# EUROPEAN WEATHER DERIVATIVES

*This paper concentrates on where the future of the weather derivatives market may lie, where the new applications may be situated and what will be the main drivers of the market size. We realise that some of the applications are not currently available or commercially viable at present but take the view that, if demand is sufficient, they will become available given time. In fact, one of the likely drivers of demand is the rate of change in the European climate. To this extent we have included a chunky appendix summarising the latest findings and views on climate change as we believe that this will have a huge influence on where the weather derivative market in Europe will be in 5-10 years time.*

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## 1. Introduction to this paper and Summary of Previous Paper

### 1.1 Introduction

Welcome! It has been great fun pulling this paper together, for most of the team weather derivatives is an area we rarely touch on during our day to day work. We have all therefore learnt a great deal from writing this paper and I hope that everyone who reads it will also learn something.

The main theme of last year's paper was to set the current scene in the weather derivative market. It covered the current market conditions, recent trades, the recent growth in the market and pricing techniques (among other topics). Rather than develop this further in our paper, we chose to concentrate on where the future of the weather derivatives market may lie, where the new applications may be situated and what will be the main drivers of market size.

We have therefore opted for a more hypothetical view, although there is plenty of analysis and fact underpinning our speculation. We realise that some of the applications are not currently available or commercially viable at present but take the view that if demand is sufficient, they will become available given time. In fact, one of the likely drivers of demand is the rate of change in the European climate. To this extent we have included a chunky appendix summarising the latest findings and views on climate change as we believe that this will have a huge influence on where the weather derivative market in Europe will be in 5-10 years time.

### 1.2 Summary of the Previous Working Party's Paper

The introduction covers some examples of weather derivative contracts and the underlying variable on which they are based. It also details who the current players are and the current situation in the market. It then goes on to describe some of the recent deals and the factors that were taken into consideration. There is some analysis around the reasons why the weather derivatives market has not yet taken off in Europe.

The introduction then moves on to detail some of the key terminology around weather derivatives and how deals can be structured. Finally, it covers in some detail the growth of the market over the past 5 years or so.

The next section deals with data issues around the pricing of weather derivatives and includes coping with missing and erroneous values, coping with discontinuities in data and dealing with and understanding trends in the data. The section goes on to state the lack of availability of data in Europe compared to the US.

The following section details the modelling of weather derivatives and how to go about pricing them using a number of approaches. It covers Auto Regressive Moving Average models in some detail as well as brushing over arbitrage pricing techniques.

Finally, the paper covers the role of forecasts in pricing weather derivatives and distinguishes between weather forecasts (10-15 days ahead) and seasonal forecasts (predicting seasons ahead). It also touches on the El Nino and other similar phenomena and describes how it would be possible to incorporate forecasts into pricing models.

We would like to thank last year's working party for their work. The paper has been an excellent start upon which to build on. Special thanks to Jeff Sayers who has attended a couple of meeting and passed on some very valuable information and opinions.

## 2. Current Market Conditions

### 2.1 Demand for weather derivatives

The majority of weather derivative deals are still carried out in the US, but there is a growing market of participants and contract types within Europe. The growth within Europe is occurring mostly in France and the UK, with Scandinavia and Germany close behind. In addition, most European deals continue to be over-the-counter (OTC) rather than exchange traded contracts.

According to a survey carried out in 2002 by the Weather Risk Management Association (WRMA), measuring activity over the year ending 31 March 2001, the European market recorded a total of 765 contracts worth a total notional value (maximum payout) of over $600m. This compares to 172 contracts worth a total of over $49m measured in the 2001 survey, an increase of 345% in terms of number of contracts and 1126% in terms of notional value.

The survey also shows that, whilst temperature-related protection continues to be the most prevalent, the proportion of rain, snow and wind related contracts have increased.

There has also been growth in other parts of the world:

- There has been rapid growth in Asia. The first deal on wind speed has been carried out in Asia, for a wind power project. In addition, the Japanese have seen the majority of their deals coming from the non-energy sector, with banks acting as intermediaries between end users and weather risk management providers.
- In Australia, many deals have involved power retailers. Weather derivatives have provided protection against losses due to extreme heat, when there may be a large rise in electricity prices.

### 2.2 The collapse of Enron

Enron was a major market player within both the US and European weather derivative markets and the collapse may have caused some slowdown in market growth. In particular:

- Enron was a major market maker and would quote both buying and selling prices for weather derivatives. However, during 2002, several exchange-traded contracts and indices have been set up throughout Europe (see sections 2.3 and 5 below).
- Enron took an active approach to marketing weather derivatives to end-users. However, other companies (such as Societe Generale and Element Re) seem to have become more active in marketing weather derivatives.
- Enron created liquidity for the market as it traded large volumes of contracts for small profits. This is perhaps the function that has been most difficult to recreate.

However, confidence in the market seems to remain high and many of Enron's laid-off traders are actively promoting weather derivatives in their new companies.

## 2.3 Current Market participants

The main market participants in the past have been energy traders, insurers and reinsurers. However several banks have recently entered the market, for example:

- French banks such as Societe Generale and Credit Lyonnaise.
- Several German banks such as Deutsche Bank and Dresdner Bank.
- Rome based Banca Nazionale del Lavoro is planning to establish a weather derivatives desk in preparation for the winter 2002/2003 season and IntesaBCI has been globally active in the market for the last year.

New exchange-traded contracts and weather indices have been set up throughout Europe. Exchange traded contracts offer the removal of long-term administrative liabilities associated with OTC instruments and the efficient management of counterparty credit risk.

- In July 2001, LIFFE launched six exchange-traded contracts based on indices of daily average temperatures in London, Paris and Berlin. The indices are based on the mean of daily average temperatures (Mean DATs) and are available monthly and for the winter season. The indices are calculated as:

Monthly Index = 100 + $\Sigma$(Mean DAT) summed over each day in the calendar month
Winter Index = 100 + $\Sigma$(Mean DAT) summed over each day of the winter season period

LIFFE has started trading with cash settled futures contracts referenced against the indices. Each contract is worth £3,000 for every degree Celsius of temperature change. LIFFE has chosen to focus on average temperature rather than Heating or Cooling Degree Days (as used in the US). This is because there is not a corresponding demand for cooling in the summer.

- Following a commercial and technical partnership with Meteo France, Euronext is launching a series of temperature indices. Euronext will offer standardised products enabling anticipation of the financial impact of a change in temperature on business.
- Entergy-Koch announced in December 2001 that it will be publishing a new wind power index which may be used to trade wind power derivatives worldwide. Entergy-Koch will be actively trading the index.

Reinsurers (e.g. Element Re, Swiss Re) have also become more active in the market. They have been proactively marketing weather derivatives and also provide a lot of credit capacity to the market. However, some reinsurers prefer to work with more traditional insurance policies, which deal with the risk of more extreme events.

Finally, new advocates for expanding use include the World Bank, who are pushing weather risk management products in countries where economic subsidies are less readily available and the impact of weather has greater economic significance.

## 2.4 Take-off speed in Europe vs US

Possible reasons why the take up of weather derivatives in Europe has been slower than in the US include:

- A lack of reliable, standardised, inexpensive European weather data.
- So far, there has been less internal hedging of weather risk by energy companies throughout Europe compared to the US market. One possible reason for this could be that there is less variation in extremes of weather in Europe compared to the States. The temperature spread is smaller and the seasons less likely to fluctuate greatly.
- Deregulation of energy markets.

Each of these reasons are discussed in more detail below.

## 2.5 European weather data

European weather data is expensive and data issued by different met offices is not standardised. As a result, major upfront investment is required. Specific problems with European data include:

- A country can change or shut down a weather station, without warning.
- Recording times of maximum and minimum temperatures are different for each country.
- The definition of daily average temperature can vary from country to country.
- Weather data delivery times are different for each country. In some cases, it can take as long as a month to obtain data.
- Data cleaning practices are different for each country.
- Have to go to each Met office to acquire the data.
- Some countries do not have long enough historical records of the quality of data needed.
- The data from each country may be provided in a different format.

