Baltic Marine Environment Protection Commission

Third meeting of Joint HELCOM/ Baltic Earth Expert Network on Climate Change — EN CLIME 3-2019

Stockholm, Sweden, 19 August 2019

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Code	3-1
Category	DEC
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Submitted by	Secretariat
Reference	

Background

The following document contains the draft key messages prepared by the Energy Cycle Team under the joint HELCOM/Baltic Earth Expert Network on Climate Change (EN CLIME).

The Energy Cycle Team experts are as follows:

Anna Rutgersson (confirmed team lead)
Andreas Lehmann
Birgit Hünicke
Eduardo Zorita
Erik Kjellström
Marcin Kawka
Markus Meier
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Peter Löwe
Urmas Lipps
Jan-Hinrich Reißmann
Jürgen Holfort
Claudia Frauen
Christian Dietrich
Janika Laht
Thomas Carlund

Key messages for the following parameters are included in this document (available experts in the team presented on the right):

Parameters	Experts
Temperature (air) and heatwaves	Andreas Lehmann; Anna Rutgersson; Erik Kjellström; Jan-Hinrich Reißmann; Janika Laht; Marcin Kawka; Markus Meier
Temperature (sea) and heat waves	Andreas Lehmann; Anna Rutgersson; Markus Meier; Peter Löwe; Urmas Lipps
Large Scale Atmospheric Circulation (e.g airpressure, AMO, NAO)	Andreas Lehmann; Anna Rutgersson; Birgit Hünicke; Claudia Frauen ; Eduardo Zorita; Erik Kjellström; Marcin Kawka; Markus Meier; Peter Löwe
Sea ice and extreme events	Andreas Lehmann; Christian Dieterich; Janika Laht; Jürgen Holfort; Markus Meier; Matthias Gröger; Peter Löwe
Solar radiation and cloudiness	Anna Rutgersson; Erik Kjellström; Markus Meier; Thomas Carlund

Guidance for preparing key messages and the fact sheet:

The following guidance has been compiled from discussions and outcomes of previous EN CLIME and Team meetings and from the background documents, e.g. Terms of Reference.

The fact sheet should present a consensus view by the regions climate experts on the climate change driven changes in the outlined parameters, as well as related issues identified as of relevance to the policy process. The intention is for the fact sheet to be a science driven exercise, relying exclusively on, and synthesizing, already existing detailed, peer reviewed information from leading marine and climate scientists. The information is to be condensed to key messages, including information on trends where possible. In the final fact sheet the information is to be present visually, in an accessible and stable way across years. To make the information as accessible as possible the parameters can at later stage of the process be combined under wider topics in order to make the fact sheet more usable for policy makers. Information to support the statements in the factsheet will be available as separate publications (BACC II, BACC III, BEAR reports etc.), clearly referenced and the fact sheet itself fully-citable. While already existing BACC reports should be used as supporting material for the EN CLIME work, that subsequent results coming out of BACC III can be used to amend the key messages where needed prior to publication.

The fact sheet will strive to be a concise and easily accessible resource from science to regulators and policymakers and will contain information, using agreed language, on what has happened and what can be expected to happen in the future. As discussed in EN CLIME 2-2019 wherever possible the information should be presented in approximate ranges (near term, medium term and long term) and that changes in extremes as well as in means should be taken into account for each of the primary parameters.
While the fact sheet should be made as approachable as possible, the overall complexity of the issue also needs to be communicated. In this respect the EN CLIME has highlighted the interlinkages between different parameters and supported the possibility to include some sort of info-graphic to visualize the interlinkages.

The titel 'Description' should be included to the fact sheet in a very concise manner, describing the underlaying factors, and linkages to other parameters.

EN CLIME has in previous meeting discussed the importance of describing the uncertainty of predictions and noted that uncertainty varies depending on the temporal ranges used and between parameters, which needs to be taken into account in the description. Hence different uncertainties can be given for different parameters and time intervals.

Action requested

The Meeting is invited to review and revise the draft key messages and agree on them, keeping in mind that the intention is to streamline he presentation of all messages to the extent possible.

