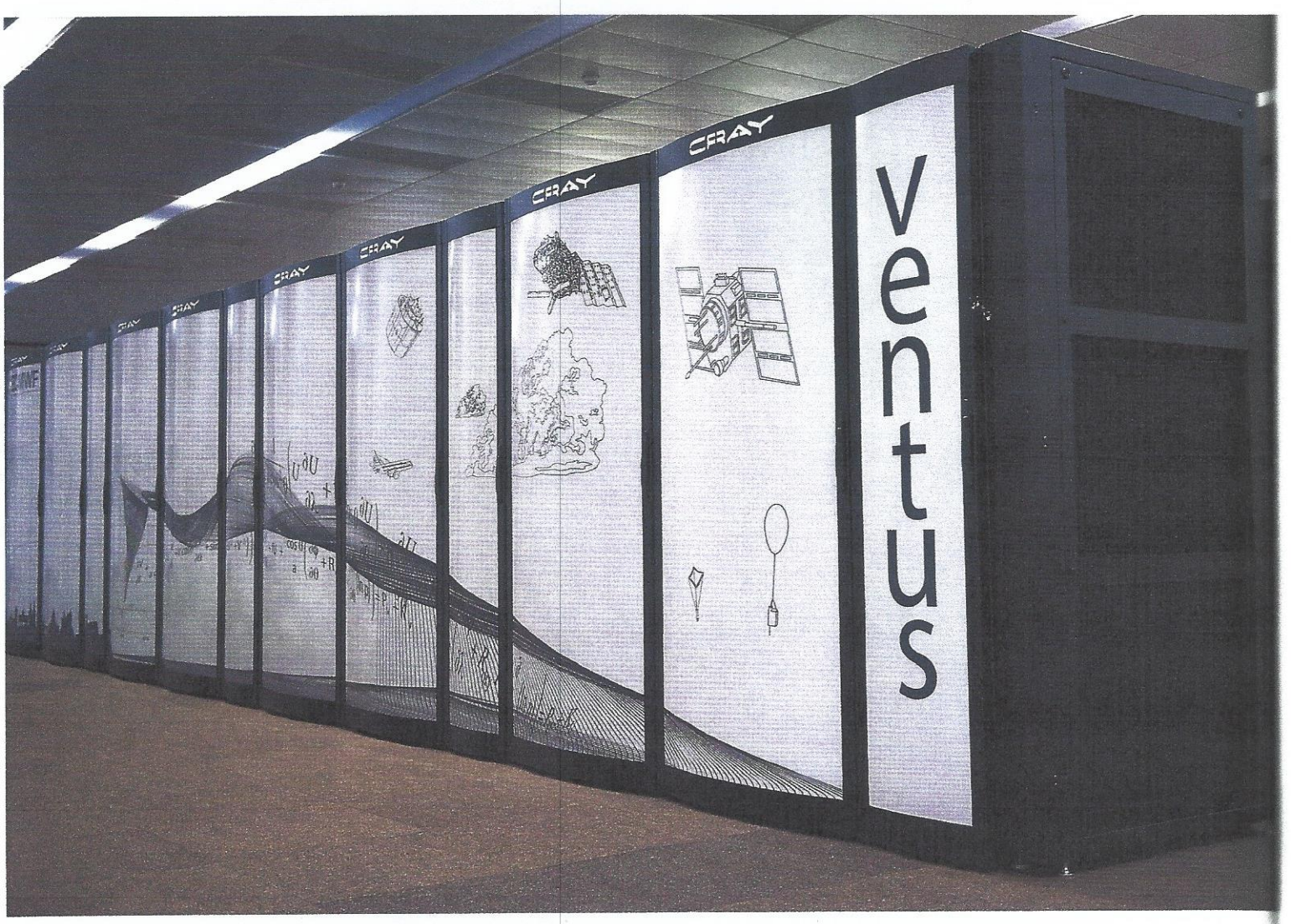
The WEATHER CENTRE

"Sunny with light winds, showers later..." Ed Ewing heads to the European Centre for Medium-Range Weather Forecasts in England to meet a super-computer that weighs 50 tonnes and a scientist who looks at the sky with a pilot's eye...



