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Analysis of Variations in Forecast Quality during 2018

Daniel Cattani, Pirmin Kaufmann, Stefan Bader, Alessandro Hering, Luca Nisi, Jonas Bhend, Mark A. Liniger

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Abstract

In order to communicate the quality of weather forecasts, MeteoSwiss has been using a global score called COMFORT since 2012. By analyzing the evolution of this score from the beginning, we can see a clear positive trend. But during the first half of the year 2018, a temporary reduction could be observed in COMFORT. This drop was the trigger to initiate the detailed analysis presented in this report.

Our approach is to first look at the methodology used to verify the quality of the forecasts, and then to understand the meteorological and climatological context. The multifaceted analysis allows us to propose some suggestions to improve the quality of the forecasts, and also to give some considerations for an improved future verification system.

Contents

1 Introduction

MeteoSwiss uses a global score, COMFORT[1], to summarize the quality of its deterministic weather forecasts and inform the management, federal ministry, parliament and the public on the long-term development of the quality of its products. Together with the Federal Department of Home Affairs, goals to reach certain levels of COMFORT are agreed upon. These targets are continuously increased to reflect the efforts in improving the weather forecasting capabilities. Such a summary measure is always a compromise in reduction of information to provide a single number and to provide as much information as possible to cover various aspects of the forecasting process, the many aspects of forecast quality, and the variety of products provided by MeteoSwiss.

Furthermore, the quality of forecasts is also influenced by the frequency of specific weather situations occurring in the corresponding season and by the methodology of the COMFORT itself. Indeed, the COMFORT exhibits fluctuations from season to season and year to year. COMFORT scores were particularly low during winter 2017-2018 and spring 2018 (Figure 1). This report aims to understand this degradation in forecast quality in an in-depth manner and from different perspectives. Of particular relevance is the question, if the forecasting methodology of MeteoSwiss itself degraded during this period and changes in the operational production would be required. The analysis may also shed light on an improved definition of COMFORT and consequently a potential adaptation in the long term.

To understand the degradation of COMFORT, we have analyzed the components of the global score as well as the quality of the numerical prediction models, and the meteorological and climatic context.

After an introduction, the second chapter is dedicated to the analysis of weather situations including the convection and thunderstorm activity. A climatological analysis is discussed in chapter three. We present the definition of COMFORT in the fourth chapter, its time evolution and we analyze its behavior according to the main regions of forecasts, and also more in details the quality of the parameters contributing to the global score. The chapter is finalized with a discussion of the quality of the numerical weather prediction model COSMO operated by MeteoSwiss and the main information source for the forecasts provided by MeteoSwiss. At the end of the report, some remarks and conclusions were discussed.

[1] COMFORT: Continuous MeteoSwiss Forecast QualityScoreScientific (CATTANI, 2015)

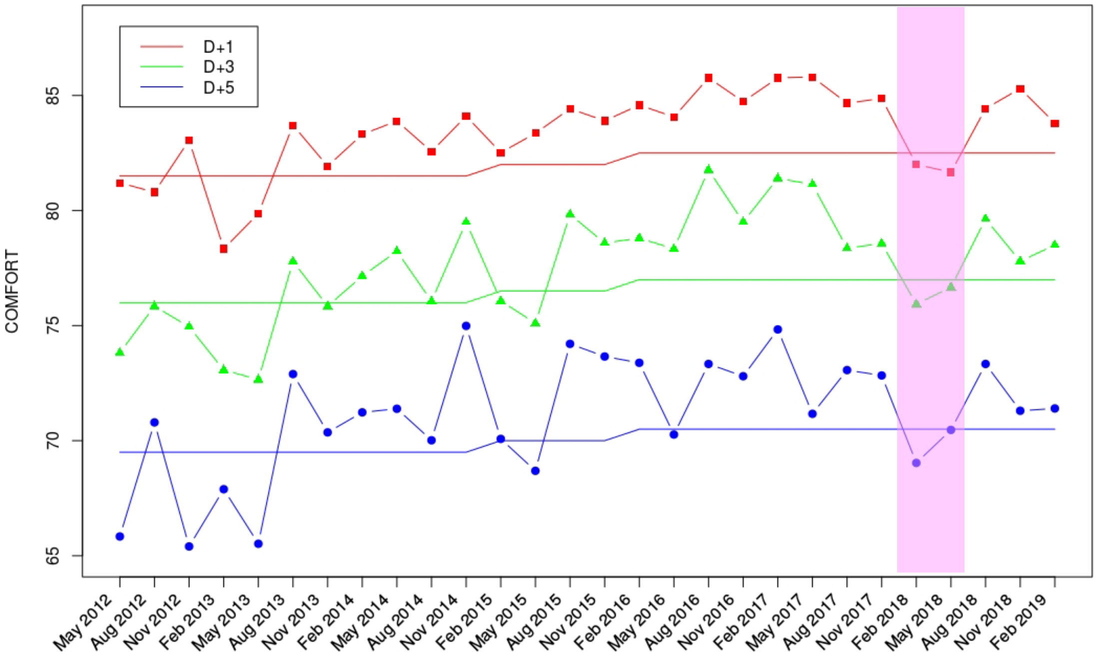

Figure 1: Seasonal global scores COMFORT for Switzerland, leadtimes at day+1 (red), day+3 (green) and day+5 (blue). The solid lines indicate the goals to be reached agreed upon with the Federal Department of Home Affairs. The period we are concerned with in this report is highlighted with pink shading.

2 Description of synoptic situations

2.1 Winter and spring weather situations

2.1.1 January

From 1 to 5 January 2018, strong currents of humid, mild air from the Atlantic region led to Switzerland. At lower altitudes, widespread rain fell. The Alpine regions above 1000 m registered heavy snowfall. Embedded in this strong Atlantic-European wind regime, the violent Burglind storm swept over Switzerland on 3 January. In the northerly lowlands the wind peaks mostly reached between 80 and 125 km/h. At four measuring locations there were values over 130 km/h. On the mountain peaks Burglind featured wind gusts between 150 and 200 km/h.

From 6 to 9 January, mild and humid Mediterranean air impinged the Alps in a south to south-east current, triggering strong precipitation especially in the Valais. At lower altitudes there was abundant rainfall. In higher areas of the southern valleys of the Valais and in the Simplon region, 40 to 90 cm of fresh snow fell from 8 to 9 January. From the Saas Valley via the Simplon region to the northern Ticino, another 20 to 40 cm of snow fell from 9 to 10 January.

Until 11 January, low pressure was the determining weather situation. From 13 to 15 January, a high-pressure area was situated over northeastern Europe. From the 16th to the 22nd, Switzerland was under a persistently stormy northwest to west current. The stormy weather from 16 to 22 January brought fresh snow in the mountains almost daily. Snowfall at higher altitudes was particularly strong on 20 and 21 January.

A short high-pressure influence from the west lead to maximum daily temperatures between 7 and almost 10 degrees Celsius in the north of Switzerland on the 23rd, and 10 to 11 degrees Celsius at Lake Geneva and 10 to 15 degrees Celsius on the south side of the Alps.

From the 24th to the 26th very mild air flowed from southwest to Switzerland. In the lowlands on the north side of the Alps, the daily maximum reached 10 to 12 degrees, on Lake Geneva and in Valais 12 to 14 degrees. Over the Alps there was a foehn situation.

From 27 January, an Atlantic high provided plenty of sunshine, first in the Alps, then in the south and west.

2.1.2 February

From 1 to 6 February, from 10 to 12 from 15 to 17 and on 20 February, low pressure systems determined the weather in Switzerland. High pressure weather determined the weather development from 7th to the 9th, on the 13th/14th and mainly from the 18th to the 28th of February.

In February 2018 clouds determined the weather regime on the north side of the Alps. On 12 days, low pressure with little sunshine was present. In addition, there were 12 days with fog. For the lowlands on the north side of the Alps, this meant 24 days with little or no sunshine.

On the south side of the Alps February counted 14 sunny days, whilst there were only 7 to 10 days without sunshine, depending on the region.

From northwestern Switzerland via the Jura to the central and eastern Plateau there were only 30 to 60 hours of sunshine. An average February here brings 70 to 90 hours of sunshine. Regionally it was one of the gloomiest February months of the last 30 years.

February 2018 was cold in the mountains. Averaged over the altitudes above 1000 m on the north side of the Alps, the February temperature was -8.7 degrees or 3.5 degrees below the 1981-2010 norm. This makes February 2018 one of the coldest February months of the last 30 years in the mountain areas on the north side of the Alps.

2.1.3 March

From 1 to 21 March, low-pressure systems were the dominant weather element. Only on 4, 8 and 14th of March the long low-pressure period was interrupted by short-term high pressure with lots of sunshine nationwide. A longer sunny period began on the south side of the Alps and in the Engadin from 20 March and in the Valais from 21 March.

On the morning of 1 March 2018, almost the whole of Switzerland was covered in new snow. In western Switzerland, the fresh snow reached 10 to 15 cm in height. Flight operations at Geneva-Cointrin airport had to be temporarily suspended. In the other areas of Switzerland, new snow heights usually ranged between 1 and 6 cm.

After regional snowfalls on 2 March, on 3 March, Switzerland was again covered by an almost complete layer of new snow of 2 to 5 cm. Many areas of Switzerland also received new snow on 18 March. In the Basel area up to 10 cm and at the eastern edge of the Alps up to 12 cm were recorded. In the Alps the highest amounts observed ranged from 15 to 20 cm. Further fresh snow was registered in some regions on the following days until the morning of 21 March, with only a few centimeters each.

In line with the persistent winter conditions and without warming spring sun, the March temperature on a national average remained 1 degree below the 1981-2010 normals.

2.1.4 April

In the first half of April, high-pressure together with southern foehn ensured widespread sunny and mild weather in northern Switzerland. There was high pressure on the 2nd, from the 5th to the 7th and on the 14th of April. Southwest and south currents with foehn brought quite sunny and mild conditions on the north side of the Alps on the 3rd and 4th, on the 8th and 9th and on the 11th and 12th. On the south side of the Alps these days were often cloudy and rainy. With more intensive precipitation also snow was observed down to an altitude of 800 m on the 12th.

In the second half of April, the weather was dominated by high-pressure situations with splendid sunshine. From the 17th to the 25th an early summer warmth laid over all parts of the country. Even at altitudes above 2500 m the temperature remained above zero degrees even at night. From 27th to 29th April the foehn was again weather determining. On the 29th, the mild foehn air reached the northern edge of Switzerland. Meanwhile, heavy precipitation fell on the south side of the Alps and in the Upper Engadin.

The nationwide average April temperature reached 7.8 degrees. It was the second warmest April in Switzerland since measurements began in 1864.

At the beginning of April there was an above-average amount of snow in the mountains. With the great warmth in the second half of April, there was a marked snow melt. The snow melted not only during the day under the laughing sun. Even at night the temperature on the Weissfluhjoch remained well above zero even at 2700 m above sea level. Towards the end of April there was an average or even below-average snow height in the mountains.

The frequent high-pressure- and foehn-situations provided a lot of sunshine. In some regions of the northern side of the Alps it was the third or fourth sunniest April in the homogeneous series of measurements, many of which date back to 1959. Also in the more than 100-year-old homogeneous measurement series of Basel and Zurich, it was the fourth sunniest April, which beautifully expresses the unusual abundance of sunshine. Much sunnier were only the April months 2011, 2007 and 1893.

2.1.5 May

In May 2018 thunderstorms were an essential weather element. Thunderstorms occurred over Switzerland from 6 to 9 May, from 11 to 13 May and then persistently from 15 to 31 May. Classic summer thunderstorm weather with flat pressure distribution determined the weather from the 20th to the 31st, with only showers being registered on the 24th.

There were high pressure systems from the 4th to the 8th, on the 11th and 12th and from the 17th to the 19th of May. The weather was low pressure determined from the 1st to the 3rd, the 9th and 10th and from the 13th to the 16th of May.

The nationwide average May temperature reached 10.4 degrees. Several series of measurements of the Alps and the north side of the Alps with 100 or more measurement years showed the second or third warmest May.

After a decidedly dry April, May on the north side of the Alps also remained dry until around mid-month. Then persistent precipitation for several days brought the long-awaited end of the period of low rainfall. On the 29th, a little rain fell again throughout Switzerland as a rainfall zone passed through from the west. The continuing thunderstorms from 20 to 31 May provided further precipitation, but not nationwide.

