Virtual Power Plant, power forecasts and grid load forecasts for the energy transition in Latin America

Experiences from a pilot with CAMMESA in Argentina

Dr. Matthias Lange, Ulrich Kaltenbach

26 January 2022

Agenda

1. Company introduction
2. develoPPP in Argentina
3. Introduction to IT solutions for vRE integration

    3.1 Virtual Power Plant

        3.1.1 Technology and applications
        3.1.2 Use case in Argentina: vRE control room for CAMMESA

    3.2 Solar and wind power forecasting

        3.2.1 Some basics of vRE forecasting
        3.2.2 Experiences from forecasting pilot in Argentina

    3.3 Vertical grid load forecast

        3.3.1 The concept of vertical grid load forecast
        3.3.2 Results from load forecasts for substation in Argentina

4. Lessons learned

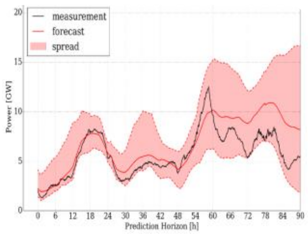
Agenda

1. About energy & meteo systems

Company

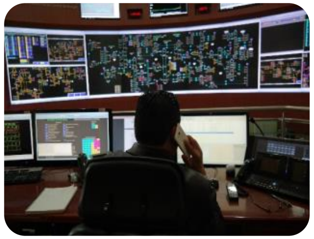
- Managed by its founders since 2004
- Located in Oldenburg, Germany
- 130 employees (physicists, meteorologists, mathematicians, engineers)

Services



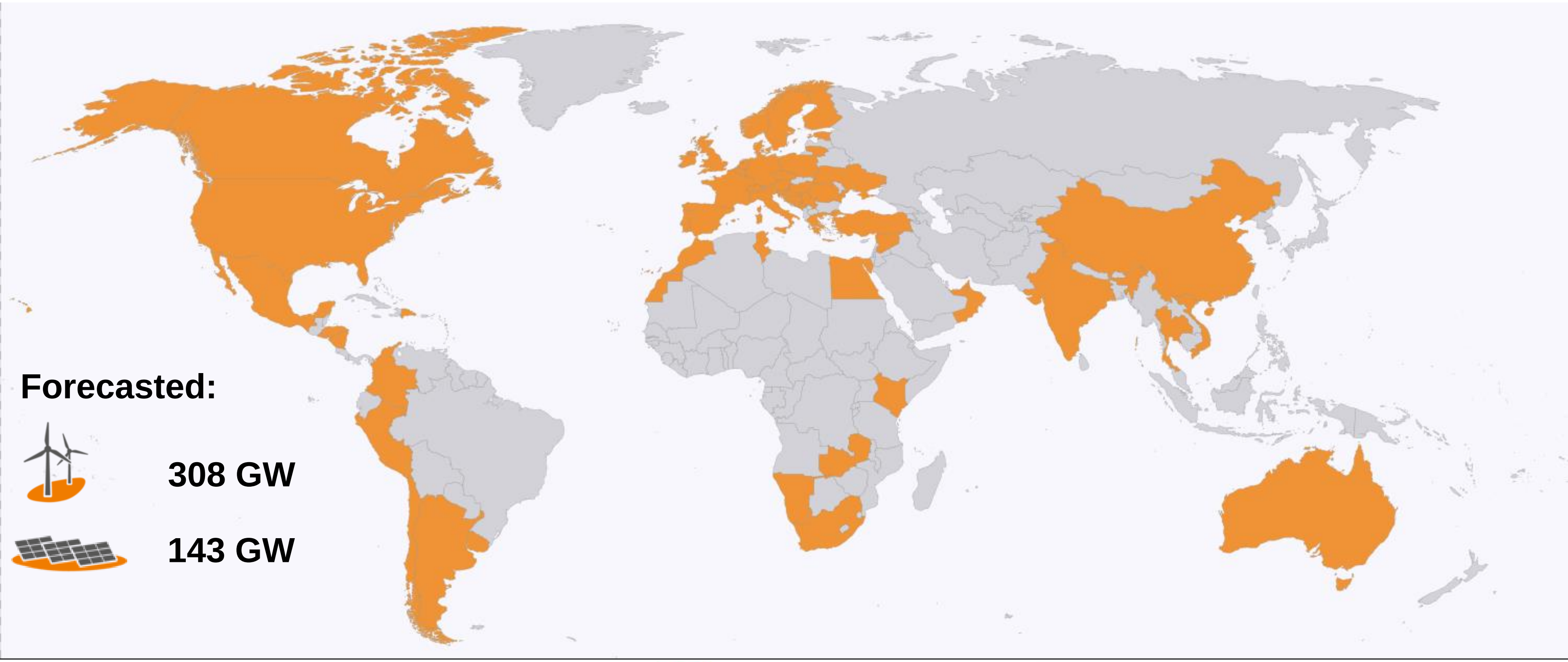
- Accurate forecasts of solar, wind, demand and grid congestions
- Market-leading Virtual Power Plant (SaaS)
- IT platform *FuturePowerFlow* for grid operators
- Consulting and R&D

Customers



- Transmission, distribution and independent system operators
- Power traders and aggregators
- Wind and solar plant operators

1. We provide our IT solutions on all continents



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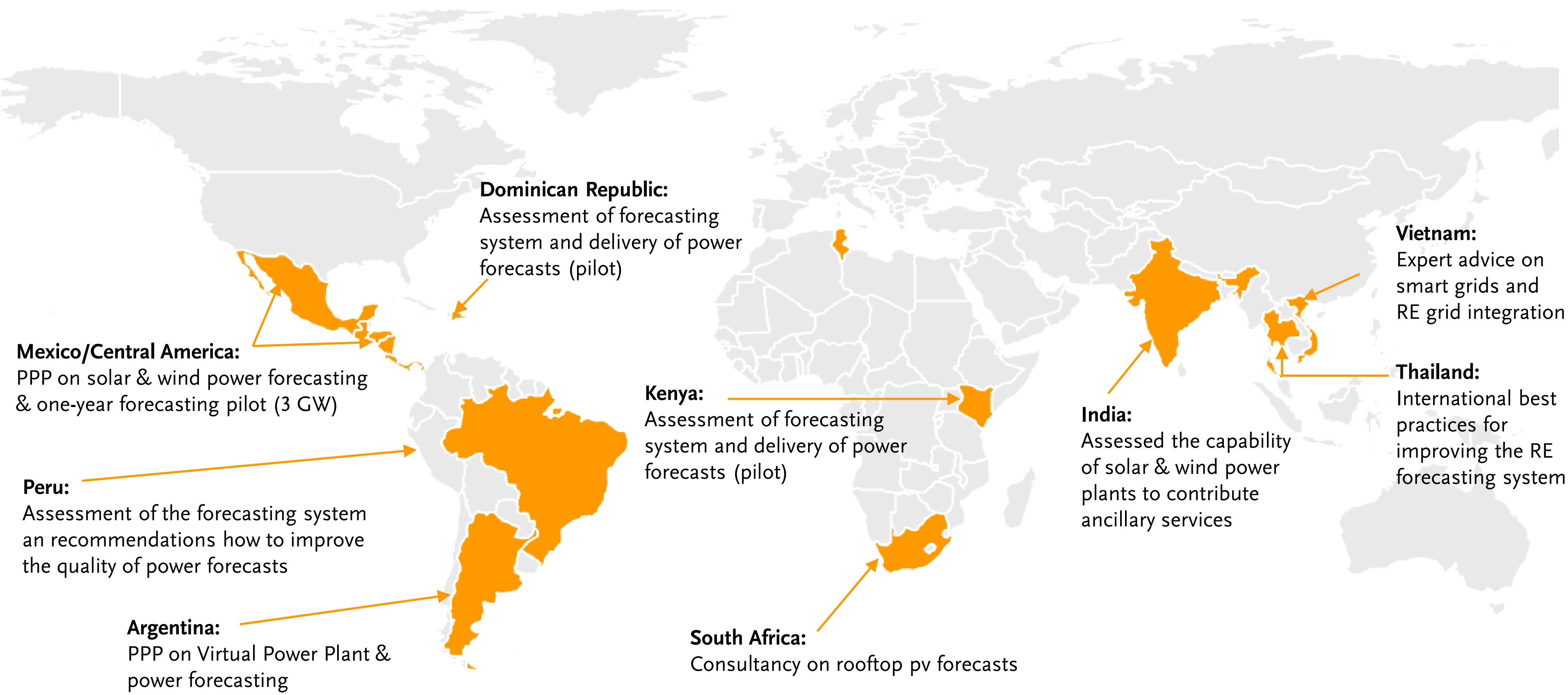
1. Consulting: international project references



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Agenda

2. develoPPP in Argentina/Latin America: objective and scope

Period: January 2019 - January 2022

Partners: energy & meteo systems, GIZ Chile, CAMMESA

Objective: Transfer of know-how to Argentina and Latin America how IT solutions help to efficiently integrate renewable energy

Scope: **Capacity building workshops** on Virtual Power Plant software and international best practices in power forecasting

Two-year pilot phase with CAMMESA which included…

- application of Virtual Power Plant
- operational delivery of power forecasts for wind and solar parks in Argentina
- set up of vertical grid load forecast for selected site

Regional dissemination workshop

2. Dynamic expansion of renewables in Argentina

- From 2016 to 2019 Argentina's government awarded contracts for 6.5 GW via the auction regime RenovAr
- Triggered dynamic installation of large-scale wind and solar parks which were continuously connected to the electricity grid
- vRE figures from 2021:
  - installation of 26 projects with 1.004 MW
  - total installed capacity: 5.181 MW (187 projects larger than 5 MW)
  - vRE covered 13% of energy consumption (goal for 2025: 20%)
- Strong concentration of solar and wind parks in regions with high resources
  - ➢ South: wind
  - ➢ North-East: solar
- Potential problem to evacuate wind and solar energy to load centres

2. Challenges for CAMMESA

- CAMMESA is not used to dealing with high numbers of distributed vRE plants
- Weather-dependent production requires new processes for system operation
- No efficient remote-control of solar and wind parks
- No operational prediction of impact from vRE feed-in on grid nodes (grid congestions)

2. Overview: support by energy & meteo systems

- energy & meteo systems implemented a Virtual Power Plant for CAMMESA to monitor feed-in from renewables
- Set up wind and solar power forecasts and integrated them in VPP
- Real-time data from 34 wind parks were integrated
- Set up and delivery of operational vertical grid load forecasts to CAMMESA

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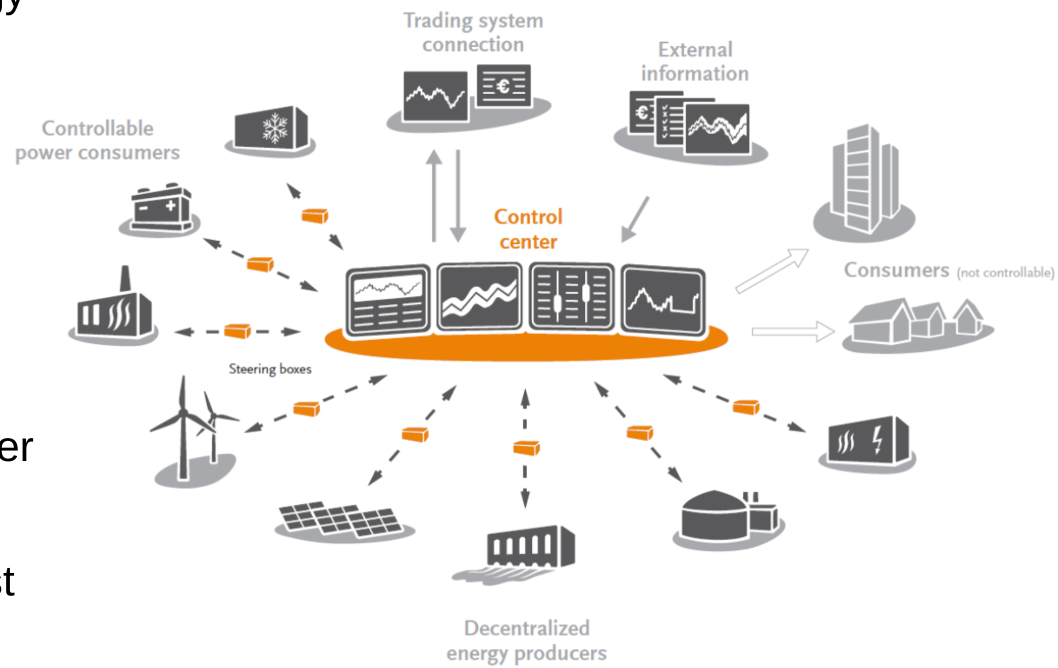
3.1.1 Virtual Power Plant
…for a smart management of distributed energy resources

- **Aggregation** of distributed energy units to single portfolio
- **Connects** to unlimited number of wind onshore & offshore, solar, hydro, storage systems…
- Integrates **power forecasts** for connected plants
- **Monitors** current and future power output (considering outages)
- **Remote-controls** plants to adjust power output (e.g. in case of grid congestions)
- **Direct interface with** power markets
- More information and video under: www.emsysvpp.com/products/virtual_power_plant/technology.php



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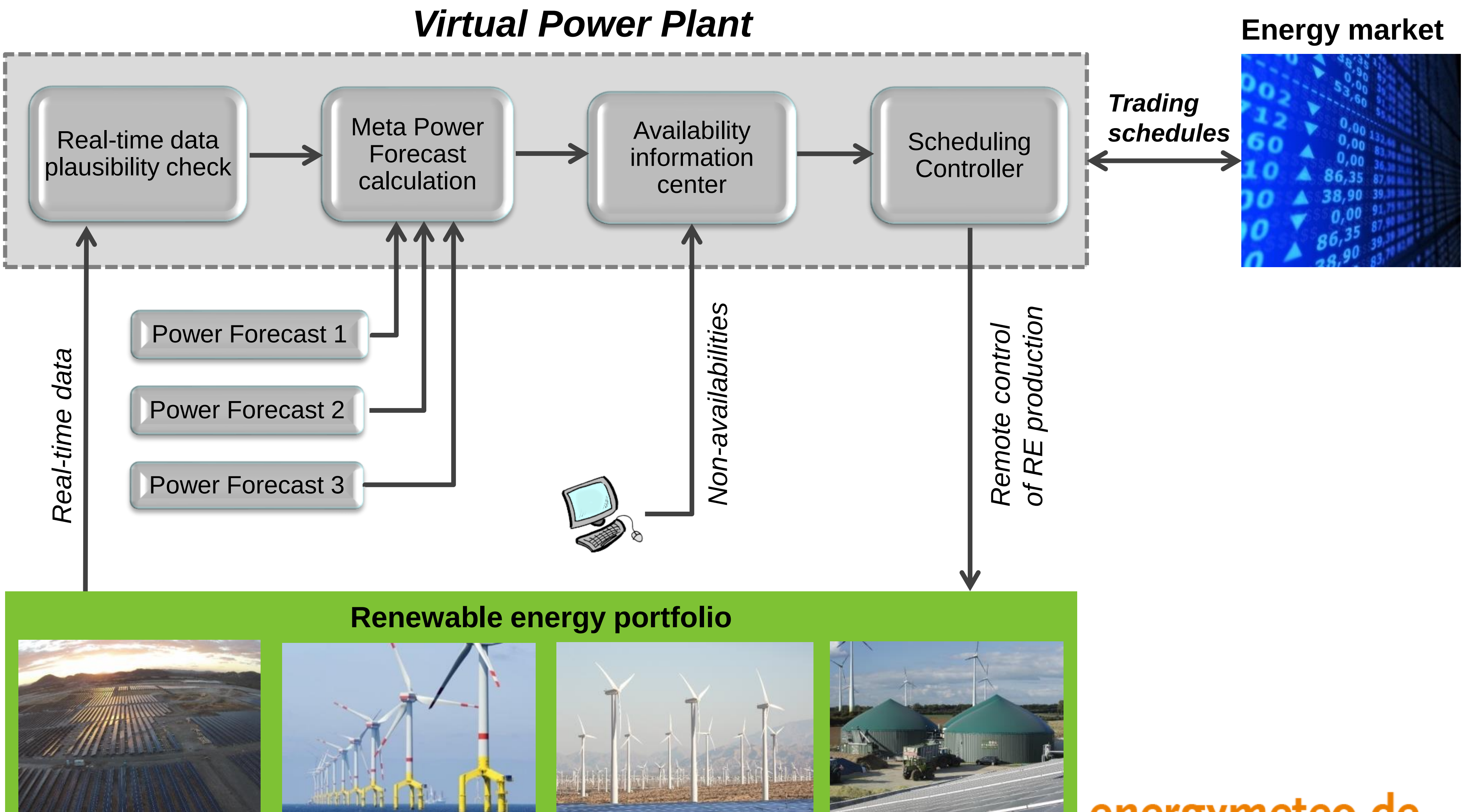
3.1.1 Virtual Power Plant: data flow



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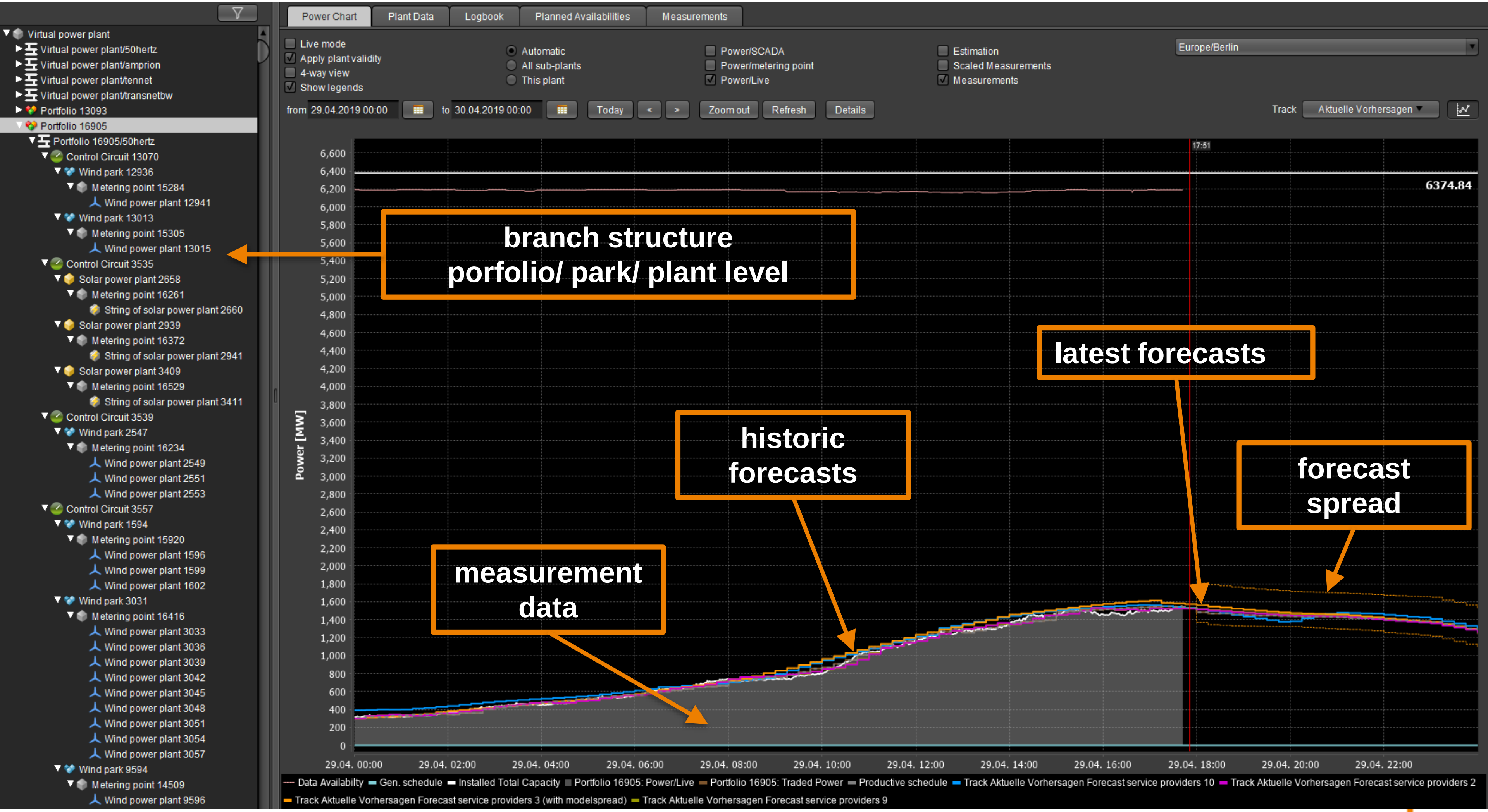
3.1.1 Virtual Power Plant: technical overview