Temperature (air) and heatwaves

Topic	Description	What is expected to happen?		What is already happening?		Knowledge gaps	Policy relevance
		Mean change	Extremes	Mean change	Extremes		
		Level of confidence:	*Level of confidence:*	*Level of confidence:*	*Level of confidence:*		
Temperature (air) and heatwaves *Anna Rutgersson, Uppsala University*	Air temperature shows the clearest response to the increased green-house effect. Changes in temperature extremes may influence human activity much more than changes in average temperature.	Air temperatures in the Baltic Sea area are projected to increase with time, with the increase generally greater than the corresponding increase in global mean temperature. This is usually the case for land areas, which warm more quickly than sea areas but is also the case for the Baltic Sea region, largely due to the strong winter increase. This winter increase is the result of a positive feedback mechanism involving declining snow and sea-ice cover, leading to even higher	The strong increase in winter daily mean temperature is most pronounced for the coldest episodes (Kjellström 2004). This is also the case for the most extreme daily maximum and minimum temperatures (Kjellström et al. 2007; Nikulin et al. 2011) with a significant decrease in probabilities of cold temperatures (Benestad 2011). In summer, warm extremes are projected to become more pronounced. For example, Nikulin et al. (2011) showed that warm extremes in today's climate	A significant surface air temperature increase in the Baltic Sea region during the last century was detected (BACC Author Team 2008;2014; Rutgersson et al., 2014). The temperature increase is not monotonous but accompanied by large (multi-) decadal variations dividing the 20th century into 3 main phases: (1) warming in the beginning of the century until the 1930s; (2) cooling until 1960s; and (3) another distinct warming during the last decades of the time series. Linear	The duration of extremely mild periods has increased significantly in winter, while the number of heat waves has increased in summer as well as during the year as a whole. A general increase has been observed for the annual numbers of days with daily maximum temperature above both 25 and 30 °C, and a decrease in the length of the frost season and in the annual number of frost days.	There are limitations in the knowledge concerning the link to changes in large scale circulation patterns.	Policy relevance: What can be done about it (possible responses)? Especially focusing on avoidance, alleviation, adjustment and adaptation. What is already being done about it? Existing agreements/policies: How does it affect measures taken to reduce pressures on the Baltic Sea? Policy gaps use examples e.g. France and Moscow 2010 (80% chance

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Commented [A2R1]: MM: I do not really agree. Some additional explanations and definitions are needed (here or in the introduction). Otherwise this text is very nice. We should discuss the level of complexity during our meeting in Stockholm.

Commented [A3]: Cover also urban climate

Commented [A4]:

Commented [A5]: actual degree range (Christian took look for initial suggestions)

Commented [A6]: add actual degree range (Christian to look for initial suggestions)

Commented [A10]: During which period?

Commented [A12]: Very general. Is it possible to be more specific?

Commented [A8]: Add references

Commented [A11]: Add definition

		temperatures—reduced snow and ice cover will enhance the absorption of sunlight, and so enable greater amounts of heat to be stored in the soil and water (BACCII, 2015). The increase in winter temperatures are projected to reach 8 degrees C in northern Scandinavia depending on the representative concentration pathway (RCP). The RCP2.6 scenario leads to a temperature rise of 3 degrees C. Less warming (2 C to 4 C) is projected for the southern Baltic Sea region. There is uncertainty in these projections from different sources. The largest uncertainty is due to the unknown future emissions (RCPs) (Kjellström et al.	(1961–1990) with a 20-year return value (defined as the temperature that will be exceeded once every 20 years as a statistical average) will occur around once every 5 years in Scandinavia by 2071–2100 according to an ensemble of six RCM simulations, all downscaling GCMs under the SRES A1B scenario.	trends of the annual mean temperature anomalies during 1871–2013 were 0.10 K decade−1 north of 60°N and 0.08 K decade−1 south of 60°N in the Baltic Sea region. This is larger than the global mean temperature trend. There are large variations, in particularly during winter, but the warming is seen for all seasons (being largest during spring). These changes are also resulting in seasonality changes: the length of the growing season has increased, whereas the length of the cold season has decreased. The number of days by which autumn and winter are delayed differs from south to north and east to west, but as an example in Tartu, Estonia, the number of deep winter days			that it would not have happened without climate warming, Rahmstorf and Coumou, 2011)

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Commented [A7]: List one or two more, e.g. global and regional model uncertainties. In addition, the natural variability is smaller than in other variables, e.g. wind.