However, secondary data providers are being set up throughout Europe to provide the data required and there is evidence that Met offices are becoming more commercially minded. For example:

- WeatherXchange is a joint venture between the UK Met office and Umbrella Brokers Ltd. It provides up-to-date weather information, forecasts, historical data and a wide range of climate prediction information. Temperature data is available from eight UK and three European sites, while rainfall data is available from eight UK sites.
- Following a partnership with Meteo France, Euronext is launching a series of temperature indices ("NextWeather") comprising a national index and five regional indices for France. In September 2002, Euronext is planning to extend the indices to Belgium and the Netherlands.

These secondary data providers can provide data of the quality required, but smaller traders may find the cost prohibitively high.

In the US, whilst weather data is plentiful and free of charge, there are still some quality issues with the data. For example weather stations can change location or instrumentation, so some data cleaning is still required.

## 2.6 Variation of extremes of weather in Europe

See section 6 and appendix A.

## 2.7 Deregulation of energy markets

Energy markets worldwide are undergoing deregulation in order to provide consumers with the lowest possible prices. In the US, Australia and the UK, deregulation has already caused utility prices to fall. In Germany, deregulation of the energy markets has just started, whereas in France the industry is still predominantly regulated.

Under regulation, utility companies tend to maintain excess capacity to protect themselves from demand fluctuations due to the weather. Consumers pay for this through higher rates. In an unregulated market, supply and demand must meet in order to have the lowest common clearing price per unit delivered. This leads to a more efficient use of infrastructure, but the utility company must bear the financial impact of being at risk from the weather.
Weather derivatives are an important tool in managing volatility of demand in a deregulated market.

## 2.8 Future growth of the market – where do we go from here?

During the development of the weather derivative market in Europe, the first targets as counterparties were energy companies. The reasons for this are that many energy companies understand their weather risk in precise terms and that they also have a trading mentality. For the next target sectors such as agriculture, tourism and retailing, these advantages do not, in general, apply. This second stage of development of the market has been slower because it involves a difficult educational process.

In addition, other market conditions that may make weather derivatives attractive in the future are outlined below:

- An increasing trend for the insurance industry to provide “holistic” products that cover all business risks instead of just standard products.
- More awareness of weather derivatives meaning that bad weather is no longer an excuse for poor profits.
- Less asymmetry in knowledge between experienced market players and new entrants.
- More exchange traded contracts as they offer the removal of long-term administrative liabilities associated with OTC instruments and the efficient management of counterparty credit risk.

- Improved techniques in analysing wind and rain risk. Energy companies and weather risk are a good fit because the weather variable most affecting revenues is temperature, which is easy to measure and model. By contrast, wind and rain are much more localised and if there is no weather station to capture an event, a derivative deal would be impossible to structure.
- Agriculture is one of the most subsidised sectors in the world. Traditional subsidies have in some cases been replaced by subsidised crop insurance. This has perhaps slowed the use of weather derivatives to manage risk. Changes in the level of methods of subsidy may have an impact on the market.
- An increase in penalties for failing to meet targets in construction could encourage more use of weather derivatives.
- The number of users able to trade in weather derivatives may have contributed to slowing growth. Smaller companies may not be sufficiently credit worthy for the risks. One possible solution would be for smaller companies to group together in a syndicate in order to purchase weather derivative protection.

## 2.9 Accounting treatment

In general, there are two ways in which a weather derivative can be accounted for:

- By treating the weather derivative as a hedge so that premium and profit/loss on the derivative is treated as ordinary income and will be subject to corporation tax.
- By treating the weather derivative as a derivative instrument so that premiums and profit/loss is treated as capital gain/loss and taxed as such.

There seems to be some confusion over how to account for weather derivatives under the current legislation. It is possible that this requirement has resulted in companies transacting fewer derivatives.

These two treatments are considered in more detail below:

<u>Accounting for weather derivatives as a hedge</u>

When a company buys or sells a derivative, it must prove that the purchase was a true and fair hedge, not speculation. In order to do this, historical and third party data may be required.

Another issue to accounting in this manner is that a winter hedge may span more than one accounting period with a single payout at the end of the season. For example, a hedge may span November to March and the accounting year-end may be 31 December. In this case, a possible approach is:

- Decide what is “expected weather” over the remainder of the hedge (i.e. January to March). For example, this may be a 10 year average or may incorporate some sort of global warming trend.

- Accrue the profit or loss on the contract given actual weather to 31 December and the expected weather from January to March.
- When the actual profit/loss on the contract is realised in March, this is accounted for as the difference between the actual profit/loss and the profit/loss accrued in the 31 December accounts.

Ordinary income treatment may or may not be preferable to capital losses, which are only deductible if capital gains exist.

Accounting for weather derivatives as a derivative

For exchange-traded derivatives, this treatment involves “mark-to-market” accounting. This means that the derivative is treated as a capital asset and any movement of the market value is treated as a capital gain or loss.

However, there has been criticism of this method, especially following the collapse of Enron. The lack of liquidity in the market for some types of weather derivative may mean that a large market maker is effectively prescribing their value.

If the derivative is not exchange traded, then the capital gain or loss is accounted for only when the derivative has elapsed/is exercised/is sold.

## 3. Case Study

### 3.1 European Weather Derivatives

A number of deals have recently been completed in the European weather derivatives market. Primarily over the counter deals which are structured as reinsurance on a bespoke basis, we introduce below some basic concepts.

### 3.2 Objective

Structured to provide an alternative to conventional high layer catastrophe reinsurance, deals to date focus on perils such as windstorm and freeze with low frequency, high severity characteristics.

In contrast to more traditional heating and cooling day based derivatives which are commonly used by US energy companies, these deals are tailored for insurers seeking alternative sources of protection against aggregation of natural peril catastrophe risk. We have therefore focussed our attentions in this part of the paper on weather derivatives recently seen in the European catastrophe reinsurance marketplace which are neither commoditised nor publicly traded.

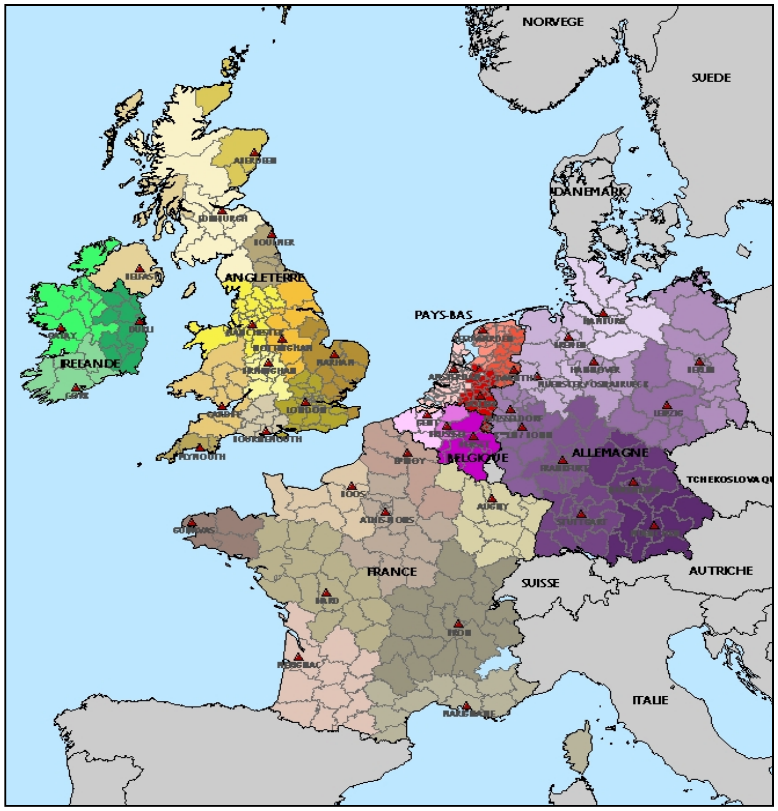
An objective approach is central to the pricing process. Typically this requires an independently produced weather index from which it is possible to define the trigger or attachment point for the derivative. When the trigger is exceeded by the index the derivative is exercised. Through constructing an index which is unique to the cedant's portfolio of risks, the payout under the derivative should be highly correlated to any losses caused by the peril hedged. This requires a non-trivial analysis of the correlations between claim experience and weather station indices.

Basis risk, whereby the loss experience of the cedant is not accurately reflected by the index is an important consideration for these products. For example, there would be significant basis risk for a derivative protecting against a concentration of flood risk in the South West of England were it to use rainfall indices with measurements taken in London.

