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nefocast

Real-time rainfall maps from satellite telecommunication signals

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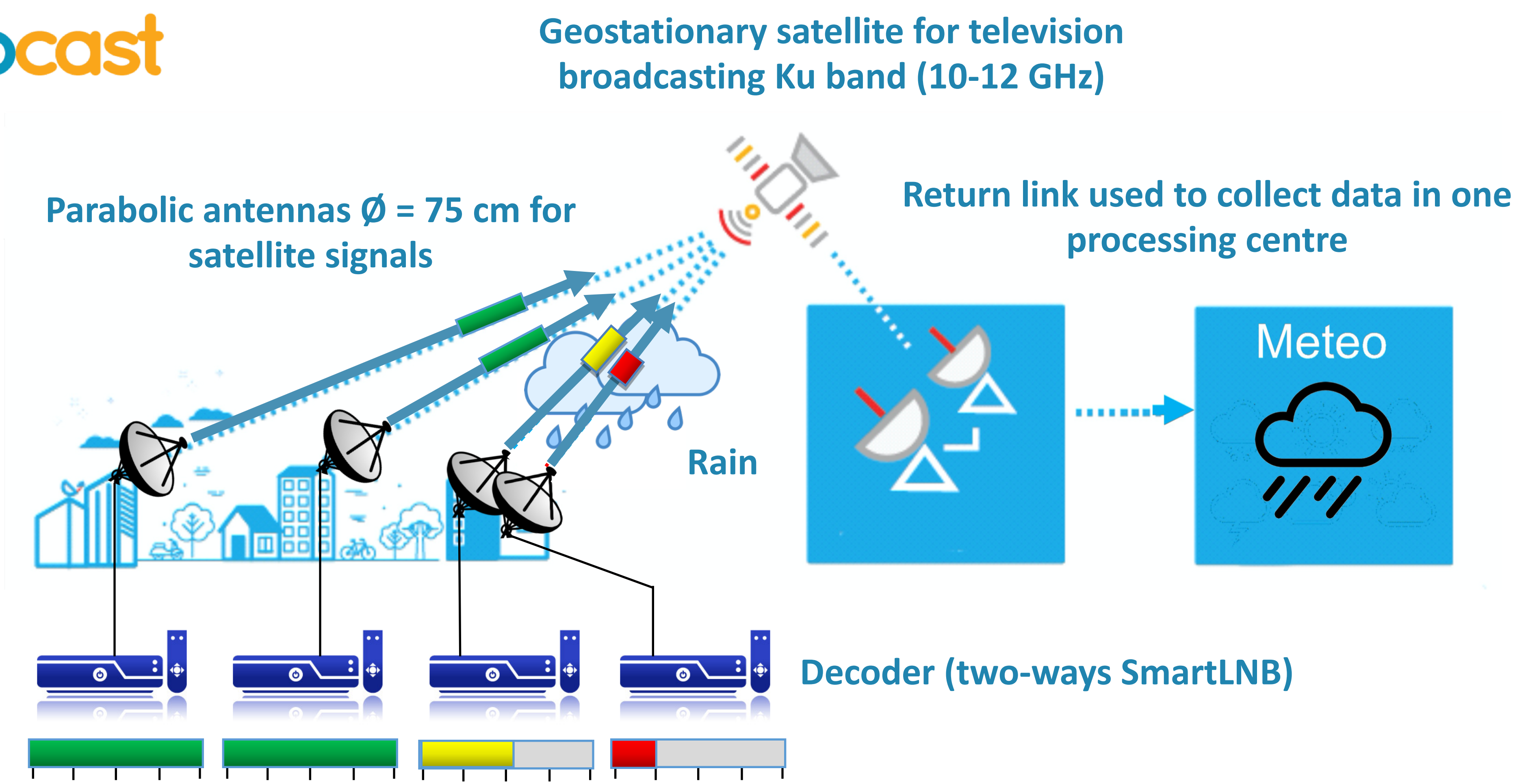
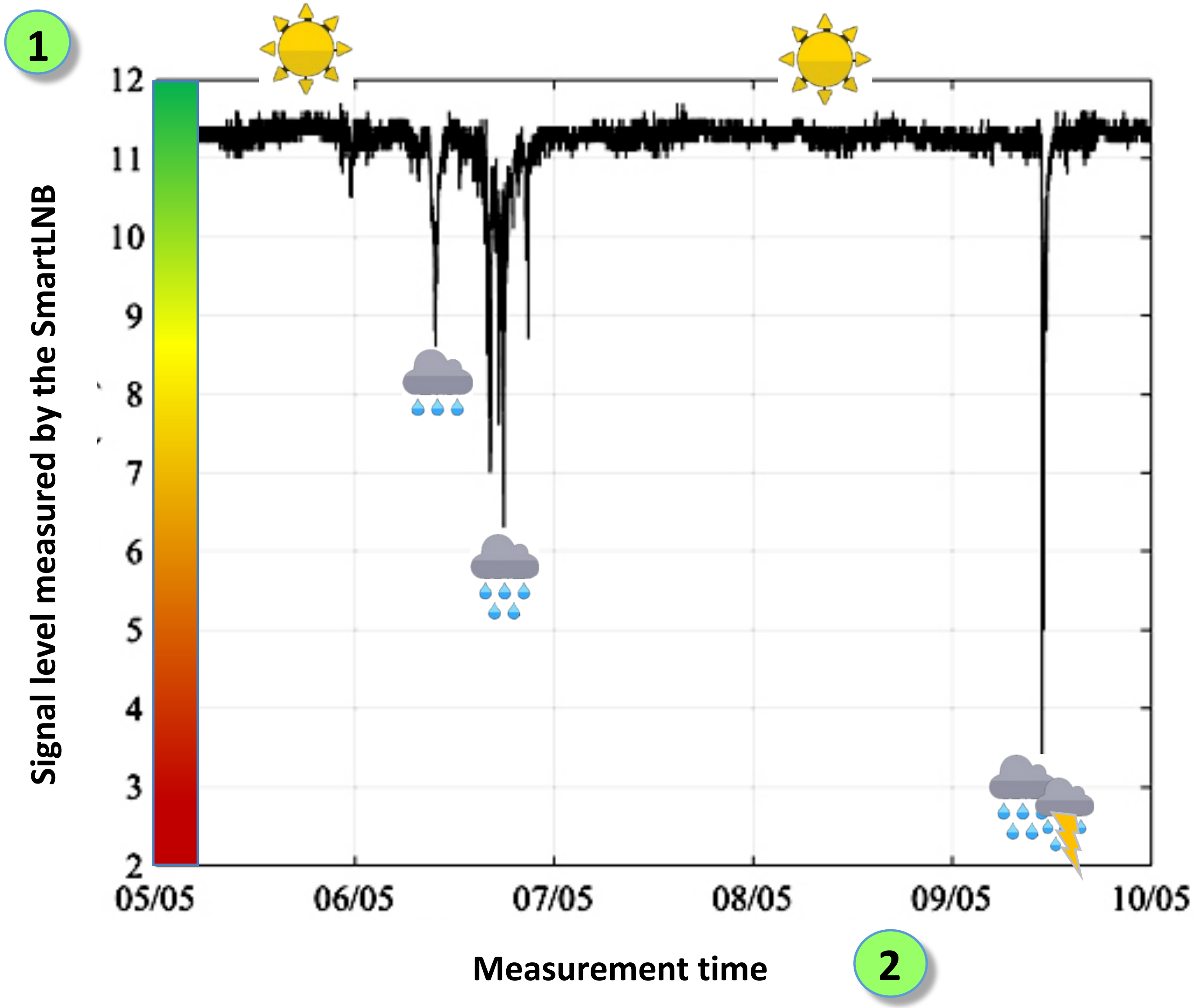
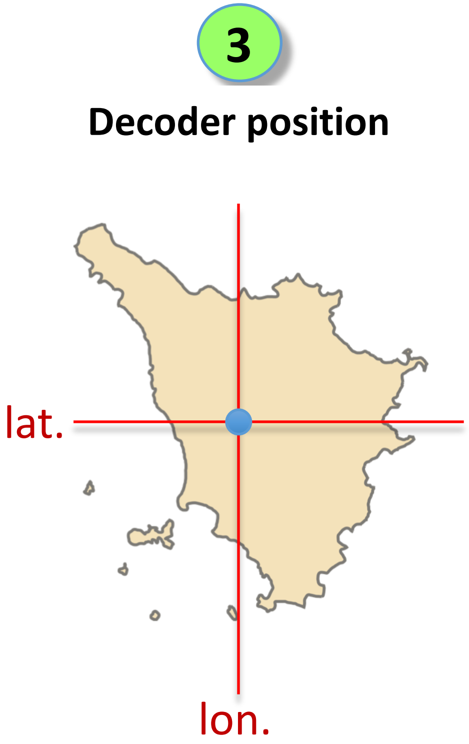
Nefocast project: the concept



