

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. Agency Use Only (Leave blank).	2. Report Date. Jan. 2, 1990	3. Report Type and Dates Covered. Proceedings Jan. 2, 1990
4. Title and Subtitle. Coupled Ocean-Atmosphere Models 21st International Liege Colloquium on Ocean Hydrodynamics: Coupled Ocean - Atmosphere Models		5. Funding Numbers. Program Element No 920101 Project No 0101 Task No 421 Accession No DN258097
6. Author(s). Alan I. Weinstein B. Edward McDonald		7. Performing Organization Name(s) and Address(es). ONR - Arlington, VA NOARL Code 322 SSC, MS 39529-5004
9. Sponsoring/Monitoring Agency Name(s) and Address(es). Sandia National Laboratory Division 1533 Albuquerque, New Mexico		8. Performing Organization Report Number. PR 89:070:322
10. Sponsoring/Monitoring Agency Report Number.		

**DTIC
ELECTE
JAN 31 1991
S E D**

AD-A231 322

plementary Notes.

istribution/Availability Statement.

oved for public release; Distribution is unlimited.

12b. Distribution Code.

tract (Maximum 200 words).

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input checked="" type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

14. Subject Terms. shock convergence, nonlinear propagation, nonlinear acoustics		15. Number of Pages. 2
		16. Price Code.
17. Security Classification of Report.	18. Security Classification of This Page. Unclassified	19. Security Classification of Abstract. Unclassified
20. Limitation of Abstract.		

which techniques will prove most useful for problems of this size. To be prepared for the WOCE hydrographic data set, it is proposed to start a cooperative (community) effort to use these data in a systematic way.

A comparison of different existing techniques can be a first step in this direction. A number of participants were actively interested in being involved. The data set is available to all participants, and also to other interested parties (contact C. Wunsch at MIT, or the mailing list WOCE IN WERSDE on telex OMNET OCEAN). It is expected that many other fields will be made available, through collaborative effort, in appropriately gridded form. These would include transient tracers, carbon related fields, improved estimates of the wind field during the period, and surface color measurements. The group agreed to share data as well as model results and code. The participation of other scientists is welcomed.

References

Anderson, D. L. T., and J. Willebrand (eds.), *Oceanic Circulation Models: Combining Data and Dynamics*. Kluwer Academic Publishers, Dordrecht, 605 pp., 1989.

Cox, M. D., A primitive equation, 3-dimensional model of the ocean, *GFDL Ocean Group Tech. Rep. No. 1*, Geophysical Fluid Dynamics Laboratory, Princeton University, Princeton, N. J., 1984.

Olbers, D., and M. Wenzel, Determining diffusivities from hydrographic data by inverse methods with applications to the Circumpolar Current, in *Oceanic Circulation Model: Combining Data and Dynamics*, edited by D. L. T. Anderson and J. Willebrand, pp. 93-140, Kluwer Academic Publishers, Dordrecht, 1984.

Fukumori, I., F. Martel, and C. Wunsch, The Hydrography of the North Atlantic in the Early 1980's: An Atlas, unpublished document, 1989.

Coupled Ocean-Atmosphere Models

21st International Liege Colloquium on Ocean Dynamics

Alan I. Weinstein
Office of Naval Research, Arlington, Va.

B. Edward McDonald
Naval Oceanographic and Atmospheric Research Laboratory, Stennis Space Center, Miss.

Global scale ocean dynamics related to El Niño/Southern Oscillation (ENSO) was the focus of the 21st International Colloquium on Ocean Dynamics. ENSO provides modelers a great deal of data revealing correlation between sea surface temperature (SST) anomalies and atmospheric pressure differentials in the tropics. (See *Enfield* [1989] for an excellent review of the data.)

The meeting was held May 8-12, 1989, at the University of Liege, Belgium. More than 50 scientists attended, from Australia, Belgium, Canada, Federal Republic of Germany, France, Hungary, Italy, Japan, Netherlands, People's Republic of China, Spain, U.K., U.S., and U.S.S.R.

The 16th Colloquium, in 1984

The 1989 colloquium followed one on the same theme in 1984. To give context for the 1989 meeting it is helpful to summarize the earlier one. In 1984 the 16th International Liege Colloquium on Ocean Dynamics was the first meeting to be devoted to coupled ocean-atmosphere models [Nihoul, 1985]. The motivation for the meeting was, in large part, the very strong El Niño of 1982-1983.

