The Human Element in Forecasting - a Personal Viewpoint

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Introduction

"It should have been obvious all along that the fog wouldn't clear..."
"Why didn't the previous shift issue the thunderstorm warnings sooner?"
"Why have we been lumbered with those snow warnings that were clearly overdone?"

How often have we asked such questions of colleagues, or even ourselves, on a forecasting shift? And what lessons can we, as forecasters, learn, not so much about the meteorological science, but how we approach decision-making?

Even though meteorology has developed into a rigorous science, the inherent uncertainty in many situations means that a variety of different outcomes can usually be envisaged especially in a finely-balanced situation. Therefore a judgement call is usually required. In an ideal world that judgement should always be balanced and analytical, based on hard evidence as well as intuition. But human factors come into the equation. Depending on each individual's respective memory-base a bias can be reinforced or reduced. Some of the human factors that influence that judgement call are addressed here.

For example, are you 'comfortable' with the decision to have or not have a warning out, given the criteria worked to? We all have different natural comfort zones given the same scenario. Do we force ourselves to re-examine the story at intervals during the shift and challenge preconceived ideas? It is easy to become overwhelmed by rapidly evolving events. Or on a quiet day the eye can stray from the ball and you can miss something obvious which can give a totally different 'feel' to the day.

In addition the whole forecasting process can unwittingly encourage rigid thinking especially with the pressure and quantity of work in a modern working environment. There is also the tendency towards so-called 'groupthink' – people reinforcing ideas amongst each other with inadequate debate since this is often the easiest option. Much of the success of a forecasting shift is therefore down to the combination of individuals on duty and their own styles and, most importantly, the quality of leadership. Many experienced Lead Forecasters recognise these all-important psychological aspects without necessarily realising it. Examples are addressed in turn in this paper.

Whilst a thorough underpinning meteorological knowledge should be a pre-requisite, *this paper aims to provide an insight and awareness into the all-important human factors that can influence the decision-making process*. Whilst other authors (e.g. Doswell 2004) have addressed decision-making in weather forecasting with the help of cognitive psychology, this paper uses examples (largely derived from the author's personal experience) to identify some potential pitfalls and barriers to effective decision-making along with how to overcome them, thereby optimising the role of humans in weather forecasting.

Stand Back and Take Stock

This involves examining the 'big picture'. Before getting down to the details of what is actually happening on the day it is often helpful to stand back and ask yourself the question "What usually happens in this type of weather scenario at this time of year?" This immediately reduces the risk of missing something obvious in the rush to get on into 'production mode'. For example, at the most basic level, for an upper trough over the UK in spring or summer – think 'heavy showers with thunder and possible convergence zones' or for a winter anticyclone – think cold with risk of persistent fog. This involves an element of 'creative thinking' which does not come easily once you are bogged down with the smaller-scale details, or indeed if you come on shift to a rapidly changing situation necessitating the immediate issuing of warnings. This 'standing back' approach is what the wisdom of an experienced forecaster should bring.

It is very important to look at the bigger picture before diving into the detail because there are usually broad-scale drivers, the behaviour of which may in turn have a large impact on the weather in a local area. Understanding these drivers should allow a clearer assessment of the uncertainties in the forecast and how these might affect the forecast in the area of concern.

The approach of standing back also helps avoid a 'collective amnesia' which can sometimes occur in the context of seasonally-dependent effects. How often have people been caught out or at least somewhat surprised by the first inland deep convection in spring, the first persistent autumn fog, the first snow or icy roads scenario or the first sea breeze of the year? A year can be a long time in meteorology – in an ideal world a brief training refresher every 6 months or so could be beneficial as a reminder of common seasonally dependent factors. It is also very important to keep 'thinking outside the box' i.e. adopting the approach "what can go wrong?" This largely only comes with experience.

This 'standing back' approach also applies to more thinking about impacts. For example, "which customer groups will this weather affect and – have they been told?" Not fulfilling this final step can be frustrating to all concerned when the message conveyed by a good forecast, or even just a change in emphasis, fails to get the through to the end user to act upon. It is no good keeping information to oneself!

