Using MATLAB to Empower Modern Numerical Weather Forecasts

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CEO

World Class Talent in Meteorology, Data Science, Drone Development and Service Delivery

We are proud of Meteomatics' fair, hardworking, 'can-do' culture and a highly skilled multi-disciplinary team who rise to the challenge with our customers in a positive fashion. Creativity is a core skill whether it be in thinking, design, architecture or science.

Why Does Weather Matter?

It affects our daily life.

Better understanding of the weather helps reducing business costs.
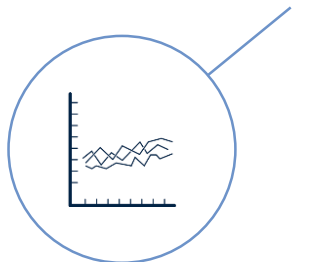
It affects our business.

Better understanding of the weather improves predictive maintenance.

It is highly variable.

Better understanding of the weather reduces the impacts of natural hazards.

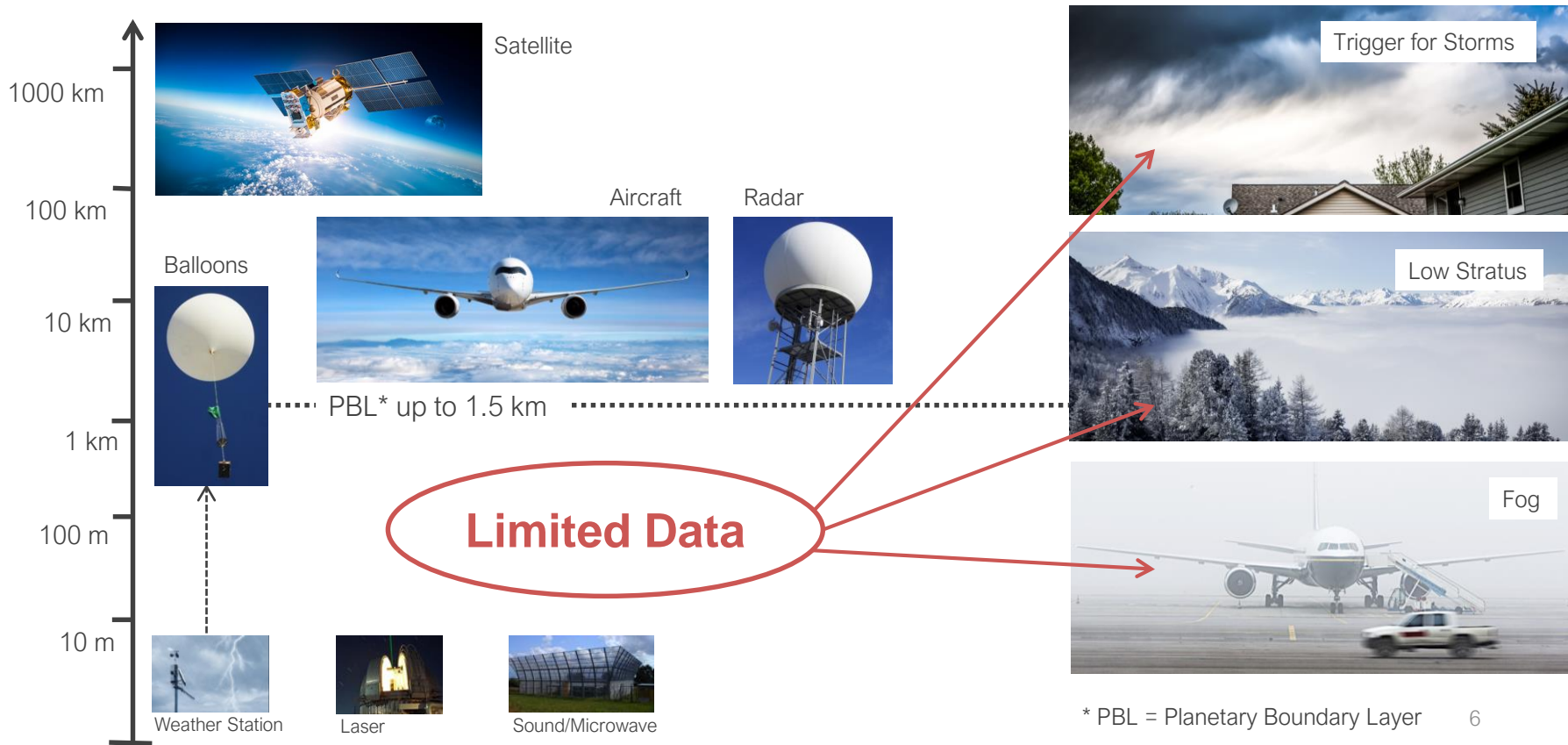# Key Takeaways

Weather API & MATLAB
enable us to:

... model gathered drone data

… simulate new measurement techniques

… implement physical parametrizations

… visualize meteorological data

… carry out statistical analyses

… enrich training of machine & AI learning with weather data

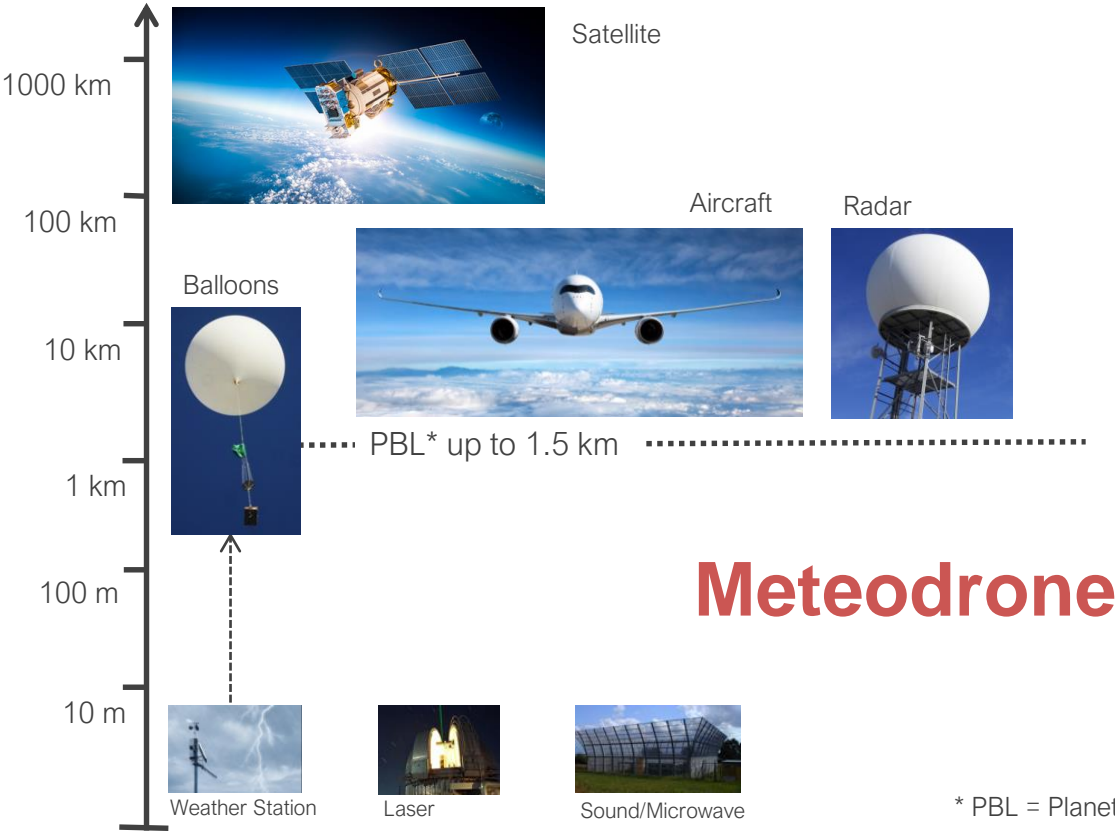… give deeper insights into your weather related business

Key Challenges

- Inaccuracy of Forecasts
- Access to Historical Data
- Huge Amount of Data
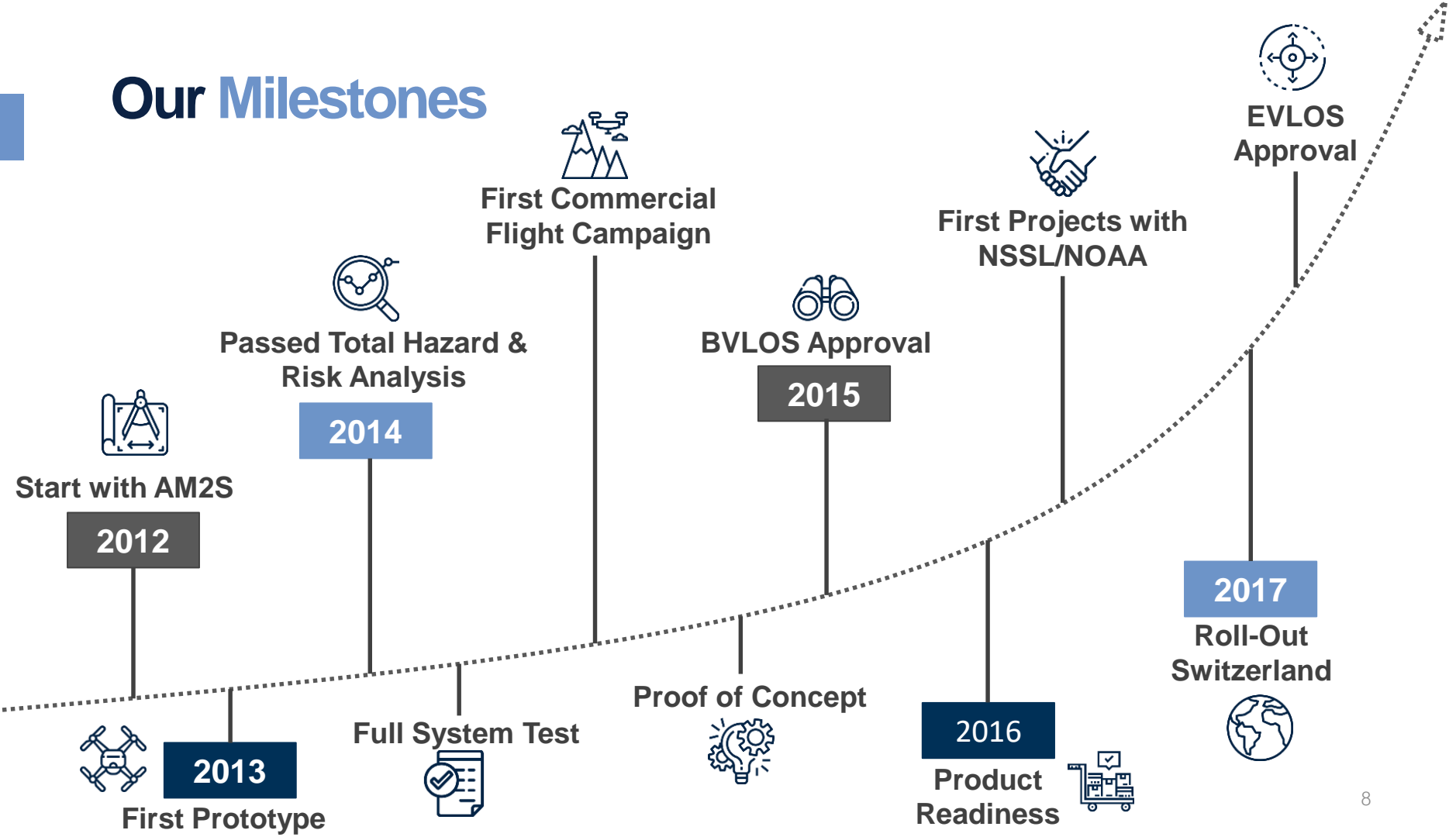- Inconsistent Data Formats

Current Data Situation

Satellite

1000 km

100 km

Aircraft   Radar

Balloons

10 km

1 km ···· PBL* up to 1.5 km ·······························

Limited Data

100 m

10 m

Weather Station   Laser   Sound/Microwave

Trigger for Storms

Low Stratus

Fog

Improving Data Situation

1000 km — Satellite

100 km — Aircraft · Radar

10 km — Balloons

PBL* up to 1.5 km

1 km

100 m

Meteodrone

10 m — Weather Station · Laser · Sound/Microwave

* PBL = Planetary Boundary Layer

Our Milestones

Start with AM2S
2012

First Prototype
2013

Passed Total Hazard & Risk Analysis
2014

Full System Test

First Commercial Flight Campaign

Proof of Concept

BVLOS Approval
2015

First Projects with NSSL/NOAA

Product Readiness
2016

EVLOS Approval

Roll-Out Switzerland
2017

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Our mobile systems allow highly flexible missions.

