Scientific basis for network evaluation and planning

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Presentation overview

- Climatic and environmental changes in the Russian Arctic.
- Spatial coherence of climatic variations.
- Case study of permafrost network.

Manifestations of changing climate in Russia

Changing temperature and precipitation

Up to 1.3 ^{0}C temperature rise since 1980; increased variability of precipitation

Environmental impacts

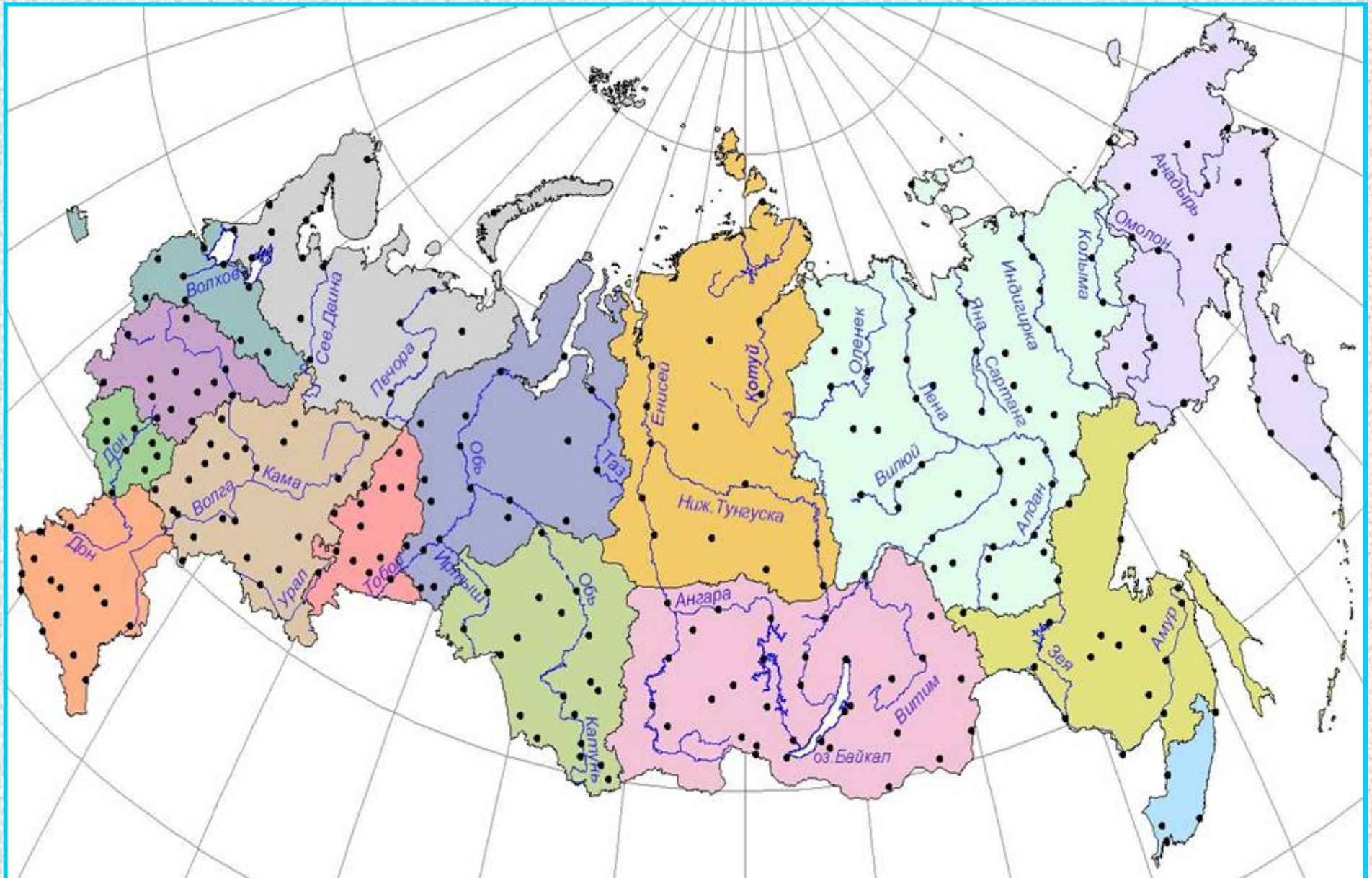
1. **Siberian river discharge:** 10% increase since 1980
2. **Ground water:** 1.0-1.5 m increase in water table since 1960
3. **Cryosphere:** sea ice (-10%), glaciers (↓), permafrost (↓), snow period (↓)
4. **Ecosystems:** changes in animal habitats; displacement of tree line

Economical and societal impacts

1. **Severity of climate:** less severe winters with implications for human health
2. **Heating energy:** 5-15 days shorter heating period since 1960
3. **Water resources:** 5-7% increase since 1980
4. **Sea navigation:** more navigatable northern sea routes
5. **Permafrost:** destructive impacts on infrastructure

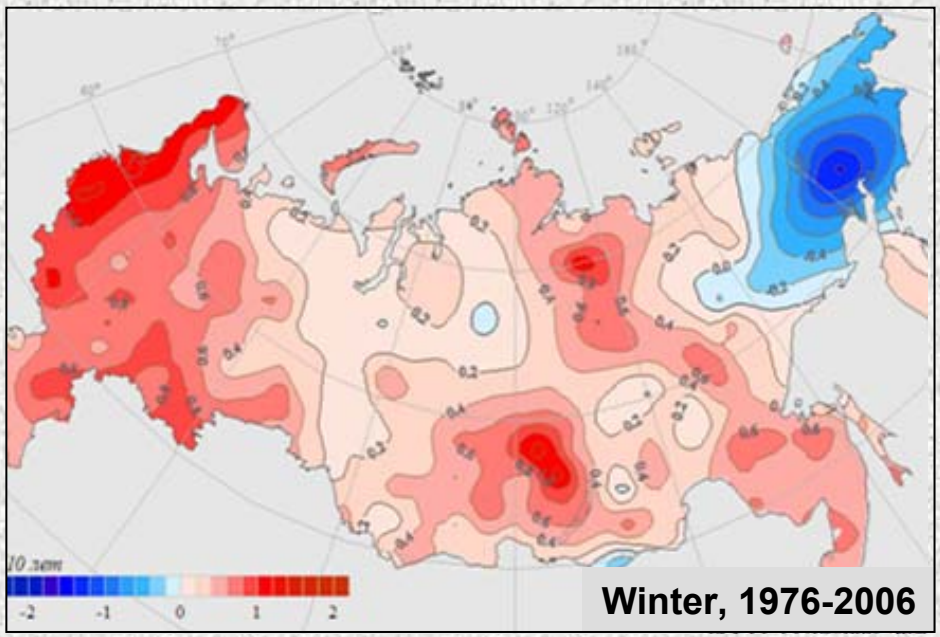
Russian meteorological network

455 weather stations, 282 above 60^0 N, 156 in permafrost regions.
(Map shows the sub-set of 122 stations with continuous century-scale observations in the period 1900-2006)

