Evaluating the effects of boundary condition update frequency on CCLMs climate

Klaus Pankatz and Astrid Kerkweg

Institute for Atmospheric Physics, University of Mainz, Germany

email: pankatk@uni-mainz.de

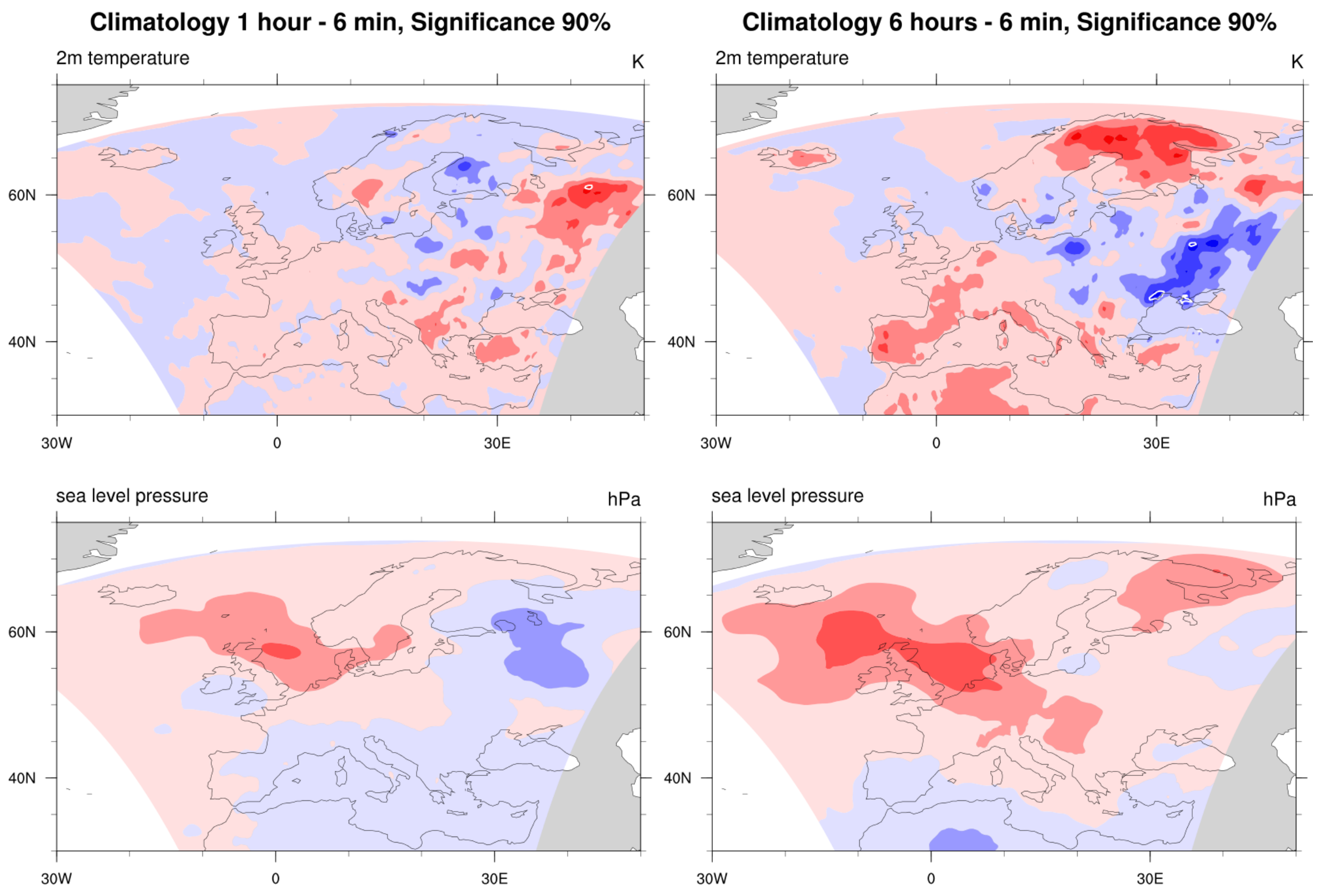
Abstract:

In regional climate modeling it is common to update the **lateral boundary conditions (LBC)** of the regional model every six hours. This is mainly due to the fact, that driving data sets like ERA are only available every six hours. Additionally, for offline coupling procedures it would be too costly to store LBC data in higher temporal resolution for climate simulations. However, theoretically, the coupling frequency could be as high as the time step of the driving model. Meanwhile, it is unclear if a more frequent update of the LBC has a significant effect on the climate in the domain of the regional climate model (RCM). This study uses the RCM COSMO-CLM/MESSy (Kerkweg and Jöckel, 2012) coupled offline to the GCM ECHAM5.

One study examines a 30 year time slice experiment for three update frequencies of the LBC, namely six hours, one hour and six minutes. The evaluation of means, standard deviations and statistics of the climate in regional domain shows only small deviations, some statistically significant though, of 2m temperature, sea level pressure and precipitation. The second part of the first study assesses parameters linked to cyclone activity, which is affected by the LBC update frequency. Differences in track density and strength are found when comparing the simulations.