The southern side of the Alps recorded 22 to 24 days of precipitation in May. Despite regular rainfall, however, the quantities remained modest. Only in most southern Ticino the monthly totals rose above the 1981-2010 normal.

In the central and eastern Plateau, May ends with two days of strong hail. On 30 May, the Baden region was particularly affected. On 31 May, heavy hailstorms hit the regions of Olten and Solothurn.

2.2 Convection or TS activity

In a long-term comparison, the month of May 2018 was surprisingly active considering convection. This is confirmed by some preliminary statistical analyses of the occurrence of ordinary thunderstorms and hail storms in Switzerland and in the surrounding areas. In this analysis all the thunderstorms (ordinary thunderstorms as well as hail storms) for the period 2002-2018 are detected objectively by means of the MeteoSwiss automatic nowcasting system TRT (Thunderstorms Radar Tracking). The analysis refers to recently published long-term studies on the frequency distribution of hail events in Switzerland, in particular (NISI, 2018), (MOREL, 2014), (NISI, 2016), and (NISI, 2016).

Table 1 shows the number of thunderstorms during the month of May, for the domain “Switzerland”, for the 17-year period 2002-2018. By definition ordinary thunderstorms produce almost no hail while hail storms are characterized by an increasing hail severity, following the sequence POH≥80% (probability of hail of any size ≥80%), MESHS≥2 cm (maximum hail size ≥2 cm), MESHS≥4 cm (maximum hail size ≥4 cm). POH was validated against car insurance data (Nisi et al., 2016; Morel, 2014). Verification results show that values of POH≥80% are correlated with car damages with high POD ≥ 0.84 and low FAR ≤ 0.54. Ordinary thunderstorms are therefore the least severe storms (almost no hail) and MESHS≥4 cm the most severe thunderstorms with hailstones sizes that can exceed 4 cm. The red color highlights the years with the highest number of storms of the whole period, orange the second highest frequency and green the third highest frequency.

As can be seen from Table 1 considering the whole of Switzerland the highest number of ordinary thunderstorms occurred in the month of May 2018, closely followed by May 2011 and May 2010/2009. For the hail storms (at least POH≥80%), May 2009 is the most frequent, followed by 2018 and 2008.

Table 1: Number of thunderstorms for whole Switzerland during the month of May for the period 2002-2018. The maximum values per parameter are highlighted in bold.

Years	Ordinary	POH≥80%	MESHS ≥ 2 cm	MESHS ≥ 4 cm
2002	604	16	14	11
2003	198	126	70	56
2004	482	35	23	16
2005	693	83	53	29
2006	780	23	17	8
2007	709	135	88	53
2008	563	133	91	70
2009	819	**178**	**130**	**87**
2010	837	24	23	12
2011	1020	88	66	42
2012	304	22	15	11
2013	422	25	21	14
2014	627	12	12	5
2015	554	47	35	20
2016	592	21	16	10
2017	586	60	35	21
2018	**1028**	159	102	51

The following figures show a summary of the standardized mean frequency anomalies (WILKS, 2006) for the month of May referred to the number of standard deviations of the whole investigation period 2002-2018. Positive (negative) anomalies indicate years where for the month of May hail was more (less) frequent compared to the multi-year average. In the entire domain, hail frequency is highly variable and follows a skew distribution.

For the whole of Switzerland (Figure 2) the years 2018 and 2011 show strong positive anomalies larger than 1.5 standard deviations regarding ordinary storms. For the severe hail storms (MESHS≥2 cm) the highest positive anomalies occurred in May 2009 followed by 2018, 2008 and 2007.

To complete this study, the same analyses were carried out also on the sub-domains “North of the Alps” and “South of the Alps”. They indicate essentially the same characteristics for the month of May.

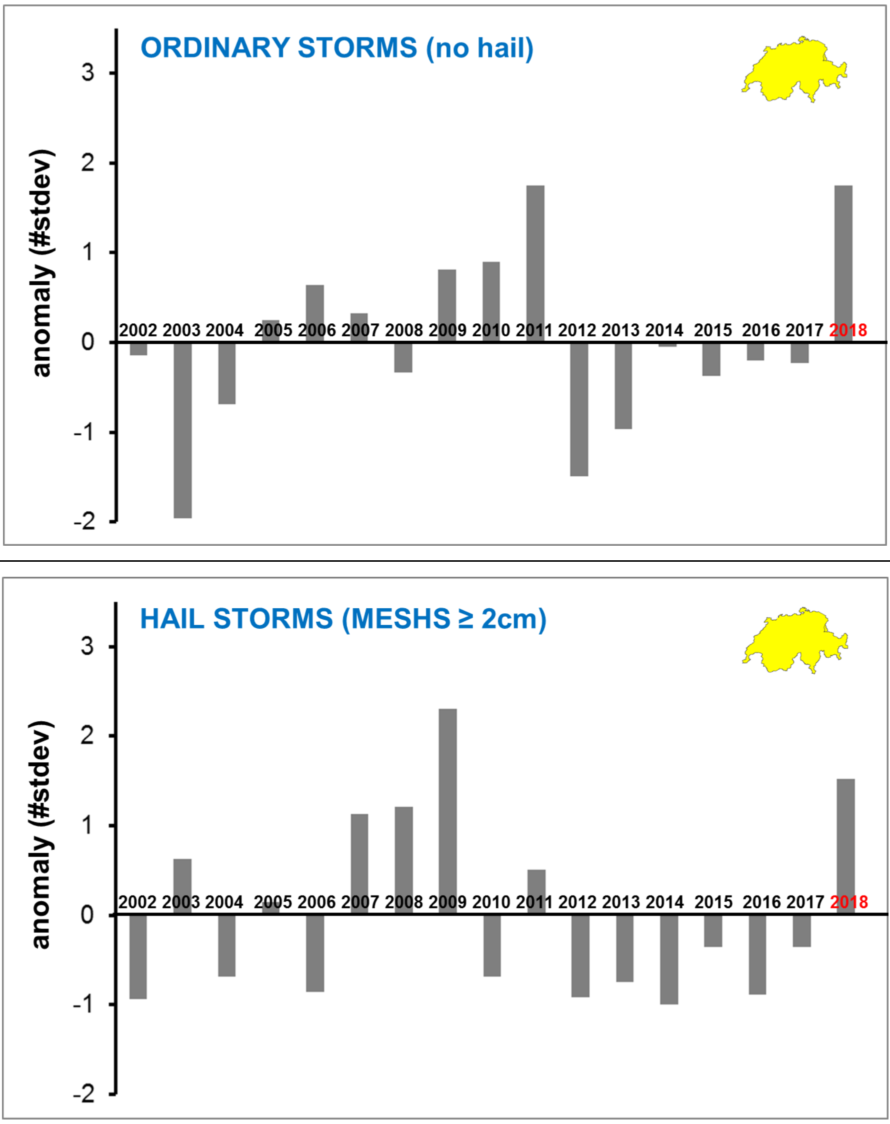

Figure 2: Standardized anomalies for the month of May, for ordinary storms (top) and hail storms (bottom) with MESHS≥2 cm for the entire domain.

It can thus be concluded that the observed differences between the occurrence of ordinary thunderstorms and more severe hail storms during the period 2002-2018 indicate a particularly active May in the year 2018, especially south of the alps. This is particularly pronounced for the hail storms. The second most active period concerning hail storms can be considered May 2015 and 2013 south of the Alps. For the northern part of the Alps May 2018 ordinary storms were more frequent compared to the multi-year average but not exceptionally frequent. Hail storms were also more frequent compared to the multi-year average, but also in this case the anomaly is weaker compared to the south of the Alps.

3 Climatological analysis

3.1 Normal winter temperature, record warmth in January

In the nationwide average, the winter temperature for 2017/18 was within the normal value range for 1981–2010. However, there were wide fluctuations from month to month. Over the whole of Switzerland December temperatures were 0.6°C below normal for 1981–2010, in February it was 3.0°C colder than the normal value. In the midst of these two months January was unusually warm. In January 2018 the meteorological station Geneva registered the record-breaking temperature of 6.0°C. Previously, the mildest January values in Geneva were around 4.5°C. In the nationwide average, too, January 2108 came top in the long series since observations started in 1864 with 3.1°C above the normal value for 1981–2010.

3.2 Abundant snow in the mountains

In a number of regions, winter precipitation amounted to over 130 percent of the normal value for 1981–2010. Many areas in the Canton of Valais and some regions in the Canton of Grisons registered over 200 percent. South of the Alps there were regions registering 150 percent, locally even 180 percent of the normal value.

In January 2018 95 weather stations announced record monthly precipitation. In 72 of these stations measurement series go back more than 50 years. In Valais January 2018 brought not only the highest January precipitation total at four stations for over 50 years, but also the highest monthly-total overall: Zermatt measured 257 mm, Stalden/Ackersand 220 mm, Visp 328 mm and Grimentz 254 mm.

In the mountains huge amounts of snow fell in December and January. Especially in January the danger of avalanches was high to very high across wide areas of the Alps. Some valleys could only be reached by helicopter for several days. In Arosa at 1880 m the winter of 2017/18 brought the considerable fresh-snow total of 5.3 m. Only in the winter 2011/12 was there a higher fresh-snow total (5.8m) during the past 50 years. The habitually dry station of Grächen in Valais at 1600 m measured a winter fresh-snow total of over 2 m, which corresponds to one of the highest winter totals since observations started 50 years ago.

3.3 Stormy winter

North of the Alps the winter brought stormy weather. In the months of December and January the station Zurich-Fluntern registered increased storm activity after several years of generally calm conditions. Especially the January storms caused considerable damage, in particular storm Burglind/Eleanor on 3 January 2018.

3.4 Substantial warming in spring

With spring 2018 as the fourth-warmest spring since the beginning of observations in 1864, the substantial spring warming continued unbroken. The six warmest springs have all been recorded after the year 2000. Since 2000 spring temperatures have in ten instances been 1°C above the normal value for 1981–2010. Previous to the year 2000, this had been the case only twice.

Spring 2018 started off with cool weather. In the nationwide average March recorded 1°C below the normal value 1981–2010. Certain regions south of the Alps registered 1° to 2°C below normal in March: one of the coldest months of March in 30 years. The cool March was followed by the second-warmest April since the beginning of observations in 1864. Averaged over the whole of Switzerland April values showed a surplus of 3.9°C compared with the normal value. Certain regions recorded April temperatures of 4° to 5°C above normal for 1981–2010. And the warm weather continued. Spring ended with the fifth-warmest May since observations started in 1864. In the nationwide average the temperature was 1.9°C above the normal value. At certain meteorological stations it was the second- or third-warmest May since observations began 155 years ago.

Below in Figure 3, 4 and 5, the monthly spatial anomalies over Switzerland for precipitation, relative sunshine and temperatures respectively. The anomalies are calculated according to the 1981-2010 reference, for the months of February, March, April and May 2018.

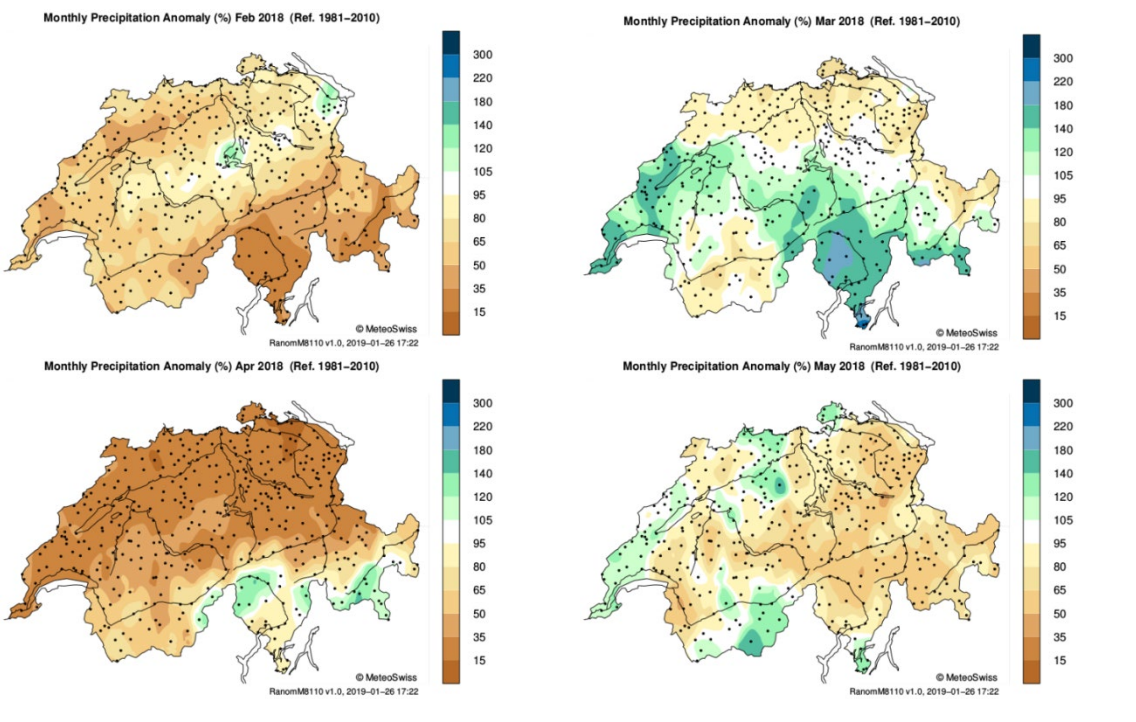

Figure 3: Monthly precipitation anomaly in (%) with respect to the 1981-2010 reference, for the months of February, March, April and May 2018.

