UKMO Unified Model Sensitivity Study

SOFOG3D Meeting

Toulouse

Monday 12th June

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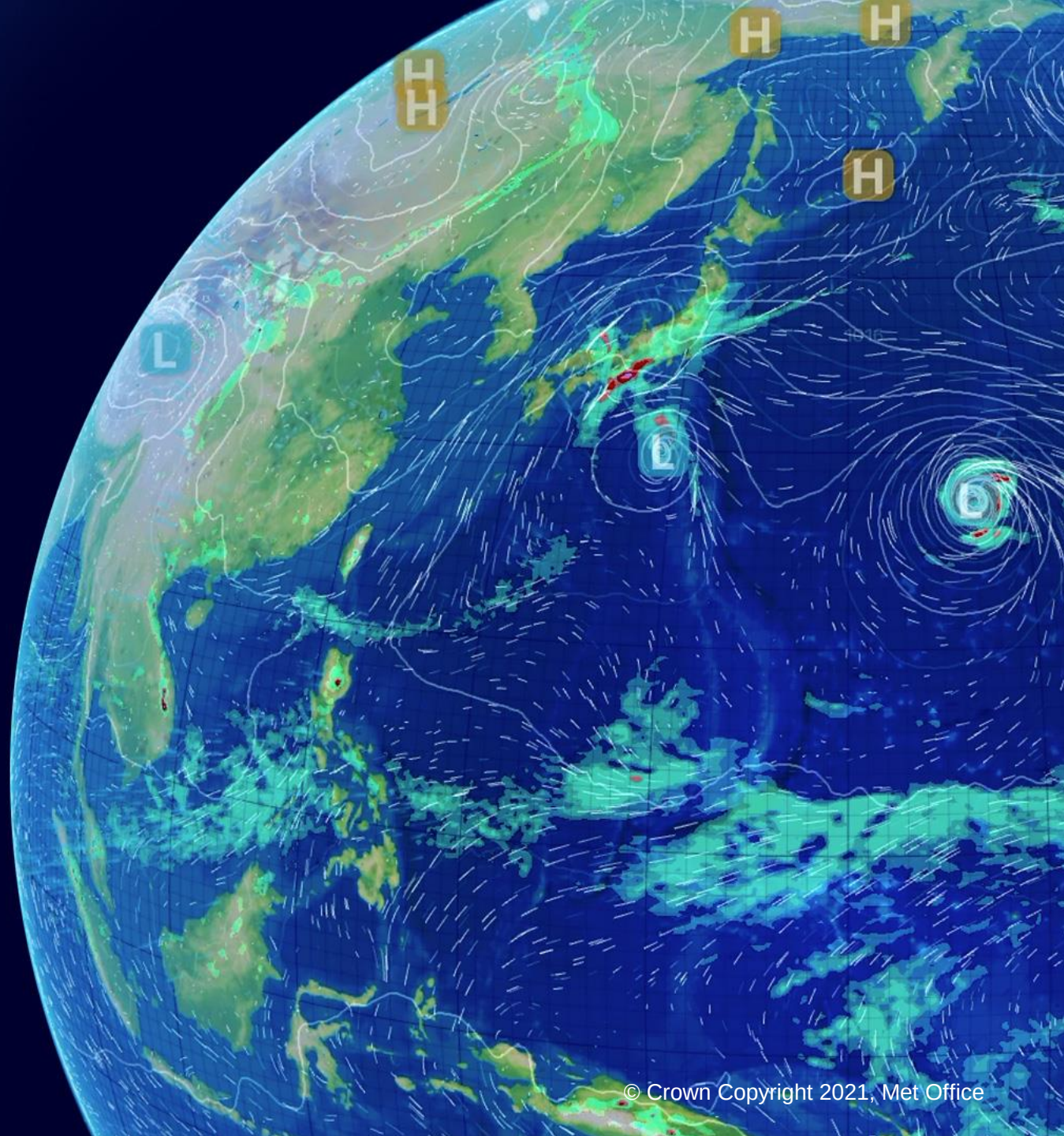


Met Office

Outline

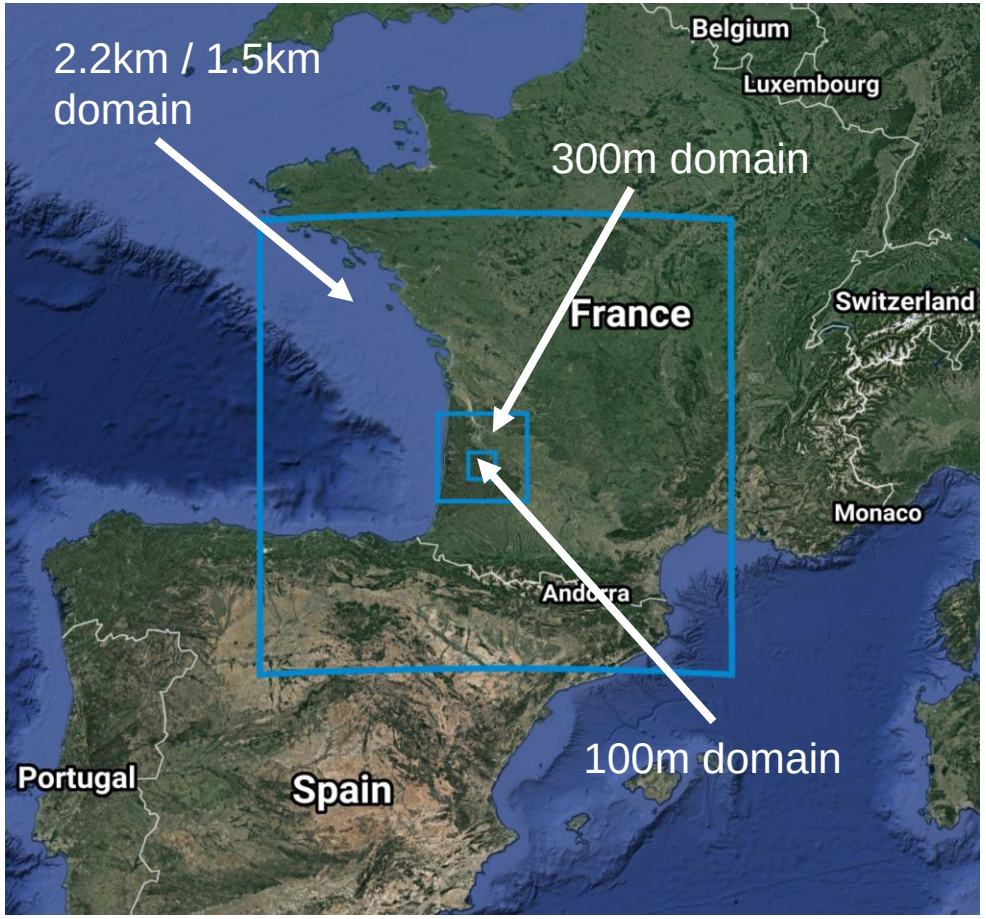
Model experiments

Ensemble sensitivity to change in science configuration

Deterministic sensitivity to targeted science changes

Future Plans

SOFOG modelling set-up



2.2km, 18 member ensemble nested inside global ensemble forecast

1.5km deterministic nested inside global deterministic forecast

300m and 100m horizontal grid forecasts run for future evaluation

Model compared with observations at:

- Le Couye – large clearing surrounded by trees
- Jachere – open site

Le Couye and Jachere site are less than 10km apart

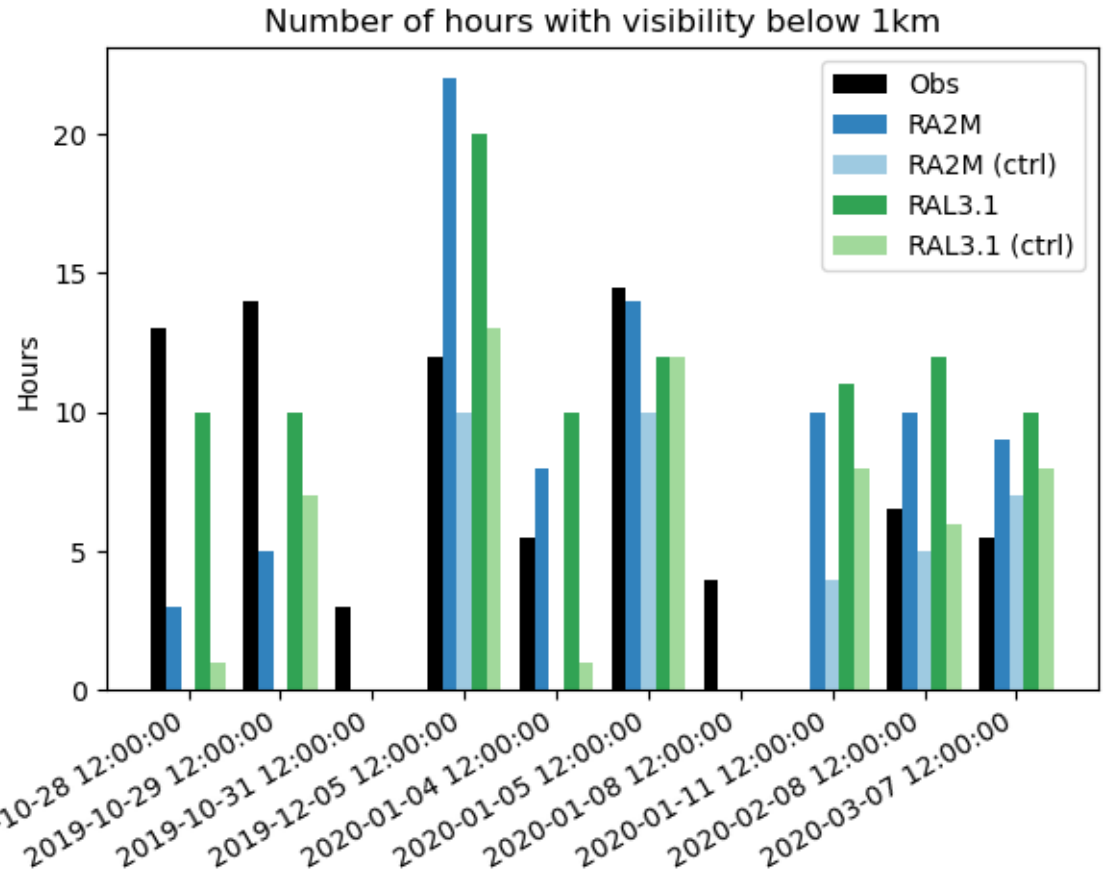
Sensitivity experiments Part 1

- How sensitive is the fog forecast to changes in science configuration?
- 2.2km ensemble forecasts
- Focus on 10 cases
- Compare with data from Le Couye and Jachere sites

Experiment	Details
RA2M	Current operational science
RAL3.1	New science with main changes to cloud scheme (Bimodal), microphysics (CASIM) and land-surface settings

Date	Type
20191028	Radiation
20191029	Radiation
20191031	Radiation
20191205	Radiation
20200104	Radiation
20200105	Stratus
20200108	Radiation
20200111	Null
20200208	Stratus
20200307	stratus

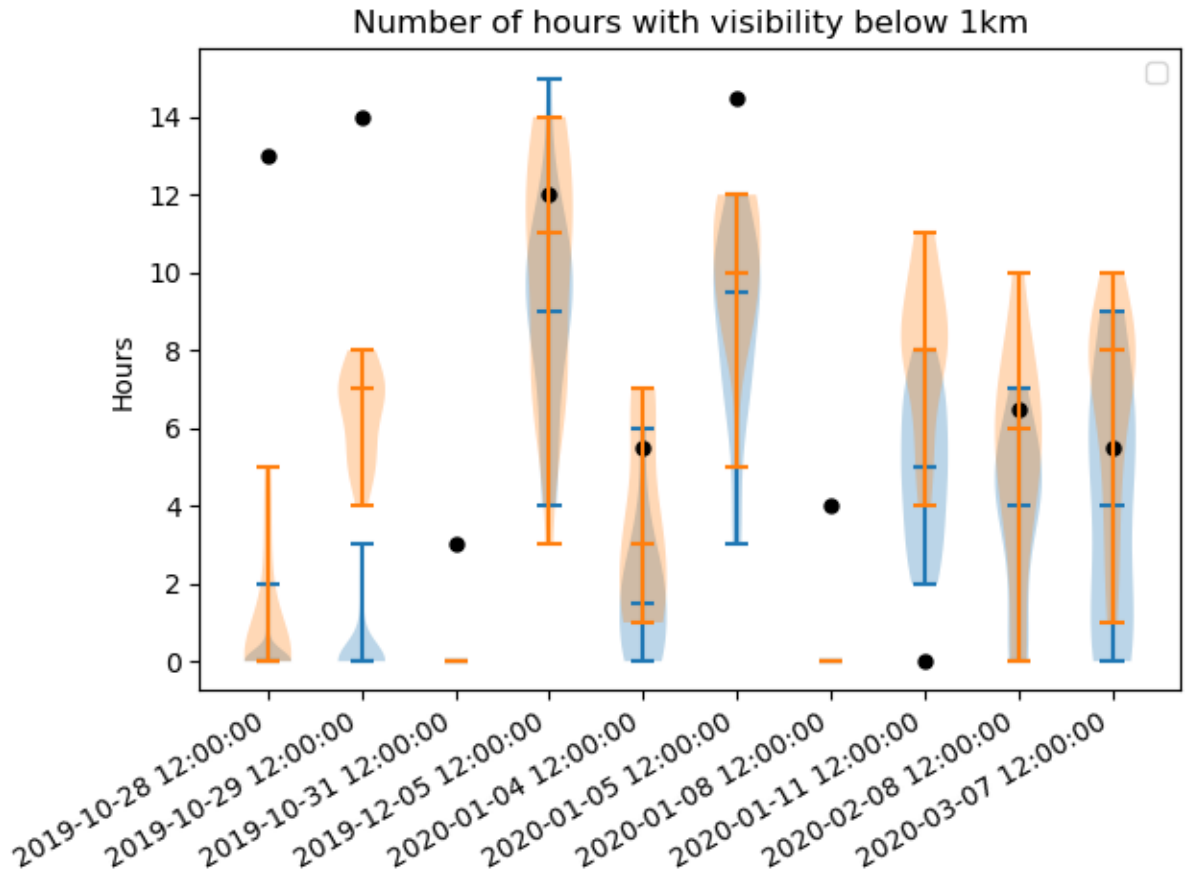
Overview of ensemble performance – does the model give any indication of the observed fog events?



- Comparison of the number of hours of fog forecast by each science configuration and the observations
- Uses full envelope of ensemble in calculation, i.e. shows the number of hours that 1 or more members forecast fog
- Ensemble gives more indication of fog events than the control member alone
- RA2M ctrl indicates fog in only 50% of the cases, the ens indicates fog in 80%
- RAL3p1 ctrl and ens indicate fog in 80% of the cases, with the ensemble indicating more fog than the control member alone for the majority of the cases

Comparison at Le Couye site

Overview of ensemble performance – are we seeing a systematic shift in all the members or a change in outliers?