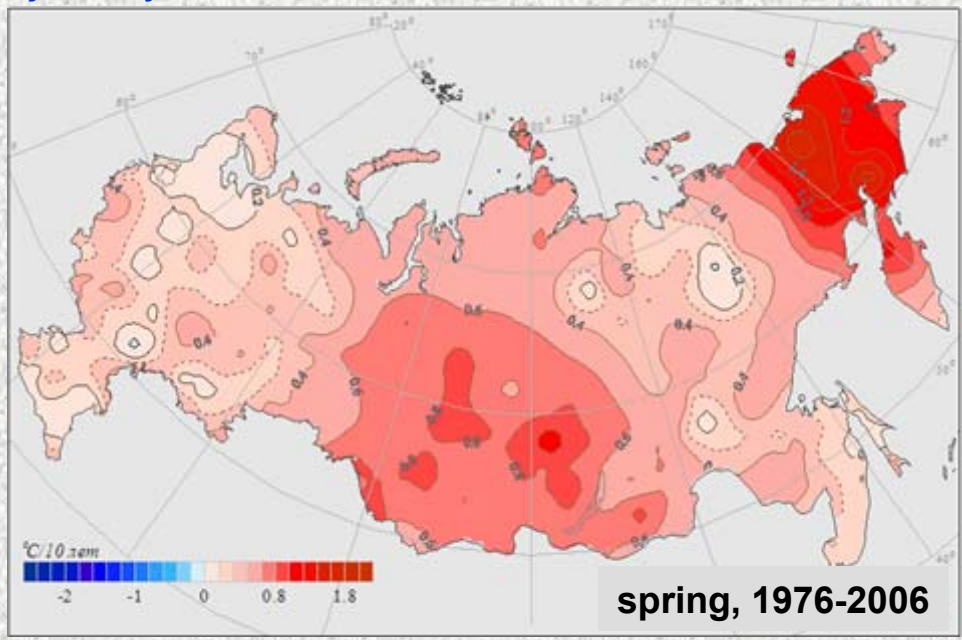


Changes in seasonal temperatures, ^{0}C/10 years, 1976-2006

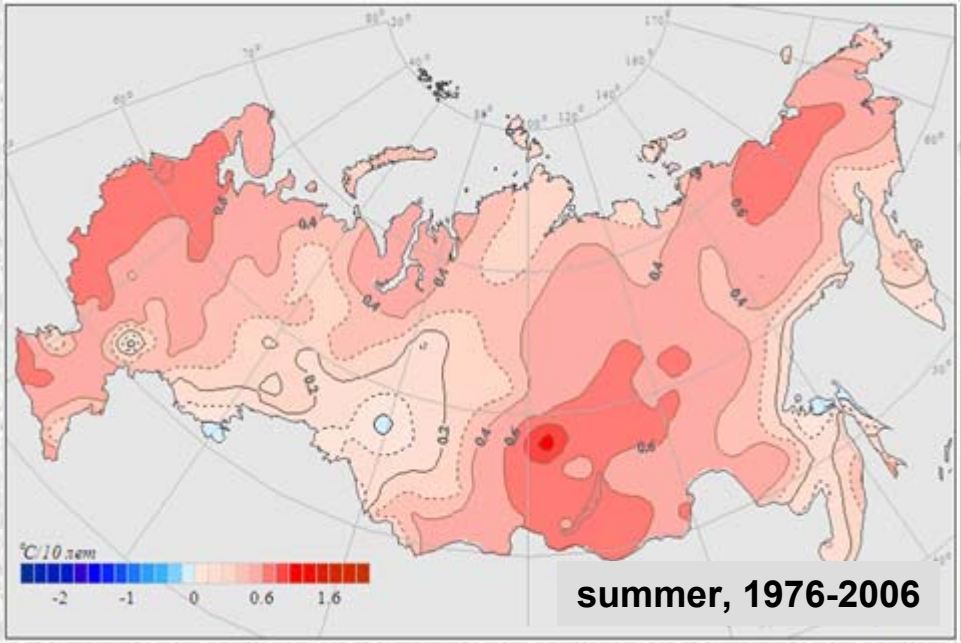
Climate assessment by Roshydromet, 2007



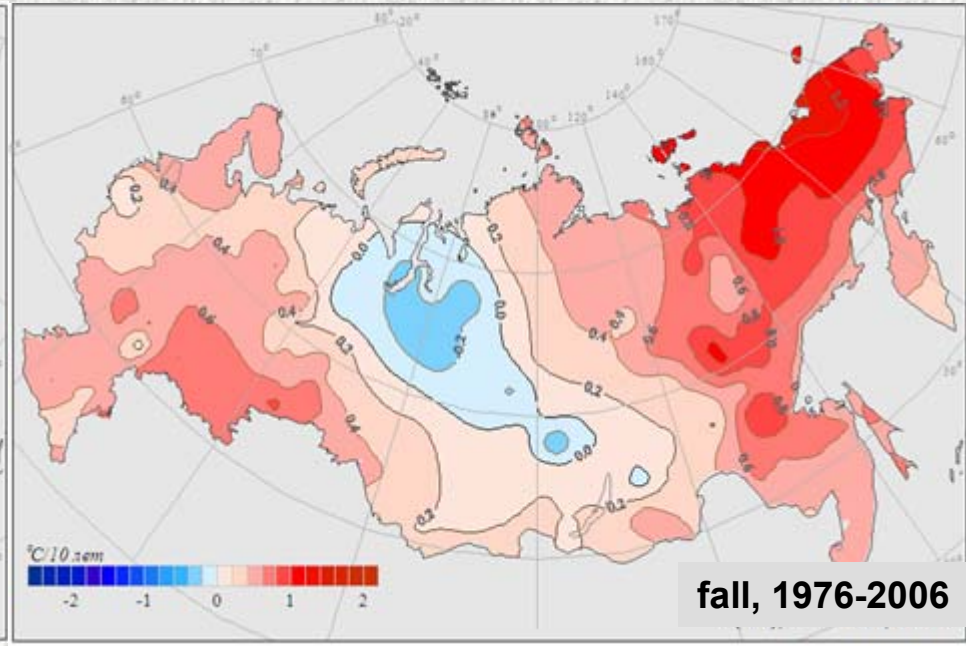
Winter, 1976-2006



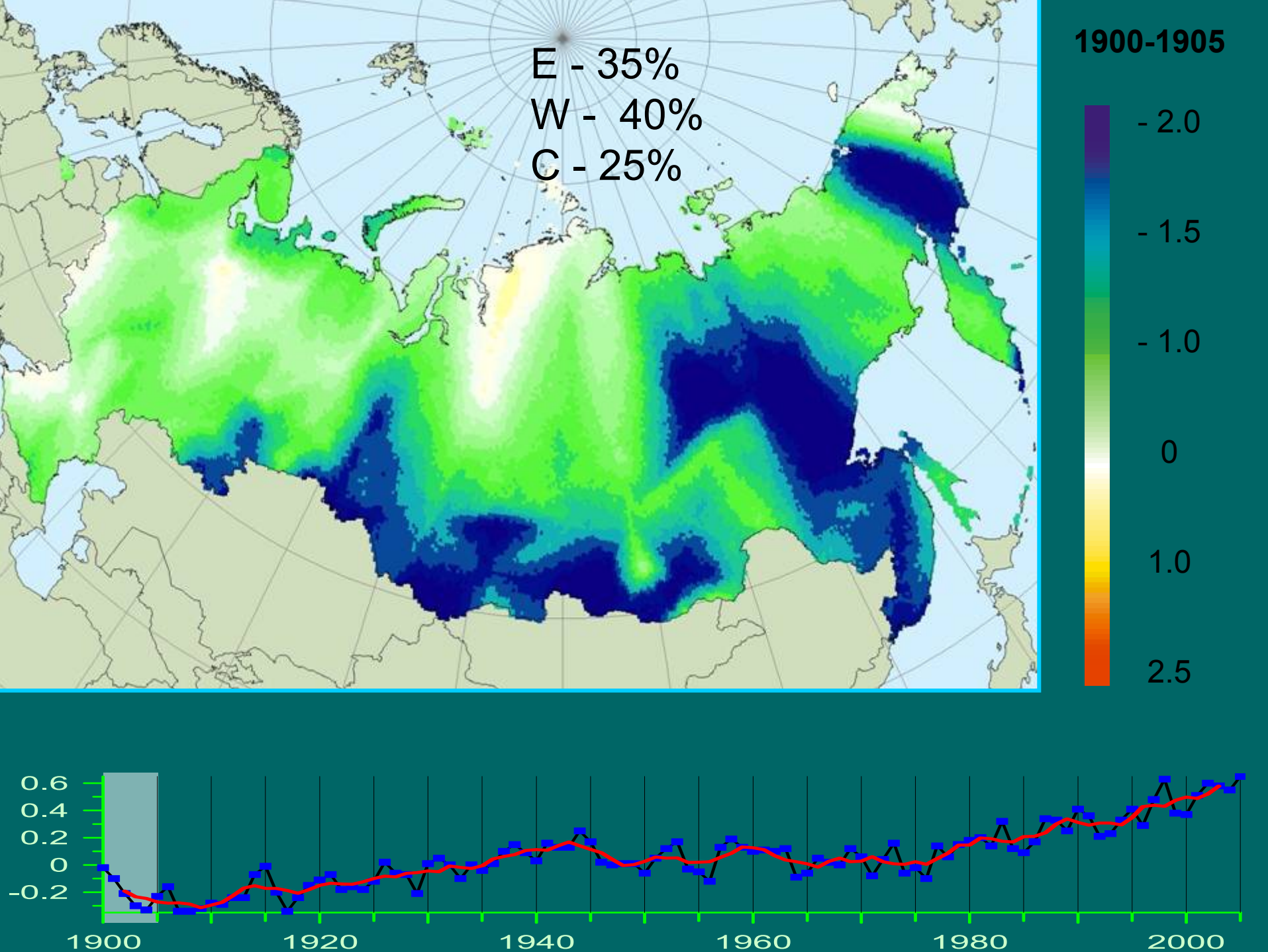
spring, 1976-2006

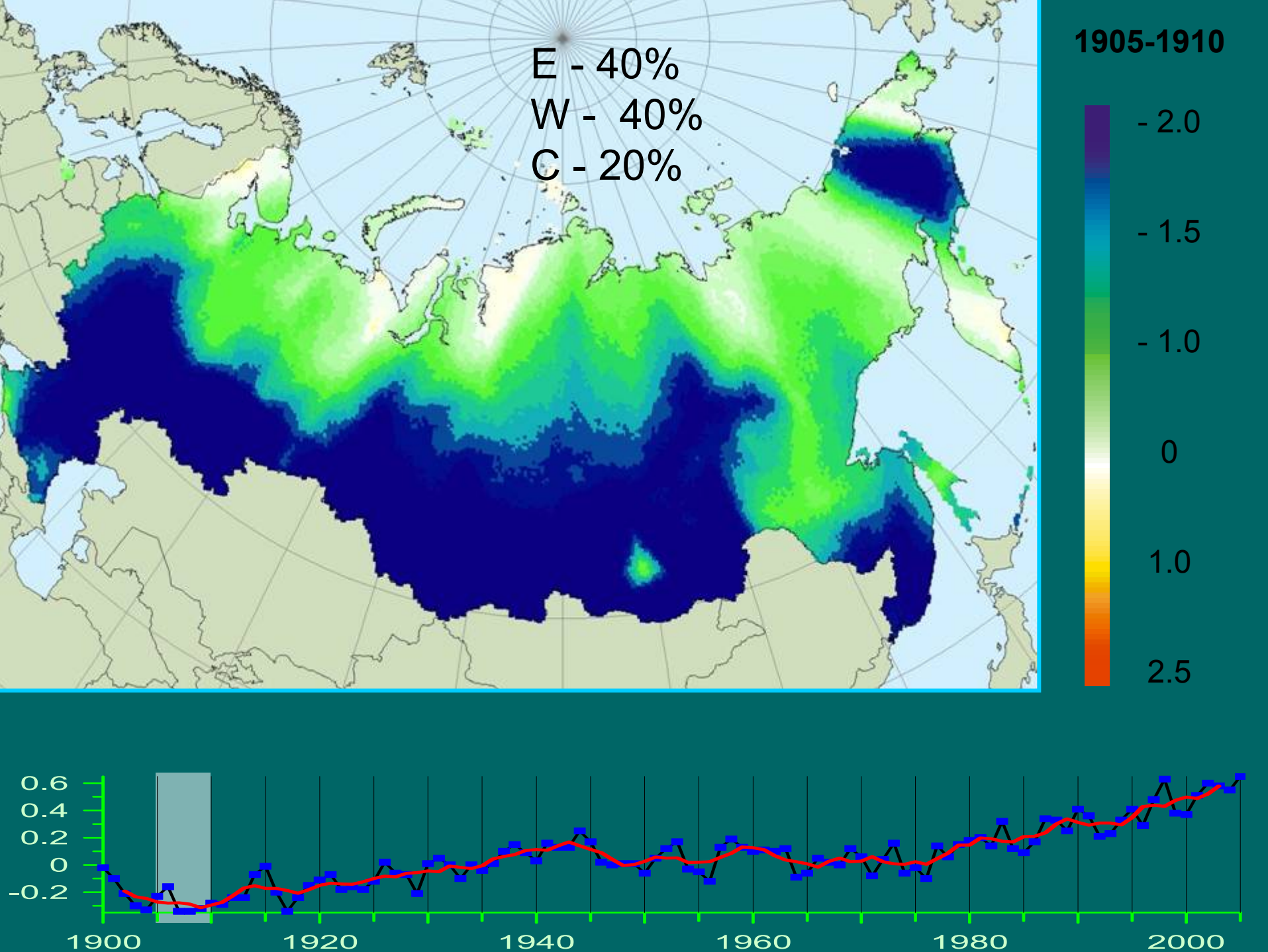


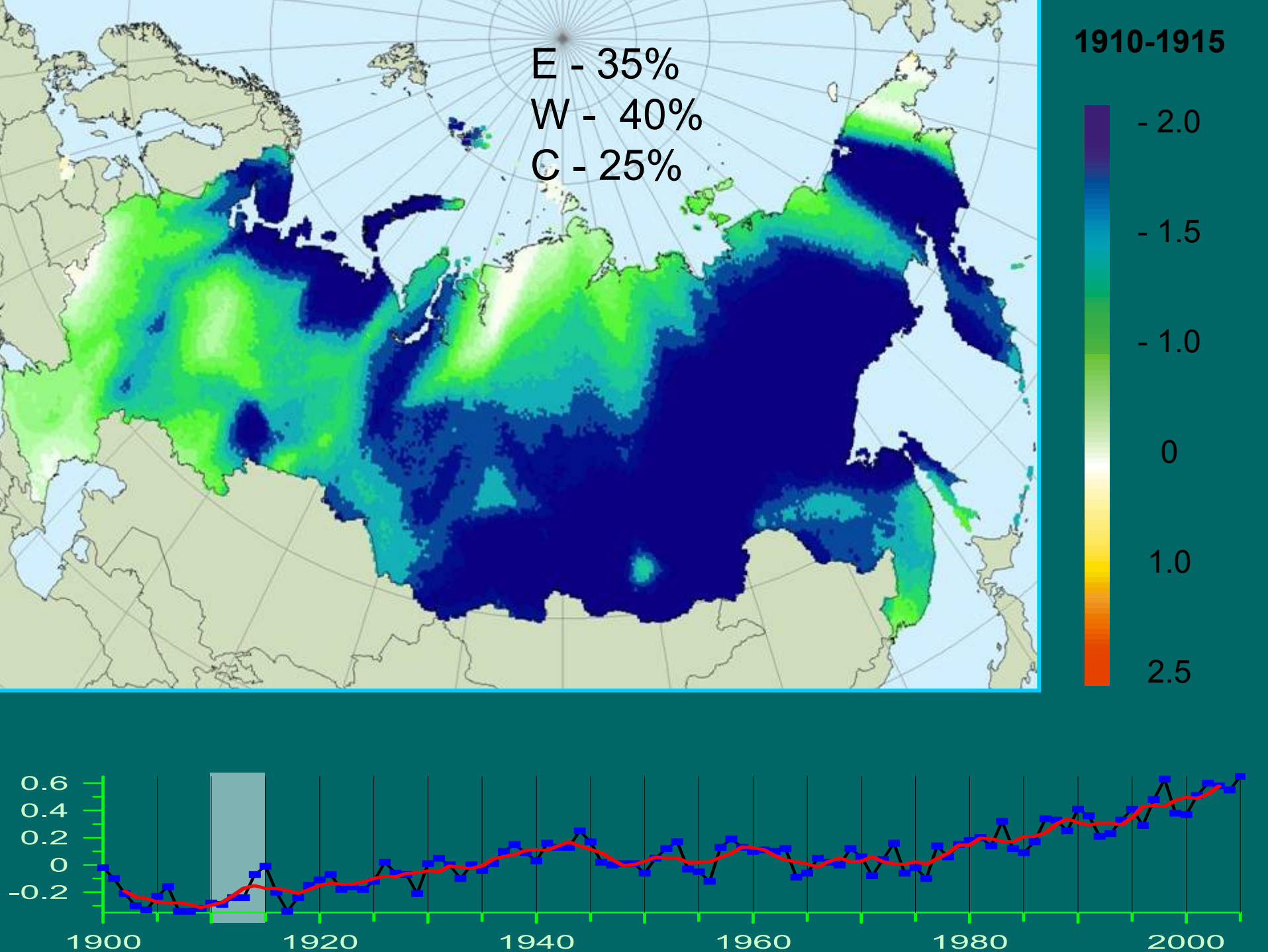
summer, 1976-2006

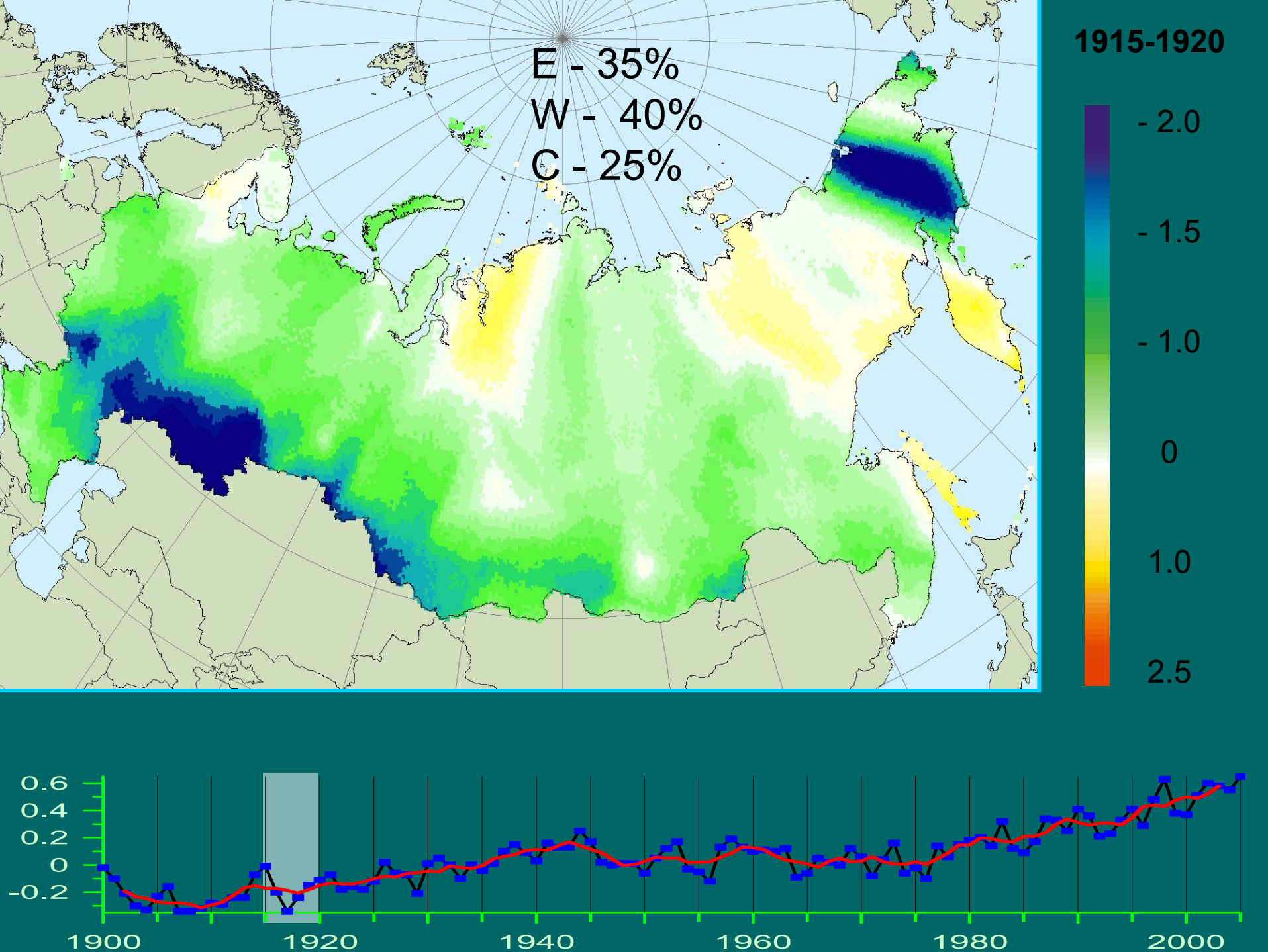


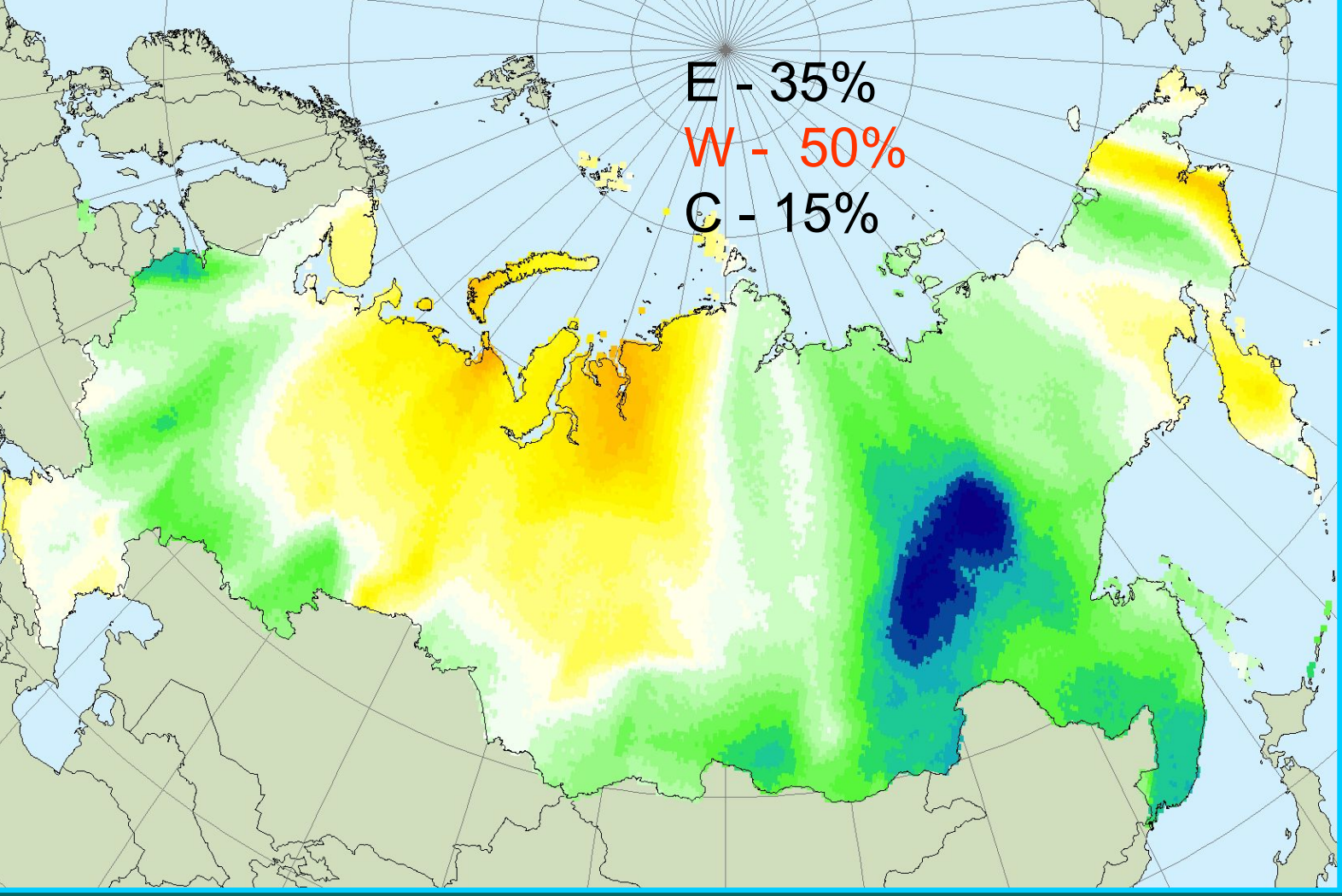
fall, 1976-2006

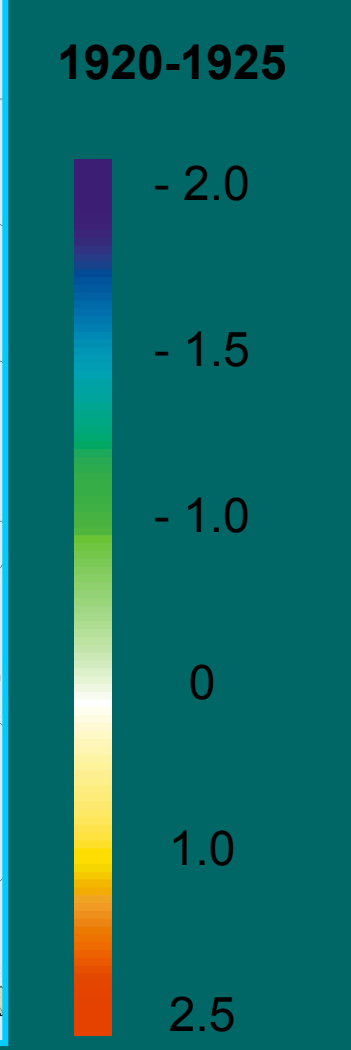

E - 35%
W - 40%
C - 25%
1900-1905
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
1920
1940
1960
1980
2000


E - 40%
W - 40%
C - 20%
1905-1910
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
1920
1940
1960
1980
2000

