# Freezing Precipitation and Freezing Events over Northern Eurasia and North America: Climatology and the Last Decade Changes

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# Objective

## (GEWEX Cross-Cut project):

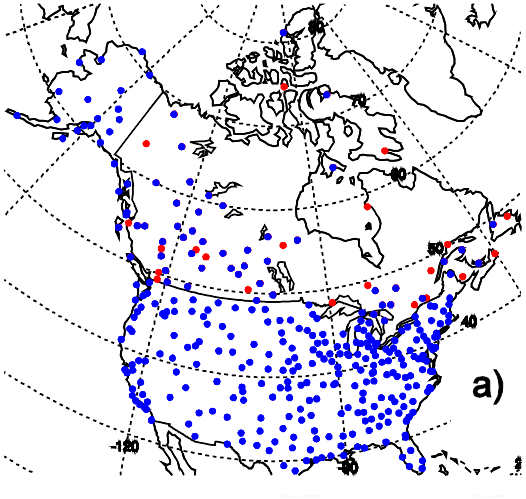
**To improve our understanding of future changes in hazardous cold/shoulder season precipitation and storms, especially occurring near 0°C. These extremes can be devastating and are subject to changing climate.**

# Specific Phenomena around °C

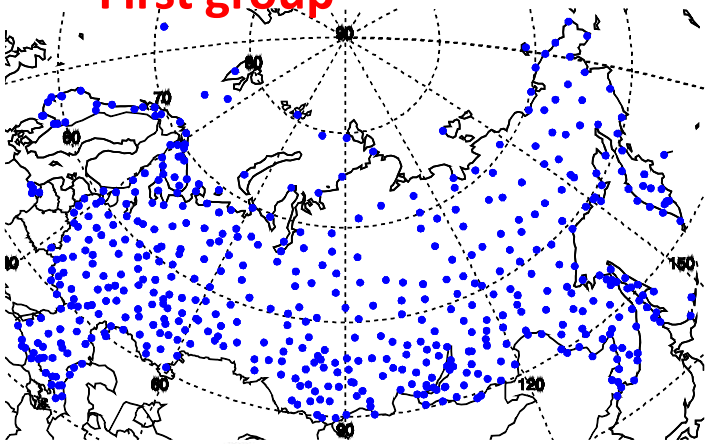
1. **Freezing rain and freezing drizzle**
2. **Heavy snowfall/rainfall transition**
3. **Large fraction of blizzards occurs near 0°C**
4. **Rain-on-snow events**
5. **Ice load on infrastructure**

**The focus of this presentation is on the first group of variables from the above list over Northern Eurasia, North America, and Europe**

# Long-term synoptic stations used in our analyses; 1- and 3-hourly data for the past 40 years



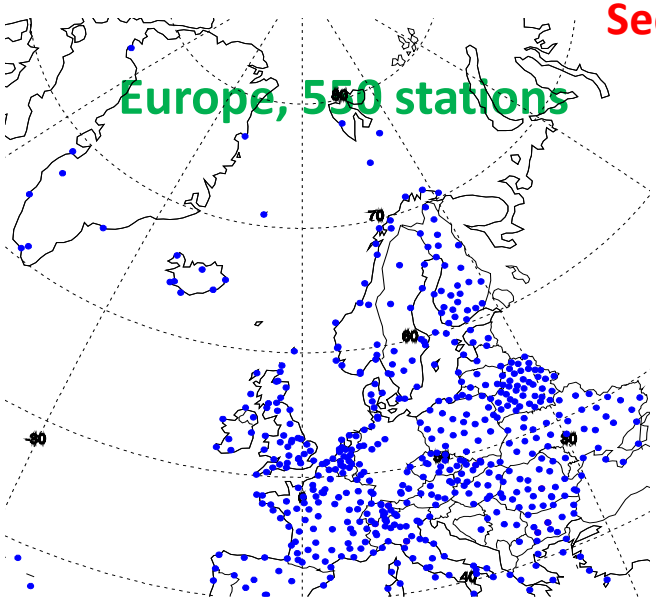

First group



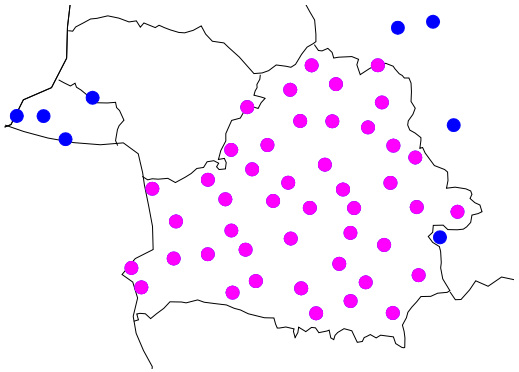
Groisman et al. 2016: Recent changes in the frequency of freezing precipitation in North America and Northern Eurasia. *Environ. Res. Lett.* 11, 045007 (published on April 2016).

Second group

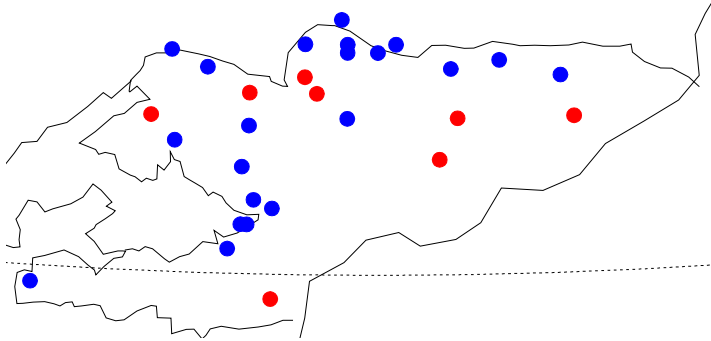
Europe, 550 stations



Belarus



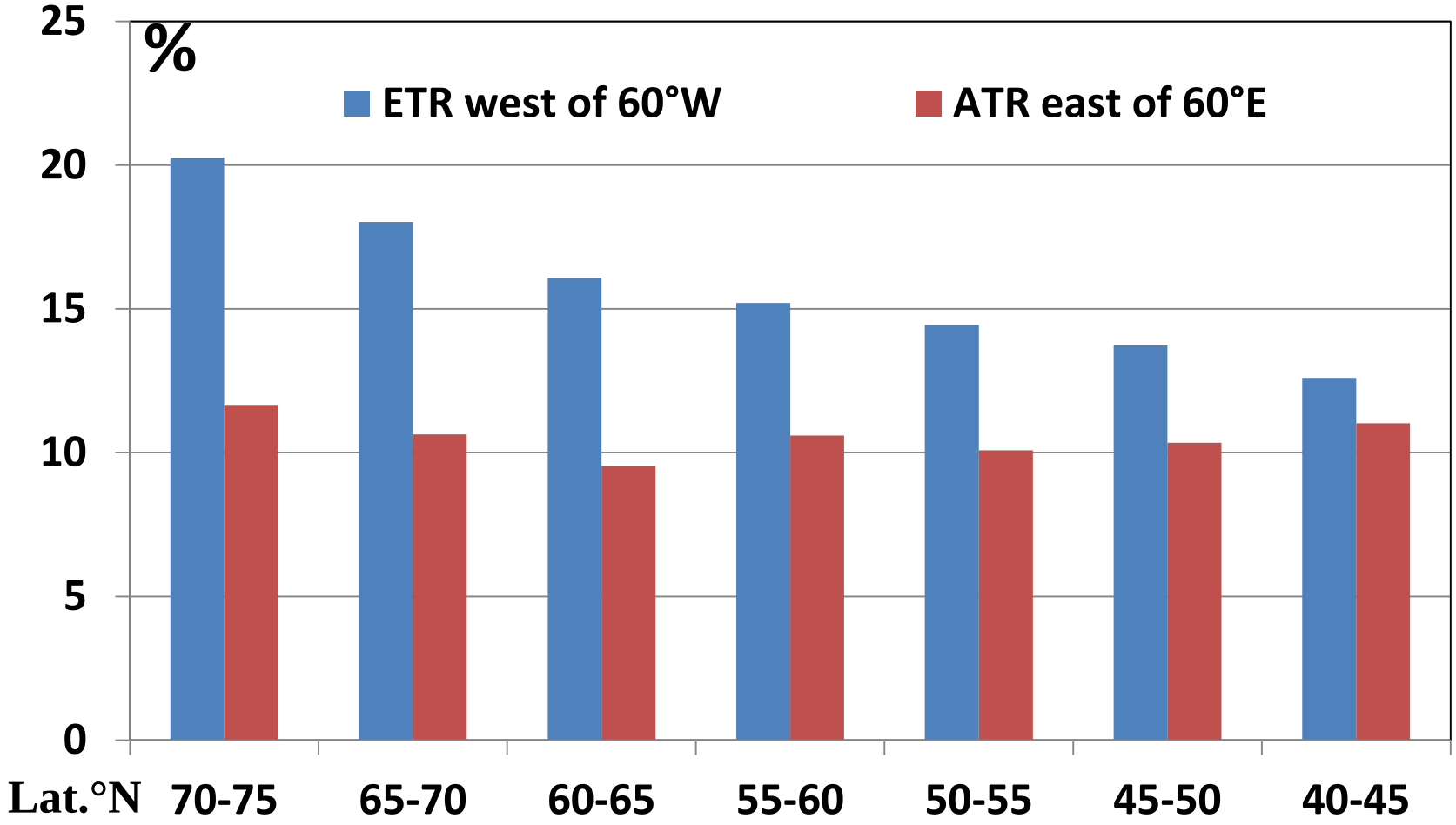
Kyrgyzstan



# Background

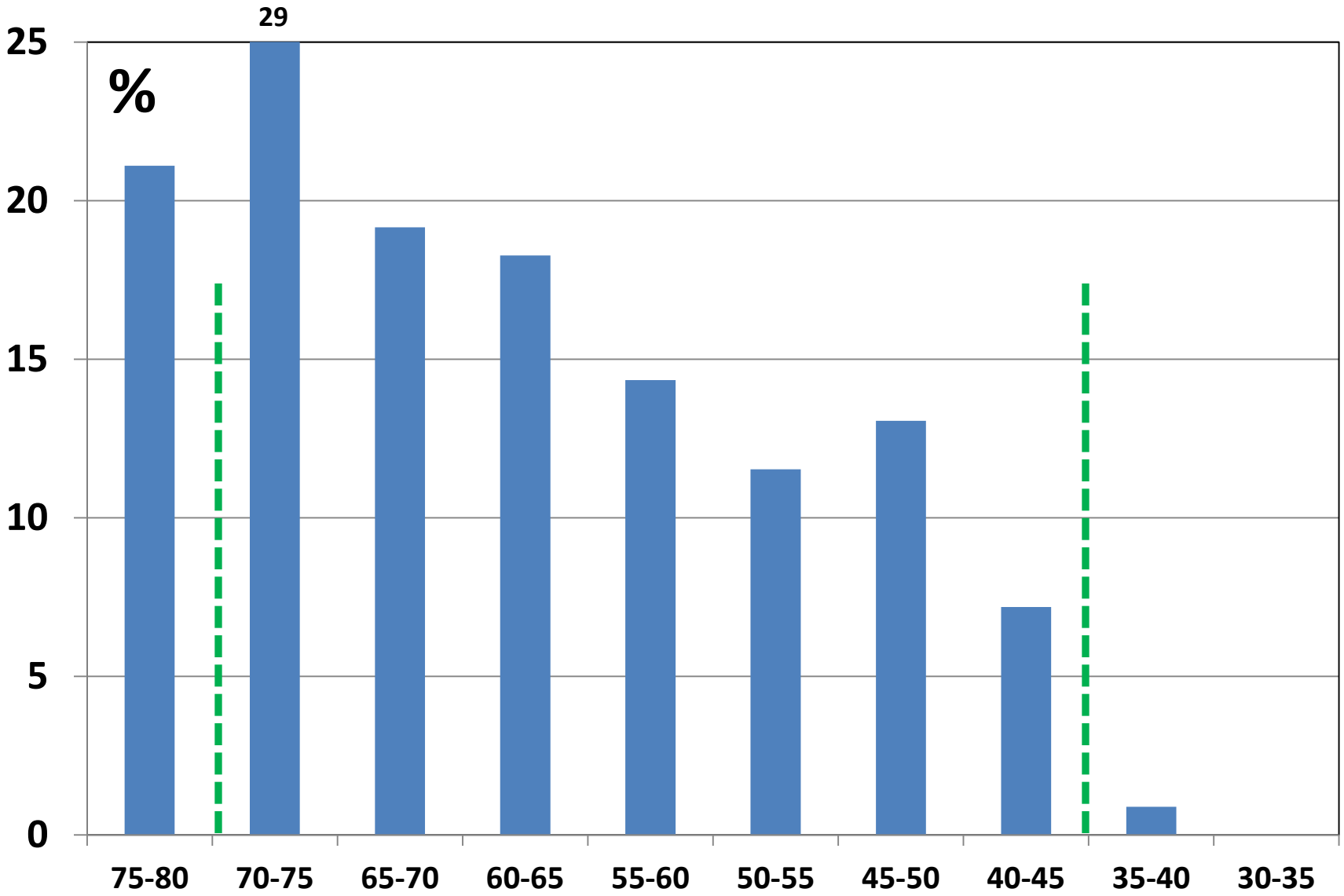
- Our ERL paper (*Environ. Res. Lett*. **11**, 045007) presents our results only for 4 countries (USA, Canada, Norway, and Russia); the current presentation in addition to the results for these 4 countries expands our findings to Europe, Belarus, and Kyrgyzstan.
- Next slides show that the occurrence of the "near 0°C weather conditions"
  - is quit frequent over the entire northern extratropics (e.g., over Russia from the Arctic Islands to the Caucasus Mountains and southern Primor'e) and
  - its temporal changes are observed only in the southernmost areas of Russia and the United States while in the past four decades over Europe these occurrences decrease.

