Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Photo by Denny Müller on Unsplash

Assimilating Lightning Data into ICON-LAM

Lisa Neef, Uli Blahak, Roland Potthast, Christian Welzbacher, Sven Ulbrich

Observations of Lightning

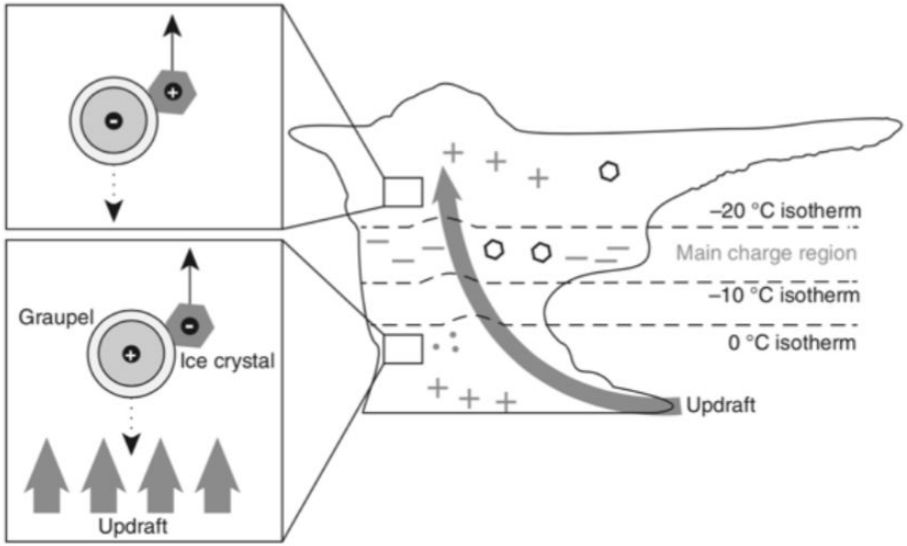


Figure 1.1: Schematic view of the non-inductive charge separation mechanism in convective clouds. The charge of graupel and ice particles are marked with + or – sign. (Lohmann et al., 2016).

We now have good observations of lightning from both ground-based and spaceborne instruments.

Observations of Lightning

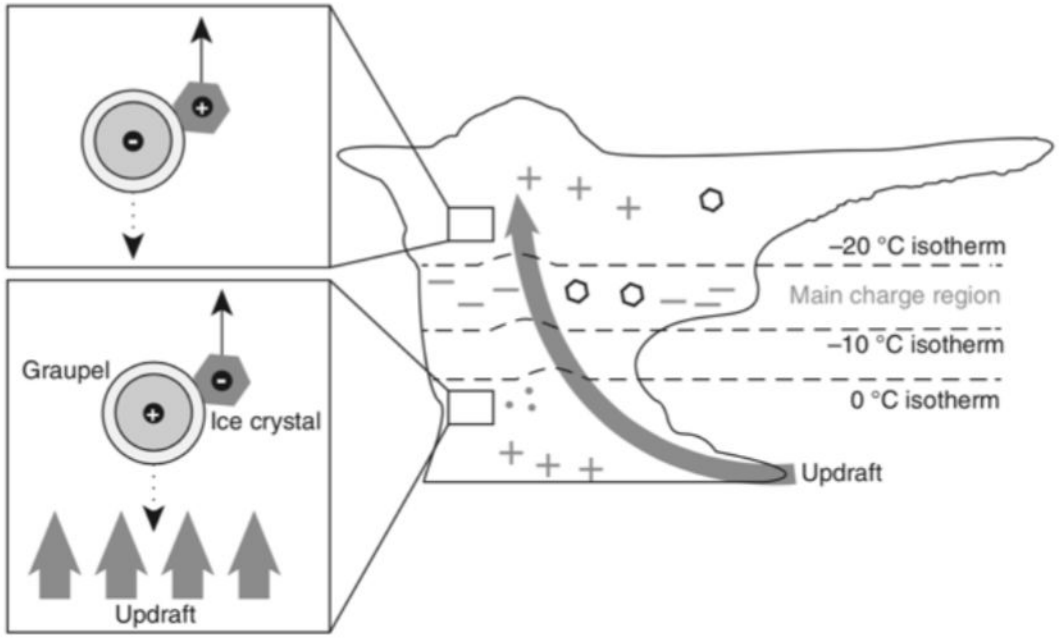


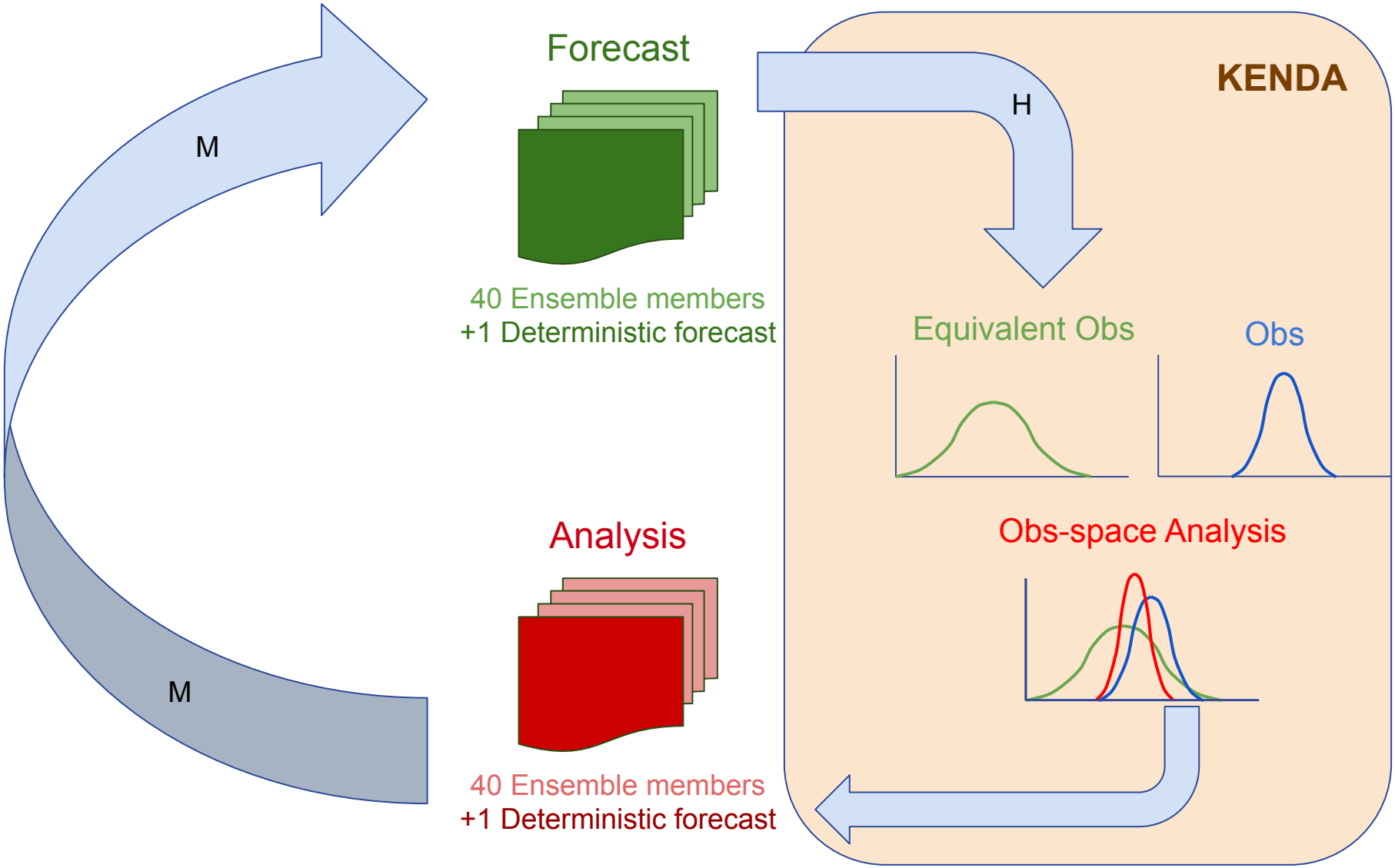
Figure 1.1: Schematic view of the non-inductive charge separation mechanism in convective clouds. The charge of graupel and ice particles are marked with + or − sign. (Lohmann et al., 2016).

