STATISTICAL ANALYSES AND RELIABILITY OF INSTABILITY INDEXES

FOR PREDICTING CONVECTIVE PRECIPITATION

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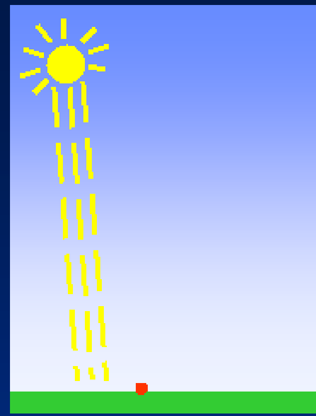
INTRODUCTION
AIM
MATERIAL AND METHODS



Study Area: Göztepe (İstanbul) and Isparta

Data: Radiozonda Data (12:00 GMT) and Daily Total Rainfalls Rates, (1976-2007)

Methods: Statistical analyses, χ^2 analyses, ANNOVA analyses, Accuracy Analyses of Stability Indexes

ANALYSIS

Ten different indexes, and six different precipitation classes, corresponding values and percentages have been defined. As a result, for ten different indexes accuracy analyses

RESULTS AND CONCLUSION

AIM

This paper presents some results of statistical analyses, comparison and reliability of stability indexes in and near vicinity of Istanbul and Isparta for predicting convective precipitation. Ten stability indexes (VT: Vertical Total, CT: Cross Total, TT: Total-Total, MTT: Modified Total-Total, HUMI: Humidity, SWEAT: Sweat, SAR: Yellow, K, DK-Modified K and KH: Kahraman Indexes) are defined based on radiosonda observations at 12:00GMT in the interval of 1976 and 2007 in two study areas

INTRODUCTION

Atmospheric stability has a key role on soaring and dispersion of air pollutants. It is also an indicator of degree of vertical motion and existing turbulence. Stability in the atmosphere is function of temperature gradient (lapse rate) and wind speed. Humidity variations play a key role on spatial and temporal variation of stability and occurrence of rain events, Momura and Takemi, (2011). There are different methods to determine stability and its degree. In general these methods are based on convective motions and mechanical turbulence in atmosphere.

There are different stability indices to estimate precipitation and thunder. They are based on thermodynamic approximations and have some empirical formula, (Kahraman and Kadıoğlu, 2008).

MATERIAL AND METHODS

Study Area and Data

In this paper, by using radiosonda data (12:00 GM) for Göztepe (İstanbul) and Isparta between 1976 and 2007 at surface, 850 hPa, 700 hPa and 500 hPa, stability indices were defined, (Figure 1 and Table 1). Air temperature, dew point temperature, wind velocity data have been analyzed to explain stability conditions at two pilot areas. Daily total rainfalls rates for the same period were also analyzed.

Study Area and Data

↑ N

Figure-1

Methods

Stability indexes and corresponding precipitation classes are given as below:

Table1- Descriptive Properties of Study Area

Station	Latitude	Longitude	Height (meter)
Göztepe (İstanbul)	40^0 58' N	29^0 05' E	33
Isparta	37^0 45' N	30^0 33' N	997

Precipitation Classes:

In order to analyze the average rainfall quantity in the range of classes, their percentages were determined. The classes and details can be identified in Table 2.

Table 2- Precipitation Classes

Class No	The range of classes	Intensity
1	0,1mm – 9,9 mm	less intensive rainfall
2	10,0 mm – 24,9 mm	normal rainfall
3	25,0 mm – 49,9 mm	less intensive shower
4	50,0 mm – 99,9 mm	intensive shower
5	100,0 mm and above	more intensive shower.

1-Vertical Total Index (VT):

Miller (1967) developed VT Index which is only function of temperature differences between 850-500 mb pressure levels. It is an indicator for instability of a low layer- parcel, (Çakır, 2004, Eq. 1 and Table3).

$$VT = T_{850} - T_{500} \qquad (1)$$

Where T_{850} (^{0}C) and T_{500} (^{0}C) are air temperatures at 850 mb and 500mb pressure levels respectively.

1-Vertical Total Index (VT):

Table 3- Critical Values of Vertical Total Index (VT), (Sturtevant, 1994)

VT Index	Event
VT-A ≤ 25	No Thunderstorm (TS)
VT-B ≤ 26	A few TS
VT-C ≤3 0	A few TS and Tornados
VT-D ≤ 32	More TS and a few Tornados
VT-E > 32	Many TS, Serve Tornado

2- Cross Total Index (CT):

CT Index takes into account low layer humidity with dew point temperature at 850 mb and air temperature at 500 mb, (Eq.2 and Table 4).

$$CT = T_{d850} - T_{500} \quad (2)$$

Where Td_{850} (^{0}C) is a dew point-air temperature at 850.

