INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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SMR/534-23

ICTP/WMO WORKSHOP ON EXTRA-TROPICAL AND TROPICAL
LIMITED AREA MODELLING
22 October - 3 November1990

"Specific Problems of LAM/Meso-Scale"
I.

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Components of a limited area NWP system

1. Forecast model

- Numerics — Usually finite differencing
  Howevers spectral models are also being used
- Time differencing — Usually semi implicit
  Quasi-Lagrangian methods are increasingly being used
- Parametrization of physical processes
  Cumulus convection
  Large scale condensation
  Surface fluxes of momentum, heat and moisture
  Horizontal and vertical diffusion
  Radiative transfer
  Heat balance at surface
  Diagnostic clouds
  Shallow convection
  ground hydrology

- Lateral boundaries

A number of options have been used

Fixed boundaries
Absolute values } From global model
Tendency values } or analyses (perfect boundaries)

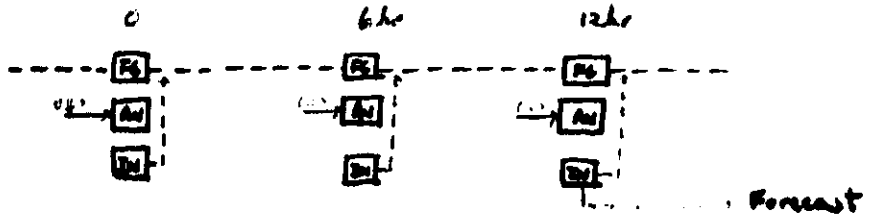
The specification of lateral boundaries is mathematically ill posed. Can lead to

- Spurious divergence
- Rapidly corrupt solution in the interior domain in some cases
- Problems can be more severe in tropics where there is a strong interaction between boundaries and physical processes such as convection and radiation

Possible solution to problems caused by lateral boundary condition

- Use of variable resolution global (or hemispheric) finite element models
- Use of variable resolution global spectral model with increased resolution in region of interest

2. Initial conditions



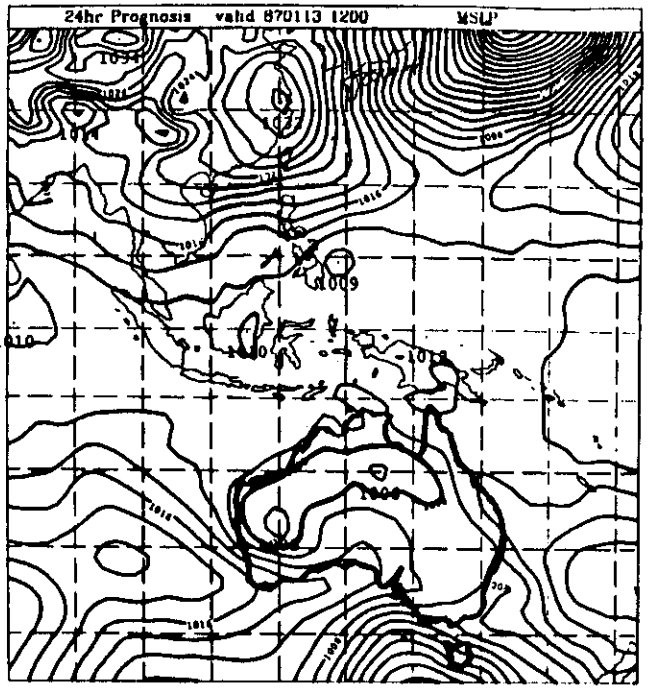
Analysis – Usually optimum interpolation
Univariate or multivariate

Data assimilation – Usually 6 hourly or continuous

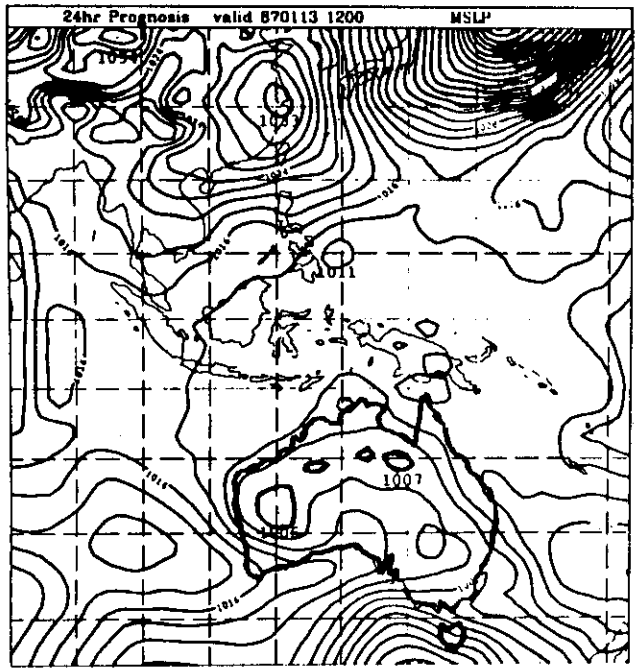
** Status for LAM not clear **

Initialization – Essential to control gravity wave oscillations.
Vertical mode initialization (VMI) or
Normal mode initialization (NMI)

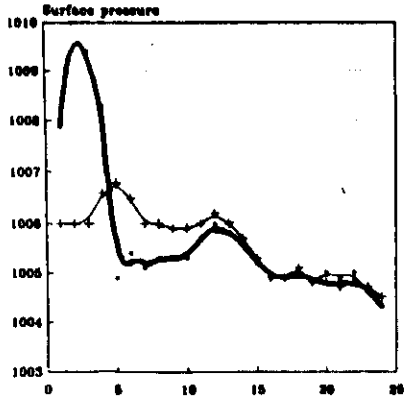
Both are effective in controlling noise
However can have harmful effect in tropics

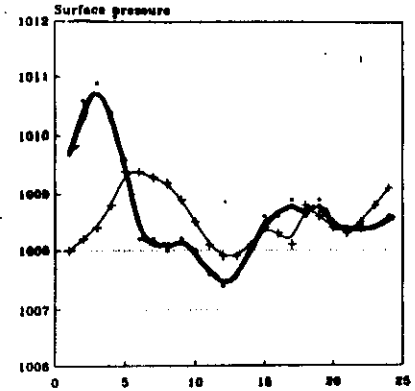


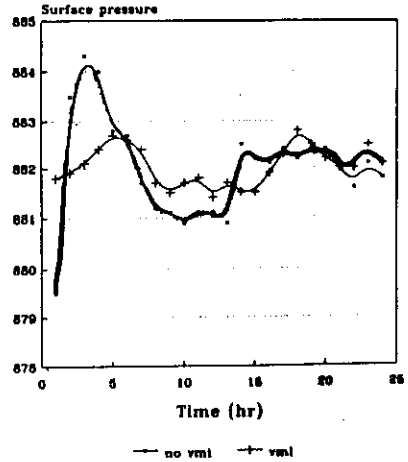
Fixed boundaries



Bdry forcing from global model



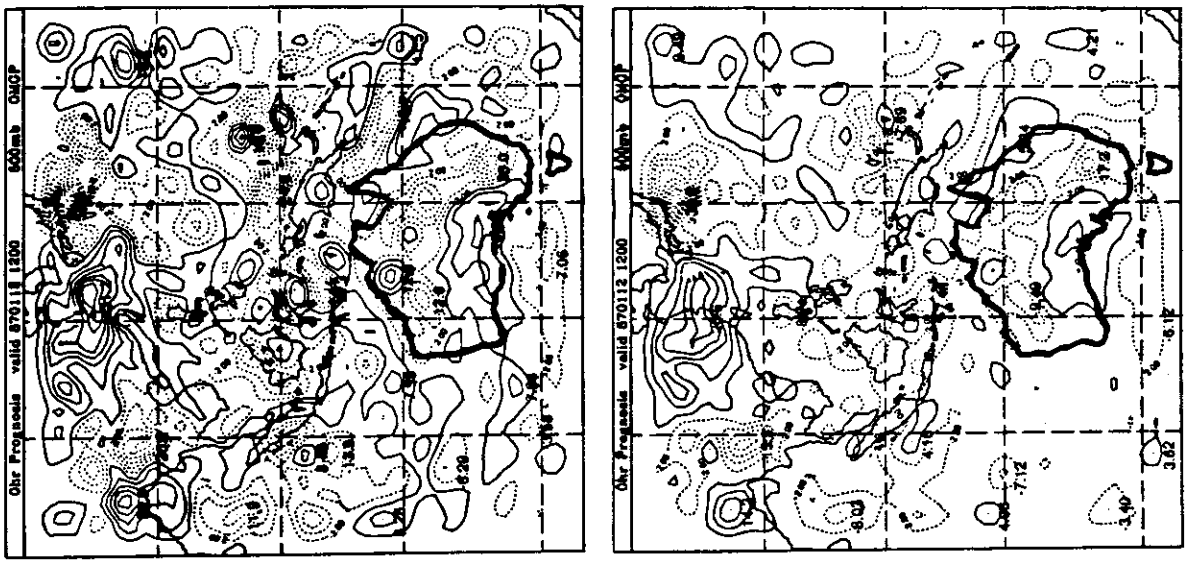




w field in BMRC TLAM

Before VMI

After VMI



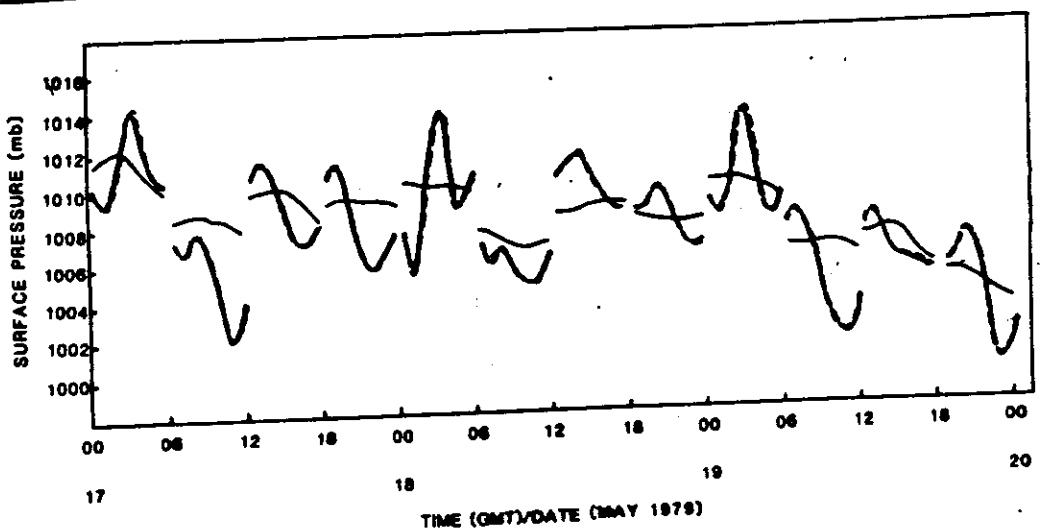


FIG. 2. Timestep-by-timestep variation in surface pressure (mb) at a selected grid point for twelve 6 h prognoses from the GRAD (dotted line) and INIT (solid line) sequences.

BMRC LIMITED AREA DATA ASSIMILATION SYSTEM - RASP

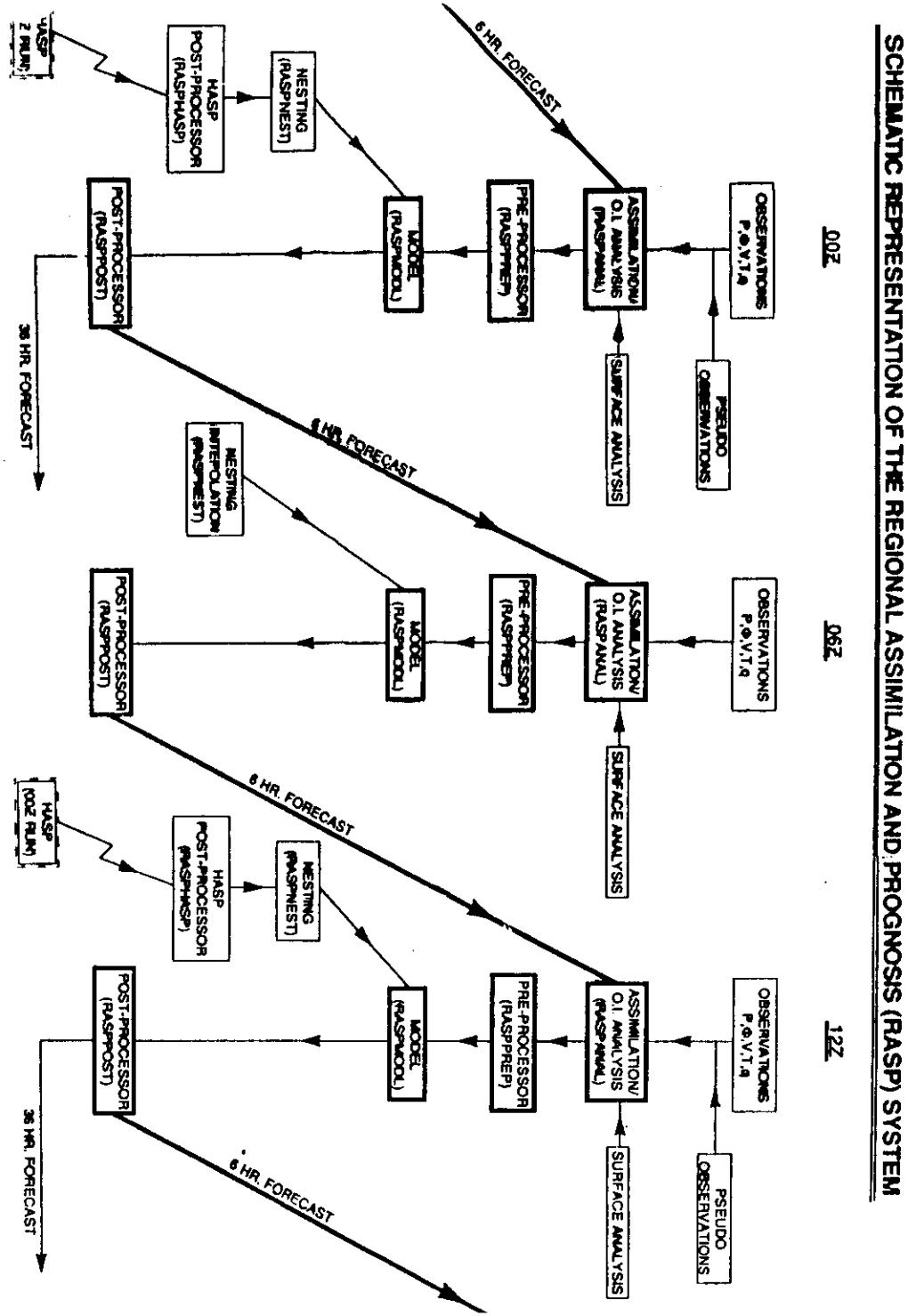
(1) THE GRID IS PARAMETERISED FOR HORIZONTAL AND VERTICAL RESOLUTION AND GEOGRAPHICAL AREA

(2) INCREMENTS FROM A CYCLED FORECAST ARE ANALYSED ON PRESSURE SURFACES

(3) FIELDS ANALYSED ARE MSLP, GEOPOTENTIAL HEIGHT, WIND COMPONENTS, TEMPERATURE AND DEWPOINT DEPRESSION

(4) ALL OBSERVATIONAL DATA IS HELD IN CORE FOR THE DURATION OF THE ANALYSIS OF THAT PARAMETER

(5) UNIVARIATE ANALYSES ARE PREPARED USING STATISTICAL INTERPOLATION OR THE SCM



SCHEMATIC REPRESENTATION OF THE REGIONAL ASSIMILATION AND PROGNOSIS (RASP) SYSTEM

(6) DATA CHECKING IS PERFORMED BOTH AGAINST THE BACKGROUND FIELD AND AGAINST NEAR NEIGHBOURS

(7) SI ANALYSIS OF WIND COMPONENTS IS EXPLICITLY 3-DIMENSIONAL
SI ANALYSIS OF MSLP AND GEOPOTENTIAL IS TWO-DIMENSIONAL

(8) GEOPOTENTIAL AND WIND INCREMENT FIELDS MAY BE COUPLED VARIATIONALLY, WITH LATITUDINALLY VARYING COUPLING FACTOR

(9) ANALYSES OF SURFACE TEMPERATURE AND DEWPOINT MAY BE MERGED WITH TROPOSPHERIC ANALYSES

(10) ANALYSIS INCREMENTS ON PRESSURE SURFACES ARE INTERPOLATED TO MODEL SIGMA SURFACES TO INCREMENT THE FIRST-GUESS FIELDS

(11) OPTION FOR EITHER DIVERGENT OR NON-DIVERGENT WIND INCREMENTS TO BE INTERPOLATED FROM PRESSURE TO SIGMA COORDINATES

REFERENCE: MILLS AND SEAMAN, 1990: THE BMRC LIMITED AREA DATA ASSIMILATION SYSTEM. MON.WEA.REV., 118, 1217-1237.

OPERATIONAL CONFIGURATION

(1) 150 KM HORIZONTAL GRID SPACING

(2) 11 ANALYSIS PRESSURE LEVELS

(1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 50 MB)

(3) 15 PREDICTION MODEL LEVELS

(.05,.10,.15,.20,.26,.30,.40,.50,.60,.70,.78,.85,.90,.95,.98)

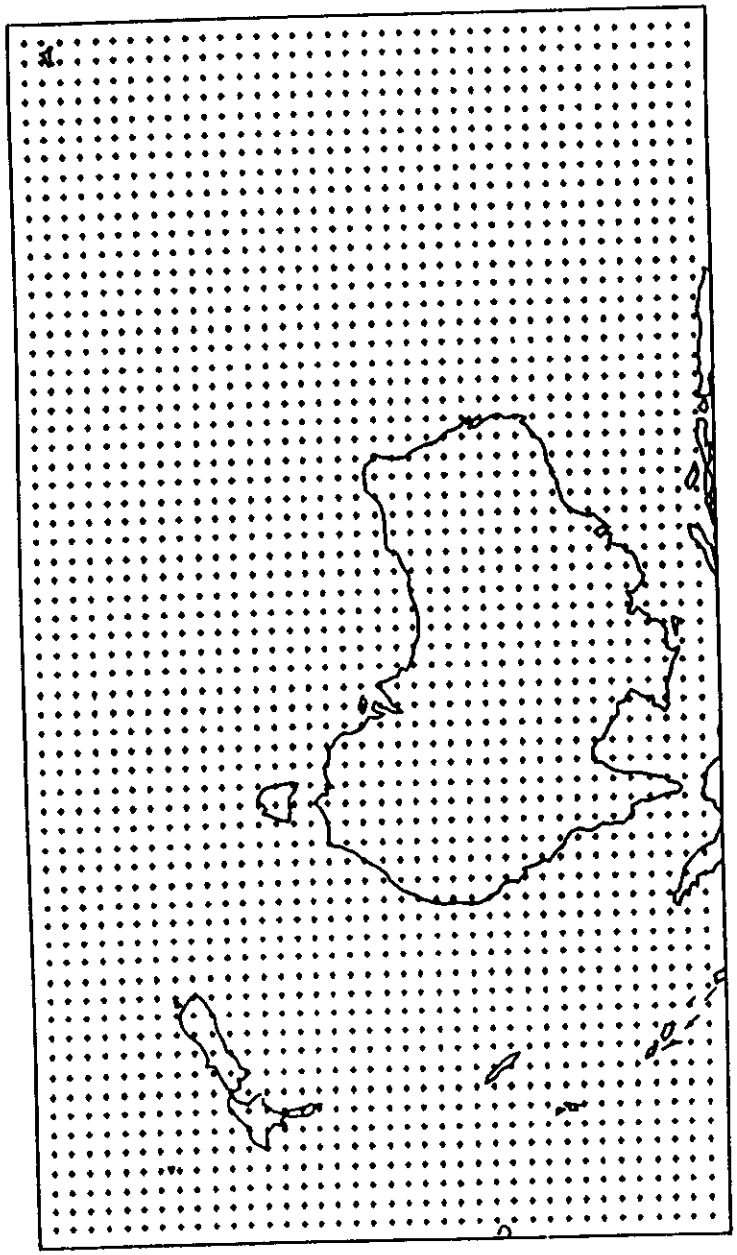
(4) MASS/WIND INCREMENTS VARIATIONALLY COUPLED, LINEAR DECOUPLING FROM 30°S TO 15°S.

