

Estimation of cloud motion vectors: exploring different approaches using a dense network of solar radiation sensors

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Surface solar irradiance can be seen as a spatio-temporal process

An **intuitive** concept: clouds advect in space through time



Advection **characterization** is key for

- Variability analysis
- Forecasting applications

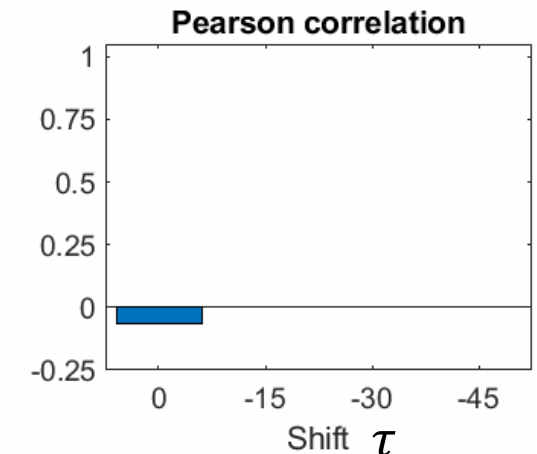
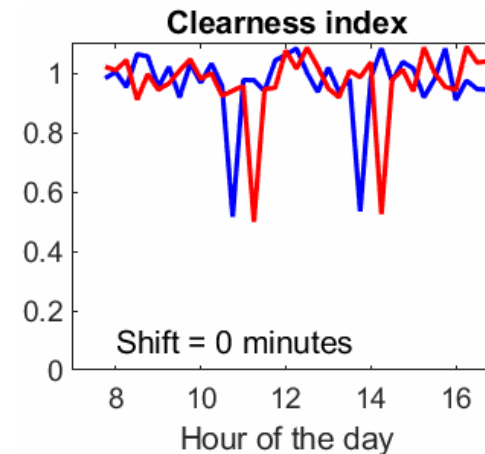
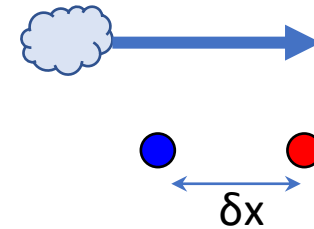
But it is **challenging** :

- There are several approaches
- In general, no “ground truth”

Our goal

Build a preliminary setup for analyzing and cross-comparing different cloud advection methods

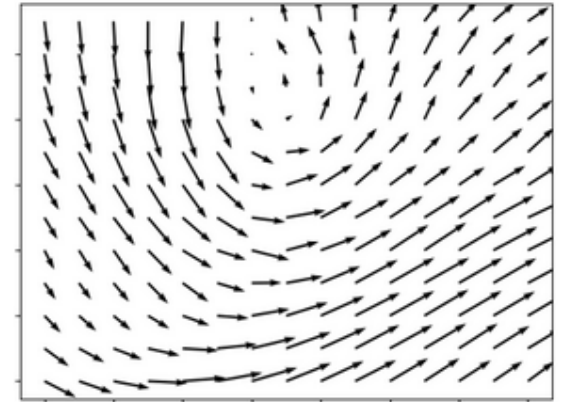
- **Cross-correlation** of neighboring ground sensors



Our goal

Build a preliminary setup for analyzing and cross-comparing different cloud advection methods

- **Cross-correlation** of neighboring ground sensors
- **Optical flow** using consecutive satellite images
 - Clear-sky index ($kc = GHI/GHIcs$) calculated using CAMS-Radiation data
 - TV-L1 algorithm with different regularization parameters



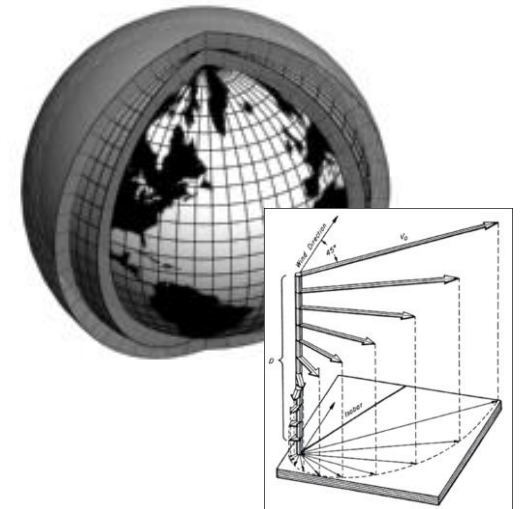
Sánchez Pérez et al. (2012), DOI: [10.5201/ipol.2013.26](https://doi.org/10.5201/ipol.2013.26)

Zach et al. (2007), DOI: [10.1007/978-3-540-74936-3_22](https://doi.org/10.1007/978-3-540-74936-3_22)