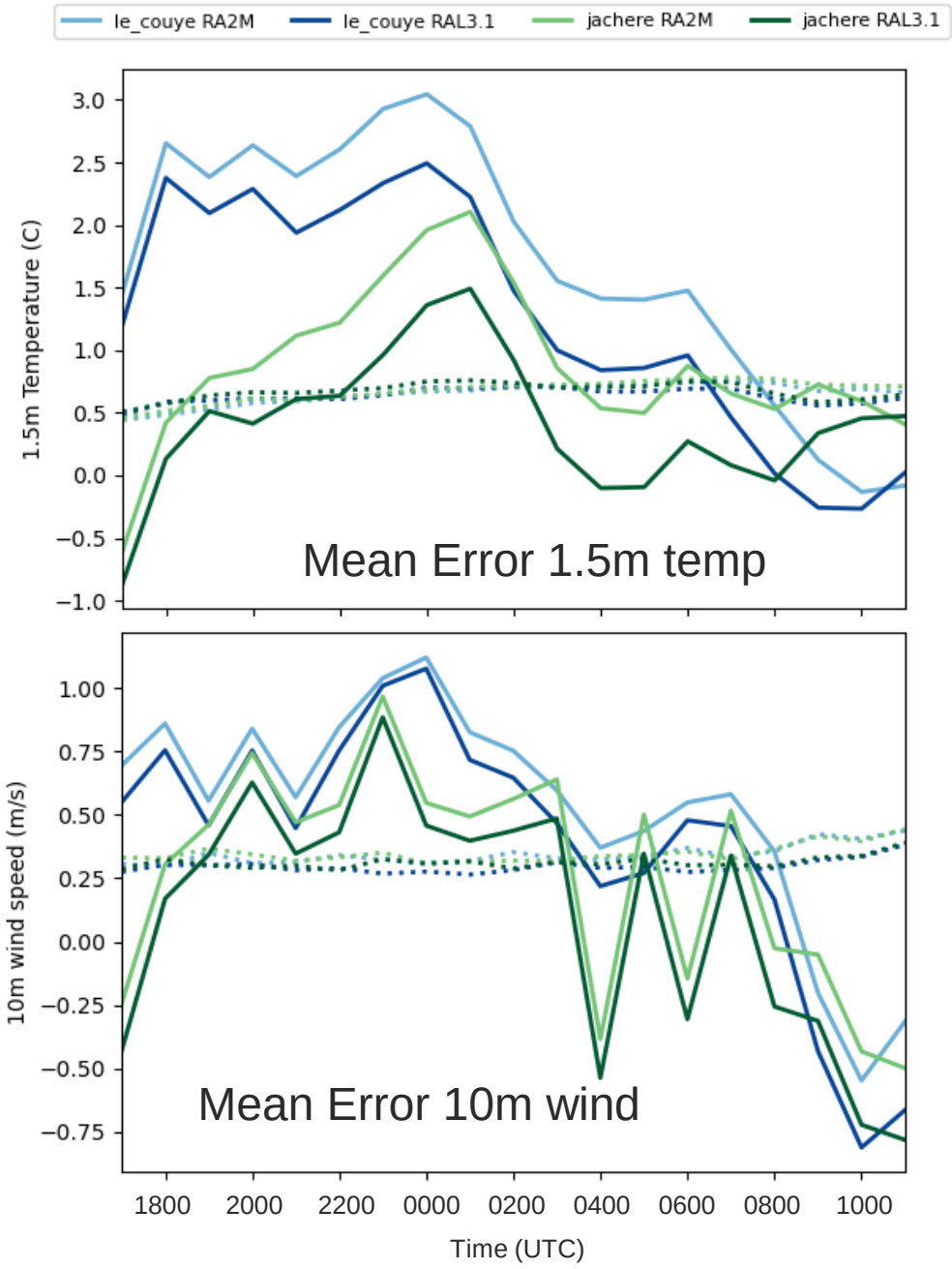


- Distribution of the number of foggy hours within the ensembles
- Comparison at Le Couye site
- In all the cases, the RAL3p1 ensemble increases the fog compared with RA2M – indicating a systematic shift
- In most cases, this moves the distribution towards the number of observed hours
- However, for the null case, this means the fog is even more over-done
- The change in science configuration shows an improvement but the model is still not capturing the full range of observed fog hours

Violin plots show the distribution of ensemble members for the RA2M (blue) and RAL3p1 (orange) configurations

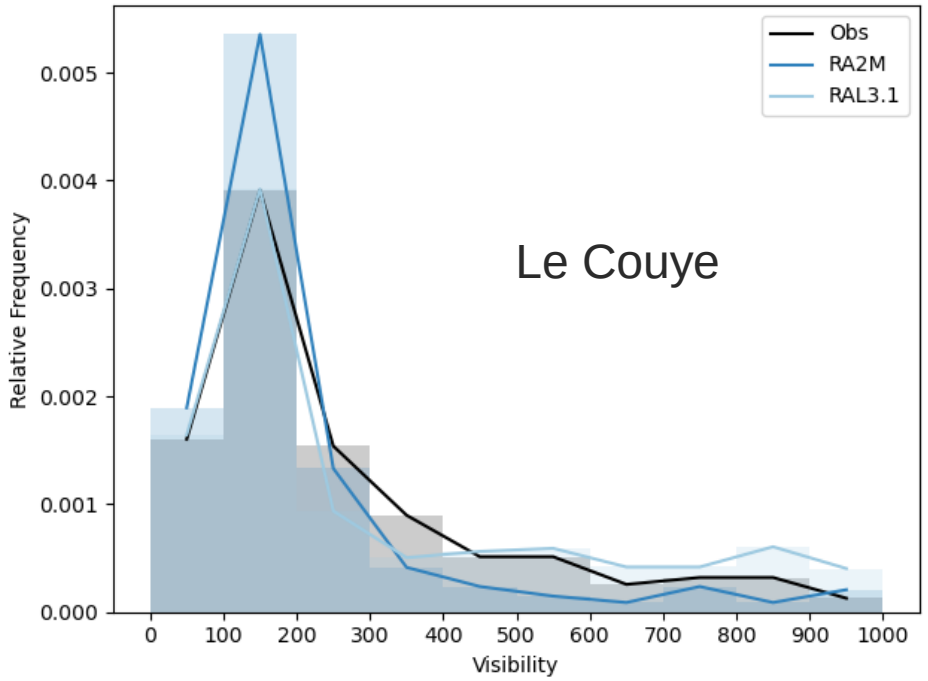
Overview of ensemble performance – error characteristics

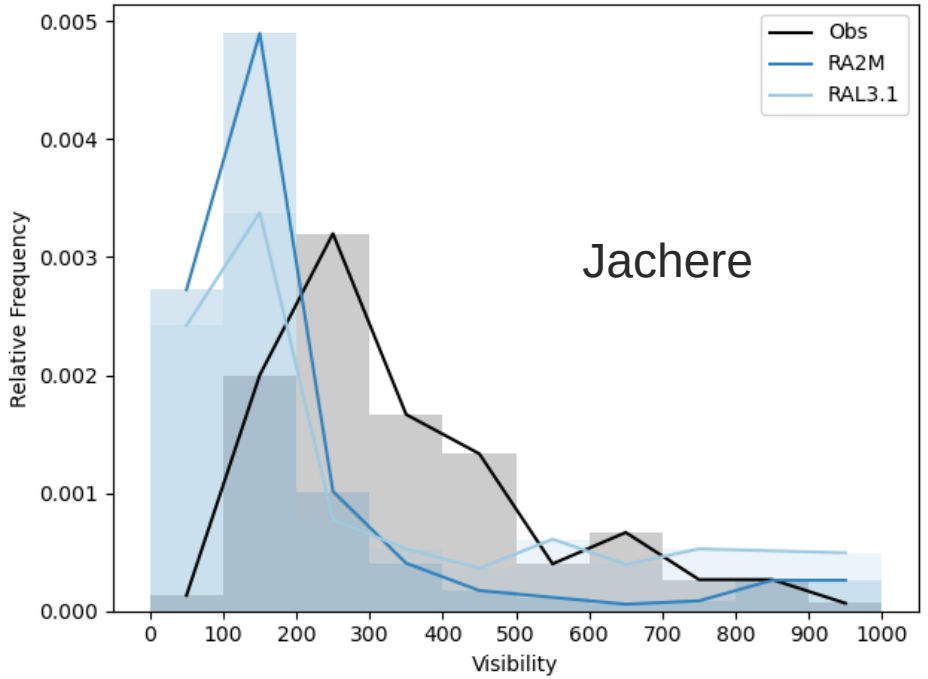
- Mean error (solid line) and ensemble spread (dotted line) for both the Le Couye and Jachere observation
- The spread is independent of science configuration or observational site
- The temperature error is larger in the evening, peaking around midnight for both sites, but the error is considerably smaller at the Jachere site
- RAL3p1 reduces both the temperature and wind error compared with RA2M
- The difference in temperature is the largest and is also seen consistently for all members across all cases, while the change in wind is more case specific