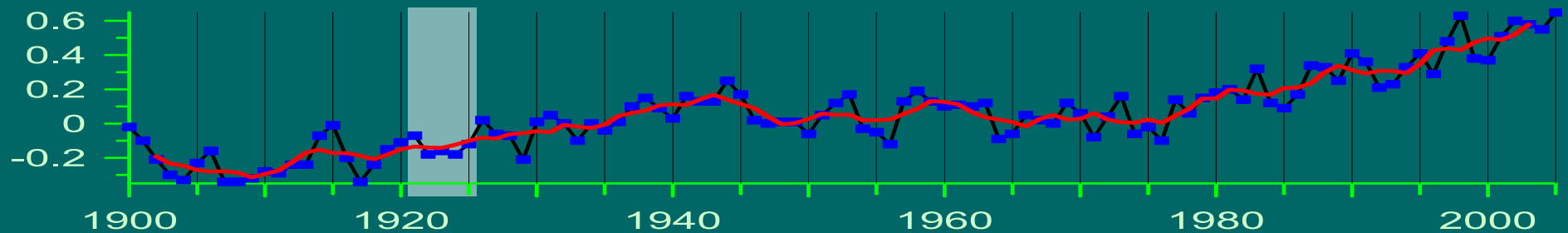

E - 35%
W - 40%
C - 25%
1910-1915
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
1920
1940
1960
1980
2000

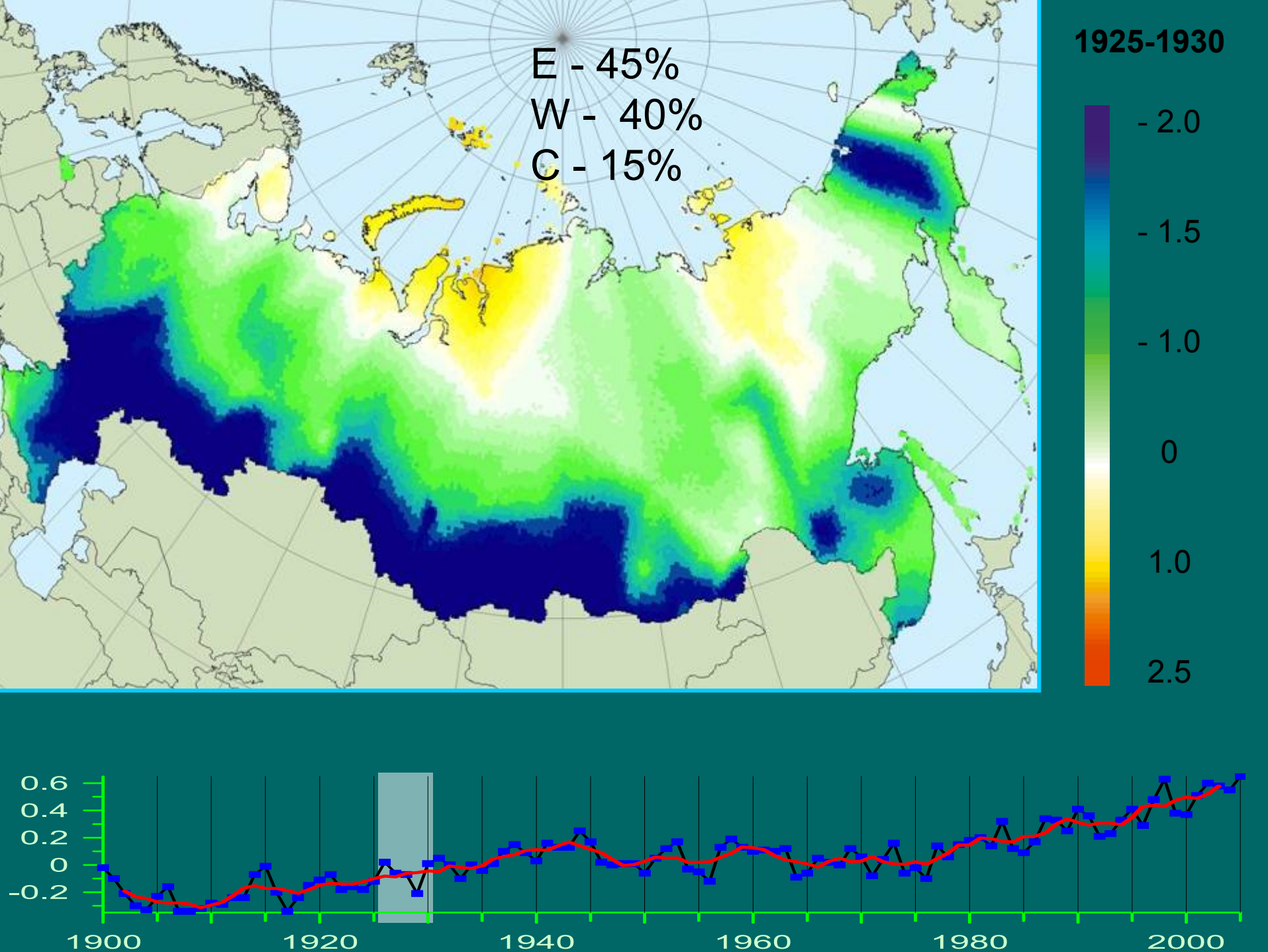

E - 35%
W - 40%
C - 25%
1915-1920
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
1920
1940
1960
1980
2000

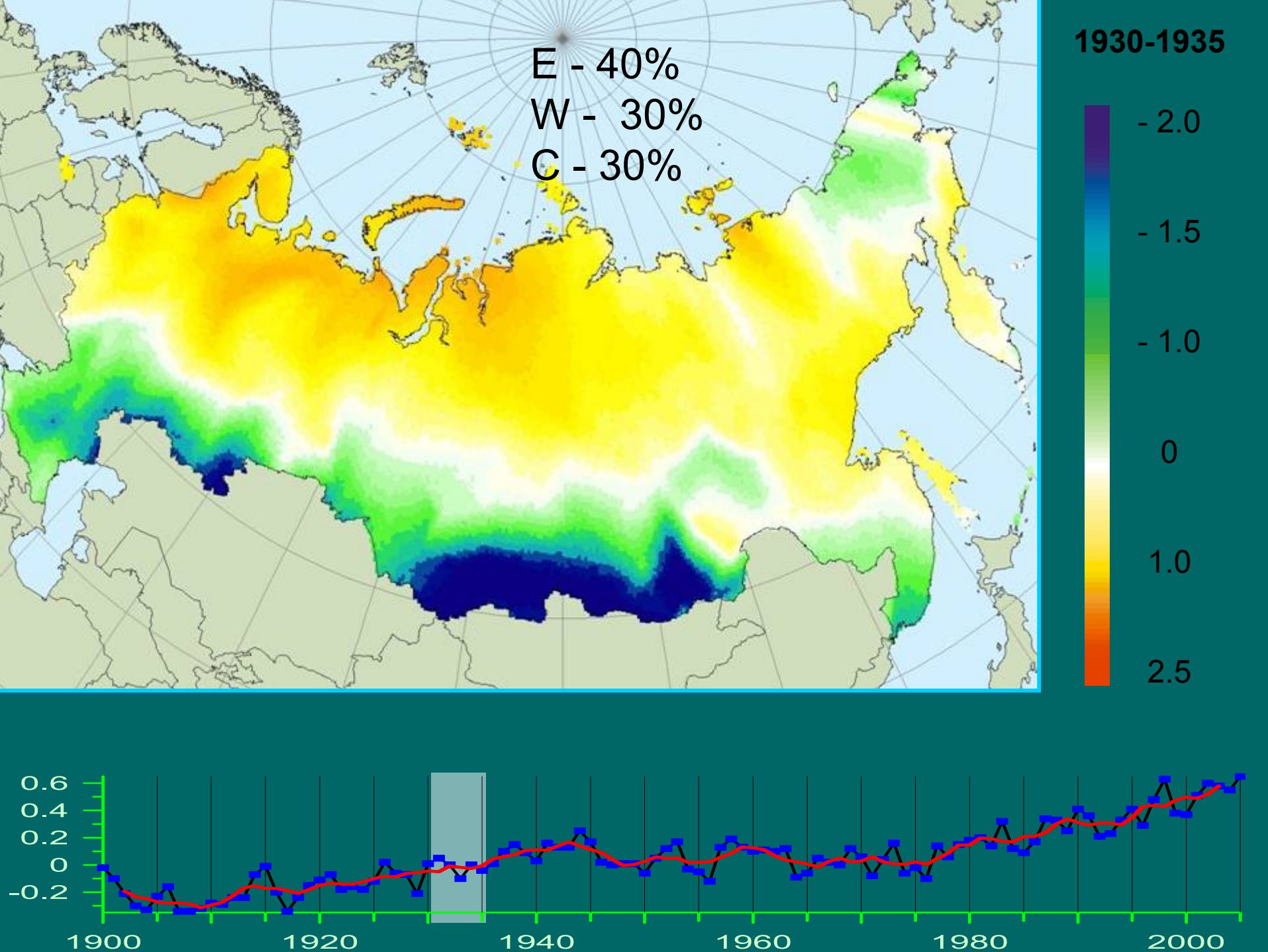


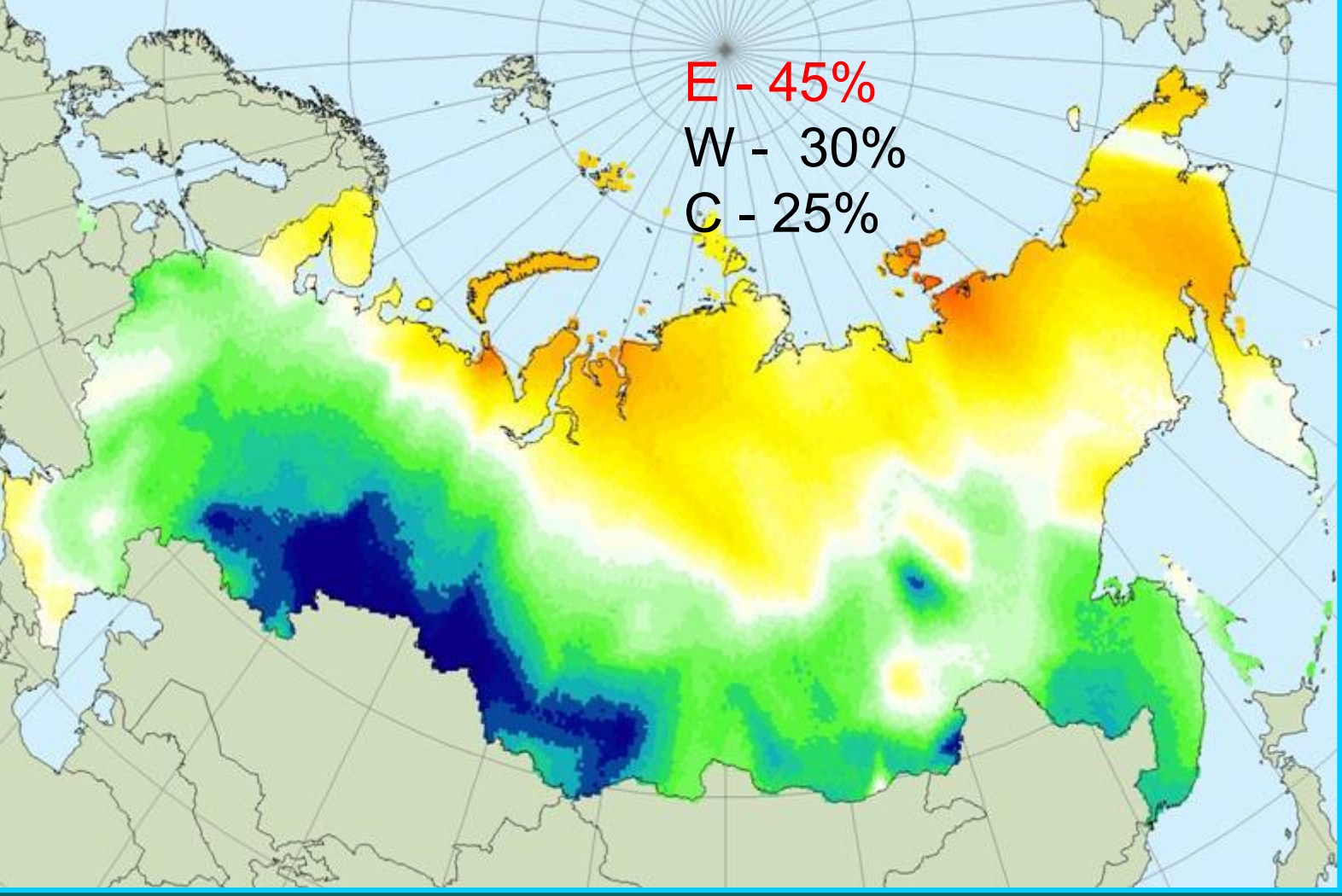


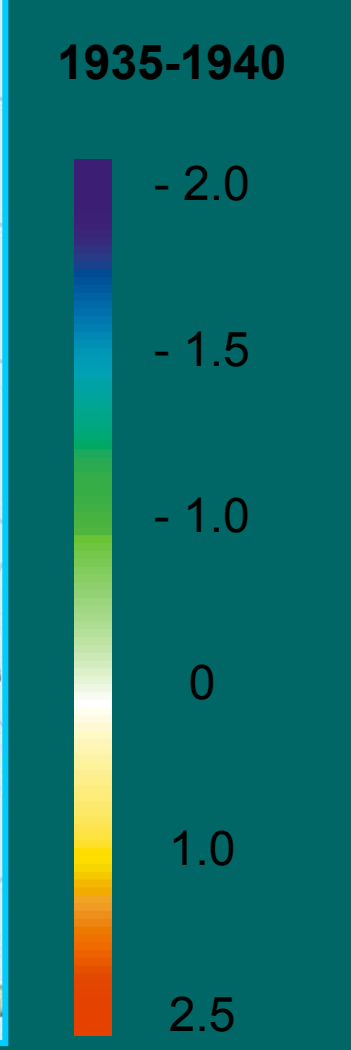
Typical pattern with distinct zonal gradient



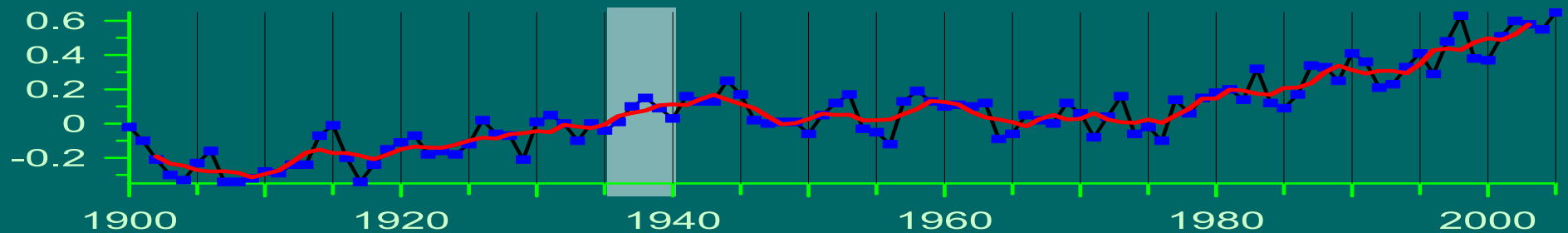

E - 45%
W - 40%
C - 15%
1925-1930
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
1920
1940
1960
1980
2000