Table 4- Critical Values of Cross Total Index (CT), (Sturtevant, 1994)

CT Index	Event
CT-A $\leq$ 17	No TS
17 < CT-B $\leq$ 19	A few TS
19 < CT-C $\leq$ 21	A few TS and Tornados
21 < CT-D $\leq$ 23	More TS and a few Tornados
23 < CT-E < 30	Many TS, Serve Tornado
CT-F $\geq$ 30	No Thunderstorm (TS)

3- Total Total Index (TT):

TT Index takes into account humidity variations, (Miller, 1967). Table 5 indicates class values and critical details, (Çakır, 2004).

$$TT = VT + CT \quad (3)$$

$$TT = T_{850} + T_{d850} - 2 * T_{500}$$

where temperature values are same as defined above.

Table 5- Critical Values of Total Total Index (TT)

TT Index	Event
TT-A < 45	No TS
45 ≤ TT-B < 50	TS Probability
50 ≤ TT-C < 55	Serve TS Probability
TT-D ≥ 55	High Probability of Serve TS

4- Modified Total Total Index (MTT):

To estimate probability of TS in USA, the modified TT Index is identified as below:

$$MTT = 0.5*(T_s + T_{850}) + 0.5*(T_{ds} + T_{d850}) – 2*T_{500} \qquad (4)$$

where,

T_s: Surface air temperature (^0C)

T_{ds}: Surface dew-point temperature (^0C).

Other variables and descriptive table as given in Table 5 and Eqs. 1 and 3.

5- Humidity Index (HUMI):

Humidity Index identifies saturation at 850, 700 and 500 mb pressure levels. Occurrence of TS is accompanied by a thick humid layer, (Çakır, 2004), Table 6 and Eq.5. In this index air temperature (T_{700}) and dew point temperature (T_{d700}) are inserted in Eq.5 as below:

$$HUMI = (T_{850} - T_{d850}) + (T_{700} - T_{d700}) + (T_{500} - T_{d500}) \qquad (5)$$

Table 6- Humidity Index (HUMI)

HUMI	Stability Condition
HUMI $\leq$ 30	Unstable (US)
HUMI > 30	Stable (S)

6- Sweat Index (SWEAT):

Sweat Index takes into account more parameters and it identifies probability of serve weather conditions, (Eq. 6and Table 7).

$$SWEAT = 12*T_{d850} + 20*(TT – 49) + 2*f_{850} + f_{500} + 125*[Sin (dd_{500} – dd_{850}) + 0.2] \quad (6)$$

TT = Total Total Index

where,

f_{850}: wind speed (knot) at 850 mb,

f_{500}: wind speed (knot) at 500 mb,

dd_{850}: wind direction (degree) at 850 mb,

dd_{500}: wind direction (degree) at 500 mb.

6- Sweat Index (SWEAT):

Table 7- Critical Values of Sweat (SWEAT) Index

SWEAT Index	Event
SWEAT-A < 250	No any development, TS risk
250 ≤ SWEAT-B < 400	Probability of Serve TS
SWEAT-C ≥ 400	Heavy Storm and Tornado

7- Yellow Index (SAR):

Definition and critical values of SAR are given in Eqs. 7a, b and Table 8, (Kahya, 2000).

$$SAR = (T_{s\theta} - T_{500}) + [(T_{850} - T_{d850}) + (T_{700} - T_{d700})] / 3 \qquad (7a)$$

where,

$T_{s\theta}$ = Surface potential temperature (^{0}C)

$$T_{s\theta} = T_s * [1000 / P]^{Rd/Cp} \qquad (7b)$$

where,

T_s: Surface temperature (^{0}C),

P: Surface pressure (mb),

R_d: Gas constant for dry air, (287J/kg^{o}C),

C_p: Specific heat at constant pressure,(1,0046*10^{3}J/kg^{o}C),

R_d / C_p = 0.286.

7- Yellow Index (SAR):

Table 8- Critical Values of Yellow Index (SAR)

SAR Index	Event
SAR-A < 35	Rain/snow, probability < % 5' Probability of frontal precipitation is more probable.
35 ≤ SAR-B < 38	Conditionally unstable, probability of rainfall: % 50 - % 80
38 ≤ SAR-C < 40	Unstable, probability of rainfall > % 75
SAR-D ≥ 40	Absolutely unstable, probability of rain is high.