The second study examines the quality of decadal hind-casts for the decade 2001-2010 if the **horizontal resolution** of the driving model, namely T42, T63, T85, T106, from which the LBCs are calculated, is altered. Two sets of simulations are evaluated. For the first set of simulations, the GCM simulations are performed at different resolutions using the same boundary conditions for GHGs and SSTs, thus in each simulation a unique circulation develops. These GCM simulations then provide LBCs for the RCM. For the second set, the GCM simulation in T106 is truncated to lower resolutions before creating the lateral boundary conditions for the RCM. Each set of simulations is evaluated regarding the quality of the 2m temperature, sea level pressure and precipitation prediction.

Update Frequency: Climatology



a) Summer

b) Winter

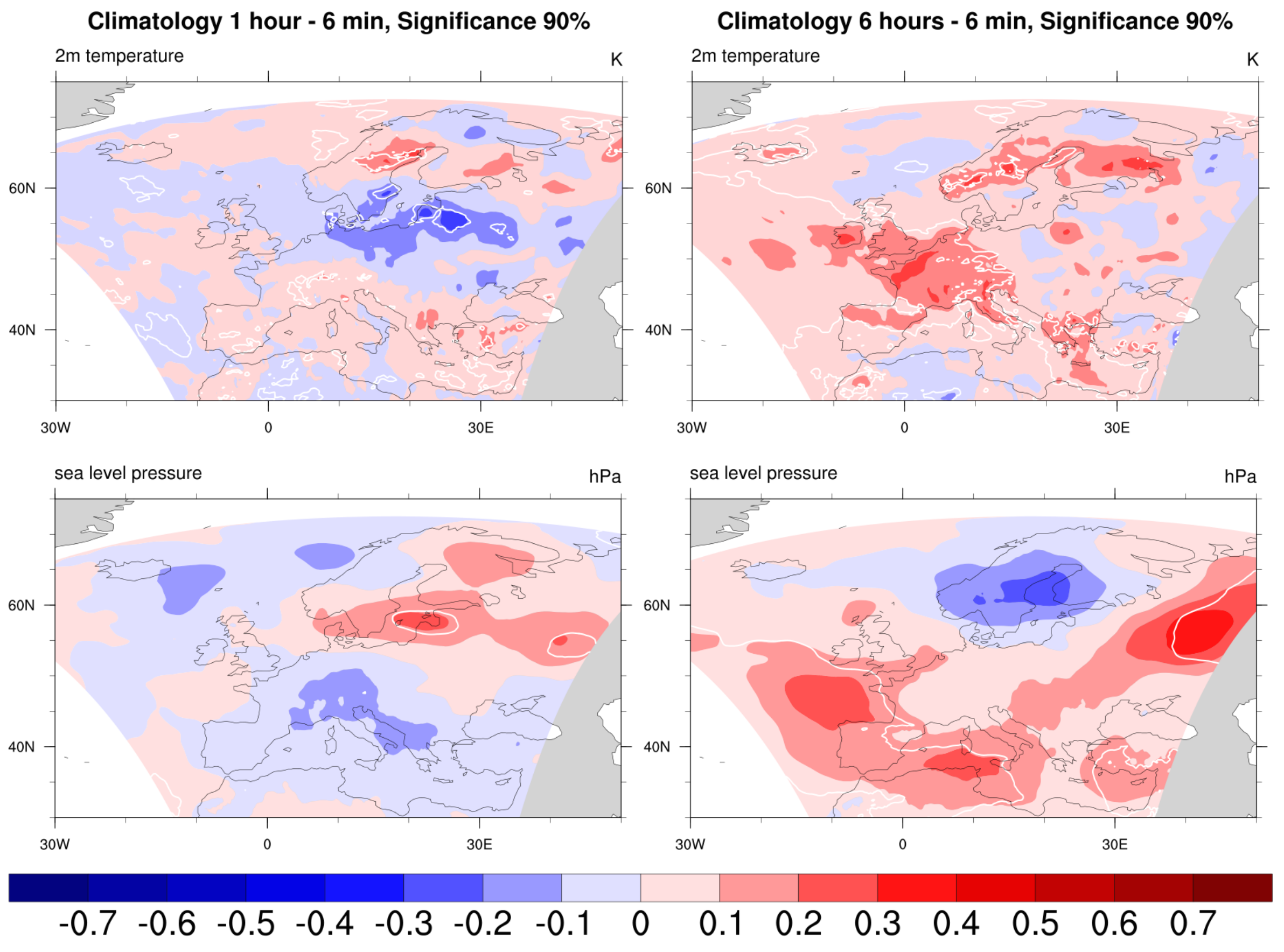


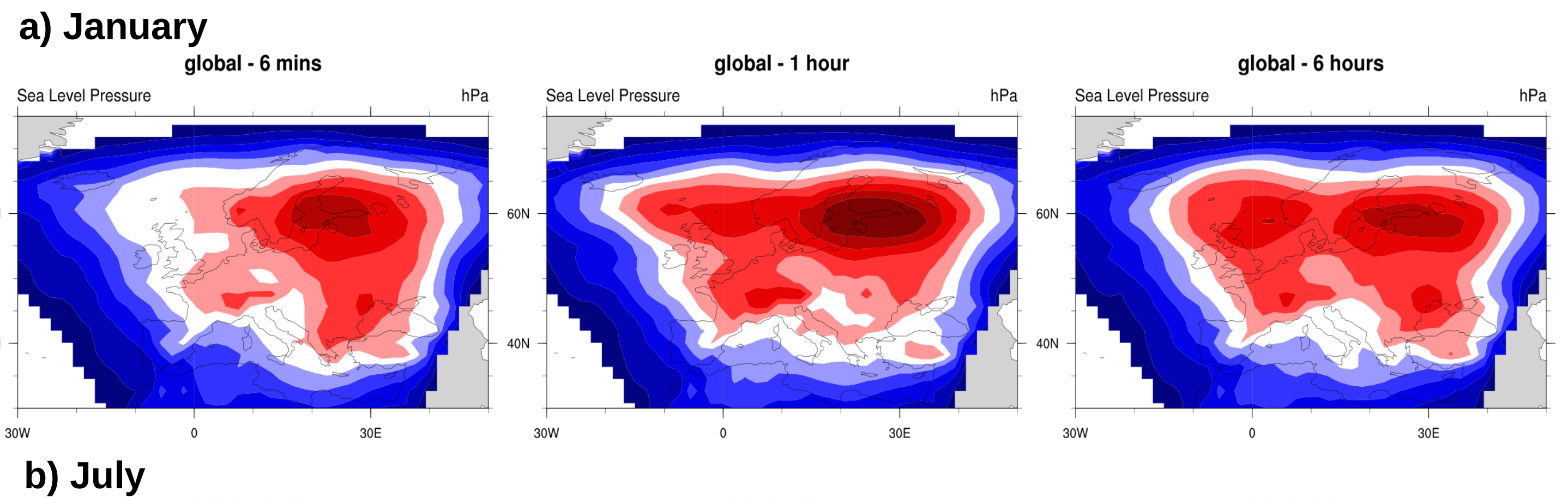
Figure 1 depicts the climatological differences between the different coupling frequencies. The summer half year climatology is shown in panel (a) and the winter half year climatology it is shown in panel (b). The climatology for each half year is calculated with a six month running mean. In each part the climatological differences of the 2m temperature are shown at the top and the sea level pressure differences are shown at the bottom. Areas in which the differences are statistically significant at the 90% level are enclosed in white contours. The significance is determined with a one sample t-test.

Differences of the summer half year climatology are less significant than the differences in the winter half year. In summer the boundary conditions exhibit less control over the domain of the local model. The timespan in which information passes through the local domain depends on the mean wind speed. (See Figure 3) In the winter half year there is a region of significant deviations reaching far into the model domain (both in the temperature field and in the pressure field).

Differences between the coupling frequencies six minutes and one hour (left) are less pronounced than differences between six hours and six minutes (right). The differences between simulations are largest for six hours minus six minutes. The (model-) physical reason for the differences in the climatology remains however unclear.