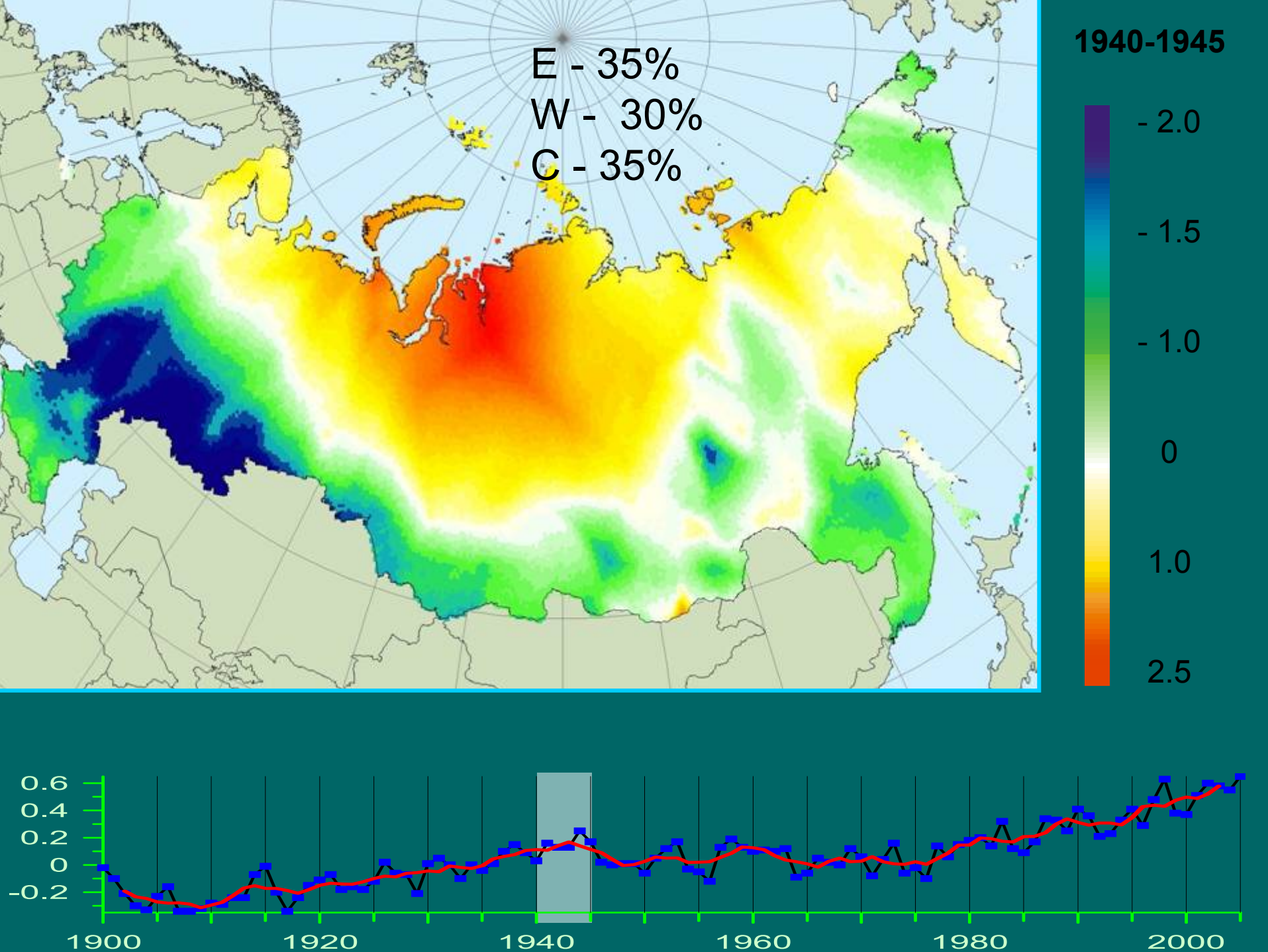

E - 40%
W - 30%
C - 30%
1930-1935
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
1920
1940
1960
1980
2000

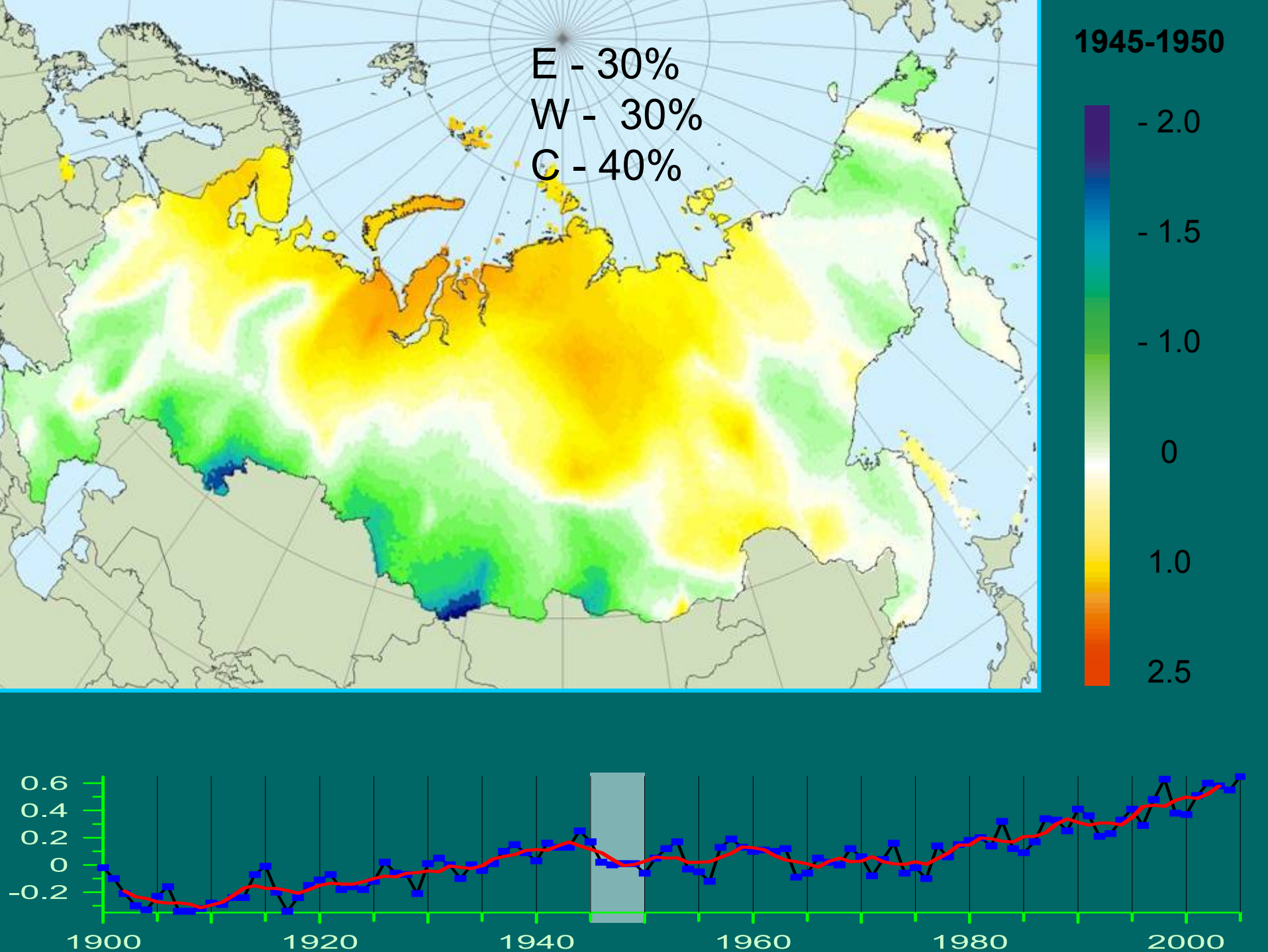


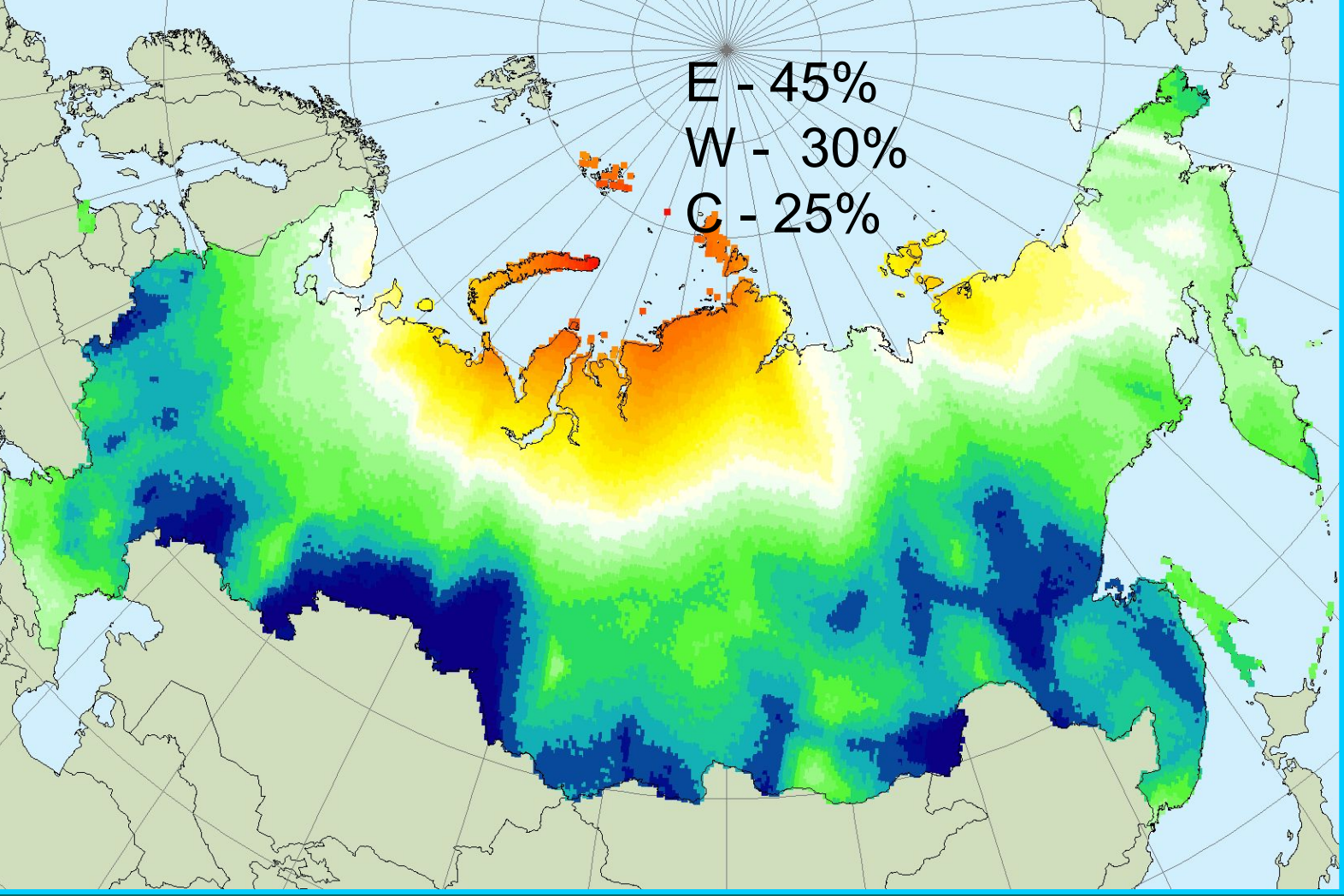


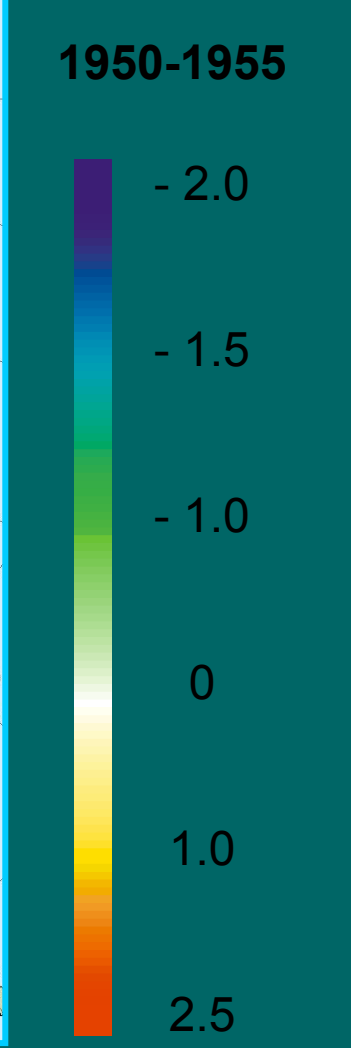
Iconic latitudinal zonation



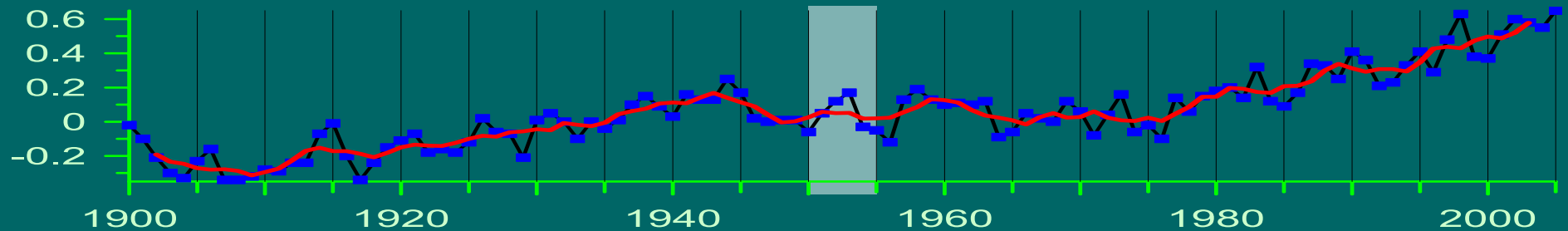

E - 35%
W - 30%
C - 35%
1940-1945
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
1920
1940
1960
1980
2000

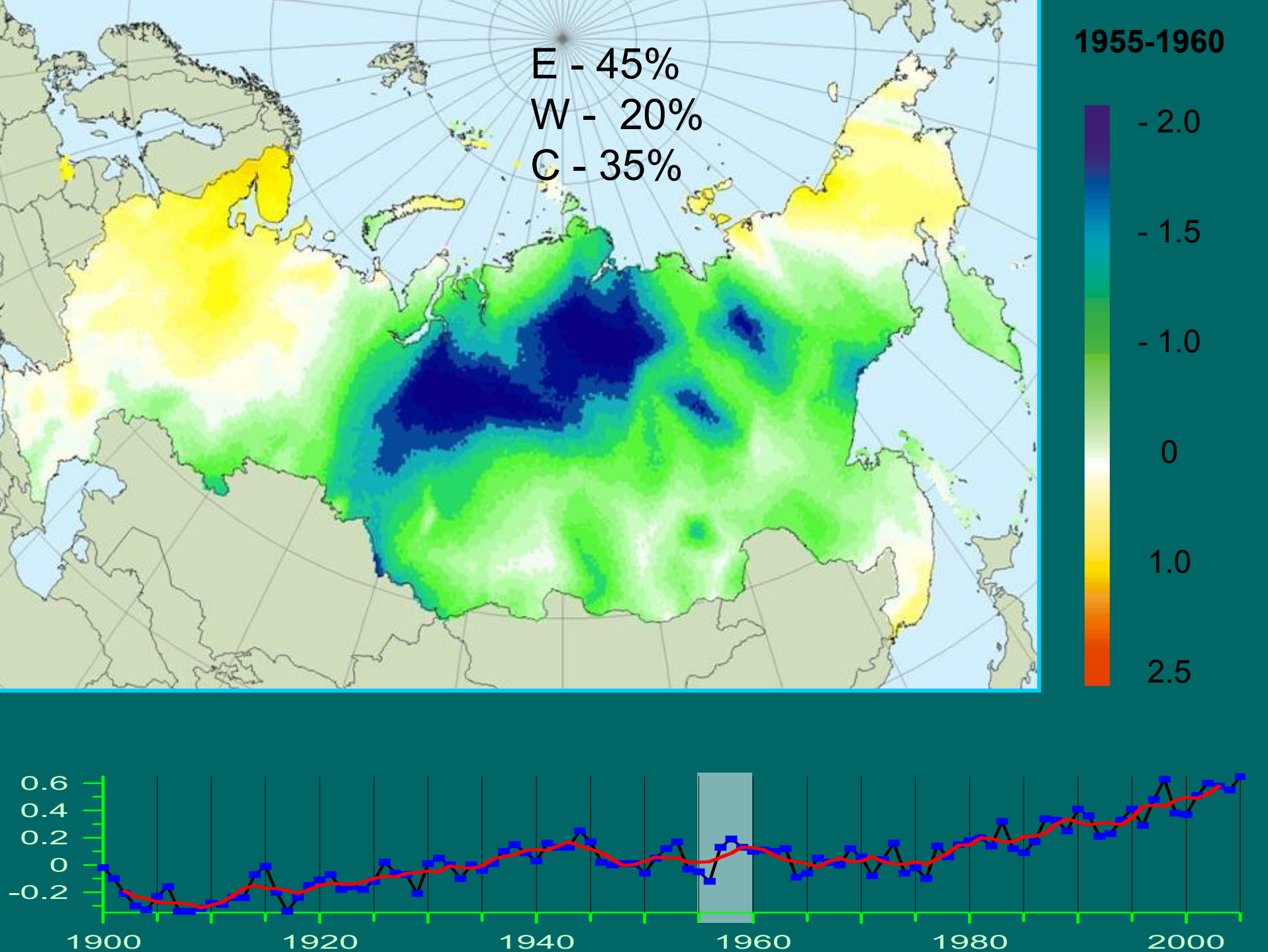

E - 30%
W - 30%
C - 40%
1945-1950
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
1920
1940
1960
1980
2000

