Weather Derivatives/Insurance

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Weather Insurance/Derivatives workshop
GIRO 1999.

Abstract

This paper and the workshop will concentrate on the issue of pricing this business, as this is likely to be where the actuary is asked to help.

Portfolio management issues will also be mentioned.

Some actual weather data, as provided in a typical submission is provided in the appendix. You may find the workshop more useful and interesting if you have an attempt at using the data provided to estimate the expected loss costs of the contracts suggested. If you wish to obtain an electronic copy of the data then E-mail thartington@qbe-london.com

Some suggested approaches to pricing these risks are suggested in this paper. These are intended to provide food for thought and are not intended to be prescriptive.

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Summary of the expected workshop

The subject of this workshop are the derivatives which have been traded in the US for the past 3 years. They are predominantly denominated in Heating Degree Days (HDD) or Cooling Degree Days (CDD) and cover a period of 3 months. This workshop will not cover the topics of Pluvius or event weather cover, which are usually for a cover period of only a few days.

A Heating Degree Day is defined in the US as:

HDD(day) = Max(0, {Average[Min (°F temp), Max (°F temp)] – 65°F})

Similarly a Cooling Degree Day is defined in the US as:

CDD(day) = Max(0, 65°F - {Average[Min (°F temp), Max (°F temp)] })

In decimalised countries the 65°F is usually replaced with 18 °C and °F temp with °C temp.

A HDD is a cold day for which heating may be desired.
A CDD is a hot day and air conditioning may be desired.

Other contracts may cover rainfall, snowfall, number of days where the average temperature is less than a given amount or various other statistics. For the sake of simplicity we will concentrate on HDD and CDD.

As the first major players in the market were energy companies who were used to selling and buying energy derivatives, the terminology used in these contracts is predominantly that of the derivatives traders. However, these are usually synonymous with terms used to describe excess of loss contracts.

For example, a deal may be described as:

CDD Call
$10K per tick
$3M limit
500 strike
800 cap.

In excess of loss terminology this is a 300 xs 500 layer.
The tick is the amount paid out per CDD more than 500. The limit is the monetary amount payable. In this example, the "cover" is $3M/$10K = 300 = cap – strike.

Similarly, a deal may be described as:

CDD Put
$10K per tick
$3M limit
500 strike
200 floor.

In this case the conversion to excess of loss terminology is more difficult, but it should be simple to see what it means.

Such weather derivatives are a recent innovation. It is understood that the total number of trades is numbered in the dozens rather than hundreds. The first trade was completed in July 1996 between Aquila Energy and Consolidated Edison, the latter protecting itself against milder than expected weather. Currently the major players in this market include:

Energy companies
Koch Industries Inc. – who own gas and oil pipelines, refineries and other petrochemical operations.
Enron – who are market leaders in the US gas and electricity supply industry
Aquila Energy – who are also major players in the US gas and and electricity supply industry.

Reinsurers
American Re
Swiss Re

Other reinsurers who also believed to participate in this market include:
St Paul Re
Employers Re
Renaissance Re
Tempest Re

Data for several specimen contracts are provided in the appendix. It may be useful if readers could think about how they may analyse the data before reading the paper. It may be interesting if workshop attendees could bring along their estimates of the prices of the contracts to the workshop so that we could see the range of figures.

Also, it may be useful to ignore the 1998 data, estimate the expected loss cost for a contract covering the 1998 season, then compare the expected loss costs against the losses that would have been suffered using the actual experience of 1998.

Suggested pricing considerations

The weather, is known to be chaotic in the mathematical sense. That is it is sensitive to initial conditions. We've heard all about what effect butterflies have on hurricanes.

This chaotic behaviour is a short-term phenomenon. Over period of time, a season, the behaviour of the climate emerges. It is not clear whether climate is chaotic to the same degree that weather is.

In fact, as climatologists are now able to predict with a degree of certainty the onset of El Nino events (El Nino Southern Oscillation, ENSO) this indicates that climate is not sensitive to initial conditions in the same way that weather is. Thus to some extent climate is predictable for some time in the future, even though weather predictions have a low credibility beyond a few days.

For the rest of this paper we will use the terms weather and climate interchangably.

When submissions for weather contracts are received from the broker they tend to have various statistics already calculated for the underwriter, such as means and standard deviations over a range of historical periods. Strike points are often quoted in terms of numbers of standard deviations away from the long-term average for the statistic (CDD, HDD, etc.). Are some underwriters using these statistics to price these contracts?