Meteodrone Sensors & Flight Profile

Pressure
Accuracy: 0.1 hPa
Response Time: 250 ms

Dew Point
Accuracy: 0.2 °C
Response Time: < 4 s

Temperature
Accuracy: 0.1 °C
Response Time: 1 s

Wind Speed & Direction
Accuracy: < 1 m/s
Response Time: 250 ms

The aircraft automatically compensates wind drag:

- Compute wind speed and direction from roll & nick angle
- Vertical flight profile up to 3'000 m
- Currently working on increasing flight altitude to 6'000 m

Relative Humidity
Accuracy: < 2 %
Response Time: < 4 s
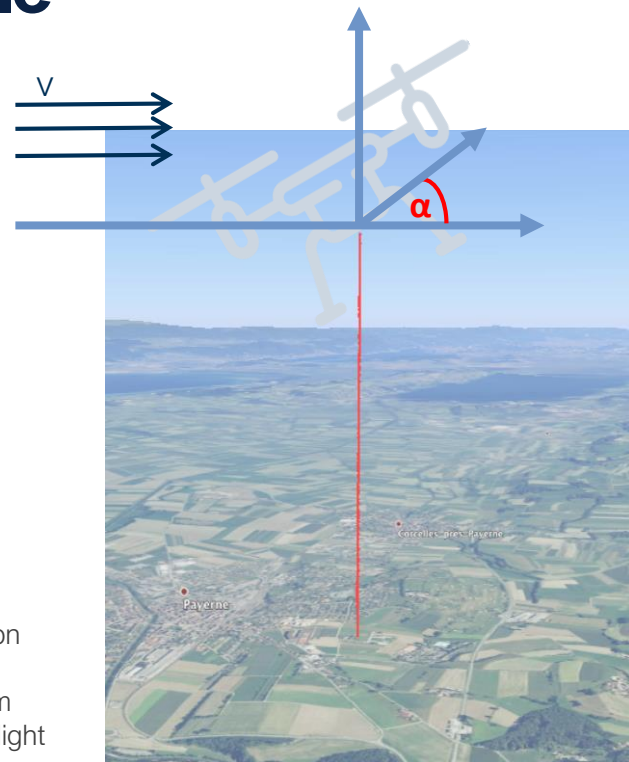
Prototyping done in MATLAB

Modelling & Simulation

Sensors are radiation-shielded and mounted in the rotor downwash.

Modelling & Simulation **of Meteodrone**

Input

- Roll and Pitch angle
- Power Consumption

Drone Model

- Physics based
- Automatic wind drag compensation
- Comparison to wind tunnel and outside conditions
- Postprocessing and calibration
- MATLAB / C++
- Deployed on ARM Processor

Share Results

- Send data in real-time to ground station
- Post-processing / WRF model-input
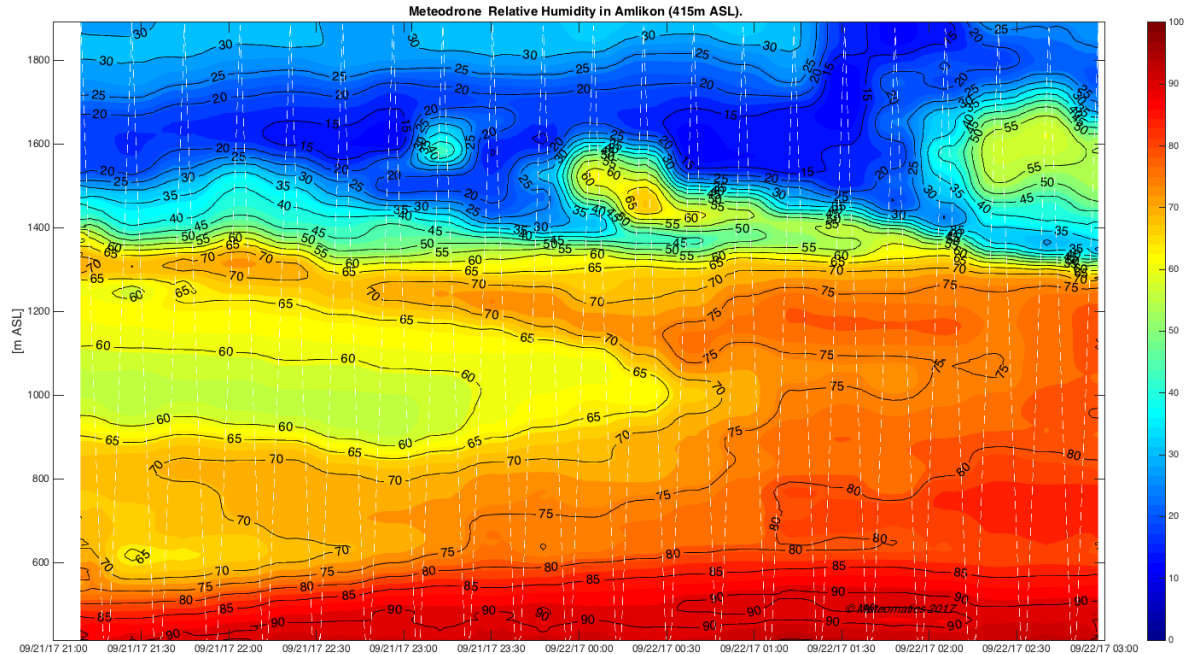- Weather API