Information Overload

An ever-increasing range of new products and model diagnostics are being brought on-stream and the task of sifting through for the most pertinent information for the day becomes ever more daunting. It can be very tempting to be prescriptive and look at standard set for ease of operating – but of course each situation demands different products. An effective forecaster will ask "what are the key diagnostics of the day?" Rapid decision-making using just a small but relevant range of key products may be often called for.

It is easy to focus in on the smaller scale details at the expense of the bigger picture. The opposite also true; one can be busy focusing attention on one larger area of interest that catches the eye and not spot something developing elsewhere. It could be as subtle as an error in model cloud fields (which might impact on the coming night's minimum temperature) or something major such as a small intense thunderstorm. Indeed that small area of radar echoes consisting of just a few bright pixels could be causing havoc in highly localised areas as was illustrated powerfully in the Boscastle floods in 2004 (Golding et al. 2005) and the Ottery St Mary storm in 2008 (Grahame et al 2009). This illustrates the danger of the eye being drawn away from the tiny area where the real and potentially newsworthy problems are occurring. With increased centralisation of forecasting services we must still remain vigilant to local detail. During periods of intensive production workload there is a danger of missing something, especially in rapidly changing situations.

There are other manifestations of the information overload syndrome; for example when looking a day or more ahead one can fail to spot something important in the short term. This classic conflict can readily occur when needing to consider severe weather several days ahead at the same time as significant events or uncertainties in the next few hours also demand attention.

The Media Roller-Coaster Syndrome ('killer storm to lash Britain!')

With dramatic advances in Numerical Weather Prediction (NWP) in recent decades we are now capable of identifying the potential for significant weather many days ahead. Now that this information is in the public domain (owing to the plethora of NWP products available free on the web) combined with many different providers of forecasts, there is little chance that even a small risk of something newsworthy won't be picked up by the news-hungry media. Once a severe weather or high impact event is in the media (or in the general consciousness of the public) it's very hard to go into reverse gear and subsequently play down a scenario that might look less likely with later information.

A typical instance may involve a potential windstorm situation in which as we get nearer to the possible event, successive NWP model runs take the associated depression on a different track or play down its intensity such that the risk becomes confined to a much smaller part of the country or the expected event might not happen at all. By this stage, based on earlier more severe predictions the media roller-coaster will probably have gathered an almost unstoppable head of steam. Because of the inherent difficulty of backtracking once a severe weather story hits the headlines it is normally considered safer to adopt the philosophy of starting with a low risk then cranking it up. However, when probabilities are falling, at what point do you cancel? If the nominal probability threshold for issue is, say, 50 percent, in practice everyone agrees that it has to fall a fair bit lower before cancellation, though this is often a subjective decision. Although these scenarios may not properly reflect what we consider to be the 'real probability' of the event occurring it is just one way of manipulating and managing the message which becomes an important priority. To assist in managing the message the National Severe Weather Warning Service at the Met

Office (Goldstraw 2012) allows for giving a low risk of a high impact event as was put to good use in the case of a potential storm on 15-16 December 2011 (Fox et al 2012).

Post-storm Neurosis

'Post-storm neurosis' refers here to the danger of over-reacting to circumstances having just had a severe (or perhaps a 'missed') event. One aspect of this does arise from real sensitivities that arise after a severe event. For example, further but less severe conditions can hamper the recovery and clearing-up process, whilst already full river-catchments can become overwhelmed once again leading to further flooding. Another aspect arises from intense media interest in an area already under the spotlight. This in turn can lead to an extreme sensitivity in being seen to react by issuing warnings – especially if the major initial event was perceived (rightly or wrongly) to have been missed in the eyes of others.

I first remember being aware of post-storm neurosis in conjunction with the 'Great Storm' of 1987 over southeast England (Prichard 2012). I recall that for many weeks afterwards, wind kept being stressed as a key element of the forecast, part of the reasoning being that trees and structures weakened by the major event would succumb more readily to a much less severe set of conditions. A 'devil's advocate' could argue that perhaps the complete opposite applies – all the 'dead wood' has been cleared out. It may be after long period of relatively quiet weather that the dead wood and weak structures are all primed to fall. A subsequent wind (or even a wet snow) event which would normally be relatively benign in its impact could then cause problems.