It is suggested that there are several factors that will affect the weather data in a way that can be quantified, and which could be used to price this business. These include:

Long-term trends in weather data

- Global Warming – this is still a contentious issue amongst climate scientists. The warming, if there is any, is not expected to affect all latitudes equally. Indeed, some computer climate models (GCMs) predict that some areas will cool despite an overall warming. It is not apparent from the data in many weather risk submissions that there has been any warming trend over the past few decades..
- Urbanisation around the weather station. Many of the weather stations used are located at airports some distance from the city centres. However, there will usually have been some degree of property development near the station which could have an impact on the weather data.
- Heat Island effect – waste heat from a city keeps night-time temperatures in winter higher than they would otherwise be.

- SO_2 pollution, and other aerosols that have a cooling effect. Aerosols (small dust particles such as those emitted by burning fossil fuels) affect cloud formation which in turn affects the amount of sunlight reaching the ground.

Cycles in climate

- ENSO (SOI Index) – This is a cyclical change in the prevailing winds across the Pacific Ocean between Australia and the west coast of South America
- North Atlantic Oscillation (NAO Index) – this is an index of winter sea surface pressures differences between Portugal and Iceland.
- North Pacific Oscillation (NP Index) – this is an index of area-weighted sea level pressure over the region 30N-65N, 160E-140W.
- Quasi-Biennial Oscillation – this is a pattern of the variable east-west oscillating stratospheric winds which circle the globe near the equator.
- Other oceanic and atmospheric circulation cycles
- Long-lasting sea surface temperature (SST) anomalies, or sub-surface temperature anomalies such as those caused by Mediterranean outflows into the Atlantic ocean.
- Great salinity anomalies – these are areas of oceans which are long-lasting anomaloiusly fresher than the surrounding areas.
- Solar-Terrestrial links – e.g. solar magnetic activity (T-Index). See the 1997 GISG Catastrophe modelling paper for a description of the causal link between solar activity and climate.

Jumps in weather data

- Volcanic eruptions (Dust Veil Index)
- Changes to the weather stations such as change in instrumentation or change of location.

Note that Bill Gray's hurricane forecasts (http://typhoon.atmos.colostate.edu/forecasts/) use a similar approach for forecasting the likely level of hurricane activity in a season.

The above indices are readily available at a number of websites.

When pricing these risks the basic approach is to estimate the expected value of the statistic in question for the cover period, then fit a distribution around this. The main questions to be answered are then:

- What is the expected value?

Do you just use the historical value of the statistic (eg HDD) or is it better to go back to the underlying daily temperatures?

How do you allow for the state of the weather at the time you are pricing the deal. For example, if you are pricing a winter deal in August, and it has been a cooler or hotter summer than usual, how do you allow for this – should you allow for this?

How do you allow for the potential for jumps in the period, say caused by a large solar flare disrupting the global climate?

- What is the expected distribution around this?

Is the distribution symmetrical?
How do you allow for the possibility of there being a jump in the period, say caused by a large volcanic eruption? How will this affect the distribution?

- What is the standard deviation of this distribution?

Is there enough data to measure this?
How much of the historical variation is random/unexplained and how much is explained by cycles and trends?

Does the amount of variability depend on the phase of the cycles? For example, are temperatures more or less volatile in El Nino years?