		2011, Strandberg et al., 2014)		(with snow cover) has decreased by 29 d over the past century while the growing season has increased by 13 d in this period (Kull et al. 2008).			

References:

- Rahmstorf, S., & Coumou, D. (2011). Increase of extreme events in a warming world. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(44), 17905–17909. doi:10.1073/pnas.1101766108
- Erik Kjellström, Grigory Nikulin, Ulf Hansson, Gustav Strandberg & Anders Ullerstig (2011) 21st century changes in the European climate: uncertainties derived from an ensemble of regional climate model simulations, Tellus A: Dynamic Meteorology and Oceanography,63:1, 24-40, DOI: 10.1111/j.1600-0870.2010.00475.x

- Strandberg, Gustav et al. (2014) CORDEX scenarios for Europe from te Rossby Centre regional climate model RCA4, report RMK 116

Temperature (sea) and heat waves

Topic	Description	What is expected to happen?		What is already happening?		Knowledge gaps	Policy relevance
		Mean change	Extremes	Mean change	Extremes		
		Level of confidence:	*Level of confidence:*	*Level of confidence:*	*Level of confidence:*		
Temperature (sea) and heat waves *Christian Dieterich, SMHI*	Give a brief description of the parameter Show links to other parameters. The temperature rises fastest at the surface. With time the heat spreads downward through different processes and eventually the whole water column warms up. This has consequences for the stratification (EN-CLIME stratification), eutrophication (EN-CLIME nutrient cycle) and sea level	What is expected to happen in the future? Present expected changes quantitatively e.g. through ranges whenever possible. The temperatures of the oceans are rising [high confidence] (e.g. Balmaseda et al., 2013a, 2013b) and will continue to rise [medium confidence]. Regional scenarios for the Baltic Sea project an ensemble mean increase of SST of 1 C (RCP2.6) to 4 C (RCP8.5) in 2100 relative to the period 1970 to	What is expected to happen in the future? Present expected changes quantitatively e.g. through ranges whenever possible. In the RCP4.5 and RCP8.5 scenarios an increase in the occurrence of tropical nights over the Baltic Sea has been observed. Tropical nights are an indicator for heat waves. This has consequences for the water temperature which will reach record breaking values from year to year much	What is happening? Provide information on already identified effects The marginal seas around the globe have warmed more than the average over the global ocean (Belkin, 2009). The Baltic Sea has warmed during the second half of the past century, although the interannual variability is high. During the period 1982 to 2006 the SST increased by 1.35 C in the Baltic Sea. No other sea has	What is happening? Provide information on already identified effects What are the direct consequences? Examples of effects can we already see, if available.		Policy relevance: What can be done about it (possible responses)? Especially focusing on avoidance, alleviation, adjustment and adaptation. What is already being done about it? Existing agreements/policies: How does it affect measures taken to reduce pressures on the Baltic Sea? Policy gaps

Commented [A13]: Some discussion about uncertainty in Kniebusch et al. (2019) for past changes and Meier et al. (2018, 2019) for future changes

Commented [A14]: This sentence is misleading. The response time of water temperature is short compared to climate warming on centennial time scales. In quasi-steady state, the warming at the surface is larger than in the deep water.

Commented [A17]: A definition is needed.

Commented [A15]: Not high confidence that there will be warming for the 21st century?

Commented [A18]: The Baltic Sea trend since 1856 is also statistically significant. The accelerated warming since the 1980s can be explained by the AMO (Kniebusch et al., 2019).