Update Frequency: Internal Variability

a) January



b) July

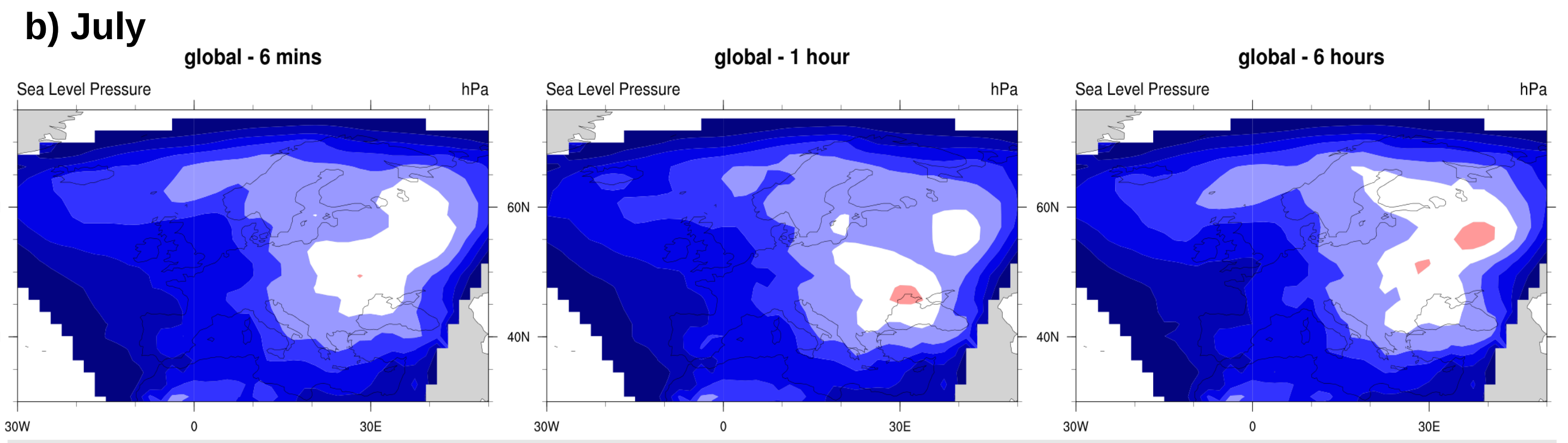


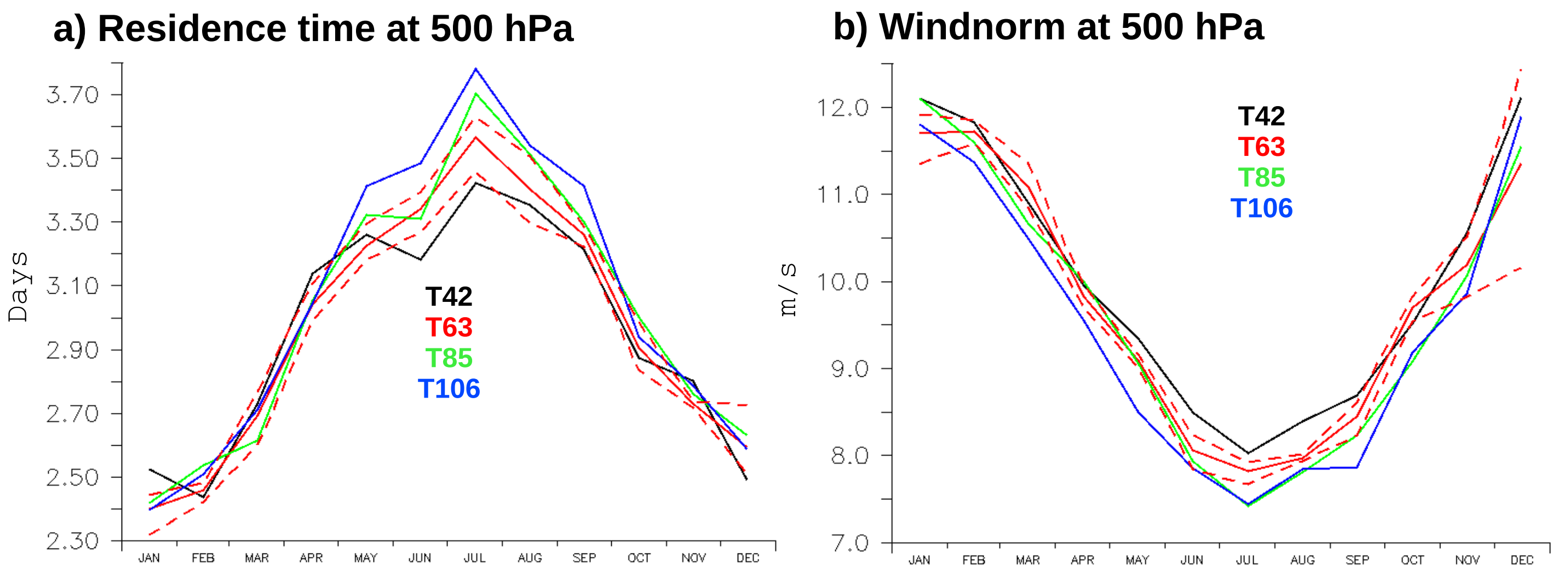
Figure 2 visualizes the variability of the SLP field of the RCM compared to the GCM for the months January (a) and July (b) for coupling frequencies of 6 minutes, 1 hour and 6 hours (from left to right). The Internal Variability of the RCM is clearly influenced by the coupling frequency. The amplitudes and the locations of maxima and minima change with the coupling frequency. It is however unclear whether the Internal Variability is biased by the coupling frequency in the way that higher coupling frequency induces lower Internal Variability. There are indications that this is the case in some months, but not in all months.

In general, Internal Variability (IV) is defined by the IPCC as „variability due to natural internal processes within the climate system“. Here, we focus on the part of the IV added by the RCM to the downscaled meteorological fields. For instance, a higher resolved orography and differently formulated physical processes contribute to the IV of the RCM. The existence of IV is a prerequisite for an added value of an RCM.

In the following, the IV of the RCM is calculated in a four stage metric:

- The monthly sea level pressure (SLP) anomalies of the global climate model (GCM) and the monthly SLP anomalies of the RCM are computed.
- The SLP field of the RCM is interpolated to the grid of the GCM.
- The difference between the two SLP anomalies is calculated for each month.
- For each month of the year the standard deviation of the difference is calculated.