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Location	Boston	Chicago	Chicago	Chicago	Dallas Fort Worth
Put/Call	Put	Call	Put	Put	Call
units	CDD	CDD	HDD	HDD	CDD
Period	6-8/99	6/99	10-12/99	11/99-03/00	5-9/99
Strike	600	150	2,100	4,800	2,500
Tick	10,000	10,000	10,000	10,000	10,000
Limit	2,000,000	1,000,000	2,000,000	3,000,000	3,000,000
Floor/Cap	400	250	1,900	4,500	2,800
1949	861				
1950	586				
1951	554				
1952	788				
1953	672				
1954	501				
1955	808				
1956	617				
1957	635				
1958	526				
1959	677	209		5,675	
1960	653	101	2,340	5,557	
1961	603	127	2,352	5,191	
1962	477	139	2,361	5,627	
1963	645	179	2,478	5,832	
1964	410	186	2,486	5,537	
1965	550	75	2,044	5,666	
1966	680	163	2,281	5,076	
1967	554	166	2,312	5,174	
1968	581	186	2,265	5,081	
1969	631	106	2,377	5,215	
1970	666	178	2,102	5,516	
1971	674	269	1,816	5,203	
1972	548	102	2,579	5,230	
1973	768	183	2,090	4,925	
1974	526	80	2,204	4,972	2,150
1975	728	197	1,887	5,053	2,218
1976	741	174	2,920	4,531	1,999
1977	689	173	2,436	5,787	2,753
1978	563	127	2,368	5,939	2,597
1979	637	157	2,093	5,852	2,160
1980	737	96	2,417	5,260	3,017
1981	703	151	2,465	5,119	2,215
1982	554	36	2,058	5,769	2,339
1983	872	182	2,680	4,725	2,100
1984	802	177	2,194	5,780	2,454
1985	513	67	2,695	5,512	2,429
1986	495	115	2,288	5,547	2,367
1987	481	235	2,206	4,796	2,348
1988	784	243	2,443	5,121	2,464
1989	589	118	2,647	5,050	2,071
1990	629	173	2,170	4,961	2,449
1991	763	220	2,348	4,854	2,287
1992	463	76	2,389	4,892	2,085
1993	737	113	2,366	5,265	2,500
1994	835	209	1,886	5,441	2,321
1995	724	245	2,525	4,704	2,350
1996	518	149	2,511	5,650	2,476
1997	650	155	2,311	5,391	2,220
1998	581	199	1,846	4,578	3,117

Location	Des Moines	Las Vegas	Philadelphia	Pittsburgh	Tucson, AZ
Put/Call	Put	Put	Put	Put	Call
units	HDD	CDD	HDD	CDD	CDD
Period	10-12/99	4-8/99	11/99-3/00	4-8/99	5-9/99
Strike	1,950	2,400	3,750	570	2,800
Tick	10,000	10,000	10,000	10,000	10,000
Limit	2,000,000	3,000,000	3,000,000	2,000,000	3,000,000
Floor/Cap	1,750	2,100	3,450	370	3,100
1949		2,239	3,446		2,530
1950		2,296	3,751		2,285
1951		2,258	3,882		2,667
1952		2,360	3,864		2,743
1953		2,153	3,562	750	2,608
1954		2,497	3,746	673	2,666
1955		2,089	3,941	829	2,357
1956		2,348	4,331	563	2,768
1957		2,239	3,875	664	2,616
1958		2,582	4,151	542	2,776
1959		2,595	4,310	881	2,495
1960	2,284	2,574	4,245	480	2,503
1961	2,610	2,486	4,535	639	2,381
1962	2,304	2,390	4,472	542	2,459
1963	2,300	2,266	4,676	452	2,598
1964	2,448	2,280	4,312	556	2,300
1965	1,961	2,135	4,242	534	2,130
1966	2,427	2,565	4,247	773	2,458
1967	2,422	2,312	4,193	620	2,413
1968	2,648	2,182	4,253	646	2,402
1969	2,543	2,543	4,402	629	2,614
1970	2,238	2,444	4,575	696	2,515
1971	2,095	2,346	4,130	657	2,259
1972	2,909	2,502	3,938	535	2,353
1973	2,275	2,554	3,804	801	2,401
1974	2,218	2,585	3,840	596	2,462
1975	2,011	2,316	3,716	633	2,333
1976	2,843	2,259	3,657	303	2,442
1977	2,468	2,611	4,616	502	2,632
1978	2,478	2,546	4,652	742	2,699
1979	2,193	2,512	4,081	547	2,628
1980	2,375	2,404	4,104	833	2,606
1981	2,309	2,836	4,431	579	2,652
1982	2,167	2,240	4,359	466	2,326
1983	2,840	2,115	3,760	745	2,561
1984	2,305	2,447	4,420	527	2,643
1985	3,038	2,787	3,973	497	2,684
1986	2,457	2,663	3,954	665	2,723
1987	2,265	2,474	3,996	834	2,686
1988	2,414	2,499	3,994	899	2,838
1989	2,717	2,763	3,877	746	3,025
1990	2,350	2,555	3,857	612	2,706
1991	2,492	2,221	3,382	965	2,600
1992	2,451	2,636	3,754	500	2,798
1993	2,465	2,500	3,863	881	2,842
1994	2,066	3,001	4,059	770	3,196
1995	2,550	2,493	3,436	1,002	2,754
1996	2,686	2,887	4,498	625	2,879
1997	2,455	2,738	3,842	484	2,927
1998	2,100	2,343	3,463	704	2,610