(5) SURFACE TEMPERATURE AND DEWPOINT ANALYSES MERGED.

(6) INCREMENTAL ASSIMILATION USING NON-DIVERGENT WIND INCREMENTS.

TABLE 1. Principal features of the BMRC limited area model.

Model Feature	Description
Horizontal resolution	Variable, typically between 30 km and 250 km.
Vertical resolution	Sigma coordinate, variable number of levels, usually between 9 and 15.
Temporal differencing	Semi-implicit
Spatial differencing	Arakawa C-grid Flux form of momentum equations with second order differencing on advective terms, or fourth order advective form.
Analysis scheme	Successive correction method and variational blending of scalar and gradient information.
Initialization	Vertical normal mode initialization.
Parameterization of physical processes	1. Stability dependent boundary layer with eddy diffusivities functions of bulk Richardson number. 2. Vertical diffusion above surface layer based on mixing length hypothesis. 3. Surface heat budget with prognostic equation for surface temperature. 4. Large-scale precipitation. 5. Modified Kuo convection. 6. Horizontal diffusion.



REGIONAL ASSIMILATION AND PROGNOSIS (RASP) SYSTEM

65 X 40 HORIZONTAL GRID

FIGURE 2

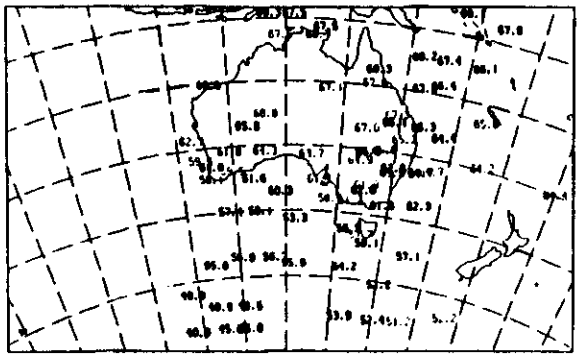
Table 1. Average number of observations from different observation vehicles at each of the four analysis times over the six day assimilation period. OPER refers to operational data out-off, LATE to an essentially infinite data cut-off. SING(L) and SING(H) refer to single-level winds at 850 (low) and 200hPa (high).

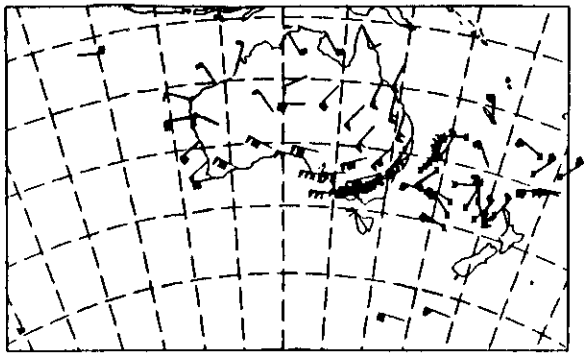
Obs Type	0500UTC		1100UTC		1700UTC		2300UTC	
	OPER	LATE	OPER	LATE	OPER	LATE	OPER	LATE
SYNOP	280	203	203	177	213	171	294	219
SHIP	33	38	[illegible]	[illegible]	25	36	[illegible]	[illegible]
R/SONDE	1	1	11	11	1	1	28	36
TOVS	58	160	[illegible]	[illegible]	82	87	[illegible]	[illegible]
RAWIN	42	42	40	49	44	44	46	55
SING(L)	169	168	[illegible]	[illegible]	110	110	[illegible]	[illegible]
SING(H)	112	107	[illegible]	[illegible]	88	88	[illegible]	[illegible]

OPERATIONAL DATA
00Z 12 MAR 1989

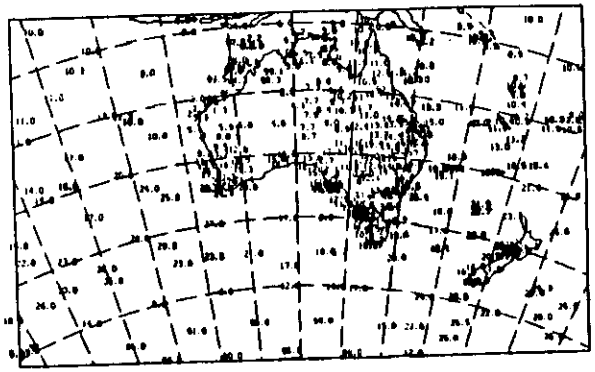
BUOYS

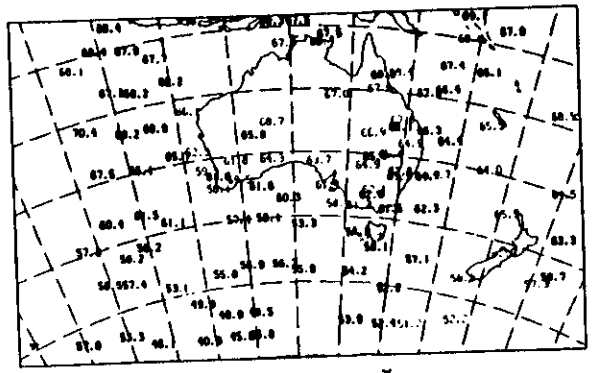
SPECTACULAR

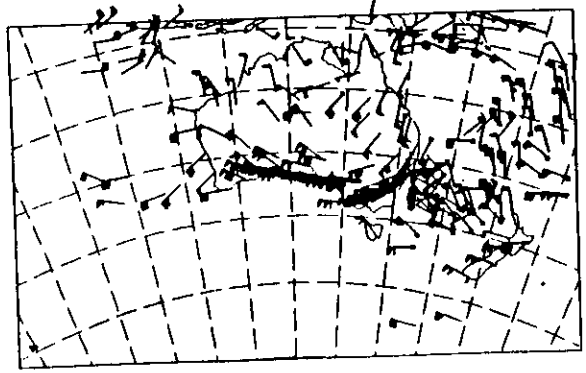




"LATE" DATA DISTRIBUTION.





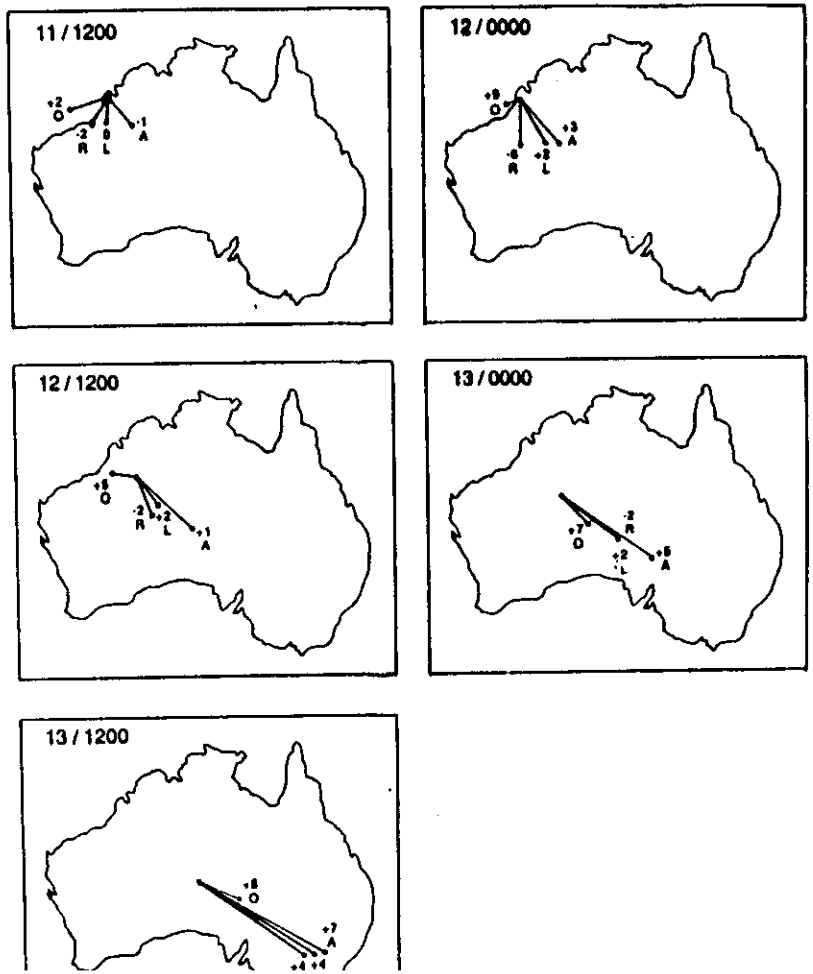


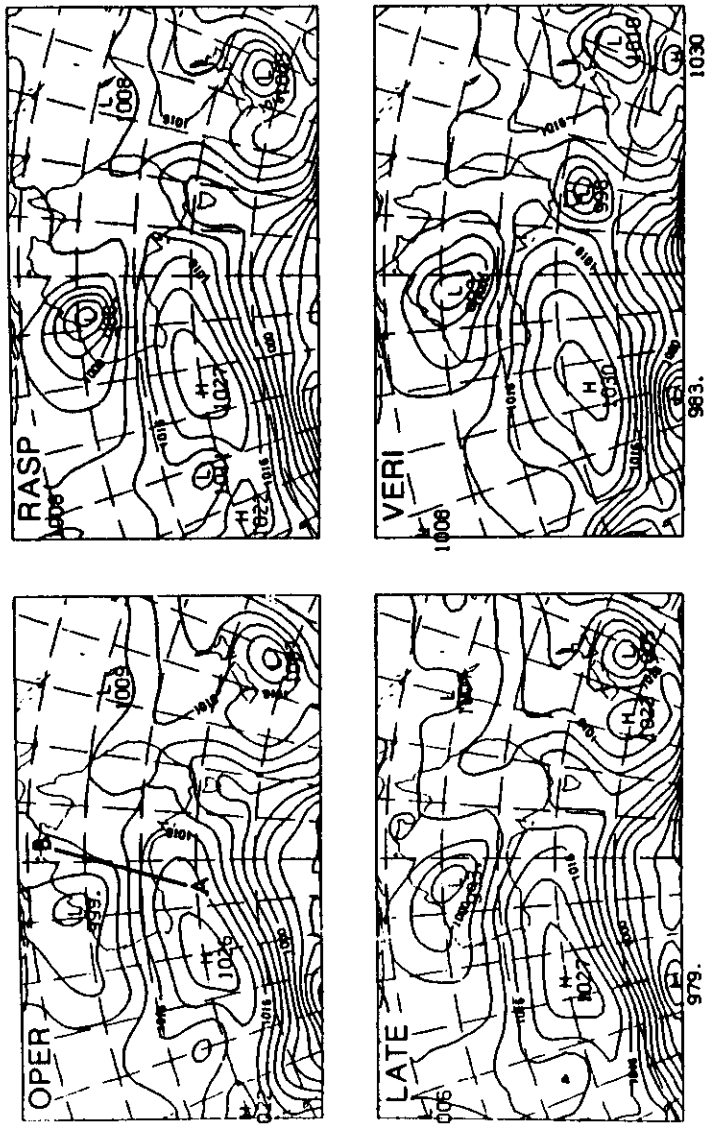
INITIAL STATE ERROR

O FINEST 24-HR MRG

R RASP

L LAPS RASP





Specific case of tropical cyclone prediction

One of the major application of TLAM is for tropical cyclone track prediction. We will consider various problem areas

1. Impact of model resolution

2. Parameterization of physical process

   Surface formulation
   Topography
   Sea surface temperature
   Cumulus convection (Kuo and Betts-Miller)

3. Impact of lateral boundaries

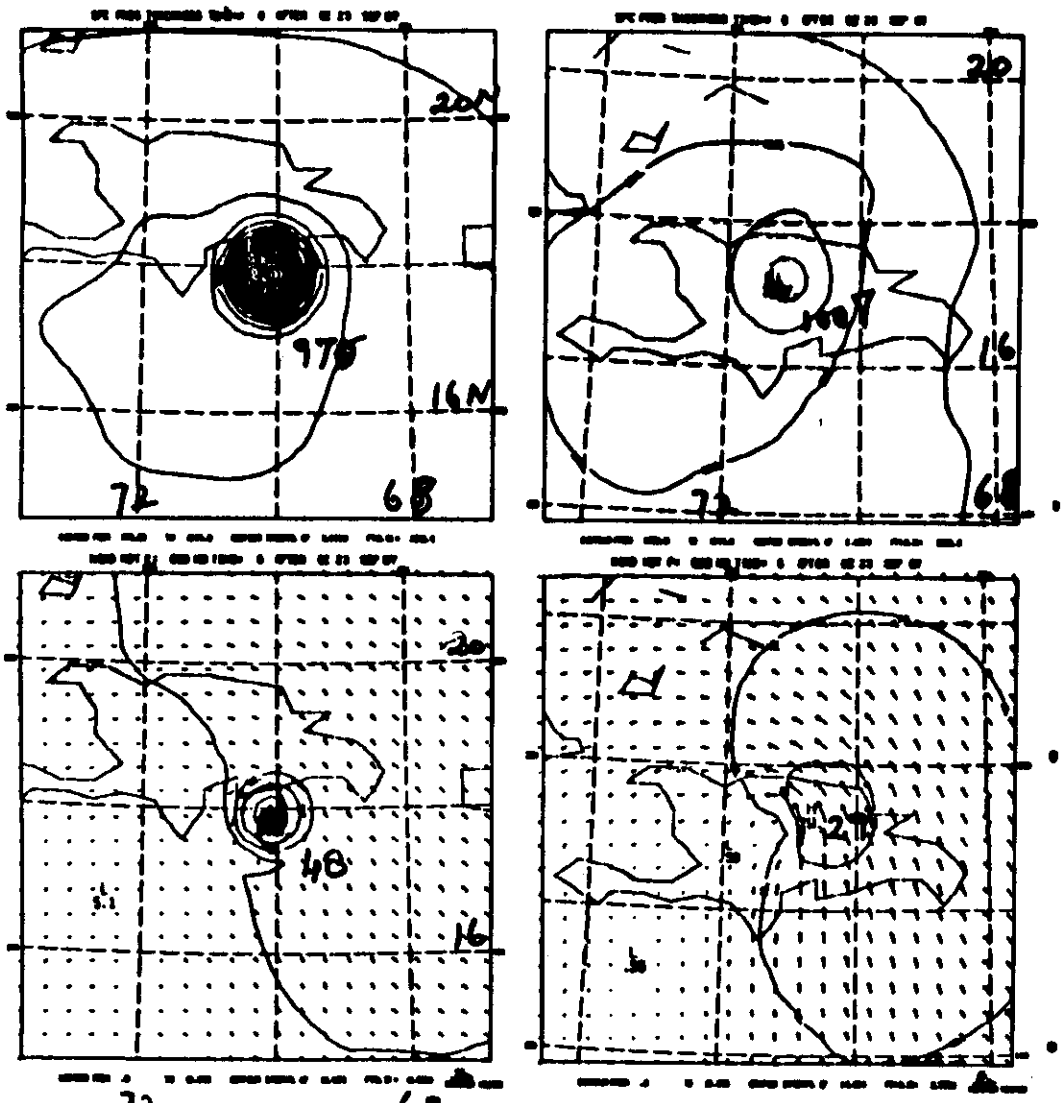
   TC motion is strongly dependent on large-scale flow which in LAM's can be corrupted by lateral boundaries. So higher resolution global models may be able to do better job in predicting TC motion.