The extent to which basis risk exists depends upon the number of weather stations for which indices are available, their location and their proximity to one another. Indices are available for the following countries:

- Belgium
- England
- France
- Germany
- Ireland
- Netherlands

An example of chosen weather stations for each of these countries and their associated catchment areas is shown graphically in the map below:




## 3.3 Advantages & Disadvantages V Traditional Reinsurance

When looking at the merits of such transactions there are a number of advantages and disadvantages relative to traditional catastrophe reinsurance products:

<u>Advantages</u>

- Cedant loss history is irrelevant as the payout is determined purely by an index of objective measurements. Problems with poor quality historic data are less important than for traditional catastrophe reinsurance.
- Catastrophe software modelling error eliminated.
- Extension of markets to reinsurers otherwise unwilling to play in this arena and wider financial markets.
- Event definition clearly and objectively defined
- Payout determined immediately by index
- Cost of structuring the deal is less than for other ART solutions such as Cat bonds.
- Difficult to insure risks can be covered.
- There are no exclusions for individual risks.

<u>Disadvantages</u>

- Damage incurred may exceed the indemnity received
- Requires a correlation analysis between cedant portfolio and selected index

### 3.4 Example Contract

| | |
|---|---|
| Coverage: | Annual windstorm cover protecting property portfolio across 10 regions |
| Index: | Multiple indices used with each weather station weighted by a loading Li representing proportion of portfolio in each region |
| Excess: | i) Monetary excess = Eur 100m of accumulated theoretical losses from all weather stations |
| Trigger | ii) Option triggers vary by station to reflect anticipated damage factors in each region<br>iii) Each day index exceeds trigger for each station contributes excess km/h x tick size in theoretical losses to layer Eur 100m xs 100m |
| Limit: | Eur 100m of accumulated theoretical losses |
| Tick Size: | Eur xm |

In determining the payout from such a contract, the windspeed at each weather station is measured on a daily basis. If the peak windspeed exceeds the individual trigger for that station on a particular day then the station contributes

(observed wind speed – trigger) x tick size x station loading (Li)

to the accumulated theoretical losses under the contract for that particular day. The accumulated losses for all stations are then applied to an excess reinsurance layer of Eur 100m xs Eur 100m.

### 3.5 Pricing Approaches

The pricing of such contracts requires either an historic index for the proposed peril and/or statistical models of the index. Models are particularly important in the event that the historic data is limited in quantity or invalidated in some other way. These are then used to quantify the risk of the observed measurements exceeding the trigger for each weather station.

The most basic approach to pricing such a contract would be akin to a burning cost calculation similar to those carried out in traditional reinsurance pricing. The historic index observations would be applied to the proposed structure and averaged across all or several years to calculate the expected value of claims to the contract. These calculations are in fact simpler than for traditional reinsurance as the usual adjustments for claim inflation, terms and condition changes are no longer relevant. This approach provides a basic estimate of the expected loss cost to which profit and expense loadings could be added to calculate the premium.

Building a statistical model where a distribution of the underlying index is generated would allow a more complete investigation of the range of possible outcomes under the contract. Standards simulation techniques would then enable a more rigorous approach to pricing.

## 4. Broker Survey

### 4.1 Introduction

Brokers currently play a small, yet significant role, in the market for weather derivatives. According to Peter Brewer, formerly of Aquila Europe, insurance brokers account for only around 5% of weather derivatives deals. However, those deals that are placed by insurance brokers tend to be much larger than their energy broker counterparts.

The history of the weather derivatives market is relatively short, yet insurance brokers have been a part of this market from the start, with Willis being involved in one of the first set of transactions back in 1997. Since then each of the major broking houses has to a greater or lesser extent, developed an interest in using weather derivatives to protect clients from weather related risks.

In order to gauge the current and likely future involvement of insurance brokers in the market a series of face-to-face interviews was undertaken with the four largest insurance brokers: MMC (Marsh), AON, Benfield Greig and Willis. In addition, interviews were also conducted with Aquila (energy commodities) and JPMorgan (merchant banking) to gain an alternative viewpoint.

### 4.2 Contracts Placed or Under Consideration

Of the four brokers taking part in this survey, each had considered placing weather derivatives deals on behalf of clients and three of them had completed at least one weather derivatives contract.

Three of the brokers had considered placing weather derivative for clients from a similar set of industries, namely:

- Utilities (gas, electricity, water)
- Retail
- Restaurants
- Agriculture
- Food and drink
- Transport
- Tour Operators
- Airports
- Construction
- Hydro
- Leisure

The vast majority of these “derivative” deals were constructed in the form of options although a few swaps have been considered. Weather derivatives can take the regulatory form of a financial instrument or insurance, depending on the wishes of the client and the regulatory environment of the country in question. With regard to location, by far the highest proportion of deals, placed by brokers, are for North American clients. However, an increasing number of deals are being placed in Europe and a number of other markets (notably in the Far East, Australasia, Central America and Russia) are continuing to develop.

All contracts placed by insurance brokers have been over the counter deals. The localised and non-standard nature of the risks covered by weather derivatives have made exchange traded deals impractical. Most deals have covered a 3-4 month period, particularly those in the retail or energy sectors. There have, however, been some contracts that have been placed for as short as 1 week or for as long as 5 years! The counter-party to most of these deals has been an insurance company, (Swiss Re and XL Re commonly being used) with some energy companies and banks also being involved.

One of the brokers in the survey has decided to take an alternative approach to the clients sought for these products, concentrating its efforts on structuring weather derivative products to serve the risk management needs of insurance companies. In effect, using weather derivatives to supplement, or replace, the traditional role of reinsurance in protecting against weather related losses. This broker, has already placed a deal to protect a client against French windstorm claims, partly in response to the hardening of the French catastrophe reinsurance market (following the 1999 storms). It was an option style contract, with the underlying index being calculated from the weighted weather readings obtained several weather stations across France, the weightings reflecting the underlying exposures of the insurer. In addition, the broker has also considered the options for protecting against freeze claims on a Europe-wide basis for clients.

All of the contracts constructed on behalf of insurance company clients have been 1 year deals, which mirrors the period covered by most traditional reinsurance treaty purchases.

### 4.3 Marketing

The marketing of weather derivative products within insurance brokers varies significantly depending on the industry type of the client. In the main, interest for weather derivative products in respect of the utilities industry is client led, reflecting the high level of understanding of the market in this industry. However, with clients from other industries, the brokers had taken a more proactive approach to marketing.

The approach taken, also varied from broker to broker. Unsurprisingly, the one broker in the survey that had not placed any weather derivatives to date was also the only broker that had not actively marketed weather derivative products. The other brokers had all, to a greater or lesser extent, recommended the use of weather derivatives to some clients within their networks.

### 4.4 Operations

Out of those brokers surveyed, the majority of weather derivative deals were placed through their structured finance/credit or capital markets divisions. However, the was some involvement of the traditional (re)insurance broking teams in some of the deals. The extent to which either is involved is heavily dependent on the structure of the deal (pure derivative or a type of insurance) and the local regulations of the market in question. In the UK, the Securities and Futures Authority Limited regulate brokers involved in the sale or arrangement of pure weather derivative products, and hence have a large impact on the placement of these products.

## 4.5 Pricing

In order for brokers to assess the fair price of a weather derivative deal for their client a set of historic weather data will be obtained, usually from government meteorological services. A range of techniques from the actuarial, financial economics and meteorological fields have been used by brokers to analyse the data and then determine a fair price, including

- Correlation and regression analysis
- De-trended time series
- Burning cost
- Scenario testing and Monte Carlo simulations
- Black-Scholes derivative pricing
- Seasonal weather forecasting

Most brokers employ the services of a team of professionals including actuaries, financial mathematicians, statisticians and climatologists in order to price weather derivatives. Long-term weather forecasting, with respect to European weather patterns is of limited use and as a result, the pricing techniques employed in Europe owe more to the statistical than the meteorological sphere.

## 4.6 Future Prospects

Most brokers felt that the market for European Weather Derivatives would continue to grow, although there was a general feeling that it wouldn't take off in the same way as in the United States due to the less volatile nature of European weather.

