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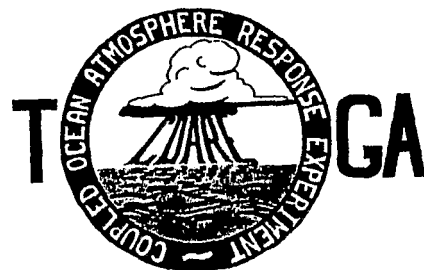
SCIENCES DE LA MER

OCEANOGRAPHIE PHYSIQUE

1990

Organisation et résultats du
" Symposium International sur le Pacifique
Ouest et Réunion de Travail TOGA COARE "
(24-30 mai 1989, Centre ORSTOM de Nouméa)

Joël PICAUT
Roger LUKAS
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INSTITUT FRANÇAIS DE RECHERCHE SCIENTIFIQUE
POUR LE DEVELOPPEMENT EN COOPERATION

CENTRE DE NOUMÉA

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l'IFREMER



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ORSTOM Nouméa
REPROGRAPHIE

RESUME SIGNALETIQUE

Le "Symposium International sur le Pacifique Ouest et Réunion de travail TOGA COARE", qui s'est tenu en Nouvelle Calédonie au Centre ORSTOM de Nouméa du 24 au 30 mai 1989, a réuni plus d'une centaine de scientifiques d'Australie, Chili, Chine, Etats Unis, France, Indonésie, Japon, Nouvelle-Zélande et du Royaume Uni. L'assemblée était composée d'un mélange d'océanographes et de météorologues, spécialistes des problèmes de circulation tropicale ou d'interactions océan-atmosphère. Le but principal de cet ensemble Symposium/Réunion de Travail était de faire le point des recherches du programme international TOGA (Océans Tropicaux et Atmosphère Globale) dans tout le Pacifique Tropical Ouest, de coordonner les efforts croissants de recherches multinationales dans le réservoir d'eaux chaudes de cette région et de préparer au niveau international l'importante expérience TOGA COARE (Coupled Ocean-Atmosphere Response Experiment) d'interactions océan-atmosphère.

ABSTRACT

The "Western Pacific International Meeting and Workshop on TOGA COARE", held at Centre ORSTOM de Nouméa, New Caledonia during May 24-30, 1989, brought together more than one hundred scientists from Australia, Chile, China, France, Indonesia, Japan, New Zealand, the United Kingdom and the United States. The assembly was composed of a mixture of oceanographers and meteorologists who specialize in tropical circulation or air-sea interaction problems. The main purpose of this combined Meeting/Workshop was to review the status of western tropical Pacific TOGA (Tropical Ocean and Global Atmosphere) related research, coordinate the growing multinational research efforts in the warm pool region, and cooperate in the planning of a major international air-sea interaction experiment in this region, the TOGA Coupled Ocean-Atmosphere Response Experiment (COARE).

AVANT PROPOS

Le "Symposium International sur le Pacifique Ouest et Réunion de Travail TOGA COARE" a fait l'objet d'un compte rendu de 850 pages. Le volume correspondant a été distribué en mars 1990 aux 106 participants du symposium et à plus de 200 scientifiques directement intéressés. Le présent rapport, destiné aux organismes français qui ont financé ce symposium, en est une version abrégée. Il se compose des résumés anglais et français, des remerciements, de la table des matières, de l'introduction, de la liste des participants, de l'agenda original du symposium et du rapport de la Réunion de Travail TOGA COARE. Une note, publiée dans la revue "ORSTOM actualités" de janvier-février-mars 1990, a été ajoutée en introduction au présent rapport. Elle vise à replacer les objectifs du symposium dans le cadre du programme international TOGA et met en évidence l'importance de l'effort de recherche du Groupe SURTROPAC du Centre ORSTOM de Nouméa au sein de ce vaste programme.

L'ensemble du compte rendu du symposium, formé essentiellement de 72 contributions scientifiques des participants, est disponible au Centre ORSTOM de Nouméa.

MAI 1989:

LE CENTRE ORSTOM DE NOUMEA

HAUT LIEU DES RECHERCHES OCEAN-ATMOSPHERE

Du 24 au 30 mai 1989 s'est tenu au Centre ORSTOM de Nouméa le "CONGRES INTERNATIONAL TOGA-COARE" (Tropical Ocean and Global Atmosphere-Coupled Ocean Atmosphere Response Experiment). Cette manifestation a réuni plus d'une centaine de participants venus d'Australie, du Chili, de Chine, des Etats-Unis, de France, d'Indonésie, du Japon, de Nouvelle-Zélande et du Royaume Uni. Il y avait là une bonne partie des scientifiques qui étudient les relations entre l'océan et l'atmosphère. Profitant de ce grand rendez-vous, d'autres manifestations scientifiques sont venues s'y greffer : le Comité Pacifique du CCCO (Committee on Climate Changes and the Ocean) a tenu sa réunion annuelle du 20 au 23 mai, et quelques-uns des participants ont prolongé leur séjour à Nouméa jusqu'au 1^{er} juin pour assister à la première réunion du Comité ad-hoc sur la Stratégie du Programme TOGA - XBT (bathythermographes à tête perdue).

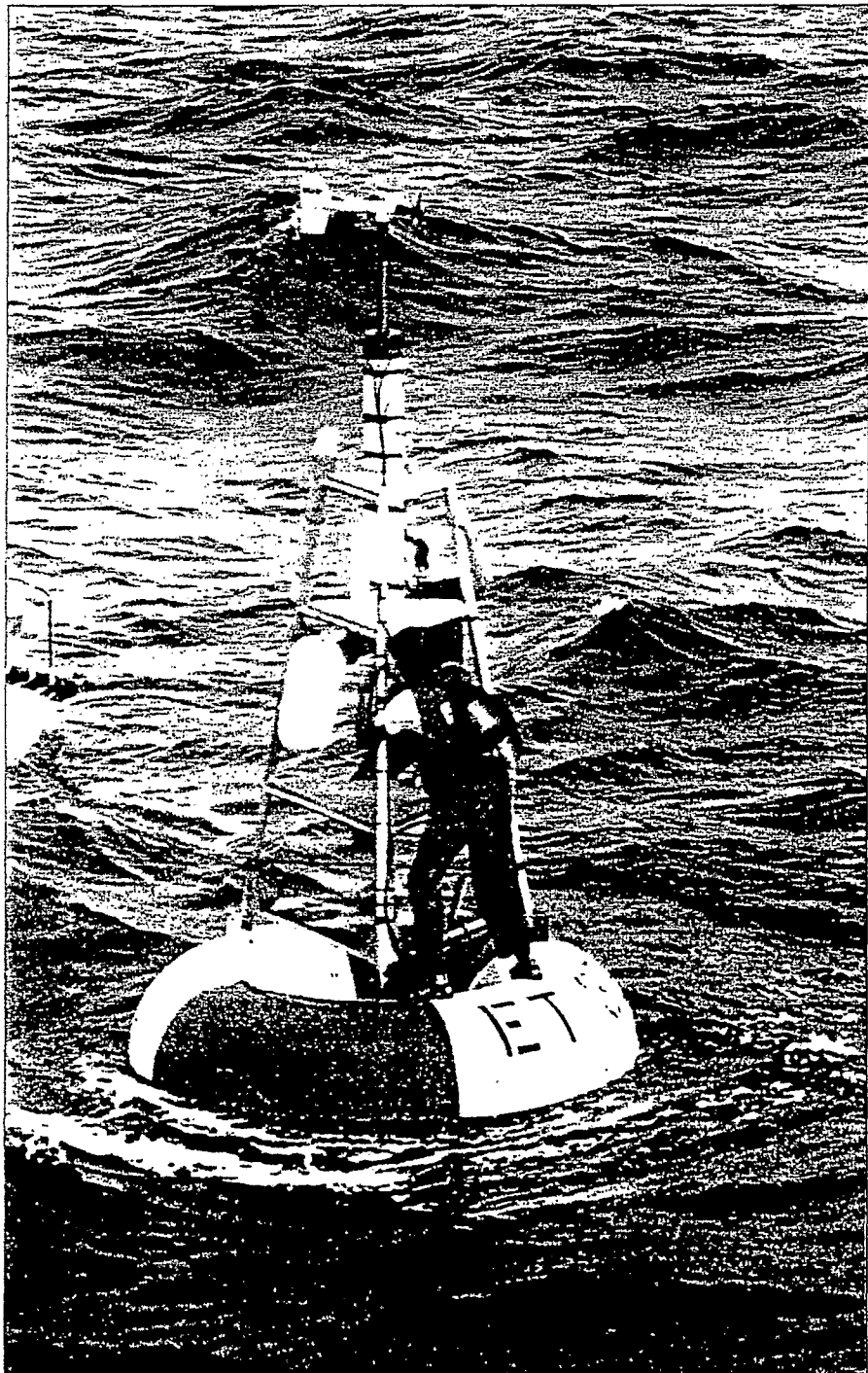
En plus de ces retrouvailles avec des scientifiques pour la plupart bien connus des océanographes de l'ORSTOM, l'aspect public de l'événement n'avait pas été négligé : le congrès a été ouvert par Monsieur Denis, Préfet de la Région Sud de Nouvelle-Calédonie, par John Marsh, Président du Bureau International TOGA, et par le Président du Conseil d'Administration de l'ORSTOM qui, en compagnie du Directeur Général de l'ORSTOM, avait tenu à se rendre à Nouméa à l'occasion de cette manifestation.

Le programme TOGA, pour prévoir le phénomène El Niño et les catastrophes qu'il déclenche

Le phénomène El Niño est connu depuis des siècles comme en témoignent des conditions climatiques anormales dont les conquistadors avaient déjà profité lors de leur progression le long des côtes ouest de l'Amérique du Sud. Ce phénomène, qui se produit tous les trois à cinq ans, le long des côtes de l'Equateur et du Pérou autour de Noël (d'où son nom d'El Niño : "l'Enfant") est caractérisé par une augmentation de la température à la surface de la mer de plusieurs degrés, associée à une renverse du courant côtier. Il peut entraîner des pluies diluviennes sur des régions habituellement désertiques, chasser les poissons et les oiseaux et ainsi bouleverser les activités économiques de ces pays en ruinant la pêche et réduisant les récoltes de guano.

Récemment seulement, les scientifiques ont réalisé que ce phénomène déborde largement les côtes d'Amérique du Sud, dépassant même le cadre du Pacifique. Le réchauffement des eaux superficielles concerne en fait tout le Pacifique Central et Est. Il résulte essentiellement du déplacement d'énormes quantités d'eaux chaudes en provenance du Pacifique Ouest, à la suite d'une renverse des Alizés. Cette renverse résulte elle-même d'un changement important de la répartition des masses d'air de l'atmosphère et d'une inversion de l'indice d'Oscillation Australe (différence de pression atmosphérique entre l'Indonésie et le Pacifique Sud-Est). Ainsi les dérèglements de la mousson en

Intervention sur une bouée ATLAS à 165° E lors d'une campagne en mer. Munies d'un capteur de vent et d'une chaîne de capteurs de température jusqu'à 500 mètres de profondeur, ces bouées enregistrent en permanence l'état des couches superficielles de l'océan au voisinage de l'Equateur. Les données sont transmises en temps réel via le système ARGOS. Cette opération se fait en étroite collaboration avec le Pacific Marine Environment Laboratory (Seattle - USA).





Les congressistes au complet, profitant d'une éclaircie.

Inde, les sécheresses du continent australien et de l'Indonésie, les typhons ou cyclones exceptionnels sur les Iles du Pacifique Sud, les pluies sur les côtes de l'Equateur, du Pérou, du Mexique et de la Californie, les hivers rigoureux de l'Amérique du Nord, ne sont que quelques-unes des manifestations d'un événement global maintenant appelé ENSO (El Niño-Southern Oscillation). Ce phénomène qui met en jeu l'océan et l'atmosphère et semble avoir sa source principale dans l'Océan Pacifique Tropical Ouest, réagit en fait sur le climat global de notre planète. Les centres de pression de l'Atlantique s'en trouvent déplacés, modifiant ainsi le climat de l'Europe et entraînant des sécheresses au Sahel, au Sud de l'Afrique et au Nord du Brésil.

Les conséquences humaines et économiques dramatiques de ces changements climatiques globaux ont fait qu'en janvier 1985 a été lancé pour dix années un vaste programme international appelé TOGA. Le but de ce programme est de déterminer jusqu'à quel point le système climatique résultant de ces interactions océans tropicaux-atmosphère globale est prévisible sur des échelles de temps de quelques mois à quelques années, modéliser ce système d'interactions et fournir des connaissances scientifiques de base à partir de réseaux d'observations et de transmission en temps réel des données, en vue de cette prévision climatique. L'Océan

Pacifique Tropical Ouest étant la source essentielle de chaleur du système couplé océan-atmosphère, il est devenu l'objectif principal des études du programme TOGA.

Les océanographes physiciens de l'ORSTOM à Nouméa, irremplaçables dans le Pacifique Ouest

Dès son implantation en Nouvelle-Calédonie, l'ORSTOM s'est intéressé à l'océanographie du Pacifique Tropical Sud-Ouest, et le chalutier de 20 mètres transformé en navire océanographique ORSOM 3 a permis l'étude de la zone équatoriale dès la fin des années cinquante. Mais c'est surtout avec l'arrivée à Nouméa du N.O. Coriolis que les travaux du Centre ORSTOM de Nouméa ont commencé à prendre une dimension internationale. En témoigne la longue coupe du Pacifique le long de l'Equateur, réalisée lors du voyage de conduite du navire de France en Nouvelle-Calédonie, qui a permis de décrire l'accroissement des réserves de chaleur de l'océan équatorial de l'Est vers l'Ouest. Cette coupe a donné lieu à une publication qui est l'une des plus fréquemment citées dans les articles relatifs au Pacifique Tropical : la pente des isothermes ainsi montrée a constitué l'une des premières caractéristiques que se doit de

restituer tout modèle réaliste des interactions océan-atmosphère.

Par la suite, les océanographes physiciens de l'ORSTOM ont recueilli de très nombreuses observations dans la Mer de Corail et dans la région équatoriale du Pacifique Ouest, notamment le long des méridiens 170° E et 165° E, et sont devenus les spécialistes incontestables de cette région. De plus, à partir de 1969, un réseau de collecte d'informations basé sur la coopération bénévole des officiers et des équipages de navires de commerce a permis d'étudier de manière quasi continue les variations de l'état de la surface de l'Océan Pacifique (température, salinité) le long des lignes de navigation de Nouméa au Japon, à l'Amérique du Nord et à Panama. La somme des connaissances ainsi accumulées depuis deux décennies sur le Pacifique Tropical, et notamment sur sa région ouest où prend naissance le phénomène El Niño, a fait des océanographes physiciens du Centre ORSTOM de Nouméa les partenaires indispensables du programme international TOGA. L'appellation "Groupe SURTROPAC" (pour : SURveillance TRAns-Océanique du PACifique) intervenue en 1982, alors que se préparait le programme TOGA, marque la volonté des océanographes physiciens de l'ORSTOM de s'intégrer aux vues et aux actions de TOGA. Et de fait, le groupe SURTROPAC a déjà contribué de façon très significative à ce

programme international en réalisant le meilleur d'un programme de lancers d'XBT dans tout le Pacifique Tropical le long des lignes de navigation commerciale. De plus, des relevés de température et de salinité et des mesures directes de courant sont réalisées deux fois par an, lors de campagnes de 20° S à 10° N le long du méridien 165° E; ces mêmes campagnes permettent, en collaboration avec le Pacific Marine Environment Laboratory (Seattle, U.S.A.) la mise en place et la maintenance d'une série de bouées fixes ATLAS qui émettent en temps réel des données de température (de 0 à 500 mètres de profondeur) et de vent, grâce au système ARGOS. Grâce à l'énorme masse de données ainsi recueillies, et grâce aux données de l'altimètre du satellite GEOSAT, le Groupe SURTROPAC de Nouméa a ainsi pu mettre en évidence certains des mécanismes qui sont à l'origine de la variabilité saisonnière et interannuelle du Pacifique Tropical Ouest, dans laquelle s'inscrit "El Niño".