Current operational global models

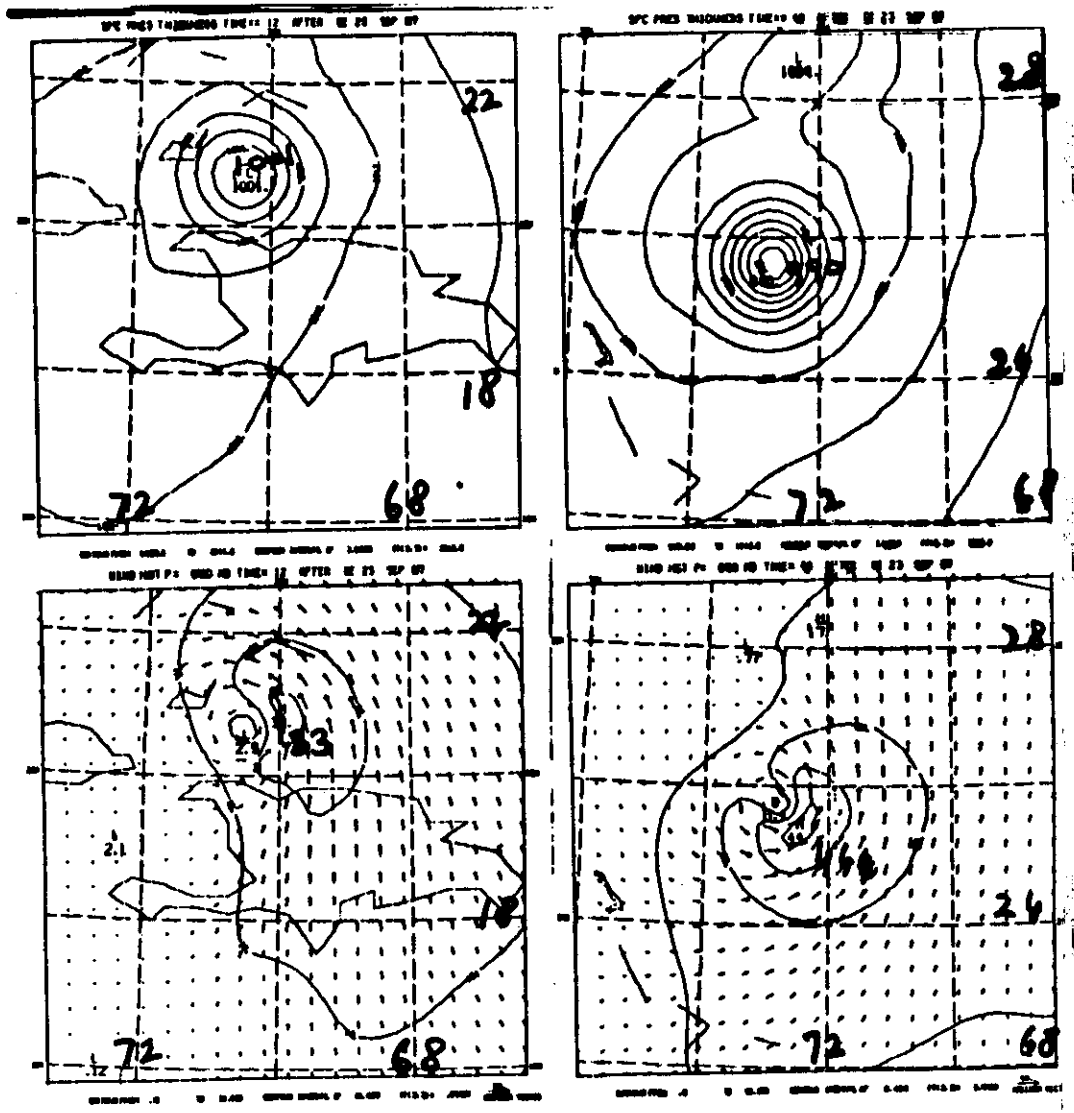
Centre	Vertical levels	Horizontal resolution
UKMO	15	$1.5^\circ \times 1.875^\circ$
JMA	21	T106 (1.12°)
NMC	18	T80 (1.48)
ECMWF	19	T106 (1.12)

Δx = 20 km

23 Sept 87 00 t Δx = 20 km



0-HR



12 hr 48h

6-hr

INITIAL

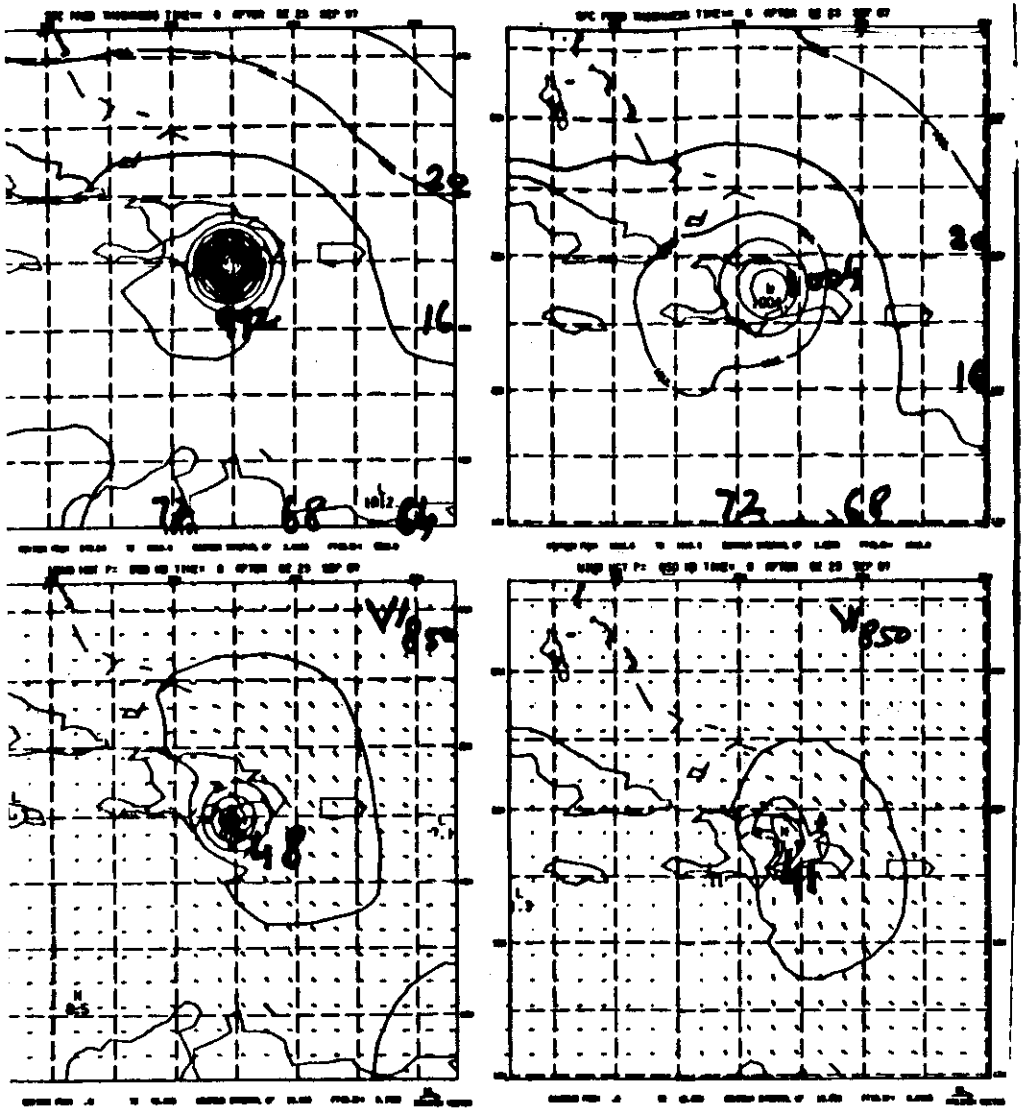
6h

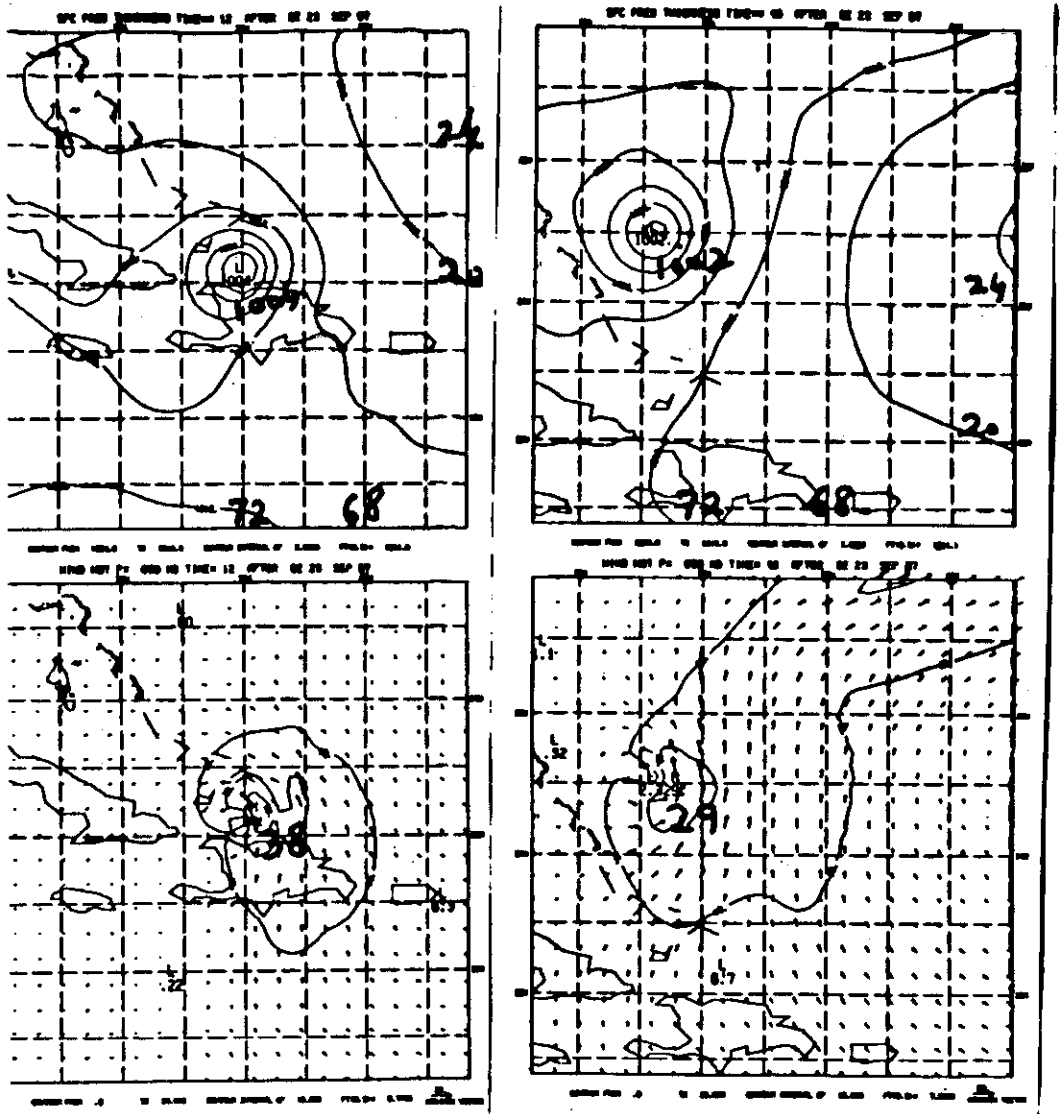
Δx = 40 km

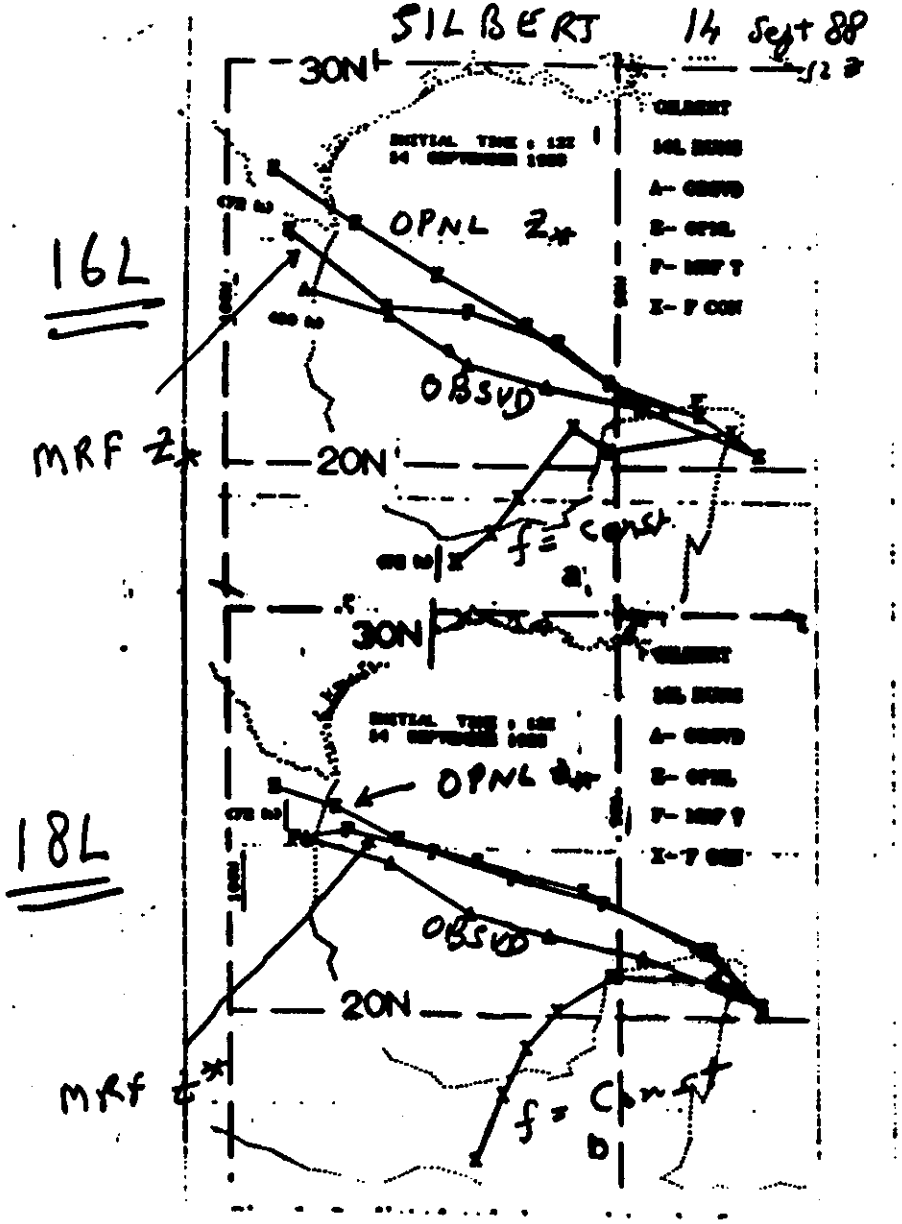
23 Sept 87 00z

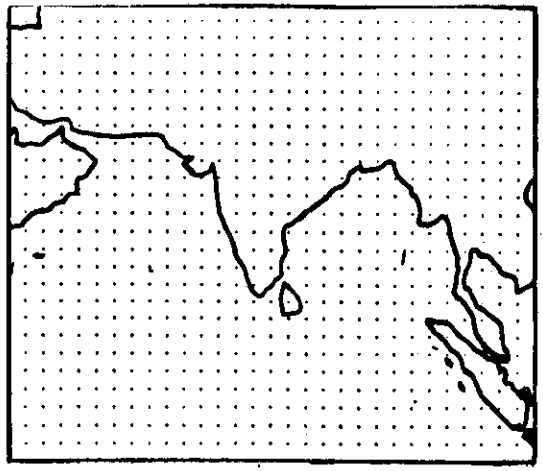
12h

48h

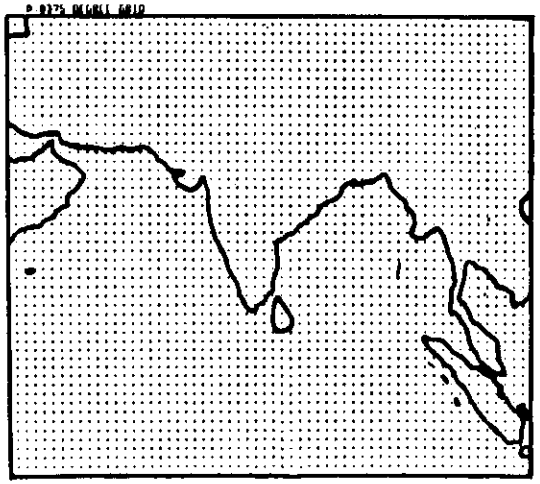




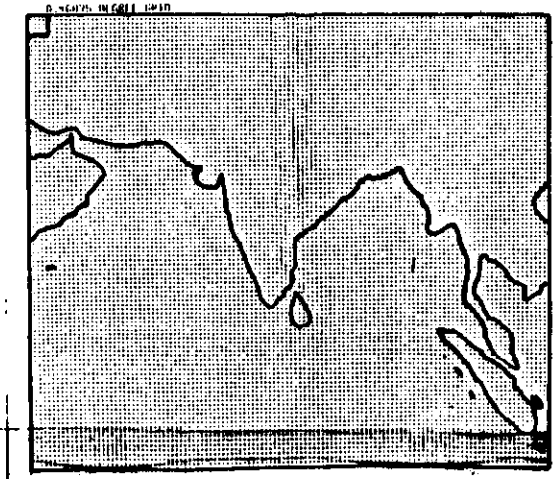




a 1.875°

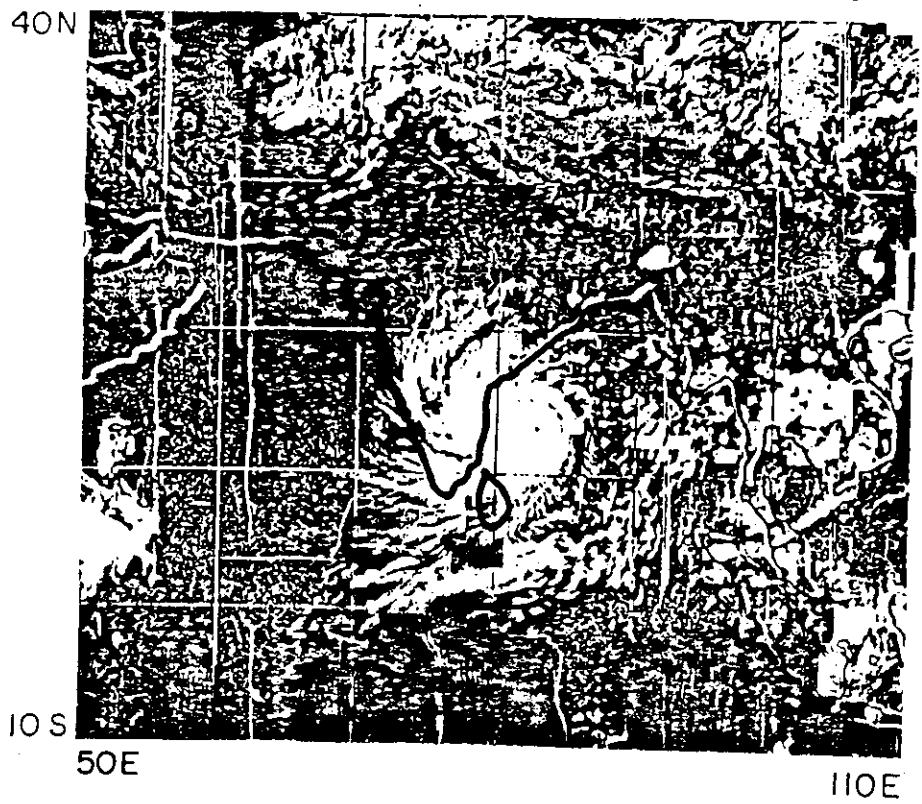


b 0.938°



c 0.469°

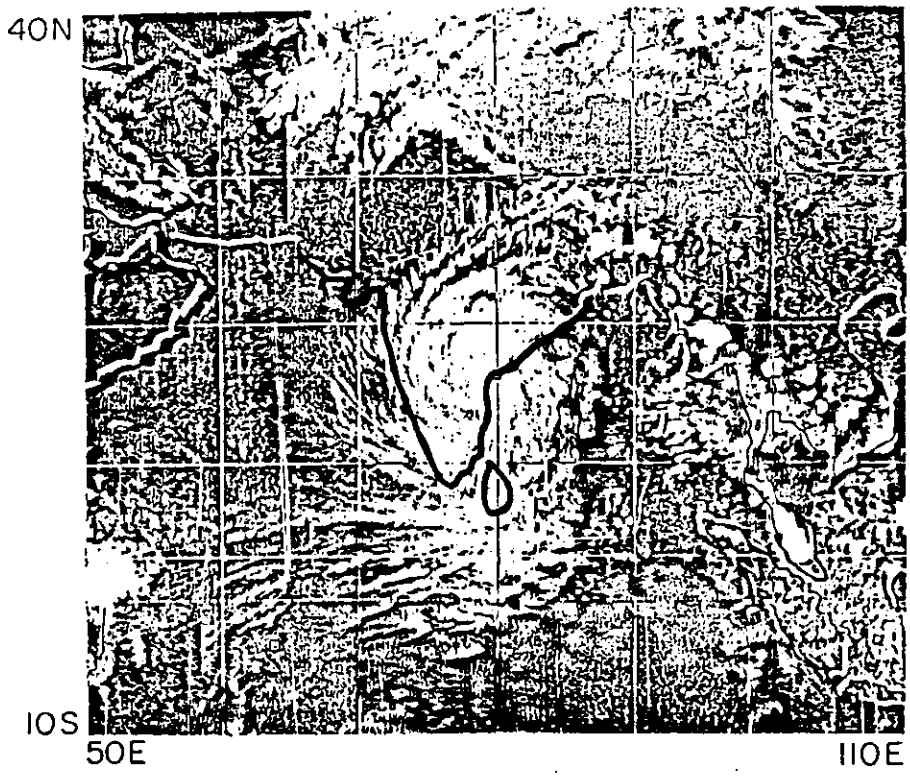
DMSP IR imagery for 0300 UTC May 12 1979