Amlikon 21. – 22.09.17

Temperature
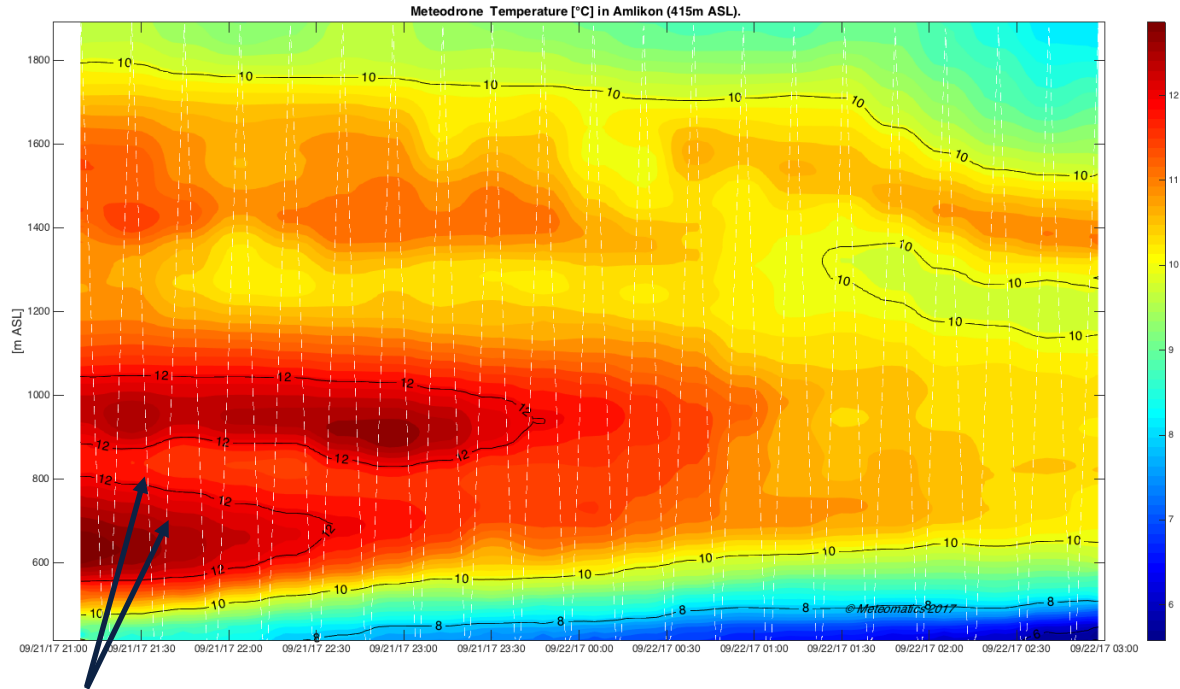
White dots indicate the drone flight track.

Visualization done in MATLAB

Amlikon 21. – 22.09.17
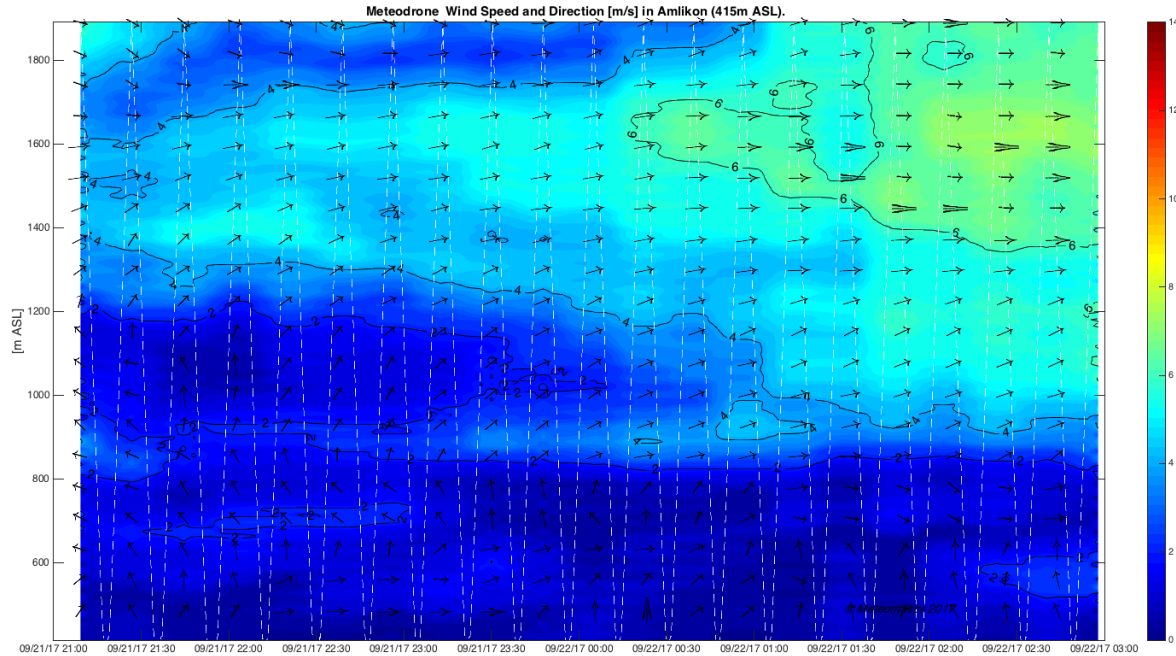
Relative Humidity

Meteodrone Relative Humidity in Amlikon (415m ASL).

Visualization done in MATLAB

Amlikon 21. – 22.09.17

Wind Speed & Direction

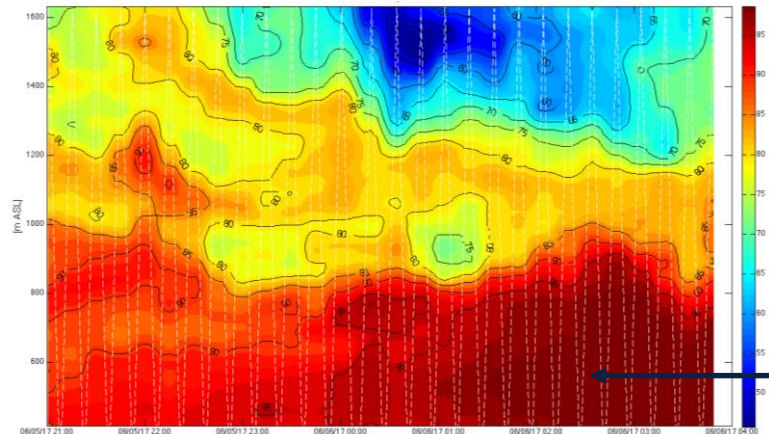Meteodrone Wind Speed and Direction [m/s] in Amlikon (415m ASL).

