Predicting astronomical seeing in the UK

Damian Peach

During the last several years the author has had a particular interest in the prevailing seeing conditions from the three sites in the southern UK where he has lived, and presents in this paper a guide to predicting astronomical seeing with good accuracy based on his experience. The study concentrates on the general prevailing seeing across the southern United Kingdom.

Introduction

Figure 1. Image of Saturn on 2005 January 13, obtained by the author from his home in Loudwater, Southern UK, under excellent seeing conditions.

The possibility of predicting the prevailing astronomical seeing they can expect on a given night has always been of great interest to observers (especially those interested in planetary observation and imaging). This to many seems very elusive, and far more difficult than simply predicting the expected general weather conditions for a given night. However this is not in fact the case.

The author has read many times in publications, and heard general comments from observers, that the UK seeing is typically poor or very poor almost every night. Also, that the crisp, clear nights of winter are the ideal time for planetary observation, perhaps due to the thought that when the planets come to opposition in winter time they are placed well above the horizon, and the long cold nights are favourable. These statements have no foundation in reality. In fact, winter is the worst time of all for planetary observation for reasons that are outlined below. The data revealed by this study (and the notes of past observers such as W. H. Pickering), in fact show distinct seasonal variation in the UK, and many areas are more favoured than others.

It was in order to better understand the most limiting phenomenon to planetary observers that the author undertook a detailed study of the seeing from the United Kingdom. During the last six years it has been possible to learn a great deal, and forecasting facilities now exist from which valuable and useful information can be obtained.

It quickly became obvious that certain times of the year were much more favourable than others for atmospheric stability and the reasons for this will be outlined below.

The polar front jetstream and its behaviour

The long nights of winter are rarely favourable for planetary observation for several reasons. The most important is the presence of the fast-moving river of air known as the polar front jetstream. This river of air, which marks the boundary between the warm temperate air masses and cold polar air masses, winds it way across the Earth's temperate regions. This jetstream consists of a fast moving (frequently

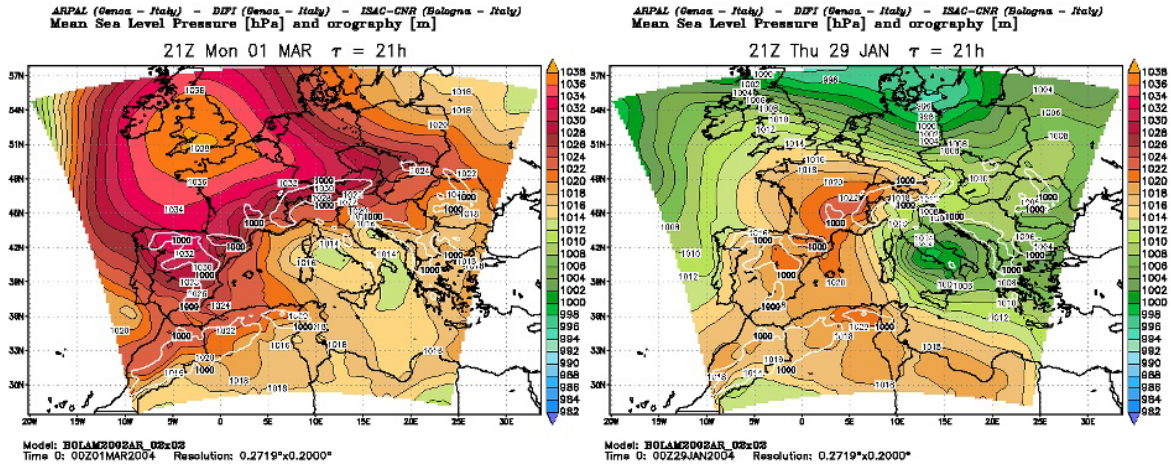

Figure 2. Two synoptic charts showing favourable and poor prospects for steady seeing conditions. The most critical observation here is that areas of stronger winds (more tightly packed isobars) will 99% of the time bring poor seeing. *Courtesy BOLAM 21km archives.*