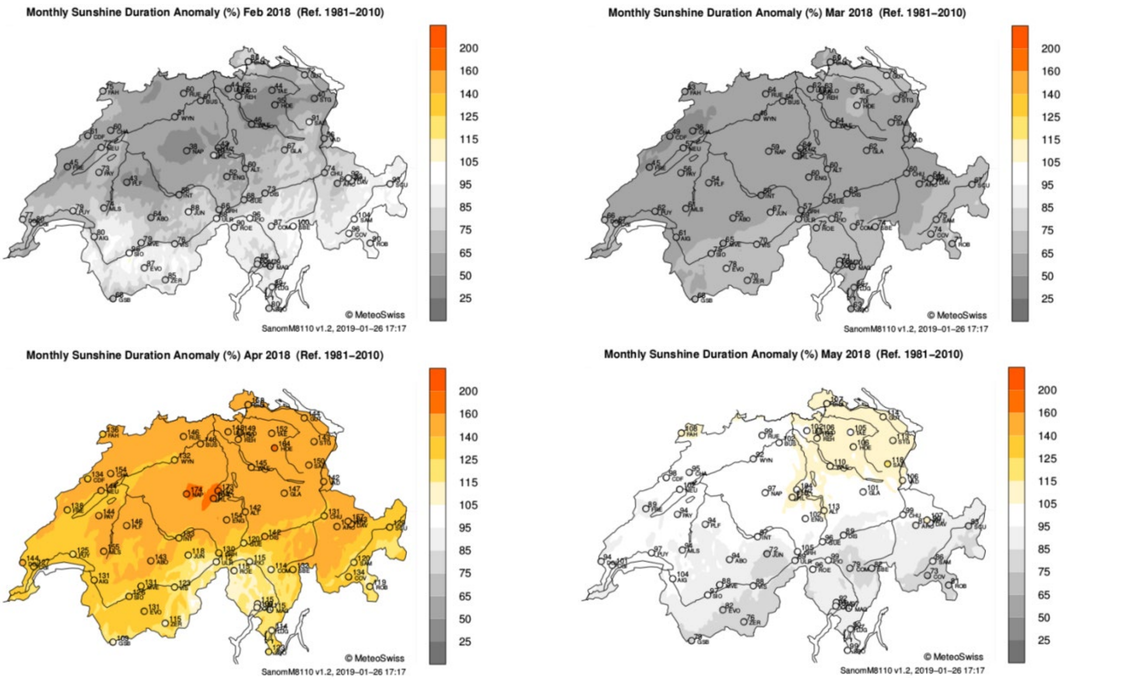

Figure 4: Monthly sunshine duration anomaly in (%) with respect to the 1981-2010 reference, for the months of February, March, April and May 2018.

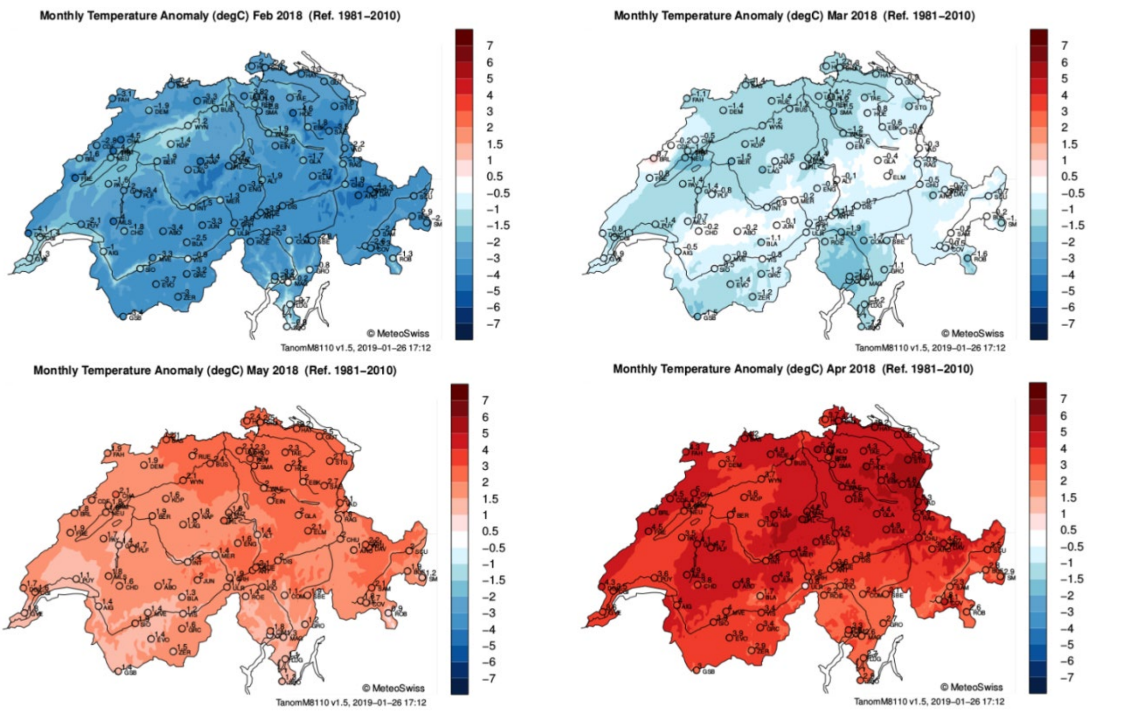

Figure 5: Monthly sunshine duration anomaly in (%) with respect to the 1981-2010 reference, for the months of February, March, April and May 2018.

4 Forecast quality

In this chapter, we will analyze the evolution of the COMFORT score as well as the forecasts issued from the COSMO numerical weather model.

4.1 COMFORT global score

The COMFORT forecast verification scheme was developed by MeteoSwiss in order to serve the following administrative purpose: provide different stakeholders, such as management, federal council and parliament, press and the general public with an overall measure of (some attributes of) the quality of general deterministic forecasts provided by MeteoSwiss.

The global COMFORT score is obtained as a weighted sum of partial scores computed for each verified parameter: precipitation, relative sunshine duration, daily minimum and maximum 2m-temperature, and wind speed.

$$COMFORT=\rho_p S_p+ \rho_{RS} S_{RS}+ \rho_{Tmin} S_{Tmin}+ \rho_{Tmax} S_{Tmax}+ \rho_V S_V$$

where ρ_p, ρ_{RS}, ρ_{Tmin}, ρ_{Tmax}, ρ_V are the weight of the partial scores for precipitation, relative sunshine, minimum and maximum temperatures and wind speed respectively.

$$\rho_p = 0.3,\ \rho_{RS} = 0.3,\ \rho_{Tmin}= \rho_{Tmax} = 0.15,\ \rho_V = 0.1$$

The COMFORT score is systematically applied to forecasts produced by the forecasters (Forecasters' value). It can also be used to evaluate the quality of the set of model data that is used as a basis for forecasting (hereinafter referred to as model proposal).

The COMFORT global score should be analyzed over a period of several months (ideally a year) to avoid being too dependent on weather situations and to draw conclusions about the quality of models or the work of forecasters. It has been observed that the score exhibits intrinsic variability over short periods of time (Figure 6); for example, a dry month results in a score above 85 (at day D+1) regardless of other factors!

The evolution of the global COMFORT score for the first 2 seasons in 2018 (December 2017 to May 2018), aggregated for entire Switzerland, shows two main features:

- the months of February, March and May have scores below the target (fixed in 2018 at 82,5 D+1, 77.0 at D+2, and 71,5 at D+5, Figure 6)
- from summer 2013 to summer 2017, we observe a clear trend towards improvement, but a drop of the forecast quality thereafter (Figure 7)

Figure 7 shows the seasonal COMFORT at Day+1 for the 3 different regions of Switzerland and the Swiss average. Despite variations in regional seasonal scores, there is for all regions a similar trend of quality improvement between summer 2013 and 2017, and then a clear decrease.

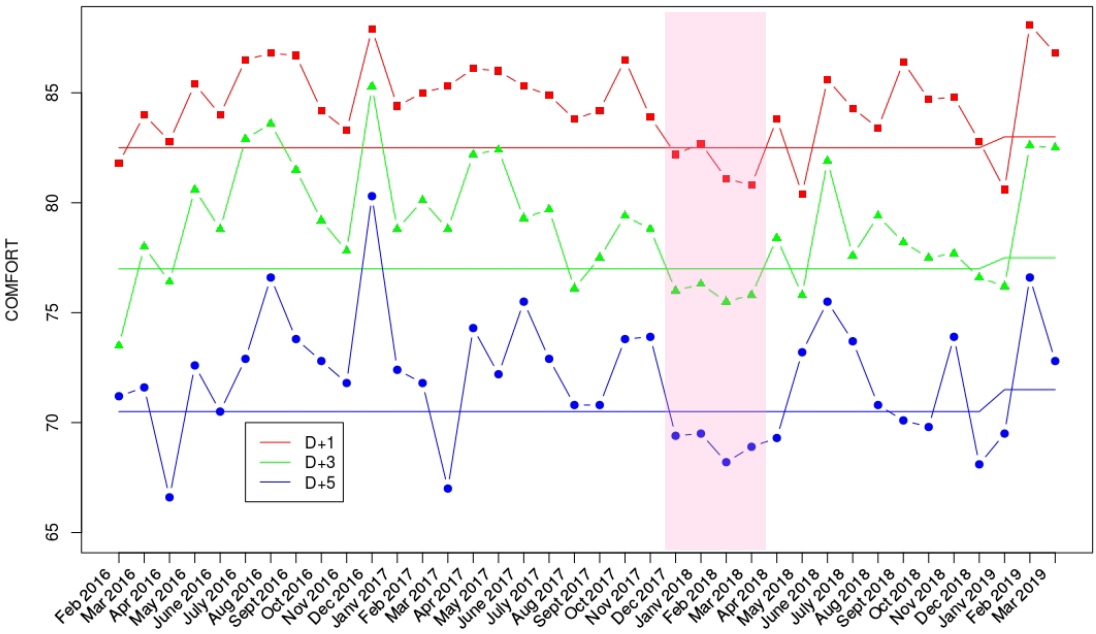

Figure 6: Monthly evolution of the global scores COMFORT for Switzerland since February 2016. Lead times of day+1, day+3 and day+5. The thin horizontal lines indicate the goals agreed with the main authority. The period we are concerned with in this report is indicated with the pink surface.

