Altevo Research

Hedge Fund Trading in Weather Derivatives

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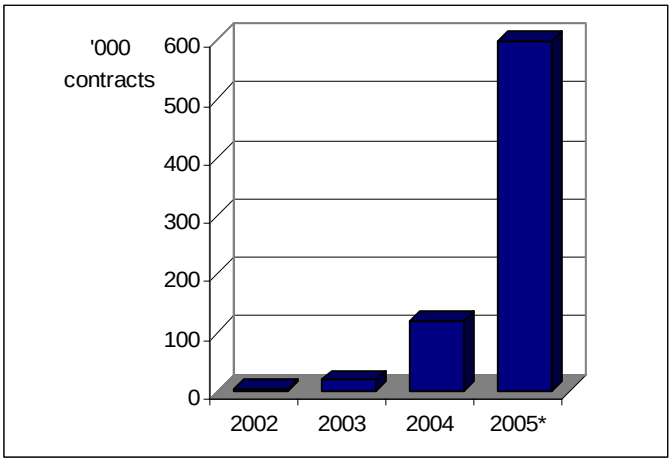
1. Introduction

The increased competition in the hedge fund industry and lacklustre performance seen in some of the strategies over the last few years has made more and more hedge funds look for alternative sources, and strategies, of revenue. One of the areas showing the fastest growth is weather derivatives.

The birth of the weather derivatives market mainly stems from a need for energy companies to hedge the impact of a much warmer or colder weather than normal. During the time with a regulated energy market the energy companies were often allowed to adjust the price towards the consumer as a result of unusual weather. When the market was de-regulated this adjustment of tariffs was no longer available and the price is now set in the open market and therefore the weather has to be hedge by other means. This was one of the major factors driving the weather derivatives market.

Another important factor is the effect of weather on the general economy. An estimate from the U.S Department of Commerce states that nearly one-third, or $3.8 trillion, of the U.S. economic activity is exposed to the weather. The impact of the weather on corporate profits seen historically, and the availability of new hedging products, has resulted in an increasing awareness in the corporate community. A risk management programme where weather risks are quantified and managed is therefore becoming more common. The explanation “due to unusual weather…” offered by several companies subject to a negative weather related earnings effect is no longer as justifiable as it historically has been.

Figure 1 Weather contracts traded on CME

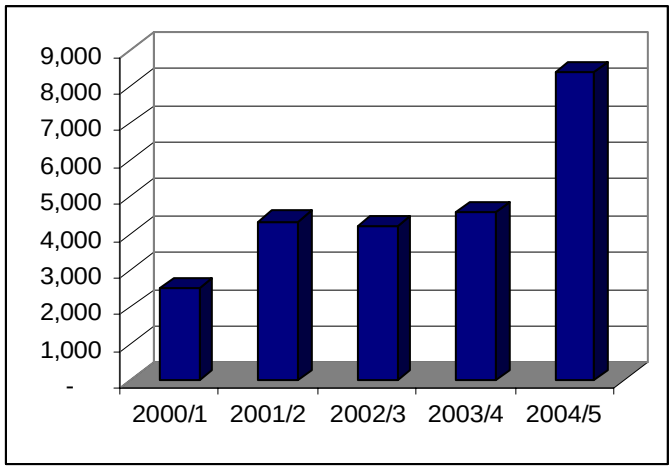


** 2005 until 20 September*
Source: The Economist, 29 September 2005

A distinction is usually made between the market for weather insurance and that for weather derivatives: insurance covers high cost, low probability events and derivatives cover low cost, high probability events. For example, insurance covers the damage from a severe storm while derivatives cover the impact of a colder than normal summer. Therefore, weather derivatives fills a gap in the product range offered in weather trading. Now companies and investors have the means to hedge and trade weather events not deemed as extreme. Starting as an OTC market in 1997, the market for weather derivatives has shown a strong growth. Standardized weather derivatives products based on temperature are now offered by the Chicago Mercantile Exchange (CME) covering 29 cities, 18 in U.S., 9 in Europe and 2 in Japan. As shown in Figure 1, up to 20th of September 2005, 612 000 contracts have been traded at the CME so far during 2005, a substantial increase from the 4,416 traded in 2002. Starting in February 2006 CME now also offers standardized products based snow fall for Boston and New York.

