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Key Points:
- Characteristics of blocks and cyclones are generally similar in ERA5 and ERA-interim
- Characteristics are more sensitive to the spatial resolution than the choice of the reanalysis, especially for cyclones
- We recommend comparing climate model and reanalysis data using a common resolution

Supporting Information:
- Supporting Information S1
- Figure S1
- Figure S2

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Sensitivity of Blocks and Cyclones in ERA5 to Spatial Resolution and Definition

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Abstract ERA5, the fifth-generation reanalysis of the European Center for Medium-Range Weather Forecasts, provides long time series of atmospheric fields at high spatial and temporal resolution. It allows detailed studies of atmospheric flow features such as blocks or cyclones. We investigate characteristics of blocks and cyclones in ERA5 using different algorithms, compare the results to ERA5's predecessor, ERA-interim, and investigate how these characteristics depend on spatial resolution. Generally, ERA5 and ERA-interim characterize blocks and cyclones similarly. For Lagrangian detection and tracking methods, blocks are more robust than cyclones to changes in resolution and reanalysis choice. Eulerian methods are robust to changes in resolution. Thus, ERA5 provides a state-of-the-art reanalysis for the synoptic-scale extratropical circulation. We find that Lagrangian cyclone characteristics are strongly dependent on spatial resolution and therefore recommend that model and reanalysis data should be mapped to a common resolution for verification.

Plain Language Summary Reanalyses are among the most widely used data sets in the geosciences as they provide a state of the atmosphere that is complete in both space and time by combining a state-of-the-art weather prediction model with historical observations. Their applications range from climatological studies to the closer examination of extreme events. Reanalyses are often the primary tool to assess the performance of climate models. Recently, the ERA5 reanalysis was published, and thus, many users may consider using this new product. However, due to its novelty, ERA5 is not yet investigated extensively. We examine midlatitudinal atmospheric flow features such as blocks and cyclones and their dependence on input resolution and choice of reanalysis. We find that blocks and cyclones characteristics are very similar in ERA5 and its predecessor ERA-interim. Input resolution often plays a more important role on block and cyclone characteristics than the choice between ERA5 and ERA-interim, particularly in case of cyclone characteristics. For many applications, the full resolution of ERA5 may not be necessary, easing the computational requirement to use this high-resolution data set. In case of modeling studies where reanalysis data is compared to modeled data, we recommend using the same resolution.

1. Introduction

Atmospheric blocks and extratropical cyclones are central features of synoptic-scale variability in the midlatitudes. Blocks are defined as quasi-stationary, persistent anticyclones that divert the storm track (e.g., Woollings et al., 2018). Cyclones can be defined in various ways, for example, by a local minimum of sea level pressure or a local maximum in vorticity (e.g., Neu et al., 2013; Raible et al., 2008). They form and move frequently within preferred regions referred to as storm tracks (Shaw et al., 2016). Both blocks and cyclones are linked to extreme weather and climate. Blocks are linked to heat waves (Black et al., 2004), cold spells (e.g., Buehler et al., 2011), and heavy precipitation (e.g., Lau & Kim, 2012; Lenggenhager & Martius, 2019; Martius et al., 2013). Cyclones can lead to heavy precipitation (e.g., Messmer et al., 2015; Pfahl & Wernli, 2012) and strong winds (e.g., Catto, 2016).

Several detection and tracking methods for blocks and cyclones exist (Catto, 2016; Neu et al., 2013; Woollings et al., 2018). Blocks may be identified as regions with a meridional reversal of the geopotential height (Scherrer et al., 2006; Tibaldi & Molteni, 1990), regions with anomalously high geopotential height (Buehler et al., 2011; Dole & Gordon, 1983), or regions with low potential vorticity (PV; Schwierz et al., 2004). Lagrangian methods detect and track blocks and cyclones in space and time (Neu et al., 2013; Raible et al., 2008). In contrast, Eulerian methods examine properties at a given point as a function of time. Storm tracks, regions with highest cyclonic activity, are often defined identified based on a 2.5–6 day band-pass filtered 500 hPa geopotential height (Z500) field, while blocks can be identified by applying a 10 day low-pass filter to the Z500 field (Blackmon, 1976).

Apart from the definition and method, results also depend on the underlying data set and its spatial and temporal resolution (e.g., Blender & Schubert, 2000; Rohrer et al., 2018; Wang et al., 2016). The new ERA-5 data set (Hersbach & Dee, 2016) is available at the unprecedented resolution of approximately 31 km. The data volume at the full resolution and for the entire time period covered by ERA-5 may exceed the storage capacity of potential users and the question arises if data at the full resolution are needed to answer specific research questions. Here, we answer this question for blocking and cyclone by (i) exploring the sensitivity of several objective detection algorithms to resolution and by (ii) discussing reasons for the sensitivity. Additionally, the results of this study will enable the reader to assess the validity of former findings of blockings and cyclones based on coarse resolutions.