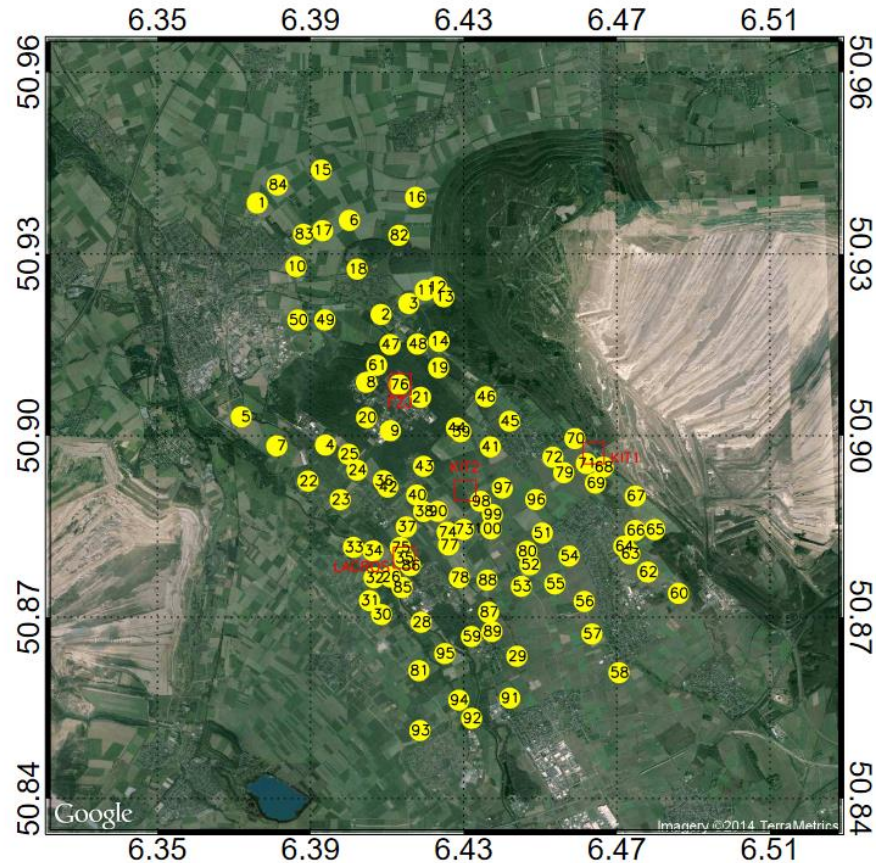
Our goal

Build a preliminary setup for analyzing and cross-comparing different cloud advection methods

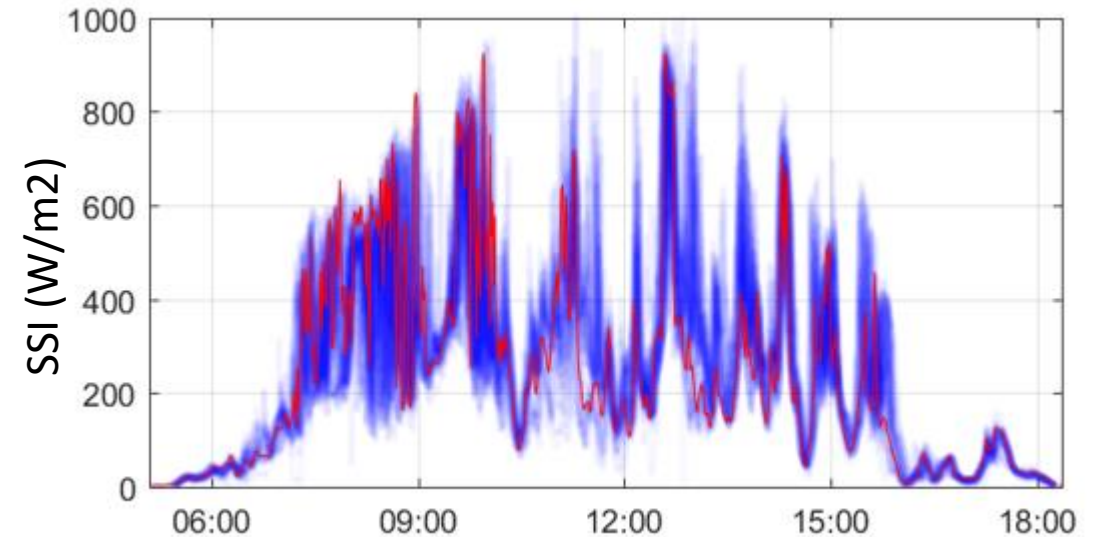
- **Cross-correlation** of neighboring ground sensors
- **Optical flow** using consecutive satellite images
- Wind speed from **ERA5** reanalysis
 - At different pressure levels (from 800 to 1000 hPa)



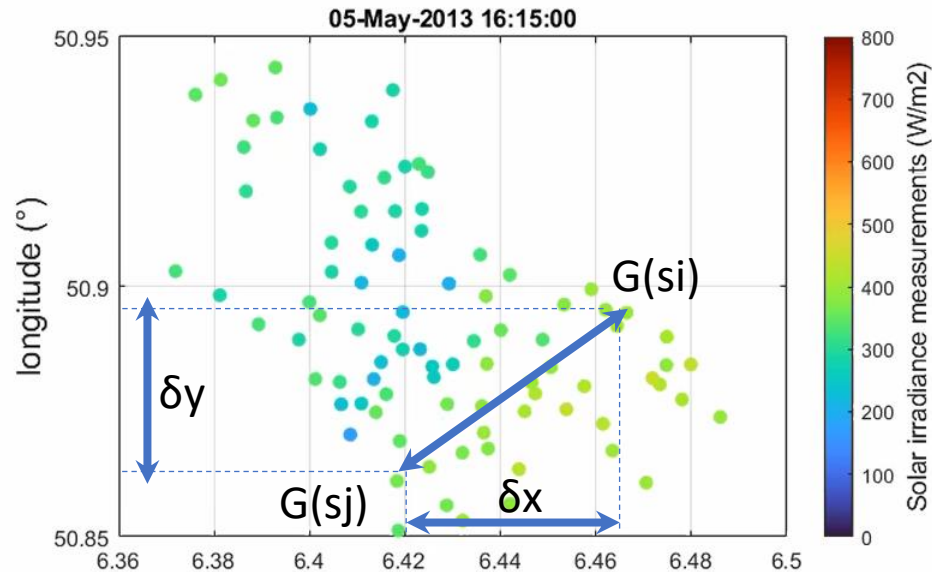
Our testbed location – HOPE-Jülich campaign



