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Dry-line, nor'westers and tornadic storms over east India and Bangladesh : An operational perspective through synergie, the new IMD forecaster's workstation

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सार – प्रादेशिक स्तर के डयूटी पूर्वानुमानकर्ताओं तथा प्रचंड मौसमी घटनाओं के प्रशमन कार्यों में तैनात लोगों के लिए मॉनसून पूर्व की अवधि अत्यंत चुनौतीपूर्ण होती है। वस्तुतः मार्च से मई के महीने में पूर्वी भारत तथा बंगलादेश में प्रचंड गर्ज वाले तूफानों की वजह से तेज पवनें चलती हैं व बड़ें–बड़ें ओले गिरते हैं और झंझावात (टोरनाडो) का आना एक साधारण सी बात है। सार्क (दक्षिण एशियाई क्षेत्रीय सहयोग संगठन) के अनुसंधान प्रकाशनों एवं सूचनाओं तथा टोरनाडों एली में नोआ के राष्ट्रीय मौसम सेवा द्वारा विकसित व्यावहारिक कार्य पद्धति (प्रणाली विज्ञान) की मदद से ऐसी कार्य पद्धति तैयार की गई है जिसका इस्तेमाल भारत मौसम विज्ञान विभाग के पूर्वानुमानकर्ता अपने नए वर्कस्टेशन सिनर्जी के साथ अच्छी तरह से कर सकेंगे। इस कार्य के लिए 13 अप्रैल 2010 को आए प्रचंड तूफान के बारे में किए गए अध्ययन का चयन किया गया है। इस तूफान में 140 से भी अधिक व्यक्तियों की जानें गई थी और करीब 5,00,000 लोग बेघर या अन्य प्रकार से तूफान से प्रभावित हुए थे। इसके लिए सिनॉप्टिक और मेसोस्केल संकल्पनात्मक निदर्शो को अच्छे तरीके से समझना आवश्यक है। स्थानीय विशेषताओं को क्षेत्रीय अथवा स्थानीय पूर्वानुमानकर्ताओं के साथ बांटते हुए और तैयार करने के लिए उपयुक्त संख्यात्मक निदर्श क्षेत्रों की मदद लेते हुए सतह विशलेषण चाट्र्स पर मौसम के प्रतीकों को समुचित ढंग से अंकित करना एक महत्वपूर्ण कदम है। इसमें ग्राफीय विश्लेषण को भी प्रतिपादित किया गया है और इसका विवेचन किया गया है।

ABSTRACT. Pre-monsoon is a very challenging period for regional duty-forecasters and those involved in mitigation of severe weather consequences. Indeed, violent thunderstorms producing high winds, large hail and even tornados are common features from March to May in East India and Bangladesh. Taking advantage of SAARC (South Asian Association for Regional Cooperation) research publications, as well as knowledge and practical methodology developed by NOAA's National Weather Service in the Tornado Alley, a methodology is proposed that might help IMD forecasters make the best use of their new workstation SYNERGIE. The case study of the 13 April 2010 severe storm has been chosen for this purpose. More than 140 reported deaths and nearly 500,000 people were left homeless or otherwise affected by the storm. A good comprehension of both synoptic and mesoscale conceptual models is needed; then, aided by appropriate numerical model fields, drawing proper weather symbols on surface analysis charts is an important step towards the building and sharing of local expertise with regional or local forecasters. A graphical analysis is proposed and discussed.

Key words – Dry-line, Nor'wester, Tornadic storm, Pre-monsoon storm, Conceptual model, Outflow boundary, Weather symbol.

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1. Introduction

A violent storm struck parts of East India and Bangladesh during the night from 13 to 14 April, 2010. Fig. 1 is the infrared satellite picture of the event. More than 140 deaths were reported, most of which were women and children crushed when their huts were destroyed.

Deep convection is quite frequent in this region at this time of the year. One could say that everyday can bring severe thunderstorm somewhere around. This might lead to issue special warning everyday of the hot season from March to May, then lowering the awareness of the large public and decision makers.

Thus, arising questions for duty forecasters are: how to precise location at higher risk on a day-to-day basis? Moreover, how to assess the severity of the expected convection?

Since early 2010, a new forecasting tool provides IMD forecasters with improved capabilities of expertise.

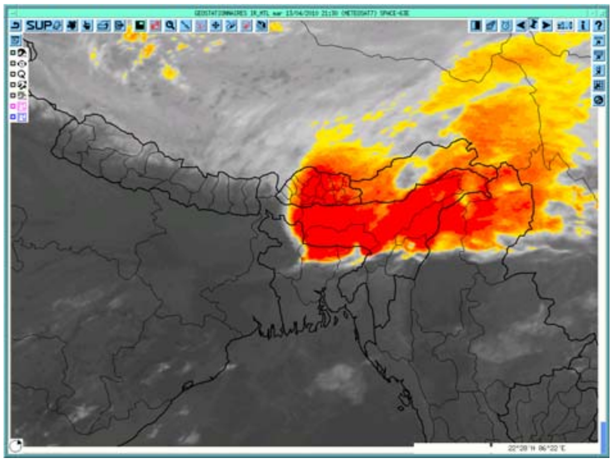


Fig. 1. Meteosat IR - 13 April, 2010 ; 2130 UTC

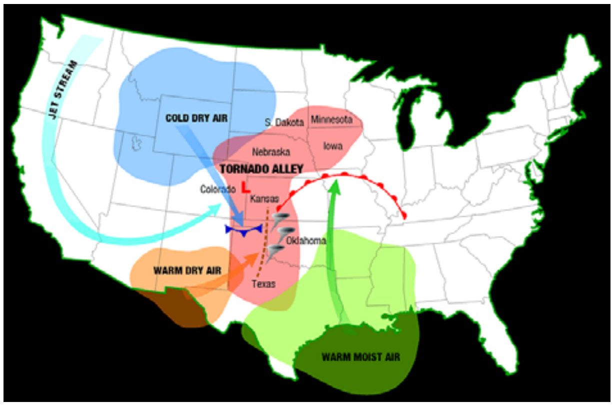


Fig. 2. Idealized dry-line situation in the USA. source NOAA NSSL

The workstation allows them to superimpose different kinds of data such as observed plottings, satellite images, The workstation allows them to superimpose different kinds of data such as observed plottings, satellite images, model fields, and vertical cross-sections. The forecaster becomes a "surgeon of the troposphere". model fields, and vertical cross-sections. The forecaster becomes a "surgeon of the troposphere".

1.1. *Milestones of studies about Nor'westers*

In 1938 already, forecasting Nor'westers in Bengal appears to be a big challenge for local experts as seen through the different issues addressed in a review of former articles about Nor'westers, by Pramanik (1938) from Met Office, Alipore, Kolkata, "originate through the overrunning of a warm moist southerly current by a westerly or north-westerly cold air with a high lapse rate". The similarity with US tornado situation was also established.

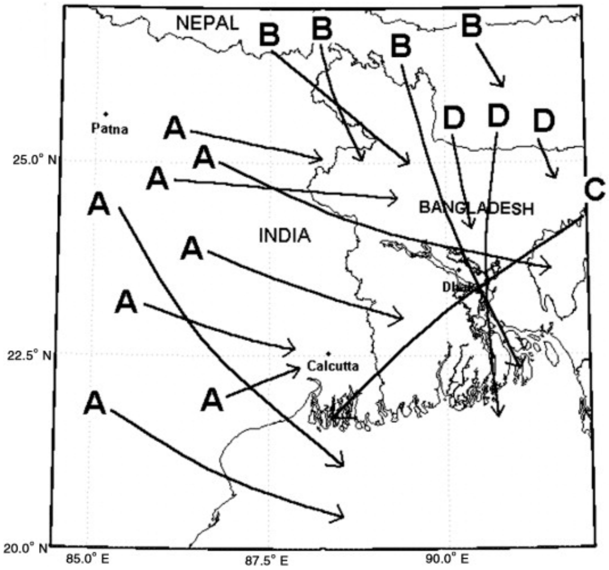


Fig. 3. Schematic of different types of Nor'wester (A, B, C, and D type) : Origin and direction of movement (Ghosh, *et al*., 2007, from IMD T. N. 10, 1944)

A bit later, Desai (1950), Bose (1957) Das *et al*., (1957), Rai Sircar (1957), Rao and Boothalingam (1957) develop comprehension of mechanism and prediction of Nor'westers.

