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Mastering the Weather Challenge

(Part 1)

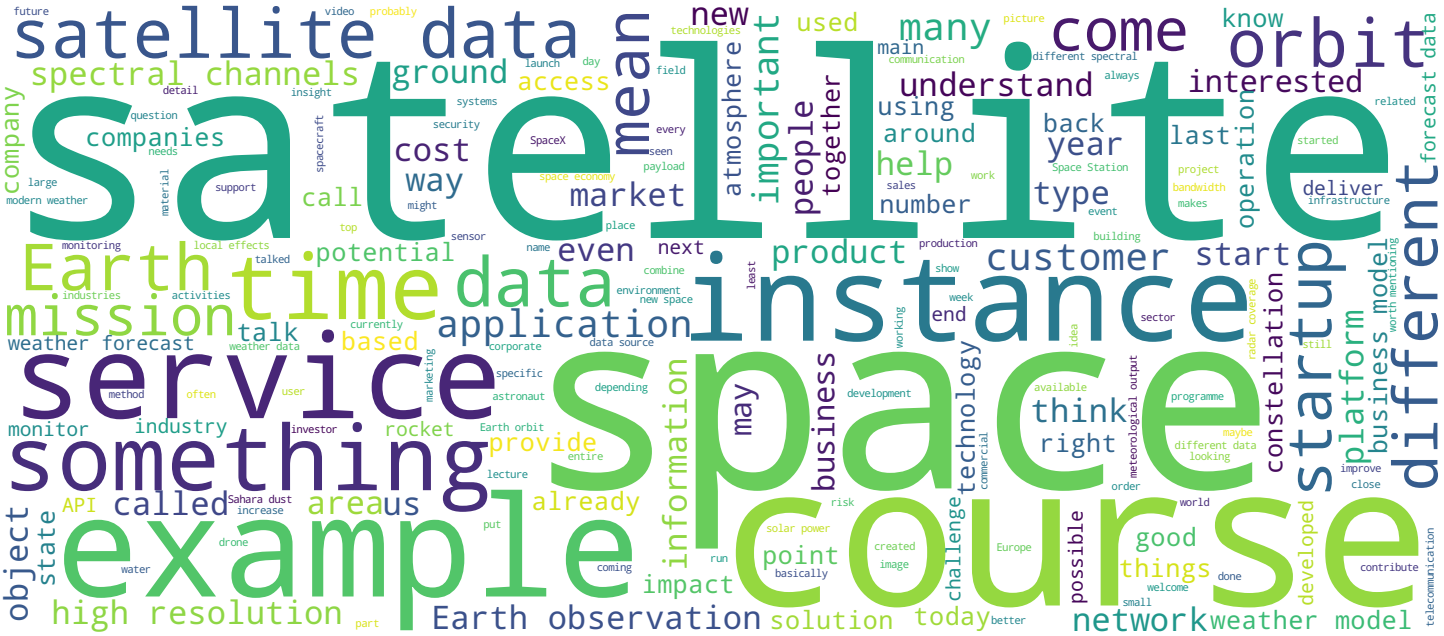
New Space Economy

meteomatics

Dr. Martin Fengler

CEO

École
polytechnique
fédérale
de Lausanne



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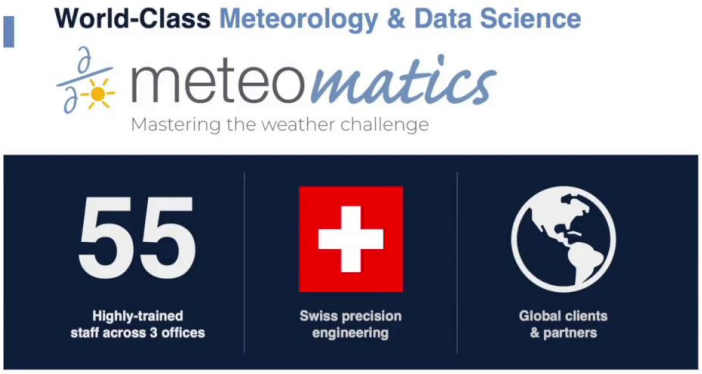
Introduction



Hello, everybody. I welcome you to today's lesson on the mastering the weather challenge. My name is Martin Fengler, I am CEO of Meteomatics. And I'd like to give you some insights how we at Meteomatics deal with satellite data or data that are related to satellite information, and how we built an entire business model around that. Meteomatics is headquartered in St. Gallen. That is very close to Lake Constance. We have around 55 colleagues, and very much focusing on providing high quality, high resolution weather data to industry. Next to our headquarter, we have also two subsidiaries in Germany and the UK.