# Percent of the surface air temperature observations within the ± 2°C interval over latitudinal zones of Russia

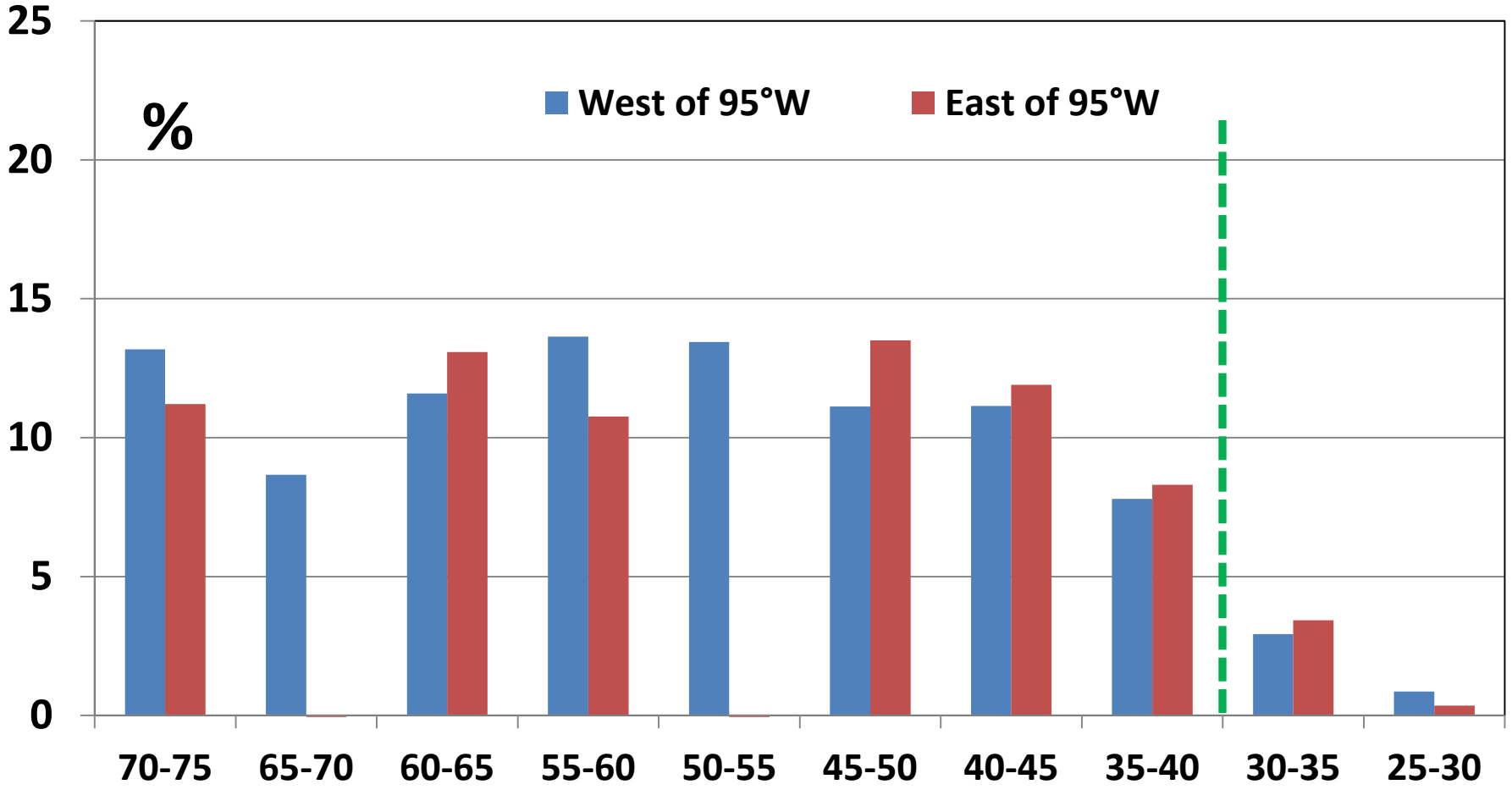



ETR – European territory of the Russian Federation

# Percent of the surface air temperature observations within the ± 2°C interval over latitudinal zones of Europe

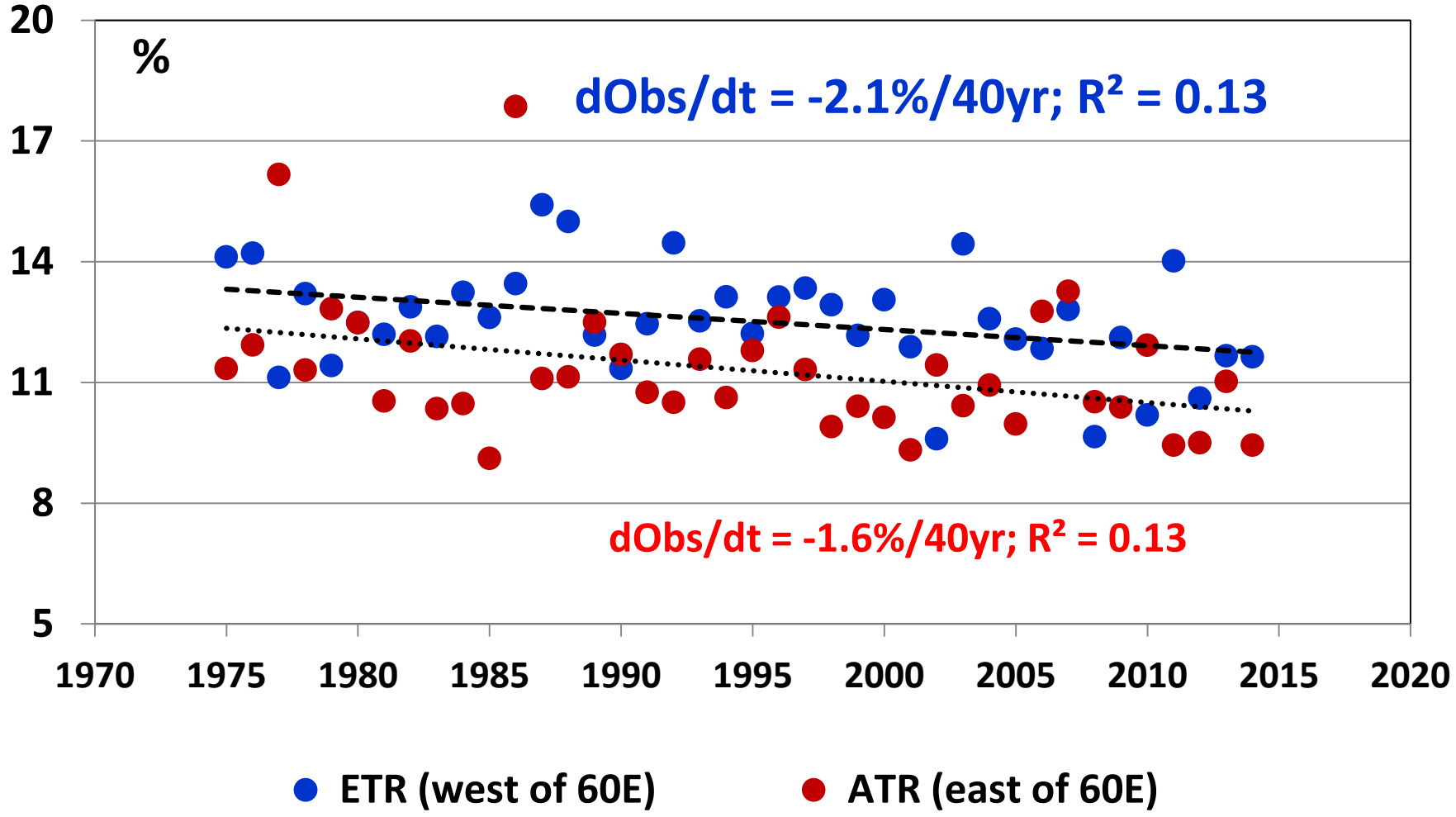


# Percent of surface air temperature observations within the ± 2°C interval over latitudinal zones of North America




**In East Canada for this analysis, we did not have long-term stations data in latitudinal zones 65°-70°N and 50°-55°N**

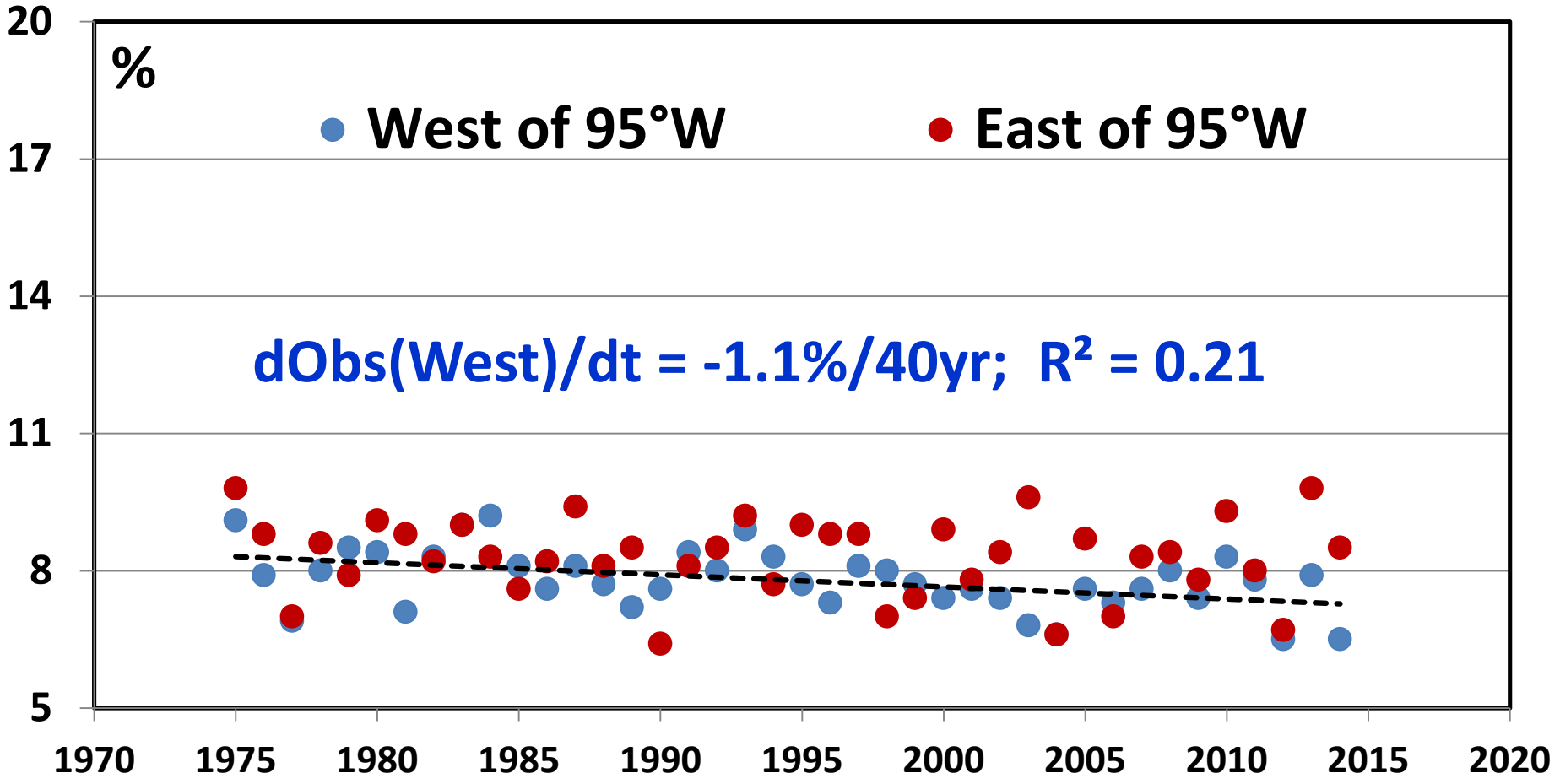
# Percent of observations with the surface air temperature within the ± 2°C interval over the 40°N - 45°N zone of Russia




**ETR – European territory of the Russian Federation;**

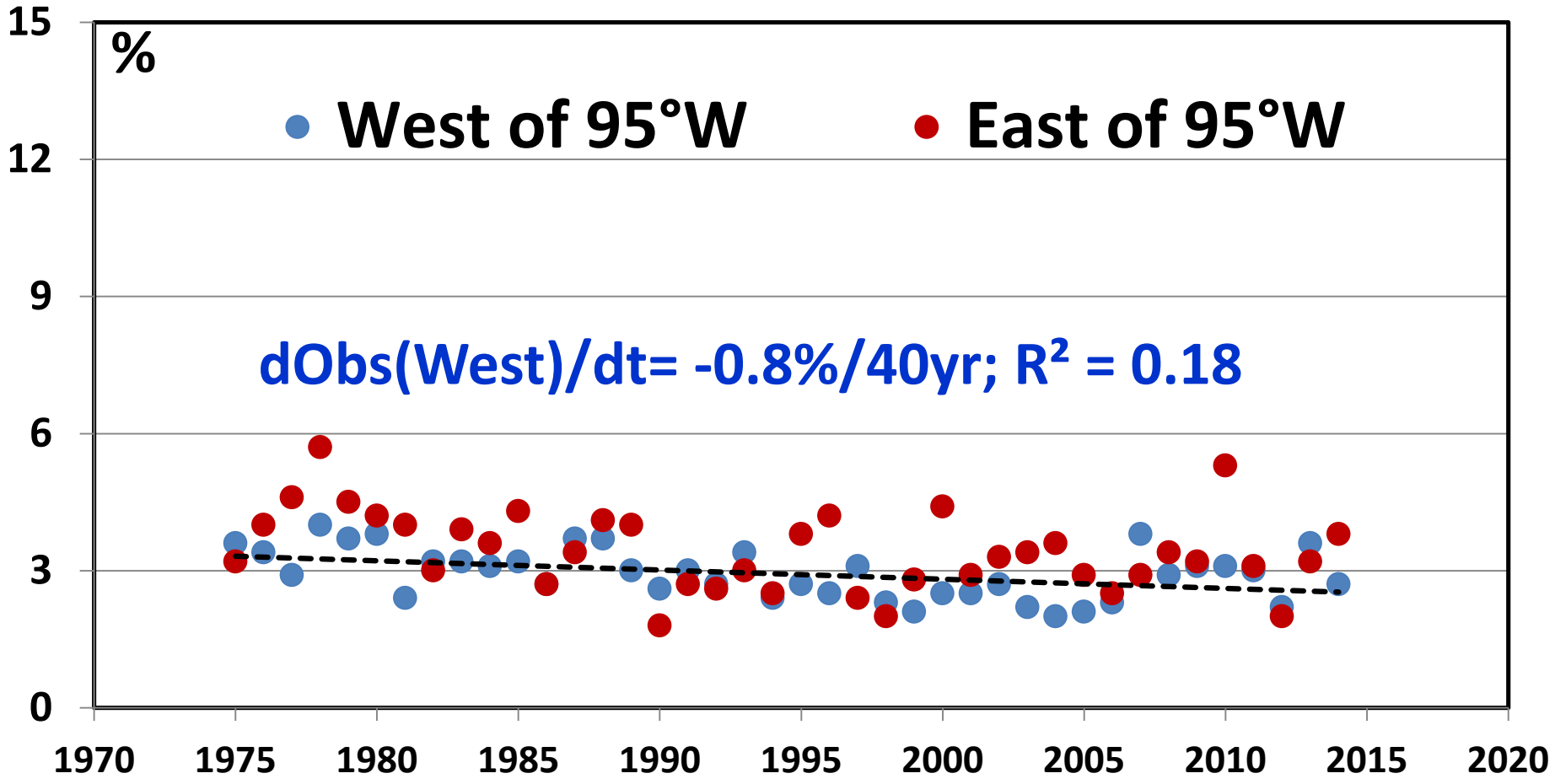
**only in the southernmost areas, we observe temporal changes**

# Percent of observations with the surface air temperature within the ± 2°C interval over the 35°N - 40°N zone of the U.S.