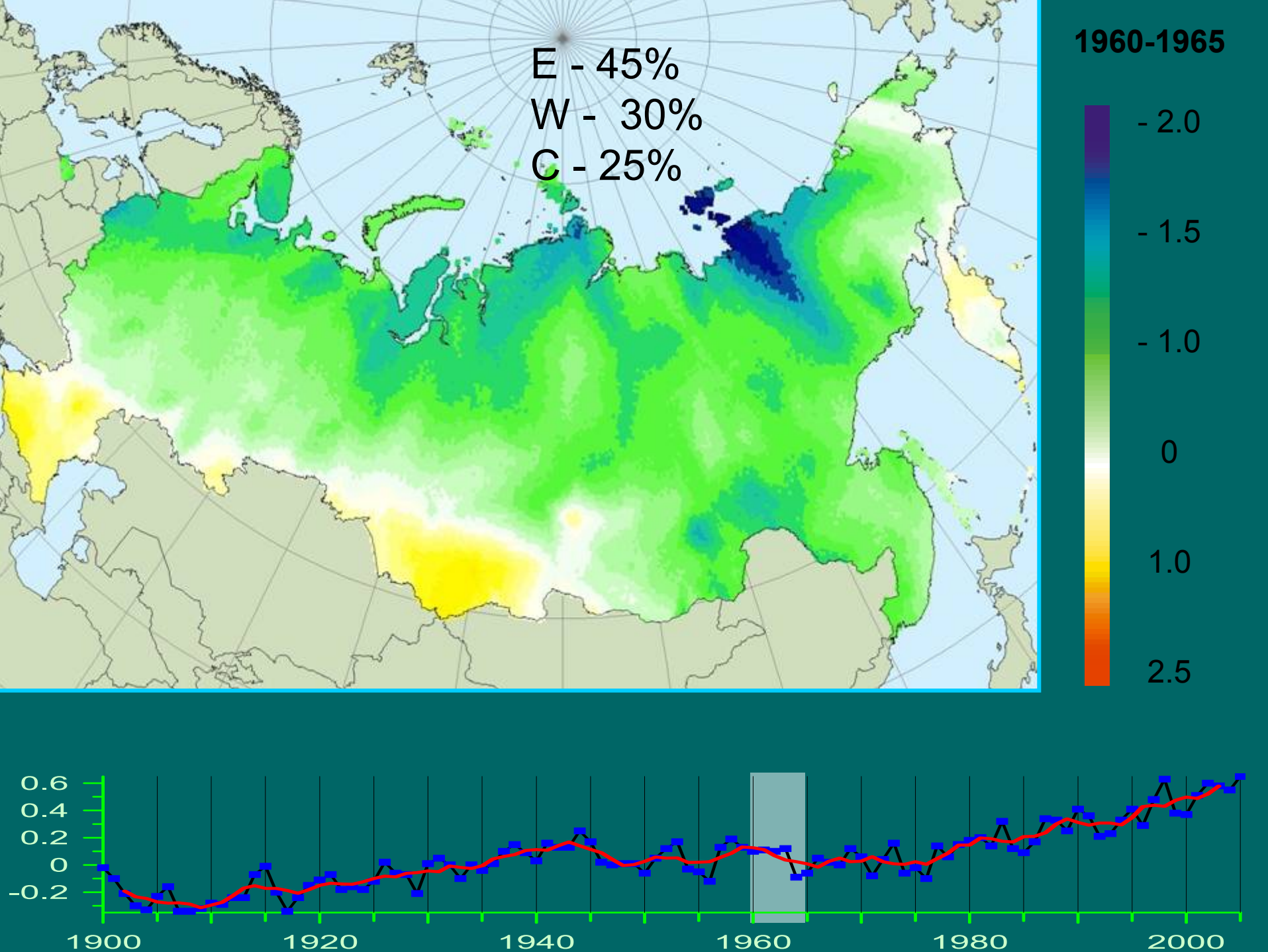




Mixed pattern with latitudinal and zonal gradients




E - 45%
W - 20%
C - 35%
1955-1960
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
1920
1940
1960
1980
2000


E - 45%
W - 30%
C - 25%
1960-1965
- 2.0
- 1.5
- 1.0
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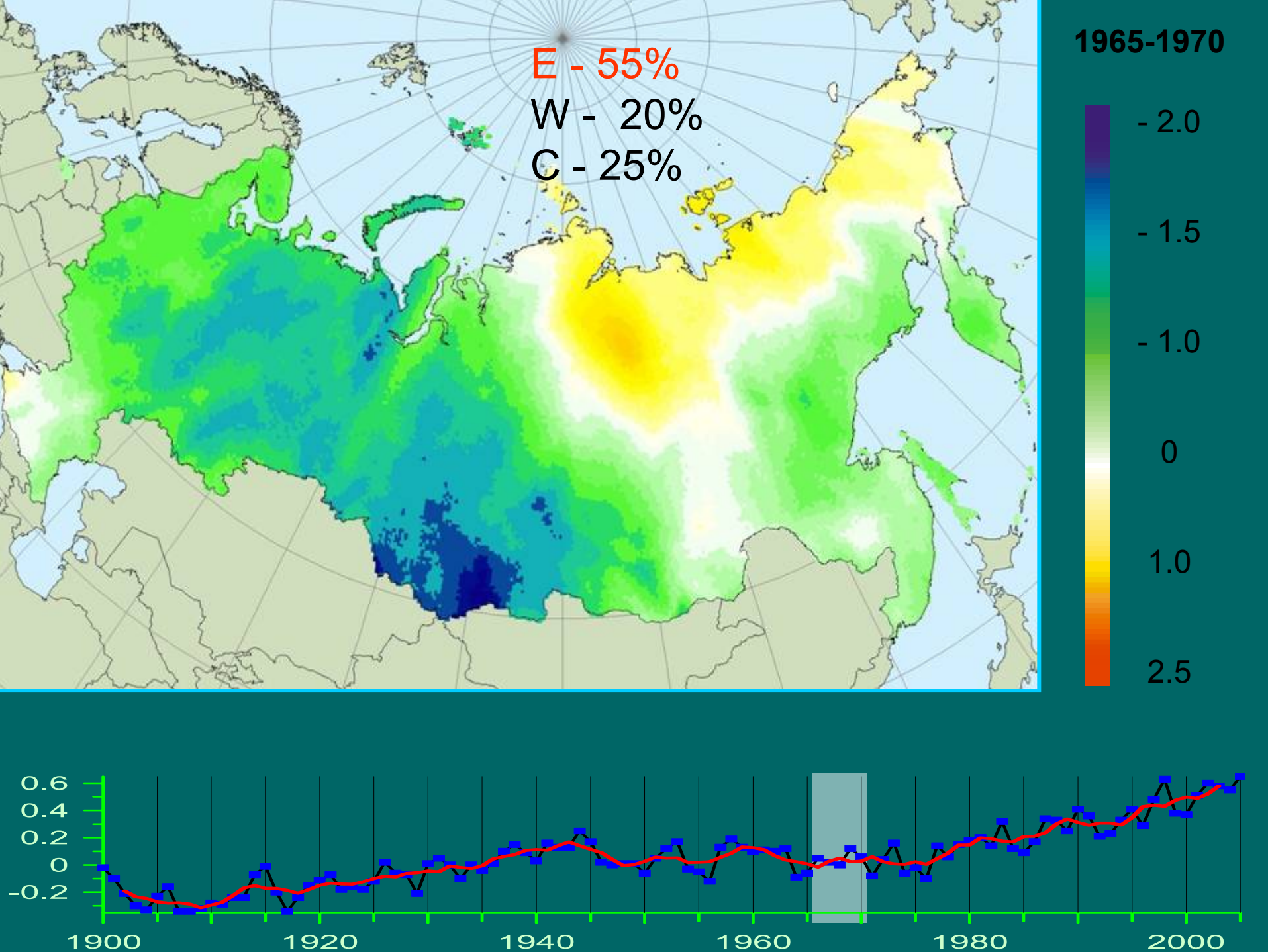
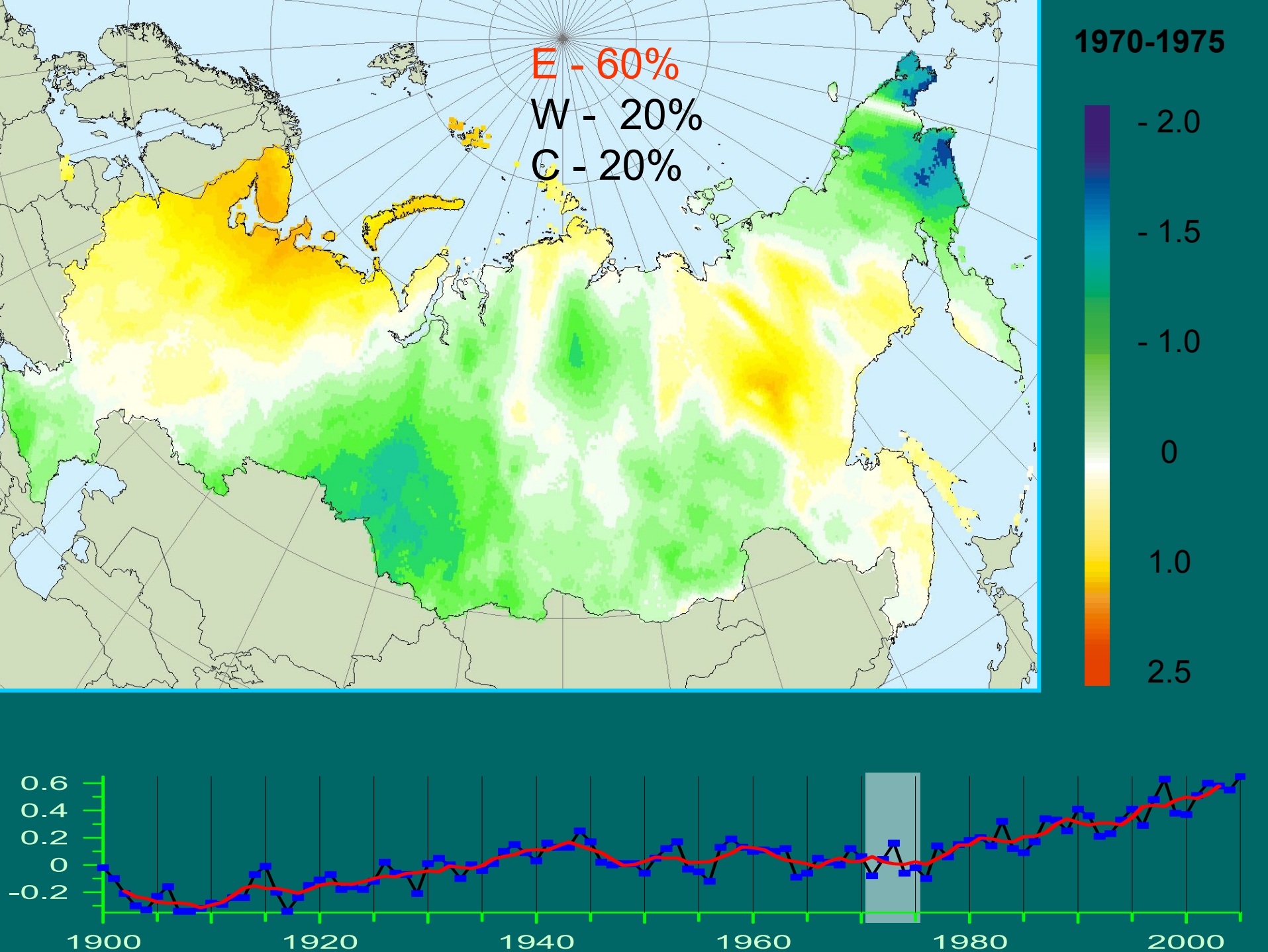
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
1920
1940
1960
1980
2000


E - 55%
W - 20%
C - 25%
1965-1970
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
1920
1940
1960
1980
2000


E - 60%
W - 20%
C - 20%
1970-1975
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
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-0.2
1900
1920
1940
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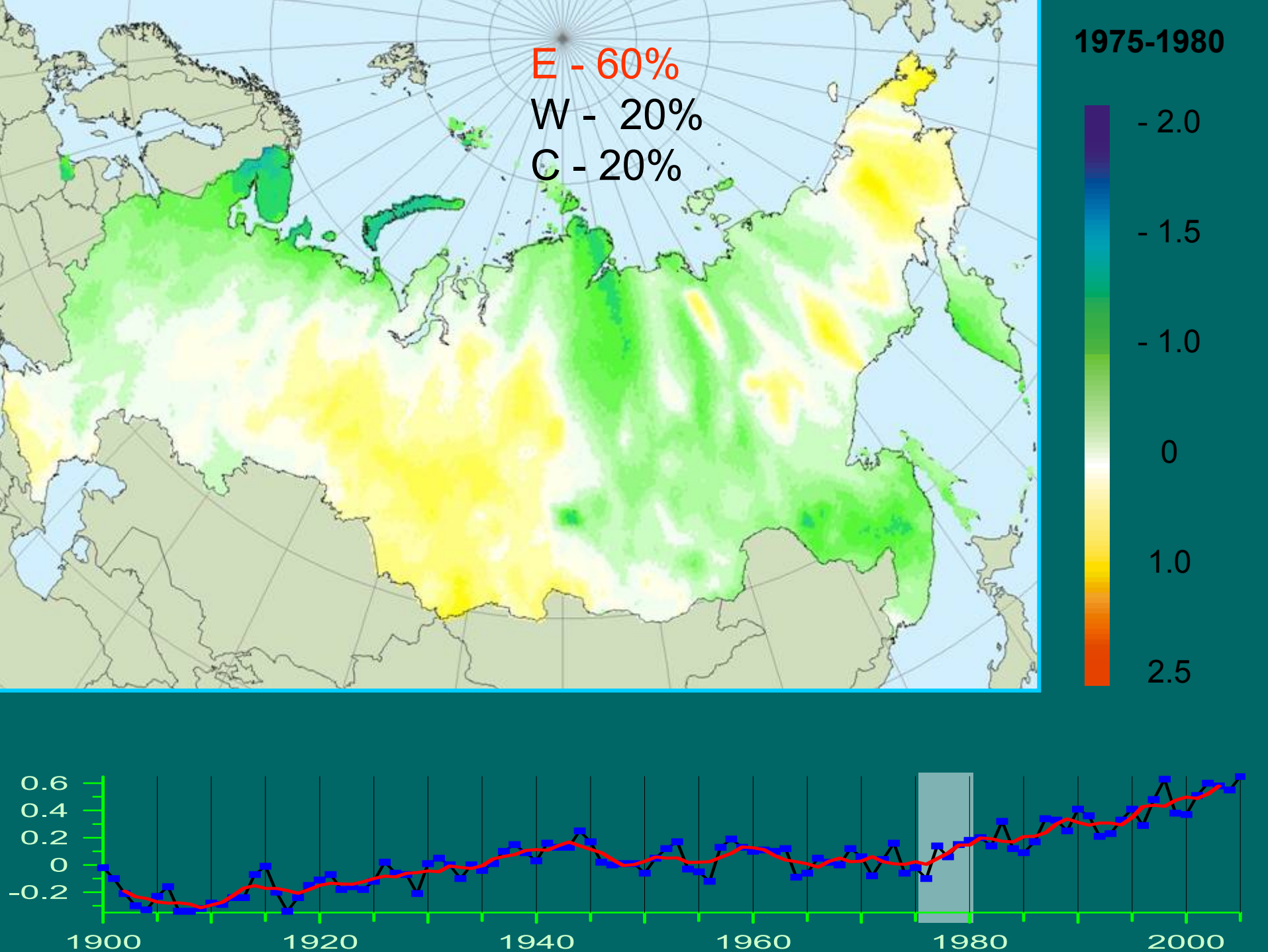
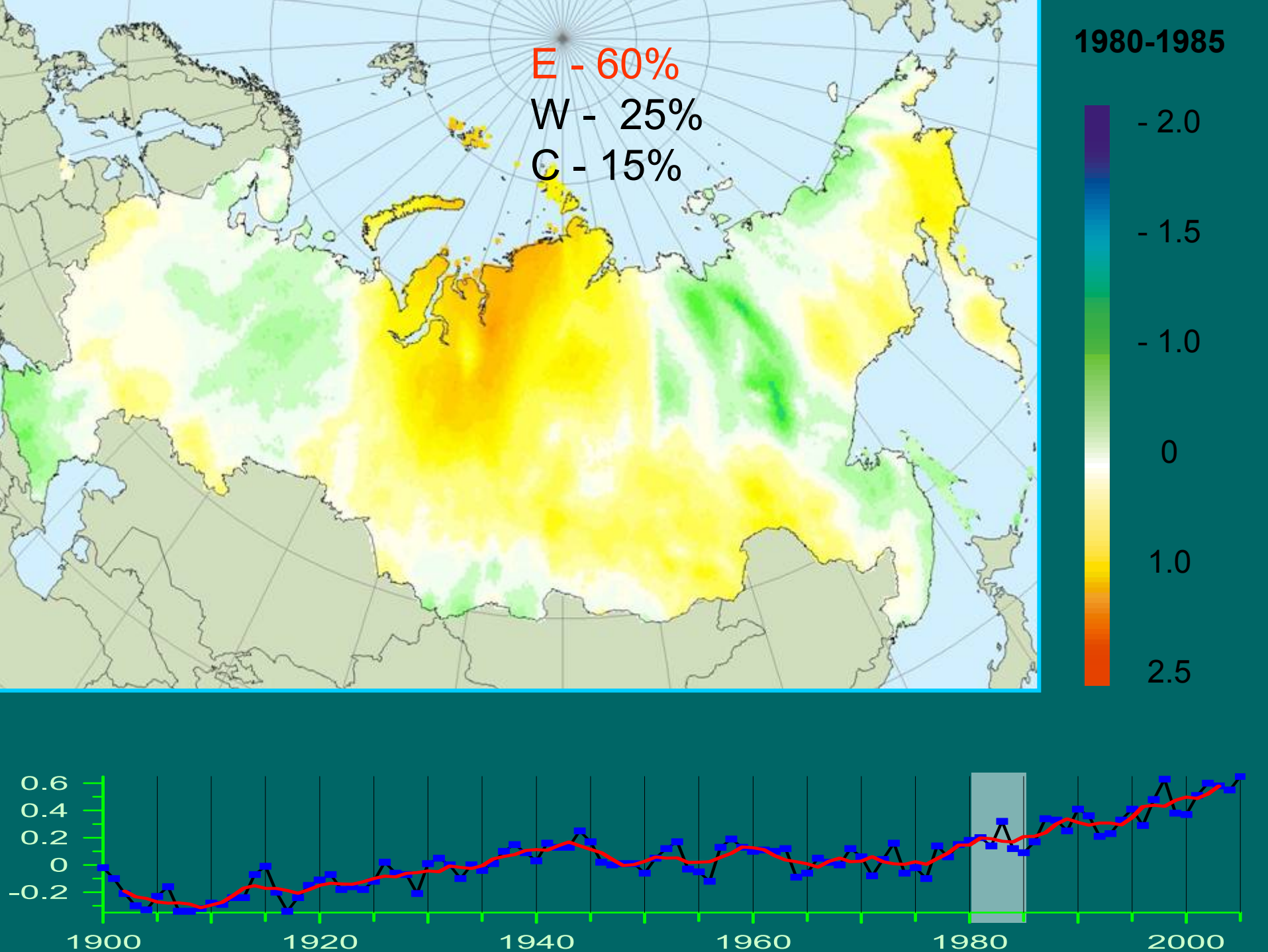
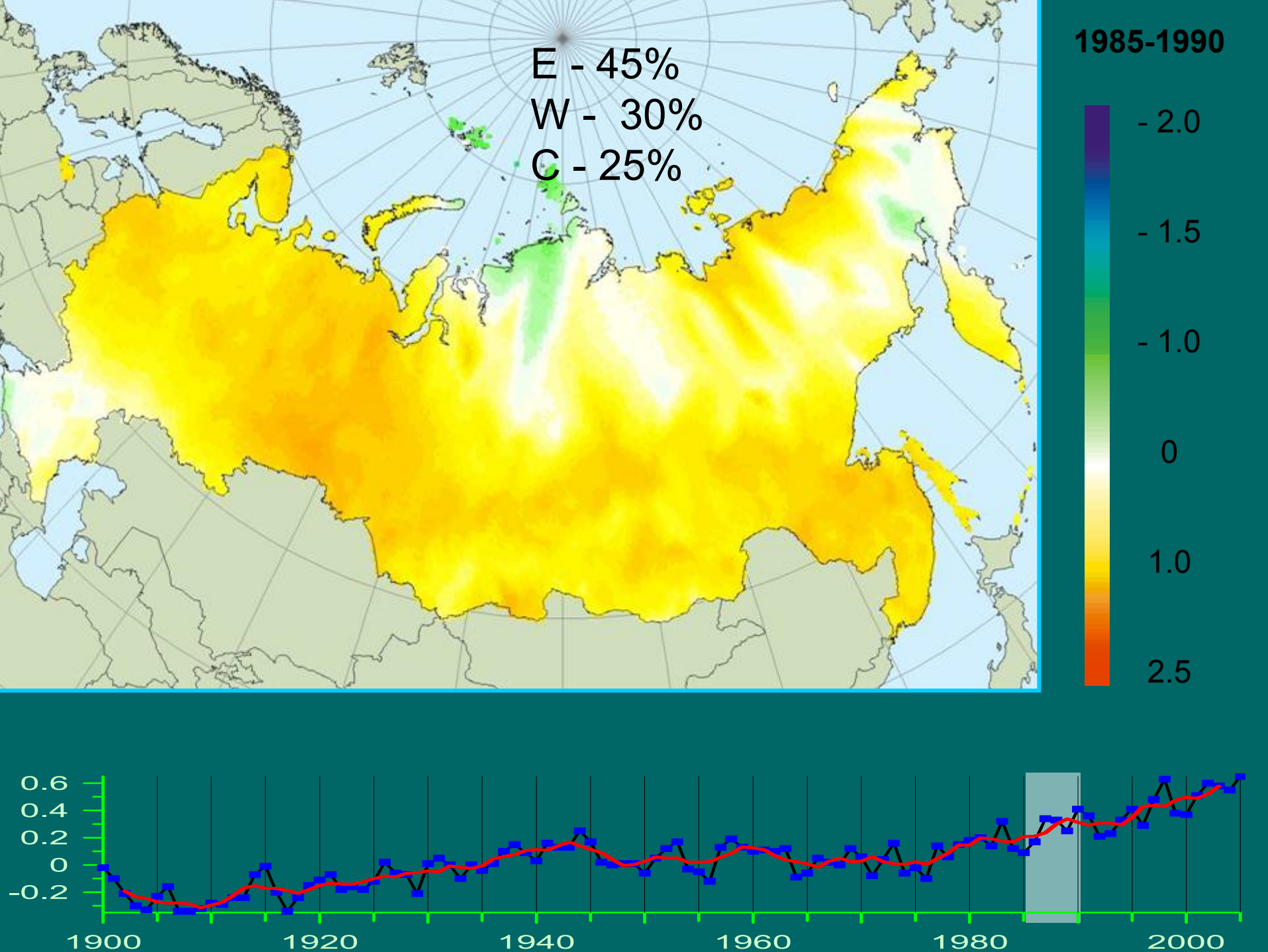
1980
2000


