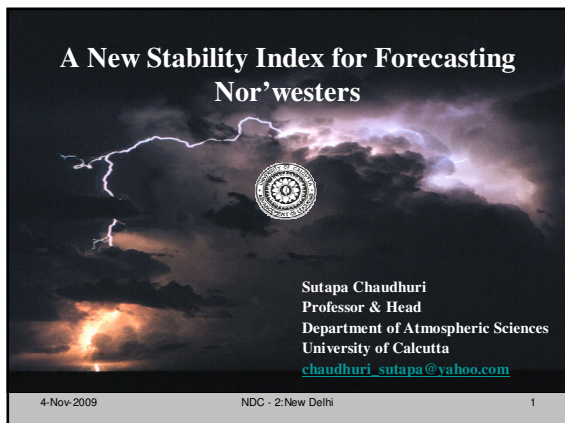



A New Stability Index for Forecasting Nor'westers





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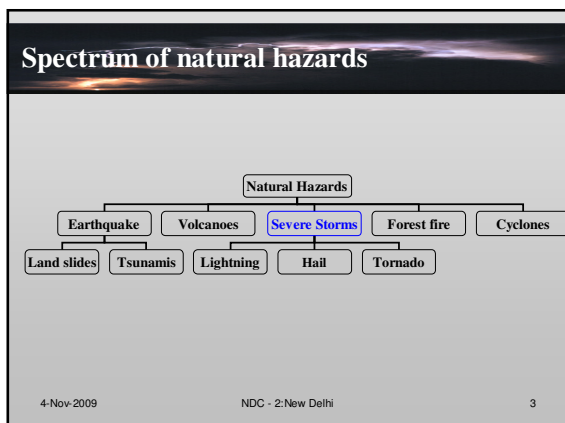
Natural hazards

Natural hazards are inevitable. However, the catastrophe caused by natural hazards are the matter of concern

Scientific endeavour thus, should be; to develop forecast / warning system so that such hazards can be predicted with adequate lead time and considerable accuracy for mitigation of the casualties associated with such hazards.

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Spectrum of natural hazards



```

graph TD
    NH[Natural Hazards] --> EQ[Earthquake]
    NH --> V[Volcanoes]
    NH --> SS[Severe Storms]
    NH --> FF[Forest fire]
    NH --> C[Cyclones]
    SS --> LS[Land slides]
    SS --> T[Tsunamis]
    SS --> L[Lightning]
    SS --> H[Hail]
    SS --> TO[Tornado]
    
```

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Nor'westers or Kalbaishakhi.

Every year, during the pre monsoon months of April and May, Kolkata (22°32' N, 88°20' E) encounters with severe thunderstorms which are locally known as **Nor'westers or Kalbaishakhi**.

The casualties associated with such severe thunderstorms demanded extensive research in this field and thus, the genesis of the National Programme **STORM**(Severe Thunderstorm: Observational & Regional Modeling)

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Nor'westers or Kalbaishakhi – cont...

The pre-monsoon thunderstorms have significant socio-economic impact over the region.

Forecasting severe thunderstorms is still a major challenge for the meteorologists and atmospheric scientists of India because the weather phenomenon is highly nonlinear and chaotic. Further, the observational network is still not adequate for such studies.

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Category of Thunderstorms over Kolkata

<u>Severe Thunderstorms</u>	<u>Ordinary Thunderstorms</u>
wind speed ~70 km/h or 38 knots,	wind speed ~55 km/h or 30 knots,
frequency ~ High	frequency ~ Low
of lightning (evident from satellite imageries)	of lightning (evident from satellite imageries)
Cloud mass ~ intense (evident from satellite imageries)	Cloud mass ~ small patches (evident from satellite imageries)

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Purpose

The purpose is to formulate a single stability index from the broad ranges of available stability indices which may help in forecasting Nor'westers over Kolkata.

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Stability Indices

Stability indices depend on the atmospheric soundings of a particular geographical location.

The indices indicate the condition of the atmosphere at a particular time and provides significant information for future.

Types and exact ranges of the stability indices for a particular location and a particular system has to be identified separately with proper care.

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Similar Studies in USA

Various studies with stability indices have been done by scientists and meteorologists of other countries for operational forecast of severe thunderstorms.

