17

REPORT ON C-MMACS

SUMMARY The addition of a world-class supercomputer during the year has resulted in a quantum increase in the computing resources of C-MMACS and of the overall CSIR system generally. Initial experience and response of the scientific community has been extremely enthusiastic. The extraordinary speed, intrinsic memory and versatility of the system makes it possible to attempt modelling and simulation of a wide variety of highly complex problems by drastically reducing the turn-around time for testing alternative solutions and offering advanced graphic visualization; indeed the supercomputer has an enormous potential for spurring an adventure of ideas and approaches for addressing a growing range of real world problems.

The year also witnessed the super computer has successful completion of a feasibility experiment designed to measure the strain field in the Southern peninsula using high precision GPS receivers with the objective of establishing a reliable approach to delineating regions of anomalous strain accumulation preparatory to rupture by earthquakes in peninsular India. The experiment was jointly conducted by scientists of C-MMACS, Indian Institute of Science, Survey of India, Southern region and University of Colorado. Concomitantly, facilities and expertise for processing and analysis of GPS data were also established at C-MMACS. These have been fruitfully utilized in processing the massive data set obtained during the experiment, and constitute an important national asset to support similar endeavours elsewhere in the country.

The Centre registered substantial enhancement in the range of both inhouse and collaborative programmes during the year. The growing variety and intensity of these programmes are each addressed by a specific interdisciplinary group of scientists drawn from the five main areas of expertise in various areas of modelling and scientific computing.

DR K S YAJNIK
Head

17.1 MODELLING AND SIMULATION

17.1A MODELLING FOR RESOURCES

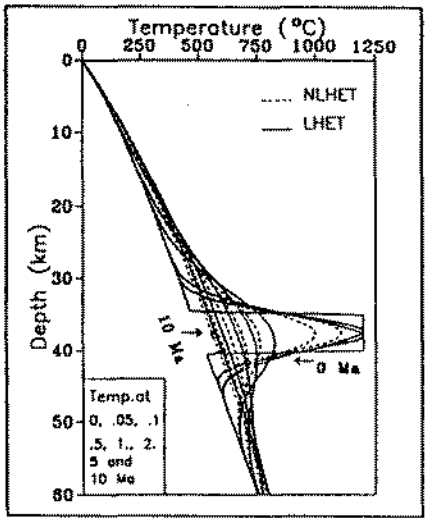
STUDIES IN GEOLOGICAL FLUID MECHANICS

Sedimentary basins formed in the post-rift phase, preserve decipherable records of the operative mechanism(s) of lithospheric deformation. However, simple models of

basin forming processes, proposed earlier, do not yield results consistent with the complex lithospheric features inferred from sophisticated deep exploration techniques. In many rift associated basins, underplating by magmatic bodies has been suggested to be the cause of the observed velocity structure. These bodies affect the evolving geometry of a basin by slowing the cooling process, and thereby modifying the pattern of subsidence during the initial stage of basin formation. The latent heat evolved during solidification further slows down the rate of cooling. A study was accordingly carried out to model the thermal structure of lithosphere following an underplating event, by including the effect of solidification. This problem has been solved for a one-dimensional case by applying the Fourier spectral method in the space domain and a modified finite difference scheme in time domain. The exact solution for this nonlinear problem is not available. The result, shown in *Figure 1*, supports the prolonged duration of the warm environment and, therefore, is suggestive of reduced subsidence in the initial stages of deformation.

*(R N Singh', M I James, A Manglik', * NGRI)*

▼ *Fig. 1 Thermal evolution of continental crust after magmatic underplating of 5 km (i) with the latent heat effect (LHET) and (ii) without this effect (NLHET).*



PROPOSAL ON COAL DATABASE

This programme was formulated during the year after an in-depth discussion amongst the scientists of CFRI, C-MMACS and INSDOC. The resulting proposal has been submitted to the Department of Coal, Govt. of India for (a) creating a national database on coal available in India, (b) design of efficient data structures for easy availability of information and higher data products to all the participating organisations as well as other users and (c) developing models of grade and spatial distribution of coal to facilitate its future exploitation.

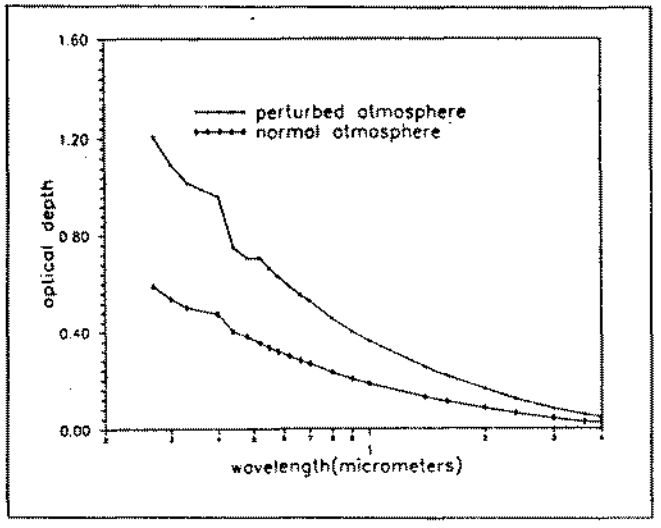
*(K S Narasimhan', S G Tumuluri', A K Mukherjee', N K Indira, R P Thangavelu, K S Yajnik, *CFRI)*

17.1B MODELLING FOR CLIMATE CHANGE

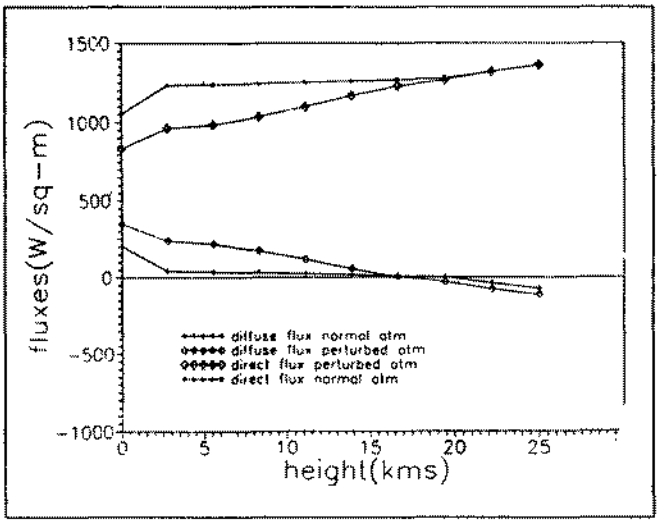
TROPICAL RADIATION BUDGET AND VOLCANIC AEROSOLS

Recent eruptions of Mt. Pinatubo have spewed massive quantities of volcanic aerosols into the stratosphere. These cause appreciable change in the radiation budget owing to their longer residence times (1-3 years). In turn, this leads to short term climate changes. These perturbations are intense but local in space and time. However estimation of their magnitudes is still a subject of considerable debate, especially on account of the treatment of multiple scattering which dominates radiative transfer in the presence of aerosols. Modelling of this phenomena at C-MMACS and computation of the radiative fluxes have been carried out as accurately as currently possible. The radiative properties of the volcanic aerosols were calculated from first principles, that is, using the Mie theory. The radiative transfer equation (RTE) including the multiple scattering terms was solved by the application of a high order spherical harmonics(P-19)

▼ *Fig. 2 Spectral optical depths of normal and perturbed atmospheres.*



▼ *Fig. 3 Solar fluxes for the normal and perturbed atmospheres.*



approximation. The RTE was solved on a spectral basis and integrated over wavelength to yield total fluxes.

The volcanic loading of the stratosphere (10-20 kms) has been assumed to be twice the concentration of aerosols in the normal atmosphere. The spectral optical depths in the solar region of the normal and the perturbed atmosphere calculated by the application of Mie theory are shown in *Figure 2*. The optical depth of the perturbed atmosphere is 1.5 - 2.0 times higher in the solar region.

The total solar radiative fluxes computed with the P-19 approximation are shown in *Figure 3*. The reduction in the direct flux of the perturbed atmosphere, due to increased optical depth, is compensated partly by an increase in the diffuse flux, due to multiple scattering. There is an increase of 41.9 W/sq-m in the diffuse radiation leaving the top of the atmosphere for the perturbed atmosphere. This indicates the magnitude of cooling of the earth-atmosphere system. On the surface of the earth the net flux (sum of direct and diffuse fluxes) in the perturbed case decreases by 76.8 W/sq-m, which indicates the extent of cooling of the earth alone. The difference 34.9 W/sq-m (76.8 - 41.9) is retained in the perturbed atmosphere. The distribution of this heating with respect to height in the perturbed atmosphere can be seen in the figure.

(P S Swathi, Nandini Harinath)

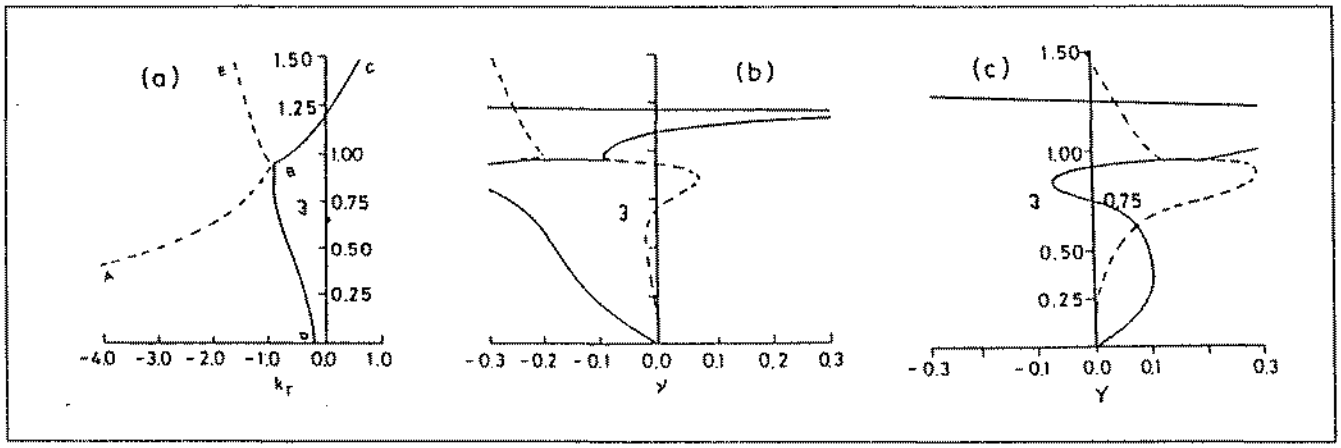
MODELLING OF LARGE SCALE TROPICAL CIRCULATION

Convection plays a vital role in tropical dynamics - Indeed, the convective towers in the tropics are the life lines of the global atmospheric circulation. Therefore modelling convection and understanding its interaction with large scale dynamics are necessary to examine various issues like low frequency variabilities and climate change. However, this task has turned out to be rather difficult. A new parameterization of interaction between convection and large scale dynamics developed at C-MMACS has provided a general framework for understanding intraseasonal oscillations.

There are three major intraseasonal oscillations, namely, (a) the 30-50 day eastward propagating planetary scale oscillation, (b) the 3-4 day westward propagating wave observed over the Atlantic and the Pacific and (c) the 10-20 day variability observed over the Indian summer monsoon region. Although several authors have tried to model the first oscillation as an equatorial Kelvin mode driven unstable by moist processes, linear models always predicted a growth rate that increased with frequency thus implying growth of the smallest scales. This problem was overcome recently (C-MMACS Annual Report 1992-93) by postulating a convective time lag which parameterized the time scale for organized convection. However, the other two intraseasonal oscillations which do not exhibit Kelvin mode structure were still outside the scope of this formalism. The results given subsequently show that the same parameterization scheme can also explain the other two intraseasonal oscillations as intrinsic modes of the tropical atmosphere. Thus, the present model provides a unified dynamical model to understand the basic characteristics of all the three major intraseasonal oscillations. This parameterization holds promise for improving performance of more complex numerical models. The investigation is continuing.