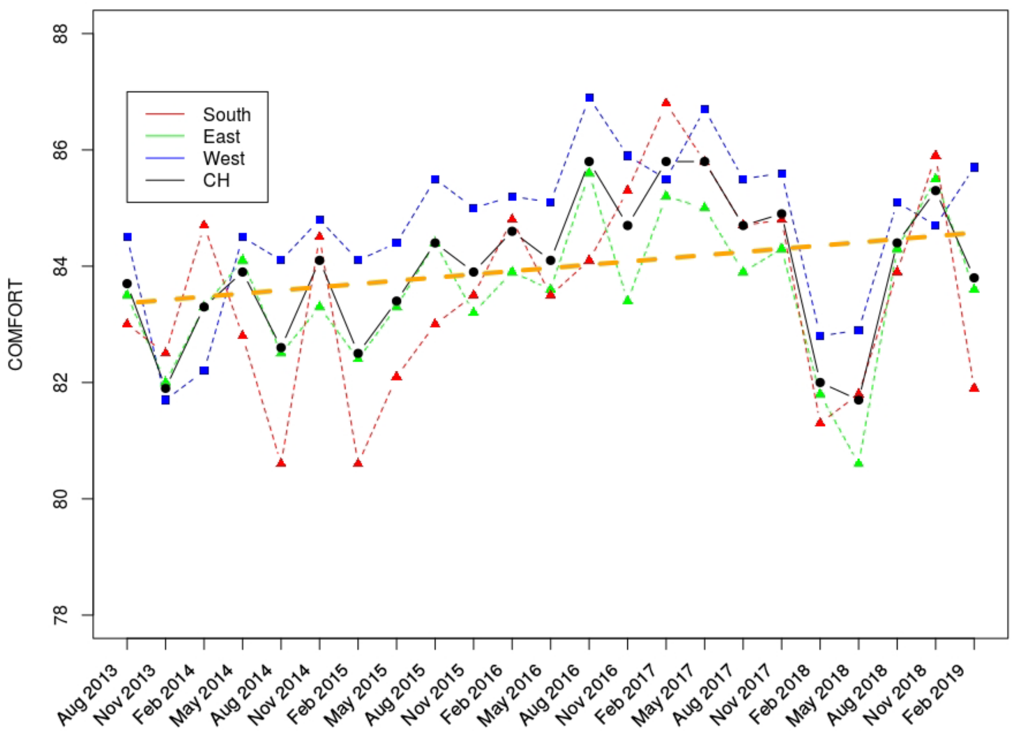

Figure 7: At leadtime day+1, seasonal global COMFORT scores for Switzerland (CH) each single region (West, East and South). With green dashed line the linear regression of the CH score between Aug-13 and Aug-17, extrapolated to Aug-18 is shown.

4.2 COMFORT partial scores

For a closer inspection, the different COMPONENTS based on different meteorological parameters are analyzed here. It can be seen from the monthly evolution presented in Figure 8 that the quality of wind speed forecasts is particularly poor compared to the quality of other parameters, especially during the period we are discussing. Nevertheless, wind quality alone cannot explain the decrease in the global score, as the weight of the partial score of wind is only 10% in the overall score.

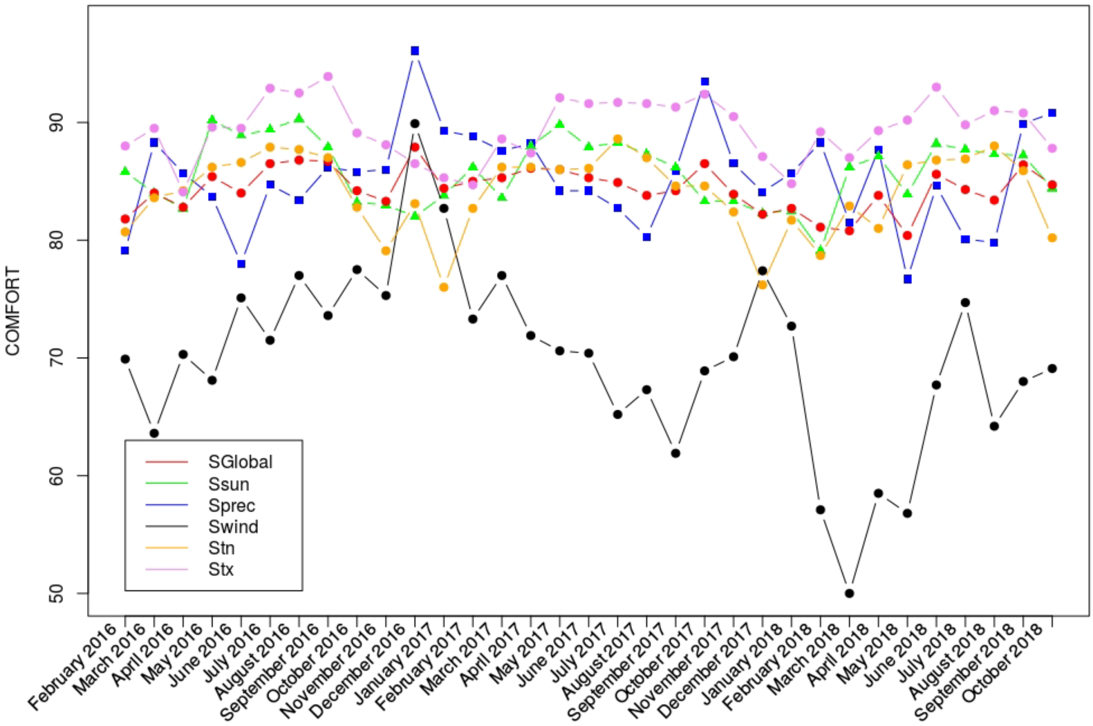

Figure 8: Monthly evolution of the global and the partial COMFORT scores, at leadtime day+1 for whole Switzerland.

To highlight the forecast performance of the various parameters, in the following tables we present anomalies of partial scores with respect to the mean values 2014-2017. While with the exception of temperatures, there are nor seasonal cycles of the partial scores (Figure 9).
From Table 2, it is obvious that forecast of the wind performed poorly over all regions and every months. On the other hand, the forecasts of temperature (minimum and maximum are considered together) scored close to the average value, or even better in May.

Regarding the other parameters, results are different depending on the month. In February, partial scores of sunshine forecasts were lower than average, while rainfall forecasts remained above average. In March, it was the opposite. In addition, in May scores related to precipitation were consistently low in all regions.

Table 2: Monthly anomalies of partial scores at day+1 for each region (W,E,S : West, East, South). Reference is the mean 2014-2017 of each partial scores.

Parameter		Dec 17	Janv 18	Feb 18	Mar 18	Apr 18	May 18
Precipitation	W	-3.6	0.2	8.1	-3.1	2.1	-7.6
	E	-0.6	2.0	0.1	-5.5	5.1	-9.4
	S	2.7	0.1	3.1	-0.3	0.3	-6.6
Rel. Sunshine	W	-0.6	0.3	-8.2	-0.8	2.0	0.2
	E	-2.0	-2.7	1.1	2.1	1.9	-1.5
	S	-6.0	-5.4	-13.3	2.9	2.8	-1.9
Tn/Tx	W	-3.7	-0.9	-1.2	-0.3	0.0	3.9
	E	-2.2	-1.5	0.7	1.0	0.1	4.9
	S	-3.3	-1.6	-2.0	0.2	2.1	1.6
Wind	W	14.3	-7.0	-6.4	-4.8	0.7	-10.3
	E	-7.7	-7.7	-25.7	-35.5	-23.3	-30.6
	S	7.4	15.9	-16.6	-30.4	-23.2	-4.9
Global	**W**	**-1.4**	**-1.4**	**-1.5**	**-2.2**	**0.8**	**-2.6**
	E	**-2.7**	**-1.9**	**-2.5**	**-4.8**	**-0.7**	**-5.4**
	S	**-1.8**	**-1.0**	**-5.8**	**-2.7**	**-1.3**	**-3.1**

In Table 3, the anomalies are rescaled according to the importance in the global score for each parameter and region. It appears that despite the low weight (10%) of the wind's contribution, the fact that the wind forecast performance was very low had a major impact since it contributed to lowering the global score in all regions (down to -3,5 points).

Table 3: Rescaled anomalies (rescaled according to relative importance in global score) of monthly COMFORT scores with respect to average monthly scores from 2014-2017.

Parameter		Dec 17	Janv 18	Feb 18	Mar 18	Apr 18	May 18
Precipitation	W	-1.1	0.1	2.4	-0.9	0.6	-2.3
	E	-0.2	0.6	0.0	-1.6	1.5	-2.8
	S	0.8	0.0	0.9	-0.1	0.1	-2.0
Rel. Sunshine	W	-0.2	0.1	-2.5	-0.2	0.6	0.1
	E	-0.6	-0.8	0.3	0.6	0.6	-0.4
	S	-1.8	-1.6	-4.0	0.9	0.8	-0.6
Tn/Tx	W	-1.1	-0.3	-0.4	-0.1	0.0	1.2
	E	-0.6	-0.5	0.2	0.3	0.0	1.5
	S	-1.0	-0.5	-0.6	0.0	0.6	0.5
Wind	W	1.4	-0.7	-0.6	-0.5	0.1	-1.0
	E	-0.8	-0.8	-2.6	-3.5	-2.3	-3.1
	S	0.7	1.6	-1.7	-3.0	-2.3	-0.5

On Figure 9 and 10, relative deviations (with respect to a 2014-2017 reference) of the monthly partial scores of the parameters analyzed are represented for Switzerland at Day+1 forecast.
The evolution of the differences in the performance of the quality of temperatures' forecasts follows a seasonal cycle. There were no significant differences for the winter-spring 2018 period.

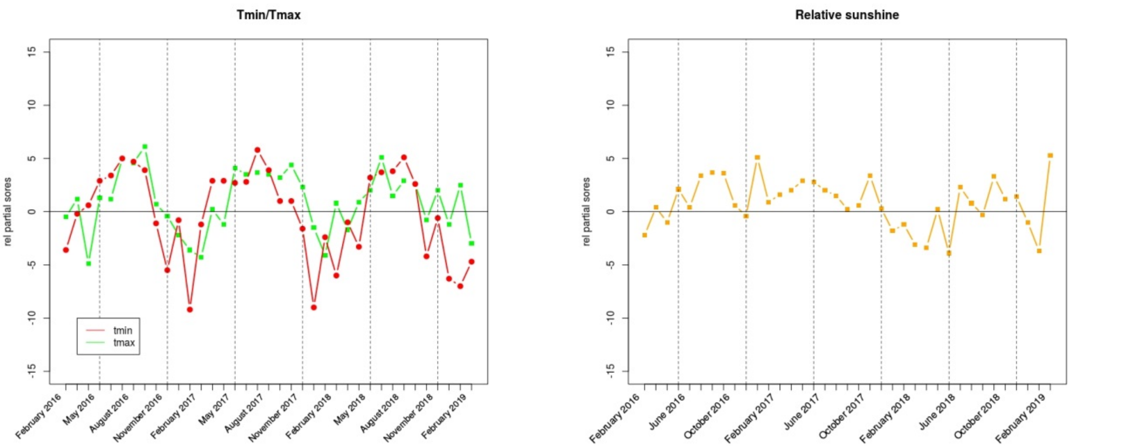

Figure 9: Monthly evolution of the partial score relative anomaly of tmin and tmax (left) and relative sunshine duration (right). Reference: mean 2014-2017. Dashed lines indicate months of May and November. Lead time day+1.

For the relative sunshine and precipitation, there is no seasonal cycle but rather variations that can be explained quite easily by weather conditions (for example, a dry month will correspond to a high partial score – such as December 2016, or February 2019).
With regard to wind quality monthly evolution, it can be noted that the amplitude of the variations is much larger than the one observed by other parameters. And there is a significant negative deviation (<-20%), during the months of February to May 2018.

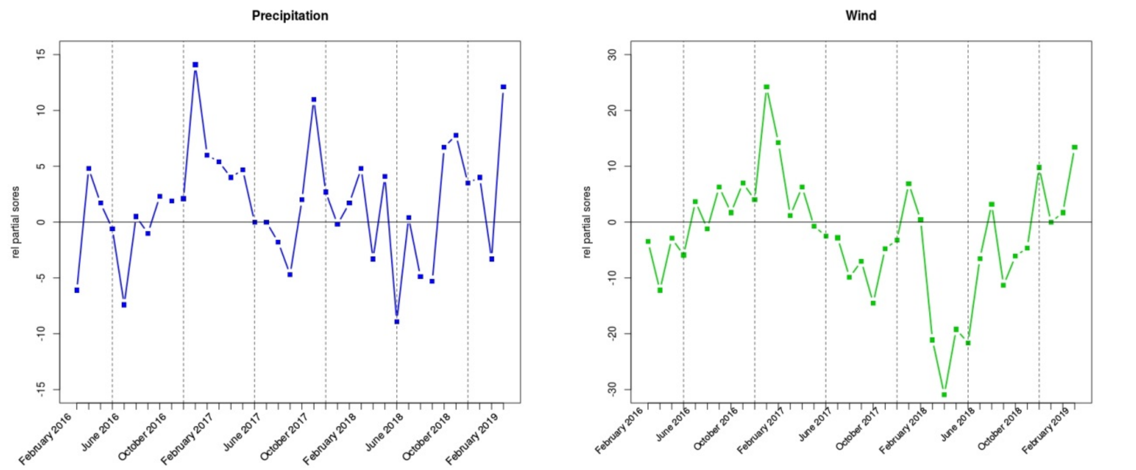

Figure 10: Monthly evolution of the partial score relative anomaly of precipitation (left) and wind (right). Reference: mean 2014-2017. Dashed lines indicate months of May and November. Lead time day+1**.**

Let's continue the exercise by looking at the spatial distribution of partial scores of precipitation and relative sunshine duration, at day+1 and for the 4 months; February to May 2018.

