THE IMPACT OF SATELLITE-DERIVED WINDS ON WEATHER FORECASTING IN AFRICA

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ABSTRACT

The increase in analysis and model resolution in numerical weather prediction in recent years has led to a strong sensitivity of the weather forecasting to wind data. While qualitative information from meteorological satellites has long been recognized as critical for forecasting activity, quantitative data are required to improve the objective analysis and numerical prediction of these events.

This paper discusses how the inclusion of high-density multispectral satellite-derived information into the analysis of weather and the comparison with the ECMWF six hourly forecasts obtained through the Meteorological Data Distribution (MOD) system have effectively improved weather forecasting in Africa with special reference to the Kenya Meteorological Department (KMD).

1. INTRODUCTION

In most countries, weather forecasting in support of safety of life and property and for the general welfare and convenience of the population is seen by the public as a necessity or even as a basic community right. Their provision is one of the primary roles of all National Meteorological Services (NMCs). It is the role in which weather forecasting is most visible and on which it is most often judged by the general public and by those whose decisions it depends for its resources.

Weather and climate are pervasive influences on human activities. Consequently, the Kenya Meteorological Department has a task to provide weather information, forecasts and warnings alone with climatological and hydrological data and analyses of a very broad range of applications. These products and services can significantly improve public safety and be of enormous socio-economic benefit if properly understood and acted upon. Well known applications include natural disaster mitigation and response, improving the safety, regularity and efficiency of all forms of transportation, facilitating tourism and recreation, supporting agriculture and forestry operations, energy production and distribution, water supply management, reduction of local and regional air pollution and response to environmental emergencies such as oil spills, toxic gas releases and nuclear accidents.

The fundamental importance of the contribution of weather services to the safety and well-being of the world's peoples must not be understated. In vulnerable regions of the globe, major reductions in loss of life and property damage due to natural disasters have been achieved following implementation of effective warning systems for severe weather. On the macro-economic level, cost-benefit studies invariably demonstrate very high rates of return to national economies from the investments made in hydrometeorological services while, at smaller scales the same holds true for many individual enterprises in weather sensitive sectors such as agriculture, fishing, forestry, construction, transportation and power generation. At the level of the ordinary citizen, the value of public weather forecast and warning programs is reflected in high listening and viewing audiences for weather broadcasts and in the great popularity of telephone and computer access to these products. Clearly, well-targeted initiatives directed towards improving the quality and timeliness of weather services, their coordination, utility and infrastructure can yield significant dividends by preventing loss of life, reducing damage to property and the natural environment, increasing overall economic efficiency and improving quality of life for individual citizens.

But all weather services rely heavily on timely dissemination of meteorological observations and derived products via the Global Telecommunications System (GTS) of the World Meteorological Organization (WMO). In many parts of the world data links are normally satisfactory, but extensive areas still unfortunately suffer from too high a degree of unreliability. Africa is particularly affected in this way but however it lies within meteosat's field of view. Such a combination of circumstances has stimulated the development of Meteorological Data Distribution (MDD) services in order to ensure regular provision of charts and synoptic data using Meteosat as a data relay, to work in complement with GTS.

The absence of a consolidated climatological description of a convincing explanation of weather and climate of Africa has always been a source of difficult to forecasters of the continent. Practicing meteorologists and workers in many related disciplines find the lack of data a constant handicap and have recently appreciated the use of satellite technology. Demonstration of the capability of the MDD in Africa has been extensive. Both graphical and alphanumeric information has been broadcast on two channels round the clock. For the tropical belt and the southern hemisphere, where radiosonde, pilot and aircraft wind data are sparse, cloud motion wind products of the ECMWF represent an established source of data.

2. WIND

Wind is a very important meteorological element which is frequently included in public forecasts since it affects many human activities. While national practices vary, it is generally true that descriptors or qualifiers used in forecasts of wind conditions for the public must well be understood by them and must relate to their local environment and their activities. In cold winter climates, for example, the hazard presented by “wind chill” is well understood by residents while in hot and humid coastal regions, the forecast development of a “sea breeze” may offer the promise of welcome relief to the population.

Very strong winds, by themselves or in combination with other phenomena, are a major hazard to people, property, crops, transportation systems, public utilities and other vulnerable sectors. In some countries, climatic or topographic factors result in regional-scale or localized strong wind phenomena.

