COMPARISON OF METEOROLOGICAL AND BIOMETEOROLOGICAL CONDITIONS IN THE NORWEGIAN ARCTIC AT THE FIRST (1882/1883) WITH THE FOURTH (2007/2008) INTERNATIONAL POLAR YEAR

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Introduction, data and methods

The polar regions are integral components of the Earth system. As the heat sinks of the climate system they both respond to and drive changes elsewhere on the planet. The poster presents the results a comparison of meteorological and biometeorological conditions at the time of First International Polar Year (IPY-1) of 1882-1883 with the Fourth International Polar Year (IPY-4) 2007/2008.

The study is based on hourly and daily data taken from meteorological stations in the Norwegian Arctic (during IPY-1: Kapp Thordsen & Jan Mayen and for IPY-4: Svalbard Airport & Jan Mayen) - Fig. 1. The diversity of meteorological and biometeorological conditions was analysed in relation to the height above sea level, the distance from the sea and the character of the active surface.

The analysis made use of such biometeorological indices as wind chill index (WCI), predicted insulation of clothing (Iclp) the cooling power of the air (H). Standard computation climatological and bioclimatological methods (Kozłowska-Szczęsna et al. 1997) were used to investigate the meteorological and biometeorological conditions. The biometeorological indices (WCI, Iclp and H) were determined with empirical formula using the BioKlima 2.6 software package (Błażejczyk and Błażejczyk 2009). For the calculation of the biometeorological indices in the Arctic the wind speed was reduced from height of the anemometer to 2m above ground level according to the formula of Milewski 1960 (after: Kozłowska Szczęsna et al. 1997).

Wind chill index (WCI) was used to determine the biothermal conditions with the assumption of heavy protection by winter clothing for arctic conditions with a 4.0 clo insulation value:

$$WCI = (10 \cdot v\ 0,5 + 10,45\ \ v)\ (33,0\ \ T) \cdot 1,163;$$

where: T - air temperature (°C), v - wind speed ($m \cdot s^{-1}$).
WCI values denote the sensations of warmth experienced by humans in contact with air (Kozłowska-Szczęsna et al. 1997). Specific WCI values include: extremely hot (WCI≤ 58.2 $W \cdot m^{-2}$), hot (58.3-116.3 $W \cdot m^{-2}$), warm (116.4-232.6 $W \cdot m^{-2}$), comfortable (232.7-581.5 $W \cdot m^{-2}$), cool (581.6-930.4 $W \cdot m^{-2}$), cold (930.5-1628.2 $W \cdot m^{-2}$), frosty (1628.3-2326.0 $W \cdot m^{-2}$), extremely frost (>2326.0 $W \cdot m^{-2}$).

The predicted insulation of clothing index (Iclp) was proposed for thermophysiological research in the outdoors. It is calculated with the formula:

$$Iclp = 0.082 \cdot [91.4 - (1.8 \cdot T + 32)] / (0.01724 \cdot M) - 1 / (0.61 + 1.9 \cdot v\ 0.5);$$

where: T- air temperature in °C, v - wind speed in $m \cdot s^{-1}$, M - metabolism in $W \cdot m^{-2}$
For the purpose of calculating the Iclp a metabolism index of 135 $W \cdot m^{-2}$ was adopted, typical of a person walking at 4 $km \cdot hour^{-1}$. Finally, Iclp values were derived for specific weather conditions (in clo). The following descriptions of weather conditions are equivalent to the various Iclp values: very warm (< 0.30 clo), warm (0.31 - 0.80 clo), neutral (0.81 - 1.20 clo), cool (1.21 - 2.00 clo), cold (2.01 - 3.00 clo), very cold (3.01- 4.00 clo) and arctic cold (> 4.00 clo).