2. Data and Methods

We use ERA5 and ERA-interim (Dee et al., 2011) data from 1979 to 2017 at 6 hourly resolution. Compared to ERA-interim, ERA5 ingests more data sources, uses an updated numerical weather prediction model and data assimilation system, and provides higher spatial resolution: T639 and 137 horizontal levels compared to T255 and 60 levels for ERA-interim. We only use the deterministic run of ERA5. We bilinearly remap the data to a resolution of 1° and 2° for the blocking identification. For cyclones, we remap to the T63 resolution by spectrally truncating at Wave Number 63 instead of the 2° resolution as some cyclone detection and tracking methods apply spectral remapping to the input data (e.g., Hodges, 1995).

We employ three Lagrangian blocking algorithms that are variations of the blocking algorithm used by Rohrer et al. (2018):

(1) TM2D: A 2-dimensional extension of the Tibaldi and Molteni (1990) blocking definition (Scherrer et al., 2006). The following two criteria must be fulfilled to detect a block:

$$\text{(i)Z500 gradient toward pole}: Z500G_P = \frac{Z500_{\varphi+d\varphi} - Z500_{\varphi}}{d\varphi} < -10\ \frac{\text{m}}{^\circ\text{lat}}. \tag{1}$$

$$\text{(ii) Z500 gradient toward equator}: Z500G_E = \frac{Z500_{\varphi} - Z500_{\varphi-d\varphi}}{d\varphi} > 0\ \frac{\text{m}}{^\circ\text{lat}}. \tag{2}$$

Here, φ denotes latitude and varies from 35° to 75°. $d\varphi$ denotes how far poleward or equatorward the second grid point is located to calculate the gradients. $d\varphi$ is the highest possible multiple of the input resolution that is smaller than 15°.

(2) Z500*: Following Dole and Gordon (1983), we define blocks as regions with a positive Z500 anomaly (Z500*) > 200 m.

(3) Vertically averaged PV (VAPV): Similar to Schwierz et al. (2004), blocks are derived from the 150–500 hPa VAPV. Blocks are detected as regions with VAPV anomalies < -1.3 (>1.3) PVU in the Northern (Southern) hemisphere after a 2 day running mean filter is applied.

For Z500* and VAPV, the anomalies are subtracted from the 30 day running mean climatology between 1979 and 2017. In all three blocking algorithms, we consider only blocks that are quasi-stationary (i.e., $A_t \geq 0.7 * A_{t+1}$, where A_t denotes the area of a block at time step t) and long-lasting (≥5 days).

To detect and track cyclones, we use two algorithms:

1. WS06: Wernli and Schwierz (2006) detect cyclones as areas of the largest enclosed sea level pressure (SLP) contour around a SLP minima. We discard cyclones over elevated terrain (surface pressure < 850 hPa) and shorter than 1 day. The locations of cyclogenesis and cyclolysis must be at least 1,000 km apart, and we merge cyclone centers that are closer than 1,000 km. For further details and refinements about the algorithm, refer to Sprenger et al. (2017).
2. B97: Blender et al. (1997) define cyclones as minima at the 1,000 hPa geopotential height level (Z1000). Minima are ignored if they are over elevated terrain (>1,000 m) or if more than 50% of the grid points in an area within the estimated cyclone radius around the center are over elevated terrain. Only cyclones

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with a mean horizontal gradient of at least 30 m/1,000 km are detected. Cyclones require a minimum distance of 1000 km from genesis to lysis and a minimum duration of 1 day to be retained in the catalog (Raible et al., 2018).

The TM2D, Z500*, VAPV, and WS06 algorithms extract binary cyclone or blocking fields. We use the Jaccard (1908) index, *J*, to investigate how similar ERA5 and ERA-interim are. *J* is the overlap area divided by the union area of a given feature in two reanalyses A and B during time step *t*: $J(t) = \frac{A(t) \cap B(t)}{A(t) \cup B(t)}$. Time steps with no blocks are set to $J(t) = 1$. Aggregated over time, we can infer the similarity between two data sets. We use this index for a crude comparison of the similarity between ERA5 and ERA-interim with two other reanalyses: CFSR (Saha et al., 2010) and MERRA-2 (Gelaro et al., 2017).