Lightning occurrence tells us about

Updrafts

Graupel / particle collisions

Data Assimilation in ICON-LAM



The LETKF spreads observed information across the model state using ensemble statistics.

Lightning Potential Index

Ingredients

$$\mathrm{LPI} = f_1 \frac{1}{\Delta z} \int_{z_{0^\circ C}}^{z_{-20^\circ C}} w^2 \epsilon g_w(w)\, g_g(q_g)\, dz$$

updraft

hydrometeors

$$\epsilon = 2\frac{\sqrt{Q_i Q_l}}{Q_i + Q_l},$$

Lynn and Yair (2010)

Lightning Potential Index

Filters

$$\mathrm{LPI} = f_1 \frac{1}{\Delta z} \int_{z_{0^\circ C}}^{z_{-20^\circ C}} w^2 \epsilon g_w(w) g_g(q_g)\, dz$$

updraft in neighborhood

updraft

graupel

Lightning Potential Index

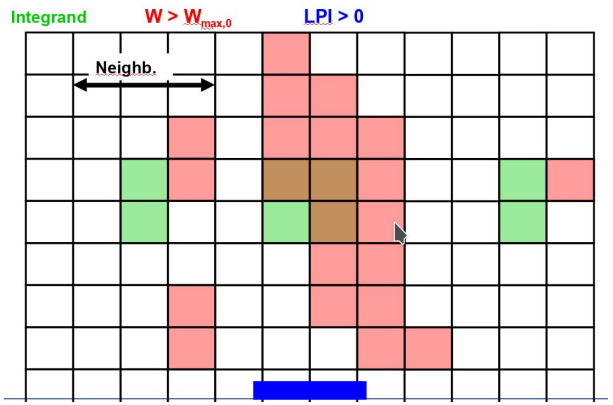
Filters

$$\mathrm{LPI} = f_1 \frac{1}{\Delta z} \int_{z_{0^\circ C}}^{z_{-20^\circ C}} w^2 \epsilon g_w(w) g_g(q_g)\, dz$$

updraft in neighborhood

updraft

graupel



wthresh = 1.1_wp
Dx=10km

Lightning Potential Index

Filters

$$\mathrm{LPI} = f_1 \frac{1}{\Delta z} \int_{z_{0^\circ C}}^{z_{-20^\circ C}} w^2 \epsilon g_w(w) g_g(q_g)\, dz$$

updraft in neighborhood

updraft

graupel

$$g = \begin{cases} 1 & w \geq 0.5\mathrm{m/s} \\ 0 & \text{else} \end{cases}$$

Lightning Potential Index

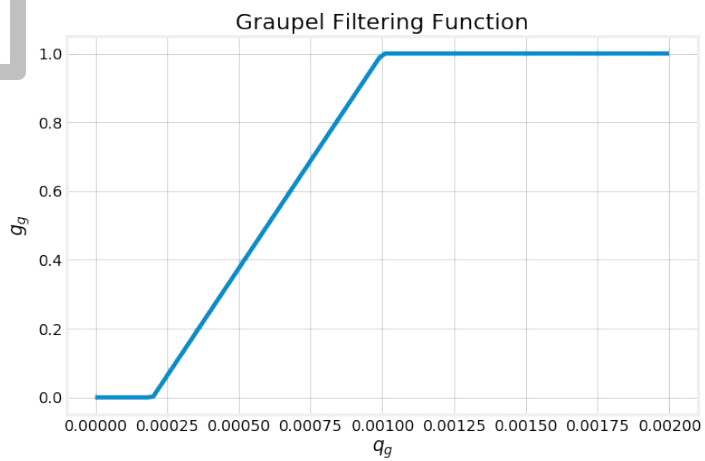
Filters

$$\mathrm{LPI} = f_1 \frac{1}{\Delta z} \int_{z_{0^\circ C}}^{z_{-20^\circ C}} w^2 \epsilon g_w(w) g_g(q_g)\, dz$$

graupel filter

updraft

updraft in neighborhood

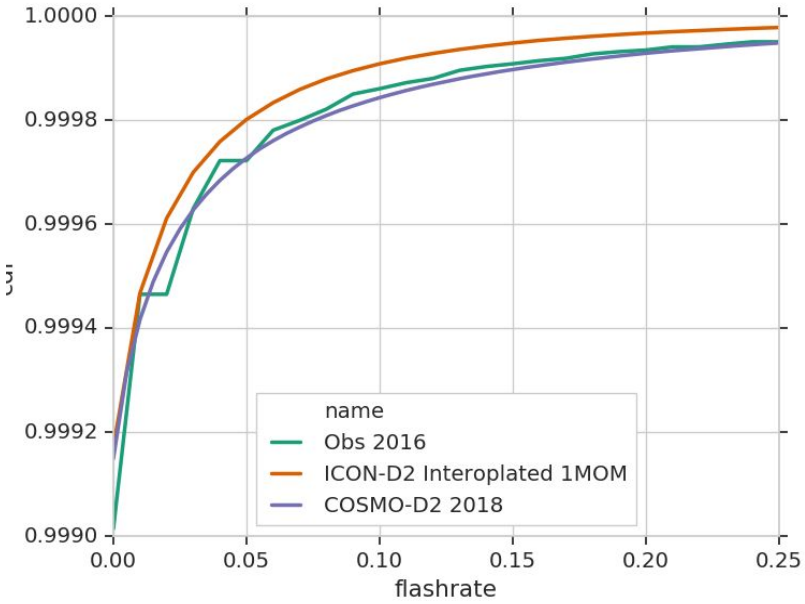


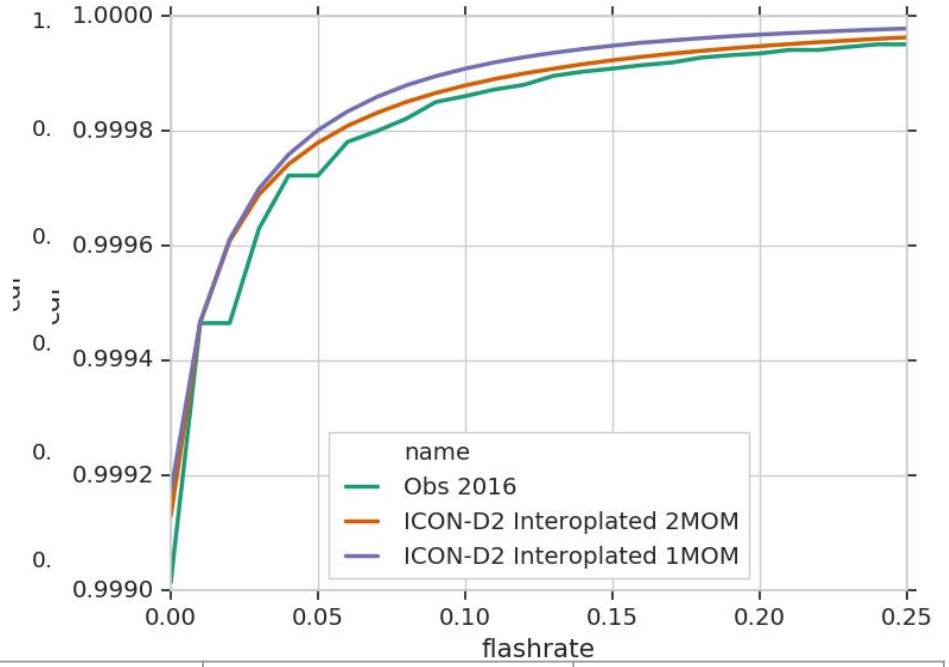
LPI in ICON vs Observed Flashrate

Prior to assimilation of flashrate: LPI is a pretty good estimate but predicts lightning in the wrong places.