Horizontal Resolution: Residence Time



a) Residence time at 500 hPa b) Windnorm at 500 hPa

c) Residence time at 850 hPa d) Windnorm at 500 hPa

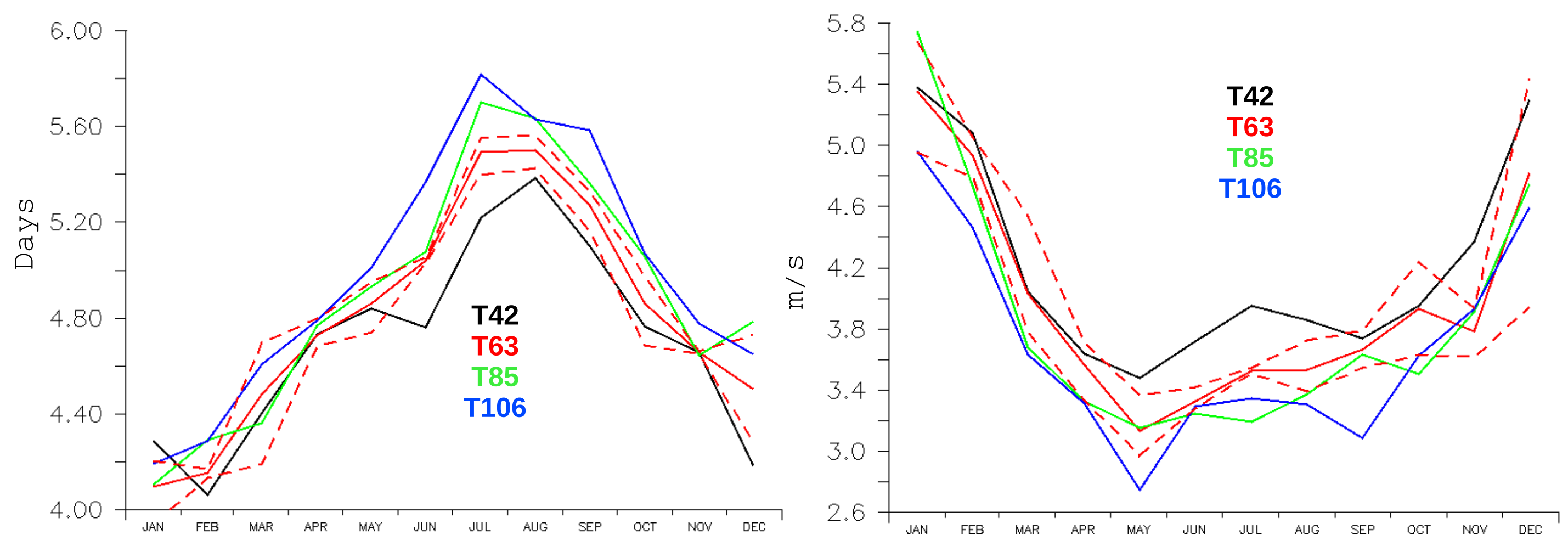


Figure 3 depicts the monthly climatology of the domain averaged residence time of air parcels in the regional domain. On the left, the residence time is shown on the 500 hPa (panel a) and the 850 hPa (panel c) pressure level. On the right, the wind-norm is shown on the 500 hPa (panel b) and 850 hPa (panel d) pressure level. Different resolutions of the lateral boundary conditions are plotted in different colors. The black curve depicts the results of the downscaled T42 simulation, the T85 results are in green and T106 results are in blue, respectively. The red curves depict the results of the downscaling of the three member ensemble in T63 (thick red line: Ensemble Mean, dashed red lines: Minimum and Maximum Values.

The resolution of the GCM (ECHAM5) clearly influences the residence time of air in the regional domain. Higher resolution enhances the residence time. The residence time increases monotonically with resolution independent of height. The higher resolved GCM simulations produce weaker winds, both in the lower and the middle atmosphere.

Residence time can be interpreted as a measure for the amount of possible modification the regional model can exert on the atmospheric flow set by the lateral boundary conditions. As the development of small scale features, only resolved by the RCM, takes some time, fine scale feature and their feedback to the larger scales can only emerge if the air stays long enough within the regional domain. Therefore, in terms of added value of the downscaling, it seems to be beneficial to have larger residence times.

The residence time of air inside the regional domain is measured by a passive tracer (Lucas-Picher et al. 2008). The tracer is initialized with a value of zero at the lateral boundaries of the regional domain. Inside the regional domain a certain value is added to the tracer at each time step. The tracer is advected and diffused by the atmospheric flow.

References:

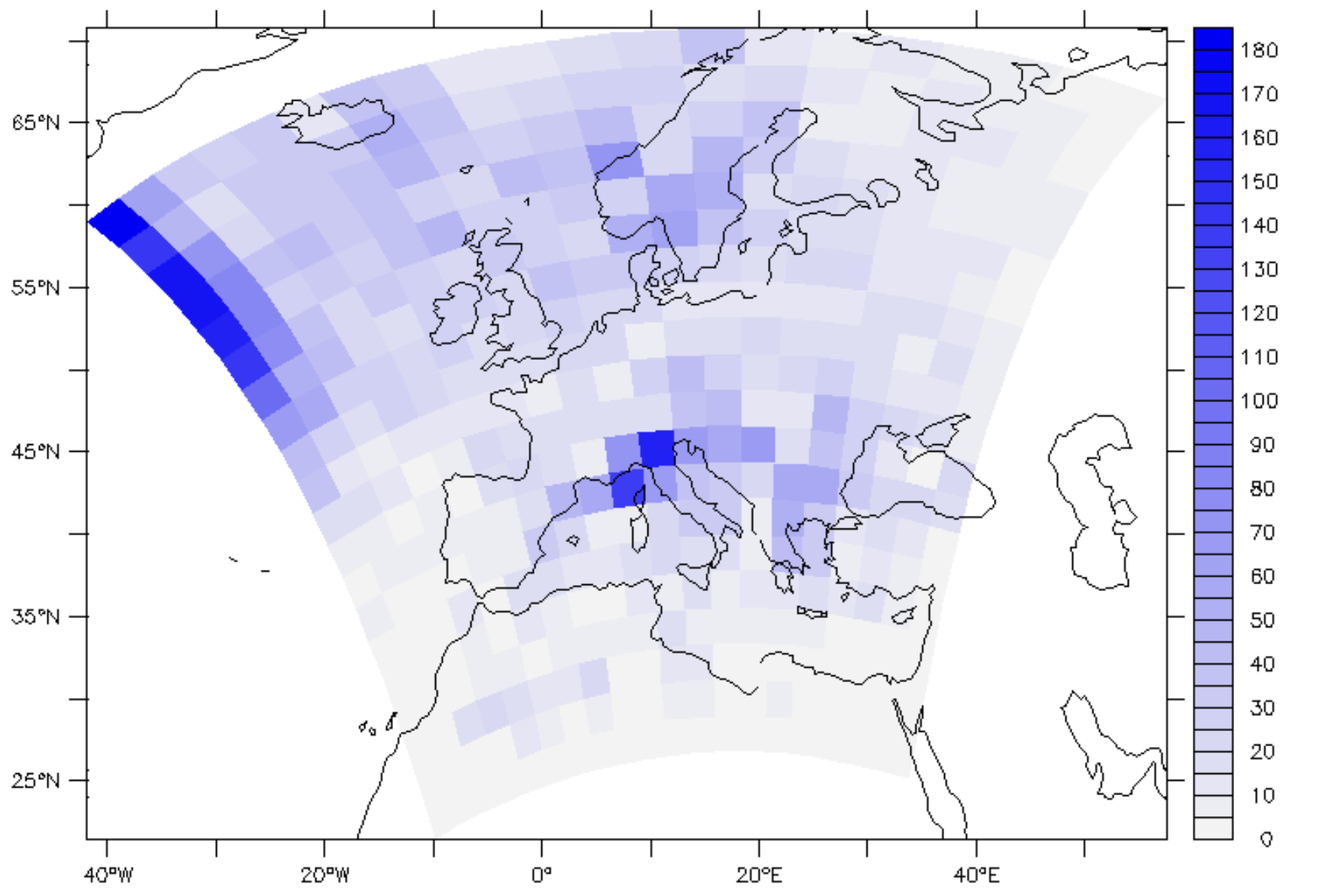
Kerkweg, A. & Jöckel, P. The 1-way on-line coupled atmospheric chemistry model system MECO(n) – Part 1: Description of the limited-area atmospheric chemistry model COSMO/MESSy, GMD, 2012, 5, 87-110

Wernli, H. & Schwierz, C. Surface Cyclones in the ERA-40 Dataset (1958-2001). Part I: Novel Identification Method