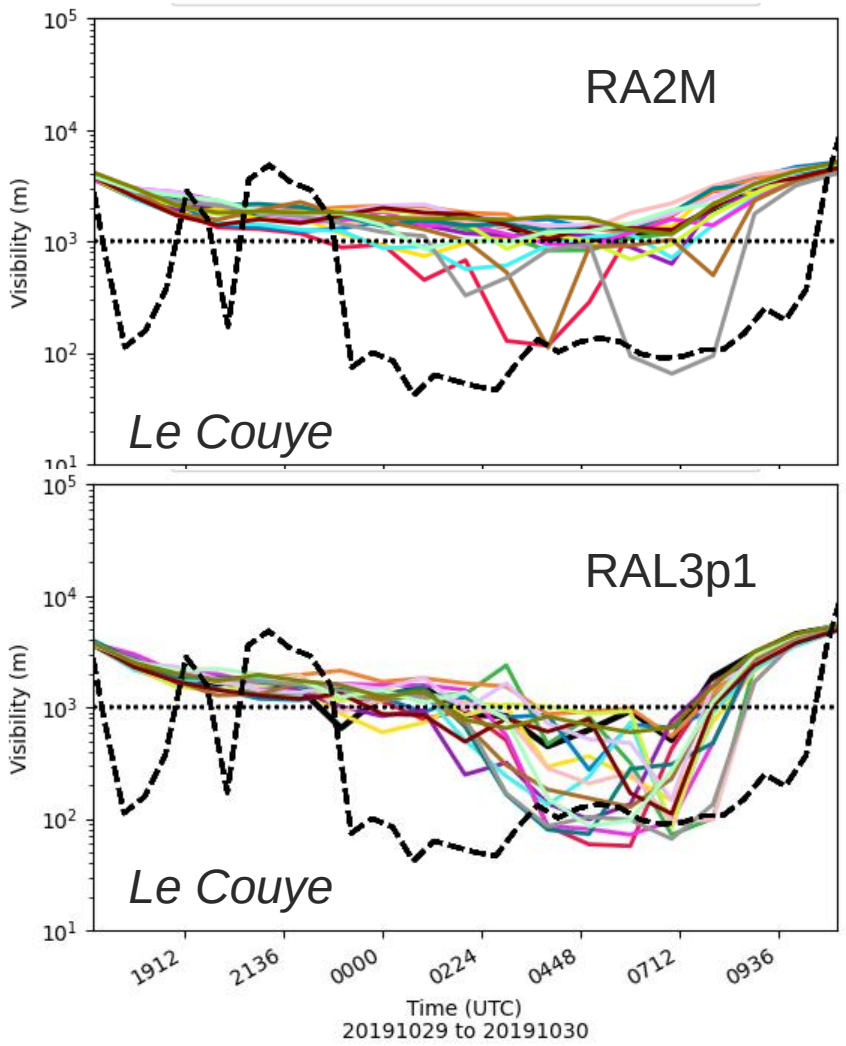
Overview of ensemble performance – relative frequency of visibilities below 1km

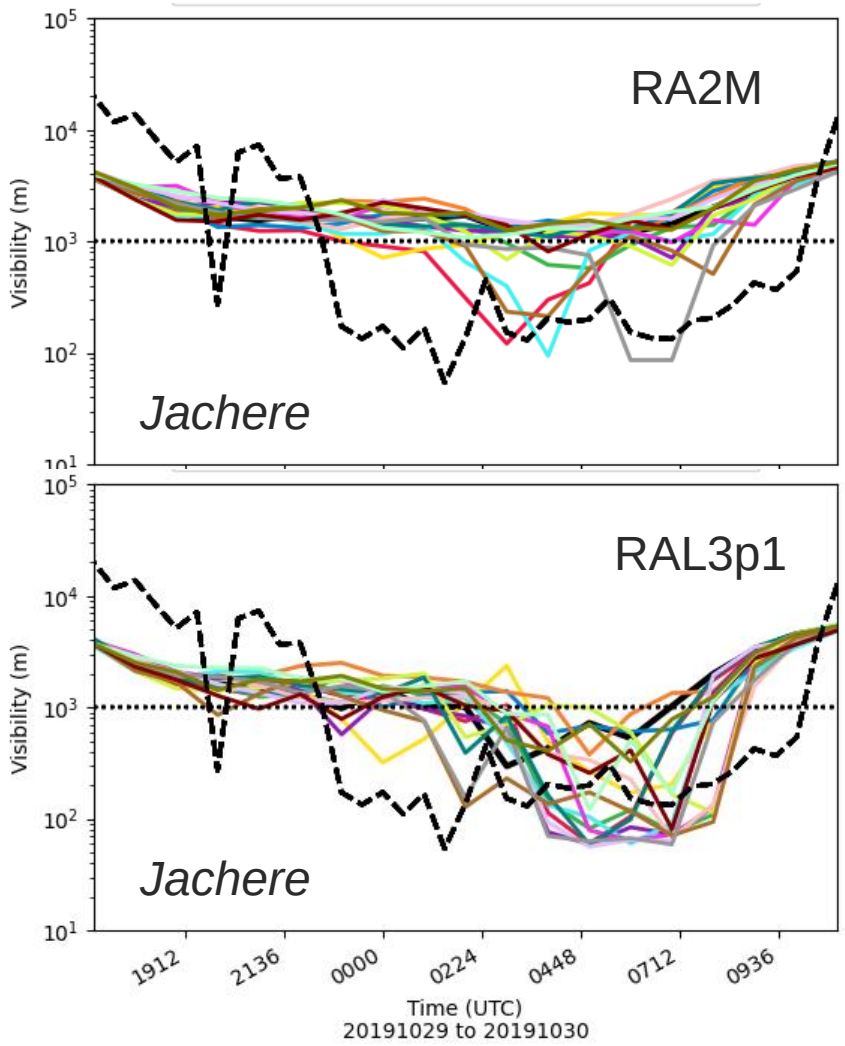
- Given a forecast below 1km, how are the visibilities distributed in the model compared with the observations
- At Le Couye, both configurations do a reasonable job - RAL3p1 gives the closest match to the observed frequencies while RA2M overdoes the lower visibilities and underdoes the higher visibilities
- For the model, the relative frequency of visibilities is very similar at both sites, but the distribution of observed visibilities is different