At the 1984 colloquium, 43 scientists presented papers. Almost 30 addressed ocean response to specified atmospheric forcing or vice versa. Only 2 attempted to couple oceanic and atmospheric general circulation models (GCMs). The modeling state-of-the-art at that time was not ready to attack a benchmark on the scale of the ENSO cycle. One problem that became evident in coupled GCMs was a discouraging downward climate drift in SST and air temperature. On the whole, the field of interactive ocean-atmosphere modeling in 1984 was in its infancy, despite years of experience with separately developed atmospheric and oceanic GCMs.

The 21st Colloquium, in 1989

At the 1989 Liege colloquium 52 papers were presented, with about 40% addressing or using ocean-atmosphere coupling parameters. R. W. Stewart of the University of Victoria, British Columbia, Canada, opened the meeting on the optimistic note that ocean models are now approaching the point where predictions are possible. He said that political decision makers will take action based on this predictive capability and that it is incumbent on the research community to express the level of uncertainty that exists in the predictions. As the conference progressed, it became clear that his assessment of predictive capability was optimistic and his warning of uncertainty well founded.

The papers given during the first half of the meeting dealt primarily with responses of one medium to the other, with little concern for coupled interaction. The stated theme of the first half was to identify the relevant physics and numerics rather than present specific results.

Scientists giving papers in the second half of the meeting reported varying degrees of success in modeling the ocean and atmosphere together. Some findings will be cited here because of their importance to the coupling issue. About 5 of the modeling papers addressed ENSO directly. Some promising signs in the model results appeared in the form of eastwardly propagating SST anomalies with time scales of order 2 years for crossing the Pacific Ocean.

Atmospheric Dynamics

Papers on the first day dealt largely with atmospheric response to El Niño. Warm SST anomalies have two immediate effects on the atmosphere above them: increased latent heat flux, and increased convergence. Since atmospheric motion is in very delicate balance in the tropics due to the prevalence of convection and the absence of geostrophic control, the warm SST anomalies quickly induce broad-scale convergence of surface air. This convergence intensifies convective updrafts, causing increased condensation and, ultimately, precipitation.

Condensation liberates heat, which intensifies the surface convergence. Hence, increased precipitation generally follows centers of SST warming. It is the convergence of surface air that is primarily responsible for the increased precipitation, rather than the simple increase in latent heat flux that comes from warmer SST. E. Rasmusson of the Uni-

versity of Maryland, College Park, described available data on ENSO and stressed the need to understand phase correlations evident in annual, biennial and lower frequency (4- to 5-year periods) modes of atmospheric variables.

The mechanism by which equatorial atmospheric responses propagate from the tropics to midlatitudes is not clear. In fact, not all model calculations propagate the response at all. When propagation occurs, it does so primarily in response to warm anomalies. One suggested propagation mechanism involves the interaction of equatorially induced convergence with the jet stream. The suggestion is that the equatorial convergence interrupts the zonal pattern of the jet stream, increasing its wave number and making it more meridional in nature.

In time, increased equatorial convection leads to increased cloudiness and increased outgoing radiation. Radiation is the least understood and most complicated heat-transfer process to calculate in the atmosphere, so it is the weakest component of atmospheric models. Since radiation plays such an important role in tropical atmospheric motion, atmospheric models suffer in the region of the world.

Fortunately, the other atmospheric processes have been simulated numerically for more than 3 decades in numerical weather prediction (NWP) models for the midlatitudes. Virtually all modern atmospheric models used for large-scale air-sea interaction research use the "primitive equations" (PE) of atmospheric motion. Such models adequately simulate the relevant physical processes, with the exception of radiation.

Ocean Dynamics

In contrast to a long history with atmospheric PE models, ocean models are relatively newer. The basic PE ocean model currently in use for research was developed by Bryan [1969]. A majority of the conference papers about large-scale ocean simulation used one of the variants of this model. Other models in use make physical simplifications (typified by approaches such as geostrophic, "quasi-geostrophic," lumped parameter, "box ocean" approaches, and one- or two-layer). Layer models relate ocean evolution to horizontal motion within vertically homogenized layers, with moving layer boundaries describing the ocean surface and thermocline.

Ocean models respond to surface winds and to evaporation and precipitation differences. Wind stress provokes the quickest ocean responses, with time scales down to less than an hour—during passage of a storm, for example. On the other extreme, the global thermohaline circulation operates on a much longer time scale. This circulation transports the ocean's heat horizontally and is driven by density anomalies that can be due to differential heating, evaporation and precipitation, or vertical mixing. The global thermohaline circulation time is on a decade scale.