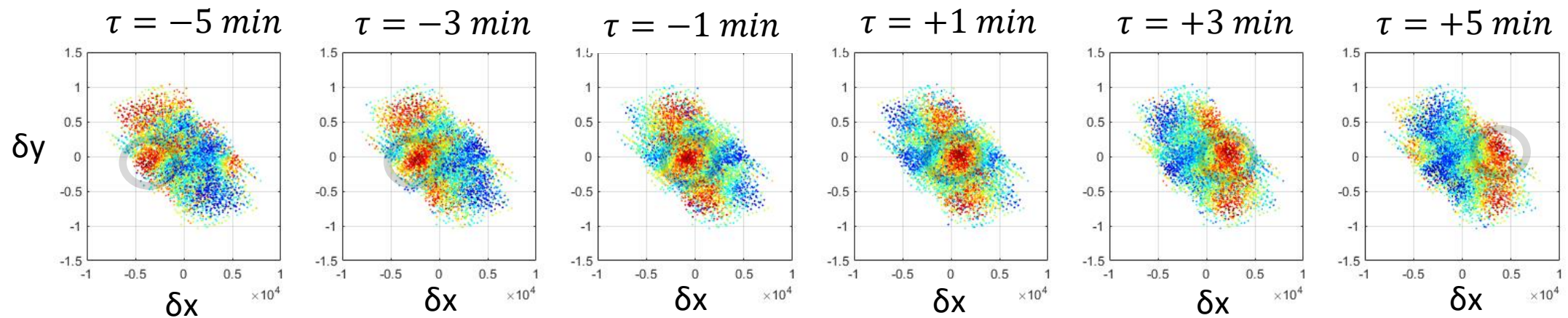
- Ground irradiance data from the **HOPE-Jülich*** campaign
- 99 sensors, 10x12 km²,
 - 15 sec measurements between April and August 2013



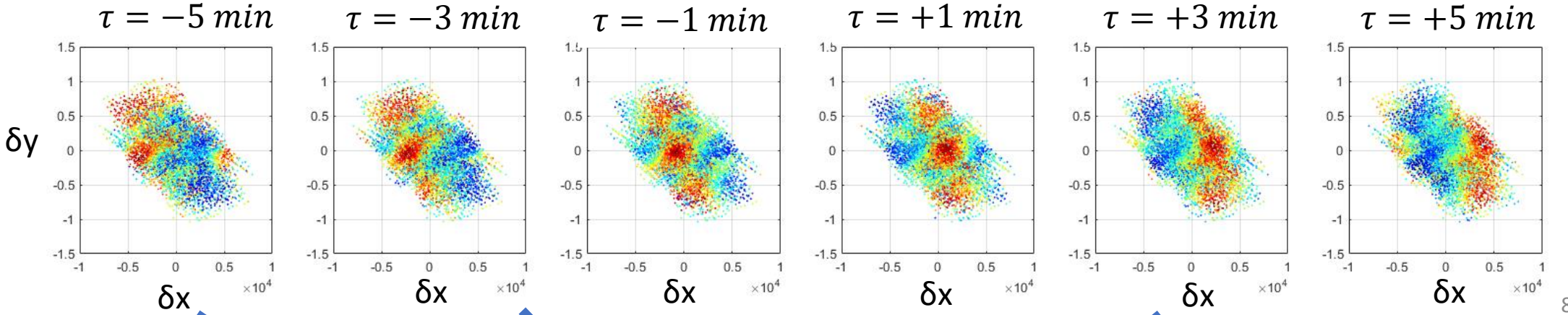
From sensor network to advection



- The correlation is calculated between **all pairs of sensors**
- A time window of **15 min** is used for the calculation of the correlation
- The correlations are represented as a function of the **spatial lags (δx and δy)**