Notes

Summary

0m 05s

Introduction

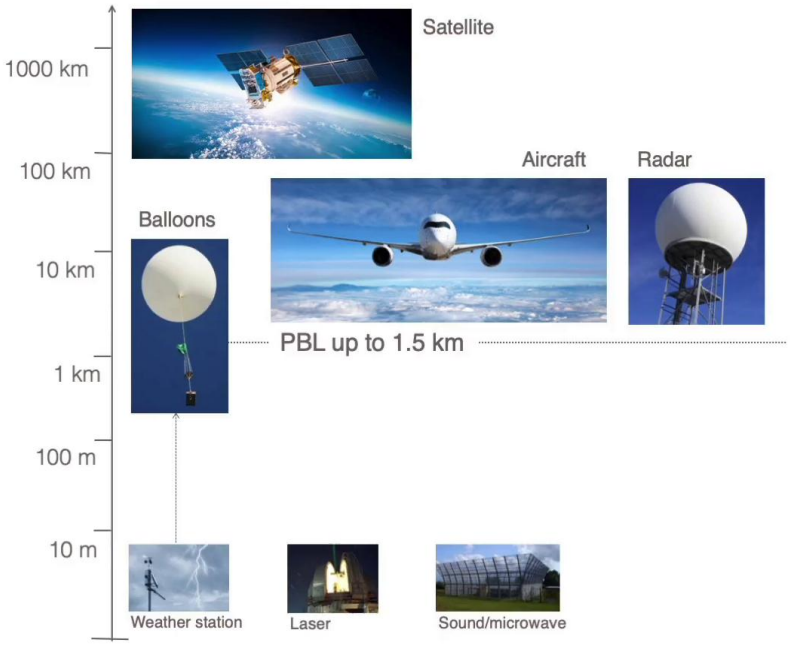
Meteomatics runs a weather API that allows easy and simple access to historical and current forecast data globally. So we provide our weather data to lots of different industries. It starts, of course, with the energy industry, if you think of renewables, but covers also the insurance space, retail, maritime shipping, and the automotive sector. For some of these industries, we provide even bespoke solutions. For instance, in the energy industry, where we transform the weather input into something that is more meaningful to these industries, like a solar or wind power forecast. To improve the future weather forecasts, we have developed, over the last 10 years, systems, which we call the meteodrones, systems that fly out to six kilometres right now under beyond visual line of sight conditions, which help us to retrieve more precise data that we can fit into our high-resolution local area models. And of course, the API that we run does not only cover historical and current short-term forecast data, but also climate projections that form the basis of the IPCC report. So it's a one-stop shop, if you say, to environmental data.

Notes

Summary

0m 51s

Some ingredients of today's recipe…



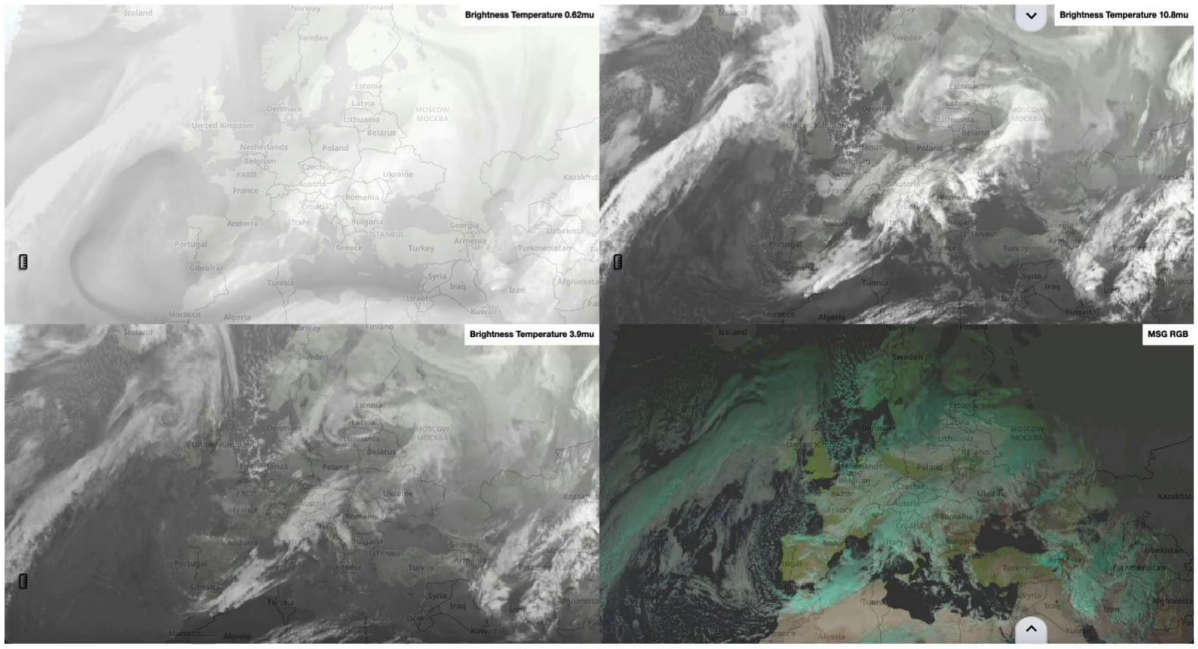
Of course, before we start getting into the details, how we set up our business model around that, it's worth reflecting how modern weather forecast is created. First, we need to have lots of different data sources. For instance, weather stations that you have on the ground. Classically, most of you probably have heard about weather balloons that have been around for about 100 years. And you have many other data sources such as aircraft data, radar, and of course, there are some remote sensing instruments also available that help support some of the airport operations, for instance. But one of the most important ingredients in modern weather forecasting are satellite data.