The brokers felt that they would not play a significant role in placing products for the utilities sector, since there was already sufficient in-house expertise in this industry to negate the need their services. However, in other sectors, it was felt that brokers would play an important role in the evaluation and execution of weather derivatives in dealing with the weather risks faced from their existing major clients.

# 5 Underlying Measures

## 5.1 Introduction

As stated previously in this report, there are a wide variety of potential uses for weather derivative contracts, such as:

- as an alternative to re-insurance for insurance companies for non-extreme but more persistent events (such as prolonged period of rain affecting motor claim frequencies)
- for turn-over or profit smoothing for companies affected by the weather

There are also a large number of weather variables that could be used as a measure, for example:

- Temperature
- Precipitation Levels (Rain or snow)
- Hours Of Sunshine
- Wind Speed

Finally, there are two main methods by which a contract could be carried out:

- Using a specific Weather Index (such as the Monthly or Winter Season Index on LIFFE)
- Using a more tailored measure of a particular weather variable

The reason for the protection and the method of the contract would influence the exact variable used. For example, if a new weather index was to be constructed, a standard variable, suitable for various uses, would be required. However, if an individual contract was to be established, a much more tailored and specific measure could be used.

In this section, we will go through each of the possible weather variables and discuss examples of its use, different measures that could be constructed, suitability for a Weather Index and disadvantages or limitations of the variable.

One other point to note is the fact that many of these weather-related variables are highly correlated. For example, if a company's results are poorly affected by lack of sunshine (e.g. wine bar on a river-front), then they will also be affected in the same way by a high rainfall index. Therefore, there may only be take-up in the weather contracts that are easiest to define and best portray the level of risk associated by the company. For example, in the wine-bar case, customers would be more put off if it was cold and raining but less put off if it was simply cloudy. What would the most relevant weather variable be in this case, therefore? Perhaps rainfall.

## 5.2 Temperature

Temperature is the measure that has been most widely used to-date – firstly in the US market and more recently on the UK's London International Financial Futures Exchange (LIFFE).

## Suitable Measures

*Heating & Cooling Degree Days (HDDs & CDDs)*

This is the most common measure that has been used to indicate temperature variability in the US. As mentioned earlier, the US weather derivatives market has been dominated by the energy companies, therefore, this measure was the most suitable in defining energy demands for heating or air-conditioning.

A "Degree Day" is defined as a one degree difference between a reference temperature and the average daily temperature. For example, if the reference temperature is set at 65°F and the average daily temperature was 55°F, this would mean 10 HDDs. Indexes are often an aggregate of the HDDs or CDDs over a certain period, for example 6 months.

*LIFFE Weather*

The London & International Futures Exchange has recently set up it's own Monthly and "Winter Season" Indexes based on temperature. These indexes are based on an average of the daily average temperature in the month for 3 locations – London, Paris and Berlin.

LIFFE states the reason for its different approach to an index is the different nature of European weather and the lower dependence on cooling in the summer. They also believe that their index will promote more growth in the weather derivatives market due to the indexes being more transparent and easy to understand.

The Winter Season Index is similar to the monthly index except it is the average index of the daily average temperatures over a specified period (namely 1$^{st}$ November to 31$^{st}$ March inclusive).

*Other Measures*

The introduction of the LIFFE Weather Indexes has vastly increased the choice open to companies exposed to European temperature fluctuations, however, it will not be able to cater for all scenarios.

For example, certain localised events (e.g. a freeze in Glasgow or a heat-wave in Athens) will not necessarily be picked up by the Monthly Indexes because the location is too far away from the three weather stations chosen by the index. Therefore, if a business was solely affected by events such as these, a more tailor-made contract specifying more detailed temperature variations might be preferable.

## Uses Of Measure

A low temperature index would be beneficial to the following industries:

- Energy companies (in terms of increased requirement for heating)
- Overseas tour operators

On the opposite side of the scale, a high temperature index would be beneficial to the following industries:

- Energy companies (in terms of increased requirement for cooling)
- Recreation/Tourism industries (including outside activities, sea-side resorts, etc.)
- Retail industry (e.g. increase in DIY/gardening activities, people more encouraged to go out shopping for clothes on warmer days, etc.)
- Food retail industry (higher demands for barbecue food/accessories and generally drinks/ice-cream, etc.) Bottled water and diluted drinks manufacturers have both stated statistics on the affect of temperature on demand for their products
- Construction is generally more productive in warmer temperatures. For example, extreme low temperatures can affect material requirements, freeze the soil and cause physical discomfort to workers (all of which will reduce production levels).

The agriculture industry generally sits somewhere in the middle of the scale – needing neither extreme low or high temperatures. One stated example is the severe damage on crop yields to citrus fruits caused by freeze temperatures.

Agriculture is also affected by the weather due to its' affect on pests and hence the amount of crop yield lost.

<u>Data Available</u>

Data availability has been investigated for the UK, France and Germany, since the weather derivatives markets are biggest in these three European countries. However, no freely available information could be found from either the Meteo France or the Deutscher Wetterdienst websites (that is the domestic meteorological offices for France and Germany respectively). Therefore, no further comments are included below. Note, that this applies to all weather variables not just temperature.

In the UK, the MetOffice, has a wealth of historic information about temperature. Freely available on their website are monthly statistics on average minimum and maximum temperatures for the following stations:

| | | | |
|---|---|---|---|
| Armagh | Bradford | Durham Lerwick | Long Ashton |
| Oxford | Sheffield | Southampton | StornowayValley |

and more are available by contacting their Customer Service department. In some cases, the data goes back to 1853.

In addition to all of this historic information, more up-to-date information is collected at a vast network of stations around the country.

Historic information would be used for pricing of contracts (probably both by suppliers and demanders of contracts because both sides would to be well informed about the level of risk involved), whereas daily information is needed either to maintain an index or to monitor specific terms of contract.

## 5.3 Precipitation (Rainfall and Snowfall)

Suitable Measures

Measures could be set up in a similar manner to the LIFFE Temperature Indexes – for example, a monthly average of the total daily rainfall at certain key locations could be used. Again, more detailed contracts may need more specific locations than those used for an index.

An alternative to a monthly average of total rainfall would be a measure of the intensity of rainfall, for example the maximum amount of rain per hour in the day. This would be of interest in the more immediate risk of a localised flood, increase in motor claim frequency, etc.

Uses Of Measure

A low index of rainfall would be beneficial to the following industries:

- Insurance industry, in relation to rain-related claims such as property flood claims and motor accidents
- Recreation/Tourism industries, especially for outdoor events and tourism, because they will generally receive higher trades in dryer conditions
- Retail industry, especially clothing and gardening
- Construction industry is usually delayed by high levels of rainfall
- Airline industry is significantly affected by rainfall. One estimate states that when precipitation exceeds 0.025 inches at the destination airport, delays are more than doubled.

On the opposite side of the scale, a high index of rainfall would be beneficial to the following industries:

- Insurance industry, if during summer months, because could reduce risk of subsidence for the following year
- Water utilities industry
- Indoor recreation/tourism facilities, such as Center-Parcs, etc.
- Energy industry (especially if heavily dependent on hydro-electrical power stations)

Again, agriculture is often somewhere in the middle of the scale, but this depends on the exact type of crop being grown. One example often given is barley – which is damaged by excessive levels of rainfall at harvest time.

Another example is councils protecting themselves against lower than expected snowfall, which offsets the cost of salt purchases which are proved to be unnecessary.

Data available

As with temperature information, the UK MetOffice has a lot of historic information about rainfall – it has the total amount of monthly rainfall at the stations mentioned in the temperature section. Since about 1960, the MetOffice has also been recording the "number of snow days" per month, which is defined as the number of days where snow is lying at 9 am at the stations concerned.

In addition to all of this historic information, again, more up-to-date information is also collected.

## 5.4 Sunshine Hours

Suitable Measures

Again, a simple measure, suitable for an index, would be monthly average of total number of hours of sunshine at certain key locations. As stated with the temperature and rainfall indexes, more detailed contracts may need more specific locations than those used for an index.

Uses Of Measure

A low index of sun-shine would be beneficial to the following industries:

Overseas tour operators

On the opposite side of the scale, a high index of sun-shine would be beneficial to the following industries:

- Recreation/Tourism industries, including pubs/wine bars, sea-side resorts, etc.
- Retail Food industry, in terms of ice-cream, cold-drinks, barbecues, etc. sales!
- Agriculture industry

One quote explained how the brewery industry was affected by sunshine levels: It explained that lower beer consumption was correlated with lower levels of sunshine because of the number of activities that result in beer consumption also being lower – for example, going to the beach, golf, water-sports, barbecues, etc.