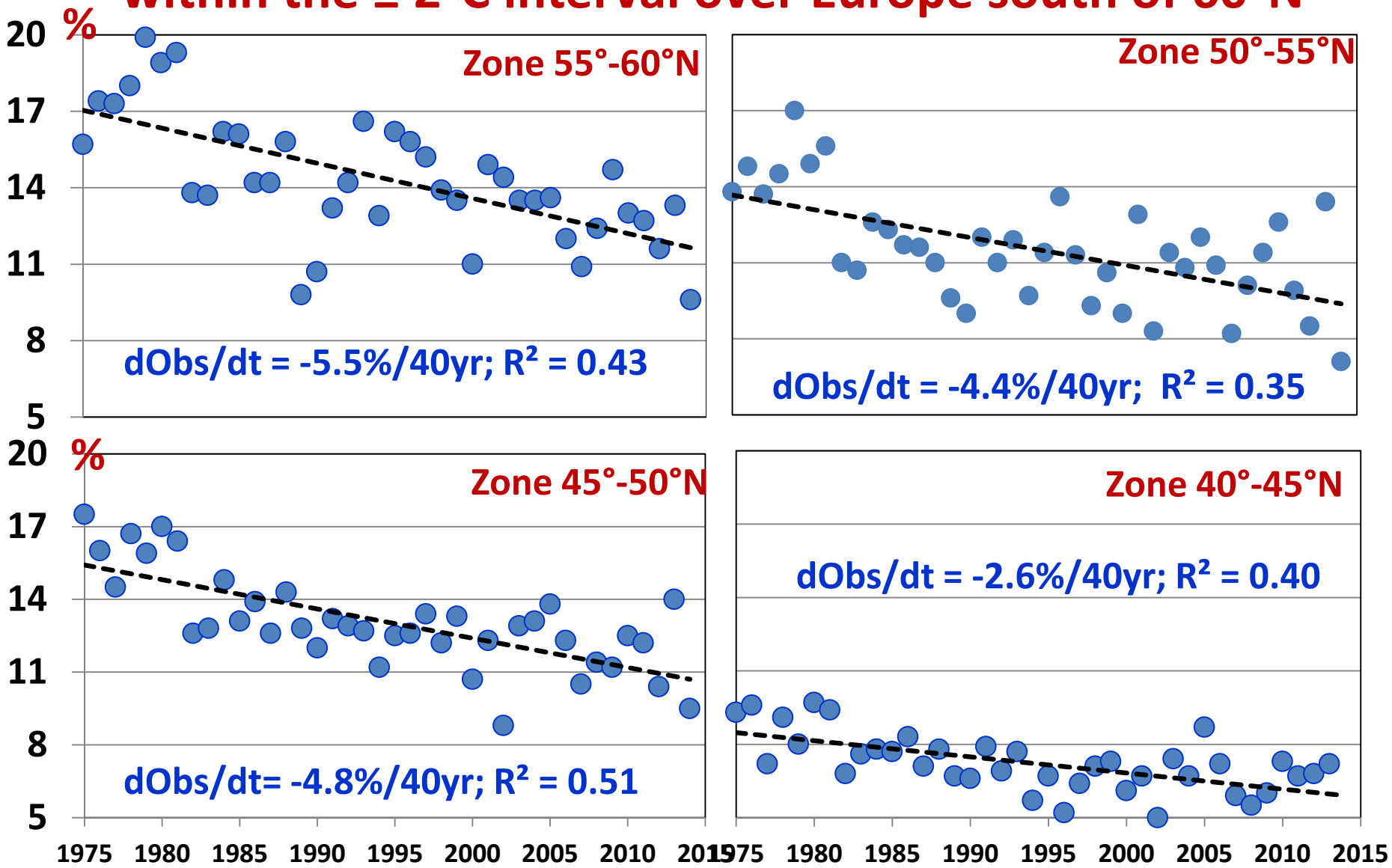

Only in the southernmost areas, we observe temporal changes

# Percent of observations with the surface air temperature within the ± 2°C interval over the 30°N - 35°N zone of the U.S.



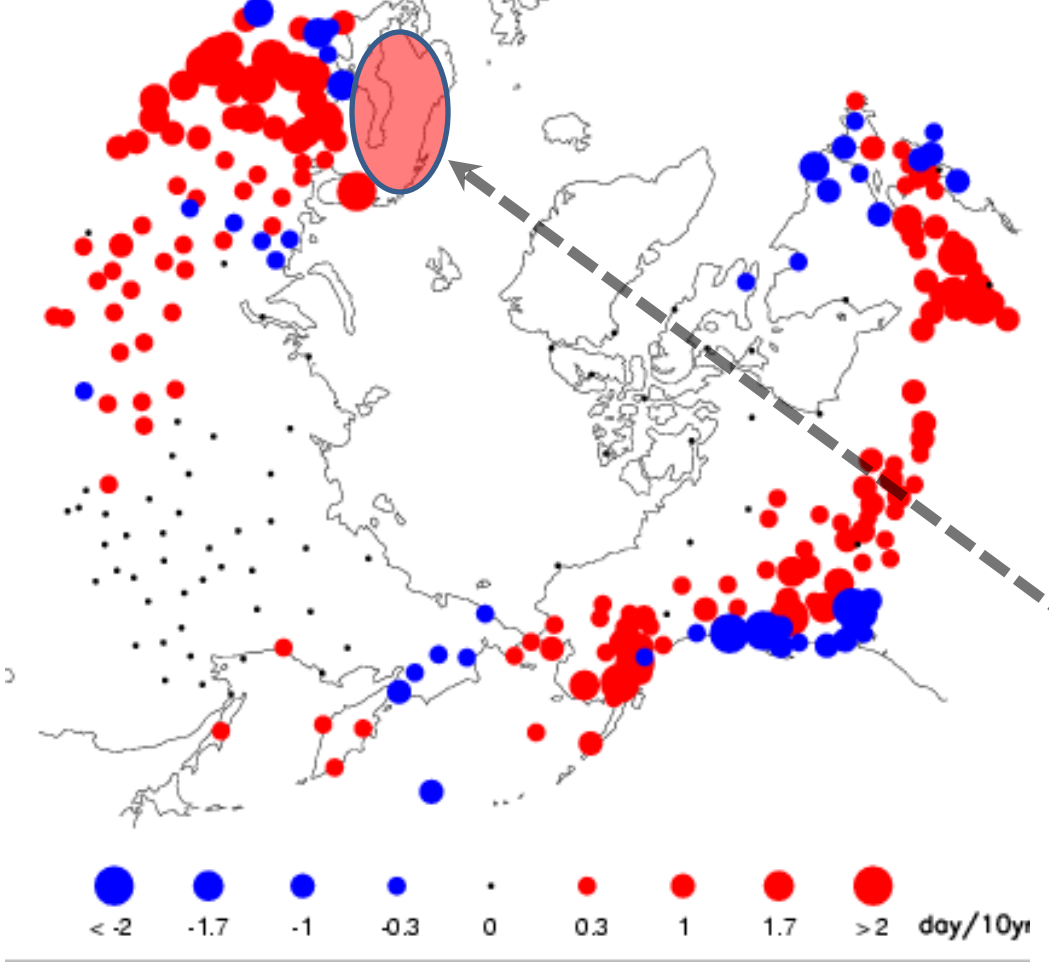

Only in the southernmost areas, we observe temporal changes

# Percent of observations with the surface air temperature within the ± 2°C interval over Europe south of 60°N



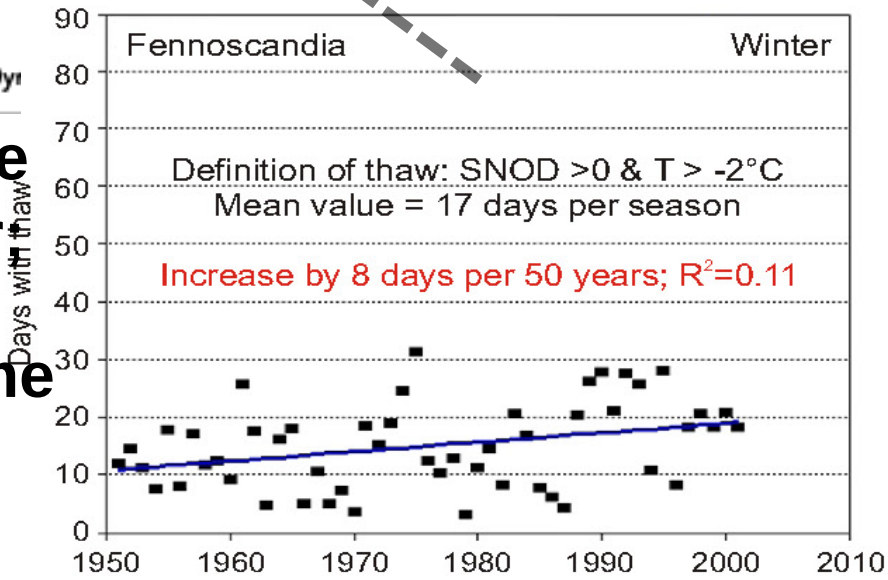

Over most of Europe, we observe temporal changes (a decrease)

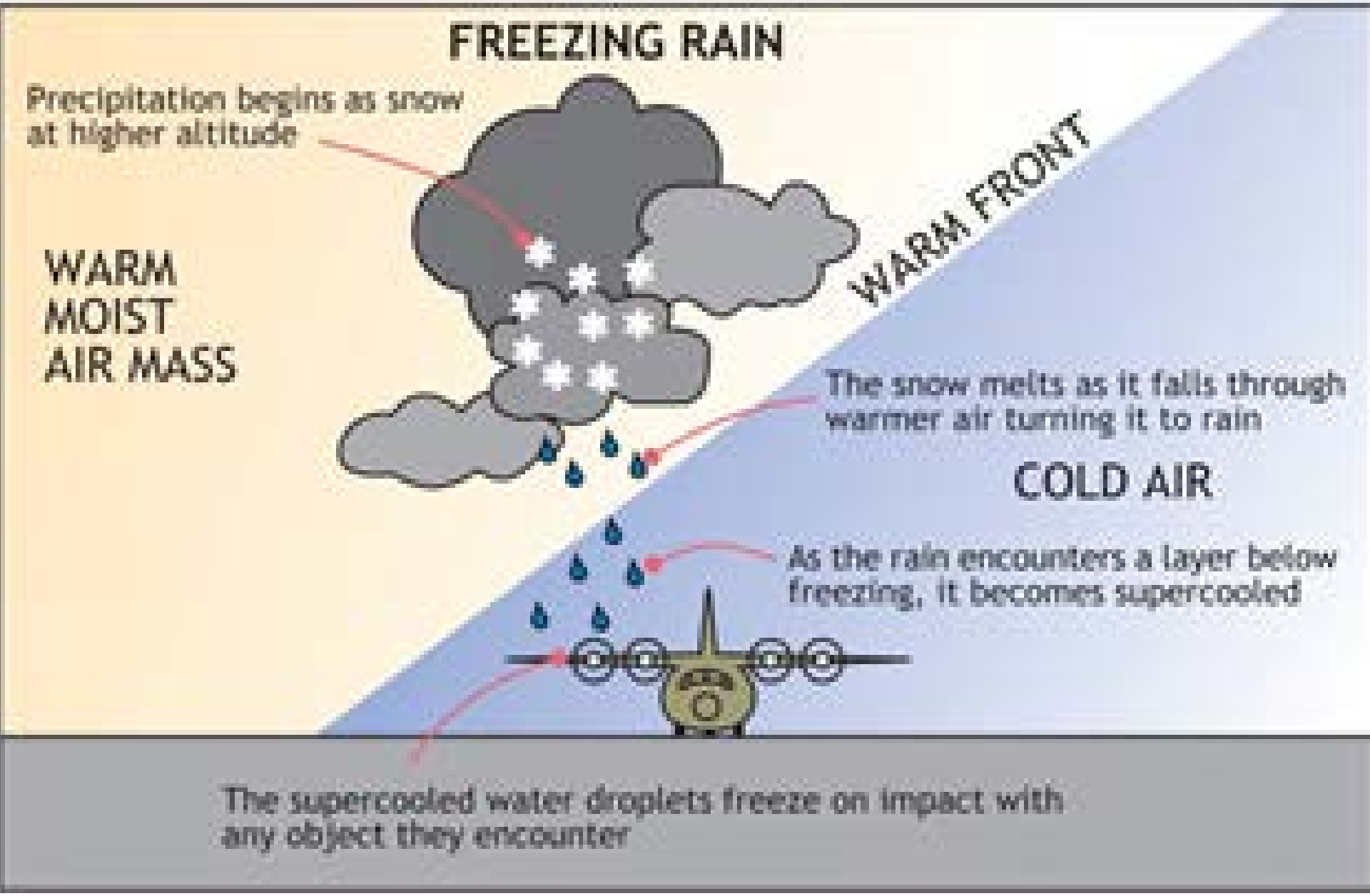
# Changes in the days with winter thaw during the 1950-2000 period




**Top.** Linear trend estimates in the days with winter thaw (days/10yr Groisman et al. 2003).

**Right.** The same, but regional time series for Fennoscandia (Groisman et al. 2009)



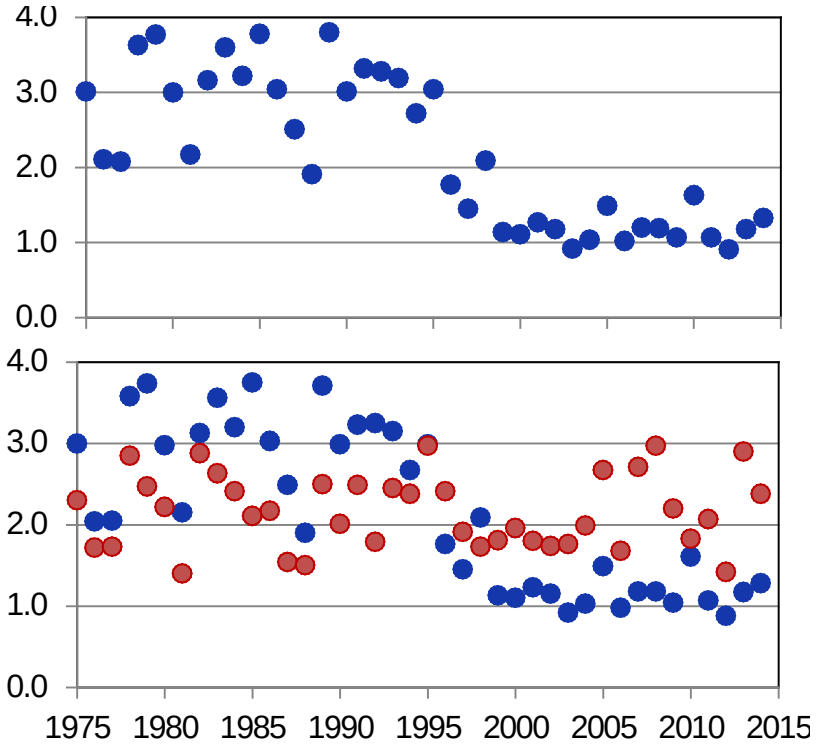

FREEZING RAIN
Precipitation begins as snow at higher altitude
WARM MOIST AIR MASS
WARM FRONT
The snow melts as it falls through warmer air turning it to rain
COLD AIR
As the rain encounters a layer below freezing, it becomes supercooled
The supercooled water droplets freeze on impact with any object they encounter

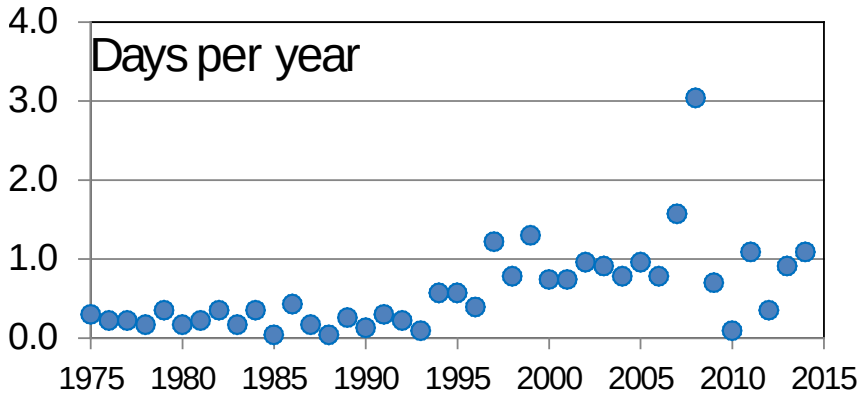
# HOMOGENEITY OF THE FREEZING EVENTS REPORTING

# Inhomogeneity issues due to automation

**Top.** Average number of days with freezing drizzle reported by the U.S. and Canadian stations.

**Bottom**. Average number of days with freezing drizzle (blue dots) and freezing rain (red dots) for the United States only.