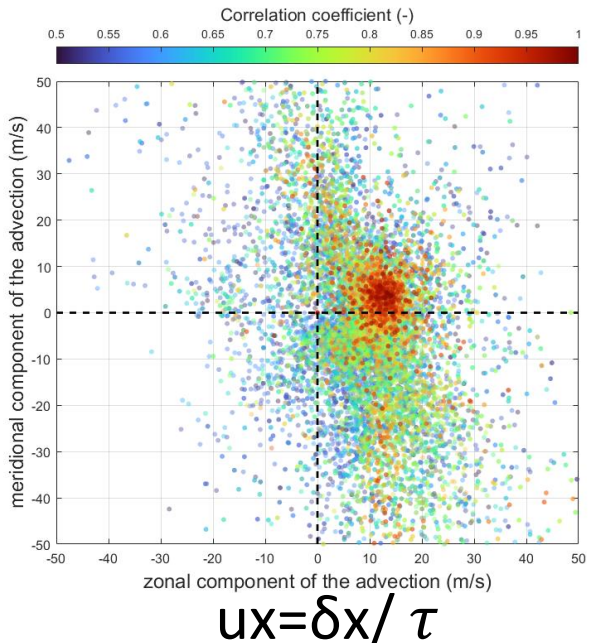


From sensor network to advection

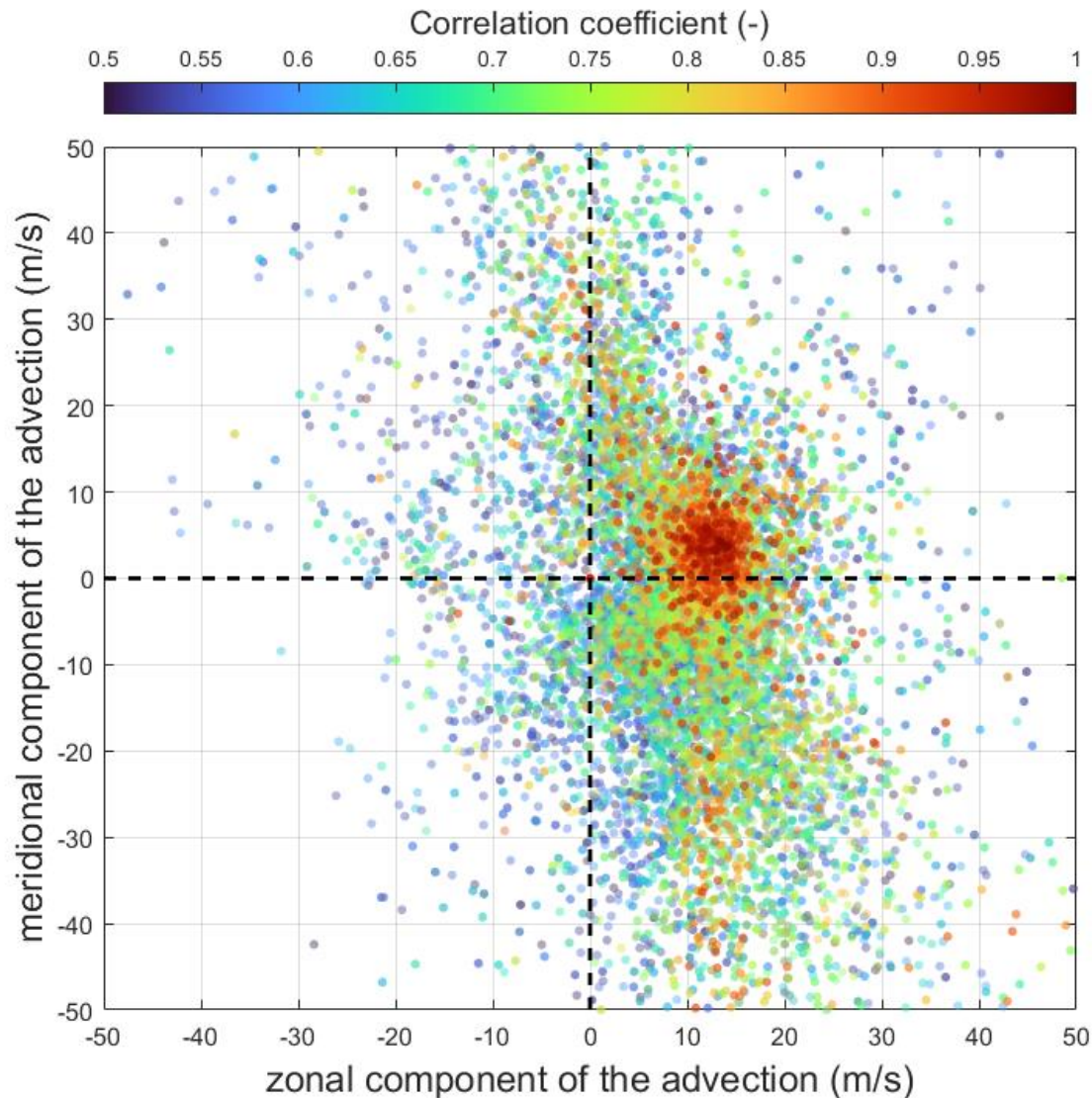


Results can be merged if spatial and temporal lags are converted to speed

$$u_y = \delta y / \tau$$



Preliminary results