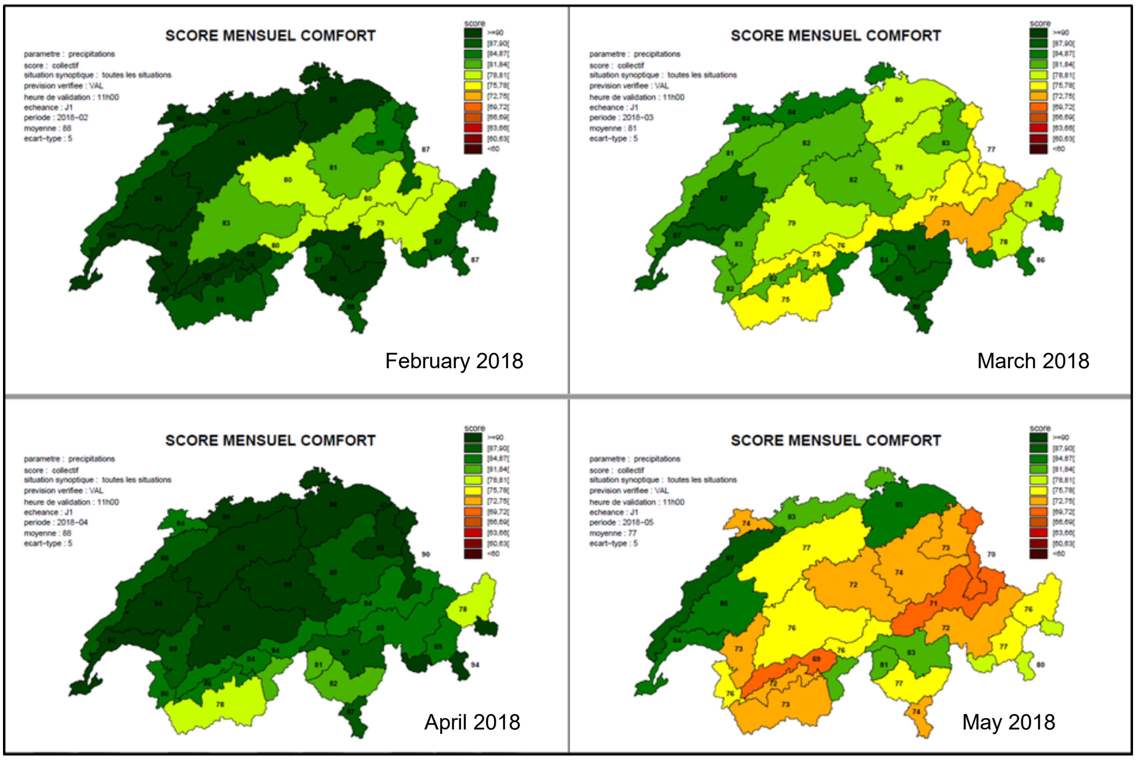

Figure 11: Partial scores of precipitation for the 27 regions at day+1.

For precipitation in March and May (Figure 11), the regions in the Alps are those for which the scores were the lowest, this is further emphasized in May. With the possible exception of regions of Lugano and Délémont, although far from the Alps they present very low scores. For these two regions, this may most probably be an intrinsic limitation of the type of score used, which in stormy conditions, is more penalizing for very small surface with respect to larger regions.

The analysis of the spatial distribution of the partial scores of relative sunshine is more difficult, there does not seem to be a clear contrast between Alpine and lower-lying areas as for precipitation, but rather a difference related to the variability of the parameter over the month (Figure 12).

Figure 13 shows for the 27 regions, the relation of the sharpness of the distribution of daily observed relative sunshine during the month (we use here the difference Q75-Q25%) and the partial score of relative sunshine. Regions with high scores are related to a sharper distribution such as in February 2018.

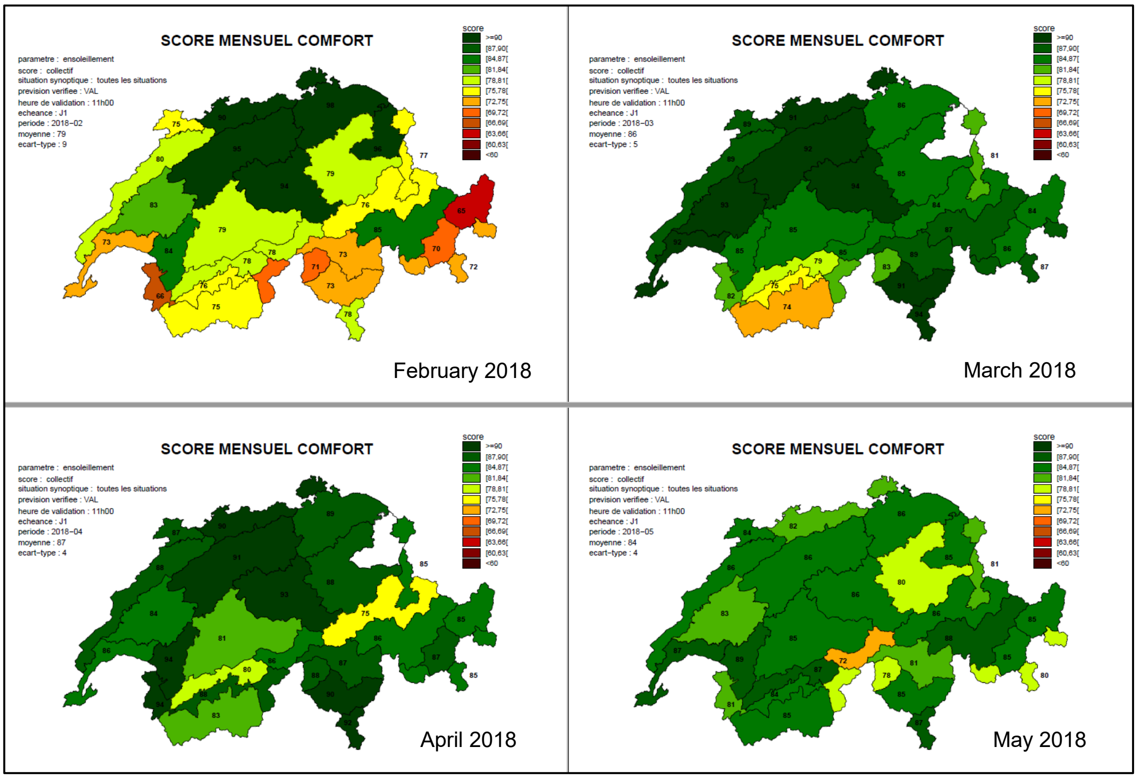

Figure 12: Partial scores of relative sunshine duration on the 27 regions at day+1

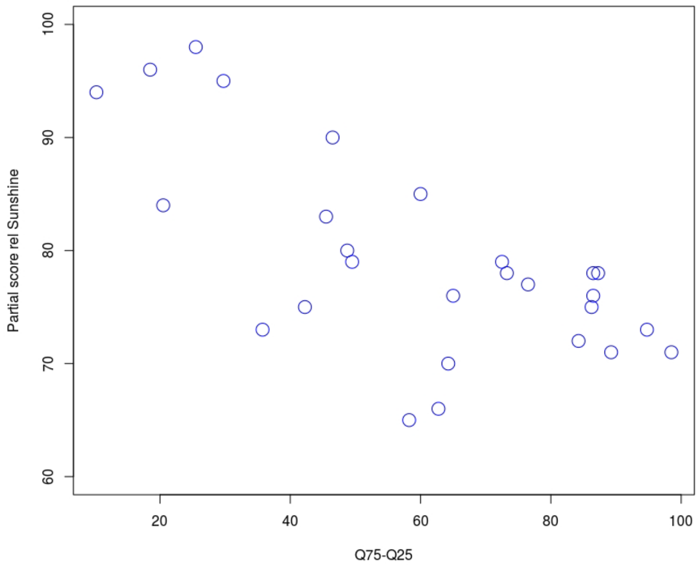

Figure 13: Partial score of relative sunshine forecast at Day+1 for all the 27 stations, in February 2018, as function of the distribution of daily observations given by Q75%-Q25%.

4.3 Convection cases in May

As demonstrated in section 2.2, May 2018 was characterized by several convective situations. In this section we will illustrate some cases of convective situations and the difficulty of achieving good scores because convective situations are intrinsically difficult to predict in particular with regard to local details.

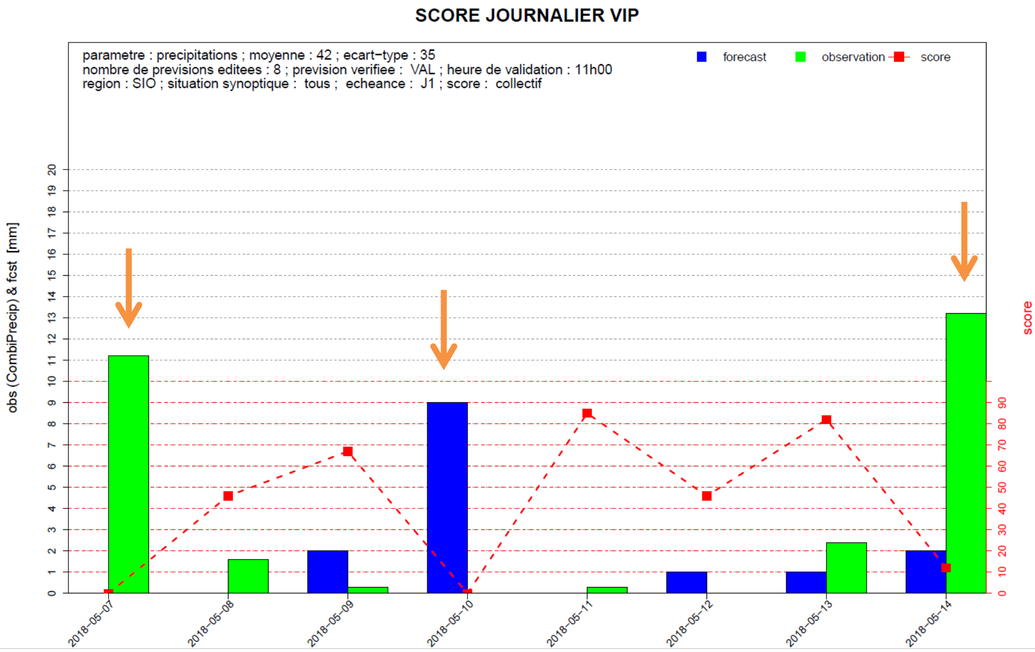

Figure 14: Daily precipitation forecasts from forecasters (blue) together with the observed values (green), at Day+1 in Rhône Valley (reference station Sion). With red points (right scale) the corresponding partial score COMFORT.

Few examples. We have selected 3 cases in May 2018, region Rhône Valley, which have scored with 0 in the partial score of precipitation (Figure 14). Precisely the 7, 10 and 14th of May (accumulated precipitation are shown in Figure 15 – weather description on Table 4).