## … and reporting

Region-wide mean changes in the frequency of **moderate and heavy freezing rain events** (days year$^{-1}$) that followed the introduction of METAR reporting formats in August 1996 over Northeastern U.S. (east of 80°W and north of 40°N).

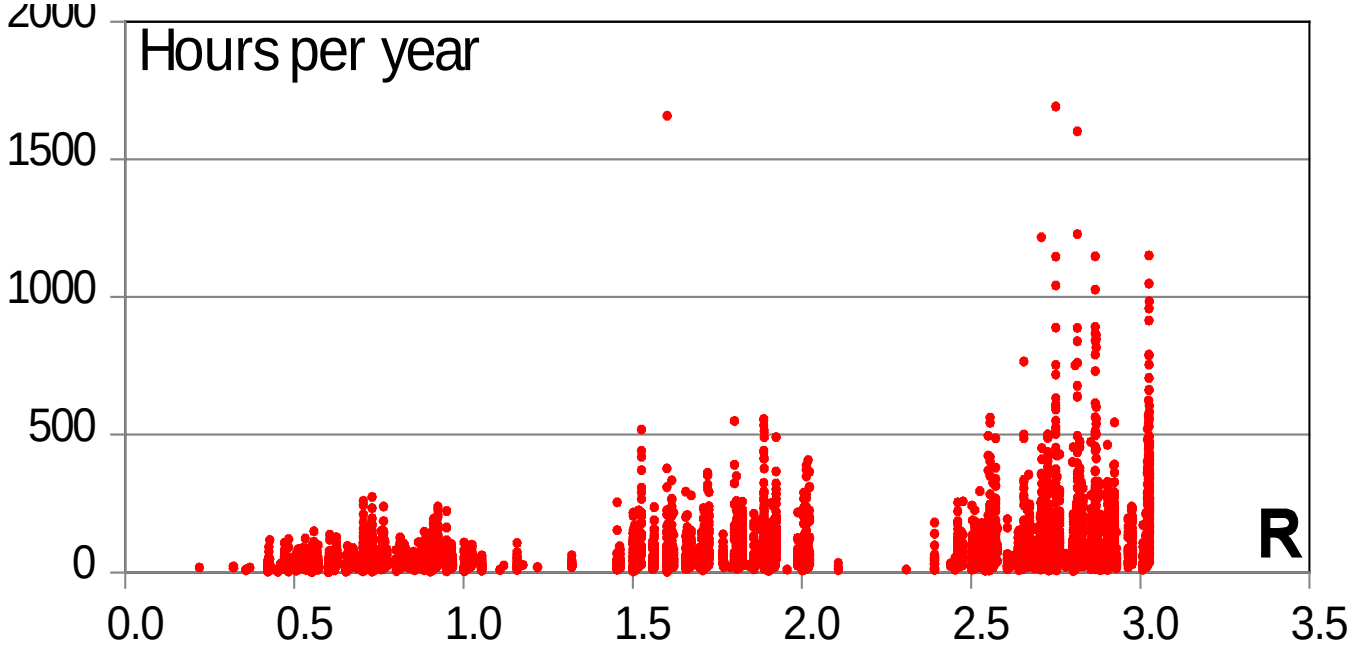
# Insufficient temporal coverage by 3-h. reports

Annual number of hours with gololed when at least one freezing event was observed during the year sorted by **R**, ratio of the number of these hours to the number of 3-h. reports of freezing events over 444 Russian stations for the 1977-2011 period

**=> true annual number of freezing events, NFE:**

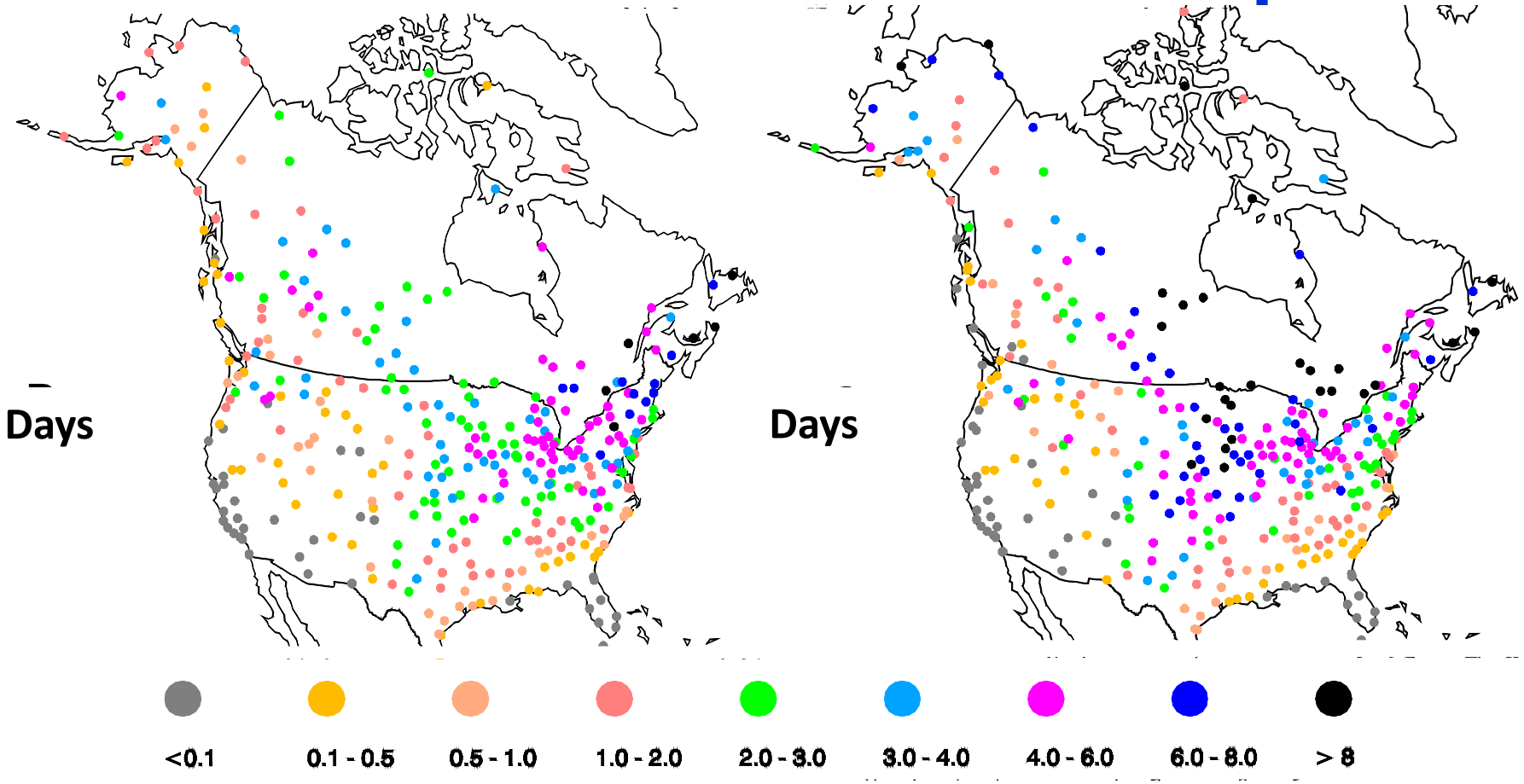
$$\mathbf{NFE} = \begin{cases} NFE_{reported} \times 3/\max(R,0.5) & (\text{if } NFE_{reported} \neq 0) \\ 0 & (\text{otherwise}) \end{cases}$$

**We have to "scale-up" the event numbers based upon 3-h reports everywhere when 3-h reports are used: Russia, Kyrgyzstan, most of Fennoscandia and Baltic States.**



# CLIMATOLOGY

# Climatology of freezing events over North America for the 1975-1994 period



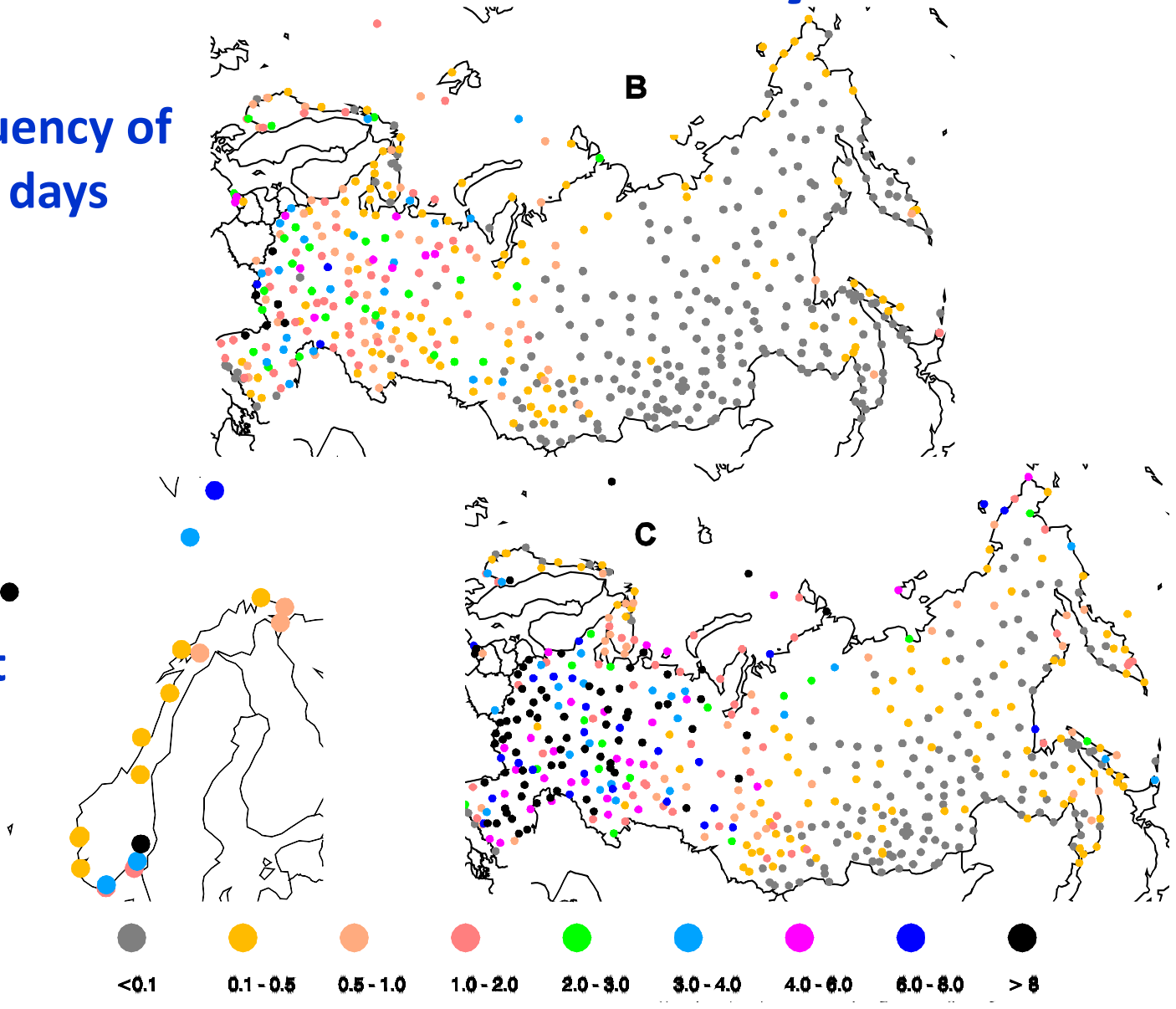

Annual freezing rain frequency

Annual freezing drizzle frequency

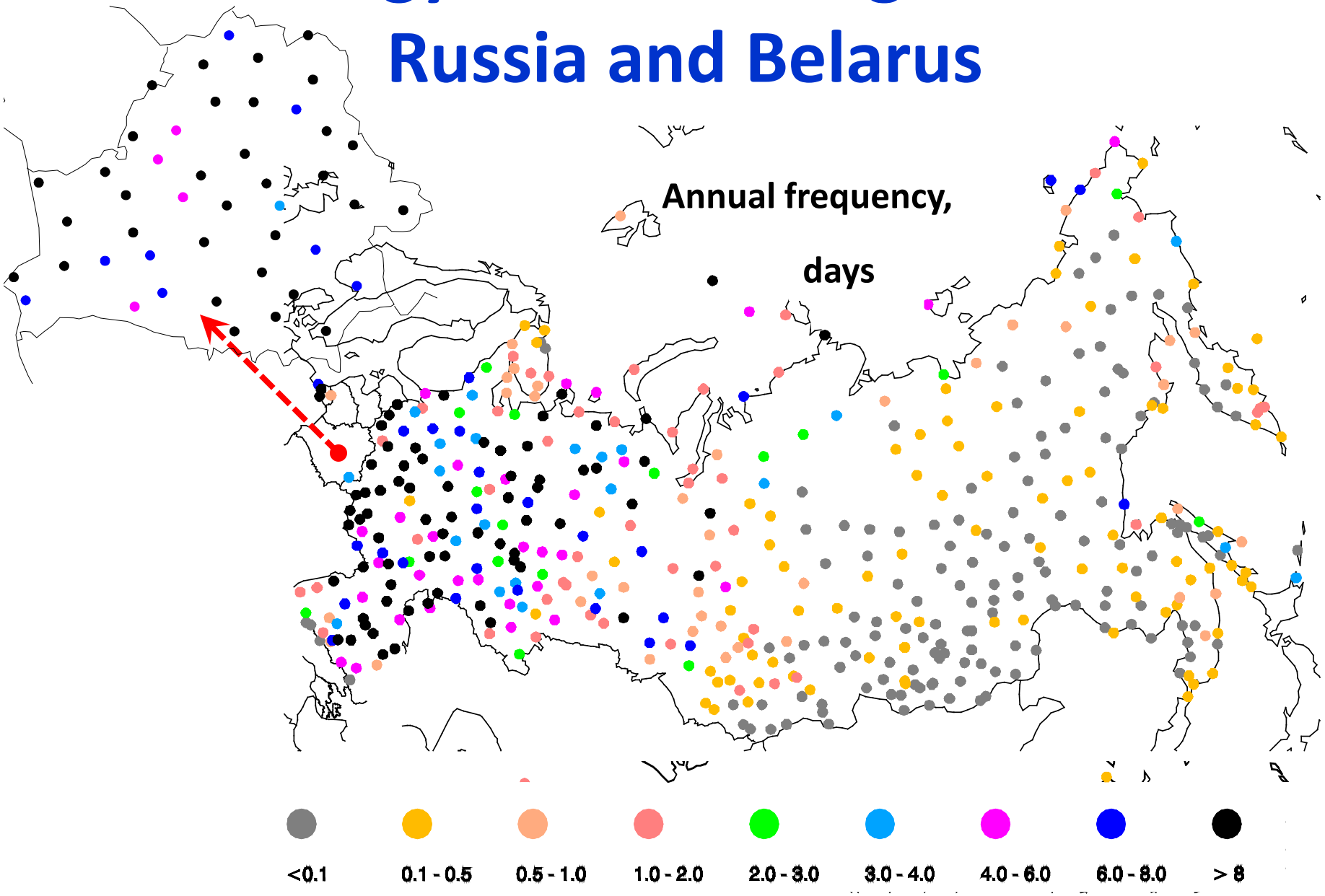
# Climatology of freezing events over Russia and Norway