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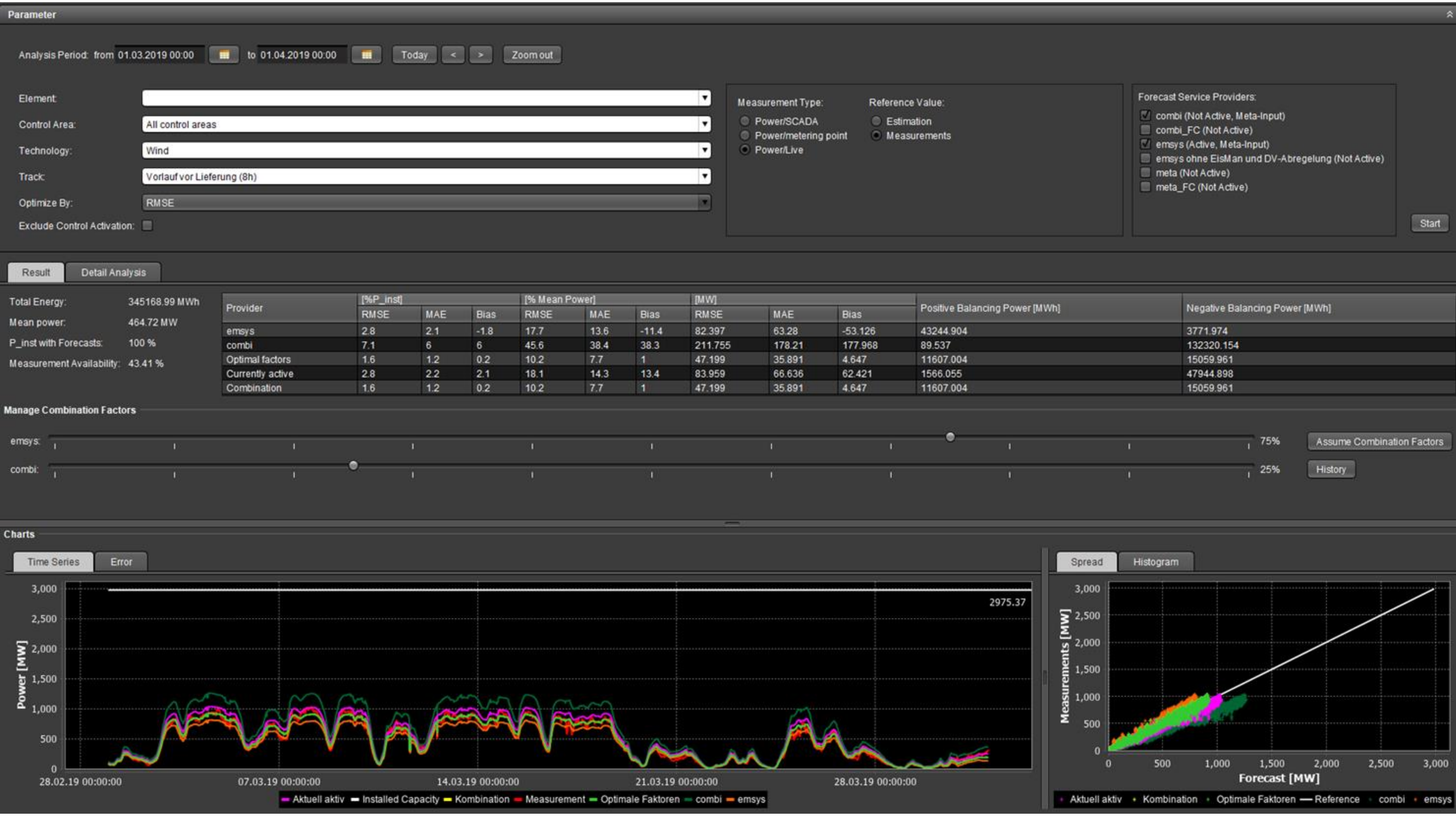
3.1.1 Virtual Power Plant: forecast analysis and improvement



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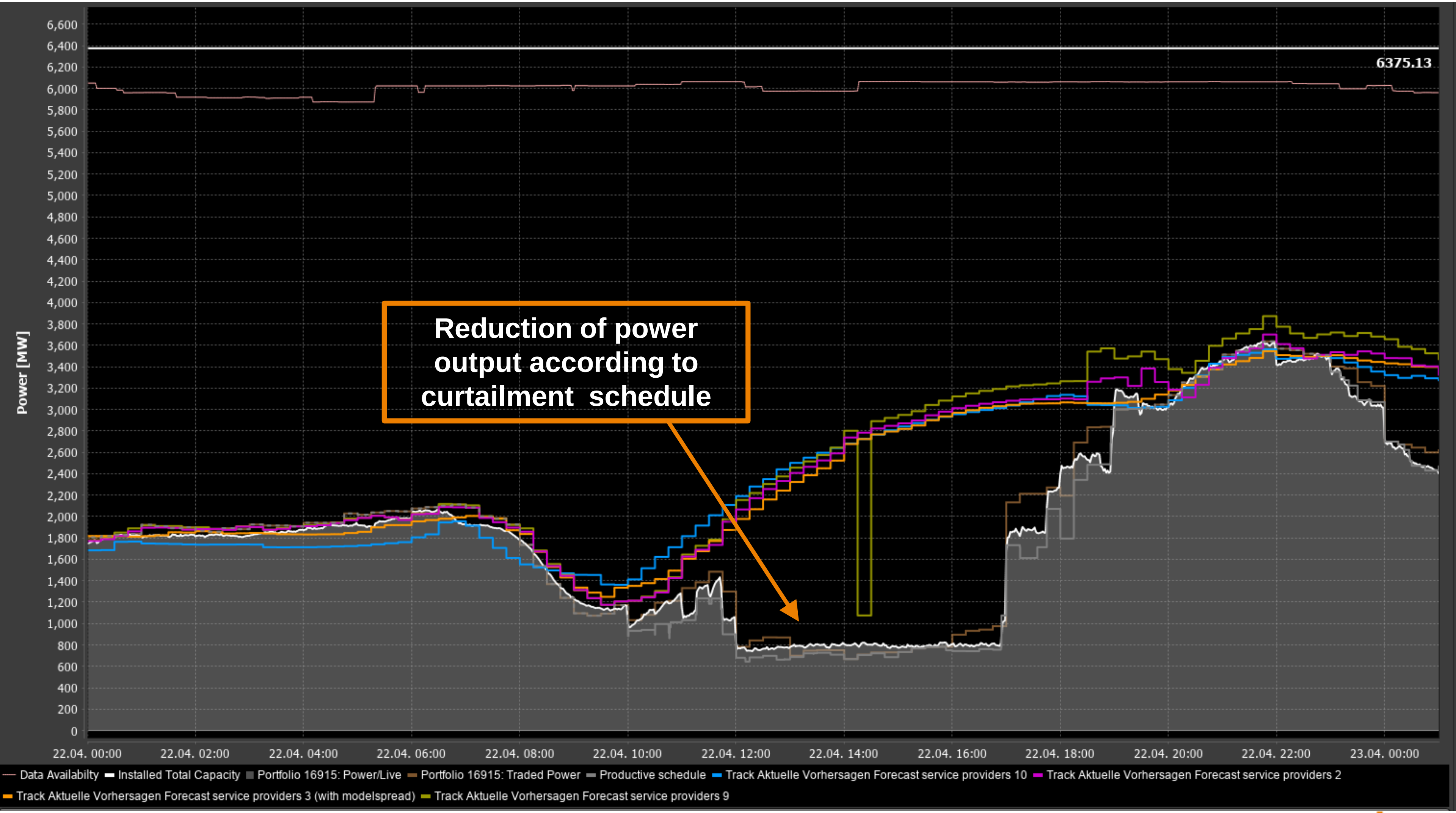
3.1.1 Virtual Power Plant: technical overview



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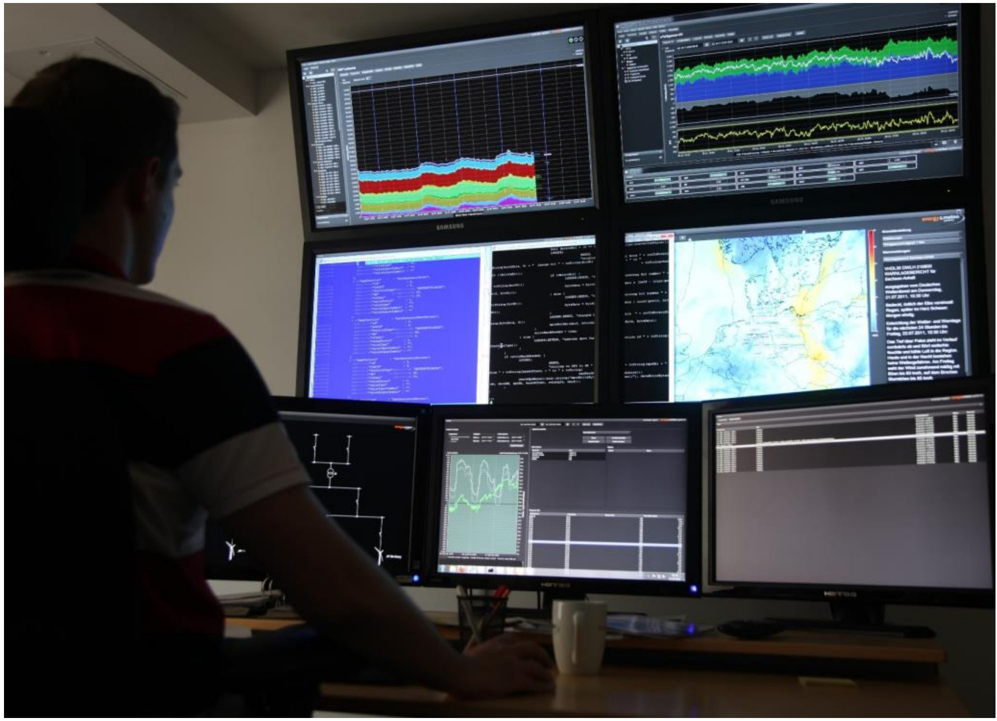
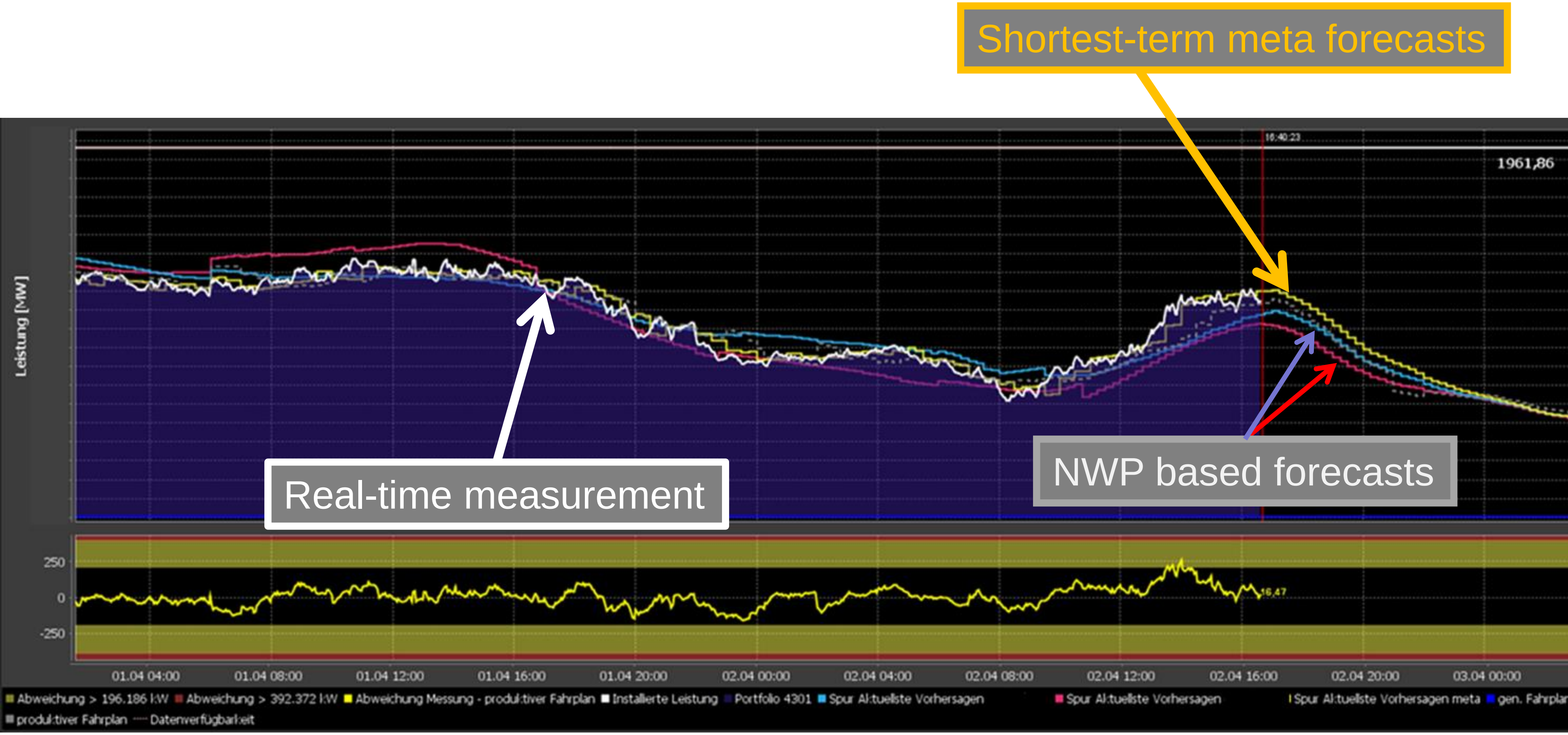
3.1.1 Virtual Power Plant: applications and business models

- **Data acquisition & monitoring** of current and future production
- **Control center** for grid operators or plant operators to remote-control production/ feed-in of renewables
- **Trading** of renewable energies on intraday and spot markets
- Providing **ancillary services** with renewable energies
- **Demand Side Management** with flexible consumers
- etc.



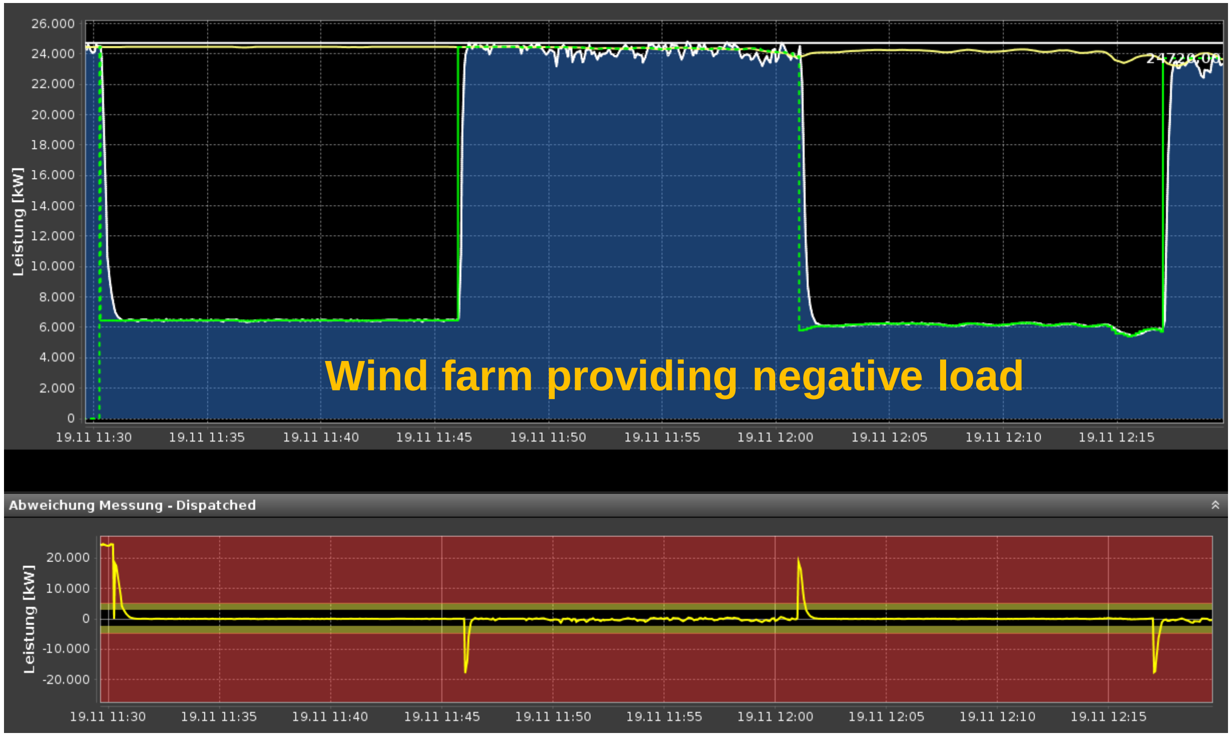
3.1.1 VPP use case 1: vRE trading

Deviations of forecast can be settled on intraday market to reduce balancing costs.



3.1.1 VPP use case 2: providing ancillary services

- Assets connected to VPP can supply primary, secondary or tertiary reserve power
- Often pre-qualification by grid operator required
- VPP has to cover high standards on availability and security
- In Germany wind farms are able to participate



Source: energy & meteo systems

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3.1.1 VPP use case 3: demand side management

- VPP can integrate controllable loads for DSM applications
- Example: cooled warehouse(s) connected to VPP as load
- Flexibility of warehouses defined in advance and considered in operational ranges of VPP
- VPP used to optimize energy supply and purchase via spot market and regulation market
- Production units such as wind farms and solar plants added
- Also used to minimize impact of forecasting errors
- https://www.energymeteo.com/es/clientes/proyectos_de_investigacion/eTelligence.php

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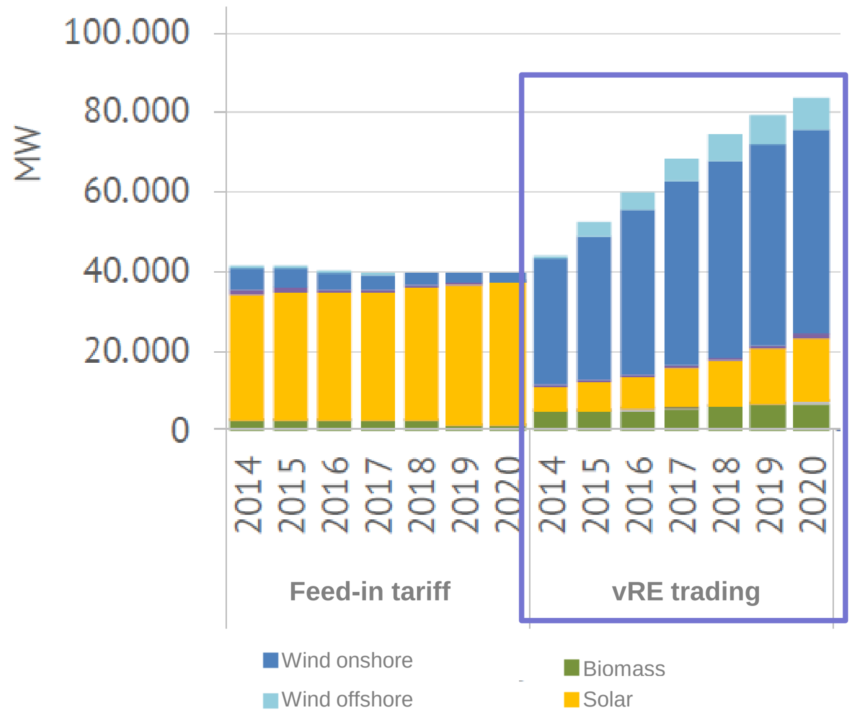
3.1.1 VPP use case 3: demand side management

3.1.1 VPP market example: Germany

- Since 2012 vRE plants above 100 kW need to actively trade their production
- Idea: vRE plants should assume more responsibility for market integration, adjusting production to market signals
- Plant owners transfer this task to **aggregators**, specialized power traders
- Aggregators bundle large portfolios of third parties´ assets
- **Virtual Power Plant & power forecasts** have emerged as state-of-the-art IT solution for aggregators
- Example: Statkraft has a **portfolio of 10 GW** controlled by a Virtual Power Plant

Development of vRE sales channels



Monitoring of direct marketing: annual report 2021.
Source: EnergyBrainpool

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3.1.2 VPP use case in Argentina: location of parks