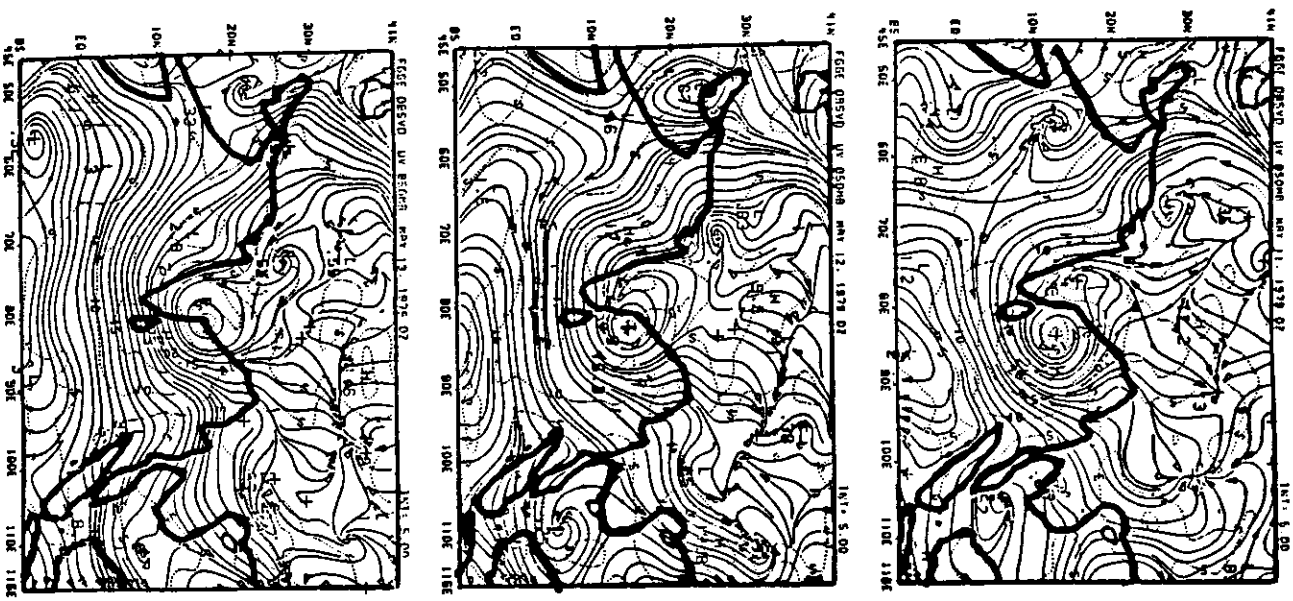
a

30

DMSP IR Imagery for 0300 UTC May 13 1979



b



c 00Z May 13 (day 2)

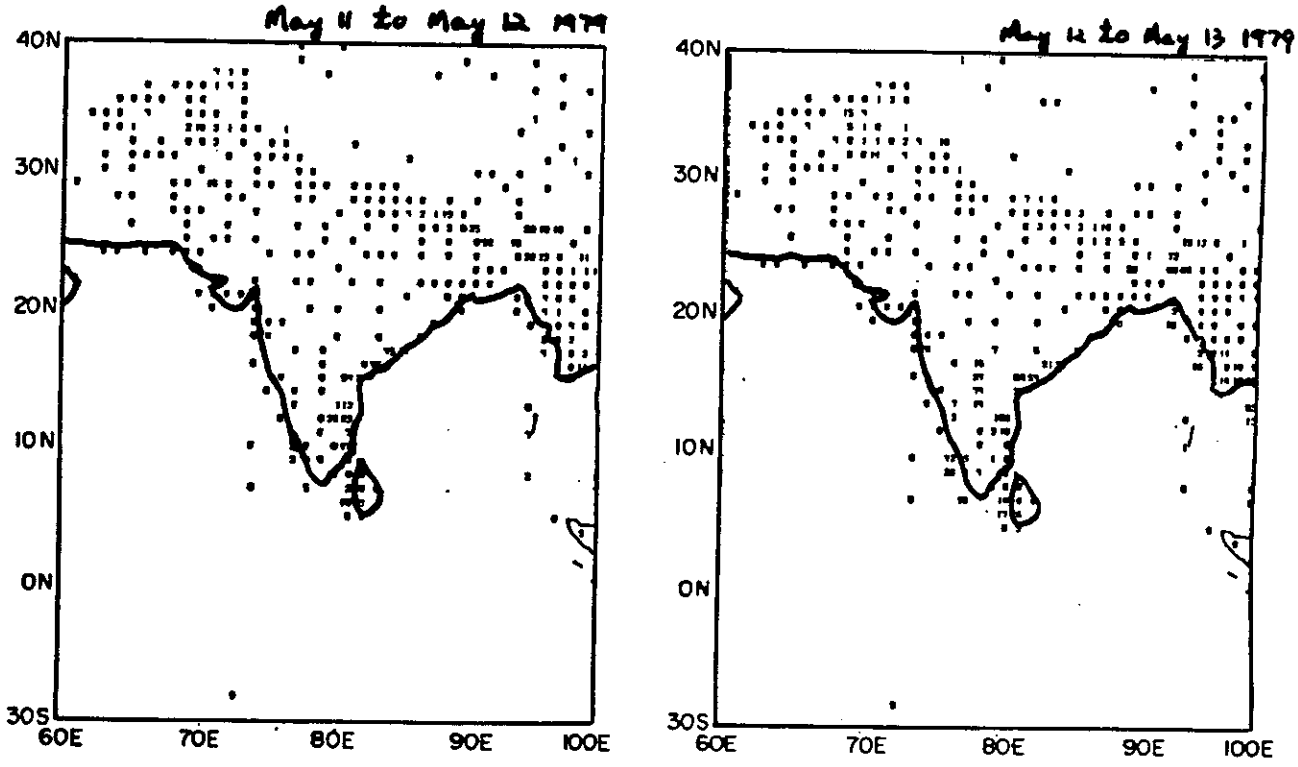
b 00Z May 12 (day 1)

a 00Z May 11 (day 0)

analyses

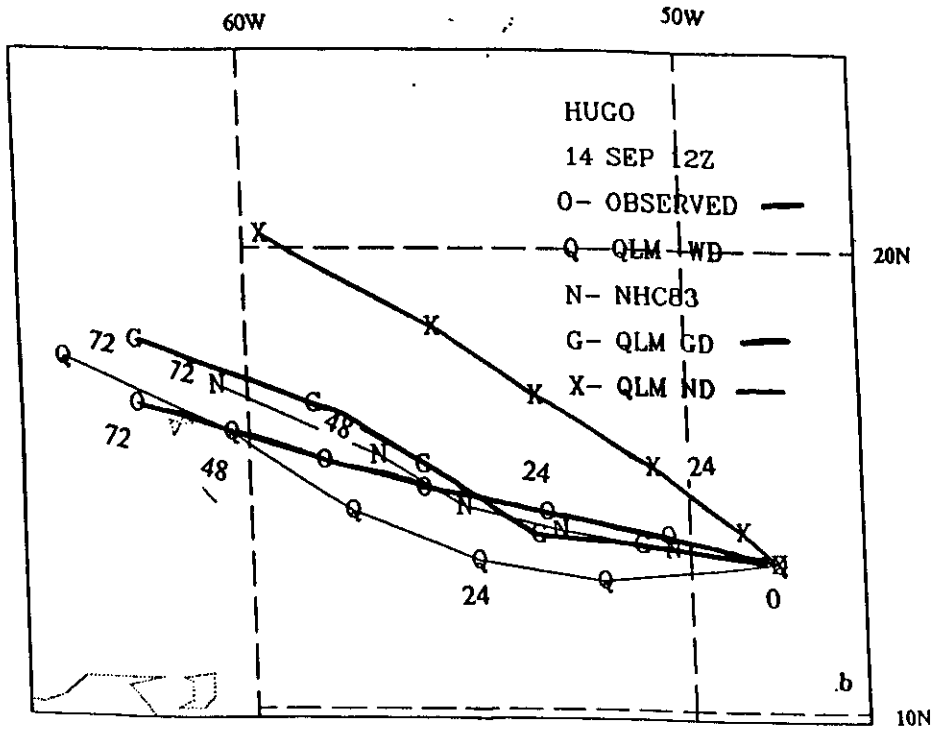
5

Observed 24hr rainfall totals (mmday^{-1})

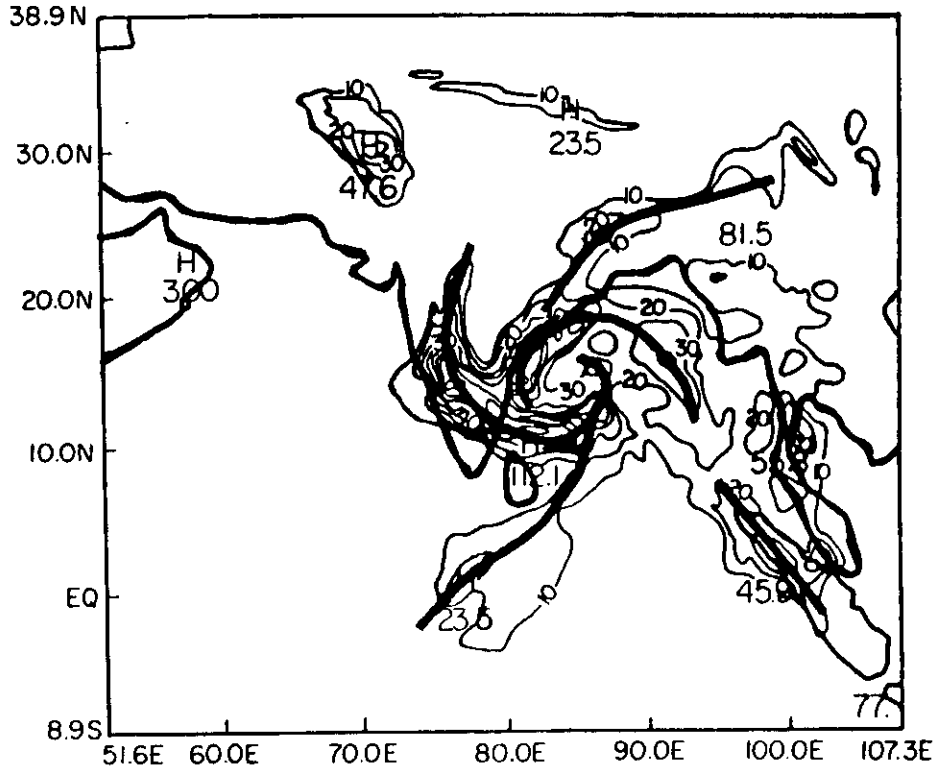


a

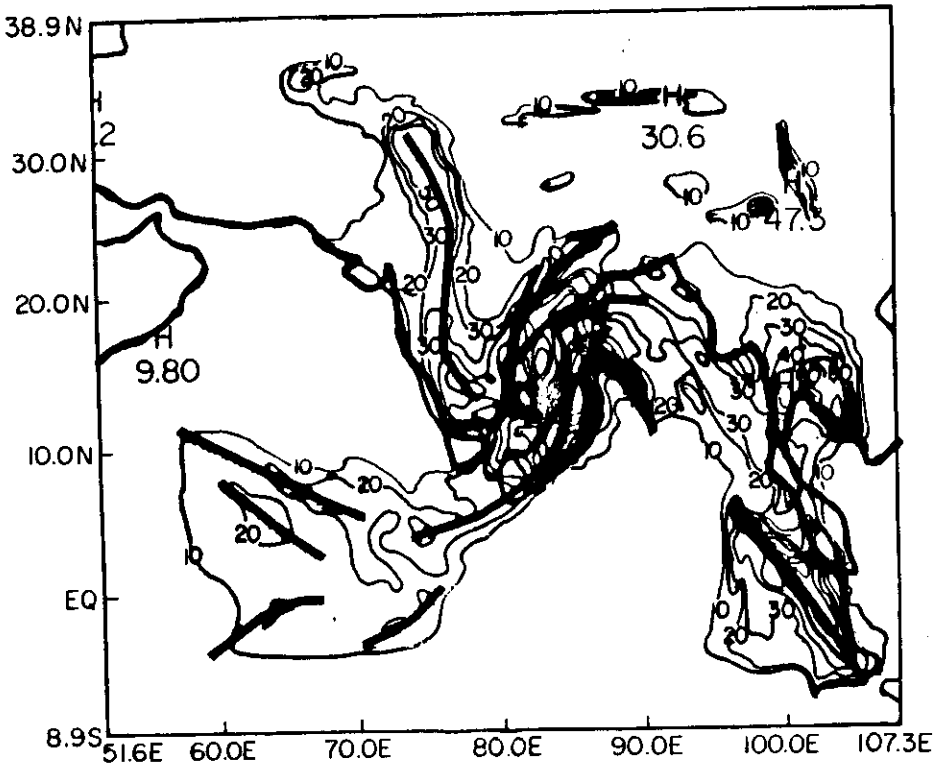
b



Predicted Rainfall 0-24hr
0.469° mesh, perfect B.C., improved param of ground wetness



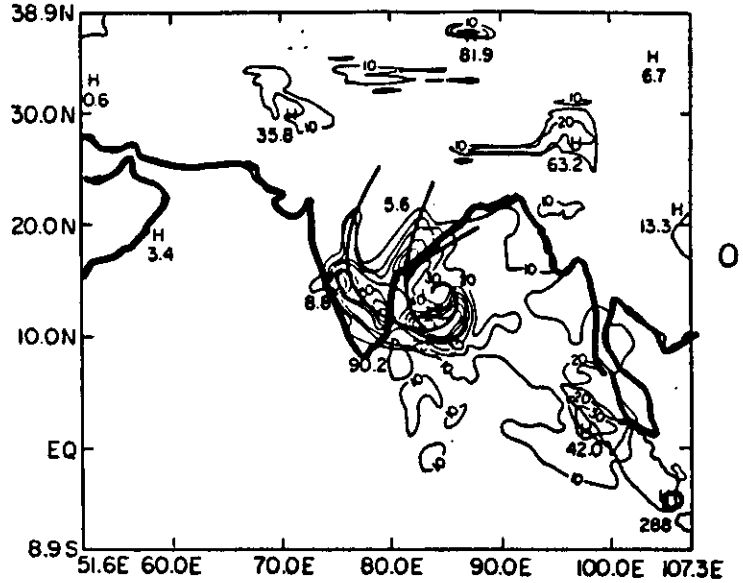
Predicted rainfall 24-48h
0.469° mesh, perfect B.C.,
Improved param of ground wetness