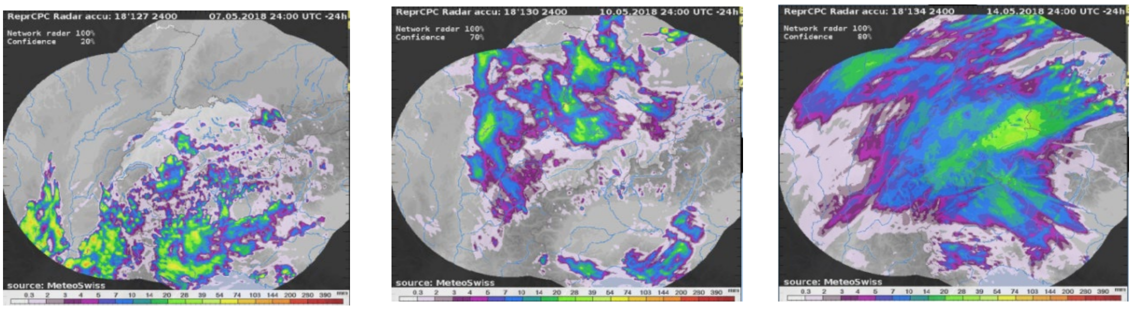

Figure 15: Daily accumulated precipitations from CombiPrecip observed the 7, 10 and 14th of May.

Table 4: Short description of weather forecasts issued one day before and the observed weather

Issue	Validity	Forecast	Observed
May 6	May 7	Stormy weather expected, with the most part of activity along Jura and Prealps, slight activity in the Alps.	The stormy developments occurred on Prealps and in the Alps. Activity in the Alps was underestimated.
May 9	May 10	An extension of the night thunderstorm activity was expected in the morning.	Stormy activity stopped earlier than expected. Resulting in a complete dry weather.
13 May	14 May	Very localized activity forecasted in the Upper Valais during the morning, and in the West in the afternoon.	Showers continued throughout Switzerland all the day.

4.4 Model quality (COSMO)

The model performance is evaluated seasonally. The direct model output and Kalman-filtered values of all operational models are verified against surface station data. Vertical profiles are verified against upper-air soundings at several stations in Europe. Here, results of the surface verification are presented.

The ability of the models for the distinction between rain and no rain is evaluated with a dichotomous verification. The threshold used is 0.1 mm. Because false alarm ratio and probability of detection both depend on the frequency bias, it is better to use a measure combining hits, false alarms, and missed events (for a detailed description of the scores, see e.g. (WILKS, 2006)). The threat score is such a measure. It is however known to become better, when the frequency of the event is higher, and to become worse, when the frequency is low. To avoid such dependence on the base frequency, the equitable threat score (ETS) is used instead. It is defined like the threat score but deducts the random hits due to chance from the total number of hits. This makes the ETS independent of the base rate.

In winter 2017/18, and then again in autumn 2018 and winter 2018/19, all model show verification scores in the normal range. All scores are however significantly reduced in spring and summer 2018.

Most prominently, the ETS for precipitation shows low values for all models, see Figure 16. The spring values and even more the summer values show downwards peaks far below the values of previous years. The summer 2018 values are the lowest since winter 2009/10.

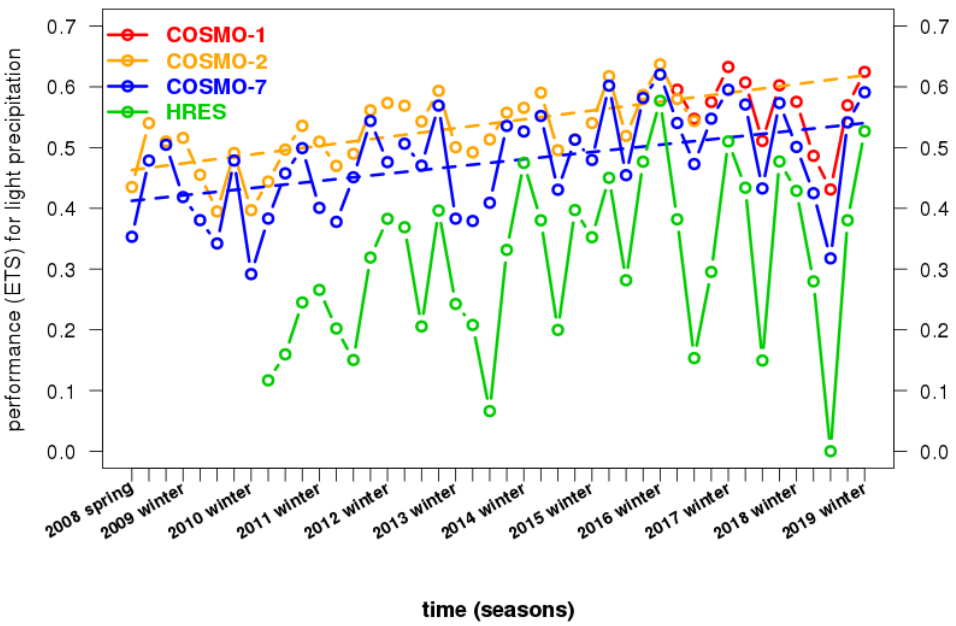

Figure 16: ETS for several models since spring 2008 (ECMWF not verified before spring 2010). 12 hours accumulated precipitation between +6 and +18h. Winter means December of previous year to February.

The ETS for the distinction between cloudy sky and no clouds (2.5 octa threshold) shows a similar evolution (not shown). Precipitation and cloudiness together make up 60% of the Model Quality Score for Switzerland, MOQUAS (KAUFMANN, 2019), which is the score for reporting the model performance to the steering board of MeteoSwiss, to the Federal Department of Home Affairs and to the parliament. Due to the two ETS values being so low, the MOQUAS also drops for spring and even more for summer 2018 (Figure 17).

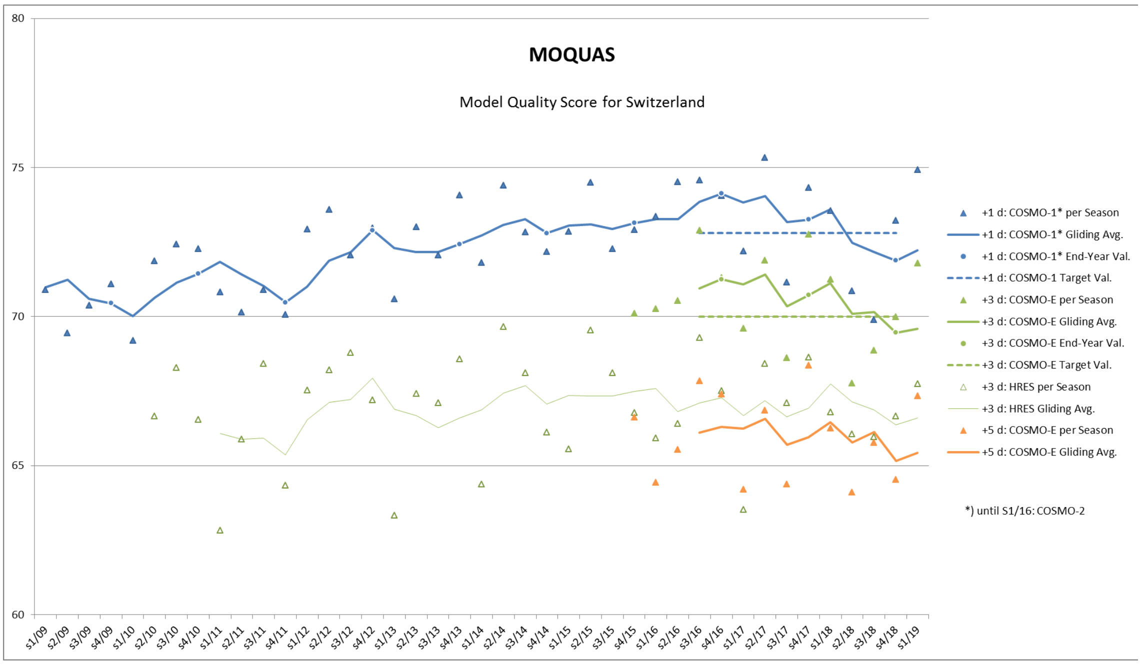

Figure 17: Time evolution of the model quality score for Switzerland for different models and lead times.

The frequency of occurrence for precipitation and cloudiness is about average in spring. In summer, the frequency is lower than usual. As the ETS is designed to compensate for changes in the base frequency, the reason for the extremely low score in summer is probably not the low frequency per se. However the little precipitation that did occur was mostly produced by local convection, and large scale frontal precipitation occurred very rarely during this summer. This localized precipitation is difficult to forecast at the precise location, and the double penalty effect penalizes location errors twice: once for the predicted precipitation at the wrong place, and a second time for the missing precipitation where it actually occurred. This leads to strongly decreased performance measures.

The scores for temperature and wind speed for spring and summer this year are in the normal range for spring and summer seasons, respectively. The MAE for temperature is even slightly better this year than in the two previous years. The MAE for wind speed is in between the values for 2016 and 2017. The frequency of strong wind cases (10-min average wind > 10 m/s) declines from January to May. The ETS for this wind class also declines considerably. This measure however is not part of the MOQUAS.

The verification of wind gusts, on Figure 18, shows a degradation of the performance in spring for the strong gusts (12.5 m/s threshold). This is however a common finding in spring. Only the higher thresholds are slightly worse in 2018 than in 2017, but on the other hand, the number of cases is small. Compared to the confidence intervals, the difference is not significant.

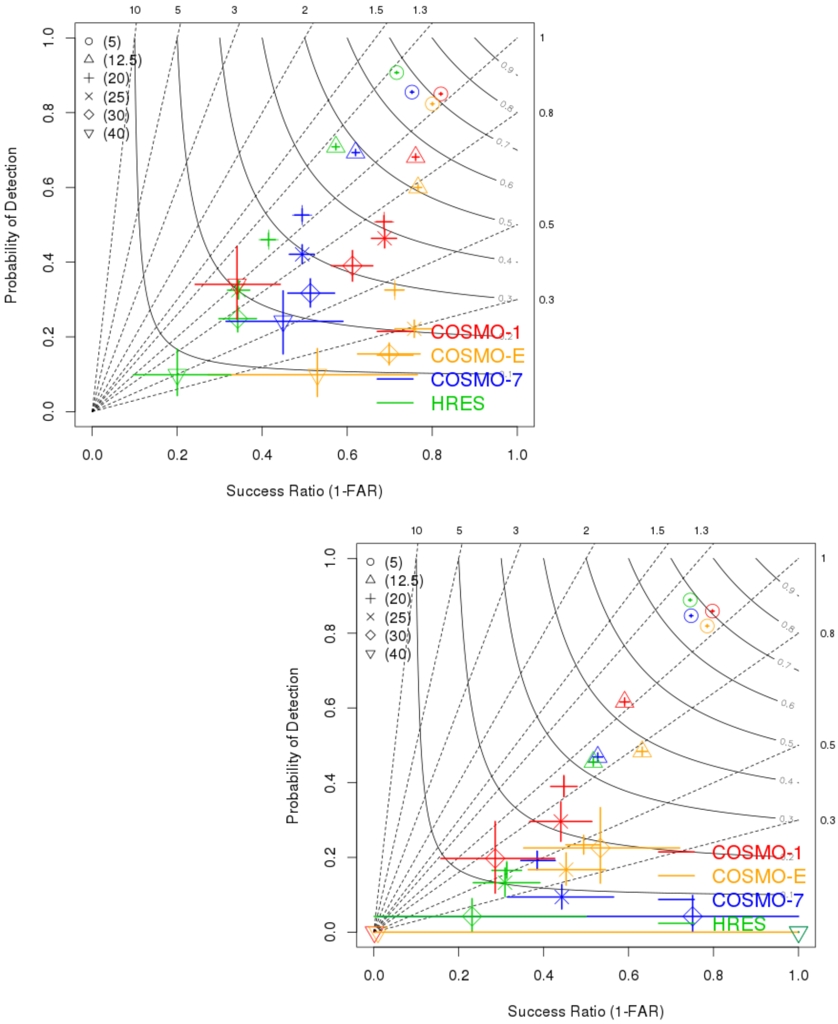

Figure 18: Performance diagrams for wind gusts for winter 2017/18 (left) and spring 2018 (right). Symbols denote thresholds in m/s, models are separated by colors.

Sunshine duration is verified only since autumn 2017. The MAE is smaller in winter than in spring 2018 and again larger in summer. As the sunshine duration is measured in minutes, this is however mainly an effect of the prolonged daytime.

5 Additional analyses

5.1 Synoptic large scale

On a large synoptic scale, there is a major feature for the months with lowest scores: the rate of cyclonic-type situations is significantly higher.