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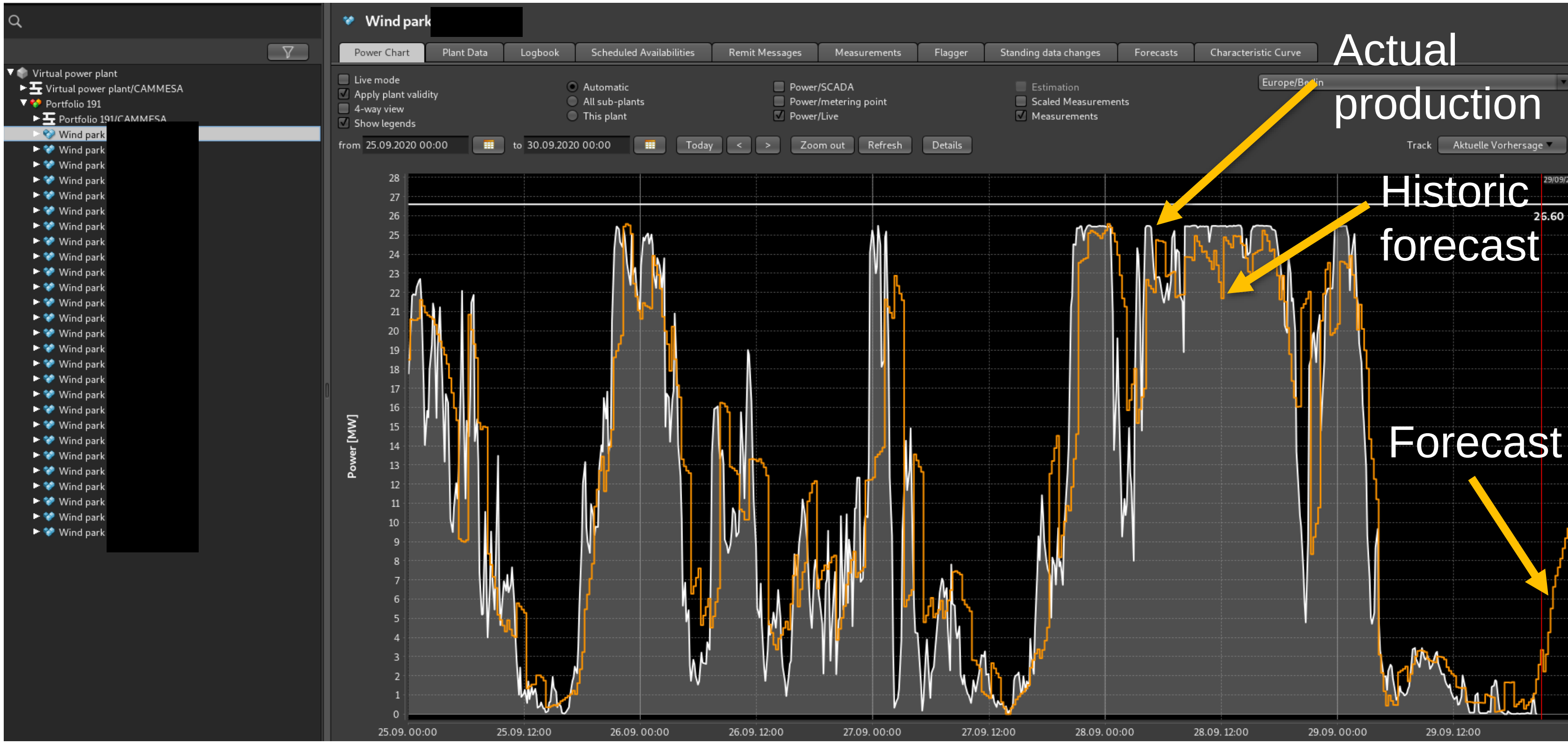
3.1.2 First phase: connection of wind farms to VPP

- Real-time monitoring of current and future feed-in from wind parks on different aggregation levels (single parks and portfolios)
- Here: view of single wind park



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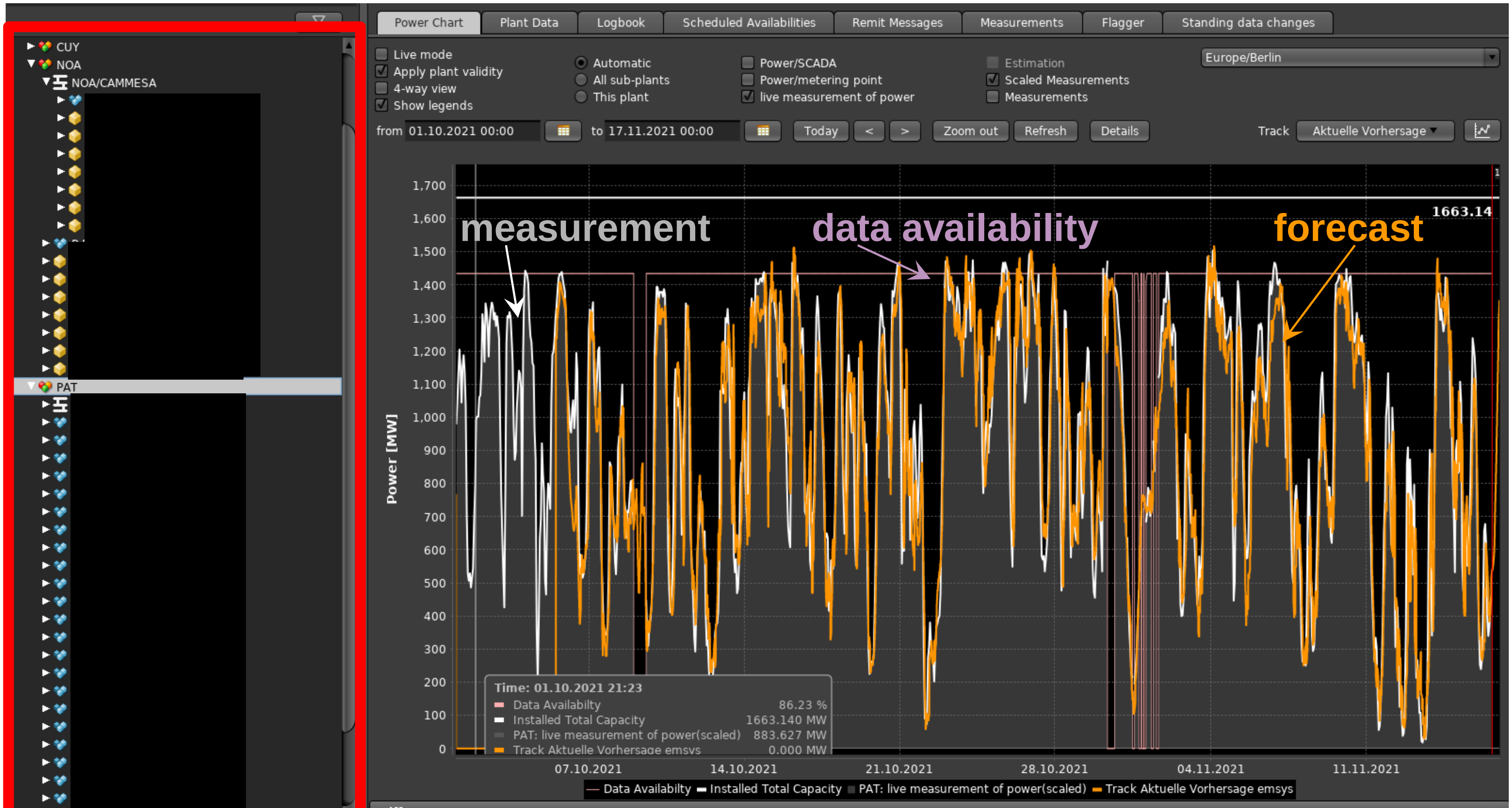
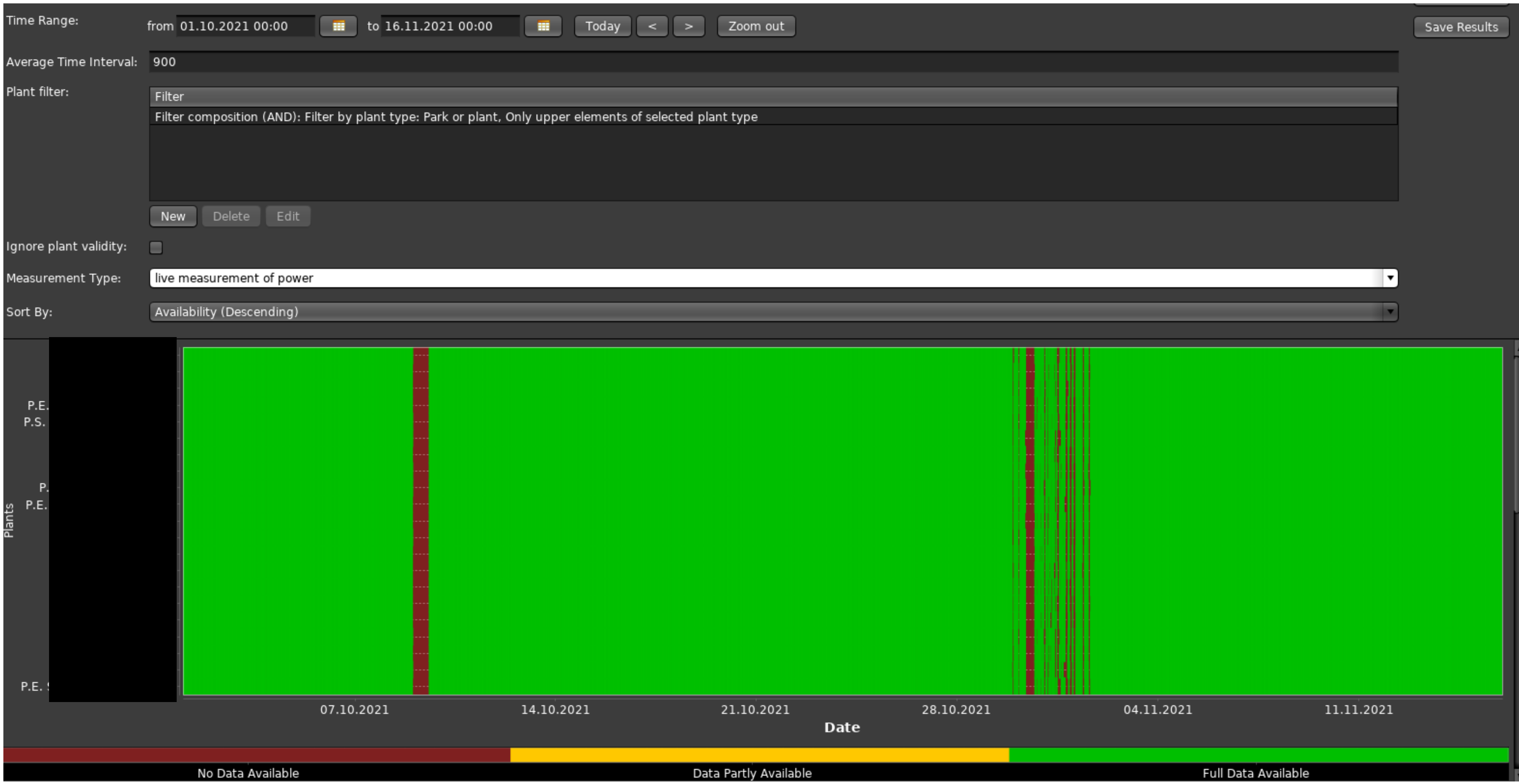
3.1.2 Second phase: connection of solar farms to VPP



3.1.2 Monitoring of measurement availability



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3.1.2 Monitoring of non-availabilities

Parent element	Related to	Type of outage	Available capacity	Installed capacity	Valid from	Valid to	reason	Source	Last changed
Wind parl	[redacted]				04.02.2020 09:32:22	04.02.2020 12:58:27	Maintenance	Webservice	04.02.2020 12:42:28
Wind parl					04.02.2020 12:58:27	04.02.2020 18:00:00	Maintenance	Webservice	04.02.2020 12:42:28
Wind parl					05.02.2020 09:00:00	05.02.2020 15:00:00	Maintenance	Webservice	31.01.2020 20:26:09
Wind parl					04.02.2020 09:32:06	04.02.2020 18:00:00	Maintenance	Webservice	04.02.2020 09:16:06
Wind parl					05.02.2020 09:00:00	05.02.2020 15:00:00	Maintenance	Webservice	31.01.2020 20:26:03
Wind parl					04.02.2020 07:00:00	04.02.2020 13:30:00	Maintenance	Webservice	04.02.2020 12:42:32
Wind parl					04.02.2020 14:15:00	04.02.2020 16:00:00	Maintenance	Webservice	04.02.2020 12:42:32
Wind parl					04.02.2020 13:30:00	04.02.2020 14:15:00	Maintenance	Webservice	04.02.2020 12:42:32
Wind parl					04.02.2020 16:00:00	04.02.2020 18:00:00	Maintenance	Webservice	04.02.2020 12:42:25
Wind parl					05.02.2020 09:00:00	05.02.2020 15:00:00	Maintenance	Webservice	31.01.2020 20:26:13
Wind parl					04.02.2020 07:00:00	04.02.2020 12:58:28	Maintenance	Webservice	04.02.2020 12:42:29
Wind parl					04.02.2020 13:15:00	04.02.2020 14:15:00	Maintenance	Webservice	04.02.2020 12:42:29
Wind parl					04.02.2020 12:58:28	04.02.2020 13:15:00	Maintenance	Webservice	04.02.2020 12:42:29

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3.2.1 Who needs power forecasts?

Grid operators

- Dispatch/Redispatch
- Planning of operating reserve (ancillary services)
- Load flow calculations

Traders/Aggregators

- Impact of vRE production on market prices
- Trading future output of aggregated portfolio
- Reduction of balancing costs

Plant operators

- Often required to submit forecasts to TSO
- Maintenance planning

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3.2.1 Possible configuration of a forecast

Scope: Single parks, portfolios, balancing areas, market, rooftop pv (estimate & forecasts)

Horizon: Up to 15 days ahead

Resolution: Hourly down to 5 minutes

Updates: Down to every 5 minutes

Non-availabilities: Consideration of outages

Service: 24/7 technical service

Monitoring: Access to web portal for monitoring real-time production & power forecasts

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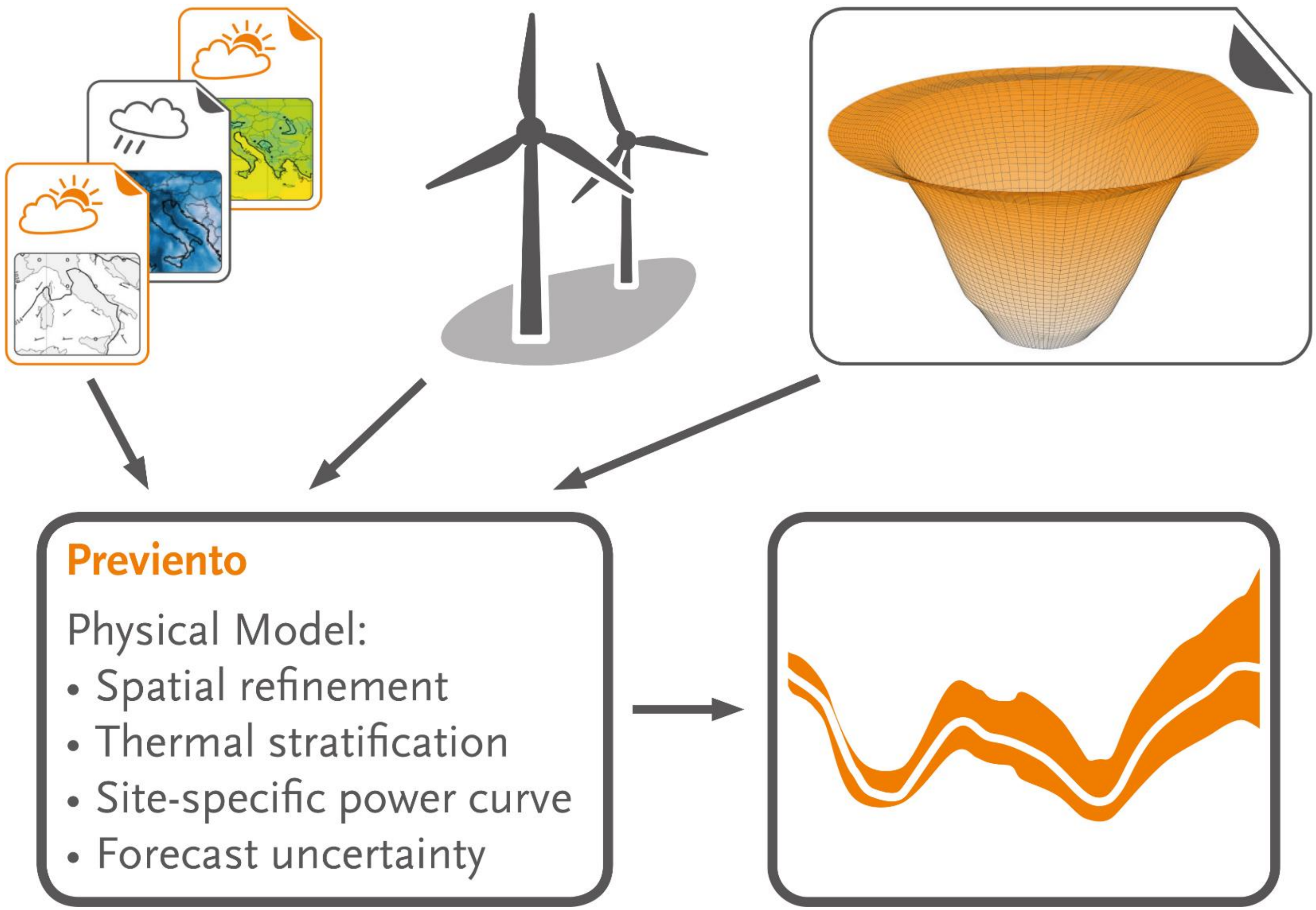
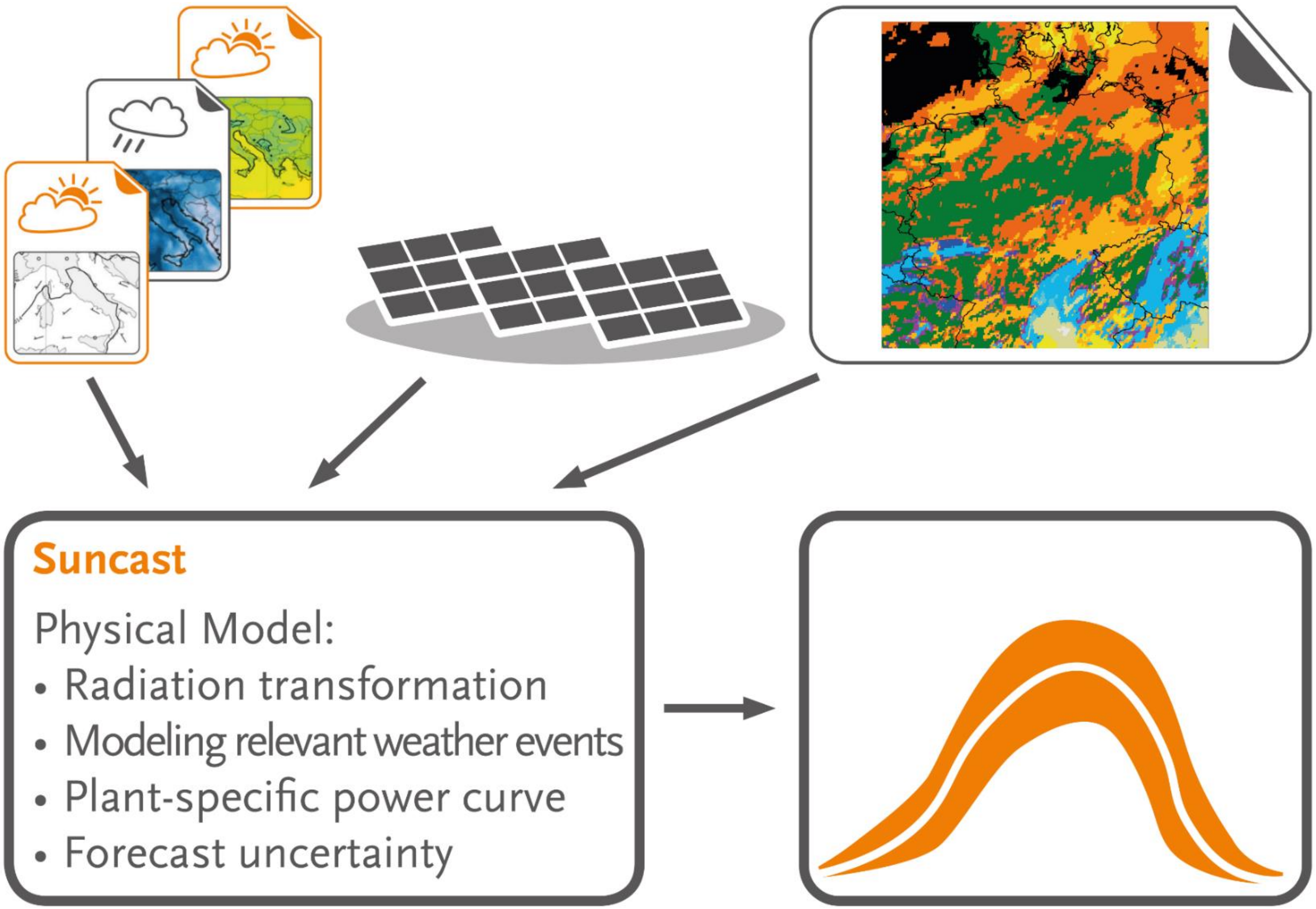
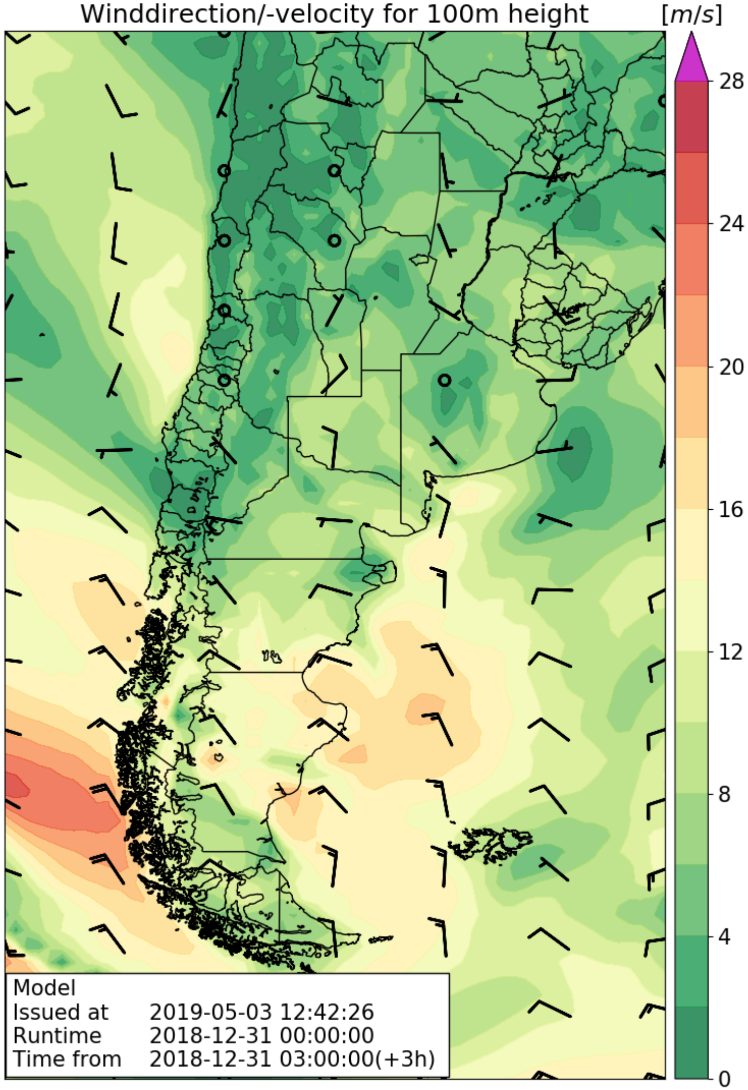
3.2.1 Scheme of a wind power forecasting system



