STATUS OF THE METEOROLOGICAL NETWORK IN THE ARABIAN GULF REGION

By MUSTAFA A. UKAYLI, TAHIR HUSAIN and HASIN U. KHAN
Water and Environment Division, The Research Institute,
University of Petroleum and Minerals, Dhahran, Saudi Arabia

Reprinted from
The Journal of Meteorology
Volume 7, issue no.71, September 1982, pp.232-237

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Abstract: A methodology based on Shannon's entropy concept is developed and applied to check the status of the existing meterological network in the Arabian Gulf region. To carry out this study meteorological records for the period from 1970 to 1977 are obtained and processed for all stations around the Arabian Gulf. The para-meters considered in this study are wind speed, temperature, and pressure. The sites for installing new stations are identified in order to update the existing meteorological network.

INTRODUCTION

For the abatement of environmental pollution and to protect human health and welfare, Meteorology and Environmental Protection Administration (MEPA) in Saudi Arabia has already initiated a number of projects on environmental assessment and pollution problems in coastal regions. Similar studies are likely to be conducted by other agencies like Kuwait Action Plan (KAP) and other international as well as regional organizations in the Arabian Gulf region. The availability of long-term meteorological records with adequate number of meteorological stations in the region will be a pre-requisite to initiate such studies.

The main objective of this study is, therefore, to test the status of the meteorological network in the Arabian Gulf region. To accomplish this objective, methodology based on multivariate entropy concept is developed and applied. This is a new concept for meteorological network planning.

FORMULATION

There are number of network design methods which are grouped into mean square error (3,5,9); station-distance correlation and iso-correlation approach (8,14); simulation approach (1,4); regionalization approach (12,13); Gandin's objective analysis (6,7); and information theory approach (2,10). Among these, Gandin's objective analysis approach has been widely applied in the past, although the applicability of this method is limited due to homogeneity and normality assumptions. Recently, a network design methodology based on Shannon's Information concept has been developed and applied (10). This methodology in true sense is able to resolve spatial and temporal uncertainties associated with the meteorological events. It is also able to take into account the multivariate and multistation interactions without any statistical assumptions.

This section summarizes the simple concept of Shannon's information theory. For comprehensive multivariate derivations, the interested readers are referred to the literature cited elsewhere (11).

Consider a meteorological variable *X* for which time-series data (x_i: $i=1, 2, \ldots, N$) are recorded at a particular meteorological station. Also assume that the probability of occurrence of the ith event is denoted by $p(x_i)$. Shannon defines measures of information of variable X in terms of its entropy $H(X)$ as

$$H(X) = -\Sigma\, p(x_i) \log p(x_i), \tag{1}$$

the summation being over all values of i from 1 to N, and the logarithum being to base 2.

This entropy $H(X)$ is also a measure of uncertainty and is measured in bits. This is a useful measure for characterising the variability in the outcome of a random variable. If the occurrence of the event is known with certainty with all probabilities either zero or one, then the entropy term $H(X)$ will be zero and there will be no uncertainty associated with the occurrence of the event. In such case the information measure for the variable X will be zero. On the other hand if the probability of occurrence of each event is the same and equal to 1/N, then the entropy $H(X)$ will be maximum and also the information content of the variable X will be maximum and will be equal to log N. In such cases, the heterogeneity associated with the variables will be maximum.

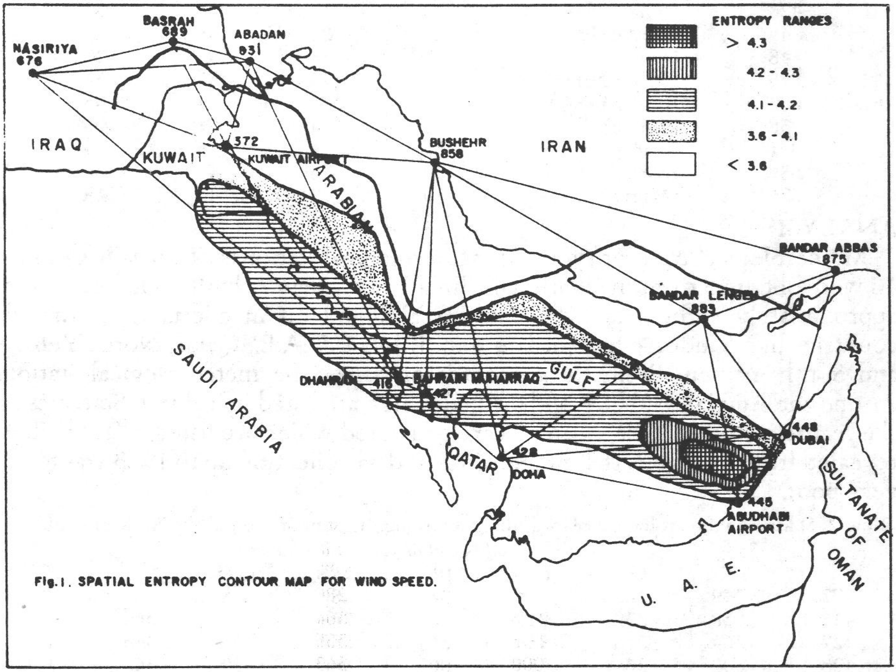

Fig. 1. SPATIAL ENTROPY CONTOUR MAP FOR WIND SPEED.