We filter the Z500 field to obtain Eulerian perspective of blocks and cyclones. Following Blackmon (1976), we retain time scales between 2.5 and 6 days for cyclones (Z500bp), while for blocks, frequencies between 10 and 90 days are retained (Z500lp).

3. Results

3.1. Blocking Characteristics

We compare annual blocking frequencies (denoted as the number of blocked time steps divided by the total number of time steps per grid point; Figure 1). Across all reanalysis and resolutions, three blocking maxima in the North Atlantic, the North Pacific, and the South Pacific emerge as robust features. Relative blocking frequencies vary depending on the algorithm. VAPV (Figures 1i–1l) and TM2D (Figures 1a–1d) detect fewer blocks in the Southern Hemisphere compared to Z500* (Figures 1e–1h). In the Northern Hemisphere, TM2D detects more blocks in low latitudes, which are rather an imprint of the subtropical high-pressure belt (Treidl et al., 1981). This is particularly evident during summer (JJA; supporting information Figure S1). Additionally, TM2D shows a summer peak over Siberia, which is shifted northeast in VAPV and is not captured in Z500*. Overall blocking activity in winter (DJF) is generally higher than in summer (Figures S1 and S2). The Eulerian method for blocks, Z500lp (Figures 1m–1p), shows a similar distribution in the midlatitudes as Z500* and VAPV with maxima along the Southern Hemispheric midlatitude, over the Aleutians, and over the British Islands. Blocks tend to last longer in Z500* compared to VAPV and TM2D (Figures 2a, 2d, and 2g). This is also evident from the mean blocking duration of 10.2 days in Z500* compared to roughly 8.5 days in VAPV and TM2D. The mean area of a block in Z500* is largest (~$5 * 10^6$ km^2) compared to TM2D (~$3.5 * 10^6$ km^2) and VAPV (~$3 * 10^6$ km^2; Figures 2b, 2e, and 2h). Note that all these measures (blocking frequency, duration, and area) depend on the subjective choices of thresholds for each block algorithm.

ERA-interim and ERA5 show very similar climatological annual blocking frequencies at a 2° resolution (Figures 1b, 1f, 1j, and 1n). Only exception is the higher (lower) low-pass-filtered Z500 variability in the Southern Ocean (Antarctica; Figure 1n). Relative differences are small (<3%) for the main blocking areas. The same holds true for other characteristics of blocks (<3%) when comparing ERA5 with ERA-interim (Figure 2 and Table 1).

Block detection algorithms are also insensitive to the input resolution of ERA5 (Figure 1). The only notable difference is between 2° and 1° resolution for TM2D (Figure 1c). The increase is related to the blocking definition, which limits the latitudinal extent of a block to the biggest possible multiple of the input resolution that is no larger than 15°. Hence, we obtain a maximum latitudinal extent of 14° for a 2° resolution and a maximum of 15° for 1° resolution, that is, a block at 1° resolution is potentially ~7% (15°/14°) larger than at 2° resolution. This also affects other blocking characteristics such as the mean duration that increases from 8.3 to 8.7 days from original to 1° and 2° resolution. Other than that, block duration (Figures 2a, 2d, and 2g), block area (Figures 2b, 2e, and 2h), and block intensity (Figures 2c, 2f, and 2i) show no substantial differences between different input resolutions. Differences are only visible in the extreme tails of the distributions with very few blocks (note the logarithmic scale). The overall number of blocks and the number of blocking time steps for the Lagrangian methods increases with increasing resolution (Table 1). This is expected as genesis (lysis) of blocking events tend to be detected earlier (later) with higher resolutions. The outcome of the Eulerian method Z500lp is insensitive to the input resolution.