A fairly simple approach often used by forecasters is to analyze forecasts by stratifying them along synoptic situations. In this section the monthly COMFORT global score is placed into perspective with the frequency of synoptic situations by applying the MeteoSwiss classification system (WEUSTHOFF, 2011).

The classification used is the GWT26_Z500, based on 500 hPa geopotential heights.

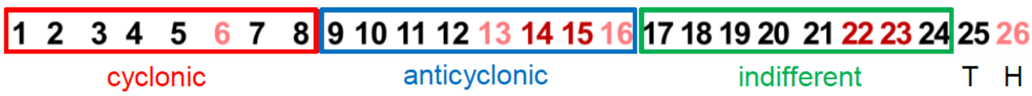

Figure 19: Grouping of the objective weather types (GWT26) into 3 groups.

We can roughly classify into three groups; cyclonic and low pressure, anticyclonic and high pressure, and the so-called indifferent situations (no major driving flow), as illustrated in Figure 19. Then we focus here on the rate of situations daily classified as cyclonic compared to all situations in the month. Such a reduction to a little number of groups makes the statistical analysis more robust and eases the interpretation.

Figure 20 shows the frequency of these groups compared to the climatology. It becomes evident, that cyclonic weather types are substantially more often than normal. February and March exhibit highly anomalous values, but also January and May are above average. It remains unclear, if these anomalies can be related to the sudden stratospheric warming (SSW) that occurred in 12th of February 2018. Temperature anomalies showed structures very typical for SSWs and the Arctic Oscillation had very negative values in March (KARPECHO, 2018)

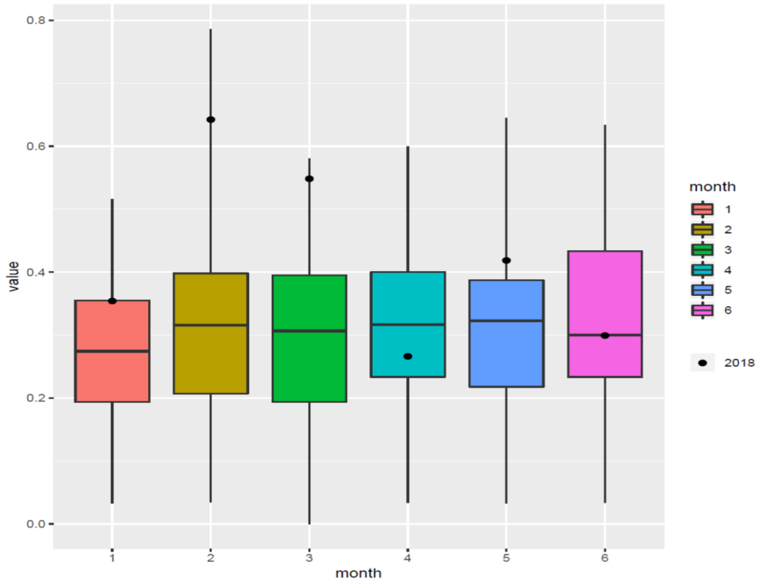

Figure 20: Monthly rate of cyclonic situations from GWT26 classification at 500 hPa. Boxes represent the distribution of the monthly rates on the period 2007-2017, the point is the monthly rate in 2018.

5.2 Forecaster's contribution

In this section, it is analyzed, to what extent forecasters provide an added value with respect to NWP data. However, it has to be kept in mind that the model proposal used as a benchmark is around 10 hours older than the information being available to the forecaster, from more recent model runs for example. Therefore, it remains unclear, if forecaster's contribution could be diminished, if more recent NWP output would be used for automatic production or postprocessed data thereof.

Clearly, forecasters have very effectively improved for the forecasts they use as proposal, especially when they were particularly low. On global score at day+1 the contribution of forecasters is in average better with 3 points (see Figure 21). Note that the contribution of the forecaster was higher than usual for most of the months in 2018. Figure 22 and 23 show forecaster's contribution on parameters of relative sunshine duration, precipitation and wind, as measured by partial scores.

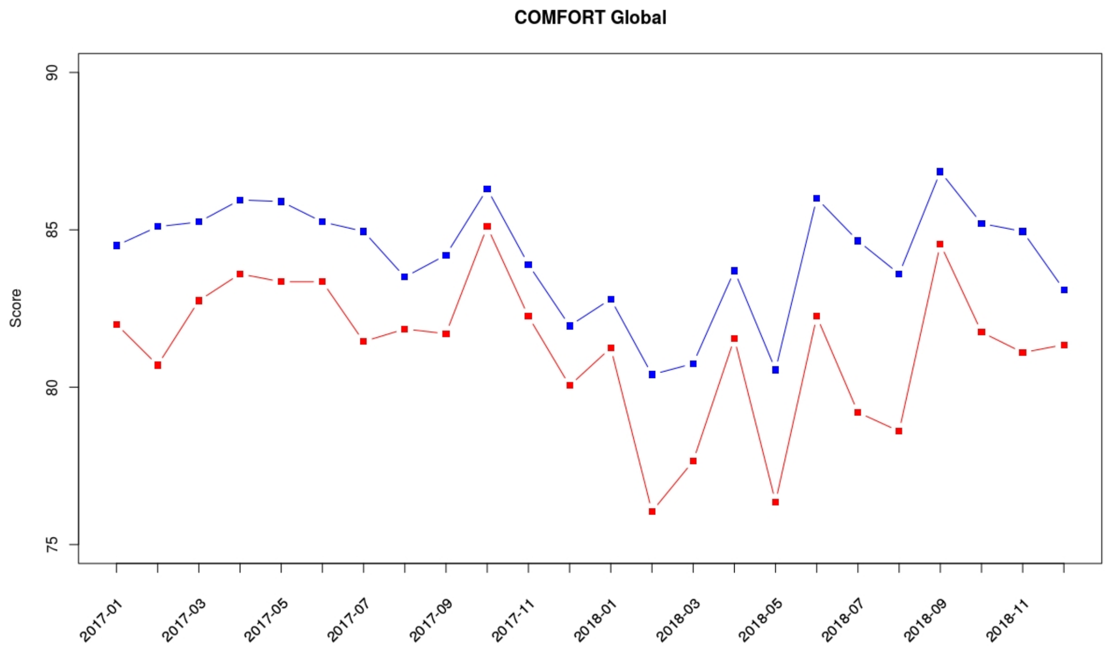

Figure 21: Comparison of the monthly COMFORT global scores, for the forecaster's contribution (blue) and the values proposed by models for day+ 1 (red).

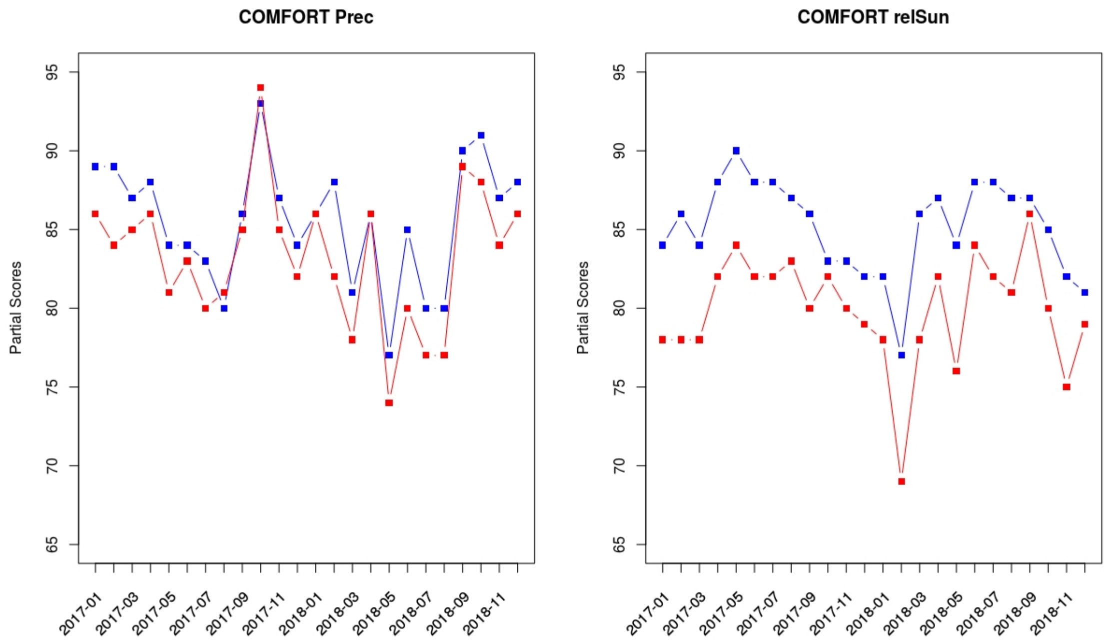

Figure 22: Comparison of the monthly COMFORT scores for the forecaster's contribution (blue) and the values proposed by the models for day+1 (red)

On Figure 23, we also remark the important improvement of the quality of wind speed forecast in 2018 while the values proposed by models were particularly poor.

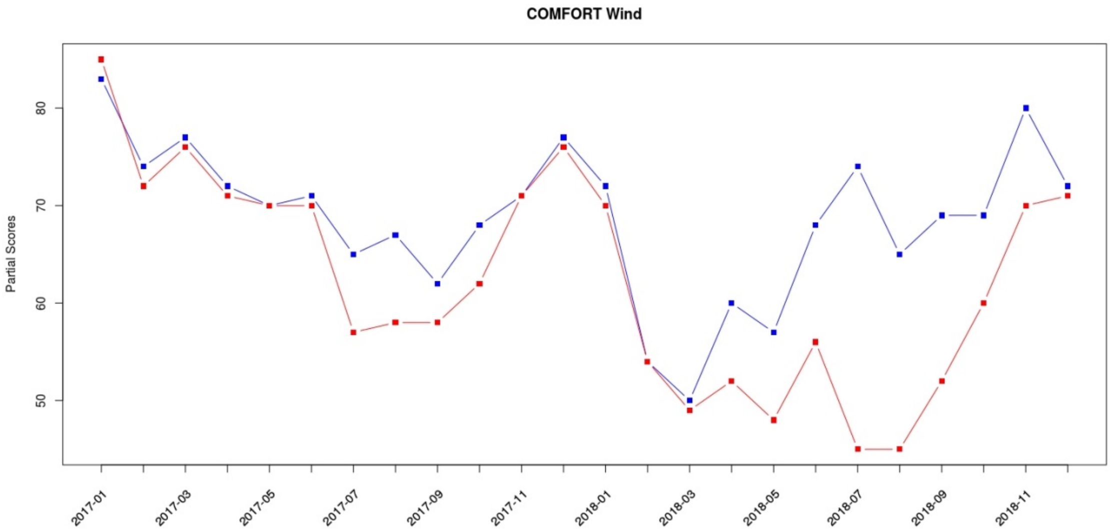

Figure 23: Monthly evolution of the partial wind score for all reference stations in Switzerland, day+1. Forecaster's contribution (blue) and values proposed by the model (red).

The most important contribution from forecasters with respect to the global score are; in relative sunshine duration by 54% and then in precipitation 25%. Wind accounts for 21% while the impact on temperatures is generally low, Figure 24.

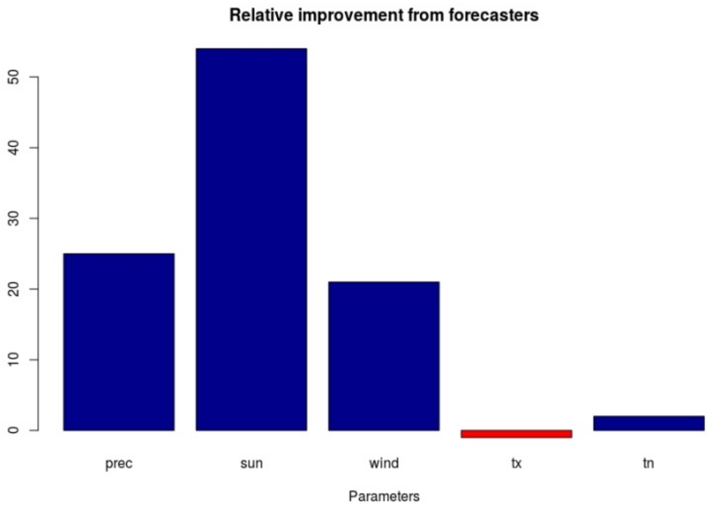

Figure 24: Relative contributions to global score of forecaster's contribution with respect to model proposal, related to each parameter, 2017-2018. Day+1.