Visualization done in MATLAB

Amlikon 05. – 06.06.17
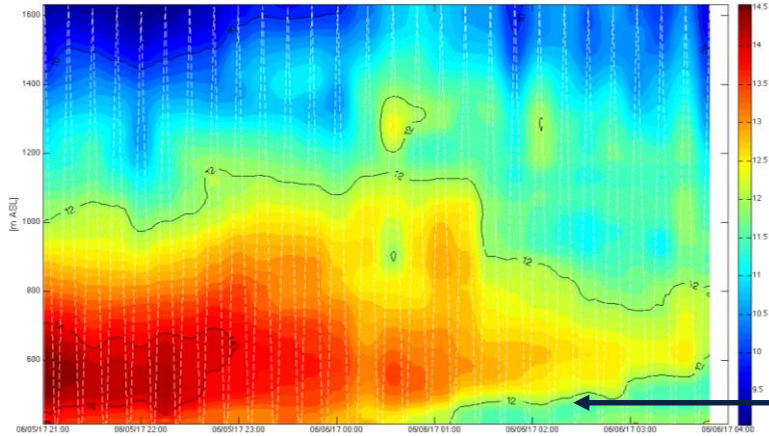
Temperature

Ground Inversion

Relative Humidity

100% RH

Shallow Fog:
Up to 150 m

Fully automated

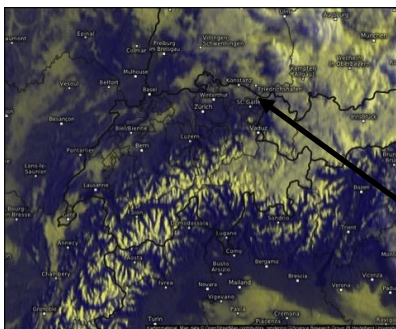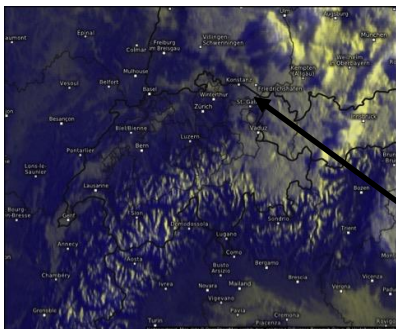**Customized to your needs**

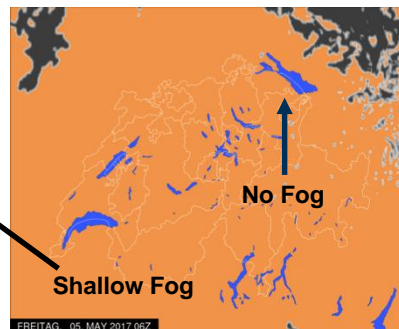**New dimension in precision**
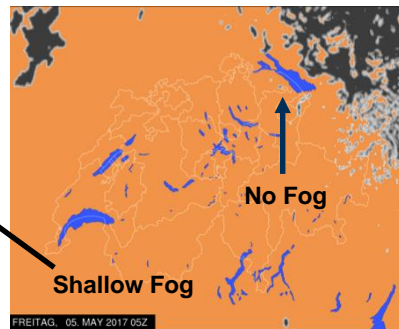
Maximum flexibility
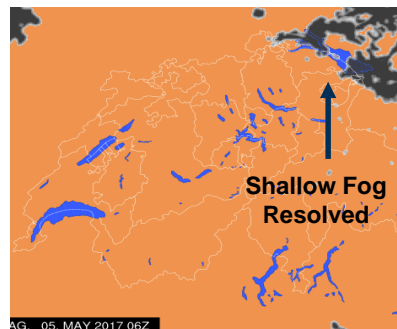
Morning Fog at Lake Constance 05.04.17, 7 am & 8 am

Satellite Cloud Cover

Swiss1k **Without** Meteodrone Data

Swiss1k **With** Meteodrone Data

No Fog

Shallow Fog

FREITAG, 05. MAY 2017 05Z

Shallow Fog Resolved

FREITAG, 05. MAY 2017 05Z

No Fog

Shallow Fog

FREITAG, 05. MAY 2017 06Z

Shallow Fog Resolved

AG, 05. MAY 2017 06Z
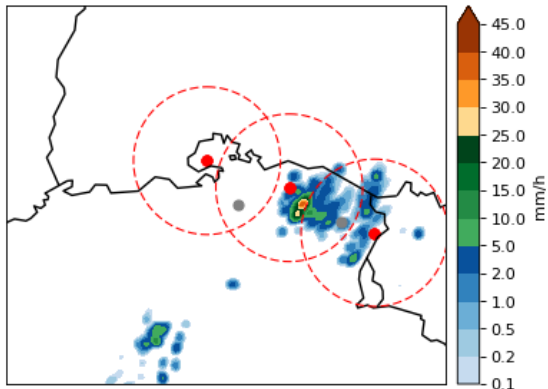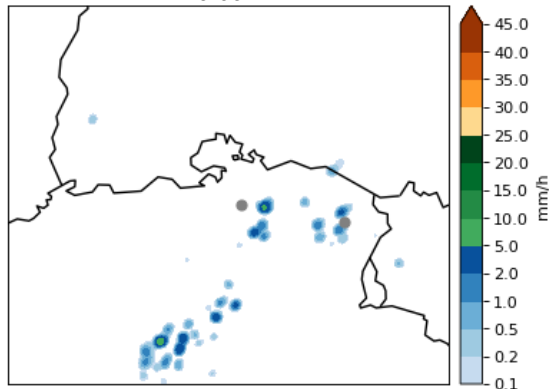
Meteodrones in Schaffhausen, Amlikon and Marbach until 5 am

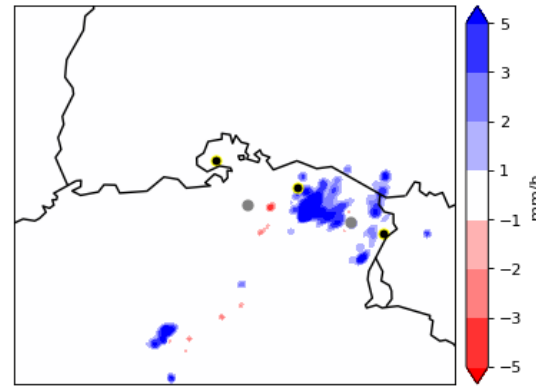# Thunderstorms in St.Gallen 29. – 30.05.17