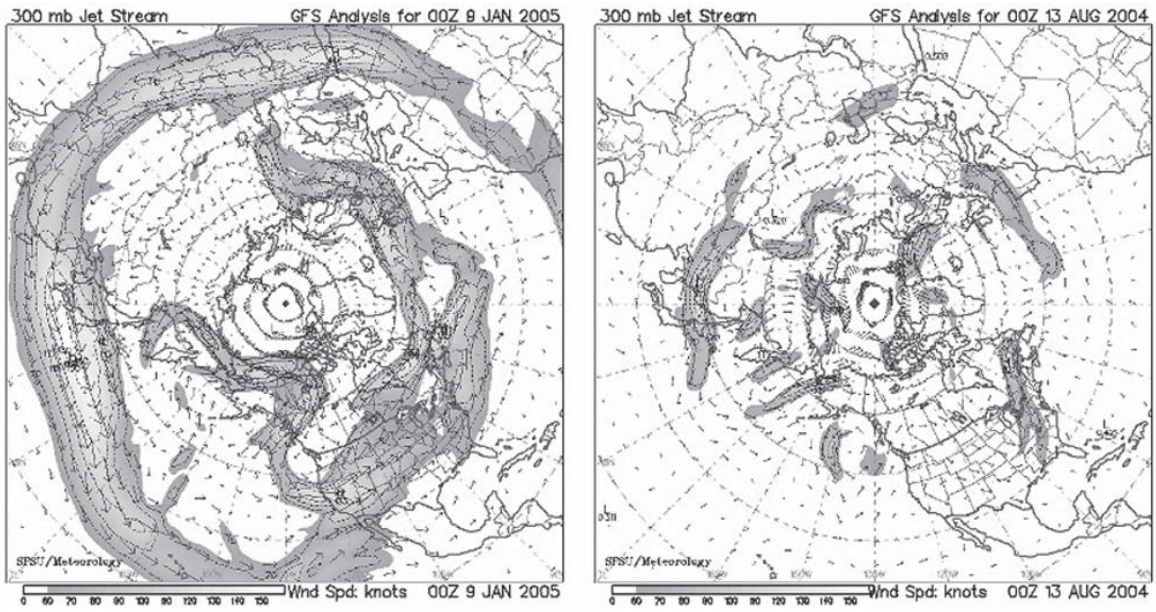

Figure 3. A map of the polar jetstream in winter and in summer. This turbulent river of air is much more prevalent during the winter months over the UK and Europe. *Courtesy CRWS Jetstream analysis.*

over 50 metres/second) turbulent air stream that is typically 400–800km wide, and encircles the entire planet between latitudes 45–65°N and S. (There is also a very high altitude mesospheric jet found at around 60km altitude. Though much stronger, with its low air density it is unlikely to affect astronomical seeing.)

The polar front jetstream is located high in the atmosphere – typically around or above 9000m (30,000ft.) During winter, when the jet is at its strongest, it is often situated across the UK. Trying to make detailed observations or images when the jetstream is present can be almost impossible. The observer will often see a very static image, that jitters little, but has continuous poor definition and contrast, as if the image were not properly focused. This is due to the fast moving turbulence outracing the eye's response time, and hence the image appears blurred, often severely so. This type of view is very common during the period from late October to late February.

At the opposite end of the scale are the months of spring, summer and early autumn, when the nights are shorter, but the conditions for planetary observation are much more favourable. Jetstreams are formed by temperature differences in the upper atmosphere between the cold polar air and the warm tropical air. During summer, the increased heating from the Sun weakens this difference, meaning that at this time of year the jetstream almost completely disappears, or becomes weak and disorganised.

During these times the best planetary definition becomes possible, especially during July to early October.

Understanding the weather and its effects

Many readers will be familiar with the BBC weather forecasts, and the information displayed on them. Of course most pay the most attention to whether the skies will be clear or not, but other useful information can also be obtained that can give a good indicator of the expected astronomical seeing on nights that are clear.

The synoptic charts that display the pressure and frontal patterns are of great value in predicting the possible astronomical seeing to be expected. The best conditions are generally experienced under high pressure systems, which tend to bring sunny weather with light winds during summer, while during winter they often bring cloud and dense fog. These 'highs' are areas of descending air, and the air within them is often very stable. It soon becomes obvious why the UK seeing is much better during the spring and summer months, when high pressure systems move over the UK with greater frequency than during winter where they often remain to the southwest of the country.