The cooling power (H) reflects the loss of heat from the body surface in time. The H index is useful in assessing thermal sensations of a walking human wearing appropriate clothing. The index was derived using Hill's empirical formula (Kozłowska-Szczęsna et al. 1997):

$$H = (36.5\ \ T) \cdot (0.20 + 0.4 \cdot v\ 0.5) \cdot 41.868 \text{ when } v \leq 1\ m \cdot s^{-1}$$

$$H = (36.5\ \ T) \cdot (0.13 + 0.47 \cdot v\ 0.5) \cdot 41.868 \text{ when } v > 1\ m \cdot s^{-1};$$

where: T- air temperature (°C), v - wind speed ($m \cdot s^{-1}$).
The calculated H values were presented as a frequency distribution against Petrovič and Kacvinsky's thermal sensation scale (after Kozłowska-Szczęsna et al. 1997). The scale is as follows: extremely cold and windy (>2100,1 $W \cdot m.^{-2}$); very cold (1680.1-2100.0 $W \cdot m^{-2}$); cold (1260.1-1680.0 $W \cdot m^{-2}$); cool (840.1-1260.0 $W \cdot m^{-2}$); slightly cool (630.1-840.0 $W \cdot m^{-2}$); neutral (420.1-630.0 $W \cdot m^{-2}$); hot (210.1-420.0 $W \cdot m^{-2}$) and very hot (< 210.0 $W \cdot m^{-2}$).

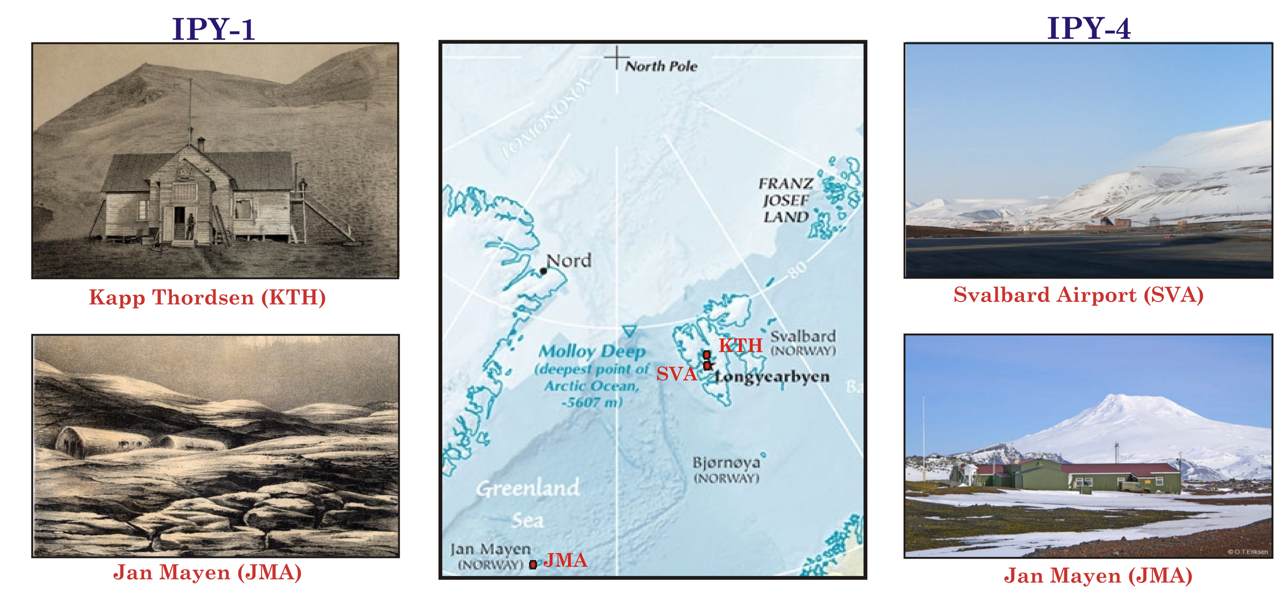

Fig. 1. Meteorological stations operated in the Norwegian Arctic during the First (1882/83) and Fourth (2007/2008) International Polar Years

Tab. 1. Mean monthly and annual air temperature, wind speed and precipitation at selected stations in the Norwegian Arctic: Svalbard Airport (SVA) - 1976-2000 and Jan Mayen (JMA) - 1971-2000