Wind increase anomalies have two effects on the ocean: wind-driven currents and mixed-layer deepening. Both effects strongly influence ocean circulation. The curl of wind stress is the principal factor in large-scale wind-driven ocean circulation. Mixed-layer deepening, along with evaporation and precipitation, contributes to the thermohaline circulation.

Fresh water input (precipitation and runoff) and evaporation contribute oppositely to mixed-layer processes that drive large-scale circulation currents. Evaporation increases mixed-layer salinity. Because saline water is more dense than fresh, increased salinity leads to increased convection, mixed-layer deepening and SST cooling. Conversely, when fresh water input exceeds evaporation, the ocean freshens, convection is decreased and the mixed layer shallows. Mixed-layer deepening or shallowing sets up a horizontal pressure gradient that manifests itself in horizontal currents. This process is the principal component of the thermohaline circulation.

Two papers described ocean models used to investigate thermohaline currents in the Atlantic and the Pacific, respectively. The Atlantic study predicted an inhibiting effect on these currents that results from increased output of the St. Lawrence River. Both studies showed that the existence of dual steady states was plausible, suggesting the possibility that different circulation patterns may have existed in the past.

Coupled Interactions

Global Scale Models Discussion of model coupling began on the third day of the meeting. About half the remaining participants discussed true coupling. Due to the complicated nature of each individual medium's response to the other, truly coupled models require enormous computer resources or considerable simplification of both. The latter greatly compromises realism and the former is very expensive. Hence, all the papers on true coupling were filled with introductory qualifications such as simplification or preliminary.

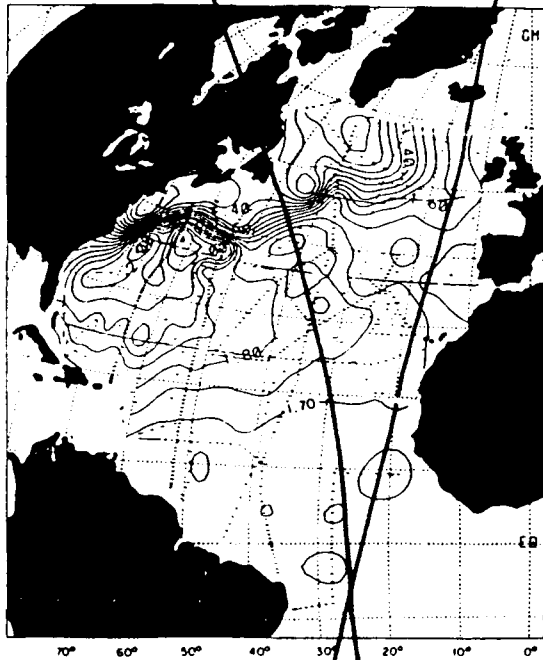


Fig. 2a

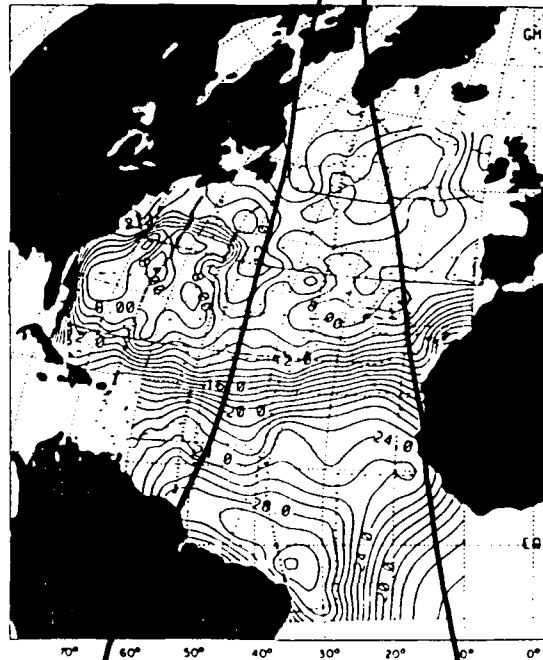


Fig. 2b

Fig. 2. Top, Dynamic topography at 250 dbar relative to 3000 dbar. Contour interval is 1 m. Bottom, Salicate at the 200 m level. Contour interval is 1 micro-mole per liter. The maps are part of an atlas containing an analysis of hydrographic observations from 1981-85 [Fukumori et al., 1989].