Another aspect of tropical dynamics being studied at C-MMACS is the effect of land-ocean contrast. The Indian ocean region is characterized by a transition from ocean to land within the equatorial belt. This land-

▼ *Fig. 4 Dispersion curves for n=0 tropical normal modes in presence of moist feedbacks and a convective time lag for mean background easterlies and background westerlies. The dashed and solid lines represent the two solutions of the dispersion relation. The results are shown for fixed value of evaporation wind feedback parameter and convective timelag (τ=6 hours). Fig. 4a shows variation of wave number (K_R) with frequency. Only one pair of solutions is shown as there is no significant variation of K_R for mean easterlies and mean westerlies. Fig. 4b and 4c represent the variation of growth rates with frequency for mean easterlies and westerlies, respectively. The co-ordinates are in non-dimensional units with length scale ~10° and timescale ~0.21 day.*



ocean contrast is likely to affect the circulation considerably by affecting among other things, the nature and distribution of evaporation. Indeed, it was found that inclusion of land-ocean contrast represented by modified evaporative forcing has a pronounced effect on the tropical eigen functions. The results from these experiments can help us to analyse and interpret observed data and results from more complex numerical models. This in turn can help us to improve performance of more complex models. Some of the results from these experiments are given in subsequent sections.

(P Goswami, B Joseph)

Mechanism of Scale Selection in Tropical Circulation at Observed Intraseasonal Frequencies

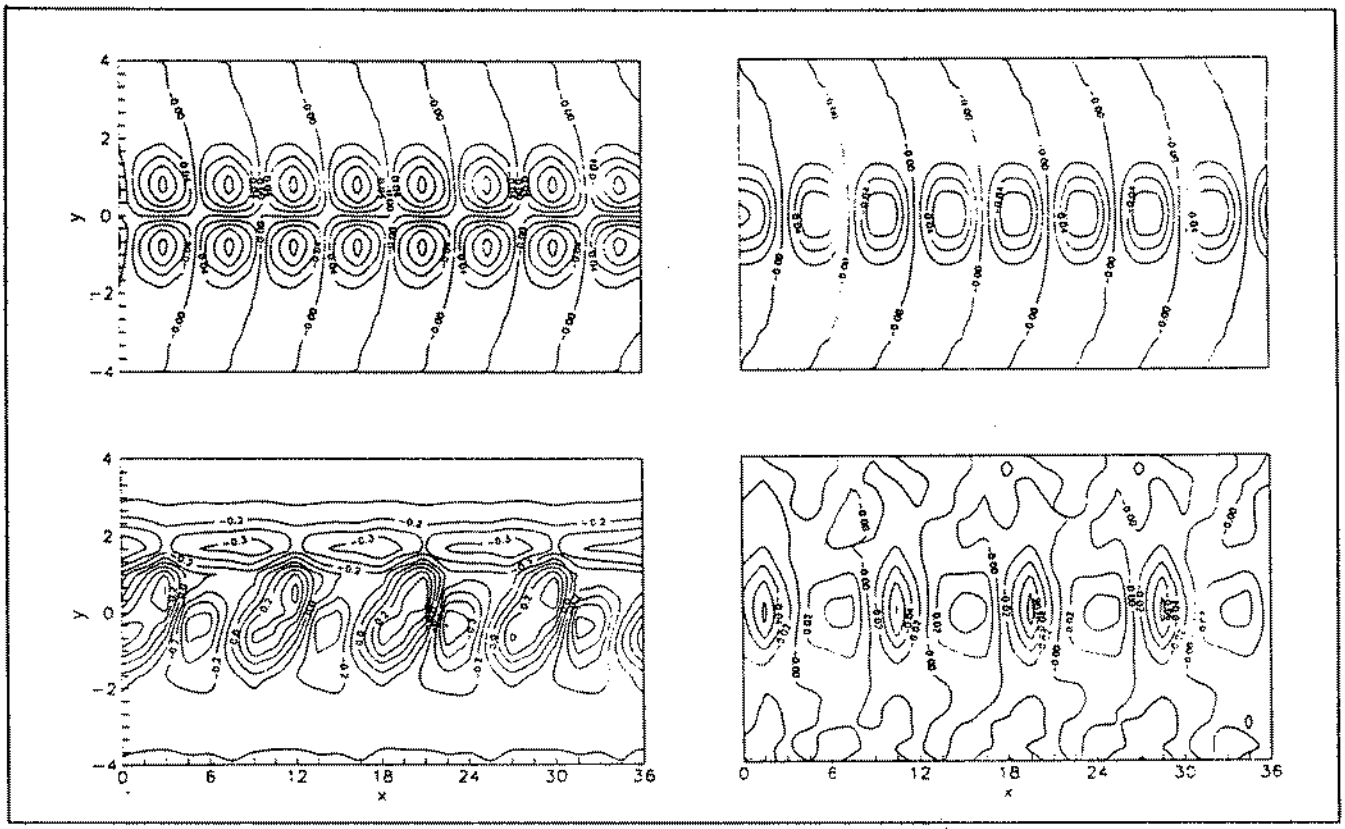
Figure 4a shows the variation of real wave number K_R with frequency for the two branches of the solutions of the dispersion relation. The segment ABC represents the well known mixed Rossby gravity mode. It should be noted that the branch DBE would be forbidden in a dry tropical atmosphere; however, in the presence of moist feedbacks this branch is allowed and can represent observed wave if the growth rates are not negative. The spectral structure does not change significantly as one changes from mean easterlies to mean westerlies. However, there is a dramatic difference between the growth rate - frequency curves for the cases with mean easterlies and mean westerlies. In the presence of mean easterlies only the MRG wave is unstable with a maximally growing wave at frequency about 0.8 (time period about 4 days), while the second branch is damped (*Figure 4b*). In presence of mean westerlies, a situation representative of the Indian summer monsoon region, the second branch of the solution has positive growth rates, representing a new mode in the tropical circulation (*Figure 4c*). This branch also has a low frequency maximally growing wave with period about 11 days and wavelength about 9000 km, which compare well with the characteristics of the 10-20 days wave observed over the Indian ocean summer monsoon region. For both these waves, the agreement between observed structure and theoretical predictions is excellent. Thus the present work establishes the relevance of the concept of a convective timelag in modelling interaction between convection and dynamics of large scale tropical atmosphere.

(P Goswami)

Modelling of Land-Ocean Contrast in Tropical Circulation

Several experiments were conducted on the linear shallow water model of tropical atmosphere on equatorial ß-

▼ *Fig. 5 Structure of the tropical circulation with and without land-ocean contrast. The left panels show the perturbation u-field while the right panels show the peturbation meridional wind field. The top panels show the fields for the case with moist feedbacks and no land-ocean contrast, while the bottom panels show the case with moist feedback and land-ocean contrast with conditional heating (positive precipitation) and evaporation over land proportional to local precipitation. Each figure represents fields after 120 days of integration. Co-ordinates are in non-dimensional units.*



plane with evaporation wind feedback and convergence feedback. In *Figure 5* the top panels show the u (left panel) and v (right panel) fields for the case without land-ocean contrast after about 120 days of model integration. The model preserves the basic structure of the initial condition which was given as a low frequency mixed Rossby gravity waves. In other experiments (Fig.5, bottom panels), evaporation over land was considered proportional to local precipitation, and heating was made conditional to positivity of precipitation. The results show dramatic change in the structure of the tropical normal modes. In particular, the u-field now has a distinct north-south asymmetry (Fig. 5, lower left panel). The v-field is still equator-symmetric as for a mixed Rossby gravity wave, (Fig.5, lower right panel) wave characteristics like time period and wavelength also show significant change. The results have an important bearing on many areas like initialization and data assimilation for tropical circulation.

(P Goswami and B Joseph)

SATELLITE SEA SURFACE TEMPERATURE RETRIEVAL ALGORITHMS

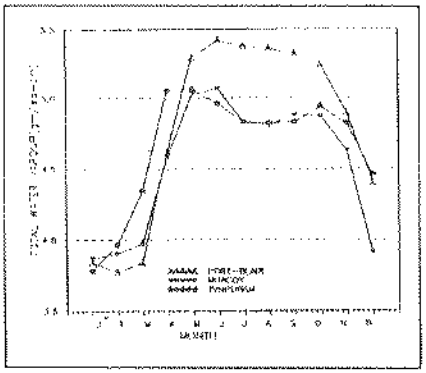
In association with the National Remote Sensing Agency (NRSA), C-MMACS has been engaged in developing algorithms for the precise estimation of sea surface temperature (SST) from satellite based radiometer data. A new algorithm has been developed which is specific to Indian conditions and overcomes several limitations of the global algorithm currently in use. Development of this algorithm involved two steps: (a) analysis of the water vapour content of the tropical atmosphere and (b) simulation of satellite brightness temperatures using these atmospheric profiles. The atmospheric water vapour content of the tropical Indian atmosphere was obtained by analysing the monthly mean radiosonde profiles from one coastal and two island stations for the period 1965-87. The dew point temperatures reported by radiosondes were converted to water vapour densities and integrated over height to yield the column integrated water vapour content. Results of the water vapour analysis are shown in *Figure 6*. After a statistical analysis of these profiles to reject outliers, a total of 567 profiles were used in radiance and brightness temperature simulations with LOWTRAN7. For each profile, simulations were performed for 17 SST's (290-306K) and 6 zenith angles (0-60 degrees). From the set of 57834 simulations, two new algorithms, TR-MCSST Ver. 2 (tropical multichannel SST) and TR-CPSST Ver. 2 (tropical cross product SST) were derived by linear and nonlinear regression. A frequency tabulation of the errors associated with these two algorithms along with the core currently used (MCSST) is shown in *Figure 7*. TR-CPSST is seen to perform remarkably well over all zenith angles and SST's. The algorithm is also free from bias. The new algorithm is being tested in NRSA.