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
	Air temperature (°C)												
SVA	-14.7	-15.4	-13.6	-11.3	-3.7	2.3	6.2	5,0	0.7	-5.3	-9,0	-12.6	-5.9
JMA	-5.1	-5,0	-4.8	-3.6	-0.5	2.1	4.6	5.2	3.1	0.3	-2.4	-4.5	-0.9
	Wind speed ($m \cdot s^{-1}$ at 2 m a.g.l.)												
SVA	4.2	3.8	3.5	3,0	2.9	3.1	3.5	3.1	3.1	3.9	4.3	4.4	3.6
JMA	6,0	5.7	5.8	5,0	3.8	3.6	3.2	3.4	4.3	4.8	5.5	5.8	4.8
	Precipitation (mm)												
SVA	14.3	19,0	20.7	11.3	6.9	9.9	14.8	25.8	22.5	12.9	17.2	17.6	192.9
JMA	63.4	60.9	66.6	43.1	42.3	35,0	46.8	60.8	74.5	75.7	65.2	71.5	705.9

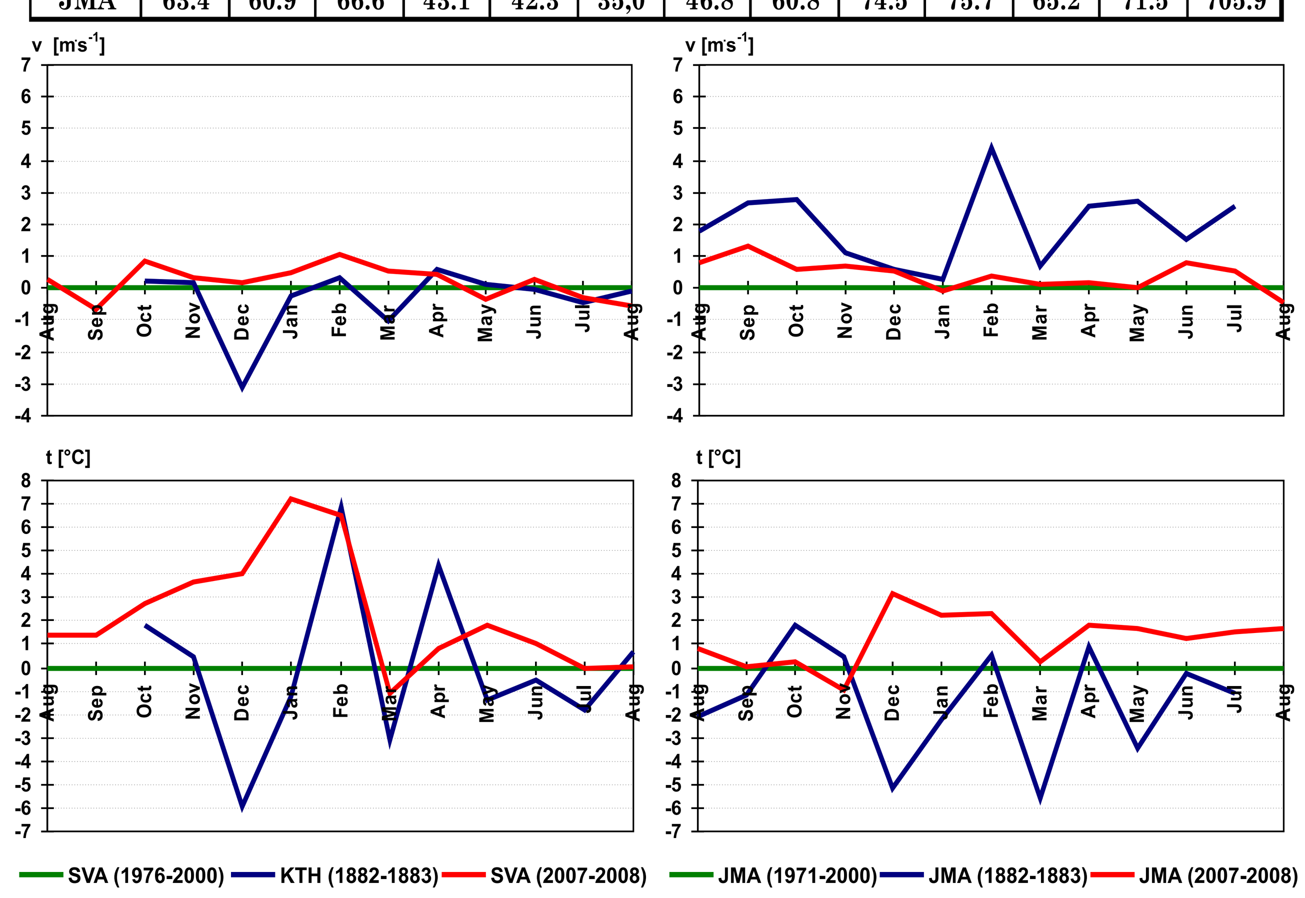

Fig. 2. Differences of the air temperature and wind speed (2m) between IPY-1 (Aug 1882 - Aug 1883), IPY-4 (Aug 2007- Aug 2008) and long-term reference period

Results

Meteorological conditions. Thermal stimuli are among the most perceptible of all climatic influences, and therefore they are the principal and universal criterion when the state of the weather is evaluated. In the whole Arctic the warmest area is western part of the Norwegian Arctic (Przybylak 2003). The mean annual air temperature in the Norwegian Arctic decreases here from south-west (JMA) to north-east (SVA) (Tab. 1, Araźny 2008). In the annual course of the air temperature the coolest month was January or February (Tab. 1, Fig. 2). The warmest month of IPY-1 and IPY-4 was July and August. During IPY-1 in the Norwegian Arctic the lowest air temperature (-35.5°C) was recorded at Kapp Thordsen on 2 January 1883, and the highest (13.6°C) at same station on 4 August 1883. During IPY-4 the lowest air temperature was occurred (-23.9°C) at Svalbard Airport on 21 March 2008, and the highest (14.1°C) at same station on 2 August 2007. In the Arctic, the high wind and low air temperature may cause substantial disturbances in the human heat balance. The mean wind speed during IPY-1, IPY-4 and long-term series, reduced to the common height of 2 m a.g.l. at all stations, in the Svalbard Airport was lower them Jan Mayen (Tab. 1, Fig. 2). In the annual course the maximum wind speed occurs in the winter months, which is connected with significant cyclonic activity. The greatest values of atmospheric precipitation occur in the southern part of this region (at Jan Mayen), which is under a strong impact of maritime air masses (Tab. 1).