3. WIND GENERATED PRIMARY TROPICAL SYNOPTIC FEATURES

3.1 Tropical cyclone

Intense cyclonic circulation on a synoptic scale occur in some tropical regions. These cyclonic storms develop much greater surface wind speeds that any other type of synoptic scale disturbance. Tropical cyclones can cause widespread damage and account for the loss of many lives. Since the first meteorological satellite was launched in 1960, hundreds of tropical cyclones have been observed from space. Observations have provided meteorologists with a lot of information concerning the relation between the cloud and wind patterns of tropical cyclones and their position, intensity and motion. Today, much of this knowledge is used in analysis and forecasting. Imagery interpretation and wind analysis play a major role in the issuance of warnings.

3.2 Intertropical Convergence Zone (ITCZ)

The confluence of winds from both hemispheres may lead to rather well-defined zones of wind convergence in the equatorial trough.
The cloud band of the ITCZ is one of the important cloud and wind systems over the tropics. Its axis is from east to west and several disturbances with dense cumulonimbus. On the satellite imagery, the clear sky cumulus, cumulonimbus and cloud clusters accompanying disturbance in the band show changes. By tracing their motion and changes, the severe connective regions and disturbance can be found out. This information is useful for tropical weather analysis and forecasting (Fig.).

3.3 The Upper Tropospheric Cold Vortex

The tropical upper-tropospheric trough (TUTT) is a shear line orientated east to west at 200 hpa, which is located over the middle North Pacific Ocean where is an average trough location in summer Meteorologists understand TUTT from the satellite-derived wind data, water vapor traces and other unconventional data.

3.4 The Easterly Wave

Easterly waves are westward propagating wavelike disturbances in the trade wind belt and can be identified on the surface chart by a weak trough line in the winds. The cloud and wind systems of the easterly wave include the inverted "V" pattern and cyclonic vortex of which only a few are like the cloud system of a classical easterly wave.

3.5 Convergence and Divergence

Low level convergence in a depression or trough causes the air to rise, leading to cloud development and precipitation. This effect is accentuated, if divergence takes place in the upper troposphere. If moist tropical air is forced to rise, organized lines of cumulus or cumulonimbus clouds may develop in the vicinity of the convergence zone.

3.6 The Equatorial Trough

Although the equatorial trough is a region of light variable winds, local thunderstorms may develop due to surface heating and orographic effects.

4. ECMWF FORECASTS

Figure 1 is an automatically plotted 24 hour forecast of 200hpa winds, produced by ECMWF. The winds are represented as vectors on a regular grid over Africa, part of the Middle East and the adjacent seas. A very marked trough-ridge-trough pattern is predicted in the Subtropical Jet across North Africa in sharp contrast to the generally zonal flow in the southern jet. Figure 2 is a map which depicts the wind and temperature at 850 hPa on a regular grid.

5. VERIFICATION OF ECMWF – A CASE STUDY

5.1 Data

This study is aimed at comparing and later verifying the ECMWF wind forecast products against radiosonde winds. At the moment radiosonde data is not available in most countries of Africa including Kenya due to economic drawbacks. However the ECMWF wind forecast products data used in this study were obtained through the MDD installed in the Kenya Meteorological Department (KMD). The radiosonde station is number 476 in block 68 situated in South Africa. Wind direction and speed has been extracted from 500hPa, 300hPa, 250hPa and 200hPa levels of the ECMWF products and the radiosonde station at 0000 and 1200 hours.

5.2 Methodology

Wind direction and speed data are manually extracted from the ECMWF products and the radiosonde data. Worksheets are then prepared using QPRO in a PC. Verification of the ECMWF products is by graphical analysis, Figures 3 ,4 &5. Correlation and Regression analysis of the wind direction and speed data at deferent levels were also carried out.

5.3 Results

The graphical analysis indicate the ECMWF wind direction and speed magnitudes for a fifteen day period are higher than those of radiosonde. The results also indicate a time lag between the two data sets. However there is a correlation between the two data sets   Rejection limits in this study depend on the assumed local guess error and reliability of the observations.