Toutefois, un certain isolement, à la fois géographique et linguistique, des membres du Groupe SURTROPAC de Nouméa par rapport à une communauté scientifique internationale très majoritairement anglophone a freiné la diffusion des résultats de ce long et vaste travail. La tenue du Congrès International TOGA-COARE au Centre ORSTOM de Nouméa a été un moyen de donner au Groupe la place qui lui revient dans le contexte international de TOGA.

Le Congrès International TOGA - COARE : une réussite

Il avait un double but : faire le point sur les résultats récents du programme TOGA, et ceux en particulier qui montrent le rôle prépondérant joué par le Pacifique Ouest dans le déclenchement des anomalies ressortissant à bien situer ENSO, et au niveau international le programme COARE. COARE, à partir de 1991, va étudier dans le Pacifique Tropical Ouest les processus qui donnent naissance à des vents d'Ouest générateurs de ces anomalies. L'organisation du congrès a été assurée par Joël Picaut (du Groupe SURTROPAC) et par Roger Lukas (de l'Université d'Hawaï). A la différence des précédents congrès, qui s'étaient tenus aux Etats Unis, en Australie et en Chine, et avaient un caractère national ou bilatéral, **le congrès de Nouméa a été le premier véritable congrès scientifique international du programme TOGA.** Le Groupe SURTROPAC a reçu la lourde tâche de le préparer. Pour de telles occasions, le courrier électronique s'est avéré un outil de choix : notre console a crépité pendant les six mois qui ont précédé le congrès. Les présidents de sessions et les orateurs invités ne se sont finalement pas faits prier, de même que la plupart des témoins mondiaux de la recherche océan-atmosphère, qui ont répondu favorablement à notre invitation.

Après les discours officiels, le congrès était magistralement lancé par le Professeur Wyrtki de l'Université d'Hawaï, et les exposés com-

mençaient, répartis en cinq sessions sur les thèmes suivants :

- masses d'eau, topographie de la surface de l'océan, et circulation;
- l'El Niño - Oscillation Australe (ENSO) de 1986-87;
- études théoriques et modélisation de l'ENSO et processus associés;
- flux de chaleur, de vapeur d'eau et de quantité de mouvement entre océan et atmosphère;
- études empiriques sur ENSO et sur la variabilité du climat.

La réunion de travail consacrée au développement du programme international COARE a été fructueuse; elle a montré l'intérêt qu'il suscite dans la communauté scientifique.

Pour la plupart des participants ce congrès restera longtemps la référence tant pour l'aspect scientifique que pour la qualité de l'organisation.

Quant au mauvais temps qui a sévi pendant tout le congrès, les experts présents étaient unanimes : c'était tout à fait explicable étant donné par ce qu'on sait sur l'ENSO.

Les recherches Océan - Climat : un atout pour l'ORSTOM

Autrefois, il y avait le climat atmosphérique, pour les animaux terrestres et les humains, et l'environnement océanique, pour les poissons. La prévision du premier est allée beaucoup plus vite que celle du second, car elle nous intéresse directement. Il faut maintenant combler ce retard pour deux raisons : d'abord à court terme, les anomalies de l'hydrologie des océans tropicaux sont des causes d'anomalies du climat atmosphérique qu'on ne peut plus négliger, et ensuite, si on se place dans le schéma à plus longue échéance, l'avenir des quantités de chaleur, de vapeur d'eau, de gaz carbonique que renferme l'atmosphère et qui déterminent notre climat, dépend presque totalement de l'océan. L'océan en effet renferme beaucoup plus de chaleur, de gaz carbonique, et, bien sûr, beaucoup plus d'eau que l'atmosphère; les échanges entre les deux milieux sont permanents et très importants, au point qu'un léger déplacement des équilibres qui gouvernent ces échanges pourrait se traduire par un changement climatique dramatique.

Le programme TOGA ne concerne pas directement les changements climatiques à très long terme, mais plutôt aux anomalies d'une durée de quelques mois à quelques années. L'effort que représente le programme TOGA est énorme. Alors que presque rien n'existait au départ, un réseau permanent d'observation des océans tropicaux se met en place peu à peu, analogue au réseau mondial d'observations météorologiques. Les données ainsi accumulées permettent la mise au point et la validation de modèles numériques qui simulent de mieux en mieux les interactions entre l'océan et l'atmosphère et permettront d'améliorer considé-

ramment les prévisions climatiques à moyen terme. En même temps, de gros progrès sont faits dans la connaissance des mécanismes par lesquels se font les échanges de chaleur et de vapeur d'eau entre l'océan et l'atmosphère. TOGA répond donc à de nombreuses questions sur le fonctionnement du climat global actuel (à la fois marin et atmosphérique), il sert de cadre au développement d'outils qui permettront une surveillance permanente de l'état de l'océan. Cette surveillance et cette compréhension permanentes de l'océan est bien l'une des clés qui permettront de prévoir les changements climatiques futurs.

Ces recherches sont coûteuses et, en général, hors de portée des pays où l'ORSTOM mène une politique orientée vers le développement. Les retombées des programmes à finalité climatique concernent, cependant, ces pays de très près : les sécheresses qui sévissent au Sahel, au Nordeste du Brésil, dans les pays qui bordent le Pacifique Sud-Ouest, pourront être prévues, ainsi que les années exceptionnelles où des cyclones s'acharnent sur les archipels du Pacifique. A l'initiative de ce programme se mettent en place des réseaux de collecte d'informations qui donnent, ou donneront, en permanence, l'état de certains écosystèmes : à titre d'exemple, on n'a jamais disposé d'autant de données pour étudier l'écologie des thonidés tropicaux que depuis la mise en œuvre du programme TOGA.

L'enjeu des programmes à finalité climatique est maintenant pris très au sérieux par les gouvernements. La haute priorité qui leur est donnée est à la mesure des problèmes à résoudre. Ces problèmes sont ardues, du fait du grand nombre de paramètres qui interviennent sur le climat, et du fait de la nécessité d'une observation globale. Déployé dans la zone intertropicale, où justement la plupart des pays ne disposent pas des moyens de participer à ces recherches, le dispositif ORSTOM occupe une position privilégiée et dispose là d'un atout unique pour remplir sa mission de recherche pour le développement.

Nous tenons à remercier le Ministère de la Recherche et de la Technologie, la Direction Générale de l'ORSTOM, le Bureau américain TOGA, le Bureau international TOGA, la NASA, la National Science Foundation, le Comité Français de la Commission Océanographique Intergouvernementale, le Ministère des Affaires Etrangères et l'IFREMER.

Les actes du Congrès sont disponibles au Centre ORSTOM de Nouméa : *Proceedings of the "Western Pacific International Meeting and Workshop on TOGA COARE" - Nouméa, New Caledonia - May 24-30, 1989 - Edited by J. Picaut, R. Lukas, T. Delcroix.*

**PROCEEDINGS OF THE WESTERN PACIFIC INTERNATIONAL
MEETING AND WORKSHOP ON TOGA COARE**

held at Centre ORSTOM de Nouméa, New Caledonia
May 24-30, 1989

compiled and edited by

**Joël Picaut*
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(December 1989)

** Institut Français de Recherche Scientifique pour le Développement en Coopération,
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ABSTRACT

The Western Pacific International Meeting and Workshop on TOGA COARE, held at Centre ORSTOM de Nouméa, New Caledonia during May 24-30, 1989, brought together more than one hundred scientists from Australia, Chile, China, France, Indonesia, Japan, New Zealand, the United Kingdom and the United States. The assembly was composed of a good mixture of oceanographers and meteorologists who specialize in tropical circulation or air-sea interaction problems. The main purpose of this combined Meeting/Workshop was to review the status of western tropical Pacific TOGA-related research, coordinate the growing multinational research efforts in the warm pool region, and cooperate in the planning of a major international air-sea interaction experiment, the TOGA Coupled Ocean-Atmosphere Response Experiment (COARE).

The first three days were devoted to the Western Pacific International Meeting, with 80 high quality scientific presentations on the following themes:

- Water masses, sea surface topography and circulation.
- El Nino/Southern Oscillation 1986-87.
- Theoretical and modeling studies of ENSO and related processes.
- Momentum, heat and moisture fluxes between atmosphere and ocean.
- Empirical studies of ENSO and climate variability.

Each of the five sessions was introduced by an invited speaker who provided a review or detailed an important aspect of the session subject.

From the large number of papers presented at the Meeting/Workshop and their vigorous discussion, it is clear that there has been a significant increase over the last years in attention given to problems of oceanic and atmospheric circulation and interaction in the western tropical Pacific. As a result, there have been some major advances in our understanding of the region.

With now more than 40 recent TOGA-related cruises in the western tropical Pacific, our knowledge about oceanic circulation in this region has grown. In particular more is known about the relation of the equatorial currents to those at the western boundary. The Indo-Pacific throughflow has been the subject of increasing modeling studies and it apparently does not show much of an interannual signal related to the occurrence of ENSO events. Linear analytical results concerning the reflection of Rossby waves off the gap in the western boundary are now in hand, and long equatorial Rossby waves (which have been definitively observed through XBT, BT, altimetry, and CTD/ADCP measurements) do not appear to lose much energy, because of the gaps, when they reflect.

Several ideas have been presented about the formation and variations of the warm pool region. Its cooling during El Nino appears more due to evaporation than advection, though the role of entrainment is still not certain. One-dimensional models suggest that the hydrological cycle plays an important role in the coupling of the atmosphere and ocean in the warm pool region, and observations show substantial variations of the salinity structures within the warm pool, leading to the conclusion that salinity effects must be included in models of the warm pool region.

It has been shown that the difficulties which modelers had previously in simulating the mean SST in the warm pool can be finessed in stand-alone ocean models. Coupled models suggest that the annual average net heat flux between atmosphere and ocean is small ($< 20 \text{ W/m}^2$) in the warm pool region, which is at odds with climatological analyses. However, new results point out problems with the bulk formulations used in the climatologies, as well as probable biasing of the observations used in the analyses. These problems may be unique to the high SST/low mean wind regime of the western Pacific warm pool.

The importance of the 30-60 day atmospheric oscillation and westerly wind bursts during the development of ENSO has been discussed. It has not been possible to be definite on this matter, but real progress on the statistics and dynamics of these fluctuations has been achieved. The relationship of these phenomena to fluctuations in deep convection, precipitation, and heat fluxes seems to be strong, and thus they are important in their own right.

Space-based observations are promising. The prospects for obtaining some of the large-scale, low-frequency fields needed for understanding the coupled system are good, however there are some substantial calibration and validation efforts that are needed. A greater challenge lies in obtaining high spatial and temporal resolution fields using remote sensing data.

A recurring conclusion among both observers and modelers was that the sparsity of observations of momentum, heat and moisture fluxes, and in some cases the quality of the observations, are a major limitation in our pursuit of understanding of the processes involved in the ocean-atmosphere coupling in the western Pacific warm pool region.

The subsequent Workshop on TOGA COARE started with a presentation of a draft of the U.S. COARE Science Plan. Following the recommendation of the Intergovernmental TOGA Board, this plan was discussed, amended and finally adopted as a first draft of an International TOGA COARE Science Plan by the multinational community present in Noumea. This was made possible through separate and plenary discussions of the following working groups:

- Air-sea fluxes and boundary layer processes.
- Regional scale atmospheric circulation and waves.
- Regional scale oceanic circulation and waves.

In addition, the working groups started the development of an Implementation Plan for COARE. During the plenary sessions, several presentations were also made on COARE-related programs and relevant observational technologies. The proposed TOGA COARE will be able to address many of the important unresolved issues that were highlighted at the meeting. In particular, COARE offers a unique opportunity for the calibration/validation of satellite observations, and for the development/validation of improved models of the oceanic and atmospheric planetary boundary layers, as well as a hierarchy of coupled models. Strong enthusiasm for TOGA COARE was expressed at the Meeting/Workshop. Modelers and observers have identified interesting and challenging problems relating to the coupling of the ocean and atmosphere in the warm pool of the western tropical Pacific. The scientific planning for COARE was advanced to near completion, and a healthy start on implementation planning was made. Cooperation and coordination between the oceanographic and atmospheric components of COARE appears to be vigorous, with plans from the three working groups converging toward an effective warm pool air-sea interaction experiment.

RESUME

Le Symposium International sur le Pacifique Ouest et Réunion de Travail TOGA COARE, qui s'est tenu en Nouvelle Calédonie au Centre ORSTOM de Nouméa du 24 au 30 mai 1989, a réuni plus d'une centaine de scientifiques d'Australie, Chili, Chine, Etats Unis, France, Indonésie, Japon, Nouvelle-Zélande et du Royaume Uni. L'assemblée était composée d'un savant mélange d'océanographes et de météorologues, spécialistes des problèmes de circulation tropicale ou d'interactions océan-atmosphère. Le but principal de cet ensemble Symposium/Réunion de Travail était de faire le point des recherches du programme international TOGA dans tout le Pacifique Tropical Ouest, de coordonner les efforts croissants de recherches multinationales dans le réservoir d'eaux chaudes de cette région et de préparer au niveau international l'importante expérience TOGA COARE d'interactions océan-atmosphère.

Les trois premiers jours ont été consacrés au Symposium International sur le Pacifique Ouest, avec 80 présentations scientifiques de haute qualité sur les thèmes suivants:

- masses d'eaux, topographie de surface et circulation.
- El Nino/Oscillation Australe (ENSO) 1986-87.
- études théoriques et modélisation des ENSO et de ses processus.
- flux de quantité de mouvement, de chaleur et de vapeur d'eau entre atmosphère et océan.
- études empiriques des ENSO et de la variabilité climatique.

Chacune des cinq sessions était introduite par un orateur invité qui a effectué une revue de synthèse ou détaillé un aspect important du thème de la session.

Le nombre très important de communications présentées durant le Symposium/Réunion de Travail et les nombreuses discussions associées, ont fait apparaître, depuis ces dernières années, un intérêt marqué pour les problèmes de circulation océanique et atmosphérique et les interactions dans le Pacifique Ouest. De ce fait, de sérieux progrès dans la compréhension de cette région ont été réalisés.

Avec maintenant plus de 40 croisières récentes en rapport avec TOGA, dans le Pacifique Tropical Ouest, notre connaissance sur la circulation dans cette région s'est améliorée. En particulier, la liaison entre les courants équatoriaux et ceux de la frontière ouest est mieux connue. Les échanges d'eaux entre le Pacifique et l'Océan Indien ont été le sujet d'un nombre croissant de modèles et apparemment ne sont pas soumis à une importante variabilité interannuelle en rapport avec les événements ENSO. Les études analytiques linéaires, sur la réflexion des ondes de Rossby sur la frontière perméable (chaîne d'îles) du Pacifique Ouest, sont maintenant au point. Les ondes longues équatoriales de Rossby (qui viennent d'être définitivement mise en évidence grâce à des mesures XBT, BT, altimétrie et CTD/ADCP) ne semblent pas trop perdre d'énergie en se réfléchissant sur cette frontière perméable.

Plusieurs idées ont été présentées à propos de la formation et des variations du réservoir d'eaux chaudes du Pacifique Ouest. Son refroidissement durant El Nino semble dû plus à l'évaporation qu'à l'advection, quoique le rôle de l'entraînement ne soit pas encore certain. Les modèles uni-dimensionnels suggèrent que le cycle hydrologique joue un rôle important dans le couplage entre l'atmosphère et l'océan dans la région du réservoir d'eaux chaudes.

Les observations montrent des variations considérables de la structure de salinité dans ce réservoir et mènent à la conclusion que les effets de salinité doivent être pris en compte pour sa modélisation.