The Supercomputer

▲HEAVYWEIGHT POWER
One of two identical Cray XC40 clusters in ECMWF's high-performance computing facility. Each cluster has 20 cabinets of compute nodes and 13 of storage and weighs more than 50 metric tonnes. Combined performance of the two clusters is about 8.5 petaflops peak and 320 teraflops sustained performance
Photo: ECMWF

▶DATA FIX
The Weather Room, where global weather data is visualised on a wall of screens
Photo: ECMWF

◀◀BUILDING CLOUD
Big clouds building at a competition in Italy. Predicting flying weather is difficult, but it's getting better
Photo: Marcus King

In early June I was lucky enough to meet the 49th largest supercomputer in the world. It's dedicated to creating the most accurate weather forecasts on the planet and it's on its own office floor about 60km west of London.

Xavier Abellan Ecija, a user support analyst at the European Centre for Medium-Range Weather Forecasts (ECMWF) showed me around. "What is your background?" he asked politely, trying to gauge what level to pitch all the tech-talk at. We decided "basic" would do, and he pushed through the door.

"We have two supercomputers in this space," he said, talking above the constant industrial whir of the cooling system. "We have two for redundancy. We are an operational centre, so we want to be sure we can deliver forecasts every day of the year."

He waved beyond the 50-tonne supercomputer – made up of long cabinets like a dozen vending machines in row. "At the back we have a room with our long-term archive. It's a tape library which holds everything we have produced since the beginning, and all sorts of data sets that go beyond that."

Set up in 1975 as an independent intergovernmental organisation, and now supported by 34 countries, the European Centre for Medium-Range Weather Forecasts is both a research institute and 24/7 operational centre. When it was founded, the aim was to go from being able to forecast the weather two days in advance to a full seven days.

It now employs 350 people at its base in Reading, outside London in the UK, and its job is to produce medium-range weather forecast data for the entire planet – up to 10 days ahead at high resolution, 15 for lower resolution. The countries that fund it have access to the information; plus ECMWF sell the data to commercial subscribers around the world. It's not cheap – it costs about £250,000 a year to get access.

When the centre was set up the satellite age was just beginning, and weather forecasts were mainly made by collecting data from weather balloons and ground stations. Now, 95% of the observations in a weather forecast comes from satellite data. That satellite data – along with observations from weather balloons, planes, ships and buoys at sea

– is then fed into a computer model, which then creates a weather forecast.

There are only a handful of organisations that do this on a global scale. The Global Weather Forecast, developed by the National Oceanic and Atmospheric Administration (NOAA) in the USA is one. It produces the Global Forecast System (GFS), runs four times a day and produces forecasts for up to 16 days in advance.

The ECMWF is another. It produces the Integrated Forecast System (IFS), runs twice a day but to a finer resolution and produces forecasts up to 10 days in advance. Other nations have their own systems too.

The different models can give different results, and there is quite a degree of competition to see who predicts the weather the best. It is generally accepted that the ECMWF's IFS model is the gold standard – it resolves the data to a sharper resolution (9km squares across the planet versus the GFS's 22km squares).

This matters more than you might think. In 2012 for example, the GFS model predicted that Hurricane Sandy would turn out to sea four days before landfall; the ECMWF model correctly predicted landfall would happen at seven days. Hurricane Sandy caused $70bn worth of damage, so getting a forecast like that wrong is a big deal.