Commented [A16]: Define the ensemble (8 members, RCA4-NEMO, only Baltic Sea?). The BalticAPP ensemble RCP8.5 is less warming (RCP8.5, 3 GCMs, ΔSST = 3 K). I suggest that we list both results from Saraiva et al. (2019), Meier and Saraiva (2019) and Gröger et al. (2019)

	rise (EN-CLIME sea level).	1999. The projections include a possible uncertainty range of 1.5 C (RCP2.6) and 2.5 C (RCP8.5). The SST changes in the RCP8.5 scenarios are significantly above the natural variability (Source SMHI).	more often under projected climate change in RCP8.5 (Meier et al., 2019).	warmed up that much. What are the direct consequences? Examples of effects can we already see, if available.			

Large scale atmospheric circulation

Brief description and links to other parameters

The climate of the Baltic Sea region is strongly influenced by the large-scale atmospheric circulation (e.g. Andersson, 2002; Tinz, 1996; Meier and Kauker, 2003; Omstedt and Chen, 2001; Zorita and Laine, 2000; Lehmann et al., 2002), in particular the North Atlantic Oscillation (NAO) and blocking and on longer time scales the Atlantic Multidecadal Oscillation (AMO).

The NAO is the dominant mode of near-surface pressure variability over the North Atlantic and its impact is strongest during winter (Hurrel et al., 2003), when it accounts for almost one-third of the sea level pressure (SLP) variance. During the positive (negative) phase of the NAO the Icelandic Low and Azores High pressure systems are enhanced (reduced), leading to a stronger (weaker) than normal westerly flow (Hurrell, 1995). For the Baltic Sea region the positive phase of the NAO is related to mild and wet winters and increased storminess (Hurrell et al., 2003).

Atmospheric blocking occurs when persistent high pressure systems interrupt the normally westerly flow over the middle and high latitudes, like e.g. the North Atlantic. This is also frequently observed in the Baltic Sea region. Due to the persistence of blocking events they are often responsible for extreme weather events (Rex, 1950a; Rex, 1950b).

The AMO describes fluctuations in North Atlantic sea surface temperature (SST) with a period of 60-90 years (Knight et al., 2006). Thus in the 150-year instrumental record only a few distinct phases have been observed. However, a recent model study suggests that variations in the AMO may have an impact on the precipitation over the Baltic Sea region (Börgel et al., 2018).

What is expected to happen?

NAO:

In the future, the NAO is very likely to continue to exhibit large natural variations similar to those observed in the past. It is likely to become on average slightly more positive due to an increase in greenhouse gases (GHG) (IPCC, 2013).

Blocking:

There is medium confidence that the frequency of blocking will not increase. However, trends in the intensity and persistence of blocking remain uncertain and therefore also the implications of blocking related changes in the Baltic Sea region (IPCC, 2013).

AMO:

Based on paleoclimate reconstructions and long model simulations it is unlikely that the AMO will change its behaviour in the future under a changing mean climate (IPCC, 2013).

What is already happening?

NAO:

Considering the whole observational period since the mid-19th century there is no statistically significant trend in the NAO. While the NAO exhibited a positive trend from the 1960s to the 1990s it has returned to lower values in the early 2000s with exceptionally low anomalies in the winters of 2009/2010 and 2010/2011, which considerably weakened the positive trend.

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Blocking:

While some studies find an eastward shift of blocking events over the North Atlantic (Davini et al., 2012; Croci-Maspoli et al., 2007) and increase in blocking duration over the Northern Hemisphere since about 1990 (Mokhov et al., 2013), there is low confidence in these changes due to methodological differences between studies (IPCC, 2013).

AMO:

The AMO has been warming from the late 1970s to the 2000s as part of its natural variability and has since remained in a warm state. Natural fluctuations in the AMO over the coming few decades will likely influence regional climates, like e.g. the Baltic Sea region, at least as strongly as human-induced changes (IPCC, 2013).

Knowledge gaps

NAO:

While CMIP5 climate models are able to simulate the main features of the NAO, its future changes might be sensitive to boundary processes, like e.g. stratosphere-troposphere interactions or atmospheric response to Arctic sea ice loss, which are not yet well represented in many climate models (IPCC, 2013).