Regression Output

Constant	166.4588
Std Err. of Y est.	31.53249
R Squared	0.227076
No. of observation	15
Degrees of Freedom	13
X Coefficient	0.206164
Std Err of Coeff	0.105493

5.4 Conclusions and Recommendations

With improving forecast skill and numerical models, ECMWF products have become very useful to quality control in Africa. But care must be taken to detect data which is in gross error and biased data which might introduce biases in the analyses. Inclusion of topographical effects to the existing models is of importance in the tropics.

ECMWF products will continue to represent a valuable data source for Numerical Weather Prediction, in the southern hemisphere and tropics. It is however necessary that the ECMWF producers bring their products up to the best possible standard of tracking techniques and quality control. Joint research and coordination efforts of numerical models, ECMWF producers and the users should aim in this direction.

6. BIBLIOGRAPHIC REFERENCES

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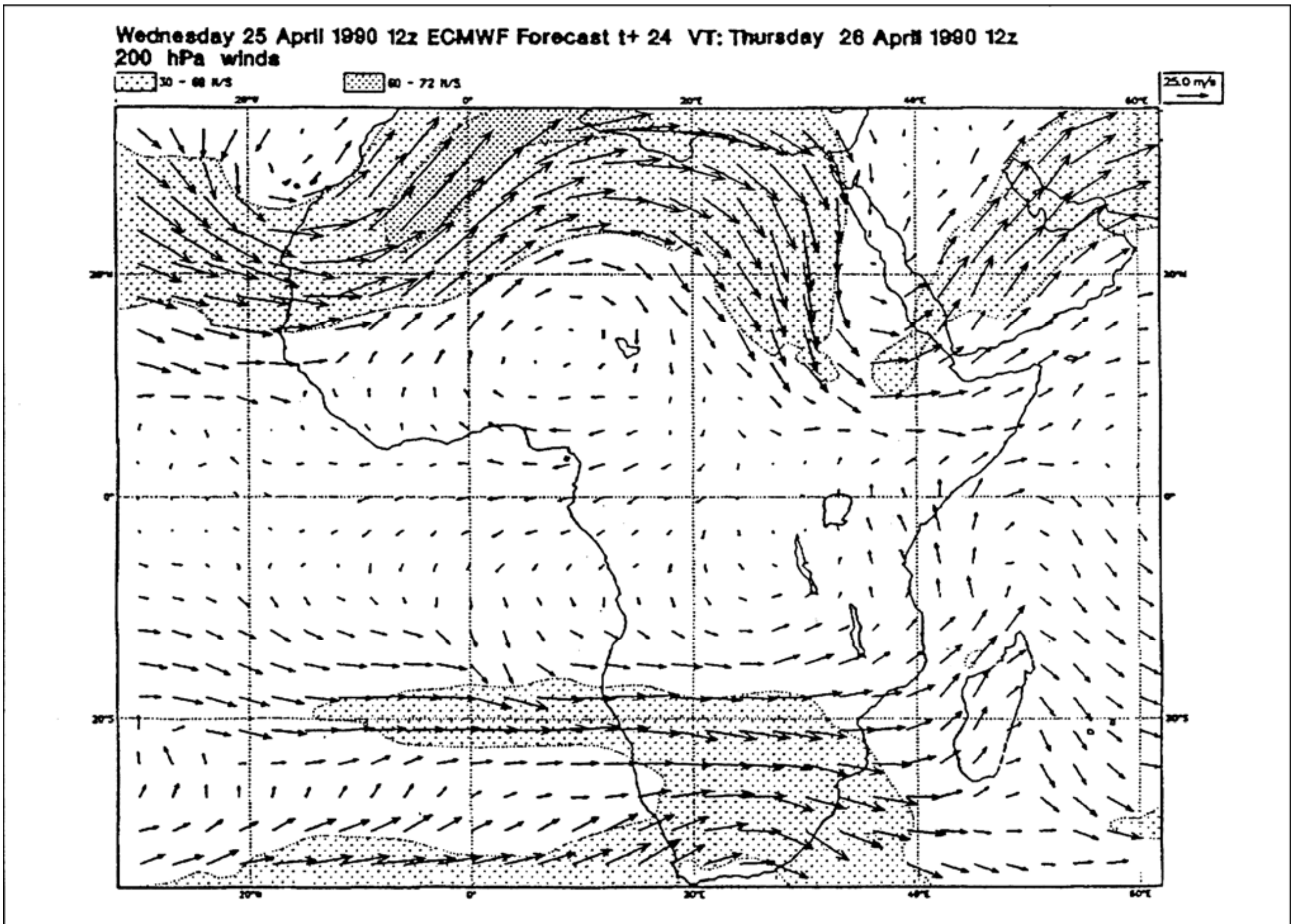