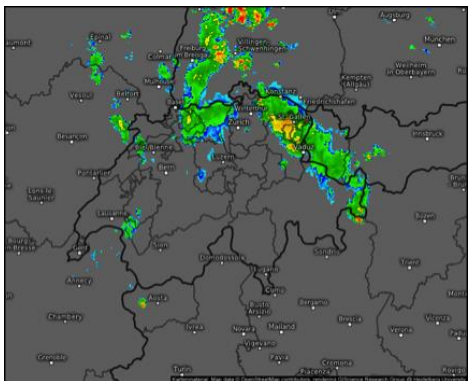**With** Meteodrone
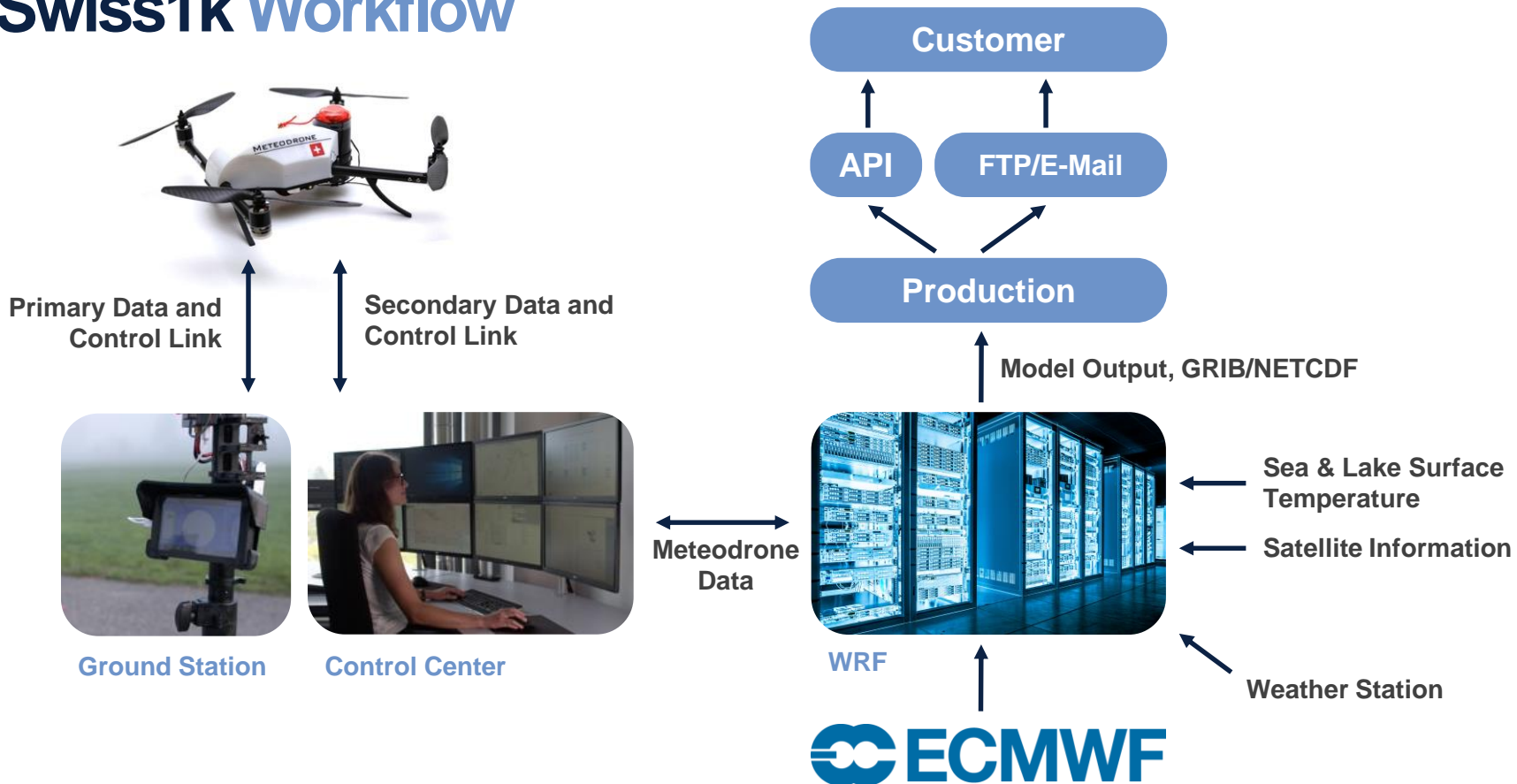29.05.17