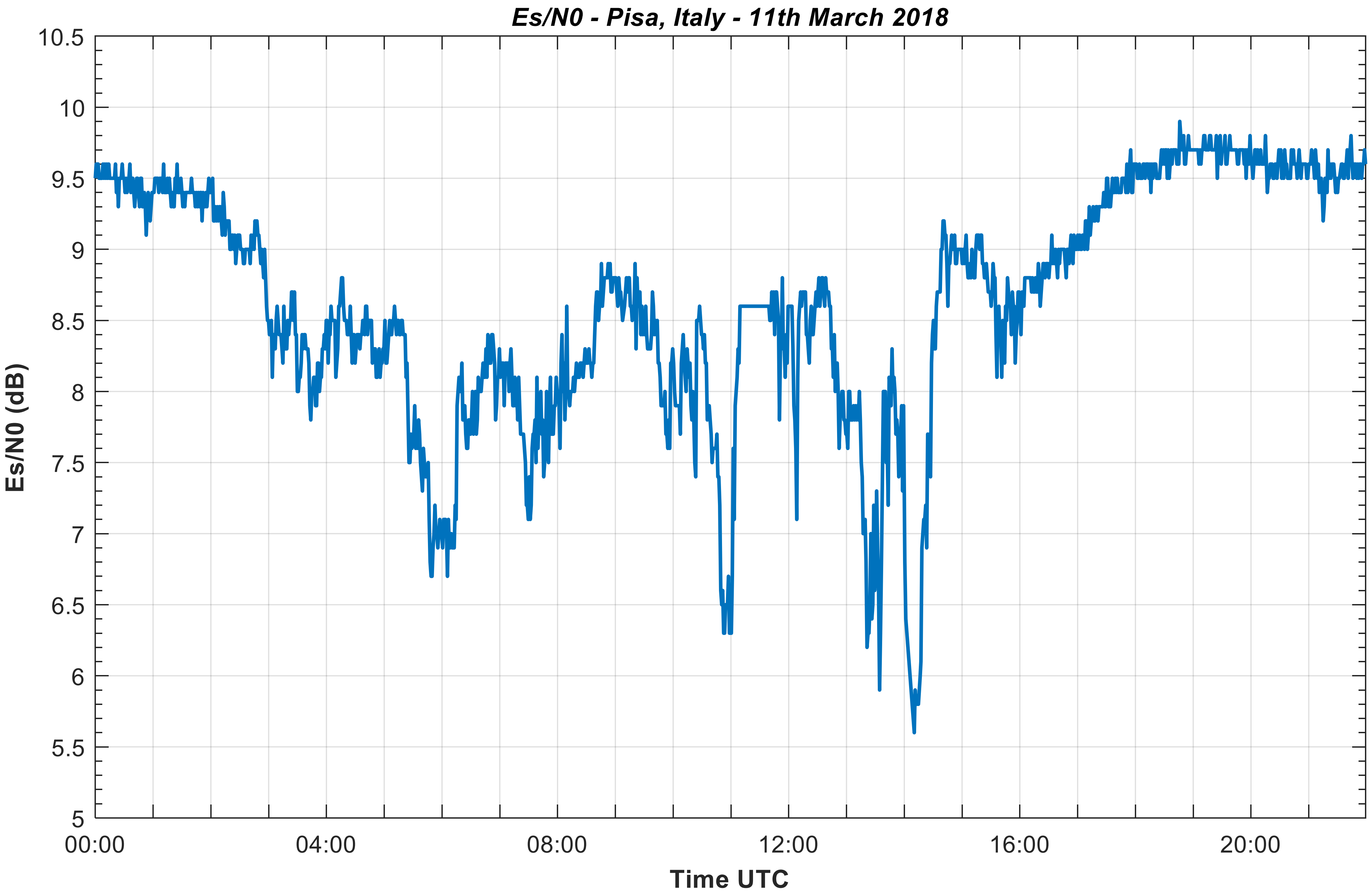
The level of the received signal varies depending on the rainfall rate along the satellite-decoder path: the lower is the signal-to-noise ratio (E_S/N_0), the higher is the intercepted rainfall. To retrieve the path-averaged rainfall rate we need the melting layer height that we estimate from the 0°C isothermal height given by high resolution operational forecasts.