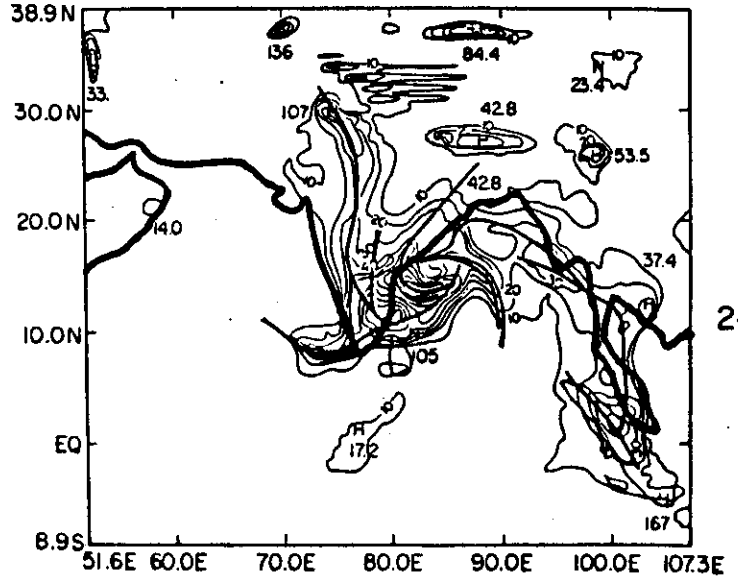
12b

0.469° mesh, improved param of ground wetness

T 106 BOUNDARY CONDITIONS



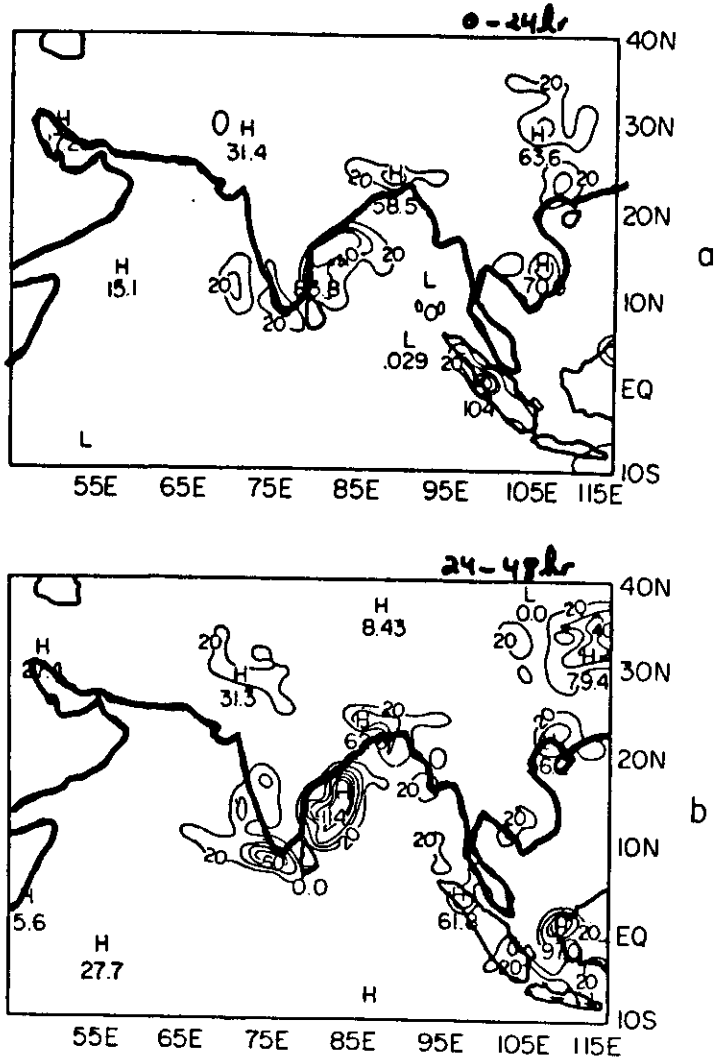
0-24
a

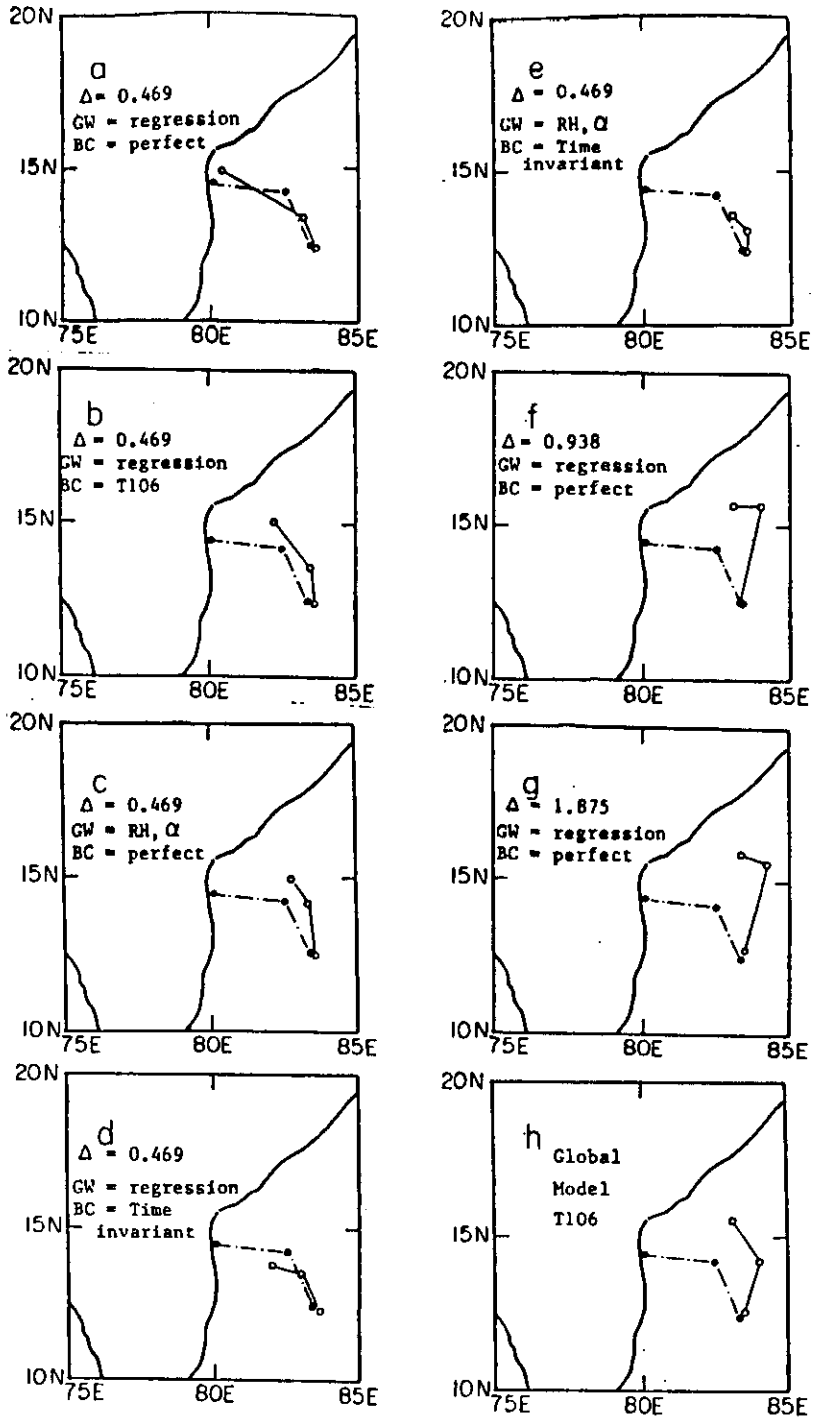


24-48
b

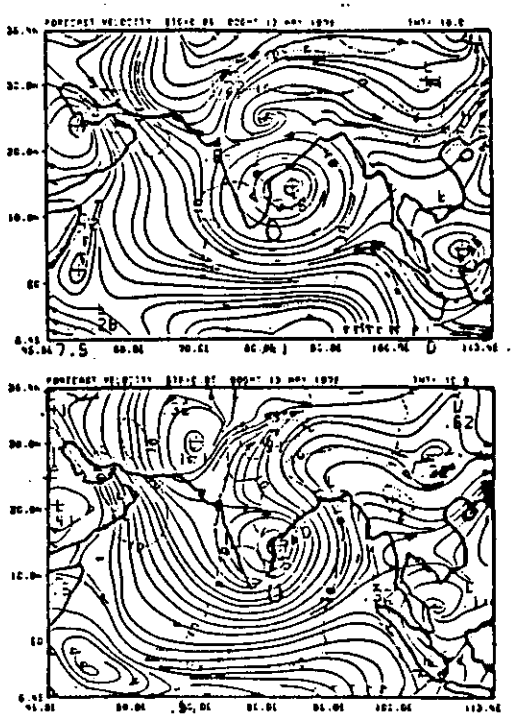
13

Predicted rainfall from T106 global model





Predicted wind field at $\sigma = 0.85$

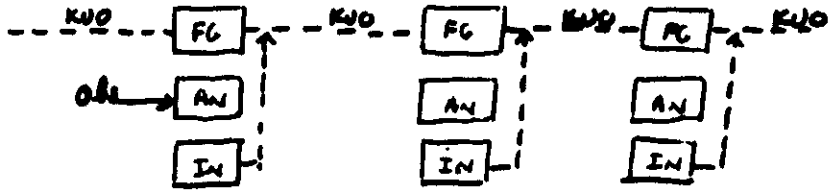


a 24hr

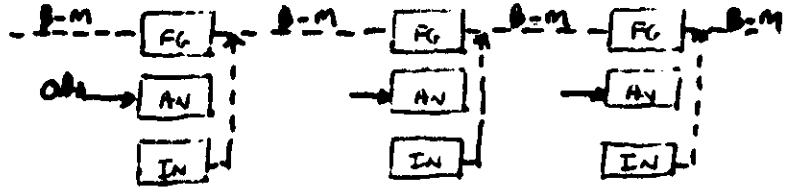
b 48hr

Two data assimilation cycles were performed

1) KUO – Kuo cumulus convection was used

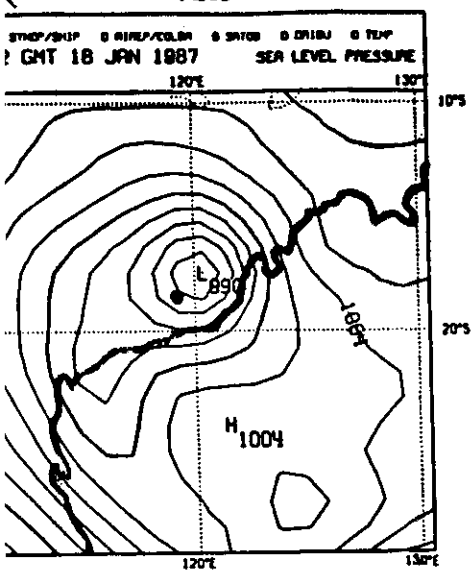


2) ADJ – Betts-Miller cumulus convection was used

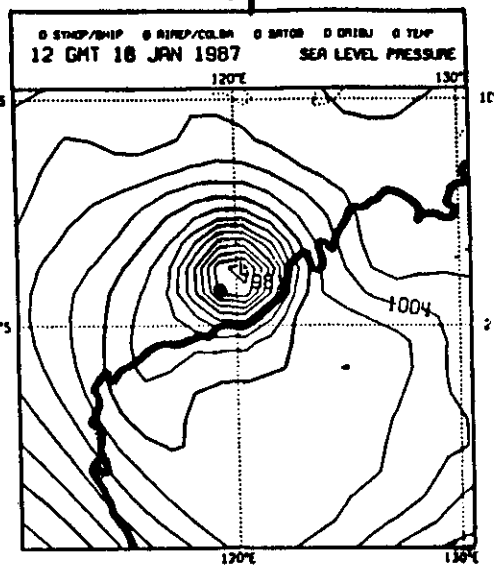


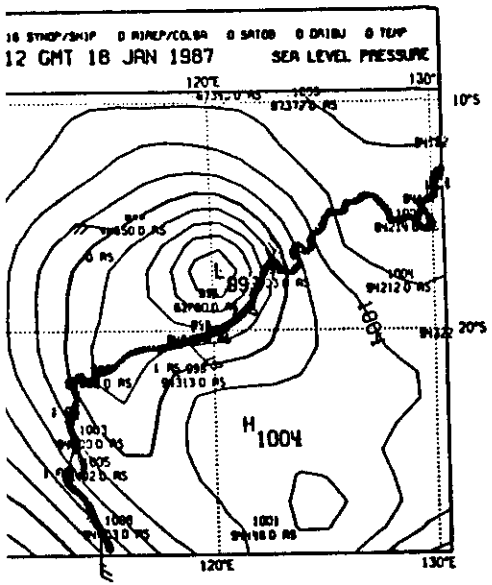
Analyses

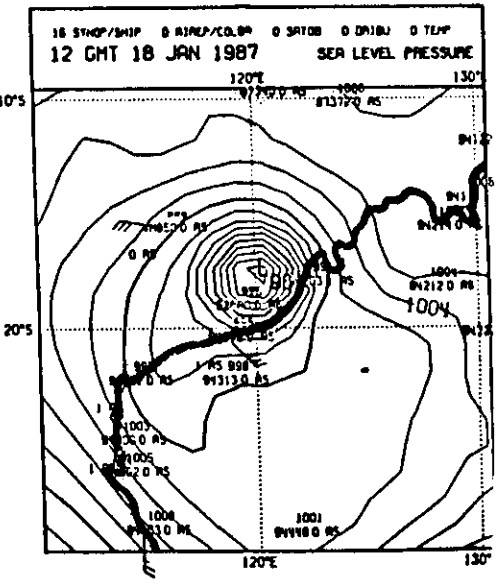
Kuo



Adj

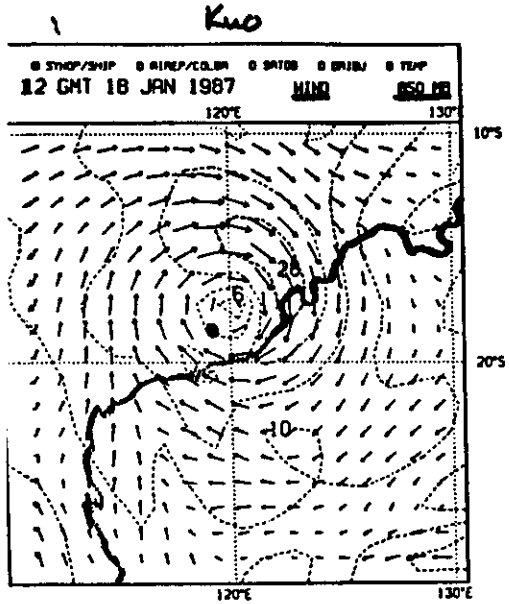






Analyses

Kuo



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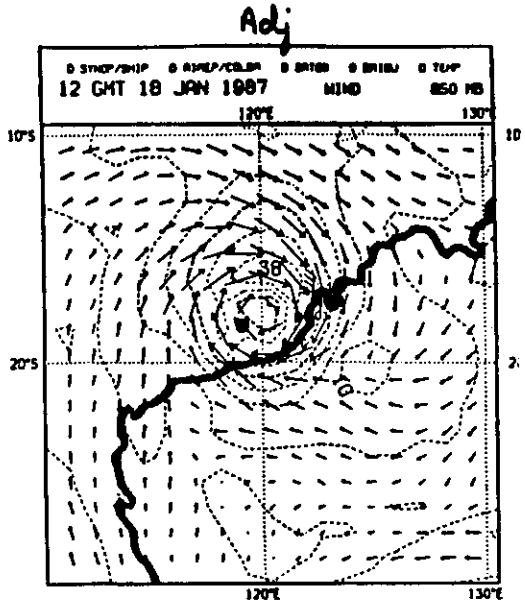
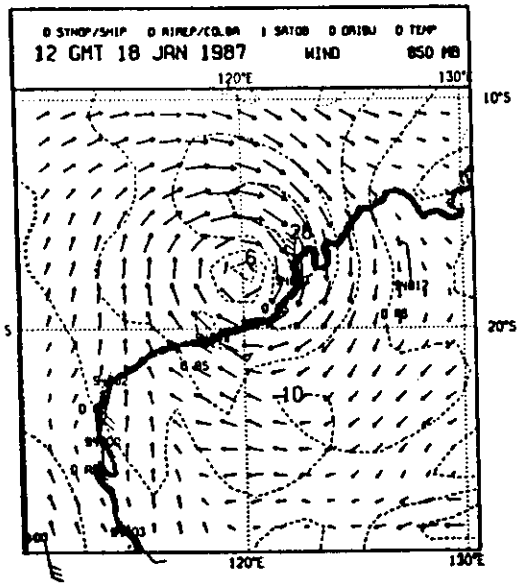
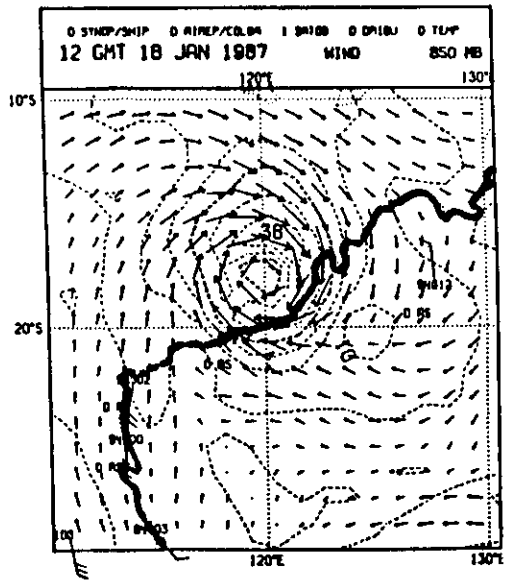






Analyses

KUO

ADJ

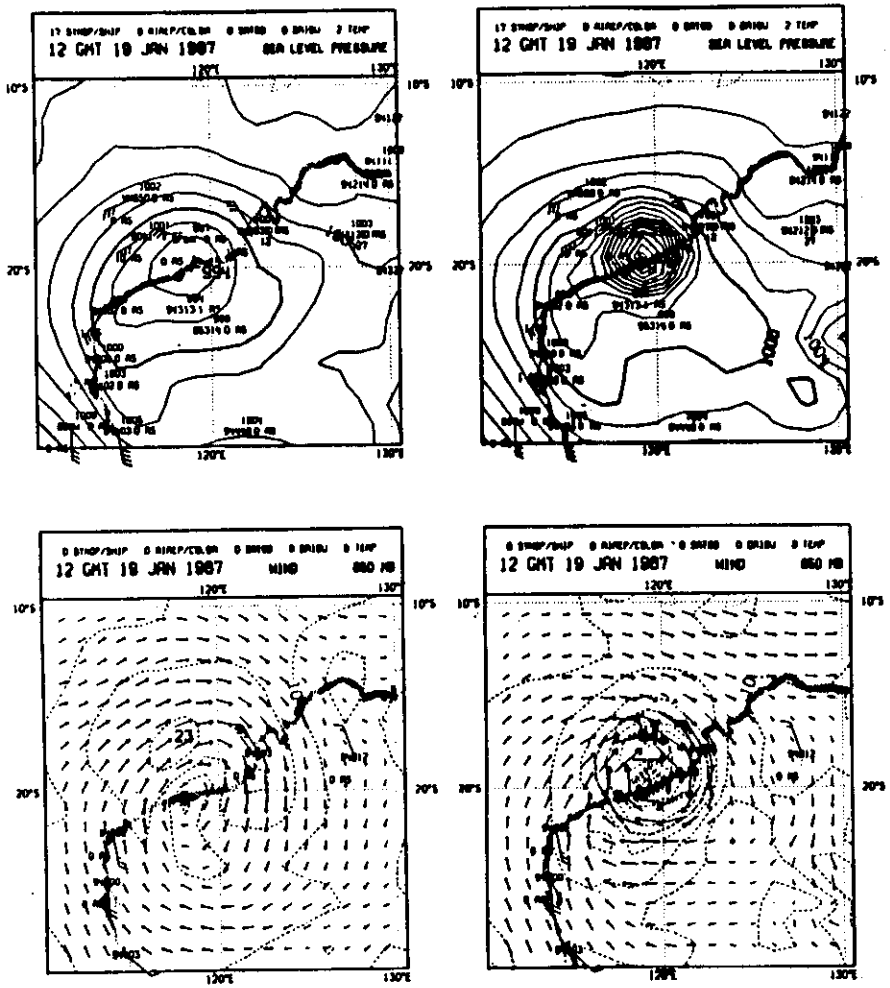
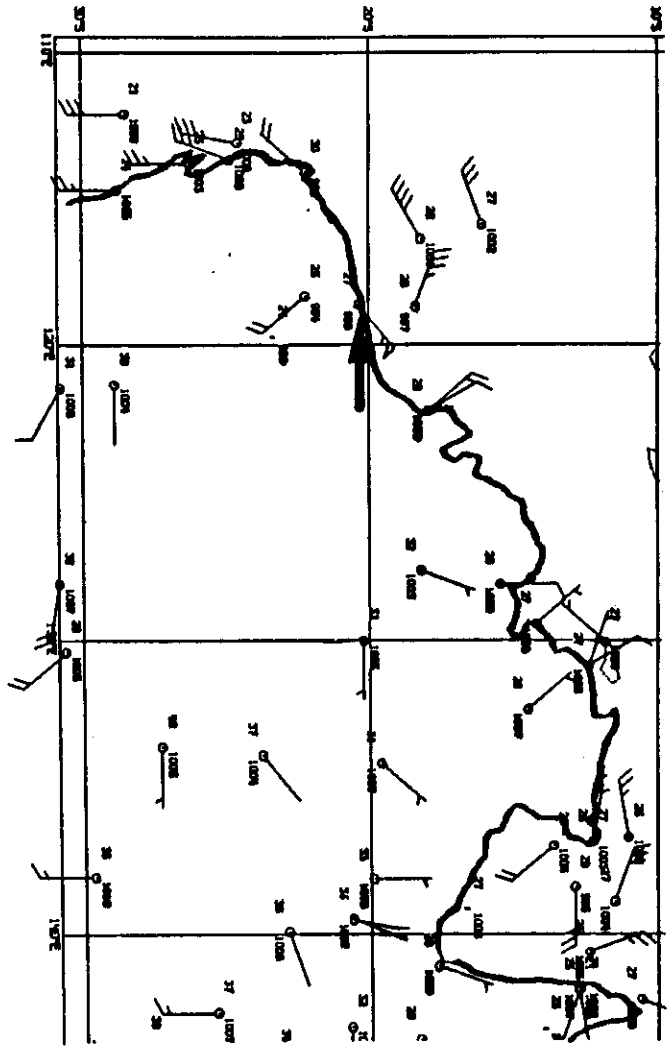
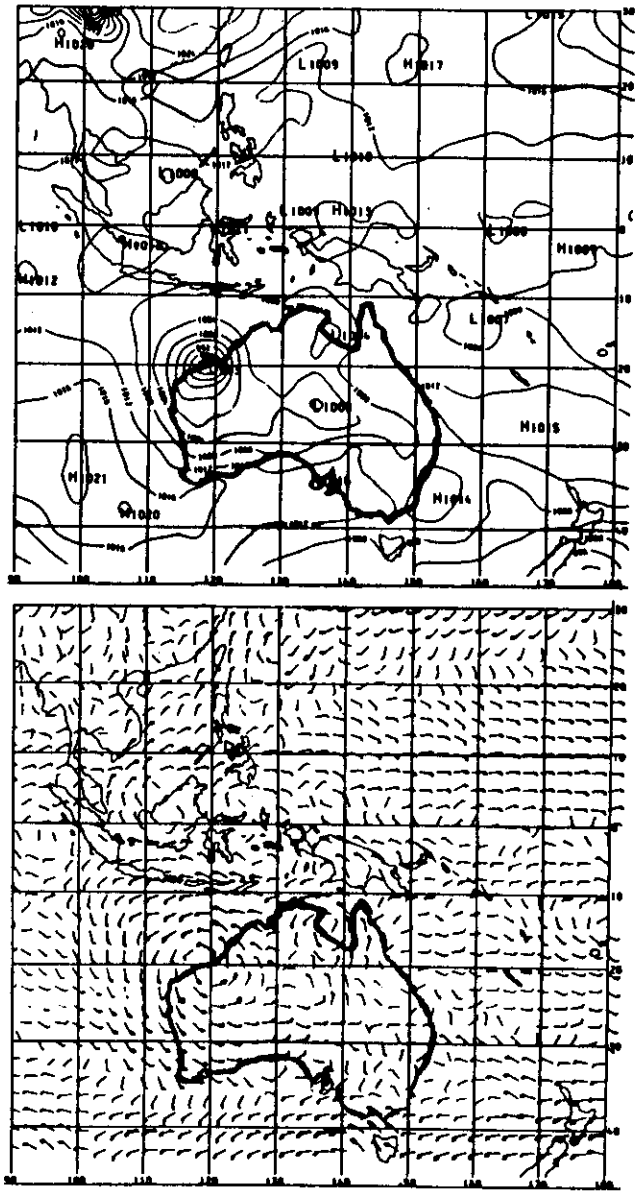