LPI to Flashrate Scaling

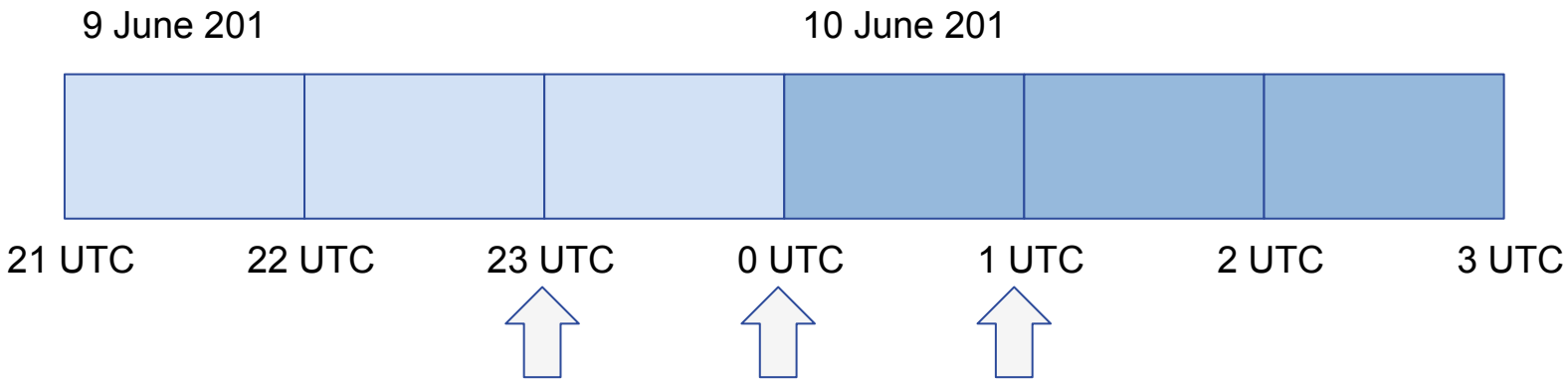
FLRequiv = f*LPI





	COSMO 2016	ILAM-D2 interpolated 1MOM	ILAM-D2 interpolated 2MOM	ILAM native grid 2mom
f	0.017	0.006	0.007	0.006

3-cycle Assimilation Experiments



Ex 1	Conventional obs only
Ex 2	Conventional obs + LINET Flashrate

Control vector:
pf, t, q, u, v, qcl, qci (default)
+qr (rain)
+qg (graupel)
+qs (snow)

Issues around Assimilating Lightning

Observation errors unclear

Uncertainty in flashrate forecast (i.e. cloud charging)

How to interpret zero-lightning observations?

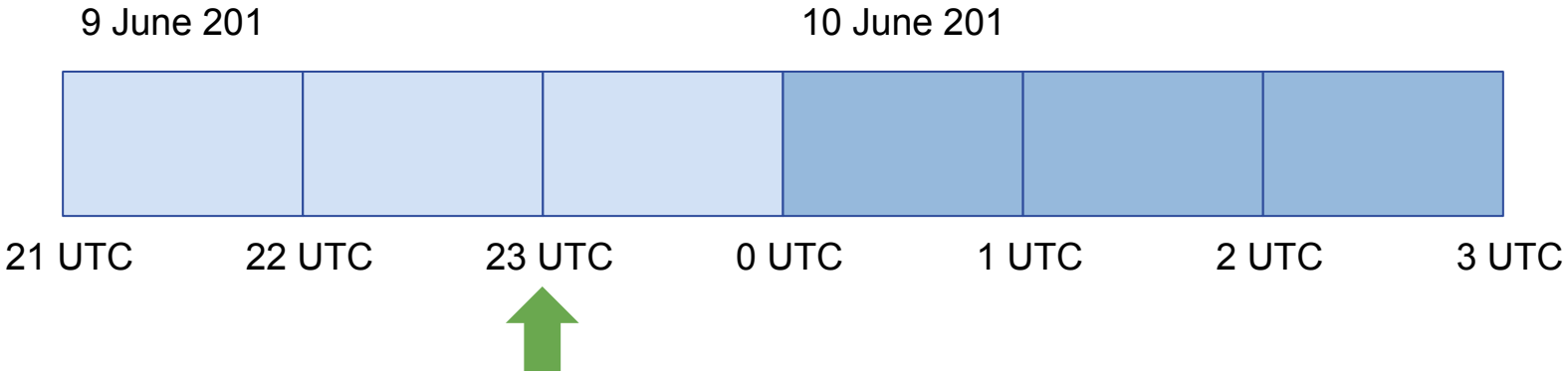
Flashrate discrete in space and time

Flashrate is positive-definite

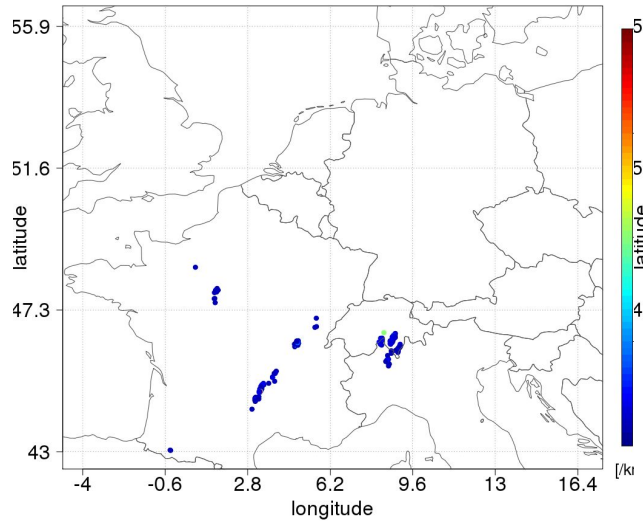
Relationship between flashrate and model variables is nonlinear