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Blocking:

Most CMIP5 models still underestimate the frequency of blocking over the Euro-Atlantic sector (IPCC, 2013).

AMO:

Since the observational record is relatively short, our understanding of the AMO and its possible changes largely depend on models, whose assumptions are difficult to verify (Knight, 2009).

However, while possible changes in these climate phenomena contribute to the uncertainty in near-term climate projections, they are not the main driver of the projected warming over Europe by the end of the century (Cattiaux et al., 2013; IPCC, 2013).

Policy relevance

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Börgel, F., C. Frauen, T. Neumann, S. Schimanke, and H. E. M. Meier (2018): Impact of the Atlantic Multidecadal Oscillation on Baltic Sea variability. Geophysical Research Letters, *45*.

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Meier, H. M., & Kauker, F. (2003). Modeling decadal variability of the Baltic Sea: 2. Role of freshwater inflow and large-scale atmospheric circulation for salinity. *Journal of Geophysical Research: Oceans*, *108*(C11).

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Omstedt, A., & Chen, D. (2001). Influence of atmospheric circulation on the maximum ice extent in the Baltic Sea. *Journal of Geophysical Research: Oceans*, *106*(C3), 4493-4500.

Rex, D. F. (1950a): Blocking action in the middle troposphere and its effect upon regional climate. Part I: An aerological study of blocking action. Tellus, 2:196-211.

Rex, D. F. (1950b): Blocking action in the middle troposphere and its effect upon regional climate. Part II: The climatology of blocking action. Tellus, 2:275-301.

Tinz, B. (1996). On the relation between annual maximum extent of ice cover in the Baltic Sea and sea level pressure as well as air temperature field. *Geophysica*, *32*(3), 319-341.

Zorita, E., & Laine, A. (2000). Dependence of salinity and oxygen concentrations in the Baltic Sea on large-scale atmospheric circulation. *Climate Research*, *14*(1), 25-41.

NOTE BY Jürgen Holfort:

This first rough draft for sea ice is based mostly on two documents together with own expertise.

Sea ice

Brief description and links to other parameters

Sea ice, and more so sea ice of a region, has many parameters which can used to characterize it. The most common is ice concentration for sea ice itself; and to characterize ice winters in the Baltic the most common is the maximum ice extent in a winter season (maximum or accumulated ice volume are also used). Further parameters are the sea ice thickness, with the distinction between level ice thickness and ridged ice thickness. Ridging and rafting itself are very influenced by sea ice drift and ice compression. Regarding the winter season an important parameter is also the length of the ice season, which in regions with intermittent ice cover can differ from the number of days with ice. There are even more ice parameters, but most are and cannot be represented in numerical models used for weather and climate predictions.

The most important factor determining the forming of sea ice in the Baltic is air temperature and wind has a large influence on sea ice drift and rafting and ridging. Other parameters like snow cover, ocean currents, precipitation, etc. have also influence. Within the energy cycle sea ice has a strong influence due to the large albedo difference between sea ice and water; sea ice reflects most of the incoming radiation lowering the near surface temperature, while water absorbs a large portion of this radiation.

What is expected to happen?

In the future it is likely, that the inter-annual variability continues to be very large, although the probability of very strong winters will very likely be lower than in the past. But in climatological sense it is very likely that the maximum sea ice extent of a winter season will decrease. The level ice thickness will also very likely decrease in the future, but there are still larger uncertainties in the thickness of ridged ice. It is likely that the length of the ice season will decrease, but with larger regional differences.

There is some indication (low confidence) in climate scenarios that the snow cover on the sea ice will decrease. This will reduce the reflectivity of the surface and more heat can be absorbed and thereby amplifying the ice reduction (Höglund et al., 2017).

What is already happening?

Looking back a little bit more than 100 years, the ice winters have become milder, the maximum ice extent has decreased and the ice season is shorter. Also indexes based on the total ice volume of the winter show a decreasing trend. Severe ice winters can still happen nowadays, but the possibility therefore has decreased.