The notional total value of trading in weather derivatives, as reported in the 2005 PwC Survey of the Weather market, is displayed in Figure 2. Comparing Figure 1 and Figure 2 confirms the same strong growth during 2005, both in terms of contracts traded and notional value.

Figure 2 Total notional value in millions USD



Source: 2005 PwC Survey of the Weather market

Many of the characteristics hedge funds are looking for in an attractive market can be found in the weather derivatives market. This market is far less efficient than the traditional markets, such as equities or bonds, where hedge funds usually are active. Lack of liquidity has, as in many other new markets, been a problem in the weather market but this is quickly changing. A parallel can be drawn to the market for credit derivatives, which in the initial period also suffered from lack of liquidity. The credit area is now an integrated part of many hedge funds' trading strategies. In the same way, weather derivatives will create opportunities for hedge funds to trade, and arbitrage from price discrepancies, in weather related products.

An area of special interest from a hedge fund perspective is the impact and correlation of weather with a number of other frequently traded assets, such as different soft commodities, retail and energy stocks, and a number of new products for example trading in emission rights. Cross market trading the weather risk in these products, as well as intra-market trading based on e.g. the correlation, will offer plenty of very interesting trading strategies and opportunities for hedge funds in the coming years.

The remainder of this paper is structured as follows, in section 2 we describe the products, section 3 contains a summary of the pricing, in section 4 we examine trading strategies for hedge funds and section 5 includes concluding remarks.

2. Instruments in Weather Derivatives Trading

Products currently traded in the weather derivatives market include options, futures, forwards and swaps. A call option protects the buyer in case of excess weather and a put protects the buyer in case of a deficit in weather. The underlying, described in more detail below, can be temperature, amount of snow, rain, wind etc and the strike is set to a certain level or amount. Options can be combined into strategies such as straddles, spreads etc in the same way as in other derivatives markets. The investor can in this way get the desired payoff profile. Generally a maximum payout is specified as part of the contract i.e. the payout is said to be capped. Therefore, a normal option structure will have the payout profile of a collar.

Weather derivatives are flexible instruments and the underlying factor can, generally, be any measurable weather related event. Many trades in the weather derivatives market are OTC trades where the underlying weather event is tailored to meet the needs of the buyer.

Temperature has so far been the most common underlying weather factor in weather derivatives transactions. The temperature in a transaction in the U.S is usually measured in Heating Degree Days (HDD) and Cooling Degree Days (CDD). HDD and CDD are calculated as how much the average daily temperature deviates from 65˚ Fahrenheit (18˚ Celsius). The day's average is the average of the day's maximum and minimum temperature. For HDD deviations below, and for CDD deviations above, 65˚ Fahrenheit are considered. HDD contracts are traded for the winter season and CDD for the summer season and both types are structured as an aggregate over predefined period. The standardized contracts at CME are traded with monthly and seasonal maturity. Contracts on European cities are traded at the CME with HDD for the winter period and a Cumulative Average Temperature (CAT) for the summer period.

Other underlying factors can be precipitation, i.e. snowfall, snow depth or amount of rain, or sunshine, measured as the aggregated number of hours of sunlight, or as a percentage of possible hours of sunshine, during a certain time frame. Wind may also be used as the underlying and it can, for example, be set as the number of days the wind speed exceeds a certain level.

Besides the normal variables considered in derivatives trading, such as strike and expiry date etc for an option, some other variables are of importance in weather derivatives trading. The selection of a weather station, which weather related factor is used as the underlying, how this underlying factor is measured and if there is a cap on the payout if the option expires in the money, are areas to consider.