Il a été montré que les difficultés rencontrées auparavant par les modélisateurs pour simuler la température de surface moyenne du réservoir d'eaux chaudes, pouvaient être réduites par des modèles uniquement océaniques. Les modèles couplés suggèrent que la moyenne annuelle du flux de chaleur entre l'atmosphère et l'océan est petite ($< 20 \text{ W/m}^2$) dans la région du réservoir d'eaux chaudes, ce qui n'est pas en accord avec les résultats d'études climatologiques. Par contre de nouvelles études mettent en évidence des problèmes avec les formules empiriques utilisées pour les climatologies, ainsi qu'un biais probable des observations utilisées pour ces analyses. Ces problèmes sont peut être uniques au réservoir d'eaux chaudes du Pacifique Ouest de par ses fortes températures de surface et son régime de vent faible.

L'importance de l'oscillation atmosphérique à 30-60 jours de période et de celle des coups de vent d'ouest pour le développement des ENSO a été discutée. Il n'a pas été possible d'aboutir à une conclusion à ce sujet, mais des progrès réels sur les statistiques et la dynamique de ces fluctuations ont été réalisés. Les relations entre ces phénomènes et les fluctuations de convection atmosphérique profonde, des précipitations et des flux de chaleur apparaissent marquées et de ce fait elles sont importantes en elles mêmes.

Les observations à partir de satellites sont prometteuses. Les perspectives sont bonnes pour obtenir quelques uns des champs basse fréquence et grande échelle, nécessaires à la compréhension du système couplé océan-atmosphère. Cependant il sera indispensable de faire un effort particulier dans l'étalonnage et la validation de ces observations. Un défi plus important est l'obtention de champs à haute résolution spatio-temporelle, à partir de capteurs satellitaires.

Une des conclusions, qui revenait régulièrement à l'esprit des observateurs et des modélisateurs était que la limitation principale à la compréhension des processus de couplage océan-atmosphère dans la région du réservoir d'eaux chaudes du Pacifique Ouest, vient du faible nombre d'observations de quantité de mouvement, de chaleur et de vapeur d'eau, et dans quelques cas de la qualité des observations,

La Réunion de Travail TOGA COARE, succédant au Symposium, a commencé par une présentation du document préliminaire du projet scientifique U.S. COARE. En suivant les recommandations du Bureau Intergouvernemental TOGA, ce document a été discuté, amélioré et finalement adopté, comme base pour un projet international TOGA COARE, par la communauté scientifique présente à Nouméa. Cela a été possible grâce aux séances plénières et séparées des groupes de travail ci-après:

- Processus des flux d'échanges air-mer et des couches interfaces.
- Circulation régionale atmosphérique et ondes associées.
- Circulation régionale océanique et ondes associées.

De plus, les groupes de travail, ont ébauché un plan de mise en oeuvre pour l'expérience COARE. Durant les sessions plénières, plusieurs communications ont aussi été présentées sur les programmes et les techniques d'observations pouvant se rapporter à COARE. L'expérience TOGA COARE proposée devrait être capable de répondre à de nombreuses questions non résolues qui ont été mises en avant durant le Symposium/Réunion de Travail. En particulier, l'expérience COARE va offrir une occasion unique pour l'étalonnage et la validation des observations et pour développer et valider, aussi bien les modèles océaniques et atmosphériques à couche limite que toute la gamme de modèles

couplés. Un enthousiasme marqué pour l'expérience TOGA COARE a été exprimé lors du Symposium/Réunion de Travail. Les modélisateurs et les observateurs ont identifié des problèmes très intéressants en rapport avec le couplage océan-atmosphère dans la région du réservoir d'eaux chaudes du Pacifique Ouest. Le projet scientifique pour COARE est presque achevé et un premier projet de mise en oeuvre a été bien avancé. La coopération et la coordination, entre les parties océanographique et atmosphérique de COARE, semblent se développer harmonieusement en suivant les projets des trois groupes de travail qui convergent vers une expérience efficace d'interaction air-mer sur le réservoir d'eaux chaudes du Pacifique Ouest.

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The contribution of all these individuals and agencies is gratefully acknowledged.

Finally we would like to thank all attendees for their participation and contribution to the Meeting/Workshop.

Joël Picaut and Roger Lukas
Co-Chairmen
Western Pacific International Meeting
and Workshop on TOGA COARE.

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INTRODUCTION

1. Motivation.

The physical oceanography group of the Centre ORSTOM de Nouméa (named SURTROPAC in 1980 for SURvey of the TROPical PACific) has a long history of research measurements and discoveries in the western tropical Pacific. One of the most reproduced figures in equatorial oceanography is the temperature section along the equator from 86°W to 160°E resulting from measurements made during the 1964-65 boreal winter, and originally published by Lemasson and Piton (1968). The corresponding hydrological section was made during the maiden voyage of the R/V Coriolis from France to its permanent port of attachment in Nouméa. About 50 physical oceanography cruises were carried out in the Pacific until the end of its research vessel career with the January 1989 SURTROPAC-TOGA #11th cruise, regularly made along 165°E. During this quarter century of research work, 150-200 papers and reports were published. As time goes, the SURTROPAC group got more and more involved in multinational research activities (e.g. the tropical Pacific XBT network in 1979) and recently dedicated all of its activities to the TOGA programme. Most of the effort of the TOGA international scientific community is concentrated in the tropical Pacific and largely in its western part. As a consequence more than 40 cruises from seven different countries have been conducted in the western tropical Pacific since 1985.

With the growing interest of the TOGA programme in the warm pool region, the accumulation of consequent scientific results, and the fact that most of these activities at sea were relatively uncoordinated, it appeared necessary to organize an international meeting on air-sea interactions in the western tropical Pacific. This had been recognized as early as December 1986 during the first WESTPAC Symposium in Townsville, Australia. National or bilateral symposia have already dealt with such matters. The U.S. community held an important TOGA Western Pacific Air-Sea Interaction Workshop in Honolulu in September 1987, where it was strongly recommended to design a Coupled Ocean-Atmosphere Response Experiment (COARE) in the western tropical Pacific. Air-sea interactions in the Tropical Western Pacific was the purpose of the US/PRC symposium held in Beijing in November 1988. Given the comfortable facilities of the Centre ORSTOM de Nouméa and of its surroundings, Joël Picaut and Roger Lukas had decided to organize, with the cooperation of John Marsh of the International TOGA Project Office, the joint Western Pacific International Meeting and Workshop on TOGA COARE in Nouméa on May 24-30, 1989. The main purpose of this combined Meeting/Workshop was to review the status of western tropical Pacific oceanic and atmospheric research, coordinate the multinational research efforts in the warm pool region, and cooperate in the planning of a major international air-sea interaction experiment, TOGA COARE.

The goals of the Western Pacific International Meeting were to document results of recent TOGA modeling and data analyses that pertain to the western tropical Pacific ocean-atmosphere system. This was done by a combination of 80 invited and contributed presentations covering the following areas of research:

- Water masses, sea surface topography and circulation.
- El Nino/Southern Oscillation 1986-87.
- Theoretical and modeling studies of ENSO and related processes.
- Momentum, heat and moisture fluxes between atmosphere and ocean.
- Empirical studies of ENSO and climate variability.

The multi-national participation at the Meeting/Workshop provided the first real opportunity for the coordination of ongoing western tropical Pacific field efforts, and also provided an important opportunity for coordination of the many national plans for future research in the western tropical Pacific.

The Workshop on TOGA-COARE brought together scientists from a number of nations with interests in the problems of the western Pacific warm pool. A draft of the U.S. TOGA COARE Science Plan was presented for discussion, and the subsequent comments and revisions were incorporated. One important objective was to develop an internationally acceptable TOGA COARE Science Plan for consideration by the TOGA Scientific Steering Group (SSG) at its meeting in Hamburg in September 1989.

In early 1989, Peter Webster, chairman of the TOGA SSG formed an International Ad Hoc Committee on TOGA COARE, and the Meeting/Workshop in Nouméa offered an ideal venue for its first meeting. This group is to represent the scientific interest of the nations participating in COARE, both in the revision of the COARE Science Plan, and in the development of the COARE Implementation Plan.

2. Structure.

Based on the large number of participants gathering in Nouméa, two other meetings were held in Nouméa. The CCCO Pacific Panel held their annual meeting on May 20-23. The TOGA XBT Ad Hoc Panel of Experts met for the first time on May 31-June 1.

At the opening ceremony of the Meeting/Workshop, the 106 scientific participants were welcomed by a representative of the High Commissioner for New Caledonia and by the President of ORSTOM, the latter having travelled from France for the occasion. Each of the five sessions of the Western Pacific International Meeting was introduced by an invited speaker, who in 45 min. either provided a review or detailed an important aspect of the corresponding session topic. Due to the large number of abstracts received after the first announcement, the meeting was divided into an equal number of 25 min. oral presentations (including 5 min. discussion) and into two one-and-a-half day poster sessions. In addition, a miscellaneous poster session was added for a few presentations not directly related to air-sea interaction in the western tropical Pacific (such as ENSO-related productivity variability or XBT improvement techniques).

The Workshop on TOGA COARE started with a presentation of the U.S. TOGA COARE Science Plan. The workshop was then divided into three working groups:

- Air-Sea Fluxes and Boundary Processes.
- Regional Scale Atmospheric Circulation and Waves.
- Regional Scale Oceanic Circulation and Waves.

The corresponding reports were discussed in plenary session and led to recommendations regarding mostly implementation plans for COARE. Related programs, such as NASA Ocean Processes and Satellite Missions, Tropical Rainfall Measuring Mission, Typhoon Motion Program and World Ocean Circulation Experiment were presented, as well as two papers on related technology. In the last Workshop plenary session, scientists of seven nations (Australia, China, France, Indonesia, Japan, United Kingdom and United States) presented their informal reports related to tentative plans for national participation in TOGA COARE.

Finally, well-prepared social events helped to compensate for the unusual rainy weather which prevailed during most of the Meeting/Workshop as a consequence of the Pacific-wide cold event.

The remainder of these proceedings does not follow the order of the Meeting/Workshop. With most of the oral and poster presentations resulting in more than 700 pages of collected papers, it has been decided to present first the report of the TOGA COARE Workshop.

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Graham, Nicholas	SIO, La Jolla, U.S.A.
Gutzler, David	Atm. and Environ. Res. Inc., Cambridge, U.S.A.
Hadi, Wasito	Meteor. and Geophys. Agency, Jakarta, Indonesia
Hagan, Denise	JPL, Pasadena, U.S.A.
Harjanto, Hery	Meteor. and Geophys. Agency, Jakarta, Indonesia
Hayes, Stanley	NOAA/PMEL, Seattle, U.S.A.
Henin, Christian	SURTROPAC/ORSTOM, Nouméa, New Caledonia
Hildebrand, Peter	NCAR, Boulder, U.S.A.
Holland, Greg	BMRC, Melbourne, Australia
Hu, Dunxin	Inst. of Ocean., Qingdao, People's Republic of China
Hurlburt, Harley	NORDA, Bay St. Louis, U.S.A.
Jarrige, Francois	ORSTOM, Paris, France
Kakar, Ramesh	NASA/H.Q., Washington D.C., U.S.A.
Kawamura, Ryuichi	Environ. Res. Center, Tsukuba, Japan
Khalsa, Siri Jodha	CIRES, Boulder, U.S.A.
Kessler, William	University of Washington, Seattle, U.S.A.
Kindle, John	NORDA, Bay St. Louis, U.S.A.
Lau, Ka-Ming	NASA/GSFC, Greenbelt, U.S.A.
Lagerloef, Gary	NASA/H.Q., Washington D.C., U.S.A.
Le Borgne, Robert	PROPPAC/ORSTOM, Nouméa, New Caledonia

Le Bouteiller, Aubert	PROPPAC/ORSTOM, Nouméa, New Caledonia
Lee, Valerie	ITPO, Geneva, Switzerland
Lindstrom, Eric	CSIRO, Hobart, Australia
Liu, Timothy	JPL, Pasadena, U.S.A.
Lukas, Roger	JIMAR/Univ. Hawaii, Honolulu, U.S.A.
Mangum, Linda	NOAA/PMEL, Seattle, U.S.A.
Marsh, John	ITPO, Geneva, Switzerland
McCreary, Julian	Nova University, Dania, U.S.A.
McPhaden, Michael	NOAA/PMEL, Seattle, U.S.A.
Meyers, Gary	CSIRO, Hobart, Australia
Miller, Laury	NOAA/NOS, Rockville, U.S.A.
Moncrieff, Mitchell	NCAR, Boulder, U.S.A.
Mooney, Kenneth	NOAA/USTPO, Rockville, U.S.A.
Morliere, Alain	ORSTOM, Paris, France
Motard, Jean Luc	Serv. Météo., Nouméa, New Caledonia
Mullan, Brett	New Zeland Met. Serv., Wellington, New Zealand
Murray, Stephen	CSI/Louisiana St. Univ., Baton Rouge, U.S.A.
Patzert, William	JPL, Pasadena, U.S.A.
Perigaud, Claire	JPL, Pasadena, U.S.A.
Pianet, Renaud	ORSTOM, Nouméa, New Caledonia
Picaut, Joël	SURTROPAC/ORSTOM, Nouméa, New Caledonia
Planton, Serge	CNRM, Paris, France
Radenac, Marie H.	PROPPAC/ORSTOM, Nouméa, New Caledonia
Rebert, Jean Paul	ORSTOM, Brest, France
Reid, George	NOAA/ERL, Boulder, U.S.A.
Reverdin, Gilles	LODYC, Paris, France
Reynolds, Richard	NOAA/NWS/NMC, Washington, U.S.A.
Rodier, Martine	PROPPAC/ORSTOM, Nouméa, New Caledonia
Rothstein, Lewis	University of Washington, Seattle, U.S.A.
Rual, Pierre	SURTROPAC/ORSTOM, Nouméa, New Caledonia
Sawyer-Crouch, Karyn	UCAR, Boulder, U.S.A.
Smith, Neville	BMRC, Melbourne, Australia
Sombardier, Laurence	SURTROPAC/ORSTOM, Nouméa, New Caledonia
Somerville, Richard	SIO, La Jolla, U.S.A.
Stephens, Graeme	Colorado St. Univ., Fort Collins, U.S.A.
Stevens, Duane	Colorado St. Univ., Fort Collins, U.S.A.
Sui, Chung-Hsiung	NASA/GSFC, Greenbelt, U.S.A.
Sumi, Akimasa	University of Tokyo, Tokyo, Japan
Takeuchi, Kensuke	Hokkaido University, Sapporo, Japan
Theon, John	NASA/H.Q., Washington D.C., U.S.A.
Thiele, Otto	NASA/GSFC, Greenbelt, U.S.A.
Tournier, Rolande	SURTROPAC/ORSTOM, Nouméa, New Caledonia
Voituriez, Bruno	IFREMER, Paris, France
Waliser, Duane	SIO, La Jolla, U.S.A.
Webster, Peter	Penn. State Univ., University Park, U.S.A.
Webb, David	IOS, Godalming Surrey, United Kingdom
Weickman, Klaus	NOAA/ERL/CRD, Boulder, U.S.A.
White, Warren	SIO, La Jolla, U.S.A.
Woodward, William	NOAA/NOS, Rockville, U.S.A.
Wyrtki, Klaus	University of Hawaii, Honolulu, U.S.A.
Xu, Bingrong	Snd. Inst. Ocean., Hangzhou, People's Republic of China
Young, John	University of Wisconsin, Madison, U.S.A.
Zebiak, Stephen	Lamont. Dorherty Geol. Obs., Palisades, U.S.A.
Zhou, Xiaoping	Inst. of Atm. Phys., Beijing, People's Republic of China

AGENDA

WESTERN PACIFIC INTERNATIONAL MEETING AND WORKSHOP ON TOGA COARE

Centre ORSTOM de Nouméa, New Caledonia

May 24-30, 1989

Wednesday, May 24

07H30: Registration/Poster setup

08H30: Official Welcome and Opening Remarks

Charles ERIKSEN (Session Chairman)

WATER MASSES, SEA SURFACE TOPOGRAPHY, AND CIRCULATION

09H15:

Invited speaker: Klaus WYRTKI: Some thoughts about the West Pacific Warm Pool

09H45 - 10H15: Coffee Break/Posters

Jean-René DONGUY, Gary MEYERS and Eric LINDSTROM: Comparison of results of two pre-COARE cruises: FOC (1971) and WEPOCS (1985-86).

