WARM AND COLD SPELLS IN ALASKA AND THEIR SYNOPTIC BACKGROUND

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INTRODUCTION

As it has been well documented, air temperature increase during the last decades is especially pronounced over northern high-latitudes. Changes in mean temperature values entail altered frequency and/or intensity of extreme events like warm and cold spells. In regard to them, atmospheric circulation is most often considered to be the factor of the utmost importance. It may be described using numerous descriptors including circulation types.

THE AIM OF THE STUDY is to investigate spatial and temporal variability of summer (JJA) warm and winter (DJF) cold spells in Alaska during 1951–2015 and to determine the role of atmospheric circulation in their occurrence.

DATA

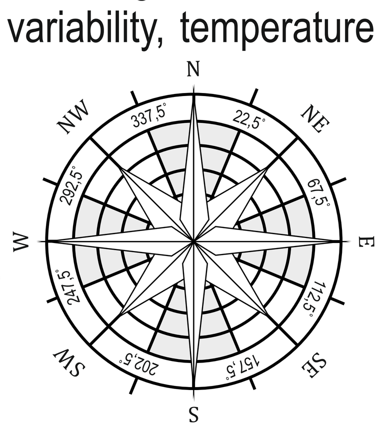
The analysis was performed using two independent datasets:

- daily maximum (T_{MAX}) and minimum (T_{MIN}) temperature values from 10 weather stations representing different climate regimes in Alaska, obtained from GSOD datasets shared by National Climatic Data Center (1951-2015),
- daily average temperature (TAVG), sea level pressure (SLP), velocity and wind direction at 850 hPa level, obtained from NCEP North American Regional Reanalysis (1979-2015; spatial resolution approx. 32 x 32 km).

METHODS

Anomalously warm day (WD) was defined as a day with T_{MAX} above 95th percentile and **anomalously cold day (CD)** as a day with T_{MIN} below 5th percentile values. Percentiles were calculated for each calendar day using a centered 15-day-long time window. **Warm spell (WS)** is an event lasting at least three consecutive WD during summer (JJA) and **cold spell (CS)** lasts at least three consecutive CD during winter (DJF). Temporal variability, temperature magnitude and duration of WS and CS in different parts of Alaska are shown.

In order to characterise **synoptic conditions** during WS and CS, the objective classification scheme of circulation types by Ustrnul (1997) was employed. On the basis of SLP, wind velocity (v) and direction (criteria shown to the right) at the 850 hPa level, 18 circulation types were distinguished: 8 cyclonic, when SLP ≤ 1013,3 hPa (e.g. NEc); 8 anticyclonic, when SLP > 1013,3 hPa (e.g. NEa) and 2 non-advective, when v < 2 m/s (i.e. Bc, Ba). Circulation types were specified at grid points located closest to each of ten weather stations. Trends were estimated per decade using the non-parametric Mann-Kendall's test and Sen's slope estimator.



RESULTS

TEMPORAL VARIABILITY OF WARM AND COLD DAYS AND SPELLS, AND THE FREQUENCY OF WARM AND COLD SPELLS DURING PARTICULAR CIRCULATION TYPES AT EACH STATION