On occasions when an important event has been missed and then a warning is issued for a separate, less severe, event later in the day (though still expected to cause some disruption), a crisis of perception can follow manifested in various ways. In one such case (Sibley 2009) the author recalls a flurry of derogatory comments appeared on newsgroups such as "have they only just noticed it's raining?" This probably reflected the wider public perception and highlights a further consequence of missing a major event. Another consequence of issuing a severe weather warning soon after (perhaps by only hours) a significant event has been missed is the risk of causing consternation amongst the responder community. The interpretation could be along the lines "this event must be going to be bad, even worse than the last event which did not even merit a warning". So it is vital to consider whether the warnings will achieve anything useful and whether there are alternative means of communicating the message.

Equally a major forecasting success can potentially imbue a false sense of confidence for an event that immediately follows. For example, an over-forecasting of snow across northern England in early February 2009 followed a major success in forecasting a seriously disruptive snowfall over London the previous day. I believe that the success of the first forecast may have led to over-confidence in the assessment of the subsequent event which occurred under more marginal meteorological conditions. In contrast, a false-alarm warning can lead to something of a 'paralysis' immediately afterwards – the perception of not wanting to make the same error twice. So the temptation could be to hold off issuing a warning, having been influenced by the earlier unsuccessful forecast – resulting in an inconsistent approach.

We must therefore examine each meteorological event independently (remembering of course that the impacts from one event may often influence the impacts from the next one and the degree of response required).

Groupthink and 'False Analogy' Syndrome

The whole forecasting process can unwittingly encourage rigid thinking, especially during periods of intense workload. There is the danger of so-called 'group think'– people reinforcing ideas amongst each other without adequate debate since this is often the easiest option. The message is to *encourage debate*. This might not be what you really wish for when you think you've got a good story - everyone is under pressure and the story might have already been discussed and agreed to earlier by a committee of people (and you're about to send the warning!). Later information then comes in, perhaps casting doubt and leading to second thoughts. It's important to discuss these second thoughts before pressing 'send' rather than just afterwards! There is also a problem with the group dynamic in that the more people involved in a decision whether or not to warn, the more likely you are to err on the side of caution/pessimism, because there can be a reluctance to override a pessimistic voice just in case they turn out to be right and say "I told you so".

In an ideal world a meteorological judgement should always be balanced, using both analytical and intuitive skills based on one's own experience as well as that of colleagues on shift. The problem is that each

individual's experience and memory of meteorological scenarios is highly selective since we can all possess only a tiny subset of the total knowledge-base of past cases. The chances are that these knowledge-bases will overlap to contain the same, usually high-impact, events. This can reinforce the bias towards 'group think'. We can more readily recall such events rather than the 'non-events' or false alarms that almost without exception, get overlooked. Therefore our knowledge-base is naturally skewed towards severe events with the consequent danger that using these as analogues can lead to over-estimating the risk of a severe event. Therefore it is vital to be objective and assess each case on its merits and ask instead – "which aspects are different this time?", and additionally, to remember some false alarms! In an ideal world the knowledge-bases of individual forecasters would be non-overlapping so that each person's experience would be different, offering a broader range of analogues and therefore better-balanced group judgements.

A human strength is to work by analogues with past events, but the only sure thing is that 'it won't happen exactly like last time'. We must also be alert to 'false memory syndrome'. We nearly always remember things differently and it is well-accepted that an individual's memory can become distorted over time (Tavris and Aronson 2008). Very often a situation will be different from how one remembered it and can lead to a false analogy. Whilst Doswell (2004) also raises concerns regarding representativeness and sample sizes in the context of analogues and pattern recognition, I believe that forecasting by analogues and conceptual models remains a vital component in assessing NWP output, indentifying likely hazards, identifying possible alternative scenarios and, in some cases, adding smaller-scale detail.

Halo (Horns) Effect

This so-called 'halo' or 'horns' effect involves preconceived notions about an individual's abilities or traits. It may be manifested by, for example, not questioning the judgement of someone respected. No individual is infallible. By the opposite token, someone who is perceived as a maverick and having a reputation for 'going off at a tangent' (and perhaps being wrong on the majority of instances) can be right on that one critical occasion – even if by chance! There are also personal biases; the natural optimists versus pessimists, degree of risk averseness etc. Understanding these character traits (if correct) in other forecasters (and indeed oneself) can allow one to assess the weight given to their point of view.

Go For It! (or 'let's wait until the next observation comes in!')

