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Ocean wave forecasting systems and their use in the financial/energy industry

The weather influences both the economy and people directly and at all times. Human irrationalities in the capital markets have been studied for some time as a separate branch of research in behavioral finance. For example, human behavior in the markets under the influence of the weather.
It is estimated that at least 80% of all processes in the global economy are indirectly or directly affected by the weather. Thus, the weather becomes the object of consideration for many industries, primarily the financial and energy industries in the context of commodity trading, renewable energy production and, in turn, the price of electricity.
The aim of this model is to determine certain ocean wave parameters such as fetch length, wave height and wave period. Input data are water temperature, air temperature, wind strength, duration of these and the exact location. The individual calculation steps are shown as examples:

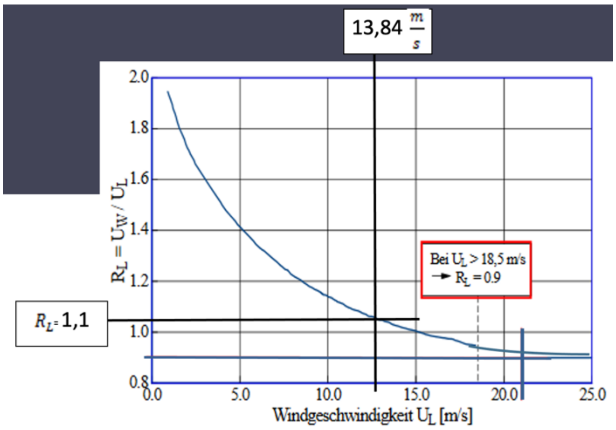
1) Calculate wind stress factor:
Equation:

$$U_{10} = U_Z \cdot \left(\frac{10m}{z}\right)^{\frac{1}{7}} \quad R_Z = 1{,}076$$

With the according values:

$$U_{10} = 11\frac{m}{s} \cdot \left(\frac{10m}{2m}\right)^{\frac{1}{7}} = 13{,}84\frac{m}{s}$$

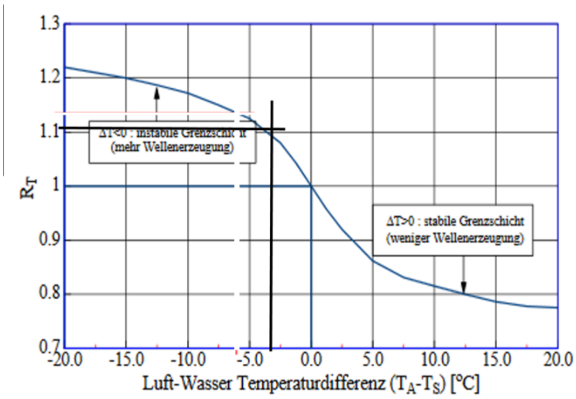
1) Wind speed conversion factor:



2) With the according values:

$$U_w = 1{,}1 \cdot 13{,}84\frac{m}{s} = 15{,}224\frac{m}{s}$$

3) Umrechnungsfaktor der Luft-Wasser Temperaturdifferenz:



4) With the according values:

$R_T = 1{,}11$

$U_{10} = U_W \cdot R_T = 15{,}224\ \frac{m}{s} \cdot 1{,}11 = 16{,}89 \frac{m}{s}$

5) Calculate wind stress factor:

$$U_A = \sqrt{0{,}53 \blacksquare 0{,}047 \cdot U_A} \cdot U_A$$

$$U_A = \sqrt{0{,}53 \blacksquare 0{,}047 \cdot 16{,}89 \frac{m}{s}} \cdot 16{,}89\ \frac{m}{s}$$

$$U_A = 19{,}43 \frac{m}{s}$$

6) Calculation of the dimensionless fetch:

T= 1,2 h (4320 Sekunden)

$$\tilde{x} = 1{,}752 \cdot 10^{-3} \cdot \left(\frac{g \cdot t}{U_A}\right)^{\frac{3}{2}}$$

$$\tilde{x} = 1{,}752 \cdot 10^{-3} \cdot \left(\frac{9{,}81 \frac{m}{s^2} \cdot 4320}{19{,}43 \frac{m}{s}}\right)^{\frac{3}{2}}$$

$$\tilde{x} = 178{,}46$$

7) Actual fetch length in m:

$$\tilde{x} = \frac{g \cdot F}{(U_A)^2} \qquad F = \frac{178{,}46 \cdot (19{,}43)^2}{9{,}81}$$

$$F = \frac{\tilde{x} \cdot (U_A)^2}{g} \qquad F = 6867{,}79\text{m} \approx 6/\ 6{,}5\ \text{km}$$