*(P S Swathi, R Padma, Narendranath', * NRSA)*

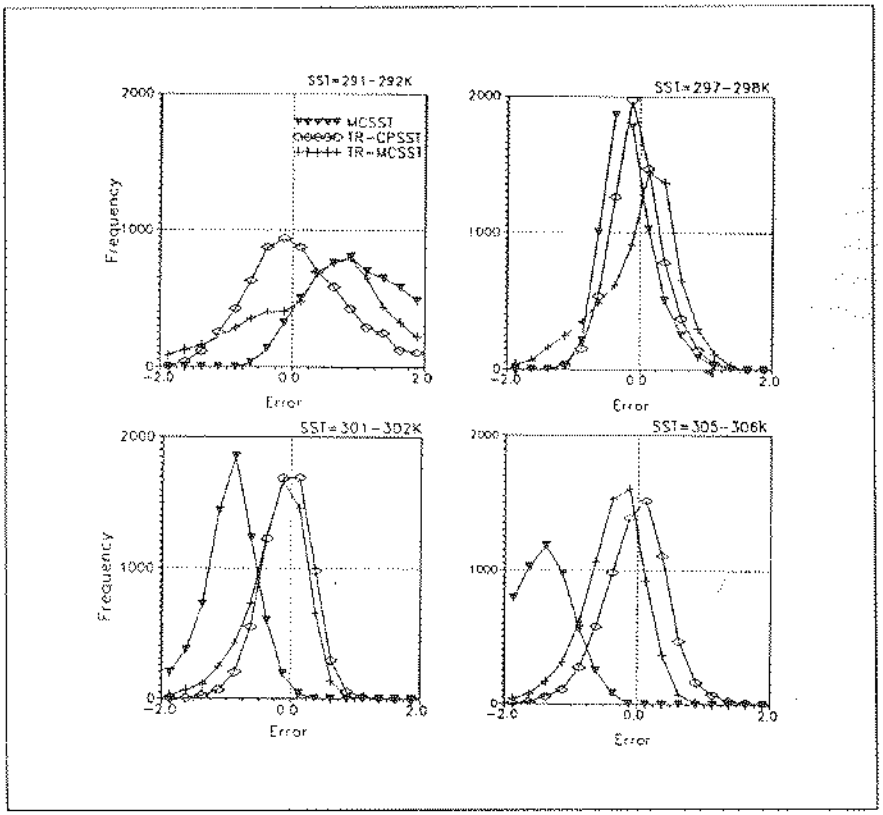
SEA LEVEL CHANGES

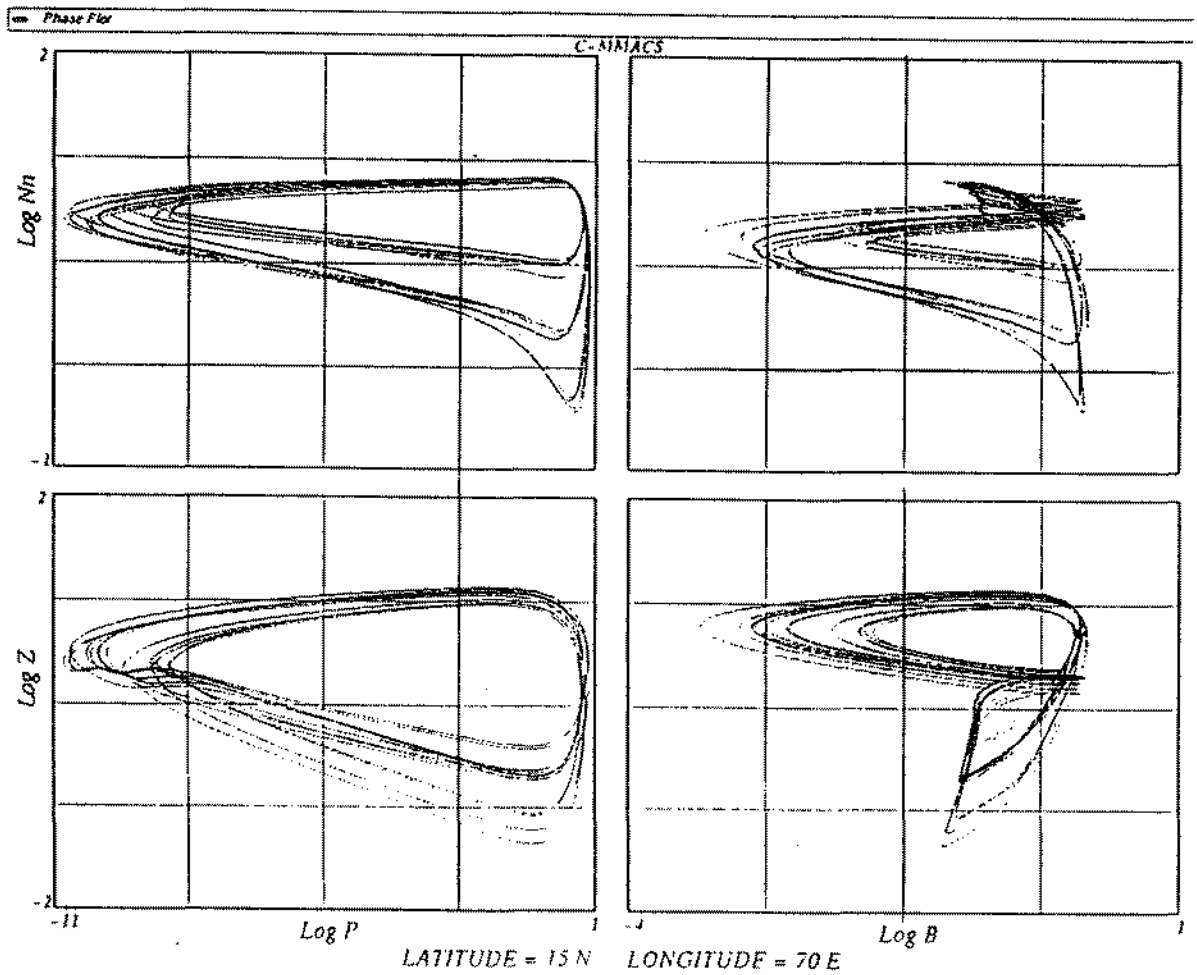
Stochastic time series analysis techniques have been applied at C-MMACS and elsewhere to obtain linear models for sea level change data measured at Bombay, Cochin, Madras, Vishakhapatnam and Sagar. In view of certain limitations of

▼ *Fig. 6 Total monthly average water vapour content obtained from analysis of radiosonde data (1965-1987).*



▼ *Fig. 7 MCSST is the algorithm currently used in NRSA. TR-MCSST and TR-CPSST are the linear and nonlinear algorithms respectively, developed in C-MMACS.*





▲ *Fig. 8 Behaviour of Phytoplankton (P), Zooplankton (Z), Bacteria (B) and Nitrate (Nn) at a station in Arabian Sea latitute 15°N, longitude 70°E. Oscillations similar to limit cycles can be observed.*

linear models, we are now investigating the applicability of nonlinear models to this process. This study, which is under the SELMAM (sea level monitoring and modelling) programme of DOD, is in progress.

*(N K Indira, R N Singh', * NGRI)*

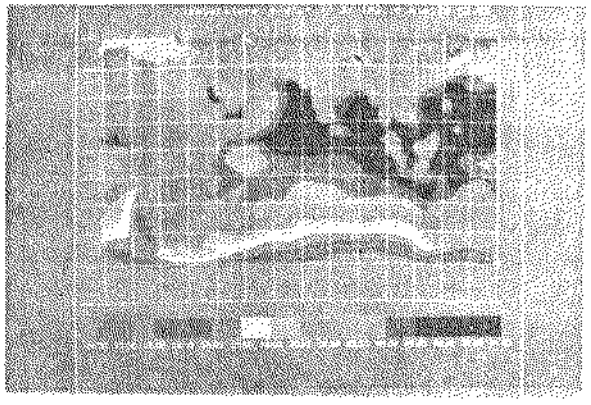
MODELLING OF MARINE BIOLOGICAL SYSTEMS

There is considerable interest in elucidating the role of biological processes, especially photosynthesis, in modulating the carbon exchange between the atmosphere and the ocean since this exchange plays a critical role in controlling climate. A 7-component model of the marine ecosystem that highlights the effect of the microbial loop has been studied at C-MMACS. These studies were aimed at investigating the effects of nutrients diffusion from the lower layers, settlement of detritus and seasonal variation of the mixed layer depth and solar radiation. Detailed simulations were carried out at selected stations using global climatic data and NIO data in the central Arabian Sea. The influence of variations in the various model parameters were examined at one station on critical factors, notably, new production, regenerated production, detritus settlement rates etc. A sharp increase in the growth of phytoplankton, zooplankton and bacteria was observed during the onset of monsoons. Also, observable quantities like chlorophyll, gross production, primary production, f-ratio and sedimentation flux were calculated for two stations in the Arabian Sea. These simulations have given an insight into the detailed dynamics. *Figure 8* shows phase plane plots of phytoplankton(P), zooplankton(Z), bacteria(B) and nitrate(Nn) on a logarithmic scale. These exhibit an approximately periodic behaviour akin to the limit cycles. Furthermore, the growth or decay of phytoplankton, zooplankton and bacteria are found to be nearly exponential in certain parts of the cycle.

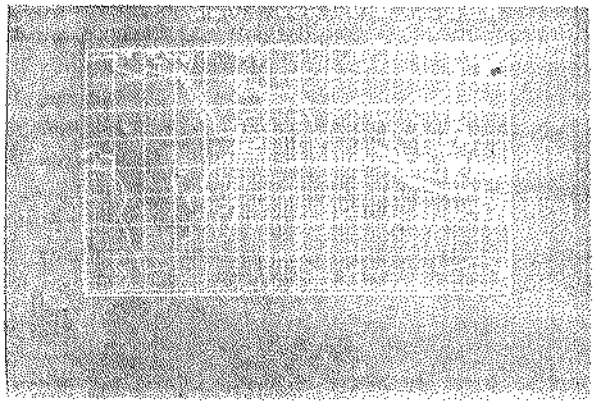
(K S Yajnik, M K Sharada)

BASIN SCALE OCEAN MODELLING

The response of the Indian Ocean basin to seasonal winds and the



▲ *Fig. 9 Temperature field in the surface layer of the Indian Ocean basin note the existing Somali gyres.*



▲ *Fig. 10 Surface circulation in the Indian Ocean basin. Note the strong Somali jet.*

influence of sea surface temperature anomalies on atmospheric circulation need careful study as they form crucial elements in medium and long term prediction of the monsoon. While the behaviour of atmosphere has received considerable attention in the past, the oceanic component has not been studied as extensively. A major effort is therefore been mounted at C-MMACS to study the thermohaline and wind driven circulation of the Indian Ocean basin using the modular ocean model (MOM) developed by Geophysical Fluid Dynamics Laboratory, (GFDL), Princeton.

With the arrival of CONVEX 3820, it has now become possible to make realistic runs of MOM at C-MMACS. A 2°x 2° model of the global ocean with 15 vertical levels (245,700 grid points), realistic topography, monthly mean boundary forcing and Levitus initial temperature and salinity profiles was thus integrated for 100 years with a time step of 1 day. Results of this study at day 3 July, year 102 are shown in *Figures 9,10*. Surface circulation in the Bay of Bengal is poorly resolved due to the coarseness of the grid. However, the circulation in the Arabian Sea including the strong Somali jet is captured quite well. Efforts are underway to improve the resolution of the model in the Indian region.

(P S Swathi)

INVESTIGATION OF DYNAMICS OF EL NINO EVENTS WITH SIMPLE COUPLED MODELS

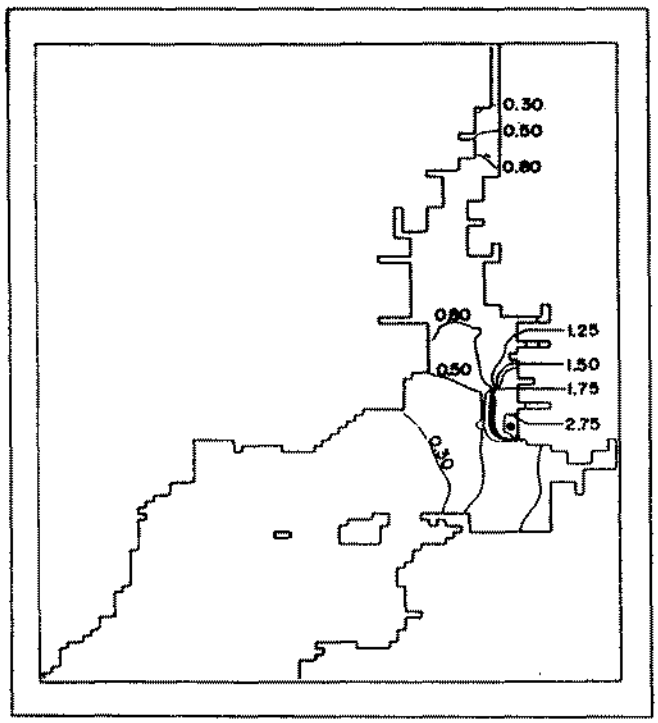
An important question in the dynamics of coupled ocean-atmosphere system is the possibility and implications of interaction between El Nino events and the Northern hemispheric summer monsoon. A simple coupled model was adopted to investigate these processes. This model, originally developed by Mark Cane and S.Zebiak at GFDL, has been highly successful in simulating El Nino type events. It uses a linear, quasi-steady atmosphere on a ß-plane coupled to an ocean basin. However as the original formulation uses a zero or constant mean wind, it is not suitable for coupling to the monsoon which depends on the reversal of the wind system. Inclusion of a mean zonal wind with a latitudinal dependence changes the formulation of the atmospheric component significantly and the results more so. In particular, the inclusion of an easterly mean wind with observed (climatic) latitudinal dependence is found to give rise to only a positive sea surface temperature anomaly in the Pacific region (El Nino). Observationally, El Nino and La Nina events have nearly equal amplitudes. The present studies indicate, therefore, that the presence of a (y-dependent) mean wind can significantly alter the dynamics of the coupled system. Further investigations are in progress.