3.2.1 Scheme of a solar power forecasting system



3.2.1 Wind speed and direction forecast from weather model



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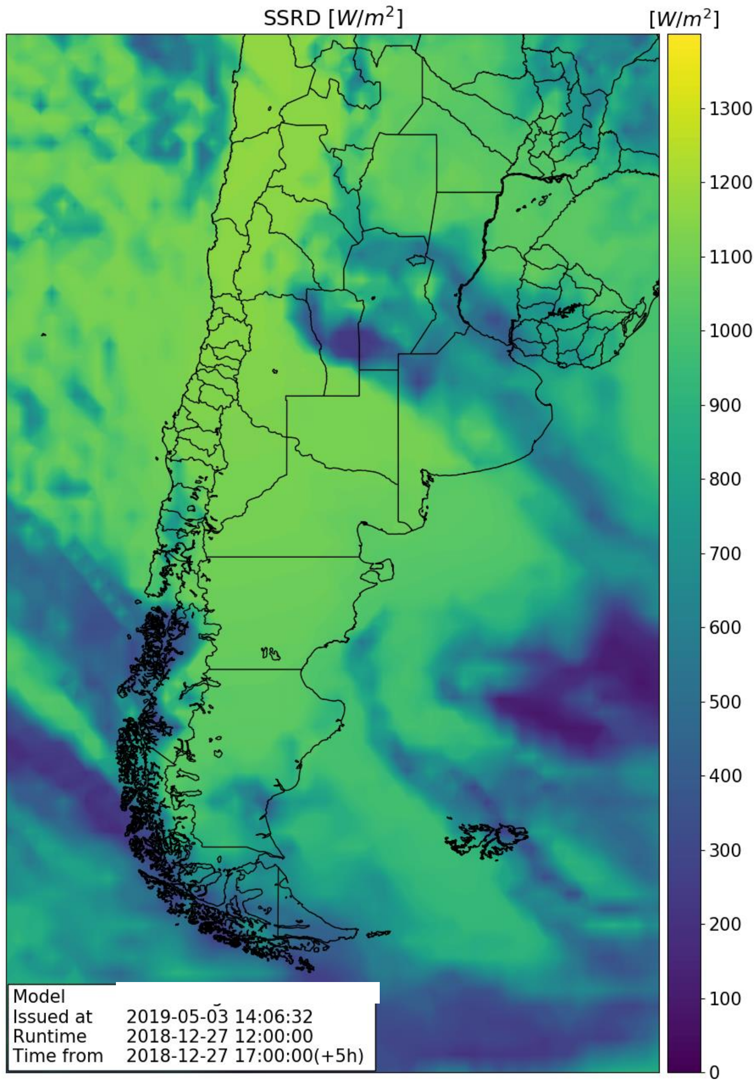
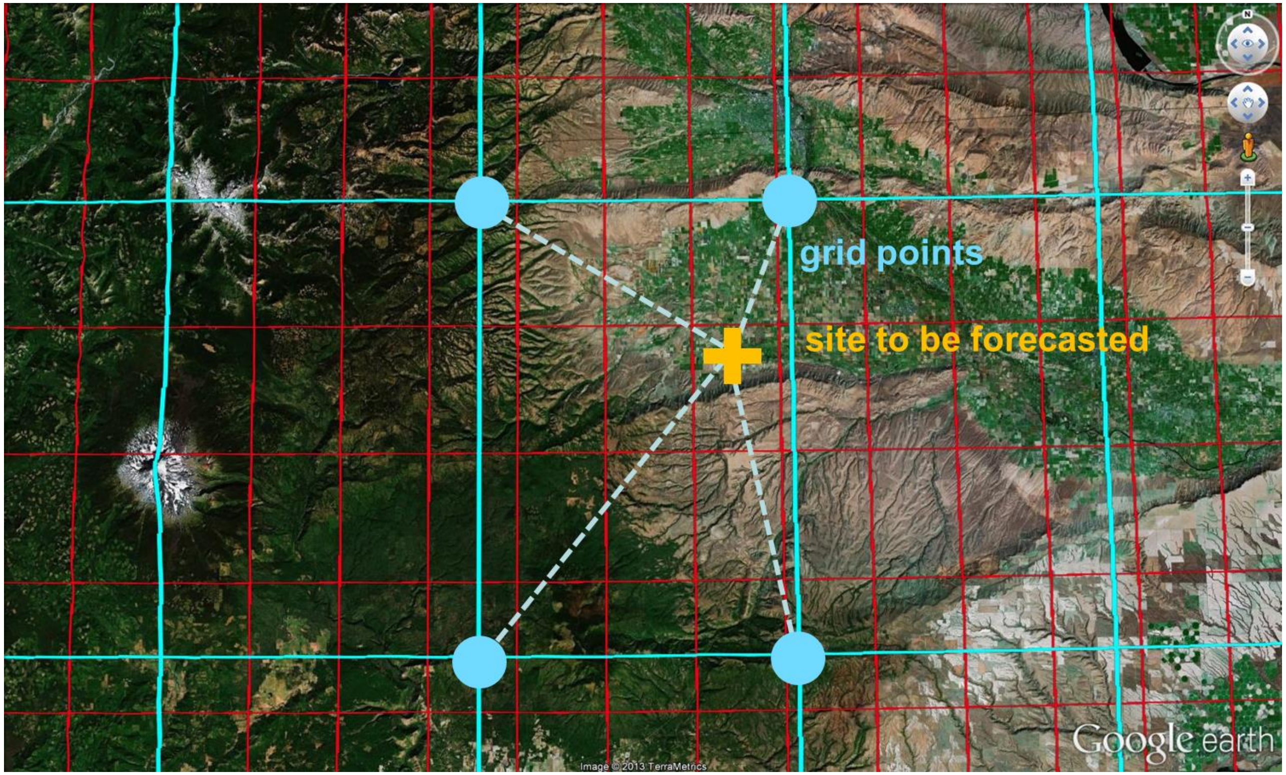
3.2.1 Solar irradiance forecast from weather model

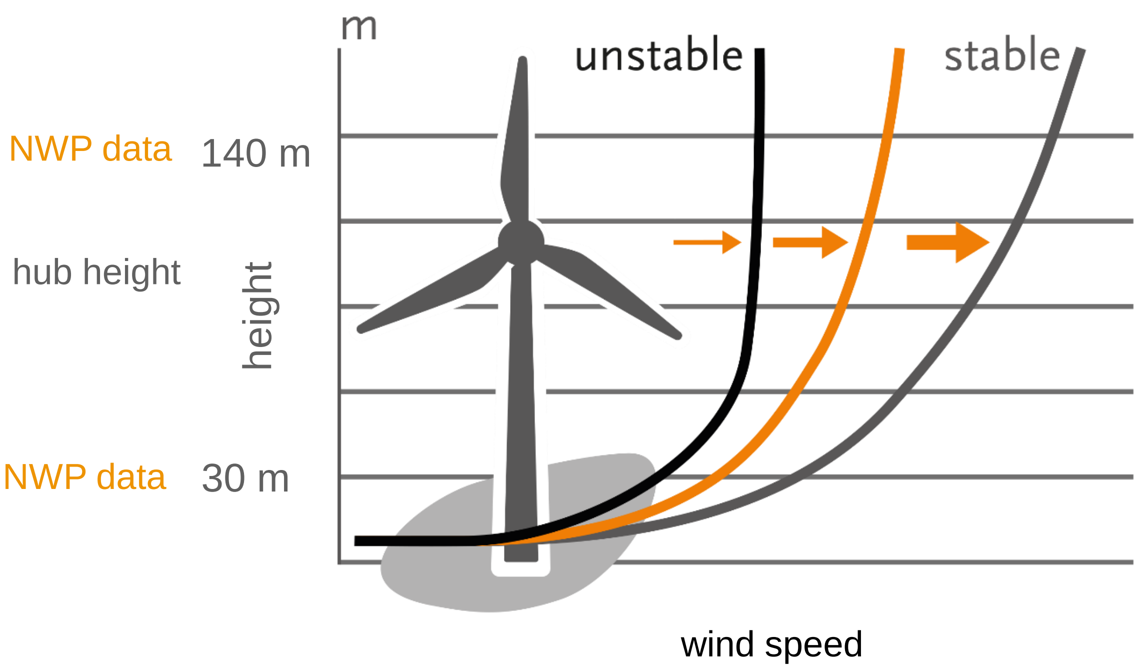


3.2.1 Spatial interpolation needed

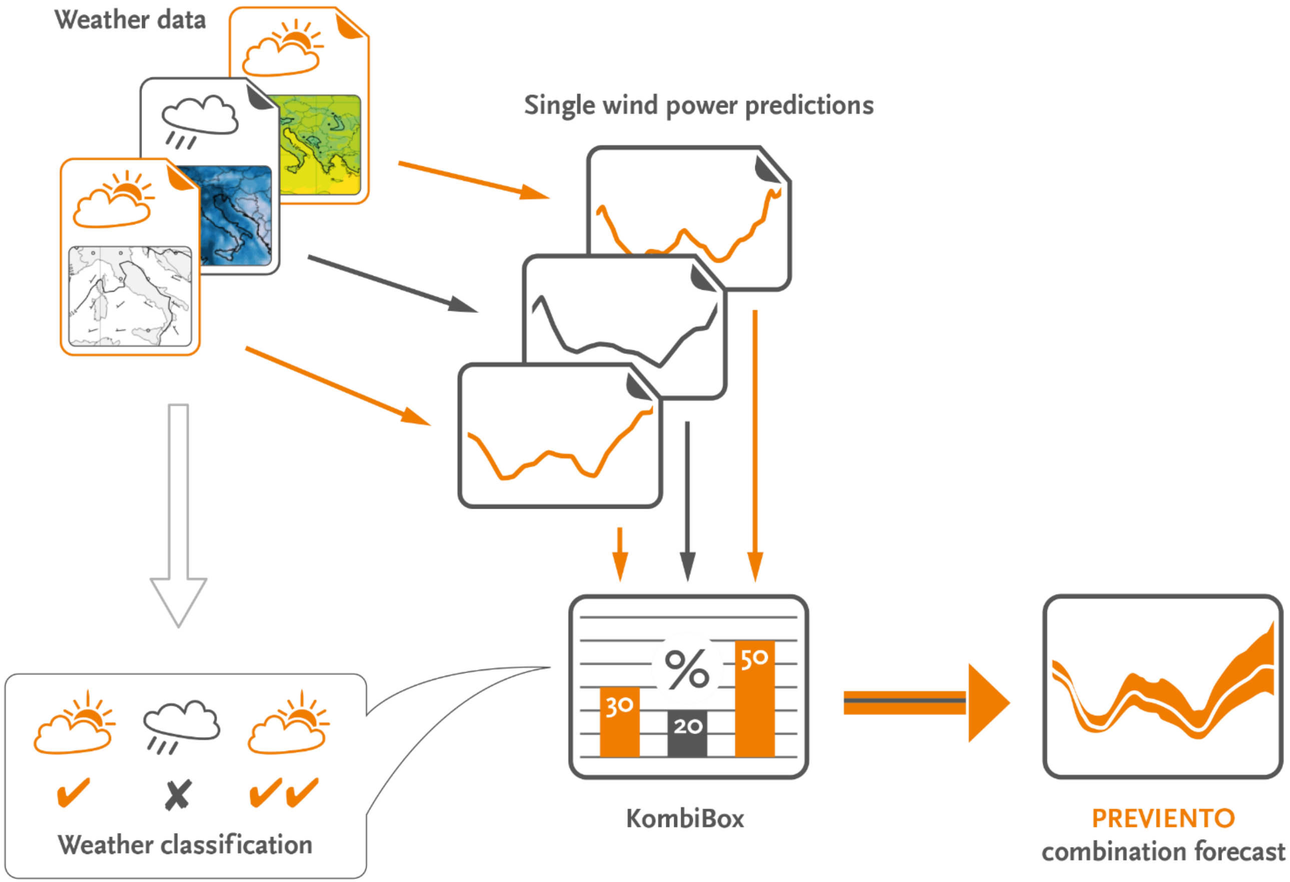


3.2.1 ... also in vertical direction

vertical wind profile changes with atmospheric conditions

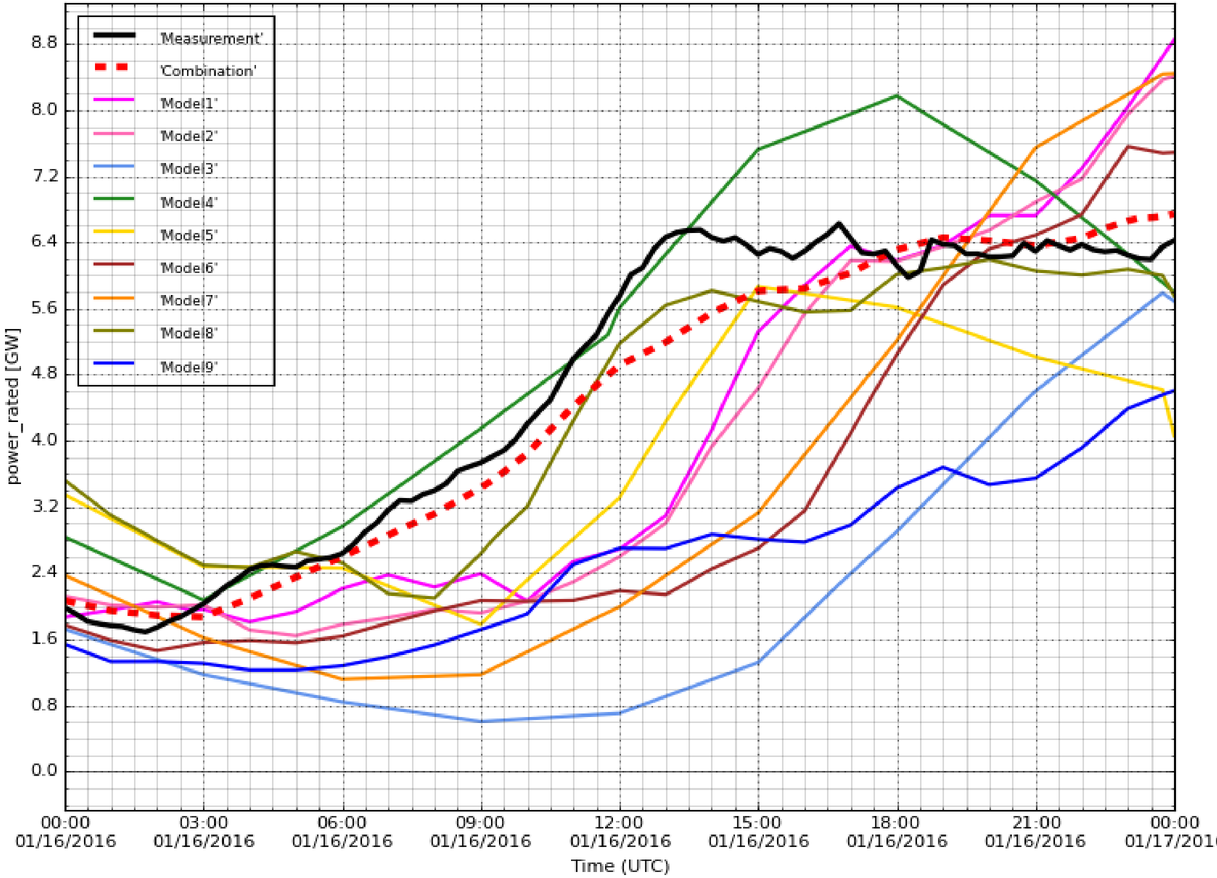


3.2.1 Combination of weather models



3.2.1 Benefit of combining several weather models

- Chart shows different power forecasts based on different weather models
- Red dotted line is the combination of single power forecasts
- Black line is the measurement
- Combination improves overall accuracy and reduces large forecasting errors



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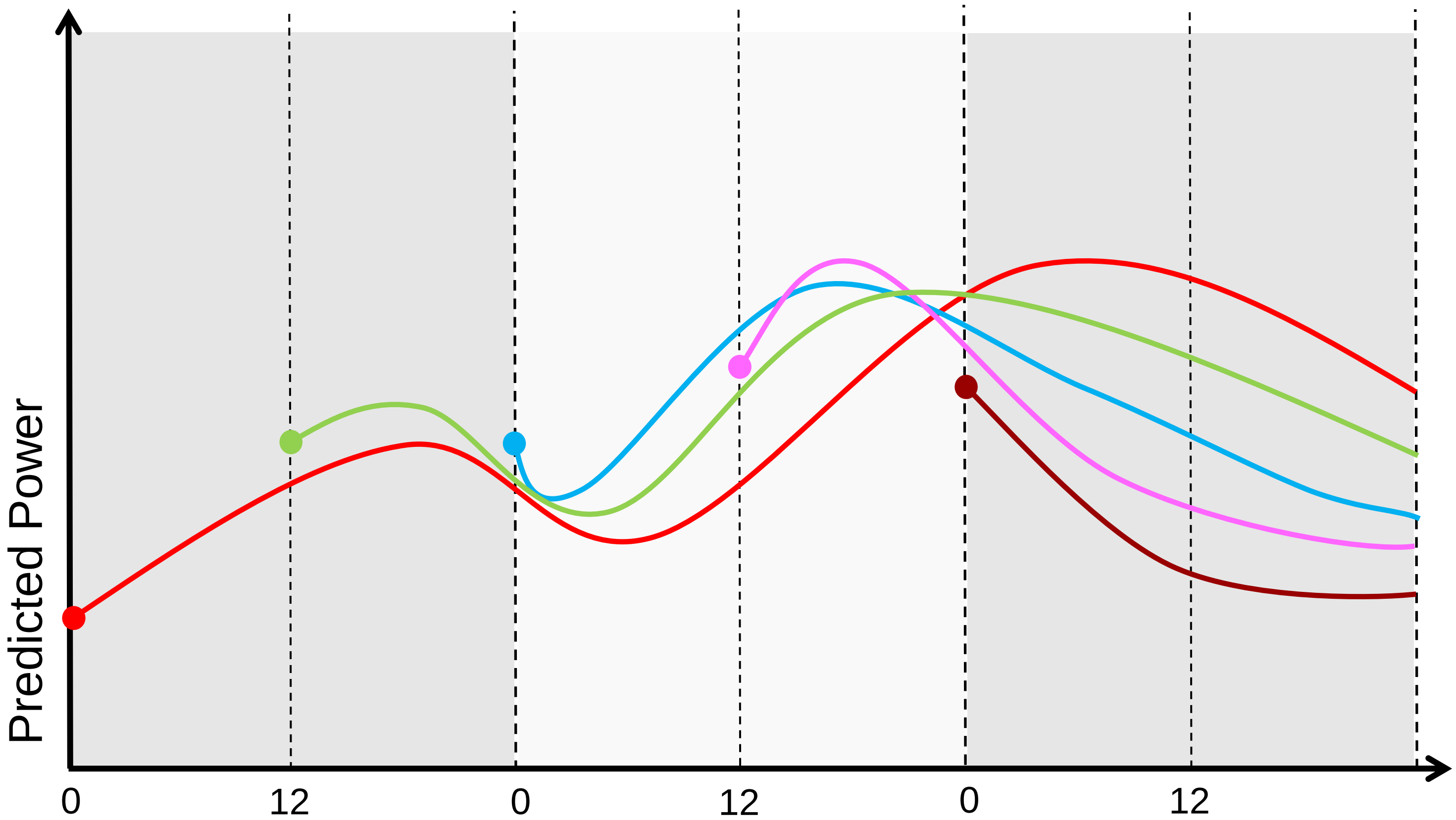
3.2.1 NWP-based power forecast updates



