5.1 Introduction

One of the major challenges of weather derivatives is that climatic variability occurs on spatial and temporal scales. This is not too evident in the case of temperature, but could have significant effects on derivatives based on rainfall.

Geographical climatic differences lead to situations where there could be correlations between many locations while at the same time, there could be low correlations between locations which are not geographically far apart. Basis risk can lead to imperfect hedging when the user wishes to cover a weather risk at one location, but is actually covered by the weather recorded at a location some kilometers away.

Most weather derivative contracts which have been traded world-wide have been based on temperature indices. However, in the case of farmers, especially in developing countries, their major interest is likely to be in rainfall index related weather derivative products. An impediment to the growth of a market in these products could be the apprehension of the acceptability of rainfall linked derivative products in the face of an associated basis risk.

An understanding of the peculiarities of what basis risk entails, would be crucially important if weather derivatives are to be widely adopted (Woodard and Garcia, 2007). This would be especially relevant in the case of farmers where a lack of knowledge or very little information about weather derivatives is further clouded by the issue of basis risk. A study of basis risk in weather derivatives where precipitation is the underlying, can be done by considering past records of rainfall.

Geographic basis risk in the case of weather derivatives can be defined as the risk that the payout does not correspond with the deviation in the underlying weather parameter at the location at which hedging is desired. This, typically comes in when the weather station, data from which is used for deriving the index, is located at a distance away from the location at which hedging is
desired. This would be a fairly common phenomenon, especially in a developing country, where the number of weather stations would be limited. Of course, whilst an increase in the number of weather stations would bring down the geographical basis risk, it would also contribute to an increase in the administrative costs and hence an increase in the cost of the option. Jewson and Brix, 2005, have brought out that there is, generally, a trade-off between basis risk and the price of the weather hedge.

Whilst geographic basis risk is the additional risk due to the use of a contract which is based on a non-local site, theoretically it is possible for location indices to be specified in terms of a set of locations which are weighted to capture the effect of offsetting the exposure risk using weather derivatives from multiple non-local markets (Woodard and Garcia, 2007).

### 5.2 An empirical study of basis risk

In order to establish the intensity of the issue, it was decided to use two weather stations located close to each other and study the correlations in rainfall. In a sense, the aim was to see the basis risk if we were to take up a rainfall index linked weather derivative at one station, with recordings at the other station being used as a proxy.

The locations chosen for this study were based on their proximity and the availability of reliable rainfall data for a period of 30 years. New Delhi has two airports – Palam and Safdarjung, both within the city and located less than ten kilometers aerial distance apart. While the former is in use, the latter is more or less defunct as an airport and sees only a few helicopter flights. However, both have weather stations of the Indian Meteorological Department which have been in existence for many decades.

Daily rainfall data was purchased from the IMD for the 30 year period from 1975 to 2005 and this was used for the study. A three stage comparison of the rainfall data was done. In the first instance, annual rainfall at the two locations was compared. Then the monthly rainfall in months of January, February, June, July and August were compared. In the other months the total rainfall was too little to give any significant results. Finally a comparison was made of the daily rainfall in the three-month period 01 June to 31 August each year for the 30 years.
5.2.1 Yearly rainfall

A comparison of the yearly rainfall at the two locations between 1975 and 2005 is shown in Figure 5.1.

The average rainfall in the 30 years was 762.03 mm at Safdarjung and 714.48 mm at Palam. While this itself is not significant, it was noted that the greatest absolute difference was in the year 2003, when it rained 1161 mm at Safdarjung, which was 280 mm more than at Palam. The greatest percentage difference was in the year 1989, when the rainfall was 47.9% more at Safdarjung.

On the whole, it can be seen below that the correlation is fairly strong (fig 5.2):
5.2.2 Monthly rainfall

The farmer, however, is more interested in the rainfall during the monsoon months, especially in the months of June, July and August for the Kharif crop and in January and February for the Rabi crop.

Rainfall in these five months at the two locations were compared. Correlations are indicated in Table 5.1 below:

<table>
<thead>
<tr>
<th>S No</th>
<th>Month</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>January</td>
<td>94.2%</td>
</tr>
<tr>
<td>2</td>
<td>February</td>
<td>86.2%</td>
</tr>
<tr>
<td>3</td>
<td>June</td>
<td>64.6%</td>
</tr>
<tr>
<td>4</td>
<td>July</td>
<td>87.6%</td>
</tr>
<tr>
<td>5</td>
<td>August</td>
<td>89.2%</td>
</tr>
</tbody>
</table>

Table 5.1. Correlations between rainfall figures at two locations.

The month of June gives us significant results with respect to basis risk. (See figure 5.3)

The correlation is just 64.6%. The largest absolute difference in rainfall occurred in the year 1998 when it was 279.1 mm at Palam, which was 147.9 mm more than the rainfall at Safdarjung. The largest percentage difference, however, was in 2004 when the rainfall in the month of June was 331.55% more at Safdarjung. Of the 30 years rainfall data in the month of June, we notice that in 15 years the rainfall was more in Safdarjung, while in 14 years it was higher at Palam.
So it is evident that the basis risk varies from month to month, and while using Palam as a proxy weather station for Safdarjung or vice-versa might be acceptable in the month of January, it could lead to a much higher basis risk in the month of June.

5.2.3 Daily rainfall

Next, an analysis was done of the rainfall on a daily basis for the months of June, July and August ie. for 92 days across the same 30 year period. (See figure 5.4)

This is probably the most relevant to weather derivatives, because in rainfall-index based derivatives, small periods of contracts are likely to be used. Here we get a R-squared of 0.688, which implies significant variations in the rainfall at the two stations which are located so close to each other. The largest difference occurred on 30 June, when the average rainfall over 30 years was 16.14 mm at Palam, which was 5.17 mm greater than that at Safdarjung. The largest percentage difference was on 04 June when the rainfall at Safdarjung was 933% higher than the rainfall at Palam. On 53 of the 92 days studied in the 30 year period, rainfall was higher at Safdarjung, while on 39 days, it was higher at Palam. Infact, on 7 days, the difference in rainfall at the two locations was more than 100 percent.

5.3 Conclusion

We could conclude that the shorter the period in which the rainfall is looked at, the greater is the difference between the rainfall between the two locations.
The difference could be as high as 330% when studied on a monthly basis and could be even higher (933% in this case) when seen on a daily basis. For short term rainfall-index based weather derivative contracts, the location of the weather station vis-à-vis the contract location assumes special significance. For longer term contracts, the use of proxy weather stations could be justified to a certain extent.

A similar study was done on data from two locations in London by Moreno (2005), with fairly similar conclusions.