Notes

Summary

2m 24s

Satellite data are everywhere…



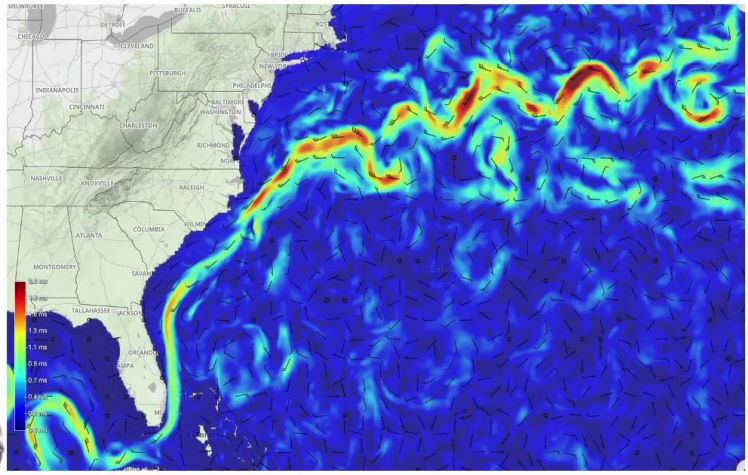
Satellite data are everywhere, and monitor the state of the atmosphere. For instance, if you consider MSG satellite data... MSG is an acronym for Meteosat Second Generation, which is European's answer to monitor the atmospheric conditions in very high-resolution temporal and spatial resolution. Then you have different spectral channels. Here you can see, for instance, the brightness temperatures for these spectral channels that are most commonly used. And if you put those spectral channels together, you get something what you would consider visual impression of the current state of the atmosphere. So you actually do not have a video camera that is just filming the atmosphere, but you have sensors that are monitoring the Earth in different spectral channels. And if you combine those spectral channels, you get something like an RGB image, which is something an astronaut would, for instance, experience the outside view of his spacecraft.

Notes

Summary

3m 17s

Satellites reveal ocean currents, wind speeds…



Ocean currents

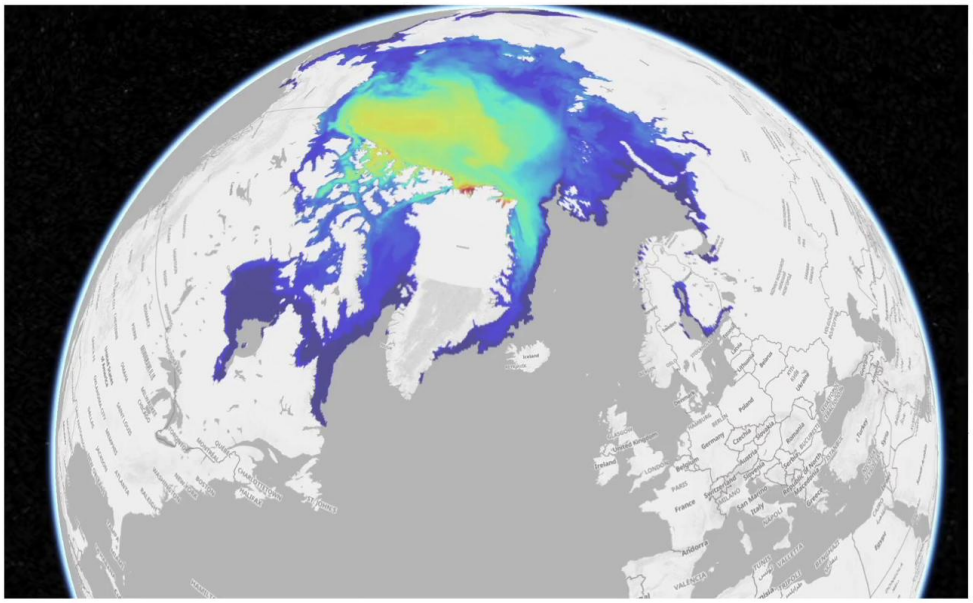
Satellites, however, also monitor other quantities such as ocean currents, for instance. Yeah, you use other optical sensors, but also radar sensors that help you to quantify the ocean currents and also the wave heights. And this also contributes significantly to modern weather forecast products.