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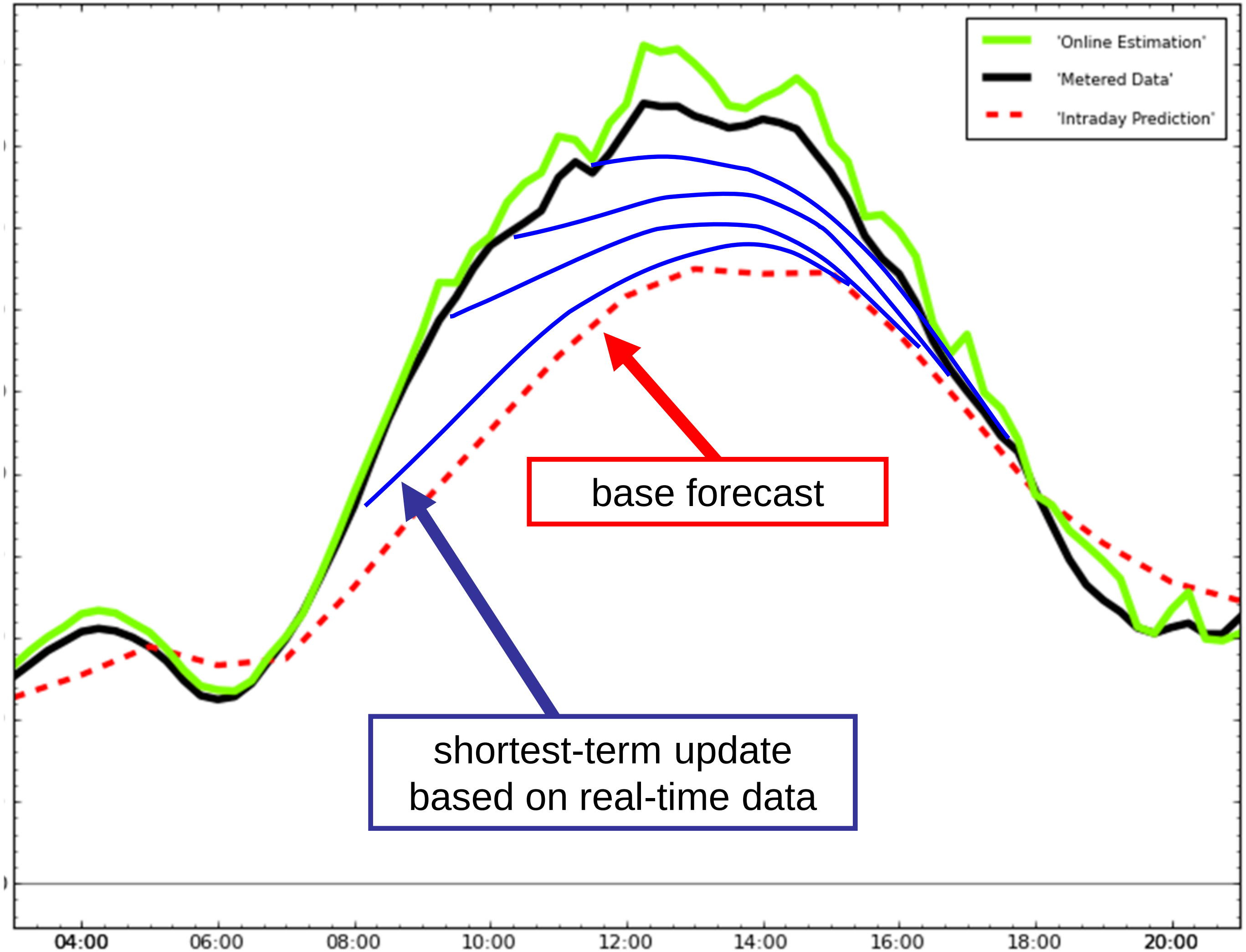
3.2.1 Principle of short-term updates



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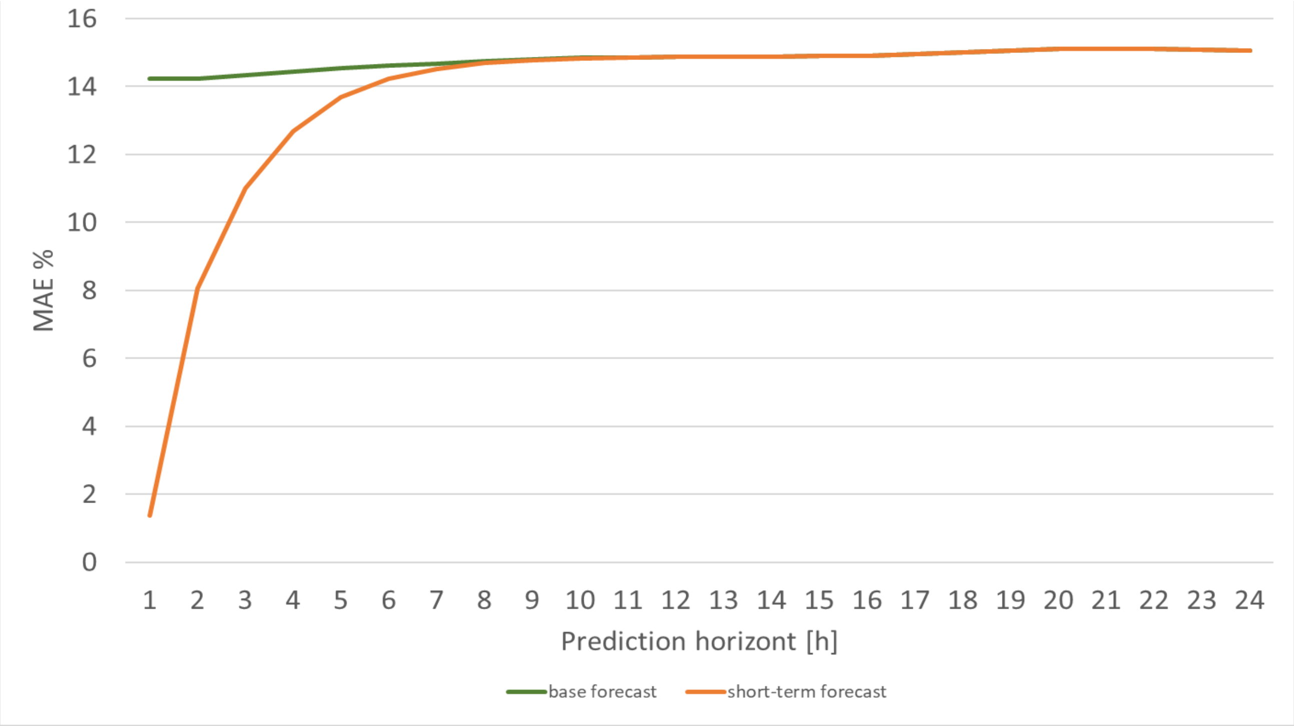
3.2.1 Value of short-term updates

- Green line: NWP based forecast
- Orange line: short-term forecast taking into account real-time measurements
- Short-term optimization provides significantly higher quality for the first six hours of the prediction horizon



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3.2.2 Details on provided wind power forecasts in Argentina

Wind farms

- Number: 34 farms
- Installed capacity: 3 GW
- Portfolio and single plant evaluation
- Evaluation period: June 2021 – November 2021
- Evaluated prediction horizons:
  - 1 - 1.25 h (short term)
  - 5 - 5.25h (intraday)
  - 24 - 48h (day-ahead)
- Production data for 30 plants

3.2.2 Reminder: Location of wind and solar parks

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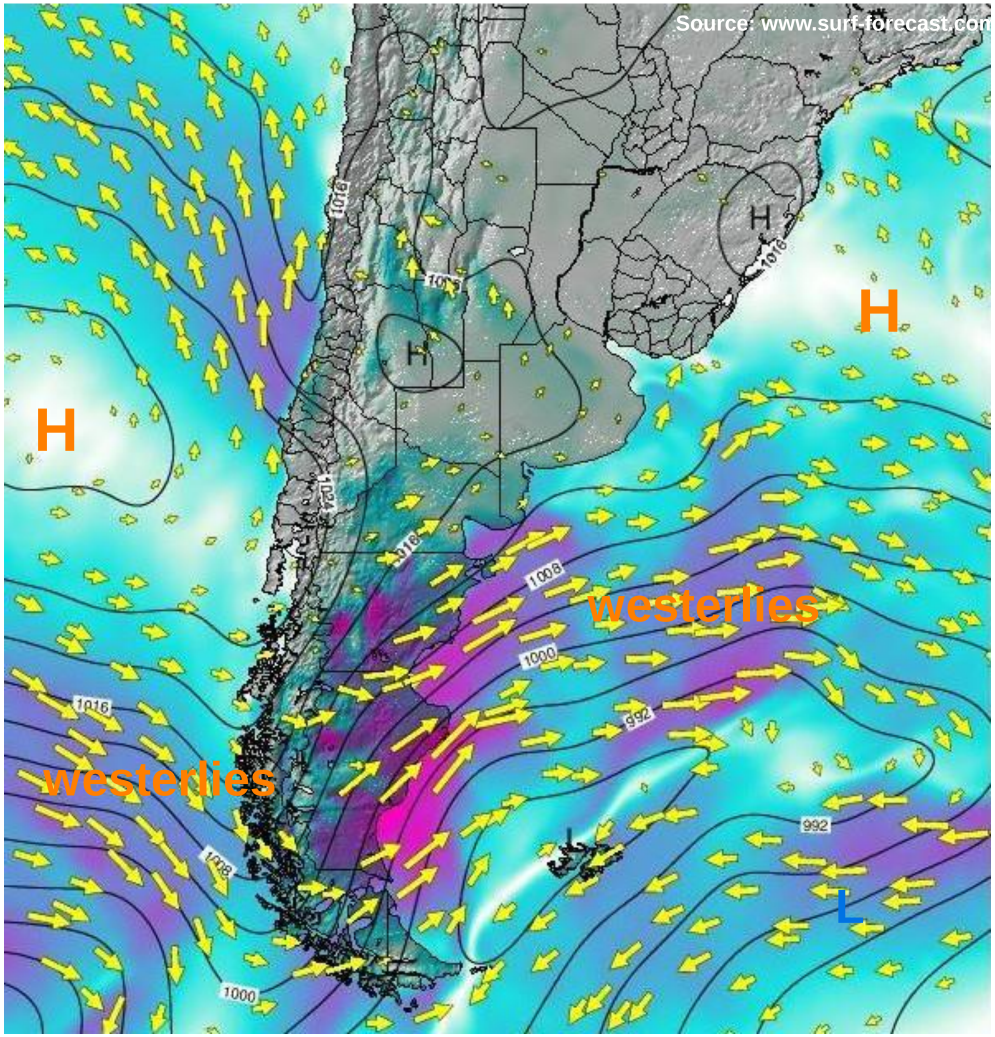
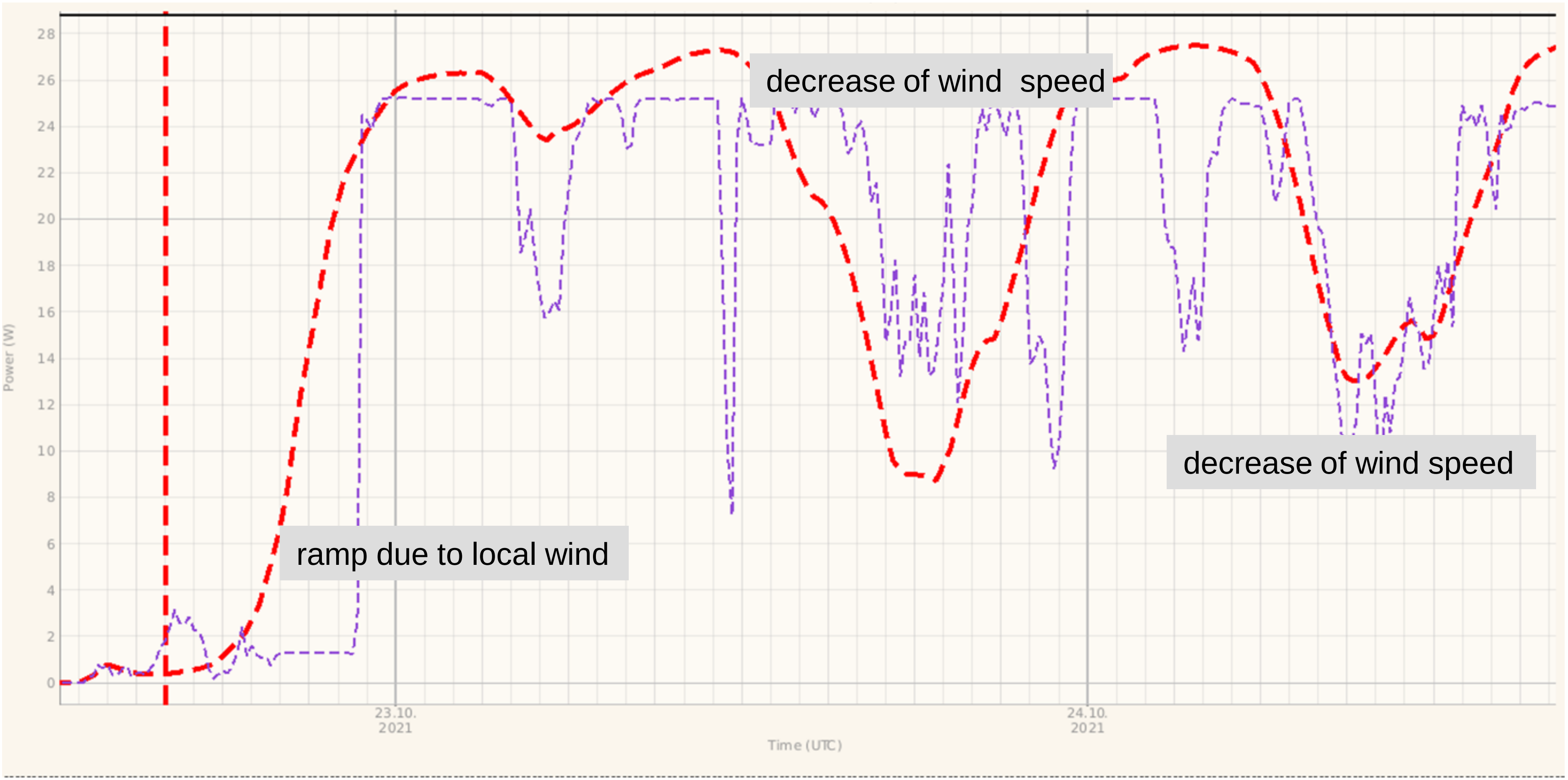
3.2.2 General weather conditions



- Strong westerly winds in Patagonia
- Andes are barrier, preventing strong precipitation across Patagonia
- Cold surges from the southwest often affect southern Argentina
- Northern Argentina influenced by higher pressure over Atlantic and Pacific.
- Northeastern Argentina has far more rain than the South

3.2.2 Ramps at single wind farms



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3.2.2 Effect of storm cut-off on single wind park forecast

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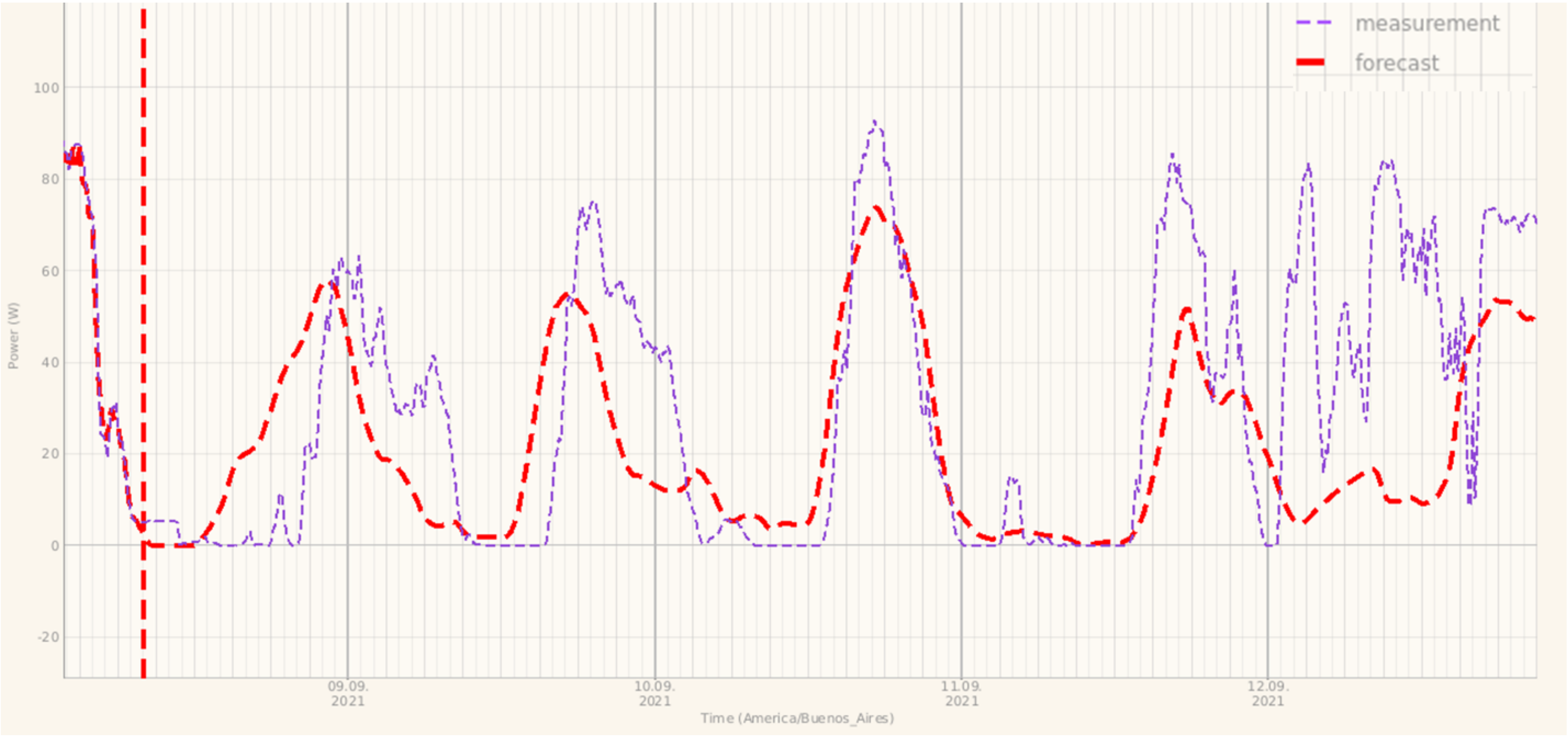
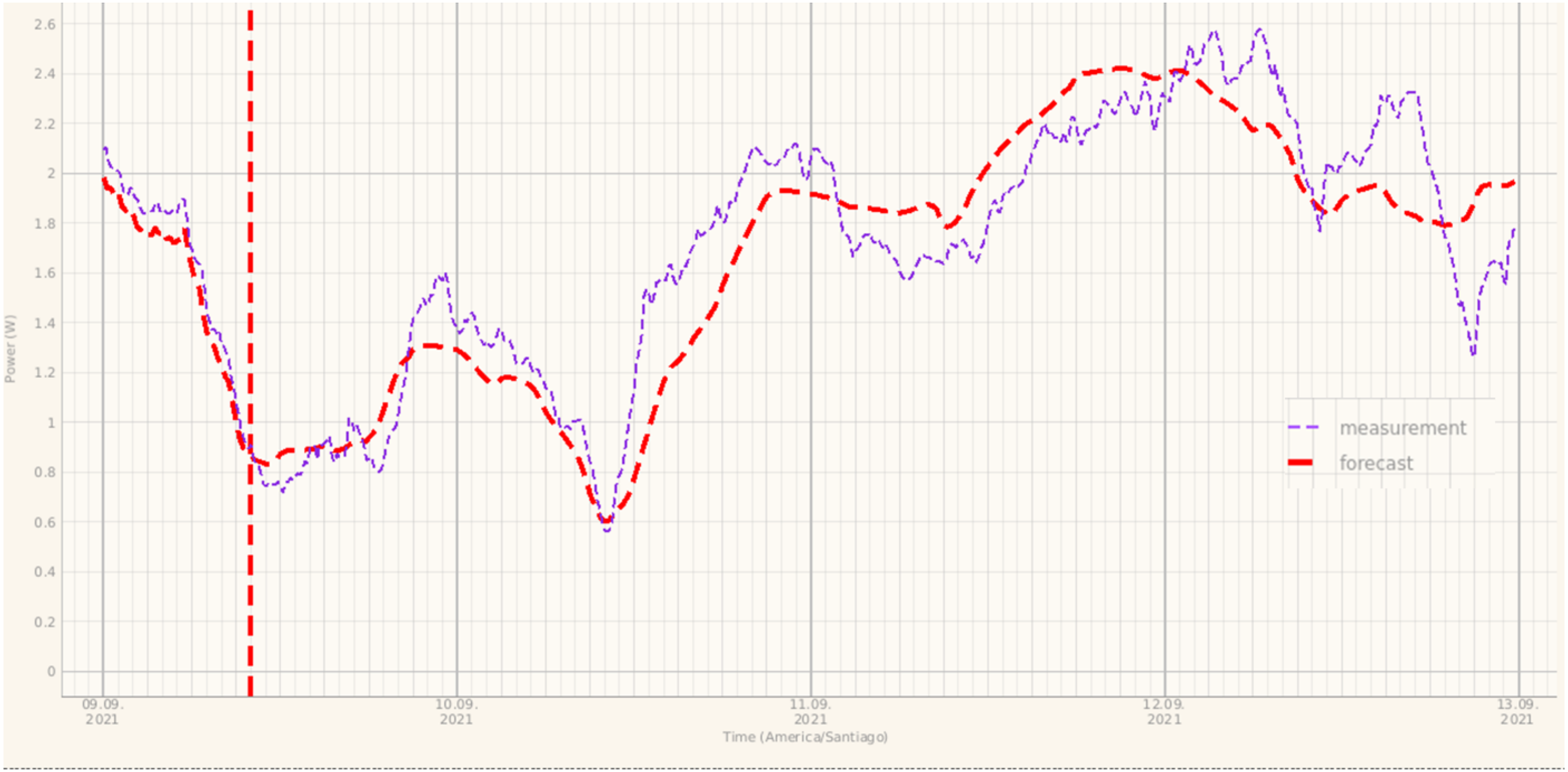
3.2.2 Daily pattern for single wind farm