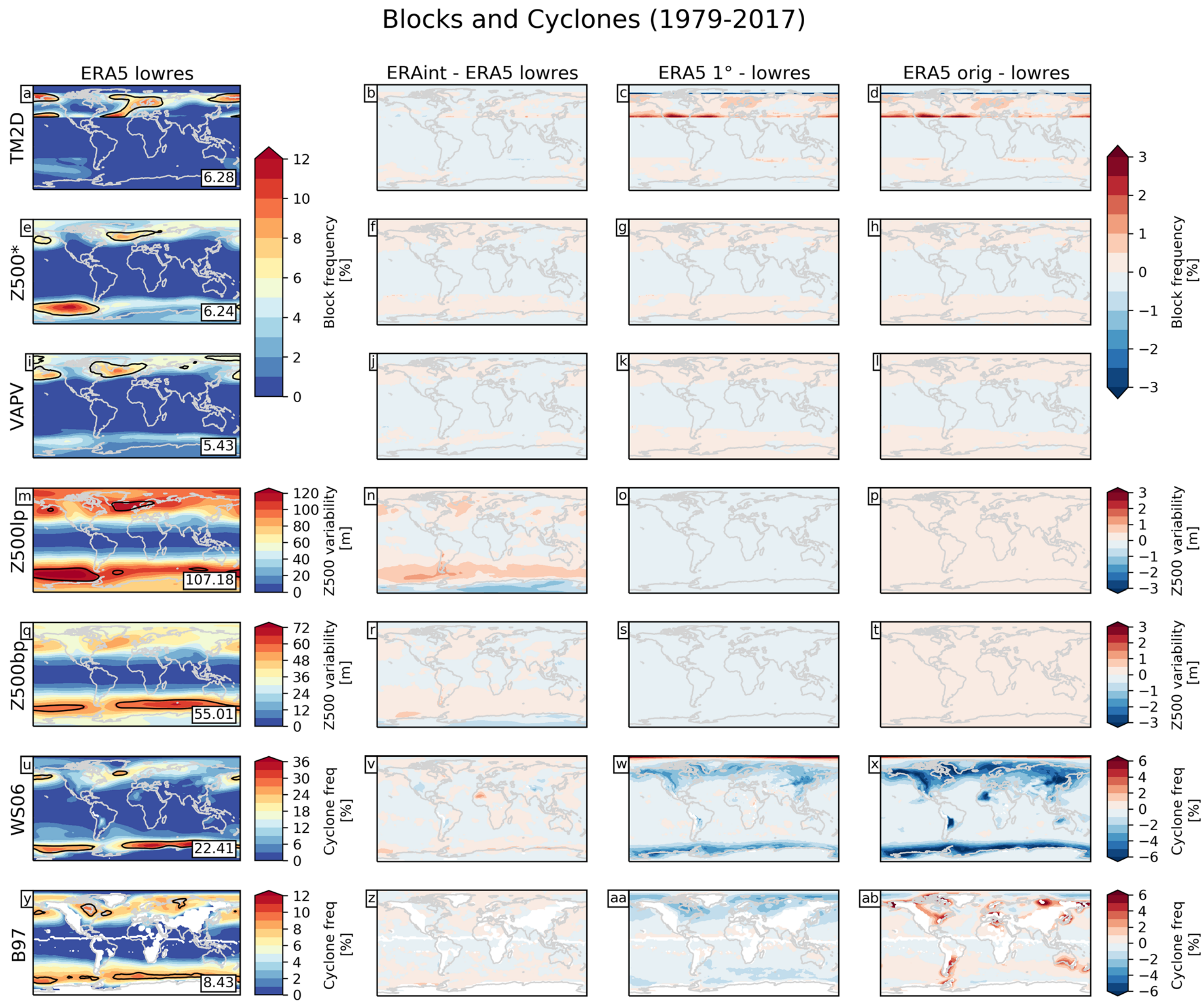

Figure 1. Climatological distribution (1979–2017) of blocks and cyclones in ERA5 remapped to low resolution (a, e, i, m, q, u, y) and the difference to ERA-interim (b, f, j, n, r, v, z), ERA5 at a 1° resolution (c, g, k, o, s, w, aa), and ERA5 at original resolution (d, h, l, p, t, x, ab). The upper four rows show the different block algorithms (TM2D, Z500*, VAPV, and Z500lp). The lower three rows show the cyclone distributions determined by Z500bp, WS06, and B97. For WS06, we show the cyclone frequency defined as cyclone presence at a grid point using the outer contour as area. For B97, the cyclone frequency is defined as cyclone presence at the grid point (without normalizing it to a unit area; Raible et al., 2018), that is, first each grid point within the radius of a cyclone (using a two-dimensional Gaussian fit to the center) is assigned to be occupied by the cyclone for on time step. Summing over all time steps for each grid point and dividing by the total number of time steps results in cyclone frequency at each grid point in %. The value of the black 95th percentile contour is given in the lower right of each panel.

In summary, differences between ERA-interim and ERA5 at the same resolution are comparable or smaller than the differences between different resolutions for the same reanalysis. Relating these differences to the interannual variability of blocks reveals that interannual variability is orders of magnitude larger than the differences found here (not shown).

3.2. Cyclone Characteristics

All algorithms identify the storm tracks over the North Atlantic, North Pacific, and a band of high cyclone frequency around the Southern Ocean (Figures 1q–1ab), but local differences can be large. The Eulerian measure for cyclones, Z500bp (Figures 1q–1t), shows a similar location of high cyclone activity as WS06 and B97 (Figures 1u–1ab). Note again, that the absolute values of cyclone frequency cannot be directly compared due to the different definitions used.