3-cycle Experiment

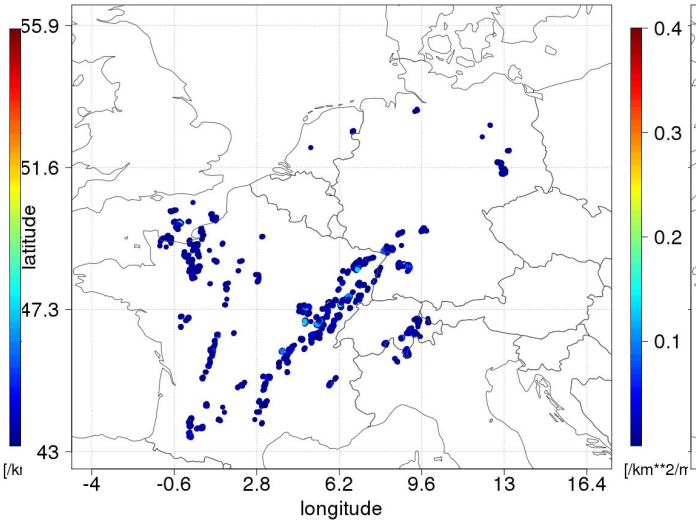
First Guess at 23UTC



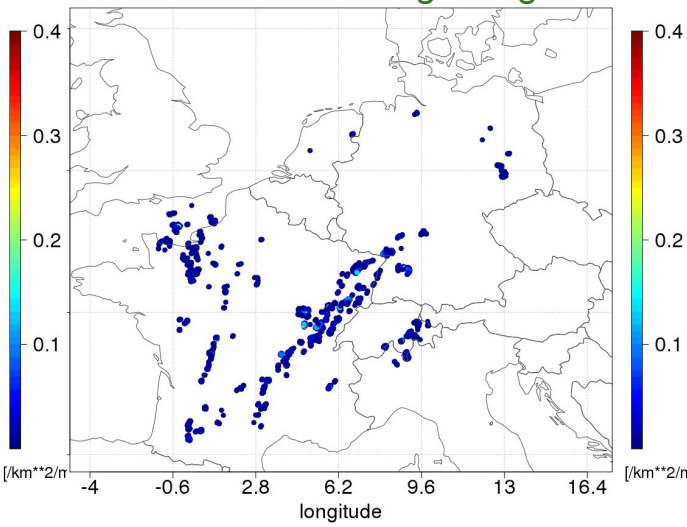
Observed Flashrate



Forecast Conventional DA

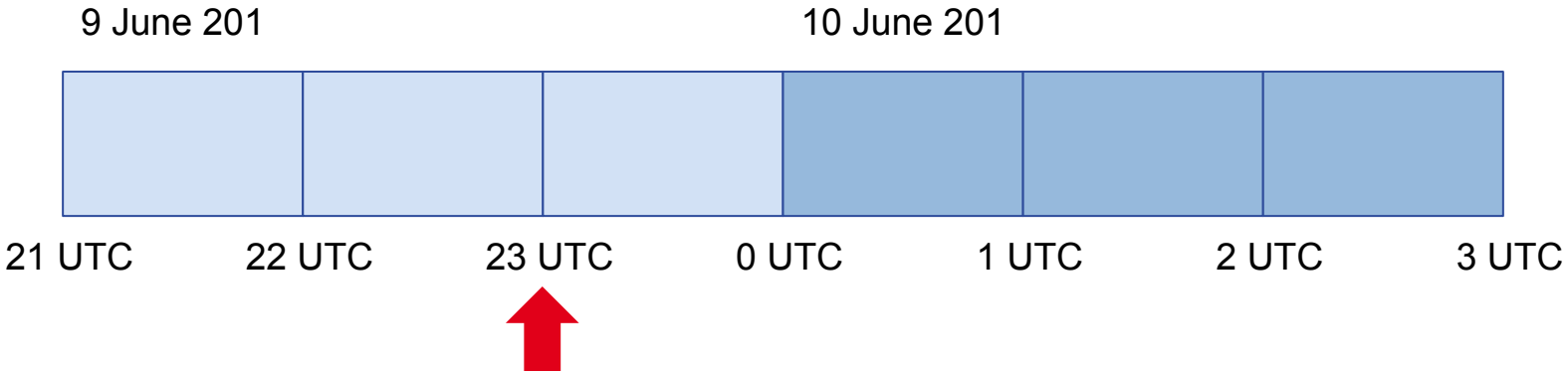


Forecast Conv+Lightning DA

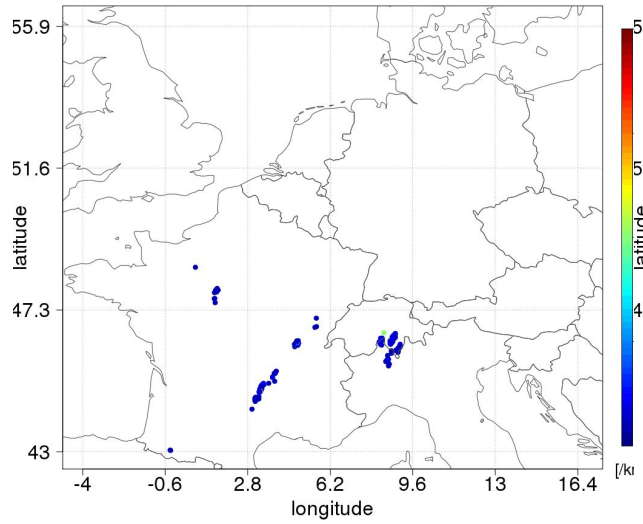


3-cycle Experiment

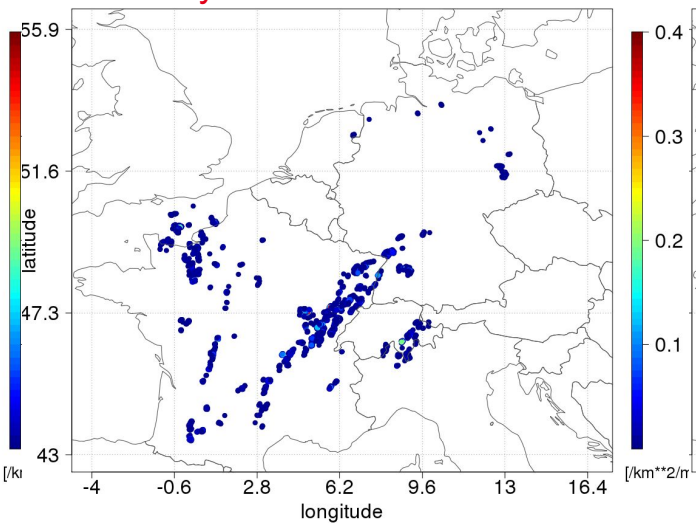
Analysis at 23UTC



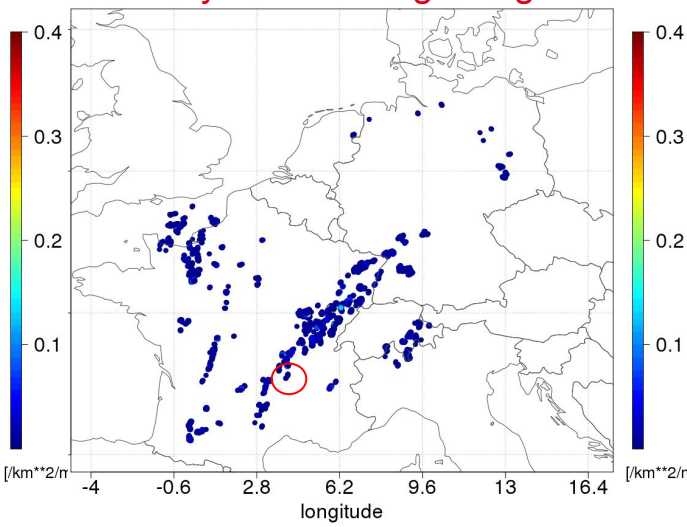
Observed Flashrate



Analysis Conventional DA

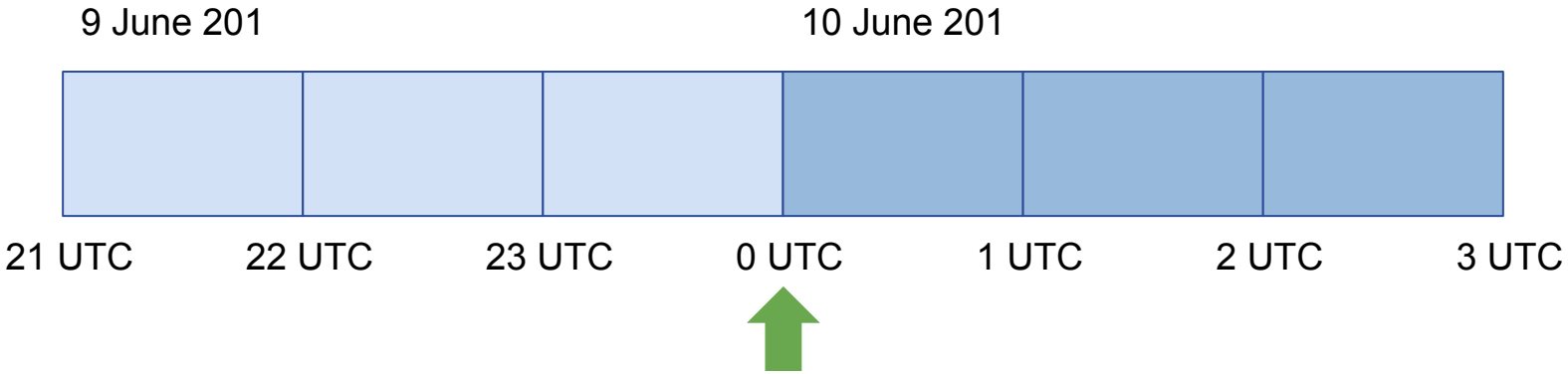


Analysis Conv+Lightning DA

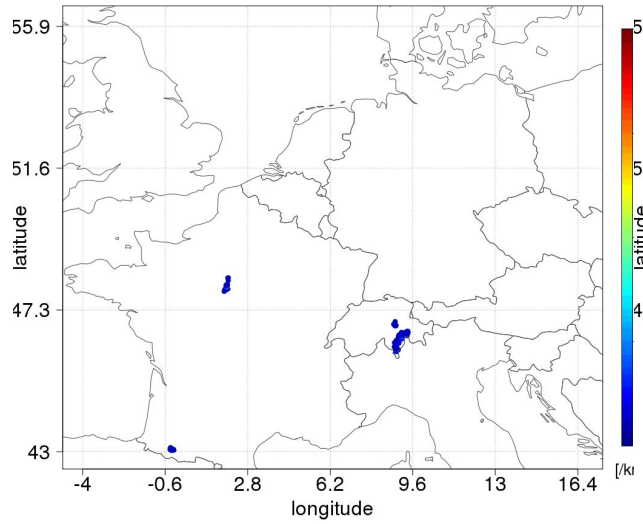