3.2.2 Daily pattern for wind portfolio



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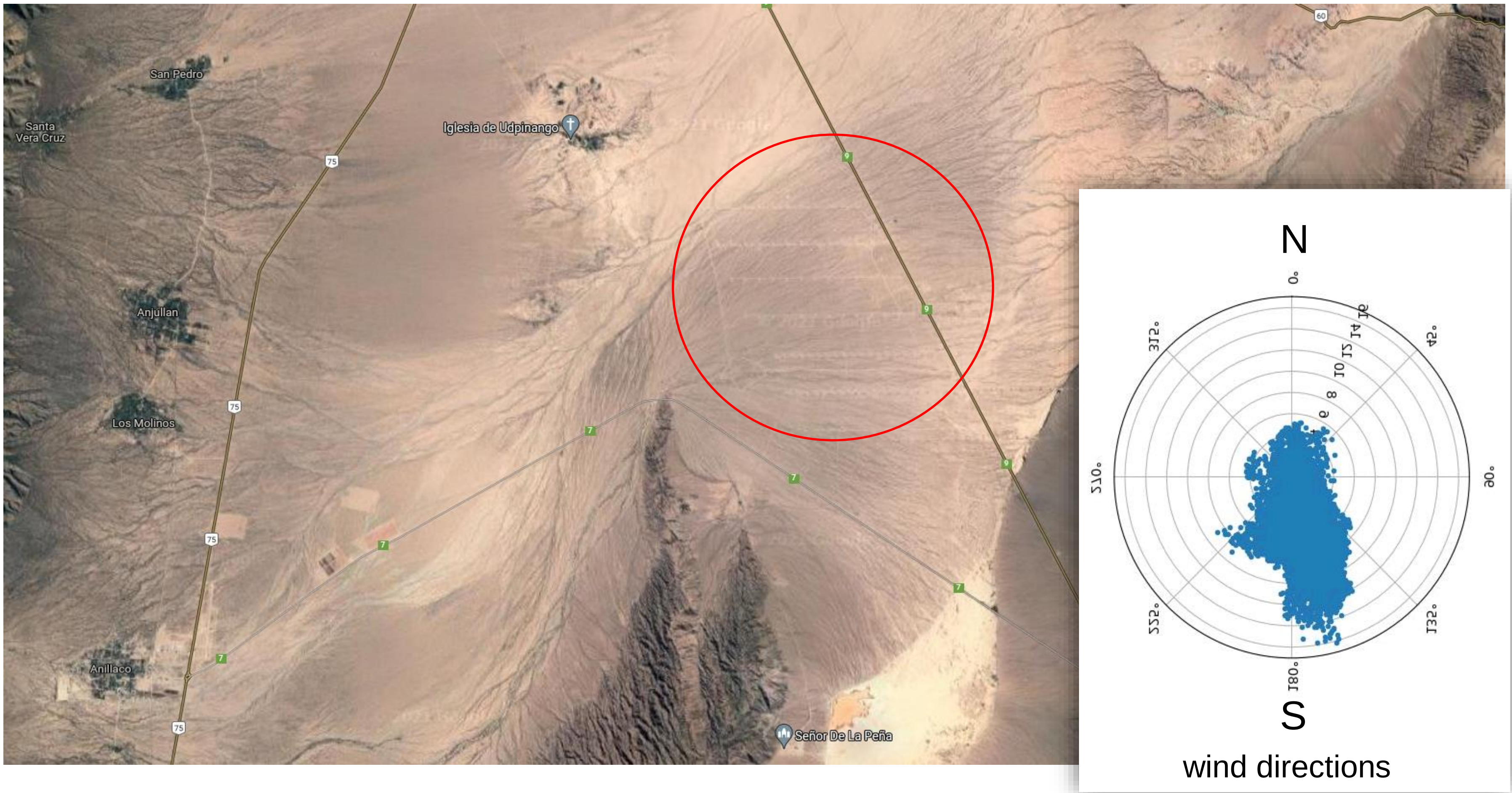
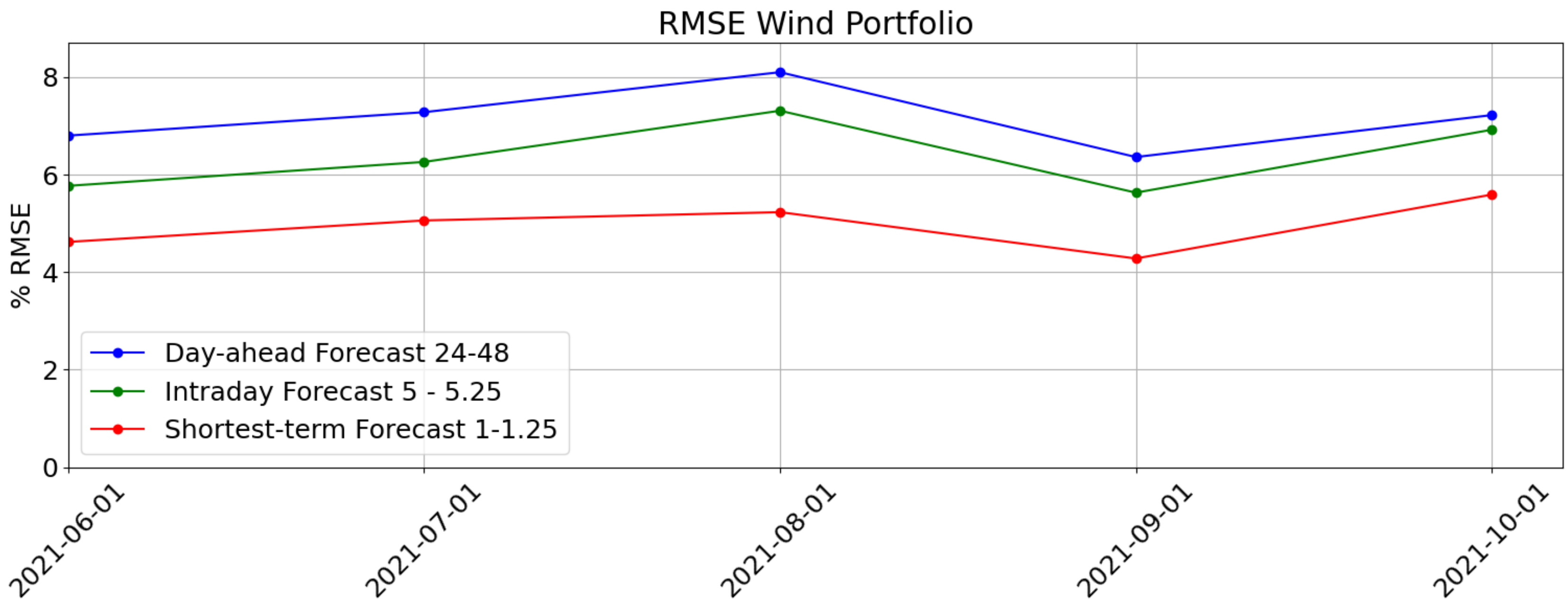
3.2.2 Challenges: for example channeling effect

P.E. Arauco II - Etapas I y II



3.2.2 Evaluation of wind portfolio forecast for different time horizons



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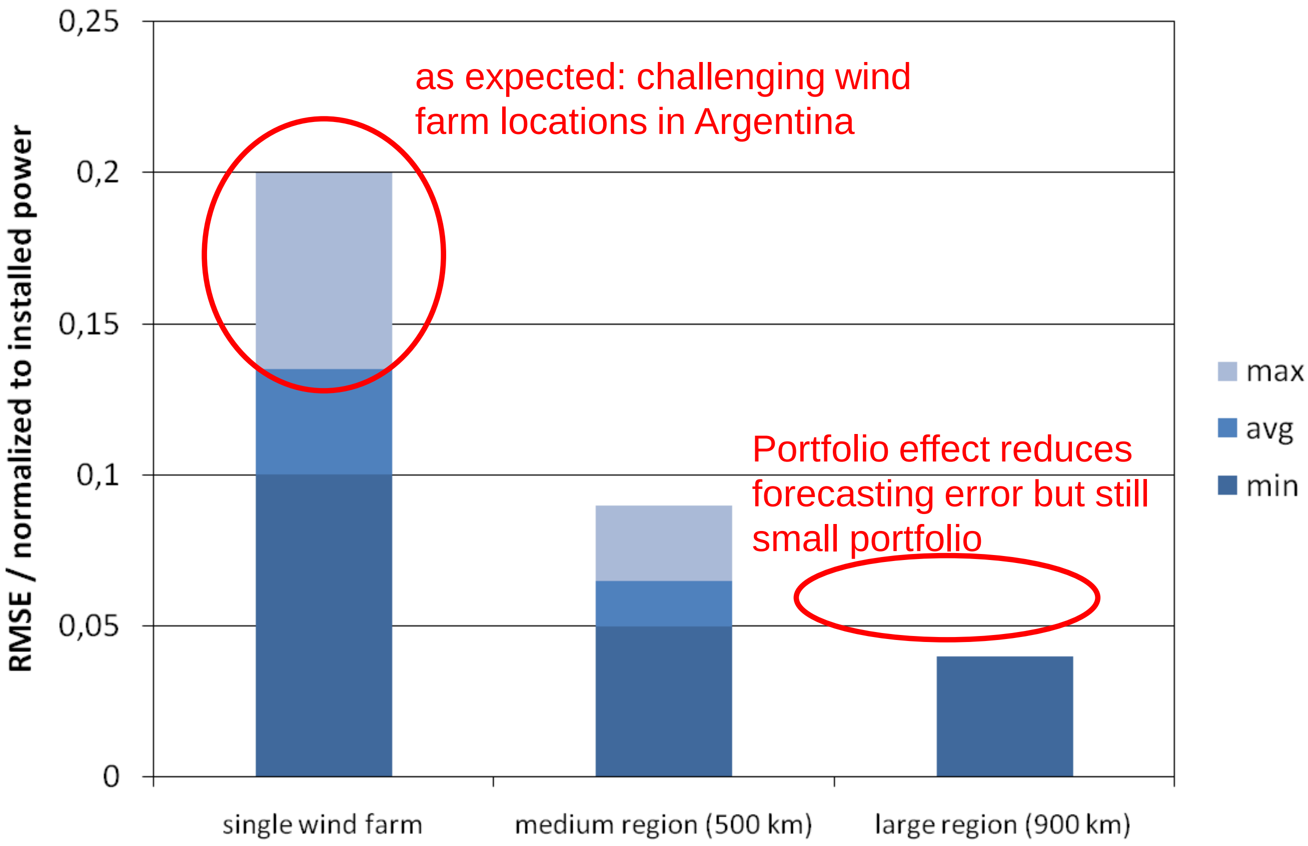
3.2.2 Accuracy aspects: single wind farm versus portfolio

- Long-term results from wind farms and aggregations over regions in Europe, North America and Australia
- The accuracy is higher the larger a region is due to smoothing effects
- The results for Argentina are in the expected range for challenging locations



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3.2.2 Details on provided solar power forecasts in Argentina

Solar parks

- Number: 10 farms
- Installed capacity: 487 MW
- Portfolio and single plant evaluation
- Evaluation period: June 2021 – November 2021
- Evaluated prediction horizons:
  - 1 - 1.25 h (short term)
  - 5 - 5.25h (intraday)
  - 24 - 48h (day-ahead)

3.2.2 Solar forecast evaluation

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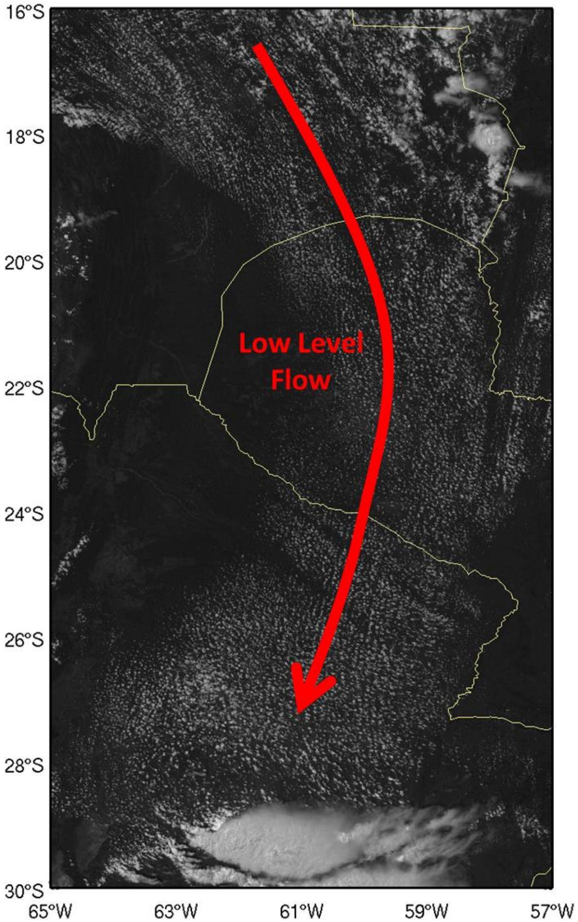
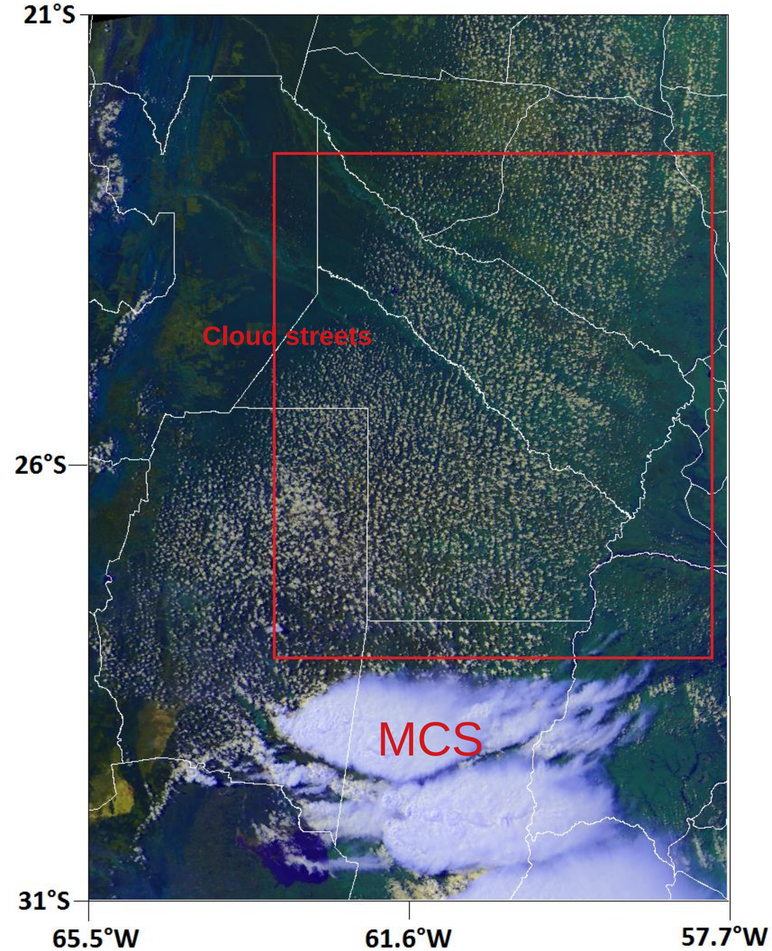
3.2.2 SALLJ: cloud formation (convection)



Cloud streets
(shallow convection)



Mesoscale convective systems
(deep convection)

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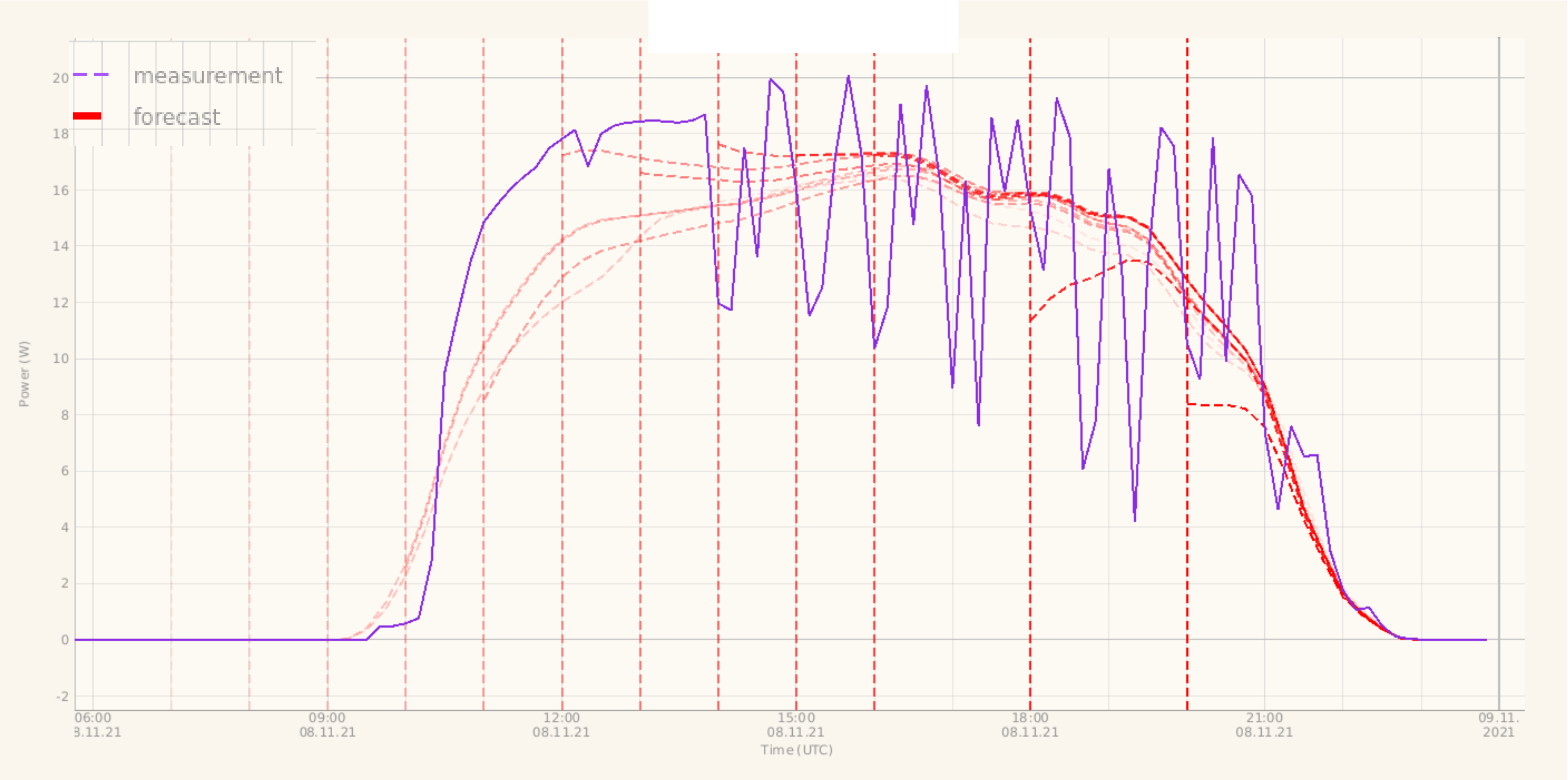
3.2.2 Convection



- Intraday updates help to consider convection effects
- Measurement data should have as little delay as possible

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3.2.2 Forecast without right tracking values

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3.2.2 Forecast after correction of standing data

Correct standing data are important!