The maximum ice extent in the Baltic Sea is changing between 50 and 400 km^2 from year to year. During mild winters just the Bothnian Bay is ice covered while in severe winter the whole Baltic Sea can be ice covered (SMHI ice service) like in the ice winter 1986.

Knowledge gaps

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Commented [A22]: And long-term observations on basin-scale are lacking.

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Commented [A24R23]: I agree. There are results of scenario simulations at least for maximum annual ice extent and ice concentration available.

Commented [A25]: Add actual numbers (ranges) where possible

Sea ice as a brittle material is not so good represented in the numerical models which represent the world as a more continuous medium. Therefore ice dynamics like rafting and ridging are not so well represented, which leads to larger uncertainties, also in sea ice thickness. Also in measurements the thickness is not so well known as the concentration and the time series of sea ice thickness are more sparse and do not reach so much back in time.

Commented [A26]: The largest uncertainty is related to the surface albedo. Melt ponds, snow covered areas on ice and leads cannot be resolved accurately. Hence, the uncertainty due to unknown surface albedo amplified by the ice-albedo feedback is large. The ice-albedo feedback together with the Stefan Boltzmann feedback is known to be the largest uncertainty in climate sensitivity in polar regions.

Policy relevance

Commented [A27]: Policy relevance for eg shipping

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References

Höglund, Anders; Per Pemberton; Robinson Hordoir and Semjon Schimanke, 2017
Ice conditions for maritime traffic in the Baltic Sea in future climate
Boreal Environment Research 22: 245–265

BACC II Author Theme(2015)
Second Assessment of Climate Change for the Baltic Sea Basin
Springer book, ISSN 1865-505X, DOI 10.1007/978-3-319-16006-1

Solar radiation and cloudiness

Topic	Description	What is expected to happen?		What is already happening?		Knowledge gaps	Policy relevance
		Mean change	Extremes	Mean change	Extremes		
		Level of confidence:	*Level of confidence:*	*Level of confidence:*	*Level of confidence:*		
Solar radiation and cloudiness *Anna Rutgersson, Uppsala University* *Thomas Carlund, SMHI*	Total cloudiness consists of clouds on all levels (low, medium and high) and is related to the general circulation as well as the water cycle. Solar radiation is to a large extent depending on the cloudiness (amount and type of clouds), but also to atmospheric aerosols. Atmospheric aerosols affect solar radiation under clear skies directly and through interaction with clouds indirectly.	Mean change is uncertain. Global climate models indicate an increase which is highest over southern Europe and decreases towards north, but still showing a slight increase over the Baltic. However, regional climate model runs could instead show a decrease in SSR over the Baltic area, i.e. there is a large discrepancy in modelled SSR between global and regional models (Bartók et	No possible to discuss around extremes.	Multidecadal variations, known as "dimming" and "brightening" have been observed both in Europe and many other parts of the world, e.g. Wild et al. 2005, Wild et al. 2012, Wild et al. 2017 (especially on the northern hemisphere). No long-term measurements over oceans. However, (aerosol-induced) multidecadal variations in surface solar radiation could be expected also over	No possible to discuss around extremes.	Multidecadal variations in SSR are generally not well captured by current climate model simulations (Allen et al. 2013, Storelvmo et al. 2018). The extent to which the observed SSR variations are caused by natural variation in cloudiness induced by atmospheric dynamic variability (Stanhill etal. 2014, Parding et al. 2016), or anthropogenic aerosol emissions (Ruckstuhl et al. 2008, Philipona et al 2009, Wild 2012, Storelvmo et al. 2018), or perhaps additional	Influences biological activity and eco-systems, in particular algae blooms.

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Commented [A29]: Explain. Which ones are important for the Baltic Sea region?

Commented [A30]: Surface solar radiation

		al., 2017). Unknown future aerosol emissions add to the uncertainty.		oceans (Wild et al. 2016). Satellite data records of trends in cloudiness since the 1980s disagree over many areas but there is some consistency about a decline in cloudiness over the Baltic area (Karlsson and Devasthale, 2018 (fig 4)).		causes, is not well quantified.	

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