A major problem during winter months when high pressure systems occur is cloudiness. Unlike the often clear and warm hazy high pressure systems of spring and summer, those that occur during winter can bring rather different weather. The strong temperature inversion that often forms beneath high pressure systems (at around 1000m altitude) can trap cool and very moist air beneath it. If this occurs in winter, a dreary grey layer of stratocumulus cloud can form at the base of the inversion. This cloudiness can last many days, owing to the very light winds and inadequate solar heating. If clear of cloud, winter highs can bring other problems, such a severe frost, or dense fog.

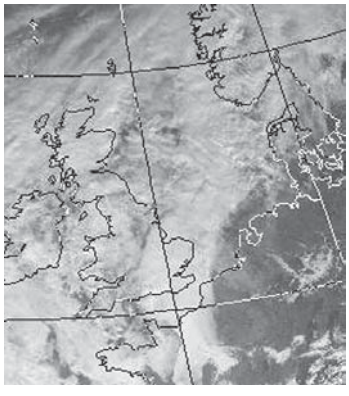

Figure 4. A satellite image of a typical cloudy high pressure system during the UK winter. If skies were clear, good seeing conditions would almost certainly be experienced. *Courtesy DSRS.*

The author can recall many such potentially good nights lost during UK winters under cloudy high pressure systems. Late night cloudiness is also a major problem due to rapid cooling of the air to the saturation point, and typically less than 50% of the high pressure systems that occur during the winter months will be clear. Obtaining good views and images during winter requires the firmest dedication to observing, and the ability to put up with many disappointments due to cloudiness.

When the synoptic charts display areas of stronger winds at sea level (be they under high or low pressure influence) these will almost certainly mean poor seeing, and areas of strong winds at sea level are quite often associated with the jetstream (though not always.) In short, the critical forecasting rule for seeing anywhere across the UK, is that areas where the isobar pattern is widely spaced meaning very light winds at both sea level (1000 hPa [mb]) and high altitudes (300 hPa level), will almost certainly bring periods of excellent seeing.

Is it possible to predict good seeing? To a degree this is possible, however the effects of one's local environment also play an important part (indeed, the observer should take every care to minimise sources of local turbulence.)

During the author's research into his own observations, it became clear that excellent seeing only prevailed under certain conditions. The two most important findings were as follows:

1. **A very low jetstream wind speed is vital.** The wind speed at the 200–300 hPa level must be below 20 metres/second.

2. **The 1000 hPa pattern must be widely spaced**, indicating very light winds at sea level. Only the far western coastal areas and Channel Islands are likely to experience good seeing under more windy conditions (provided point 1 is attained), due to the laminar airflow from the ocean at sea level.

During the author's research none of the nights of excellent seeing experienced (see Table 1) occurred under windy conditions, or when the 300hPa level wind speeds were above 20m/s velocity. Also nights when the 300hPa level wind speed is very high tend not to be the worst conditions, since the strong wind speed tends to give very stable, but rather fuzzy images.

Also worth mentioning are the comments made by past observers of seeing conditions at sunrise or sunset seeming particularly favourable. The author has also found this, with many nights that have turned subsequently poorer being much more stable at the time of sunset for example. This seems a very favourable time for observations – even when seeing is forecast to be mediocre or poor, at sunset or sunrise it is often notably better. This is likely due to a much more even temperature gradient with altitude within the boundary layer (the air layer near the surface.) As soon as cooling begins, things often deteriorate, and may improve later in the night if the 300hPa winds are low. After sunrise is the most favourable time for seeing for solar observations, and beyond midday, seeing is notably worse.

Table 1. Prevailing weather conditions on nights of excellent seeing since 1999

All observations made by the author from sites in the southern UK.

Date	*Seeing conditions*	*Sea level pressure*	*300hPa wind speed*
1999-10-06	Pickering 8–9	High 1028 hPa	12 m/s
2000-10-13	Pickering 8–10	Low 1002 hPa	12 m/s
2003-09-29	Pickering 8–10	High 1016 hPa	20 m/s
2003-12-16	Pickering 8–9	High 1030 hPa	18 m/s
2004-03-01	Pickering 8–9	High 1036 hPa	20 m/s
2004-04-14	Pickering 8	High 1018 hPa	12 m/s
2004-10-01	Pickering 8–9	High 1020 hPa	17 m/s
2004-12-11	Pickering 8–9	High 1026 hPa	12 m/s
2005-01-13	Pickering 8–9	High 1032 hPa	14 m/s

Sources for forecasting seeing and how to use them

Fortunately in today's world of the Internet, many sources are available to help predict the astronomical seeing with good accuracy. Many detailed and frequently updated forecasts exist primarily for the aviation industry, as commercial aircraft frequently fly within the jetstream altitudes.

