Monsoon Climatology:

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Lay out …

- Introduction
- Features of monsoon
- Circulation
- Precipitation
- Monsoon prediction
  - Circulation features
  - precipitation
- Conclusions

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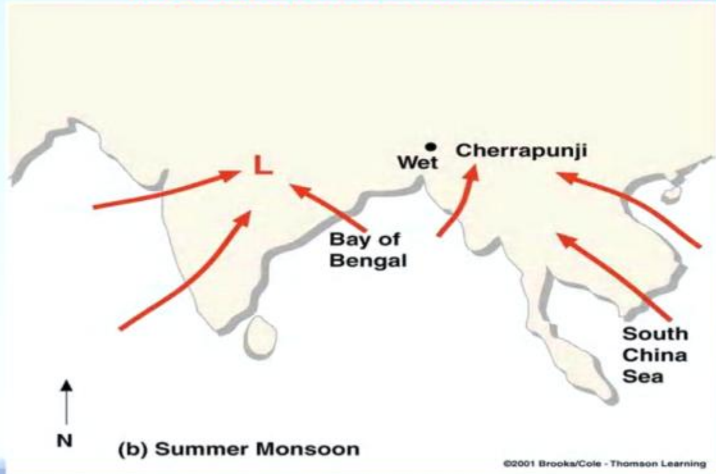
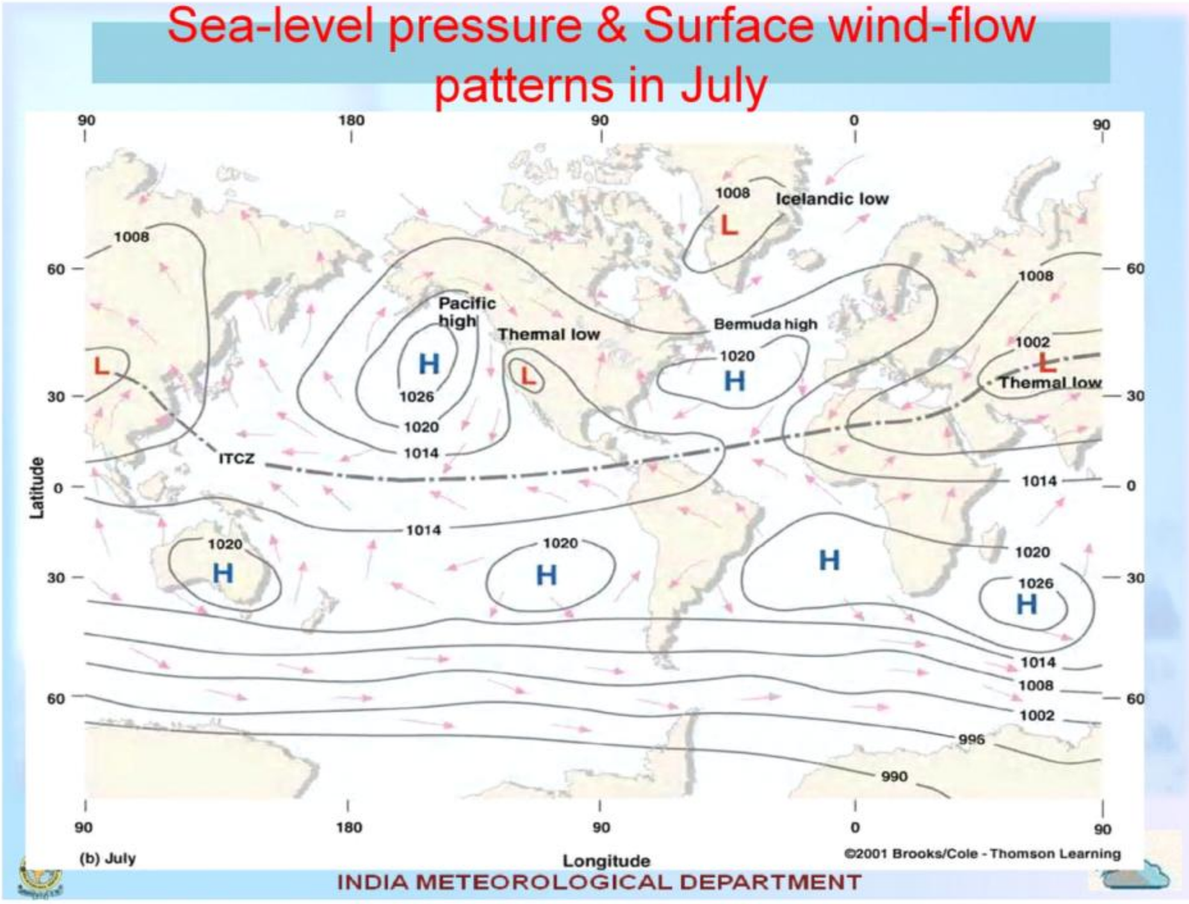
Monsoon : A Reversal of Wind



- Monsoon is characterized by s<u>easonal wind reversal in tropics</u>
- Many regions of the world have their monsoons: south asia, south east asia, east asia, africa, australia, south america and north america
- The south asian monsoon is the most pronounced of all of these because the differential heating between the landmass in the north and the oceans in the south is very large during summer.


Sea-level pressure & Surface wind-flow patterns in July
Icelandic low
Pacific high
Thermal low
Bermuda high
Thermal low
ITCZ
1008
1026
1020
1014
1002
996
990
Latitude
Longitude
(b) July
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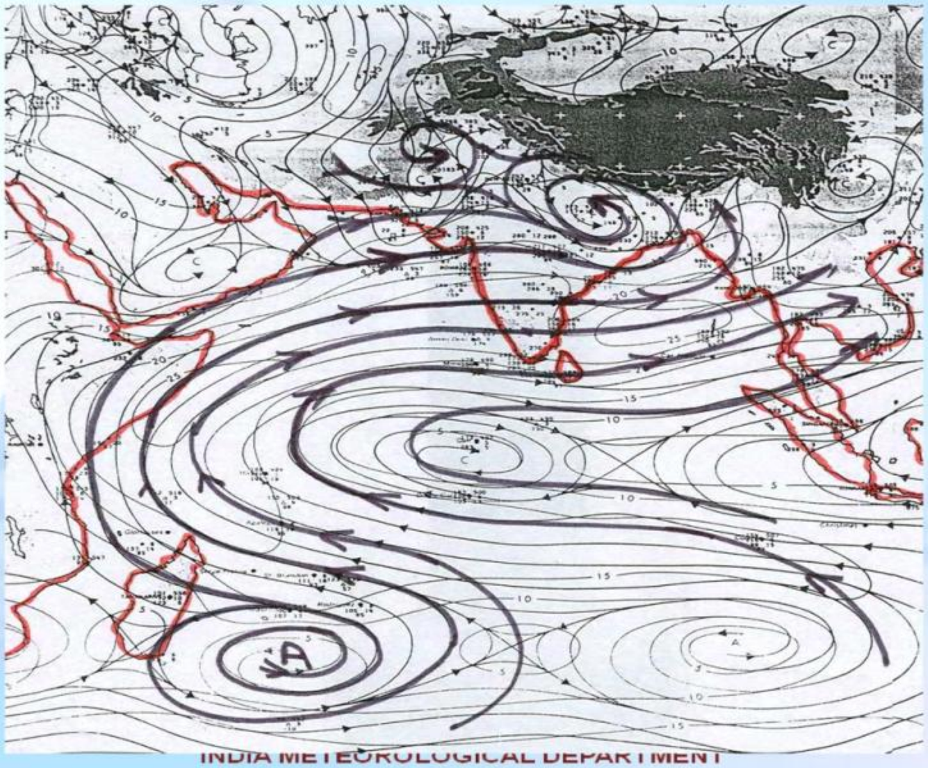
LOWER LEVEL WINDS DURING JULY



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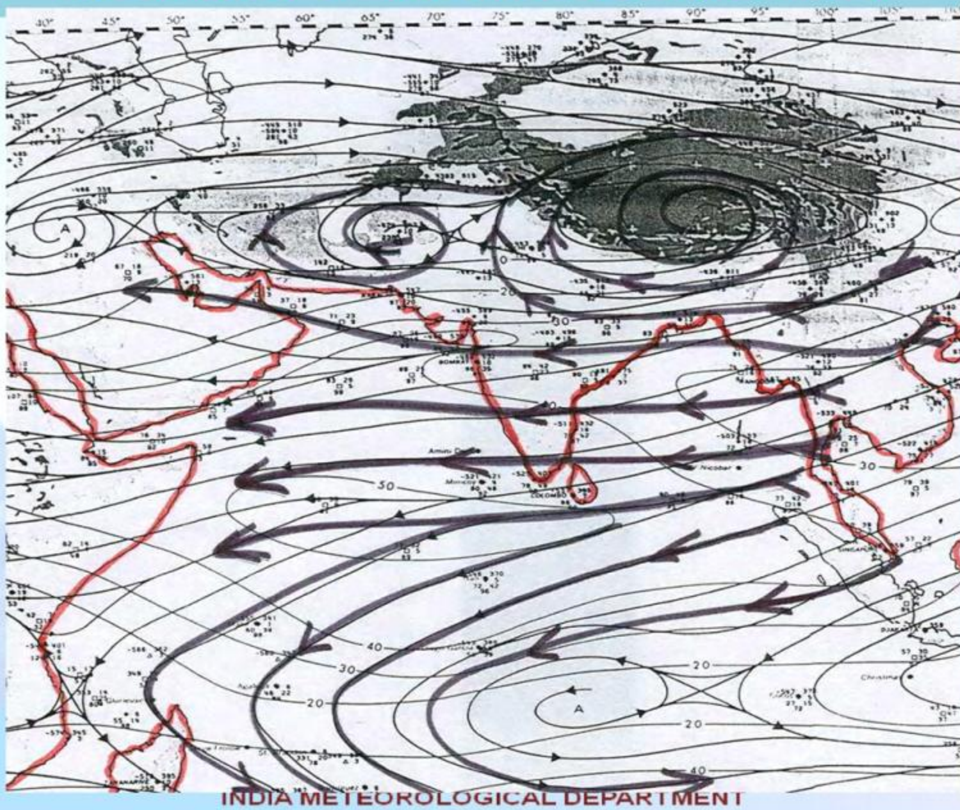
HIGHER LEVEL WINDS DURING JULY



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What causes Monsoons

The differential heating of LAND and OCEANS

(Monsoon is a giant Sea Breeze)

- **The poleward landlocking of the Indian Ocean adds to its distinguishing features.**
- **The inter tropical convergence zone extends to its farthest limit over the South Asian landmass. Himalayan orography comes into play, creating an unique feature for the Indian monsoon.**
- **Finally, teleconnections of the Pacific basin anomalies adds to the number of dominant forcing factors affecting the South Asian monsoon.**

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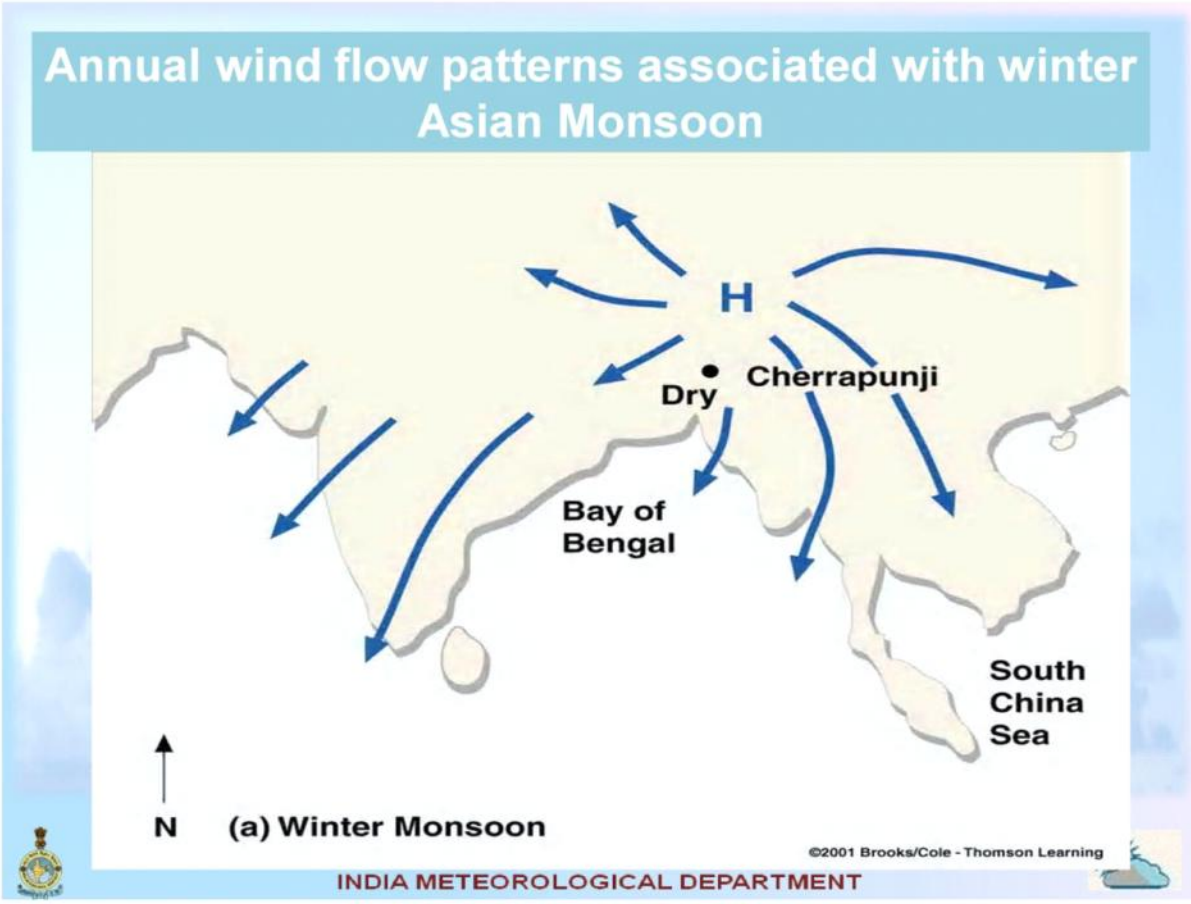
Annual wind flow patterns associated with winter Asian Monsoon
H
Dry
Cherrapunji
Bay of Bengal
South China Sea
N
(a) Winter Monsoon
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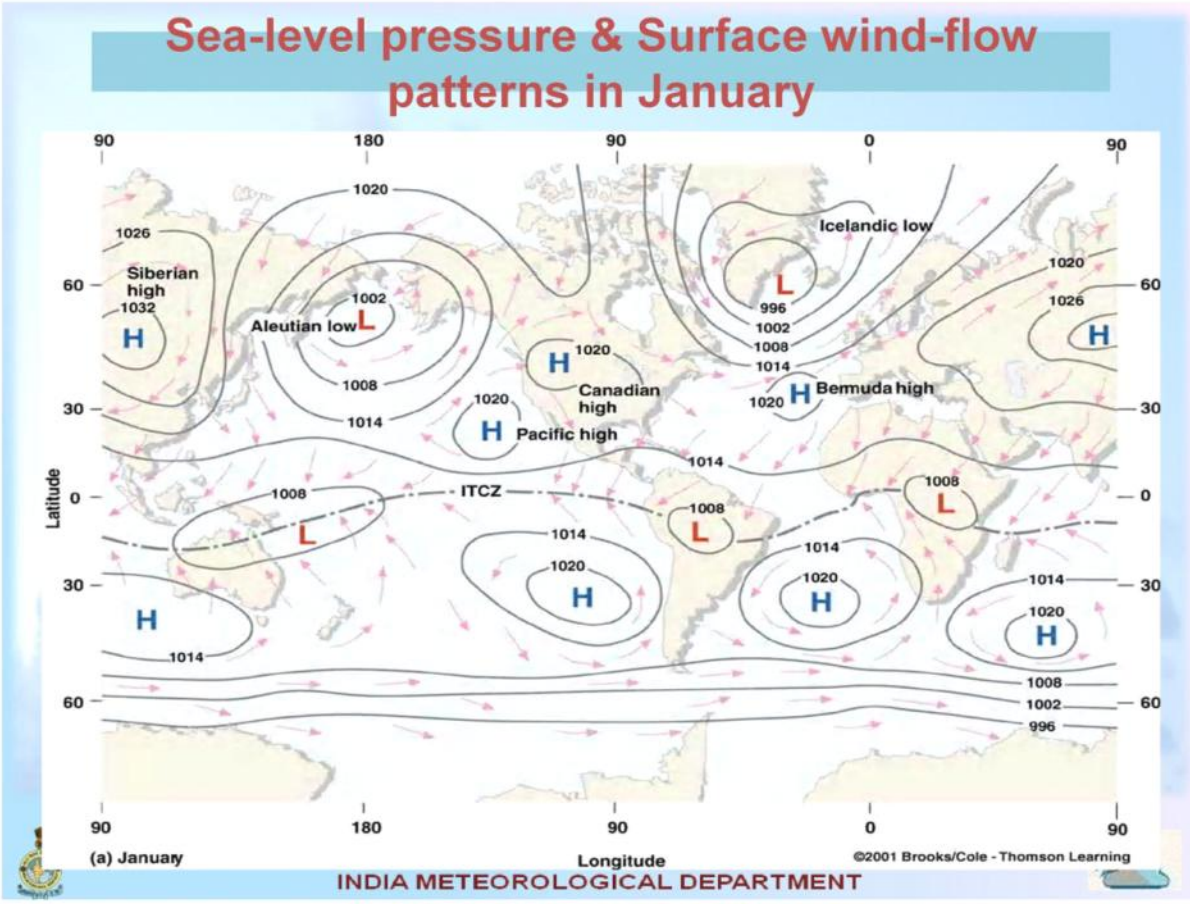

Sea-level pressure & Surface wind-flow patterns in January
Siberian high
1032
1026
Aleutian low
1002
1008
1014
1020
Canadian high
Pacific high
Icelandic low
996
Bermuda high
ITCZ
Latitude
Longitude
(a) January
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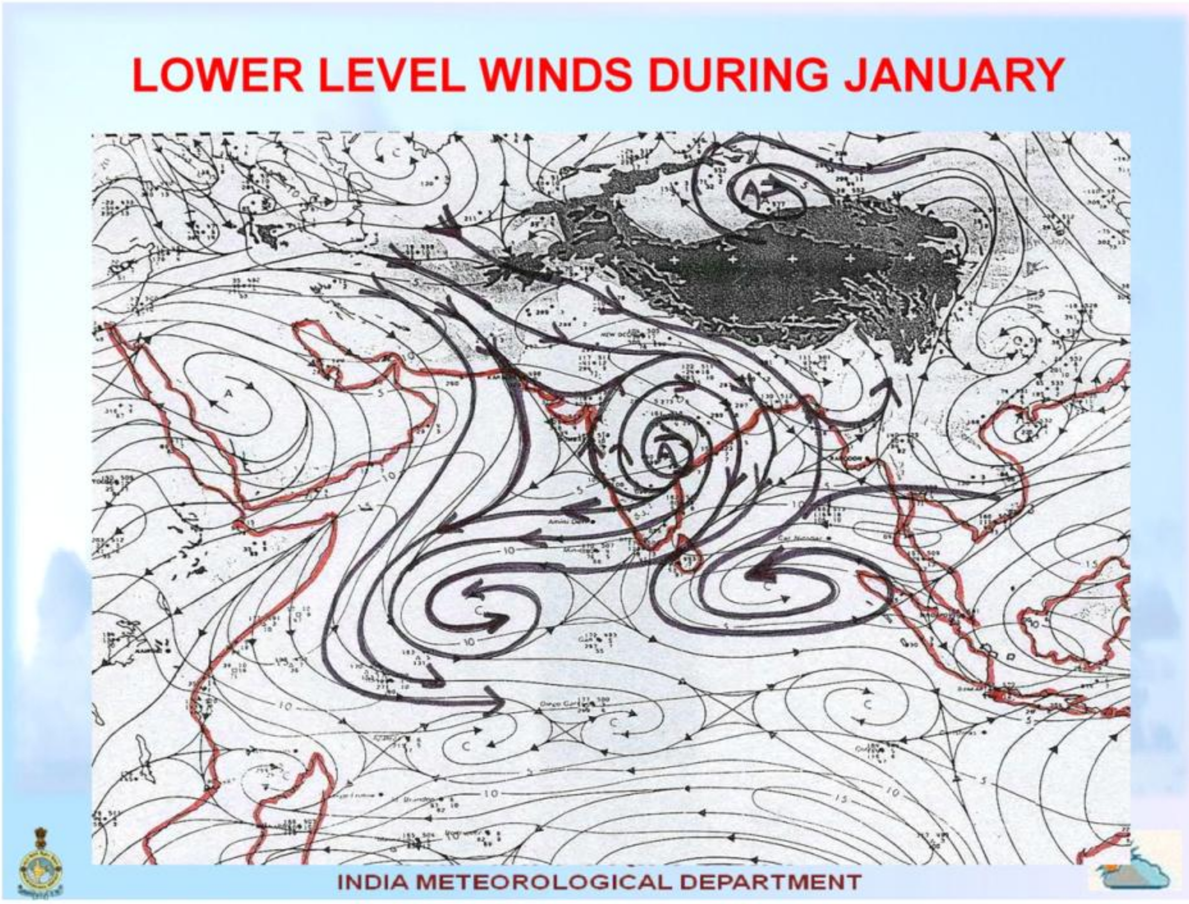
LOWER LEVEL WINDS DURING JANUARY
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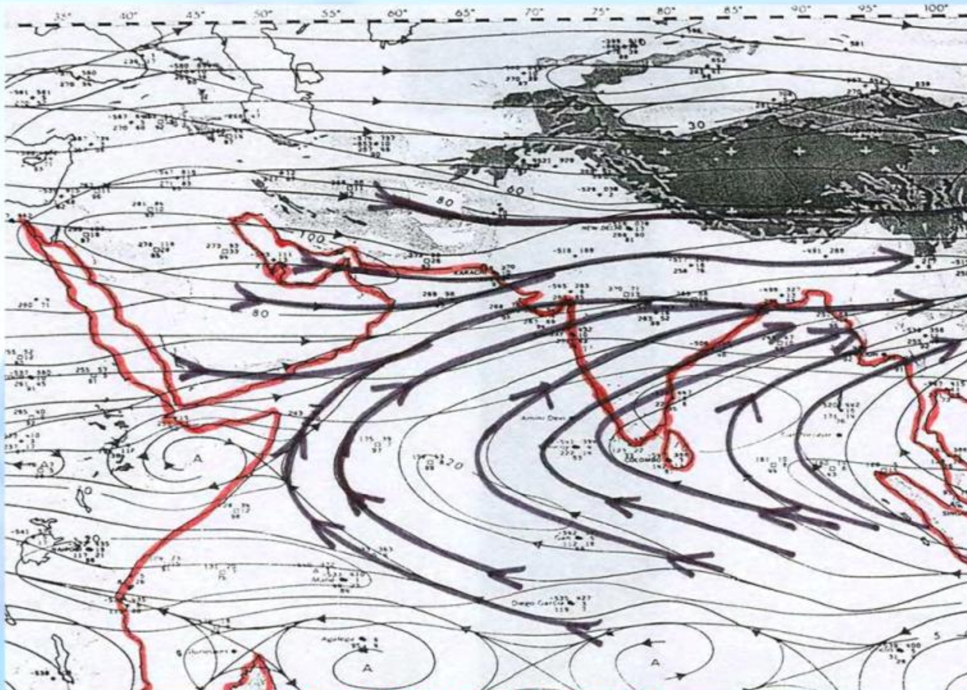
HIGHER LEVEL WINDS DURING JANUARY