3-cycle Experiment

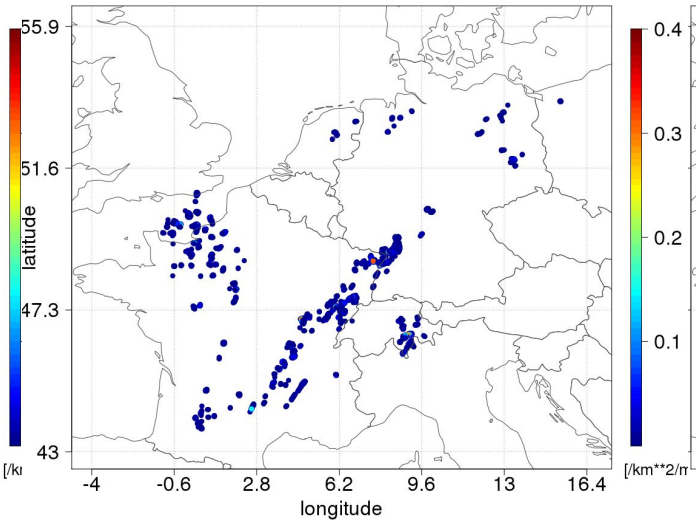
First Guess at 0UTC



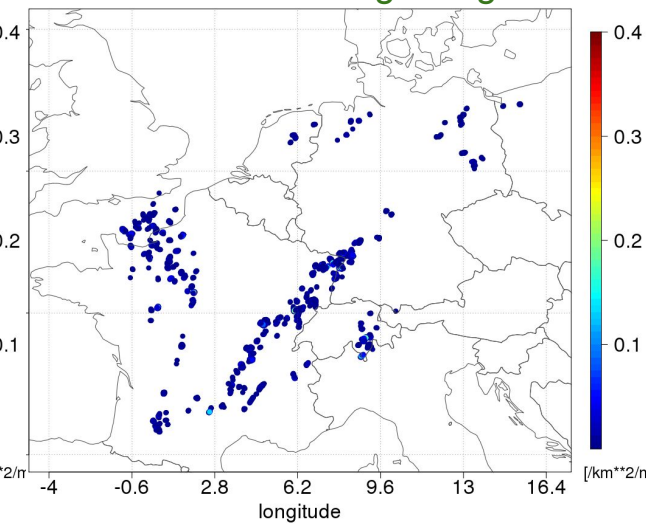
Observed Flashrate



Forecast Conventional DA

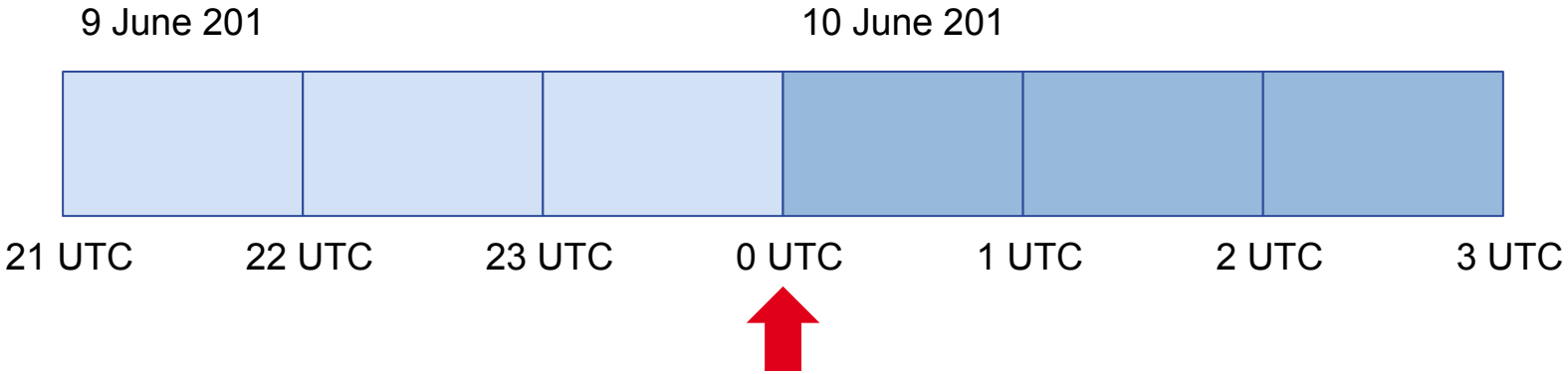


Forecast Conv+Lightning DA

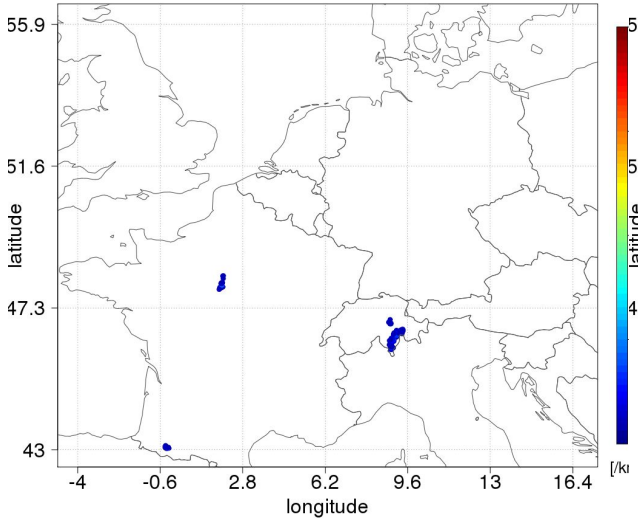


3-cycle Experiment

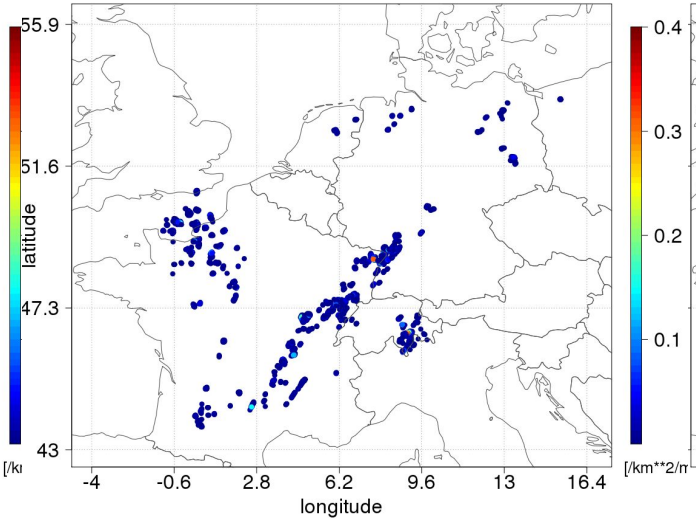
Analysis at 0UTC



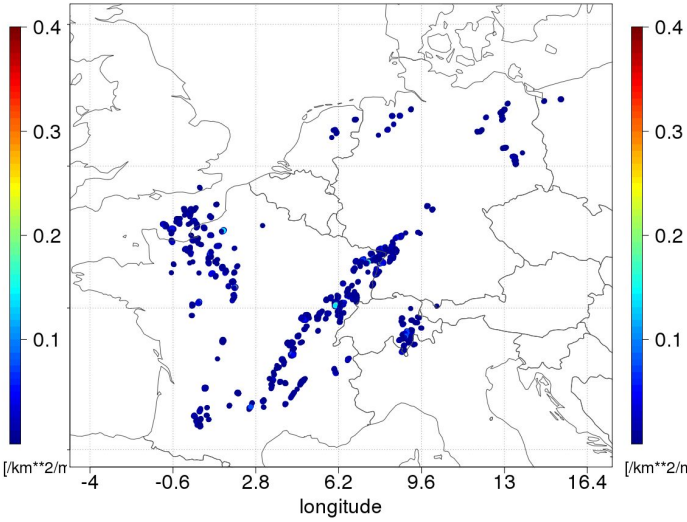
Observed Flashrate



Analysis Conventional DA

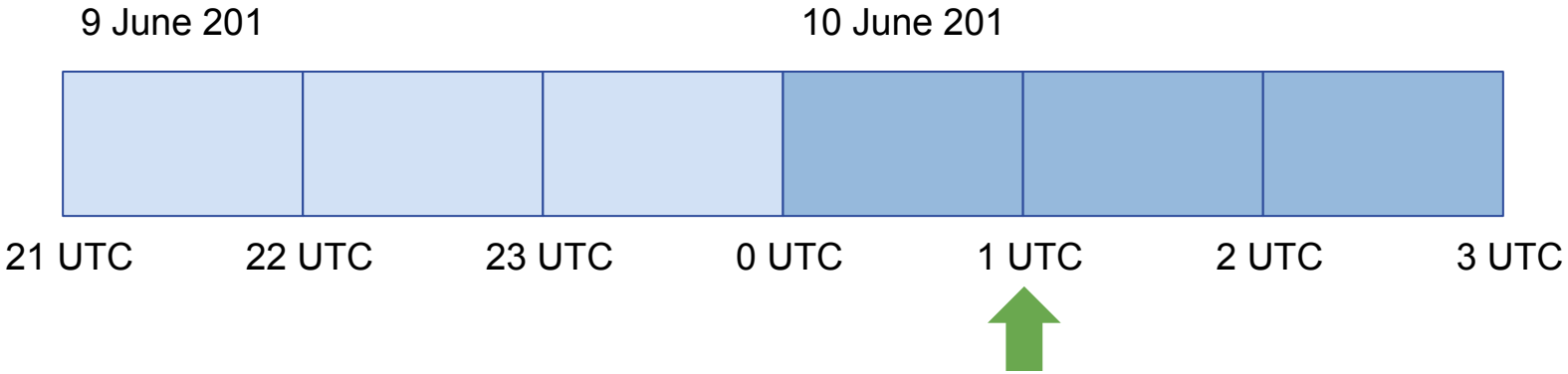


Analysis Conv+Lightning DA