One of the most useful and easy to understand pages is operated by the Unisys Weather Corporation and this is explained in more detail below. It can be found at:

http://weather.unisys.com/aviation/index_eur.html

Other pages showing similar analysis can be found here:

http://grads.iges.org/pix/euro.fcst.html
http://www.meteoliguria.it/tabbolam21.asp
http://squall.sfsu.edu/crws/jetstream.html

Here is found a six panel graphic that displays information on the prevailing pressure situation across Europe. Particular attention should be paid to the sea level forecast, and the 300hPa high altitude forecast. The author finds that the forecasts are very accurate indications of what the seeing will be like in practice.

The 300hPa charts are perhaps the most interesting and important. These charts show the high altitude wind speeds represented by coloured areas, with red, green and yellow areas meaning high wind speeds (and turbulence) while blue and pink represent low wind speeds (and more stable air.)

The author's seeing forecast page: **http://www.damianpeach.com/forecast.htm**

The author's Pickering scale animations: **http://www.damianpeach.com/pickering.htm**

Conclusions

It is evident from the research that the 300hPa wind speed prevailing across the UK is perhaps the most important indicator of how good the seeing will be. This of course explains why the seeing is so much better during the spring and summer months. We are also fortunate in the southern UK that no high mountains exist to disturb the airflow, for this

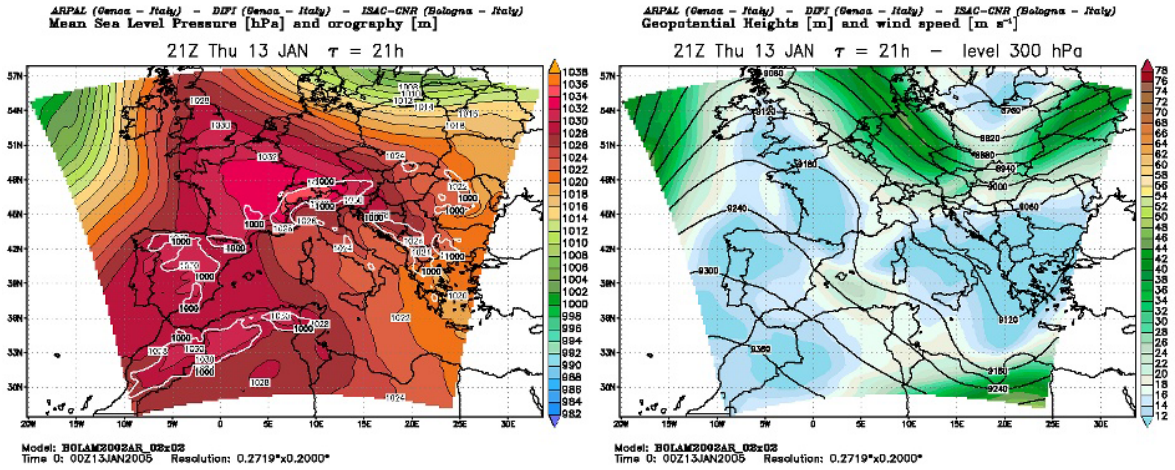

Figure 5. These two charts showing the sea level isobar and wind patterns (1000hPa) at left, and the high altitude jetstream level wind patterns (300hPa) at right, reveal in detail how stable the prevailing air masses are. These charts show a time when excellent seeing prevailed, under which Figure 1 was taken. The charts show the forecast conditions for 12h and 00h each day. *Courtesy BOLAM 21km archives.*

