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WEATHER CLASSIFICATION AS A TOOL IN PREDICTION OF OUTDOOR SOUND PROPAGATION

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ABSTRACT
Weather classification is a meteorological tool often used to connect synoptic or larger scale circulation to local meteorology. In this paper is Sea level pressure in a 5*5 degrees grid is classified according to geostrophic wind (wind in balance between air pressure and coreolis effect) direction and curvature. These classes are connected to various meteorological parameters, including directional sound velocity gradients (DSVG). DSVG governs the deviation of sound propagation from the pure topographical effects, thus saying that large atmospheric circulation governs local sound propagation conditions. To find the effect of variations in DSVG has a few selected DSVG been used as environment in OASES.

1 - INTRODUCTION
Two parts govern long distance sound propagation: Terrain and meteorology. The effect of terrain, topography and ground type is not discussed in this study. It's been known for a long time that meteorology effect outdoors sound-propagation [1]. Meteorologists are able with a fair accuracy to predict meteorological conditions a few days ahead. Weather classification is a tool that has been used to help meteorologists forecast local impact of various meteorological conditions. In this paper is a weather classification system developed, and applied to forecast sound propagation conditions.

2 - WEATHER CLASSIFICATION
The objective weather classification (OWC) presented in this paper is based upon a subjective weather classification made by Harald Johansen [2].
The idea in this system is to calculate the geostrophic wind (1), which is a theoretical wind in the balance between pressure and coreolis forces. Geostrophic wind will deviate from local wind since friction and topographical effects are ignored.

$$\begin{aligned} \vec{V}_G &= \frac{1}{f}\vec{k} \times \nabla\Phi \\ f &\equiv 2\Omega \sin(\phi) \end{aligned} \tag{1}$$

The classes are defined from geostrophic wind direction and curvature in a defined area. Practical implementation in this study uses a pressure field with 5 ×5 degrees resolution. From a set that covers the Northern Hemisphere is a subset of 5 ×5 grid points (20 ×20 degrees) with a central grid point near the chosen location. Pure high and low pressure situations are extracted by comparing the corners with the central point. For situation that's neither high or low pressure is geostrophic wind in three sets of 3 ×3 grid points calculated (central, upwind and downwind). The central set is used to classify the weather into 8 groups dependent on direction of geostrophic wind. Upwind and down wind is compared to reveal curvature the curvature of the pressure-fields, the 8 groups are split into two according curvature. The classification provides 18 circulation indexes (CI) according to table 1.

Wind direction	Cyclonic curvature	Anti-cyclonic curvature
North-east	11 / C-NE	21 / A-NE
East	12 / C-E	22 / A-E
South-east	13 / C-SE	23 / A-SE
South	14 / C-S	24 / A-S
South-west	15 / C-SW	25 / A-SW
West	16 / C-W	26 / A-W
North-west	17 / C-NW	27 / A-NW
North	18 / C-N	28 / A-N
Low/High	19 / LOW	29 / HIGH

Table 1: Definition of weather classes.

3 - VERIFICATION OF THE CLASSES

To verify that the classes constructed in last section really discriminates between different kinds of climate has multiple data sets been used, in this paper will one example be provided. Data is from a synoptic meteorological station at Ferder in Oslofjorden. Meteorological data from the period of January 1951 to February 1998 has been used.

The first parameter to be examined is absolute temperature. Measured temperature has various time scales, the two major time scales are seasonal and diurnal. This study uses daily mean temperature and will not predict diurnal variations. The main seasonal effect is removed from the data set by removing the 30 years normal daily temperature. Figure 1 shows monthly mean temperature deviation from the 30 years normal and standard deviation from Ferder. It is clear that most types of circulation, as captured by OWC, have different effect in the wintertime than summer time. It is also clear that the various CI shows different effects on the temperature. Studies of different stations reveal that this effect is not singular for this weather station, but represents a typical response.