The regional boundary is given a name by Weston (1972) the dry-line of Northern India. A comprehensive description is given, as well as explanation through a numerical simulation. The diurnal motion of the boundary is also described and discussed. Vertical cross-sections based on radiosondes and pilot balloons depict well the characteristics of the moist layer and the transition zone with the hot, very dry air. Weston remarks that the Indian dry-line is not routinely recognized and marked on surface weather charts except as a pressure trough. He stresses that days on which intense convection occurs are characterized by a narrow transition zone with a position well to the east of the mean for the time of year.

This assumption addresses the following question : is the mean position well known in 2011, so that we can assess the anomaly on a day-to-day basis? a "transition zone" in Kharagpur. Thanks to flux data acquired during monsoon trough Boundary Layer Experiment.

Lohar, *et al*., (1994) describe the dry-line of India as

Ziegler and Rasmussen (1998) from NOAA National Severe Storm Laboratory in Oklahoma show results about processes that force the initiation of deep convection

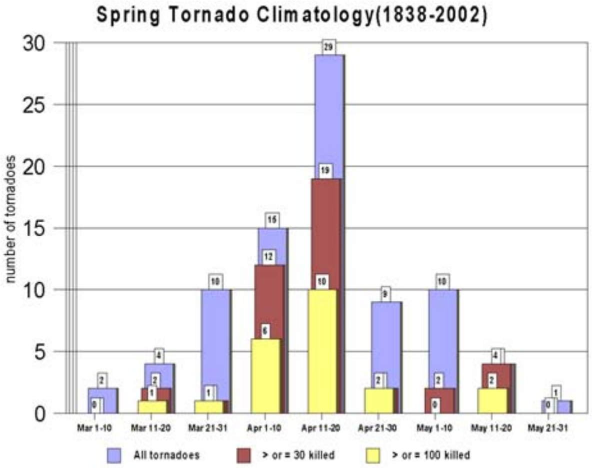


Fig. 4. Climatology (Finch, 2008)

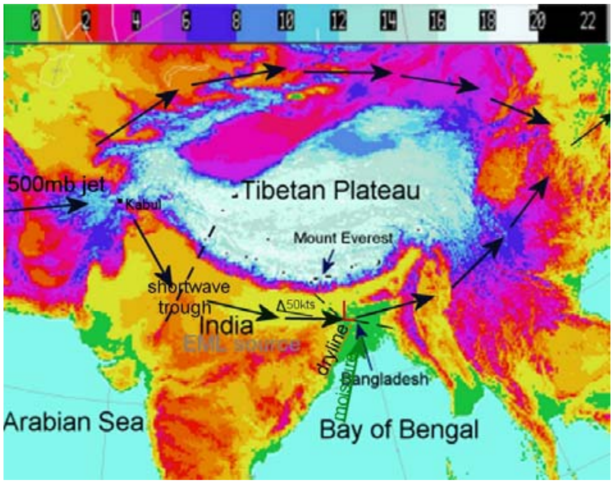


Fig. 5. Typical circulation pattern in April (Finch, 2008)

along the american dryline, inferred from special mesoscale observations obtained during several field projects. They suggest a peak cloud frequency 15 km to the east of the dryline. Fig. 2 depicts an idealized dry-line situation in USA.

Mukhopadhyay, *et al.*, (2005) and again Mukhopadhyay, *et al.*, (2009) show the usefulness of Doppler radar and satellite imagery for nowcasting purposes. They also stress the importance of the outflow boundary sometimes present near Kolkata.

Gosh, *et al.*, (2007) studied the initiation of Nor'westers in relation to water vapor and infrared patterns on Meteosat-5 images. They follow an old subjective classification in four varieties (Fig. 3) of pre-monsoon thunderstorms, then called "type A, B, C or D Nor'westers". Type A is the dryline type : Cb develop near Chota-Nagpur plateau and adjoining areas, mainly in the afternoon. Type B originates in the submontane districts of North Bengal. They base their study on WV boundaries (Krennert and Zwatz-Meise, 2003), supposed to favor upward motion and deep convection under dry slot due to differential solar radiation reaching the ground.

The results show that :

(*i*) Forty per cent of all thunderstorms and more than half of B type storms are initiated when a water vapor boundary overruns moist low levels.

(*ii*) Type D dominant pattern is a normal mid-upper dry air above moist low levels : mesoscale features like orographic triggering and the presence of a convective outflow boundary are enough for daily convection.

(*iii*) For A-type, dominant pattern is respectively above moist low levels in March, WV boundary above dry-line in April, pure dry-line in May (dry hot air above moist low levels)

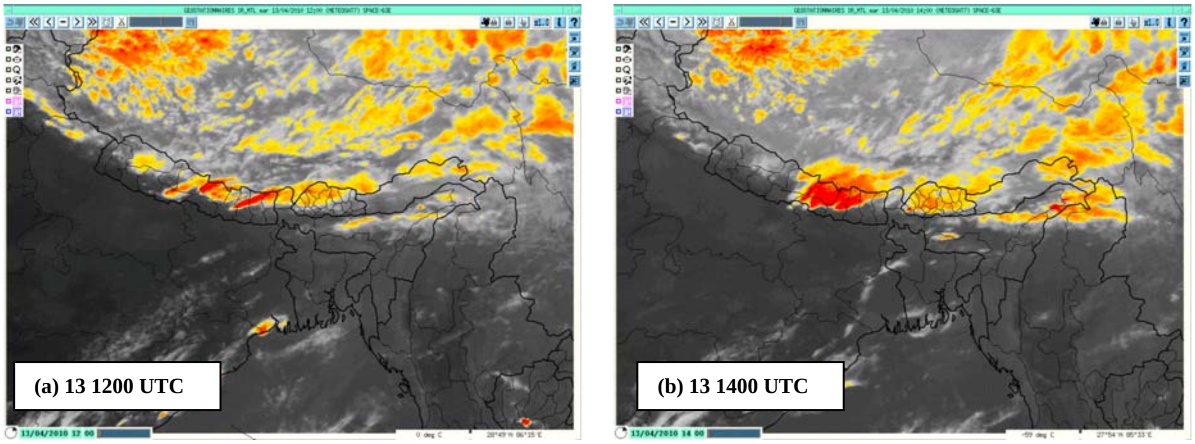
In previous years, the South Asian Association for Regional Cooperation (SAARC) was created with a Research Centre (SMRC) based in Dhaka, Bangladesh. http://www.saarc-smrc.org/. Several SAARC reports based on radar, *in situ* measurements and fine-mesh model simulations give more detailed characteristics of Nor'westers (Someshwar, 2009).

1.2. *A more insight feeling and operational experience*

Marshall (1992) finds the good words to let us feel what the American dry-line is about. He also gives some key features like dry-line bulges and intersection of a dry-line with a front or a thunderstorm outflow boundary.

Rai (2010) shows very well the extreme importance Nor'westers have in India and Bangladesh. Since it is the main source of rainfall, but it also brings destruction, Nor'westers are really part of the life of the people there from March to May.

Finch (2008) documented 84 tornados in Bangladesh (Fig. 5). The second decade of April appears to be the most dangerous period (Fig. 4). He also produced some composite anomaly charts based on 62 tornado cases. Tornado situations have a northwesterly wind anomaly at 500 hPa, west southwesterly wind anomaly at 700 hPa.



Figs. 6(a&b). Metosat 7 infrared on 13 April 2010 (a) 1200 UTC and (b) 1400 UTC

2. Case study of the 13 April, 2010 through operational workstation

2.1. *Synoptic environment*

A methodology is proposed hereafter, in order to exploit the new IMD forecaster's workstation. This study uses the model from ECMWF (European Centre for Medium-range Weather Forecast), on a 0.5 degree grid display.

2.1.1. *Upper dynamics analysis*

Satellite imagery matched with relevant model analysis or short-range fields - especially water vapor - are known to be crucial in order to get a good understanding of synoptic scale atmospheric processes.

One question to address when analysing satellite images is to distinguish what is due to synoptic evolution/forcing, and what is due to diurnal cycle of convection.

Infra-red images with below –40 °C in orange and red help underline deep convection. As soon as 1200 UTC, slopes of Nepal are uncommonly experiencing several growing Cb next to each other, while Eastern Ghats typical diurnal convection is already decaying at 1400 UTC [Figs. 6(a&b)]. But the presence of a synoptic forcing is unclear solely looking at infra-red images.