FIGURE 2a



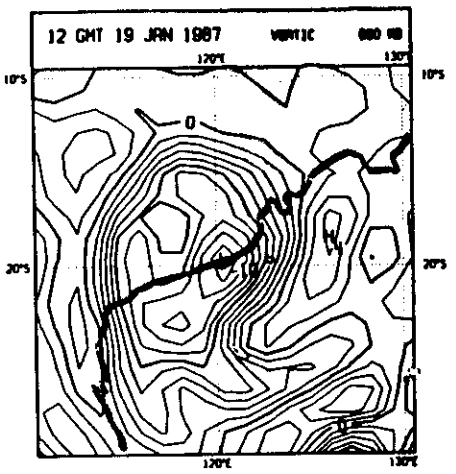
UKMO analysis for 122 Jan 19

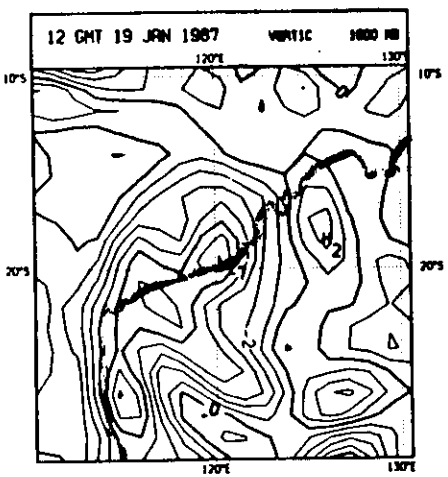


983 mb

Analyses

KUO





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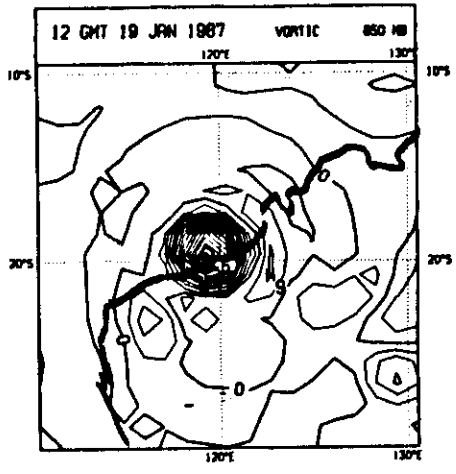

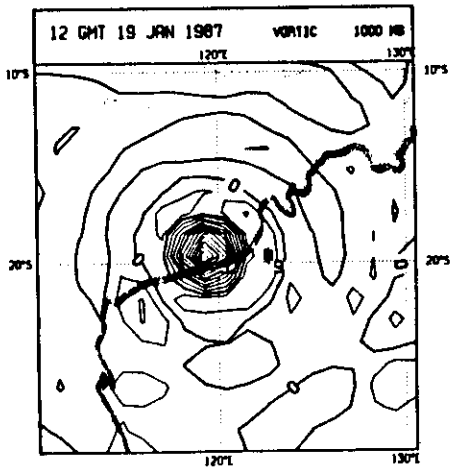

FIGURE 3a

Analyses

KJO

ADJ

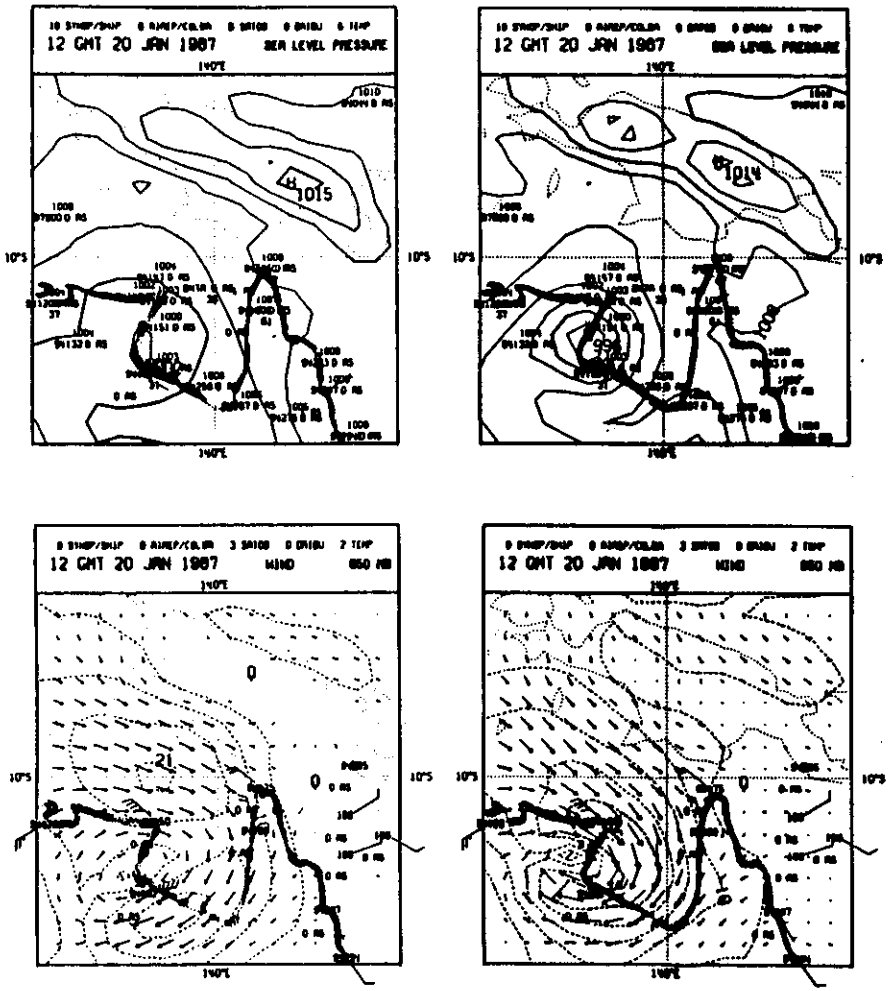

FIGURE 2b

Analyses

KJO

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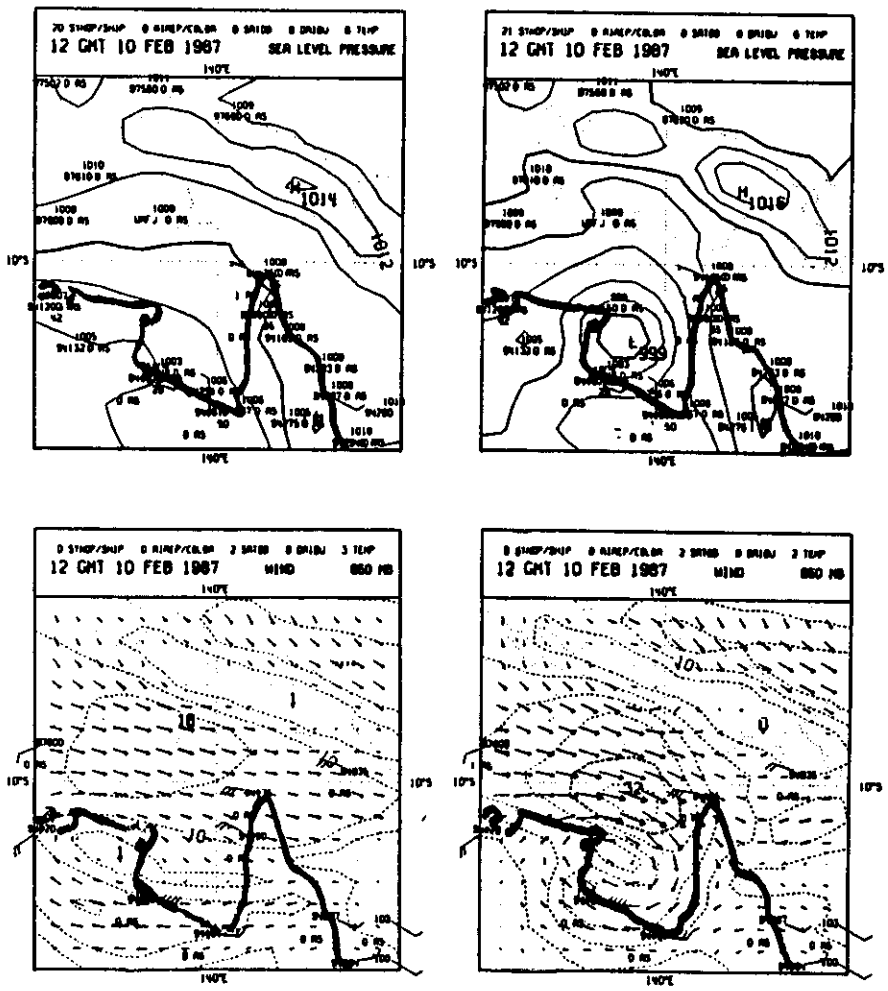


FIGURE 2d

4. Analysis / Assimilation of tropical cyclones

A major problem is the lack of data in the region of a tropical cyclone

One way of overcoming this problem is to generate tropical cyclone (TC) bogus data

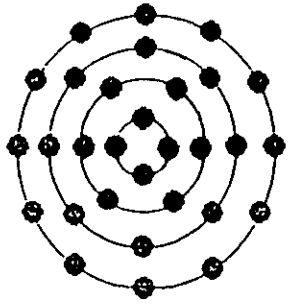
Very briefly bogussing includes the following steps (details may vary at different centres)

a) An axisymmetric sea-level pressure is computed using an empirical formulation
An anticyclone is formed at an upper troposphere (cloud-top) level

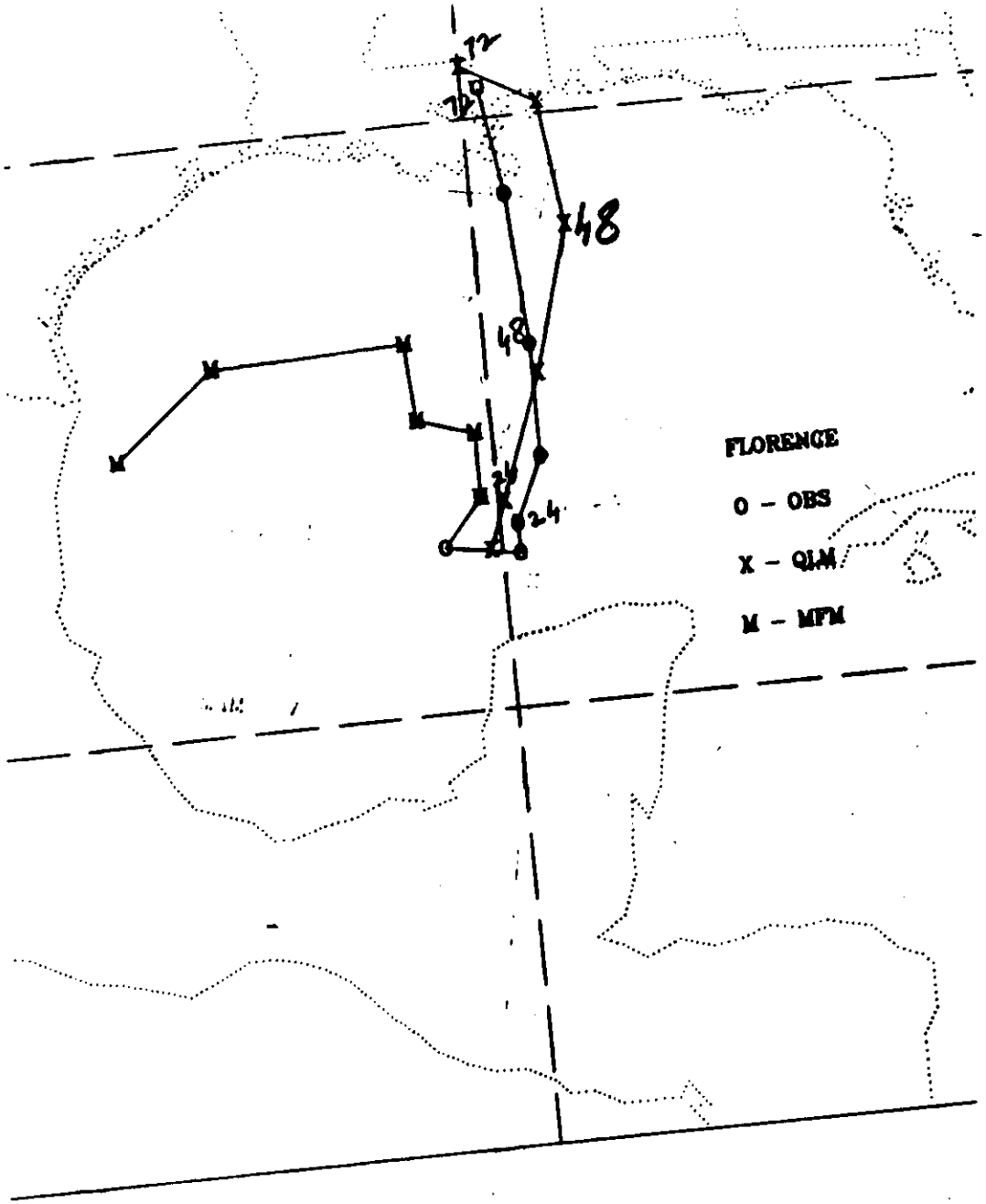
b) Initial cyclone movement is specified as an asymmetric wind component

c) Once the bogus vortex is generated there are two options in including it

- The bogus vortex can be smoothly merged with an objective analysis – this can cause large shocks
- The bogus vortex is treated as data to be fed in the normal way into an OI analysis This can lead to data being rejected by the analysis



.1 Horizontal distribution of the bogus observations. The number of concentric circles and the radius of each circle are changed according to typhoon size.



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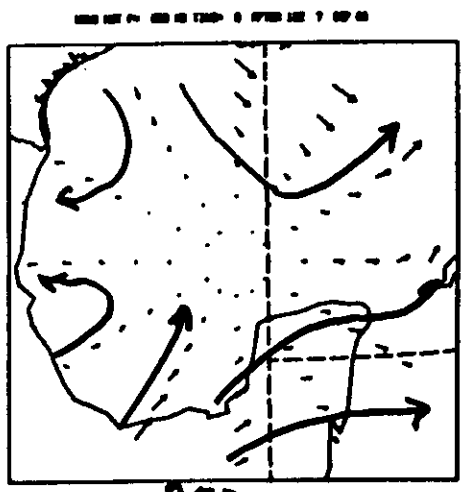

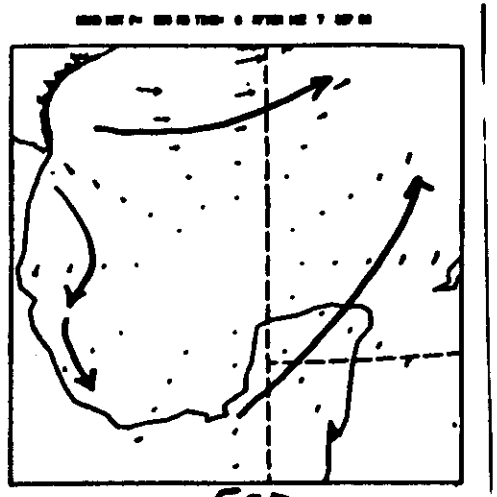

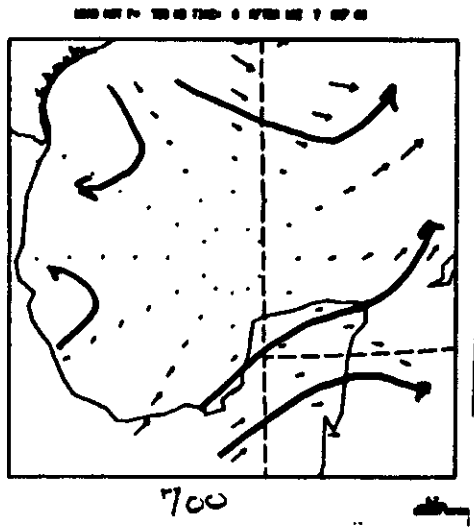

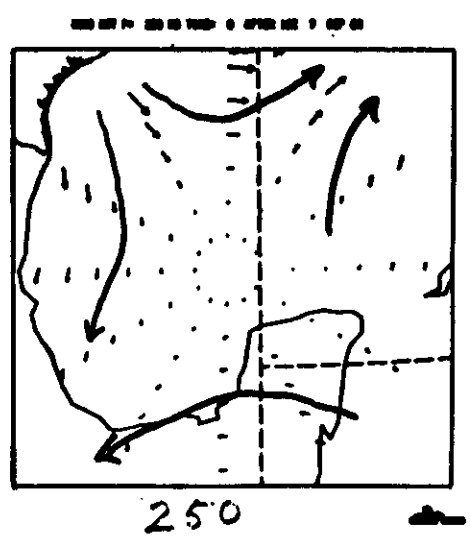

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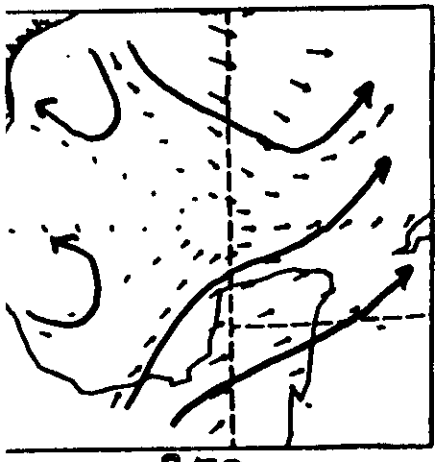