Annual frequency of freezing rain days

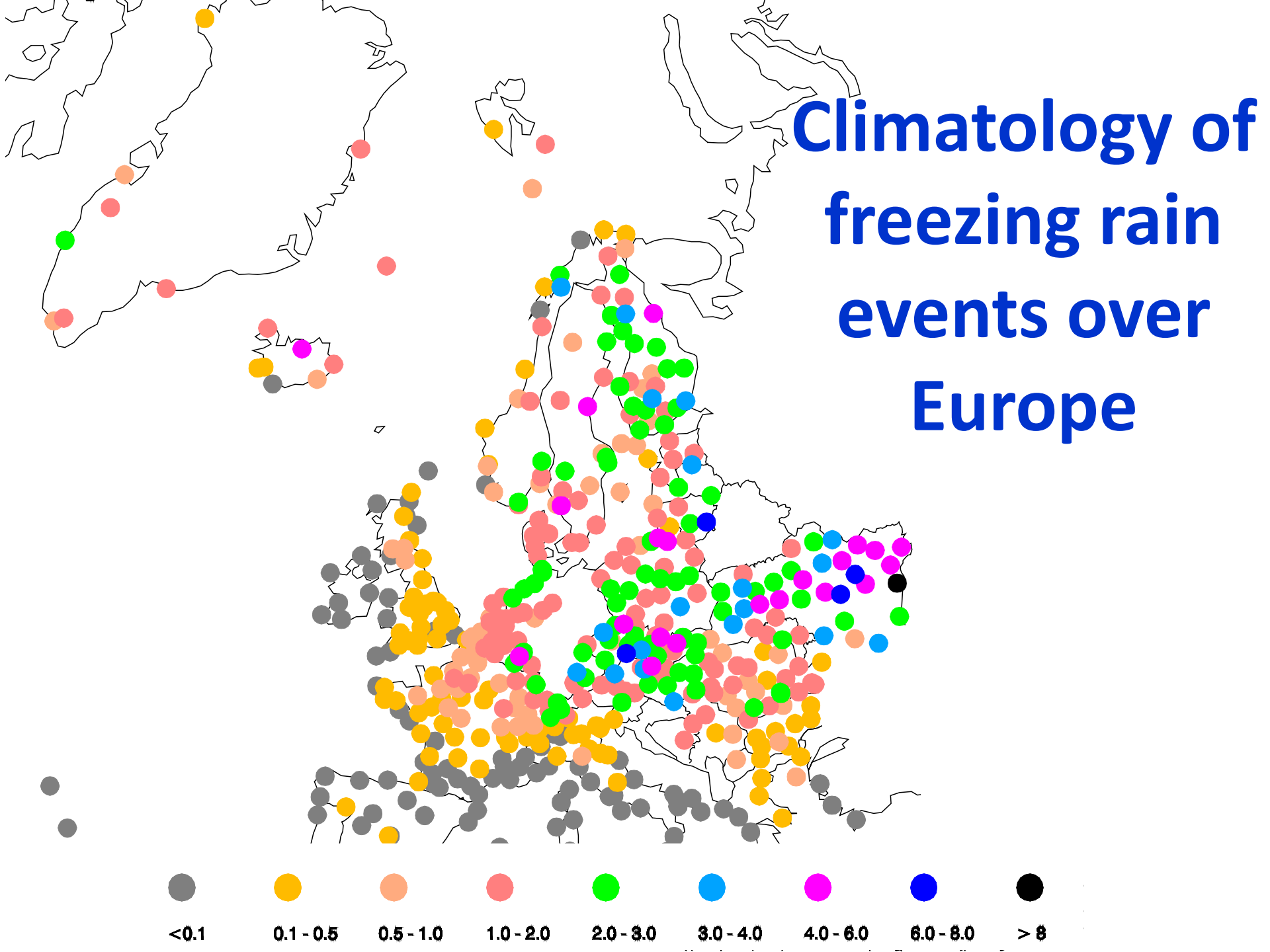
The same, but for freezing drizzle days



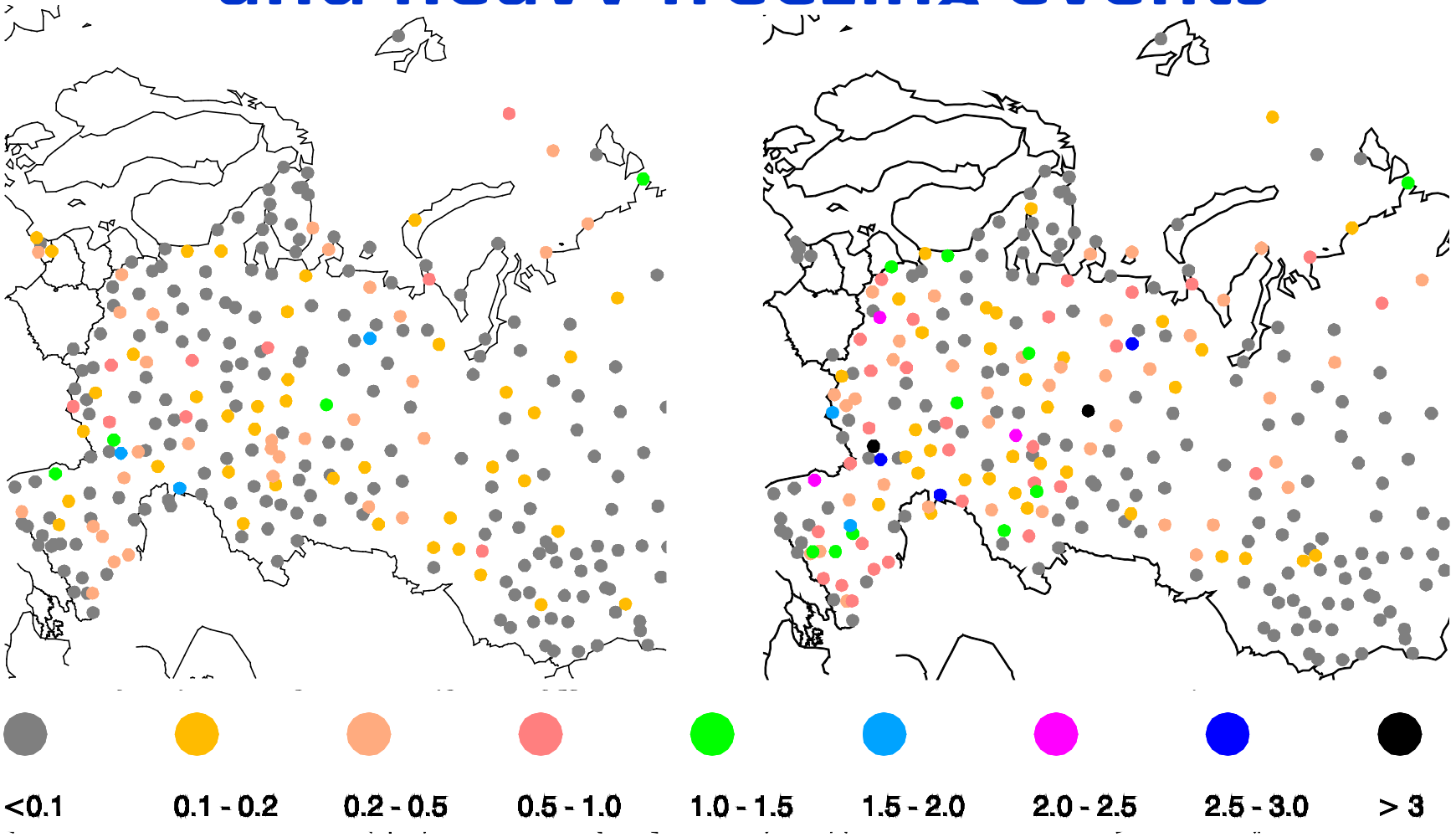
# Climatology of all freezing events over Russia and Belarus