When do we jump and issue a severe weather warning? There is a trade-off between giving adequate lead-time (to allow the recipients sufficient opportunity to take appropriate action) and waiting until we are sufficiently confident that the event might actually occur (i.e. avoiding a false alarm). However, the most difficult decisions are often the 'no warning' decisions – because it can leave one feeling 'exposed' if conditions do then unexpectedly deteriorate.

Consistency of approach will always be a problem in any situation where human judgement is called for. Some individuals are perceived to issue warnings very readily ('trigger-happy') whilst others hang back (or as they claim 'hold their nerve'). This appears linked to some individuals being seen as pessimists and others as optimists and reflects a different interpretation of risk between these individuals.

The philosophy of "let's wait and see ..." (or "let's wait until the next observation comes in") can represent an inertia (or paralysis) problem. There can be a reluctance to issue warnings for potentially severe events. This is sometimes manifested by the response from colleagues (either in the same office or at another forecasting site) "let's see if we get any reports...". Such a response can act as a check on unwarranted impulsiveness. However, the problem is that by the time something has occurred and the reports of weather impacts have filtered through, the damage is largely done.

A big problem can be the sudden onset of certain severe weather events. A developing Mesoscale Convective System can do most of its damage (in terms of flash flooding and lightning) in the first 30 minutes to an hour of its existence. With the usual time-lag between relevant imagery coming in, making the decision and warning dissemination time (allowing for possible technical problems just at the wrong time) this adds extra delay and can be critical. By the time the emergency services are reporting problems it is too late.

Therefore it can sometimes be counter-productive to 'wait until the next observation comes in'. In small-scale heavy convective rain, the observations often miss the intense cells anyway – short period integrated radar rainfall forecasts can be very helpful in this respect. Such scenarios are always a difficult judgement call, but at least we can still warn areas in the downstream firing-line even if we miss the onset of the initial event.

Solutions to individuals' variation of approach might focus on consulting colleagues as well as the use of objective probabilistic (e.g. ensemble) products. Personal verification scores might help. Individuals could then see their biases and hopefully modify their behaviours accordingly, resulting in greater consistency of approach to warnings.

Holding One's Nerve

How long do we hold onto a story which might just be starting to go wrong? How strong have the contra-indications got to be and how confident do we need to be before we start amending or updating existing forecasts or warnings?

There are many examples. One such example is waiting for thunderstorms to develop in the late spring/summer in a convergence zone. Predicted activity may only spark off in early evening just when you are beginning to lose faith –do you 'hold your nerve' or cancel a warning already in force? Another may be long-awaited overnight fog eventually forming suddenly after dawn when you might have just about given up on it.

NWP models can present similar dilemmas. Following a sequence of similar model solutions, a new run then throws up a significantly different story and a decision has to be made whether to accept it or not. Confidence regarding whether to accept the new story depends on a number of factors. For example, is it safely within the range of solutions offered by an 'ensemble' (Richardson 2011,Young and Hewson 2012) or is it close to (or even beyond) the 'statistical tails'? What are the risks involved in changing the story? Might it later have to be changed back resulting in a 'flip-flop' in guidance – a scenario guaranteed to undermine the confidence of customers? If the change is over four days ahead it is usually preferable to await confirmation from models from other forecasting centres. If the change is only 12 hours ahead it will often require a bolder decision, especially if severe weather is involved. It usually requires a careful consideration of the risks involved based on available evidence.

A psychological phenomenon can occur whereby as a possible weather event approaches, the forecast can remain the same, but people's nerve can break. For example it might be expected that fairly widespread snow is expected but probably not heavy enough to cause serious disruption. As that fairly widespread snow becomes a reality and it is realised that it does not take much to tip the balance to something worse, people can become more risk averse and issue warnings even when there is no substantive change to the forecast - this is more likely to be done by an oncoming shift.

Denial (Versus Keeping an Open Mind!)

Imagine the scenario. Having spent the forecasting shift building up a picture of what is happening and perhaps feeling you have staked your reputation on having ruled out certain alternative possibilities, an observation comes in which is at odds with your expectations. This can come as a particular blow (or perhaps even humiliation) if arrived at after a vigorous debate in which you've persuaded reluctant colleagues that the development was unlikely.