Wednesday 25 April 1990 12z ECMWF Forecast t+ 24 VT: Thursday 26 April 1990 12z
200 hPa winds
30 - 60 M/S
60 - 72 M/S
25.0 m/s

FIG 1

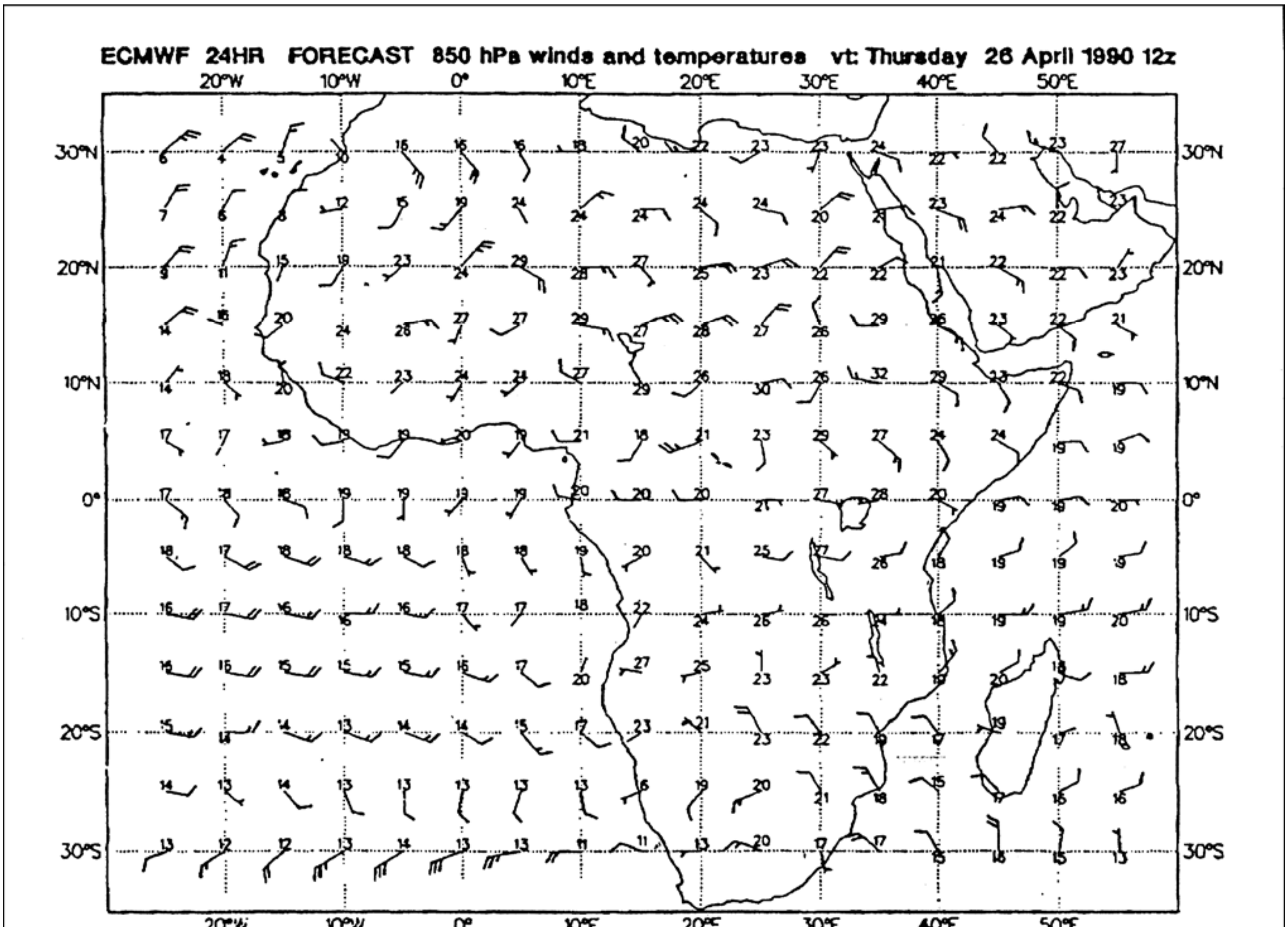

ECMWF 24HR FORECAST 850 hPa winds and temperatures vt: Thursday 26 April 1990 12z
20°W
10°W
0°
10°E
20°E
30°E
40°E
50°E
30°N
20°N
10°N
0°
10°S
20°S
30°S