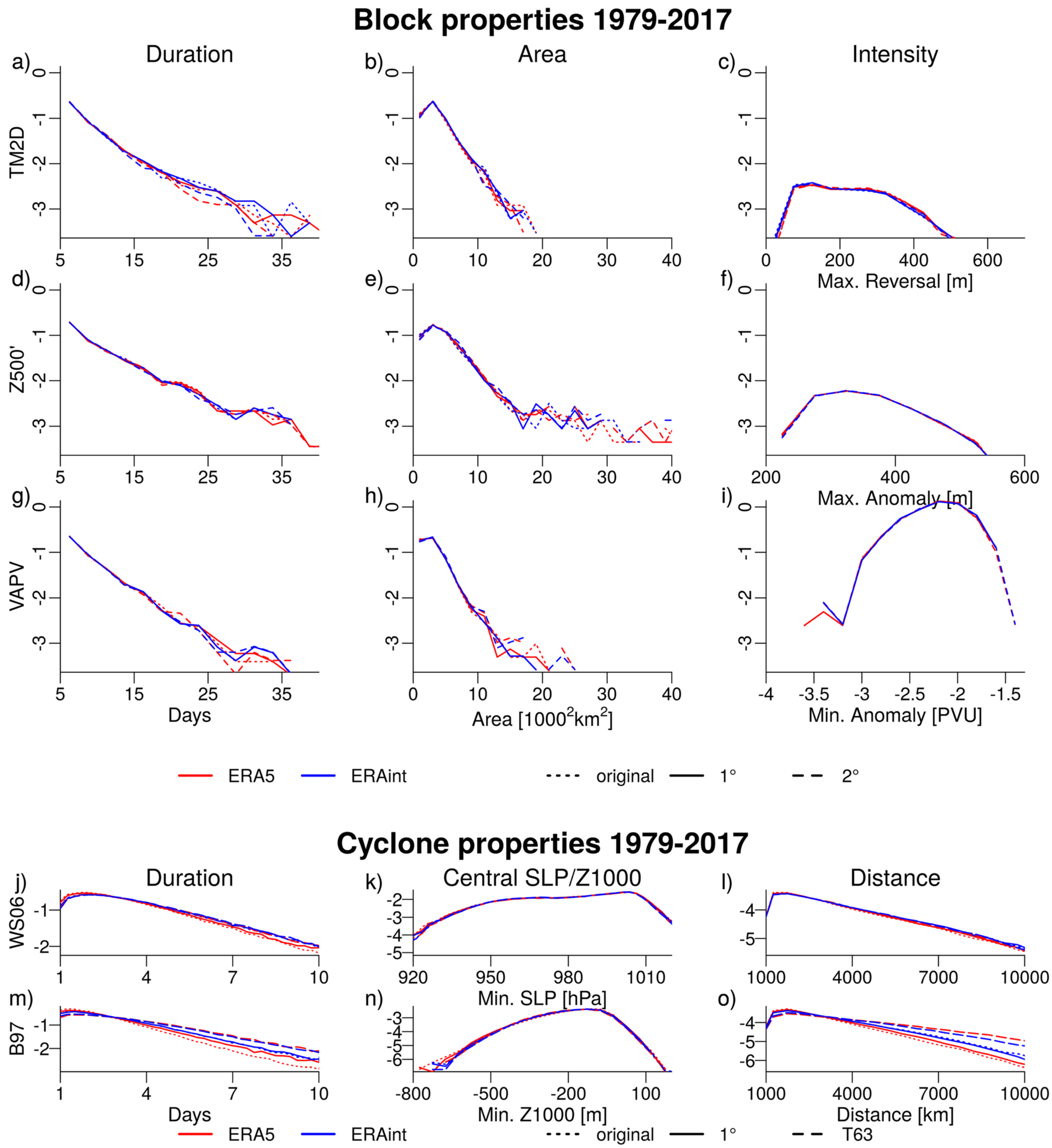

Figure 2. The probability distribution function for block duration, block area, and block intensity for different blocking algorithms (a–i). (j–o) The probability density function for cyclone duration, central pressure-geopotential height, and the distance traveled between cyclone genesis to lysis. ERA5 is shown in red; ERA-interim in blue. The line type distinguishes different input resolutions. For presentational reasons, the *y* axis only shows the exponent of the logarithmic scale (e.g., -3 denotes 10^{-3}).