8) Determine wave height:

$$H_s = 0{,}0016 \cdot \left(\frac{g \cdot F}{(U_A)^2}\right)^{0{,}5} \cdot \left(\frac{(U_A)^2}{g}\right)$$

$$H_s = 0{,}0016 \cdot \left(\frac{9{,}81\frac{m}{s^2} \cdot 6867{,}79m}{\left(19{,}43\frac{m}{s}\right)^2}\right)^{0{,}5} \cdot \left(\frac{\left(19{,}43\frac{m}{s}\right)^2}{9{,}81\frac{m}{s^2}}\right)$$

$$H_s = 0{,}822\,\mathrm{m}$$

9) Calculate wave period:

$$\frac{gT_P}{U_A} = 0{,}2857\left(\frac{gF}{U_A^2}\right)^{1/3}$$

$$T_p = 0{,}2857 \cdot \left(\frac{g \cdot F}{(U_A)^2}\right)^{\frac{1}{3}} \cdot \left(\frac{(U_A)}{g}\right)$$

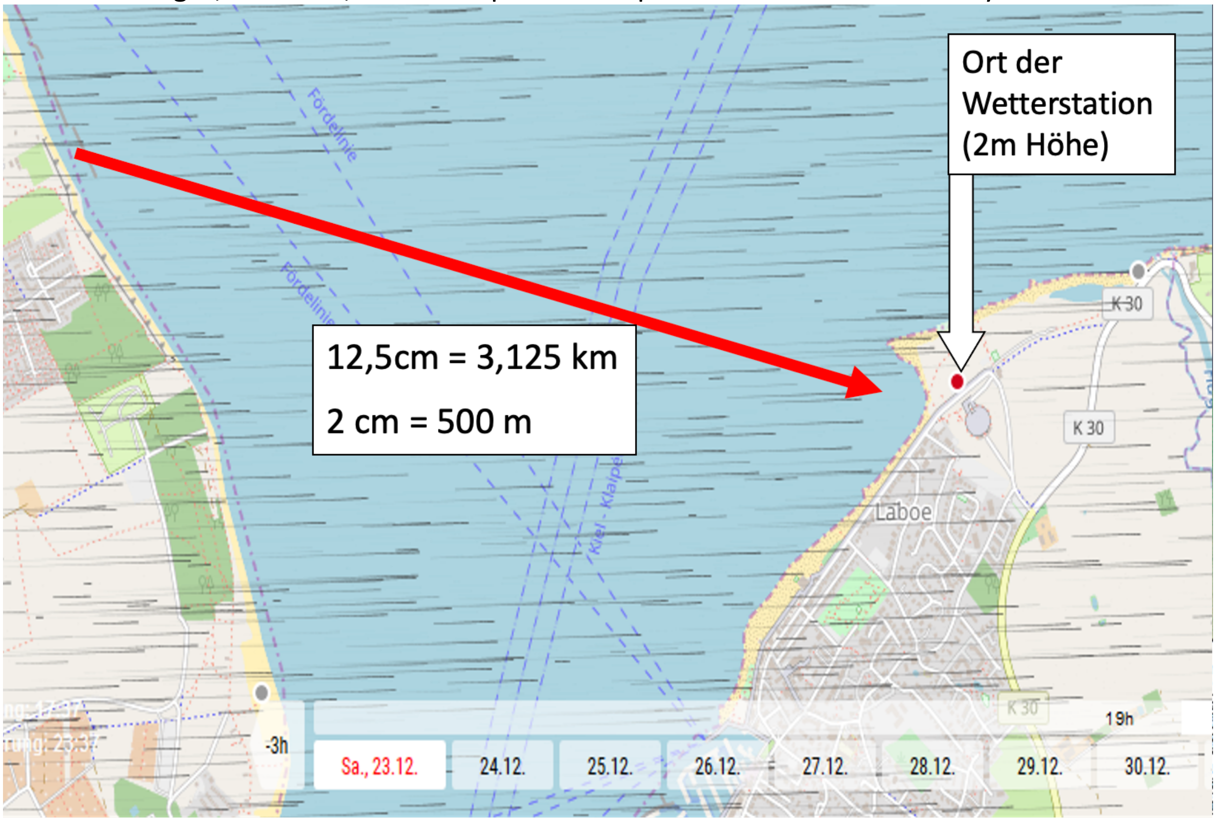
$$T_p = 0{,}2857 \cdot \left(\frac{9{,}81\frac{m}{s^2} \cdot 6867{,}79m}{\left(19{,}43\frac{m}{s}\right)^2}\right)^{\frac{1}{3}} \cdot \left(\frac{\left(19{,}43\frac{m}{s}\right)}{9{,}81\frac{m}{s^2}}\right)$$