Data available

In the UK, the MetOffice has less historic information on sunshine hours. The average number of hours of sunshine in a month has been recorded since 1930.

In addition to this historic information, more up-to-date information is collected at a vast network of stations around the country.

Limitations

The main limitation with this variable is the fact that it is heavily correlated with temperature. Since temperature is significantly easier to measure and probably is done so in many European countries, it may be some time before sunshine weather derivatives are used.

## 5.5 Windspeed

Suitable Measures

Similar to the other weather indicators, a simple measure would be the daily average wind speed averaged over a month. This could be recorded at specific locations.

A more detailed measure could be maximum wind speed over a month. This would be an indicator of more stormy weather.

Uses Of Measure

Wind probably has less direct effect on industry. Although, it is highly correlated with other weather scenarios, such as heavy rain (with high winds) or sunny, warm conditions (with light winds).

Therefore, the uses of such a measure would probably be more limited.

A low index of wind-speed would be beneficial to the following industries:

- Insurance industry to a small extent because high winds may result in damage to property, car collisions, etc.
- Agriculture industry, because higher levels of winds usually result in lower crop yields and eventually damaged crops.
- Ferry companies are affected by high winds, causing delays and cancellations

On the opposite side of the scale, a high index of wind-speed would be beneficial to the following industries:

- Wind-generating power stations

Data available

The MetOffice in the UK does not appear to collect either average or maximum wind speeds.

Limitations

The main limitation for all the weather variables described above involves data problems. This was discussed in the last paper and involves:

1. *Data availability*
   For example, out of the three European countries investigated, freely available data could only be found for the UK and then not all variables or sufficient detail was available

2. *Data reliability*
   This covers different countries recording data in different ways, missing and erroneous values and discontinuities in data.

3. *Data anomalies/trends*
   For example, urban heat islands or trends caused by climate change

## 5.6 Summary

In addition to the variables discussed above, there are numerous other weather measures that could possibly be used. One particular example is humidity. This has been proved to have a direct affect on the sales of cold/flu products (because lower humidity in the winter is the cause, rather than temperature, of the easier spread of viruses – due to the nasal passages being dried out more and therefore, more susceptible to infection).

Another variation in the weather derivatives field is the ability to protect against short-term forecasts – such contracts are provided, for example, by GuaranteedWeather.com. Potential clients of such contracts are out-door event organisers, agriculture industry, recreation industry, etc.

Particular conditions are also emerging under specific contracts – for example "Guaranteed Growing Days," which is a contract also offered by GuaranteedWeather.com. This contract is based around the number of days whereby growing conditions (i.e. the correct mixture of weather variables) exist.

The table below summarises the potential trade-off between industries for the various weather variables discussed in the sections above:

| **Measure** | **Low** ⟷ | **High** |
|---|---|---|
| Temperature (Average In Month) | Energy Industry (higher heating demand)<br>Overseas Tour Operators | Energy Industry (higher cooling demand)<br>Recreation/Tourism Industries<br>Retail Industry<br>Construction Industry |
| Rainfall (Average In Month) | Insurance Industry (Flood/Motor)<br>Recreation/Tourism Industries (Outdoor)<br>Retail Industry<br>Construction Industry<br>Airline Industry | Insurance Industry (Subsidence)<br>Water Industry<br>Agriculture<br>Recreation/Toursim Industries (Indoor)<br>Energy Industry (Hydro generators) |
| Sunshine Hours (Average In Month) | Overseas Tour Operators | Recreation/Tourism Industries<br>Food Retail Industry<br>Agriculture Industry |
| Windspeed (Average In Month) | Insurance Industry<br>Agriculture Industry<br>Ferry Companies | Energy Industry (Wind Generators)<br>Recreation Industry (wind surfing/sailing) |

## 6. Climate Change

### 6.1 Summary

One of the reasons why the weather derivatives market has not taken off in Europe may be because the weather has been relatively stable and uniform across Europe. Thus, demand for derivative products that protect against the volatility of weather related profits have been muted, and the market to trade risk has been small. However, demand for weather derivatives could increase if the widely anticipated changes in European weather materialise.

Several indicies have been developed to monitor changes in the Earth's climate. The most useful index is the average surface-air temperature of the planet. Changes in this index indicate that global temperatures have risen by about 0.6$^{o}$C since the beginning of the 20$^{th}$ Century. About 0.4 $^{o}$C of this warming occurred in the Century's last 30 years. This trend is expected to continue; the IPCC has projected an average global surface temperature rise of between 1.4 and 5.8 $^{o}$C from 1990 to 2100. A more detailed discussion of climate change is given in Appendix on page #.

This section concentrates on the likely effects of climate change on the weather derivatives market.

### 6.2 What impacts will this have?

#### 6.2.1 Background

Climate affects both social and economic systems, as well as having an impact on the environment. This happens through weather extremes, climate variability and longer-term climate change. For insurers, the future behaviour of extreme weather events is critical. For other industries, for example tourism, weather variability is a key influence on profitability.

The range of impacts associated with future climate change can be better understood by looking at how climate extremes and weather variability have affected society and the environment in the past. Various issues can be considered such as the impact of climate on supply and demand, or the positive and negative consequences of change. The development of opinion over time obtained through population and management surveys from different European countries gives an indication of how seriously the impacts of climate change are being taken. Analysis of existing provisions made for change can then identify the potential for new financial and risk-related products, such as weather derivatives, to assist society to adapt.

In the following sections, we take a closer look at specific industries and discuss the impact that climate change has already had, and will have in the future. Within each section, the various issues relevant to different European countries are also considered. Results have been taken from population and management surveys carried out by the WISE (Weather Impacts on Natural, Social and Economic Systems) workshop – an EU-funded project. The industries covered are:

- Recreation and tourism
- Energy and water industries
- The construction industry and property insurance

### 6.2.2 Recreation and tourism

Demand within different European countries may well change in the near future as a result of global warming. Northern Europe may experience increased demand during the summer peak period, decreasing demand in southern Europe. Demand for southern Europe destinations may shift more towards off-peak seasons. Rapidly changing demands could result in increased need for protection and insurance in developing holiday destinations. Consequences for accommodation transport links or employment could be dramatic.

Increased occurrence of extreme events will lead to increased flood and storm risk to people and property. Increased running costs of flood vulnerable tourist facilities, coupled with higher demand, could have a gearing effect on the sensitivity of profitability to extreme events. The need for increased sea defences and the impact of extreme events on land erosion reduces amenity value in many areas. For example, golf courses in coastal areas are vulnerable to erosion and changes in the environment – a fact that has been recognised and discussed in the golfing community.

Differences in perception amongst European countries are consistent for most issues regarding climate. Mild winters were generally viewed positively. Hot and dry summers were generally viewed positively in northern countries such as the UK, whereas southern countries such as Italy viewed them negatively. Tourism and recreation companies considered extreme weather events to be of minor importance to their operations and in most cases (golf being one notable exception) little to no planning is being adopted to deal with climate change in the near future. Some countries such as the UK and Germany are responding by developing insensitive tourist facilities (e.g. indoor leisure complexes), whereas other countries like Italy are more concerned with the impact of hot summers on agriculture and forest fires. The reduction of the skiing season due to mild winters has negative impacts on winter resorts dependant on tourism, but in many cases can be managed through the use of snow machines.

Whilst climate does have an influence on recreation and leisure patterns, it is unlikely to be the driving force to changes. Social, economic and cultural changes are more likely to have a stronger influence in shifting demands. The complexity of the processes involved make it difficult to draw firm conclusions from analyses carried out. For example, there is a lack of data differentiating between pre-booked and spontaneous trips or between destination type (coastal, urban, winter sport).

In summary, the factors affecting demand for recreation and tourism are complex, but are influenced by climate. Changing climate will potentially influence recreational patterns in the near future. Despite evidence highlighting climate change, the leisure industry has generally not taken any major steps in formulating plans to deal with changing demands. As awareness is raised, and parallels drawn with experiences in the USA, there should be potential to provide new financial and risk-related products such as weather derivatives.