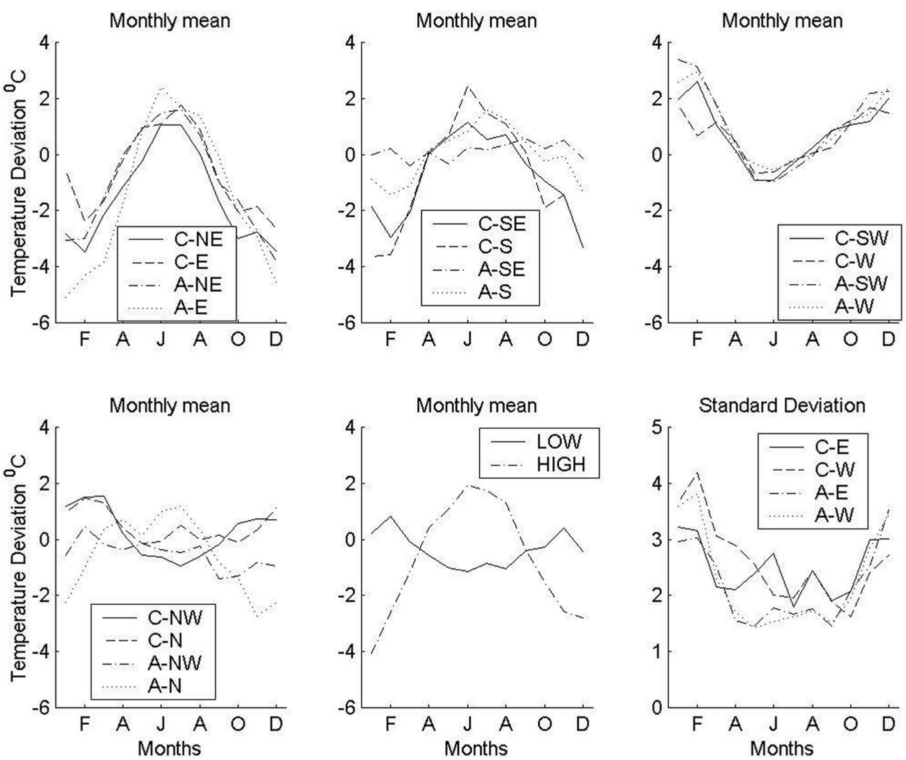

Figure 1: Class dependent variations in seasonal temperature anomaly at Ferder; title of plots indicates direction of propagation.

The next parameter is wind direction. Same station and data period as above is used. Figure 2 shows scatter-plots of wind direction split into classes. There is three scatter plots representing three different groups of geostrophic wind. This to the belief that strong pressure fields (high geostrophic wind) connects stronger to the ground than weak pressure fields. A clustering along the diagonal of the plots indicates direct effect of geostrophic wind direction on measured wind direction. Horizontal bars in the plots indicate the class-defined direction. The clustering is mostly to the left of the bars, which is consistent with friction. There is also a clustering of measurements at 0, 180 and 270, this is due to topographical effects of Oslofjorden.

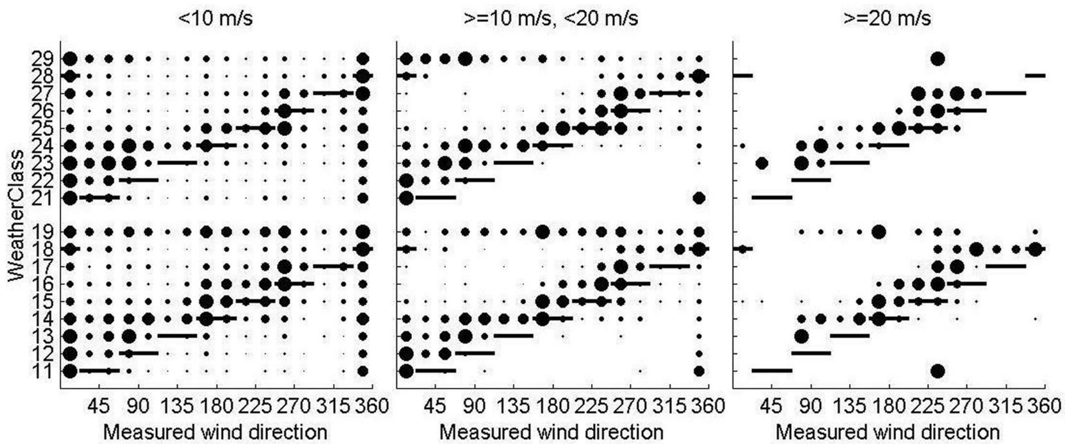

Figure 2: Class dependent wind direction at Ferder; radius of the circles is proportional to number of occurrences.