E - 60%
W - 20%
C - 20%
1975-1980
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
1920
1940
1960
1980
2000


E - 60%
W - 25%
C - 15%
1980-1985
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
1920
1940
1960
1980
2000


E - 45%
W - 30%
C - 25%
1985-1990
- 2.0
- 1.5
- 1.0
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1.0
2.5
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0
-0.2
1900
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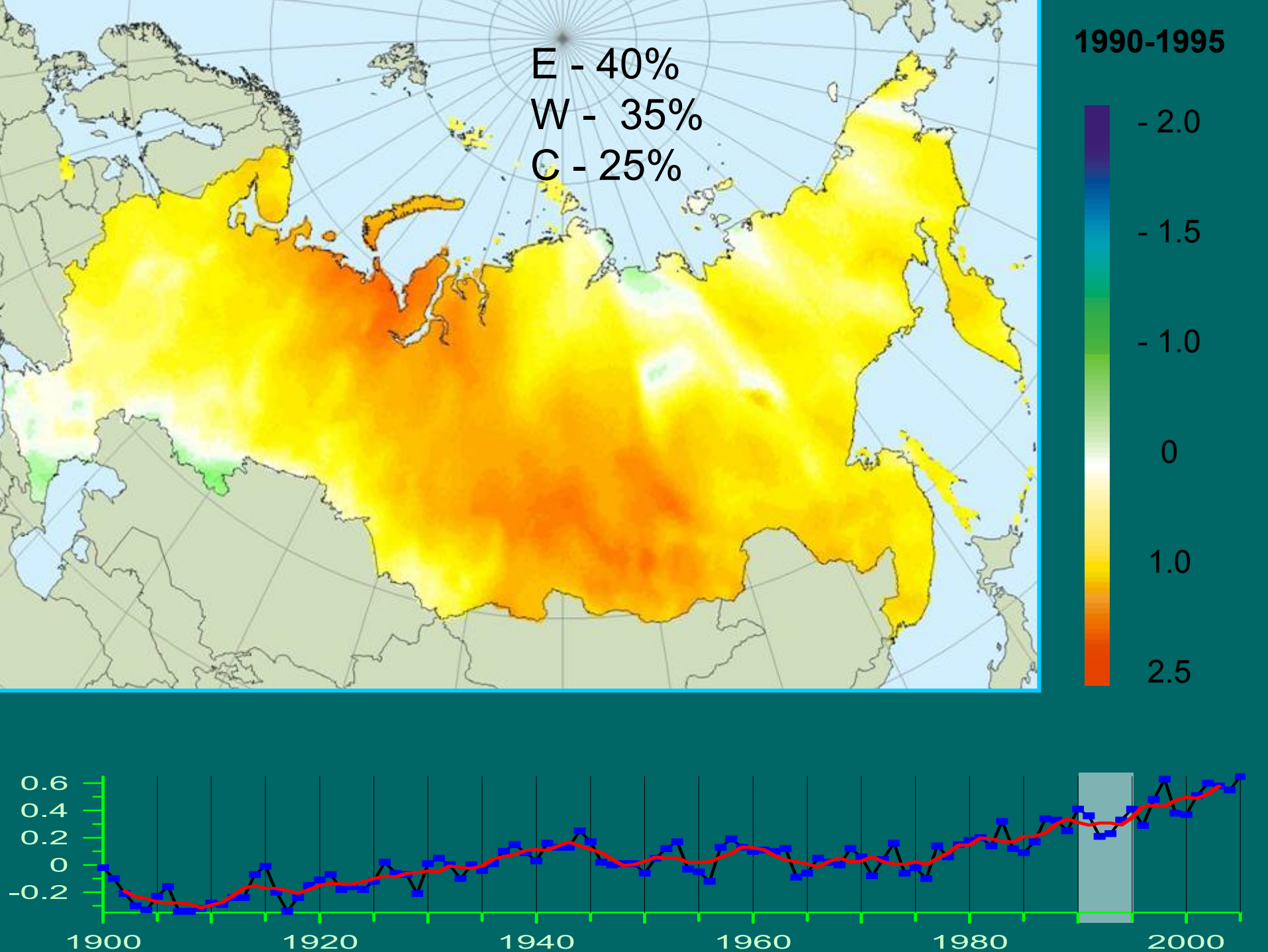
1940
1960
1980
2000


E - 40%
W - 35%
C - 25%
1990-1995
- 2.0
- 1.5
- 1.0
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1900
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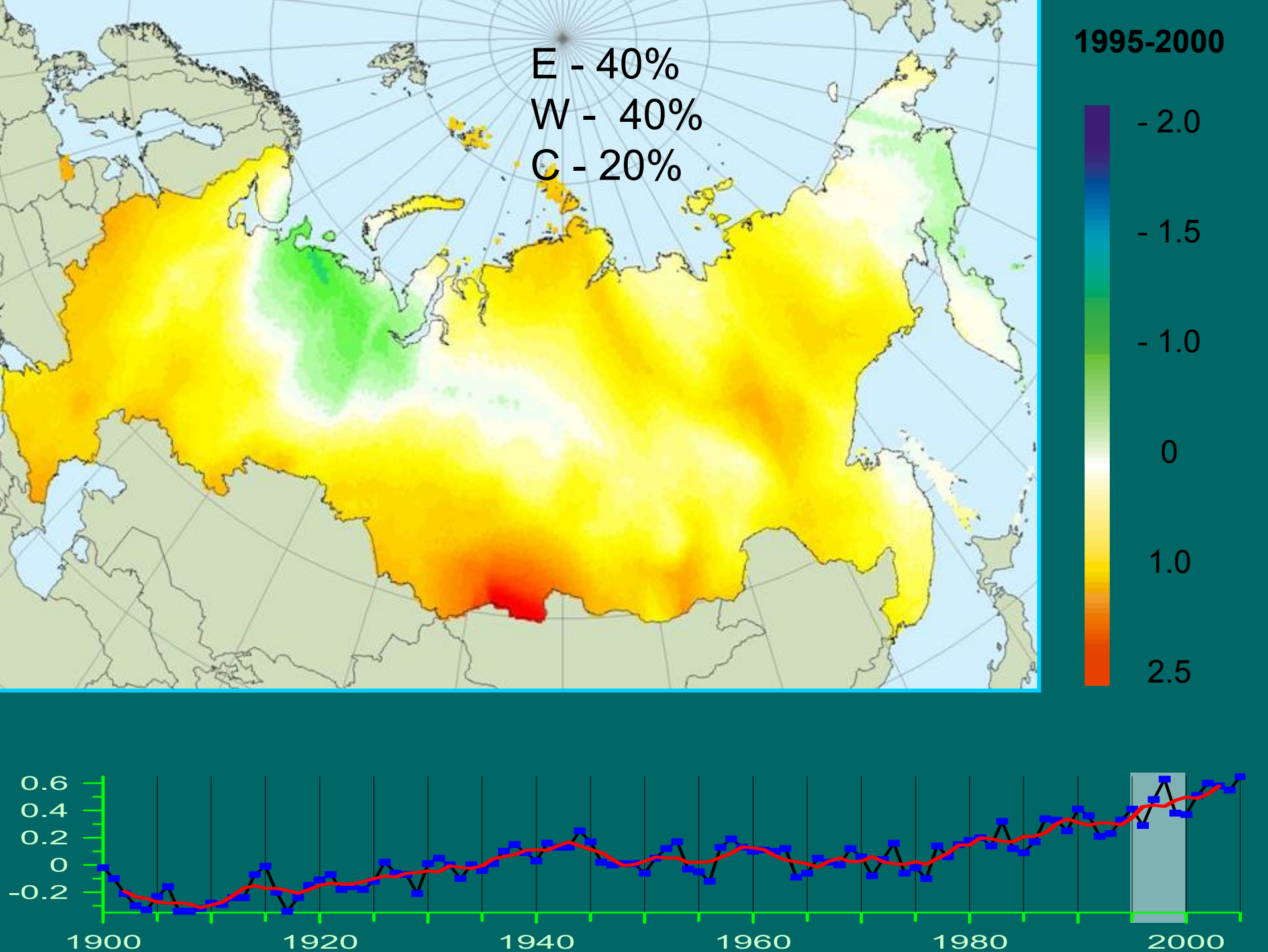
1980
2000