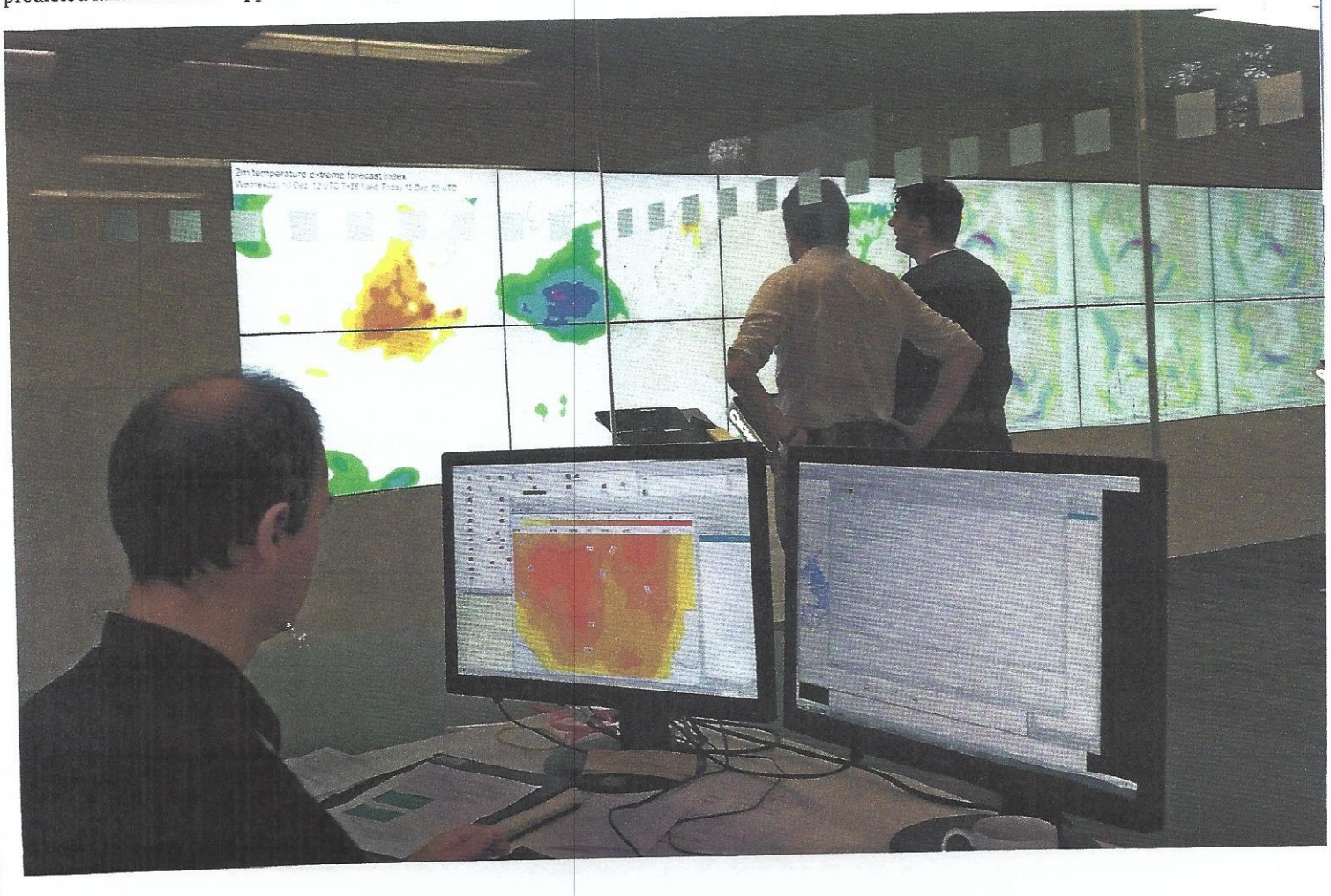
Forecasting is all about computing power. To double the resolution of a forecast requires 16 times the computer power, which is why after Hurricane Sandy the US upgraded their GFS supercomputers from 776 teraflops to 8.4 petaflops. A petaflop is one quadrillion floating-point operations per second. Don't ask me.