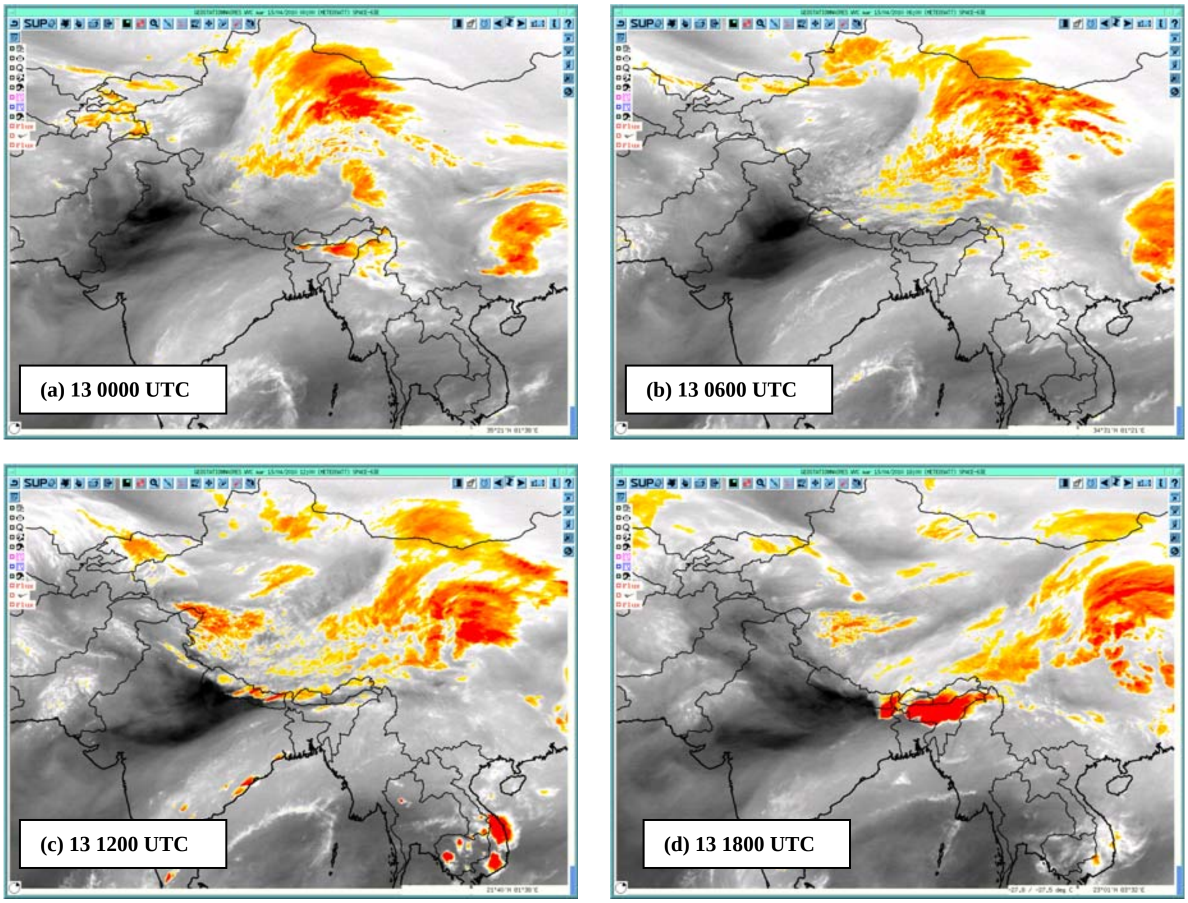
Water vapour channel images serve operational forecasters as a valuable tool for synoptic scale analysis (Santurette and Georgiev, 2005). For example, dark grey shade patterns on the WV imagery may be associated with various mid-to-upper level dynamical features like :

(*i*) Descending motions, particularly when darkening occurs

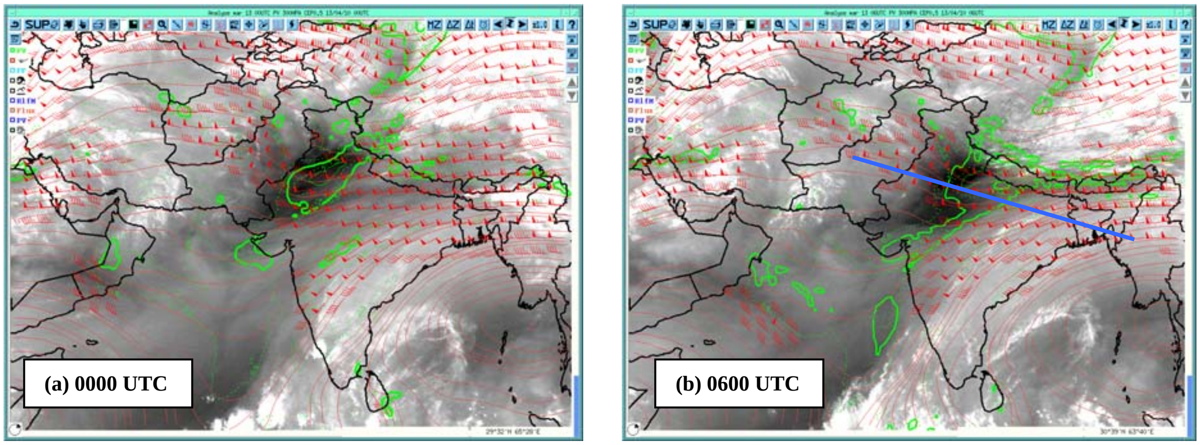
(*ii*) Dry intrusion regions associated with high potential vorticity and low wet bulb potential temperatures at high and mid-levels

Figs. 7(a-d) show a large scale 6-hourly sequence of water vapour images, supersimposed with cold tops of infra-red, in order to emphasize deep convection. See the dark region over Northwest India at 0000 UTC. It is moving east and has become darker by 1200 UTC.

A good way to facilitate image interpretation is to superimpose numerical model prediction output. Potential vorticity fields and water vapour images show a close relationship (Santurette and Georgiev, 2005) and have been used for many years now in many forecasting rooms. Their application to subtropical and tropical latitudes might be more recent. For exemple at Meteo-France, continental France operational forecasters match water vapour images with geopotential, wind and isotaches on the 1.5 PVU surface, while those in overseas territories like La Reunion island use 0.7 PVU surface. If parameters are not available on a PV surface, looking at the value of potential vorticity at a pressure level is possible. The 300hPa pressure level is generally a good one for synoptic analysis over India, as shown in Figs. 8(a&b). Streamlines give at low latitudes a clearer indication of the location and deepness of troughs and ridges as geopotential would