*(P Goswami, K Rameshan, * IIT, Kanpur)*

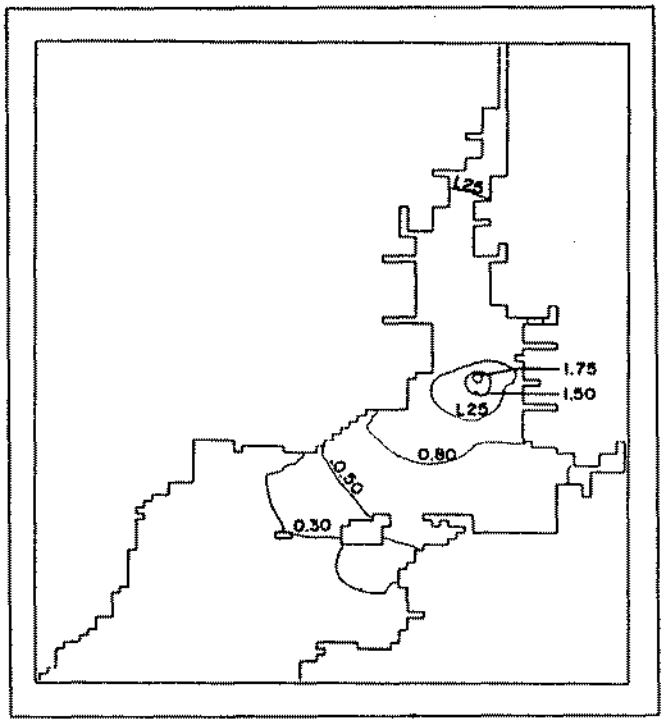
17.1C MODELLING FOR ENVIRONMENT

COASTAL POLLUTION MODELLING

A study of the pollutant transport and concentration regime in the Thane Creek near Bombay and the Bombay harbour region was taken up at C-MMACS under the sponsorship of the Department of Ocean Development. This exercise has been carried out at C-MMACS with the assistance of NIO, RC and other local bodies, towards the design of an operational model for predicting the pollutant regimes in these coastal areas under varying conditions. Three versions of a model were reported earlier (Oceanography of the Indian Ocean, B.N. Desai (Editor), pp. 395-405, 1992, IMACS Symposium, Book of Abstracts, pp. 66-67, 1992). In the latest version of the model, a realistic tidal boundary condition has been used to represent the tidal loading at the southern boundary where the sea interacts with the creek. 34 spectral components have been used for this purpose. Further more the present version of the model permits flooding of mudflats on either side of the creek to simulate real conditions. The model was validated in a limited



▲ *Fig. 11 Contours of pullutant concentration (gm/m): effluent discharge point near the right bank.*



▲ *Fig. 12 Contours of pullutant concentration (gm/m): effluent discharge point at the centre.*

way using the available field measurements (M.S. Phanikumar, M.D. Raghunath, K.S. Yajnik, 1993).

This model has been used to study the effect of shifting effluent discharge points on the mean concentration field in the creek. This study was carried out with a view to designing strategies for conserving the quality of the creek water.

Two locations - the first being 3 km and the other 6 km away from Trombay (towards north) - were chosen to represent two *nallas* discharging effluents into the creek. In another study, three discharge points - two on either bank and the other at the centre, were considered. *Figure 11* shows the presence of localized regions of high pollutant concentration when the effluent is discharged near the right bank. In contrast, *Figure 12* depicts significant dilution in the pollutant concentration field (discharge point at the centre). For the test cases considered, an idea about the dilution can be obtained by noting that the contour corresponding to a level of 0.3 gm/m^3 (in Fig. 11) shifts southwards by about 6 km (Fig. 12) when the pollutant discharge point is shifted to the centre.

(M S Phanikumar, M D Raghunath, K S Yajnik)

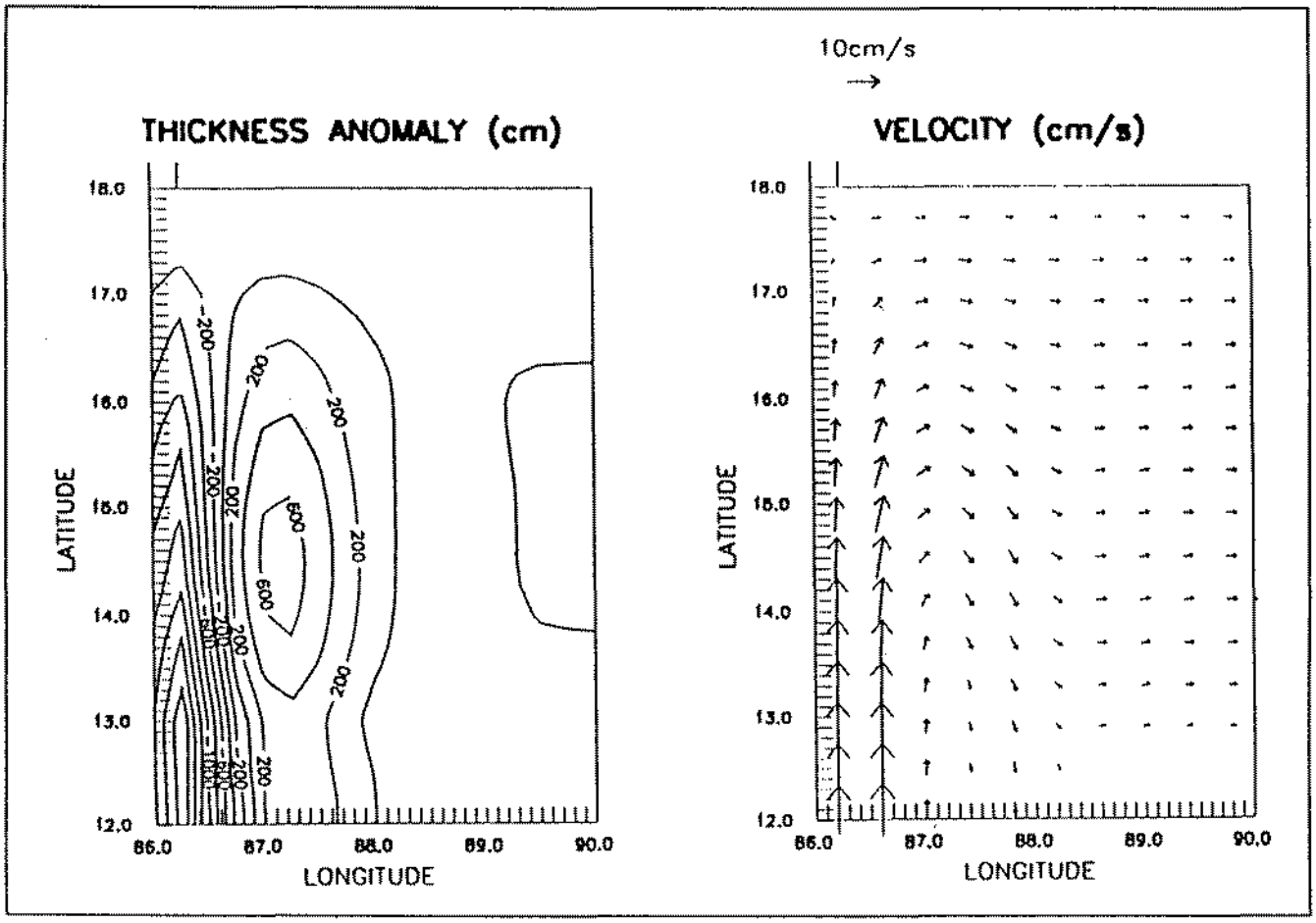
Modelling the coastal circulation in the Bay of Bengal

The role of prodigious amounts of fresh water discharged in the Bay of Bengal, on determining its dynamics, has been a matter of considerable debate. A 1-1/2 layer reduced-gravity ocean model was developed at C-MMACS to study the impact of the local forcing, i.e. the seasonal monsoon winds and the freshwater influx from rivers, on the circulation in the Bay of Bengal. The model ocean consists of two constant-density layers. The denser lower layer is much thicker than the upper layer and is assumed to be motionless. The interface between the layers represents the model pycnocline.

The model equations, which are fully nonlinear and include equations for energy and salt conservation, are solved numerically for a rectangular basin on an equatorial beta-plane. The model uses the Arakawa-C grid and leapfrogs in time. The boundaries may either be closed, i.e. coasts, or open. The gradient condition is applied at open boundaries. In addition, rivers may be specified at the coastal boundaries. The model ocean is forced by wind-stress and by freshwater influx from rivers.

The code has been documented (C-MMACS TR 9402) and some simulations carried out to study the impact of open boundary conditions and river influx. In *Figure 13*, a river on the northern boundary discharges 0.1 Sv, which is roughly the peak discharge of the Ganga-Brahmaputra system, into a basin which is open to the east and the south. The ocean is forced by a northward wind-stress of 1 dyne/sq.cm. A quasi-steady situation is found to settle after 60 days, and the thickness anomaly and velocity fields show that the river discharge has no discernible impact, thereafter. This study thus shows that the inflow from the Ganga-Brahmaputra system may not have a significant direct impact on the circulation in the Bay.

*(D Shankar, S R Shetye', * NIO)*



▲ *Fig. 13 Simulation of a 1-1/2 layer ocean model with an open eastern boundary to show the effect of inflow of 0.1 Sv*

Modelling the anticyclonic gyre in the Bay of Bengal

The wind-stress curl over the North Indian Ocean exhibits a distinct seasonal cycle caused by the monsoons. A linear, analytical model has been developed to isolate the contribution of the wind-stress curl to driving of the circulation in the Bay of Bengal.

Equations for vertical modes given by McCreary (Phil. Trans. R. Soc., 1981, *298A*, 603-635) have been simplified to describe the large-scale, sub-inertial response of a mode to a periodic wind-stress curl over the open-sea regime of an oceanic basin. The 'no normal geostrophic flow' condition is applied at the eastern boundary; this permits Ekman flow normal to the boundary, and thereby eliminates other forcing mechanisms.

The basin is forced by the observed wind-stress curl, which is decomposed into a temporal mean and annual and semi-annual harmonics. This yields a peak transport of about 3 Sv in the upper 1000 m of the western boundary current of the gyre; this is one-third the observed value.

This leads to the conclusion that the wind-stress curl is a significant forcing parameter, but it alone cannot account for the anticyclonic gyre; other mechanisms too must be invoked.