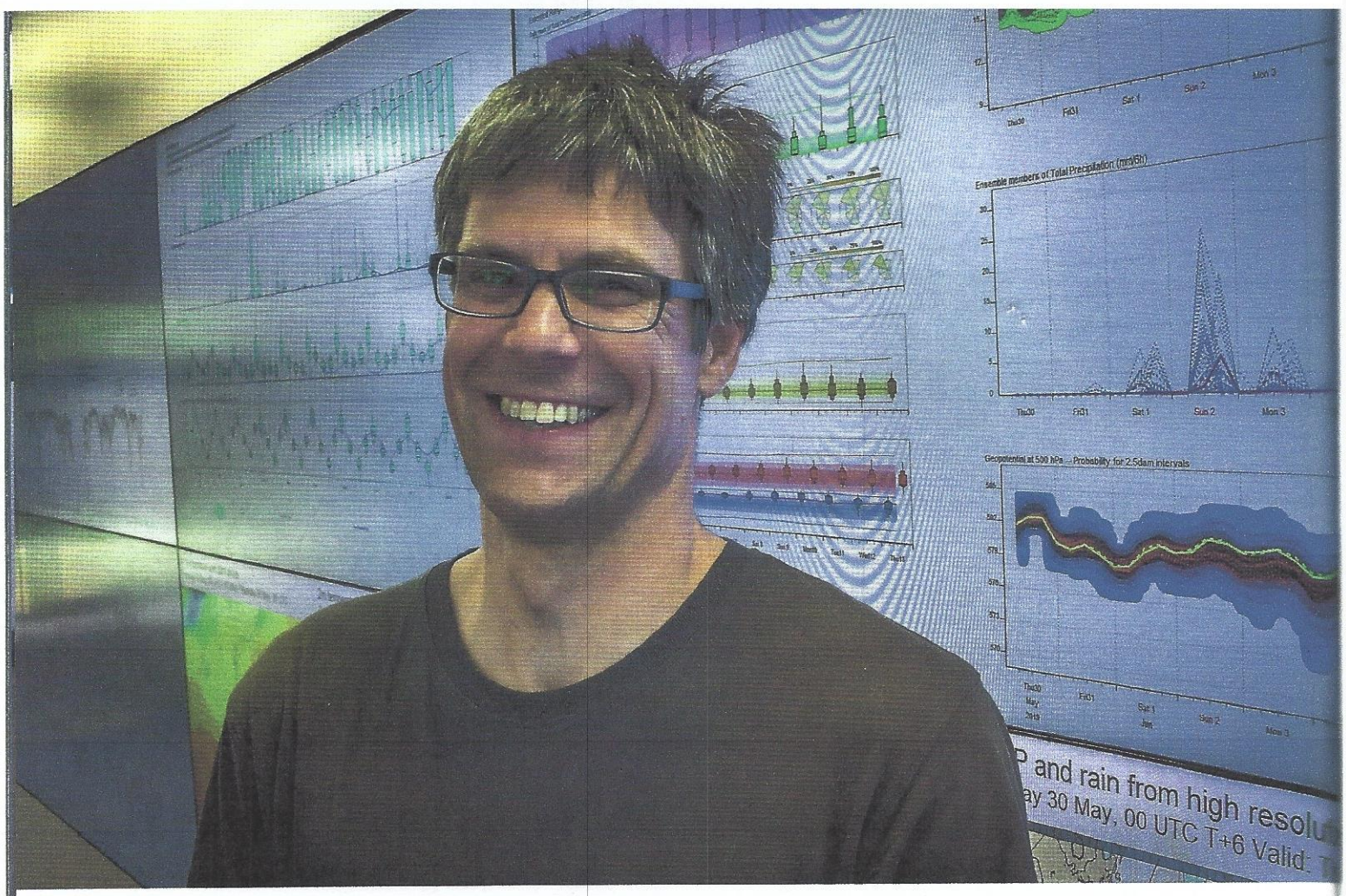
The point is the computing power behind weather forecasting is massive. And like your mobile phone, supercomputers are constantly being upgraded – every five years in fact. And of course more computing power means more data, all of which has to be kept somewhere.

Back in the computer room Xavier expanded on just that point. "Actually we are moving our data centre to Italy next year," he said. "Not because of Brexit!" he hastened to add. It's a 10-year plan, and because they need more room. The new data centre in Bologna will be on the site of a former tobacco factory and is vast. They will move the data next year. "We have so much data we can not transfer it over the internet, it would take years. So we have to physically move the tapes from here to Italy. Probably by trucks!"

DATA MIGRATION

The ECMWF is moving its data centre to Bologna, Italy. A 10-year strategy adopted in 2016 set ambitious goals for Earth-system modelling at high resolution. It specifies a target of 5km grid spacing for forecasts by 2025, down from 18km in 2016. These resolution upgrades will need ten times as much computer power – and more space. The new facility in Bologna will give the ECMWF the flexibility to accommodate the latest technologies in supercomputing. The result? Much better forecasting.
Illustration: ECMWF





The Forecaster

▲PHYSICS IS FUN
Miha Razinger in the Weather Room
Photo: Ed Ewing

►TAPE DECK
Inside one of ECMWF's large tape libraries. All the data in the centre's data handling system archive resides on tape. The latest tapes can each contain 8.5 terabytes of uncompressed data. The centre has four main tape libraries, each of which can hold about 10,000 tapes. When users log in to retrieve archive data, robots select the right tape
Photo: A. Brookes/ ECMWF Copernicus

Miha Razinger is one of the 350 scientists that work at the ECMWF. A paraglider pilot and forecaster he has been there for 14 years. "I am from Slovenia, and it's an accident that I ended up here!" he laughed. "I was working as a forecaster in Slovenia, and by chance I saw a vacancy notice. I applied for a one-year contract."

Miha, who has flown on the Slovenian team at the Paragliding World Championships and supported Red Bull X-Alps teams with weather advice, studied physics and then meteorology at university in Ljubljana. But his interest in the weather was sparked by his fascination with flight. "I started flying 26 years ago, when I was still at high school. A friend of mine did a course, and then I did one. We flew together for five or six years."