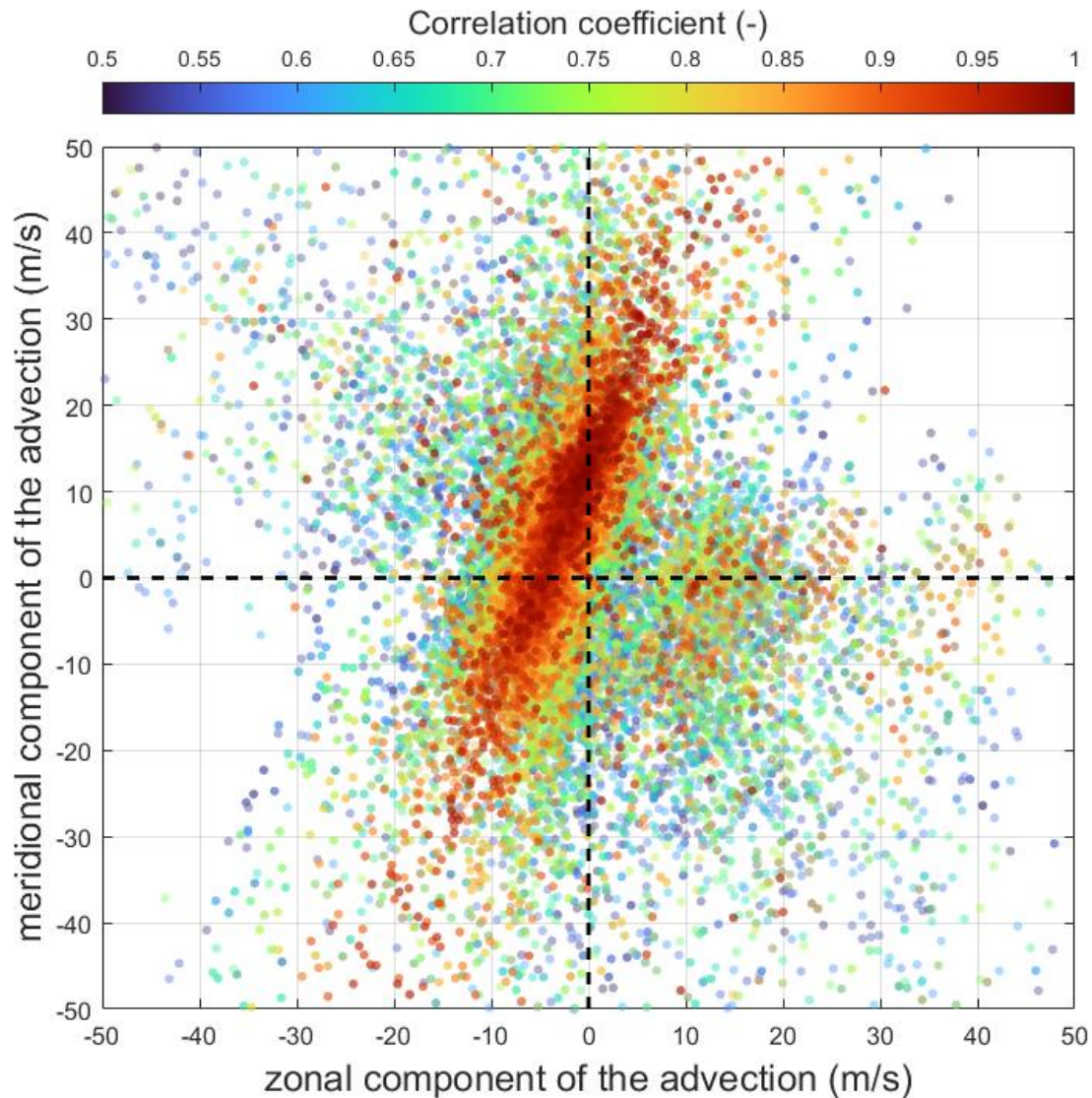


Estimating the advection with the ST autocorrelation function can be **very effective**

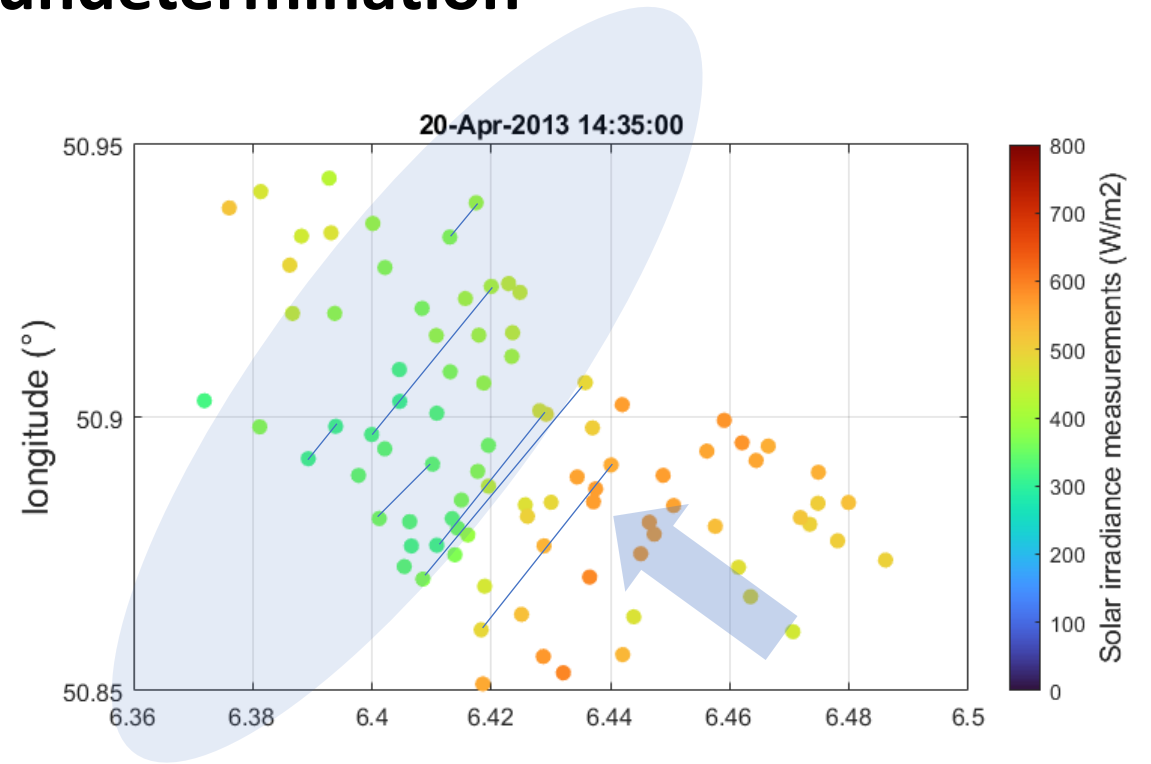
- ✓ pure advection
- ✓ homogeneous flow
- ✓ no cloud formation/dissipation
- ✓ clear patterns to track