Comparing the two reanalyses (in T63 resolution) shows that all methods (WS06, B97, and Z500bp) identify a similar spatial cyclone frequency climatology (Figures 1r, 1v, and 1z). Correspondingly, the number of cyclones is relatively similar in ERA5 and ERA-interim for the T63 resolution (Table 1). We find 4% more (8% fewer) cyclones for WS06 (B97) in ERA5 compared to ERA-interim for the T63 resolution. If we only consider deep cyclones (SLP minimum <960 hPa for WS06 and Z1000 minimum

Table 1
Number of Blocks and Cyclones Detected Globally in ERA5 and ERA-Interim Between 2000 and 2017 Using Different Blocking (Upper Part) and Cyclone (Lower Part) Algorithms and Resolutions

Algorithm		ERA5			ERA-interim		
Resolution	Type	Orig.	1°	2°	Orig.	1°	2°
VAPV	Blocks	4,585	4,528	4,310	—	4,412	4,234
TM2D	Blocks	3,563	3,502	3,437	3,631	3,488	3,389
Z500*	Blocks	2,491	2,482	2,465	2,495	2,489	2,462
VAPV	Time steps	156,702	154,631	146,735	—	149,950	142,816
TM2D	Time steps	124,747	122,460	114,768	126,863	121,461	112,887
Z500*	Time steps	101,754	101,229	99,635	102,366	101,761	100,131
Resolution		**Orig**	**1°**	**T63**	**Orig**	**1°**	**T63**
WS06	Cyclones	83,656	88,334	80,059	86,195	85,183	76,701
WS06deep	Cyclones	13,726	14,088	12,637	14,030	13,725	12,361
B97	Cyclones	198,440	150,691	94,554	135,854	127,706	102,357
B97deep	Cyclones	4,148	3,655	2,199	3,176	2,894	2,134
WS06	Time steps	1,073,444	1,170,977	1,132,062	1,203,202	1,201,374	1,096,298
WS06 (no filter)	Time steps	2,487,269	2,565,175	2,339,972	2,392,562	2,356,335	2,209,104
B97	Time steps	2,129,026	1,741,991	1,507,054	1,678,702	1,588,450	1,450,087

Note. WS06deep presents results for deep cyclones only (i.e., cyclones with a SLP minimum <960 hPa, for B97deep, less than −400 m). Also, the number of block or cyclone time steps per algorithm is given. For WS06, additionally, the number of cyclone time steps before any filtering is given.

<400 m for B97 at least once in their lifetime), we find 2% (3%) more cyclones using WS06 (B97) in ERA5 than ERA-interim.

WS06 and, to an even greater extent, B97 are sensitive to changes in input resolution, whereas Z500bp is insensitive (Figures 1s, 1t, 1w, 1x, 1aa, and 1ab). Seasonality for WS06 and Z500bp shows a peak of cyclone activity in the winter hemisphere (Figures S1 and S2). B97 shows a peak in summer in many regions, partially related to its high sensitivity to detect heat lows (e.g., over the Sahara).

For WS06, we find a decrease of cyclone frequency by approximately 10% with increasing input resolution (Figures 1w and 1x), while the number of cyclones (and cyclone time steps) increases from T63 to 1° resolution by 10% and then decreases by 5% for the original resolution of ERA5 (Table 1). The latter contrasts with ERA-interim showing a steady increase. The ERA-interim behavior is expected as with higher-resolution weaker cyclone can exceed threshold of the WS06 method and genesis (lysis) of cyclones can be detected earlier (later; Blender & Schubert, 2000). The ERA5 behavior is unexpected for the number of cyclones and the cyclone time steps (i.e., the sum of time steps of all cyclones). One reason lies in the merging of cyclone centers as one can see an increase in cyclone time steps from T63 to the original resolution for the nonfiltered case (only topography is accounted for but no constraint on travel distance or duration) but a decrease after filtering (Table 1). Another factor is the changed topography in the different resolutions as mountains are better represented with increasing horizontal resolution. We find that cyclone frequency decreases from T63 to 1° resolution whereas cyclone time steps increase. The reason lies in the definition of cyclone frequency per grid point without any normalization to a unit area, that is, the area of a grid point is reduced stronger than the cyclone time steps increase. The other cyclone characteristics show that WS06 cyclones tend to be shorter with increasing input resolution (3.5 days for T63 resolution and 3.2 days for original resolution; Figure 2). The mean cyclone trajectory length also decreases from 3,022 to 2,858 km from a T63 to original resolution in ERA5. Cyclone depth expressed as the minimum SLP of a cyclone is indifferent to both the choice of the reanalysis and the choice of resolution.