Dunxin HU: Interannual Variability of the Western Boundary Current in the Pacific Ocean.

Peter HACKER, Eric FIRING and Roger LUKAS: Observations of the Low-Latitude Western Boundary Circulation in the Pacific during WEPOCS III.

Stephen MURRAY, Dharma ARIEF and John KINDLE: Throughflow between the Western Pacific and the Indian Ocean: Comparison between model and observations.

12H00 - 13H45: Lunch

Dunxin HU (Session Chairman)

13H45:

Christian HENIN: Thermohaline structures variability along 165°E in the Western Tropical Pacific Ocean (January 1984-January 1989).

Linda J. MANGUM and Stanley P. HAYES: Zonal scales of thermohaline variability in the Western Equatorial Pacific.

David J. WEBB and Brian A. KING: A survey of the Western Equatorial Pacific in September 1988.

15H15 - 15H45: Coffee Break/Posters

Poster session: Wednesday morning through Thursday midday

Eric FIRING and Jiang SONGNIAN: Variable currents in the Western Pacific measured during the USA-PRC bilateral TOGA Project.

John Stuart GODFREY: Steric height gradients, the Indonesian throughflow and the Leeuwin current.

Phillip L. RICHARDSON and Curtis A. COLLINS: Preliminary results from WEPOCS Drifters.

John M. TOOLE, Robert MILLARD, Maggie FRANCIS, Zongshan WANG and S. PU: On the bifurcation of the North Equatorial Current at the Philippine coast.

Rolande TOURNIER and Joël PICAUT: Thermal and current structure variabilities in the Western and Central Tropical Pacific during 1979-85.

Xiaoping ZHOU: An introduction of the four year expedition on West Pacific conducted by China Academy of Sciences.

EL NINO/SOUTHERN OSCILLATION 1986-87

15H45:

Invited speaker: Gary MEYERS (and Rick BAILEY, Eric LINDSTROM and Helen PHILIPS): Air-Sea interaction in the Tropical Pacific ocean during 1982-83 and 1986-87.

Laury MILLER and Robert CHENEY: GEOSAT observations of sea level in the Tropical Pacific and Indian oceans during the 1986-87 El Nino event.

Thierry DELCROIX, Gerard ELDIN and Joël PICAUT: Major GEOSAT sea level anomalies in the Western Tropical Pacific during the 1986-87 El Nino, elucidated as equatorial Kelvin and Rossby waves.

Gerard ELDIN and Thierry DELCROIX: Vertical thermal structure variability along 165°E during the 1986-87 ENSO event.

Michael J. McPHADEN and Stanley P. HAYES: Westerly wind forcing and SST variations in the Western Pacific during the 1986-87 event.

Poster session: Wednesday morning through Thursday midday

John Stuart GODFREY, Ken RIDGWAY, Gary MEYERS and Rick BAILEY: Sea level and thermal response to the 1986-87 ENSO event in the far Western Pacific.

Joël PICAUT, Bruno CAMUSAT, Thierry DELCROIX, Michael J. McPHADEN, and Antonio J. BUSALACCHI: Surface equatorial flow anomalies in the Pacific ocean during the 1986-87 ENSO using GEOSAT altimeter data.

18H30: Official reception at ORSTOM Hall

Thursday, May 25

John Stuart GODFREY (Session Chairman)

**WATER MASSES, SEA SURFACE TOPOGRAPHY,
AND CIRCULATION (continued)**

08H15:

Warren B. WHITE, Chang-Kou TAI and Stephen PAZAN: The study of thermocline development in the Western Tropical Pacific during El Nino using TOGA XBT's GEOSAT altimetry, and the FSU Tropical Pacific model.

William S. KESSLER: Observations of long Rossby waves in the Northern Tropical Pacific.

**THEORETICAL AND MODELING STUDIES OF ENSO
AND RELATED PROCESSES**

09H00:

Invited Speaker: Julian P. McCREARY: Coupled Ocean-Atmosphere models of El Nino and the Southern Oscillation.

09H45 - 10H15: Coffee Break/Posters

10H15:

Kensuke TAKEUCHI: On warm Rossby waves and their relation to ENSO events.

Yves du PENHOAT and Mark A. CANE: Effect of low latitude western boundary gaps on the reflection of equatorial motions.

Harley E. HURLBURT, John KINDLE, Joseph E. METZGER and Allan WALLCRAFT: Results from a global ocean model in the Western Tropical Pacific.

John KINDLE, Harley E. HURLBURT and Joseph E. METZGER: The dynamics of the Pacific to Indian ocean throughflow.

12H00 - 14H00: Lunch and poster changeover

Daniel CADET (Session Chairman)

14H00:

Nicholas E. GRAHAM and Warren WHITE: A simple 2-dimensional coupled model of the Equatorial Pacific.

Antonio J. BUSALACCHI, Michael J. McPHADEN, Joël PICAUT and Scott SPRINGER: Sensitivity of wind driven Tropical Pacific Ocean simulations on seasonal and interannual time scales.

Stephen E. ZEBIAK: Intraseasonal variability - a critical component of ENSO ?

Akimasa SUMI: Behavior of convective activity over the "Jovian-type" aqua-planet model.

15H45 - 16H15: Coffee Break/Posters16H15:

Ka-Ming LAU: Dynamics of multi-scale atmosphere-ocean Interactions over the Tropical Western Pacific.

Edmund D. HARRISON and Benjamin S. GIESE : Some OGCM studies of the oceanic response to westerly wind episodes.

Roland W. GARWOOD and Pecheng C. CHU: Hydrological effects on the air-ocean coupled system.

Sam F. IACOBELLIS and Richard C.J. SOMERVILLE: A one-dimensional coupled air-sea model for diagnostic studies during TOGA/COARE.

Poster session: Wednesday morning through Thursday midday

Allan J. CLARKE: On the reflection and transmission of low frequency energy at the irregular Pacific Ocean boundary.

Roland W. GARWOOD, Peter MULLER, Pecheng CHU and Niklas SCHNEIDER: The equatorial mixed layer system: mean state and diurnal modulation.

Peter R. GENT: The sensitivity of the annual cycle in the Tropical Pacific Ocean to vertical mixing parameterizations.

Wasito HADI and NURAINI: The steady state response of Indonesian sea to a steady wind field.

Pedro RIPA: Instability conditions and energetics in the Equatorial Pacific.

Lewis ROTHSTEIN: Modeling the warm pool of the Western Equatorial Pacific Ocean.

Neville R. SMITH: An oceanic subsurface thermal analysis scheme with objective quality control.

Duane STEVENS, Qi HU and Graeme STEPHENS: The hydrologic cycle of the intraseasonal oscillation.

Peter J. WEBSTER, Hai-Ru CHANG and Chidong ZHANG: Some new insights on the joint interaction of the tropics and the extratropics.

Friday May 26

Akimasa SUMI (Session Chairman)

MOMENTUM, HEAT, AND MOISTURE FLUXES BETWEEN ATMOSPHERE AND OCEAN

08H00:

Invited Speaker: Timothy W. LIU: A brief review on the bulk parameterization and remote sensing of latent heat flux in tropical oceans.

Frank E. BRADLEY, Peter A. COPPIN and John S. GODFREY: Measurements of heat and moisture fluxes from the Western Tropical Pacific Ocean.

Richard W. REYNOLDS and Ants LEETMAA: Evaluation of NMC's operational surface fluxes in the Tropical Pacific.

Stanley P. HAYES, P. Michael J. McPHADEN, John M. WALLACE and Joël PICAUT: The influence of sea surface temperature on surface wind in the Equatorial Pacific Ocean.

09H15 - 10H15: Coffee Break/Posters

10H15:

Peter J. WEBSTER: The hydrology cycle: Interlocking processes between the ocean and the atmosphere.

T. KEENAN and Richard E. CARBONE: A preliminary morphology of convective systems in Tropical Northern Australia.

Phillip A. ARKIN: Estimation of large-scale oceanic rainfall for TOGA.

Catherine GAUTIER and Robert FROUIN: Surface radiation processes in the Tropical Pacific.

Poster session: Thursday midday through Friday evening

Thierry DELCROIX and Christian HENIN: Mechanisms of subsurface thermal structure and sea surface thermohaline variabilities in the South Western Tropical Pacific Ocean during 1979-85.

Greg J. HOLLAND, T.D. KEENAN and M.J. MANTON: Observations from the Maritime Continent: Darwin, Australia.

Roger LUKAS: Observations of air-sea interaction in the Western Pacific warm pool during WEPOCS.

M. NUNEZ and K. MICHAEL: Satellite derivation of ocean-atmosphere heat fluxes in tropical environment.

12H00 - 14H00: Lunch

William PATZERT (Session chairman)

**EMPIRICAL STUDIES OF ENSO AND SHORT-TERM
CLIMATE VARIABILITY**

14H00:

Invited Speaker: Klaus M. WEICKMANN (and Siri Jodha S. KHALSA): Fluctuations of convection and circulation over the oceanic warm pool during September-December 1981.

Claire PERIGAUD: 30 days oscillations in the Tropical Pacific Ocean observed with GEOSAT altimeter.

Ryuichi KAWAMURA: Air-Sea interactions in the Tropical Western Pacific on interannual and intraseasonal time scales.

David S. GUTZLER and Tamara M. WOOD: Observed structure of convective anomalies.

15H45 - 16H15: Coffee Break/Posters

16H15:

Siri Jodha S. KHALSA: Remote sensing of atmospheric thermodynamics in the tropics.

Bingrong XU: Some features of the Western Tropical Pacific: Surface wind field and its influence on the upper ocean thermal structure.

Brett A. MULLAN: Influence of Southern Oscillation on New Zealand weather.

Kenneth S. GAGE, Ben B. BALSLEY, Warner L. ECKLUND, D.A. CARTER and J.R. McAFEE: Wind profiler related research in the Tropical Pacific.

Poster session: Thursday midday through Friday evening

John J. BATES: Signature of a west wind convective episode in special sensor microwave imager (SSM/I) data.

Daniel L. CADET, Gerard BELTRANDO and Richard PASCH: Interannual variability of the Indian Ocean surface fields.

John K. EISCHEID, Siri Jodha S. KHALSA and Klaus M. WEICKMANN: Relationships between the 30-60 day oscillation in the tropics and the varying frequency of atmospheric angular momentum oscillations.

David S. GUTZLER: Seasonal and interannual variability of the Madden-Julian oscillation.

Edmund D. HARRISON: Westerly wind anomalies from Central Pacific islands 1950-1980.

Marie-Helene RADENAC: Fine structure variability in the Equatorial Western Pacific Ocean.

George C. REID, Kenneth S. GAGE and John R. McAFEE: The climatology of the Western Tropical Pacific analysis of radiosonde data base.

Chung-Hsiung SUI and Ka-Ming LAU: Multi-scale processes in the Equatorial Western Pacific.

Stephen ZEBIAK: Diagnostic studies of Pacific surface winds.

Miscellaneous posters: *Thursday midday through Friday evening*

Rick BAILEY: Relevance to TOGA of systematic XBT errors.

Jean BLANCHOT, Robert LE BORGNE, Aubert LE BOUTELLER and Martine RODIER: ENSO events and consequences on the nutrients, planktonic biomass and production in the Southwestern Tropical Pacific Ocean.

Yves DANDONNEAU: Abnormal bloom of phytoplankton around 7°N in the Western Pacific during the 1982-83 ENSO.

Cecile DUPOUY: Sea surface chlorophyll concentration in the Southwestern Tropical Pacific as seen by NIMBUS CZCS from 1978 to 1984.

Pierre RUAL: A better data reduction method for XBT bathymessage.

William E. WOODWARD, Michael SZABADOS and Darren WRIGHT: Field evaluation of real-time XBT systems.

18H30: ORSTOM Dinner at Club Med

Sunday, May 28

08H00: Phare Amedee coral island trip (meeting point at Club Med pier, return at sunset)

Monday, May 29

08H00:

Overview of COARE Science Plan (plenary)

Working Group Discussions on Science Plan

12H00-14H00: Lunch

14H00:

Working Group Discussions on Science Plan

Presentations on Related Technology for COARE (plenary)

Tuesday, May 30

08H00:

Implementation Considerations and Related Programs (plenary)

Working Groups on Experimental Design

12H00-13H45: Lunch

13H45:

Working Group Reports (plenary)

National Reports (plenary)

Closing (plenary)

WORKSHOP REPORT

1. Introduction.

a. Historical Perspective.

Peter Webster, Chairman of the International TOGA Scientific Steering Group, presented the following overview of the development and planning for TOGA/COARE.

The U.S. TOGA Workshop on Western Pacific Air-Sea Interaction was held in Honolulu in September 1987 (Lukas and Webster, 1988), and the idea for a TOGA Coupled Ocean-Atmosphere Response Experiment (COARE) was outlined there in response to the need for new observations to answer many of the important questions raised at that Workshop.

A draft of a COARE Science Plan was prepared by Webster and Lukas (1988) following the Honolulu Workshop, and presented to the U.S. National Academy of Sciences TOGA Advisory Panel in April 1988, to the Joint Scientific Committee of WMO and ICSU in June 1988, and to the TOGA Scientific Steering Group at Cairns in July 1988.

The U.S. TOGA Panel, at its August 1988 meeting, endorsed the concept of a TOGA warm pool process experiment, and authorized the formation of a U.S. COARE Science Working Group (SWG) to continue the planning of COARE. This SWG met for the first time in Seattle in mid-September 1988, and again in Anaheim, California in late January 1989.

A revised version of the Science Plan was distributed in January 1989, which incorporated suggestions from the scientific community. The U.S. COARE SWG suggested further revisions, and a third draft of the COARE Science Plan was finished just prior to the present Meeting/Workshop, and distributed to all participants. It has been proposed as the first draft of an International TOGA/COARE Science Plan.

b. Presentation of Science Plan.

Roger Lukas gave an overview of the scientific background and tentative plans for TOGA/COARE, as contained in this draft Science Plan. The goals of the program were discussed, and it was emphasized that the exchange of heat, moisture, and momentum between the atmosphere and the ocean in the western Pacific warm pool region is the primary focus of COARE. The interactions among processes responsible for these fluxes, acting on a hierarchy of time and space scales, give rise to the complex and vigorous coupling of the atmosphere and ocean in the warm pool region; this hierarchy suggests a research strategy which is the foundation of the COARE. The nested time and space observational strategy proposed for COARE was illustrated, and it was emphasized that COARE will be embedded within the large scale TOGA monitoring program.

c. Discussion of Science Plan.

A general discussion of the draft COARE Science Plan was conducted in plenary. Numerous scientific and logistical issues were raised, and it was pointed out that the purpose of having the Workshop was to resolve these issues.

2. Working group discussions, recommendations, and plans.

The Workshop was then subdivided into three working groups:

- Air-Sea Fluxes and Boundary Layer Processes
- Regional Scale Atmospheric Circulation and Waves
- Regional Scale Oceanic Circulation and Waves

These groups were asked to address the draft COARE Science Plan on the first day of the Workshop, and to suggest additions and modifications as appropriate. For the second day of the Workshop, the groups were asked to address implementation considerations, such as array design and logistics. The working groups reconvened in plenary following each day's working sessions and at the beginning of the second day in order to hear presentations on related programs and relevant technologies.