Notes

Summary

4m 30s

Satellites monitor sea ice…



Sea ice concentration

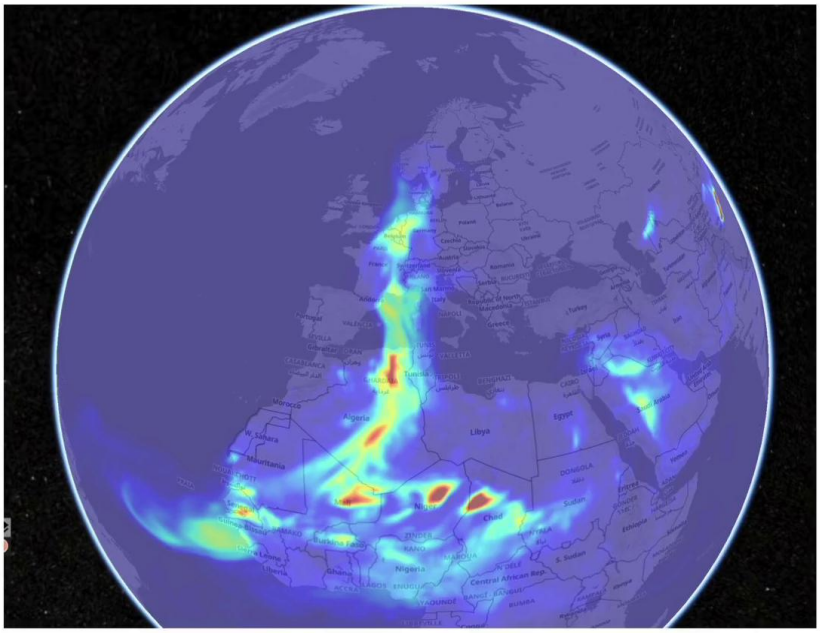
Another example of high resolution optical sensors or radar data is the monitoring of sea ice, because this is also super important in case of a global model that you run. And if you think of climate change, the anti climate change topic, then this is of course also a quantity which is a huge driver in such a model.

Notes

Summary

4m 57s

Satellites help monitoring Sahara dust…



Aerosol optical depth

Last but not least, it's worth mentioning that also other atmospheric parameters are monitored. For instance, if you think of Sahara dust, which has a significant impact from time to time, also to European weather. So this is an example of February this year, and there was a Sahara dust outbreak to Central Europe. And you might argue, how is this going to affect our daily life here? Then it's worth mentioning that the optical depth was affected, and this immediately has an impact on solar power production. So the forecast without considering Sahara dust and then considering the Sahara dust may have had an impact of around five to six gigawatts in Germany. And of course, this is super critical, and depending on the other weather conditions, this might lead to a blackout if this is not taken into account.

Notes

Summary

5m 25s

All goes into a weather model…

Momentum equation:

$$\frac{\partial U}{\partial t} + \frac{1}{a\cos^2\theta}\left\{U\frac{\partial U}{\partial \lambda} + V\cos\theta\frac{\partial U}{\partial \theta}\right\} + \dot{\eta}\frac{\partial U}{\partial \eta} - fV + \frac{1}{a}\left\{\frac{\partial \phi}{\partial \lambda} + R_{\mathrm{dry}}T_{\mathrm{v}}\frac{\partial}{\partial \lambda}(\ln p)\right\} = P_U + K_U$$

$$\frac{\partial V}{\partial t} + \frac{1}{a\cos^2\theta}\left\{U\frac{\partial V}{\partial \lambda} + V\cos\theta\frac{\partial V}{\partial \theta} + \sin\theta(U^2+V^2)\right\} + \dot{\eta}\frac{\partial V}{\partial \eta} + fU + \frac{\cos\theta}{a}\left\{\frac{\partial \phi}{\partial \theta} + R_{\mathrm{dry}}T_{\mathrm{v}}\frac{\partial}{\partial \theta}(\ln p)\right\} = P_V + K_V$$

Thermodynamic equation:

$$\frac{\partial T}{\partial t} + \frac{1}{a\cos^2\theta}\left\{U\frac{\partial T}{\partial \lambda} + V\cos\theta\frac{\partial T}{\partial \theta}\right\} + \dot{\eta}\frac{\partial T}{\partial \eta} - \frac{\kappa T_{\mathrm{v}}\omega}{(1+(\delta-1)q)p} = P_T + K_T$$

Moisture equation:

$$\frac{\partial q}{\partial t} + \frac{1}{a\cos^2\theta}\left\{U\frac{\partial q}{\partial \lambda} + V\cos\theta\frac{\partial q}{\partial \theta}\right\} + \dot{\eta}\frac{\partial q}{\partial \eta} = P_q + K_q$$