### 6.2.3 Energy and water industries

Supply and demand for energy and water is clearly heavily influenced by climate and weather extremes. For water, hot summers increase demand whilst reducing supply. A mild winter will reduce demand for energy thus lowering profits for energy providers.

The energy sector has recognised this and actively tried to establish the relationships between changes in the weather and the demand for energy. In the USA, weather derivatives have been primarily used by energy companies to "weather-proof" their results and help achieve a greater level of stability. There is clearly scope for European utilities to make use of weather derivatives in the same way.

The impact of extreme weather events can in many cases by managed by insurance cover. However, increased variability in weather extremes or steady long-term changes in climate, creates the potential for a range of other risk-related products like weather derivatives. Other factors are likely to be more important to utilities such as management actions, market developments or technological advancements. Actions taken by governments or the public in general to make more efficient use of scarce resources may also have an effect in shifting demands.

Changing climate may create further opportunities for alternative energy sources, changing supply. Increased storminess may offer potential for increasing wind and wave as sources of energy. Some European countries such as the Netherlands have already adopted these environmentally friendly sources of energy. Combined with the establishment of new energy and water infrastructures (reservoirs, distribution systems etc.), this may lead to new risks and opportunities for insurers and other providers of risk-related products.

Water suppliers and users are likely to be affected to varying degrees by climate change. In Germany, the water sector considers itself robust to all types of weather variability and its effects on supply or demand. In the UK, water companies have taken large-scale measures to increase efficiency and reduce vulnerability following encouragement by national regulation and the problems faced in the 90s.

Overall, whilst climate change will change supply and demand for energy and water companies, the future of these industries is likely to undergo more rapid change through changes in other factors such as technological advancements and development of new business opportunities outside of their traditional market-places. It is possible that with increased diversification, and larger companies adopting a more holistic approach to managing risks, that demand for "balance sheet" protection will increase.

### 6.2.4 The construction industry and property insurance

The very nature of the construction industry means that companies must be alert to weather conditions and long term predictions as well as the consequences of climate change. Construction is susceptible to both hot and cold extremes, and building sites are susceptible to extreme weather events. European codes of practise must be continually updated to reflect climate change. Whilst building standards are not always enforced, they are a prime driver of adaptation strategy for construction.

Property insurance is also naturally linked to the consequences of climate change. Increasing frequency and severity of extreme weather events in Europe could have dire consequences for insurers and reinsurers if these events are not predicted and priced accurately. Practices of bearing disaster costs vary in different European countries - flood damage is often provided by the state for example. France and Spain provide state guaranteed natural perils reinsurance. In other countries, insurance is not widely available or affordable, meaning costs are borne by property owners, state aid or charitable aid.

Changing climate will alter the mix of risks from region to region. Hotter, drier summers will lead to more subsidence claims – ultimately, if the occurrence of subsidence becomes more common and predictable, it may become difficult for insurers to provide cover in a way that is profitable. Rising sea levels and increasing storm severity could create flooding in new areas. New developments, for example expanding tourist hotspots, will compound the costs associated with extreme events or weather variability. Building materials may need to alter to cope with changing climates possibly adding unforeseen costs to construction projects.

Climate change, combined with increasing concentrations of people and property values, makes it more important than ever for the construction industry and property insurers to ensure they are prepared to meet future costs. It is possible that government intervention could assist, for example by allowing tax effective catastrophe reserves to be established. Alternative risk-related financial products could ease the burden of costs – alternatives already exist, such as ART. Weather derivatives may be an option in future for these industries. For example, insurers could make use of them to offset subsidence costs after a particularly hot and dry summer.

## 7. Weather Derivatives vs other types of risk management

### 7.1 Personal Lines Hedging Opportunities

#### 7.1.1 Background

Most re-insurance currently used in the personal lines insurance market is to protect against one-off big 'hits'. For example, a large weather event affecting property is usually covered by catastrophe re-insurance. For motor, there may be an excess of loss arrangement that pays out the excess over a set value on a claim.

Such re-insurance arrangements do not cover the medium to longer-term effects. How are claims affected over a wet summer or an especially cold winter, for instance?

#### 7.1.2 Household Insurance

Subsidence costs are heavily weather related. Not to a single weather event but to a continuing set of weather conditions which increase the possibility of subsidence or heave.

Using a sample of household subsidence claims over the past 7 years, a reasonably strong correlation can be found between summer rainfall (May to Sept) in the current and previous year and the current year subsidence frequencies. Thus it would be theoretically possible to purchase a weather derivative with pay out measured in rainfall - the less rain the more it paid out, hence going some way to covering the higher expected subsidence claims.

A similar approach could be used to protect against persistent continued rainfall over a long period. For example, from autumn 2000 to summer 2001, an exceptional amount of rainfall occurred in southern Britain. This lead to many small flood events (as well as a large event on 31st Oct 2002), all of which were related to the heavy rainfall, but where unlikely to invoke catastrophe arrangements due to being spread out over a number of weeks or months.

#### 7.1.3 Motor Insurance

Collision frequencies are intuitively affected by weather. We all know that it is more dangerous to drive on wet roads than when they are dry, that warm summer mornings are safer than icy mornings etc.

Using a sample of claims data by day and summarised daily weather data, we were able to do some basic GLIM analysis on several of the weather statistics. The resulting model found minimum and maximum temperature, wind speed, rainfall and snow depth to be good indicators of collision frequency.

Once day of the week and hours of daylight were added to the model, we experienced a monthly correlation of around 80% between the predicted collision frequency and the actual frequency over the past 5 years.

Limitations of the model were the unavailability of fog data, the inability to detect when the roads were wet rather than when it rained and combinations of factors such as rain in the evening followed by freezing temperature in the night. However, these would only serve to increase the correlation one would suspect.

On one particular day in December 2000, when there was significant afternoon rainfall followed by temperatures well below freezing point, resulted in a collision frequency around 2.5 times the average for that time of the year. Hence, persistent difference from the norm can build up to a significant deviation in claims costs.

Cost and availability aspects aside, there could be real potential for weather derivatives to reduce the volatility of claims costs. Take a derivative that pays out dependent on the amount of rainfall over a certain period. The more rain there is the more the derivative pays out. This pay out (partially) covers the extra cost due to the rain causing more motor accidents. Conversely, if the period is very dry, then the cost of buying the derivative is offset (or more than offset) by the low collision frequency.

The same principle can be applied to other weather statistics such as temperature, which is especially important in the winter as it can be a good indicator of whether there is ice on the roads or not. There could also be scope to go one step further and devise combinations of weather derivatives to hedge against specific insurance portfolios.

#### 7.1.4 Other Insurance

Most other types of personal lines insurance are not directly affected by weather, the obvious exception is event insurance, such as wedding policies which pay out on rainy days.

#### 7.1.5 Inherent Hedging

It is worth noting that for any given insurance portfolio, a degree of hedging already occurs. For example, if an insurance company writes just motor and household policies, to some extent, dry or wet weather will affect the two lines of business in opposite ways. So a wet summer may reduce the subsidence frequency but increase the motor collision frequency.

Using weather derivatives to hedge against some of the classes could in fact increase the claims cost volatility of the whole portfolio.

### 7.2 Non Insurance Industry Weather Derivative Opportunities

#### 7.2.1 Background

Most industries are affected by weather either directly or indirectly. In fact estimates in the US have pointed to around 15% of business are affected by weather. This is likely to be lower in Europe due to less extreme weather, but nevertheless, still a significant factor.

#### 7.2.2 Profit or Turnover Hedging

If it can be established that a company's profits or turnover are correlated to weather conditions, then in theory it could purchase a weather derivative to offset the variability. For example, a wine bar may conclude that during the summer its revenue is correlated to how warm and sunny the weather is - who doesn't like sitting out on a warm summer's evening sipping a cool glass of wine! The wine bar owner may justifiably be concerned if the weather is poor. He could purchase a weather derivative that pays out depending on how warm it has been over the entire summer, the warmer it has been, the less it pays out, up to a point where no pay out is generated.

Thus, on cold summers, the bar takings are down but there is some compensation from the derivative pay out. On warm summers, bar takings are good, but the derivative premium is paid and bears nothing. The derivative has effectively smoothed good and bad years.