and Global Climatology, Journal of the Atmospheric Sciences, American Meteorological Society, 2006, 63, 2486-2507

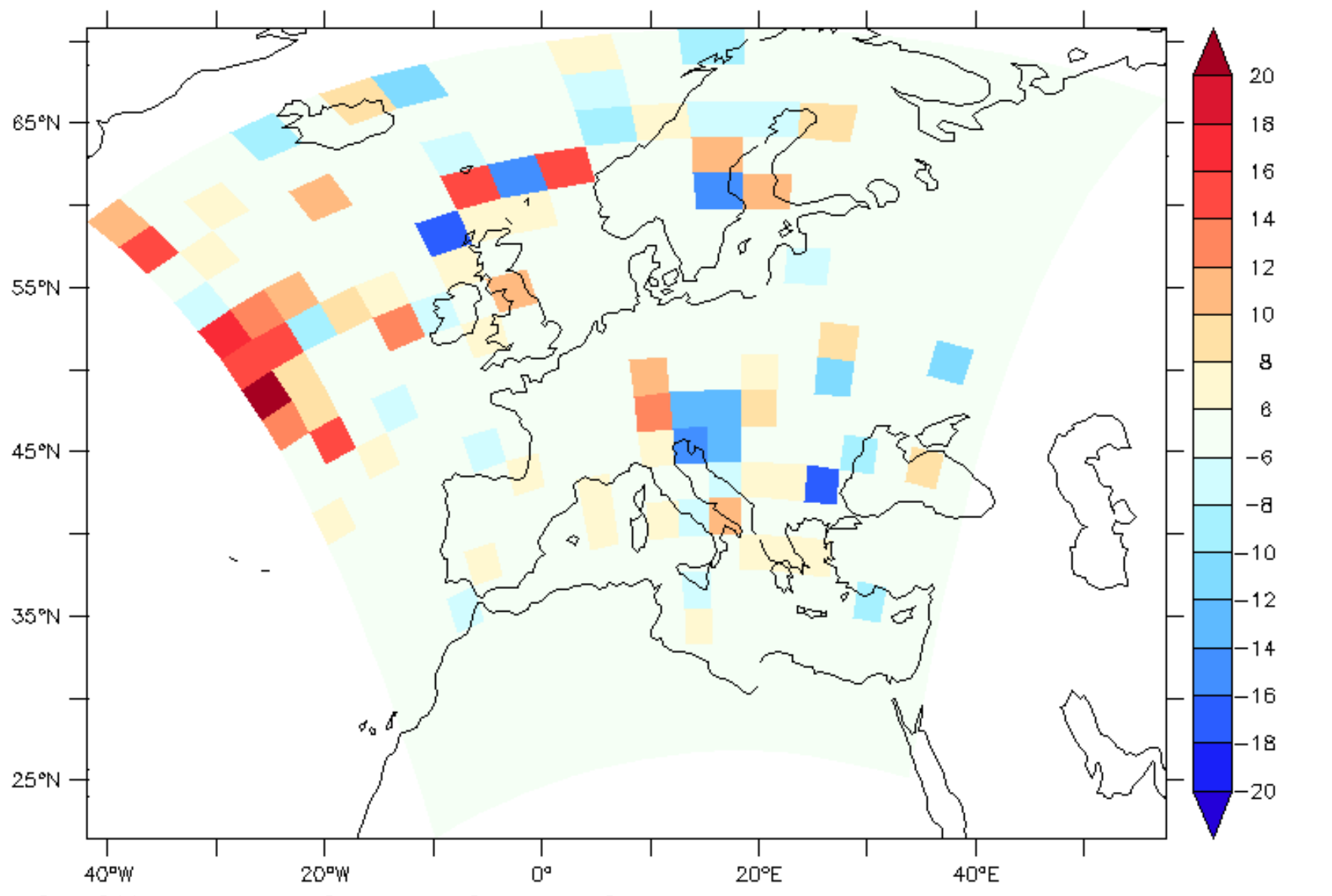
Lucas-Picher, P.; Caya, D.; Biner, S. & Laprise, R. Quantification of the Lateral Boundary Forcing of a Regional Climate Model Using an Aging Tracer, Monthly Weather Review, 2008, 136, 4980-4996