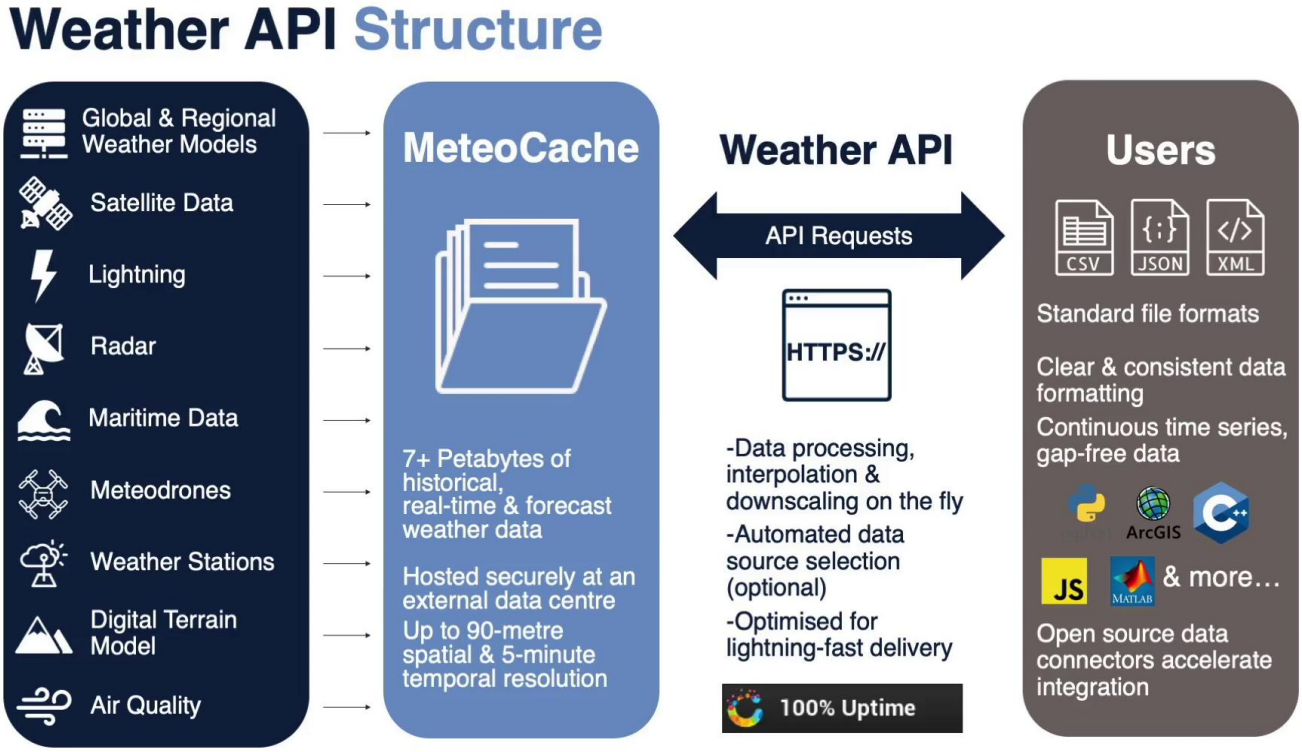
Reference: ECWMF IFS documentation Cy47r3

Now, we have talked a lot about the input data to a weather model. Then of course, it's also worth mentioning that the weather model itself is a hypercomplex set of partial differential equations that describe the atmospheric flow and motion. So here on the top, you have the Navier-Stokes equation, in spherical coordinates that we call the momentum equation. And that is coupled into the thermodynamic equations that you have here, and the moisture equations. The entire set of equations get closed by continuity equations and equations for pressure tendency. And all of that can be found in a really extensive documentation by the ECMWF. The ECMWF model is, for certain, currently the most pioneering and the best global weather model that is currently available.

Notes

Summary

6m 27s



Now, how does Meteomatics come into this global game? The naked truth is, no one is really interested in satellite data. And this is of course a shocking moment. And it's also true that no one is really interested in plain weather data. What people are interested in, and especially our customers from industry, how the weather is impacting their business. And of course, the weather information contribute and help to improve the stats around business relevant insights, and to forecast those. So what we developed at Meteomatics is something what we call the MeteoCache. It's a proprietary technology— you could think of an in-memory database technology— in which we ingest lots of different data sets, global regional weather models, again, also satellite data, lightning data, radar data, and so forth. Current and forecast data are served from RAM, which makes it super fast, and historical data are served from an enterprise storage. So currently, we are able to provide around seven petabytes of data, real-time access to around seven petabytes of data to our customers. To make the access to this huge data set as convenient as possible, we created an API on top. And of course, it makes a lot of sense to provide connectors to this API.

Notes

Summary

7m 31s

Variety of possible integrations

So for many programming languages, we have open source connectors published with GitHub, who are available on request. And this makes it really convenient to interact with this huge amount of data, which of course covers the atmospheric data, but also ocean data, environmental data, and even climate data. Among scientists and analysts, we often see Python in use, MATLAB and R. And thanks to the WMS and WFS capability, we are also able to support geoinformation systems that you see, for instance, in use with government agencies or blue light organisations.

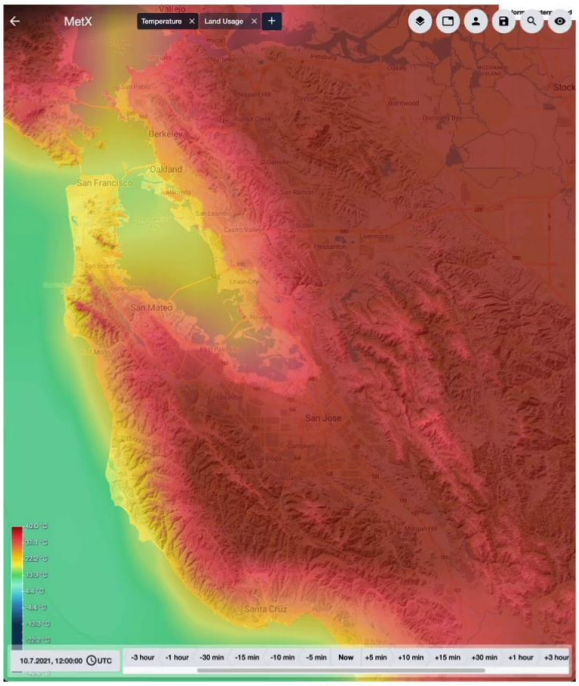
Notes

Summary

9m 07s

Temperature

- Historical, real-time, and forecast temperature available
- Downscaled to 90 metre spatial resolution
- Calculated values: max, mean, min temperature over a 1-hour to 24-hour interval
- Fully customisable height: from soil temperatures up to 150 cm underground to air temperature up to 20,000 metres above ground



24-hour max temperature in MetX (height: 2 metres)
SF Bay Area heat wave, 9 July 2021

Here are some examples. The temperature is of course a quantity which is affecting lots of business processes. Here, you can see that it is possible to apply some sort of downscaling to the meteorological output, which means that the coarse grid meteorological output is combined with a digital elevation model in 90 metres resolution that is globally available, thanks to the NASA SRTM data, for instance, or there are also similar data sets available thanks to the Copernicus programme. And this allows us to resolve really local effects around the weather conditions here, for instance in the Bay Area, where you have higher temperatures inland and pretty cold temperatures close at sea.