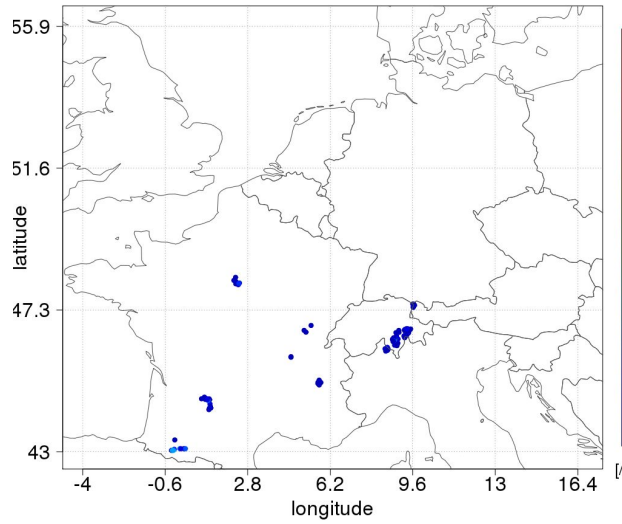


3-cycle Experiment

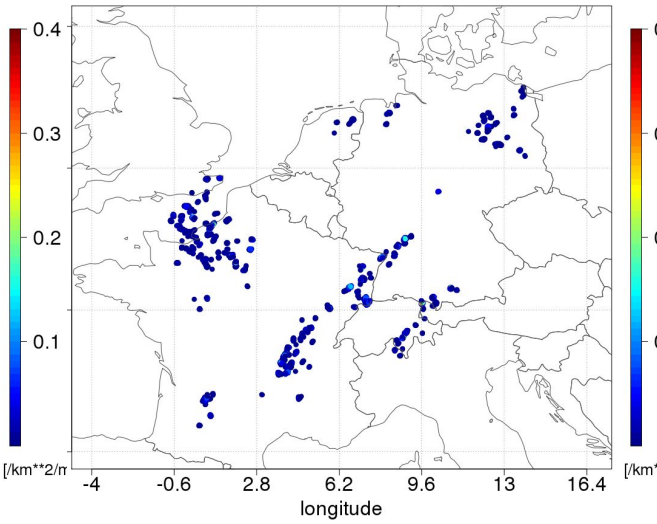
First Guess at 1UTC



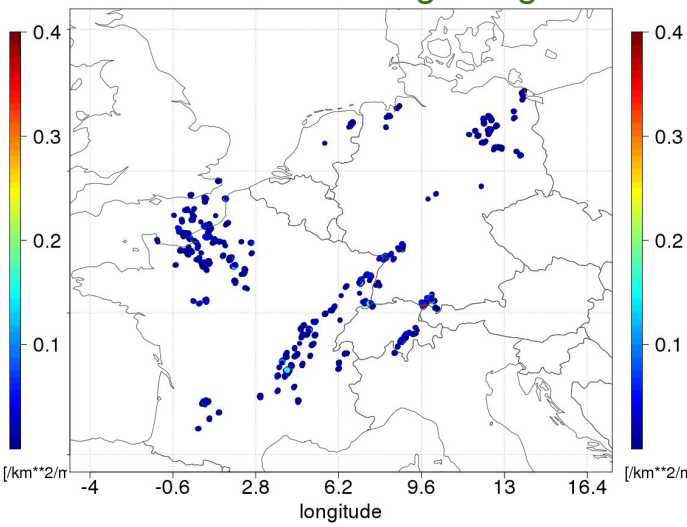
Observed Flashrate



Forecast Conventional DA

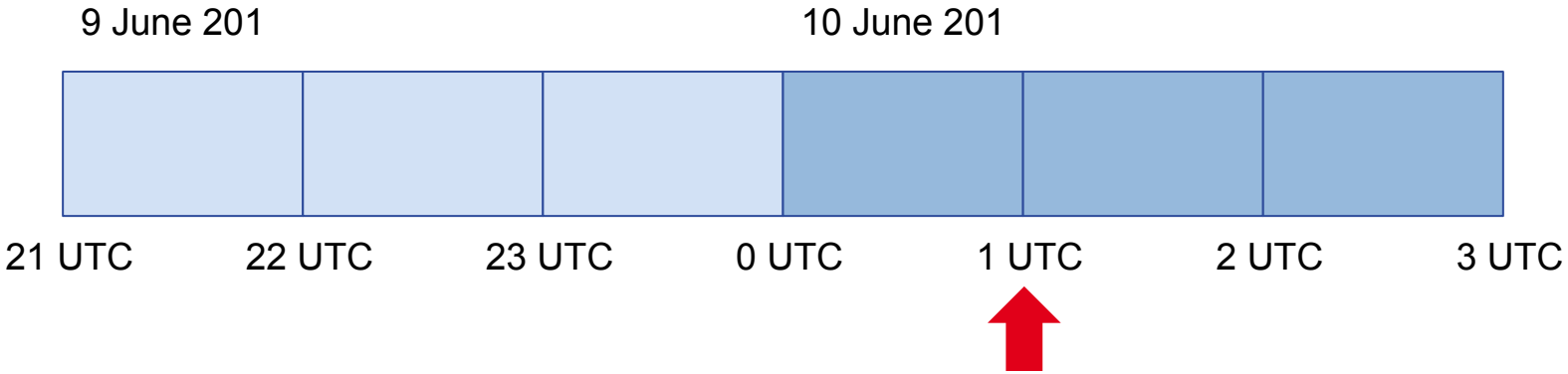


Forecast Conv+Lightning DA

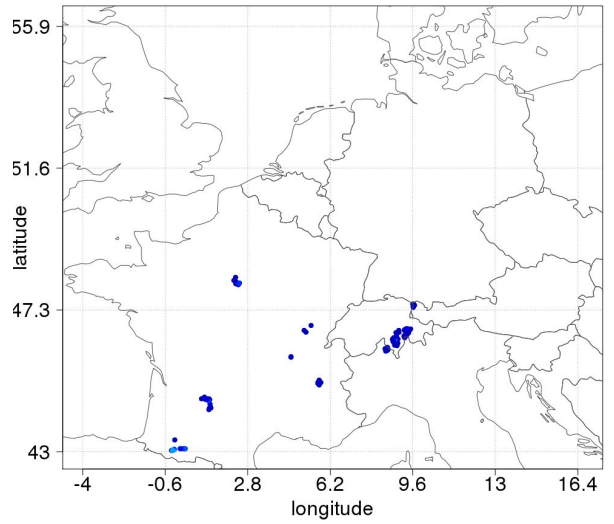


3-cycle Experiment

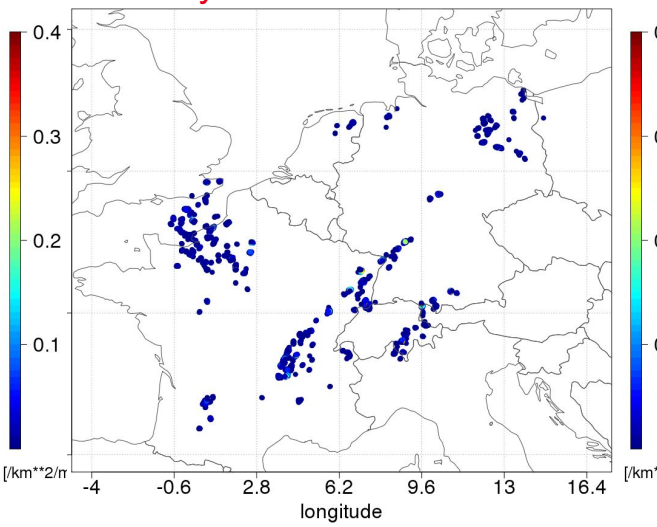
Analysis at 1UTC



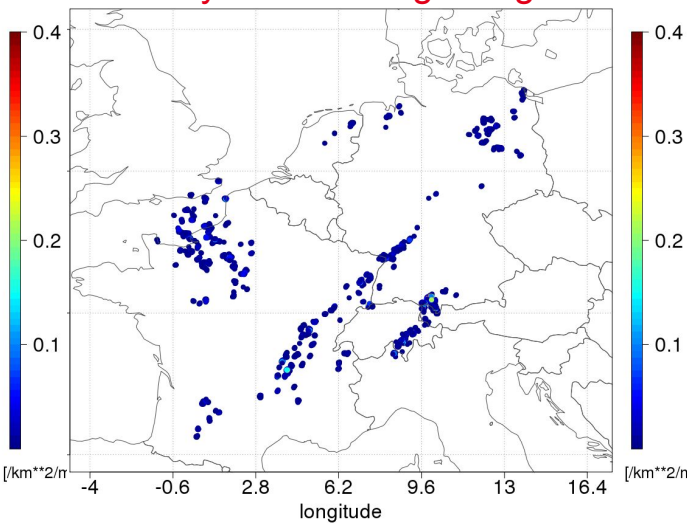
Observed Flashrate



Analysis Conventional DA



Analysis Conv+Lightning DA



Focus on Last Assimilation Time