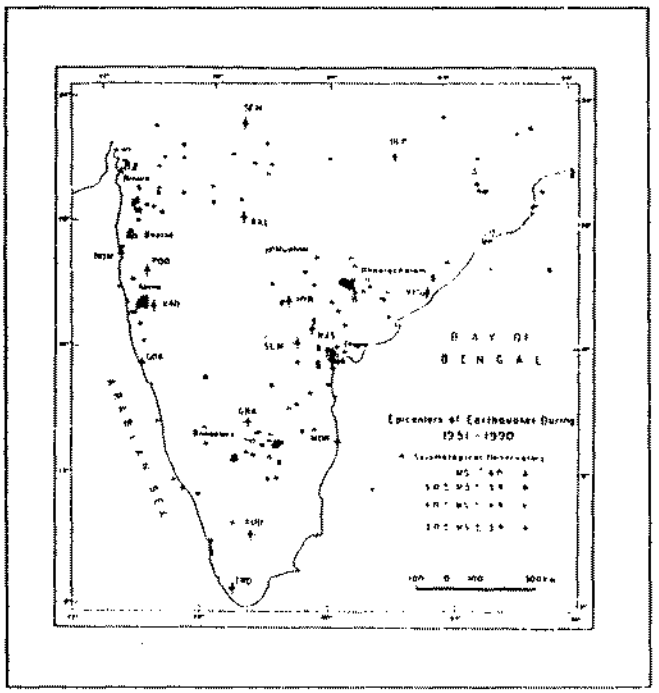
*(Shankar D, S R Shetye', * NIO)*

17.1D MODELLING FOR HAZARD QUANTIFICATION

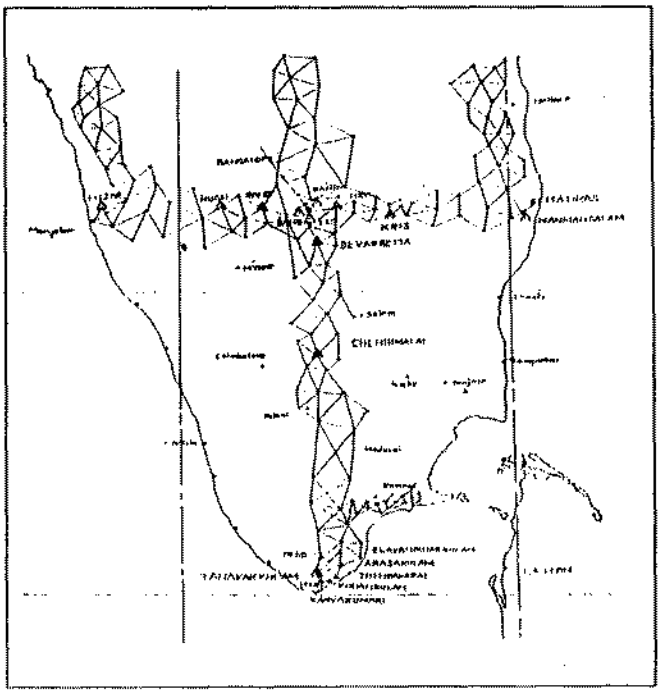
SOUTH INDIAN STRAIN MEASURING EXPERIMENT

The recent Latur earthquake clearly underlined the strong possibility of significant strains being accumulated in other parts of penisular India. Indeed, the distribution of seismicity in Southern India (*Figure 14*) itself calls attention to some of these areas although other areas not marked by earthquakes are not necessarily free from earthquake hazard as these apparently quiet zones may have escaped detection by the sparse and outdated seismic network. In any case, seismicity alone cannot determine the distribution of crustal deformation in an area required for the quantification of seismic hazard.

A feasibility experiment for measuring slow accumulating crustal strain in South India (SISME) was accordingly designed at C-MMACS using six high precision global positioning system (GPS) receivers. This experiment was carried out jointly in association with Prof. R. Bilham, University of Colorado, Mr. Dave Mencin, University Navstar Consor-



▲ *Fig. 14 Seismicity map of South India.*



▲ *Fig. 15 Plot showing the great triangulation survey network established by the Survey of India in the 19th century and the points occupied during 1994 - GPS Survey (Denoted by Δ mark).*

tium (UNAVCO), Boulder, Dr. Burgamann, Standford University, Survey of India (Southern region) and the Indian Institute of Science, Bangalore

The experiment involved an extensive field campaign (*Figure 15*) between March 24 and April 16, with the GTS point at the Indian Institute of Science serving as a fixed point synchronous with all measurements, where one receiver was operated for 22 hours each day throughout the campaign. Two other receivers were operated for 22 hours a day for 3 days at two ends of the Bangalore baseline. Three mobile teams travelled west, east and south of Bangalore, each covering 3 stations, each station being surveyed for 8 hours (9:00 - 17:00 IST) for 3 days. Concomitantly, the GPS processing software was implemented on the C-MMACS computing network and an intensive training programme carried out to establish in-house expertise for GPS data processing and analysis at C-MMACS. This is currently in progress and some of the initial results are quite exciting. Indeed, with the supercomputing facilities now available at C-MMACS, and excellent networking, particularly the ftp which permit easy access to delayed time refined orbital parameters available at Scripps, C-MMACS scientists have shown continued repeatability of base line determinations within a few mm. These facilities are also being exploited by C-MMACS scientists to establish longer intercontinental high precision baselines between Bangalore Canberra, Capetown and sites in Nepal and Japan.

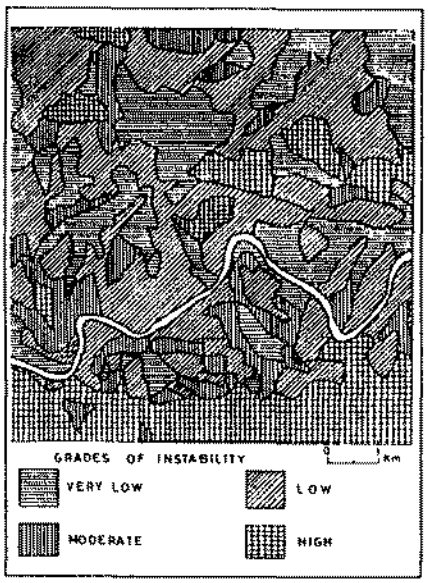
(V K Gaur, John Paul, P S Swathi, Sridevi Jade)

MODELLING STRESSES IN THE INDIAN LITHOSPHERE

A knowledge of the stress field distribution in continental areas, resulting from plate driving forces, is essential to studying its deformation and fragmentation, which in turn provides the basic perspective for management of its resource and hazard regimes. A numerical model of the Indian lithosphere has been accordingly developed at C-MMACS to study the simulated patterns of stress and deformation subject to various kinds of plate driving forces.

This preliminary model consists of a flat isotropic elastic plate of 100 km thickness, subjected to boundary forces slab pull, trench resistance; body forces such as ridge push and shear forces such as basal drag. These forces which are lithospheric age dependent have been analytically computed considering the geometry and the age distribution of the Indian plate. This finite element model showed development of compressive stresses in the central and northeast Indian ocean to the west of Sunda arc, in contrast to the tensile stresses in the neighbouring Central Sunda arc. This feature is attributed to the age of the subducting plate. The plate subducting near the Central Sunda arc is old, thick and dense and results in a larger slab pull than the young and thin plate subducting to the west of Sunda arc resulting in a weaker slab pull. Other simulations involving basal drag are in progress.

(V K Gaur, John Paul)



▲ *Fig. 16 Landslide risk mapping by regression analysis.*

PROGNOSTIC MODELLING OF LANDSLIDES

Statistical models in the field of slope stability in hilly regions have been developed in collaboration with Central Building Research Institute at Roorkee. The objective is to delineate areas according to their susceptibility to landslides. A software based on information theory and regression analysis has been developed to accomplish this. Functional inputs for the software are factors governing the slope instability and landslide phenomena. Some results classifying the region in different categories of instability are illustrated in *Figure 16*.

Towards the next step to model a particular landslide for determining the surface along which it is more susceptible to slip, a user-friendly interactive software has been developed to determine the global optimum factor of safety and the corresponding slip surface using a random search global optimisation algorithm. This algorithm automatically searches the critical slip surface of arbitrary shape for any given slope height, slope angle, lower and upper bounds of coordinates of the slip surface and geotechnical parameters of the slope material.

(Sridevi Jade)

STUDIES ON GENESIS AND INTENSIFICATION OF BAY OF BENGAL CYCLONES

Tropical cylones are among the most energetic phenomena in geophysics and in terms of devastation potential comparable only to earthquakes. Each year these intense vortices with winds of 100 km/hour or more visit the Indian coasts, especially the east coast, quite often causing heavy loss of life and property. Considering their devastation potential it is very important to be able to issue timely alerts and warnings in cyclone-prone areas.

A prime objective in the study and modelling of tropical cyclones is to be able to provide a 24-hour warning of the onset of cyclonic gales at coastal localities. However, not many warning centres can meet this objective. Over the eastern coast of India cyclogenesis often takes place within a few hundred kms of the coast. In addition, the Bay of Bengal cyclones quite often require very little intensification time, sometimes as low as twelve hours. This makes timely issue of warnings and alerts even more difficult. It is also now generally recognised that while the tropical cyclones exhibit a remarkable universality in their mature structure, there are individual as well as basinwise variations in properties like size, intensity and intensification time. It is also important to identify processes and parameters that govern the genesis and intensification of tropical cyclones. At C-MMACS an organised effort was initiated to look into the processes of genesis and intensification of Bay of Bengal disturbances with three major objectives: (a) to identify key parameters to improve early warning and prediction (b) to identify crucial parameters for observational programmes and (c) to supplement, by way of providing better parameterization and interpretation, results from large numerical prediction models. A series of experiments using an axisymmetric model and a mean thermodynamic state representative of the Bay of Bengal was conducted to determine the various factors that affect intensification with the goal of understanding genesis and intensification of Bay of Bengal disturbances to improve early warning and prediction. Earlier studies showed the existence of a scale selective intensification of tropical disturbances which was reported earlier (C-MMACS Annual Report 1992-93). Among vortices of size ranging from 100 to 450 km (radius), embedded in the same large scale condition, it is the vortex with size about 250 km that intensifies to the most severe system. One of the findings from the present series of experiments is that the process of diffusion, both horizontal and vertical, plays an important role in the scale selective intensification. While moderate diffusion does not alter the magnitude of intensification significantly, the scale selection is quite sensitive to the strength of diffusion. Interestingly, the three diffusion processes of momentum, moisture and heat do not affect the scale selection in the same fashion. The scale selection turns out to be a result of a combined effect of these three diffusion processes. Similarly, the vertical diffusion of momentum also plays a significant role in scale selective intensification. These results are summarized in section 4.4.2 below.

In other numerical experiments, attention was focused on the effect of sea surface temperature (SST) on the process of genesis and intensification. Although previous modelling studies have addressed and partially answered some of the straightforward questions regarding the role of air-sea interaction on cyclogenesis, there are several questions to which the answers are not obvious and can be useful. The specific questions that were addressed during this set of experiments are (a) whether the response of an incipient vortex to a given SST field depends on the strength of the vortex and (b)

how the response of the incipient vortex depends on the distribution of the SST field. It was found that the response of an incipient vortex depends strongly on the strength of incipient vortex. There results are summarized in section 4.4.1.