Update Frequency: Origin of Cyclones

a) 6 hours: Number of cyclone origins per box



b) Difference 6 minutes minus 6 hours



c) Difference 1 hour minus 6 hours

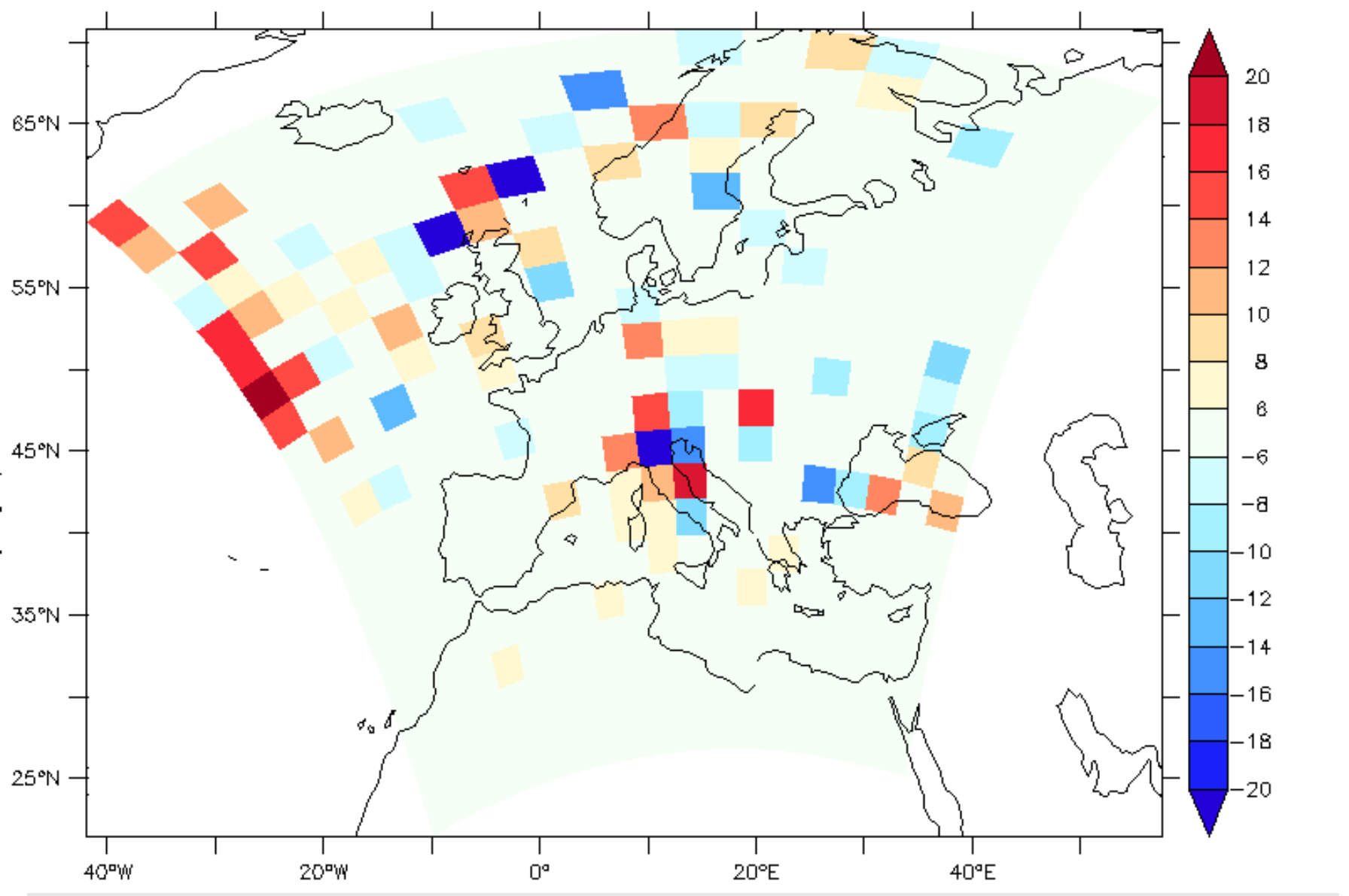


Figure 4 depicts the climatological number of cyclone origins per 10x10 (~2.2°x2,2°) grid boxes of the regional model (panel a) and the differences between boundary update frequencies (panel b and c). A cyclone origin is defined as the first pair of coordinates of a cyclone track (Wernli and Schwierz, 2006).