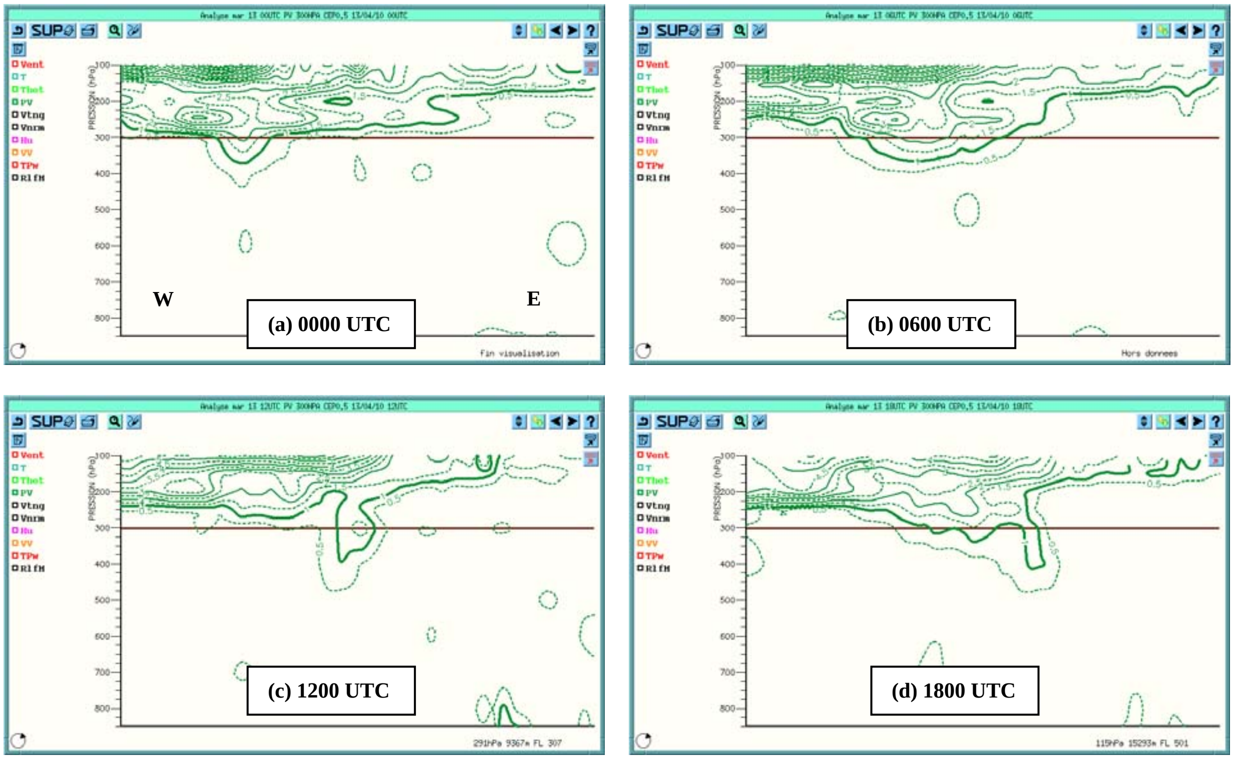


Figs. 7(a-d). Water vapour superimposed with cold tops of Infra-red images of 13 April, 2010 (a) 0000 UTC (b) 0600 UTC (c) 1200 UTC (d) 1800 UTC



Figs. 8(a&b). Metosat 7 water vapour pictures on 13 April (a) 0000 UTC and (b) 0600 UTC. Superimposed potential vorticity at 300 hPa (green, above 0.5PVU), wind (red, above 40 kt) and streamlines (red) at 300 hPa

show. Wind barbs over a relevant threshold (varying according to the situation and the season, here 40 kt) give the position of jet streaks, sometimes isolated from the main branch, see south of Oman in Figs. 8(a&b). Potential vorticity at this level is shown in green, taking 0.5 PVU as a threshold, and 1 PVU in bold line. Look how dark



Figs. 9(a-d). Sequence of 6-hourly analysed vertical cross-sections of potential vorticity (green) along an W-E axis from Rajasthan to North Myanmar as shown on Fig 8. Values display above 0.5 PVU threshold, 1PVU in bold. Vertical scale is from 850 hPa to 100 hPa level, in order to avoid noisy model output PV field in the atmospheric boundary layer

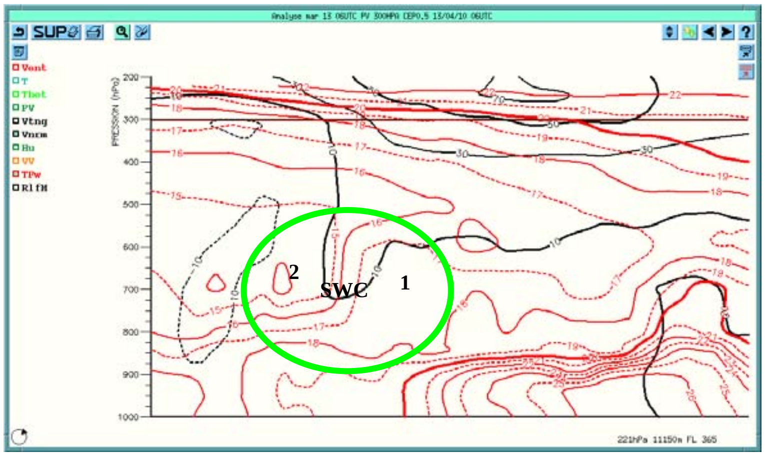
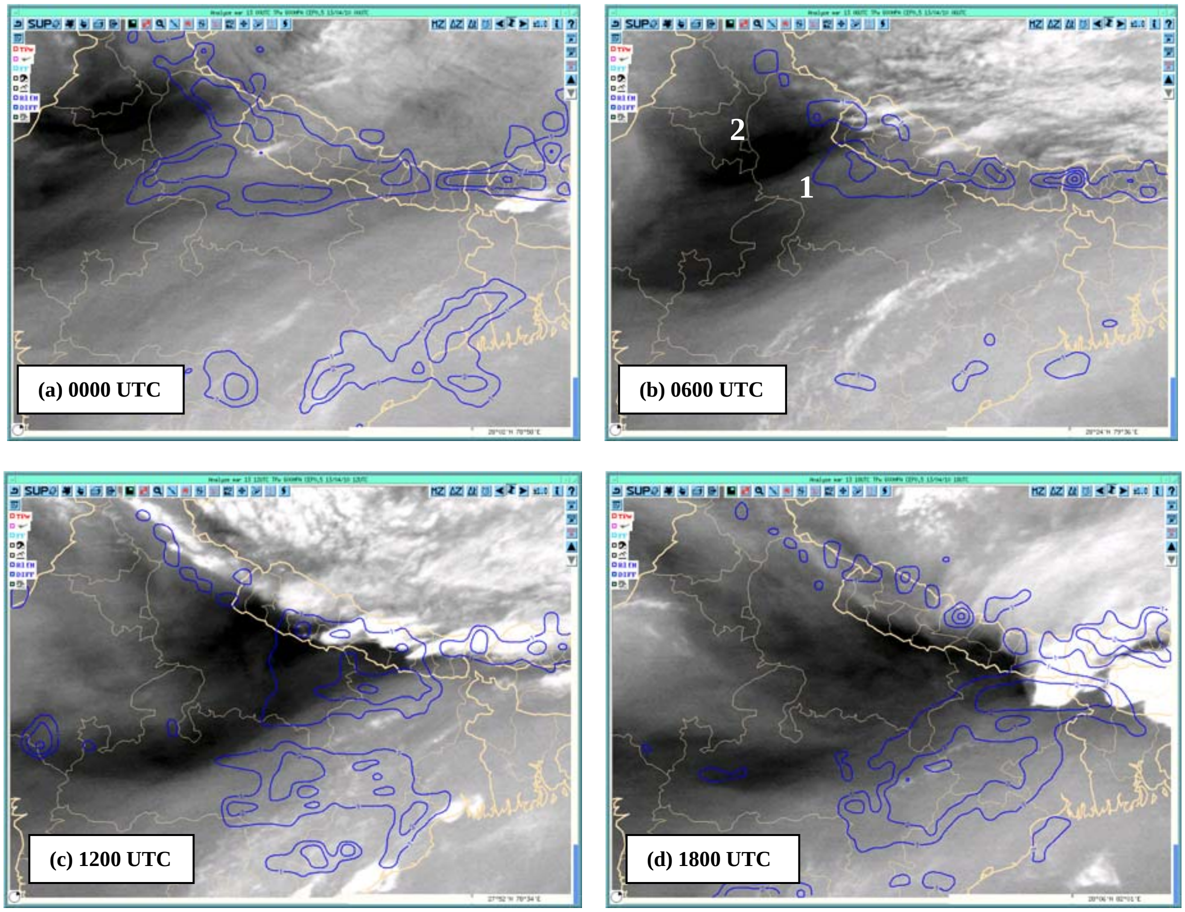


Fig. 10. Vertical cross-section of 0600 UTC analysis: wet bulb potential temperature in red, normal wind in black (southerly cross-Himalayas component in plain, post-trough northerly component in dashed line). Regions 1 and 2 as explained in the text. The leading of the mied-level trough is marked by the max of southerly component of the wind SCW

regions of the WV images and PV field match well over Northwest India. This cyclonic circulation, as used in IMD synoptic glossary, moves east. Note also the trough over the Arabian Sea, associated to a dark grey area that goes deep into the tropics. It is also well depicted by the 0.5 PVU field. It is of course of great importance in order to explain the clusters of deep convection to the West of Maldives.