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COMPONENTS OF SW MONSOON

1. HEAT LOW

(Pakistan & adjoining west Rajasthan)

2. MONSOON TROUGH

(Sri Ganganagar to Kolkata and then to north BOB)

3. TIBETAN HIGH

(30^{O} N/95^{O} E at about 12 km above sea level)

4. MASCARIAN HIGH

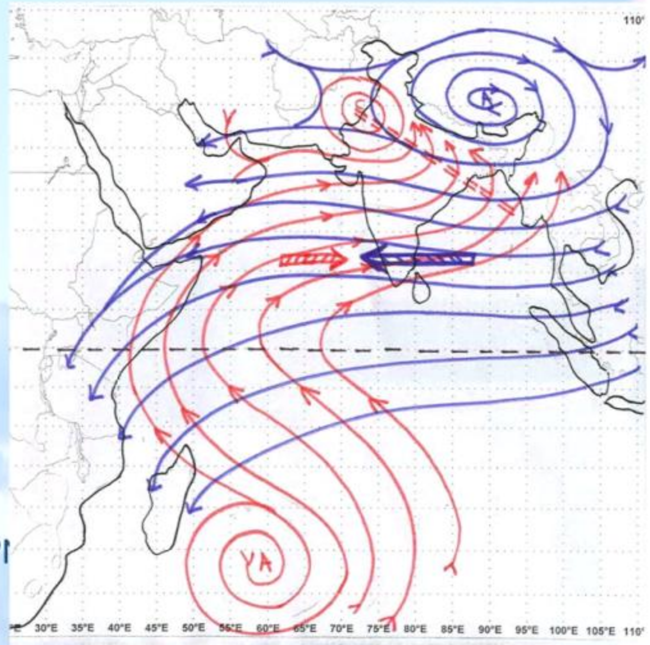
(30^{O} S/50^{O} E)

5. TROPICAL EASTERLY JET STREAM

(14 km above sea level along 13^{O}

6. LOW LEVEL JET STREAM

(Over the Arabian Sea roughly along 14^{O} N at 1 km asl)



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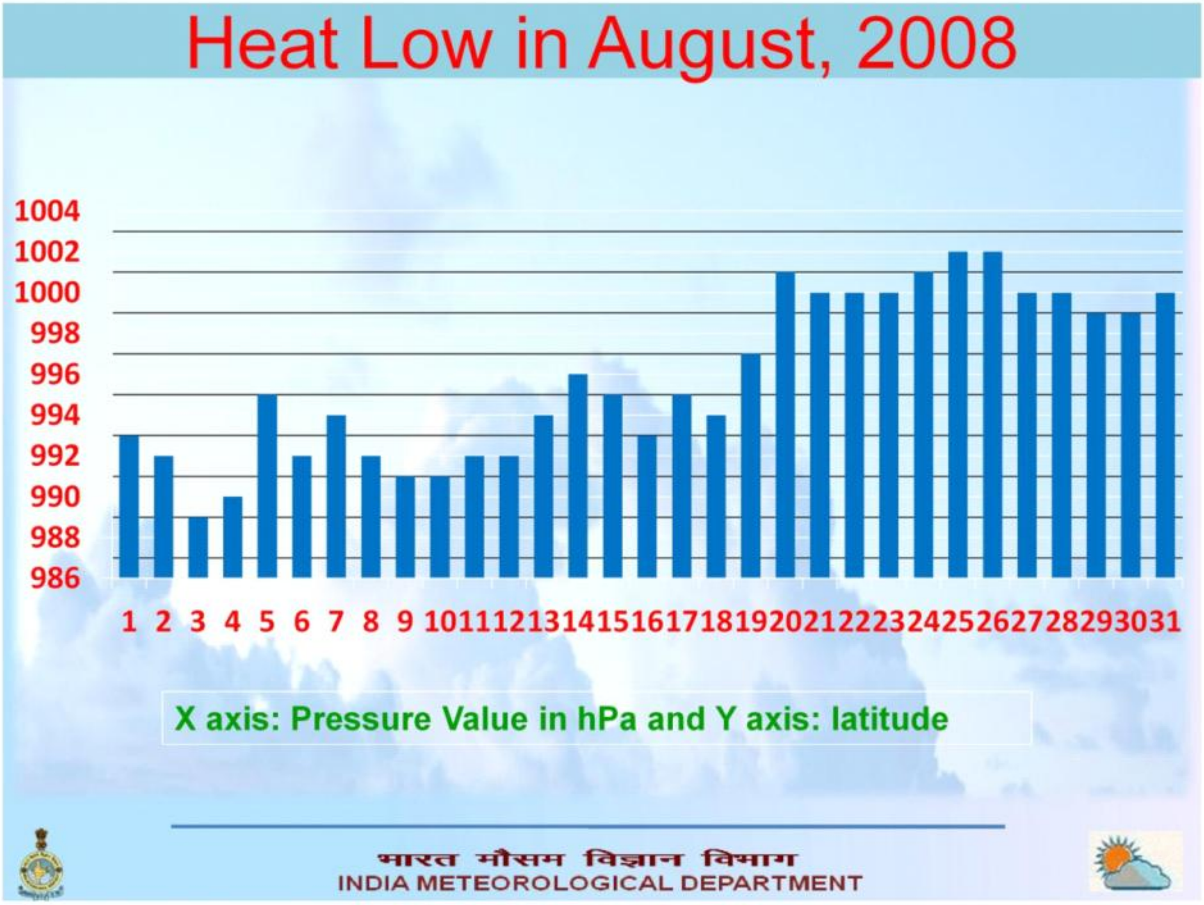

Heat Low in August, 2008
1004
1002
1000
998
996
994
992
990
988
986
1 2 3 4 5 6 7 8 9 10111213141516171819202122232425262728293031
X axis: Pressure Value in hPa and Y axis: latitude
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MONSOON TROUGH

- EXTENDS THROUGH JACOBABAD IN PAKISTAN, GANGANAGAR IN RAJASTHAN, ALLAHABAD IN UTTAR PRADESH AND KOLKATA IN WEST BENGAL TO MYANMAR-SOUTH CHINA SEA.
- MONSOON ACTIVITY IS SIGNIFICANTLY CONTROLLED BY THE MONSOON TROUGH
- TILTS SOUTHWARDS WITH HEIGHT IN VIEW OF THE LOWER TEMPERATURES TO THE SOUTH
- THE RAINFALL MAINLY DEPENDS ON THE ACTIVITY OF MONSOON TROUGH.
- RAINFALL ASSOCIATED WITH THE NORMAL SOUTHWARD SLOPE OF THE TROUGH IS DISTRIBUTED MAINLY TO THE SOUTH OF THE MEAN SEA LEVEL POSITION OF THE TROUGH
- WHEN THE TROUGH SHIFTS TO THE FOOTHILLS OF THE HIMALAYAS WE HAVE A BREAK SITUATION

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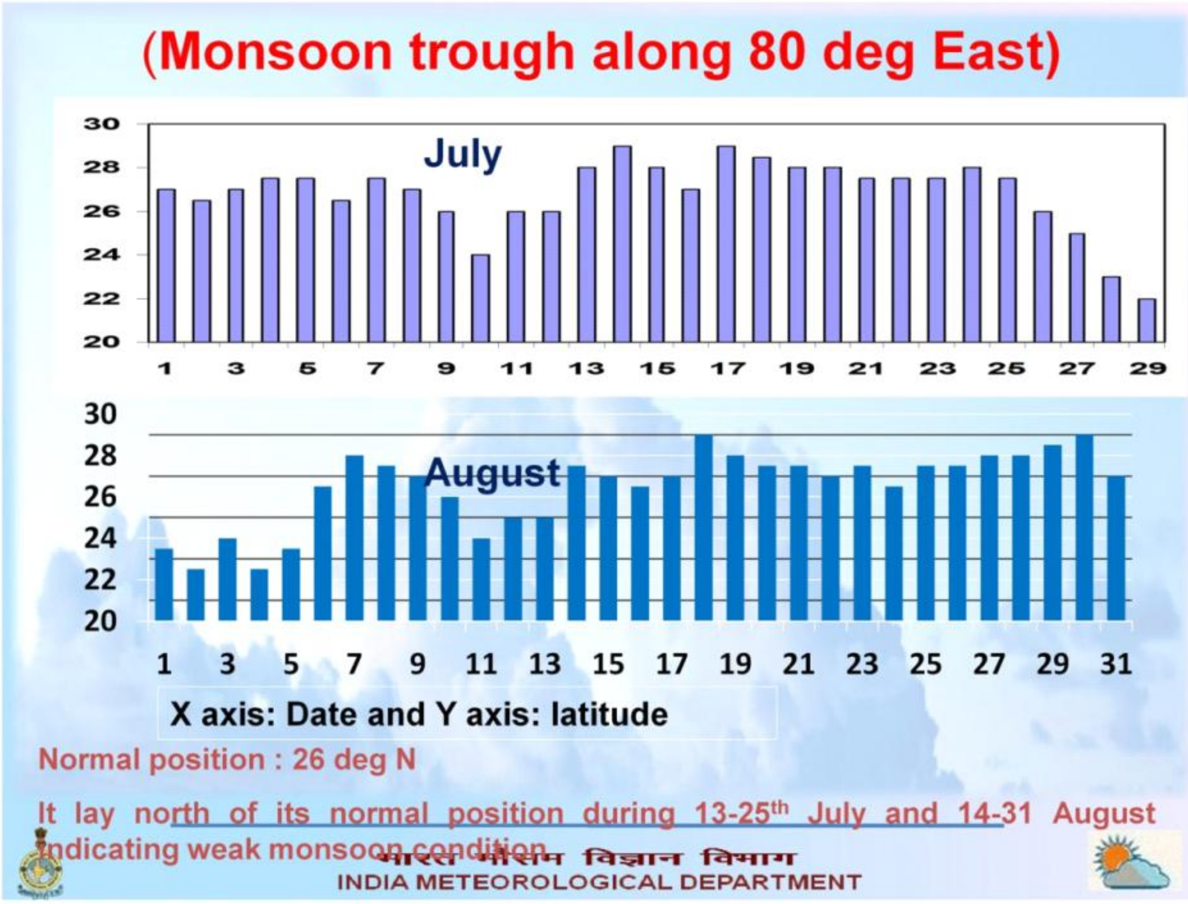
(Monsoon trough along 80 deg East)
July
30 28 26 24 22 20
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
August
30 28 26 24 22 20
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
X axis: Date and Y axis: latitude
Normal position : 26 deg N
It lay north of its normal position during 13-25th July and 14-31 August indicating weak monsoon condition
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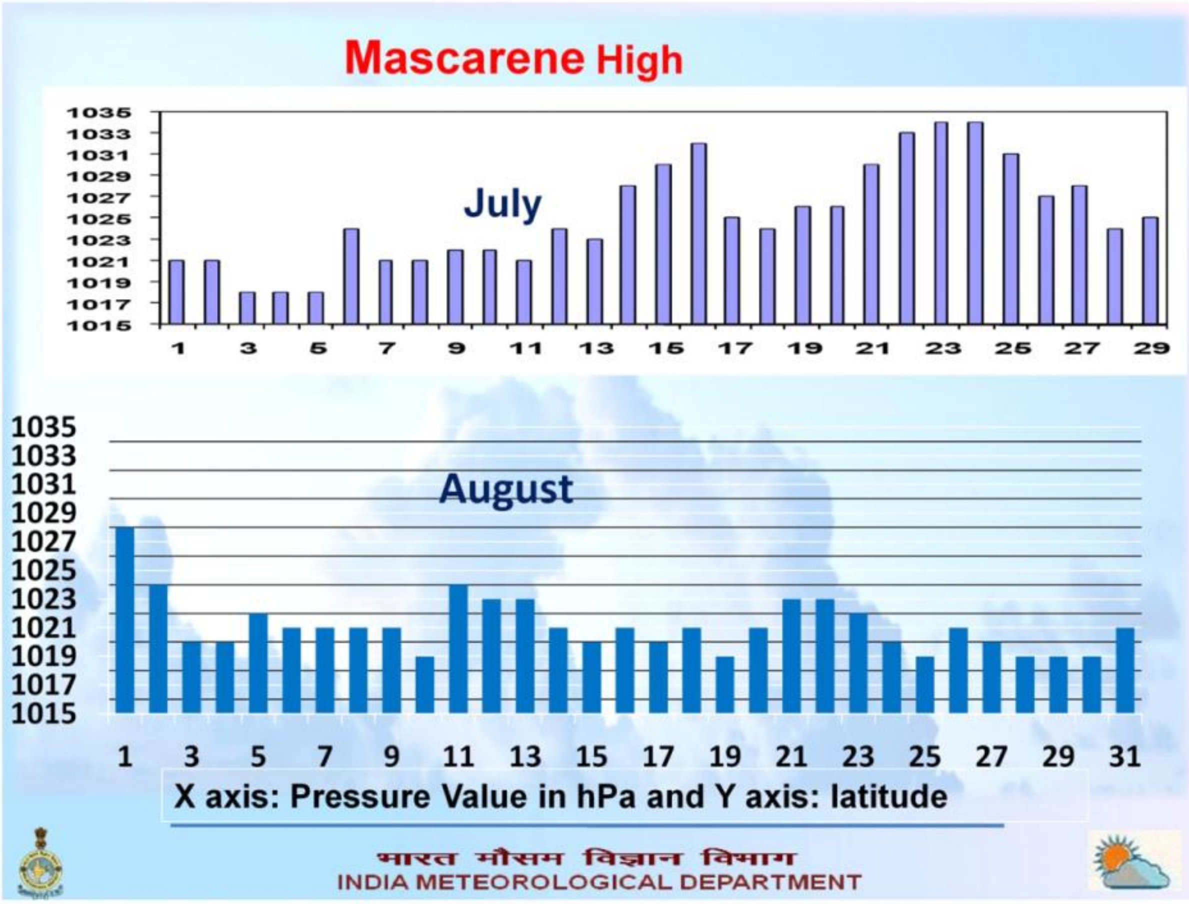
Mascarene High
July
1035
1033
1031
1029
1027
1025
1023
1021
1019
1017
1015
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
August
1035
1033
1031
1029
1027
1025
1023
1021
1019
1017
1015
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
X axis: Pressure Value in hPa and Y axis: latitude
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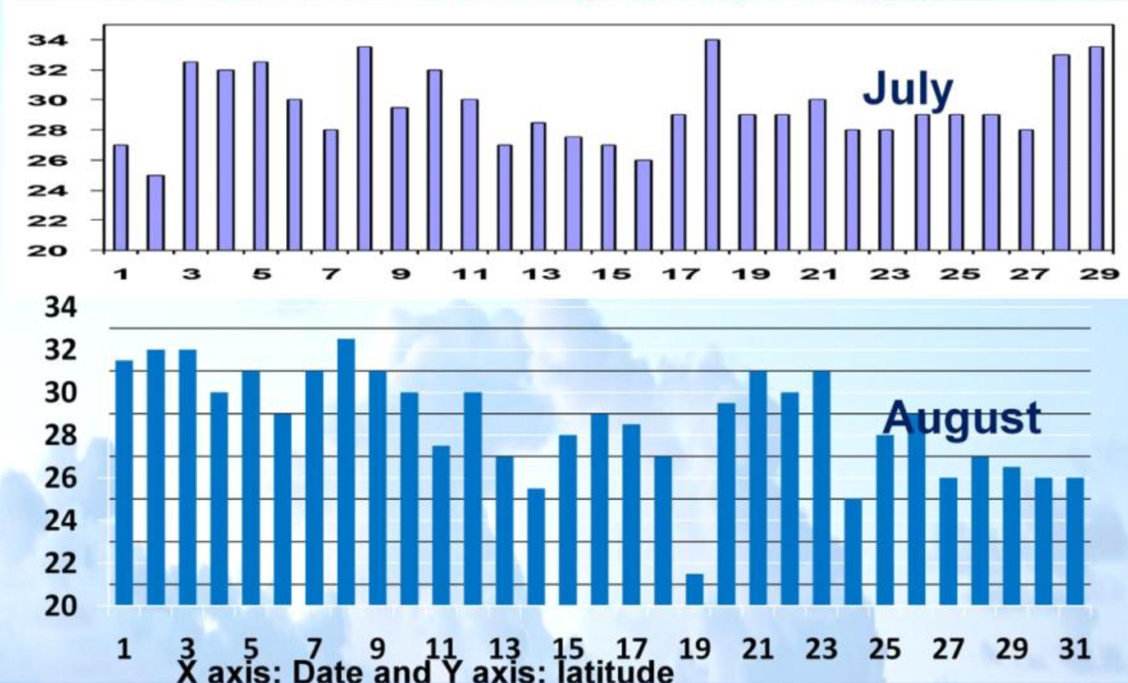
Position of 200 hPa Ridge (along 75 deg E)



Normal position : 30 deg N.