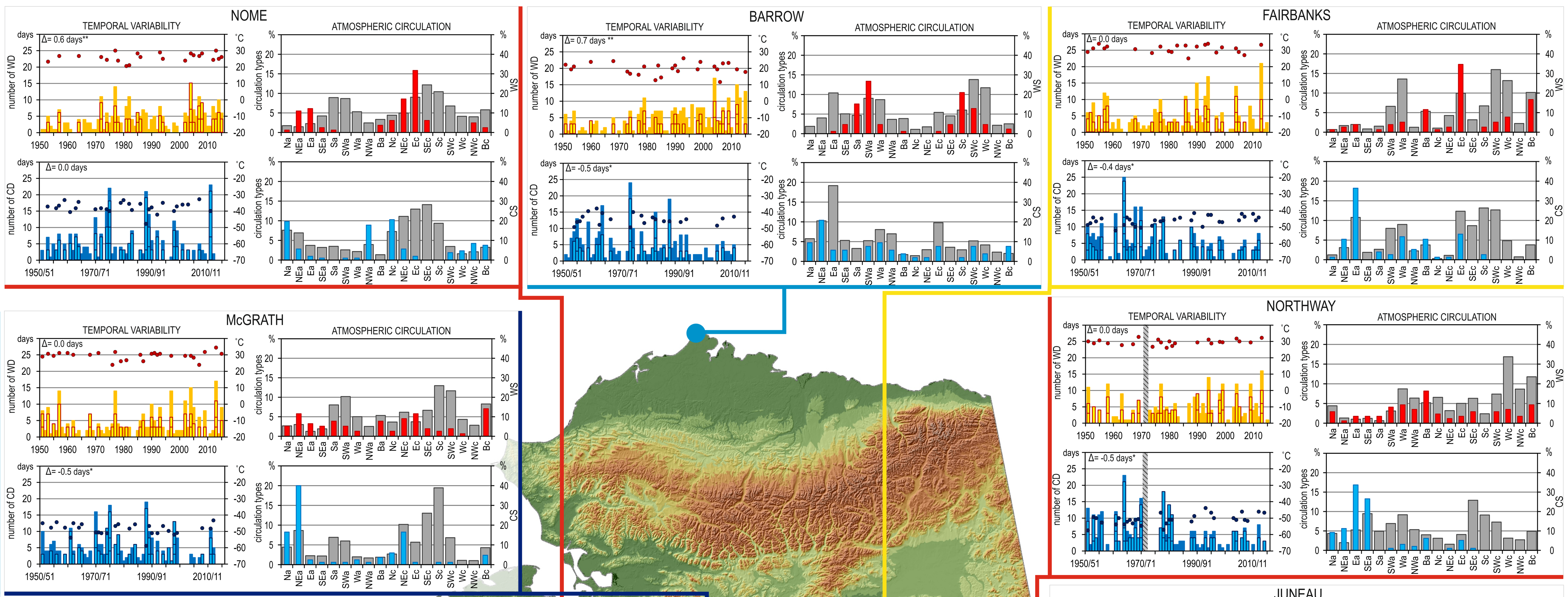
LEGEND

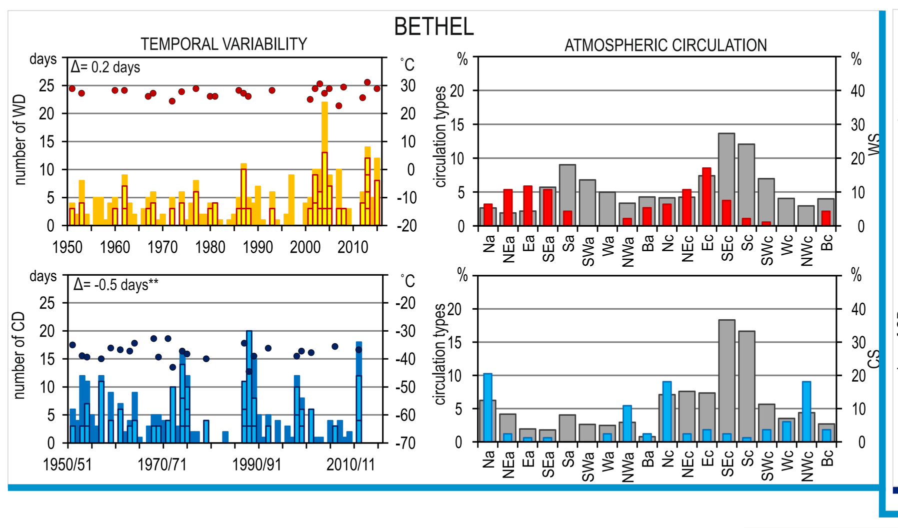
TEMPORAL VARIABILITY CHARTS

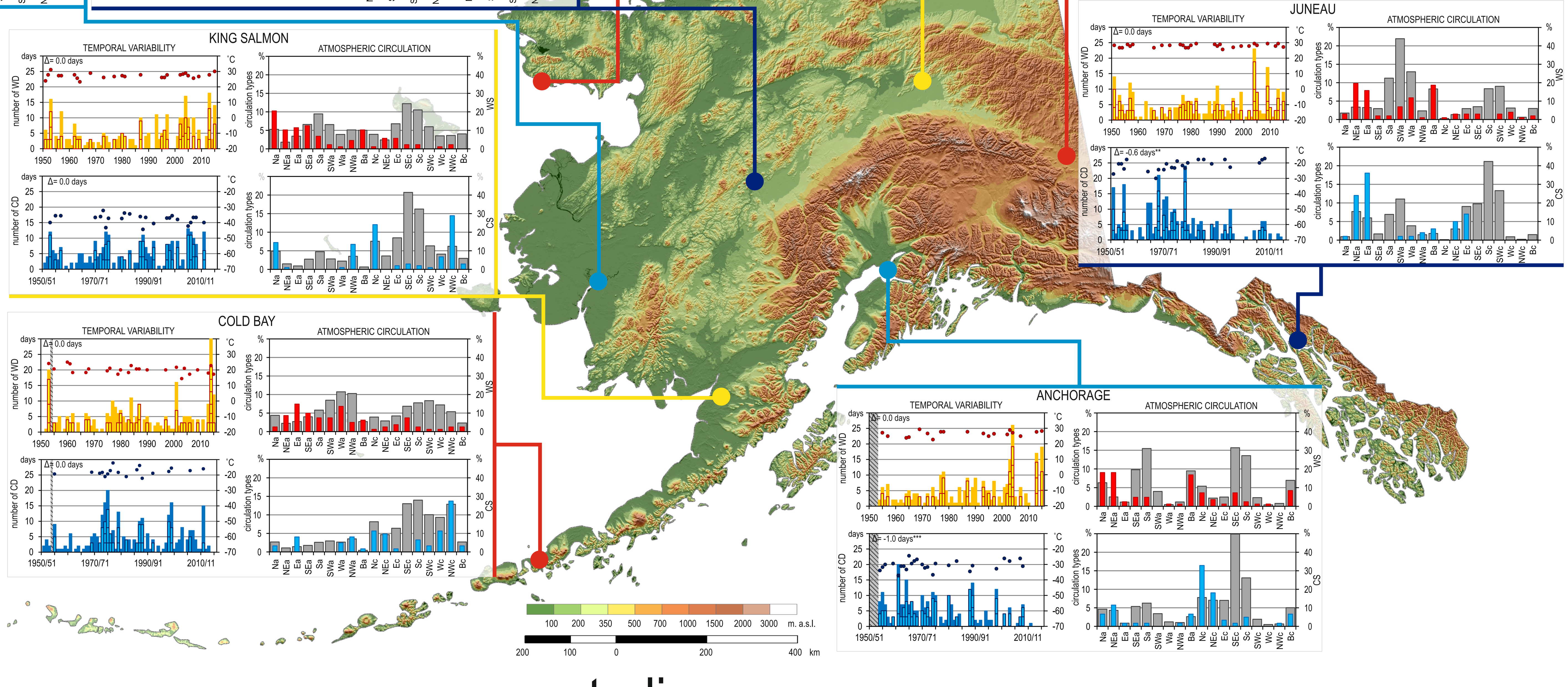
- ■ / ■ number of warm days (WD) in summer (JJA) / cold days (CD) in winter (DJF)
- ■ / ■ warm spells (WS) in summer / cold spells (CS) in winter
- • / • the highest T_{MAX} / lowest T_{MIN} observed during a WS / CS within a year
- Δ tendency of number of WD and CD per 10 years at significance levels (α): * 0,05 ** 0,01 *** 0,001
- no data