E - 40%
W - 40%
C - 20%
1995-2000
- 2.0
- 1.5
- 1.0
0
1.0
2.5
0.6
0.4
0.2
0
-0.2
1900
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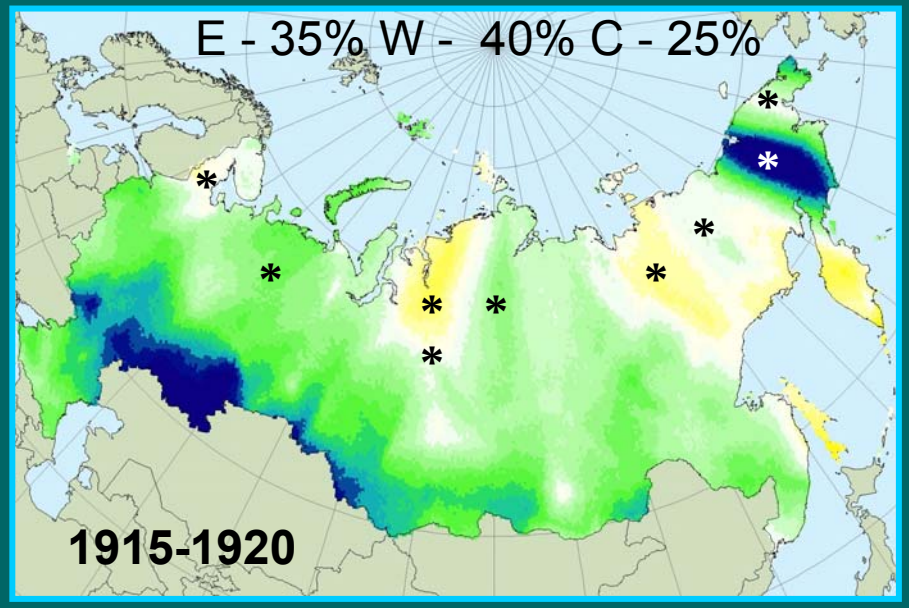
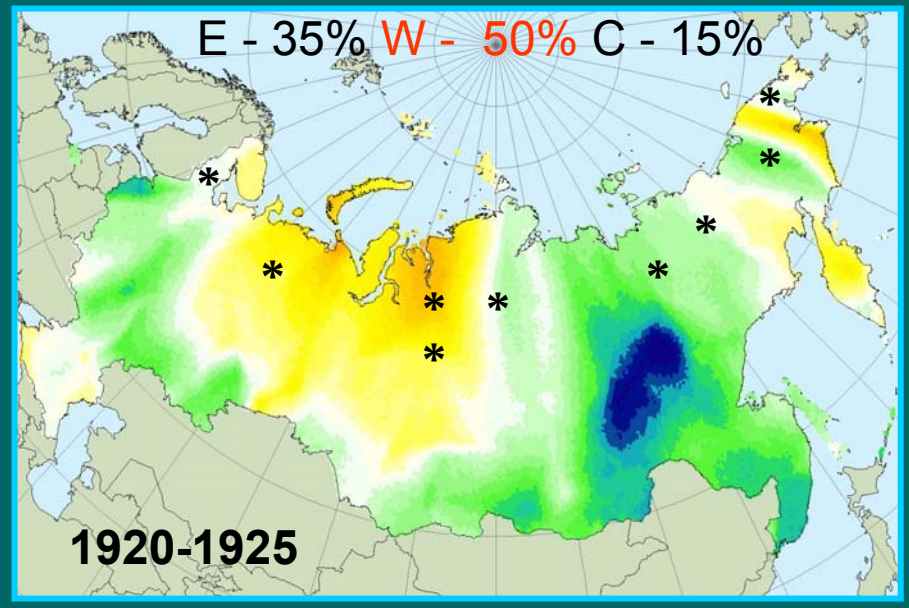
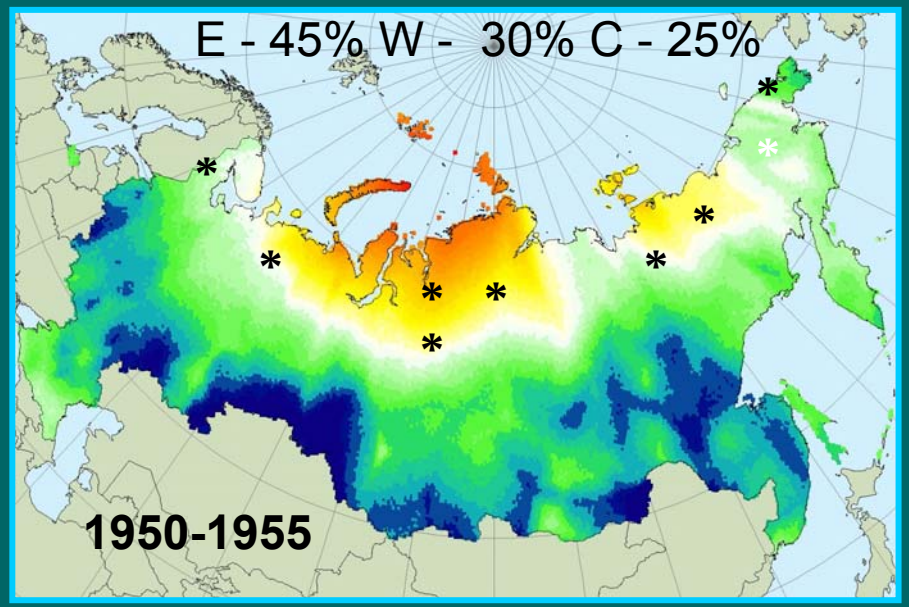
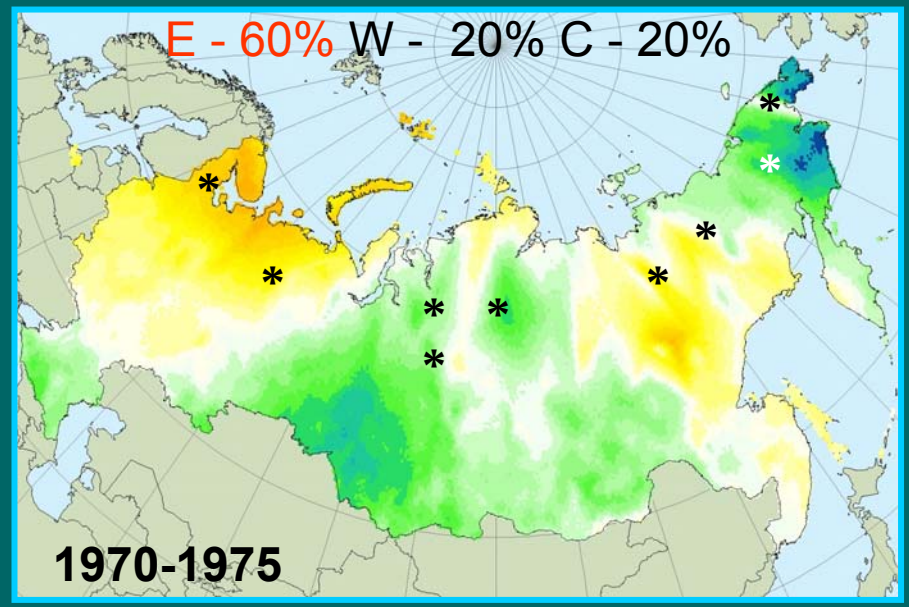
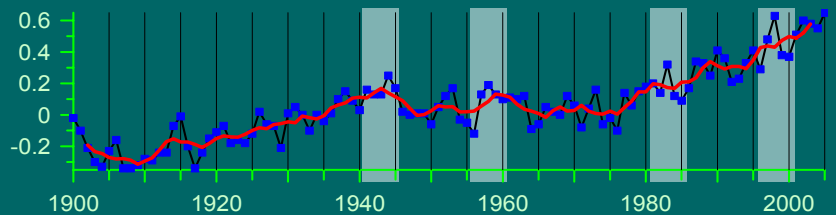








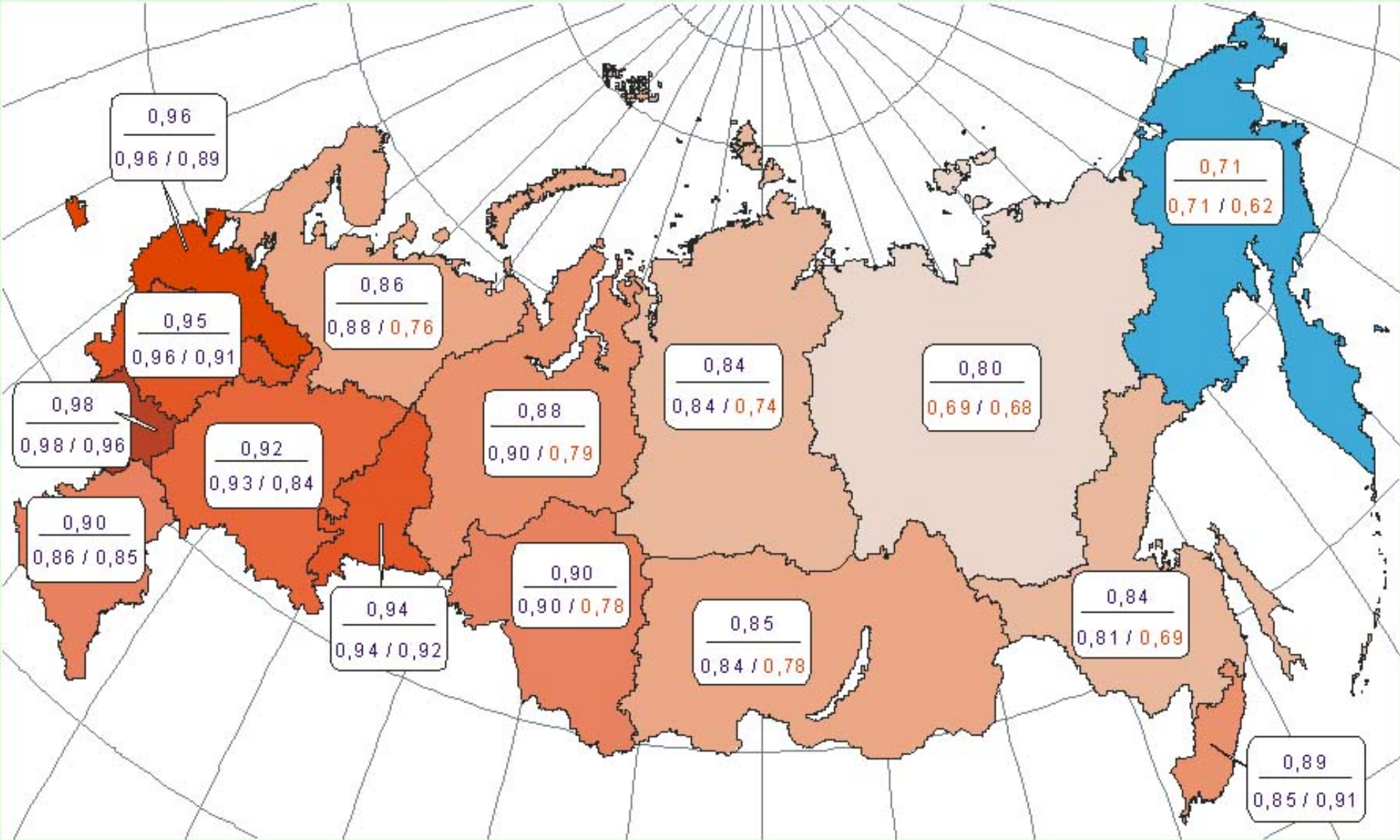


Departures from 1961-1990 norm, MAAT

-2.0 -1.5 -1.0 0 1.0 2.5

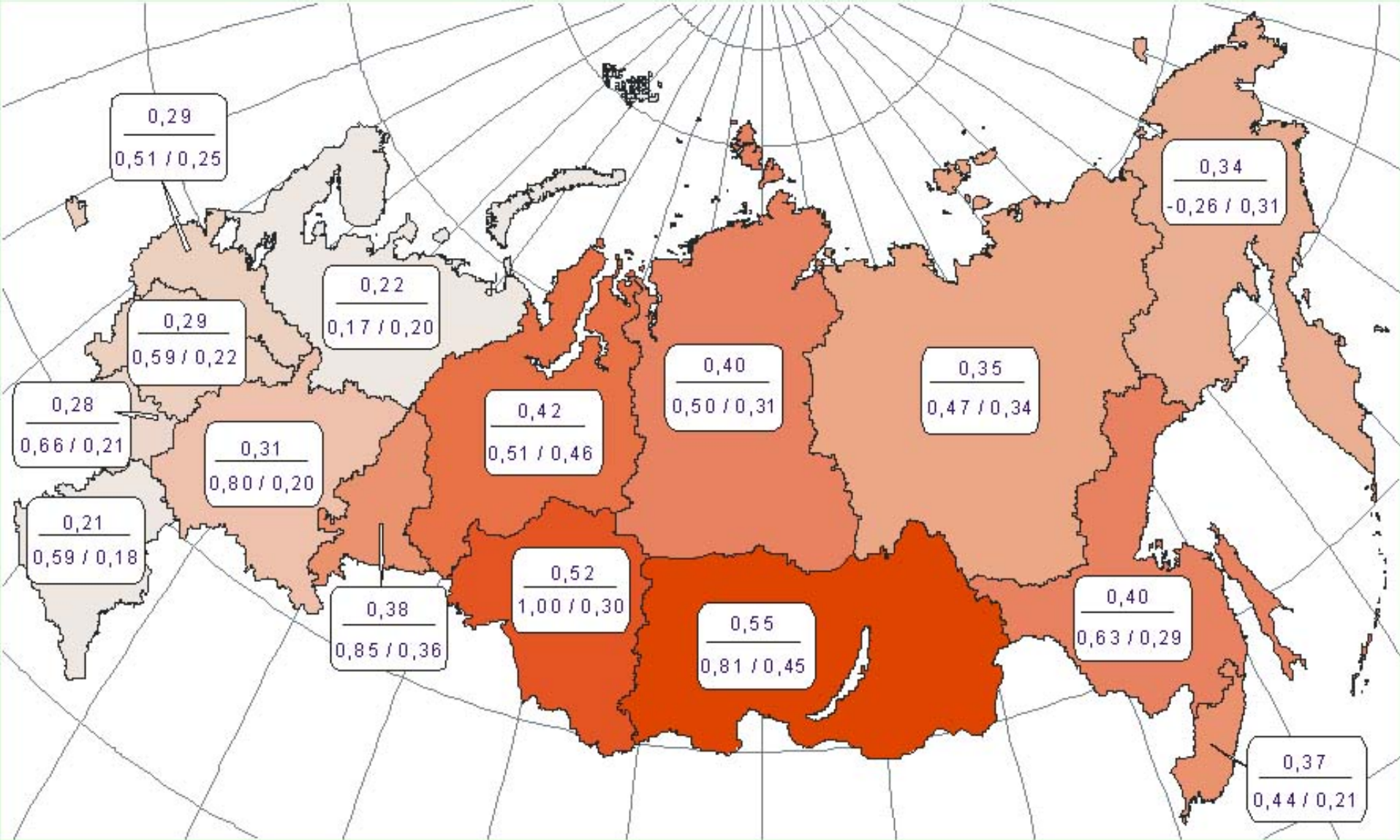
Spatial coherence of the temperature variations characterized by mean regional correlation coefficient, 1970-2006

Numerator – mean annual T; denominator – winter / summer



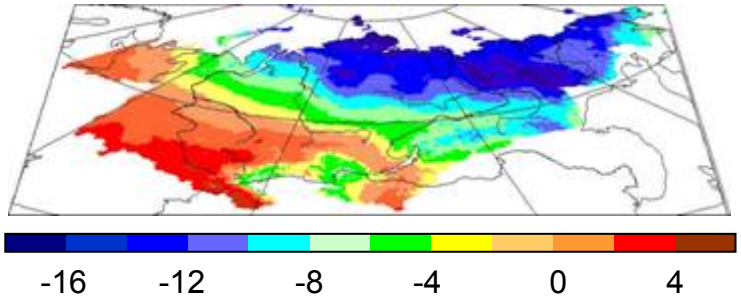
Regional temperature trends, 1970-2006, °C/10 years.

Numerator – annual mean, denominator - winter/ summer
Mean for Russia: 0.38 (annual); 0.51 (winter); 0.32 (summer)