Schultz, P., 1989, *Weather and Forecasting*.
 Jacovides and Yonetani, 1990, *Weather and Forecasting*.
 Huntrieser et al., 1996, *Weather and Forecasting*.
 Baldi, M. et al., 2008, *J. of Appl. Met. And Clim.*

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A Coñucopia of Indies

- Lifted Index (LI)
- Total Total Index (TT)
- Showalter Index (Sw)
- K-Index (KI)
- Lapse Rate
- CAP Strength (700mb LI)
- Perceptible water (PW)
- Warm Cloud Depth (WCD)
- Moisture Convergence (MC)
- Convective Available Potential Energy (CAPE)
- Convective Inhibition (CIN)
- Bulk Richardson Number (BRN)
- Vertical Wind Shear (VWS)
- Normalized CAPE (NCAPE)
- Storm Relative Helicity (SRH)
- Vorticity Generation Parameter (VGP)
- Downdraft CAPE (DCAPE)
- Wind Index (WINDEX)
- Theta-E Index (TEI)
- Dry Microburst Index (DMI)
- Energy Helicity Index (EHI)
- Supercell Composite Parameter (SPC)
- Significant Tornado Parameter (STP)
- Dew point Temperature (Td)
- Haines Index (HI)
- Lid Strength Index (LID)
- Hybrid Microburst Index (HMI)
- Deep Convective Index (DCI)
- Strong Tornado Parameter (STP)

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Relevant Stability Indices

- Lifted Index (LI)
- Showalter Index (SwI)
- Total-Total Index(TT)
- K-Index (KI)
- Boyden Index(BI)
- Severe Weather Threat (SWEAT)
- Convective Available Potential Energy (CAPE)
- Convective Inhibition Energy (CIN)
- Bulk Richardson Number (BRN)
- Storm Relative Helicity (Srh)
- Vorticity Generation parameter (VGP)
- Surface Dew Point Temperature (Td)

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Probability distribution of the stability indices

	Storm Generating Factors	
	Strong	Weak
Lifted Index	≤ -5 °C	≥ 0 °C
CIN	≤ 150 J/Kg	≥ 200 J/Kg
CAPE	≥ 2000 J/Kg	≤ 1000 J/Kg
Bulk Richardson No.	≥ 45	≤ 25
Showalter Index	≤ -4 °C	≥ 0 °C
Boyden Index	≥ 99	≤ 97
K-Index	≥ 35	≤ 20
Total Total Index	≥ 55	≤ 45
SWEAT	≥ 500	≤ 300
VGP	≥ 0.6	≤ 0.4
SRH	≥ 250 m ² /s ²	≤ 100 m ² /s ²
Surface Td	≥ 22 °C	≤ 20 °C

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Statistical skill score analysis

A wide variety of forecast verification procedures are available (Murphy, 1983). The statistical parameters computed and analyzed for the accuracy measurement of forecast are (Huntrieser et al, 1997);

- **Probability of Detection (POD)**
- **Critical Score Index (CSI)**
- **Hit Rate (HR)**
- **False Alarm Rate (FAR)**
- **Odd Ratio Skill Score (Yule's Q)**

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Statistical skill score

Skill score is more appropriate than accuracy-based POD and FAR in evaluating the ability of the parameters for forecasting a system (Wilks 2006).

The Heidke Skill Score (HSS) uses random forecasts as the control set.

However, Jolliffe and Stephenson (2003) demonstrated that Odds Ratio Skill Score (Yule's Q) is more preferable than HSS in evaluating the performance of binary forecasts since Yule's Q satisfies the criteria of equitability, regularity, and consistency. HSS only satisfies equitability.

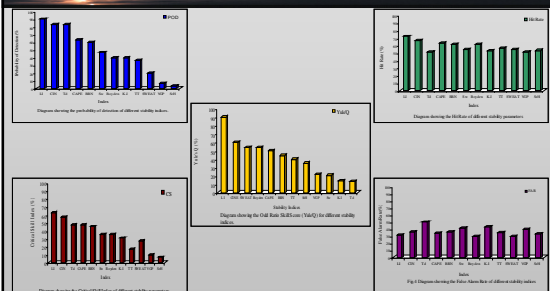
Nevertheless, either HSS or Yule's Q should provide a better assessment of performance than POD and FAR for binary events.

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Schematic of Statistical skill score analysis



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Significant stability indices for Nor'westers

Three significant stability indices are identified for Nor'westers;

Lifted Index (LI)

Convective Inhibition Energy (CIN)

Convective Available Potential Energy (CAPE)

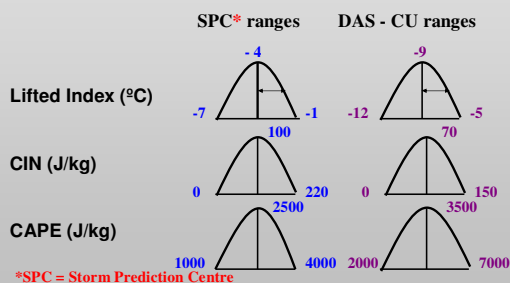
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Comparative Threshold Ranges

Ranges of stability indices during severe storm over USA & Kolkata



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Nor'wester Prediction Index (NPI)