It lay south of its normal position during 12-27th July and 13-31 August excluding a few days indicating weak monsoon condition

TEJ OBSERVATION in August

Date	Location (1) SE Coast Strength (Kt)		Location (2) A7N Strength (Kt)	
14	12	60	-	-
15	13	50	-	-
16	13	55	19	50
17	13	55	19	65
18	13	55	-	-
19	-	-	19	75
20	08	65	20	55
21	12	50	20	30
22	15	50	19	50
23	-	-	-	-
24	-	-	20	50
25	-	-	21	60
26	-	-	19	60
27	-	-	19	60
28	-	-	19	55
29	13	50	-	-
30	13	70	16	60
31	15	50	19	50

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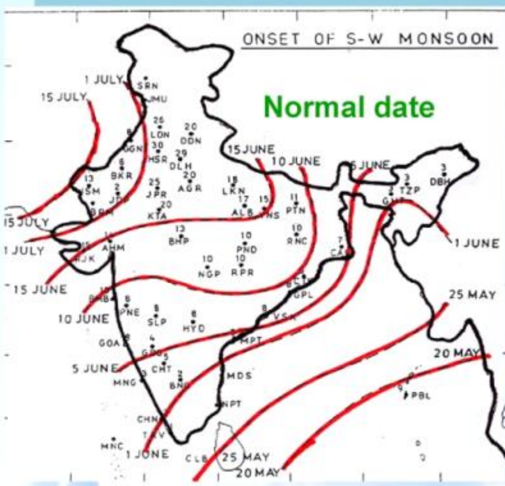
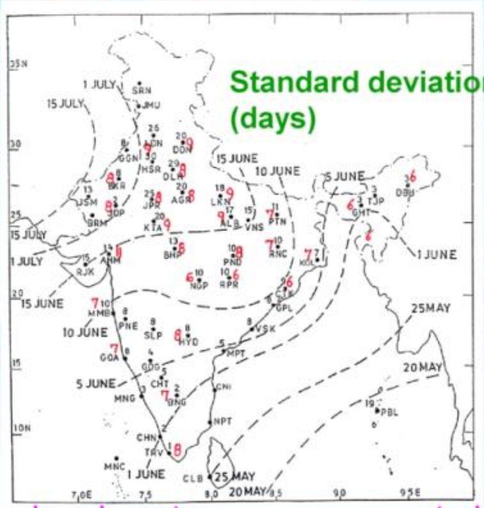
ONSET OF SOUTHWEST MONSOON





- Present normal dates of onset are based on long term average pentad (five day non-overlapping) rainfall graphs prepared for several observatory stations. The middle date of the pentad which starts an abrupt increase in rainfall is taken as the monsoon onset date for each station.
- Onset and intraseasonal variation of monsoon rains shows interannual variation. Similarly the onset dates also show interannual variation

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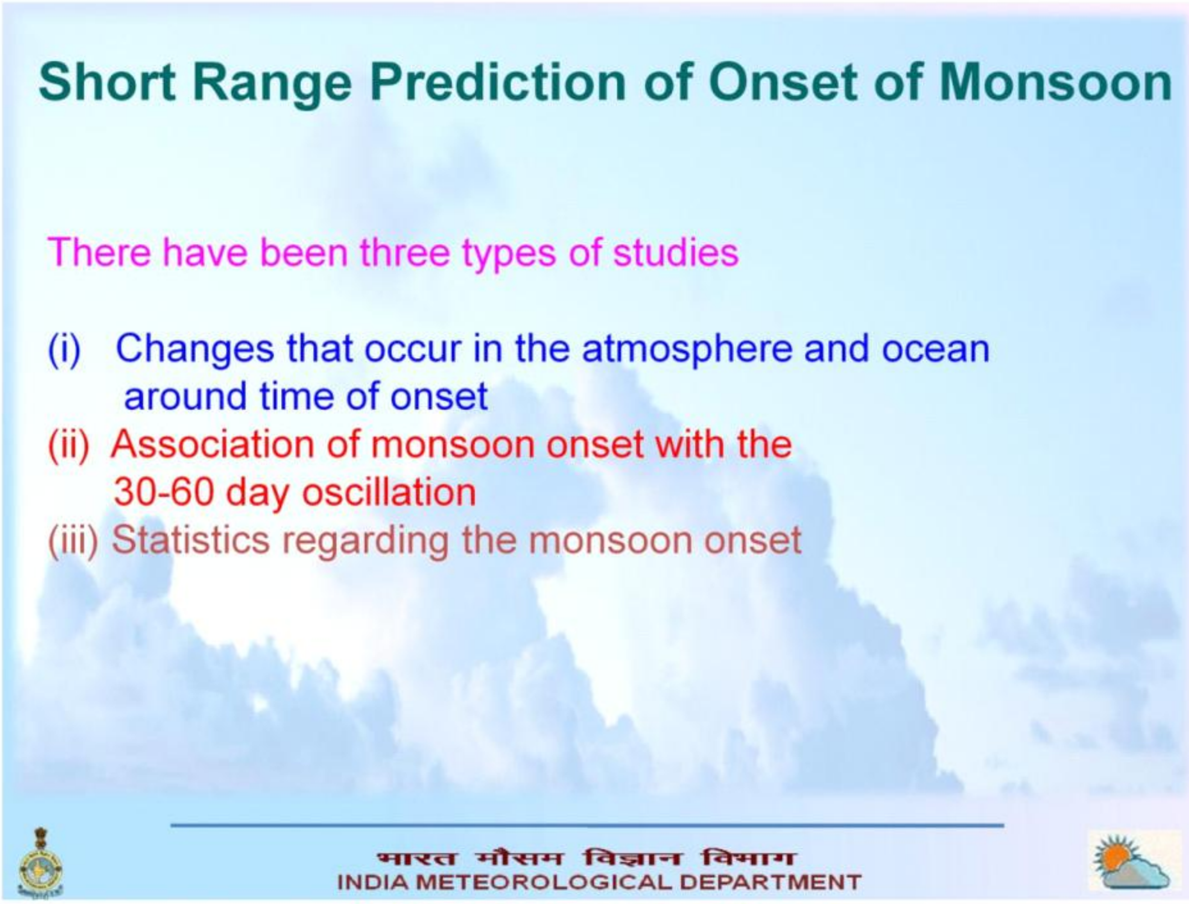
Short Range Prediction of Onset of Monsoon
There have been three types of studies
(i) Changes that occur in the atmosphere and ocean around time of onset
(ii) Association of monsoon onset with the 30-60 day oscillation
(iii) Statistics regarding the monsoon onset
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ONSET OF MONSOON OVER SOUTHERN TIP PF INDIA

(AN EXAMPLE)

a) **Rainfall:**

Fairly widespread rainfall for two consecutive days,

b) **Wind field:**

Depth of westerlies should be maintained upto 600 hPa, over equator to Lat.10 N and Long. 55E to 80E. Zonal wind speed over Lat. 5-10 N, Long. 70-80 E should be of the order of 15 -20 Kts at 925 hPa. The source of data can be RSMC wind analysis/satellite derived winds.

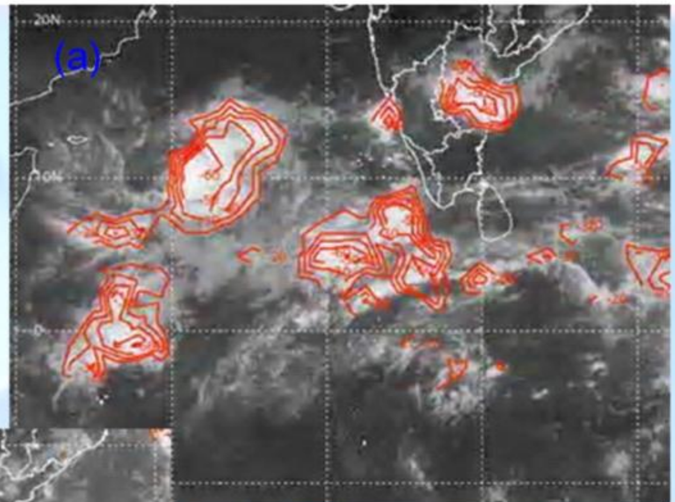
On date of onset and two days prior to it, the SSM/I derived surface wind maximum over 5-10deg N and 55- 80 deg E should be greater than 16ms-1, with water vapour maxima remaining 6gcm-2 (optional)

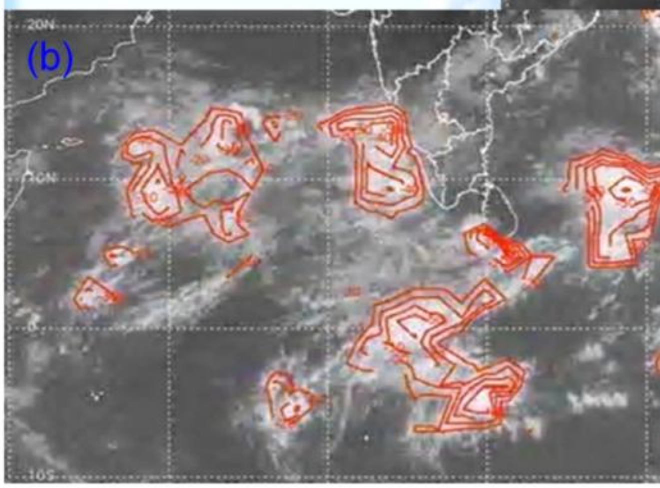
c) **OLR:**

Steady increase of convection over north of equator and east of long 60 deg E. INSAT derived OLR value should be below 200 wm^{-2} in the box confined by Lat. 5-10 deg N and Long. 70-75 deg E.

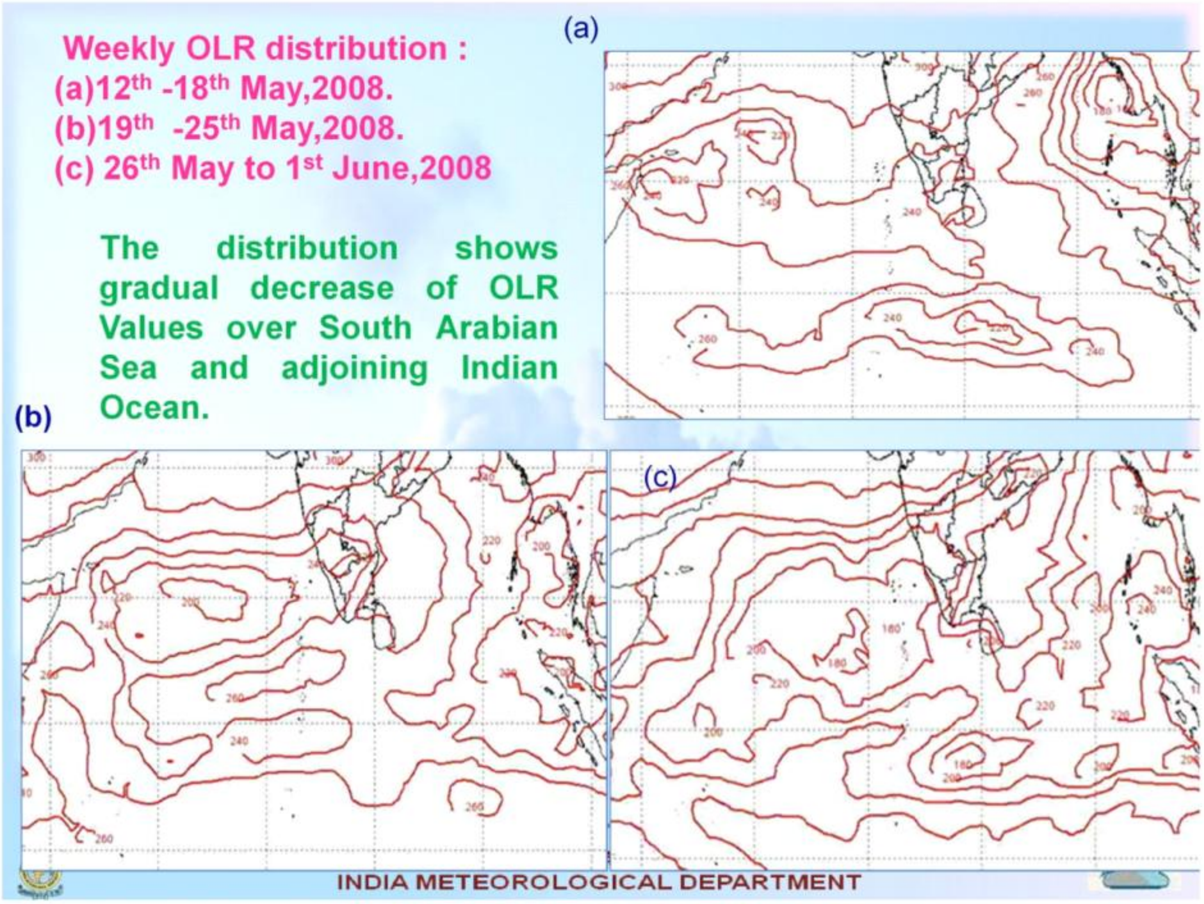
Steady increase of cloudiness/convection over area 0 -15^0 N and east of long 60^0 E and gradual movement towards west coast associated with onset.

Onset date over Kerala in 2008: 31st May.





CTT contour analysis of (a) 30th and (b) 31st May,2008



Weekly OLR distribution :
(a)12th -18th May,2008.
(b)19th -25th May,2008.
(c) 26th May to 1st June,2008
The distribution shows gradual decrease of OLR Values over South Arabian Sea and adjoining Indian Ocean.
(a)
(b)
(c)
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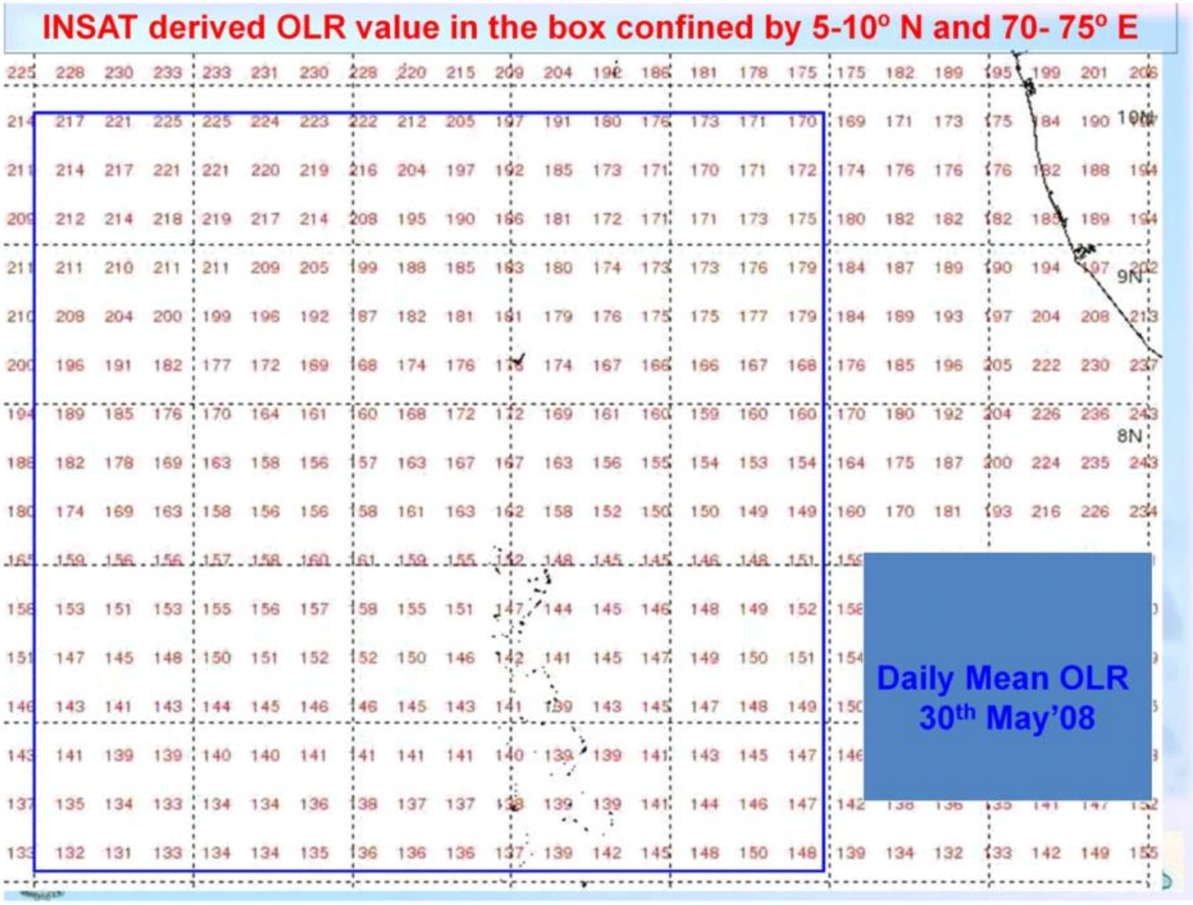

INSAT derived OLR value in the box confined by 5-10° N and 70- 75° E
10N
9N
8N
Daily Mean OLR
30th May'08

INSAT derived OLR value in the box confined by 5-10° N and 70- 75° E

231	225	224	222	213	195	178	138	120	109	102	96	95	99	107	115	126	131	136	144	158	166	174
206	202	205	207	207	202	195	173	154	137	127	114	109	108	112	119	125	122	122	126	153	166	173
201	201	206	207	207	202	197	181	166	152	144	128	121	119	122	126	123	116	115	122	158	174	183
207	207	217	218	214	204	194	179	169	161	157	151	146	142	141	137	122	115	114	121	159	177	192
217	216	227	229	224	212	198	174	167	163	166	168	166	163	160	151	124	117	116	120	150	171	196
226	221	226	227	222	212	201	179	171	167	171	180	180	176	170	157	127	120	118	118	141	163	194
231	226	212	202	198	195	200	196	183	173	173	184	187	183	168	150	136	139	140	144	161	174	195
230	230	207	192	185	183	191	204	198	192	192	199	201	197	180	159	146	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
225	229	203	185	174	168	173	204	210	212	214	218	216	210	195	177	163	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
213	219	199	183	173	164	162	192	208	220	227	231	225	216	203	190	177	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
198	197	183	176	174	170	164	161	170	185	197	218	218	212	204	201	203	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
202	196	179	173	171	167	162	157	162	169	174	193	202	201	195	190	207	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
206	197	179	173	168	164	159	158	164	166	164	171	182	184	179	175	204	221	233	239	245	246	247
208	196	180	173	169	166	162	162	169	170	165	161	167	169	165	162	193	212	227	236	241	240	238
211	200	181	173	171	173	174	171	173	171	167	160	162	162	158	157	177	191	206	219	232	231	225
202	196	177	175	182	194	204	192	183	178	174	166	167	167	167	163	162	166	170	174	186	192	193
194	192	182	183	188	196	203	195	189	188	187	176	174	177	179	178	173	174	173	170	164	167	174

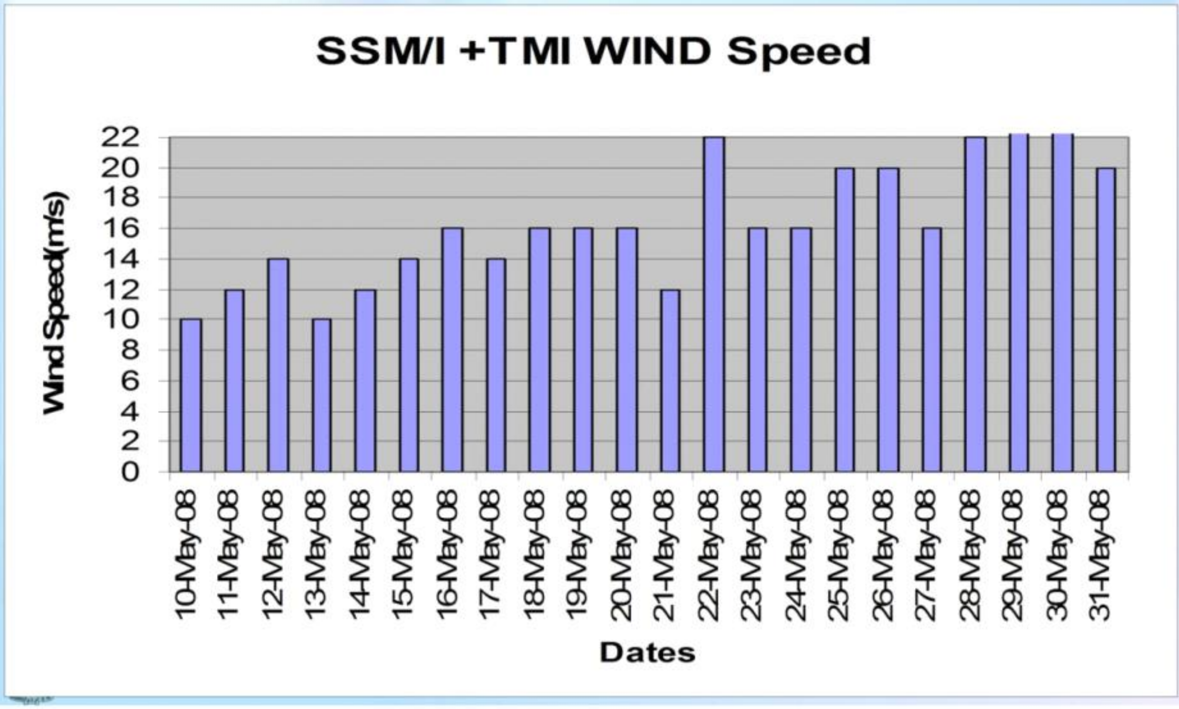
10N

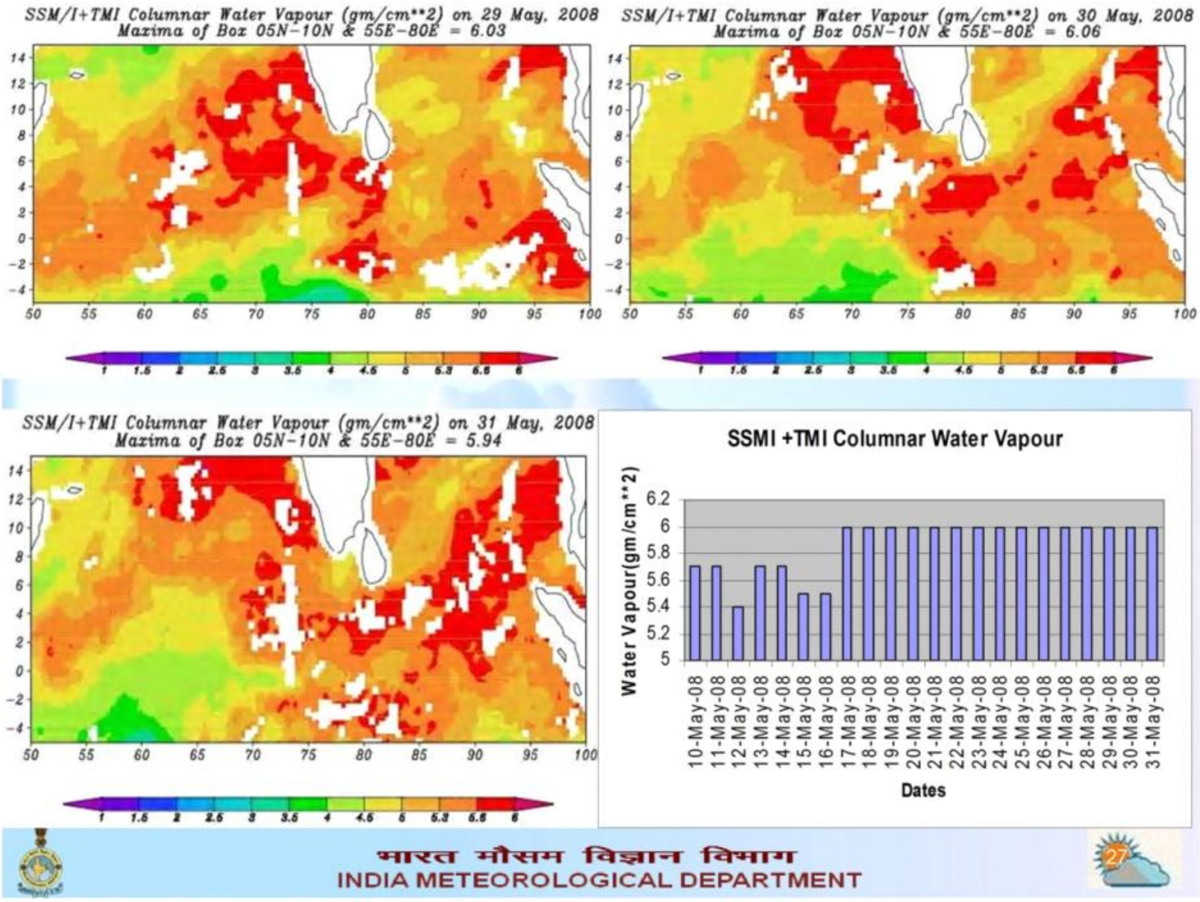
9N

6N

Daily Mean OLR
31 May'08

On the date of onset and two days prior to it, the SSM/I derived surface wind maximum in the box defined by 5-10° N and 55- 80° E were greater than 16ms^{-1}