3. Forecasting Weather and Pricing of Weather Derivatives

Forecasting weather for time horizons longer than circa 10 days is well-known to be difficult. Winter forecasts are generally having a higher level of accuracy then summer forecasts. Spring and autumn represent transition periods between winter and summer and are therefore hard to predict. When pricing weather derivatives longer forecasts are needed, and preferable also ones that include the full probability distribution. Point estimates of the weather at a given time are of little value. The probability distribution used for analysing weather, and pricing of weather derivatives, are usually based on a model incorporating historic data and a forecast prediction. Most forecast and prediction models include a trend factor, due to global warming and urban heating, and a seasonal factor to reflect the time of the year. We here present an overview of different ways to price weather derivatives and for more in-depth material we refer to Jewson and Brix (2005).

Actuarial methods

Burn analysis

When weather derivatives are priced using a burn analysis average historic prices of an instrument with the same characteristics as the one being priced are used to determine the value. This method is fairly straight forward and simple and is a good staring point for pricing a weather derivative instrument. The advantage of the method is that is based on only a few assumptions and therefore also a limited amount of error sources. The main disadvantage is the sometimes low level of accuracy, as demonstrated by Cao, Li and Wei (2004) where they show that an HDD option priced with burn analysis can vary 300% in price depending on the length of the historic time period used in the analysis. As with any model based on historical data a weakness is that is assumes that the future will be a perfect reflection of the past, which is often not the case.

Statistical models

This group of pricing methods contain models that can provide more accurate pricing than actuarial pricing or burn analysis but generally subject to the trade off of being more complex. As we will discuss and demonstrate in more detail later in this paper, weather have cyclical- and trend patterns and often show a high autocorrelation. This is especially the case for temperature

and, together with a sometimes non-normal distribution in particular for monthly contracts, causes some challenges for the use of statistical models and adds to the complexity of the pricing.

One variant of a statistical method is named index modelling and here a distribution is fitted to the underlying weather index, i.e. the settlement index of the contract. An advantaged with this method is that it is easy to extract and calculated different variables with data from the model, while a problem can be to fit the correct distribution to the underlying weather distribution. Jewson and Brix (2005) summarize the use of burn analysis compared to index modelling by concluding that, among other things, index modelling is to prefer when longer data series are available, gamma is calculated and estimations of the variance in pay-offs are made.
Even more accuracy can be obtained, with an added level of complexity and an increased risk of model errors, when using the daily actual temperature instead of the settlement index when pricing a weather derivative contract. This method uses the whole distribution of the underlying, which is not the case for burn analysis or index modelling, and can therefore be used to estimate events that have rarely or never occurred in the available data.

Arbitrage-free pricing models

The arbitrage-free option pricing model by Black-Scholes in its original form is generally not applicable to weather derivatives. Some of the assumptions underlying their model are not valid for the behaviour of weather e.g. the underlying weather event is not a traded asset and for shorter time frames the distribution can be non-normal with a negative skew. Other types of pricing models have been suggested in academic papers during the last years but no one pricing formula or model seems yet to have established itself, as Black-Scholes for equity derivatives, as a standard in the industry.

4. Trading Strategies for Hedge Funds

Strategies involving weather derivatives can be applied by hedge funds in several ways, some of them discussed here.

