early Definitions

Originally (1902) salinity was defined as "the total amount of solid material in grams contained in one kilogram of seawater when all carbonate has been converted to oxide, all the bromine and iodine replaced by chlorine, and all the organic material oxidized."

It was discovered in the late 19th century, and confirmed many times since, that the major constituents of seawater occur in almost constant proportions in the major oceans. A consequence of this is that the total dissolved salts can be determined from the concentration of any one major constituent, provided that the relationship between the two is known.

The relationship between salinity and chlorinity was established by determining the total dissolved salts, by the evaporation technique, and the chlorinity, by silver nitrate titration, on a selection of seawaters from the Baltic, Mediterranean, and Red seas and the North Atlantic. On the basis of these determinations the formula

$$S‰ = 1{,}805\ Cl‰ + 0.05$$

was adopted and widely used for more than 60 years.

The conversion of silver nitrate titrations to chlorinity required a knowledge of atomic weights, the accepted values of which were liable to change with time as methods of their determination improved. In order to eliminate this dependency of chlorinity on atomic weights, the definition of chlorinity was later changed to "the mass of pure silver just necessary to precipitate the halogens in 0.3285234 kilograms of seawater."

This definition, as well as being independent of accepted atomic weights, uses pure silver as the ultimate standard and provides a continuous link between all chlorinity determinations.

With minor modifications to conform to the International System of Units, it remains the current definition of chlorinity.

Enter Electrical Conductivity

In the late 1950s the measurement of electrical conductivity started to replace the chlorinity titration as a means of estimating salinity. Salinometers, incorporating high precision comparator bridges and thermostatically controlled baths, were developed to compare the electrical conductivity of the sample with that of a standard seawater of known chlorinity (and hence salinity) at the same temperature. The measured conductivity ratio was then converted to salinity by means of relationships which had been established in 1934 but which were not of the desired quality.

New relationships between salinity, conductivity ratio and temperature were, therefore, established based on measurements carried out on natural seawaters covering a wide salinity range. Thus the chlorinity based salinity became re-defined in terms of conductivity ratio and at the same time the equation above was replaced by

$$S‰ = 1.80655\ Cl‰$$

This made both salinity and chlorinity conservative properties. Equations and tables based on the new measurements were published in 1966 by United Nations Educational, Scientific & Cultural Organization (UNESCO) and were widely adopted.

Although the new conductivity/salinity relationships and definition of salinity helped to establish uniformity in salinity determinations, they had limitations. As they were originally intended for use with laboratory salinometers, they had a limited temperature range so could not be used for converting data from *in situ* instruments which were mostly used at temperatures below 10°C. Also the samples of seawater used for the basic measurements were natural seawaters in which there were probably variations in ionic ratios which affected conductivity/chlorinity rela-

(Continued on page 48)

In addition, the standard [International Association for the Physical Sciences of the Ocean (IAPSO) Standard Seawater] used for all salinity determinations was certified only in chlorinity which was not satisfactory for a conductivity standard.

Now: 'Practical Salinity'

The Practical Salinity Scale 1978 was introduced to rectify the shortcomings associated with the chlorinity / conductivity relationship. In this scale the existing link between chlorinity and salinity was broken in favor of a definitive salinity/conductivity relationship. All waters of the same conductivity ratio thus have the same practical salinity.

By definition, a seawater of practical salinity 35 has a conductivity ratio of unity at 15°C with a KCl solution containing a mass of 32.4356 grams KCl in a mass of 1 kilogram solution. From measurements on weight diluted (with pure water) or weight evaporated North Atlantic surface water, the following relationship was established:

$$S = a_0 + a_1 R_T^{1/2} + a_2 R_T + a_3 R_T^{3/2} + a_4 R_T^2 + a_5 R_T^{5/2} + \frac{(T-15)}{1+K(T-15)} \{ b_0 + b_1 R_T^{1/2} + b_2 R_T + b_3 R_T^{3/2} + b_4 R_T^2 + b_5 R_T^{5/2} \}$$

where

a_0 =	0.0080	b_0 =	0.0005
a_1 =	−0.1692	b_1 =	−0.0056
a_2 =	25.3851	b_2 =	−0.0066
a_3 =	14.0941	b_3 =	−0.0375
a_4 =	−7.0261	b_4 =	0.0636
a_5 =	2.7081	b_5 =	−0.0144
Σa_i =	35.0000	Σb_i =	0.0000
		k =	0.0162

In all cases temperatures are measured according to the International Practical Temperature Scale (1968).