There are a number of measures which could be appropriate in this example on which to base the pay out on, e.g. rainfall or hours of sunshine, either whole days or lunchtimes and evening etc. Most of the possible combinations are not widely available at present in Europe.

### 7.2.3 Sales Aids

There's nothing worse than buying a new 'toy' and no being able to use it because of the weather! Take for example skidoos (snowmobiles), a company in the US is offering money back on the purchase price if there is less than x numbers of snowy days during the next winter. For the salesman, this removes the argument of not being able to use it if the weather is not right and can be financed as a fixed marketing cost by purchasing a weather derivative.

This principle can be utilised across many products, for example convertible cars, sunglasses and even raincoats. Possibly one of the most popular uses would be on holidays, whereby the holidaymaker gets a refund which depends on the weather experienced while they were at their holiday destination. If you booked a week in southern Spain and it rained all the time you were there, you could claim back, say 75% or the original cost!

## 8. Acknowledgements

Conversations with Geroid Lane, Centrica

WRMA website (& information within)

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European Weather Derivatives…Update (article by William Gebhardt & David Pethick)

LIFFE website

Climetrix website(& information within)

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**APPENDIX A**

## CLIMATE CHANGE

One of the key reasons that the weather derivatives market may not have taken off in Europe is the fact that the weather has been both relatively stable and similar across Europe. This has meant that 1) there has been little demand to protect against volatility of weather-related profits and 2) there has been only a small market to trade risk because all areas have experienced relatively similar weather patterns.

However, anticipated climate changes may alter this picture and create a higher demand across Europe. Therefore, in this section, we look into:

- What has happened already?
- What changes are predicted to happen next?
- What impacts will this have? (especially on the weather derivatives market)

For each of these sections, we first look at the issues from a global perspective, including Europe and then more specifically at the UK.

Numerous research bodies have produced reports - which summarise what can be measured to have occurred already and predictions for the future (based on models they have built). We have summarised information from publicly available reports from the following bodies:

- Intergovernmental Panel On Climate Change (global government sponsored panel which summarises various research bodies reports)
- Tyndall Centre for Climate Change Research at the University of East Anglia
- Chartered Insurance Institute
- Weatheronline.co.uk

<u>Definitions</u>

Before considering the evidence we have that the climate is changing, and how changes are likely to develop in the future, it is worth stating a few definitions and discussing the causes of climate change.

- **Climate**

  Climate describes the average weather experienced in a region over a period of time, typically 30 years. A description of weather will include reference to temperature, wind and rainfall. The Earth's climate is not static; it has changed many times in the past in response to a variety of natural causes.

- **Climate Change**

  However, the term "climate change" usually refers to changes in climate that have been observed since the early 1900's.

- **What Causes Climate Change?**

  The Earth's climate varies naturally as a result of interactions between the ocean and the atmosphere; changes in the Earth's orbit; fluctuations in the amount of energy received from the sun and volcanic eruptions. Since the industrial revolution, the atmosphere has become increasingly polluted, and there is a large body of evidence to suggest that some pollutants are accelerating the process of climate change. For example, greenhouse gases (e.g. carbon dioxide), that have accumulated in the atmosphere over the last 200 years, are thought to trap the sun's energy in the lower atmosphere and alter the global climate. The overall picture is complicated because the effects of individual causes can cancel each other out or heighten each other's effects. Feedback mechanisms are thought to mask the effects of individual causes as well. For example, greenhouse gas emissions will be increased due to warming of the soil. It is therefore almost impossible to distinguish between the effects caused by individual factors.

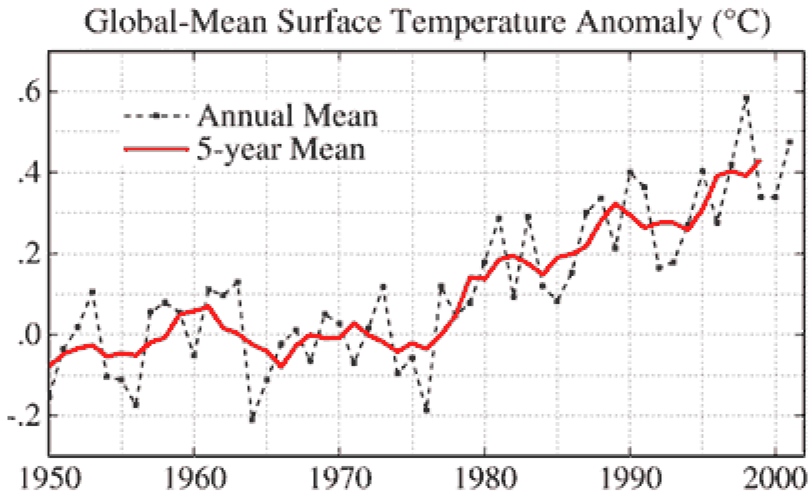
**What has happened already?**

**E**vidence For **C**hanges In The **G**lobal **C**limate

**Temperature**

Many different aspects of climate and its effects on the Earth's environment have been used to develop indices that highlight changes in climate. They range from noting changes in the fossil record to measuring changes in the make-up of gases trapped in ice cores dug from polar ice caps. However, the most useful index to describe the state of the global climate is the average surface-air temperature of the planet. Measurements are collated from millions of individual thermometer readings positioned around the world. Climate change indicators derived from this source go back to 1860 and show that global temperatures have risen by about 0.6$^{o}$C since the beginning of the 20$^{th}$ century. About 0.4$^{o}$C of this warming has occurred since the 1970's. To put these apparently small changes in temperature in context, the average temperature during the last Ice Age was only 5$^{o}$C below today's average. 1998 was the warmest year on record, and the 1990's were the warmest decade in the last 100 years. It is likely that the last 100 years were the warmest century in the last millennium. On 17$^{th}$ May 2002, the US National Oceanic and Atmospheric Administration (NOAA) reported that global temperatures for the month of April 2002 were the second warmest on record, with land and ocean surfaces 0.6$^{o}$C above the 1880 – 2001 long term average. April 2002 continues the recent trend of warmer than average temperature. Already, January and March 2002 have been the warmest months on global record.

The graph below shows the global annual surface temperature relative to 1951 – 1980 based on surface air measurements at meteorological stations and satellite measurements of sea surface temperature.




Source: Hansen, J., Ruedy, R., Sato, Mki., 2002. Global Warming Continues. Science 295, 275.

The following are direct consequences of a rising global temperature:

The length of the freeze-free season in mid-high latitude areas in many Northern Hemisphere areas has increased.

- Snow cover has decreased by about 10% since the 1960s.
- A near world-wide decrease in mountain glacier extent and ice mass.
- A decrease in Northern Hemisphere sea-ice amounts and a substantial thinning (some studies mention a reduction of up to 40%) of Arctic sea-ice in late summer.
- A rise of between 10 and 20cm in the global average sea level during the 20$^{th}$ century.

**Precipitation**

World precipitation patterns have shifted. This has been most marked in the mid and high latitudes of the Northern Hemisphere where levels of precipitation have been increasing. The table below documents the changes that have been observed to date:

| Direction of Change | Size of Change per Decade (%) | Region Affected by Change |
|---|---|---|
| Increase | 0.5 – 1.0 | Most mid and high latitudes of the Northern Hemisphere |
| Increase | 0.2 – 0.3 | Tropical regions |
| Decrease | 0.3 | Sub-tropical regions in the Northern Hemisphere |
| No significant changes | | Southern Hemisphere |

Indeed, during the latter part of the 20th Century, there has been a 2 – 4% increase in the frequency of heavy precipitation events in the Northern Hemisphere.

**E**xtreme **W**eather **E**vents

Extreme weather refers to slightly out of the ordinary weather conditions, and therefore does not include catastrophic events such as hurricanes. The increasing frequency of extreme weather events has also been cited as an indicator of climate change. Proponents point to the following to support their hypothesis that the climate is changing:

There has been a reduction in the frequency of extremely low temperatures with a corresponding increase in the frequency of extremely high temperatures.

- Warm episodes of the El Niño-Southern Oscillation phenomenon have been more frequent, persistent and intense since the mid-1970's compared with the previous 100 years.
- During the 20th century, there has been a small increase in the total land area experiencing severe drought or severe wetness.
- The frequency and intensity of droughts have increased in recent decades.