4 - PREDICTION OF SOUND PROPAGATION CONDITIONS

One parameter that is important for sound propagation has already been mentioned, wind direction. The next is to look for temperature inversions and vertical gradients in directional sound velocity (DSV).

$$DSV = C_0 * \sqrt{1 + \frac{T}{273.15}} - V * \cos(\alpha - \beta) \tag{2}$$

Temperature inversions are by definition layers in the atmosphere where the temperature increases with height. This is important information, considering sound propagation, as this might give wave-guide effects on emitted sound. Similar to absolute temperature does the temperature gradient have a seasonal and a diurnal component, figure 3 is an example from Hengsvann in southern Norway. The weather classes might provide information on some of the deviation from the mean gradient. Table 2 shows this deviation for Hengsvann. The gradient here represented as the temperature difference between two weather stations located in the same area, one on a local height, and one in a valley. Height difference in this example is 150 m. It is clear that the various CI represents different types of temperature gradients.

	NE	E	SE	S	SW	W	NW	N	Low/High
Cyclonic	0.04	-0.82	-0.50	-0.59	-0.53	-0.30	0.13	0.05	-0.64
Anti-Cyclonic	0.11	1.04	-0.24	0.04	-0.13	0.41	0.86	0.74	1.29

Table 2: Class dependent deviation from seasonal and diurnal variations in temperature gradients.

DSVG has been treated similar to temperature gradients. The separation between CI is not as clear as for temperature gradients, but seems to be significant. Table 3 contains the circulation-governed offset, and figure 4 shows the seasonal and diurnal component.

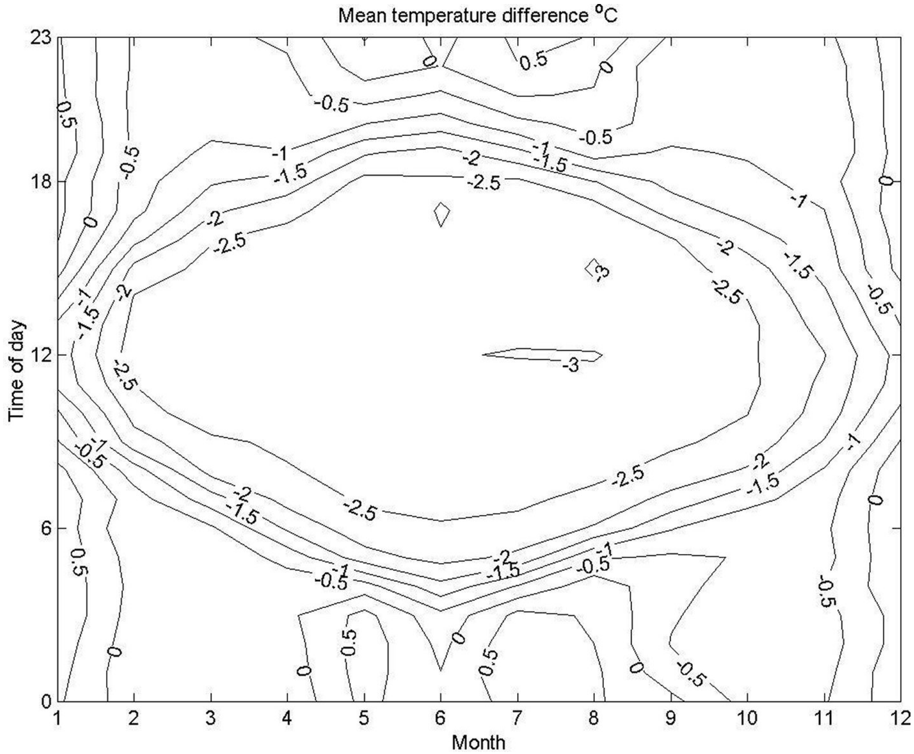

Figure 3: Seasonal and diurnal component of temperature difference at Hengsvann.