A supplementary equation was also established for converting conductivity ratios measured at pressure greater than one atmosphere (i.e., for CTD measurements in subsurface waters).

This equation enables practical salinity (S) to be calculated from conductivity ratio (R_T) measured at temperature T°C and atmospheric pressure and is valid in the temperature range −2°C to +35°C and salinity range 2 to 42. This equation also constitutes the new definition of salinity but the following points should be stressed:

- Although the basis of the conductivity ratio is the conductivity of a defined KCl solution, in practice it is necessary to use a seawater, calibrated against the KCl standard, for routine conductivity ratio measurements. The practical standard is thus IAPSO Standard Seawater, produced and calibrated by the IAPSO Standard Seawater Service.
- Salinity is now a dimensionless quantity because the algorithms in the Practical Salinity Scale 1978 were adjusted to eliminate the ‰ and 10^{-3} which were used in previous scales.
- Chlorinity is now regarded as an independent chemical parameter to describe the properties of seawater and has no defined relationship to salinity.

In the past 90 years or so, only two methods have been widely used for the determination of salinity.

Chlorinity Titration. This method consists of titrating a sample of seawater with silver nitrate solution of known concentration to the point where all the halides (chloride plus a small amount of bromide) have been precipitated as silver halide, as detected by suitable indicators or electrode systems. Usually most of the silver nitrate is added as a strong solution, to just short of the endpoint, and then the titration is completed with a more dilute solution of silver nitrate. The silver nitrate solutions are calibrated against IAPSO Standard Seawater certified in chlorinity and the chlorinity of the unknown seawater is calculated as follows

$$Clu = \frac{Cls\ Ws\ Tu}{Ts\ Wu}$$

where

Clu and Cls = chlorinity of unknown and standard

Wu and WS = weight of unknown and standard

Tu and Ts = silver nitrate titre for unknown and standard.

Chlorinity was then converted to salinity by means of equation 1 or (later) equation 2, prior to the introduction of the Practical Salinity Scale 1978.

Electrical Conductivity. In the past 20-30 years, the chlorinity titration, which was time-consuming and required a certain degree of analytical skill, has been largely replaced by the measurement of electrical conductivity as a means of estimating salinity. The laboratory method consists of comparing the electrical conductivity of the sample with that of a standard (IAPSO Standard Seawater) of known salinity at the same temperature. The measured conductivity ratio is then converted to salinity by means of the equations in the Practical Salinity Scale 1978 or tables derived from these equations (available from UNESCO). In recent years the use of *in situ* conductivity, temperature, and pressure measuring instruments—calibrated against standard seawater either in the laboratory or at sea against bottom samples—has increased as a means of obtaining continuous salinity profiles.

Use of Standards

Salinity is the most frequently studied parameter of seawater. In many applications there is a requirement for high precision and accuracy, as well as large numbers of data sets. Many oceanic water masses can be identified by their characteristic salinity and temperature, for example, but such identification requires that different laboratories should be capable of agreeing in their salinity determinations very precisely.

The problem of comparability between measurements of salinity was recognized early in oceanographic studies. To some extent the chlorinity titration was improved by the design of special burettes and pipettes, but a source of variability remained in determining the concentration of the silver nitrate solution used in the titrations.

Silver nitrate is not a good primary chemical standard because it decomposes when dried by heating. This means that it is not possible to prepare a solution of silver nitrate of known concentration by dissolving a known weight of crystals in a given volume of water. Instead, the practice has always been to prepare a solution of approximately the desired concentration and then calibrate this against a standard of known composition, such as potassium chloride. This practice of each laboratory preparing its own standards was thought to be one source of disagreement between laboratories in chlorinity determinations.

Considerable improvement was achieved by the Danish hydrographer Knudsen who prepared a number of sealed glass ampules of seawater on some of which he determined the chlorinity by a high precision method. The remaining ampules, certified in chlorinity, were distributed to other laboratories for calibration of silver nitrate solutions.

Striving for Consistency

In effect this was referring all chlorinity determinations to one standardization, so giving greater consistency. Knudsen thus established what later became known as the IAPSO Standard Seawater Service with the responsibility for supplying a standard seawater, certified in chlorinity as determined by a high precision gravimetric/potentiometric method referred to pure silver, for salinity determinations.