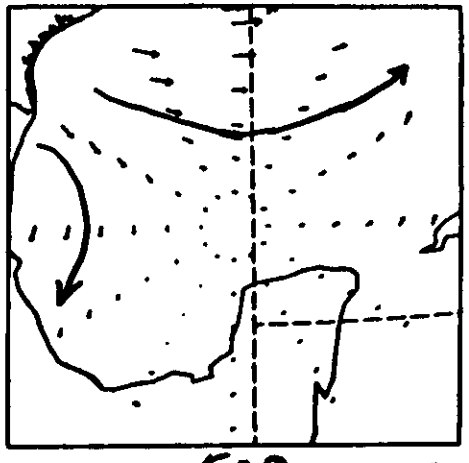

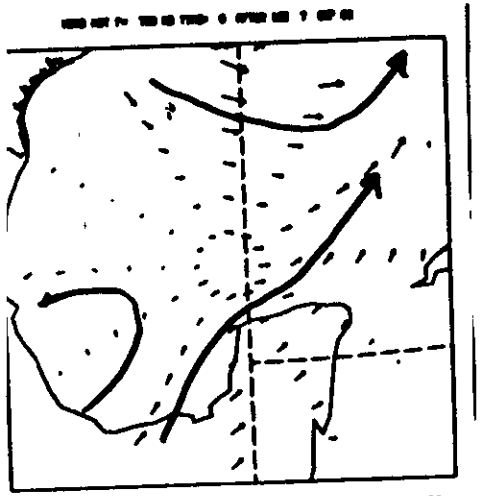

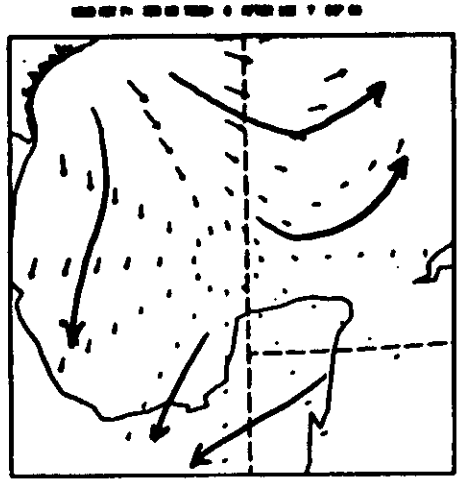

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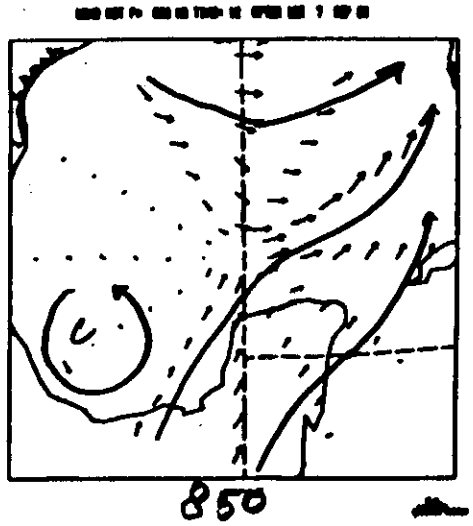

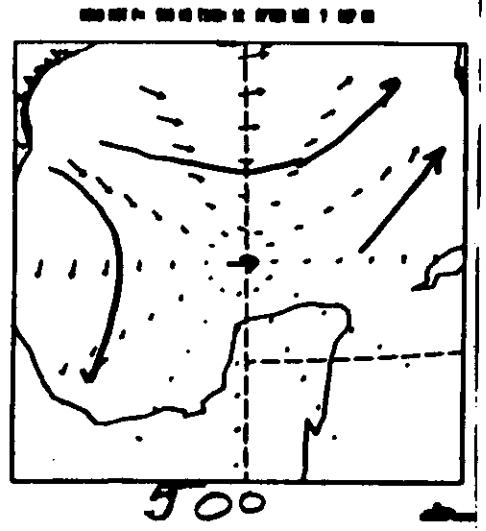

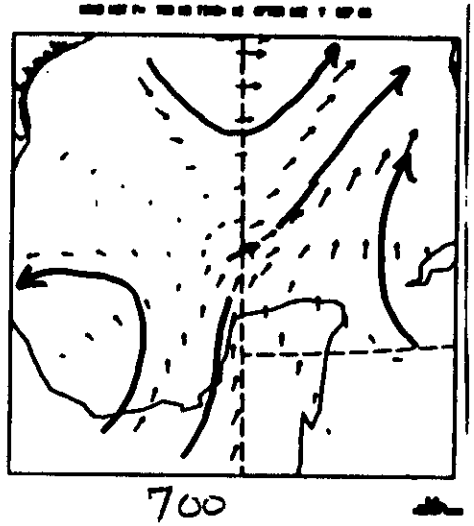

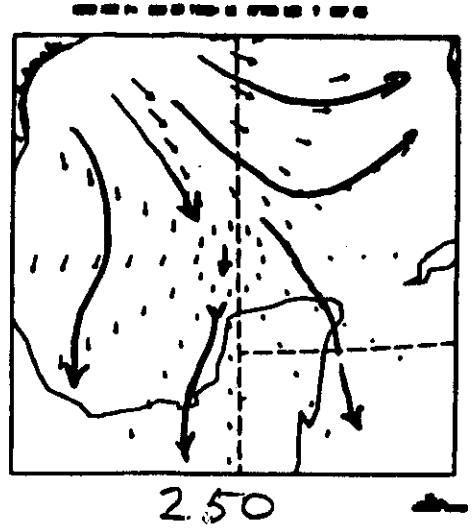

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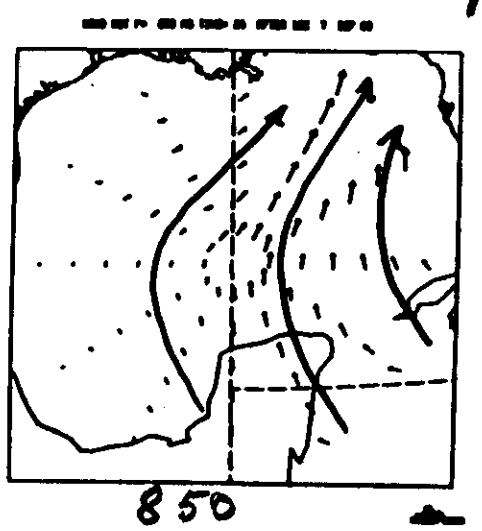

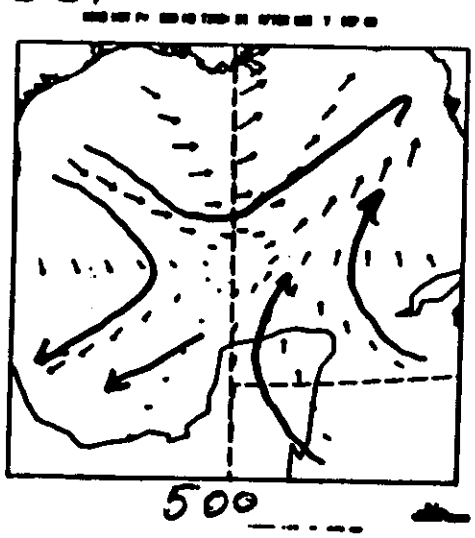

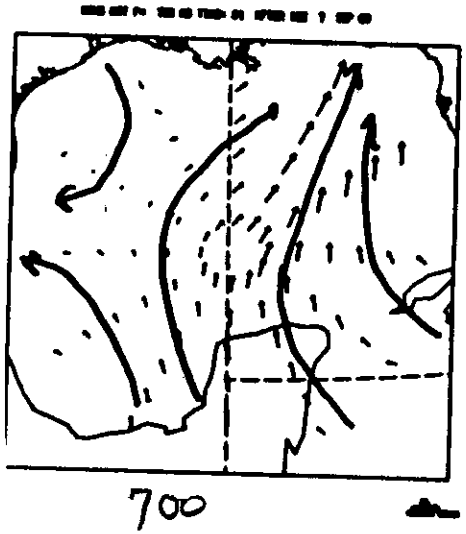

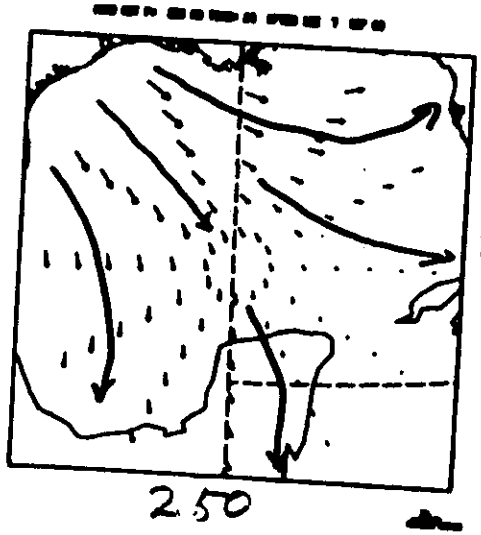

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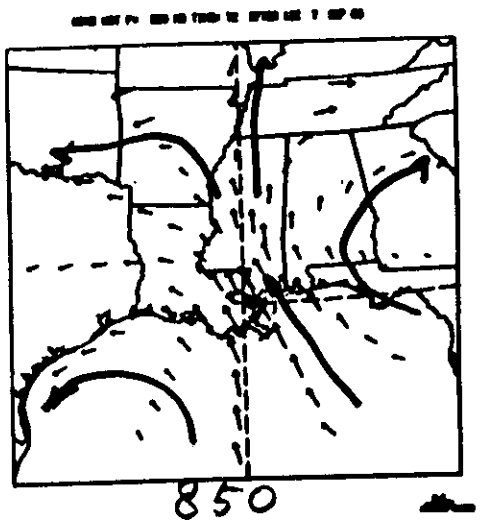

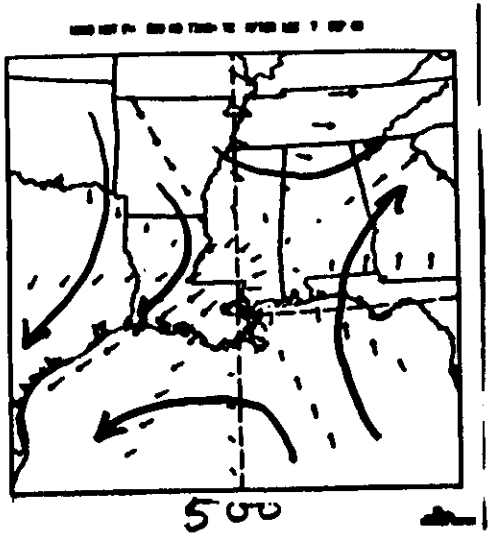

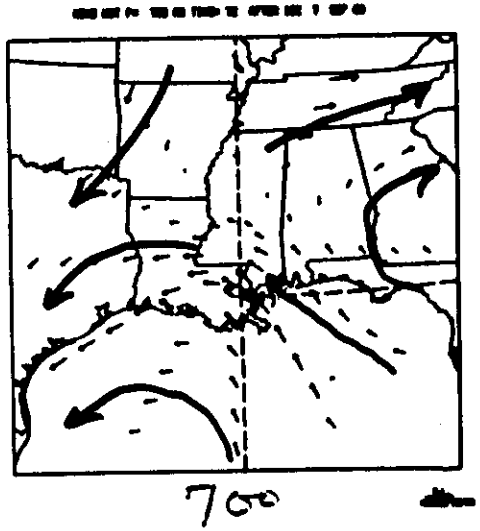

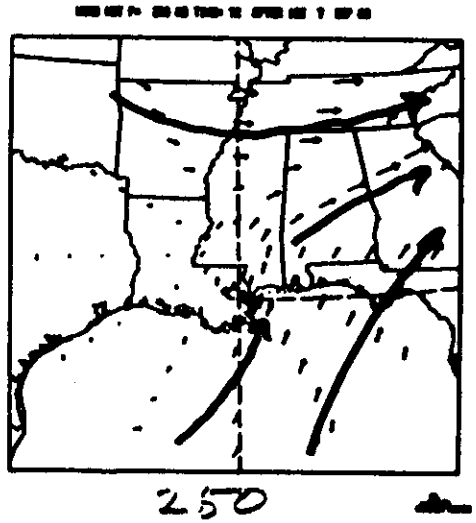

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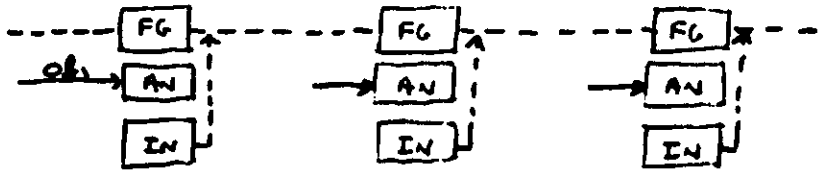
Two further data assimilation cycles were performed

1) Control — standard analysis settings



2) HRES+ Forced Data — High resolution structure functions + modified quality control (QC) were used in analysis

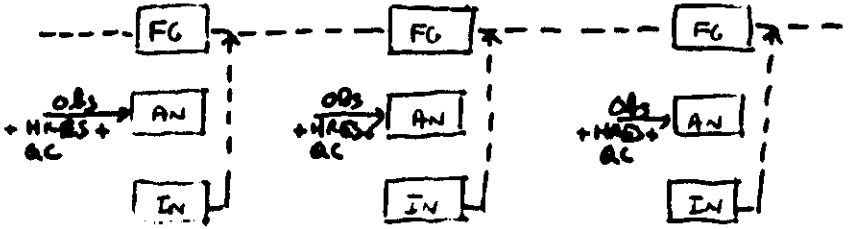
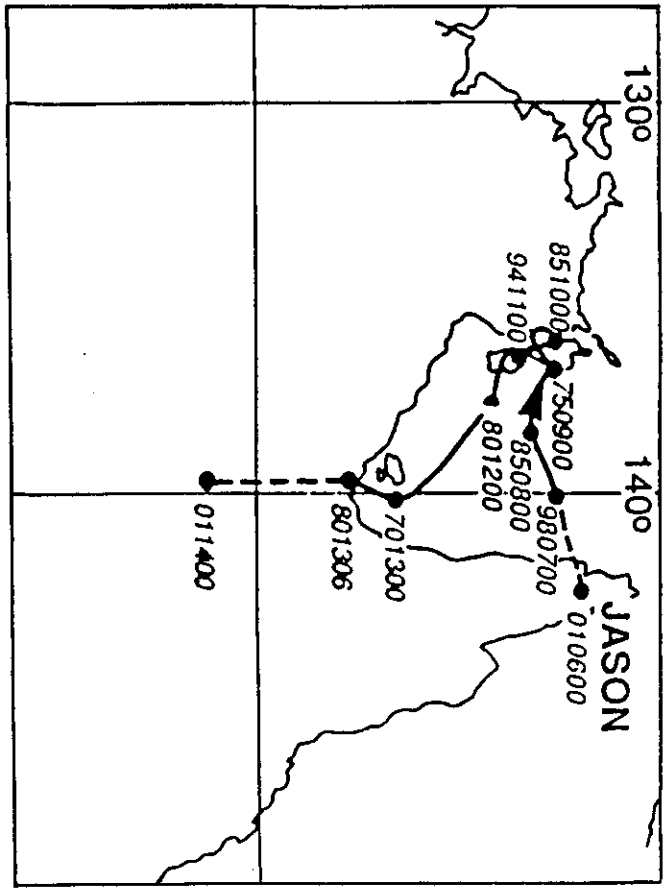


FIGURE 2



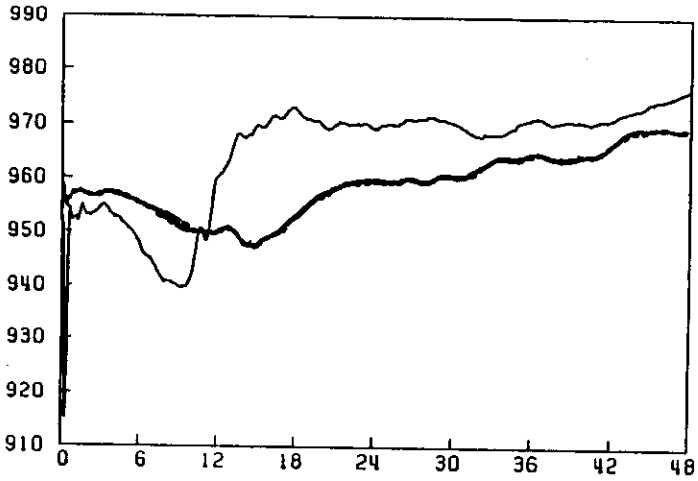


Fig.3 Time evolution of the minimum mean-sea-level pressure for the two simulations. Without NNMI (solid line) and with NNMI of five vertical modes with four iterations (broken line).