ATMOSPHERIC CIRCULATION CHARTS

- ■ frequency of circulation types in summer (JJA) and winter (DJF) (left axis)
- ■ / ■ frequency of warm spells (WS) / cold spells (CS) during particular circulation types (right axis)







KEY FINDINGS

The total number of WS oscillated between 30 (Nome) and 42 (Juneau). At particular stations less than a half of WD contributed to WS, except Juneau and Northway, where 55% of WD contributed to all WS. In the case of CS, their total number oscillated between 27 (Barrow) and 43 (Northway). Comparing to WD, CD formed spells more frequently – only in Cold Bay, Juneau and Barrow less than a half of CD accounted for CS, at other sites their contribution was higher with a maximum of 74% in the Interior Alaska. As a rule CS tended to be more persistent than WS. The longest WS lasted for 10 days, whereas there were 13 CS longer than that, with a maximum of 17 days. CS lasting 10 or more days occurred mainly in northern, interior and western Alaska (except Cold Bay). The longest WS (8-10 days) were noted in the Interior, west and south-east regions.

TEMPORAL VARIABILITY

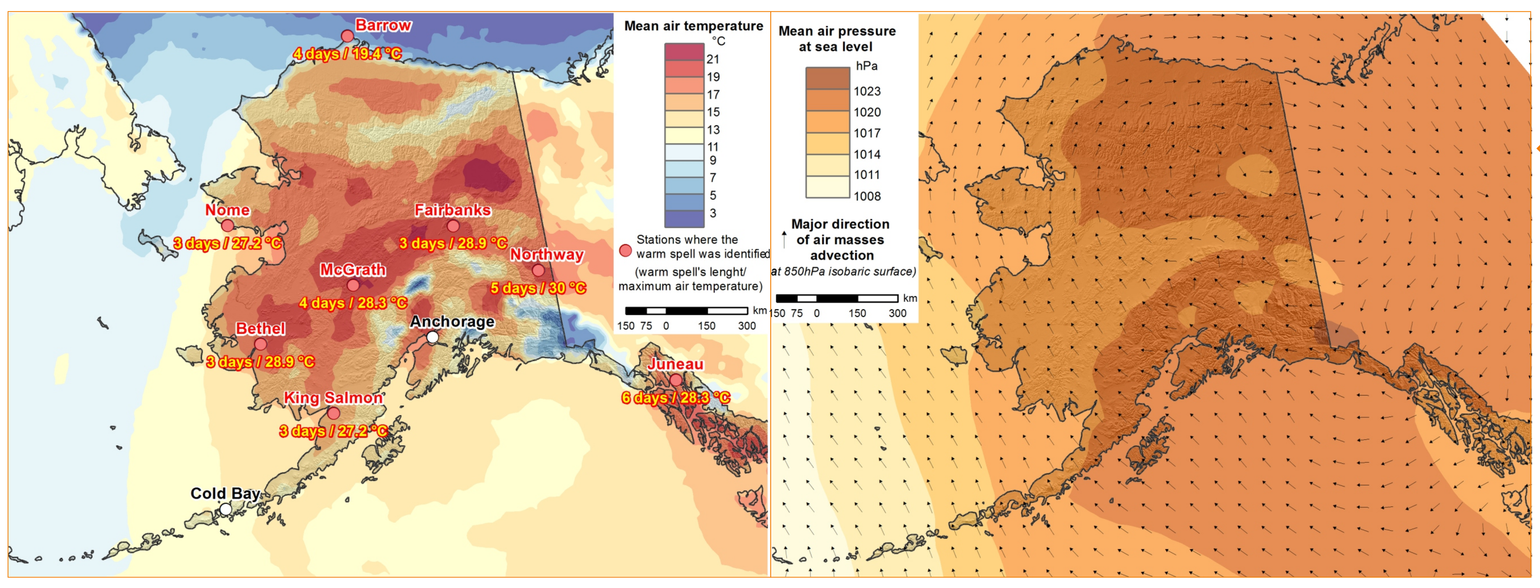
- an increase in WD was observed only at three stations in northern and western Alaska
- a decrease in CD was statistically significant at all stations except three located in the west
- considering all stations, 2004 was record-breaking in regard to WS – in total 25 WS occurred all around the state; second in turn was the 2013 with 22 WS
- in case of CS, the record was the winter of 1988/89 with 17 CS noted all around the state; 1974/75 and 1975/76 were next on the list with 17 and 19 CS, which in most cases occurred in northern and western Alaska
- the highest T_{MAX} during WS peaked up at about 33˚C and occurred in the Interior; in the west it oscillated around 30˚C, in the south T_{MAX} did not exceed this value; the coolest WS were noted in Barrow, but even there T_{MAX} reached up to 26˚C
- the lowest T_{MIN} during CS occurred in the Interior Alaska, where it dropped down to -59˚C; in the arctic region T_{MIN} rarely lowered to -50˚C; in the west (except Cold Bay) it oscillated around-40˚C; in the south – between -20˚C and -30˚C; the warmest CS, with T_{MIN} around -20˚C were found in Cold Bay