8- K Index (K):

K index estimates occurrence of TS by using vertical temperature gradient between 850 and 500 mb. and humidity depression by dew point temperatures at 850 mb and 700 mb (Çakır 2004; Kahya, 2000). Eq. 8 and Table 9 defines more details.

$$K = (T_{850} – T_{500}) + T_{d850} – (T_{700} – T_{d700}) \qquad (8)$$

Table 9- Critical Values of K Index (K)

K Index	Probability of Event (%)
K-A< 15	TS (0)
15 ≤ K-B < 30	TS and heavy rain(20-60)
30 ≤ K-C < 40	TS and heavy shower (60-90)
K-D ≥ 40	TS and heavy shower (~100)

9- Modified K Index (Modified-K) :

Modified K Index is defined by Charma (1997).It takes into account mean air temperature and dew point temperature between surface layer and 850 mb, (Çakır 2004). KI, which indicates the largest significance in distinguishing the difference between rain and no-rain days, is formulated as follows, (Eq.9 and Table 9):

$$\text{Modified-K} = [(T_s + T_{850}) / 2 - T_{500}] + [(T_{ds} + T_{d850}) / 2] - (T_{700} - T_{d700}) \quad (9)$$

where; *T* is temperature, *Td* dew-point temperature, and the subscripts denote pressure levels (mb). The subscript s denotes surface layer.

T_{dy} = Surface layer dew point temperature

10- Kahraman Index (KH):

The most reliable variables for definition of instability indexes are dew point temperatures at 850 and 700 mb and air temperatures at 500 and 700 mb, (Kahraman and Kadıoğlu, 2008). Table 10 and Eq. 10 identify more details.

$$KH = T_{d850} - T_{700} + T_{d850} - T_{500} + T_{d700} - T_{500} = 2 * (T_{d850} - T_{500}) - (T_{700} - T_{d700}) \quad (10)$$

Table 10- Kahraman Index (KH)

KH Index	Event
KH-A < 31	Probability of precipitation < %30
KH-B ≥ 31	Threshold for occurrence of precipitation
KH-C ≥ 34	Probability of precipitation is % 70.
KH-D ≥ 40	Probability of precipitation % 80
KH-E ≥ 45	Probability of precipitation % 90
KH-F ≥ 50	Occurrence of precipitation is Certain

Verification Stability Indexes:

Accuracy of stability indexes based on radiosonda data was qualitatively verified by using ANOVA, χ^2 test and the following formula (Nomura and Takemi, 2011; Group working, Gill, 2011).

The results of the evaluations of the 12:00GMT index values against the midday and afternoon lightning occurrences are listed in tables. The accuracy is defined as;

$$Accuracy = \frac{CorrectHits + CorrectNonHits}{Total} \qquad (11)$$

ANALYSES

Accuracy Analyses of Stability Indexes in Göztepe

In this part of the paper, for ten different indexes, and six different precipitation classes, corresponding values and percentages have been defined. As an example only one table for VT indexes is presented in Table11.

Table 11. VT Index Values, Precipitation Classes and Corresponding Number of Days (Göztepe)

	Drizzle	Drizzle/Rain	Rain	Shower	Heavy Shower	Serve Shower	No Rain
VT-A	199	1855	334	60	14	0	2842
VT-B	38	291	45	11	0	0	719
VT-C	107	649	91	17	0	0	2107
VT-D	6	50	4	1	0	0	312
VT-E	6	16	1	0	0	0	178
Total	356	2861	475	89	14	0	6158

Accuracy Analyses of Stability Indexes in Göztepe

As a result, for four different indexes accuracy analyses are summarized in Table 12. Where the Correct Hits is the number of correctly forecasted storm occurrences according to the above indexand lightning criteria, and the Correct NonHits is the number of correctly forecasted no-storm conditions, i.e. where none of the above criteria were met. For all date and we get Probability of Detection(POD), False Alarm Rate (FAR) and Accuracy.

Table 12-Verification results for Istanbul (Göztepe)

Index	Accuracy	Index	Accuracy	Index	Accuracy	Index	Accuracy
MTT		SWEAT		SAR		MODIFIED K	
-A	0.25	-A	0.92	-A	0.34	-A	0.31
-B	0.21	-B	0.92	-B	0.32	-B	0.28
-C	0.39	-C	0.98	-C	0.47	-C	0.56
-D	0.66			-D	0.57	-D	0.82

Statistical Analyses of Stability Indexes
χ^2 Analyses of Stability Indexes

Data observed between 1976 and 2007 are classified in two total precipitation intervals:

i) Normal Rainfall Rate: Between 0.0-10.0mm

ii) More than Normal Rainfall Rate: Between 10.1-80.0mm.

Tables13 a and b show test results for two intervals. Last two indexes (SWEAT and Modified K) are not fit with rainfall rates and their reliability is very low for two rainfall classes in Istanbul (Göztepe).