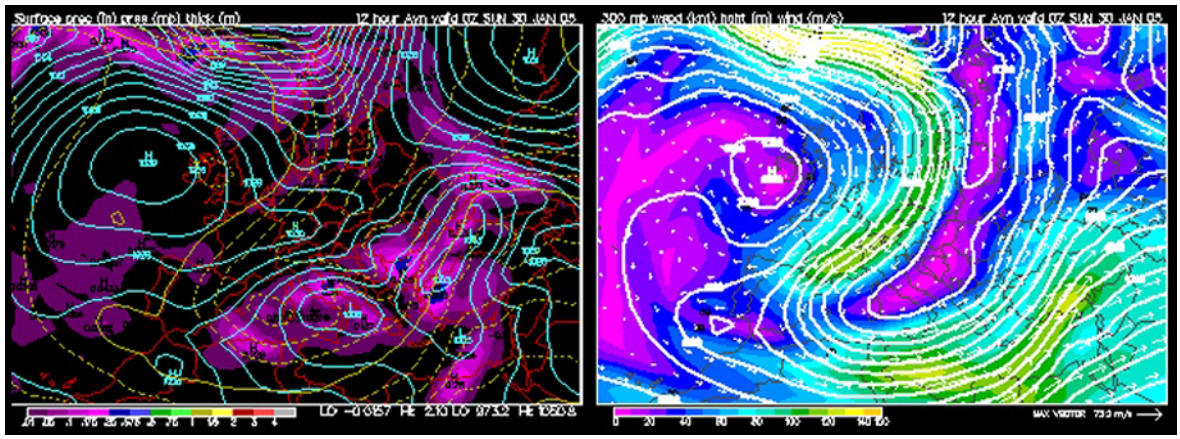

Figure 6. An example chart from the Unisys weather pages showing the sea level pressure (SLP) and 300hPa wind speed/pressure situation. The charts are issued at 12 hour intervals. *Courtesy Unisys.*

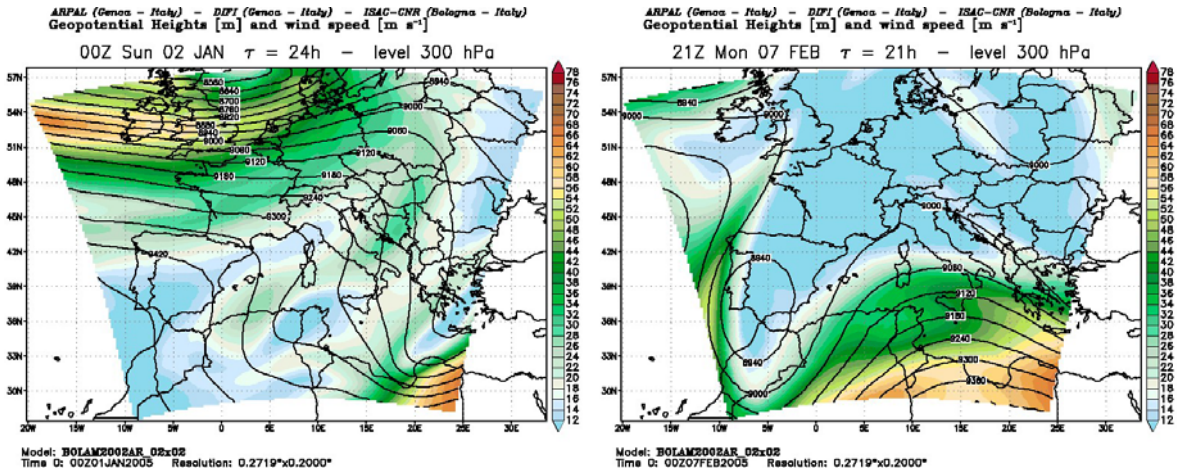

Figure 7. Two example charts showing typical good and poor seeing situations at the 300hPa level. These situations are present on almost every observation made by the author. *Left:* 2005 January 1. A night of very poor seeing due to strong winds at the 300hPa level. *Right:* 2005 February 7. A night of excellent seeing due to very light winds at the 300hPa level. *Courtesy BOLAM 21km archives.*

can complicate seeing prediction tremendously.

It must be stressed that, as normal weather forecasting can never be 100% accurate, this is also the case with forecasting seeing. Observers located at more rural open sites have an advantage over those in built up city areas, however under the typical conditions that bring steady air across the UK (light winds, with high humidity) the differences between those in urban areas and those in rural areas will be small.

The author hopes observers will find the information useful in making better use of observing time, and knowing when to expect those tranquil nights when breathtaking views of the planets become possible.

Address: c/o British Astronomical Association, Burlington House, Piccadilly, London W1J 0DU. [dpeach_78@yahoo.co.uk]

Received 2005 January 30; accepted 2005 March 30