Biometeorological conditions. The wind chill index is a valuable biometeorological tool allowing us to determine the thermal conditions of the environment at low temperatures. The occurrence of the most favourable conditions on individual days at the stations analysed is connected with the higher air temperatures and lower wind speeds (Tab. 1, Fig. 3). During IPY-1 and IPY-4 in the Norwegian Arctic the values range from "comfortable" to "extremely frosty". In the analysed period "cold" sensations definitely prevailed, usually accounting for over 65% of all observations made at individual stations (Fig. 4). In the human thermal sensation scale of Petrovič and Kacvinsky (for H), the optimum conditions for a moving person range from 420.1 to 840.0 $W \cdot m^{-2}$ and include the sensations of "neutral" and "slightly cool". During IPY-1 and IPY-4 the optimum conditions in the summer occurred only 5% of the time at Jan Mayen and 12% in the centre of Spitsbergen. The feeling of cold discomfort (H > 1260.1 $W \cdot m^{-2}$) comprises such sensations as "cold", "very cold" and "extremely cold and windy". The cold discomfort days were most frequent during two IPY at Jan Mayen (83%), and occurred least often in the centre of Spitsbergen (65%) (Fig. 4).Clothing is the simplest protection against the unfavourable influence of the weather, particularly in the polar regions. In order to assess the biometeorological conditions in the analysed area from the point of view of clothing requirements that would ensure proper thermal comfort, the predicted insulation index of clothing was used for a person walking outdoors at 4 $km \cdot h^{-1}$. Considering the demand for clothing with optimum insulation properties for a walking person, during the winter months of IPY-1 and IPY-4 heavy arctic clothing was a necessity (Fig. 4). In the summertime, the ideal clothing is 1.5-2.0 clo (Figs 3 and 4). In addition, a human body needs twice as much clothing insulation for thermal comfort when standing upright as does a body in motion (Araźny 2006; 2008). A standing body produces only 70 $W \cdot m^{-2}$ of heat, which is roughly 50% of what is produced by the metabolism of a walking person.