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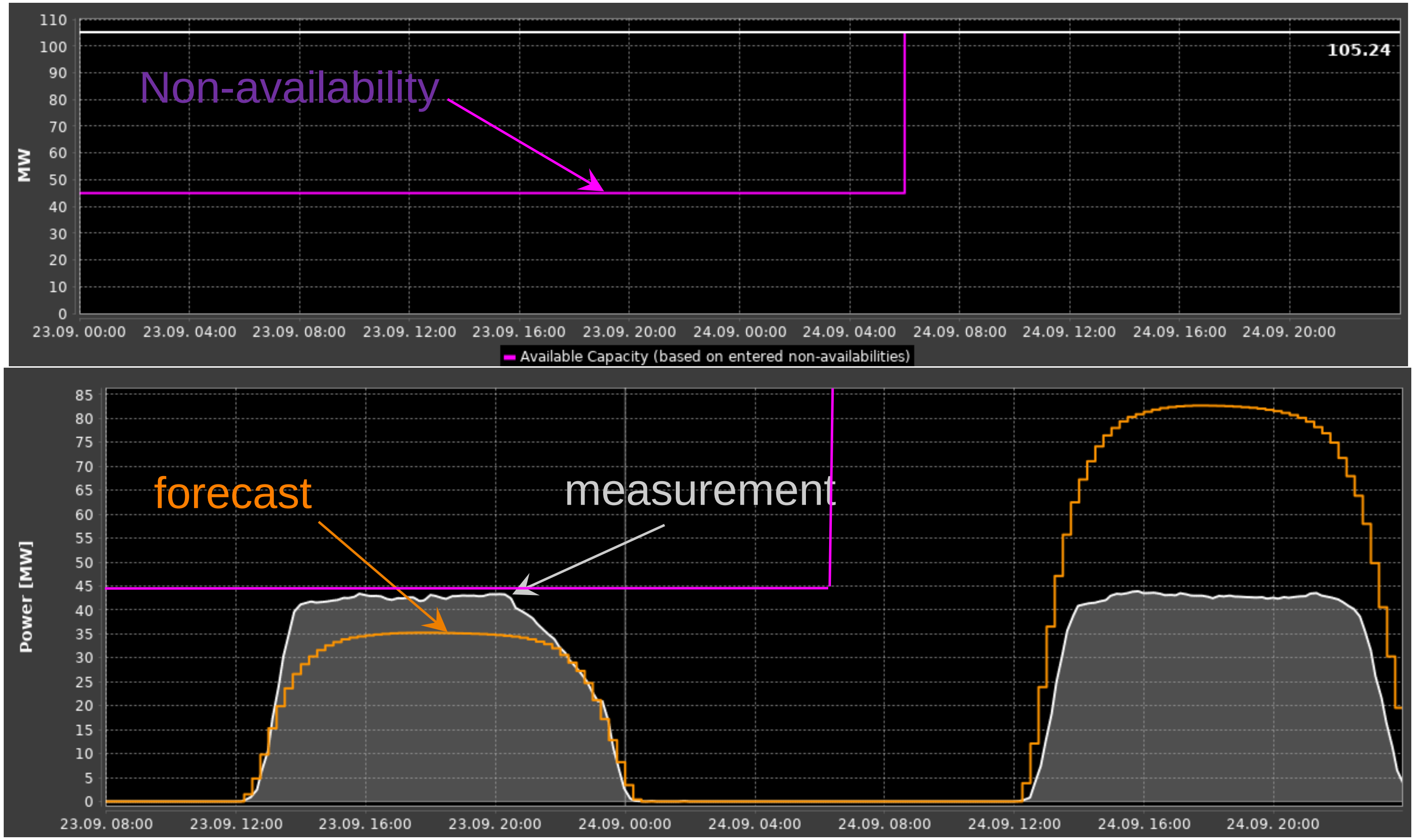
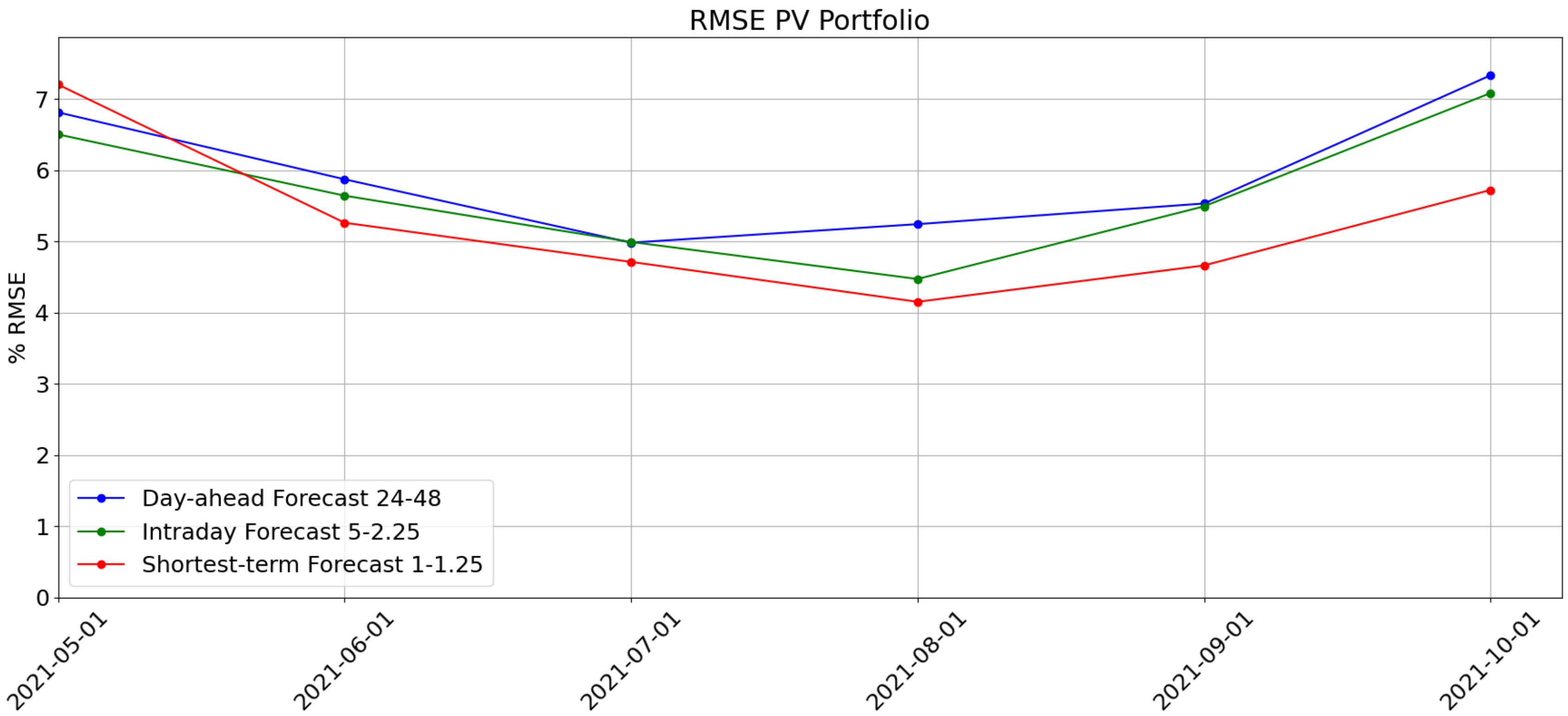
3.2.2 Forecast after training

Measurement data are important!

3.2.2 Issues with non-availabilities



3.2.2 Evaluation of solar portfolio forecasts



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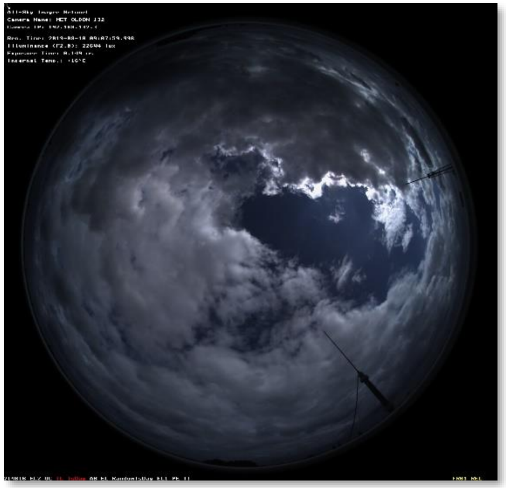
Outlook: use SkyCam for PV forecast

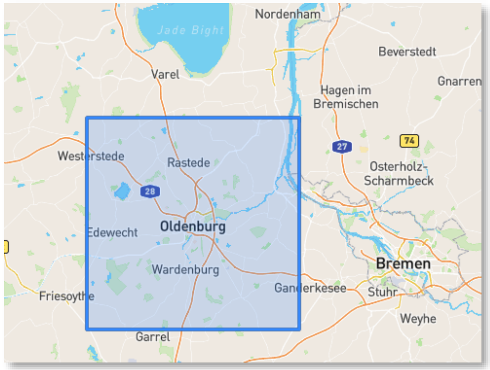
Idea:

Use input data from Skycam data from Eye2Sky Test Case (DLR) to improve shortest-term PV forecast

www.dlr.de

- irradiance maps (ghi and dni)
- temporal resolution 30s
- 800 x 800 pixel (40 x 40 km)
- reprocessed by DLR
- for Mar, Jun and Nov 2020





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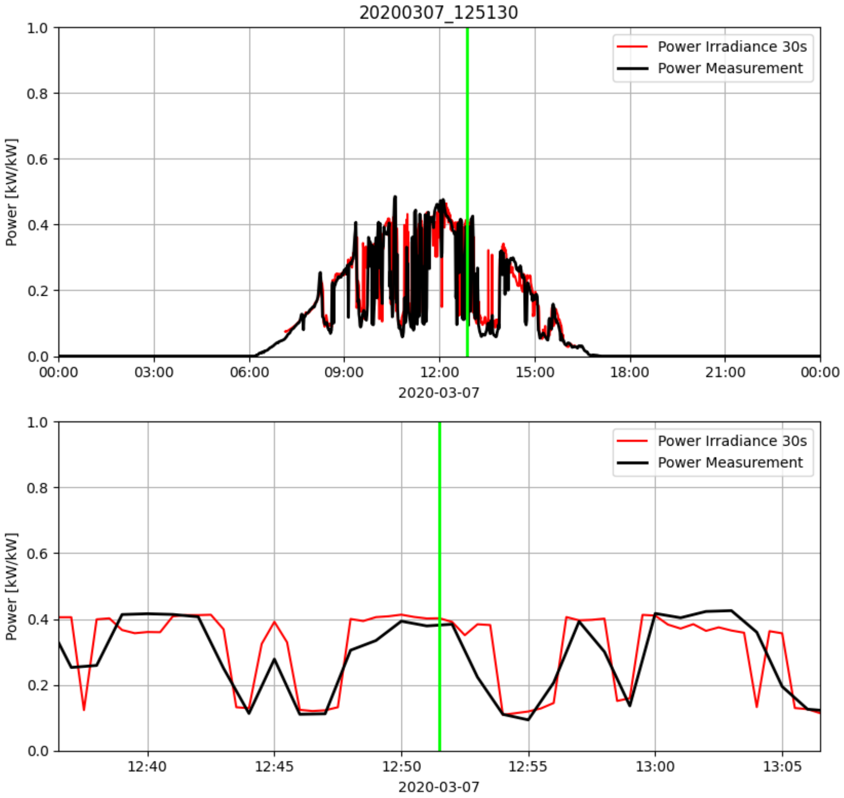
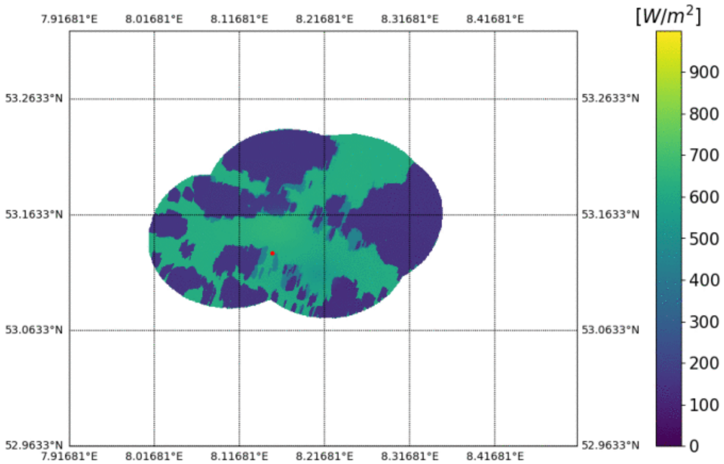
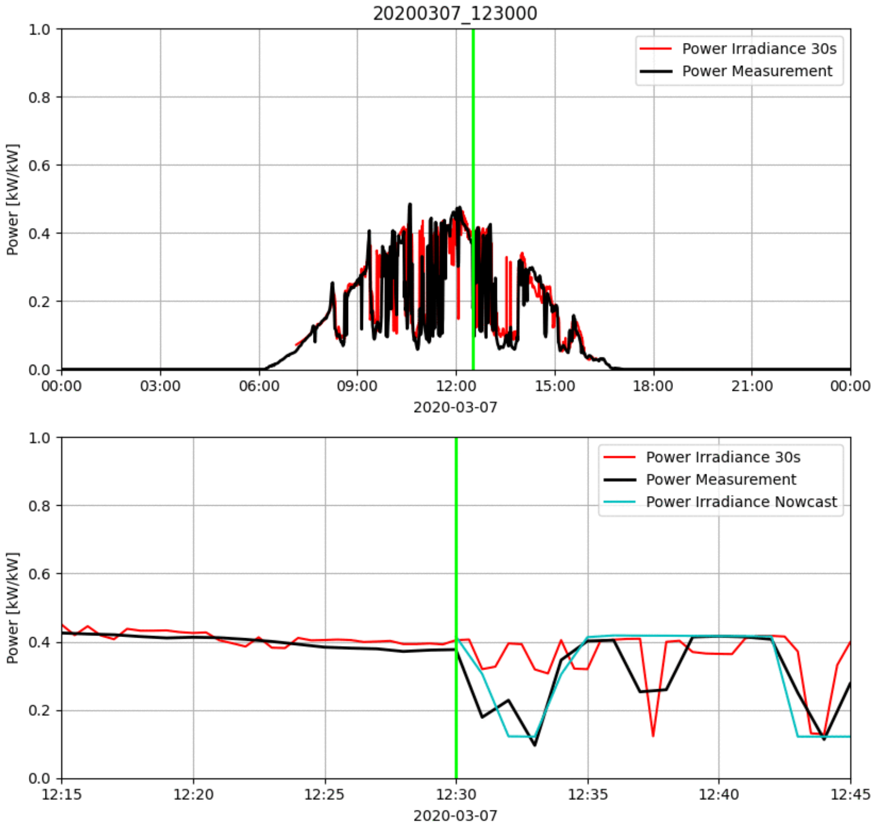
Outlook: use SkyCam for PV forecast

- Multi-source data approaches: Skycam
- Analysis for a single PV plant
- Very good agreement between power calculated from irradiance data and real power measurement of PV plant



Outlook: use SkyCam for PV forecast





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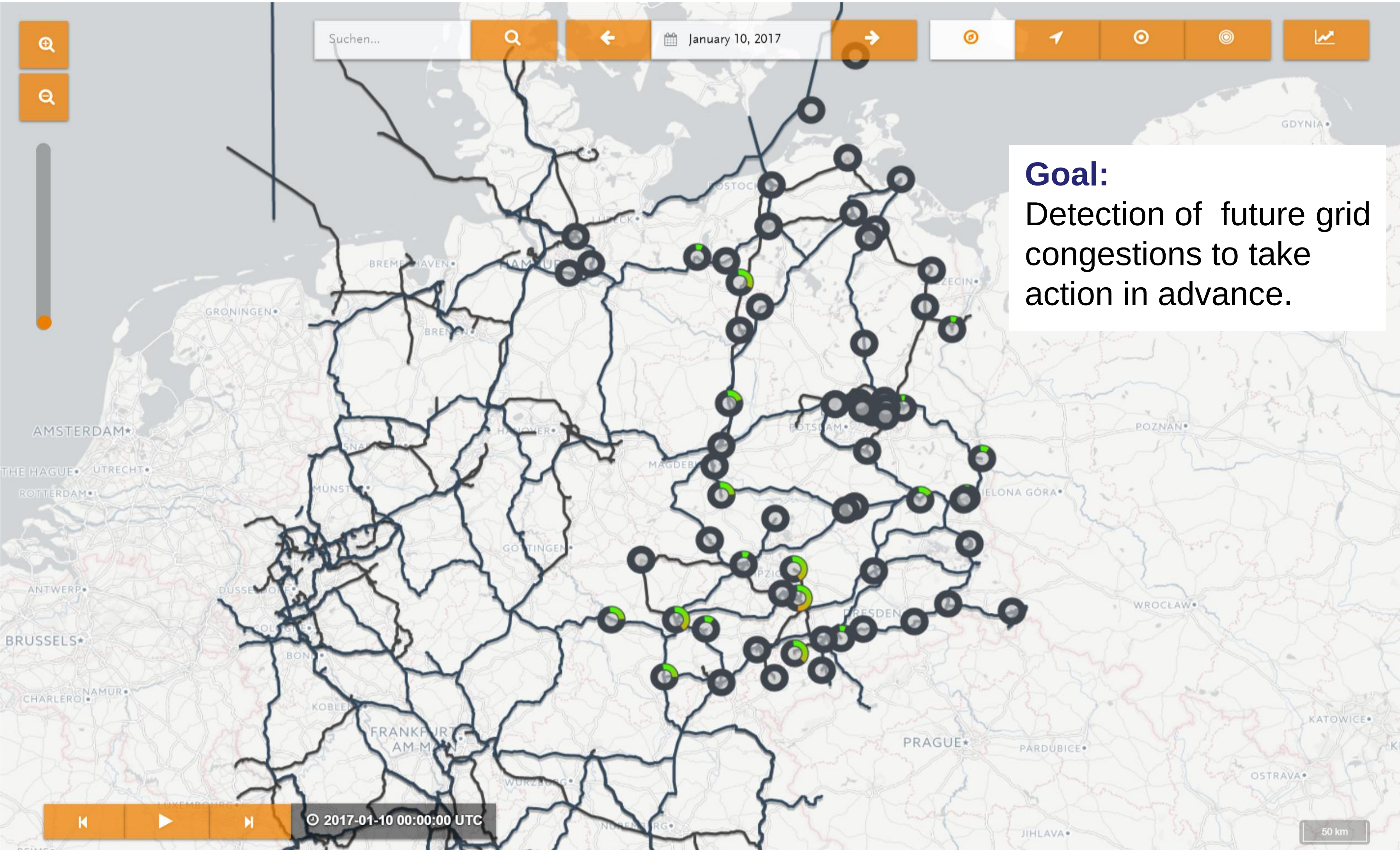
Agenda

3.3.1 Predictive load flow calculation



Goal:
Detection of future grid congestions to take action in advance.

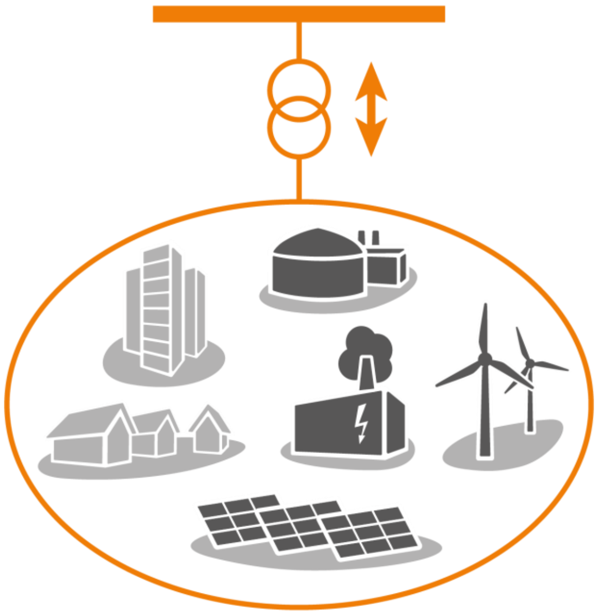
3.3.1 Approach: decomposing the measurement signal

Equation for every substation:

vertical grid load = consumption + production

Further splitting into „known“ sources:

Production = Wind
+ Solar
+ Biogas/-mass
+ CHP
+ Run-of-river plant
+ …

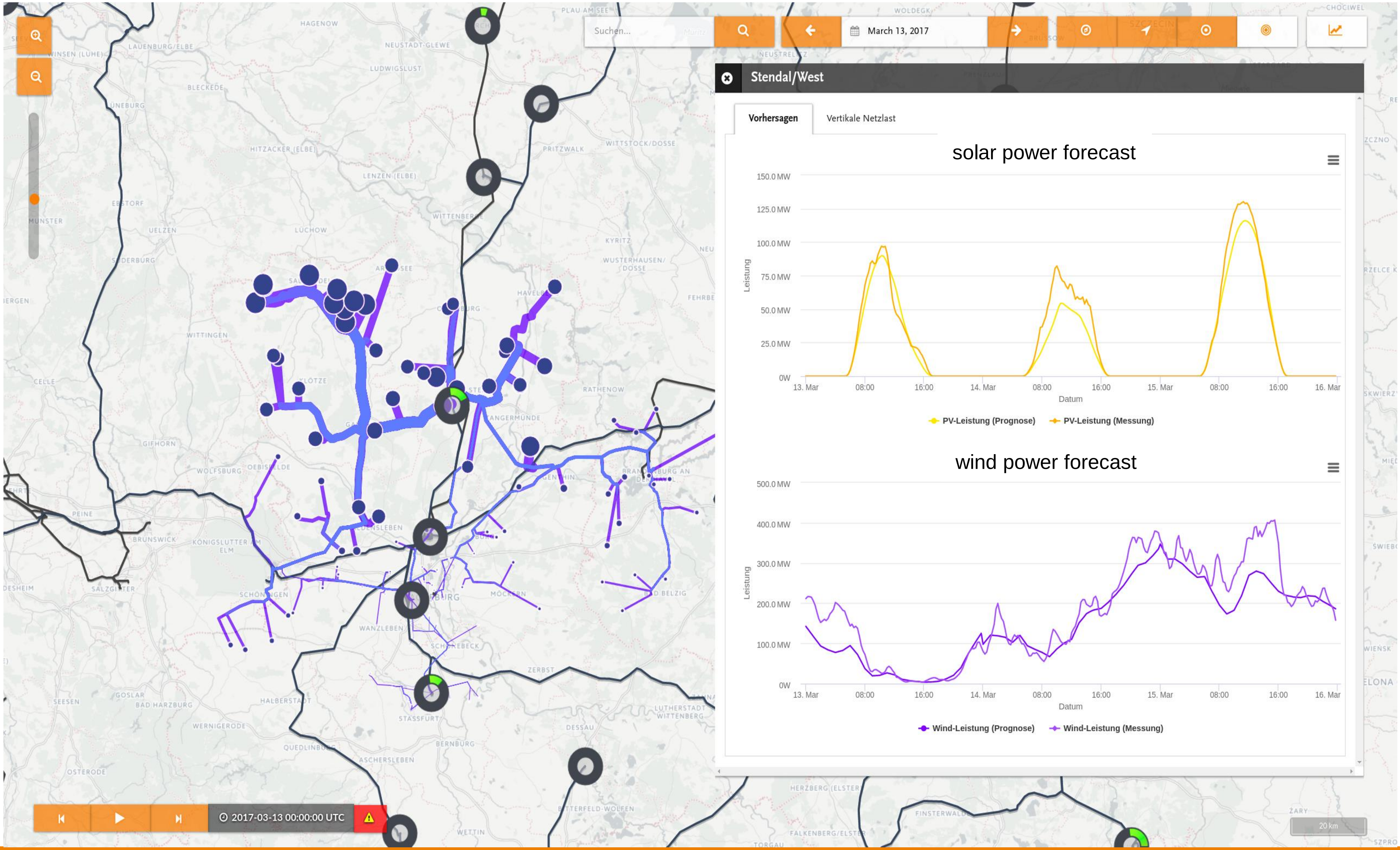


Components for wind and solar power are known!