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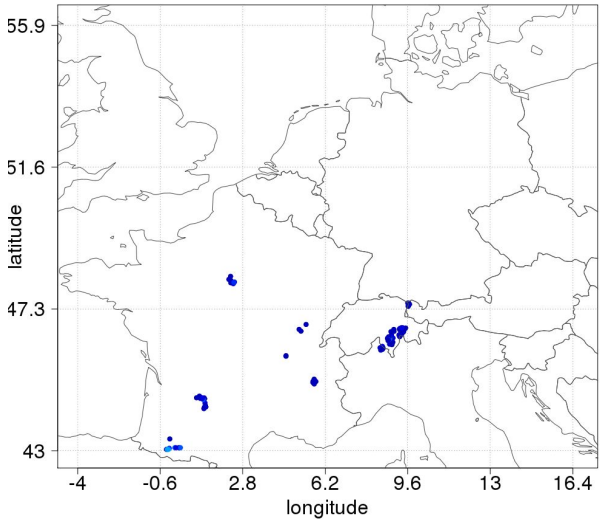
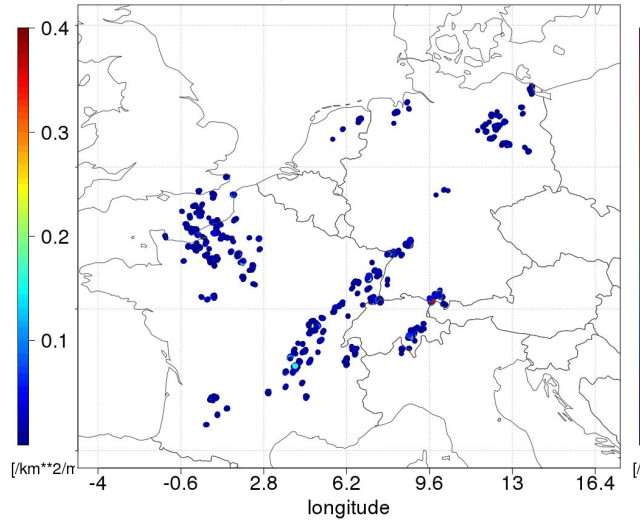
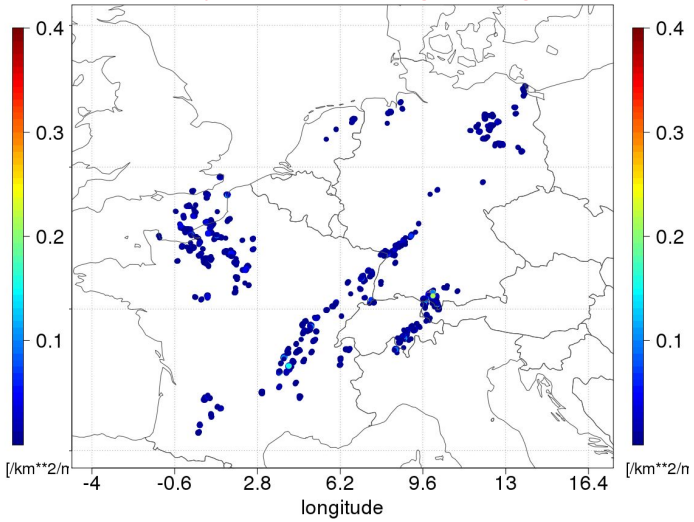
Observed Flashrate



(New) Analysis Conventional DA



Analysis Conv+Lightning DA



By far, most of the obs we assimilate are “no lightning”. ¯_(ツ)_/¯

We ingest half of observed lightning strikes (would like this to be 100%)

	Observations	Nonzero	Percent
Available	536,051	135	0.03%
Assimilated	11,183	63	0.6%
Percent	2%	46%	

What happens where lightning is assimilated?