Case Study: 29th – 30th October





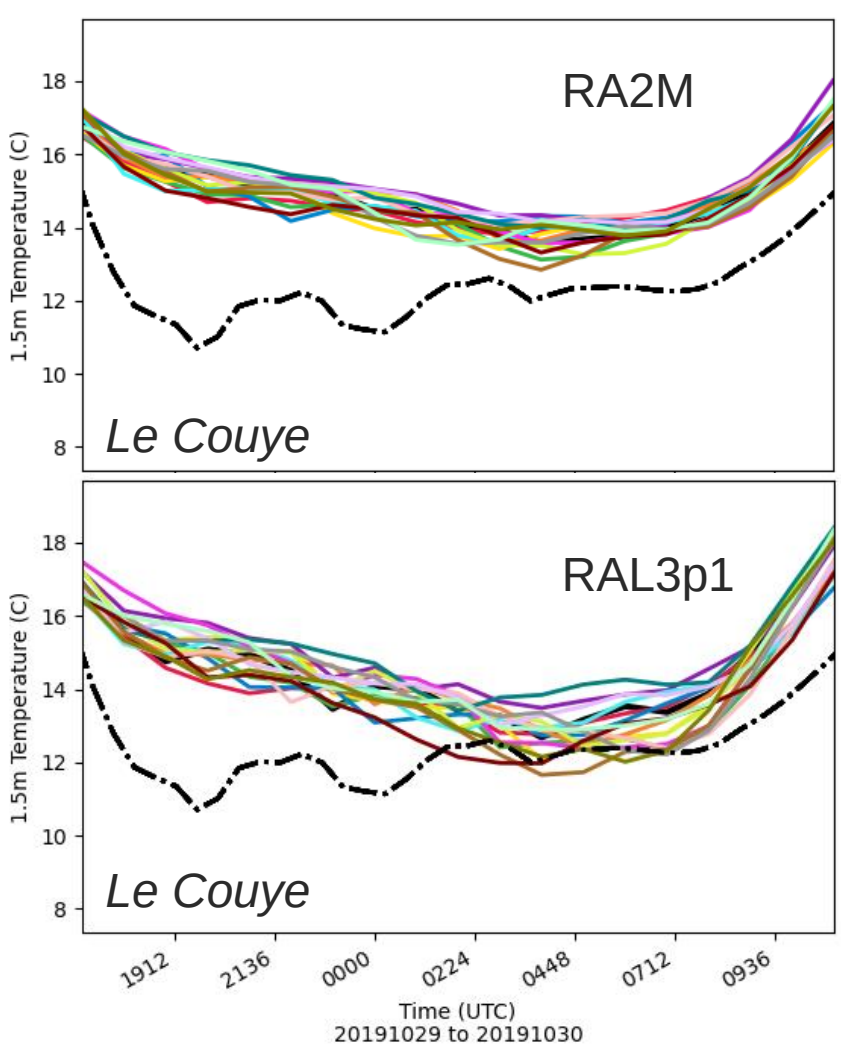
Time series of visibility

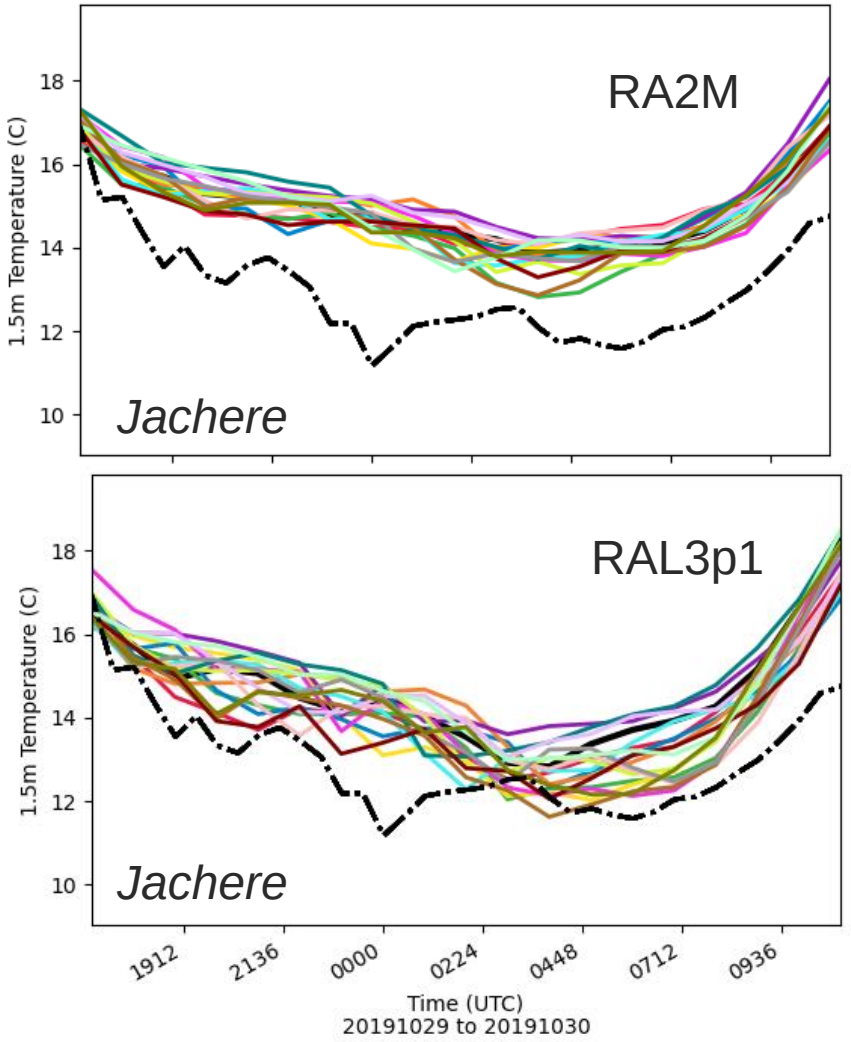
Observations are black dashed line

Each ensemble member is shown in a different colour

At both sites RA2M gives a low probability of any fog occurring, while in RAL3p1 all members forecast some fog with a spread in the duration and visibility

Case Study: 29th – 30th October





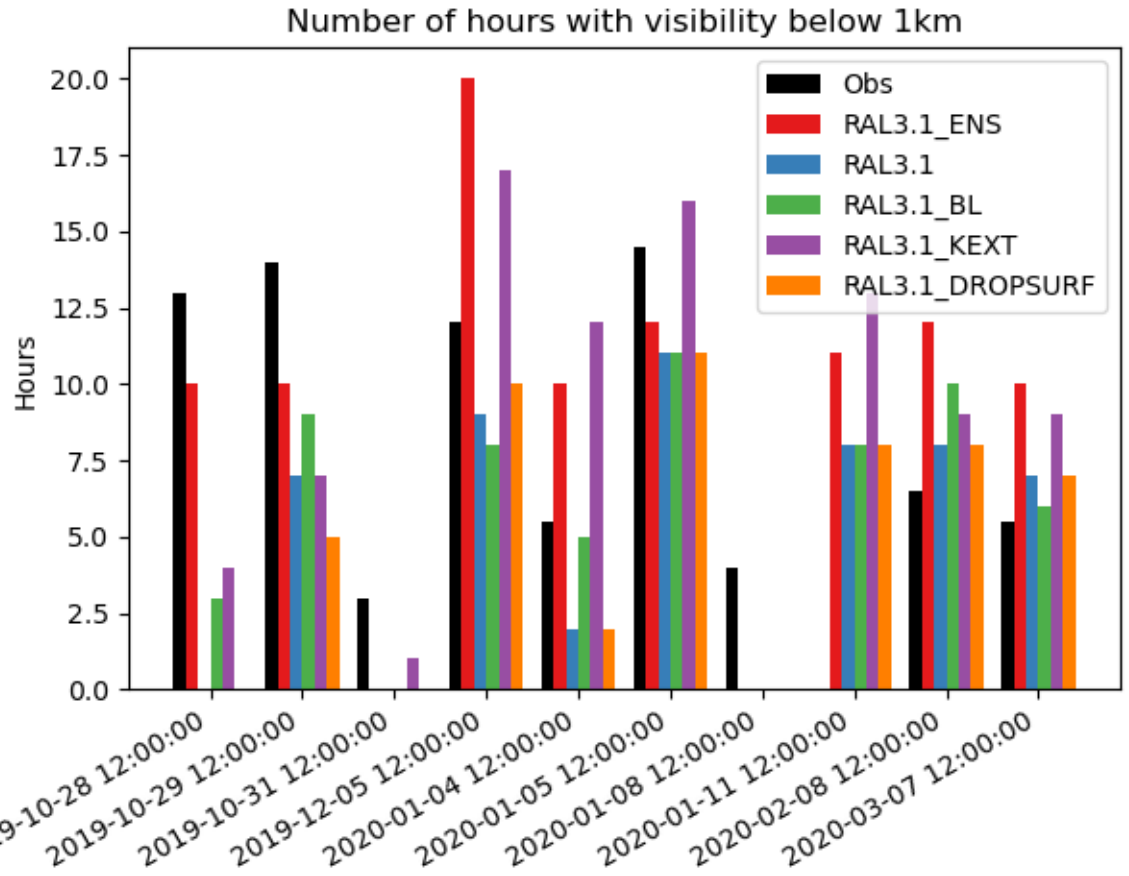
Temperatures are cooler in RAL3p1 with the model matching the observations at Jachere more closely than at Le Couye

Sensitivity experiments Part 2

Deterministic forecasts with targeted science changes on top of base line RAL3.1

Experiment	Details
RAL3.1 (REFERENCE)	New science with main changes to cloud scheme (Bimodal), microphysics (CASIM) and land-surface characteristics
RAL3.1_BL	New science with decreased Stable Boundary Layer (SBL) mixing - should make near surface cooler
RAL3.1_KEXT	New science with increased kext (which impact vegetation fraction) – this will make the surface colder
RAL3.1_DROP_SURF	New science with increased droplet number near the surface – may prolong fog and/or help with initial development