The above concept can be generalized for multivariable, multistation cases as follows:

$$H(X_{k,1},\ldots,X_{k,M},X_{l,1},\ldots,X_{l,M},X_{m,1},\ldots,X_{m,M})$$

$$= -\sum_{j=1}^{N} p(x_{K,1,j},\ldots x_{k,M,j},x_{l,1,j},\ldots,x_{l,M,j},x_{m,1,j},\ldots x_{m,M,j})$$

$$\log_2 p(x_{k,1,j},\ldots x_{k,M,j},x_{l,1,j},\ldots x_{l,m,j},x_{m,1,j},\ldots,x_{m,M,j}) \tag{2}$$

where p(. . .) is the joint probability of the occurrence of the jth concurrent event at all locations, *k.l.m* each containing M variables. This measures the interactions within the variables at each station and among the stations. High entropy values indicate high heterogeneity in the region and hence requires its intensification in order to reduce spatial and temporal uncertainties.

Table 1.: Meteorological stations around the Arabian Gulf.

Station number	*Name of Station*	*Latitude*		*Longitude*	
		Deg.	*Min.*	*Deg.*	*Min.*
372	Kuwait	29	13	47	58
416	Dhahran	26	16	50	10
427	Bahrain	26	16	50	37
428	Doha	25	16	51	33
445	Abu Dhabi	24	26	54	28
448	Dubai	25	15	55	20
875	Bandar Abbas	27	10	56	34
883	Bandar Length	26	20	54	35
858	Bushehr	29	05	51	06
831	Abadan	30	24	48	14
689	Basrah	30	56	47	50
676	Nasiriya	30	12	46	15

ANALYSIS

Meteorological data for synoptic meteorological stations within WMO Block 40 were obtained from the National Climatic Centre in Ashville. The records for approximately eight years (1970-1977) obtained on magnetic tapes include countries like Saudi Arabia, Jordan, Iran, Kuwait, U.A.E., Qatar, North Yemen, and South Yemen. From these records on tapes, the meteorological stations around the Arabian Gulf were identified which are listed in Table 1. Statistics on the record status of these stations were generated which are listed in Table 2. As revealed from this table, the meteorological data collection up to 1973 was found very poor.

Table 2: Status of meteorological records on meteorological stations around the Arabian Gulf.

Stations	*Total No. of concurrent observations*							
	1970	*1971*	*1972*	*1973*	*1974*	*1975*	*1976*	*1977*
372	049	165	314	317	280	348	161	262
416	058	232	016	364	364	362	364	364
427	364	218	355	364	355	353	348	298
428	000	364	000	000	363	359	365	364
445	000	000	000	000	193	266	000	232
448	000	000	000	000	364	363	365	364
676	045	221	352	348	364	363	353	362
689	025	214	349	344	364	363	365	364
831	364	364	352	364	352	350	000	363
858	000	000	000	000	000	315	362	361
875	000	198	351	364	357	360	345	348
883	282	334	365	364	363	364	360	115

Concurrent observations for all meteorological stations in the Arabian Gulf were obtained by processing daily meteorological data on wind speed, temperature, and pressure. Data on each variable was then discretized into eight equal intervals ranging from minimum to maximum values and relative frequencies were obtained. Using relative frequencies at each station, point entropies were obtained using equation (1). These values are listed in Table 3.

These point entropies do not resolve spatial uncertainties associated with the variable but indicate the relative variability of data at each station. For example,

Table 3: Point Entropies for wind speed, temperature and pressure.

Station No.	*Point entropies in (nats)* Wind speed	Temperature	Pressure
1	1.450	1.974	1.641
2	1.655	1.950	1.898
3	1.509	1.972	1.815
4	1.780	1.541	1.714
5	1.774	1.567	1.655
6	1.579	1.952	2.036
7	1.584	2.033	1.996
8	1.376	1.940	1.044
9	1.142	1.787	1.945
10	1.418	1.916	1.861
11	1.516	1.871	1.568
12	1.055	1.590	1.863

Doha station which has the highest entropy for wind speed shows maximum variability in its data set. The wind-speed data at station Bandar Length has the lowest entropy which reveals relatively high homegeneity in its data set. In case of temperature the highest entropy is at station Nasiriya (2.033 nats) and lowest is found at station Doha (1.541 nats). The maximum variability in the pressure data, based on entropy values, is at Dubai and the minimum at Basrah. These values also indicate the randomness in the data set.