(P Goswami, R Koteshwar Rao)

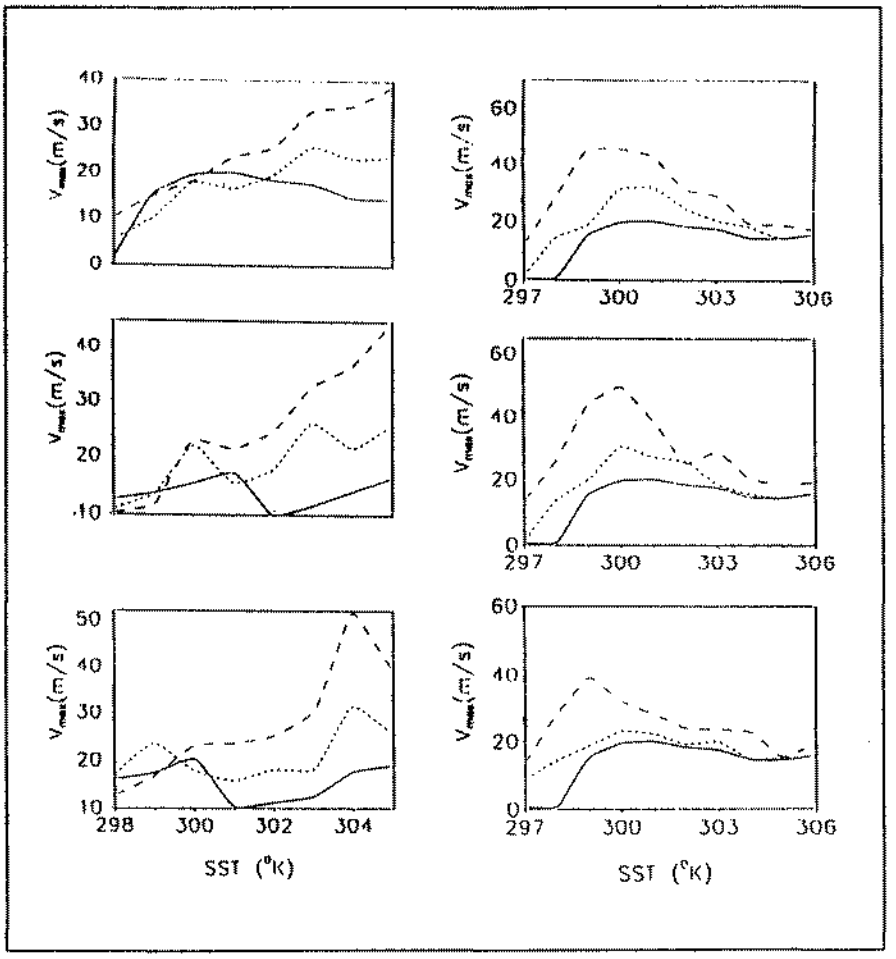
Role of SST Field in Organisation and Development of Bay of Bengal Disturbances

It is well-known that no tropical cyclone can form with SST below about 26 C. In addition studies of Hanson and Long (1985) emphasize the importance of SST gradients in inducing cyclogenesis. Numerical experiments were conducted on a model to study the response of tropical disturbances to the structure of underlying SST field for the Bay of Bengal region. The significant findings can be summarised as follows:

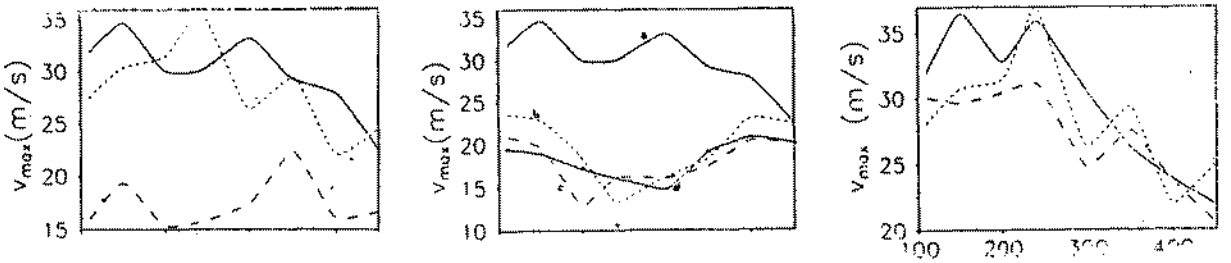
- For a uniform background SST field, the nature of the response depends on the strength of the incipient vortex. In *Figure 17*, the left panels represent the response (measured by maximum intensity attained) of a weak (solid line) moderate (small dash line) and strong (big dash line) incipient vortex to different mean SST field (in °K) for three different months May (top left panel), June (middle left) and September (bottom left). As can be seen from these figures, the response of a weak vortex is dramatically different from that for a strong vortex. Since for a strong vortex the initial flow itself has a certain amount of organization, this again shows the importance of organized motion in the process of cyclogenesis. In no case does intensification take place for SST less than 26° C.

- In the presence of an anomaly in the SST, the intensification is significantly enhanced. Here again the response depends on both the nature and the extent of the anomaly. The intensification is much higher for a nonuniform anomaly than for a uniform anomaly. Some of the results of the experiments with an anomaly in the SST field are shown the right panels of Figure 17. In each of the figures, the curves a,b and c represent, respectively, results for SST anomaly amplitude 0, 0.5 and 1.0°C imposed upon the background SST field. The SST anomaly was taken to be maximum at the centre, decaying outward with three different extents: 100 km (top, right) 250 km (middle, right) and 500 km (bottom,right). Comparison with the case with uniform SST field (left panels) show the importance of the spatial variation of the SST field in the intensification process.

- As can be seen from Figure 17 left panels, the intensification of Bay of Bengal disturbances exhibits a finite amplitude perturbation characteristics. For each month the weak and the moderate vortex fail to reach cyclonic strength. An incipient vortex of a minimum strength is required for



▲ *Fig. 17 Role of background SST in the development of a tropical disturbance. The left panels show the results for three strengths of the incipient vortex : weak (solid line), moderate (small dash line) and strong (big dash line). The results are shown for the months of May (top panel) July (middle panel) and September (bottom panel). The right panels show the response of a tropical disturbance to a nonuniform SST field. In each figure the x-axis represents the mean SST field, while the y-axis represents the maximum intensity attained. Three different values for the extent of the SST anomaly were used: 100 km (top) - 250 km (middle) and 500 km (bottom). In each figure on the right the curves a,b and c represent three different value of the amplitude of the SST anomaly, 0,0.5 and 1.5°C respectively.*



▲ *Fig. 18 Role of diffusion in scale selective intensification of tropical disturbances. The x-axis shows the incipient vortex size in kms and the y-axis shows the maximum tangential velocity attained (intensity) in m/s.* Left Panel: *Role of horizontal diffusion of momemtum (K_m), moisture (K_q) and heat (K_h) with $K_m = K_q = K_h = K$. The solid, small dash and large dash line represent respectively K = 0, K = 1000 m²/s and K = 5000 m²/s.* Middle Panel: *Effect of a single horizontal diffusion process. Curve a: zero diffusion, b: only momentum diffusion, c: only moisture diffusion, d: only heat diffusion.* Right Panel: *Effect of variation of strength of vertical diffusion on intensification. The solid, small dash and large dash lines represent, respectively, the cases of zero, moderate (10 m²/s) and high (50 m²/s) diffusion.*

attaining cyclonic intensity.

Mechanism of scale selective intensification of tropical disturbances

Figure 18 summarizes some of the results on effect of diffusion on scale selective intensification of Bay of Bengal disturbances. The top panel shows the effect of variation of the horizontal diffusion coefficient with equal value (K) for the coefficients of horizontal diffusion of momentum (K_m), heat (K_h) and moisture (K_q). The three curves a,b,c represent, respectively, the results for zero, moderate (K = 1000 m²/s) and high (K = 5000 m²/s) diffusion. It can be seen that the scale selection is less sharp for the zero diffusion case while for high diffusion there is no scale selection around r_0 = 250 km. The overall intensities are also much reduced by the increase in diffusion. The middle panel shows the effect of a single diffusion process while the other (horizontal) diffusion processes are switched off. The solid line represents the zero diffusion case for reference while the curves b,c and d represent, respectively, the cases with K_m = 1000 m²/s, K_q = 1000 m²/s and K_h = 1000 m²/s. It can be seen from these figures that a combination of the three diffusion processes is necessary to bring about the scale selection. The bottom panel shows the effect of vertical diffusion. Once again, the scale selection is less sharp for zero (solid line) or high (K_d = 50 m²/s, large dash line) vertical diffusion; the scale selection is the sharpest with moderate (K_d = 10 m²/s, small dash line) vertical diffusion.

These studies emphasize the importance of modelling of the diffusion process in numerical models of atmospheric and oceanic flows. While the gross features may be relatively insensitive to the process of diffusion, effects like scale selective intensification are quite sensitive to it. The adopted numerical model in this case uses upwind difference scheme which suffers from implicit diffusion. Investigation of impact of improved representation of the diffusion process (such as inclusion of grid-spacing dependence) is important and is in progress.

(P Goswami, R Koteshwar Rao)

17.1E MODELLING FOR DESIGN

COMPUTER-AIDED CHEMISTRY CONFORMATIONAL SPACE SAMPLING OF BIOLOGICALLY ACTIVE MOLECULES

Till quite recently drugs were "discovered" by testing extracts of natural products for potential therapeutic properties. Drugs were also "developed" by synthesising and empirically screening a large number of compounds for the desired biological activity. This was then followed by a systematic chemical modification of the lead compound in order to optimize its biological properties. This kind of drug development and/or discovery would often take upto 12 years and costs could run into millions of rupees. Naturally a need was felt for an optional method that would compress the research and development cycle and curtail the snowballing cost factor. The choice of computers in the chemist's quest for solving his problems is logical.

The area of computational chemistry, though it began with the development of programmes for molecular structure elucidation, now encompasses a wide class of applications ranging from organic synthesis to spectral analysis and molecular simulation of properties, amongst others.

A wide variety of molecules have been studied as modulators of diverse biological functions. The knowledge of their three-dimensional structures is of primary importance in understanding the mode of action. The existence of many local minima in the conformational energy space, which quickly becomes a combinatorial problem as the size of the system increases, has proved to be

intractable. Molecular recognition, which forms the basis of biological phenomena, involves the binding of a guest molecule to a receptor (host). For rational conformational design of a guest molecule, which exhibits specific functionalities, it becomes necessary to examine all energetically feasible conformations extensively and, above all, efficiently.

For flexible molecules, interest lies in generating all the significantly populated conformers. This can only be done by a systematic generation of all the likely conformers, which is again a challenging problem. Several groups around the world have been working on the conformer generating programmes. The approach of Prof. Osawa is being used in the joint project between C-MMACS and IICT on the conformer generating problem of cyclic peptides and peptidic-organic molecules. Two computer codes have been developed, namely, CONFLEX-AMBER for the study of cyclic peptides and a program for the molecular dynamics simulation. The former generates all the likely conformers and the latter is used for local perturbation with experimental constraints to generate all the chemically meaningful conformers. The programs have undergone extensive testing and now the production runs are being carried out for identified biologically active molecules with a view to carry out structure-activity studies.

(B Jagannadh, R P Thangavelu, * IICT)*

TURBOMACHINERY

Several of transition pieces required to build up the test facility for the development of a scaled scramjet combustor for the hyperplane (sponsored by DRDL) were modelled on the graphics workstation and the CAD geometry was developed. Appropriate models among these were chosen, fabricated and incorporated into the test rig.

A project titled "Experimental Studies of Rupture of Intake Cap" sponsored by DRDL, Hyderabad, in relation to the "AKASH" missile programme was taken up by NAL. For these studies, experiments were to be conducted at an inlet velocity of Mach 2.0. To obtain this velocity, a convergent-divergent nozzle was designed.

This nozzle was modelled on the IRIS graphics workstation in C-MMACS and CNC software was generated to machine this component. The machined supersonic nozzle was used to generate the required Mach number for tests and experiments.

(C I Haque, B B C Kumar*, * NAL)*

MODELLING OF MACROSEGREGATION DURING SOLIDIFICATION OF BINARY ALLOYS

Binary alloys, specially those having long range freezing characteristics, show considerable segregation of solutes during solidification. Understanding this complex phenomenon requires modelling of the transient multiphase heat and mass transfer and fluid flow. In view of the importance of segregation in predicting inhomogeneities produced during solidification, a project has been initiated at C-MMACS in colloboration with scientists from National Metallugical Laboratory, Jamshedpur.