... but it can also lead to **unsharp ACF** and **undetermination**

Preliminary results

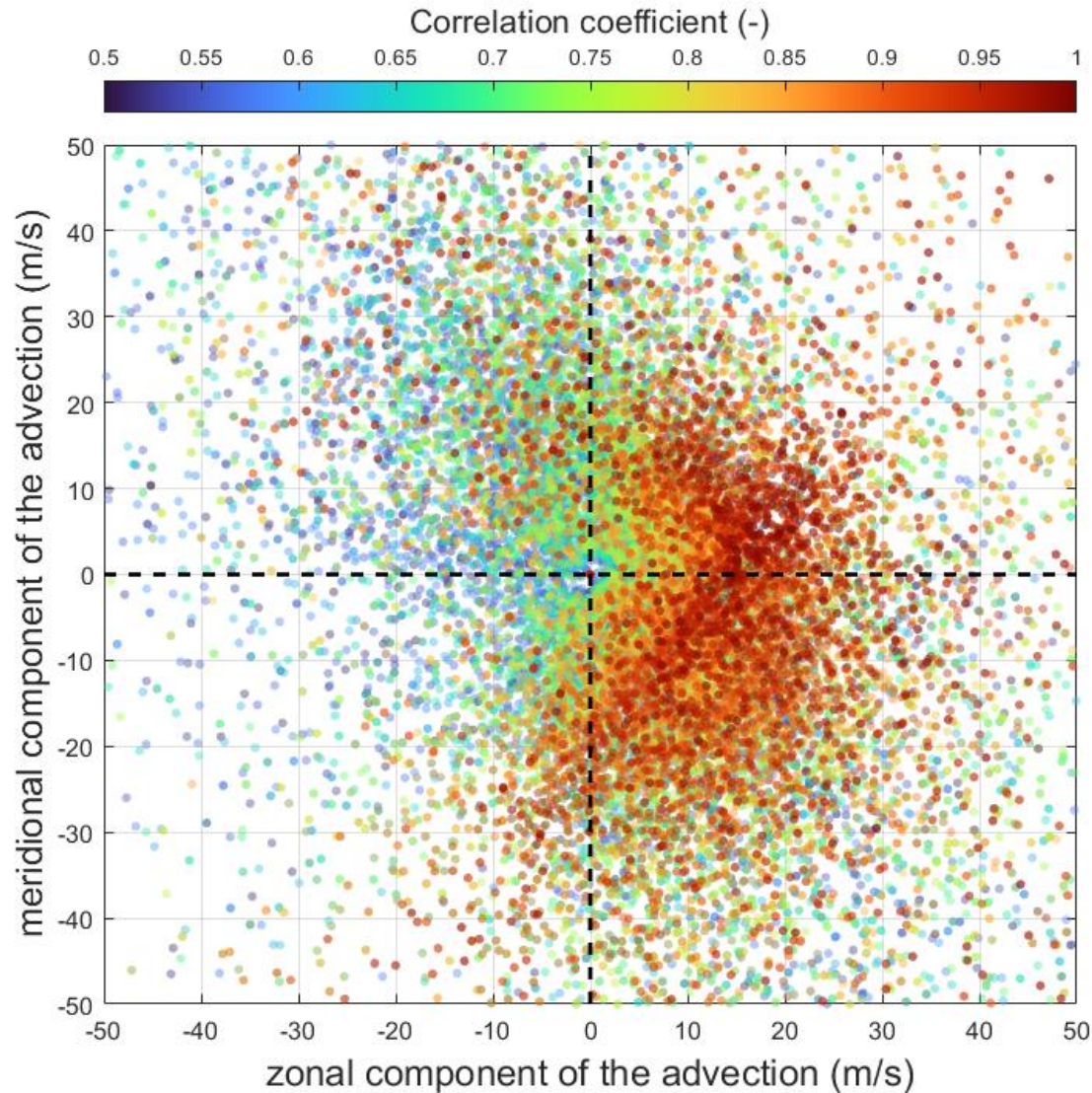


The **spatio-temporal structure** of the irradiance field can lead to **undetermination**



-> *All pairs of sensors sensors along the cloud edge will behave synchronously*

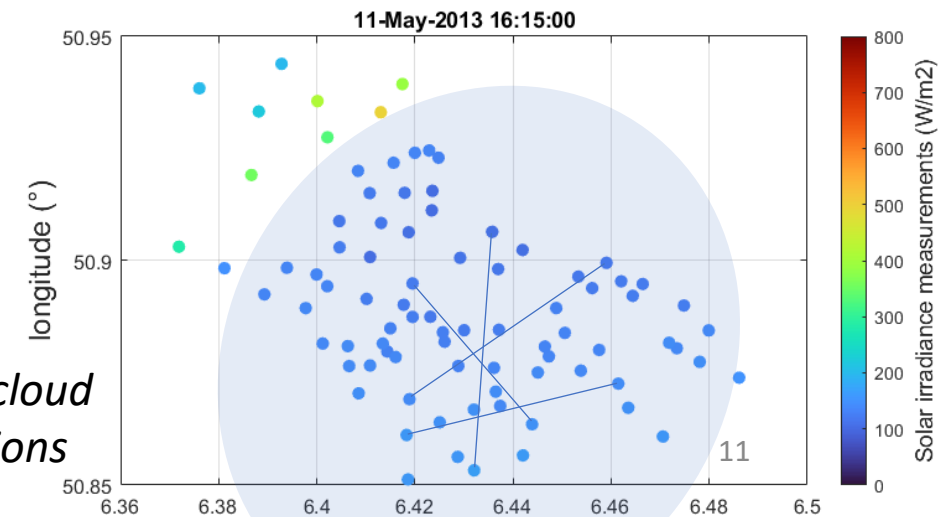
Preliminary results



Blurry autocorrelation functions are very frequent:

- **no feature** to track (clear sky or overcast)
- **no pure advection** (e.g. presence of different flows)
- ...