SSM/I+TMI Columnar Water Vapour (gm/cm**2) on 29 May, 2008
Maxima of Box 05N-10N & 55E-80E = 6.03
SSM/I+TMI Columnar Water Vapour (gm/cm**2) on 30 May, 2008
Maxima of Box 05N-10N & 55E-80E = 6.06
SSM/I+TMI Columnar Water Vapour (gm/cm**2) on 31 May, 2008
Maxima of Box 05N-10N & 55E-80E = 5.94
SSMI +TMI Columnar Water Vapour
Water Vapour(gm/cm**2)
Dates
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Precursors For monsoon onset

May 2008	850 hPa Wind		SSMI Wind speed(**kts**)	SSMI Water vapour (6g)	OLR (W/m^2)
	Strength (kts)	Depth (hPa)			
21	10-15	700	26	5.8	240
22	10-15	850	22	6.0	235
23	10-15	850	21	6.0	219
24	10-15	700	21	6.0	199
25	10-15	700	24	6.0	223
26	10	700	23	6.0	259
27	10	850	25	6.0	179
28	10-15	850	24	6.0	176
29	10-20	700	27	6.0	239
30	10-15	600	25	6.0	222
31	15-25	600	25	6.0	165

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Rainfall (mm) over Kerala & Lakshadweep

Station	21 May	22 May	23 May	24 May	25 May	26 May	27 May	28 May	29 May	30 May	31 May
Minicoy	1.2	6.7	0.0	10.9	Nil	0.3	26.3	2.1	Nil	4.1	2.6
Amini	39.8	17.4	11.4	0.2	2.2	Nil	46.2	Nil	0.5	NIL	5.2
Trivandrum	Nil	0.7	0.0	1.6	8.8	5.8	5.7	Nil	Nil	56.2	37.3
Punalur	Nil	Nil	N/R	Nil	Nil	47.2	Nil	Nil	Nil	2.8	2.6
Kollam	3.0	8.0	N/R	3.0	19.0	34.0	Nil	Nil	Nil	4.0	190
Allapuzha	23.0	16.2	0.0	3.6	Nil	22.3	0.2	Nil	22.0	12.5	20
Kottayam	1.0	Nil	N/R	Nil	3.0	0.6	Nil	Nil	13.6	13.2	5.4
Kochi	12.8	1.0	0.7	Nil	Tr	10.2	3.4	Nil	21.3	19.8	83.2
Trissur	1.0	Nil	4.0	Nil	Nil	9.8	Nil	Nil	Nil	51.6	2.5
Kozhikode	20.6	6.7	6.4	Nil	0.3	4.4	0.8	0.5	0.4	Tr	8.6
Talassery	3.0	27.0	Nil	Nil	N/R	3.0	Nil	Nil	Nil	Nil	13.2
Cannur	Nil	Nil	0.0	Nil	Nil	1.8	Nil	Nil	Nil	21.8	3.6
Kasargode	Nil	2.2	0.6	Nil	Nil	9.8	Nil	Nil	11.2	69.4	0.0
Mangalore	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	3.4	0.1	0.6
% Stations	43	43	22	22	22	64	29	00	36	71	88

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Further advance of monsoon

a) Further advance be declared based on the occurrence of rainfall over parts/sectors of the sub-divisions and maintaining the spatial continuity of the northern limit of monsoon, further advance be declared.

The following auxiliary features may also be looked into.

b) Along the west coast, position of maximum cloud zone, as inferred from the satellite imageries.

c) The extent of moisture incursion. satellite water vapour imageries

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INTRASEASONAL VARIABILITY OF MONSOON

- THERE ARE FOUR MODES OF OSCILLATION

  (I) ANNUAL/ SEASONAL CYCLE (122 DAYS),

  (II) 30-60 DAYS CYCLE IDENTICAL TO MADDEN-JULIAN OSCILLATION (MJO),

  (III) 10-20 DAYS QUASI-BIWEEKLY (QBW) CYCLE

  (IV) SYNOPTIC MODE (3-9 DAYS)

  IN DAILY RAINFALL AND SOME OF THE METEOROLOGICAL FIELD PARAMETERS LIKE WIND, PRESSURE, OCCURRENCE OF LOW AND DEPRESSION, SATELLITE CLOUDINESS AND OLR

- ATTEMPTS HAVE BEEN MADE TO USE THESE OSCILLATIONS TO PREDICT WET AND DRY SPELLS

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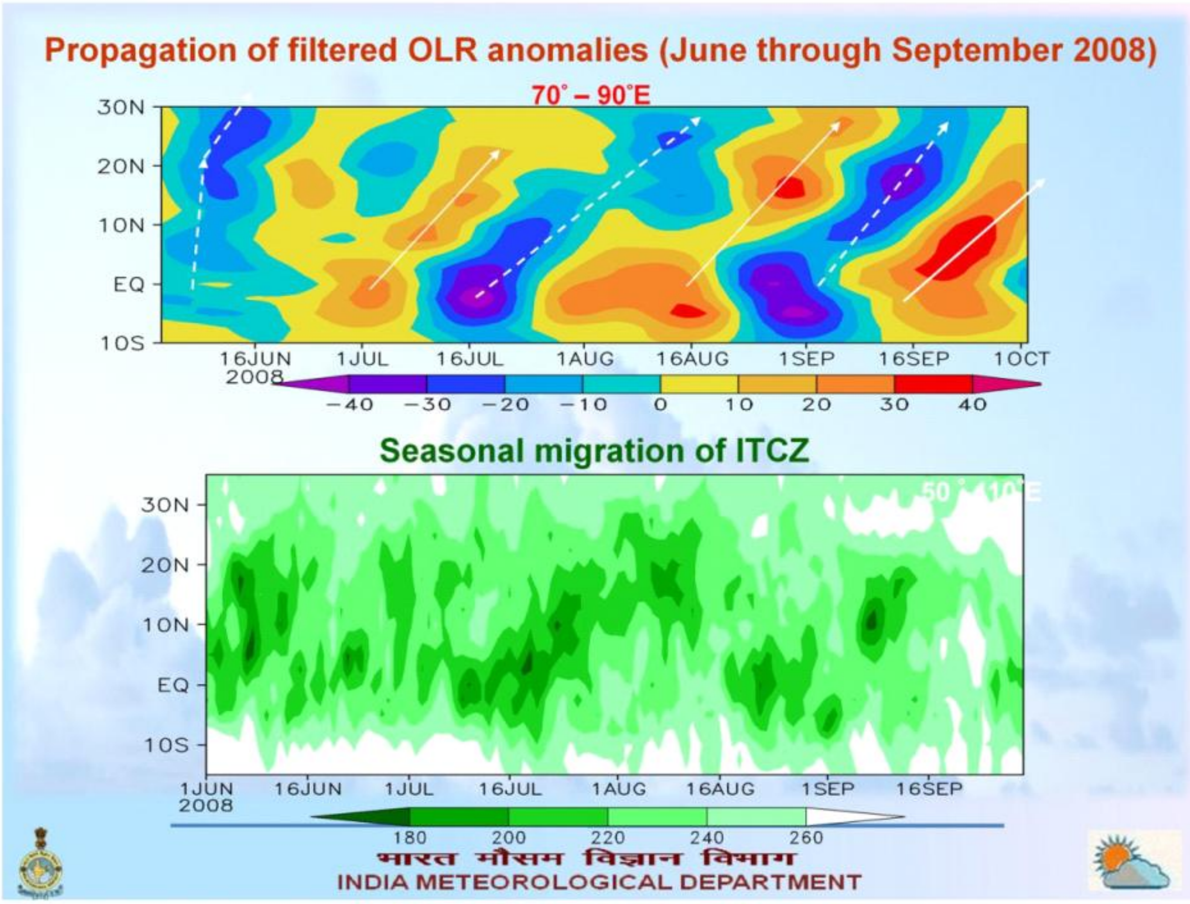
Propagation of filtered OLR anomalies (June through September 2008)
70° – 90°E
30N
20N
10N
EQ
10S
16JUN 2008
1JUL
16JUL
1AUG
16AUG
1SEP
16SEP
1OCT
−40 −30 −20 −10 0 10 20 30 40
Seasonal migration of ITCZ
1JUN 2008
180 200 220 240 260
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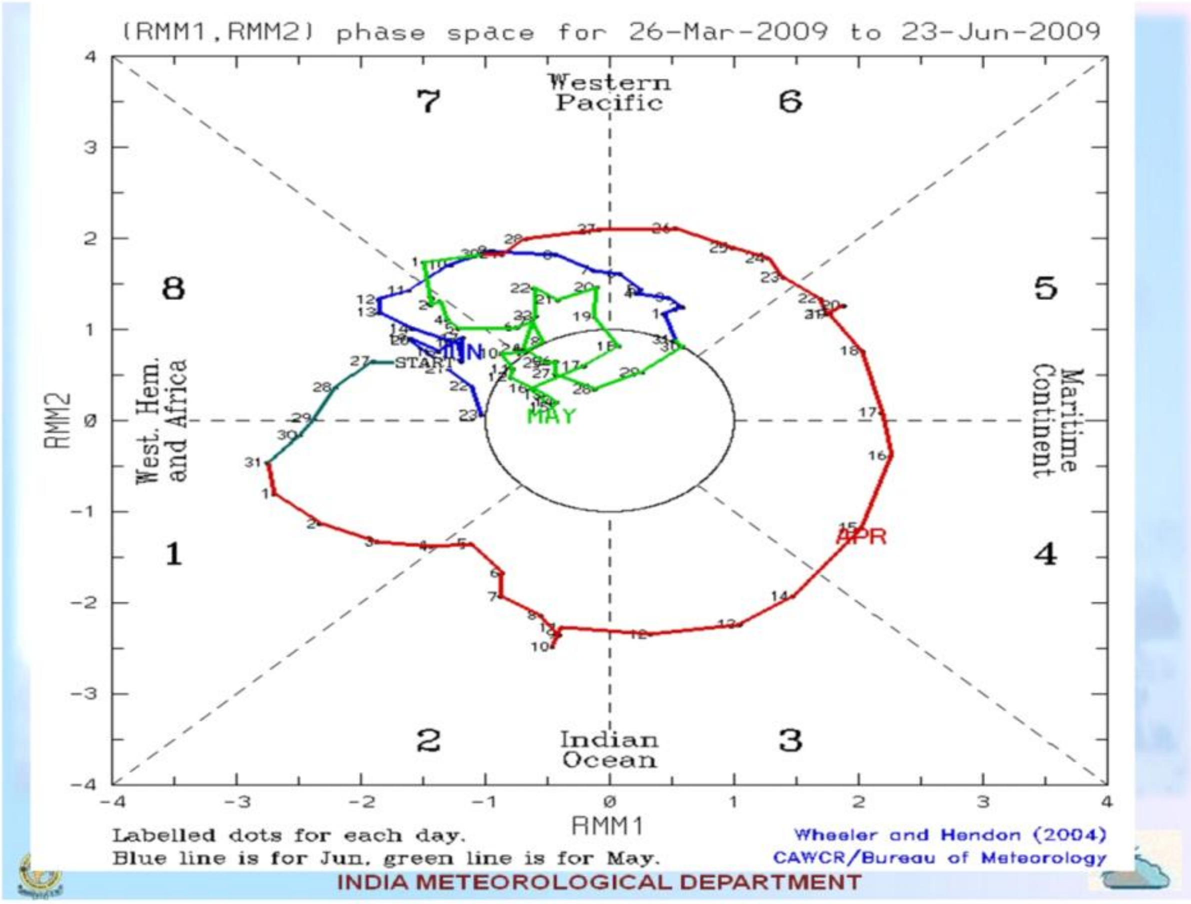
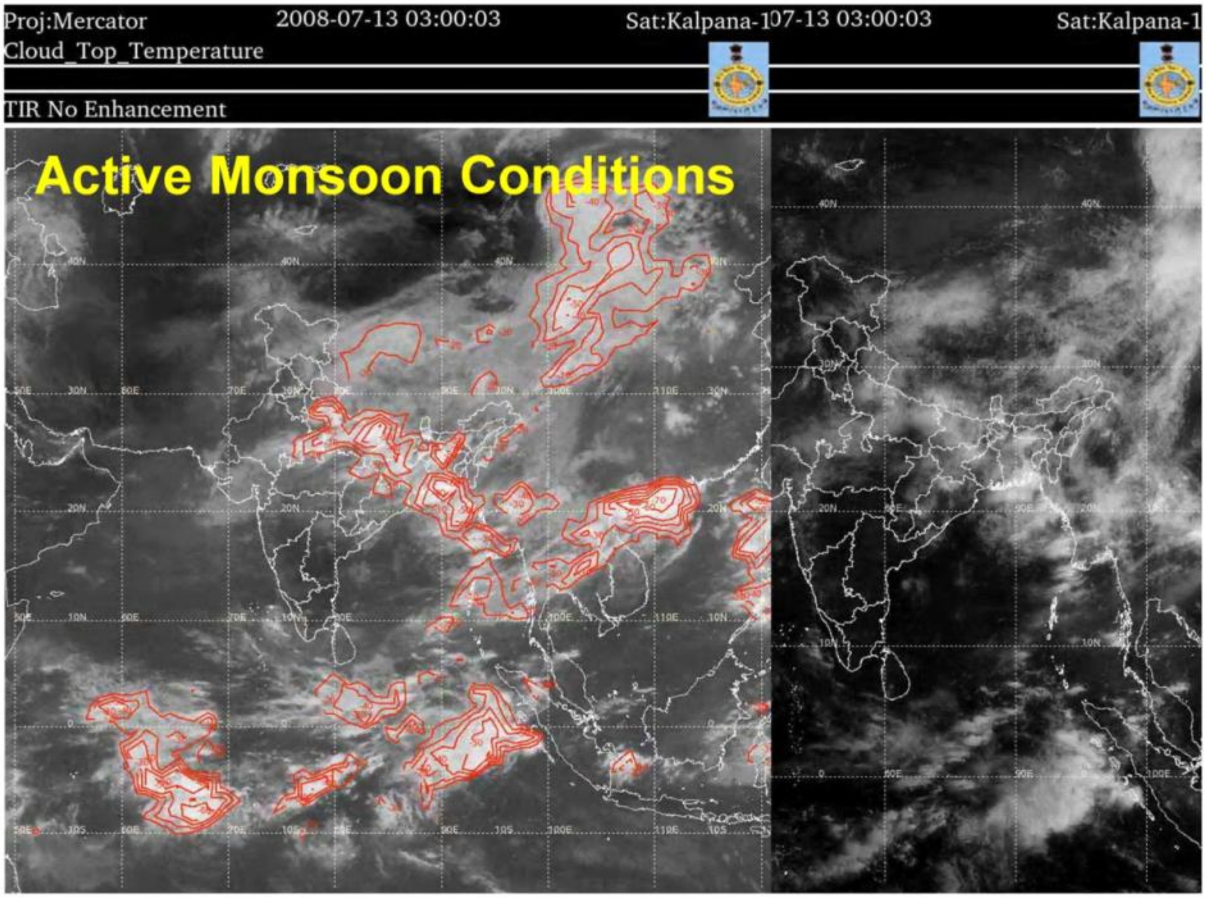

(RMM1,RMM2) phase space for 26-Mar-2009 to 23-Jun-2009
Western Pacific
Indian Ocean
West. Hem. and Africa
Maritime Continent
RMM1
RMM2
START
APR
MAY
JUN
Labelled dots for each day.
Blue line is for Jun, green line is for May.
Wheeler and Hendon (2004)
CAWCR/Bureau of Meteorology
INDIA METEOROLOGICAL DEPARTMENT


Proj:Mercator
2008-07-13 03:00:03
Sat:Kalpana-1
07-13 03:00:03
Sat:Kalpana-1
Cloud_Top_Temperature
TIR No Enhancement
Active Monsoon Conditions

MONSOON DISTURBANCES

Low pressure system	Maximum sustained winds	
Low	< 17 knots	< 31 kmph
Depression	17 – 27 kts	31 – 51 kmph
Deep Depression	28 – 33 kts	52 – 62 kmph
Cyclone	34 – 47 kts	63 – 87 kmph
Severe Cyclone	48 – 63 kts	88 – 117 kmph
Very Severe Cyclone	64 – 119 kts	118 – 221 kmph
Super Cyclone	120 kts & above	222 kmph & above

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AVERAGE FREQUENCIES (PER YEAR) OF DIFFERENT CATEGORIES OF MONSOON DISTURBANCES DURING 1901-2000.

PERIOD	MEAN FREQUENCY OF MONSOON DISTURBANCES/ DISTURBANCES DAYS							
	CD-NIO		CD-BOB		LPS		LPS DAYS	
JUNE	1.34		0.93		2.84		10.7	
JULY	1.37		1.27		3.31		13.7	
AUG	1.64		1.58		3.56		16.8	
SEPT	1.46		1.37		3.23		16.1	
SEASON	5.81		5.15		12.9		57.3	

CD-NIO: CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN

CD-BOB: CYCLONIC DISTURBANCES OVER BAY OF BENGAL

LPS: LOW PRESSURE SYSTEMS

CYCLONIC DISTURBANCES HAVE DECREASED DURING JULY, SEPTEMBER AND SEASON. LPS DAYS HAVE INCREASED IN SEASON

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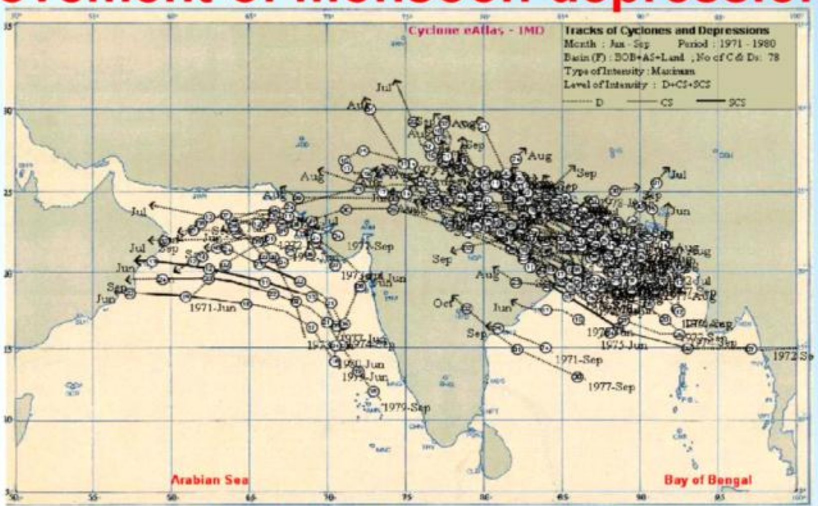
Movement of monsoon depression



- ❖ Average westward longitudinal movement : 77.8 deg E
- ❖ More in Aug and July and less in Sep and June
- ❖ No clear relationship between the westward displacement and excess/deficient rainfall during season

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GENESIS AND INTENSIFICATION

- WEAK CYCLONIC CIRCULATION FORMS IN MIDDLE TROPOSPHERE AND DESCENDS TO SURFACE AND FORMS A LOW
- LOW LEVEL WESTERLIES STRENGTHEN OVER SOUTH BAY OF BENGAL AND SOUTH PENINSULA LEADING TO INTENSIFICATION OF SYSTEM
- WEAK LOW PRESSURE SYSTEMS MOVE FROM SOUTHEAST ASIA AND INTENSIFY OVER BAY OF BENGAL. PRESSURE DROPS IN NEIGHBOURHOOD OF NORTH VIETNAM COAST AS A TROPICAL STORM ARRIVES. DURING NEXT WEEK PRESSURE RISES OVER INDO-CHINA AND BURMA. DURING FOLLOWING WEEK A MONSOON DISTURBANCE FORMS OVER NORTH BAY OF BENGAL.

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GENESIS AND INTENSIFICATION

- SURGES IN SOUTHERLY FINDLATER JET FOLLOWING PASSAGE OF MIDDLE LATITUDE SYSTEMS SOUTH OF MOZAMBIQUE CHANNEL ARE BELIEVED TO RESULT IN STRENGTHENING OF WESTERLIES OVER SOUTH BAY OF BENGAL.
- HIGH SEA SURFACE TEMPERATURE (>29 degC), DIPPING OF MONSOON TROUGH INTO NORTH BAY INDICATING PRESENCE OF LOW LEVEL CYCLONIC VORTICITY, HIGH SPECIFIC HUMIDITY AT MIDDLE LEVELS AND WEAK VERTICAL WIND SHEAR ARE FAVOURABLE FACTORS.