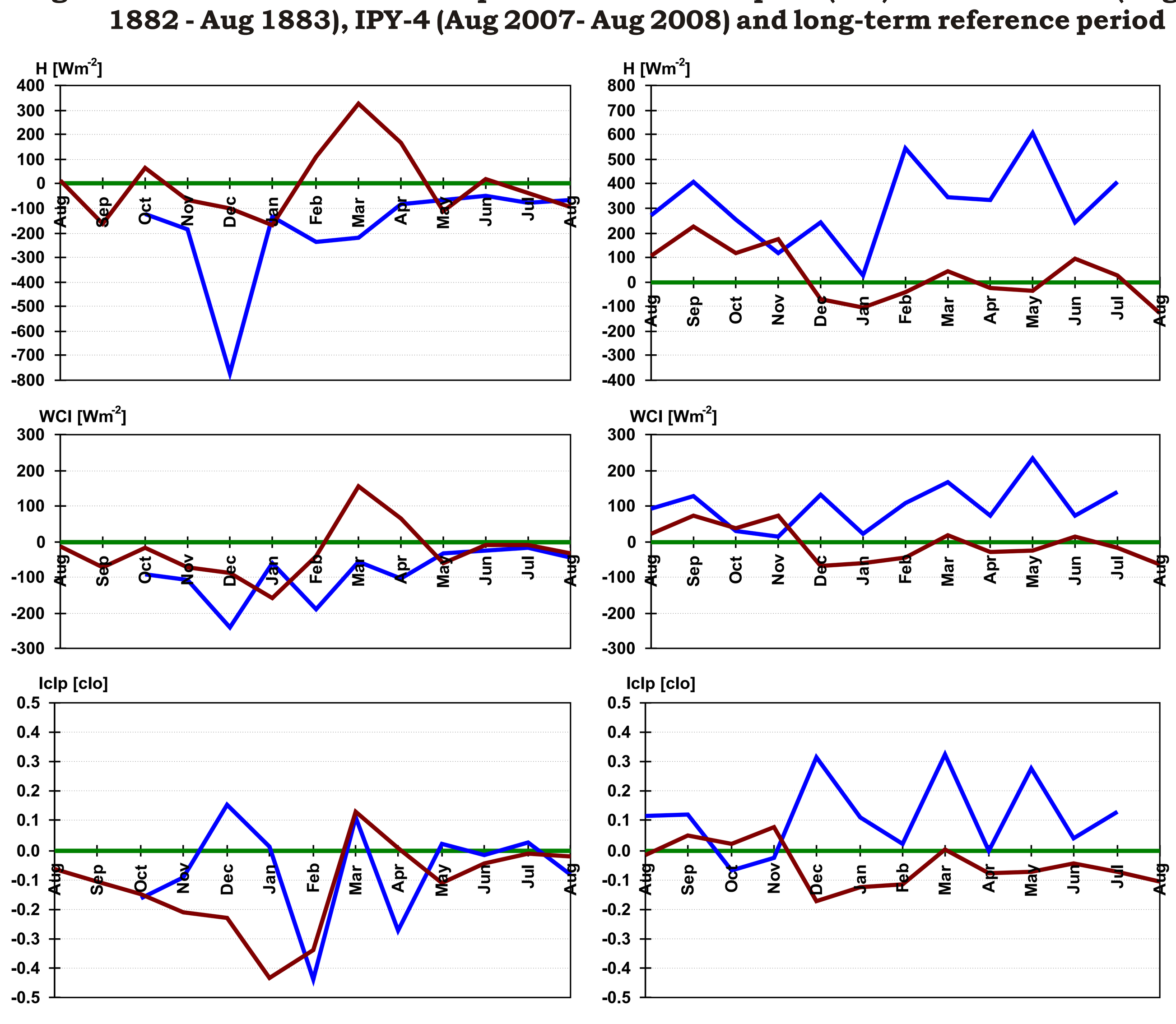

Fig. 3. Differences of the biometeorological indices (WCI, H and Iclp) between IPY-1 (Aug 1882 - Aug 1883), IPY-4 (Aug 2007- Aug 2008) and long-term reference period

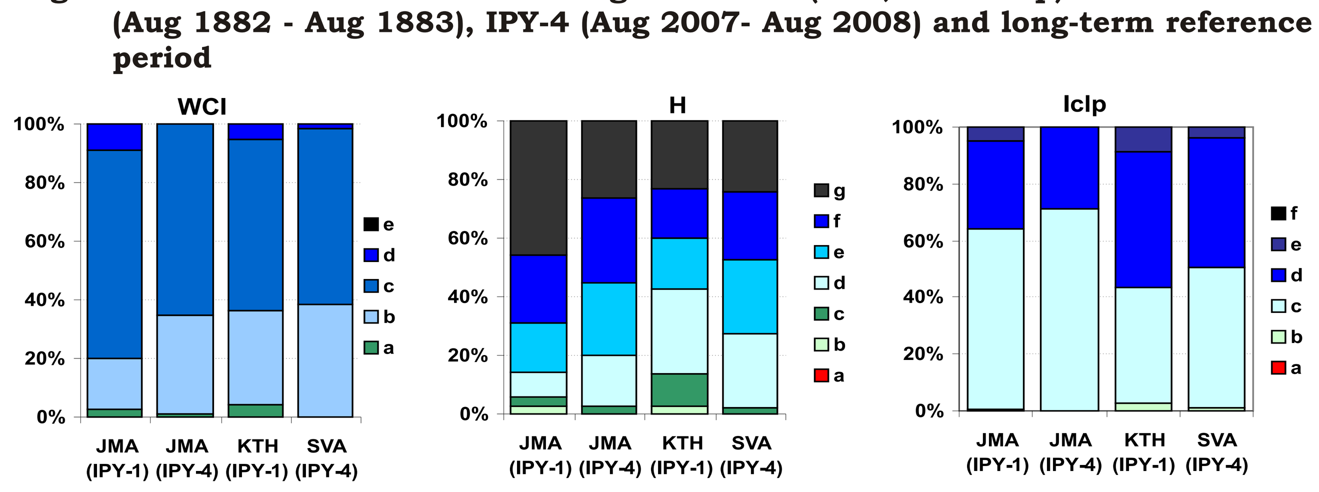

Fig. 4. Frequency (%) of wind chill index (WCI), cooling power (H) and predicted insulation of clothing (Iclp) during temperate (M=135 $W \cdot m^{-2}$) physical activity in the Arctic during IPY-1 (Aug 1882 - Aug 1883) and IPY-4 (Aug 2007- Aug 2008)
Explanations - WCI: a- comfortable; b- cool; c- cold; d- frosty; e- extremely frost
H: a- hot; b- neutral; c- slightly cool; d- cool; e- cold; f- very cold; g- extremely cold and windy
Iclp - thermal conditions: a- warm; b- neutral; c-cool; d- cold; e- very cold; f- arctic cold

Conclusions

- **Unfavourable thermal conditions in the Norwegian Arctic are caused by low temperature and its great variability, especially in winter.**
- **In the Norwegian Arctic hygric conditions, differently from other Arctic regions, are characterised by high values of relative humidity as well as of atmospheric precipitation.**
- **The occurrence of high winds added to the unfavourable thermal sensations.**
- **A comparison of bioclimatic conditions at the time of IPY-1 with IPY-4 indicates that human thermal sensations in the historical period were worse (at Jan Mayen) and the same (in the centre of Spitsbergen) as in contemporary period.**

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