-> *all pairs of sensors below a stationary cloud have similar correlations*



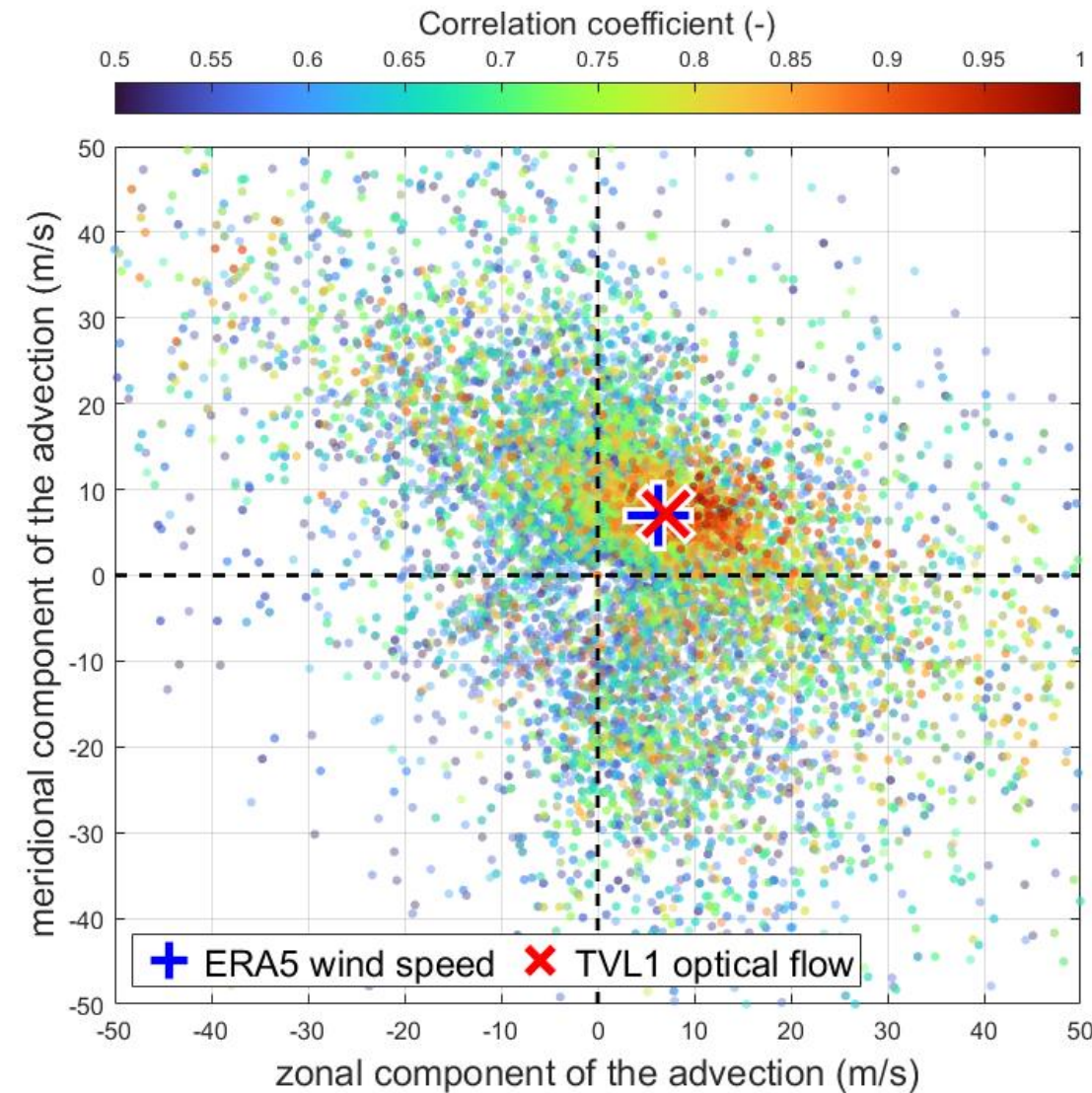
Conclusion and outlook

- **Lessons learned:**

- The performances of the spatial-autocorrelation method vary with the structure of the irradiance field
- Understanding the performances of ACF is an important prerequisite for our analysis