Many cyclones enter the regional domain through the western boundary. There are other hotspots of cyclone origins located in the Mediterranean close to the alpine region, near the Norwegian coastline and near Iceland. Some of these cyclone origins may be artifacts due to the topography which is imprinted on the pressure field.

No clear picture can be given when looking at the differences between the coupling frequencies for the inner domain. With higher coupling frequencies there are more cyclone origins near the boundary of the domain..

Horizontal Resolution: Spatial Correlation

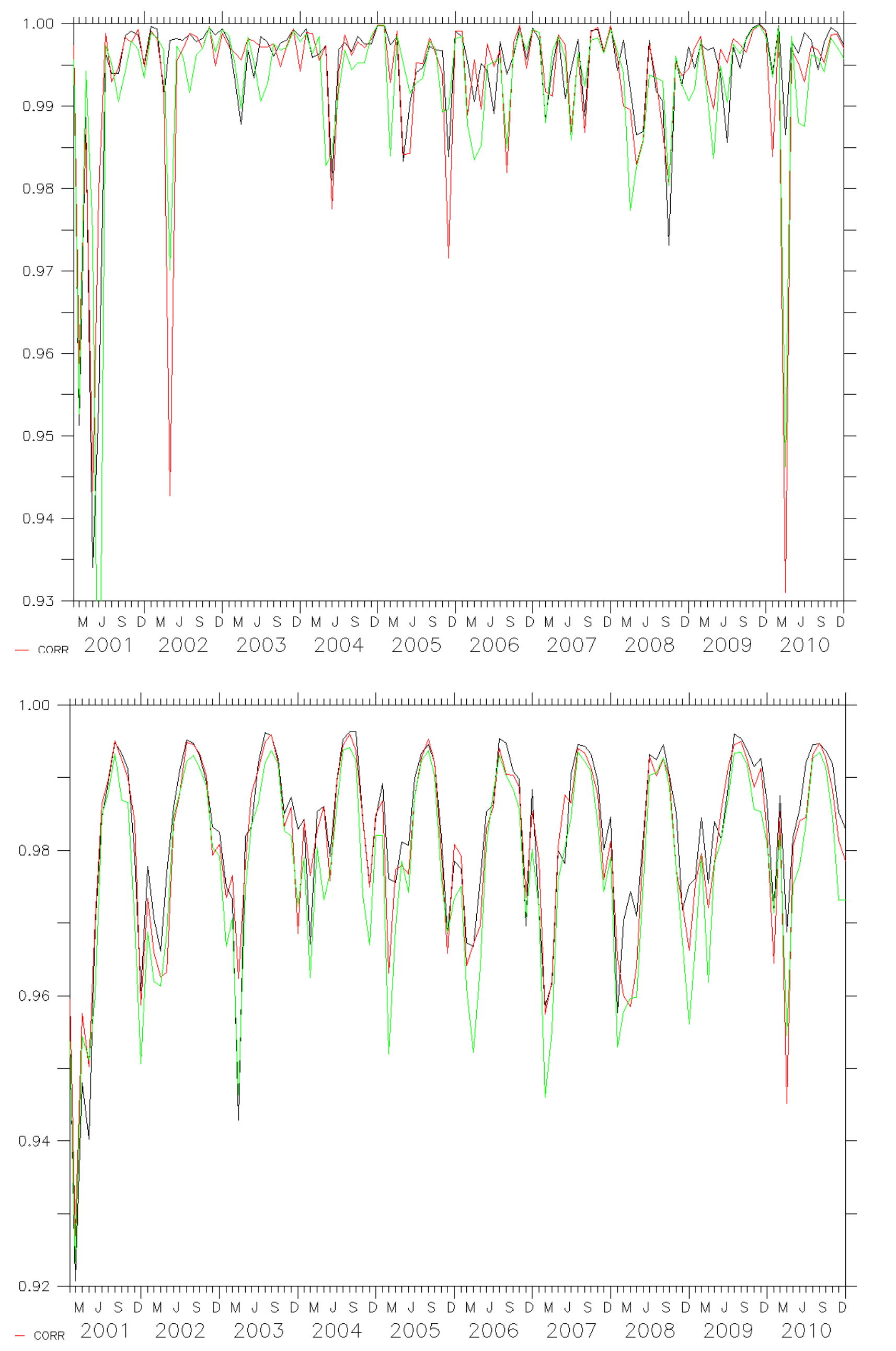


Figure 5 Spatial correlation of the large-scale component (left) and small-scale component (right) of sea-level-pressure (monthly means). Crossover wavelength is 500 km. The correlation of T85 and T106 is depicted in black, T63 and T106 in red, T42 and T106 in green. Correlation of the large-scale component is mostly high (>0.98) except few outliers. The outliers arise from short episodes (few days) of high internal variability. Correlation of the small-scale component shows a distinct seasonality with lower correlations during summer.