Nefocast project: the concept

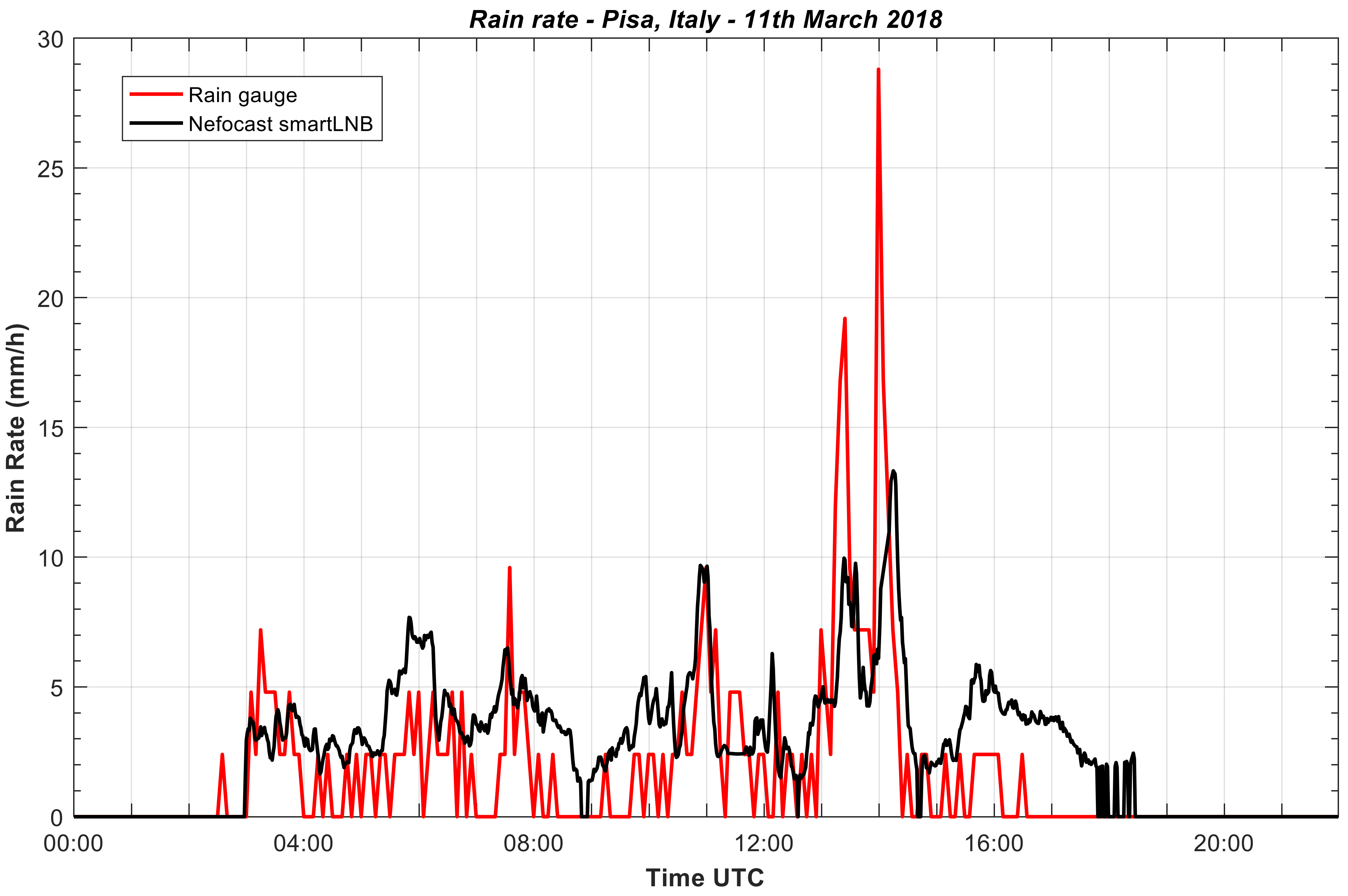




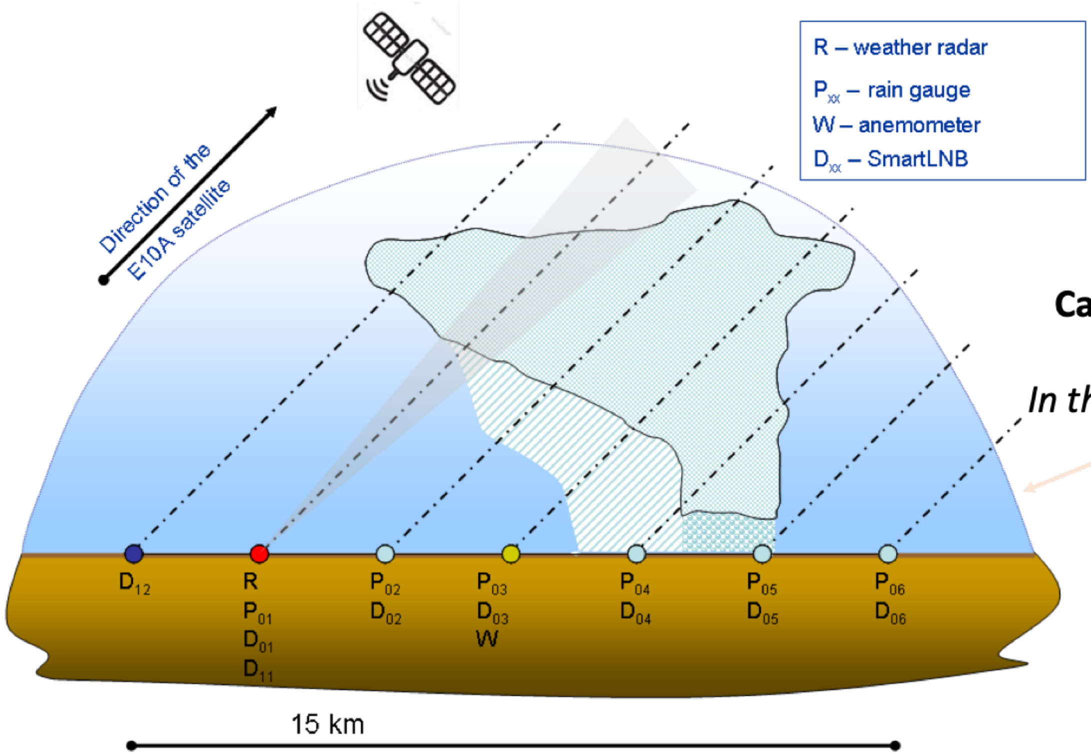
Measurements (example)