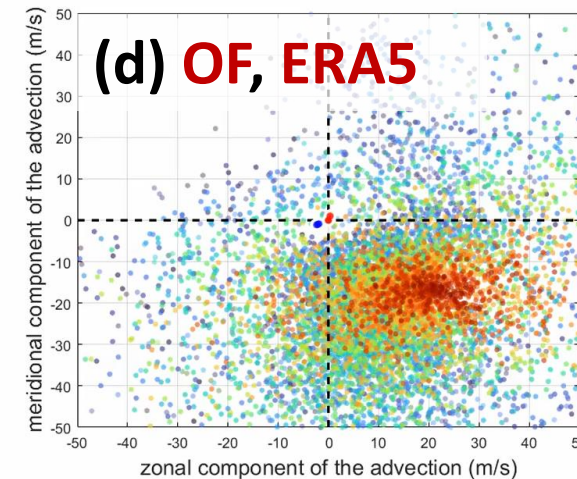
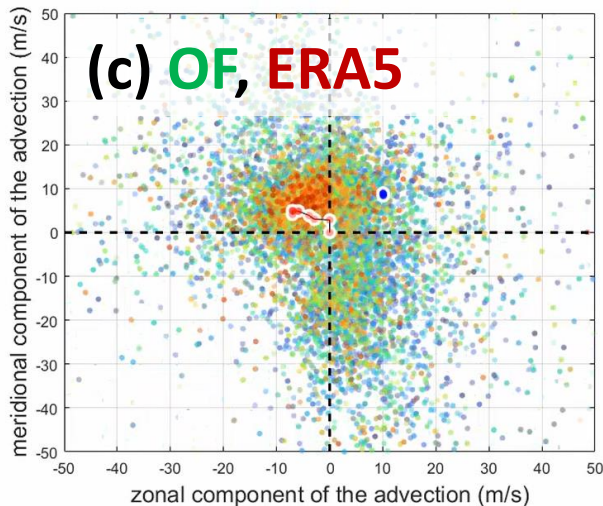
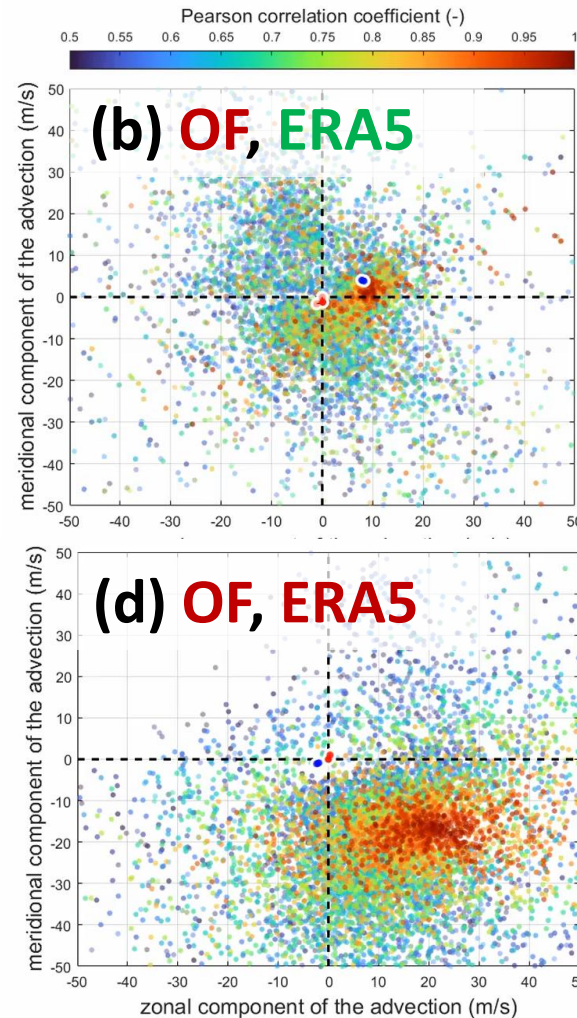
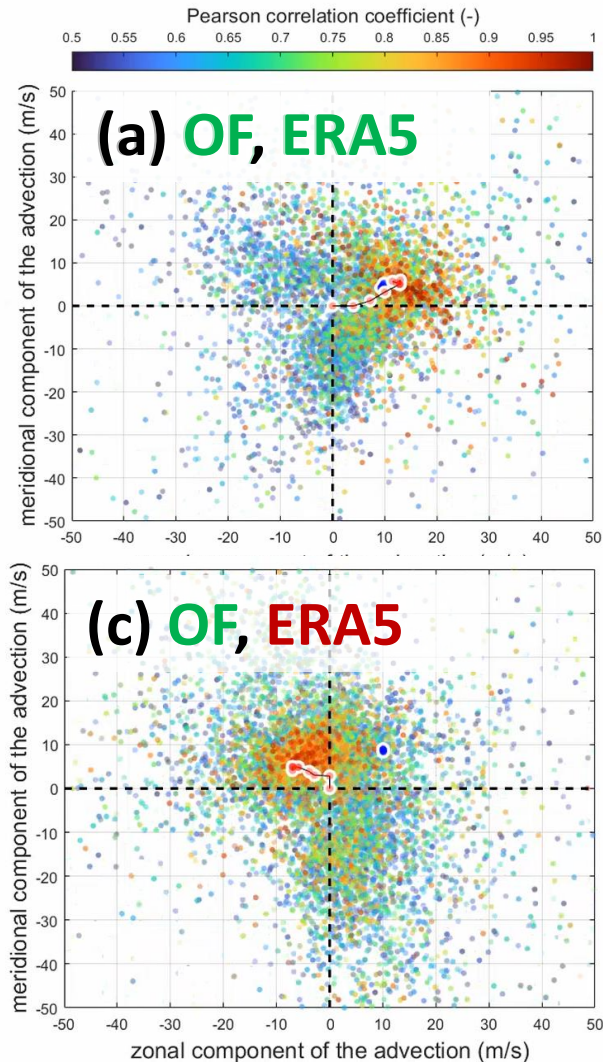
- **Next steps:**

- Use of the ST ACF as a reference for the evaluation of ERA5 wind speed and optical flow
- Understand the effect of the spatial scale & weather situation on the performance of the different approaches



Additional slides

Preliminary results



No systematic results:

- (a) OF and ERA5 can both perform well
- (b) ERA5 can be better than OF
- (c) OF can be better than ERA5
- (d) Both approaches can fail

Questions:

- Does this depend on the **meteorological situation**?
- For **Optical Flow**, how do we **choose the regularisation parameter**?