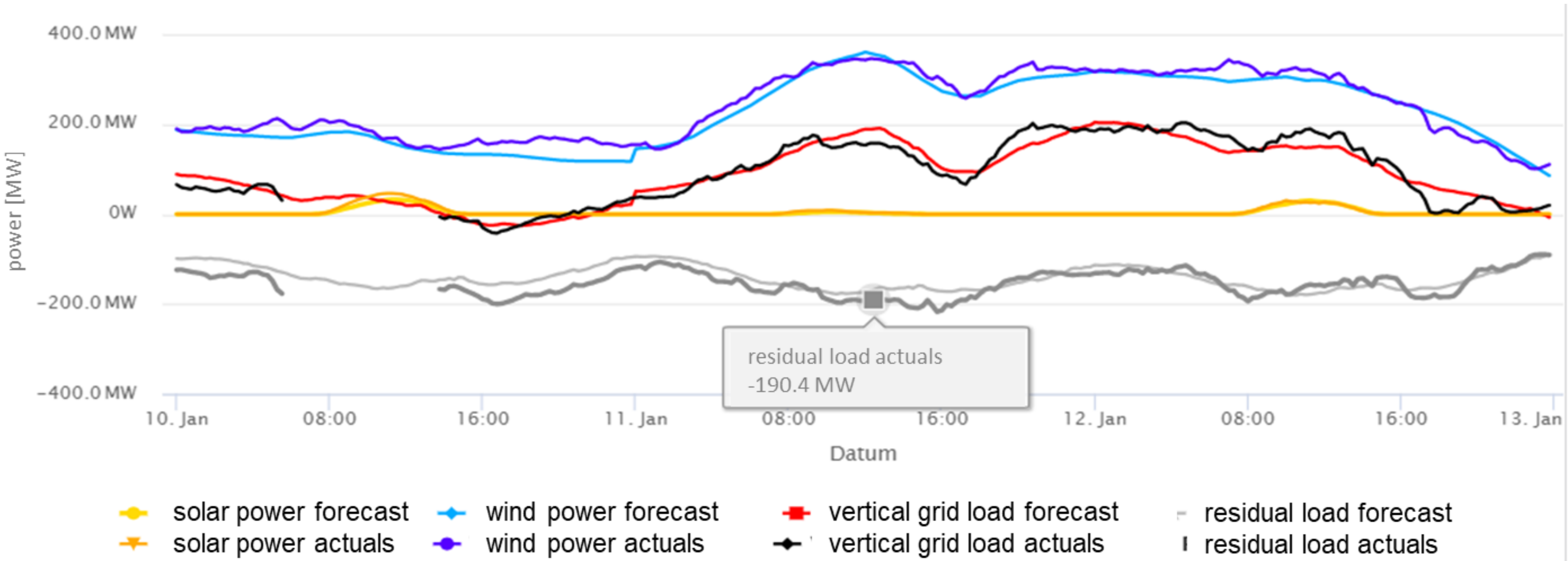
All unknown components are considered as residual signal:

vertical grid load = Wind + Solar + Residual signal

3.3.1 Predict power output of plants with impact on grid node



3.3.1 Vertical grid load forecast for substation



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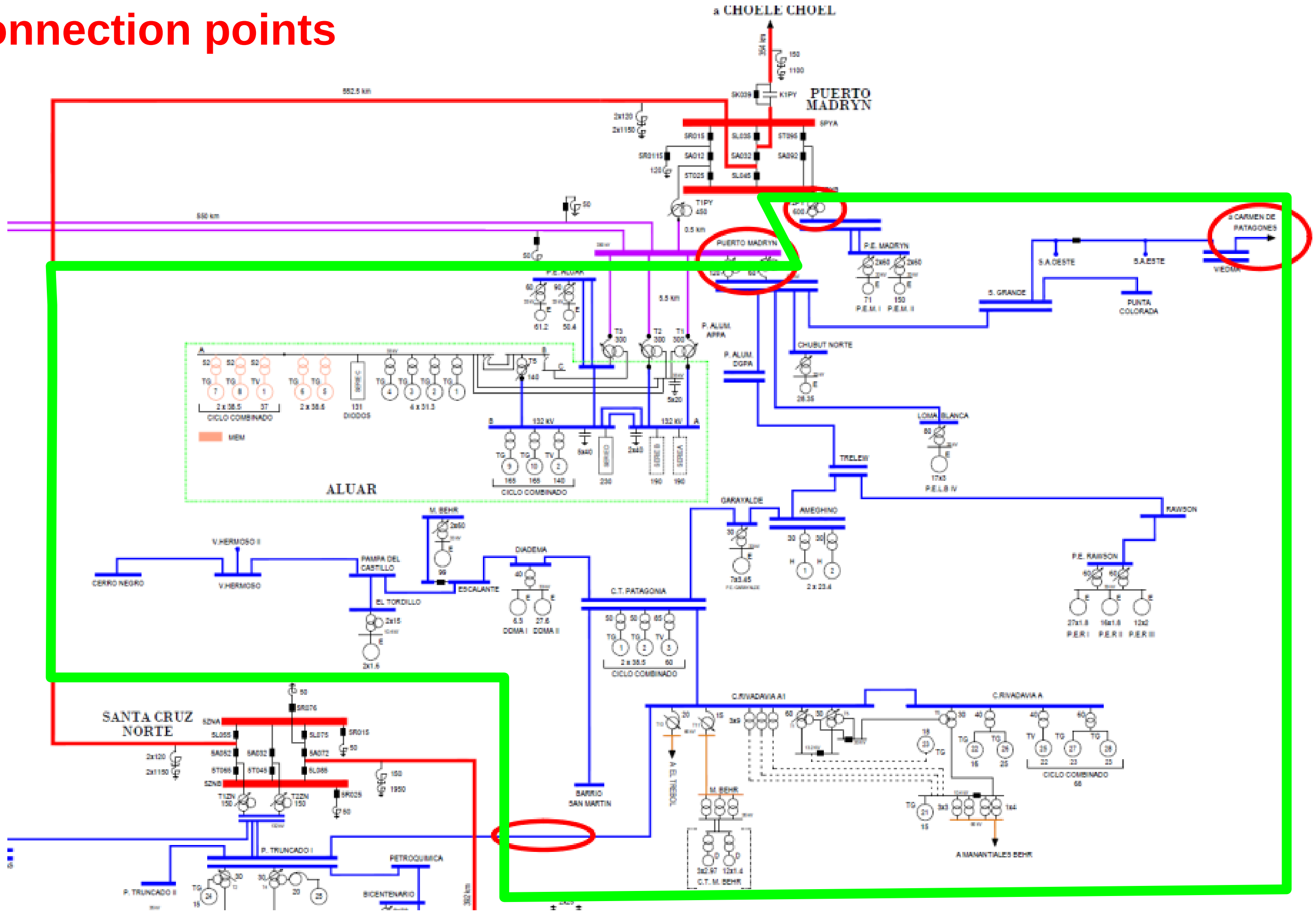
3.3.2 Argentina: VGL forecast for substation Puerto Madryn

Connection points



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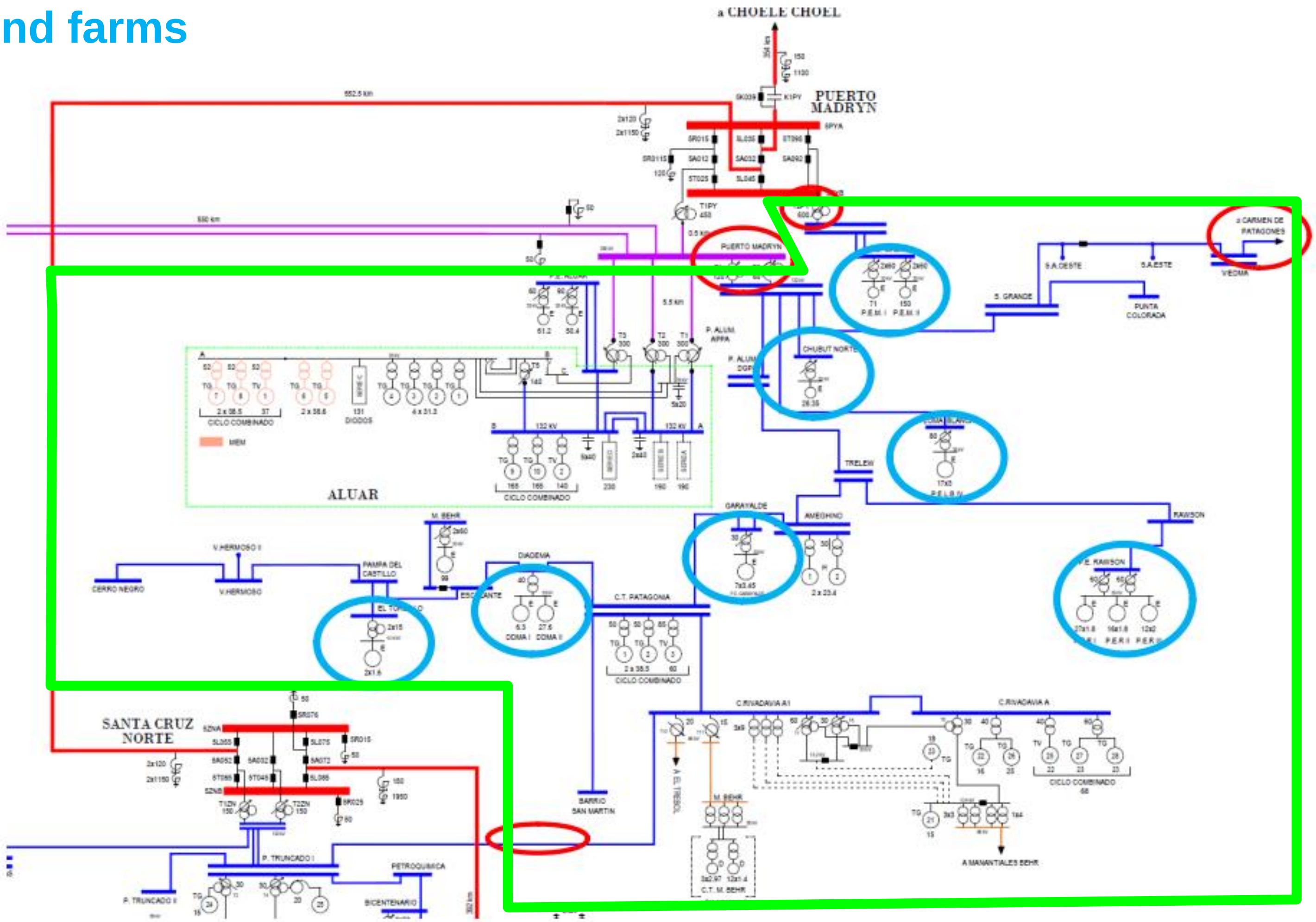
3.3.2 Argentina: VGL forecast for substation Puerto Madryn

Wind farms



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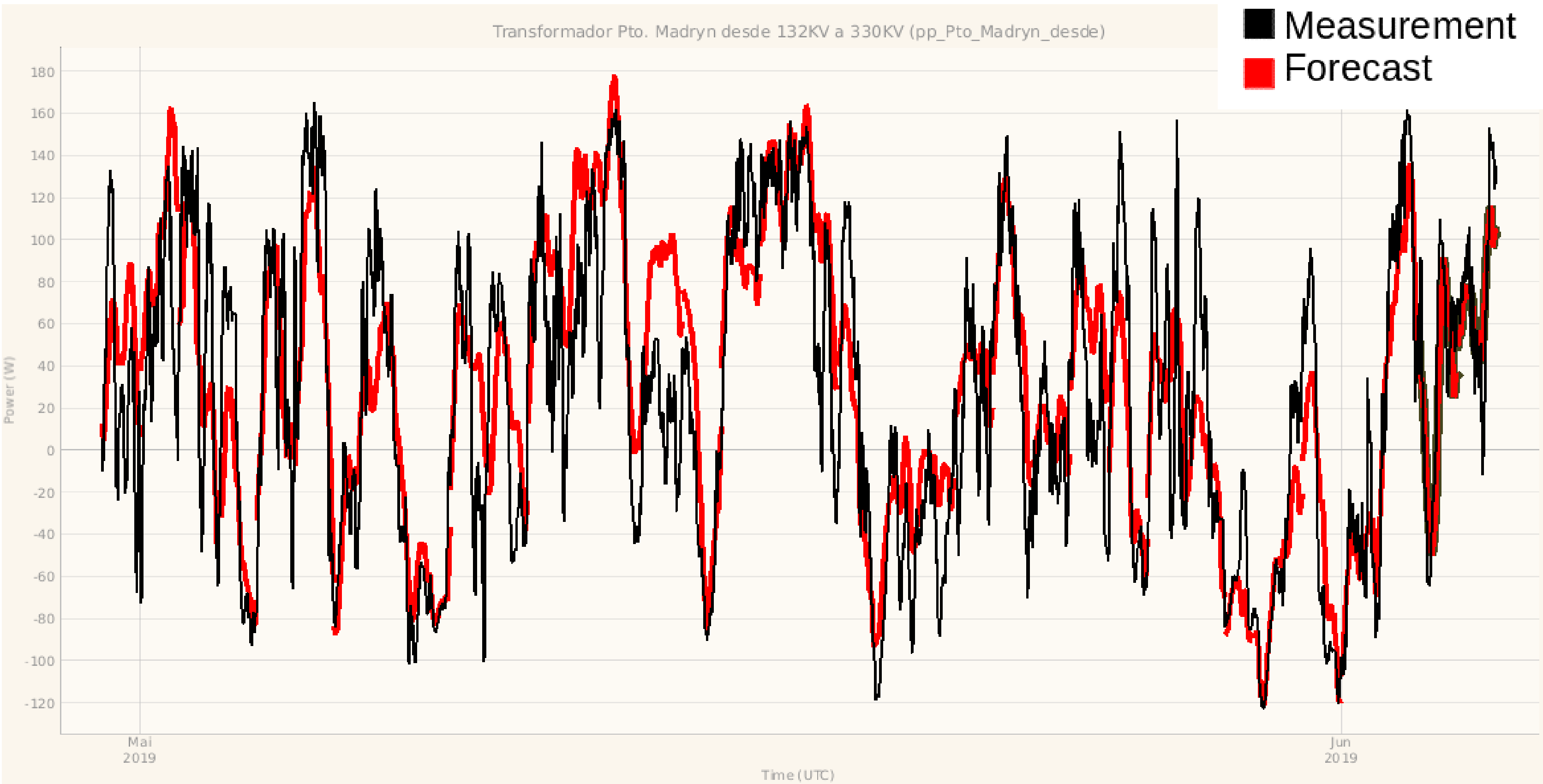
3.3.2 Argentina: VGL forecast for substation Puerto Madryn



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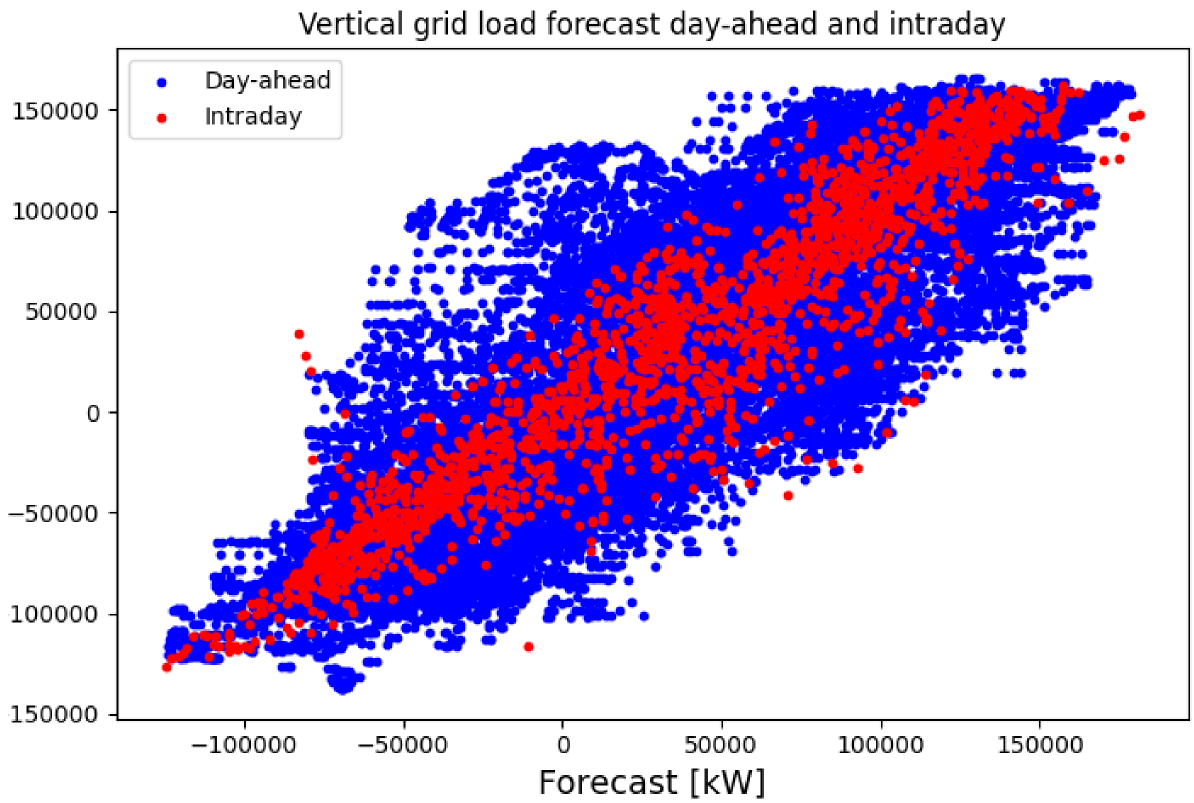
3.3.2 VGL proof of concept evaluation



- Pto Madryn DA MAE 22.4 %
- Average MAE DA Germany up to 20%
- Pto Madryn ID MAE 14.9 %
- Average MAE ID Germany 15%

Agenda

4. Lessons learned

Power forecasts

- The sites in Argentina can be affected by challenging weather conditions but a state-of-the-art accuracy is possible
- Non-availabilities should be reported accurately and modified on short notice if there is a change of plans
- Suitable measurement data are important to train the forecasts

Vertical grid load forecasts

- Proof of concept for one site in Argentina
- The vertical grid load forecast can contribute to avoiding congestions
- Intraday forecasts of grid load have higher accuracy, therefore, grid operation processes should be able to react on the intraday

4. Lessons learned

Virtual Power Plant

- First-time application of the Virtual Power Plant in Latin America
- VPP has multiple features that can support an efficient vRE grid integration
- Due to regulation in Argentina CAMMESA did not remote-control the parks
- The full scope of benefits of the VPP still needs to be explored by market participants in Latin America

Muchas gracias por su interés!

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