# Climatology of freezing rain events over Europe



# Annual frequency of moderate and heavy freezing events

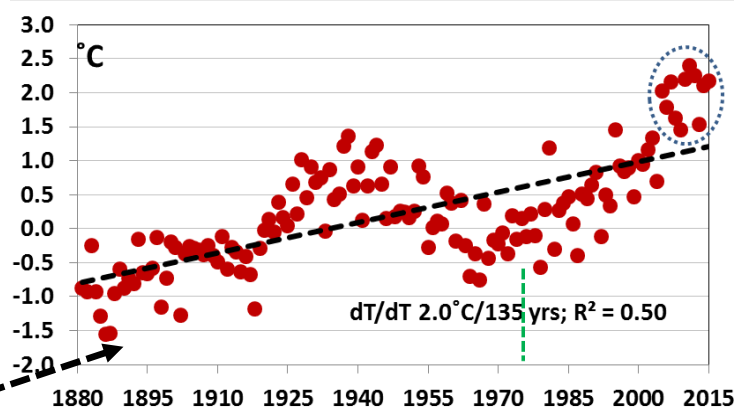



Freezing rain days

Freezing drizzle days

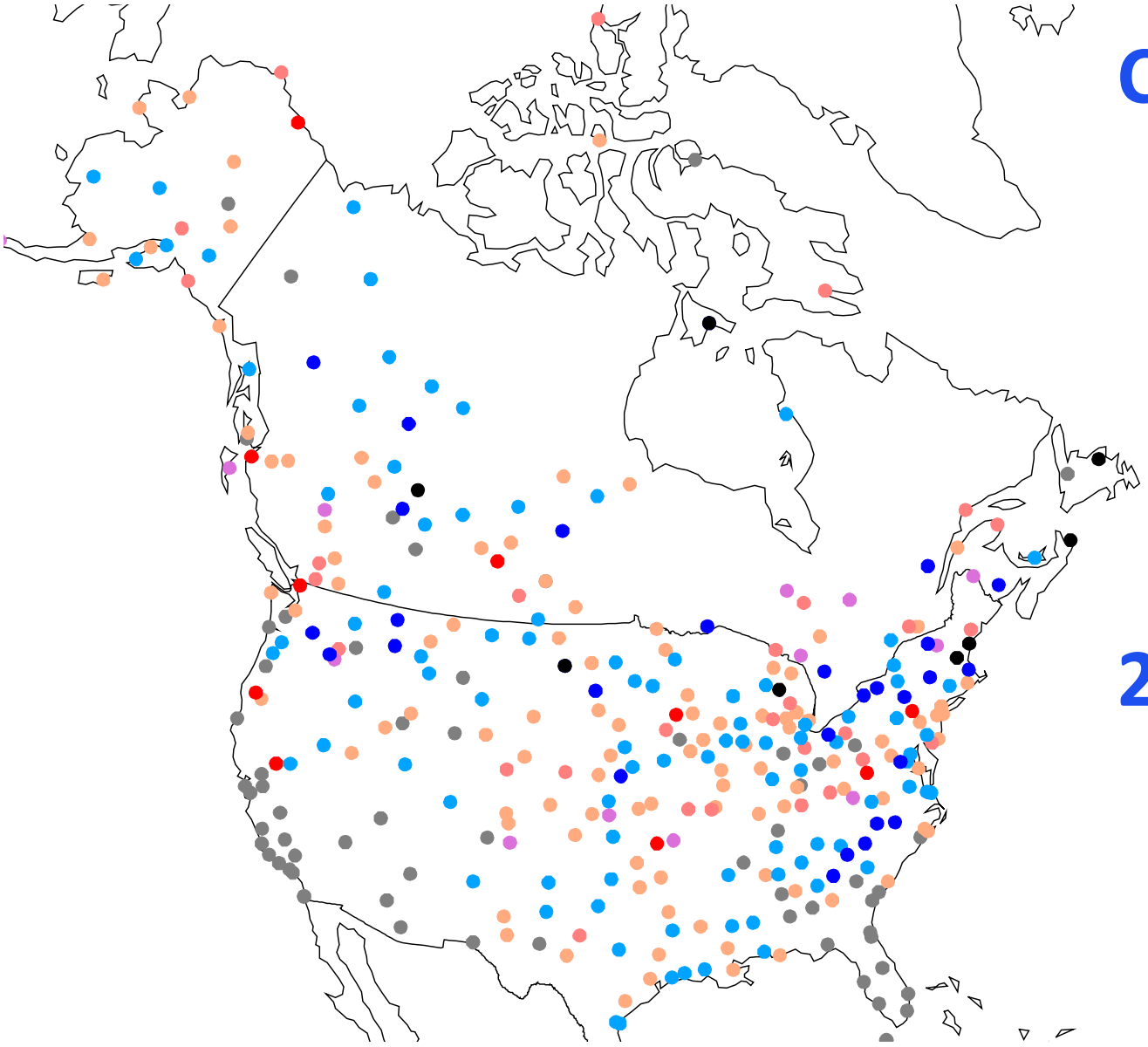
# CHANGES IN THE LAST DECADE

# Recent changes in the freezing precipitation frequency

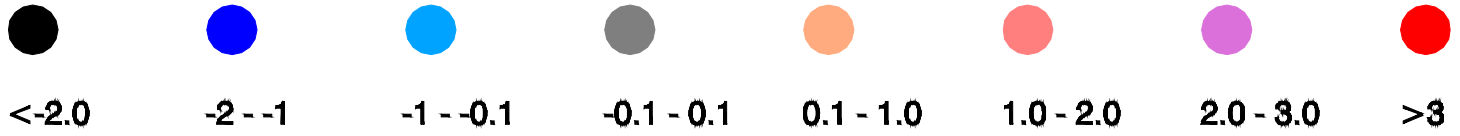


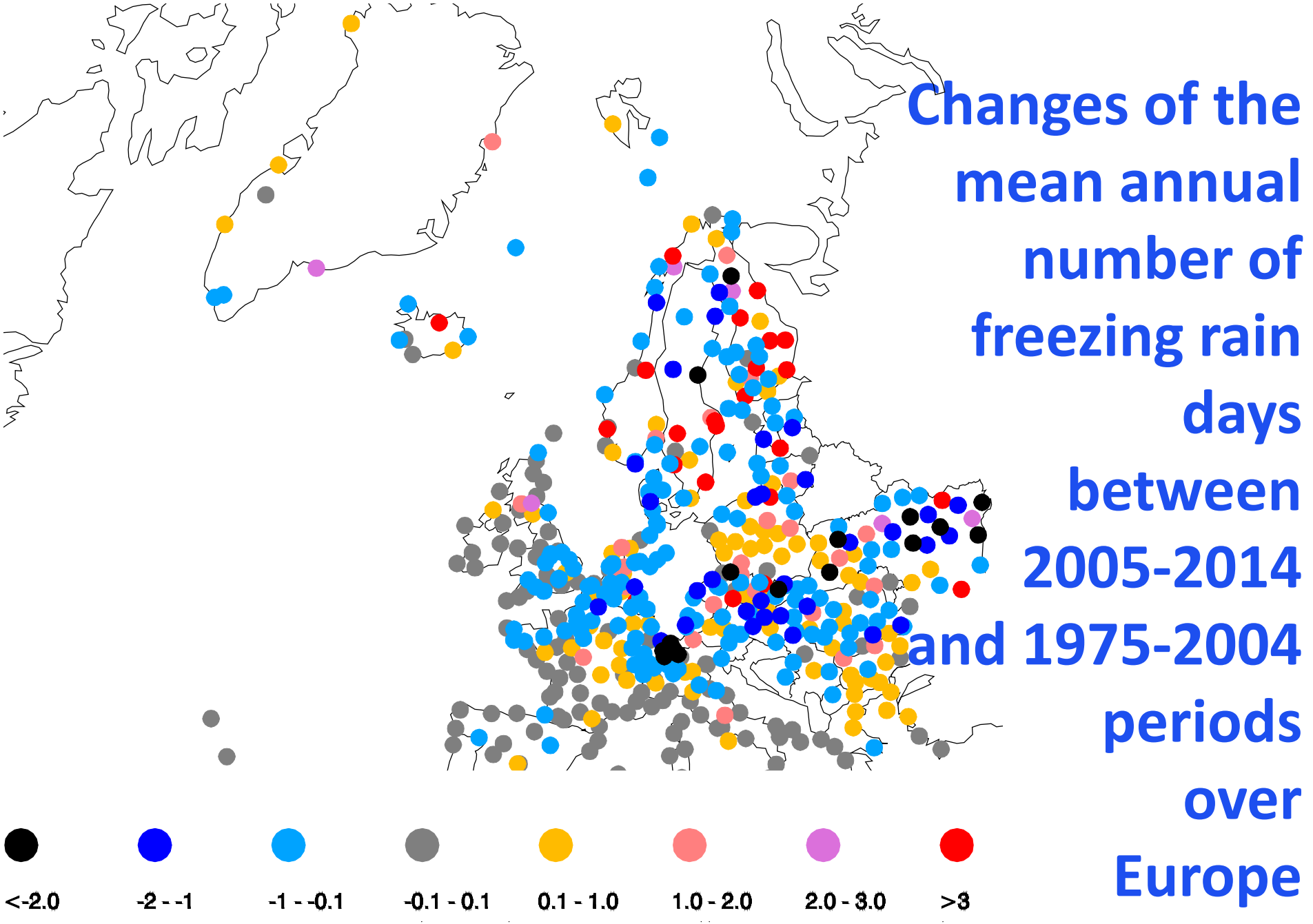

**Climate conditions in the last decade have been very different from the past decades. For example, each year the Arctic (60°-90 °N) surface air temperature was warmer than any year during the period of instrumental observations.**

**Therefore, we conducted change assessment in the freezing precipitation characteristics by comparing them in the last decade (2005-2014) with those for the previous three decades (1975-2004). We show these changes in day $yr^{-1}$ for freezing rain, freezing events (Northern Eurasia), freezing drizzle (for Russia only), and separately for occurrences of intense freezing rain and drizzle over Russia. Thereafter, we present a Table with regional climatologies and the estimates of the last decade change for selected climatic regions of Russia, Europe, and North America.**

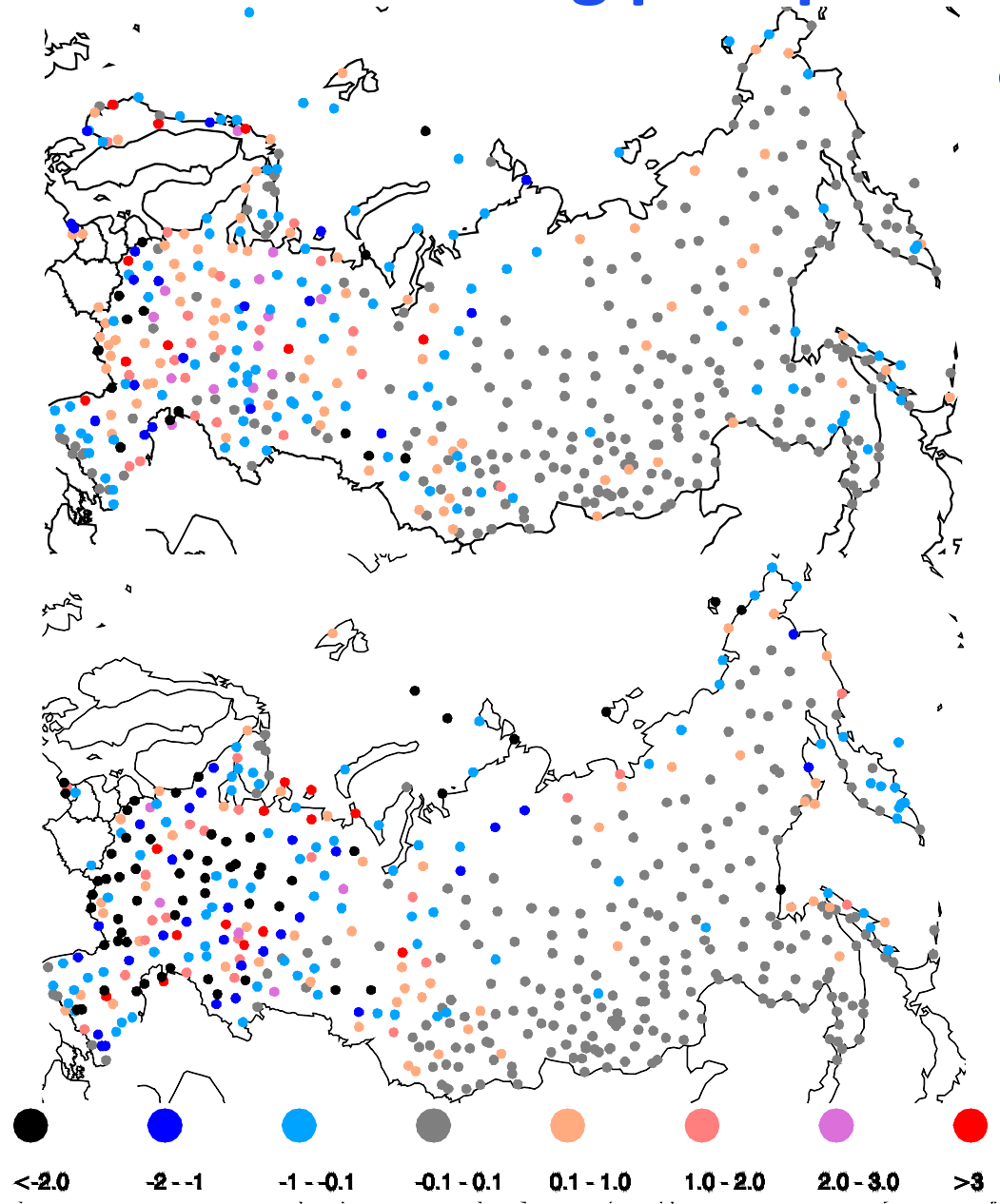


# Changes of the mean annual numbers of days with freezing rain between 2005-2014 and 1975-2004 periods




Changes of the mean annual number of freezing rain days between 2005-2014 and 1975-2004 periods over Europe
<-2.0
-2 - -1
-1 - -0.1
-0.1 - 0.1
0.1 - 1.0
1.0 - 2.0
2.0 - 3.0
>3

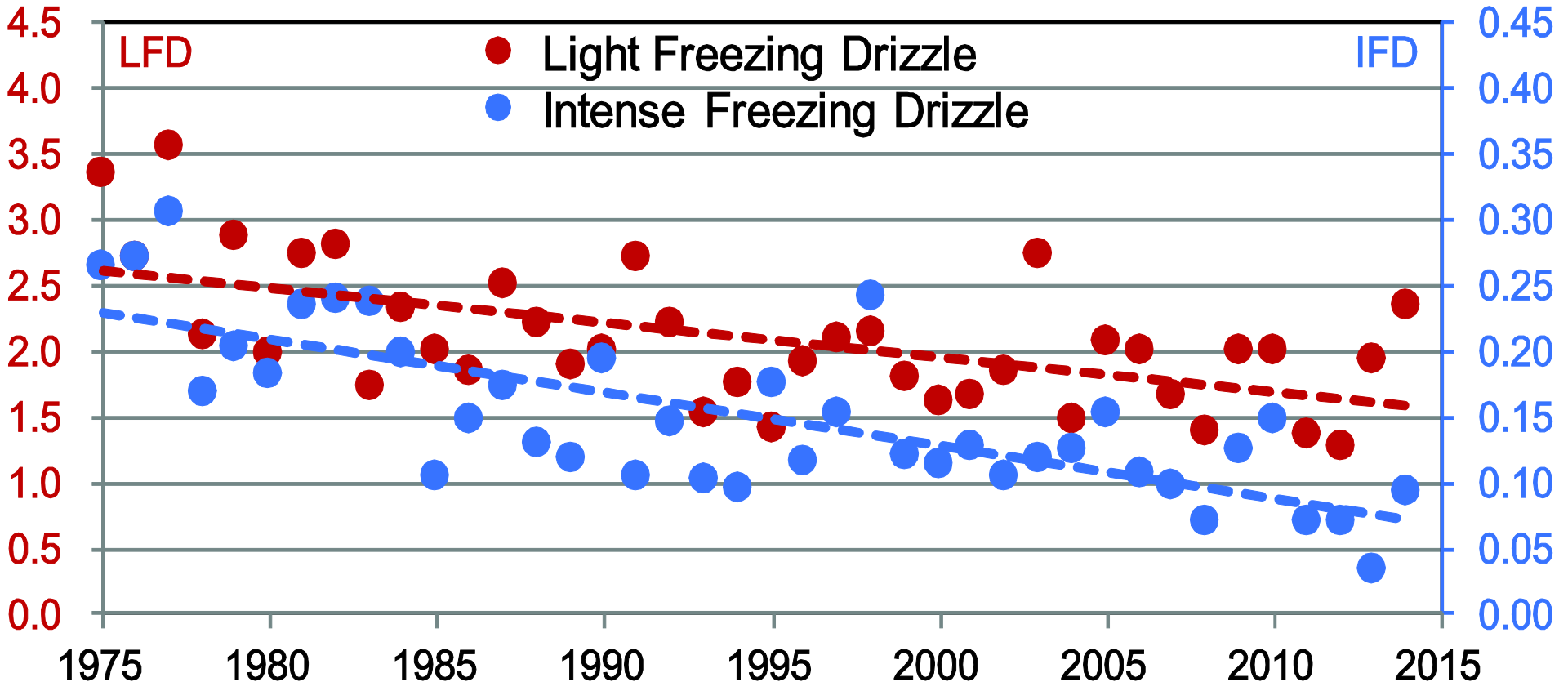
# Changes of the mean annual numbers of days with freezing precipitation between 2005-2014 and 1975-2004 periods