There can be a temptation to dismiss the observation. In some cases there will be an element of justifiable doubt if the observation has a chequered history. I recall one senior forecaster trying to persuade a meteorological observer that a thunderstorm he'd reported could not be occurring at his own station. I also recall a small radar echo being dismissed as spurious only minutes before that echo produced a severe overhead thunderstorm. Perhaps apocryphal was the tale of a meteorological assistant forced to dump a pile of snow on the forecaster's desk at London in a desperate attempt to persuade him of the deteriorating conditions outside – all these events occurred many years ago it must be said, but are extreme examples of a failure to be open-minded.

Heads Down!

When you're really busy in production the eye is often 'off the ball'. Changes can be subtle but have major impact. For example, unexpected showers appearing on the radar at the end of a night with sub-zero road surfaces could lead to widespread unanticipated 'black ice' and many road accidents.

This is particularly the case in complex or high impact events. Just when someone needs to be keeping an eye on what's going is when everyone is busiest issuing or updating warnings, amending forecasts, dealing with phone calls, requests for extra interviews, telephone conferences etc. More often than not, with the usefulness of medium range forecasts, the event will have already been predicted and acted on but it doesn't stop subtle things changing in the final hours before or even during the event e.g. rain not being quite as intense, snow affecting a slightly different area or winds not quite as strong as originally expected.

There is the risk of having insufficient opportunity to examine the very products that could be useful e.g. latest high resolution NWP or radar products. Conference or interview overload sets in and this can really distract – especially when having TV crew around all wanting a slice of the sensation/action and spinning up the story. In such situations it is vital for the Lead Forecaster to try and take a 'bird's eye view' amidst the pandemonium and delegate work or, better, anticipate the situation and call on additional emergency resources in advance to monitor developments. It is also very important to keep 'thinking outside the box' by adopting the approach "is the story still proceeding as expected?"

Take a Break!

An inevitable consequence of information overload is the need to keep up with the constant stream of new information and data. An optimum amount of the right information needs to be assimilated to enable the most-considered judgements to be made. The temptation becomes strong to be 'chained to the workstation' to avoid missing something but this can lead to progressively inflexible thinking, perhaps failing to spot the obvious contra-indications. Even just stepping out for five minutes can bring fresh ideas to mind that can provide insight into e.g. the story going wrong or an additional product to examine. Recognising when one's attention span has lapsed and taking a break helps to force oneself to re-evaluate the story at intervals. 'Flashes of inspiration' sometimes occur when the mind is allowed to wander, even for a short time.

Change of Shift Syndrome

This often involves a natural winding-down process and failing to spot things going wrong towards the end of a shift. This can manifest itself as, for example, rain turning to snow, or thunderstorms suddenly cropping up. How often have you noticed that 'rogue' observation just when handing over... the 15mm in an hour somewhere when we'd held off issuing a heavy rain warning, or the sub-60m visibility that suddenly appears at dawn in winter which so often coincides with handover time!

A strong temptation can be to "wait until new shift takes over". Shift changeover time can be notorious for the story going wrong. During the time taken to handover and log off and on to a workstation, the weather may not be being monitored actively. When forecasting on a national scale, it takes a while at the start of a shift to gain a fully integrated picture of what is going on because of the atmosphere's inherent complexity and so much data to take in This can potentially add to the duration of this 'dead period'.

The oncoming shift can sometimes be forced into the situation of rapidly-considered 'on the fly' decisions if things have been allowed to drift at the end of the previous shift. However, judgement calls made in such circumstances are usually correct because they are based on what is already evident and should arguably have been noticed an hour previously! However, we still have to be wary of discarding an earlier story entirely, only to discover on closer reflection that some major element of the existing story was OK because of the time/opportunity the previous shift had invested in arriving at it.

The fresh eye coming on shift often spots something that no-one else has. In a similar vein it's amazing how often a forecaster on an admin duty just walking around (or the oncoming shift) can spot something you hadn't thought of when standing aside from the hurly-burly! I remember when a well-known television presenter used to come for briefing at London in the early afternoon or in the small hours of the morning he could readily spot other possibilities/scenarios or a story beginning to drift in the middle of everyone else's shift.