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STRUCTURE OF MONSOON DISTURBANCES

- CYCLONIC CIRCULATION OF DEPRESSION EXTENDS UP TO 300 HPA
- HORIZONTAL DIMENSION OF DEPRESSION : 1000 KM
- INFLOW TAKE PLACE FROM SURFACE TO 5 KM AND MAXIMUM OUTFLOW OCCURS AT AROUND 10-11 KM
- WIND FIELD IS MORE PROMINENT AT 700 HPA LEVEL WITH MAXIMA BOTH IN THE SOUTH AND NORTHEAST SECTOR. EASTERLY WIND MAXIMUM IN NORTHEAST SECTOR MOVES CLOSER TO CENTRE WITH INCREASE IN INTENSITY OF DISTURBANCE.
- STRONG WESTERLY FLOW DECREASES WITH HEIGHT AND STRONG WIND ZONE SHRINKS IN EXTENT
- STRONG VEERING OF WIND BETWEEN 700 AND 500 HPA LEADING TO SLOPING OF THE VORTEX SOUTHWARD WITH HEIGHT

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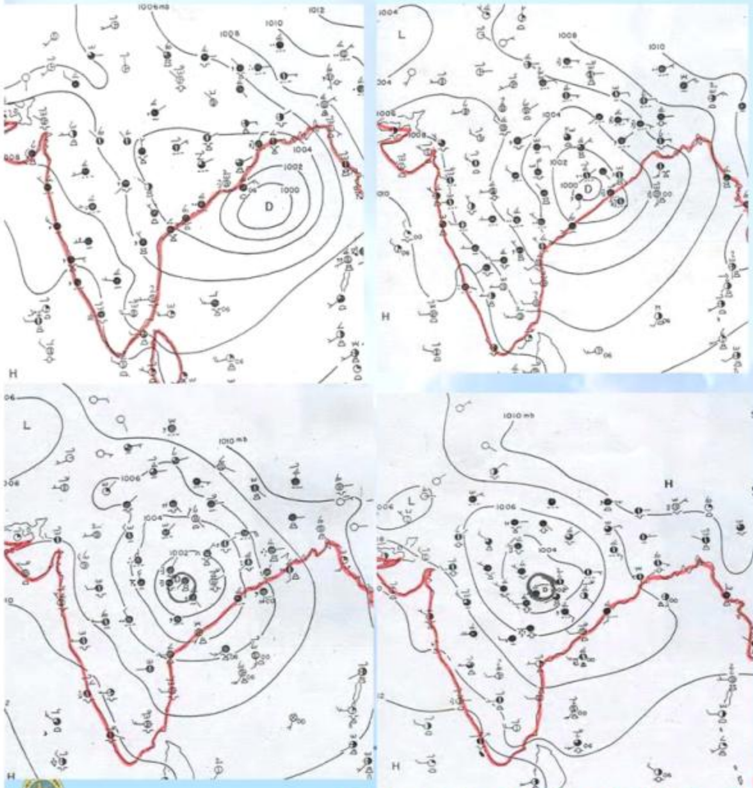
Movement of Monsoon Depressions



- MOSTLY MOVE WEST-NORTHWESTWARDS ALONG MONSOON TROUGH DUE TO PRODUCTION OF VORTICITY IN THIS SECTOR
- WESTWARD MOVEMENT PHASE SPEED : 6 METER PER SECOND (5 DEG LONG PER DAY)
- 1.5 TO 3 M/S TO EAST OF 85 DEG AND 3 TO 6 M/S TO THE WEST
- SOME RECURVE UNDER INFLUENCE OF WESTERLY TROUGH

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STRUCTURE OF MONSOON DISTURBANCES

- NORTHNORTHEAST-SOUTHSOUTHWEST TILTING SUGGEST THAT DISTURBANCES MAY DRAW ON ZONAL KINETIC ENERGY AND GROW BY BAROTROPIC INSTABILITY
- NORMAL NORTH-SOUTH TEMPERATURE GRADIENT IS SOMEWHAT WEAKENED DURING FORMATION OF MONSOON DEPRESSIONS AND NORMAL EASTERLY VERTICAL SHEAR IS REDUCED. REDUCTION OF VERTICAL SHEAR POSSIBLY AIDS CUMULUS CONVECTION
- THE CENTRAL REGION OF THE DEPRESSION IS COOLER UPTO 600 MB AND WARMER ALOFT
- TO WEST OF DEPRESSION CENTRE, TEMPERATURE (OR THICKNESS) IN LOWER TROPOSPHERE IS SLIGHTLY LOWER THAN TO EAST OF DEPRESSION CENTRE RESULTING IN NORTHWARD TRANSPORT OF SENSIBLE HEAT

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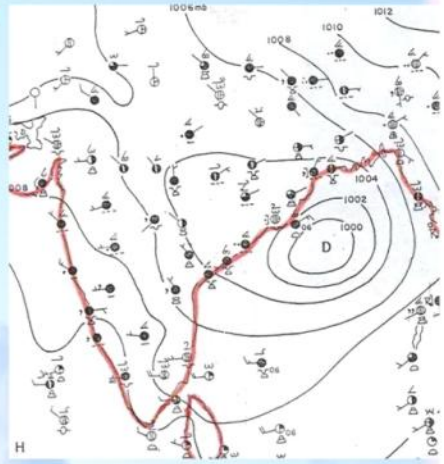
VERTICAL MOTION AND ENERGETICS IN MONSOON DISTURBANCES



- UPWARD MOTION IN SOUTHWESTERN AND WESTERN SECTOR OF DEPRESSION WHICH IS IN GENERAL AGREEMENT WITH RAINFALL AND ENHANCED CLOUDINESS IN THAT SECTOR AND DESCENDING MOTION OCCURS TO EAST OF DEPRESSION WHICH IS A RELATIVELY CLEAR REGION
- IN THE SOUTHWEST SECTOR, THERE IS A NET EXCESS OF CYCLONIC VORTICITY IN LOWER TROPOSPHERE AND OF ANTICYCLONIC VORTICITY IN UPPER TROPOSPHERE

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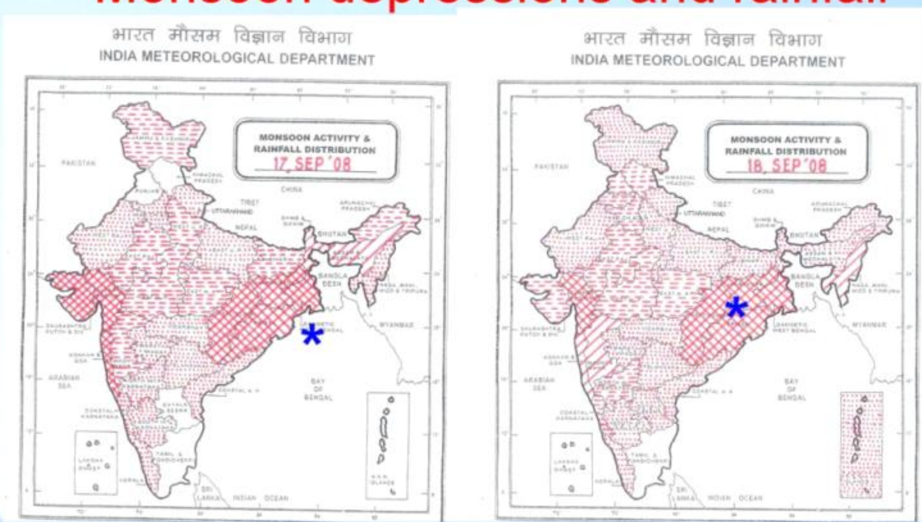
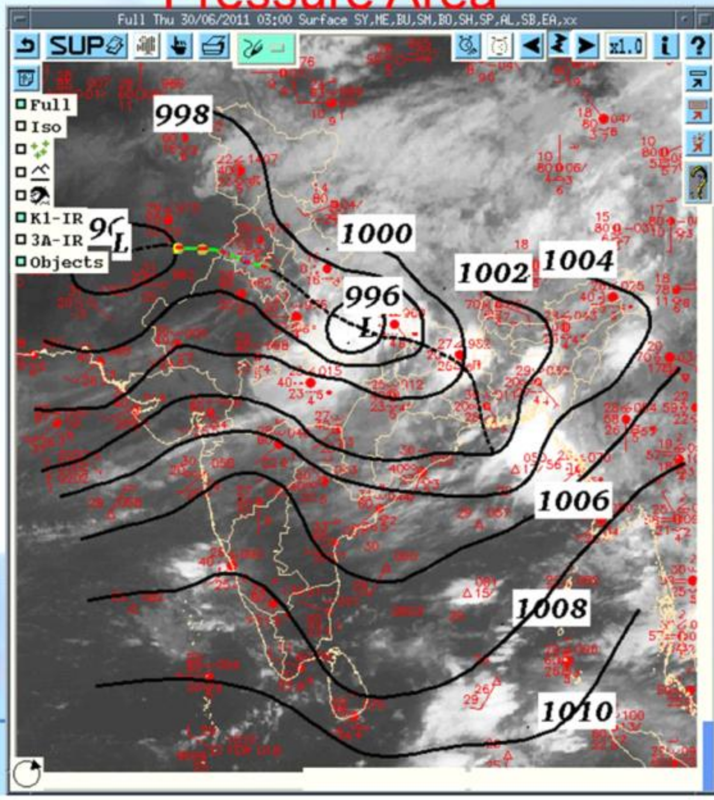
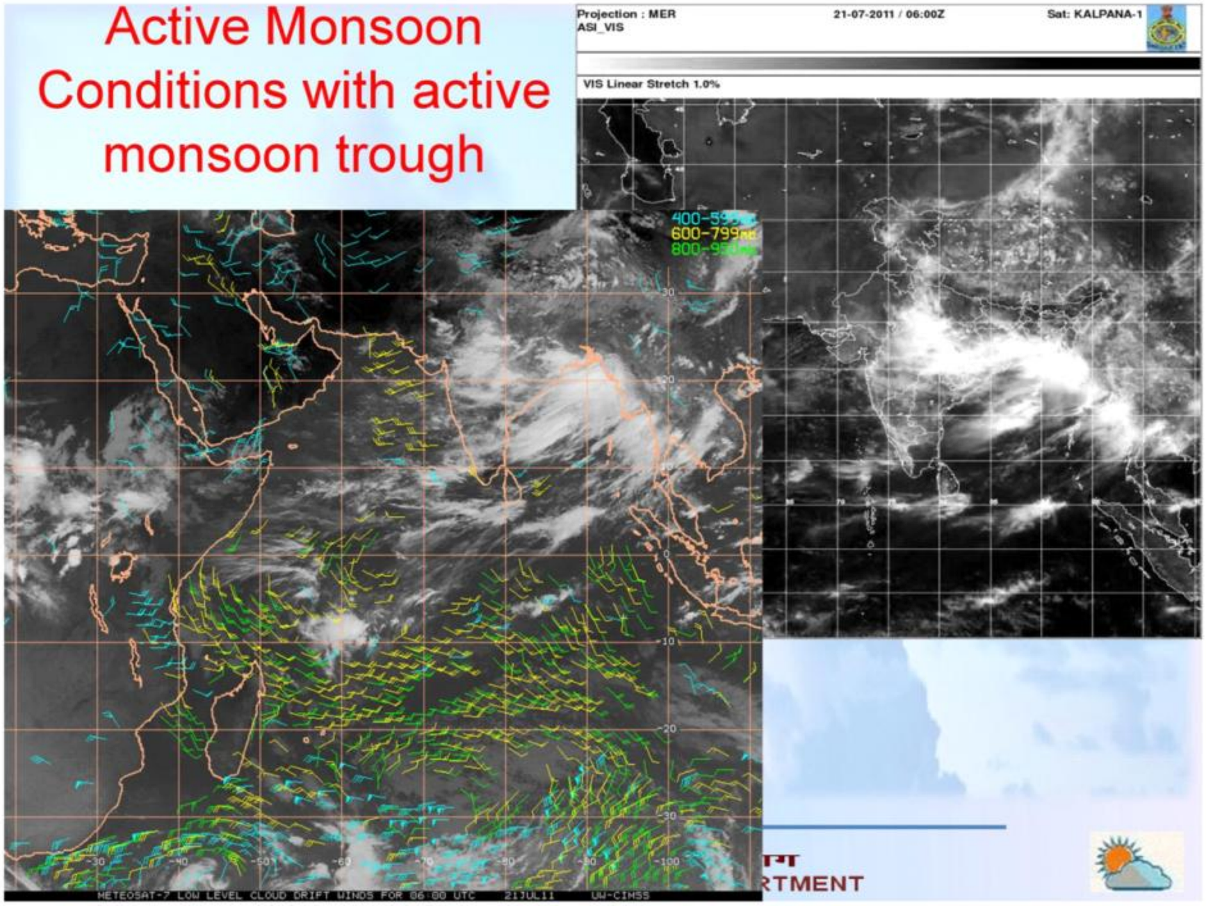
Monsoon depressions and rainfall



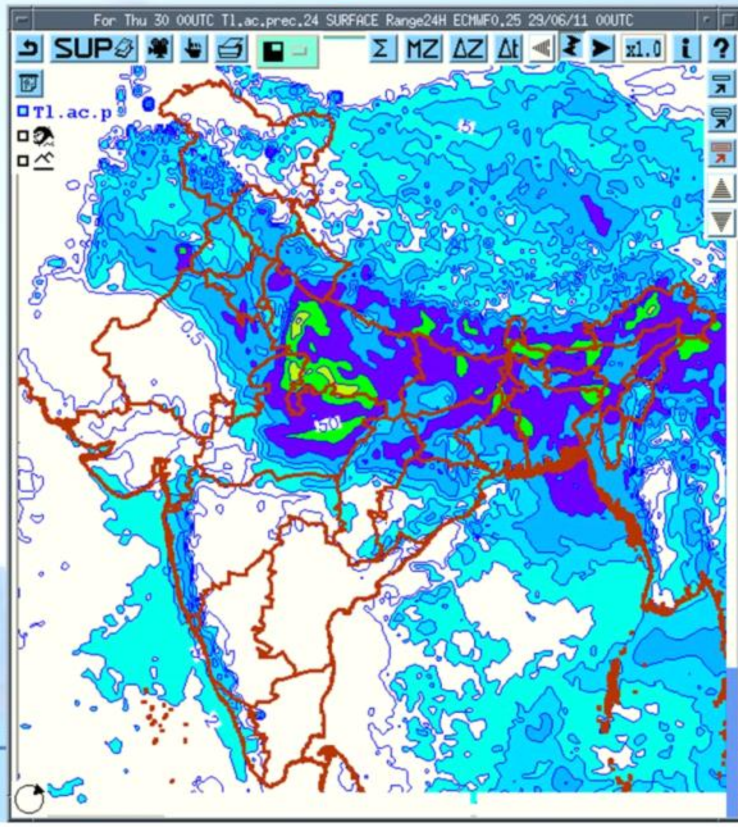
- INTENSE AND HEAVY RAINFALL OCCURS OVER RELATIVELY SMALL AREA IN THE LEFT FRONT QUADRANT DUE TO MAXIMUM LOW LEVEL CONVERGENCE AND VERTICAL MOTION
- HEAVY RAINFALL (OFTEN EXCEEDING 10 CM IN 24 HOURS) FALL OVER 400 KM WIDE STRIP TO THE LEFT OF MONSOON DEPRESSION TRACKS
- THE RAINFALL ASSOCIATED WITH A LOW COVERS RELATIVELY A MUCH LARGER AREA AND HEAVY RAINFALL IS SCATTERED IN CHARACTER

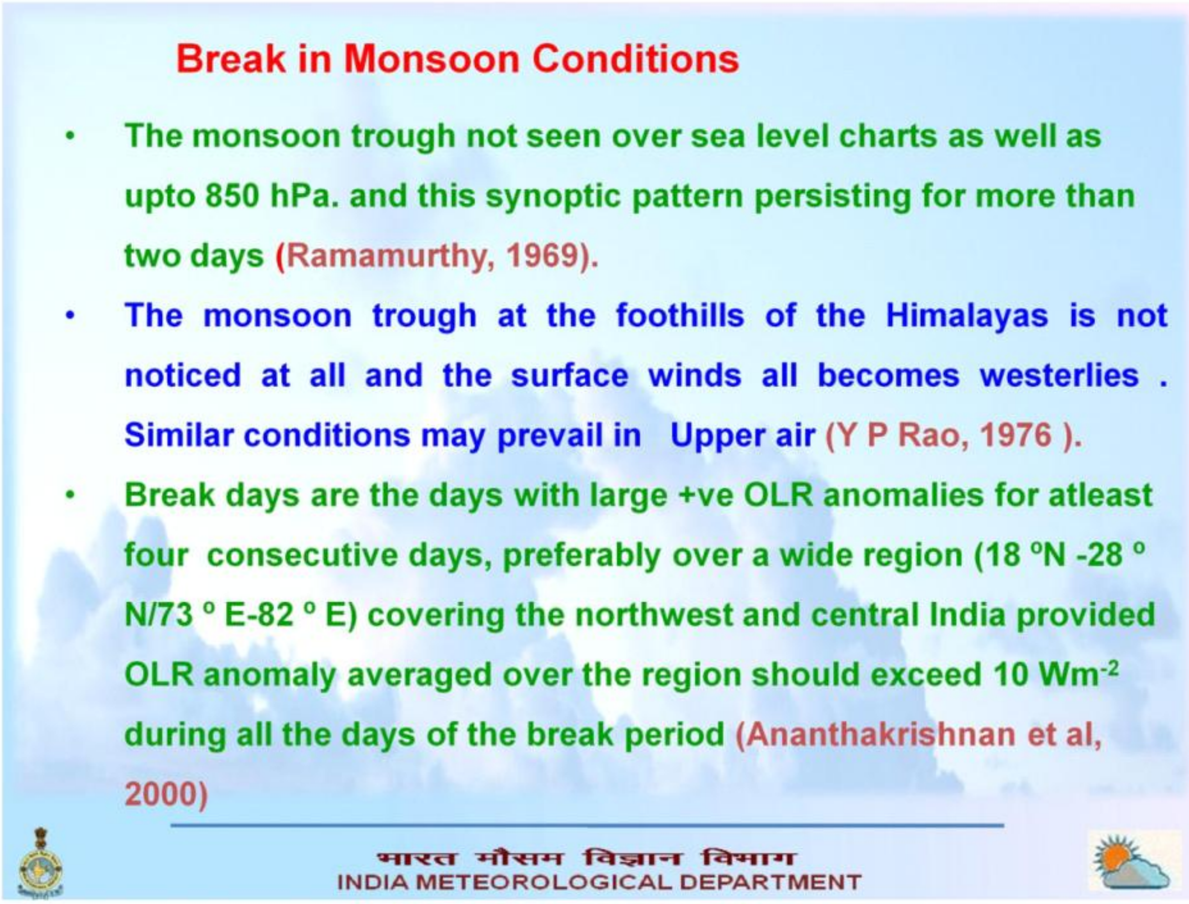
Active Monsoon Conditions Example with Low Pressure Area




Active Monsoon Conditions with active monsoon trough
Projection : MER
ASI_VIS
21-07-2011 / 06:00Z
Sat: KALPANA-1
VIS Linear Stretch 1.0%
METEOSAT-7 LOW LEVEL CLOUD DRIFT WINDS FOR 06:00 UTC 21JUL11 UW-CIMSS