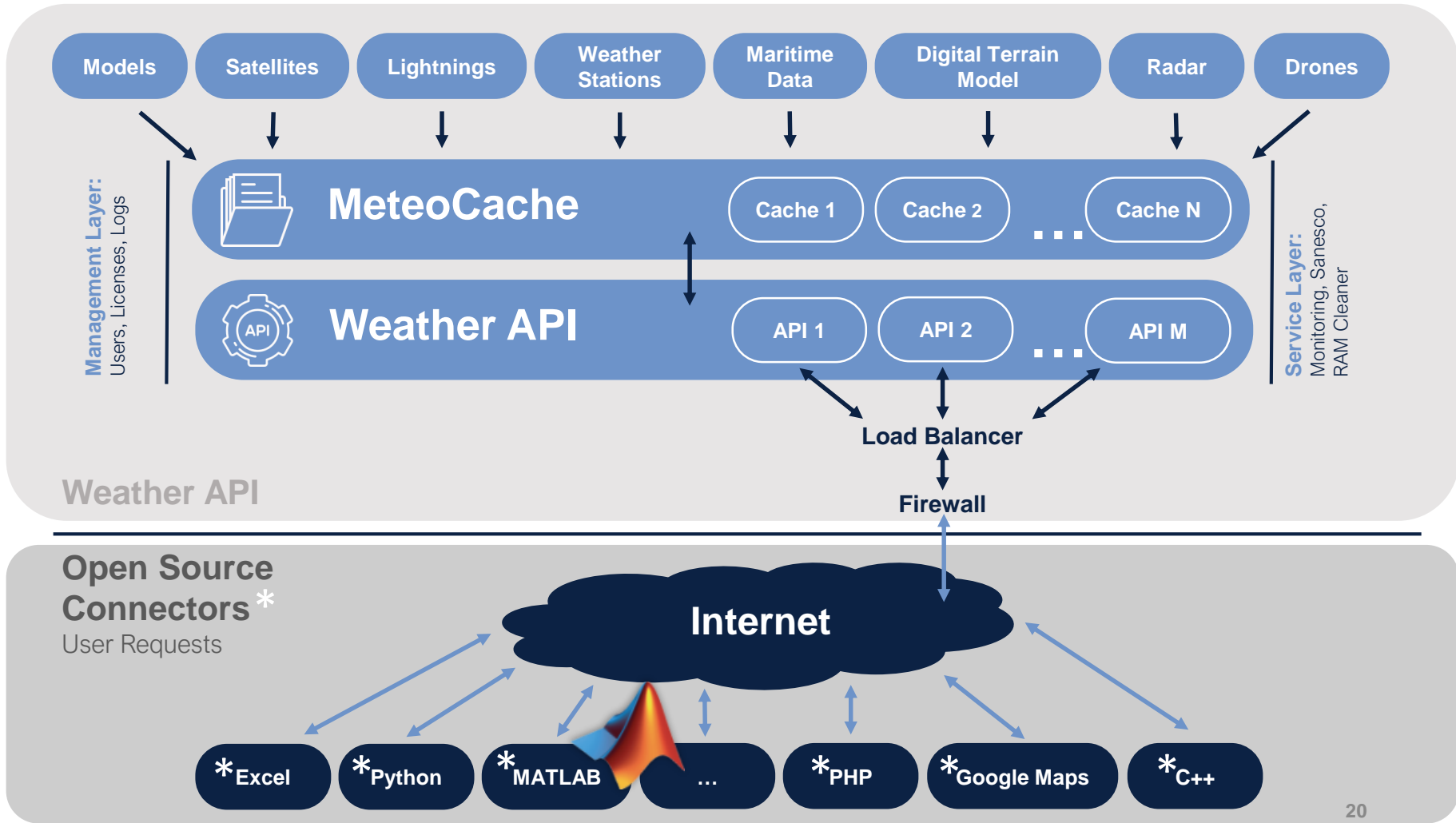**Without** Meteodrone
29.05.17

Difference
29.05.17

Swiss1k was the only model to capture these storm cells and forecasted them 23 hours ahead!

Swiss1k Workflow

Customer

API **FTP/E-Mail**

Production

Model Output, GRIB/NETCDF

Primary Data and Control Link

Secondary Data and Control Link

Ground Station **Control Center**

Meteodrone Data

WRF

Sea & Lake Surface Temperature

Satellite Information

Weather Station

ECMWF

Models Satellites Lightnings Weather Stations Maritime Data Digital Terrain Model Radar Drones

Management Layer: Users, Licenses, Logs

MeteoCache Cache 1 Cache 2 . . . Cache N

Weather API API 1 API 2 . . . API M

Service Layer: Monitoring, Sanesco, RAM Cleaner

Load Balancer

Firewall

Weather API

Open Source Connectors *

User Requests

Internet

*Excel *Python *MATLAB … *PHP *Google Maps *C++

Weather API

USP

Weather data as a single version of truth

On the fly calculation for most up-to-date forecasts

Hyperlocal forecasts delivering enhanced temporal and spatial resolution

Variety of formats and connectors in different programming languages
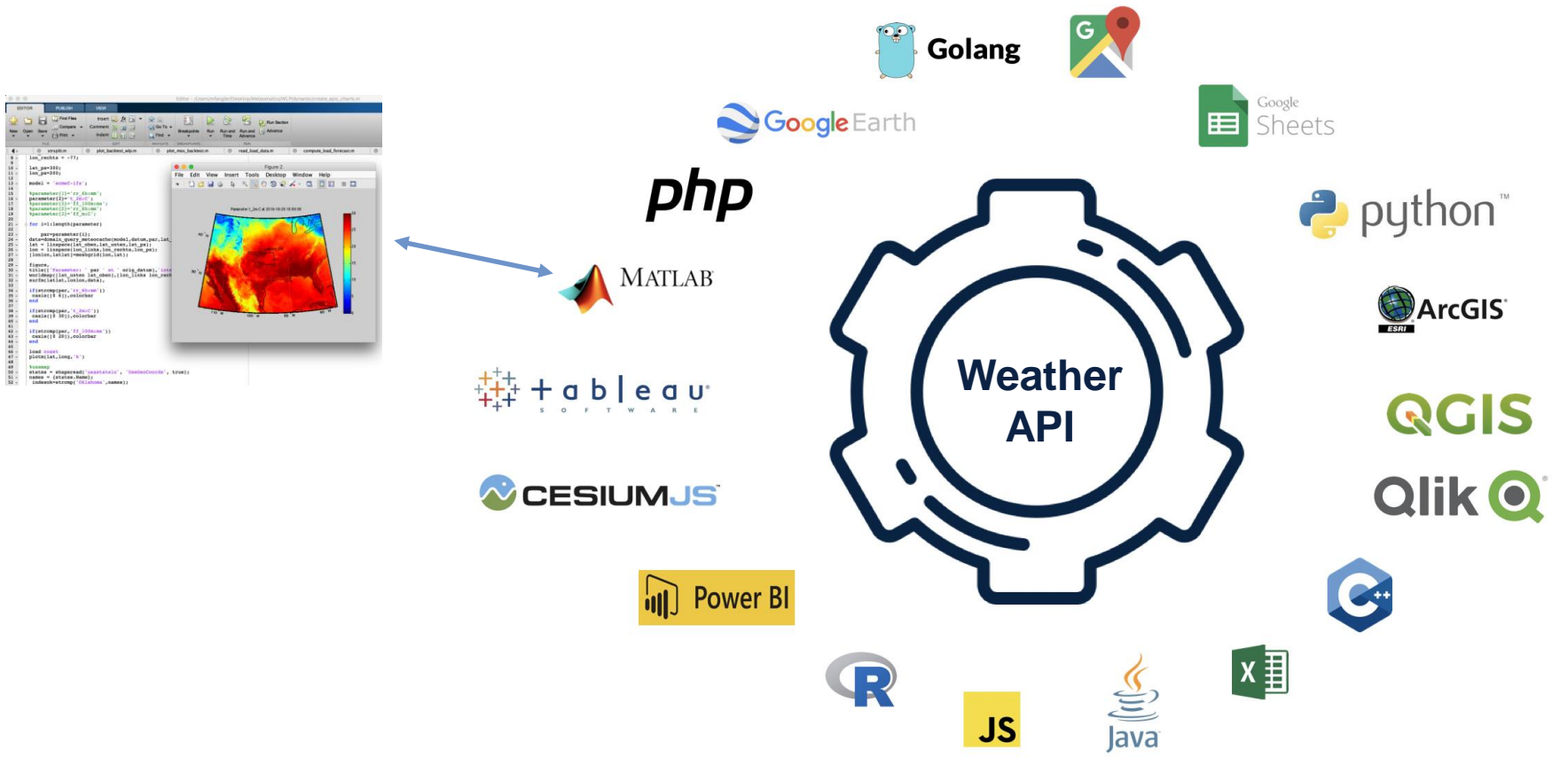
Detailed and up-to-date documentation