The following charge to these working groups was given by Lukas:

- Make written contributions.
- Build on the existing framework.
- Translate COARE goals into specific scientific objectives and questions to be answered by COARE.
- Consider linkages among time and space scales for the Science Plan and for implementation. Specify needs from other working groups. State assistance that can be given to other working groups.
- Consider resolution, precision, accuracy, and duration requirements for observations.
- Begin to consider cost/benefit of particular observations.
- Planning letters from PI groups are welcomed.

The following subsections are intended to provide the substance of these working group deliberations and recommendations. The Science Plan contributions from these working groups have since been incorporated into the post-Noumea revision of the Science Plan. Recommendations regarding implementation are discussed in some detail. The bulk of the material is from the write-ups provided by the leaders of the various working groups.

a. Air-Sea Fluxes and Boundary Layer Processes.

co-Chairs: John Young, U. of Wisconsin/Madison, U.S.A.
Timothy Liu, JPL/Cal. Tech., U.S.A.

This group met together briefly, then broke down into smaller working groups in order to concentrate on particular aspects of the air-sea fluxes and boundary layer problems.

Before subdividing, J. Young urged the participants to consider the current status of our understanding of the air-sea fluxes, and to make sure that the mesoscale observations contribute to the goals of TOGA/COARE. An extended discussion of the draft COARE Science Plan then took place. The primary focus of discussion was the relative importance of the annual average heat flux into the warm pool versus the variability of the fluxes.

P. Gent said that the present COARE document overemphasizes the western Pacific climatological heat fluxes, and that present ocean numerical modeling results support the Newell hypothesis of near-zero net heat flux. In his model, Gent finds that

vertical diffusion in the upper ocean accounts for 9.4 Wm^{-2} , while horizontal advection can only account for 3.9 Wm^{-2} . These balance the net heat flux through the sea surface which was 13.5 Wm^{-2} . D. Anderson agreed that models show near-zero net heat flux, but that this result depends on model physics. Should the models be trusted? Anderson suggested that they must be verified.

When the minimum wind speed used in Gent's latent heat flux formulation is changed from 4 ms^{-1} to 3 ms^{-1} , the SST increases from 29.5°C to 32°C , and the net heat flux increases to 18 Wm^{-2} . SST in the warm pool thus appears to be quite sensitive to small changes in the net heat flux, and as R. Reynolds pointed out, SST might therefore be used as an observational constraint on flux estimates.

With regard to the radiative fluxes, C. Gautier pointed out the importance of understanding the contribution of mesoscale systems in reducing the incoming solar radiation, while S. Godfrey mentioned problems with the parameterization of the longwave radiative flux. G. Stephens expressed concern in relation to our ability to measure fluxes, including radiative fluxes, in the required range of $0\text{-}20 \text{ Wm}^{-2}$.

R. Lukas expressed the opinion that COARE will not measure the climatological net heat flux of $O(0\text{-}20 \text{ Wm}^{-2})$, rather the day-to-day variations in the fluxes. R. Garwood echoed this, saying that it is the range of the fluxes and their variances that are needed for understanding of the coupling. D. Anderson maintained that air-sea fluxes have no special significance in coupled models, only in stand-alone models.

M. Moncrieff discussed the role of mesoscale processes (spatial scales of $2\text{-}2000 \text{ km}$) in COARE, and suggested that the super cloud cluster is the response of convection rather than the scale of energy input. There is a total lack of quantitative knowledge of scale interaction, though convective transports are apparently important. Moncrieff felt that the best strategy for obtaining information on the fluxes during COARE is to make observations both remotely and *in situ*, on a limited scale, and to use modeling systems to analyze the observations. This amounts to data assimilation on the mesoscale, which will involve interactive nested models, one of which will need to be a non-hydrostatic mesoscale model, while the other will need to be a regional scale hydrostatic model.

1) PBL/Mesoscale Subgroup. (reporter, R. Carbone, NCAR, U.S.A.)

Observing Domain.

The domain for the PBL/mesoscale observations is defined as an area with observations sufficient in spatial and temporal resolution so as to close sensible and latent heat, precipitation, radiation and momentum budgets in the circumstance of large amplitude mesoscale variability usually caused by atmospheric convection. This domain corresponds to the intensive flux area (IFA) of the draft COARE Science Plan.

Since mesoscale convective forcing is both frequent (every $1\text{-}6$ days) and relatively short-lived ($3\text{-}24 \text{ hrs}$), it was deemed sufficient and practical to obtain comprehensive flux data sets in $1\text{-}3$ day bursts (FIOPs) less than 10 times during the 4 -month-long IOP. For those observing systems and platforms for which it is practical, observations will be taken continually during the IOP.

It was judged unlikely that budgets could be closed over an area larger than $500 \times 500 \text{ km}$. This task becomes more tractable with smaller domains (e.g. $100 \times 100 \text{ km}$) but less relevant in its relationship to larger scales of atmospheric forcing. It was the sense of the sub-group that COARE should strive to devise a measurement/analysis strategy which would be effective at the 500 km scale while recognizing that resources and sensor limitations may eventually require a reduction in the size of the flux domain.

The range of domain sizes considered does not permit flux measurements on the scale of a convective supercluster or a large westerly wind burst. The observing strategy calls for representative sampling and determination of structure within such phenomena. Soundings and airborne and land-based radar observations outside the flux domain together with satellite imagery will permit the FIOP data to be placed in the larger scale, longer period context.

The flux experiment would rely on the larger COARE domain observations to schedule FIOPs. The concept of flexible scheduling may be extended to flexibility in location. Compromises would be required for a "floating domain" implementation, since several key observing systems would be land-based. A hybrid implementation should be examined whereby some of the FIOPs are conducted at alternate locations as required. Because of the heavy reliance on ships and aircraft, some degree of mobility is possible.

The primary domain location was not discussed in detail. One alternative to equatorial symmetry was advanced based upon a climatological maximum of precipitation south of the equator. Since organized convection appears to be frequent throughout the COARE domain, the importance of this point may be secondary to issues of oceanic circulation symmetry about the equator. Logistical matters, including island locations, further complicate these considerations since some instrumentation will need to be on land. Finally, there is consideration of the phase relationship of the flux domain to the larger scale atmospheric circulations in a potential El Nino onset event.

Observational Platforms.

The sense of the group, taking resource limitations into account, was that 4 long-range research aircraft and 4 research vessel stations (which likely means eight vessels over the 4 month period) are a minimum requirement for the flux domain. In addition, the availability of one or two land "platforms" is essential. The research vessels would steam around drifting marker buoys to minimize advection terms with continuous Seasoar CTD profiling and Doppler current profiling. In addition to hosting eddy correlation and dissipation *in situ* flux measurements and rawinsonde sounders, research vessels should be of sufficient size and capability to accommodate the needs of shipboard remote sensing devices such as lidar, UHF wind profiler, passive thermodynamic profiler and microwave radar in order to permit continual monitoring of precipitation, and wind and thermodynamic profiles during the FIOPs. These devices generally require precise platform attitude and position information.

The research aircraft are assumed to include the NASA DC-8, 2 NOAA P-3s and the NCAR Electra as a minimum set. While not discussed explicitly in the sub-group, the CSIRO F-27 could also make significant contributions to the flux domain program. The NASA ER-2, if logistically feasible, would also contribute greatly to the radiative flux component. In addition to standard flight level eddy correlation data, the primary aircraft would include three airborne Doppler radars (which can double as scatterometers), Doppler lidar, full long- and short-wave radiation packages, GPS dropsondes, AXBTs, AXCPs and possibly AXCTDs.

Land-based systems should include Doppler radars, and various atmospheric sounding stations (including surface observations and radiation) as site availability permits. At least six 5-cm Doppler radars are potentially available including NCAR(2), CRPE(2), US TOGA(1) and MIT(1). The TOGA and MIT systems are most amenable for shipboard installation. Two land-based systems would complete the flux domain network for precipitation and momentum flux estimation. The remaining two Doppler radars would be placed at equatorial land-based sites several hundred km east and west of the flux domain for precipitation climatology and morphology objectives.

Ocean moorings, including meteorological sensors on a surface buoy and supplemented with high vertical resolution thermistor chains in the upper few tens of meters, are considered highly desirable bounding and within the flux domain. For the oceanic boundary layer, it is important that Kelvin and Rossby wave-induced vertical motions be distinguished from thermodynamic changes below the mixed layer. Thus, the PBL domain should be sited within a carefully designed array of moorings.

Observational Strategy.

FIOPs will be short in duration as a consequence of the short residence time of organized convective systems (10 h) and expected rapid response of the ocean mixed layer. Three days will be a typical FIOP duration. This is close to the staffing resource limits on research vessels and research aircraft.

The guiding principle, in the conduct of observations from all measurement platforms will be to characterize the oceanic-atmospheric state according to phase of the mesoscale forcing event. We will seek to identify and quantify the "pre-storm" undisturbed state; the highly disturbed state in the heart of the aggregate mesoscale disturbance; and the "wake" state following the passage of large amplitude events.

Within each FIOP, there are several potential applications of the aircraft owing to their mobility and wide range of instrumentation. Some FIOPs will require 24 h sequential use of the P-3s and the Electra for the purpose of continual ABL flux, precipitation measurement and ocean response studies. Other FIOPs may be envisioned where these aircraft, together with the DC-8, are flown simultaneously at the expense of 24 h coverage. The optimal use of aircraft resources is a most challenging aspect of the flux domain experiment design.

Precipitation Estimation.

No single instrument or observing platform can adequately address the precipitation estimation problem so crucial to the success of COARE. Implicit in our discussions was a hybrid approach which employs latent heating budgets, rain gauges on ships, aircraft, moorings and islands; ground-based and airborne Doppler radar reflectivity and kinematic techniques; airborne and space-based radiometric techniques.

An area as large as 500 x 500 km will require contributions from all methods and this will be a major consideration in the final determination of the flux domain size. The higher time/space density of tropospheric soundings in the flux domain should permit time-resolved latent heating profiles which serve to separate convective and stratiform components of the precipitation. Latent heating profiles also serve as an integral constraint for more highly time-resolved analyses from the direct measurements of precipitation by means of radar.

2) Remote Sensing Subgroup. (reporter, T. Liu, JPL/Cal. Tech., U.S.A.)

Determination of Wind Stress from Satellite.

The requirement for an accurate and detailed wind stress product for the initialization of models will probably be met only in an adequate manner through a combination of *in situ* and satellite measurements.

The NASA Scatterometer (NSCAT), which measures at the Ku-band, will not be launched in time for COARE. But the AMI on ERS-1 will be in operation during COARE and could measure surface wind vectors at C-band when put in the scatterometer mode. However, there are serious sampling problems because it has only

half the swath width of NSCAT and can only operate in scatterometer mode for part of the time. The sensitivity of C-band radar to surface wind is not as well studied as Ku-band. A useful product may be derived from an atmospheric GCM with assimilated ERS-1 scatterometer observations.

The algorithms relating scatterometer observations to surface wind vectors are empirical and should be tested for a large range of conditions. For this purpose NASA has built aircraft-borne Ku-band and C-band scatterometers and has deployed them in various field experiments. The scatterometer geophysical algorithms have not been adequately tested in low wind conditions and scatterometer measurements were found to be sensitive to sea surface temperature and atmospheric stability (Liu, 1984; Freilich, 1986). The western Pacific, with its unique conditions of light winds, high sea surface temperature, and high instability, provides an ideal location to extend these aircraft studies. COARE will have high quality *in situ* measurements and the aircraft scatterometer will provide mesoscale area coverage of wind vectors in return.

Determination of Heat and Moisture Fluxes from Satellite.

There were studies in the central and eastern tropical Pacific using latent heat flux and shortwave radiation derived from satellite data during the 1982-83 ENSO and in the Tropic Heat Experiment (Liu, 1988; Liu and Gautier 1989). It would appear natural to extend these efforts to the warm pool regions of the western Pacific ocean. Only data from operational spaceborne sensors, DMSP/SSM/I, NOAA/AVHRR, GMS/VISSR are required. They could be supplemented by other operational sensors such as NOAA/TOVS and DMSP/SSMT. Intense efforts in algorithm development and retrieval techniques are underway.

The establishment of *in situ* monitoring of surface shortwave radiation, longwave radiation and atmospheric humidity, in addition to routine meteorological reports will help to solve the validation problem. The retrieval of surface heat flux from satellite data could be conducted in close cooperation with the International Satellite Cloud Climatology Project, the Surface Radiation Budget Program and the Global Precipitation Climatology Project to produce surface thermal and buoyancy forcing on the ocean.

b. Regional Scale Atmospheric Circulation and Waves.

co-Chairs: William Lau, GSFC/NASA, U.S.A.
Gregg Holland, BMRC, Australia

1) Science Plan discussions.

During the morning session of the first day of the Workshop, discussions were focused on the revisions of the TOGA Science Plan. It was felt that there should be more emphasis of the connection between TOGA/COARE with other current national and international climate research programs and initiatives such as Global Change, GEWEX. The large scale atmospheric component is a vital link of TOGA/COARE to the climate community. It was generally felt that the section of the science plan on global teleconnections, particularly the section on modeling was seriously deficient. In particular, the relationship of COARE in improving climate predictability through improvement of flux parameterization or other means need to be addressed. Each of the Workshop participants were asked to put in writing their recommendations to the Science Plan.

Gregg Holland suggested there needs to be a clear concise statement at the beginning of the document to point out the need for coupled ocean atmosphere studies. It was agreed that understanding of global climate change, the El Nino/Southern Oscillation, and intraseasonal oscillations requires a better specification of the coupling of the ocean and atmosphere. The lack of understanding of basic mechanisms and errors in general circulation models have the largest potential impact in Pacific warm pool region.

There are two specific concerns that need to be brought out clearly. These are:

- The sensitivity of the large scale climate system to the warm pool air-sea interaction,
- The convective/mesoscale feedback to the surface fluxes.

The traditional gap between the large scale atmospheric component and the convective/mesoscale component has to be bridged by TOGA/COARE. This is directly related to the fourth goal of COARE.

S. Zebiak and N. Graham pointed out that there is very little discussion of the state-of-the-art coupled model development in the Science Plan. It was felt very strongly by this subgroup that such a discussion be included. One of the main uses of the COARE data set will be for diagnostic purposes and for initialization and validation of coupled models. A hierarchical approach to coupled modeling should be adopted. At present, coupled models have demonstrated a rich variety of interannual modes of the coupled system. However, it is not clear which one of these theoretical modes can be applied to the real system. Observations from COARE will help to resolve some issues regarding the origin of these coupled modes.

While coupled GCMs are the ultimate tool for coupled ocean-atmosphere studies, intermediate and simple coupled models also play important roles for hypothesis testing and for elucidating certain phenomenological aspects of coupled ocean-atmosphere interaction. Given the high data density from COARE, one class of process-oriented models should be emphasized. These are coupled boundary layer models. Sensitivity to various input parameters can be first tested in one-dimensional models and then on to more sophisticated models. These models will be very useful in improving the parameterization of the coupling between atmosphere and ocean in GCMs. For data assimilation purposes, mesoscale models embedded in regional scale models or GCMs will be most useful.

It was agreed that the Science Plan should contain specific discussions of the possible mutual influences of teleconnections on phenomena of the western Pacific. It was pointed out that there is observational evidence to suggest that atmospheric teleconnections may indeed be important for the development of ENSO-related westerly wind anomalies in the western tropical Pacific. The subgroup agreed that most of the sources of problems arising from current GCMs in simulating intraseasonal oscillations and teleconnections may lie in the uncertainty in the convective and surface flux parameterization. It seems that a careful set of measurement in the warm pool is necessary both for diagnostic and forecasting purposes. In addition to the specific objectives for the Atmosphere component listed in the present version of the Science Plan, the following objectives should be included:

- To study the transition of the tropical planetary boundary layer from the descending regions of the eastern Pacific Ocean to the convective western Pacific Ocean region, and to identify how it relates to the changes in wind regimes during westerly wind burst.
- Apply the knowledge gained from the pursuit of the objectives above to improvements in operational forecasting models and global climate models.