Fig 2

Fig 3

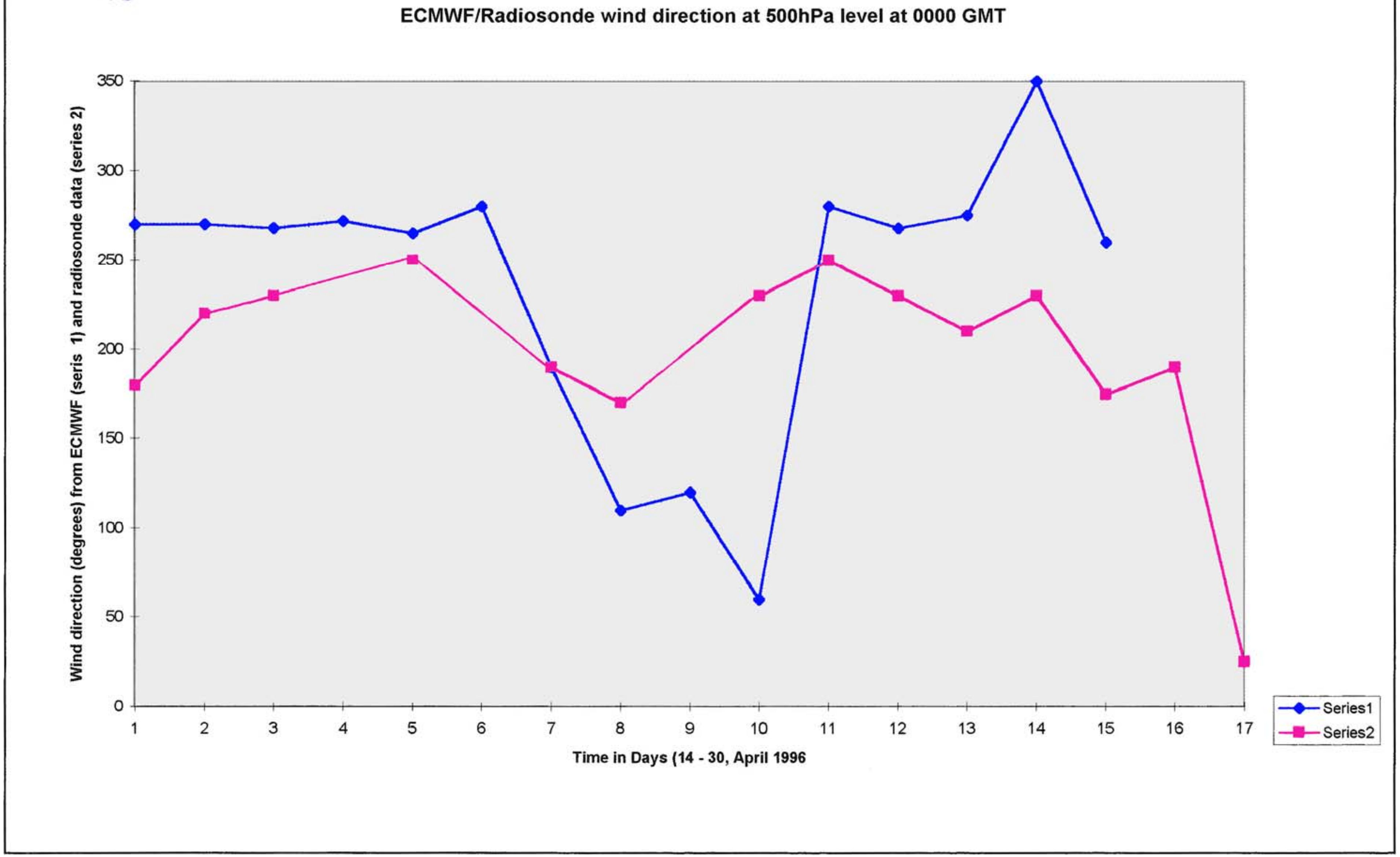

ECMWF/Radiosonde wind direction at 500hPa level at 0000 GMT
Wind direction (degrees) from ECMWF (seris 1) and radiosonde data (series 2)
350
300
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Time in Days (14 - 30, April 1996
Series1
Series2