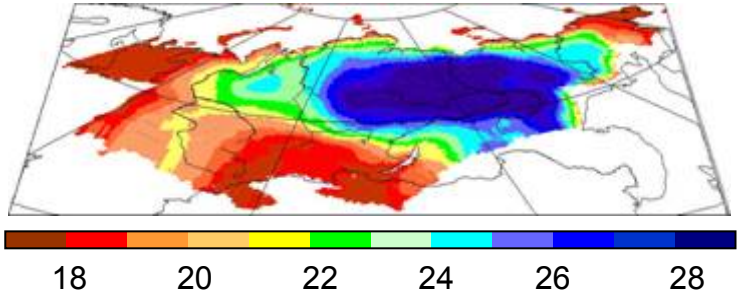


Implications for permafrost observations

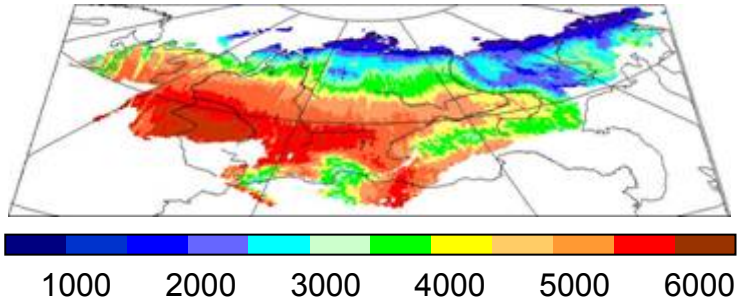
Mean annual air temperature, ^{0}C

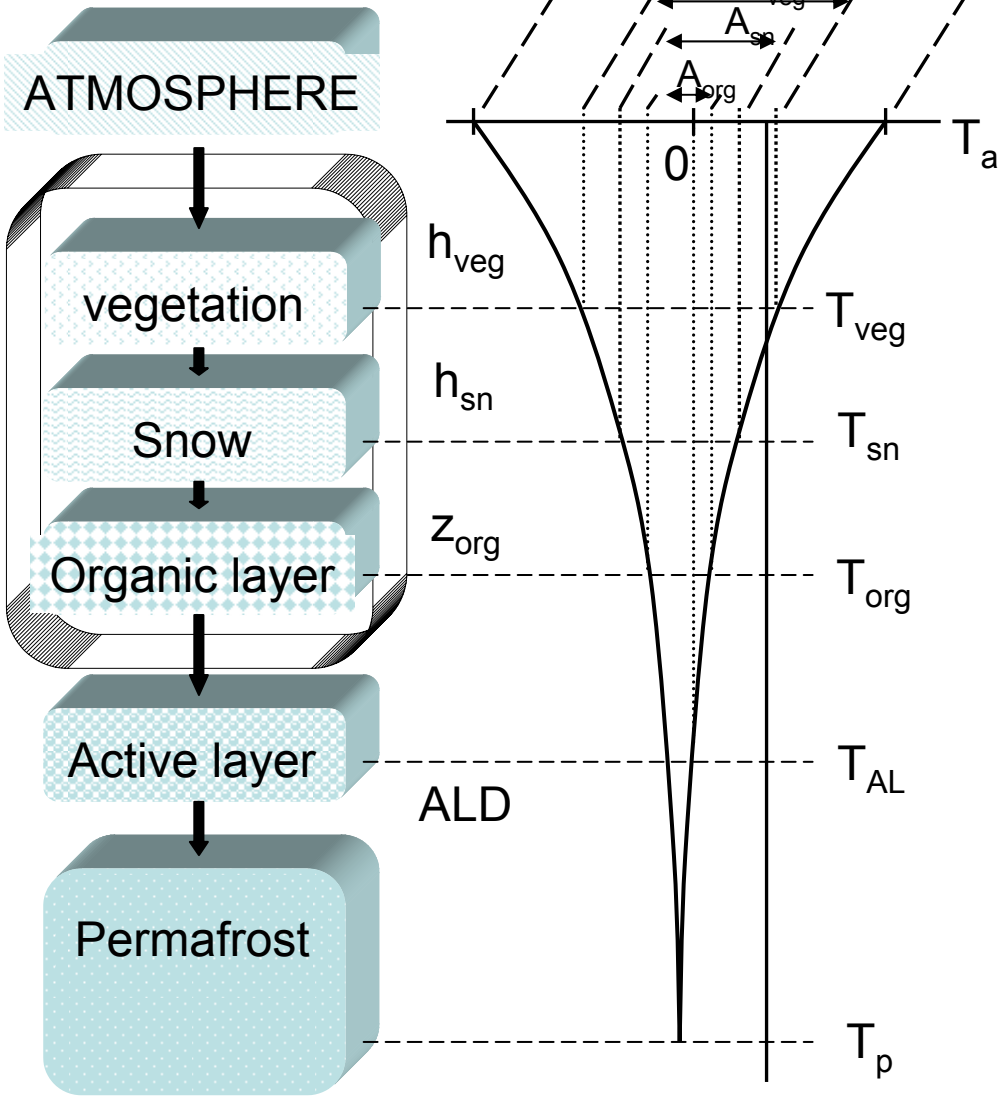


Annual air temperature amplitude, ^{0}C



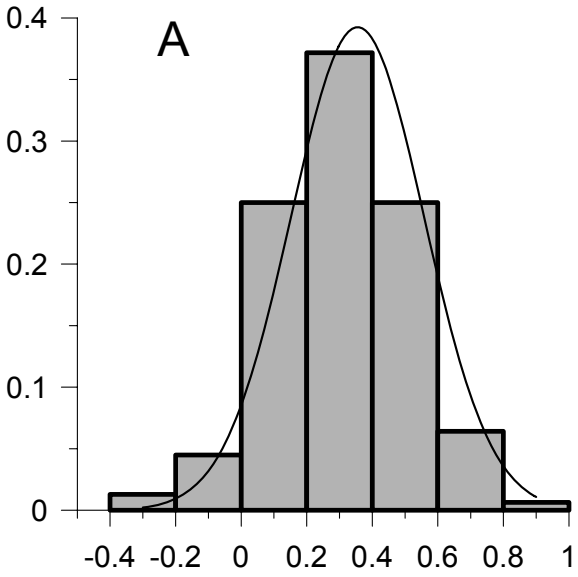
Thawing degree-days, ^{0}C d



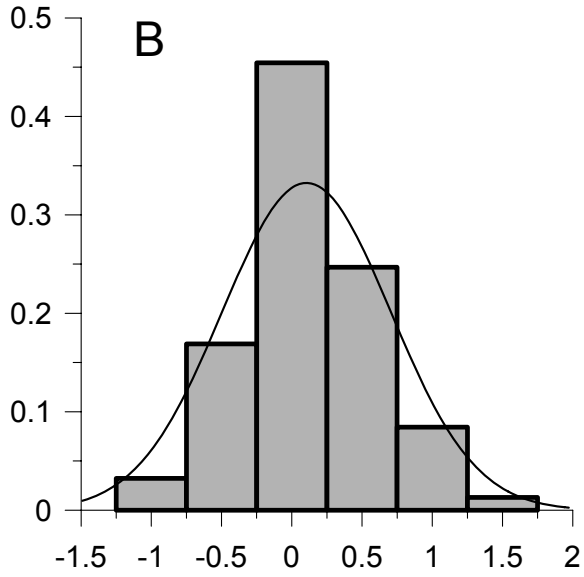


Implications for permafrost observations

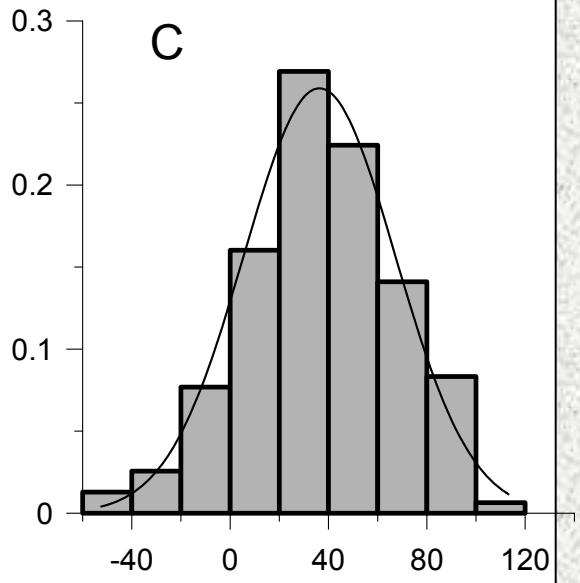
Frequency distribution of the decadal changes of temperature characteristics in the period 1970-2006 based on data from weather stations in Russian permafrost regions (156 stations).



Mean annual air temperature, ^{o}C/10y



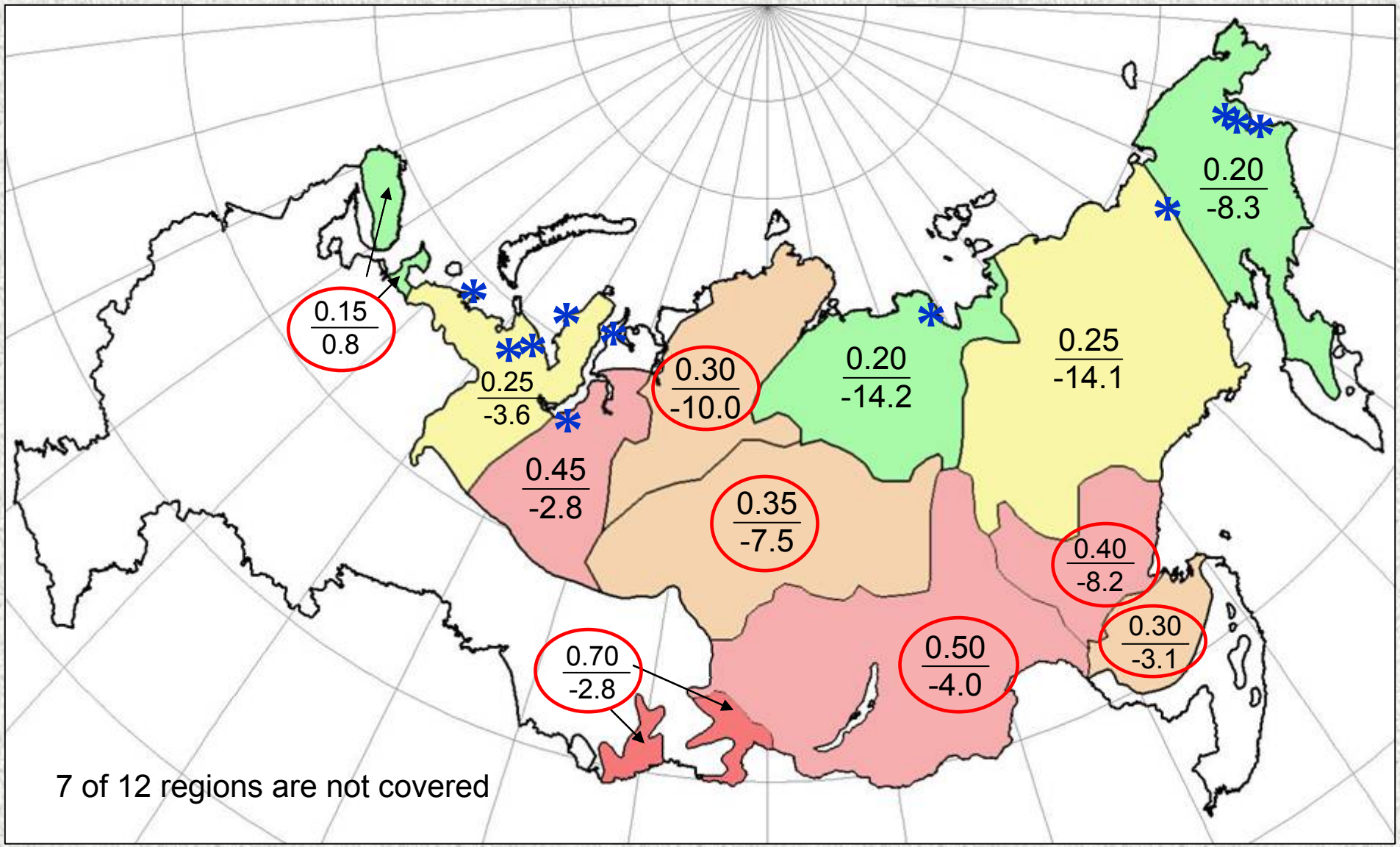
Annual temperature amplitude, ^{o}C/10y



Thawing degree-days, d ^{o}C/10y

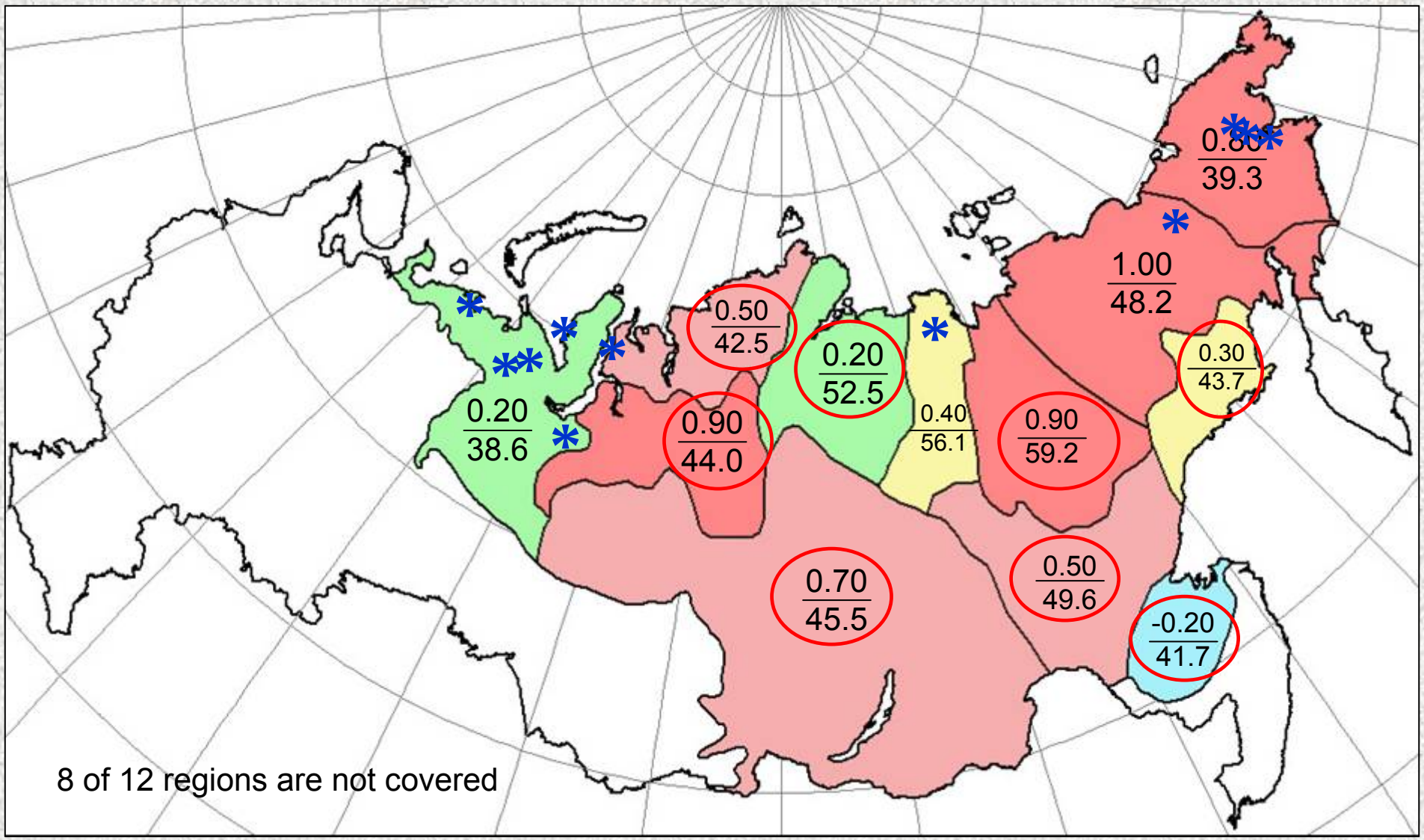
Implications for permafrost observations

Mean annual air temperature, 1970-2002.
Numerator - trends, ^{0}C/10 years, denominator – regional mean.



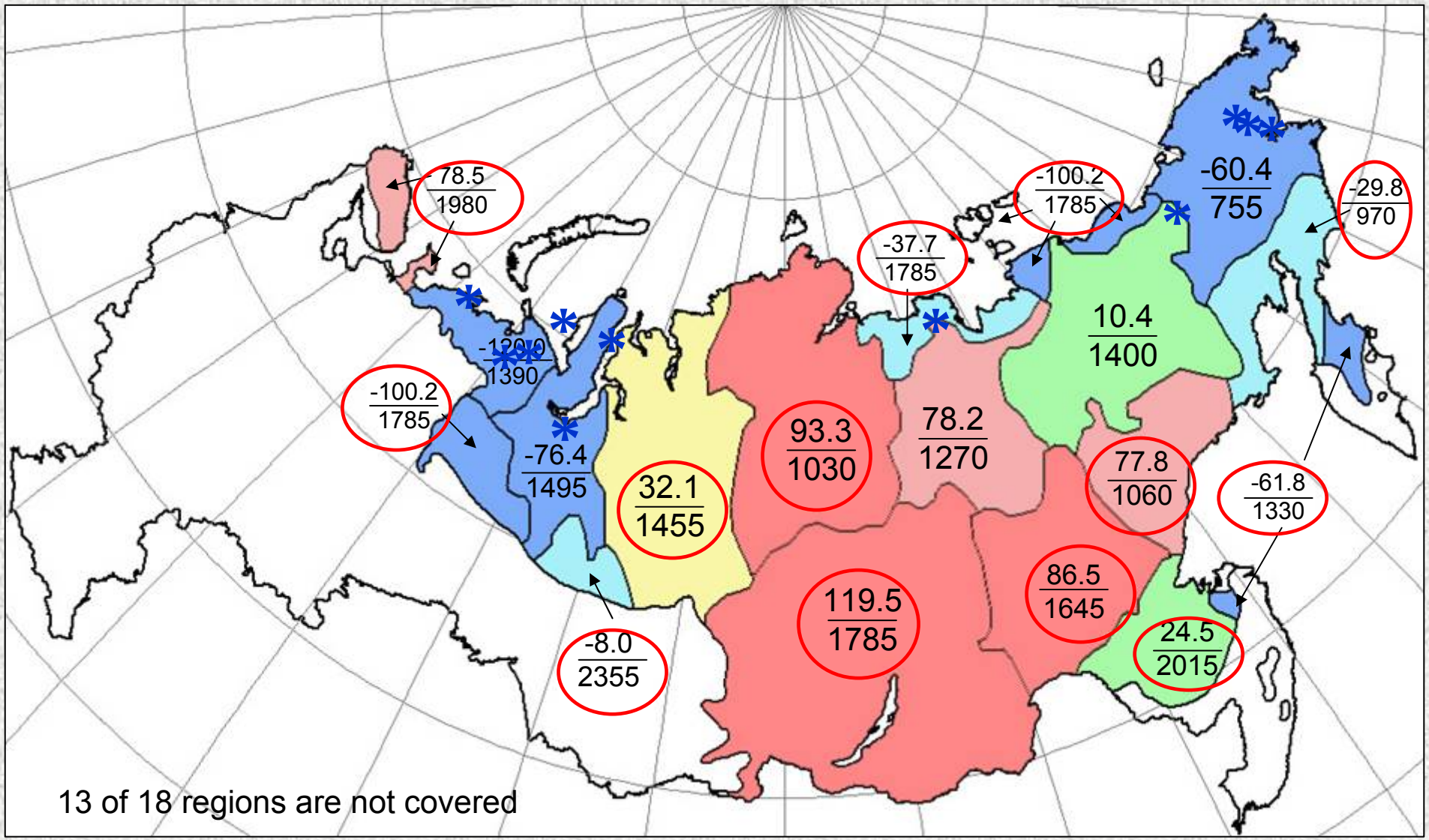
Implications for permafrost observations

Annual air temperature amplitude, 1970-2002.
Numerator - trends, ^{0}C/10 years, denominator – regional mean.



Implications for permafrost observations

Thawing degree days, 1970-2002.
Numerator - trends, ^{0}C d/10 years, denominator – regional mean.



Conclusions

1. Climatic changes have distinct coherence patterns that depend on the atmospheric circulation.
2. Existing networks are not targeted at representation of spatial coherence and thus do not capture the full range of variability under different conditions of atmospheric circulation.
3. Case study indicated that up to 65% of variability is lost in the currently existing permafrost (CALM) network.
4. Analysis of spatial coherence may be used as effective tool for the cost-effective network planning.

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