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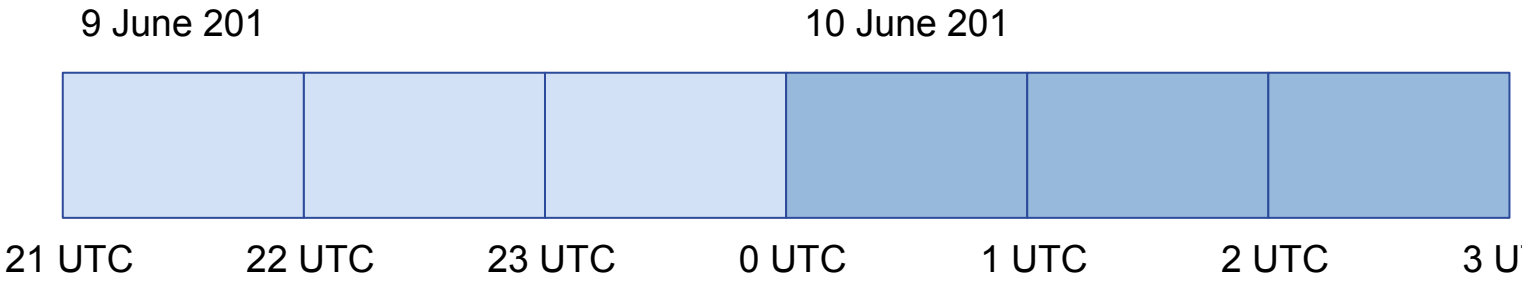
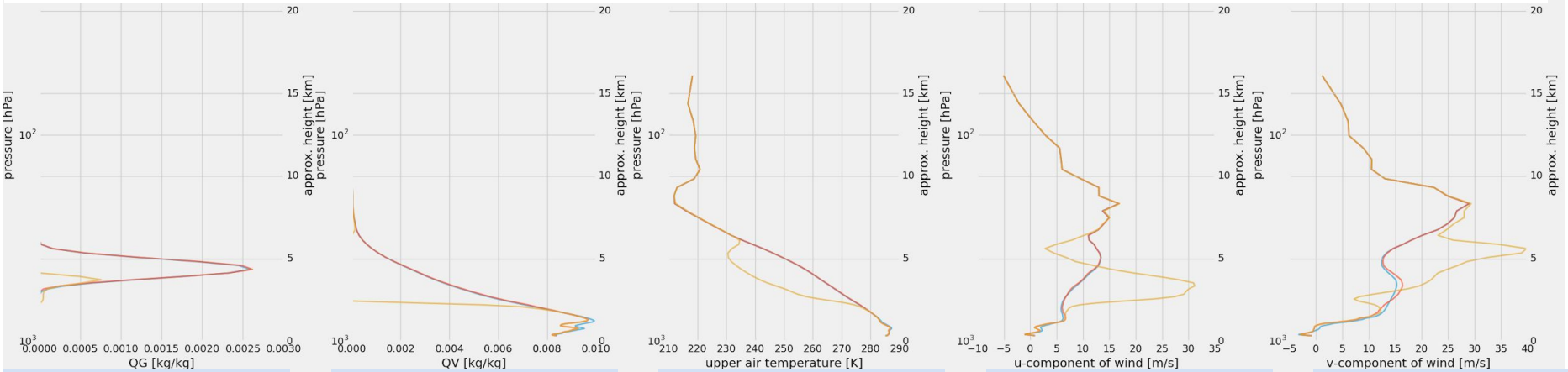


Strongest increment: -0.37 /km2/min (removing ca. 22 flashes)
lat 9.93 x lon 47.74



QG	QV	T	U	V

forecast

analysis conv only

analysis conv+lightning

1h forecast following lightning DA

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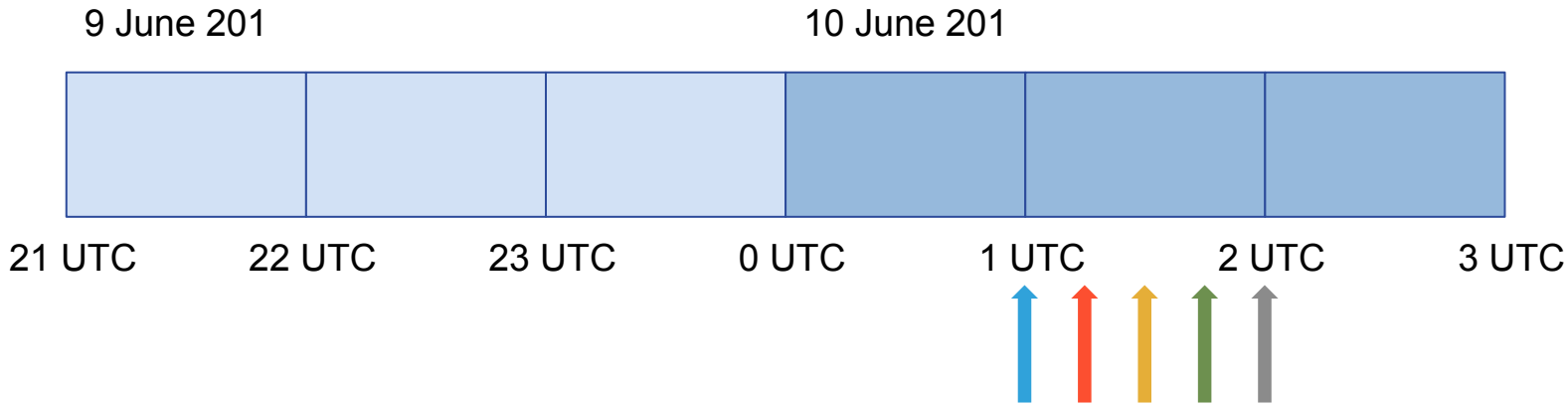

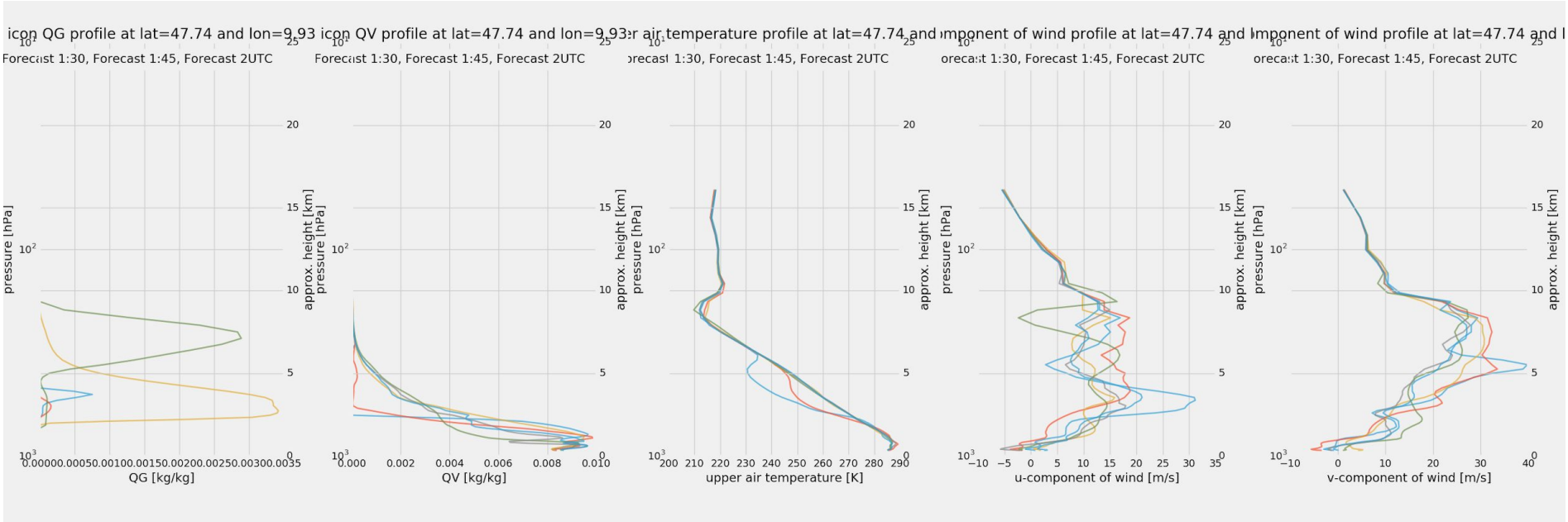

Tuning the Assimilation to Accomodate Lightning

Height	*What is the most sensible altitude to assign to flashrate for assimilation?*
Localization	*How far should we allow the influence of observations in the vertical and horizontal?*
Observation error	*What size obs error best represents the uncertainty of lightning observations?*
w in control vector	*Can we get a useful update of w by assimilating flashrate*
special covariance inflation	*How to create ensemble spread where there is no lightning? (Klaus Vobig)*

Photo by Johannes Plenio on Unsplash