'Meteorological Cancer' and the 'Reality Check'

'Meteorological cancer' (Snellman 1977) essentially refers to being a slave to the NWP model. This could be manifested by automatically following latest model run or indeed opting to follow the best-packaged or most easily viewed product. Although NWP models are now generally extremely good we must still remember to look at the observations and other independent information. Back in the 1980s models were often badly in error e.g. under-deepening of depressions, failure to forecast convection and snow etc. Hence in that era forecasting skills were regularly invoked to make major changes to model predictions to avoid a serious forecast failure. With the advent of far superior models and a generation of forecasters having grown up with these, there is now a risk of 'dot following' or blindly accepting the latest model run and missing subtle but important shortcomings.

It is therefore important to periodically apply 'reality checks' (otherwise known as 'rules of thumb' or 'heuristics') when relevant. These might include tradi-

tional forecasting tools at our disposal e.g. statistical min/max temperature methods (independent of the model), using tephigrams to assess depth of instability and fog points. A critical attitude is essential. For example, ask "does the latest model output match the rainfall radar and satellite imagery, or latest buoy observations?"

In some cases, the reality check may only occur on stepping out of the building on finishing a shift. For example in springtime, over central England, seeing overcast stratus and spots of drizzle accompanied by a stiff NE wind in the morning leads to the immediate conclusion that the predicted early diurnal clearance just won't happen. One can argue that a lack of contact with human observers who can 'sense' more than just the raw readings, has contributed to a 'detachment' from the weather which I believe presents a risk in a large centralised environment. Other examples include only appreciating how widespread or dense the fog is on driving home, seeing the snow beginning to gather, or noticing the cumulus tops looking ragged and evaporating, indicating dry air aloft, when you had been expecting heavy showers to be forming. The realisation is usually instant, often correct – but too late!

Stock Phrases Perpetuating a Myth

These largely result from 'cardboard cut-out thinking' and prescriptive ideas applied indiscriminately in an inappropriate meteorological context. At best, this reflects a laziness of approach and at worst insufficient understanding of the relevant processes.

Thankfully, with the spread of knowledge, the understanding of mesoscale meteorology and high resolution models as well as rigorous professional training we are gradually overcoming this problem. However there follow some actual examples in italics, with countervailing argument in brackets, of inappropriate generalisations that I have occasionally heard repeated through the years in scripts for the UK:

"Showers heaviest and most frequent near west coasts." True in autumn/winter (but not inspring/summer where clearances often occur on coasts in unstable airmasses)

"Any mist or fog will quickly disperse"' (....but it's now early autumn or the fog is 200m deep and will persist well into the morning!)

"Showers will die out this evening" (...but there's a small vortex aloft so showers will continue overnight even inland)

"Risk of snow, especially on hills' in a situation where it is just as likely at low levels.

"More cloudy on the east coast" in a NE'ly airstream (but.. the cloud often extends a long way inland also)

"Windy, particularly on west coasts" (but what about lee effects in eastern areas which can be more significant?)

"Warm in the south but rather cool in the north"..... are these comparisons to long term averages (higher in the south than the north) or an attempt to describe the 'feel' of the day?

Key learning points

The following key messages, aimed at Lead Forecasters, emerge from the foregoing discussion:

- Encourage open debate - value the opinions of your trusted critics – avoid groupthink
- Encourage others on shift to be your eyes and ears – especially those who happen to be less busy.
- Foster the ability to maintain a 'detached' objective view and to remain calm.
- Revisit the story at regular intervals during a shift, and especially towards the end – this helps avoid 'shift changeover syndrome'. Above all, keep an open mind.
- Think 'outside the box' by adopting the approach "what can go wrong?"
- Avoid the immediate temptation to dismiss that 'rogue' observation.
- Don't necessarily jump to a new forecast based on the latest model run -treat the latest run of a good model seriously but keep in mind any weight of evidence for the existing story.
- Consider the risk in changing (or not changing) the story. Avoid the 'flip-flop' effect.
- What is likely to be the customer's perception of the weather – what is the 'feel' of the day?
- Carry out a 'reality check' independent of the model if possible.
- Accept that things do go wrong – a certain amount of hindsight investigation is a valuable learning tool and makes one aware of alternative developments. A good forecaster accepts failure but is never satis fied with it.
- And... if you think the story is going wrong at the end of a shift, come clean, hand over and get out of the door quickly!

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