Northward Shifting of monsoon trough




Break in Monsoon Conditions
• The monsoon trough not seen over sea level charts as well as upto 850 hPa. and this synoptic pattern persisting for more than two days (Ramamurthy, 1969).
• The monsoon trough at the foothills of the Himalayas is not noticed at all and the surface winds all becomes westerlies . Similar conditions may prevail in Upper air (Y P Rao, 1976).
• Break days are the days with large +ve OLR anomalies for atleast four consecutive days, preferably over a wide region (18 °N -28 ° N/73 ° E-82 ° E) covering the northwest and central India provided OLR anomaly averaged over the region should exceed 10 Wm^{-2} during all the days of the break period (Ananthakrishnan et al, 2000)
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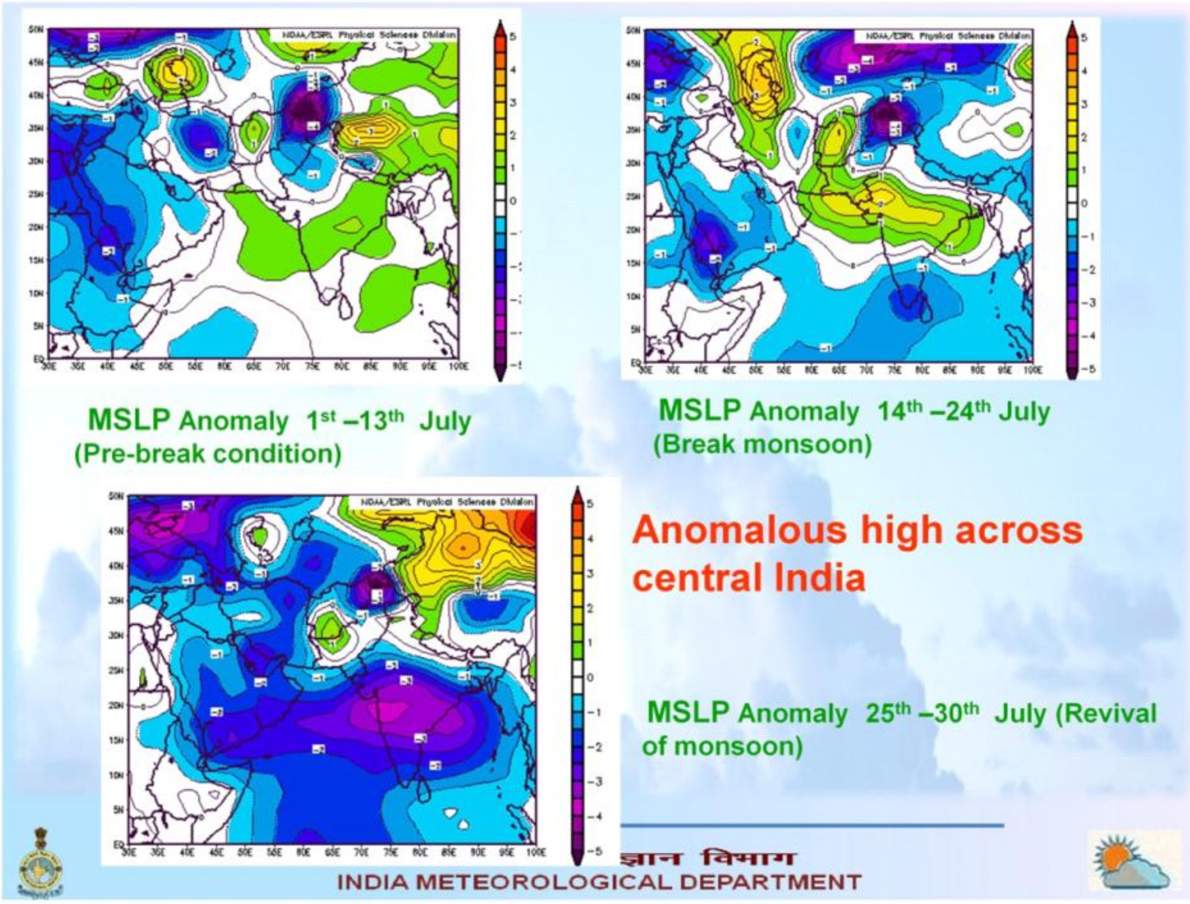
MSLP Anomaly 1st –13th July
(Pre-break condition)
MSLP Anomaly 14th –24th July
(Break monsoon)
Anomalous high across
central India
MSLP Anomaly 25th –30th July (Revival
of monsoon)
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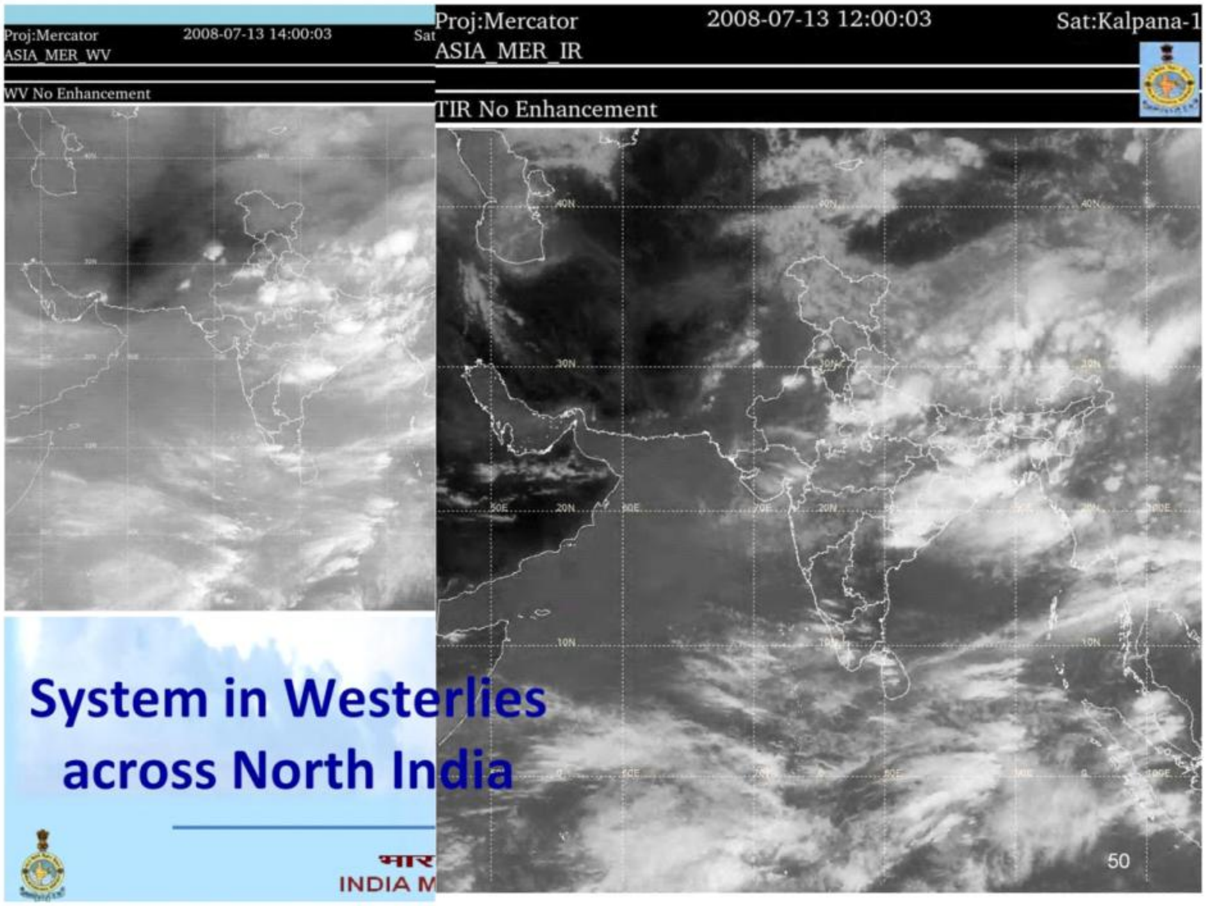
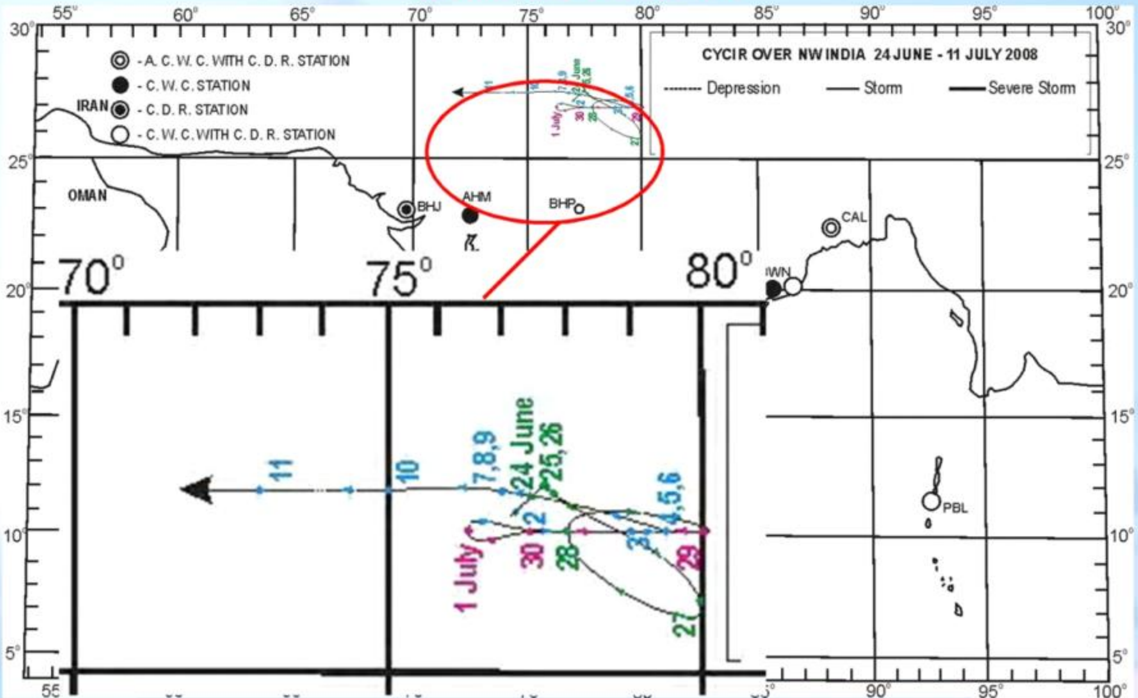

Proj:Mercator
2008-07-13 14:00:03
ASIA_MER_WV
WV No Enhancement
Proj:Mercator
2008-07-13 12:00:03
Sat:Kalpana-1
ASIA_MER_IR
TIR No Enhancement
System in Westerlies across North India
50

Anomalous movement of cyclonic circulation (Example: 24 June – 11 July 2008) as a result of the interaction between monsoon easterlies and mid latitude westerlies



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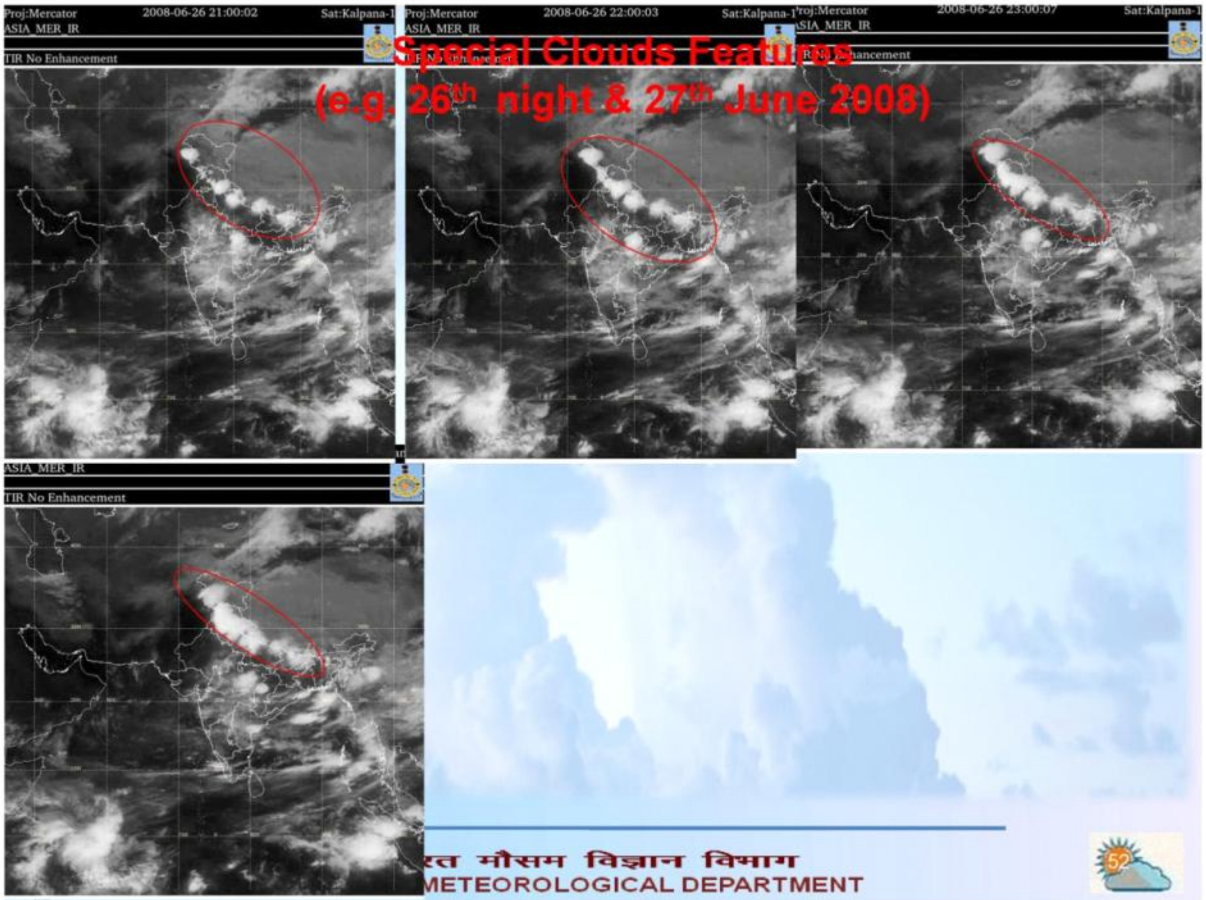
Proj:Mercator
2008-06-26 21:00:02
Sat:Kalpana-1
ASIA_MER_IR
TIR No Enhancement
Proj:Mercator
2008-06-26 22:00:03
Sat:Kalpana-1
ASIA_MER_IR
2008-06-26 23:00:07
Sat:Kalpana-1
Special Clouds Features
(e.g. 26th night & 27th June 2008)
ASIA_MER_IR
TIR No Enhancement
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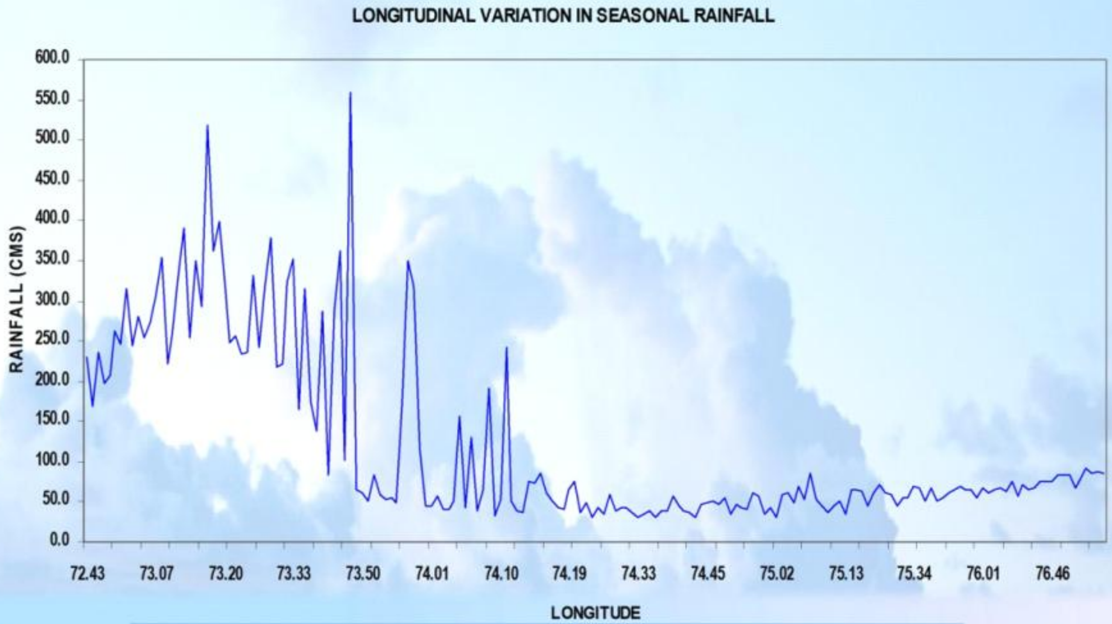
Impact of orography : Example- Western Ghats



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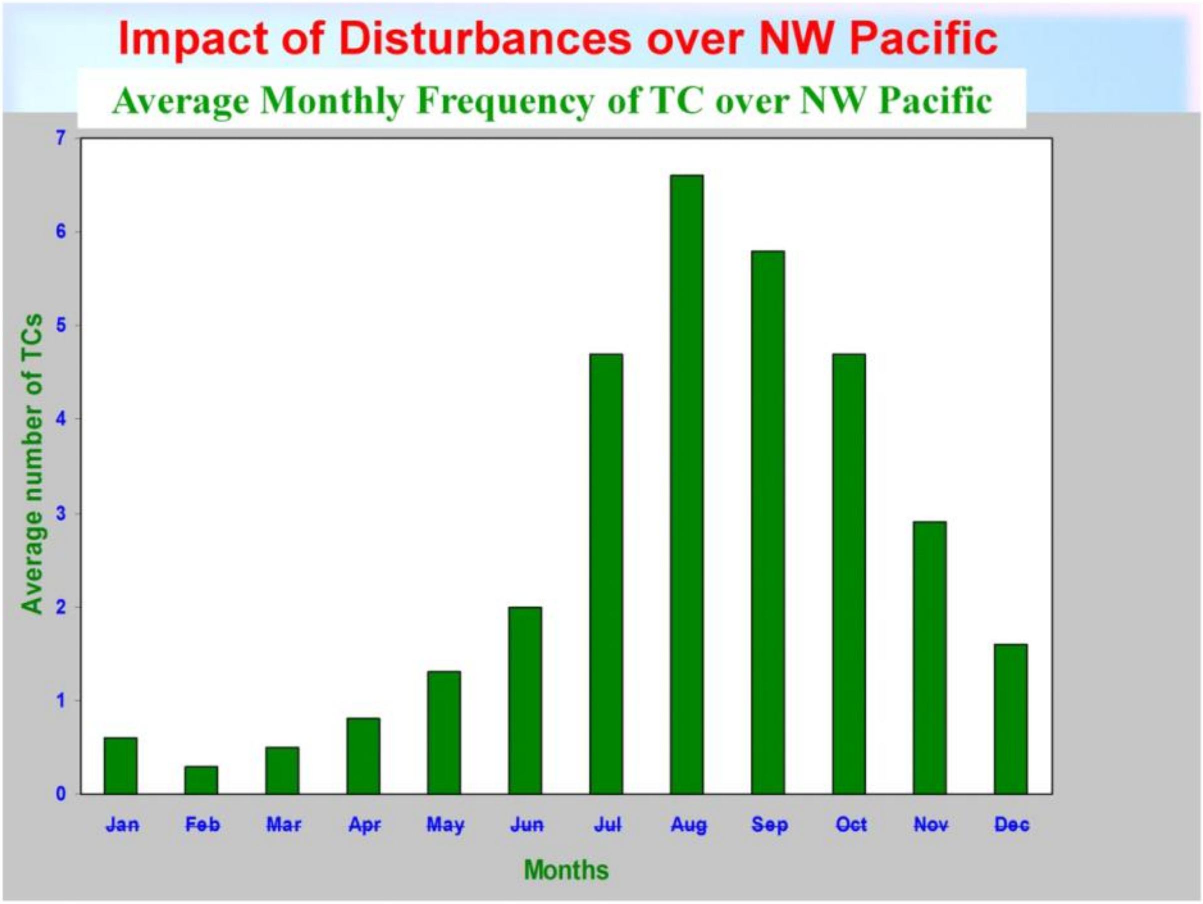
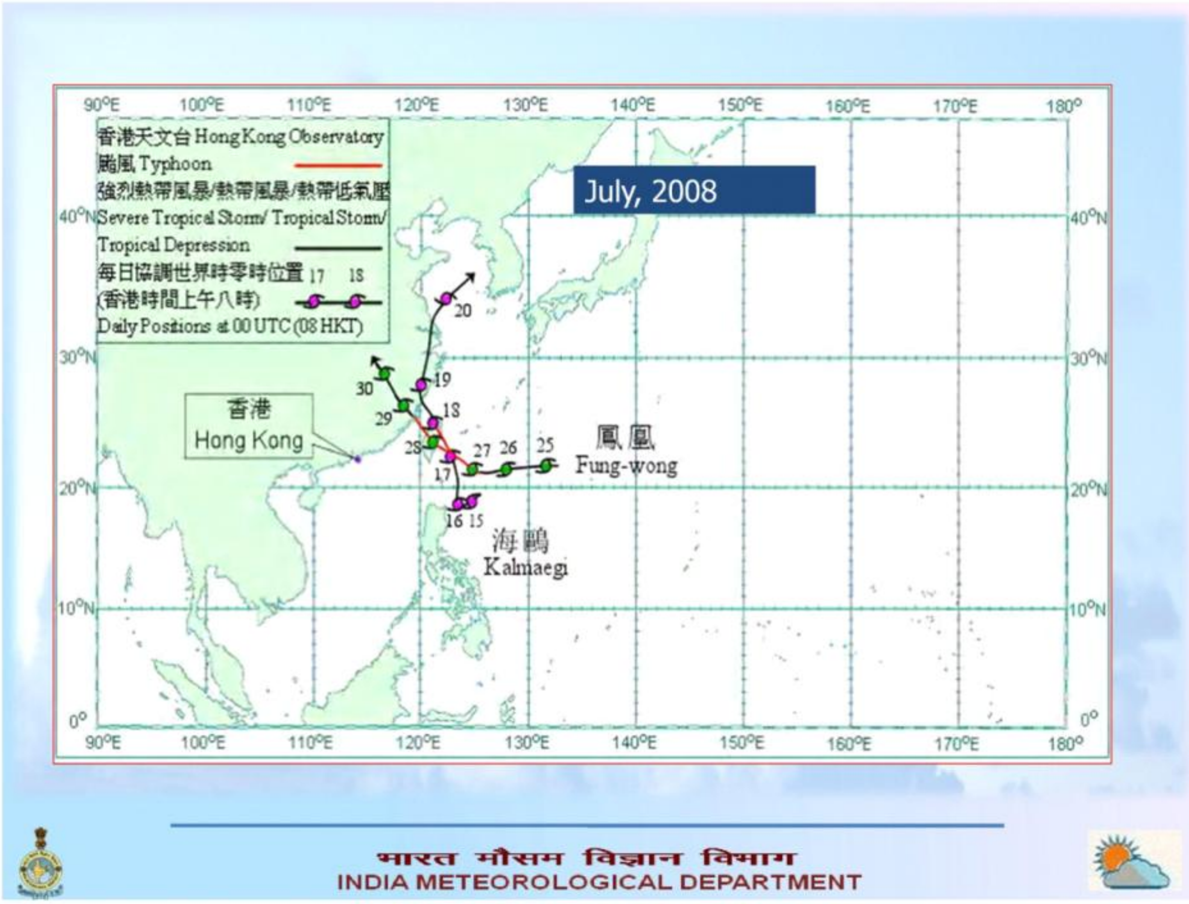


Impact of Disturbances over NW Pacific
Average Monthly Frequency of TC over NW Pacific
Average number of TCs
0
1
2
3
4
5
6
7
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months