ATMOSPHERIC CIRCULATION

- in Barrow most of WS occurred during air masses advection from SW and S (regardless of barometric conditions), whereas CS were mainly accompanied by anticyclonic types, especially with airflow from NE and N;
- at stations located in the west, similar patterns are visible – WS occurred mainly during advection from E and NE (regardless of barometric conditions), this pattern fades away to the south and towards interior Alaska where other types gain in importance; CS occurred mainly during N and NW airflow (regardless of barometric conditions) with an increasing significance of cyclonic types to the south; only in McGrath, lying towards the Interior, airflow from NE was dominating;
- in the Interior Alaska distribution of WS and CS among circulation types was different; in general, at both stations occurrence of WS was accompanied by Ba and Bc types and CS – by Ba type and anticyclonic types with advection from E and NE
- in the south WS occurred mainly during Ba type, anticyclonic types with advection from NE and – depending on the station – N and E; CS were associated with advection from N, NE, E (regardless of barometric conditions) and Ba type

case studies

MEAN TEMPERATURE, SEA LEVEL PRESSURE AND DIRECTION OF AIR MASSES ADVECTION DURING TWO PERIODS WITH WARM AND COLD SPELLS OCCURRING AT THE GREATEST NUMBER OF STATIONS



WARM SPELLS PERIOD
9-16.08.2005

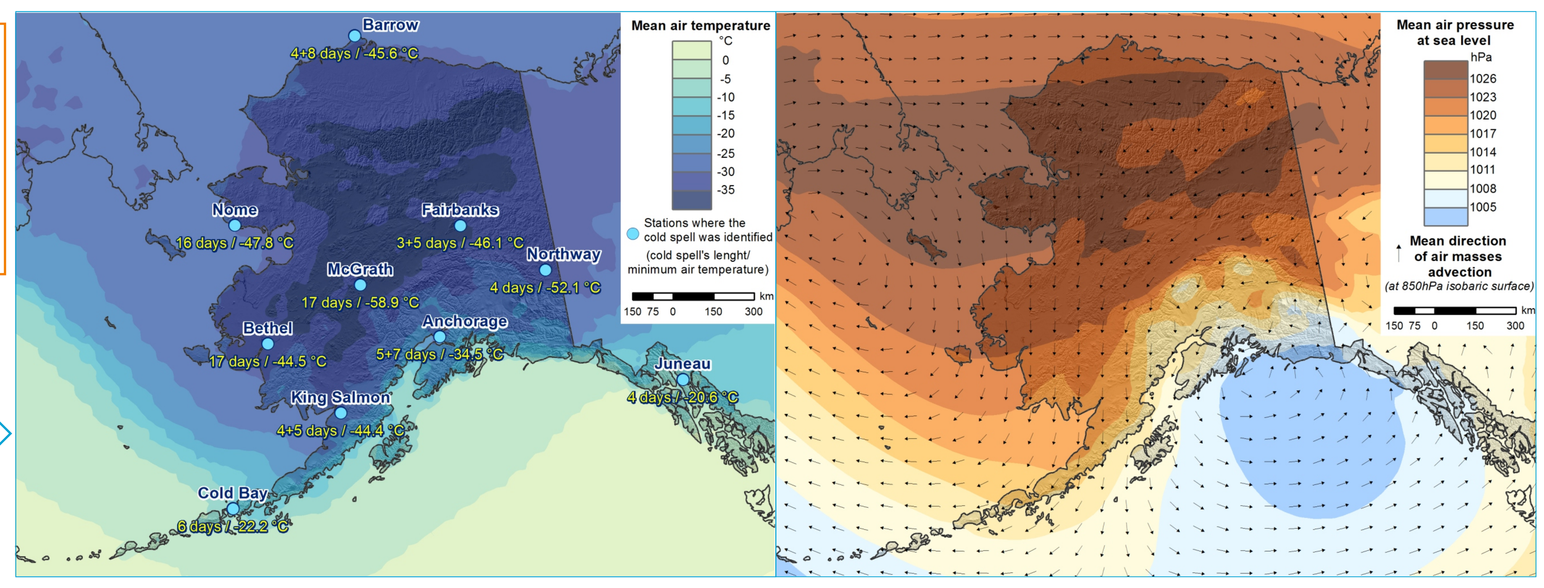
During WS at particular stations circulation types associated with continental air masses and the influence of high pressure system were prevailing:

- SWa, Sa in the arctic region
- Ba, Ea in the Interior Alaska
- Ea, Ec, Sa, NEa in the west
- NEa, Ea in the south

COLD SPELLS PERIOD
16.01-2.02.1989

During CS at particular stations circulation types associated with arctic air masses and the influence of high pressure system were prevailing:

- NWa, Na, Wa in the arctic region
- NEa, Ea, Ec in the Interior Alaska
- Na, Nc, NEa, NWa in the west
- NEa, Nc, NEc, Ea in the south



CONCLUSIONS