Figs. 11(a-d). 6-hourly sequence of difference field of wet bulb equivalent temperature: 600 minus 500 hPa. Regions 1 and 2 as explained in the text

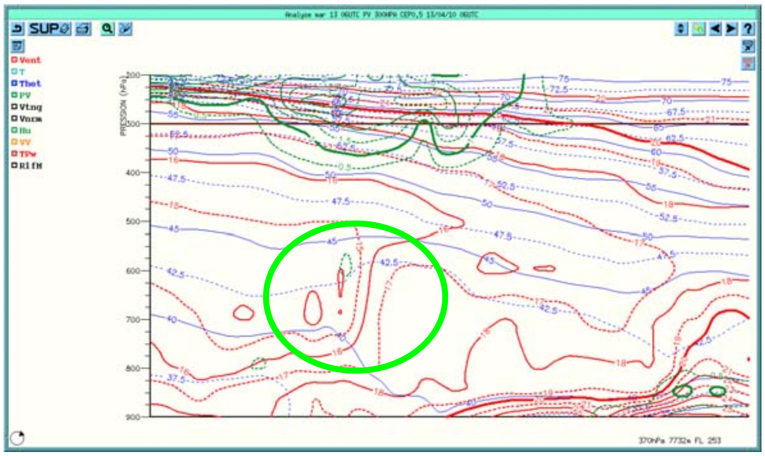
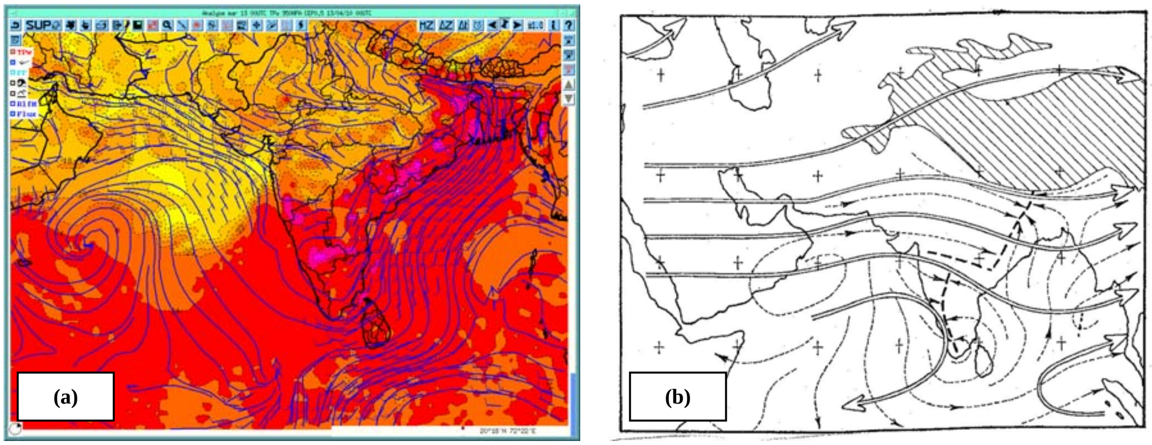
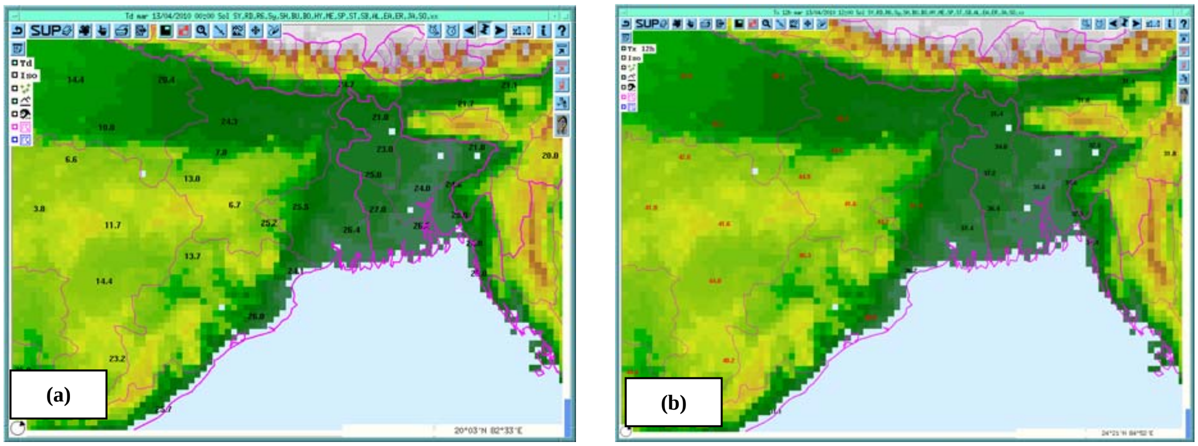


Fig. 12. Cross-section of theta (blue), wet bulb temperature (red) and PV (green)

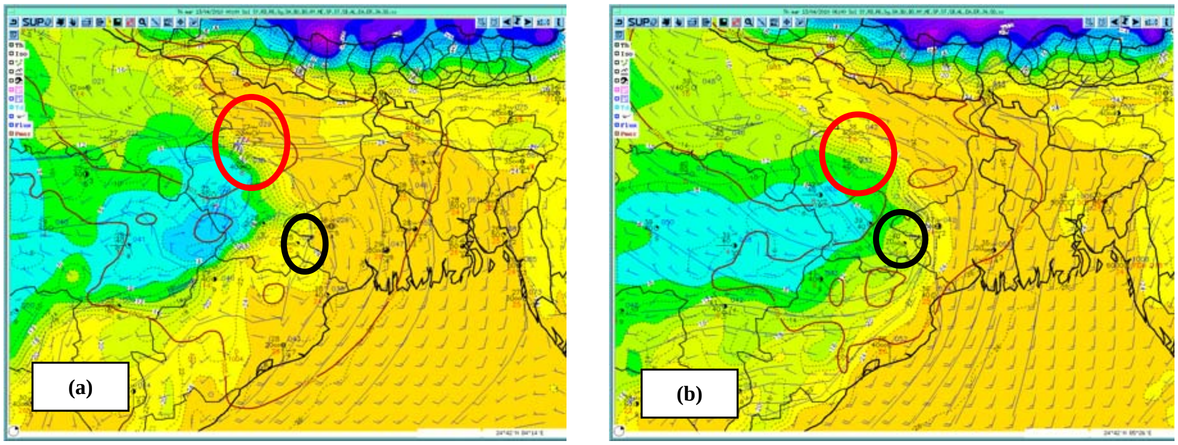
By 1800 UTC, the dynamic tropopause anomaly clearly gets a vertically elongated shape, reaching below 400 hPa level [Figs. 9(a-d)]. Synoptic subsiding motion leads to stratospheric air parcels diving down to mid-levels over Northeast India and Bangladesh. Over these regions, at least for this case study, the anomaly tends to



Figs. 13(a&b). Model analysis of wet bulb potential temperature, streamlines and wind analysis 14 April 2010, (a) 0000 UTC, to be compared with (b) Fig. 2 in Weston 1972



Figs. 14(a&b). Surface plotting of (a) dew point temperature and (b) afternoon maximum temperature



Figs. 15 (a&b). Surface plot, model 2m dew point, 10 m wind and streamline analysis (a) 0000 UTC (b) 0600 UTC