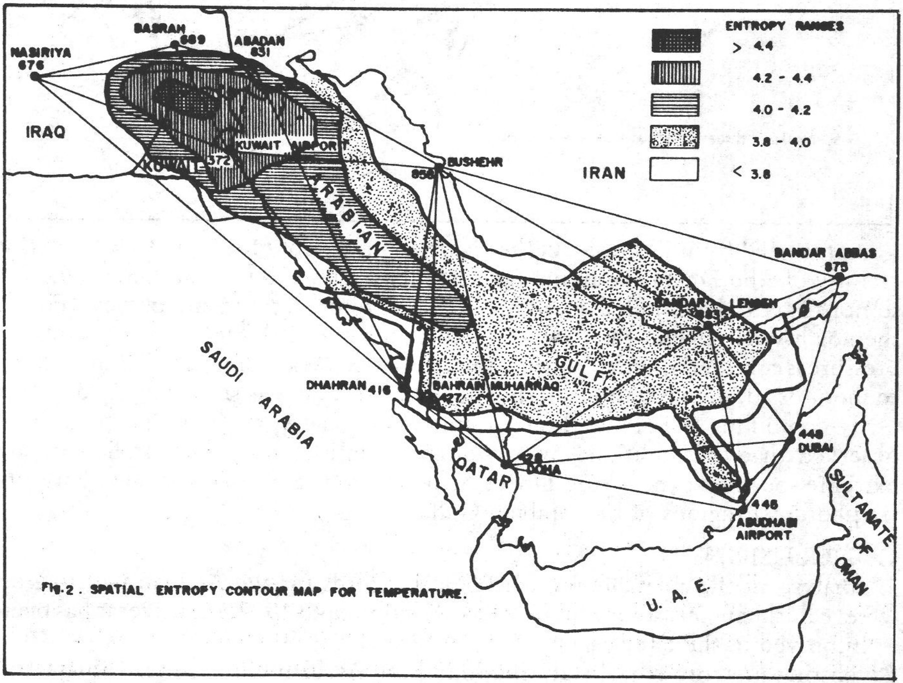

Fig.2 . SPATIAL ENTROFY CONTOUR MAP FOR TEMPERATURE.

In order to determine the spatial uncertainty, the whole study area was divided into feasible subregions by joining three station sets. The joint probabilities for each variable using concurrent observations at three station sets were determined and joint entropy using equation (2) was computed for each subregion. It is assumed that the centroid of each triangle is the most representative point for the corresponding joint entropy values in each subregion. The contour maps were then drawn to identify the region of spatial uncertainty with respect to each variable. These contour maps are shown in Figs.1-3.

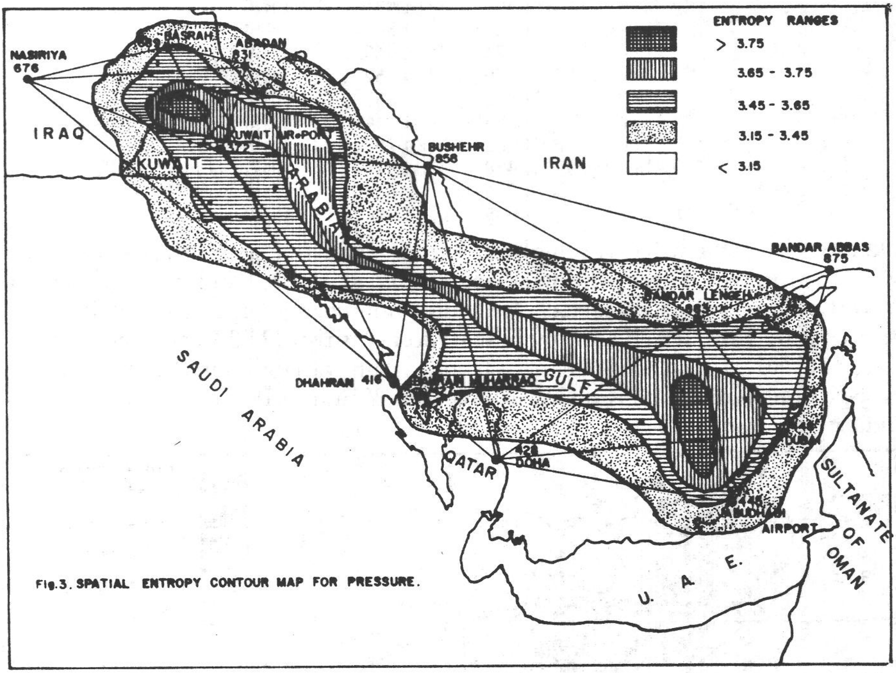

Fig.3. SPATIAL ENTROPY CONTOUR MAP FOR PRESSURE.

As revealed from Fig.1, the highest spatial uncertainty for wind speed is in the vicinity of Abu Dhabi. To minimize such uncertainty additional meteorological stations have to be installed in this region. From temperature point of view (Fig.2), the north-west zone of the Arabian Gulf is the zone with highest uncertainty. If pressure is considered as the main parameter for network design, it will be necessary to monitor additional stations in the high entropy zones as shown in Fig.3.

By combining the above three parameters for network design purposes, it is observed that the additional meteorological stations must be installed in the extreme south-east (near Abu Dhabi Airport) and the north-west (near Kuwait-Iraq borders) regions of the Arabian Gulf.

CONCLUSIONS

1. Analysis of the available meteorological records for the Arabian Gulf region reveals the inconsistency in the data collection upto 1973. However it has been improved in the later years.
2. Existing meteorological stations around the Arabian Gulf are inadequate and hence network intensification is needed.

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