Overview of performance across all 10 cases



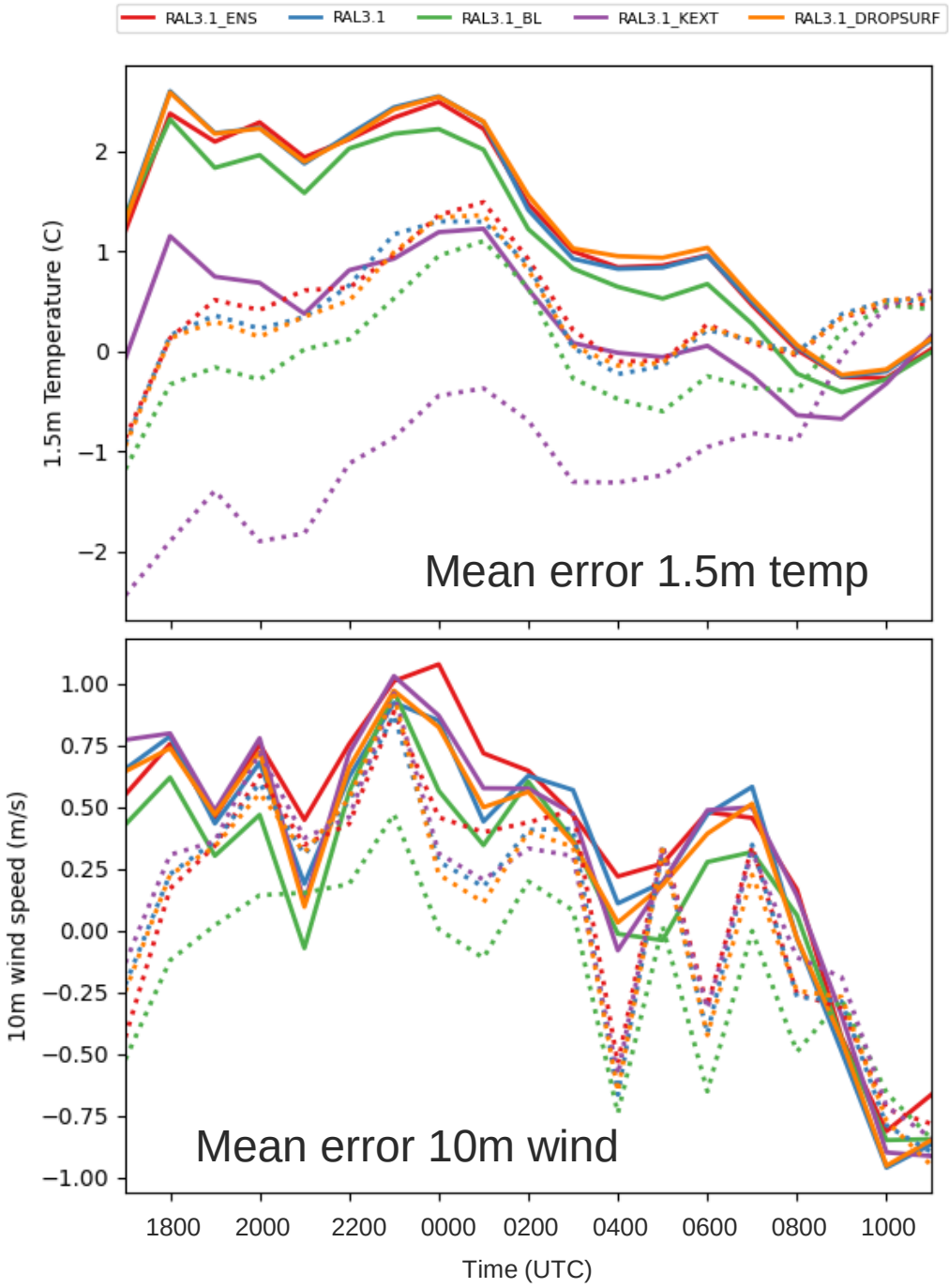
- Number of hours of fog forecast for each experiment compared with the reference deterministic and ensemble forecasts with RAL3p1
- The forecast is sensitive to all the experiments but the results are case sensitive
- In general, RAL3.1_KEXT shows the most sensitivity, typically increasing the number of hours of fog forecast and sometime forecasting more fog than the ensemble

Comparison at Le Couye site

Error characteristics over all 10 cases

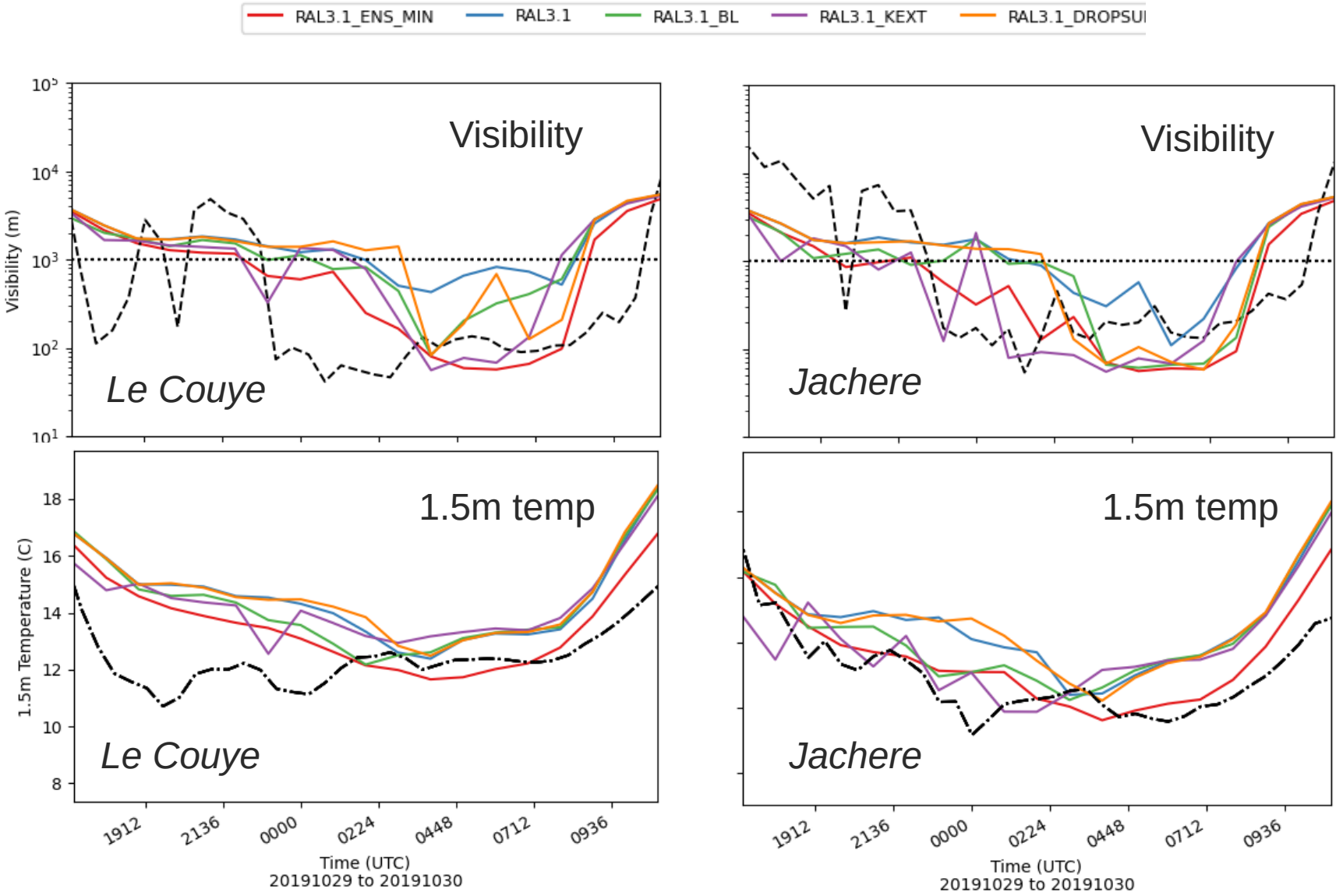
- RAL3.1_KEXT has the largest impact on the temperature error
- At Le Couye, there is still a mean temperature error in the early part of the evening, but for Jachere, both RAL3.1_BL and RAL3.1_KEXT cool the surface too much
- RAL3.1_BL has the largest impact on the mean error for wind, with a more pronounced response at Jachere
- RAL3.1_DROPSURF has a minimal impact on either temp or wind