Much of the remaining time of the morning session was devoted to the discussion of beefing up the COARE modeling component of the Science Plan. It was felt that, to approach the goals of TOGA/COARE, a major developmental program of ocean, atmosphere and coupled system models is necessary. The modeling component of TOGA/COARE should emphasize those aspects of modeling relative to the warm pool regions of the tropics and will cover the extended period from 1989-1996. It is crucial that this component of the program should consist of a hierarchy of modeling approaches ranging from simple conceptual models, process models, nested mesoscale models to atmosphere-GCM, ocean-GCM and coupled ocean-atmosphere GCM. Some of the phenomenological aspects and simple hypotheses discussed in the Science Plan are best tested with simple conceptual or process models. They will aid in the interpretation of data and results from more complex global models. The use of GCMs is essential to study the far-field influence or teleconnections associated with the multi-scale processes in the western Pacific warm pool region. Process models and mesoscale models will provide the needed detailed information for improving parameterization in GCMs. The coupling between ocean and atmosphere, and the scale interaction between processes with short (order of days), intermediate (order of months) and long (order of years) time scales will require coupled ocean-atmosphere GCMs.

Issues related to data management were also discussed. TOGA/COARE will provide the scientific background for designing an observing and data transmission system for operational prediction. In order to adequately represent the multi-scale phenomena in TOGA/COARE and to assimilate the diverse observing facilities in a spatially and temporally coherent fashion, the use of both atmosphere-GCM and ocean-GCM are necessary. For the atmosphere, nested mesoscale models may be needed to resolve the hierarchical structures found in the superclusters to scales of 500 km or smaller. The two-way interaction between mesoscale models and large scale models is needed to incorporate scale interactions and interactive feedback between convection, radiation and dynamics in the assimilation system. The 4-dimension assimilation of the full TOGA/COARE data including remote and *in situ* measurements in the atmosphere and ocean, and surface fluxes at the interface, will be the key to the development of future ocean-atmosphere prediction systems and will be a challenge to coupled ocean-atmosphere modelers.

It was also felt by the working subgroup, that the original Table 1 on the modeling elements of COARE was inadequate. A new table was developed, and incorporated into the final version of the Science Plan.

2) Implementation Plan discussions.

Discussions of the Implementation Plan took place in the afternoon session of the Workshop. The scientific justifications for reconsidering the COARE regional scale domain were discussed. It was pointed out that by moving the domain by 10° of longitude to the east, the domain would cover more of the region of large SST gradients while still keeping the domain within the region of SST greater than 28°C. It was also pointed out that most of the air-sea interactions associated with the 30-60 day oscillation occur at the eastern edge of the warm pool and the eastern-most extent of the 28°C appears to define the limit of the eastward penetration of convective activities associated with the 30-60 day oscillation. Shifting the large scale domain to the east is especially important in case a warm event should occur during the IOP of COARE. It was therefore recommended that a contingency plan be developed whereby the regional domain of COARE can be shifted by 10° east in case a warm event occurs during the IOP. This will complement the TOGA-TAO II ATLAS moorings at the eastern edge of the warm pool.

The working group felt that a large scale domain covering 30°N to 30°S, 120°E to 160°W should be included as part of the overlapping observation strategy of COARE. Six-hourly synoptic scale upper air and surface observations and at least 24 hour temperature reports are needed at all available stations within the domain. It is essential to ensure that operational wind and temperature data are reported and transmitted through the regular GTS or the TOGA enhanced monitoring facilities. G. Holland discussed the possibility of enhancing all the weather stations of the southern hemisphere near Australia and the possibility of installing portable sounding units at remote island sites. The Gilbert Islands were mentioned as sites where more observing stations are desirable. It was agreed that an eventual goal of the large scale component COARE is to obtain an unprecedented atmosphere-ocean data with high spatial and time resolutions. It is suggested that a mesoscale model embedded within large scale regional model or GCM should be adopted to assimilate all the atmosphere and surface information for later analyses. A real time data assimilation system with feeds to operational and research centers are highly desirable and the COARE data system should work with that goal in mind.

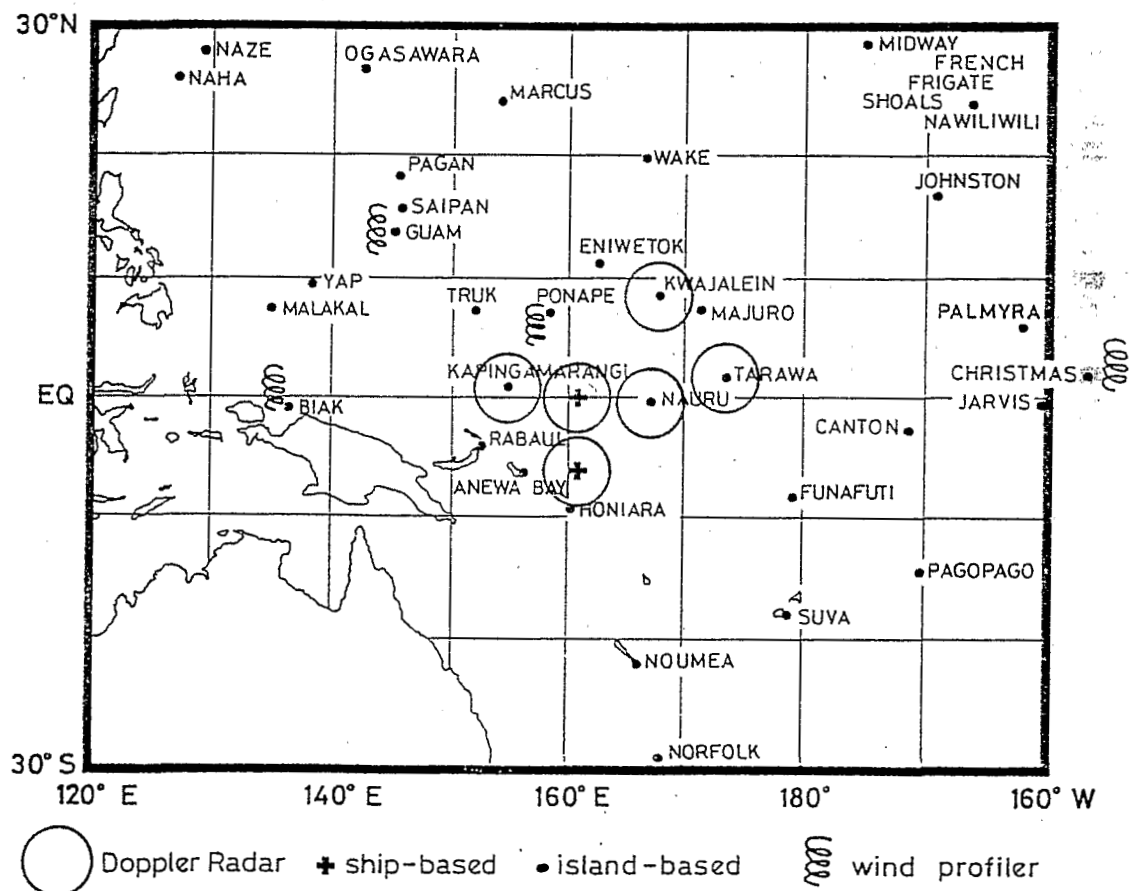


FIG.1. Suggested positions of ship- and island-based Doppler radars for the COARE Intensive Observation Period. Wind profiler locations are also suggested.

The need to leave behind key instruments after the IOP (the "care-taker" array) was also discussed. It was suggested that certain automated systems or systems that required minimum maintenance should be left behind. Since intense observations can only be taken for periods of weeks, the synoptic scale monitoring together with the satellite monitoring will provide the needed continuity for the large scale parameters. For the care-taker array, the TOGA Radar, enhanced monitoring over the Gilbert Islands, the Kwajalein radars and NOAA integrated sounding systems including wind profilers should be considered.

The site of the operation center for the IOP was also discussed. The choice is going to be severely constrained by the available ground facilities, proximity to the convective centers and the intensive flux domain, and above all, humane living conditions for crews and field scientists. Tarawa and Nauru were mentioned as possible sites. The concept of multiple centers was also discussed but was considered unsatisfactory because of the difficulty of logistical coordination. These issues need to be resolved in coordination with other working subgroups.

In order to monitor the large scale aspects of phenomena over the warm pool region of the tropical western Pacific, the Atmospheric Circulation and Waves subgroup recommended the following implementation strategy for the enhanced monitoring and intensive observation phase:

- The proposed COARE domain (10°N-10°S, 140°E-180°) should be embedded in a larger domain (30°N-30°S, 120°E-160°W). Observations from the existing radiosonde network should be enhanced and, where possible, new portable stations should be set up on strategic island sites (See Fig. 1).
- Six hourly wind, moisture and temperature profiles are needed within the large scale domain. These observations should be coordinated with the TOGA-TAO II ATLAS moorings with enhancement at the eastern edge of the warm pool.
- There should be an "ENSO contingency plan" to shift the COARE domain eastward during the Intensive Observing Period. This involves changing the deployment of mobile units (e.g. ships, aircraft, etc.) of the observing system.
- Proposed radar, ship, and enhanced surface observation sites (including advanced surface radiation measurements and rain gauges) are shown in Fig. 2. Sites have to be chosen to facilitate 4-D assimilation of COARE observations into a mesoscale grid mesh (50 x 50 km) over the COARE domain embedded in a large scale domain (500 x 500 km, see Fig. 3).
- A real-time satellite communication system, in particular with links to GTS, should be set up so that there will be continuous coverage of the COARE domain and the large scale domain. We recommend the installation of an on-site 4-D assimilation center where real-time COARE observations can be ingested into models and distributed to operational centers such as NMC and ECMWF.
- An IOP operation center should be chosen close to the eastern part of the COARE domain to facilitate deployment of ships and aircraft in case the ENSO contingency plan needs to be implemented. The IOP center should also provide adequate landing facilities and hospitality for the crews. Tarawa or Nauru were suggested as possible candidates.
- There should be a "care-taker array" consisting of specific observation elements that can be left behind for an extended period after the IOP. Suggested arrays include:
 - . the TOGA Radar,
 - . Upper air and surface stations including the NOAA Integrated Sounding System,
 - . the Kwajalein Radar,
 - . Wind Profilers.

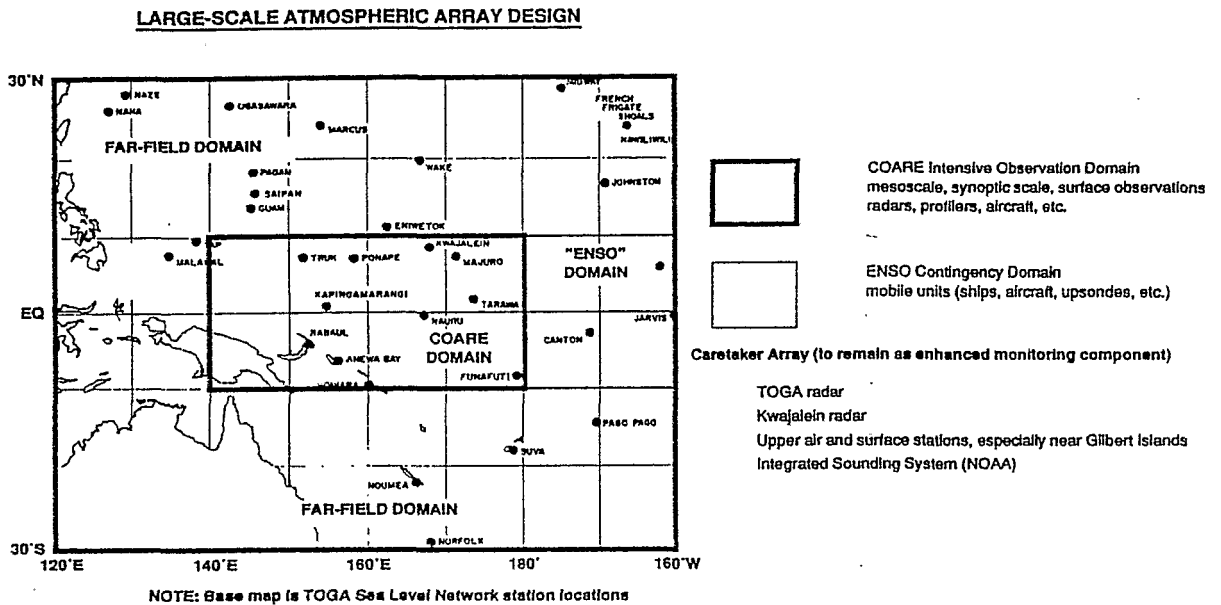


FIG.3. Large-scale atmospheric array design for COARE. The far-field domain requires an enhancement of the TOGA atmospheric observing system.

c. Regional Scale Oceanic Circulation and Waves.

co-Chairs: Charles Eriksen, University of Washington, U.S.A.
Antonio Busalacchi, GSFC/NASA, U.S.A.

Discussions during the first day's morning session were not well focused and reflected the collective uncertainty/concern/doubt with the primary goals of the TOGA/COARE oceanographic component (and the balance between the oceanographic and meteorological components in general), as expressed in the Science Plan.

Some of the early discussions considered questions regarding the role of horizontal advection in the upper 100 m of the COARE domain, particularly during westerly wind bursts and at the eastern edge of the warm pool. During such episodes, 1-dimensional mixed layer models are not likely to be adequate. This pointed to the need for a hierarchical approach to the oceanographic modeling. There is also a need for models that resolve the halocline and subduction. The early consensus was the oceanographic component of COARE would be along the lines of a 3-dimensional mixed layer experiment. The observations must be capable of observing the subduction of saline water from the east under the less saline water in the west, and the two different time scales for dynamic and thermal response of the warm pool.

COARE provides an opportunity for enhanced Western Pacific observations. By 1991-92, all TOGA-TAO moorings are to be in place west of the dateline. The exact placement of the ATLAS moorings west of the dateline is open to discussion and modifications in support of COARE.

The French plan to continue their occupation of the 165°E section twice per year. France plans on providing two research vessels during the IOP of COARE. The possibility exists that a Sea Soar may be able to be used for underway CTD profiling on one of these ships.

Fundamental questions were then raised with respect to westerly wind bursts (WWBs). Concern was expressed that WWBs were not necessarily directly correlated with SST, and that they are not necessarily more frequent prior to or during ENSO. Concern was expressed that COARE had the appearance of a high frequency/WWB experiment.

The following questions were posed as the motivation for *in situ* observations for the oceanographic component of COARE:

- What is the space-time structure of sea surface temperature (and sea surface salinity) in the western Pacific warm pool?
- What processes contribute to SST and SSS variability on time scales of days to months to years in the warm pool?
- How does mixing of heat, salt, and momentum occur in the upper western tropical Pacific Ocean?
- What is the net mass, heat, and salt flux into the COARE domain?
- What far-field processes affect the upper ocean in the warm pool and vice versa?

The issue of the location of the COARE domain was raised. After consideration of R. Weisberg's equatorial mooring at 170°W, the planned Japan/Australia mooring at 147°E, present and proposed ATLAS moorings, climatological distributions of highest SST and largest SST gradients, there were no compelling arguments for modifying the COARE domain.

Early on during this session it became clear, based on Sea Soar (towed CTD) sections, that at least two possible IOP regions were of interest or required; one near the equator where the thermocline is shallow and the other off the equator near the North Equatorial Countercurrent where the thermocline is relatively deep. Sea Soar profiles indicated meridional scales such that there was not much change in temperature or salinity within $\pm 2^\circ$ of the equator yet there was also evidence of small scale fronts, especially in salinity.