FIG 4

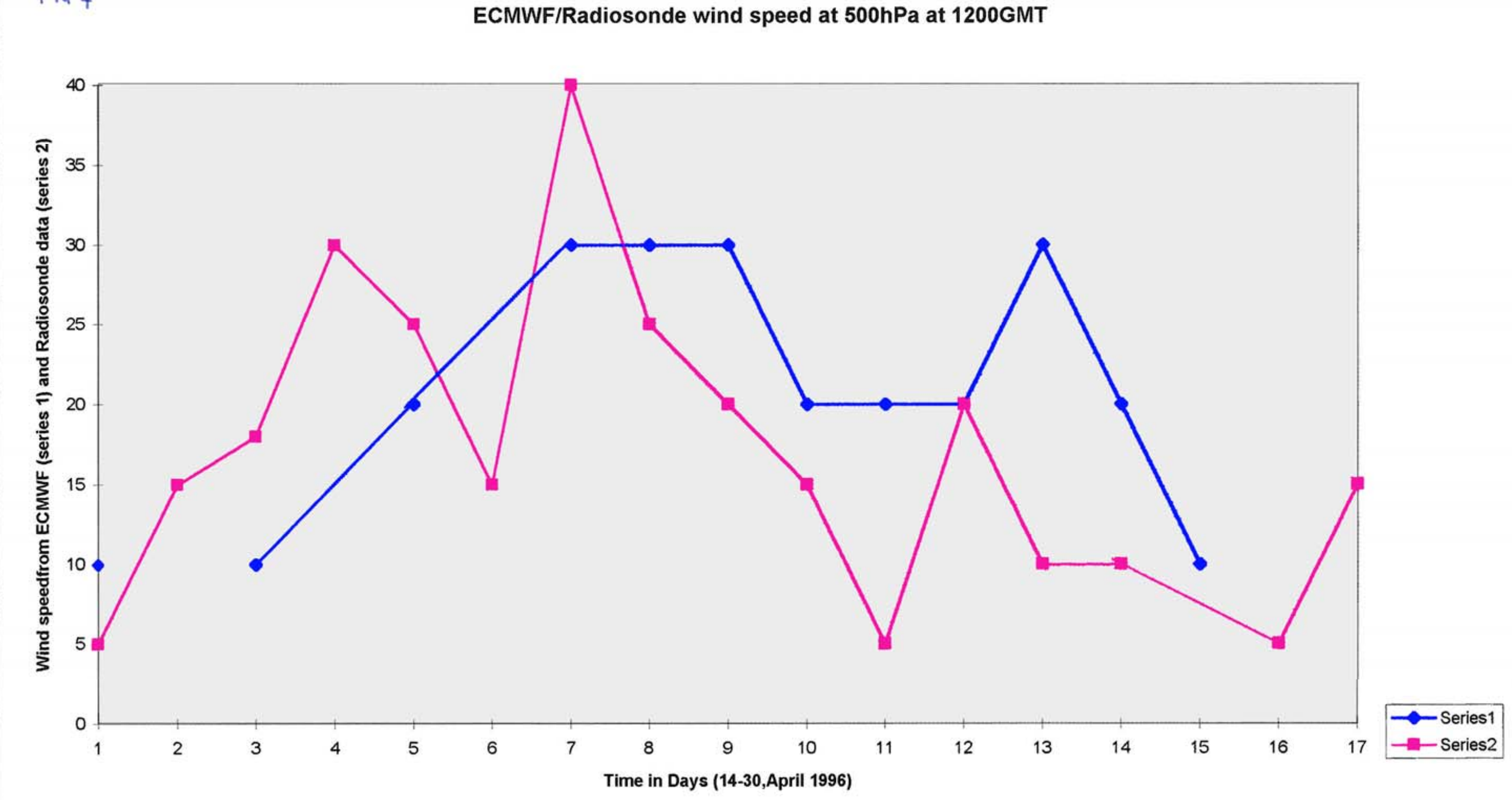
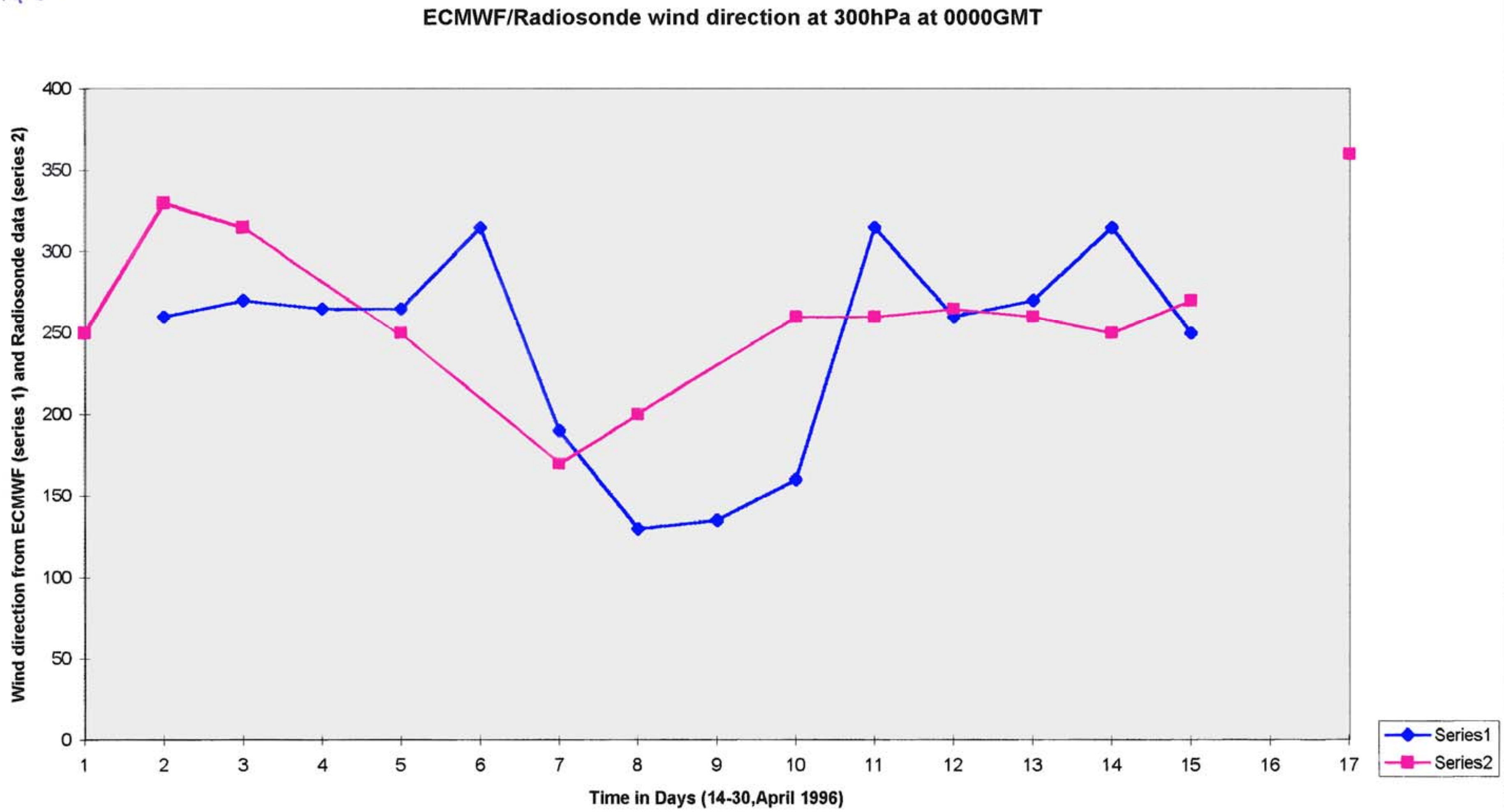

ECMWF/Radiosonde wind speed at 500hPa at 1200GMT
Wind speedfrom ECMWF (series 1) and Radiosonde data (series 2)
0
5
10
15
20
25
30
35
40
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Time in Days (14-30,April 1996)
Series1
Series2

FIG 5


ECMWF/Radiosonde wind direction at 300hPa at 0000GMT
Wind direction from ECMWF (series 1) and Radiosonde data (series 2)
0
50
100
150
200
250
300
350
400
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Time in Days (14-30,April 1996)
Series1
Series2