	N	E	S	W
Cyclonic				
North-East	-0.0119	-0.0101	0.0148	0.0130
East	-0.0090	-0.0141	0.0043	0.0095
South-East	-0.0018	-0.0176	-0.0019	0.0139
South	0.0059	-0.0148	-0.0103	0.0104
South-West	0.0113	-0.0011	-0.0151	-0.0027
West	0.0020	0.0100	-0.0055	-0.0135
North-West	-0.0107	0.0152	0.0113	-0.0146
North	-0.0152	-0.0021	0.0157	0.0025
Low Pressure	-0.0046	-0.0047	0.0003	0.0003
Anti Cyclonic				
North-East	-0.0026	-0.0046	0.0050	0.0070
East	-0.0010	-0.0068	0.0098	0.0156
South-East	0.0011	-0.0132	-0.0029	0.0114
South	0.0059	-0.0088	-0.0054	0.0093
South-West	0.0122	0.0018	-0.0136	-0.0032
West	0.0072	0.0165	-0.0049	-0.0143
North-West	-0.0057	0.0132	0.0106	-0.0083
North	-0.0115	0.0011	0.0167	0.0041
High Pressure	0.0045	0.0025	0.0049	0.0069

Table 3: Class dependent offset of DSVG relatively to seasonal and diurnal component shown in figure 4.

5 - CONNECTING DSVG TO SOUND PROPAGATION

There is no use in predicting DSV and DSVG if there is no way to tell what effect a given DSVG or group of DSVG. This connection has been done theoretically with OASES [3], a numerical tool build on wave-number integration.

Fig 5 shows that the main difference is between upward (-0.06 to -0.005) and downward refracting (0.005 to 0.06), thus showing that the possibility to separate situations with downward refracting conditions