Table 13 (a). χ^2 Analyses for R >10mm

Index	Index	χ^2	No
VT	.000	465.019a	1
CT	.440	317.098a	2
TT	1.000	275.588a	3
MTT	1.000	150.939a	4
K	1.000	149.897a	5
Kahraman	1.000	147.331a	6
HUMI	1.000	141.412a	7
Modified K	1.000	49.642a	8
SWEAT	1.000	.000a	9

Table 13 (b). χ^2 Analyses for R ≤ 10mm

Index	Index	χ^2	No
VT	.000	5602.397[a]	1
CT	.000	4098.177[a]	2
TT	.000	2991.193[a]	3
MTT	.000	2117.966[a]	4
K	.000	1929.426[a]	5
Kahraman	.000	1423.490[a]	6
HUMI	.000	1392.696[a]	7
Modified K	1.000	807.024[a]	8
SWEAT	1.000	12.874[a]	9

ANOVA of Stability Indexes

Tables 14 (c-d) define ANOVA results for two precipitation classes in Istanbul.

Table 14 (c) - ANOVA for R > 10 mm

Index	F	Sigma	No
MTT	.648	1.000	1
VT	.729	.995	2
TT	.767	.984	3
CT	.820	.946	4
SWEAT	.817	.942	5
Modified K	.860	.882	6
K	.920	.746	7
Kahraman	.923	.738	8
HUMI	1.163	.113	9

Table 14 (d) - ANOVA for R ≦10 mm

Index	F	Sigma	No
SWEAT	.916	.709	1
MTT	.919	.702	2
TT	.925	.688	3
VT	.938	.653	4
CT	.969	.569	5
Modified-K	.994	.500	6
Kahraman	1.055	.339	7
K	1.057	.333	8
HUMI	.916	.709	9

There is sufficient evidence of the relation between precipitation and index value with the confidence level of α=0.025. For high degrees of freedom df >100, F critical table value is equal to 1,8799. All table values for F are less than critical value of F. Hence, all indexes are reliable to estimate and classify rainfall rate in two precipitation classes with α=0.05. The most reliable indexes are identified as first five indexes.

With combined identification of indexes by χ^2 test and ANOVA, VT and CT indexes are more reliable indexes in Istanbul respectively.

Analyses Of Stability Indexes in Isparta

In this part of the paper, for ten different indexes, and six different precipitation classes, corresponding values and percentages have been defined. As an example only one table for VT indexes is presented in Table15.

Table 15. VT Index Values, Precipitation Classes and Corresponding Number of Days (Isparta)

	Drizzle	Drizzle/Rain	Rain	Shower	Heavy Shower	Serve Shower	No Rain
VT-A	63	289	21	6	0	0	1036
VT-B	9	72	9	0	0	0	293
VT-C	62	359	30	5	3	0	1490
VT-D	16	111	10	4	0	0	741
VT-E	15	67	4	0	0	0	748
Toplam	165	898	74	15	3	0	4308

Analyses of Stability Indexes in Isparta

For four different indexes accuracy analyses are summarized in Table 16. (Isparta)

Table 16-Verification results for Isparta

Index	Accuracy	Index	Accuracy	Index	Accuracy	Index	Accuracy
MTT -A -B -C -D	0.32 0.31 0.62 0.89	SWEAT -A -B -C	0.92 0.92 0.99	SAR -A -B -C -D	0.22 0.21 0.35 0.44	MODIFIED K -A -B -C -D	0.39 0.38 0.73 0.97

RESULT AND CONCLUSION

It is recommended that the first five indexes; VD, CT, TT, MTT and HUMI are more reliable to predict the convective precipitation conditions in these study areas.

The most favorable stability indexes are SWEAT and Modified K for two study areas.

SUMMARY

Atmospheric convection and prediction of its characteristics are essential for planning gliding activities. Climate changing and increasing frequency of serve weather conditions are the primary focus of short range forecasting in recent years. This paper presents some results of statistical analyses, comparison and reliability of stability indexes in and near vicinity of Istanbul and Isparta. Ten stability indexes (VT: Vertical Total, CT: Cross Total, TT: Total-Total, MTT: Modified Total-Total, HUMI: Humidity, SWEAT: Sweat, SAR: Yellow, K, DK-Modified K and KH: Kahraman Indexes) are defined based on radiosonda observations at 12:00GMT in the interval of 1976 and 2007 in two study areas. These indexes are evaluated statistically against the occurrence of five different precipitation classes at eight provinces of Istanbul and Isparta (city center). It is recommended that the first five indexes; VD, CT, TT, MTT and HUMI are more reliable to predict the convective precipitation conditions in these study areas.

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