In the time domain, the shortest time scales of interest may range anywhere from the passage of individual squall lines on up to the passage of WWBs. There is a clear need for a Sea Soar type instrument to map the halocline structure.

In order to facilitate the detailed planning, there needs to be an effort to analyze the existing data, especially the high resolution Sea Soar data, to see what can be learned.

The end result was the consensus that there is a broad spectrum of space and time scales that need to be considered by the oceanographic component of COARE, similar to the space-time partitioning present in the planning for the atmospheric component:

	space scale	time scale
Fine Scale T-S	10 km	1 month
Westerly Wind Burst	100-1000 km	day-month
Large-scale, Far Field	>1000 km	year

1) Oceanographic observations for COARE

Overall Strategy.

The observations in support of the oceanographic component of COARE must balance intensive surveys with long time series. This requires a combination of enhanced monitoring and the IOP. The enhanced monitoring for the oceanographic component should be in place at least 4 months prior to the IOP; one year is preferable. In order to place the IOP in a proper context, the duration of the enhanced monitoring should be 1-2 years. Strong concern was expressed that there be an intense oceanographic component capable of complementing the atmospheric component.

Intensive surveys during the IOP.

The scientific objectives of the intensive surveys are to quantify the vertical mixing of heat, salt, and momentum; to quantify the horizontal advection of temperature and salinity; and to quantify the air-sea fluxes of heat, moisture, and momentum. The observations must resolve the diurnal cycle and convective events.

The basic strategy for these month-long experiments is to have a central mooring which is boxed in (on two space scales) by two research vessels. The inner box would be roughly 10 km on a side, and would take 4 hours to sample. The outer box would be 100 km on a side, and would take 2 days to repeat. Figure 4 illustrates this strategy.

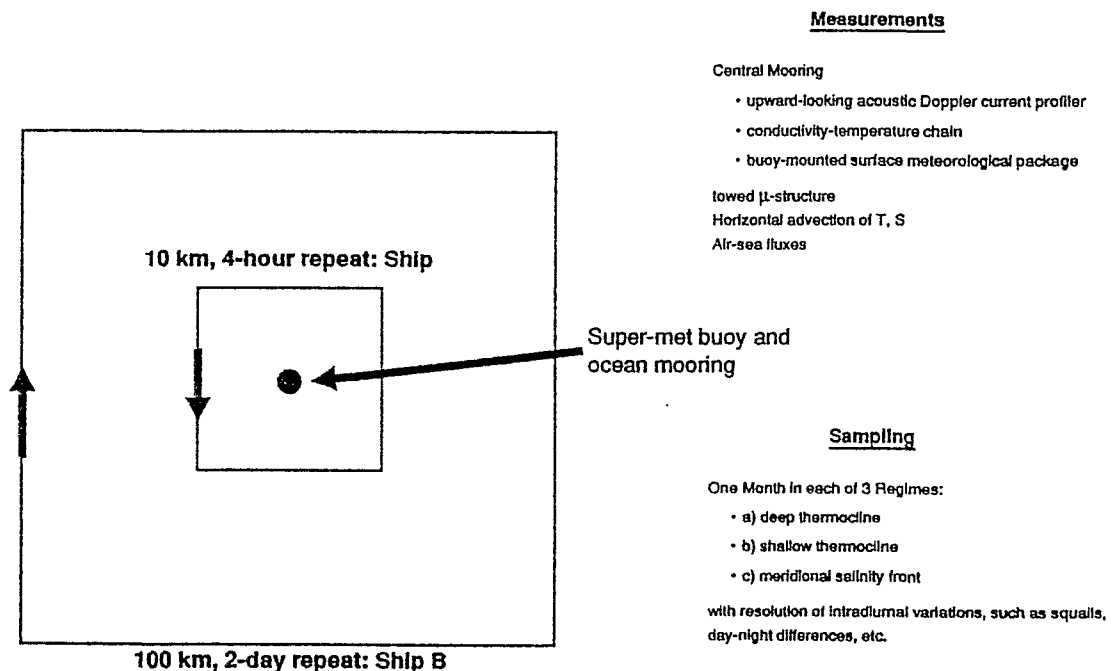


FIG.4. COARE IOP ocean mixed layer experimental design.

It was considered important to conduct intensive surveys in different regimes where one could expect either lateral or vertical processes to dominate. The three regions suggested were 1) where the thermocline is deep, 2) where the thermocline is shallow, and 3) where there is zonally-oriented salinity front near the equator.

The one month duration of each intensive survey is a compromise between the research vessel logistics and the desire to sample during a wide range of meteorological forcing.

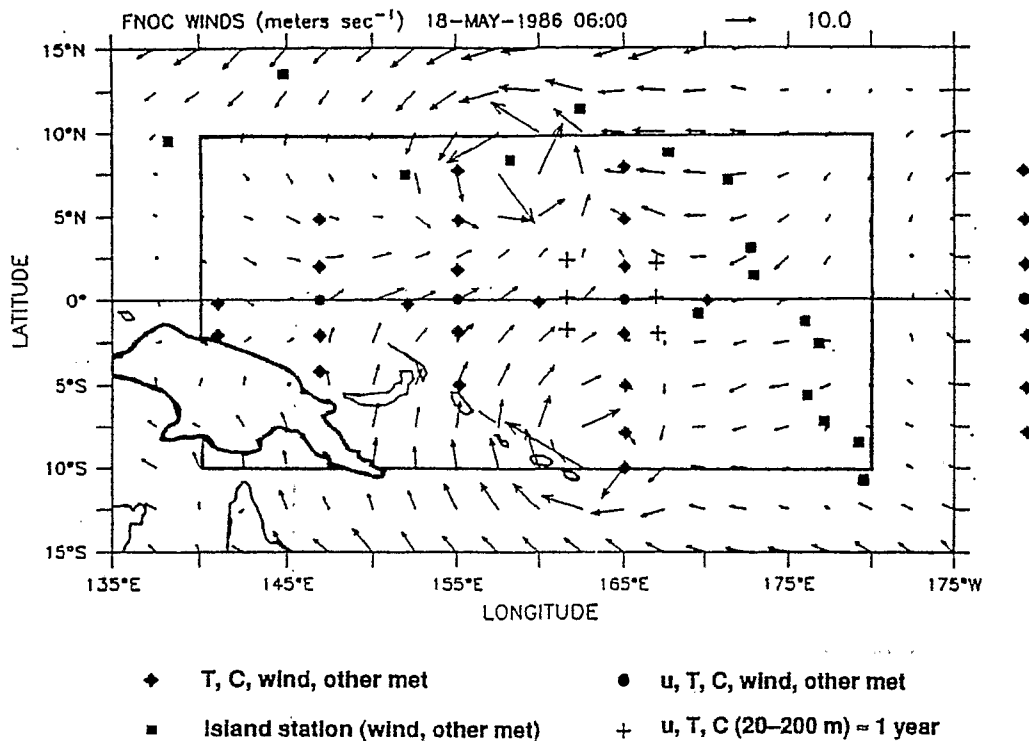
Moored observations during the intensive surveys are important to provide high-resolution time series at fixed points. Currents will be measured using an acoustic Doppler current profiler, and temperature and salinity profiles will be estimated by discrete sensors on a thermistor/conductivity chain. A WHOI-type meteorological package on the surface buoy of the mooring will provide high-resolution time series of wind, air and sea temperature, humidity, barometric pressure, short- and long-wave radiation, and rain (see paper by Weller and Hosom, in the Appendix).

Shipboard measurements should be made while the ship is underway in order to maximize spatial coverage within a time frame over which the measurements might be considered synoptic. Observations should include currents measured by acoustic Doppler current profiler, as well as towed CTD and microstructure measurements. It will be necessary to stop the ship occasionally for standard CTD stations for calibration purposes and to get deeper into the water column. High-resolution meteorological observations, including those needed to estimate air-sea fluxes, should be made wherever possible. A shipboard Doppler weather radar is needed to estimate precipitation and wind stress over the experimental region.

Enhanced Monitoring: Regional long time series.

The objective of the enhanced oceanographic monitoring is to place the intensive observations properly within the context of the large-scale, low-frequency evolution of the warm pool. The existing TOGA monitoring is not sufficient: the variability of currents and thermohaline structure of the upper ocean in the warm pool must be observed with sufficient spatial resolution to resolve the response to monsoon and wind burst forcing.

The basic strategy for the enhanced monitoring is to augment the moored ATLAS array of thermistor chain moorings in conjunction with TAO-II to provide better spatial coverage of the thermal structure variations of the warm pool, and to enhance these observations with conductivity sensors to obtain time series of salinity at key locations. Also, current meter moorings are needed along the equator to resolve the vertical and zonal structure of current variations over at least two seasonal cycles. A special array of profiling current meters (PCMs) should be considered to obtain time series of temperature, salinity, and velocity profiles on and near the equator in the middle of the enhanced array.



Ships and drifters to fill in structure during IOP

FIG.5. COARE ocean enhanced monitoring array.

The locations suggested for the elements of the oceanic enhanced monitoring for COARE are shown in Fig. 5. The zonal separation of 5° is dictated by the scales of observed energetic variability in the wind field, and the meridional separation of 2-3° is determined by both the meridional scales of wind variability and the dynamics of the equatorial waveguide. Some elements were suggested to observe boundary-related processes.

The duration of the enhanced monitoring should be two seasonal cycles, preferably one before the COARE IOP and one after. Some elements of the enhanced monitoring array should be considered for inclusion in the long-term, post-TOGA monitoring, on the basis of the results of the COARE IOP observations.

2) Oceanographic modeling for COARE.

Since the modeling component of COARE extends through the entire lifetime of the experiment, there will be a great deal of synergy between the modeling and observational elements of the experiment. Hence, the modeling will be evolutionary in nature. Going into COARE, TOGA-TAO together with improvements to operational AGCMs should lead to better estimates of the surface wind field over large areas and over long time scales. However, evaporation-precipitation estimates will remain uncertain and until they are certain, it will be difficult to include salinity effects properly in the OGCMs. In the mean time, much work needs to be done in order to include buoyancy fluxes in a whole suite of ocean models including the requisite idealized and sensitivity studies to buoyancy forcing.

The ocean modeling element of COARE will proceed with a hierarchical approach that considers both buoyancy fluxes and the large-scale ocean circulation of the western Pacific warm pool. In regions where horizontal gradients are small, 1-dimensional mixed layer models will be employed. Process-oriented models will be used to perform sensitivity studies to idealized specifications of buoyancy fluxes. The upstream and downstream effects of remote forcing, particularly the role of the western boundary, or the large-scale circulation in the warm pool will be addressed with process models. The sensitivity of the oceanic response to westerly wind bursts as a function of various thermohaline states will be considered by process and OGC models. OGCMs will also prove invaluable in interpreting the large-scale state of the warm pool and providing a context for the small scale oceanographic experiments within COARE. This will be accomplished via budget studies of mass, heat, and salt within the COARE domain, through the assimilation of the *in situ* and space-based measurements of the enhanced monitoring and IOP. The end result of the model development, intercomparison with *in situ* data, and incorporation of *in situ* data will be new ocean models that consider the effects of buoyancy forcing, that resolve both the thermal and haline structure, improved mixed layer parameterizations, and ultimately improvements to OGCMs and operational modeling capabilities.

3. Related Programs.

a. NASA Ocean Processes and Satellite Missions.

Gary Lagerloef of NASA Headquarters described the NASA Oceanic Processes program and satellite missions that relate to TOGA/COARE. He noted that about 20% of the program is devoted to developing spaceborne techniques and evaluating their utility for observing the oceans, while the application of these techniques to advancing our understanding of the oceans comprises the bulk of the program.

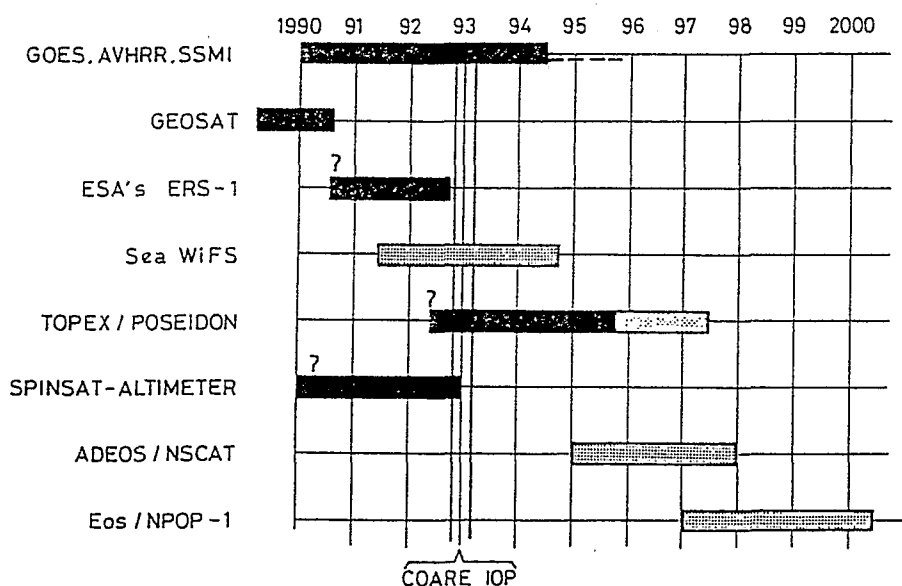


FIG.6. Timing for proposed satellite missions for ocean process studies. Operational satellites are indicated at the top. The timing of the COARE IOP is indicated.

Figure 6 shows the current status of a variety of ocean-related satellite missions. Light shading indicates that the mission is not yet funded; question marks indicate launch dates that are uncertain. It was noted that the intersection of these missions with the COARE IOP is presently only certain for the operational satellites (GOES, DMSP, NOAA polar orbiters).

The Oceanic Processes program can contribute to COARE by providing access to NASA and non-NASA ocean satellite data, and by providing airborne remote sensing observations during field experiments. One of the sensors that could be flown during COARE are the NUSCAT scatterometer, which can yield high spatial resolution vector winds over an area comparable to that of the outer box of the ocean mixed layer experiments (Fig. 7).

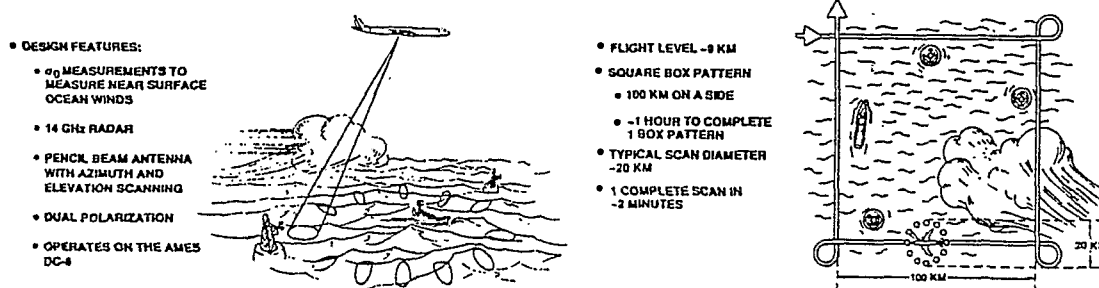


FIG.7. Overview of NUSCAT airborne scatterometer measurement capability. This observing system could become available for use during the COARE IOP.

The ESTAR-0/SFMR microwave radiometer (Fig. 8), which can provide SST and scalar wind speed estimates, is also a candidate for research aircraft flights. It is also possible that sea surface salinity might be inferred from these radiometer observations (Fig. 9).