The adoption of the Practical Salinity Scale 1978 led to an additional calibration of IAPSO Standard Seawater. In addition to chlorinity it is now calibrated in conductivity ratio K15 relative to a defined potassium chloride. IAPSO Standard Seawater remains the only internationally recommended standard for all salinity determinations.

This service operated from a laboratory in Copenhagen until 1975 when responsibility for its operation was taken over by the Institute of Oceanographic Sciences (IOS) in Wormley, Godalming, Surrey, England. In April 1989, operation of the service transferred to Ocean Scientific International Ltd., based at IOS. Its function is to prepare, calibrate, and distribute IAPSO Standard Seawater for use in all chlorinity and salinity determinations.

This standard is a natural surface water collected in the North Atlantic. It is filtered through activated carbon, cartridge filters (0.3 μm) and irradiated with UV light. Water is added to the batch process to provide the required salinity. The water is thoroughly mixed in a large (1,000 liter) tank and finally sealed in glass ampules of about 280 cubic centimeters. Selected ampules from each batch are then calibrated in conductivity ratio and/or chlorinity.

The principal standard seawater (P-series) of salinity (approximately 35) is intended for single-point calibration of laboratory salinometers. It is certified in electrical conductivity ratio (K15) relative to a defined potassium chloride solution at 15°C and one atmosphere pressure.

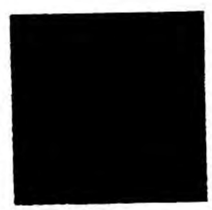
Because chlorinity is still useful in its own right, although it is no longer regarded as related to salinity, the standard is also certified in chlorinity.

Checking Offsets

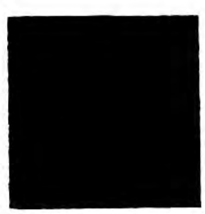
For checking the offset of salinometer comparator bridges at other points on the salinity scale, the following secondary standard seawaters, certified in conductivity ratio only, are also available or being considered. A low salinity standard (30-L series) of salinity *ca.* 30 provides a second calibration point for most oceanic waters. Another low salinity standard (10-L series) of salinity *ca.* 10 is particularly relevant for the measurement of samples from the Baltic Sea or estuarine waters.

These low standards provide calibration points in addition to that provided by the principal standard seawater (P series). According to demand, a high salinity standard (H series) of salinity *ca.* 38-40 may be produced for use in areas such as the Mediterranean or the Red Sea.

To summarize, the use of one standard—IAPSO Standard Seawater—for all determinations of salinity and chlorinity has done much to ensure uniformity in salinity measurements throughout the world. Its continued use is recommended by all the major international oceanographic bodies.



Dr. Frederick Culkin previously was principal scientific officer and group leader in marine chemistry at the Institute of Oceanographic Sciences. He was also director of the IAPSO Standard Seawater Service from 1975 and was a member of the Joint Panel on Oceanographic Standards until his retirement this year.



Paul Ridout previously worked for 11 years in the Marine Chemistry Department at the IOS Deacon Laboratory. His work there—apart from management of the Standard Seawater Service—included research in several aspects of chemical oceanography. Ridout's journal publications include studies of pigments in marine systems, pore water chemistry, and trace metals in marine organisms and sediments.

APPENDIX A: ORDERING SAMPLE SALINITY BOTTLES

The bottles and caps can be ordered from:

Fisher Scientific
7445 Exchange Drive
Orlando, Florida 32809
PHONE: **1-800-766-7000**
FAX: **1-800-926-1166**

The bottles are called KIMAX Brand Glass Sampling Bottles.

Fisher catalog # 02-945-10 (93/94 Fisher Catalog pg.216)

Capacity of 200 ml (250 ml to the neck). Screw cap size 28mm.

The Marine Technology Group does not use the caps that come with the bottles. The caps are purchased separately.

The caps are called Nalgene Polypropylene Screw Closures

Fisher catalog # 02-923-14C (Not in 93/94 catalog but is a valid number)

Cap size 28mm.

Call Fisher Scientific to verify price.

If you have a Fisher Scientific customer account number there may be a discount

The Nalgene caps do not come with plastic insert thimbles (liners)

The plastic inserts for a 28mm. cap size are purchased from:

Univ. of Califorrnia at San Diego
Atn: Vickie Tencer
La Jolla, Ca. 92093-0214
phone: (619) 534-4425