Analyses

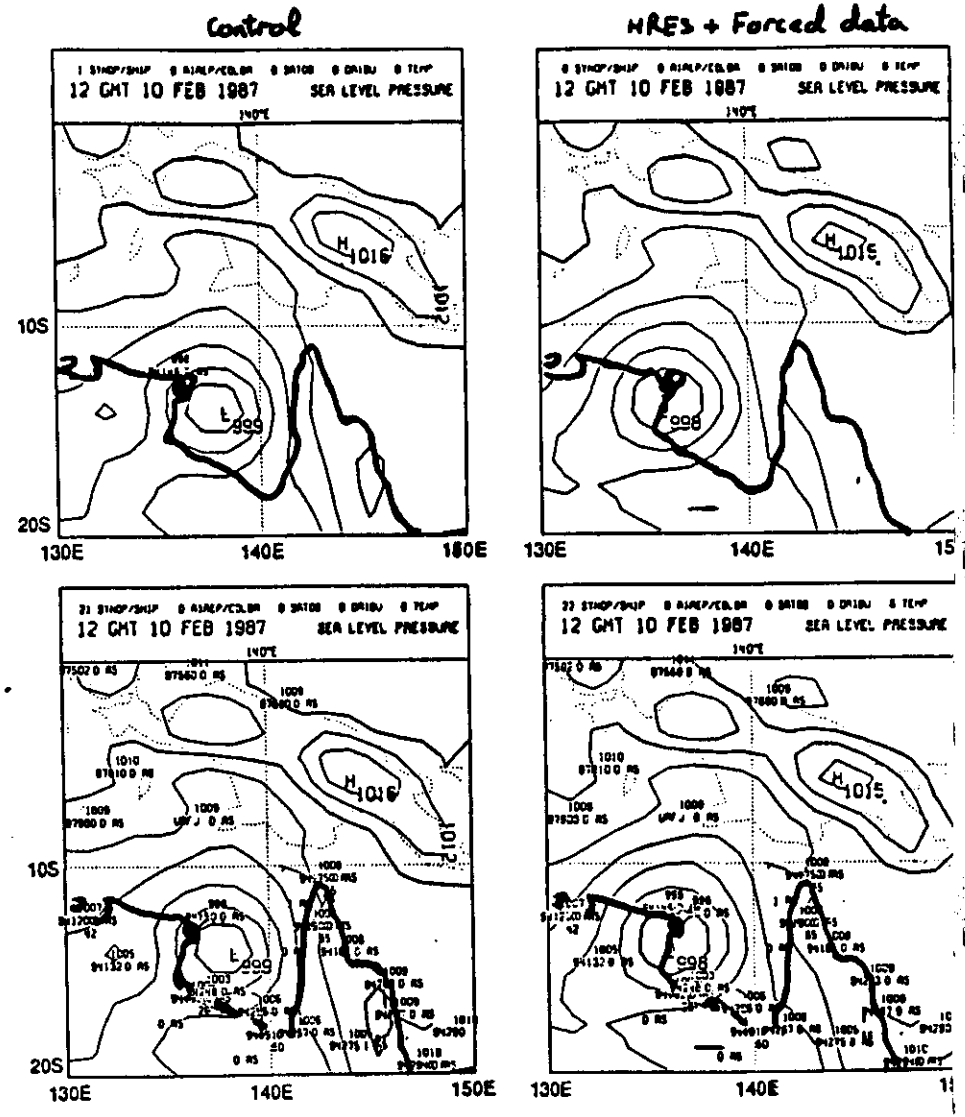


FIGURE 3a

Analyses

Control

HRES + Forced Data

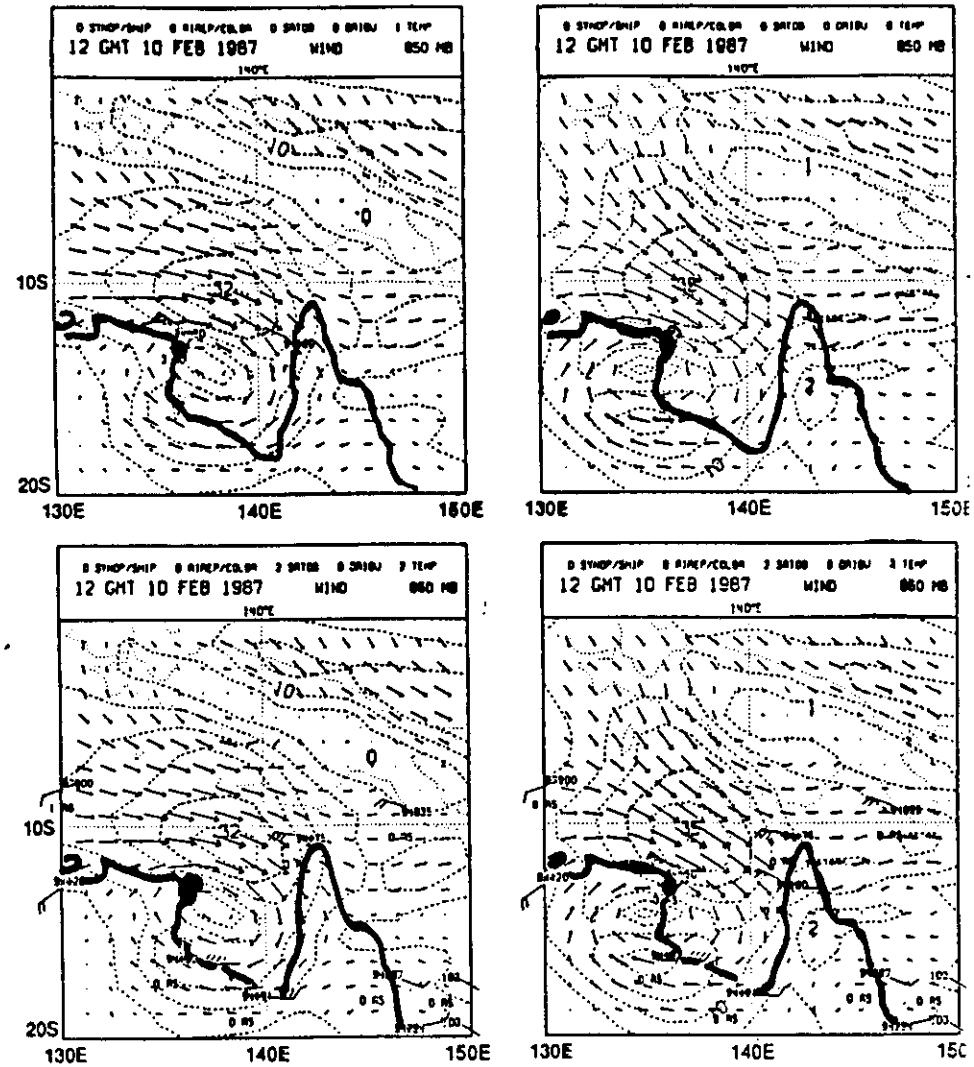


FIGURE 3b

Analyses

Control

HRES + Forced data

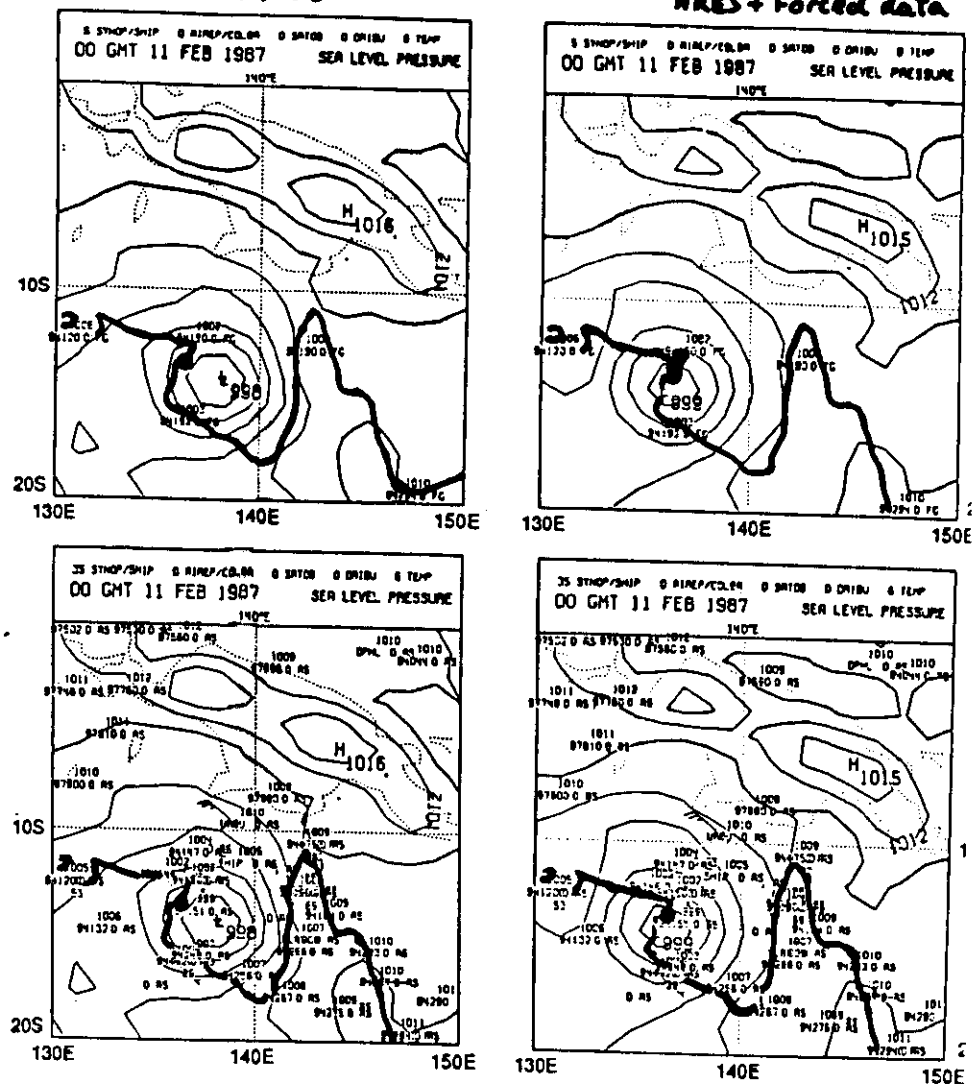


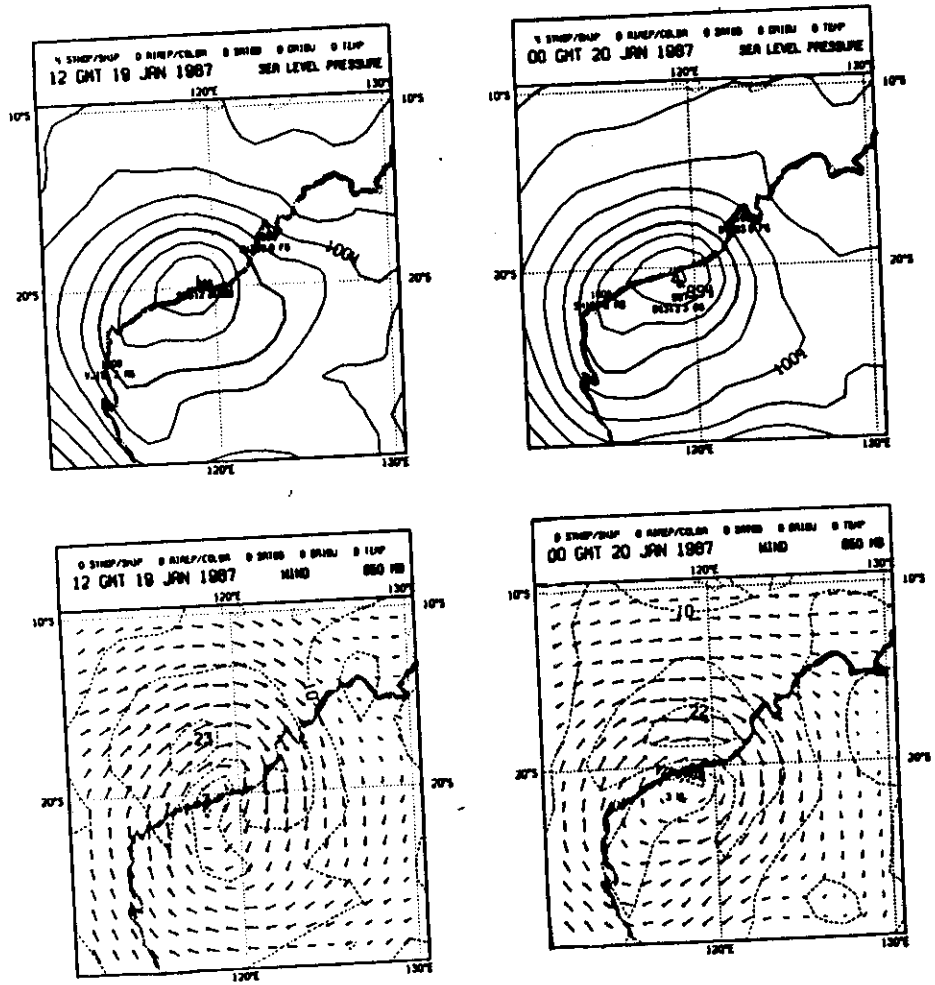
FIGURE 4a

Rejection of data by analysis scheme

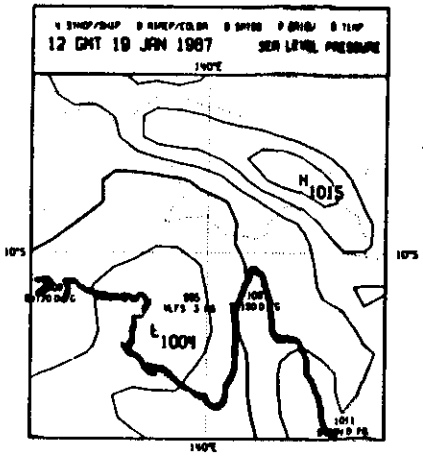
Rejection of data can occur because of the following reasons

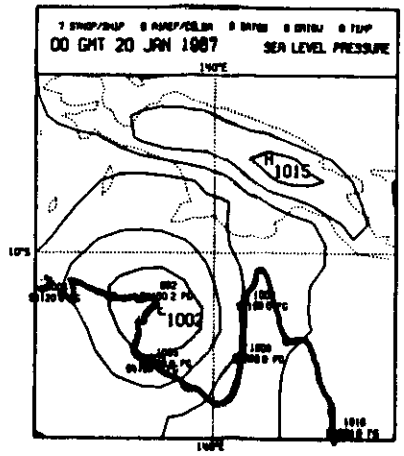
- Errors in the first guess
- The structure functions used in the analysis do not have sufficient resolution to resolve small scale structures such as tropical cyclones
- The use of inappropriate parameters such as forecast error variances and quality control limits for tropical cyclones.

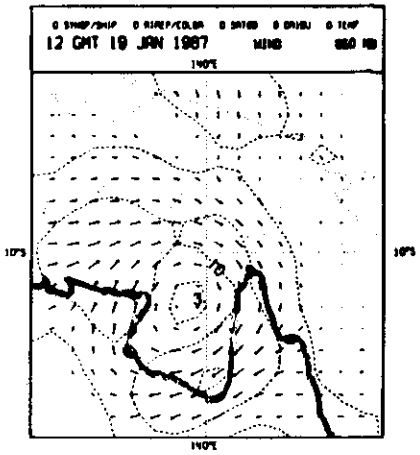
Observations rejected by analysis
TC Connie

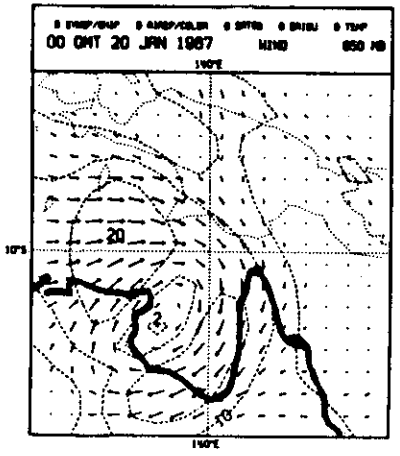


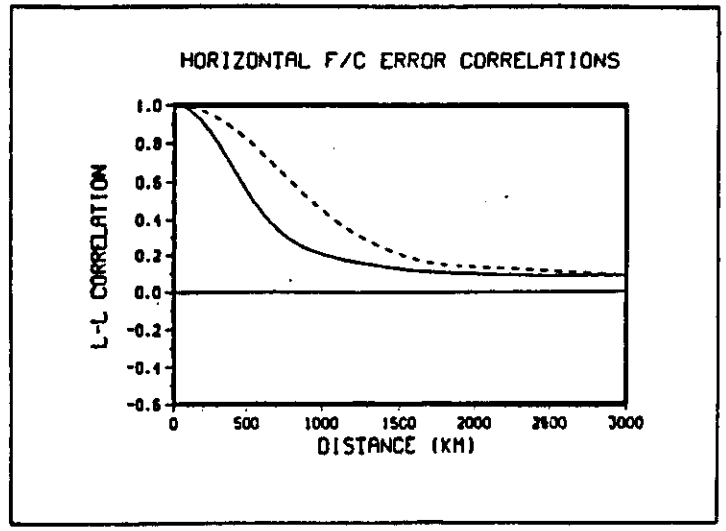
Observations rejected by analysis
TC Irma











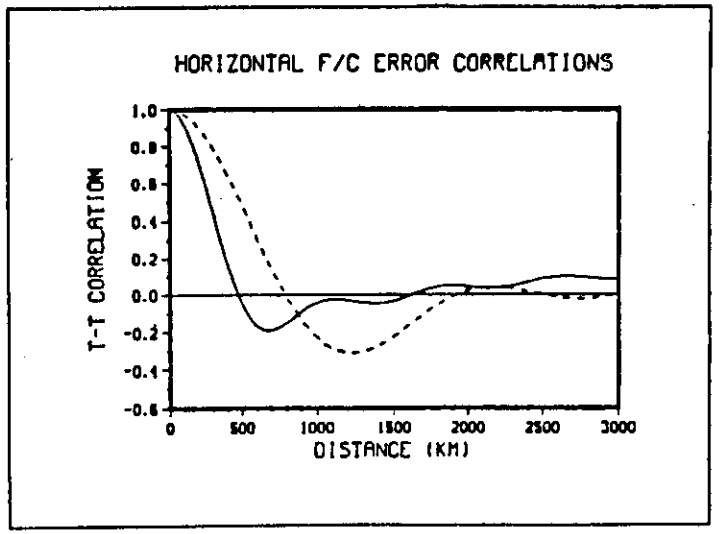


FIGURE 1

Analyses

Control

HRES + Forced data

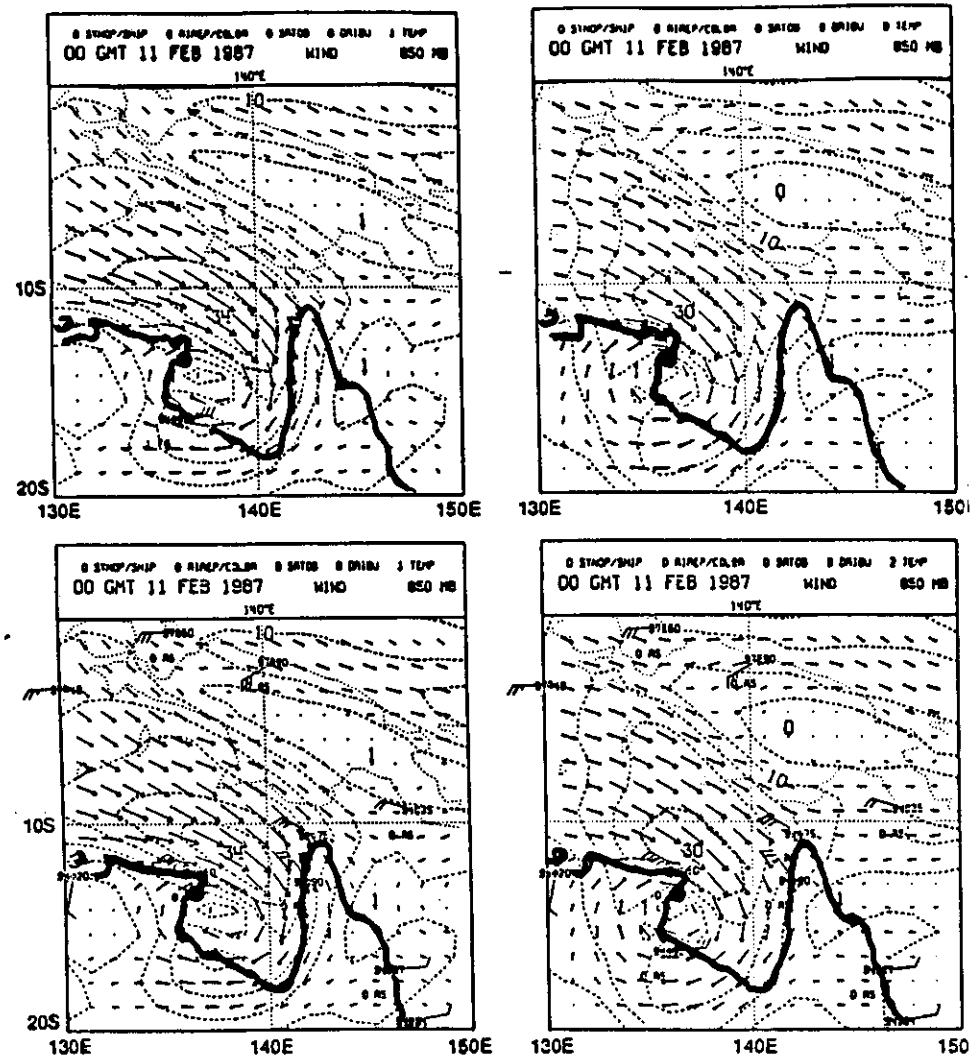


FIGURE 4b