July, 2008
香港天文台 Hong Kong Observatory
颱風 Typhoon
強烈熱帶風暴/熱帶風暴/熱帶低氣壓
Severe Tropical Storm/ Tropical Storm/
Tropical Depression
每日協調世界時零時位置
(香港時間上午八時)
Daily Positions at 00 UTC (08 HKT)
香港
Hong Kong
鳳凰
Fung-wong
海鷗
Kalmaegi
90°E
100°E
110°E
120°E
130°E
140°E
150°E
160°E
170°E
180°
40°N
30°N
20°N
10°N
0°
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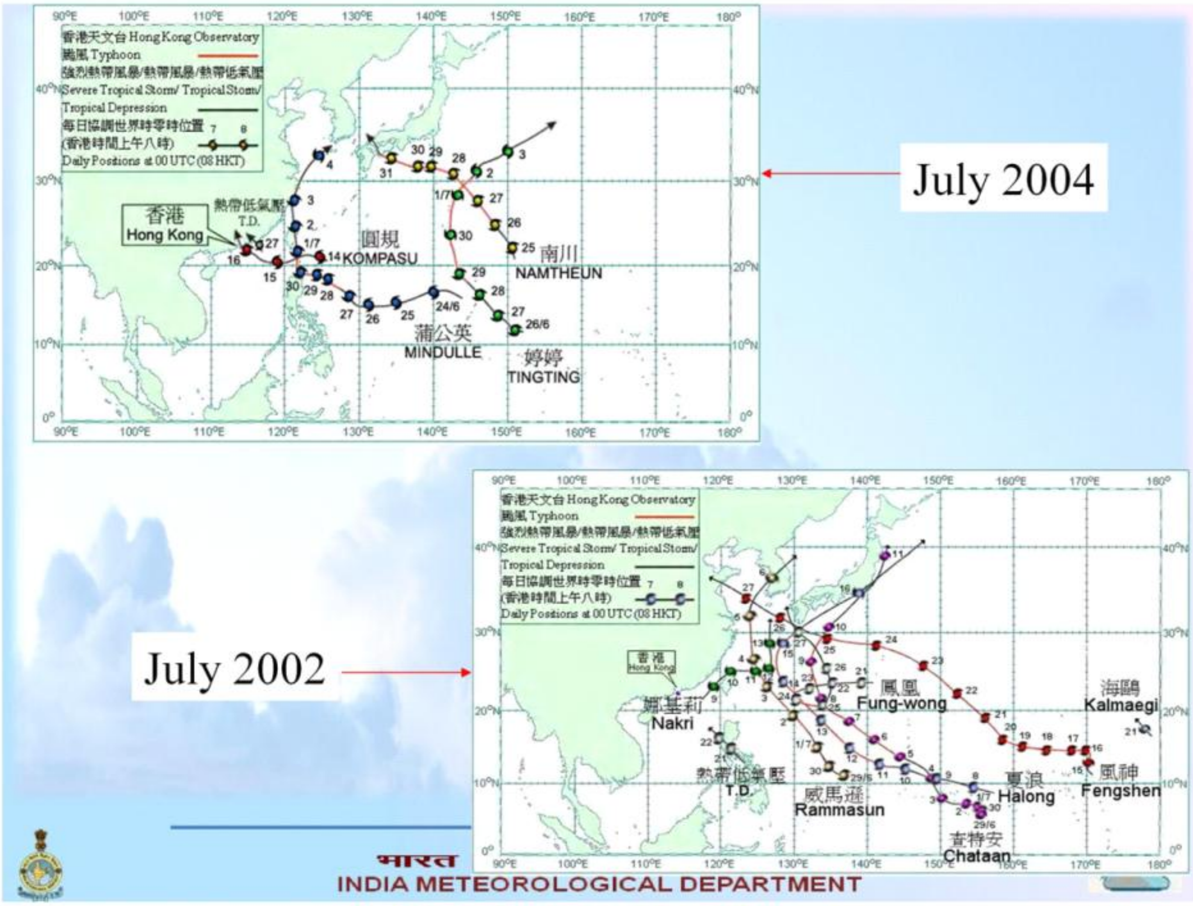

July 2004
July 2002
香港天文台 Hong Kong Observatory
颱風 Typhoon
Severe Tropical Storm/ Tropical Storm/ Tropical Depression
Daily Positions at 00 UTC (08 HKT)
香港 Hong Kong
圓規 KOMPASU
南川 NAMTHEUN
蒲公英 MINDULLE
婷婷 TINGTING
鳳凰 Fung-wong
海鷗 Kalmaegi
娜基莉 Nakri
熱帶低氣壓 T.D.
威馬遜 Rammasun
夏浪 Halong
風神 Fengshen
查特安 Chataan
भारत
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Some other Important Features of Monsoon and intraseasonal variation

- ❖1. Tropospheric Temperature index
- ❖2. OLR , Wind and SST pattern

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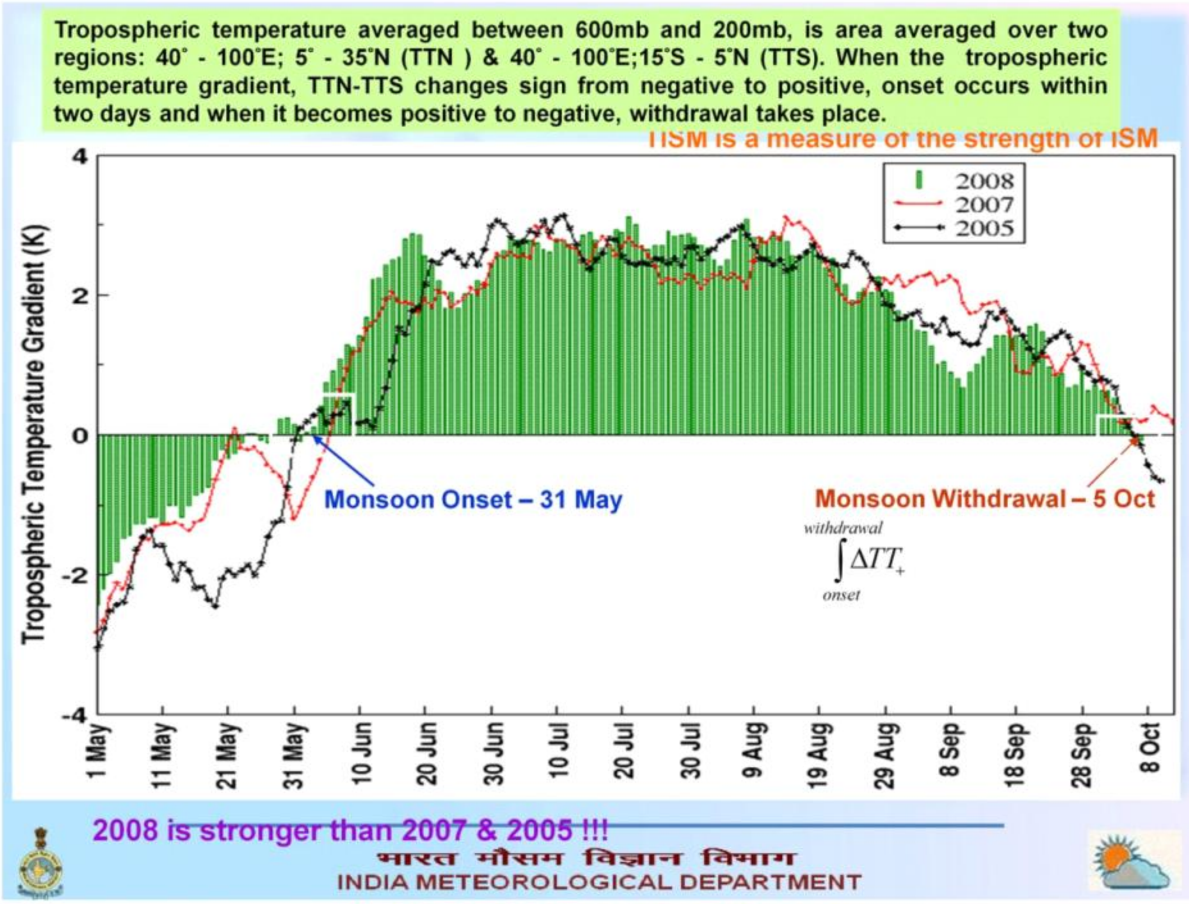
Tropospheric temperature averaged between 600mb and 200mb, is area averaged over two regions: 40° - 100°E; 5° - 35°N (TTN) & 40° - 100°E;15°S - 5°N (TTS). When the tropospheric temperature gradient, TTN-TTS changes sign from negative to positive, onset occurs within two days and when it becomes positive to negative, withdrawal takes place.
TISM is a measure of the strength of ISM
Tropospheric Temperature Gradient (K)
2008
2007
2005
Monsoon Onset – 31 May
Monsoon Withdrawal – 5 Oct
$\int_{onset}^{withdrawal} \Delta TT_+$
4
2
0
-2
-4
1 May
11 May
21 May
31 May
10 Jun
20 Jun
30 Jun
10 Jul
20 Jul
30 Jul
9 Aug
19 Aug
29 Aug
8 Sep
18 Sep
28 Sep
8 Oct
2008 is stronger than 2007 & 2005 !!!
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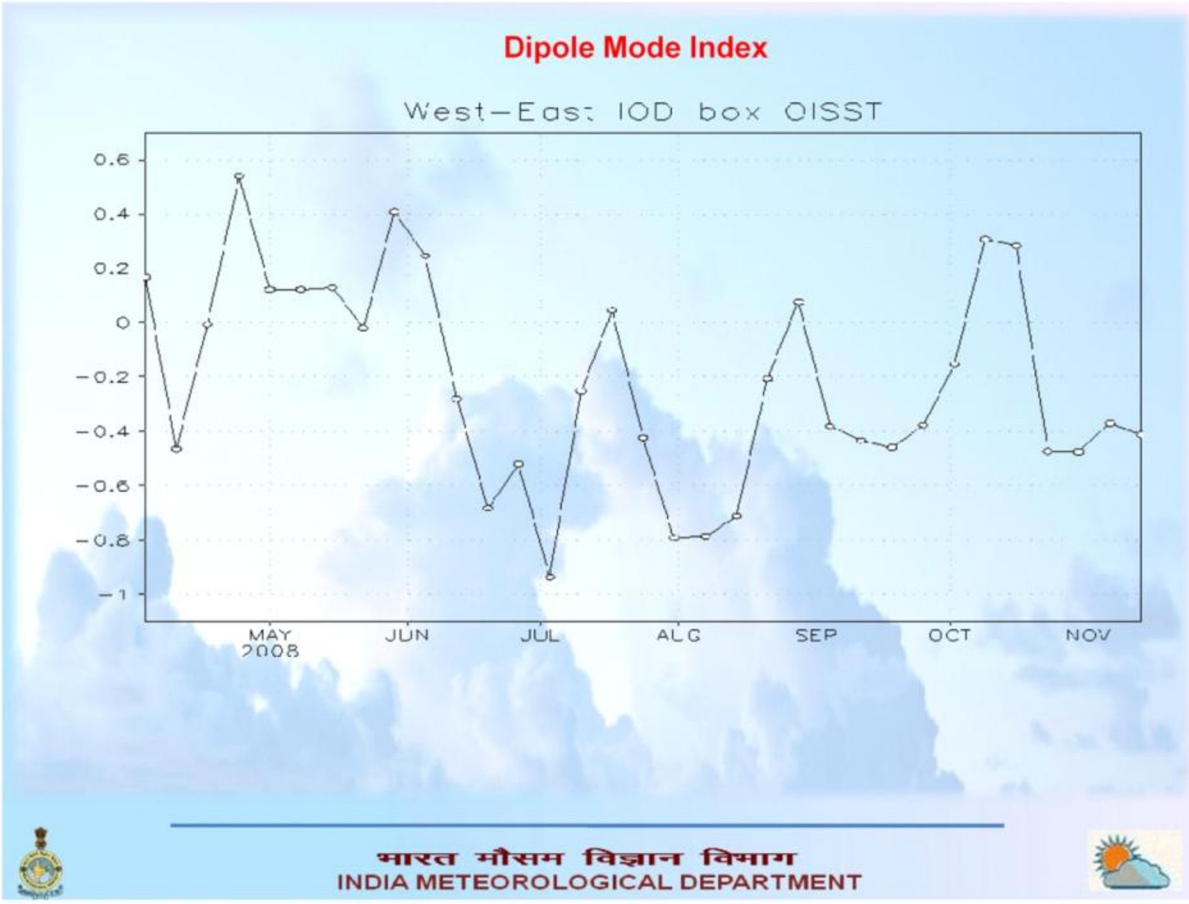
Dipole Mode Index
West-East: IOD box OISST
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
MAY
2008
JUN
JUL
AUG
SEP
OCT
NOV
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Daily OLR Time series of East box and West Box during June and July

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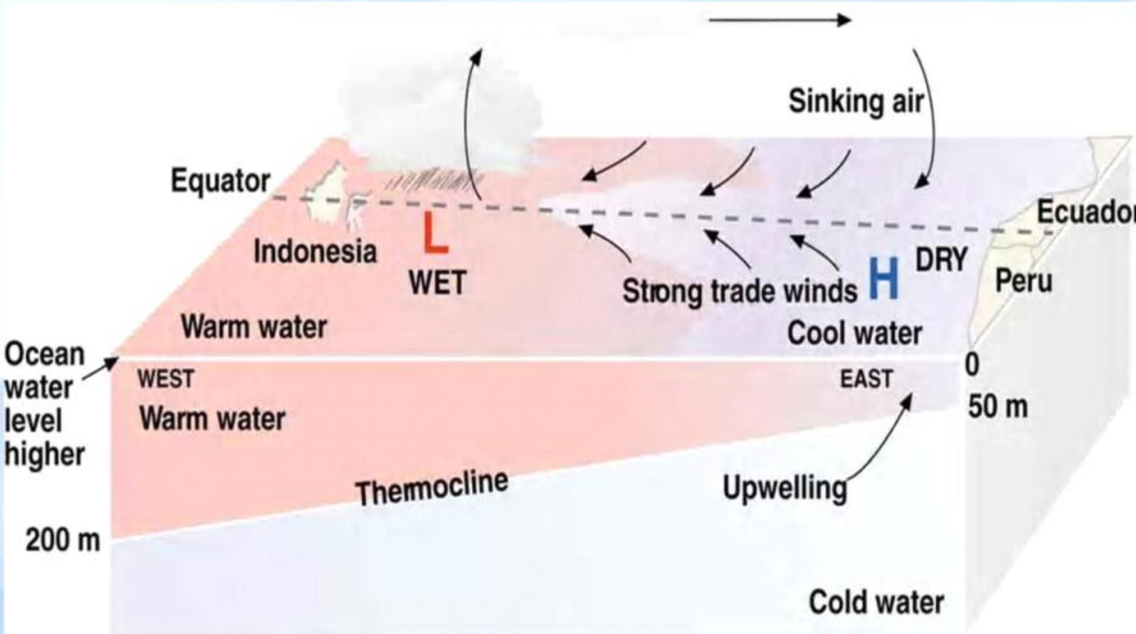
Ordinary condition - Higher pressure over the southeastern Pacific & lower pressure near Indonesia



(a)Non-El Niño Conditions

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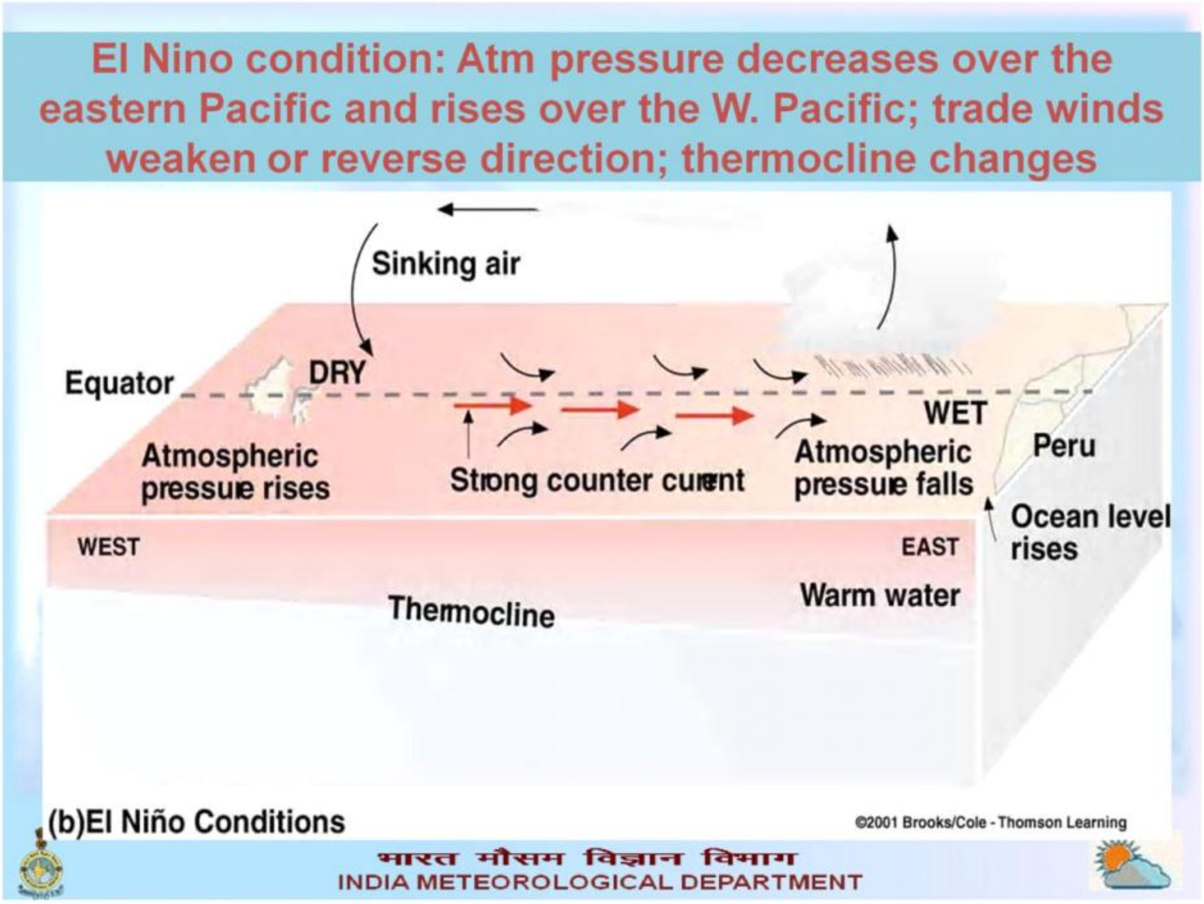
El Nino condition: Atm pressure decreases over the eastern Pacific and rises over the W. Pacific; trade winds weaken or reverse direction; thermocline changes
Sinking air
Equator
DRY
WET
Peru
Atmospheric pressure rises
Strong counter current
Atmospheric pressure falls
Ocean level rises
WEST
EAST
Thermocline
Warm water
(b)El Niño Conditions
©2001 Brooks/Cole - Thomson Learning
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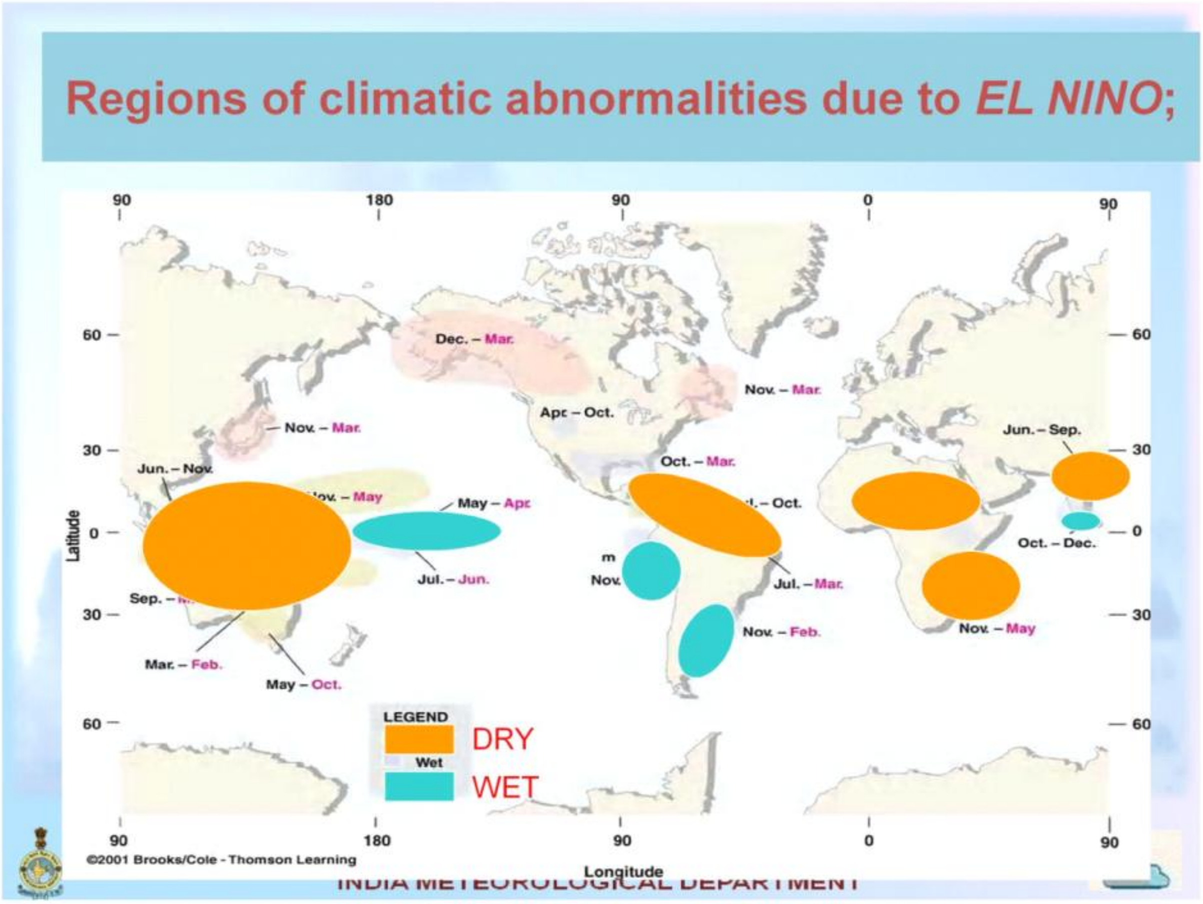
Regions of climatic abnormalities due to EL NINO;
Dec. – Mar.
Nov. – Mar.
Apr – Oct.
Nov. – Mar.
Jun. – Sep.
Oct. – Mar.
Jun. – Nov.
May – Apr
Jul. – Jun.
Jul. – Mar.
Oct. – Dec.
Nov. – Feb.
Nov. – May
Mar. – Feb.
May – Oct.
LEGEND
DRY
Wet
WET
Latitude
Longitude
©2001 Brooks/Cole - Thomson Learning
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Intraseasonal variation-

Problems and prospects

- Most challenging task is the prediction of Intra Seasonal Oscillation(ISO).