Measurements (example)

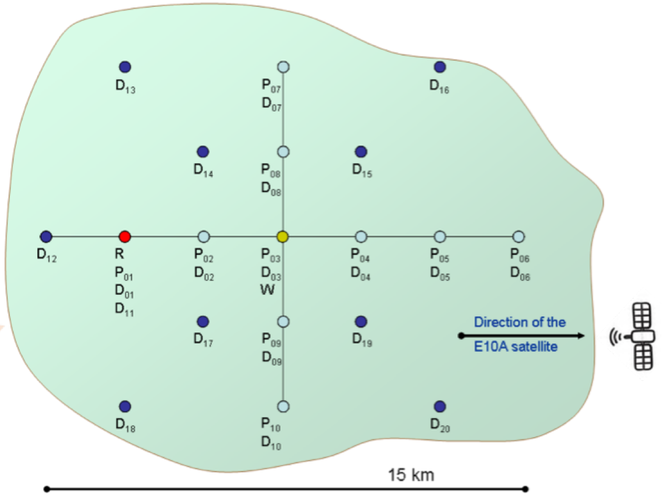


Cal/Val network in Tuscany (Italy)

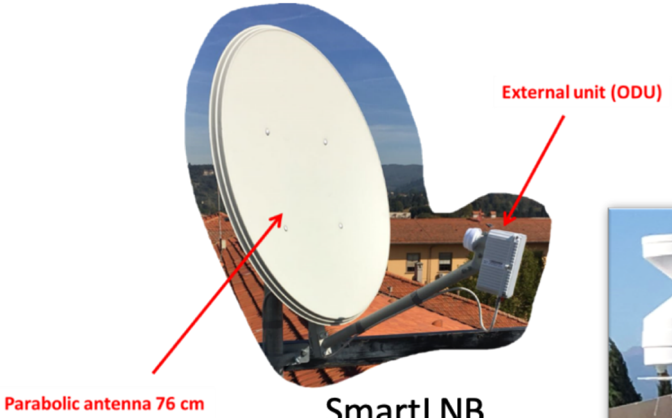


Cal/val network:

In theory



In practice

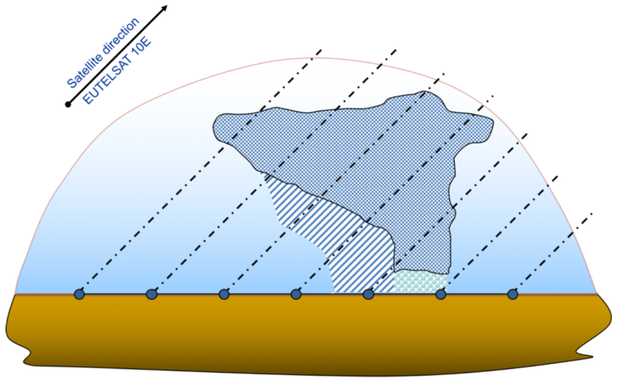


SmartLNB

Raingauge

X-band radar

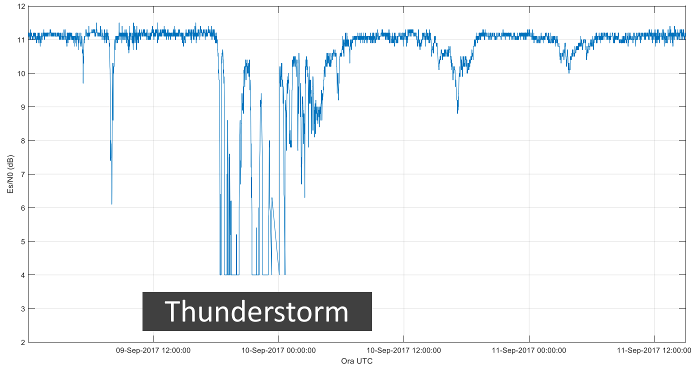
Major limits/problems



- Rainfall system boundaries necessary to estimate rain rates along the path: complex in some cases (e.g. convective systems)

- Non point rainfall rates but path-integrated (i.e. averaged) values

- Signal interruption in case of heavy rains



- Slow variation in clear-sky (i.e. reference) signal due to several reasons (e.g. satellite displacement and repositioning)

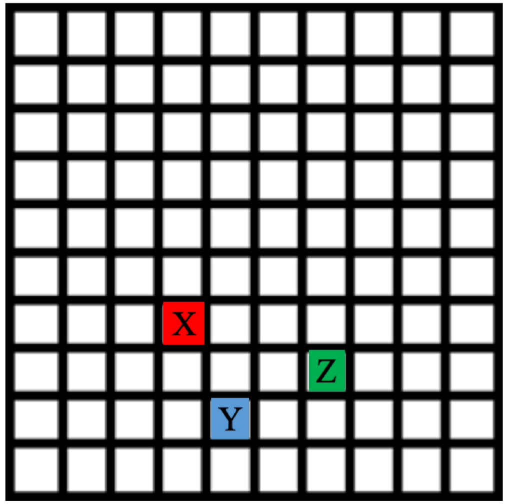
- Short-time receiver blinding due to sun radiation when close to the equinoxes

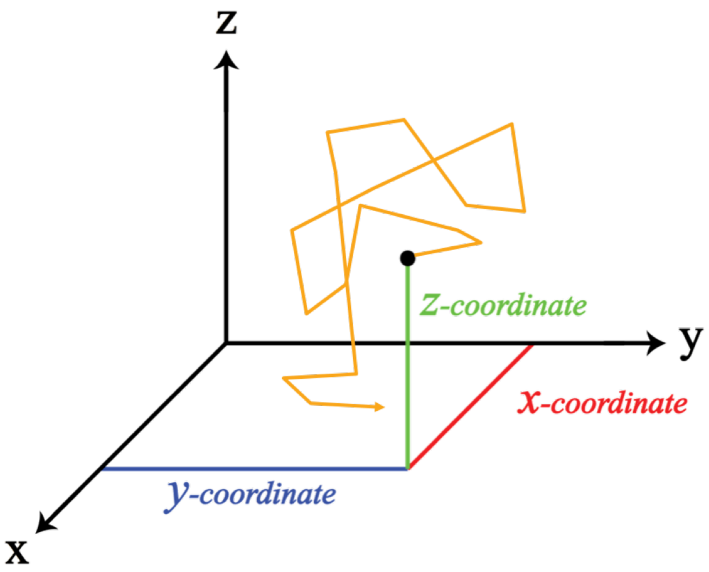
Including meteorological satellite data in the data processing and adopting a network approach can help for a large part of these problems