MEASUREMENT CHARACTERISTICS OF THE AIRBORNE MICROWAVE RADIOMETERS FOR NASA OCEAN PROCESSES	
L-BAND ESTAR-0	C-BAND - MODIFIED SFMR
SWATH FOR 10 KM ALTITUDE (H):	SWATH:
SWATH WIDTH ($2.8 \times H$) = 28 KM	15° SINGLE BEAM, 2.6 KM WIDTH
NUMBER OF CELLS CROSS TRACK = 13	
CELL SIZE : 1x2 KM (average);	SENSIVITY:
1x1 KM (center);	BRIGHTNESS TEMPERATURE ~0.3°K
1x4 KM (edge)	EQUIVALENT SST ~1.0°C OR BETTER
	EQUIVALENT WIND SPEED ~1.4 M/S
SENSIVITY:	VIEWING GEOMETRY:
BRIGHTNESS TEMPERATURE ~0.3°K	VERTICAL INCIDENCE ANGLE 60°(AFT)
EQUIVALENT SALINITY (@25°C SST) ~0.5‰	VERTICAL POLARIZATION

FIG.8. Measurement characteristics of the airborne microwave radiometers for NASA's Ocean Processes studies. Airborne sensors may complement *in situ* and satellite-based observations, providing coverage on an intermediate space scale.

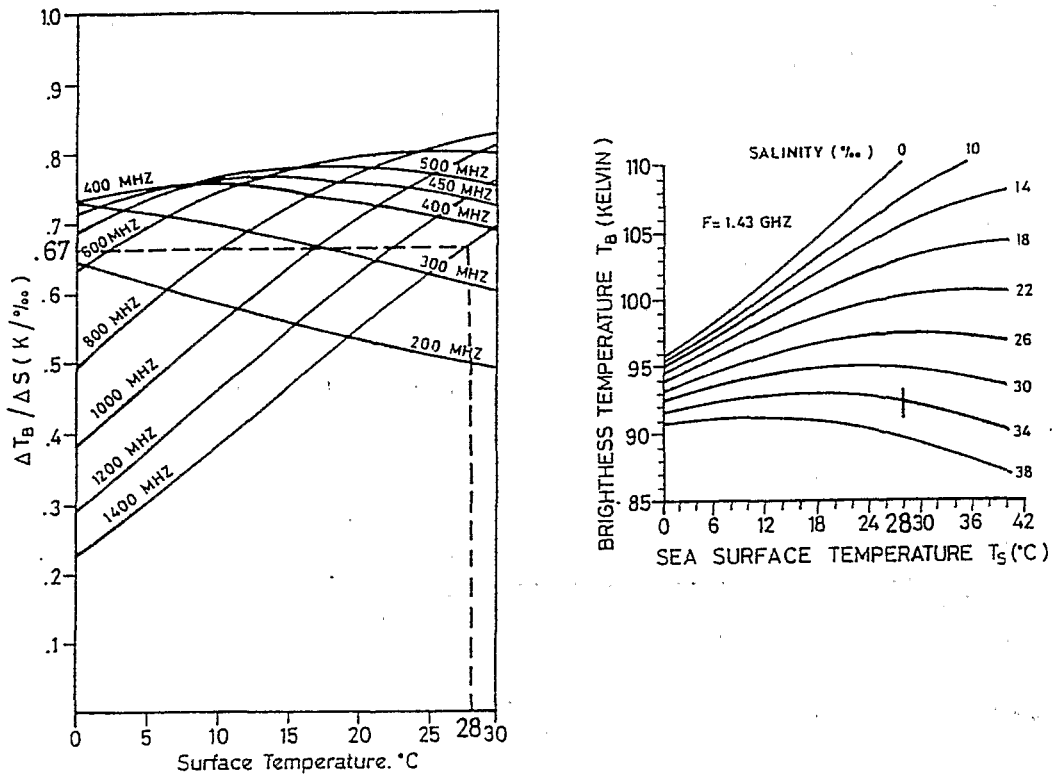


FIG.9. Sensitivity of emissivity of seawater with salinity, as a function of SST (left), and brightness temperature as a function of SST for various surface salinities (right).

Other instruments that could be flown on research aircraft missions include the C-SCAT C-band scatterometer, and a lidar which measures chlorophyll/primary productivity.

COARE will contribute to the Oceanic Processes program by providing high quality surface data for improving geophysical algorithms. If the TOPEX/Poseidon mission is launched in time, COARE will provide an excellent regional validation in view of the dense sea level network and the supporting environmental data that will be obtained.

b. Tropical Rainfall Measuring Mission.

Otto Thiele of Goddard Space Flight Center/NASA described the Tropical Rainfall Measuring Mission's status and the preflight activities that are related to TOGA/COARE. Phase-A studies by U.S. and Japan were completed in May, 1988. Japan's Science and Technology Agency approved initiation of Phase-B in May, 1989. NASA approved Phase-B studies to start in June 1989 with completion by September 1990. A decision will be made before 1 October 1990 for a FY91 new start for TRMM, with a planned launch in early 1996 from Tanegashima, Japan.

The Kwajalein atoll groundtruth facility was highlighted for its contribution to pre-COARE studies, as well as its obvious contribution to the observing system for the COARE IOP. It was suggested that an intensive groundtruthing experiment using three

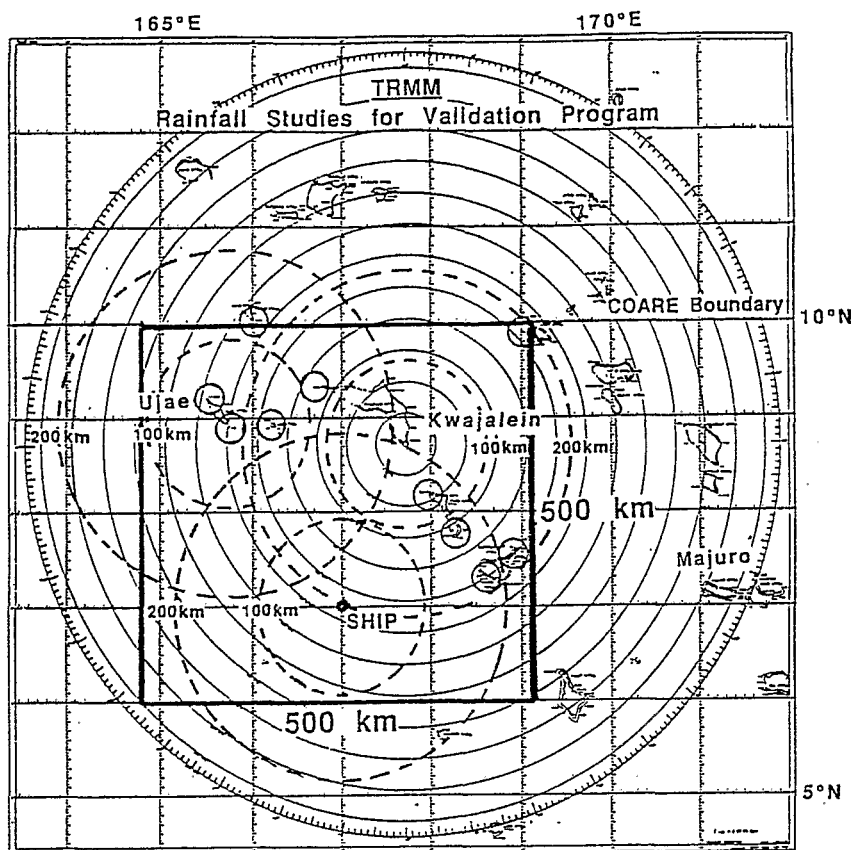


FIG.10. A suggested *in situ* rainfall measurement program for NASA's Tropical Rainfall Measurement Mission validation program.

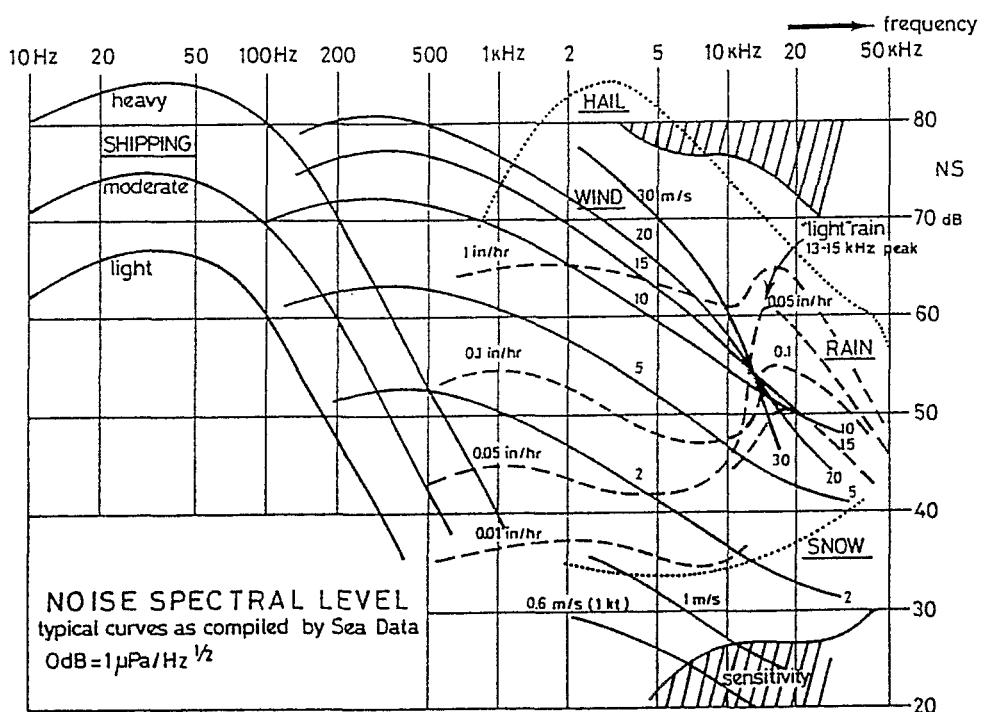


FIG.11. Typical oceanic frequency spectra for various noise sources. Rainfall has a narrow and relatively stable peak at relatively high frequencies due to bubble collapse. This might be exploited on oceanic moorings to get open ocean rain rates during COARE.

radars (including Kwajalein) could be conducted in conjunction with COARE (Fig. 10) such that a 500 km square box was covered by radar precipitation estimates, and where there are sufficient rain gauges to calibrate the radar estimates.

Another area of research being conducted as part of pre-TRMM efforts is in using acoustic signatures of rainfall on the ocean surface to estimate area-averaged precipitation rates. Figure 11 shows an ocean noise spectrum; the rain peak is around 14 kHz, which does not vary much with rain rate. TRMM researchers will conduct an experiment off-shore of Florida with a WOTAN acoustic system at a depth of 45 m.

c. Typhoon Motion Program.

Gregg Holland of the Bureau of Meteorology Research Center (Melbourne, Australia) presented the field program plans for the U.S. Office of Naval Research Tropical Cyclone Motion Initiative. This multinational effort is focusing on the off-equatorial tropical atmosphere to the east of the Philippines, though some oceanographic observations will be made during the program. The time frame for the observational effort will be August-September 1990.

This program is a large, multinational field effort in the western Pacific involving a large variety of observing systems and platforms. It therefore will provide valuable experience relative to COARE planning and implementation.

d. World Ocean Circulation Experiment.

Eric Lindstrom of the Commonwealth Scientific and Industrial Research Organization (CSIRO), on assignment to the U.S. WOCE Project Office, presented aspects of the WOCE plans that bear on COARE objectives and/or the western equatorial Pacific ocean circulation.

The areas where there is substantial overlap of WOCE and TOGA interests are:

- Meteorological sensors for air-sea flux measurements on ships and buoys (*)
- Improving models for estimating air-sea fluxes (*)
- Low-latitude western boundary currents (*)
- Surface drifters (design and deployments)
- Pacific Volunteer Observing Ship network (XBT, ADCP, MET)
- Sea level array
- Indonesian throughflow (*)
- Reanalysis
- Data management
- Satellites (*)

(* : areas with the greatest intersection with COARE)

Robert Weller of Woods Hole Oceanographic Institution is funded by WOCE to develop a package of air-sea interaction sensors that can be used to make high quality flux estimates from moored buoys or ships (a description of this effort is attached in the following appendix.) The results of this research will be of great benefit to the moored flux estimates made during COARE.

The improvement of atmospheric GCM boundary layer formulation for better estimation of air-sea fluxes is a high priority for WOCE and for COARE. The intensive observations made during COARE will aid in algorithm development, and will provide excellent validation of those algorithms.

Low-latitude western boundary currents in the western Pacific likely influence the size and location of the warm pool. These currents are also potentially important in the cross-equatorial transport of heat, so WOCE plans include moored measurements in some of these currents, such as the Mindanao Current. If these measurements can be coordinated with COARE observations, then the combined dataset will have even more value to the two programs. It will then be possible to calculate the correlation between fluctuations of the boundary currents and the near-equatorial currents.

The Indonesian throughflow is important to WOCE for the heat and mass budgets associated with the global ocean circulation. It is possible that changes in the air-sea interaction over the western Pacific warm pool influence the throughflow, and it is likely the case that the throughflow influences the size and location of the warm pool to some degree. If WOCE scientists are able to make observations within the Indonesian seas coincident with COARE, then the analysis of throughflow fluctuations and warm pool variations will be most useful for model validation studies.

4. Presentations on related technology.

Because many Workshop participants were generally unfamiliar with recent advances in the technology for measuring air-sea fluxes, two invited presentations were made. P. Hildebrand (NCAR/U.S.A.) spoke on, "Flux Measurements Using Aircraft and Radars", and W. Dabberdt (NCAR/U.S.A.) talked about "Determination of Boundary-Layer Fluxes With an Integrated Sounding System". These papers are included in the following appendix.

5. National reports.

Reports were made in the final plenary session by the scientists from the following nations:

- Australia (E. Lindstrom)
- China (X. Zhou)
- France (D. Cadet)
- Indonesia (H. Harjento)
- Japan (A. Sumi)
- United Kingdom (D. Webb)
- United States (K. Mooney)

These reports were not official statements regarding TOGA/COARE, but were instead intended to communicate to the international group a sense for the areas of interest (related to COARE) by scientists from these nations, and some idea of the future plans that these groups will try to undertake. It was clearly stated that the official forum for commitments to COARE can only come through the international TOGA mechanism of the Intergovernmental TOGA Board, which will consider COARE at its January 1990 meeting in Geneva.

6. Meeting of the International Ad Hoc Committee on TOGA/COARE.

Members of this group are: P. Webster (Chairman), R. Lukas, J. Picaut, A. Sumi, J.S. Godfrey, G. Holland, D. Anderson, X. Zhou. A short organizational meeting was held the evening of May 29th.

The committee approved the suggestion by Webster that Lukas and Webster revise the existing version of the Science Plan, and distribute it as the second draft International TOGA/COARE Science Plan prior to the September TOGA SSG meeting. The hope was that a final Science Plan (SP) could be presented at that meeting. The revised draft SP was to be distributed by 15 July. *[Editor's note: This deadline was met.]*

Data management issues were raised. Some concern was expressed about priority for data usage given large personal and national investments in the collection of COARE datasets. It was agreed that explicit arrangements concerning exchange of data among nations should be developed. The suggestion was made to include some statements of principle concerning data management and exchange in the next revision of the SP, and to develop a considered policy of data management and exchange for the TOGA/COARE Implementation Plan.

The development of the Implementation Plan (IP) was discussed. The results of the present Workshop represent a good start on the IP, but there is clearly a need for much more input. In the U.S., plans are to issue a program announcement around the end of August, and to solicit planning letters from PIs or PI groups to address aspects of the program as outlined in the SP. These planning letters will provide important information for the IP, and will begin the process of matching scientists with specific tasks within COARE. This raised the question of how other nations intend to handle the development of national plans for participation in COARE, and any associated review/funding cycles.

The intention is to develop a draft IP for presentation to the International TOGA Board at least one month prior to its January 1990 meeting. Hopefully, this will allow time for national discussions and feedback at the the Board meeting.