Solid lines: Le Couye; Dotted line: Jachere



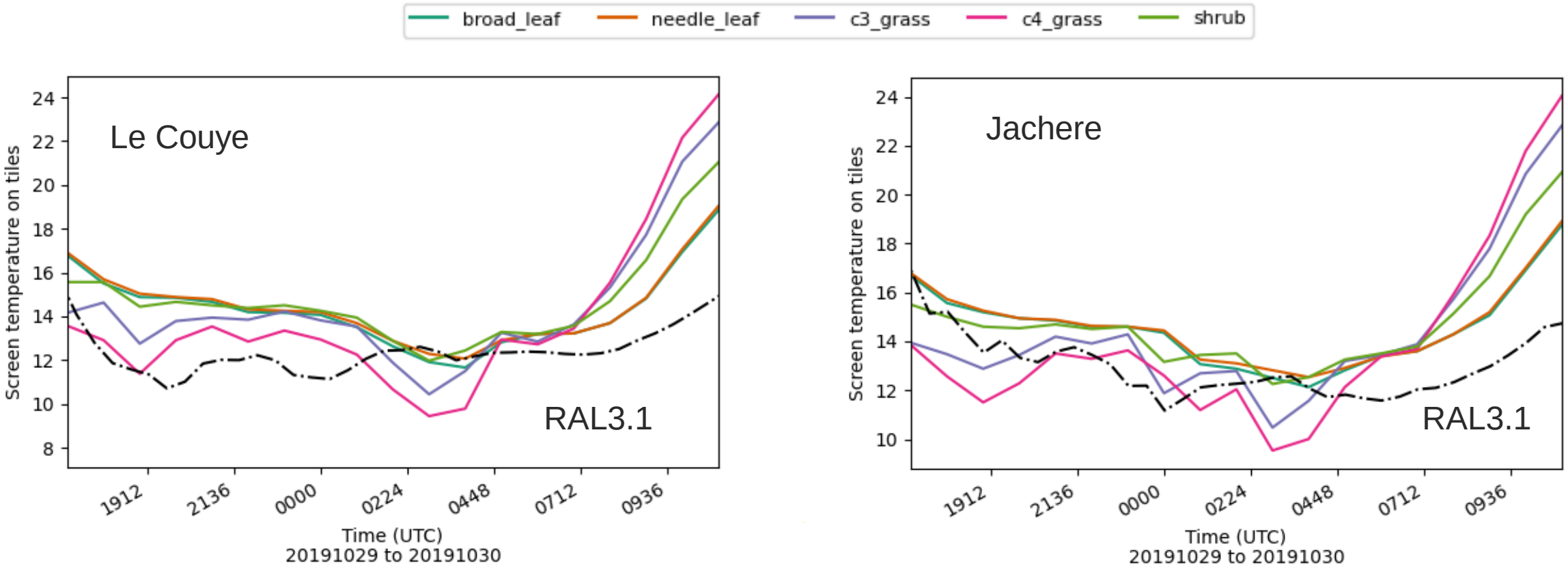
Case Study: 29th – 30th October

- All experiments increase the amount of fog forecast
- At Le Couye, the deterministic forecasts are still within the ensemble envelope
- At Jachere, RAL3.1_KEXT predicts fog earlier than the ensemble and is slightly cooler in the early part of the fog event
- RAL3.1_NDROPSURF increases the fog without a change to the temperature



Case Study: 29th – 30th October

- Break down of 1.5m temperature by surface type (tile) for RAL3.1 (reference deterministic)
- Model temperatures over the different tiles are very similar at both sites while the observed values are quite different
- Heterogeneity at the two sites is quite different – could this be causing the differences in the temperature errors?
- See Jenna Thornton and Jeremy Price's talk on the difference between the two observation sites



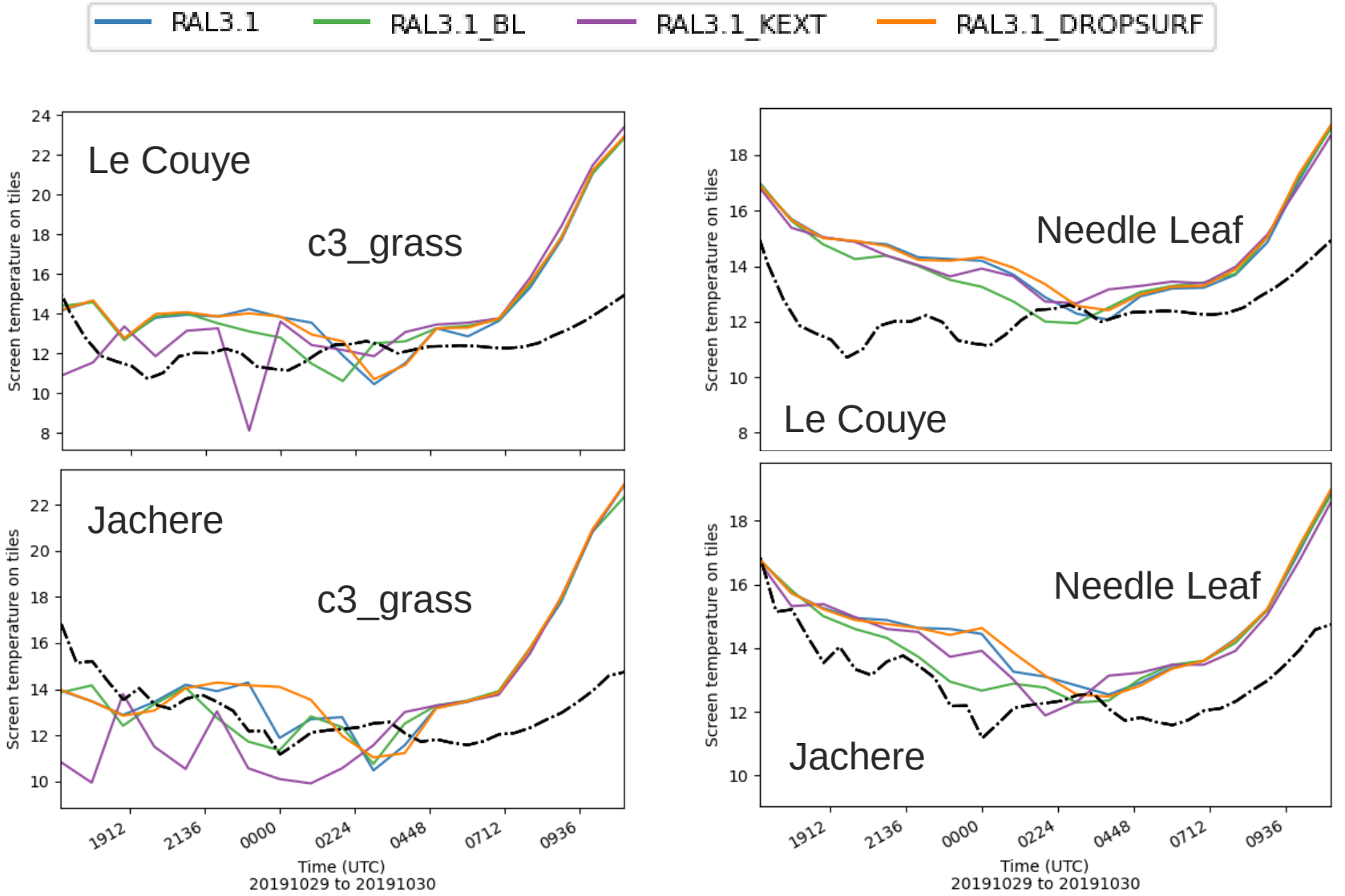
Case Study: 29th – 30th October

Impact of experiments on needle leaf tree and c3 grass tiles

1.5m temp

RAL3.1_BL has the largest impact on the tree tiles

RAL3.1_KEXT has the largest impact on the grass and shrub tiles



Summary of modelling sensitivity tests

- Ensemble experiments show the forecast is sensitive to different science configurations with the model that is cooler at the surface producing more fog
- The deterministic forecast is sensitive to changes in science that impacts the near surface: SBL mixing, vegetation fraction and droplet concentration
- Of these experiments, the change to the vegetation fraction had the largest impact, cooling the surface more and increasing the amount of fog; for some cases this resulted in an improved fog forecast, while for other cases, this over-did the fog compared with the observations
- The temperature error in the model was larger at Le Couye compared with Jachere. This may be due to the differences in vegetation types between the two sites and suggests that we are not representing these differences sufficiently in the model
- See the talk by Jenna Thornton and Jeremy Price on the differences between the two sites

Future Work

- Continue with evaluation of sensitivity experiments and write up as a paper (hopefully)

- Explore the use of the new VERA diagnostic (Bernie Claxton)
  - VERA creates probabilities of visibilities from single (deterministic) forecasts
  - Recent evaluation of the new diagnostic during a testbed event was very positive
  - More work is needed to understand the best way to use this diagnostic in an ensemble context
  - Early results suggest that the VERA output from a single forecast can out-perform the full ensemble …. but … the full ensemble is needed to find the single forecast with the best VERA output

- Explore the potential benefit of 300m and 100m horizontal resolution forecasts
  - At the Met Office we currently run (semi-operationally) a 300m deterministic forecast over London
  - With increased computing power becoming available, we would like to explore whether there is any benefit of running such a model as an ensemble
  - Evaluation of RA2M at 300m and 100m resolution looks promising – we now want to look at the impact of the increased resolution with RAL3p1

Science Configurations

RA2M

Bush et al (2023) The second Met Office Unified Model–JULES Regional Atmosphere and Land configuration, RAL2
https://doi.org/10.5194/gmd-16-1713-2023

RAL3p1

Publication in preparation (Bush et al, 2024)

Includes new cloud scheme:

Van Weverberg, K., C. J. Morcrette, I. Boutle, K. Furtado, and P. R. Field, 2021: A Bimodal Diagnostic Cloud Fraction Parameterization. Part I: Motivating Analysis and Scheme Description. *Mon. Wea. Rev.*, **149**, 841–857, https://doi.org/10.1175/MWR-D-20-0224.1.