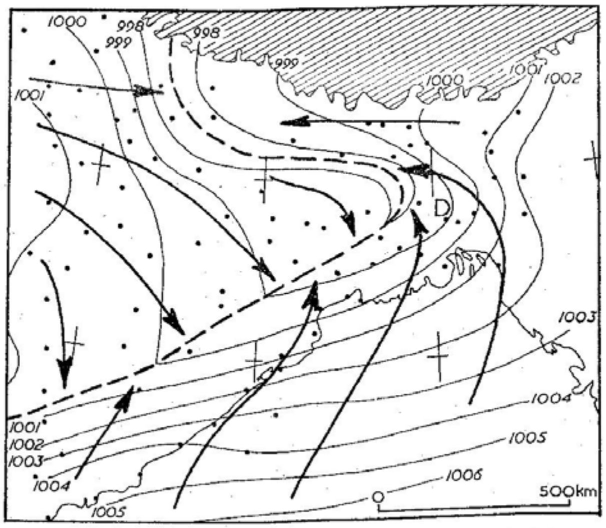


Fig. 16. Conceptual scheme of an April situation at the surface, by Weston 1972

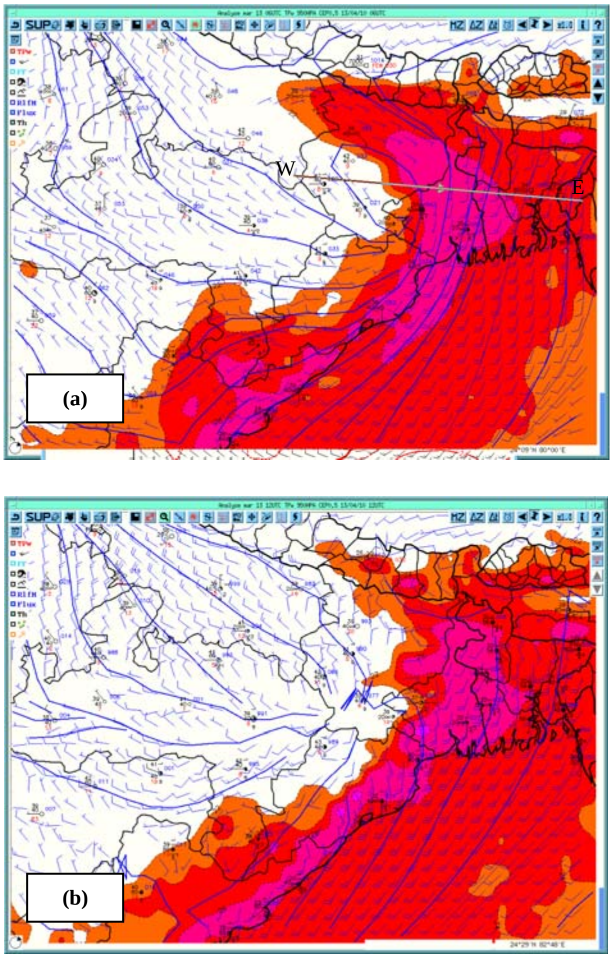
accelerate at 400 hPa; it might be due to channeling effect south of the Himalayas.

Dark WV imagery patterns may also be associated with dry intrusions, *i.e.*, low wet bulb equivalent temperature at mid-to-upper levels.

Fig. 10 shows a cross section at 0600 UTC for same axis as Fig. 9. The region inside the green circle is of particular interest. At 700 and 600 hPa, there is a well marked horizontal gradient between region 1 : high wet bulb equivalent temperature (above 17 degree) and rather high humidity (50%, not shown), and region 2 that is much drier. Moreover, the vertical gradient of wet bulb equivalent temperature is very strong in region 1. Even if Meteosat 7 does only give a deep layer averaged radiance and no information about a precise mid or high layer, vertical gradient of wet bulb temperature seem to be correlated to a sharp gradient between the medium-grey shade (Santurette and Georgiev, 2005; in our case region 1 of the cross-section) followed by much darker region (region 2) [Figs. 11(a-d)].

Note that in Fig. 10, the relative maximum of southerly component of the wind (SWC) also shows the leading edge of the mid-level trough; it is also found at 600 hPa.

This potentially very unstable air layer (around 4000 m altitude) is then orographically lifted when encountering the steep slopes of the Himalayas. Both reasons are sufficient to explain early Cumulonimbus over Nepal.

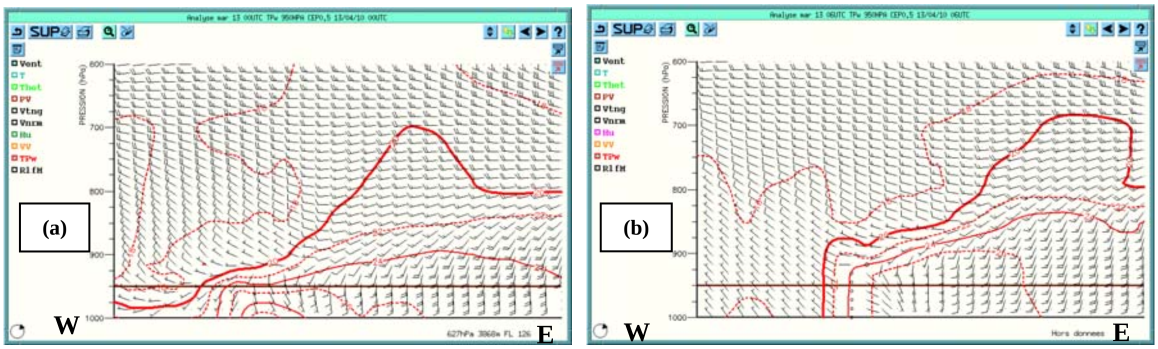


Figs. 17(a&b). Wet bulb potential temperature (shaded over 22°), streamlines and wind analysis 14 April (a) 0600 UTC (b) 1200 UTC. Surface synop plotting superimposed. Axis of the cross-section seen in Fig. 15

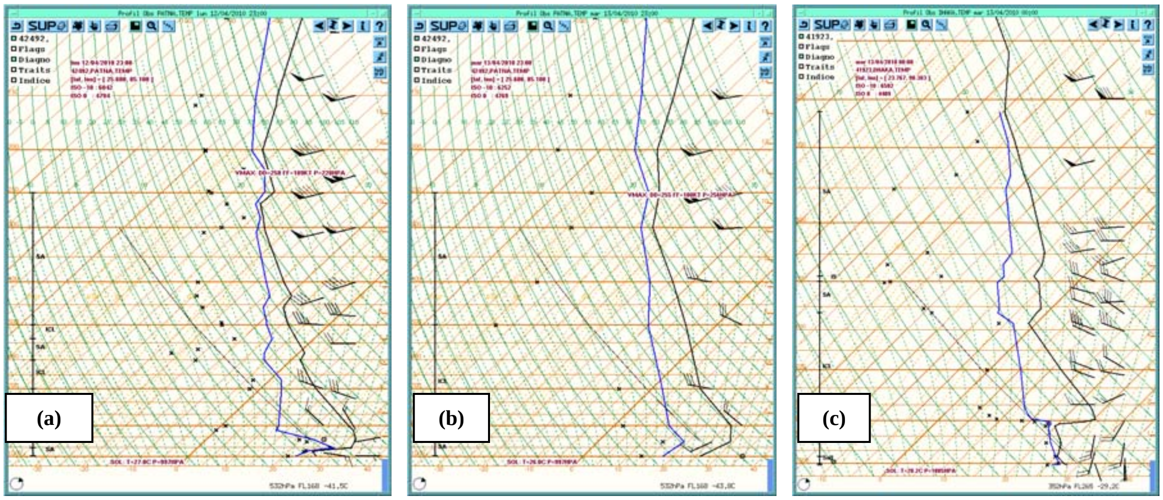
Another way to stress the importance of that area inside green circle is recognizing the shape of the isentropes (iso-theta lines in blue) on Fig. 12. The way isolines 42.5 and 45 move away from each other is a strong signal of weak static stability. Upward motion is easy in such areas; thus, the tropopause, high potential vorticity anomaly aloft will find a response in that precise area.

2.2. *Low level analysis*

Low level moisture content or thermodynamic energy is often assessed through fields of wet bulb potential temperature. It is an invariant parameter in adiabatic processes, which can be tracked from one day to another. Since the maritime inflow of moist tropical air is very shallow in April, 950 hPa is a good level to look at.



Figs. 18(a&b). West-east cross-section of wet bulb pot. temp. (red) and total wind on axis seen of Fig14. (a) 0000 UTC (b) 0600 UTC



Figs. 19(a-c). Observed temp at Patna (a) 12 April, 2300 UTC (b) 13 April, 2300 UTC and (c) Dhaka 13 April, 0000 UTC

In Figs. 13(a&b), colour shading shows how the circulations above the Arabian Sea and the Bay of Bengal are different. Note the similarity with the schematic map of Weston (1972).

Of course, real surface data are essential to a good analysis. In Figs. 14(a&b), 13 April, 2010 is a typical situation with a shallow inflow of moist air from the Bay of Bengal towards the foothills of Himalayas, while dry air remains over central India, where highs daily reach 40-45 °C. A sharp dew point gradient can be roughly sketched, but surface data are too scarce in order to draw it precisely.

Model output is very valuable since it gives a detailed field, provided you check its accuracy with surface plotting. One parameter you can easily verify is 2 m dew point temperature. In Figs. 15(a&b), how Patna (North, 60 m high) and Gaya (South, 116 m high) are on both sides of the dry line for real and also in the model? See the city of Jamshedpur (black circle) that lies on the transition zone; it is in the tropical air most of the day, except at noon. The model is also able to catch this diurnal cycle of dew point and wind. And again, the similarity in wind discontinuities with Weston (1972) is striking: see Fig. 16.