- It is essential to predict the phase of the ISO correctly to get the active and break cycle of monsoon.

- The dynamical and statistical models are showing some skills, although it need further improvement.

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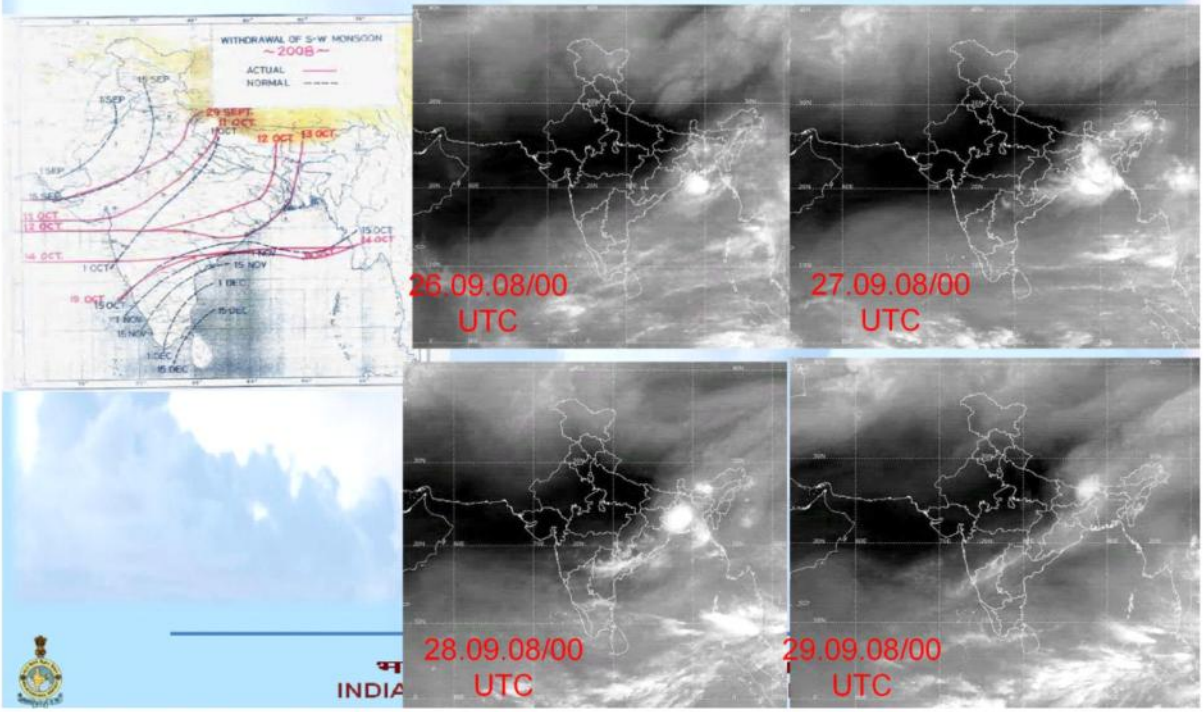
withdrawal of Monsoon : An Example



INDIA

Monsoon prediction

The following is the list of ranges for which forecast skills exist with different techniques.

Range	Method
Short	NWP (Objective), Manual (Subjective)
Medium	NWP (Objective)
Extended	NWP (under R&D) uses Ocean-Atmosphere coupling in some form or the other.
Intra-seasonal	Dynamical - uses Slab Ocean - Atmosphere coupling
Seasonal/inter-annual Ocean-	Empirical, Dynamical - uses complete Atmosphere coupling

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Statistical Model

Mainly used models

- Climatological Models
- Analogues
- Regression Techniques (Multiple regression, Principal component regression etc)
- PPM
- MOS
- Ensemble forecast

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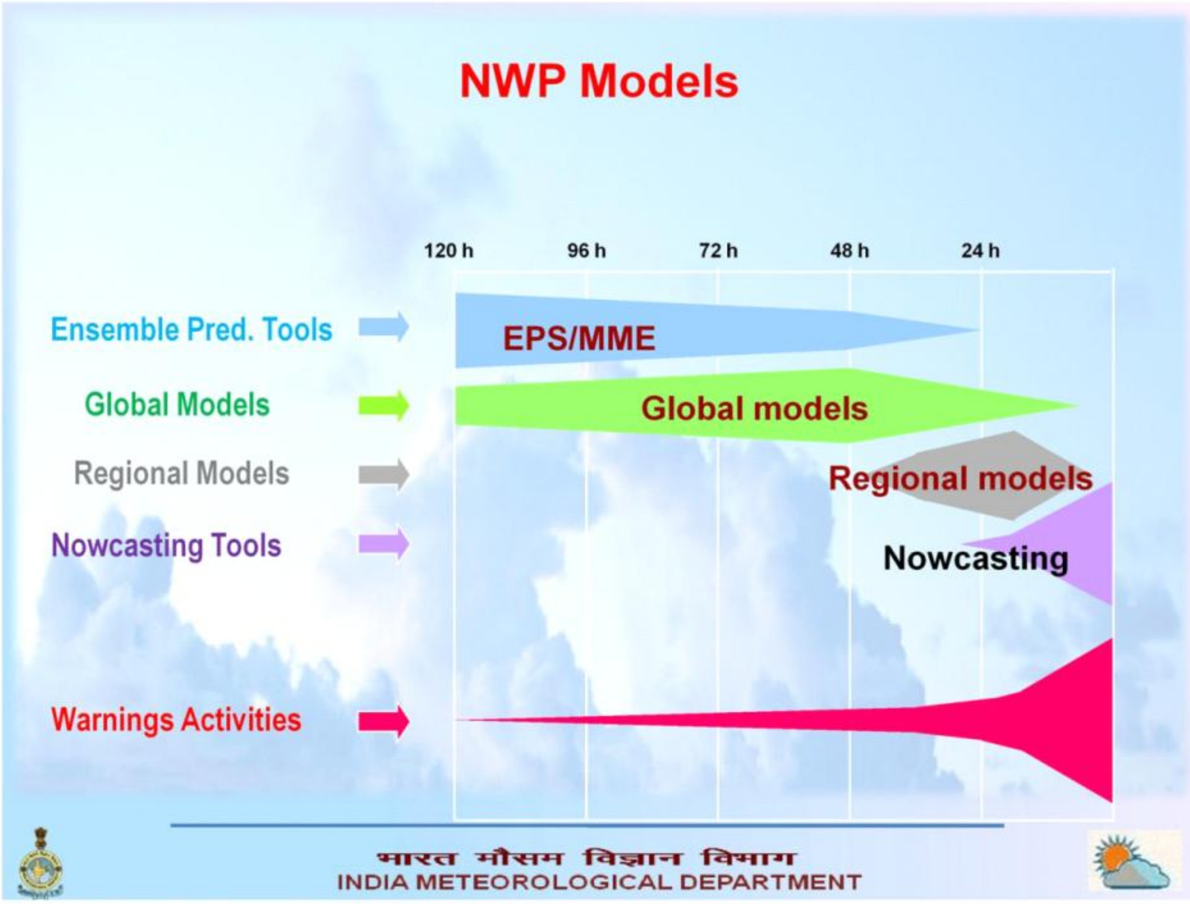
NWP Models
120 h
96 h
72 h
48 h
24 h
Ensemble Pred. Tools
EPS/MME
Global Models
Global models
Regional Models
Regional models
Nowcasting Tools
Nowcasting
Warnings Activities
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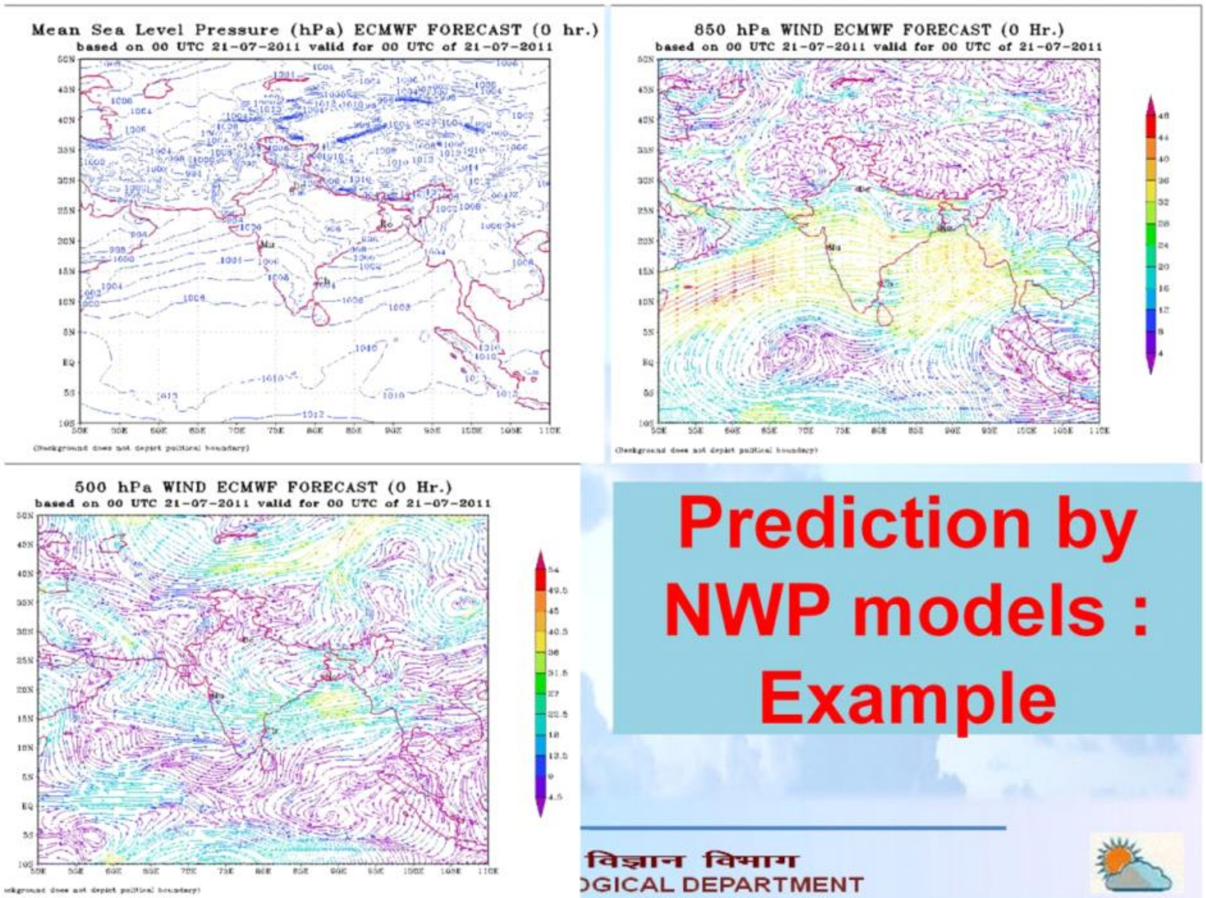
Operational NWP Systems

- ❖ **Extended Range**
- ▪ ***MME***
- ❖ **Medium Range Forecast**
  - > ***GFS T-574/L64 with GDAS (00 & 12 UTC)***
  - > ***MME based District Level Forecasts***
  - > ***GEFS (EPS) : Circulation and rainfall***
- ❖ **Short Range Forecast**
  - > ***WRF (ARW) VAR at 27 km and 9 km***
  - > ***HWRF***
  - > ***MME based cyclone track prediction***
  - > ***Polar WRF for Antarctica***
- ❖ **Nowcast and Very Short Range Forecast**
  - > ***Hourly venue specific forecast- WRF (3 km)***
  - > ***ARPS with assimilation of DWR***
  - > ***Nowcast System with assimilation of DWR***

GFS T-574 (25 km)	WRF –ARW 27 km, 9 km Polar WRF 15 km MME TC	WRF – ARW 3 Kms Venue Specific F/C 24 Hours (hourly)	ARPS 9 kms Hourly updates Next 6 hours	SWIRLS (Trigger every 10 minutes)	WDSS-II (Trigger with every data received)	Extended Range Probabilistic Forecast
Medium Range (1-7 days)	Short Range (1-3 days)	Short Range (36 houurs)	Very short range (6-24hrs)	Nowcasting (0-2 hr)	Nowcasting (0-1 hr)	Week to month
Products Available Analysis (MSLP & Winds at 925,850, 700,500,300,200 100 hPa) F/c for 7 days (MSLP, & Winds at 925,850,700 500,300,200, 100 hPa and R/f)	Products available Analysis (MSLP & Winds at 925,850,700, 500,300,200 hPa) F/c for 3 days (MSLP & Winds at 925,850,700, 500,300,200 hPa and R/f) Location specific f/c for 100 cities thru 9 kms	Products available Meteograms For Location specific sites in Delhi /major airports Wind spd (10m) Rainfall RH Temperature (DB & DP)	Products Available Winds Reflectivity Rainfall	Products Available CAPPI (3km) (every T+6,12… minutes upto 2 hours)	Products Available Maximum Reflectivity field (ZMax) (T+10,30,60 ,90, 120 mins)	Products Available Rainfall, Temperature


Mean Sea Level Pressure (hPa) ECMWF FORECAST (0 hr.)
based on 00 UTC 21-07-2011 valid for 00 UTC of 21-07-2011
850 hPa WIND ECMWF FORECAST (0 Hr.)
based on 00 UTC 21-07-2011 valid for 00 UTC of 21-07-2011
500 hPa WIND ECMWF FORECAST (0 Hr.)
based on 00 UTC 21-07-2011 valid for 00 UTC of 21-07-2011
Prediction by NWP models : Example
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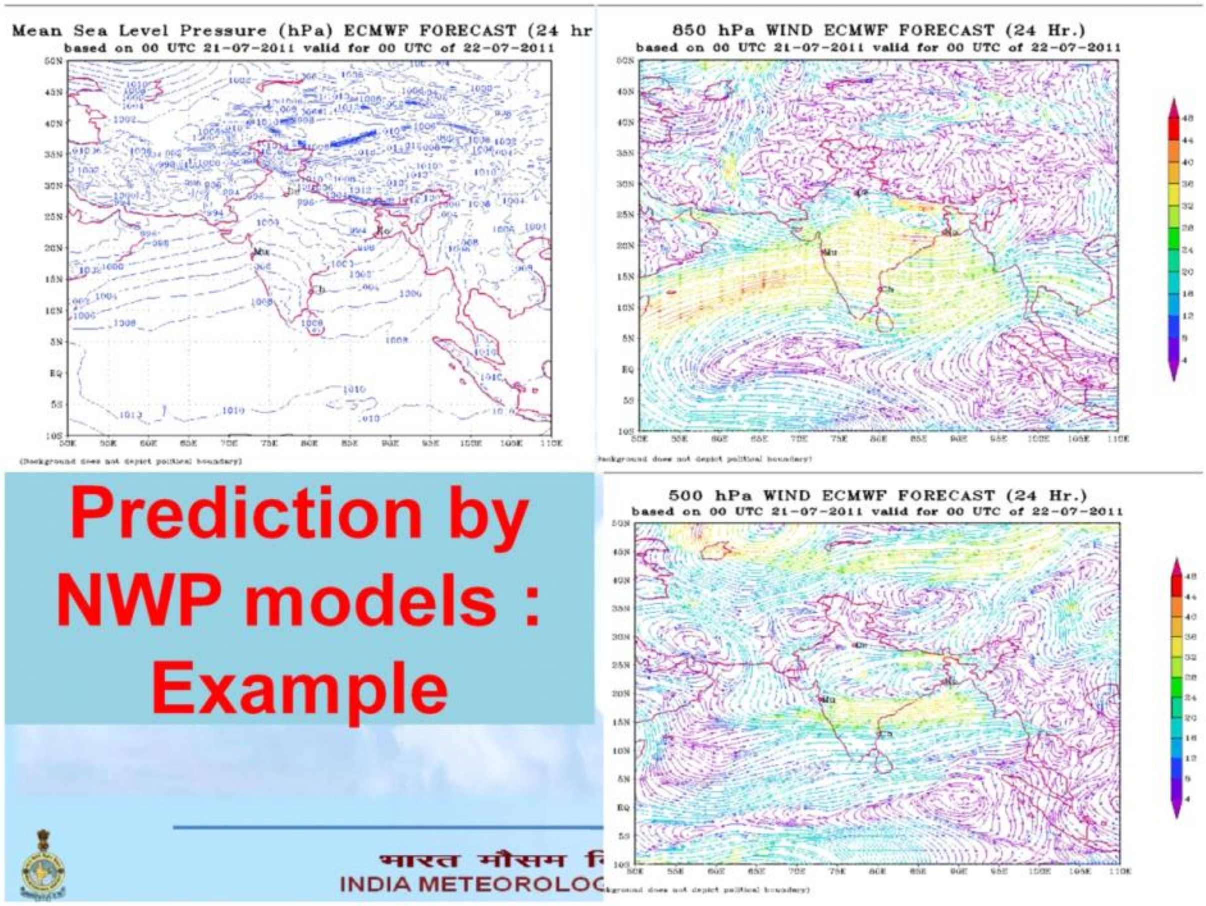
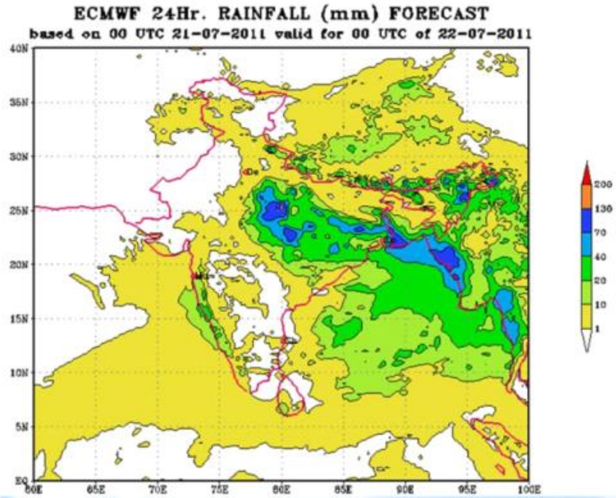
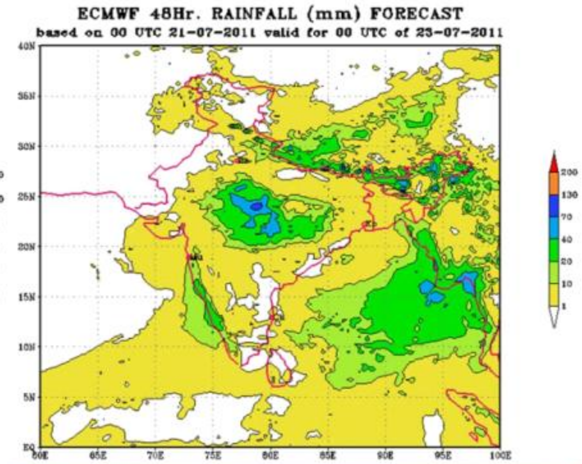

Mean Sea Level Pressure (hPa) ECMWF FORECAST (24 hr
based on 00 UTC 21-07-2011 valid for 00 UTC of 22-07-2011
850 hPa WIND ECMWF FORECAST (24 Hr.)
based on 00 UTC 21-07-2011 valid for 00 UTC of 22-07-2011
Prediction by NWP models : Example
500 hPa WIND ECMWF FORECAST (24 Hr.)
based on 00 UTC 21-07-2011 valid for 00 UTC of 22-07-2011
भारत मौसम





Prediction by NWP models : Example

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Short Range Monsoon Forecasting-Rationale

1. Attempts to predict future changes in the state of atmosphere from its initial state.
2. Takes into consideration both theoretical knowledge and its experience of evolution of weather situations in the past.
3. Involves a subjective assessment of the evolution and projection of weather systems into the near future from the study of surface and upper air weather charts.
4. Success of forecast depends on the skill and experience of the forecaster and his knowledge about the weather systems.

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Conceptual Model

- Specification of idealized or generalized space distribution of meteorological elements, such as clouds, precipitation, wind, temperature and or pressure in a distinct type of atmospheric system.
- It attempts to condense general results of extensive empirical investigations in a manner which describes the essential kinematics, dynamic and thermodynamic aspects of particular type of atmospheric system.
- For instance, there is a sequence of stages in the life history of a monsoon lows and depressions.
- Although, individual disturbances may have their own peculiarities, they all have certain properties and structural characteristic in common which can be combined into a typical Model.
- A knowledge of the Model of a weather distribution associated with them helps forecasting.

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Thank You
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