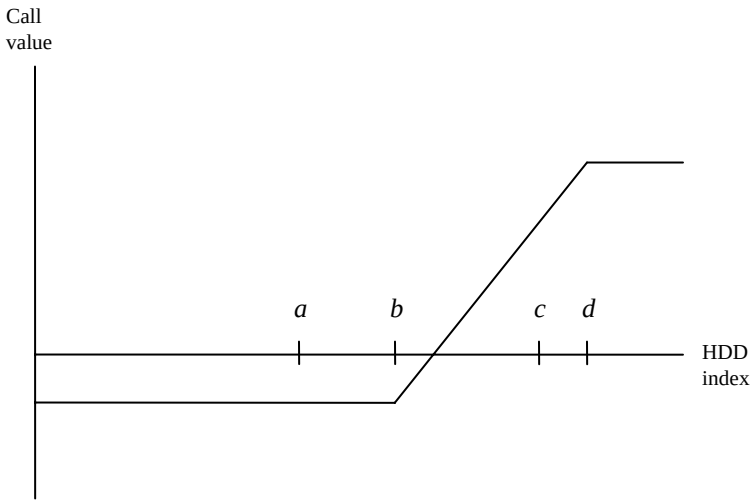
Directional trading

A long or short position in a weather related product is established based upon a meteorological model or forecast. If one believes to have a model for forecasting weather that is more accurate then the model used by most market participants, a long or short position can be initiated to exploit the advantage. We illustrate this form of directional trading with an HDD call option example, presented in Figure 3. Here *a* represents the value of the HDD index for a normal winter season and this also reflects what is currently expected and priced in by the market. The hedge fund has a different view, here the prediction for the coming winter is a much colder than normal with a HDD index value at *c*. A call option on the seasonal HDD index with a strike set at *b,* i.e. an out of the money call, is therefore purchased. If the hedge fund turns out to be right in its prediction for the winter season a substantial gain will be made. The payout is capped at a maximum payout representing a HDD index value of *d*.

Issuer of protection

The hedge fund can provide liquidity by acting as a seller of protection in the weather option market. The buyer can be a natural hedger, e.g. a utility company, with a high level of weather related risk. The hedge fund is then collecting premiums against offering weather protection. Although this can seem attractive, without a proper hedging program in place including a diversified portfolio with low average cross-correlations, a return profile with a significant tail risk can be the result. The return profile will be similar to that of other hedge fund strategies e.g. merger arbitrage.

Figure 3 HDD index call option



Even if the portfolio is geographically diversified a weather phenomenon such as El Niño could cause correlations moving towards one and cause several options expiring in the money, with a resulting negative impact on the return. If the options are structured with a maximum payout, as is normal, the downside risk for the written option is specified. This is a useful feature when doing different types of downside risk analysis and scenario analysis.

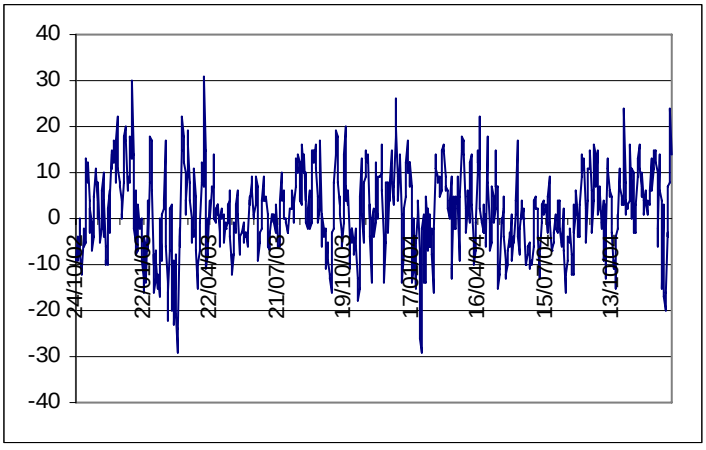
A short option strategy can create an artificially high Sharpe-ratio, that is, as long as no weather related event occurs and the options expire in the money. It is something to keep in mind when hedge funds with this kind of risk profile are ranked or evaluated according to measures assuming a normal return distribution, for example the Sharpe-ratio.

Correlation trading and relative value arbitrage

A correlation trading strategy is based upon the correlation between two entities, e.g. the temperature between two weather stations in the same area.

Although a long term trend of rising temperature exists, as mentioned earlier, temperature is mean reverting. An illustration can be seen in Figure 4, showing the daily temperature departure from normal in Minneapolis, U.S.

Figure 4 Minneapolis daily temperature departure from normal 24 Oct-02 – 31 Dec-04, ˚F



Source: National Weather Service

Trading strategies similar to those in statistical arbitrage or relative value arbitrage aiming at capturing the mean reverting feature can therefore be implemented. Here, the spread between the temperatures at two correlated weather stations can be traded on, for example, a model based on moving averages and set up on a long – short basis. The entry and exit points for initiating a position and taking profit/stop loss can be set to a pre-specified number of standard deviations from the mean.