B97 shows a different dependence on input resolution. For ERA5, the cyclone frequency decreases between T63 and 1° resolution particularly in the Northern Hemisphere (Figure 1z vs. Figure 1aa). Further increasing the resolution to the original resolution of ERA5 increases cyclone frequency again (Figures 1aa and 1ab): It is roughly 8% higher than for T63 resolution. The cyclone frequency is particularly enhanced close to high topography for the original resolution of ERA5 (e.g., on the leeside of the Andes; Figure 1ab). In contrast to WS06, the number of cyclones and the cyclone time steps steadily

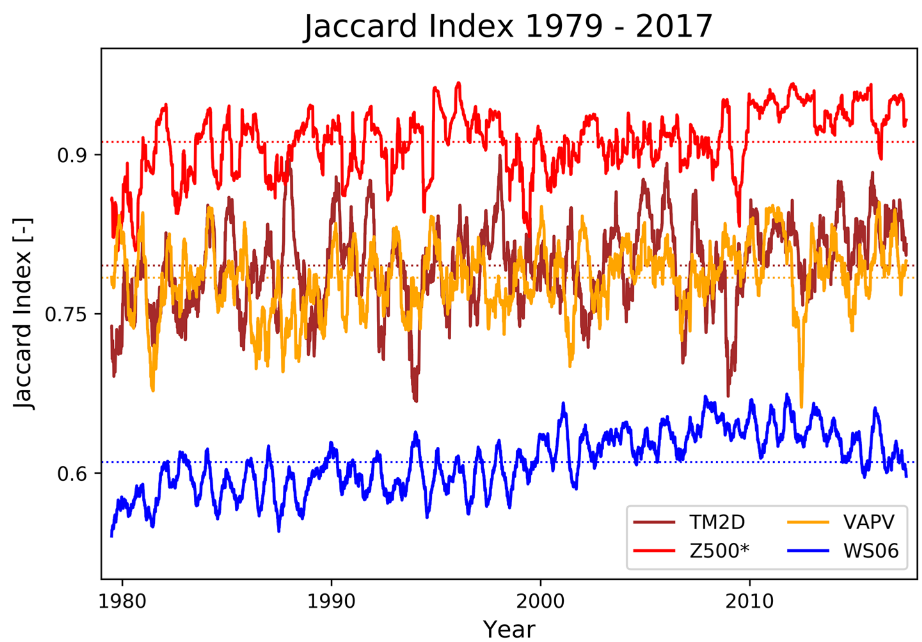

Figure 3. Jaccard Index for TM2D, Z500, VAPV, and WS06 as a measure of the spatial overlap of features between ERA5 and ERA-interim over time. A 180 day running mean for better readability. The dashed line denotes time average between 1979 and 2017.

increase with resolution for both reanalyses (Table 1). For ERA5, we find a doubling of detected cyclones between T63 and original input resolution. Again, the reduced cyclone frequency from T63 to 1° resolution is unexpected given an increase in the number of time steps. The reason is the definition of the cyclone frequency without normalizing it to a unit area. This effect is however overcompensated by the strong increase in the time steps of cyclones when comparing the resolution 1° and the original resolution of ERA5 explaining thus the increase of cyclone frequency. Cyclone duration and distance are sensitive to the input resolution for both reanalyses (Figures 2m and 2o). B97 cyclones are on average shorter (from 3.4 days at T63 to 2.4 days at original resolution) and travel shorter distances (from 3,753 km in T63 to 2,550 km at 1° to 2,404 km in original resolution).

Cyclone depth expressed as minimum Z1000 is indifferent to the choice of resolution (Figure 2n). ERA5 shows more extremely deep cyclones compared to ERA-int. The differences found between reanalyses and between different input resolutions are larger than the interannual variations of global cyclone counts.

3.3. Similarity Between Different Reanalysis Products

Figure 3 shows the 180 day running mean Jaccard index for all algorithms that detect features based on binary fields (TM2D, Z500*, VAPV, and WS06) for 2° or T63 resolution. A linear regression finds a significantly increasing trend of the annually averaged Jaccard index for all algorithms between 1979 and 2017 at a significance level of 0.05, that is, the differences between the reanalysis data sets become smaller. For VAPV and WS06, the Jaccard index is 0.03–0.05 lower during summer compared to other seasons. Blocks show a larger overlap than WS06, with Z500* showing a higher Jaccard index than the other two blocking algorithms, probably partially related to the average spatial extend of the detected feature in the different algorithms.

Averaged over time, we find lower values between ERA5 and CFSR or MERRA-2 than between ERA5 and ERA-interim. For example, the Jaccard index for TM2D (WS06) drops from 0.79 (0.61) between ERA5 and ERA-interim to 0.73–0.74 (0.55–0.56) for any combination of ERA5, ERA-interim, CFSR, and MERRA-2 (not shown).