However, there has been no systematic change in the frequency of tornadoes, thunder days or hail events, and the following region specific indirect climatic change indicators have not changed by a measurable amount:

- Temperature in the Southern Hemisphere
- The extent of Antarctic sea-ice since 1978

**E**vidence for **C**hanges in the **UK C**limate

Records of the UK's climate, which extend back three and a half centuries, also show a measurable change in temperature. The 1990s were the warmest decade in central England. This year, in England and Wales, the mean temperature during April was 9.2$^{o}$C, some 1.3$^{o}$C above the 1961 – 1990 long-term average.

The increased over-land temperatures have been accompanied by warming of UK coastal waters as well. Other indications that the UK's climate is changing include:

- The thermal growing season for plants in central England has lengthened by about one month since 1900. Analysis of data collected over 47 years on 385 plant varieties showed that on average, the plants bloomed 5 days earlier during the 1990s than they had during the previous 4 decades.
- Heat-waves have become more frequent in summer, with the 1990s experiencing twice as many days with an average temperature above 20$^{o}$C than the rest of the 20$^{th}$ Century.
- There are now fewer frosts and winter cold spells.
- Winters over the last 200 years have become much wetter relative to summers throughout the UK; indeed, the 24-month period up to March 2001 was the wettest in England and Wales since records began in 1766.
- A larger proportion of winter precipitation in all regions now fall on heavy rainfall days than was the case 50 years ago.
- After adjusting for natural land movements, the average sea level around the UK is now about 10cm higher than it was in 1900.

One particularly memorable extreme weather event was the heat-wave during the summer of 1976, which lasted nine weeks. It represented the culmination of a prolonged drought that had begun in April 1975 causing extensive heath and woodland fires in southern England. A Drought bill was rushed through Parliament and a Minister for Drought was appointed to co-ordinate water conservation. Remarkably, temperature climbed to 32$^{o}$C on 15 successive days from 23$^{rd}$ June to 7$^{th}$ July inclusive; no previous or subsequent heat-wave has produced more than 5 consecutive days in which temperatures reached 32$^{o}$C or more.

A slightly more recent example of extreme weather occurred during December 1981 in which the mercury plunged to -18$^{o}$C across many areas and large parts of the country were snowbound for more than three weeks. At RAF Shawbury in Shropshire, the temperature sank to -22.6$^{o}$C at daybreak on the 12$^{th}$ and rising to only -12.1$^{o}$C during the afternoon. Whilst most exceptionally cold winters are characterised by long spells of dry and sunny weather punctuated by occasional snowfalls, December 1981 was different. Widespread and heavy snow fell regularly throughout the month, paralysing the transport system, closing schools and disrupting electricity supply.

**What changes are predicted to happen next?**

**W**hat will **H**appen in the **F**uture on a **G**lobal **S**cale?

A number of projection models have been evaluated by the IPCC to predict the effect of global warming on the Earth's climate. These models are based on four different emission scenarios: low emissions; medium-low emissions; medium-high emissions and high emissions. It is not possible to say which scenario is most likely, because this will depend on the future choices made by society. The scenarios simply provide alternative views of the future.

The results of these studies can be categorised under the general headings:

- Temperature
- Precipitation
- Sea Level Changes
- Snow and Ice
- Extreme events

Temperature

The average global surface temperature is projected to increase by between 1.4 and 5.8$^{o}$C from 1990 to 2100. Interestingly, this is significantly higher than the 1.0 to 3.5$^{o}$C increase projected for the same period in a previous IPCC report. This represents an acceleration in the rate of warming experienced during the 20$^{th}$ Century.

However, this warming will not be uniform across the globe – warming will exceed the global average by more than 40% in North America and North and Central Asia, but will be below the global average in South America and South-East Asia.

Precipitation

Global precipitation is expected to increase during the 21$^{st}$ Century as shown in the table below:

| **Region** | **Nature of Change** |
|---|---|
| Mid to high-latitudes | Increase |
| Antarctica | Increase |
| Low Latitudes | A mixture of increases and decreases |

**S**ea **L**evel **C**hanges

It is thought that global sea levels will increase by between 9 and 88 cm during the period 1990 to 2100. This will be caused primarily by thermal expansion of existing oceans and seas and by the loss of mass from glaciers and ice caps.

Snow and Ice

The extent of snow cover and sea-ice are expected to decrease further in the Northern Hemisphere. Glaciers and ice caps are projected to continue their widespread retreat during the 21st Century.

Extreme Events

The table below shows the predicted changes in extreme events along with the degree of confidence associated with each change.

| Region Affected | Change | Confidence |
|---|---|---|
| All land areas | Higher maximum temperatures and more hot days | Very likely |
| All land areas | Higher minimum temperatures and fewer cold and frosty days | Very likely |
| Many areas | More intense precipitation events | Very likely |
| Most mid-latitude continental interiors | Increased summer continental drying and associated risk of draught | Likely |
| Some areas | Increase in tropical cyclone peak wind intensities | Likely |
| Some areas | Increase in tropical cyclone mean and peak precipitation intensities | Likely |

Other studies broadly agree with these findings. The consensus of opinion is that unusually hot summers and other climatic extremes relative to current conditions are expected to become increasingly frequent in the future. For example, one study suggests that one-third of all years could have summers as hot as 1997 by 2050 and 12% of these summers could have less precipitation than 50% of the 1961 - 1990 average. Summer temperatures around the Mediterranean basin are expected to increase by more than $3^{o}C$ by 2050, exacerbating the existing heat-wave problems.

The trend towards windier winters is expected to continue with some models suggesting increases of up to 11% b 2080. Summer gales are also expected to increase in frequency. In north-western Europe, an increase in the mean and variance of wind speeds from south-east to north-west is expected, which will be augmented in coastal regions at high latitudes.

What will Happen in the Future in the UK?

One of the most comprehensive studies to date on the possible effects of global warming on the UK's climate was carried out by the Tyndall Centre for Climate Change Research at the University of East Anglia. Results were obtained using the latest global climate model from the Hadley Centre (one of the most comprehensively validated climate models in the world). It is based on the four different emission scenarios developed by the IPCC mentioned above.

The key findings of the research group at the Tyndall Centre can be grouped under the headings:

Temperature
Precipitation
Sea Level Changes

Temperature

- The UK climate will become warmer.

  By the 2080's, the average annual temperature in the UK may rise by between 2oc for the low emissions scenario, and 3.50c for the high emissions scenario.

  There will be greater warming in the south and east than the north and west, and there may be more warming in the summer and autumn than in the winter and spring.

  The temperature of UK coastal waters will also increase, although not as rapidly as over land.

- High summer temperatures will become more frequent, whilst very cold winters will become increasingly rare.

  A very hot August, similar to that experienced in 1995 when temperatures in England and Wales averaged about 3.4oc above normal, may occur one year in five by the 2050's for the medium-high emissions scenario, and as often as every three years in five by the 2080's. Even for the low emissions scenario, by the 2080's, about two summers in three may be as hot, or hotter than, the exceptionally warm summer of 1995.

Precipitation

- Winters will become wetter and summers may become drier throughout the UK. The relative changes will be largest for the high emissions scenario and in the south and east of the UK, where summer precipitation may decrease by 50% up to 30%. Summer soil moisture by the 2080's may be reduced by 40% or more over large parts of England for the high emissions scenario.

- Snowfall amount will decrease throughout the UK.

  The reductions in average snowfall over Scotland might be between 60% and 90% (depending on the region) by the 2080's for the high emissions scenario.

- Heavy winter precipitation will become more frequent.

  By the 2080's, heavy winter precipitation intensities that are currently experienced around once every two years, may become between 5% and (low emissions) and 20% (high emissions) heavier.

Sea Level Changes

- Relative sea level will continue to rise around most of the UK's shoreline.

  The rate of increase will depend on the natural vertical land movements in each region and on the scenario. By the 2080's sea level may be between 2 cm below (low emissions) and 58 cm above (high emissions) the current level in western Scotland, but between 26 cm and 86 cm above the current level in south-east England.

- Extreme sea levels will be experienced more frequently

  For some east coast locations, extreme sea levels could occur between 10 and 20 times more frequently by the 2080s than they do now, under the medium-high scenario.

Summary

Europe will become warmer and wetter than at present. In itself, this will not have a direct impact on the weather derivative demand, but a change in variability could do so.