We will illustrate correlation trading with an example from two weather stations in the U.S. One is located in Minneapolis, Minnesota, and the other one in Eau Claire, Wisconsin. The distance between the two stations is approximately 148 km. The data covers daily observations for the period October 2002 until December 2004 and was obtained from the National Weather Service. The data series used here is very short and the example should therefore only be considered as an illustration of a correlation based trading strategy. When implemented a similar strategy a much longer time series is needed to accurately model the relationship.

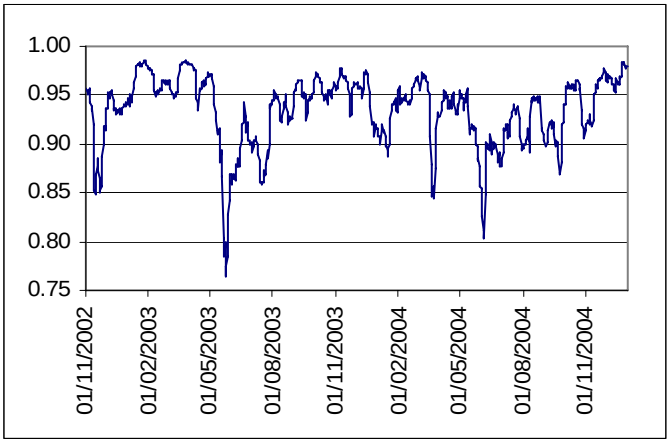
Table 1 Correlation Minneapolis – Eau Claire

Average temperature	0.99
Departure from normal	0.94
HDD*	0.97
CDD+	0.93

* Period November to March
+ Period May to September
Source: Author's own calculations

As seen in Table 1, the correlation is generally very high between the two stations. The average temperature is calculated as maximum plus minimum temperature divided by two. Departure from normal is measured as how much a single day's temperature deviates from the normal value, HDD and CDD values are calculated as described earlier. Although the correlations are generally very high they do change over time.

Figure 5 Correlation average temperatures Minneapolis – Eau Claire, rolling one month



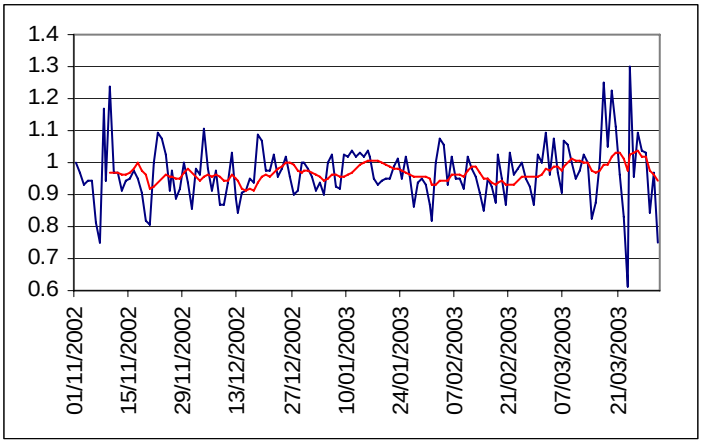
Source: Author's own calculations

In Figure 5 we display the correlation of average temperature calculated as a one month rolling window for the period November 2002 – December 2004. Here we clearly see the correlation being time-dependent and during periods substantially deviates from the near perfect correlation seen in Table 1. The stability of the correlation is an important factor to examine when a correlation based strategy is implemented.

Figure 6 shows the ratio spread, with the red line being a 10 days moving average, of HDDs between Minneapolis and Eau Claire during the HDD season of 2002 - 2003. The ratio spread illustrates some interesting features of the HDD concept. We earlier established that autumn and spring weather is harder to predict because both are transition periods between winter and summer. The impact of this can be seen in the spread ratio, the volatility is higher

during the start and the end of the HDD season. Compared to other ratio spreads, e.g. in the stock market, the temperature spread in this example is extremely volatile. This together with the very high correlation and the mean reverting feature makes for a compelling investment case for a hedge fund.

Figure 6 Ratio spread HDD Minneapolis/Eau Claire Nov 02- Mar 03



Source: Author's own calculations

For an arbitrage strategy like the one described here it is more suitable to use monthly contracts than seasonal as the underlying. With the seasonal contracts a single day's deviation will have a lesser impact since the contract is structured as an aggregate over a longer time period.