Flexible & fast integration & usage

Simple one-stop access to high quality weather data worldwide

Variety of Possible Integrations

Weather API in MATLAB File Exchange

Weather API in MATLAB

```matlab
% ------------------------------------------------------------------
% Sample to query weather data at a certain location time series
% ------------------------------------------------------------------

lat   = 50.123;
lon   = 10.843;

start_date  = floor(now);  % Could be anything like a datenum
period      = 'P5DT3H15M'; % period of 5 days, 3 hours, 15 min
resolution  = 'PT1H';      % 1h resolution

parameters = 't_2m:C,d_2m:C';  % Temperature and Dew Point at 2m

[dn,data]=time_series_query_meteocache(user,password,'mix',start_date,period,resolution,parameters,lat,lon);
```
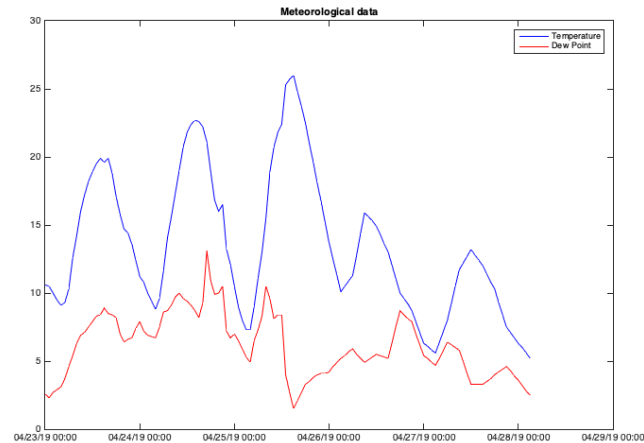
Weather API in MATLAB

```
% -------------------------------------------------------------
% Sample to Query a domain for temperature
% -------------------------------------------------------------

% Define corners of a rectangular domain in decimal degrees
lat_top     =   65;
lon_left    =  -10;
lat_bottom  =   30;
lon_right   =   30;

% Define Pixel resolution
lat_px = 300;
lon_px = 600;

% Create Lat/Lon grid for visualization
lat = linspace(lat_bottom,lat_top,lat_px);
lon = linspace(lon_left,lon_right,lon_px);
[lons,lats] = meshgrid(lon,lat);
lats = flipud(lats);

% Set date
validdate = floor(now)+0.5; % datenum(2016,12,24,15,35,0);

parameter = 't_2m:C';

% Query the grid:
data=domain_query_meteocache(user,password,'mix',validdate,parameter,lat_top,lon_left,lat_bottom,lon_right,lon_px,lat_px);

figure, surf(lons,lats,data,'EdgeColor','none')
```
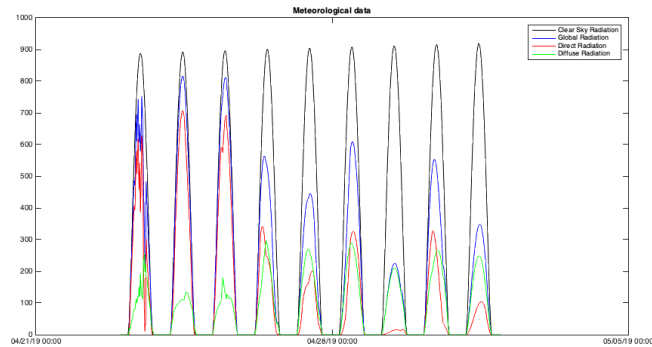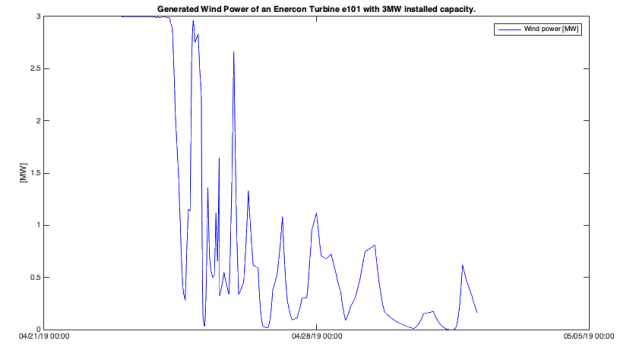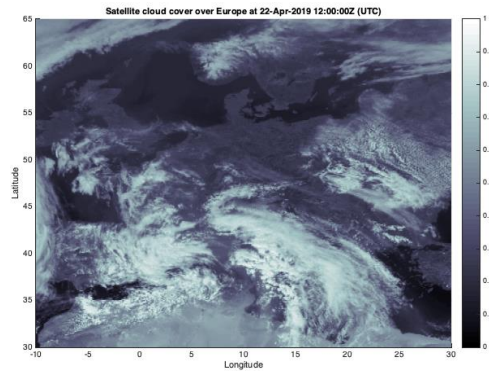

Temperature over Europe in [°C] at 23-Apr-2019 12:00:00Z (UTC)
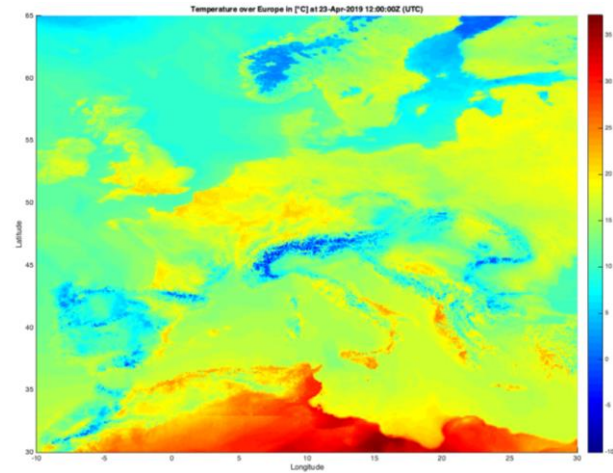
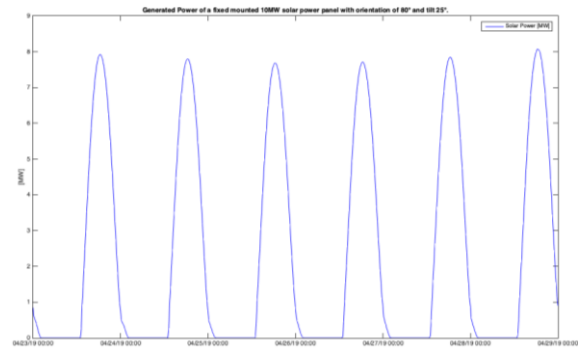# Weather API in MATLAB

Global, diffuse, direct and clear sky radiation

Wind Power

MSG Satellite Data

Solar Power

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Key Takeaways

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Thank **You**

Your Contact

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