4. Discussion and Conclusion

Different Lagrangian and Eulerian algorithms to detect blocks and cyclones are applied to the ERA5 reanalysis and compared to ERA-interim. Further, the sensitivity of cyclone and block characteristics to the spatial resolution is investigated.

Overall, blocking characteristics in ERA5 and ERA-interim are very similar (<3% difference), and results are insensitive to the resolution with the exception of the TM2D algorithm. Depending on the employed algorithm, block characteristics such as frequency, duration, or average area vary substantially.

For cyclones, the dependence on the employed reanalysis is much higher than for blocks, and this dependence increases with higher resolution. Moreover, different algorithms show different dependencies. The Eulerian method using band-pass filtered geopotential height at 500 hPa is insensitive to the reanalysis and resolution. The different sensitivity of cyclone frequency for the Lagrangian methods, WS06 and B97, to resolution changes is explained by the specific definition of cyclone frequency. Additionally, cyclones become shorter lived with increasing resolution.

A striking difference between the WS06 and B97 methods is the sensitivity of the number of cyclones (or time steps) to the input resolution. B97 identifies more cyclones with increasing resolution in line with Blender and Schubert (2000) and Wang et al. (2016) who also found that higher spatial resolutions lead to higher cyclone counts. This is expected as weaker cyclones and early and late states within a cyclone lifetime are better represented so that thresholds of the method are exceeded more often. In contrast, the number of cyclones detected with WS06 decreases when increasing the resolution from 1° to the original resolution of ERA5. Reason for this behavior is the employed merging of cyclone centers in WS06. Thus, the merging in WS06 leads to a more consistent behavior between resolutions and reanalysis data sets, but it does so at the expense of losing secondary cyclogenesis, an important process for extreme cyclones (e.g., Ludwig et al., 2015). B97, on the other hand, shows a dramatic increase in the number of cyclones for the original resolution of ERA5 (factor of 2 compared to T63 resolution). We find a general increase in the detected number of cyclones accompanied with the detection of weak heat lows and potentially artificial lows around major mountain ridges. This goes along with the strongly decreased cyclone duration and distance with increasing resolution in B97. Indeed, Blender et al. (1997) recommended adjusting thresholds when using a data set with a different resolution than the one used to develop the method. Many cyclone detection algorithms were developed when resolutions around 1–2° were the state of the art, and they need to be adapted to added detail (and noise) that modern high-resolution data sets provide (e.g., Blender et al., 1997; Hodges, 1995; Murray & Simmonds, 1991; Wernli & Schwierz, 2006).

Based on these results, we recommend remapping data sets to a common resolution before any comparison. This is also important in the context of climate model evaluations that often rely on reanalyses as validation data sets. Moreover, users of Lagrangian methods should be cautious as sensitivity of some methods to resolution requires adjustments of the scheme (B97), and some processes are ignored by a method, for example, secondary cyclogenesis for WS06. We have shown that comparing reanalyses and/or model data at a common resolution of T63 or even lower may be beneficial to avoid problems that can arise at higher resolutions.

We find blocks are more consistently represented than cyclones in ERA5 and ERA-interim due to their large-scale, quasi-stationary nature. ERA5 and ERA-interim are more similar recently for all examined algorithms, indicating that ERA5 and ERA-interim are less certain going back in time. Moreover, ERA5 and ERA-interim are more similar (i.e., the time-averaged Jaccard index is higher) compared to CFSR or MERRA-2, arguably related to their similar reanalysis setup. Still, due to the numerous updates in ERA5, the two ECMWF reanalyses do not match. This was already shown in Rohrer et al. (2018) using a larger variety of reanalyses, and several other studies confirm these findings (e.g., Rohrer et al., 2019; Tilinina et al., 2013; Wang et al., 2016). Other intercomparison studies showed that other variables, especially smaller-scale and parameterized variables, depend more strongly on the chosen reanalysis (e.g., Horton & Brönnimann, 2018; Sun et al., 2018).

In conclusion, block characteristics in ERA5 are similar to ERA-interim. For extratropical cyclones, larger differences are discernible, particularly at higher horizontal input resolution and depending on the cyclone detection algorithm employed. Using the Jaccard index, we find that agreement back to 1979 slightly but significantly decreases. We recommend that modeling and reanalysis intercomparison studies remap to a common, if feasible preferentially rather low, resolution before applying algorithms to detect and track blocks and cyclones.

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Erratum

In the originally published version of this article, the title appeared twice. This error has since been corrected, and the present version may be considered the authoritative version of record.