$$T_p = 3{,}185\ \text{Sekunden}$$

Examination of the results shows a relatively good approximation:

Lokales Datum	Samstag, Dez 23														
Lokale Zeit	07h	08h	09h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h
Windrichtung															
Windgeschwindigkeit (m/s)	13	13	13	13	14	14	14	14	13	13	14	14	13	13	13
Windböen (max m/s)	21	21	21	21	22	21	22	21	21	22	23	24	24	23	23
Bewölkung															
Niederschlagsart															
Niederschlag (mm / h)															
Lufttemperatur (°C)	7	7	7	7	7	7	7	7	7	7	8	8	8	8	8
Gefühlte Temp. (°C)	1	1	1	2	1	1	1	1	2	2	2	2	3	3	3
Rel. Luftfeuchte (%)	100	100	100	100	99	100	100	100	100	100	96	96	94	93	92
Luftdruck (hPa)	1021	1020	1019	1020	1019	1019	1018	1018	1018	1017	1017	1016	1016	1015	1015
Wellenrichtung															
Wellenhöhe (m)	0.8	0.8	0.8	0.8	0.9	0.9	0.8	0.9	1.0	1.0	0.9	0.9	0.9	0.9	0.9
Wellenperiode (s)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

The fetch length, however, does not quite correspond to the actual in reality.



Since the weather represents a major risk factor for many industries, an attempt was made to find some kind of insurance option for it on the stock exchange. This was the birth of weather derivatives at the end of September 19997 , which are traded exclusively by institutional market participants to hedge against precisely these weather risks. The exact design of these financial products traded as weather derivatives consists of.
¾ options and ¼ swaps, collars, straddles and strangles.

Unterschiede Wetterderivate und herkömmliche Derivate:

- Daily temperatures, precipitation amounts or snow depths not tradable in an economic sense
- no fluctuations of the market price
- value fluctuations exclusively from past weather data
- market participants cannot influence the market price
- no delivery of the commodity or a maturity date
- Underlying value depends on risk depends on the underlying:

    Temperature as a base value is very common worldwide, around 95 percent of derivatives refer to this base value Wind speed, rain, water level, cloud cover or even the duration of sunshine or humidity. Which reference value is sensible to choose depends on the risk to be hedged and on the company in question.

7 central features of weather derivatives:
Location: Usually, weather derivatives refer to a measuring station at a specific location, e.g. Frankfurt Airport.

Underlying index: The most common indices are HDD and CDD indices. However, precipitation amounts, wind speeds, and other weather characteristics are also possible.

Time Period: Weather derivatives usually refer to monthly, e.g., January 2001, or seasonal periods, e.g., heating season from October 2000 to March 2001.

Exercise price: In most cases, the exercise price is expressed in HDD or CDD. It indicates the value above which one side of the contract must make financial compensation payments to the other.

Nominal amount: This is the value measured in euros, e.g. euros 10,000 per measured HDD, that one contract side must pay to the other.

Upper limit (cap) or lower limit (floor): Caps and floors limit the maximum payout that can result from a weather derivative. They are usually also expressed in HDD or CDD.

Premium: In option contracts, the buyer of the option pays the seller an individually agreed premium. Swaps generally manage without premium payments due to the symmetrical payment structure.