A macrosegregation model has been formulated taking into account the latent heat release, the flow in the mushy zone and thermosolutal convection. The solute balance equation is coupled with this model along with the Scheils' equation to determine the extent of segregation. A computer program has been prepared to solve the above system of governing using finite-difference methods.

(M S Phanikumar, Chattopadhyay, * NML)*

COMPUTER AIDED DESIGN OF TUNNELS

Preliminary design of supports for tunnels is made by empirical methods because the behaviour of surrounding rock mass is difficult to predict due to complexity of rock mass like anisotropy and heterogeneity. Hence, the instrumentation in tunnels is necessary and it guides the field engineer about the face advancement. In order to characterise the behaviour of rock mass, load cells and closure meters have to be installed at different locations along the face advance and monitored periodically for a long time to assess the stability of the tunnel. The field data of load cells and closure from five different tunnelling projects of the Himalayan region were collected. This data was processed by means of statistical analysis and the necessary software was developed for this purpose. The drawn curves for load verses time and closure verses time were also extrapolated to study for long term stability of the tunnels. An inverse analysis is to be followed up by the theory of elasticity and elastoplasticity to determine the state of stress surrounding the rock mass. The stress state is helpful in determining the stability of rock mass and the effect of overburden of the rock mass. The software for back analysis was also developed to predict the characteristics of the stability of the long-term solutions.

(A K Dube, V V R Prasad, A K Soni*, A Swarup*, B Sudhakar, N K Indira)*

17.1F OTHER MODELLING AREAS

DETERMINISTIC CHAOS STUDIES

Interpolation and extrapolation of attractors

This study was aimed at determining whether a system C derived from two chaotic systems C_1 and C_2 as given below

$$C = \lambda C_1 + (1 - \lambda) C_2,\ 0 \leq \lambda \leq 1$$

would also be a chaotic system. C_1 and C_2 were taken to be the Rossler

and Lorenz systems respectively. Then $\lambda = 0$ and $\lambda = 1$ yield Lorenz and Rossler systems. It was found that it is possible to obtain attractors for all values λ of by adjusting the Lorenz and Rossler parameters suitably, and that the restriction $0 \leq \lambda \leq 1$ was not necessary. Attractors obtained for $\lambda < 0$ can be called contra-Rossler infra-Lorenz and those for $\lambda > 1$ contra-Lorenz ultra-Rossler. Attractors obtained for $0 \leq \lambda \leq 1$ constitute interpolation and the rest extrapolation. Another conclusion is that for any value of λ including 0 and 1 many very different attractors can be obtained by choosing the other parameters over a wide range.

*(P S Moharir', N K Indira * NGRI)*

Compound chaos

There are innumerable instances of modelling physical systems wherein some physical phenomena are neglected as of negligible or subsidiary importance. The studies reported here indicate that this practice may not be justifiable. Parameters of one chaotic system are modulated according to the variables of another chaotic system. These two systems are called compoundee and compounder systems respectively and the resultant system the compound system. Lorenz and Rossler systems were used as compoundee and compounder systems. Compound system was shown to be chaotic when the compoundee and compounder systems were both chaotic, the former a limit cycle and latter an attractor, or the latter a limit cycle and former attractor. When the compoundee and compounder systems were both limit cycles, it is possible that the compound system is also a limit cycle or an attractor, depending on the modulating mechanism and its parameters. The most interesting observation was that the compoundee system may be a focus and yet a compounder limit cycle or attractor may yield a compound attractor. The phenomenon of compound chaos throws new light on the behaviour of interacting nonlinear systems. Chaos means sensitivity to initial conditions, multiplicity of attractors within the same system, sensitivity to control parameters, including fractal transitions among various attractors with different characteristics etc. All these considerations are compounded when compound chaos is possible. The compound system would have sensitivity to control parameters of the compoundee system, the compounder system or the compounding mechanism. Thus the compound chaotic systems are 'chaoticer'. This means that modelling and estimation, wherein possible compounder systems are ignored, may be misleading.

*(P S Moharir', N K Indira * NGRI)*

STUDIES IN TIME-SERIES METHODS

The 'tri' algorithm

One of the important problems in the use of time-series models is the adequacy of parameter estimation. In the present study the problem of estimating the order of auto-regressive time series was taken up. There are methods based on minimizing criteria such as the final prediction error, description length and information criterion. These methods are not satisfactory. For example for the true orders of 3, 5 and 7, the estimated order would be correct only about 61%, 46.5% and 34% times. This cannot be regarded as too satisfactory. An experiment was performed to test whether the autoregressive order can be estimated directly from the reflection coefficients obtained through Durbin's algorithm. Different norms of the reflection coefficient series were combined into a weighted sum for the purpose. It was shown that the estimator can do well for any particular true order but not for a range of true orders. This brings out the inadequacy of drawing conclusions on the basis of a large number of models of a fixed order. Subsequently an algorithm named 'tri' (Sanskrit for three) was developed. It uses three orders which give the three lowest values for the conventional criteria viz., final prediction error etc. and three statistics of order one, two and three and obtains the order estimate in terms of a weighted sum of these six. The weights which improve the estimator performance for a range of true orders from three to seven have been obtained.

(N K Indira)

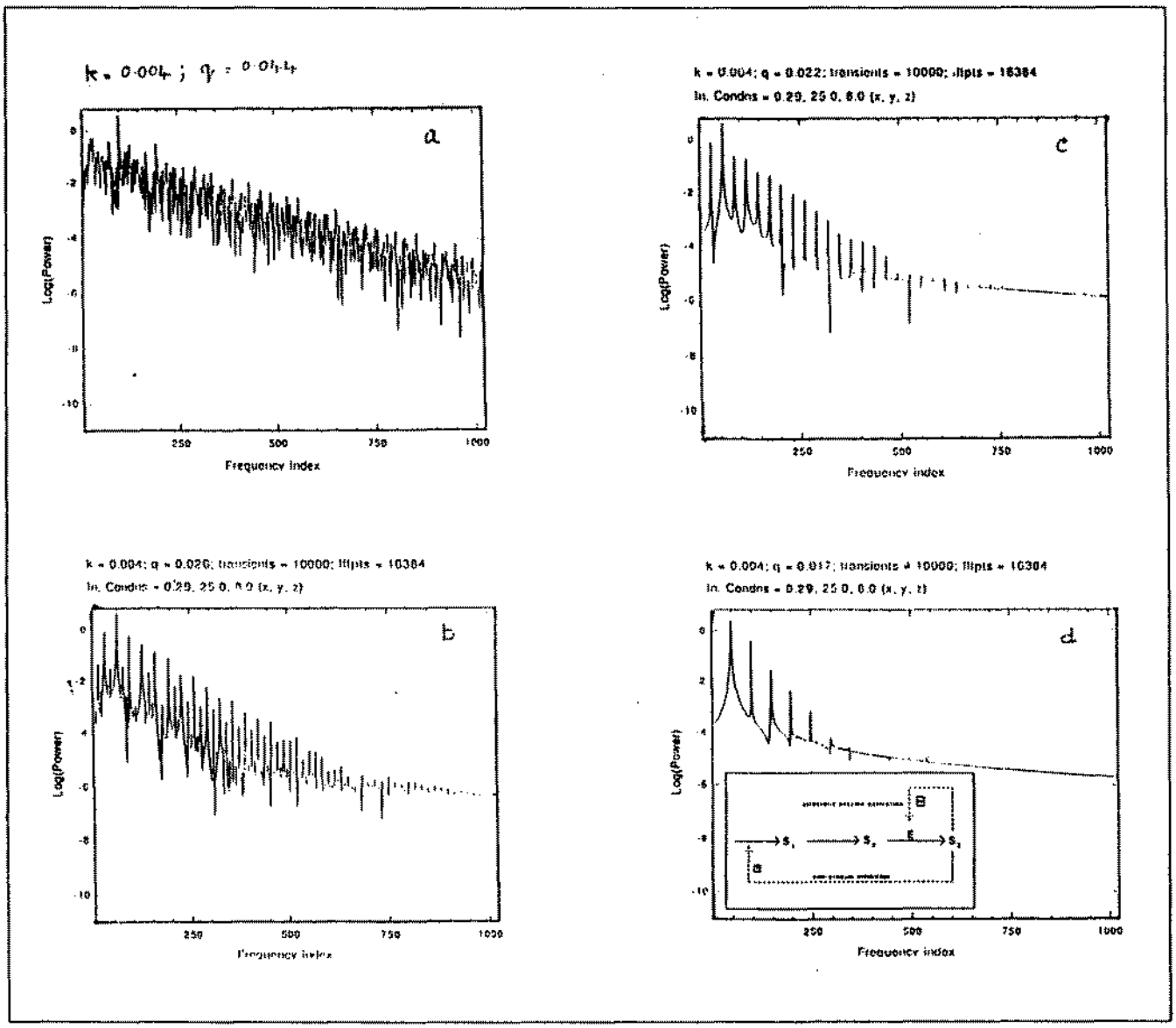
Parametric time-frequency distributions

Simultaneous localization in time and frequency domains is an aim of many descriptions. One method of studying it is provided by the time-frequency distributions. When it is integrated with respect to time, it gives energy distribution in frequency and vice versa. There are many time-frequency distributions. Many of them can be given a unified treatment. Time-frequency distribution can be calculated starting from the signal or its spectrum. The latter possibility has been used to define parametric time-frequency distributions, because there are many methods to estimate the spectrum without Fourier analysis. In the work completed the spectrum used is the autoregressive spectrum. The autoregressive order can be used as a parameter to generate a family of time-frequency distributions. This gives a desirable means of extracting information from the time-frequency distributions. The correct order of the time-series is then not a very essential notion, the order becoming a control parameter for filtering of and super-resolution in the time-frequency distributions.

(N K Indira)

BIFURCATIONS AND CHAOS IN A MODEL BIOCHEMICAL REACTION PATHWAY

It is becoming increasingly evident that chaotic processes are more generic and ubiquitous in biological systems than expected from the age-old concept of homeostasis in biology. Biological systems, being nonlinear and maintained far away from equilibrium, achieve the apparent homeostasis through a combination



▲ *Fig. 19 Power spectrum plots of the S3-time series; the k value is fixed at 0.004 and q is varied between: (a) q = 0.044, chaotic oscillation; (b) q = 0.026, period-two oscillation, and (d) q=0.017, limit cycle. Given in the inset of (d) is the schematic of the metabolic pathway being modelled.*

of system parameters that yield a state that persists. Such a condition may be a steady equilibrium, a periodic oscillation or seemingly irregular oscillations.

The most common type of controls observed in biochemical reactions are through feedback processes of the positive and negative kinds. A model of metabolic pathway with coupled positive and negative feedback processes has been investigated in a joint project of C-MMACS & CCMB. These feedbacks model the common processes of genetic repression (end-product inhibition) and allosteric enzyme activation (see schematic in *Figure 19*).

The work during the earlier years numerically established different types of behaviours for different values of the two system parameters governing the degradation rates of substrates S1 (=k) and S3 (=q). The results showed clearly that the period-doubling route to chaos was exhibited by the system. A parameteric study led to delineation of regions of steady states, limit cycles and period doubled chaos; the existence of reverse bifurcations was also shown. It becomes possible through such parametric mappings to identify ranges of pathological and normal behaviours as a function of the control parameters.