Representing rainfall in the phase space

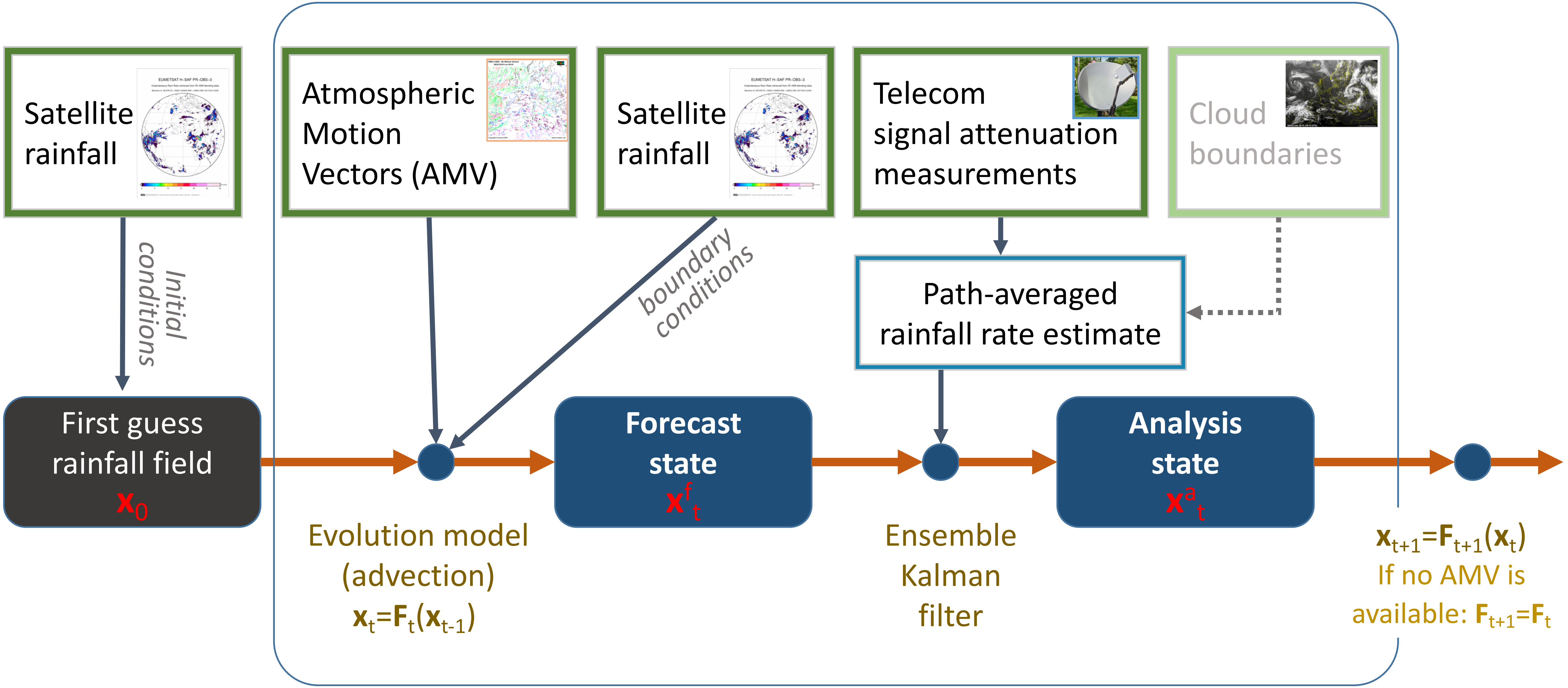
Each grid point of the retrieval domain is associated to a phase space axis, e.g. grid point X in the left picture corresponds to the X axis in the right one, same for Y, Z etc. (the phase space is represented 3-dimensional but has to be imaged N-dimensional, with N number of pixels in the retrieval domain). Coordinates in the phase space are associated to rainfall rates.

A point in the phase space gives the rain rates in all the domain pixels; a trajectory in the phase space determines the rainfall rate variation with time. An ensemble Kalman Filter (EnKF) is used to determine this trajectory: a first guess for the rainfall field provides the starting point, then at each time step it is moved with advection information (forecast) and its position is corrected with the available measurements (analysis).