- **Freezing rain days**

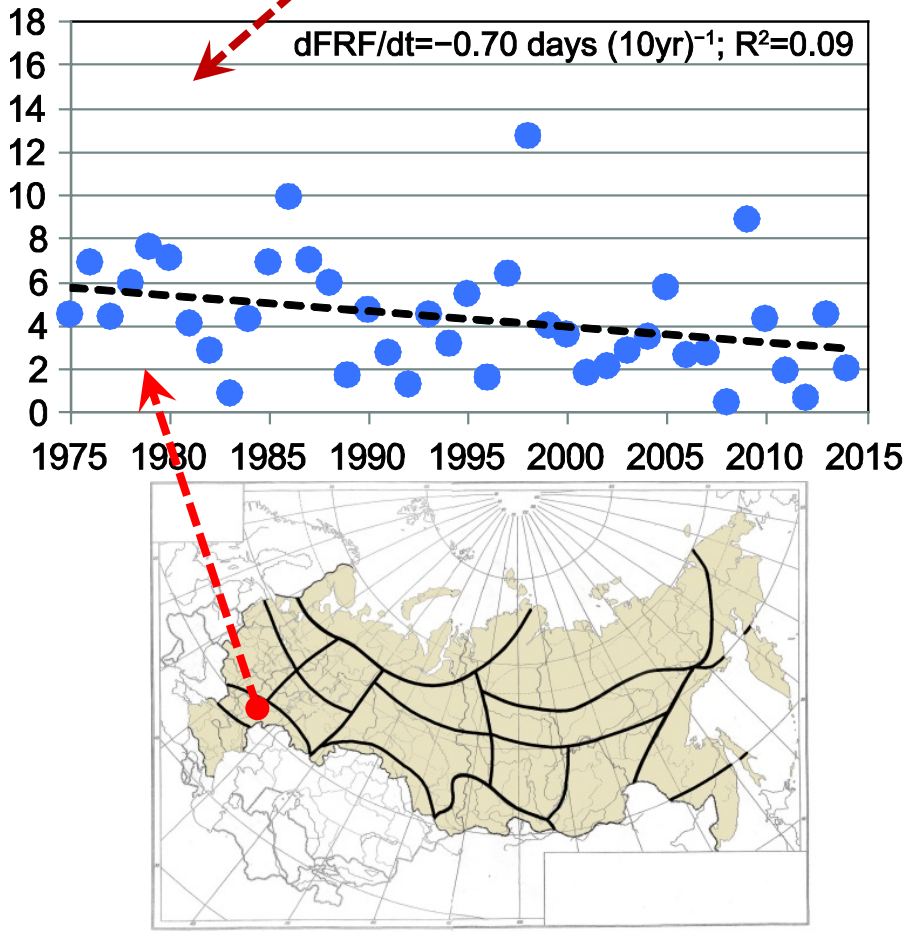
- **Freezing drizzle days**

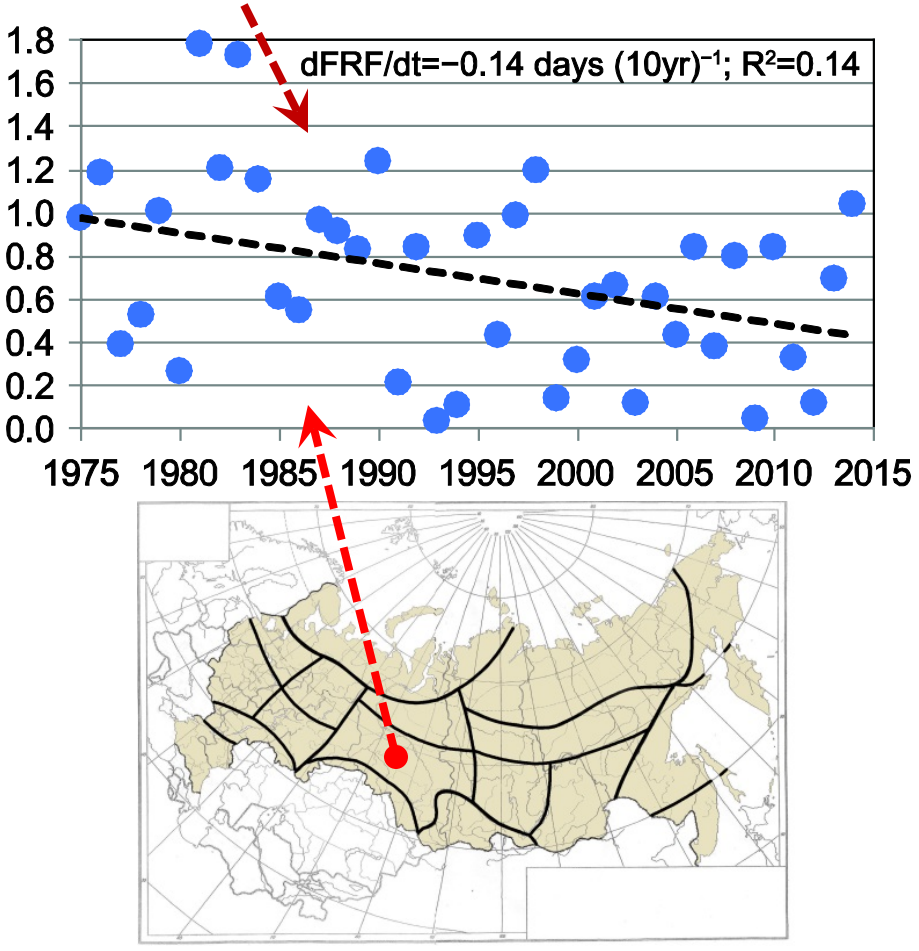
# Annual Freezing Drizzle Frequency area-averaged over Russia




**Light and intense freezing drizzle event frequency arithmetically averaged over the long-term stations of the Russian federation. Light freezing drizzle occurrence (LFD) is approximately 10 times larger than this occurrence for intense freezing drizzle (IFD).**

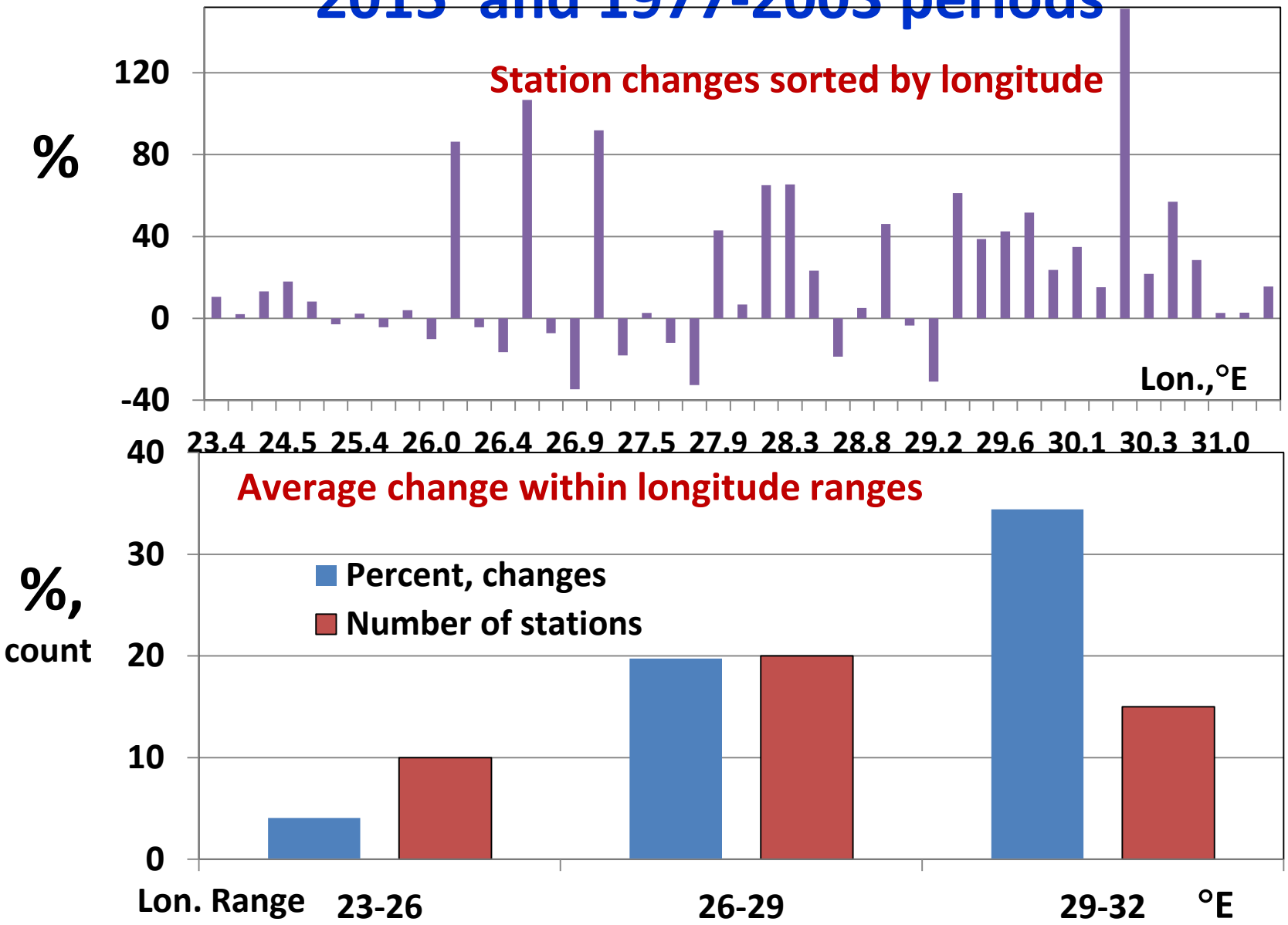
# Annual freezing rain frequency, FRF, area-averaged over the Steppe Zone of European Russia and the southern West Siberia



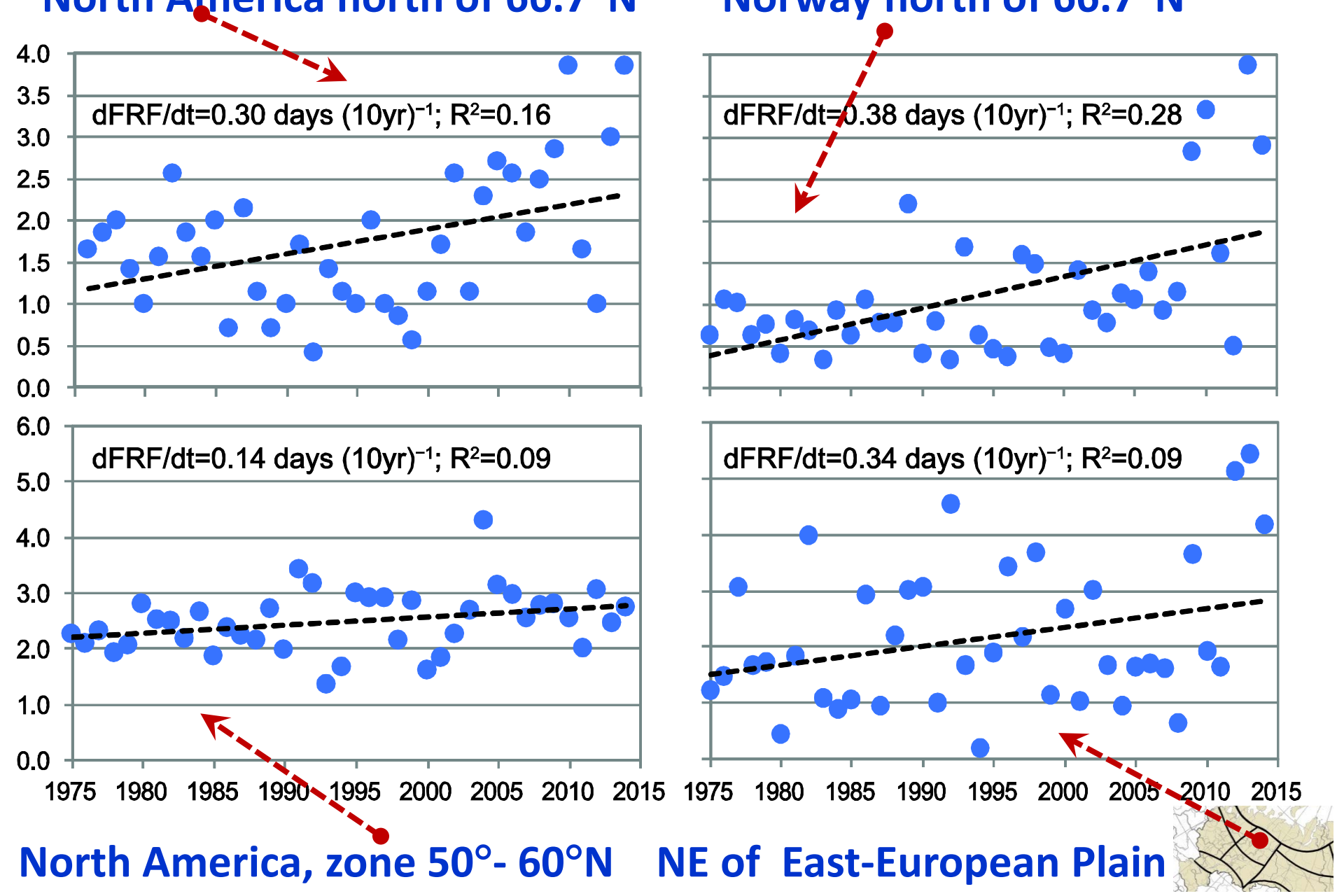



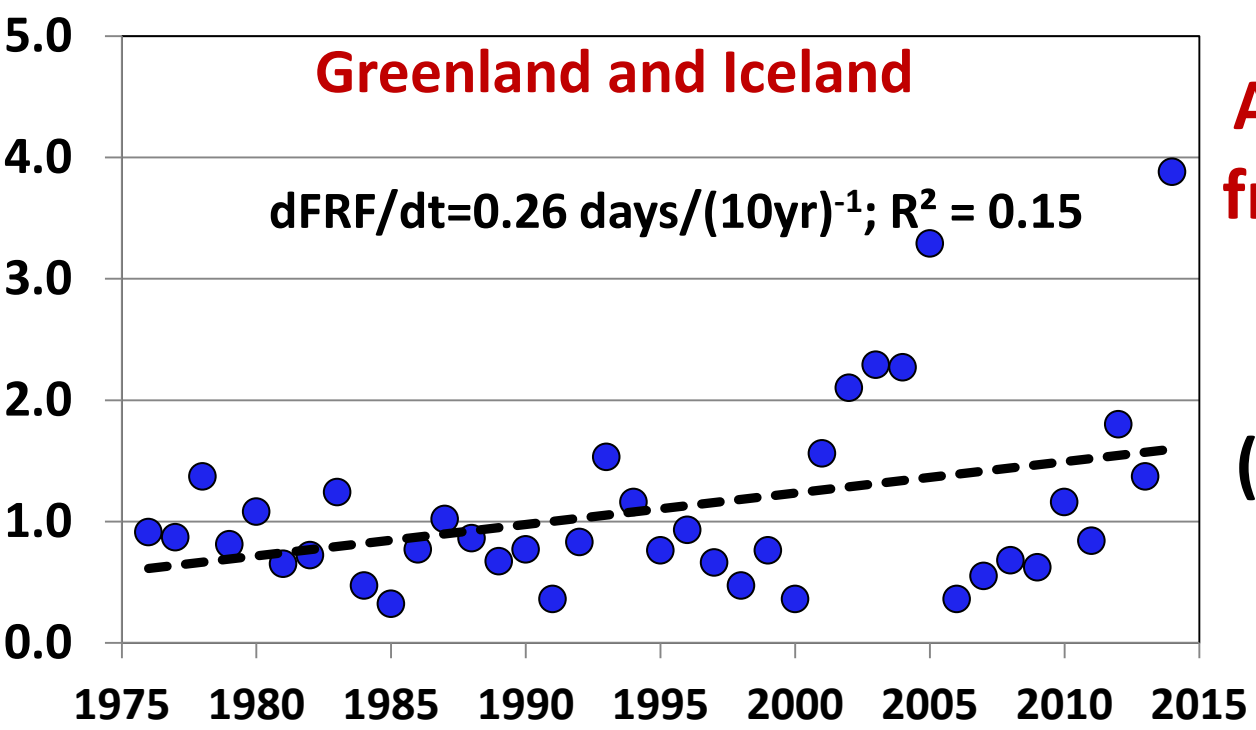

- **Note the order of magnitude scale difference between the continental Siberian region and the Steppe Region of European Russia**