The diurnal cycle motion of the dryline, already well described by Weston, is more obvious when displaying colors above a certain threshold [22 °C in Figs. 17(a&b)] and even more through a cross-section [Figs. 18(a&b)]. The transition zone is farther west at night and early morning, then retreats eastwards with solar heating, as vertical mixing forces the drying trend in the lowest 50 hPa layer (Ziegler and Rasmussen, 1998). The moist air layer is very shallow at night, around 500 m deep; at 0600 UTC, it is around 1000 m deep, and the transition zone is much sharper, strengthening convergence.

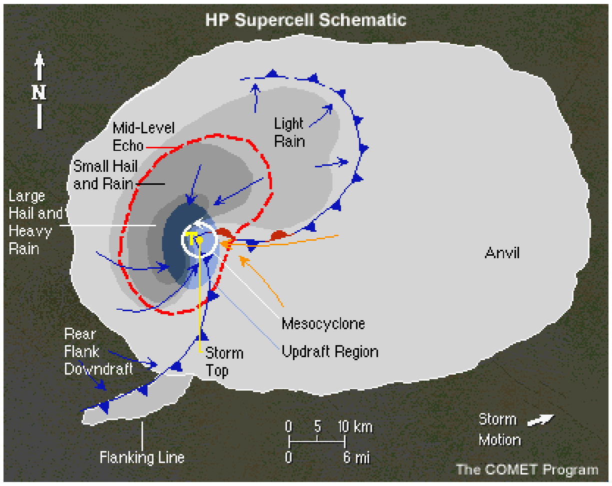
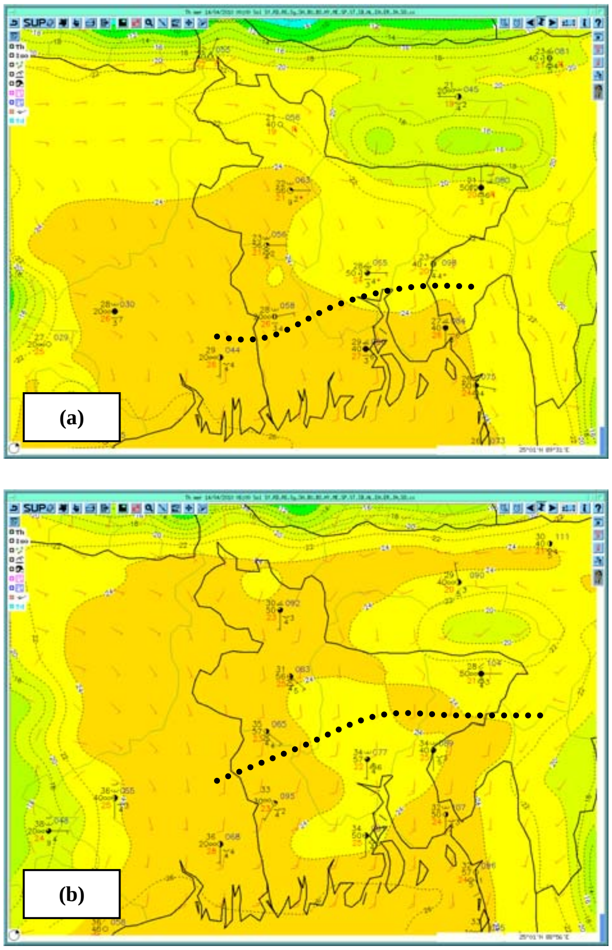
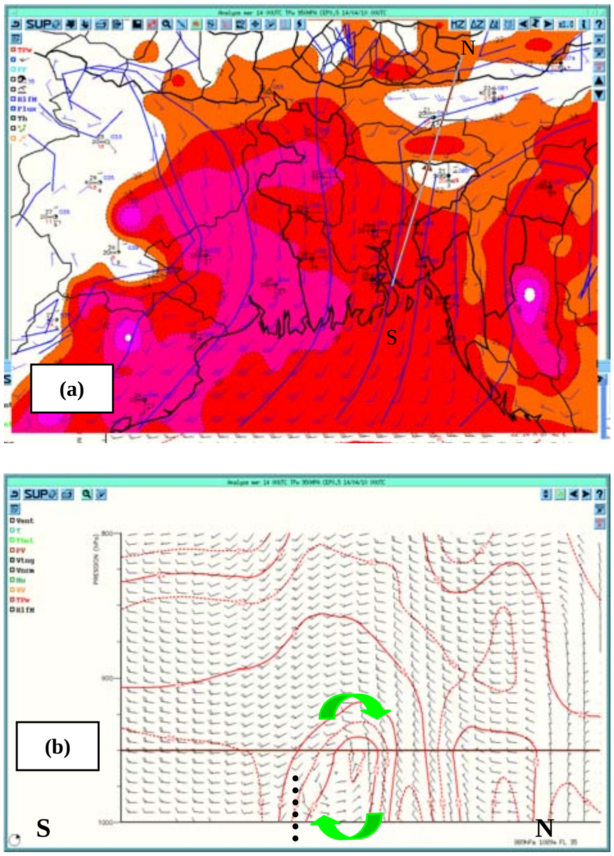


Fig. 20. Conceptual model of a High Precipitation Super cell (*Source* : the COMET program)



Figs. 21(a&b). Surface synop observations and model output on (a) 14 April 0000 UTC (b) 0600 UTC Convective outflow boundary is the black dotted line



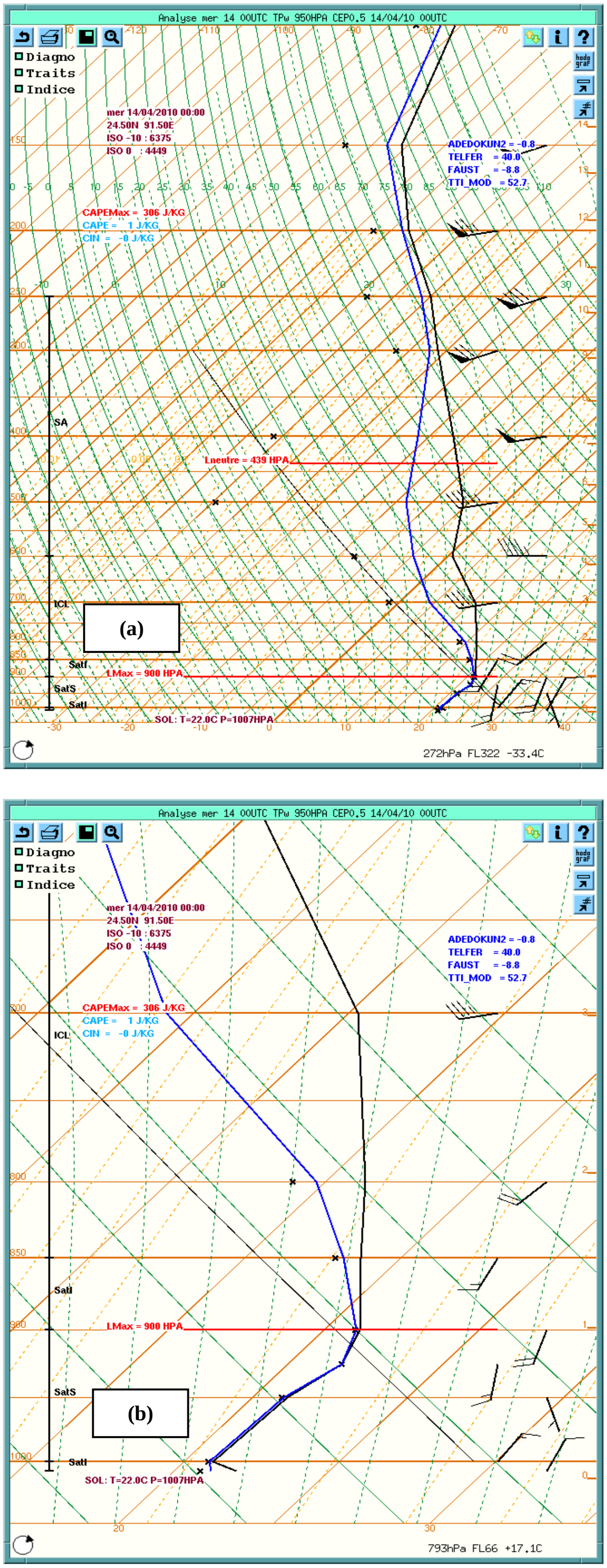
Figs. 22(a&b). (a) 950 hPa wet bulb potential temperature and (b) cross-section. Black dotted line is the Khasi hills outflow boundary over the plain of Bangladesh

In Figs. 19(a-c): the actual temp of Patna on 12 April, 2300 UTC show the very shallow moist layer with surface easterly winds and on top a hot, dry and very unstable airmass. On 13 April 2300 UTC, dried cool air has spread around at the rear of the super cell. At Dhaka, the moist layer is 1500 m deep, with a strong inversion on top.