Algorithm flow-chart



Synthetic experiments (example)

Retrieval of a synthetic moving storm

Domain: 15 x 15 km, 500 m resolution

True state: moving storm from SW to NE with u=6 m/s, v=6 m/s; top precipitation height= 4.0 km

Observations and ancillary information:

- 80 randomly placed receivers for satellite Telecom signals: sensitivity error = 1 mm/h, signal interruption at rain rate = 40 mm/h
- AMV (Atmospheric Motion Vectors) assumed from meteo satellites products: velocities u_model=7, m/s v_model= 3 m/s (note the error w.r.t. the true state velocities)
- Melting layer height assumed from meteo model: height=4.5 km (note the error w.r.t. the true state top height)

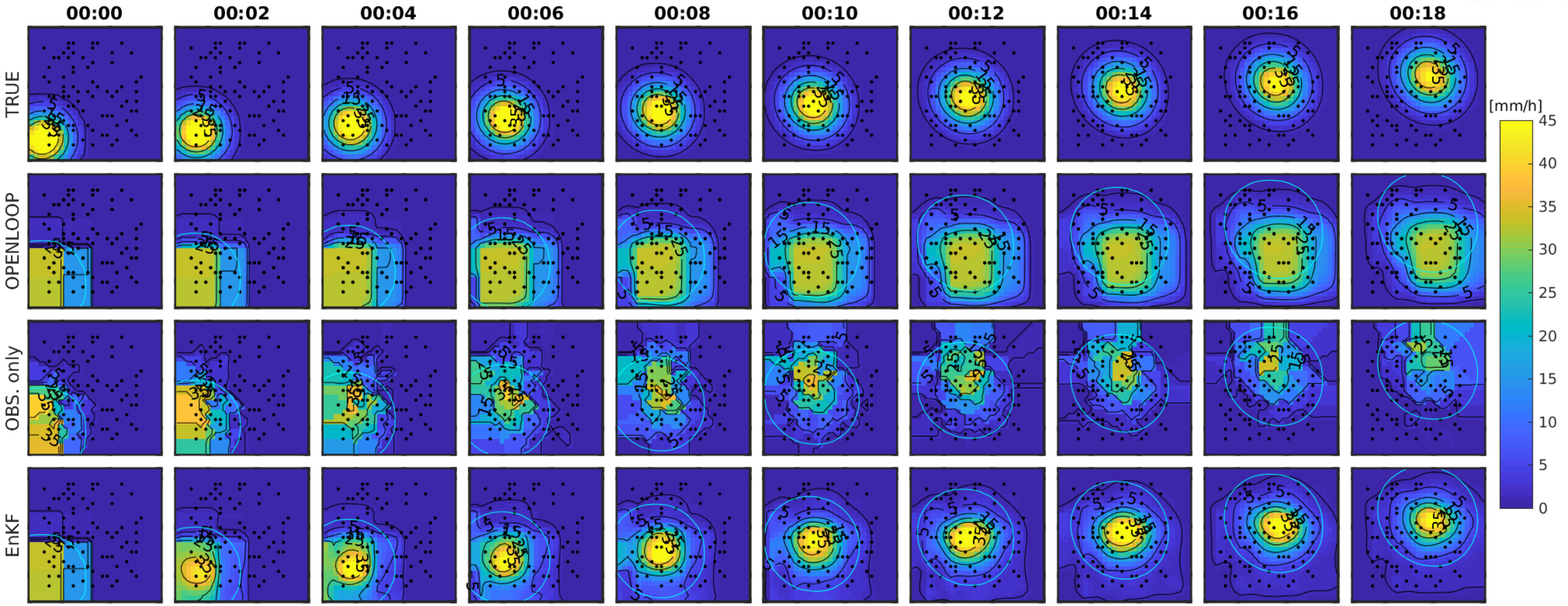
Prediction: advection model according to AMV velocities

Correction: Ensemble Kalman Filter with 100 ensemble members

Retrieval time step: 1 min.

Synthetic experiments (example)

Time (time step: computed=1min. shown=2 min.)



True = synthetic reality; Openloop = only advection, no measurements; Obs. Only = no advection, only measurements; EnKF = Ensemble KF processing

Final remarks

We have the possibility to show only one example in this presentation but the technique has been tested with a number of very different synthetic phenomena showing its capability to retrieve rainfall fields also with the highlighted measurement limitations.

Test with real data have been also started, confirming the technique validity, and are part of a paper in preparation.

SmartLNB decoding the Eutelsat satellite signal stimulated the development of the retrieval method, but it is conceived for a wider applicability, e.g. when having path-averaged measurements from different satellite beacons or cellular microwave links.