Using the three significant stability indices, a new stability index Nor'wester prediction Index (NPI) is formulated as;

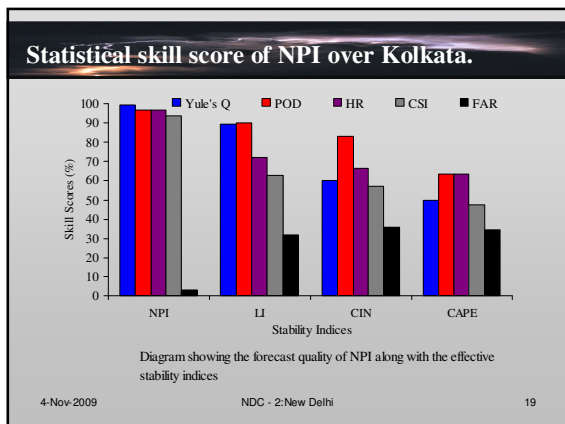
$$NPI = \frac{CAPE}{2000 \text{ J / Kg}} \times \frac{-150 \text{ J / kg}}{CIN} \times \frac{LI}{-5^\circ \text{ C}}$$

Where "CAPE", "CIN" and "LI" are the values of the stability indices of a particular day of concern.

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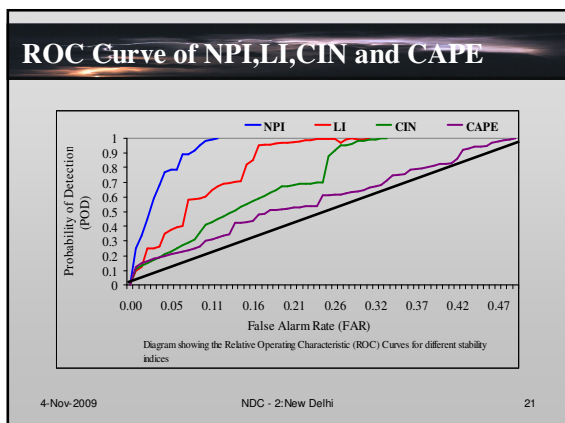


ROC Curves

The relative operating characteristic (ROC) curves (Jolliffe and Stephenson, 2003) are more appropriate for multi-dimensional or graphical evaluation.

The ROC is based on signal detection theory and is a graph which depicts the FAR (abscissa) versus POD (ordinate) for varying decision thresholds.

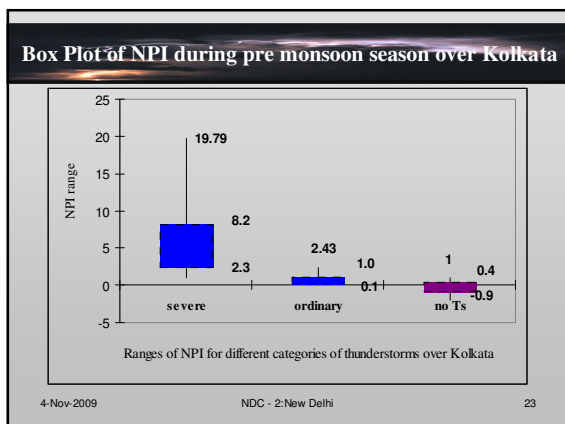
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The ranges of NPI for Nor'westers over Kolkata with 10 year (1997-2006) data

	Generalized Ranges	Actual Ranges
Severe Thunderstorm	$NPI > 1$	$NPI > 1$
Ordinary Thunderstorm	$0 < NPI \leq 1$	$0.1 \leq NPI \leq 1$
No thunderstorm	$NPI < 0$	$-0.9 \leq NPI < 0.4$

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Validation - 2007,2008 and 2009

TS date wind speed 2007	NPI Value Category of TS	TS date wind speed 2008	NPI Value Category of TS	TS date wind speed 2009	NPI Value Category of TS
9.4.2007 70 km/h	7.747 Severe	10.5.2008 81 km/h	3.907 Severe	11.5.2009 87 km/h	48.64 Severe
21.5.2007 81 km/h	2.65 Severe	18.5.2008 99 km/h	8.076 Severe		
3.5.2007 42 km/h	0.4792 Ordinary	17.5.2008 48 km/h	0.3746 Ordinary	12.5.2009 54km/h	0.0098 ordinary
22.5.2007 51 km/h	0.0195 Ordinary	5.4.2008 55 km/h	0.140 Ordinary	25.5.2009 54km/h	0.28 ordinary
10.4.2007	- 0.0008 CAPE = 10.32 No TS	7.4.2008	- 0.002 CAPE = 70 No TS	23.4.2009	0.4601 CAPE = 4488 No TS

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Thank you

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