The work during the present year concentrated on characterising the chaotic oscillations and identifying the region in parameter space that corresponds to reverse bifurcations. Both manifest for appropriate ranges of low values of k and q. A step-by-step scan of this region of parameter space using power spectrum analysis along with phase plots and time series plots were used to establish that as values of k and q are continu-

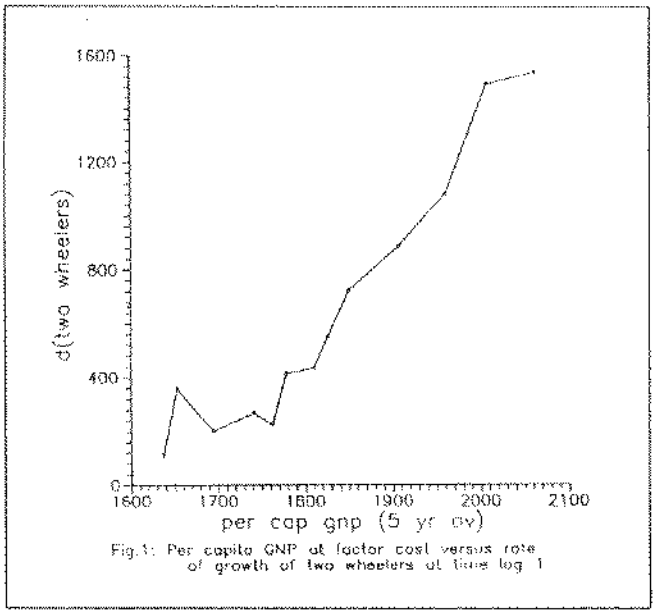
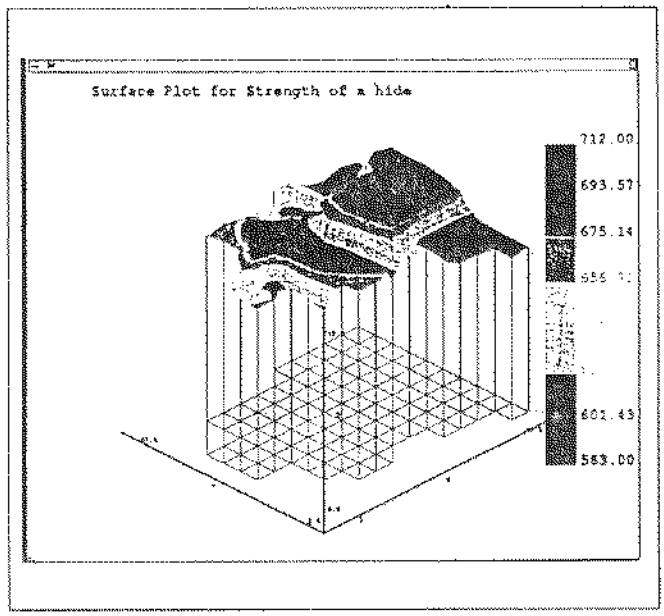


Fig.1: Per capita GNP at factor cost versus rate of growth of two wheelers at time lag 1

▲ *Fig. 20 Per capita GNP at factor cost versus rate of growth of two wheelers at time lag breakdown.*



▲ *Fig. 21 Surface plot for strength of a leather.*

ously reduced, the system evolves back towards limit cycles. *Figure 19* gives examples of this reversal sequence in terms of power spectrum plots and the period-halving phenomenon is illustrated. An attempt is being made to map, in detail, the transition surface in k-q space across which this reverse bifurcation takes place. This work is, however, being slowed down by the fact that the ODEs that model the system show extreme stiffness in this region of parameter space.

Liapunov exponents and fractal dimensions for (k,q) values that correspond to chaotic oscillations are also being computed. These numbers can be used to characterise chaos apart from the visual aids of phase plots and time series plots.

*(T R Krishna Mohan, Somdatta Sinha', * CCMB)*

TRANSPORT SECTOR

In an earlier study, long term trends in road, rail and air transport were examined (C-MMCS Annual Report 1992-93, TM CM 9301, CM TR 9401). The rate of growth of motorised two-wheelers is exceptionally large, about 17% per year over four decades. Since such high growth rates lead to acute problems in traffic control, pollution, road safety etc., it was decided to explore the relationship of this growth with other factors. Various indicators of growth of purchasing power were considered. *Figure 20* shows how the annual increase in the two-wheeler population is related to the five year average of per capita gross national product with the lag of one year. Clearly, the increase in the size of middle class, as indicated by the growth of purchasing power, increasing urbanisation and increasing mobility requirements of individuals for personal needs combine to result in large growth rates. What the figure seems to show is the net effect.

(N K Indira)

DETERMINATION OF MATERIAL PROPERTIES OF ROAD PAVEMENT COMPONENT LAYERS FROM SURFACE MEASUREMENTS - DEVELOPMENT OF MATHEMATICAL MODEL AND SOFTWARE

Determination of subsurface structure of road pavements is of considerable importance as it leads to structural capacity of in-service pavements and maintenance requirements. It is proposed to develop a mathematical model and indigenous software to determine material properties of different layers of the pavement using the deflection data. The problem of determining deflections of a multilayer pavement of known properties and layer depths for a given load is called the direct problem. The present problem of inferring properties from the given load and deflections is an inverse problem which requires special techniques. A joint exercise between C-MMACS and CRRI has been initiated to review and to develop multilayered models for road systems and to assess their applicability under Indian conditions. A mathematical model for the direct problem of determination of stresses and strains and displacements at any point in an ideally elastic multi layered road system, in response to surface loads, has been developed. A detailed review of the existing literature has been carried out and simulation software has been written. It is being evaluated for the existing data. The next step is to formulate an inverse problem to determine the material properties of the multilayered system which is presently being studied.

*(Sridevi Jade, K R Sudarshan, John Paul, P K Nanda', * CRRI)*

STRENGTH CONTOURS OF LEATHER SURFACES

Central Leather Research Institute (CLRI) is interested in developing a methodology to display strength variation in leather with a view to have more effective use of available leather in footwear and to obtain resulting increase in the value of production. C-MMACS is assisting CLRI in a study of strength contours of leather surfaces with the objectives of developing methodologies and appropriate software for contour mapping the physical strength of leather surfaces and facilitating better material optimisation in leather product industry. C-MMACS has developed a computer graphics package to display the strength contours of leather. *Figure 21* shows one typical strength profile.

(T Ramasami, B Lokanddam*, M I James, * CLRI)*

MOTION OF AN ARBITRARY BODY NEAR A PLANE RIGID WALL

The motion of an arbitrary body near a plane rigid wall in viscous flow was taken up as a joint project between RRL, Trivandrum and C-MMACS as it has applications to metal matrix composites. The aim of the project was to develop equations for the resistance coefficients for the torques and forces acting on a rigid body moving near a plane rigid wall. An initial survey of available methods for solving similar problems showed that the method of Hsu and Ganatos (1989) is best suited. Initial studies suggest errors in their analysis. This approach after corrections is being applied to a new class of bodies.

(S Savithri, T R Ramamohan*, M I James, * RRL (Tri))*

17.2 COMPUTING RESOURCE DEVELOPMENT

The reporting year culminated with the introduction of a state-of-art supercomputer among the C-MMACS computing facilities. The resulting qualitative change in computing power is beginning to add a new dimension to scientific computing in CSIR.

The process leading to the above change involved extensive technical evaluation, fulfilment of procurement requirements and site preparation work for the large compute server and associated systems.

Table 1
C-MMACS Supercomputer Configuration

System	*Convex C3820*		
CPU	Two 64-bit integrated scalar and vector processors		
	Gallium Arsenide (GaAs) technology		
Memory	512 Mbytes		
Disk	34 Gbytes (IPI-2 disk array)		
Performance	LINPACK	100 x 100 DP	62 Mflops
		1000 x 1000 DP	222 Mflops
	PEAK	64-bit	240 Mflops
		32-bit	480 Mflops
Operating System	ConvexOS	(UNIX 4.3 BSD)	
Compilers	Fortran, C, C++, application compiler *(with automatic parallelisation and vectorisation)*		
Other Software	VAX user environment *(COVUE)*		
	Vector libraries *(VECLIB)*		
	Application visualisation system *(AVS)*		

17.2A TECHNICAL EVALUATION OF HIGH-PERFORMANCE COMPUTER SYSTEMS

Technical evaluation of large compute-servers (LCS) and graphics workstations through specially designed benchmark suites was carried out during April-July 1993. The benchmark suite for LCS contained a set of 10 programs with 25 tests, each varying in the CPU time required, memory usage and I/O requirements. The programmes were in computational fluid dynamics, computational chemistry, structural analysis and were contributed by users in C-MMACS and CSIR laboratories. Each test was given a weightage based on the nature and application area of the program, the resource requirements of the test and the frequency of its usage at C-MMACS. The weighted harmonic mean of the relative performance on the individual tests was defined as the performance index of a computer system and the selected configuration ranked first among the benchmarked compute-servers. The multiuser performance was tested using a throughput run that contained 9 of the 25 tests. These benchmark tests revealed that the RISC based servers did not have the kind

of I/O bandwidth required to carry out computations using large application programs that need a balanced CPU and I/O performance. The benchmark suite for graphics workstations included a mix of graphics and number crunching programs. The outcome of the graphics benchmark tests is that, not surprisingly, the actual performance of a workstation is significantly lower than the theoretical peak performance.

Based on the recommendations of the technical evaluation committee in August 1993, orders were placed for the supply of (a) CONVEX C3820 Supercomputer, (b) DEC Alpha 3000 model 800 AXP workstations, (c) Control Data CD9140 (Indigo 2) workstations and (d) Ungermann Bass Router with FDDI network equipment.

(R P Thangavelu, H Krishnamurthy, K S Yajnik, * IISc)*

17.2B CONVEX SUPER-COMPUTER

The CONVEX C3820 computer system arrived in January 1994, installation was completed in February 1994 and operations started immediately. The existing local area network was expanded to link the CONVEX C3820 and the terminal servers. The system is currently under acceptance. This system is an air-cooled vector supercomputer which is unique in its use of advanced technology gallium arsenide (GaAs) gate arrays and is rated at 240 Mflops on 64-bit and 480 Mflops on 32-bit computations (peak). The configuration details are given in *Table 1*. Several application programs have been ported on C3820 and they were found to require very little changes in the source code as the Convex OS is UNIX based and the compilers are compatible with many other compilers. Also, the automatic parallelisation, vectorisation and optimisation capabilities of CONVEX compilers are extremely helpful in utilising the computing power of this system.

The high-performance graphics workstations and router with FDDI network are expected to be installed in June/July 1994.

(R P Thangavelu, A Saldanha, H Krishnamurthy, K S Yajnik, * IISc)*

INTERNET CONNECTIVITY

With the commissioning of the 4-wire leased data circuit between C-MMACS and ERNET backbone at IISc, C-MMACS became the first CSIR centre to establish Internet connectivity through ERNET. This connection provides a direct access to computer systems connected on Internet across the world. With the restructuring of the local area network within C-MMACS, and installation of a network router, it will become possible for a user who has access to internet elsewhere in India to use the CONVEX Supercomputer and high-performance workstations at C-MMACS in near future. The internet facility is being widely used by C-MMACS scientists to obtain atmospheric, oceanic and other geophysical data and public domain software available on Internet.

(Maya Rai, R P Thangavelu)

OTHER FACILITIES

Site preparation

The site preparation work for the supercomputer and associated systems was completed during 1993-94.

(Antony Saldhana, R P Thangavelu, M D Raghunath, K S Yajnik)

Databases

Global database on annual and monthly averages of sea levels has been obtained from Permanent Service for Mean Sea Level (PSMSL).

C-MMACS published last year an updated report TM CM 9301 on its study of the growth of the Indian transport sector. The database used in this study is now available (CM TR 9401).

(N K Indira, T R Krishnamohan)

Utilisation of facilities

The COSMOS supermini computer continued its role as a workhorse in 1993-94. Table 2 shows its utilisation in comparison with previous years.

Table 2
COSMOS utilisation (CPU hrs)

	Main processor	i860 satellite processor
1992-93	1892	2348
1993-94	3216	2493