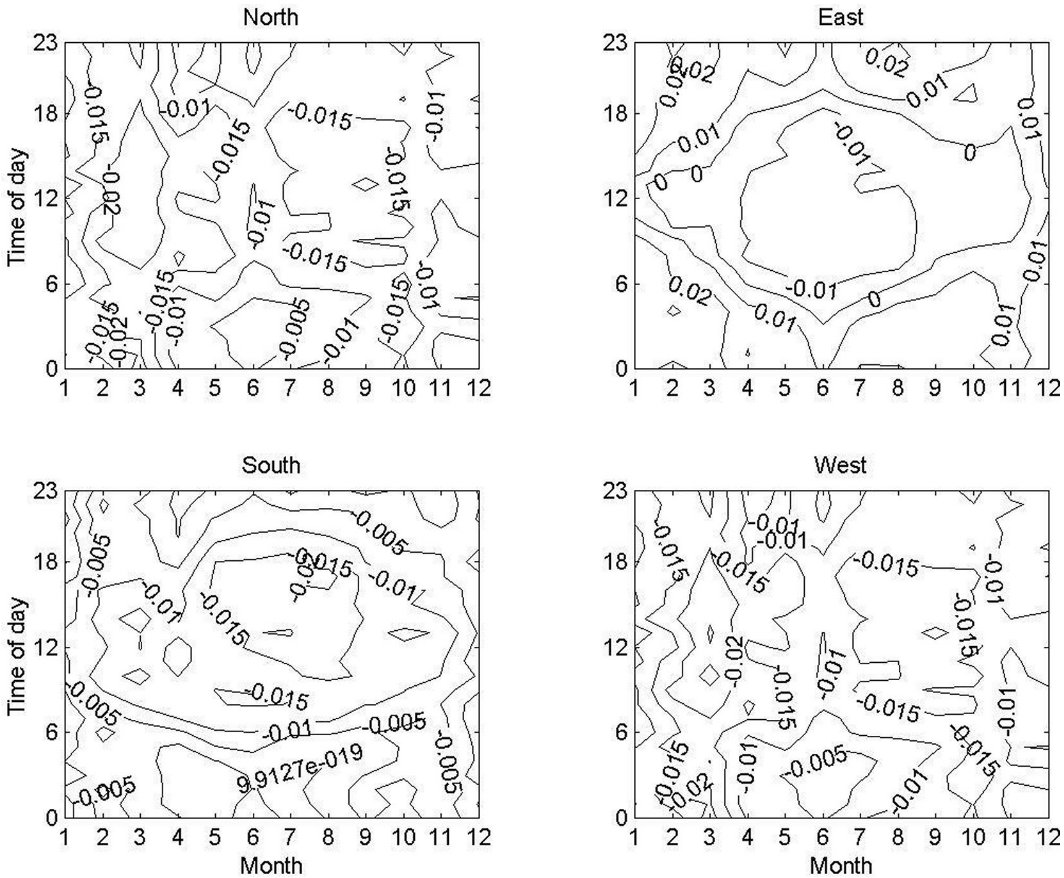

Figure 4: Diurnal and seasonal component of DSVG at Hengsvann.

for upward refracting conditions. For long distance propagation is there no clear difference between the various downward refracting conditions, this is due to the wave guide effect of downward refraction

6 - CONCLUSIONS AND SUMMARY

This paper presented a weather classification bases on geostrophic wind direction and curvature in the pressure field. These CI was applied as discriminators and shown to represent different regimes of temperature and wind direction. The CI was further used to represents different regimes of temperature gradients and DSV gradients. The paper ended with connection of DSV gradients to sound propagation with theoretical studies done with OASES. OWC presented here was shown to be a possible tool to predict outdoors sound propagation.

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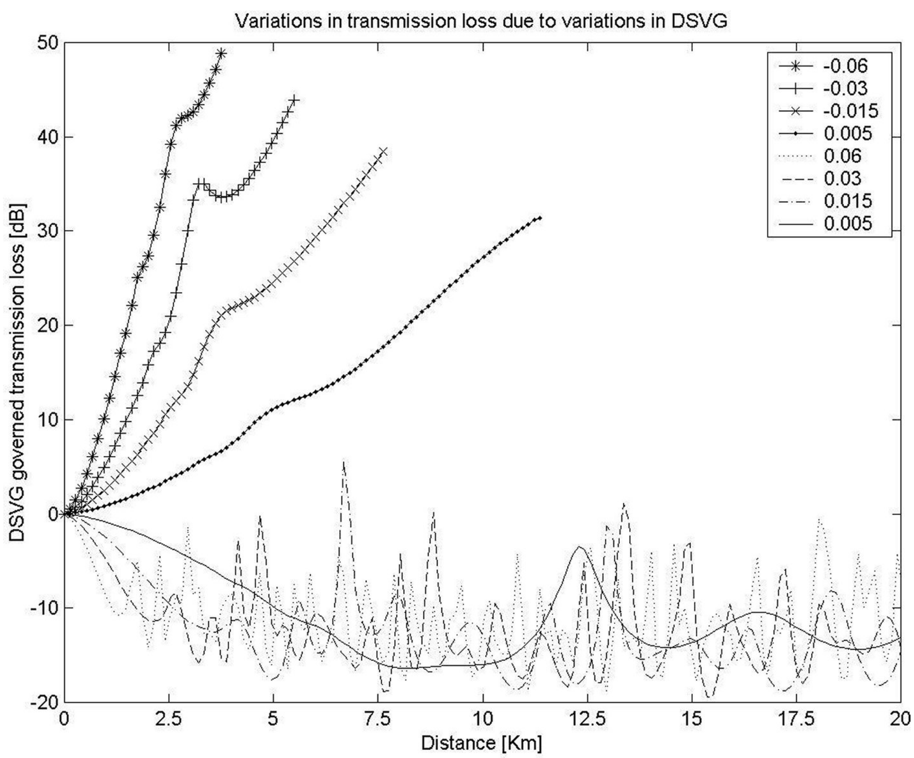

Figure 5: Single frequency (50 Hz) transmission loss calculated by OASES for various DSVG over a hard surface (108.78 m/s, $0.12 g/cm^3$); spherical effect is removed from the curves; numbers in the legend indicate the gradient.