Always interested in physics, when he started reading the weather books that was it. "There was also a teacher who encouraged us, she knew we were flying and she told us we could take the afternoons off to go flying if our grades were OK."

He flew a lot with fellow Slovenian pilots Primož Suša and Jurij Vidic. "We were a tight group, always pushing a little bit. It was a nice environment. We used to fly from Sorica, where those guys flew 300km from. I even got in the Slovenian team for the World Championships once, in 2003."

Now a dad to three kids – two girls and a boy, 10, 7 and 5 – he has less time for flying, but still manages "20-30 hours" a year on his Triple Seven King.

The most important thing for pilots to understand when looking at weather forecast data, he explained, is the idea of scale and resolution. Because although the weather supercomputers crunch their way through "tens of millions of observations every model cycle", there is still a need for human interpretation, especially at the local level where we fly.

"You can model big things like high pressure systems and so on quite well, up to 15 days ahead. But if you have processes that are less defined, then they are more sensitive.

"As you move towards a finer scale you start to approximate. Especially over complex terrain, or with the build up of clouds or convection, then it becomes very difficult."

The IFS model works on a grid of 9km squares and that means relatively small-scale processes like convection, local winds and turbulence cannot be

irectly resolved in the models. Instead they have) be simulated separately. It's not guesswork, but iere's definitely human interpretation involved. he scale of the resolution is also why your local)recaster can confidently predict "local showers iis afternoon" but never "showers over the town quare at 3pm." It's also why no one can ever)redict exactly where, for example, tornadoes will orm.

However, that looks like it will change in the uture. The goal of the ECMWF is to reduce the ize of the grid they use from a resolution of 9km o 5km by 2025. That would allow much more granular, local forecasting.

"If you ever modelled at 1km resolution you would be able to model where big cumulus clouds would form," Miha said. "At 10km you can't do anything. But at 5km you will be able to resolve at least some of the bigger clouds."

Getting better weather forecasting is a slow process. Miha flashed up a chart that showed ECMWF forecasts were accurate to five days in 1998, increasing to 6.5 days in 2018. "It's very difficult to improve," he explained. "You spend a lot of money for smaller and smaller returns."

And although the goal of the ECMWF is still focused on creating an accurate seven-day forecast, there is now increased emphasis on forecasting extreme weather events correctly. "For most people it doesn't matter if it is 12C or 14C on Wednesday," Miha said, "But if there is a tropical storm hitting some megacity in Asia then that is important." XC

HOW TO MAKE A FLYING FORECAST

Flying forecasts are difficult to make precisely because we rely on such local scale phenomena. Our sites are affected by things like sea breezes, upslope flow, katabatic winds, thermals, valley winds, the sun, showers, shade, fog, you name it. It means you have to become an expert at learning how to develop your own forecasts for your own situation. ECMWF forecaster Miha Razinger tells us how to (hopefully) get it right.

1. **Start watching the forecast early.** To make a forecast for the weekend I'd first look on Monday. I'd look at the general situation first, to get an impression about whether we are in a high pressure system, at the edge, or just after a front. The general situation will give you a lot of details.

2. **Build up your own picture of certainty and uncertainty.** Look at the forecasts and see how they work. Register when they get it right, and when they don't. Is there a pattern? Do they over- or under-predict certain events or conditions? Find out what the model is that they use to make the forecast, so you can compare different forecasts and models.

3. **Monitor the forecast for a few days.** Consistency is a good indicator of forecast reliability. If the forecast is consistent over a few days, then I tend to trust it more. If it flips all the time, then it means there is some sensitivity there, it's not certain. If the forecast through the week is good then it allows you to build confidence.

4. **As the day approaches I would then look at the details.** What is the forecast wind direction? What is it forecast to do through the day? Is there any overdevelopment forecast? Rain?

5. **On the day I would of course check in the morning.** And if the morning is as forecast then that's a good sign. Then trust your judgment and the forecast and use the day. Of course there are sites that require a lot of local knowledge, and then you need to talk to local pilots. I would also trust a local meteorologist's forecast first. It will come from a model, but it will have local knowledge applied by humans. So they will know about the local winds or any storm development, for example.

Windy.com

Windy.com uses the ECMWF IFS model data to underpin its free-to-user website. This excellent site also shows the world's kitesurfing and paragliding sites. If you haven't visited it, check it out – it's good!