6 Conclusions

The quality of MeteoSwiss forecasts (as measured by COMFORT) has declined significantly during the two seasons analyzed in this report: winter 2017-2018 and spring 2018. Especially during the months of February, March and May. There are certainly many reasons explaining the forecasting difficulties during this period. The findings in this report confirm that depending on the month and sometimes on the regions, the parameters not well predicted are not the same.

6.1 Temperatures

Despite values that may have been outside the seasonal norms (warmer in January, April and May; cooler in February and March – see Chap. 2), the scores of minimum and maximum temperatures follow a similar seasonal behavior over the past 3 years. Each time with lower quality forecasts in winter, higher in summer. The winter of 2018 did not deviate from this rule (Section 4.2, Figure 9). Only the December 2017 temperatures' forecasts had a negative impact around -1 point on the global score (Table 3).

6.2 Wind forecasts

Clearly, the wind quality was poor from February to May 2018. Excluding the Burglind event, an exceptional storm, but over a very short period of time, there were no major wind events that would have made forecasting supplementary difficult on the winter and spring 2018 (Chap. 2). Except the very frequent situations with strong convection, and associated strong winds, where the forecast is very dependent on the spatial and temporal location of the convection.

It can be seen that the model used as a proposal, COSMO-e median, was mostly poor and although forecasters added a significant contribution (Figure 23), this was not enough to raise wind scores to the level of values measured in the past (Figure 8).

6.3 Sunshine duration

Considering the overall evolution of the quality of the relative sunshine forecasts over 3 years, we do not notice any significant change for the winter that concerns us (Figure 9). In detail, it is during the month of February 2018 that the relative sunshine scores had a major impact on the overall score of the winter 2017-2018. With -2.5 points for the West, and -4 points for the South, slightly positive for East +0.3 (Table 3).

This could be explained considering that the best scores were achieved when the weather was stable, dry and sunny (April over the whole of Switzerland – Figure 12, Table 2 and 3). On the opposite, in variable situations forecasters tend to avoid extreme sunshine classes (completely cloudy or sunny), which inevitably reduces the score while the distribution of forecasted classes does not match with observations.

We see in Figure 25 the frequency of the forecasted sunshine duration classes compared to the observed ones during the month of February at stations of South and West. Over northern and eastern of Switzerland with a dominant pattern of persistent low level clouds, the scores were much better.

As over the whole period the number of changing situations were higher than usual (Section 5.1), the quality of the forecast has consequently decreased.

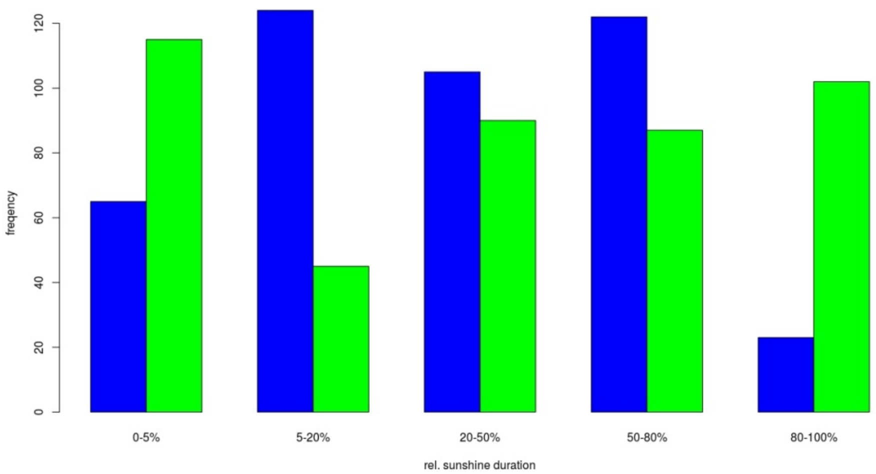

Figure 25: Frequency of relative sunshine duration classes, forecasted (blue), observed (green). Month of February 2018, at stations of South and West of Switzerland, where scores were low.

6.4 Precipitation

Despite a dry April (Chap. 3, Figure 3) which allowed us to have better scores, the agitated weather of the other months made forecasting difficult for models and forecasters. The stormy month of May is a perfect example (Section 2.2).

Especially with regard to precipitation. Phenomena such as storms are undeniably linked to a double penalty when verifying precipitation. Because they have to be precisely forecasted in space (27 verification regions) and in intensity, as presented in Section 4.3. Even if synoptically the stormy situations can be well forecasted, it is in the detail of the forecast that it will always be difficult to make a good forecast more than 24 hours in advance, especially for the smallest regions.

6.5 Recommendations

Based on the presented findings, it is difficult to draw clear conclusions to provide recommendations for the forecasters to improve sunshine forecasts. Potentially, the forecasters could issue stronger signals and chose the extreme situations (no sunshine, full sunshine) more often. Further analysis would be necessary to strengthen this point. For example, it is not clear if the models provide enough information to choose the extreme classes.

It is worth recalling though that for the medium range, it is recommended to use for precipitation the median values of the IFS Ensembles instead of the IFS Hres, as shown by (CATTANI, 2014) Figure 26. However, these results do not apply to COSMO models for the short term. It must be considered that the same holds true for relative sunshine duration.

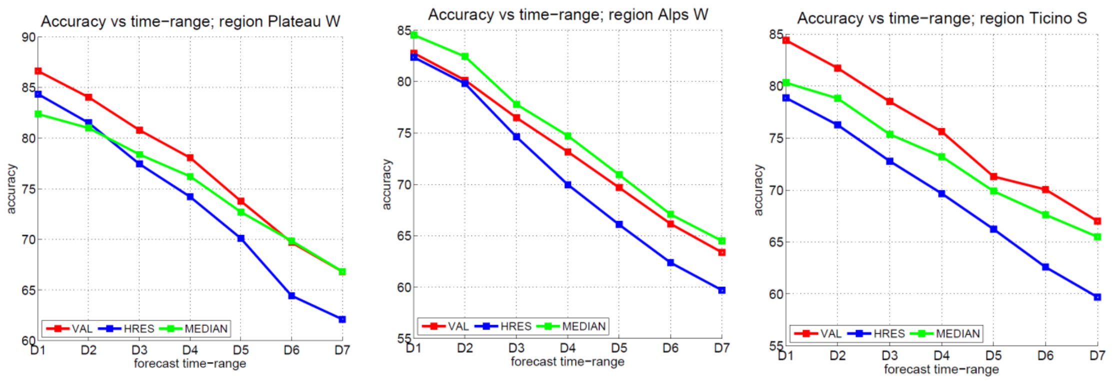

Figure 26: Accuracy of precipitation over large regions, comparison between forecasters' values, IFS Hres model, and IFS ENS Median. Analysis on 2010-2013.

6.6 Possible artefact of COMFORT ?

To persuade us that the situation we experienced in 2018 could also be linked to an artifact of the COMFORT score, we used another score (VIP) to assess the overall quality of the forecasts over the same period. Without going into details, it should be noted that the difference between VIP and COMFORT is only in the formulation of the partial score of wind; within VIP, 27 stations are used and the wind is verified in strength and direction while within COMFORT, 6 stations and wind strength only.

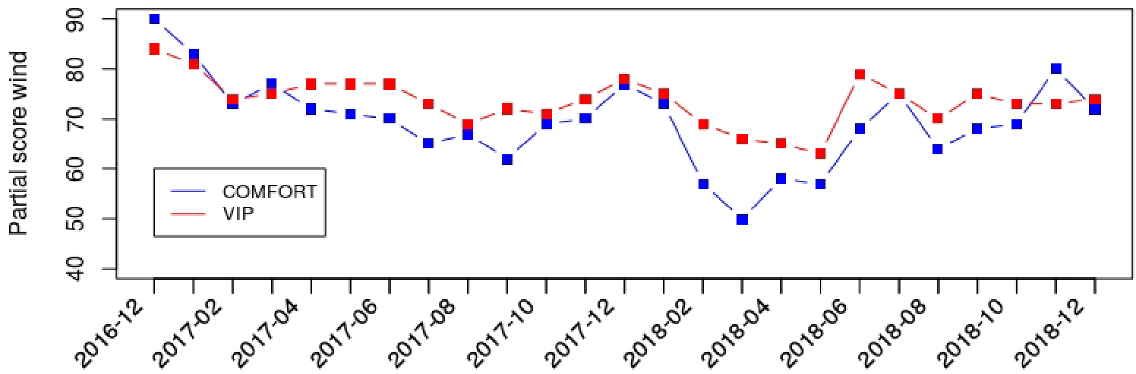

Figure 27: Comparison of monthly wind partial score for all Switzerland, as measured with VIP and COMFORT. Day+1.

Figure 27 shows that the COMFORT score accentuated the drop in wind performance between February and April 2018. While with VIP there is definitely a decrease but it could be integrated into the "normal" fluctuations of the score. We see in Figure 28 that this difference observed on the partial score of wind impacted the global score so that COMFORT reaches values below the objectives for February and March 2018, while using VIP we keep the global score higher enough to meet the target.

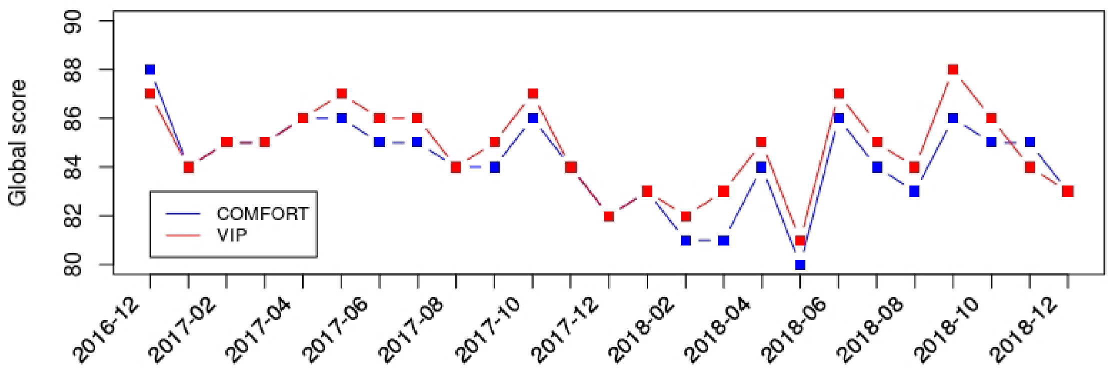

Figure 28: Comparison of monthly global score for all Switzerland, as measured with VIP and COMFORT. Day+1.

6.7 Concluding remarks

The COMFORT score is basically intended to assess the quality of forecasts on a large scale (space and time), and does not allow the quality of forecasts to be studied in detail. To have such a view, it is necessary to integrate complementary measures with other types of scores into the analysis.

Beyond the complementarity with conventional scores, it is important to note further known limits of the current verification system in order to take it into consideration for the development of a future evaluation system;

- ✓ Relative sunshine duration is measured on a limited number of stations (from 1 to 6), it is expected that a verification against gridded values will offer a better representativeness (treatment should be analog to the precipitation)
- ✓ Since precipitation is evaluated as regional average, double penalty can occur in small regions also for precipitation during convective situations
- ✓ The threshold used to decide if a wind speed forecast is useless (difference of 5 kt with observation) is too harsh.

This current study shows, that COMFORT is very sensitive to specific weather regimes, such as westerlies (in February and March) and to convective situations (in May). The combination of several such regimes within the same season or even year, can substantially degrade the quality measures of MeteoSwiss, even if the forecasters can actually compensate to some of the problems of the models. Therefore, one has to seek ways to make such a summary measure as little sensitive to weather variability as possible. On the one hand, it is recommended to use longer periods for averages. Ideally one would chose annual values or even longer periods. Further, one has to consider benchmark forecasts. Such a benchmark should ideally be based on a forecasting system that does not change over time, but is also susceptible to the same weather variability. As an example, one could use the forecasts that are calculated to generate the reanalysis time series, such as the recently operationalized ERA5, the successor of ERA-Interim. Alternatively, one could try to estimate the predictability through statistical measures a posteriori and use this information as a benchmark, such as sketched by the work of (PRAPLAN, 2014).

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