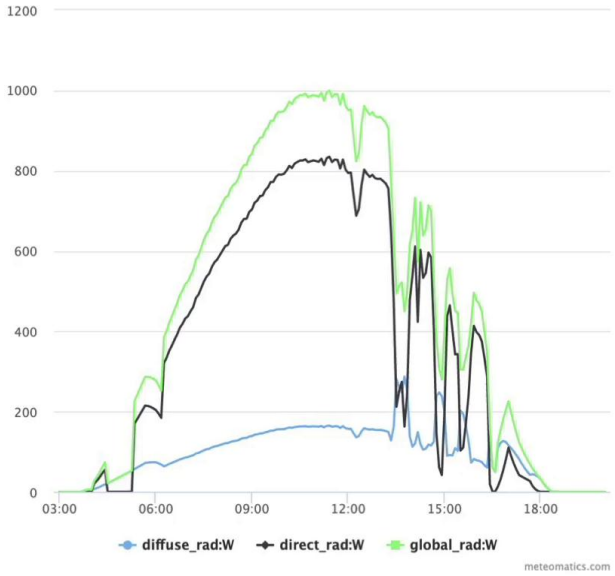
Notes

Summary

9m 50s

Irradiance

- GHI, DNI, DIF available
- Instantanteous and accumulated flux (1h, 3h, 6h, 12h, 24h) available
- Terrain-based shading calculated dynamically (e.g. sun goes behind a mountain)
- Temporal resolution up to 5 minutes
- Spatial resolution up to 90 metres



Radiation data (instantaneous flux) for St. Gallen, Switzerland

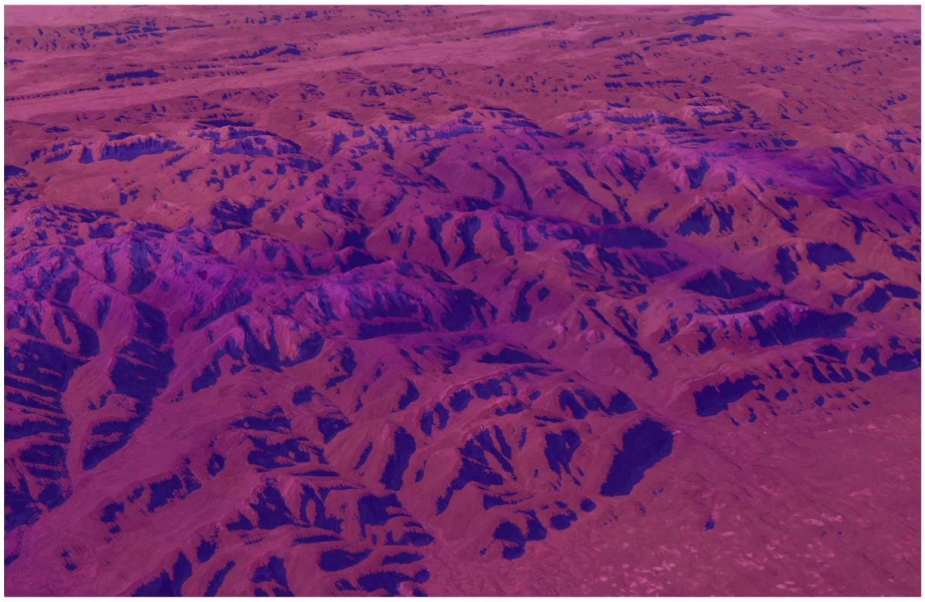
Another quantity a lot of players are interested in is information on global radiation, direct and diffuse radiation, and this is something that you could also derive from satellite data. So there are methods like the Helio set method, which combines different spectral channels and allows us to come up with an estimate on the surface flux for the radiation.

Notes

Summary

10m 49s

Irradiance



Global Radiation (GHI) data, showing terrain shading impact in morning

And of course, this is affected not only by the atmosphere, but if you take into account also the high-resolution digital elevation model, the shadowing of the terra is also affecting the radiation input at ground. Here in those areas, where you see the shadowing, direct radiation is cancelled out, and only the diffuse radiation stays apart. So this is of course for customers from the solar industry, and super helpful input in estimating the power output of the PV panels.