Warm and cold spells (WS, CS) are considered as extreme events with regard to their consequences. The most dramatic effect of warm spells in Alaska are wildfires, which cause huge losses in forestry and infrastructure as well as air pollution increase. During the study period there were two years with unusually high number of wildfires burning across the tundra and forests of the state – 2004 and 2015. Effects of CS include health problems and large air pollution increase especially in towns located in mountain valleys.

Results of the study suggest that **the decrease of CD in Alaska is much more expanded and strong than the increase of WD**. This stays in the agreement with other research studies, proving that trends of T_{MAX} and T_{MIN} in Alaska are both tending toward warmer, but the magnitude of the trend is much greater for winter than summer. Both the most intensive WS and CS were found in the Interior Alaska, what indicates that the thermal conditions of this region are the most extreme. The mildest, in terms of air temperature, are the conditions of southern coasts of the state. Occurrence of long-lasting CS especially in the Interior and western Alaska (except Cold Bay) was the result of high frequency of low-level temperature inversions associated with anticyclonic pressure patterns and insulating influence of seasonal sea ice in the west. **Atmospheric circulation plays a key role in the occurrence of WS and CS in Alaska**, however the direction of air masses advection seems to be more important than the predominant pressure system. Considering all stations, WS occurred most frequently during the airflow of continental air masses originating from the Interior Alaska and Canada, and CS during the airflow of arctic or continental air masses. It is also important to note, that the circulation influence on temperature in Alaska as well as the direction of an airflow is largely modified by the local topography.

CITED LITERATURE: Ustrnul Z., 1997, Variability of atmospheric circulation in Northern Hemisphere during the 20th century, Materiały Badawcze, Ser. Meteorologia, Nr. 27, IMGW, Warszawa (in Polish)