Van Weverberg, K., C. J. Morcrette, and I. Boutle, 2021: A Bimodal Diagnostic Cloud Fraction Parameterization. Part II: Evaluation and Resolution Sensitivity. *Mon. Wea. Rev.*, **149**, 859–878, https://doi.org/10.1175/MWR-D-20-0230.1.

and new microphysics scheme:

Field, P.R., Hill, A., Shipway, B., Furtado, K., Wilkinson, J., Miltenberger, A., et al. (2023) Implementation of a double moment cloud microphysics scheme in the UK met office regional numerical weather prediction model. *Quarterly Journal of the Royal Meteorological Society*, 149(752), 703– 739. Available from: https://doi.org/10.1002/qj.4414

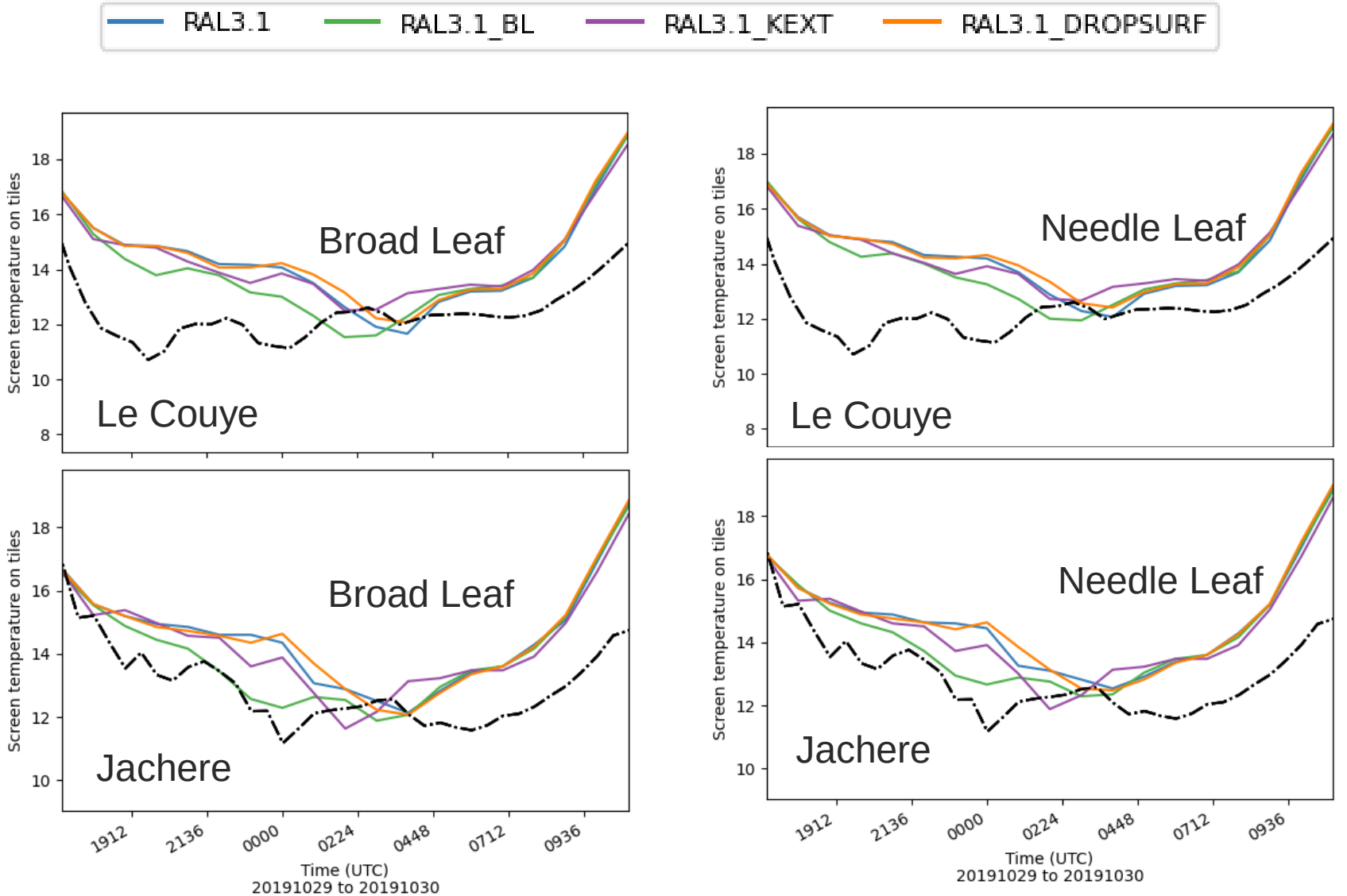
Case Study: 29th – 30th October

Impact of experiments on tree tiles

1.5m temp

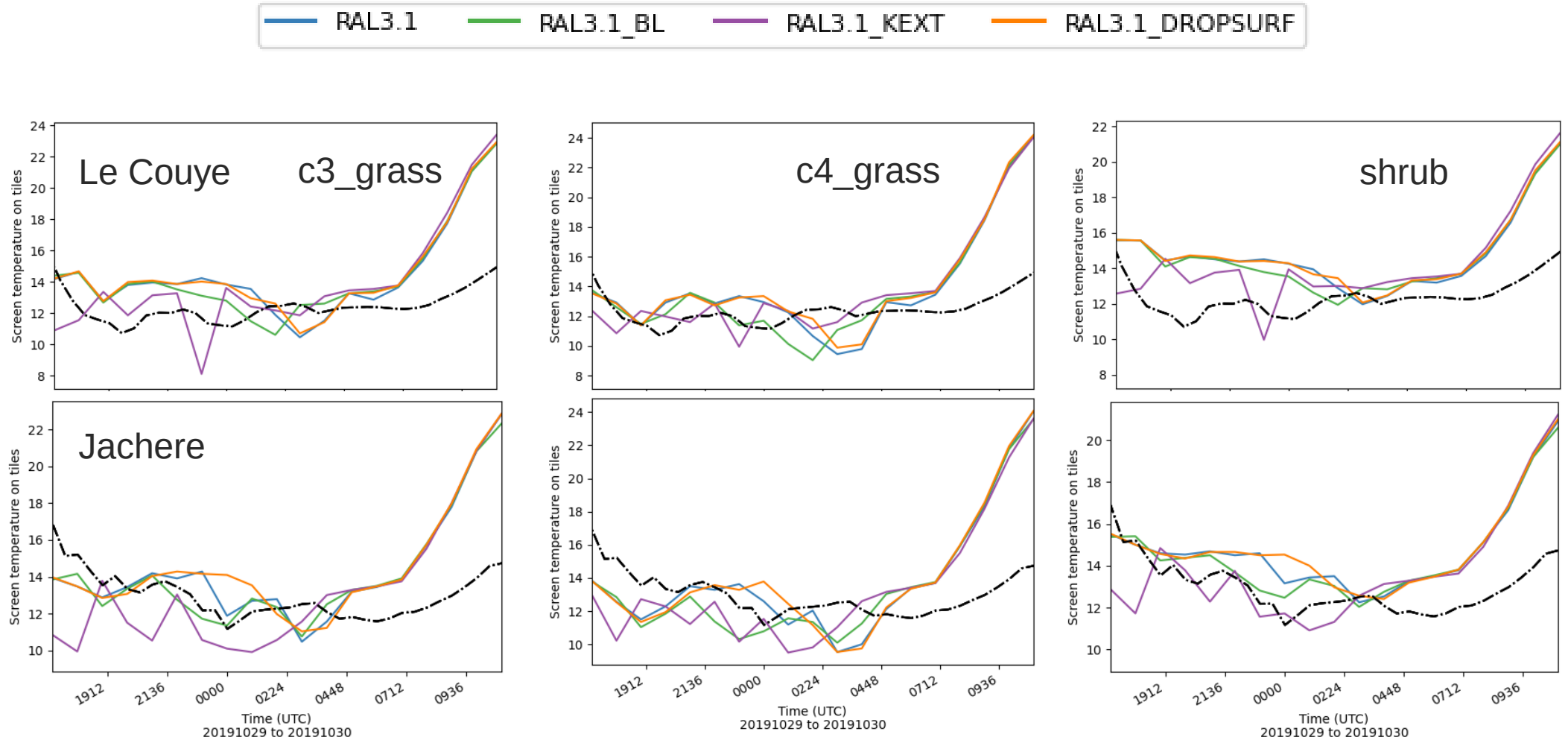
RAL3.1_BL has the largest impact on the tree tiles

At Jachere, RAL3.1_BL captures the drop in temperature in the early evening well, while at Le Couye, the model is still too warm



Case Study: 29th – 30th October

1.5m temp



RAL3.1_KEXT has the largest impact on the grass and shrub tile temperatures