Notes

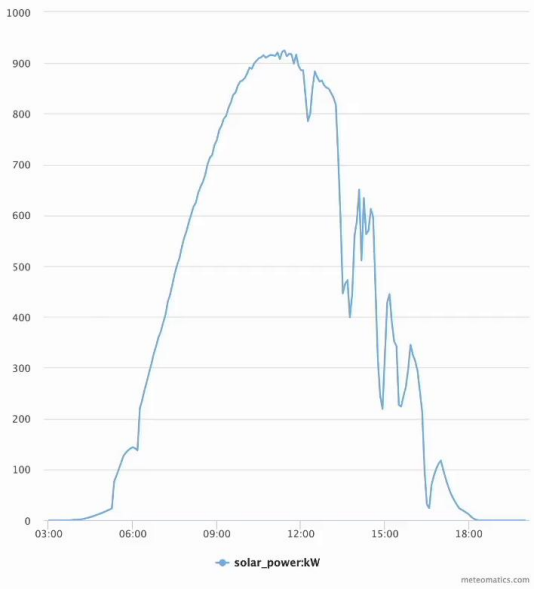
Summary

11m 30s

Solar Power Generation

“solar_power“ parameter
takes into account radiation, temperature, wind, snow cover & panel configuration to provide power output forecasts or historical data

Inputs (customisable)
-Site capacity
-Tracking type (fixed, azimuth, tilted north-south)
-Panel tilt
-Panel orientation
-Panel specifications



Solar generation forecast for St. Gallen, Switzerland

Thanks to our in-memory database technology, we are not only able to provide the output of the weather models and the downscaled version out of it, but also able to come up with what we call derived parameters. So we are transforming the meteorological output already into something that is meaningful to the industry, such as the solar power. You could specify in our API the orientation of the panel, the tilt angle, and even the tracking mode or specific module parameters, and then you get the solar power output for that specific location.

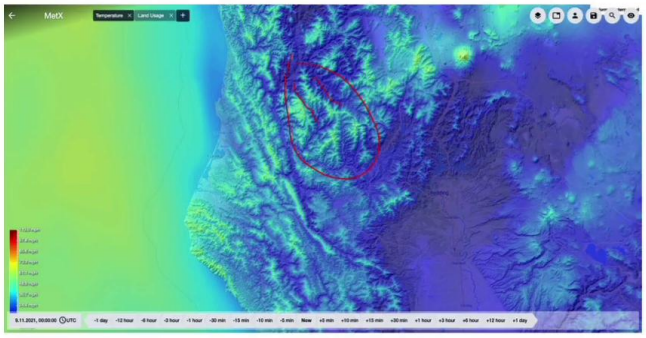
Notes

Summary

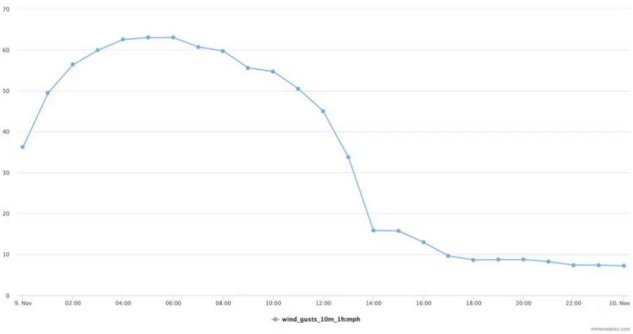
12m 04s

Wind

- Wind speed and direction data available worldwide
- Instantaneous & interval values available for sustained winds and gusts
- Examples: 24-hour maximum wind gust, 6-hour average wind speed
- Data available at any height above ground: fully customisable from 2 metres to 20,000 m
- 90 metre spatial resolution



Gridded data: 1-hour max wind gusts in MetX (9 Nov)



Wind gust observations & forecast for Eureka, CA

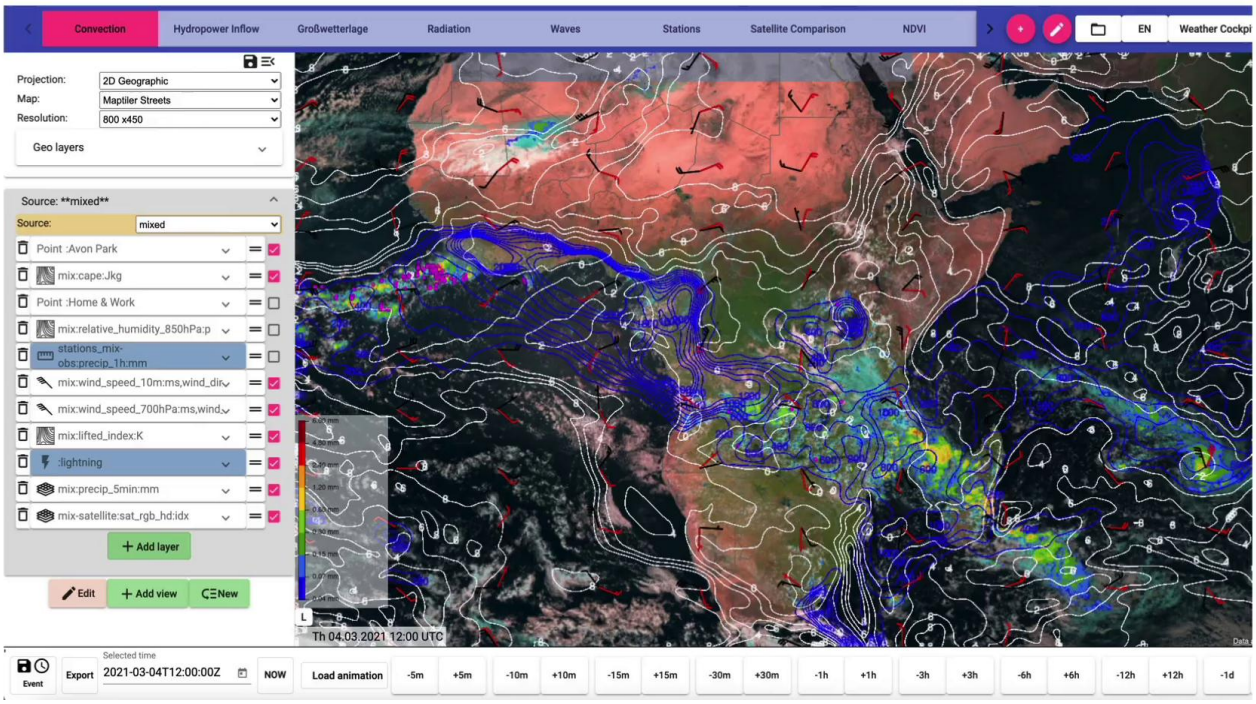
Same is done for the wind and wind speed, so we are able to resolve even very local effects thanks to our downscaling methodology. And as you can see here, for instance in this close-up again of the Bay area, that the mountain ridges show here higher wind speeds than you would experience here in the valley, for instance.