# Changes in the annual number of freezing precipitation-hours over Belarus between 2004-2015 and 1977-2003 periods

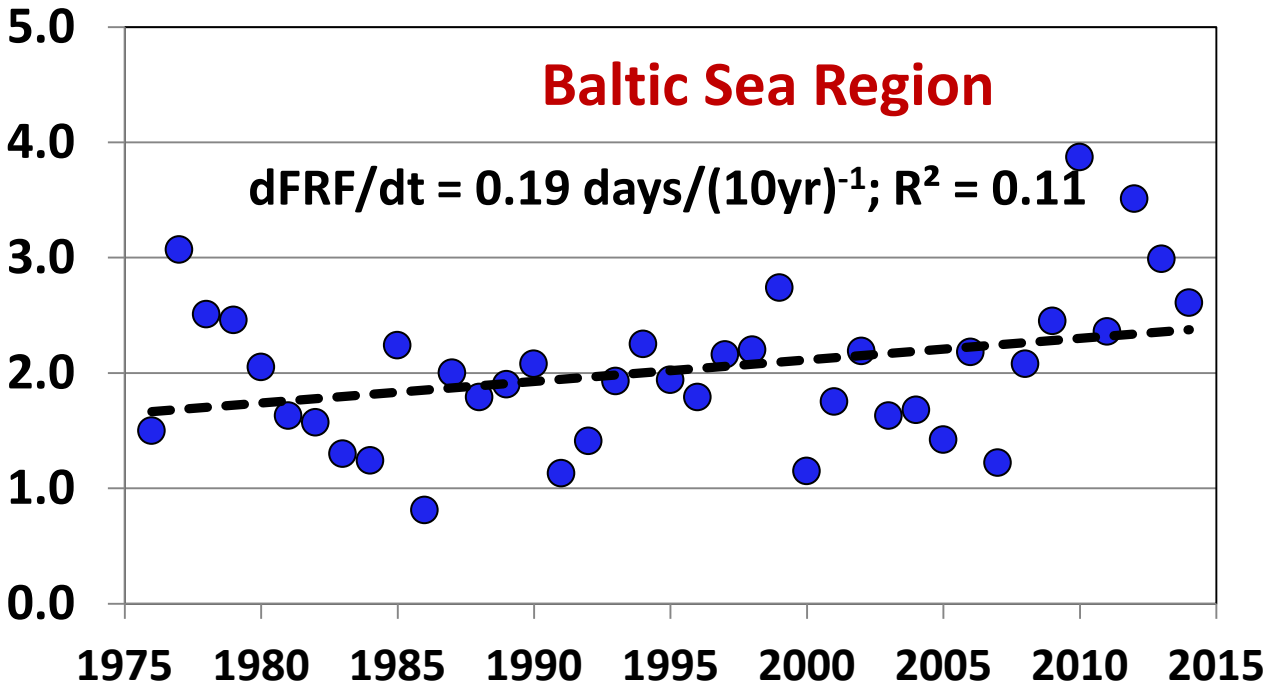


# Annual freezing rain frequency, FRF, area-averaged over






**Annual freezing rain frequency, FRF, area-averaged over Northern Europe (without Russia and Norway)**



# Annual frequency of all freezing precipitation events (freezing rain, freezing drizzle, and ice rain) over Kyrgyzstan during the 1966-1990 period and recent changes in this frequency during the 21st century

| Freezing events at different elevation | below 1 km | from 1 to 2 km | above 2 km |
|---|---|---|---|
| Climatology, days(yr)$^{-1}$ | 0.98 | 0.61 | 0.25 |
| Changes between two periods, days(yr)$^{-1}$ | -0.31 | -0.16 | **0.50** |

Data of 26 synoptic stations. For the 2009-2011, the data were not available for analysis

Long-term regional mean values of freezing rain frequency over Norway and selected regions of North America and Russia for 1975-2014 and differences between the mean values for the last decade (2005-2014) and the previous 30-yr-long period (1975-2004)

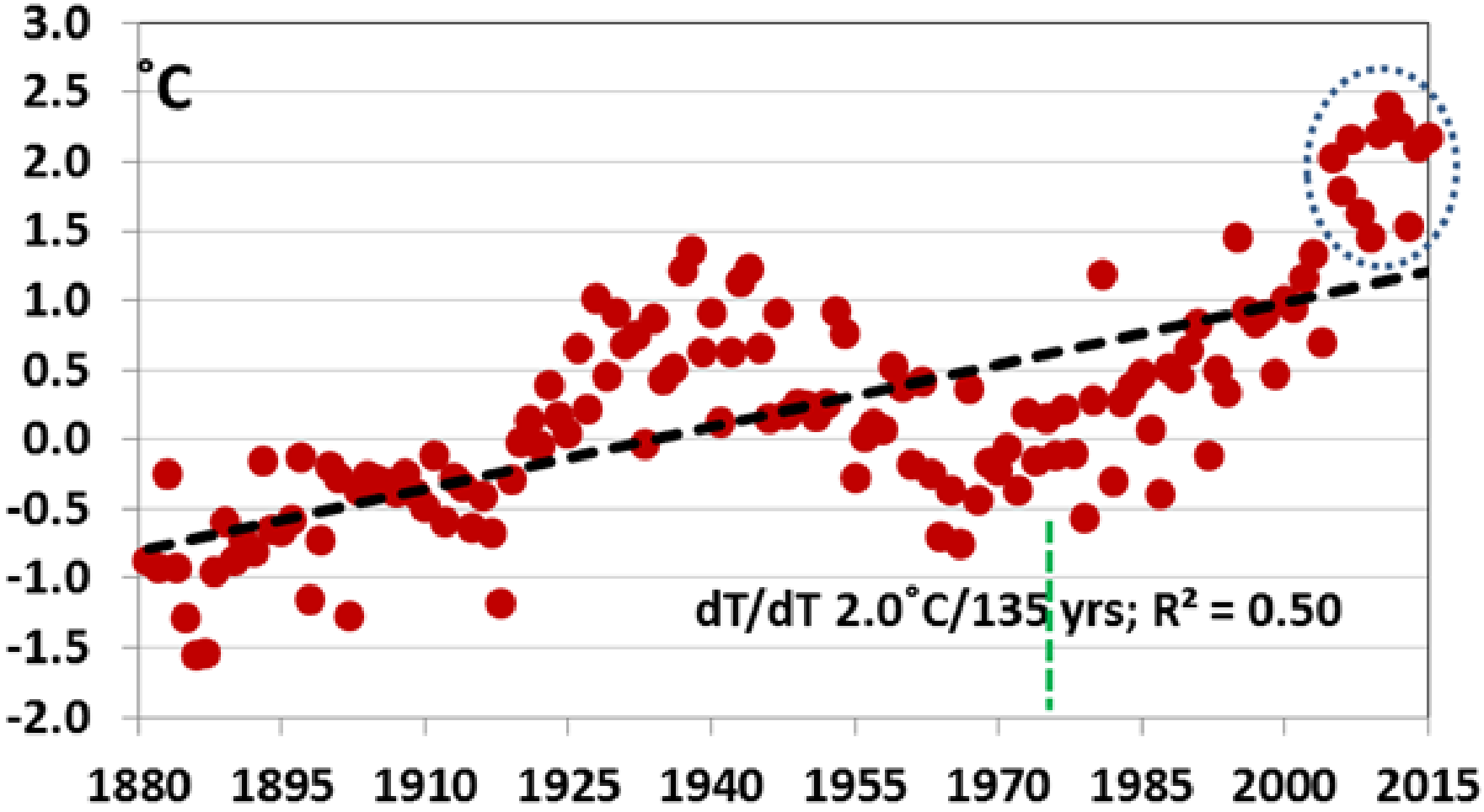
| Region | Regional mean values days $yr^{-1}$ | Diff. days $yr^{-1}$ | Significant changes by following tests |
|---|---|---|---|
| North America north of 66.7°N | 1.8 | **1.06** | **t- & L- tests** |
| North America, between 50°N and 60°N | 2.5 | ***0.28*** | ***L-test & $R_s$- test*** |
| North America, between 36°N and 50°N east of 95°W | 4.0 | 0.05 | |
| North America south of 36°N, east of 85°W | 0.8 | **-0.21** | **t-test** |
| Norway south of 66.7°N | 1.1 | **1.05** | all three tests |
| Norway north of 66.7°N | 1.1 | **1.10** | all three tests |
| Russian Atlantic Arctic | 1.4 | ***-0.20*** | ***L- & $R_s$- tests*** |
| Northwest of the Great East European Plain | 1.3 | 0.28 | |
| Northeast of the Great East European Plain | 2.2 | ***0.77*** | ***L- & $R_s$- tests*** |
| Southwest of the Great East European Plain | 4.2 | 0.32 | |
| Southeast of the Great East European Plain | 1.8 | 0.28 | |
| Steppe Region of European Russia | 4.3 | **-1.30** | **L- & $R_s$- tests** |
| Northern Caucasia Steppes and Piedmont | 2.1 | 0.16 | |
| Northern part of the forest zone of West Siberia | 1.0 | ***0.67*** | ***t-test*** |
| Southern part of the forest zone of West Siberia | 0.7 | **-0.20** | **L- & $R_s$- tests** |
| Steppe zone of West Siberia | 0.9 | -0.33 | |

Statistically significant changes at the 0.05 level are in bold and at the 0.10 level are in bold italic

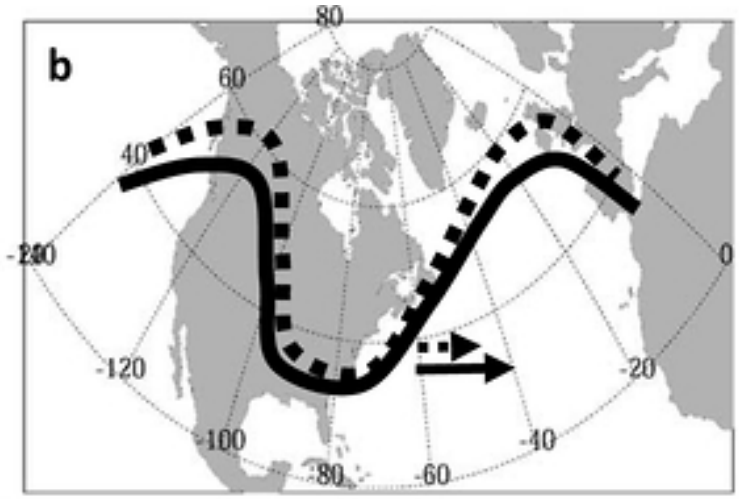
# Results in a nutshell

- **Freezing precipitation events frequency and intensity are changing in contemporary climatic changes, and these changes are not yet well understood and/or documented**
- **Automation (where it was introduced) and temporal paucity (e.g., 3-h. versus 1-h. reports) affect the homogeneity of reporting of freezing events (especially, for freezing drizzle and intense freezing events)**
- **Using synoptic data for the past 40 years, we estimated the climatology of the frequency of freezing rain and drizzle occurrence for North America, most of Europe, Russia, and Kyrgyzstan and their changes in the past decade**
- **During the last decade, substantial changes in the annual freezing rain occurrence were found:**
  - **On the southern edge of our study domain (southeastern U.S., Central Europe, southern Russia) the frequencies of freezing events decreased along with the duration of the cold season;**
  - **In the Arctic (North America, Europe, and North Atlantic north of 60°N), in some taiga areas of Russia, and at high elevations (The Tian Shan Mountains), the frequencies of freezing events increased "following" the expansion of the short warm season.**
- **Changes in the occurrence of freezing drizzle were estimated only for Russia. We found a statistically significant nationwide decrease in this element.**

# Possible cause:
# The Arctic temperature increase



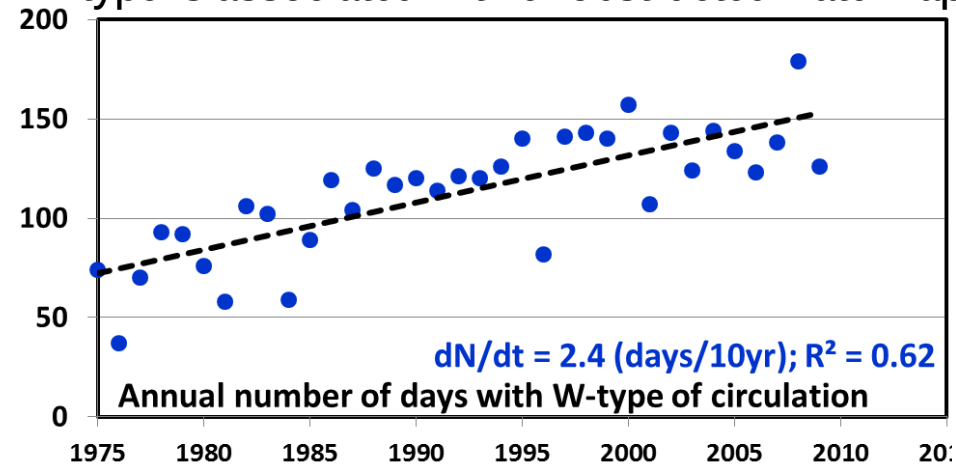
# Possible causes related to changes in atmospheric circulation

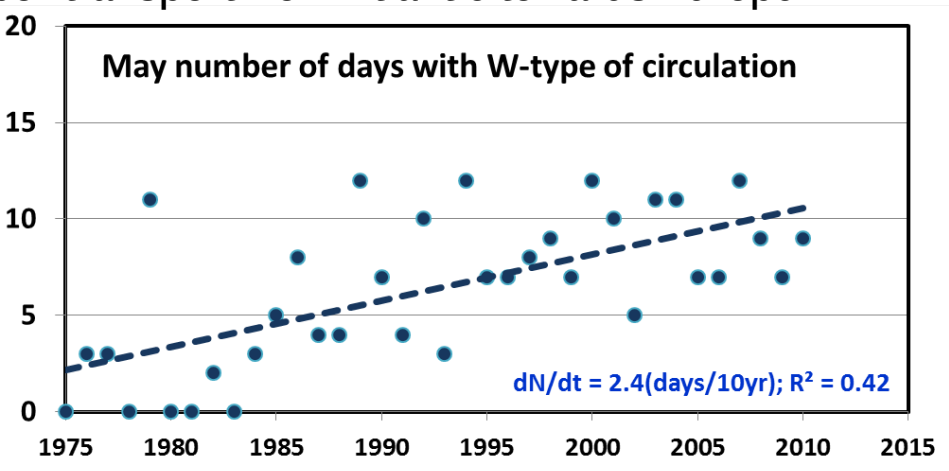



1. Large-scale meandering.
Figure 2b from Francis and Vavrus, 2012, *GRL*, 39, L06801. Schematic of ridge elongation (dashed vs. solid) in upper-level heights caused by enhanced warming in Arctic relative to mid-latitudes. Higher amplitude waves progress eastward more slowly, as indicated by arrows.

**2. Northward shift in Eurasian storm tracks (warm corner of cyclones can be more frequently found over the cold surfaces**)

3. Changes in the number of days with Wangengheim-Girs circulation type W. This circulation type is associated with unobstructed water vapor transport from Atlantic towards Europe**.**




Girs, A.A., 1974: *Macrocirculation method of long term forecasts*. Gidrometeoizdat, Leningrad, 488 pp.

***Acknowledgements.*** ***The work was supported by:***

- ***the Ministry of Education and Science of the Russian Federation (grant 14.B25.31.0026),***
- ***NASA LCLUC Program (grant "How Environmental Change in Central Asian Highlands Impacts High Elevation Communities"), and***
- ***the "ARCTIC-ERA: ARCTIC climate change and its impact on Environment, infrastructures, and Resource Availability" Project sponsored by: ANR (France), RFBR (Russia), and NSF (USA) in response to Belmont Forum Collaborative Research Action on Arctic Observing and Research for Sustainability.***