Another area that can offer interesting trading opportunities is relative value arbitrage strategies. Here, one can exploit the mispricing of weather risk in instruments within the same product category. The trades can be of similar structures as those in fixed income arbitrage, or equity market neutral strategies and set up on a long – short basis.

One area of special concern when applying some form of arbitrage strategy in weather derivatives is how the weather data is collected and measured. To facilitate a strategy not subject to a measurement bias, one should ensure that the weather stations or meteorological companies involved use the same measurement techniques.

Cross market trading

Weather derivatives can be used as a tool to isolate weather risk impacting other markets such as commodities and equities. The demand for many commodities, for example, is highly impacted by the weather. Cao, Li and Wei (2004) demonstrate with data from the state Illinois in U.S., that short-term demand for natural gas is driven by the temperature. They obtain an R^2 of 0.94 when regressing the monthly delivery of natural gas against the monthly average temperature. Arbitrage strategies can be structured to exploit mispricings of weather risk in a commodity relative to the weather risk reflected in the weather derivatives market.

A large number of companies, both in U.S and Europe, have during the last years issued profit warnings related to the weather. These companies are operating in a variety of sectors, e.g. utilities, retailers, and beverages manufactures and, except from for example utilities and energy companies, the profit warnings are usually volume related and not price related. As it is normally not possible to compensate a lower volume with increased prices a negative effect on earnings will be the result. Hence, hedge funds with long positions in stocks with a high degree of weather risk, such as a clothing retailer, can for example hedge the impact of a warmer than normal winter with a weather option. Buying a put option with the underlying set to a specified seasonal HDD index value reflecting normal winter conditions, can offset the negative impact from the stock position should the winter turn out to be warmer than normal.

As an example from the food&beverage sector, Unilever AS issued a profit warning on September 20 2004, blaming a drop in ice-cream sales and ready-to-drink tea on a colder than

normal summer weather. The stock subsequently dropped more than four percent that day. A problem when hedging weather risk as displayed in the Unilever case is the choice of a suitable hedge. An analysis of the company's sales by European region is required. Is the sales located to a certain area or spread across Europe? If sales are spread over several regions, as for Unilever, hedging with just one weather station can cause problems. If a similar structure is applied there is a risk that a drop in correlation could occur, resulting in an inefficient hedge. One way of addressing this issue can be to include several weather stations in the hedge. For example, the weights in the hedge can reflect the proportion of sales from different regions. Applying a hedge including several stations instead of just one can result in a more efficient hedge.

Ameko (2004) use a portfolio of utilities and natural gas related stocks to demonstrate that a superior performance can be achieved when the weather risk is hedged with CDD and HDD put options. As the volatility of the return in his study also is lower than if no weather hedging is applied a higher Sharpe-ratio will be the result, an attractive feature for any hedge fund. To conclude, if a company listed on the stock exchange does not have a weather hedging program in place the investor can hedge the risk himself with the use of weather derivatives.

5. Conclusions

The weather derivatives market offers many new and interesting trading opportunities for hedge funds and many of the strategies now available have not been possible to exploit earlier. Furthermore, the characteristics of weather as an underlying asset, e.g. on an aggregated level uncorrelated to traditional assets, mean reverting and highly volatile, also add to the attractiveness of these products. As the market grows and liquidity improves the number of potential strategies will increase dramatically. Combining the traditional markets for hedge funds, such as equities and commodities, with the use of weather derivatives can further enhance performance and at the same time lower risk. Especially arbitrage strategies, like cross market trading and correlation trading discussed in this paper, could offer a skilled hedge fund manager a vast range of possibilities to create alpha.

Other new products depending on the weather, e.g. emission rights trading and renewable energy, will also offer a range of possibilities when traded together with weather derivatives. After the success of temperature based derivatives traded on the CME it is also likely to see further products added to the existing ones. Standardized products in areas like precipitation and wind would add even more new areas for hedge funds to exploit.

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