Notes

Summary

12m 50s

Real-time thunderstorm detection and nowcast



Now, let's go back to satellite data and how these can contribute to nowcasting. Nowcasting is something which is like a weather forecast, but covering the next two hours. And we use different spectral channels, again from the geostationary satellites typically, to derive areas where you would expect thunderstorms or areas of high turbulence and issue warnings out of that to support, for instance, the aviation industry. And this is of course a really good product, especially in those areas where they do not have radar coverage. Radar coverage is something that you have more in Europe, in the US, and some other areas. But in large parts across Africa or the Atlantic and Pacific ocean, of course, they do not have radar coverage, and their real-time information from satellites is super helpful to get a precipitation estimate, storm parameters that you could estimate. And from those parameters that you combine with high-resolution upper level wind data, you could come up with a nowcast.

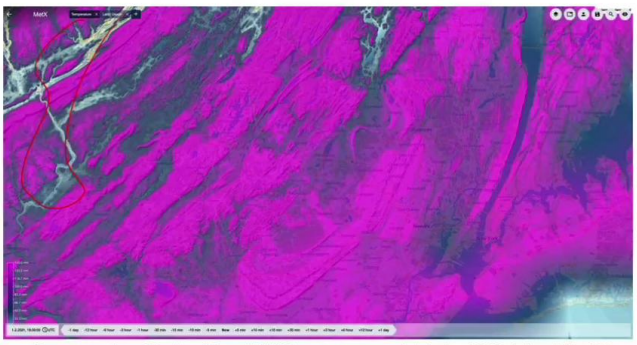
Notes

Summary

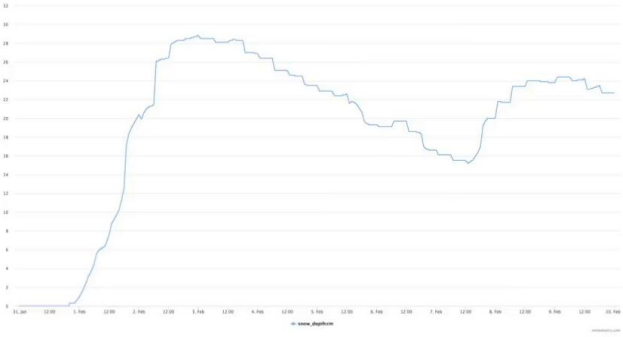
13m 20s

Snow

- Snow depth updated in real-time based on precipitation and snowmelt
- Snowfall amount also available (e.g. 1 hour, 24 hour fresh snow accumulation) – historical, real-time, or forecast
- Differentiation of precip types: rain, snow, mix, sleet, freezing rain, hail



Snow depth in the NYC area on 1 Feb 2021 in MetX



Snow depth in Central Park over 10 days in February
Shows a major storm, gradual melting, and a second storm

Another example. I talked about this in a different form before when we was about monitoring sea ice is coming up with a snow estimate. Of course, here, we combine the snow data that we derive from satellite data with weather station data and also forecast data to predict the snow depth in a certain area. And this, at a really high resolution, as you can see in this example, that we are able to resolve even very local effects, again, by combining these different data sources.

Notes

Summary

14m 54s

Contact us

Your contact

Dr. Martin Fengler

CEO

www.meteomatics.com

Meteomatics AG
Lerchenfeldstrasse 3
9014 St. Gallen
Switzerland

Meteomatics GmbH
Schiffbauerdamm 40
Office 4406
10117 Berlin
Germany

Meteomatics Ltd
Sigma House Oak View Close
Edginswell Park
Torquay, Devon
United Kingdom, TQ2 7FF

I'd like to say thank you. I'm happy to answer questions and give you more insights how this weather information could contribute to some of your projects. Thank you very much.

Notes

Summary

15m 36s