2.3. *Meso-scale features*

The infra-red satellite image (Fig. 1) matched the conceptual model of a High precipitation supercell (Fig. 20). The ranking line is very clear. Patna got an amazing three-hour drop in dew point from 22 to 3 degrees with northeasterly wind (not shown), proof of the rear flank downdraft.

Another regional mesoscale feature is very well described by Finch on his website: the convective outflow boundary across northern and central Bangladesh, due to cold pool and meso-high formed after downslope flow has taken place every night from the mountainous terrain



Analyse mer 14 00UTC TPw 950HPA CEP0.5 14/04/10 00UTC

mer 14/04/2010 00:00
24.50N 91.50E
ISO -10 : 6375
ISO 0 : 4449

ADEDOKUN2 = -0.8
TELFER = 40.0
FAUST = -8.8
TTI_MOD = 52.7

CAPEMax = 306 J/KG
CAPE = 1 J/KG
CIN = -0 J/KG

SOL: T=22.0C P=1007HPA

272hPa FL322 -33.4C

793hPa FL66 +17.1C

Figs. 23(a&b). Model profile for NE Bangladesh, within the convective cold pool: analysis for (a) 14 April 0000 UTC (b) same but zoomed in lower levels

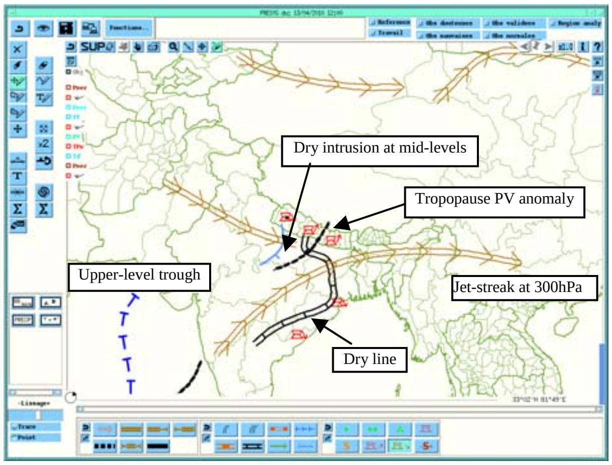


Fig. 24. Graphical summary of synoptic situation, 13 April 1200 UTC

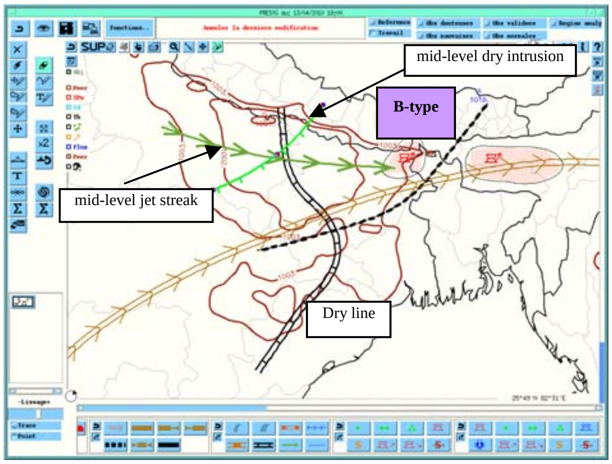


Fig. 25. Graphical summary of synoptic situation, 13 April 1800 UTC

around Cherrapunji in the Khasi hills of Meghalaya, India. Once again, the forecaster can check model wind and surface dew point versus surface plottings. In Figs. 21(a&b): low dew points and weak easterlies have spread over northern half of Bangladesh, after the heavy downpours of last night thunderstorms. The outflow boundary has been drawn in dotted black line. There is a hint of some discontinuity zone in the model, but it is far from perfect. A fine mesh model is necessary in order to catch such details due to orography and convective activity.

A South-North cross-section of the lower layers [Figs. 22(a&b)] show the cold pool south of the Khasi hills, and the associated solenoïdal circulation that lead to a narrow enhanced convergence line over the plain of Bangladesh. A model profile in its cold pool gives an idea of the airmass profile [Figs. 23(a&b)].

3. Charts analysis

As stressed by Weston in 1972, the Indian dry-line is not routinely recognized and marked on surface weather charts even though it is among the most significant features of the flow pattern over Northeast India during the pre-monsoon months.

A revised graphical summary of the synoptic situation has been operational at Meteo-France since 2001 (Santurette and Joly, 2002). It emphasizes large-scale dynamics: the actual and potential baroclinic interactions.

Two charts are proposed for the day: the first one for 1200 UTC (Fig. 24) is a synoptic chart over a large domain. The dry-line symbol used in USA was not available on the work-station, so the symbol of African inter-tropical front has been used. Proper dry-line symbol should be provided. Note that this weather symbol does not show the direction of its movement.

Ahead of the dry intrusion, humid mid-levels have been lifted by PV anomaly, then by orographic effect over slopes of the Himalayas Cb are multiplying over central and eastern Nepal, but are still located over mountainous areas. Cells are decaying over western Nepal, in a now synoptically subsident area.

The second chart (Fig. 25) is zoomed in over NE India and Bangladesh, at 1800 UTC (refer to satellite image in Fig. 7). The dry-line is then located over central Nepal. Afternoon storms density current is meeting the moist low layers covering Tarai Plain. Multiple cells merge into one that rapidly moves southeastwards. The mid-level westerly jet streak has been given a symbol since it plays an important role in increasing the vertical wind shear and helicity of the storm. The type of storm is given in a text box.

4. Summary

We could sum up the scenario through the following steps:

(*i*) Presence of a dynamic tropopause anomaly over Northwest India.

(*ii*) This enables upward motion in a low static stability area in mid levels over Uttar Pradesh, just ahead of dry intrusion drawned on the graphical summary.

(*iii*) Upward motion then orographically enhanced along steep slopes of Nepal lead to high ground storms.

(*iv*) Density current of one Nepalese storm meets the moist easterlies east of the dryline. The strong induced convergence initiates strong updraft. The breaking of the inversion cap on top of the moist layer allows explosive deep convection over Bihar.

(*v*) The storm motion then goes right compared to the westerly steering flow. It is due to vertical wind shear vector that turns clockwise.

This was clearly a B-type storm, born on the foot of the Himalayas (Fig. 3). It became a HP (high precipitation) supercell over Bihar.

Many aspects of dryline remain unclear and every case is a combination of many synoptic and mesoscale factors. This paper does not aim to bring a ready to use miracle method. It neither wants to say that this event was obvious through model outputs. Besides, model did not show any hint of heavy precipitation over Bihar and Gangetic West Bengal. Furthermore, duty-forecasters have only a limited time before issuing routine and warning bulletins.

Nevertheless, methodology proposed here stresses the importance of different parameters and practices:

(*i*) Relevant model fields superimposed on satellite animations.

(*ii*) Water vapour and the use of potential vorticity are also important for the Indian subcontinent.

(*iii*) Wet bulb potential temperature is needed at different levels as an indication of moisture content.

(*iv*) Checking model output versus observations is of course essential in order to assess confidence in forecast scenario.

(*v*) Finally, drawing maps help acquisition and transmission of synoptic and mesoscale concepual models among different forecast teams. On the graphical summary or within regional technical guidance bulletin, the naming of the storm type: A, B, C, D would also add to the message.

Provided you prepare a complete set of refined macros, a tool like SYNERGIE enables quick analysis and useful graphical products to be delivered on time.

For the situation, expressing the risk for each type of storm could be done through a table (with climatology as a reference, provided it is available)

Storm type	*A*	*B*	*C*	*D*
Risk	Normal (climatology)	High	High	Low

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Fruitful exchanges with friendly IMD forecasters in Kolkata and Pune have motivated this work. The author is grateful to Sarah Puginier for her keen interest in such time-consuming activity and her constructive suggestions. Thanks also to Thierry Barthet for retrieving the data, and Sebastien Laflorencie for help with document.

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