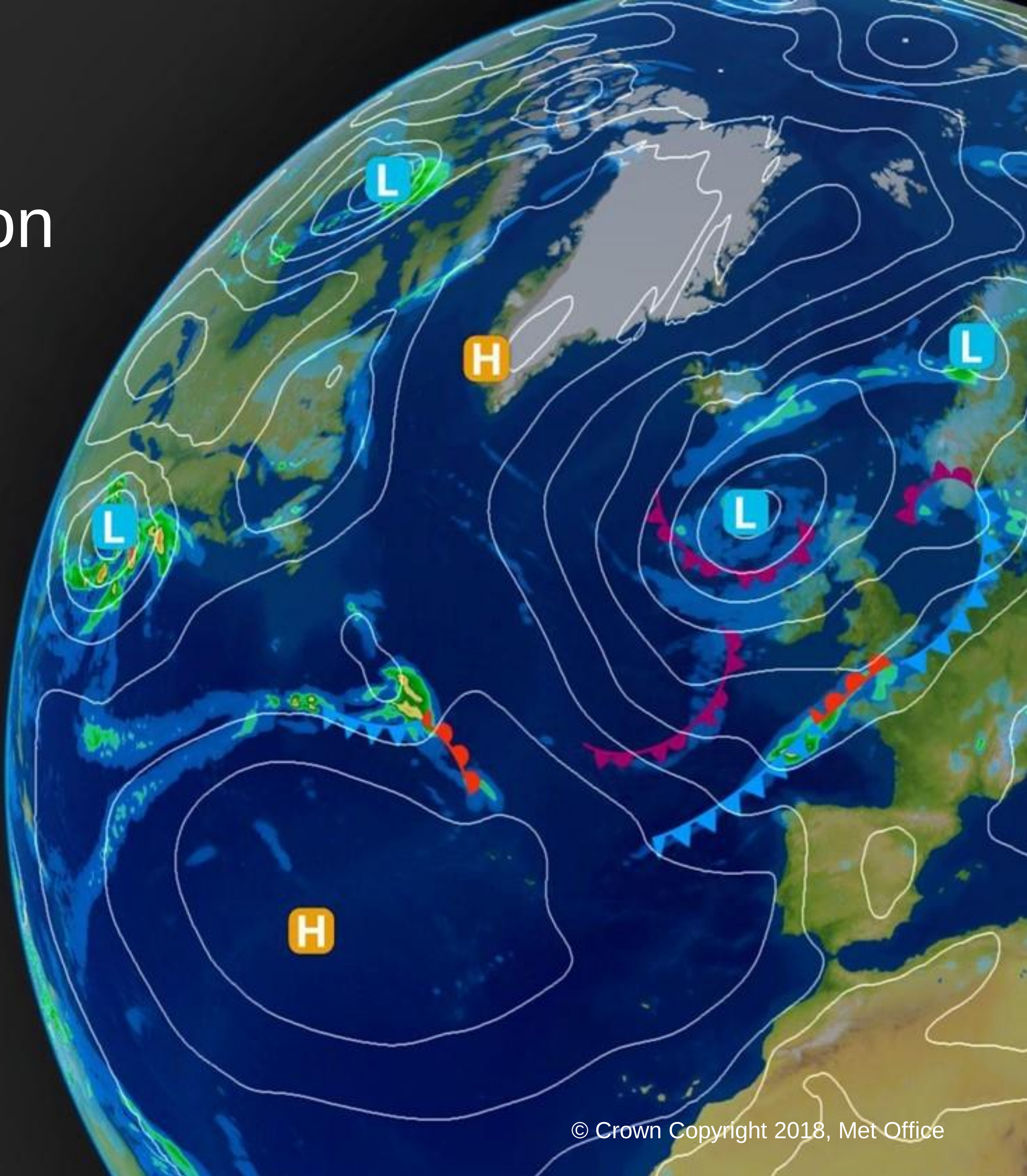
Data assimilation and initialization developments at the Met Office

43rd EWGLAM

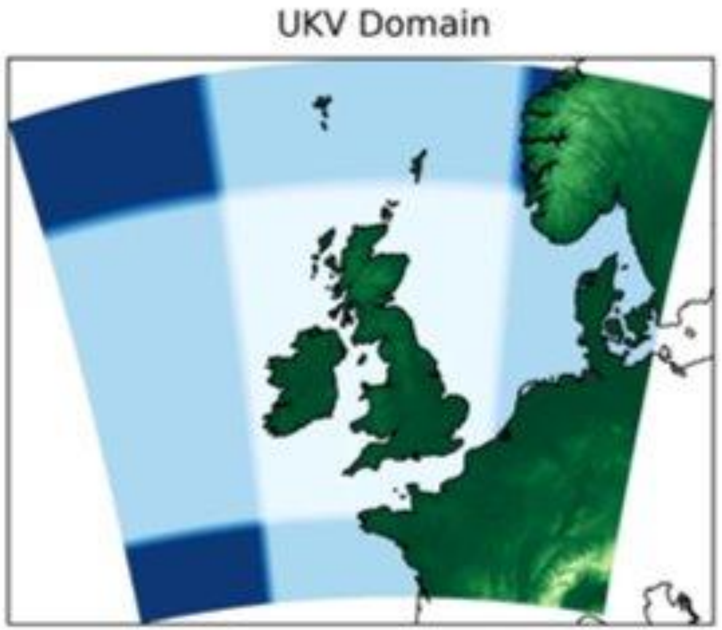
28th SRNWP

Marco Milan, Bruce Macpherson, Gareth Dow,
Lee Hawkness-Smith, Helen Buttery

27th September 2021



Hourly 4D-Var configuration



- Hourly 4D-Var assimilation method.
- Linear Perturbation Forecast (PF) model and DA, 4.5 km resolution (constant on the whole domain).
- UM model resolution in UK region 1.5km. Resolution 1.5x4 km along the edges and 4x4 km at the corners.
- Global boundary conditions 10km resolution.
- LBC from 00, 06, 12, 18 UTC from global model
- Ages of LBC runs lies in range T-3 : T-8.
- Observation cut-off 45 mins, 80 mins only for 11UTC and 23 UTC (to catch radiosonde data).
- VarBC applied to satellite radiances.
- Operational forecast in range T+12:T+120.

Large-scale blending (LSB) : overview

- General: blending of fields between host model and regional model.
- Host model state. Use a cut-off wavelength which selects only the large-scales, low pass filter. SL operator.
- At the Met Office we are not using the high pass filter of the regional model. We noticed that large scale power spectra of the LAM model is much lower than the one of the host model.
- We can compute the difference between host model and regional model:

$$\delta \mathbf{x}^h(t) = R(\mathbf{x}^h(t)) - \mathbf{x}^r(t)$$

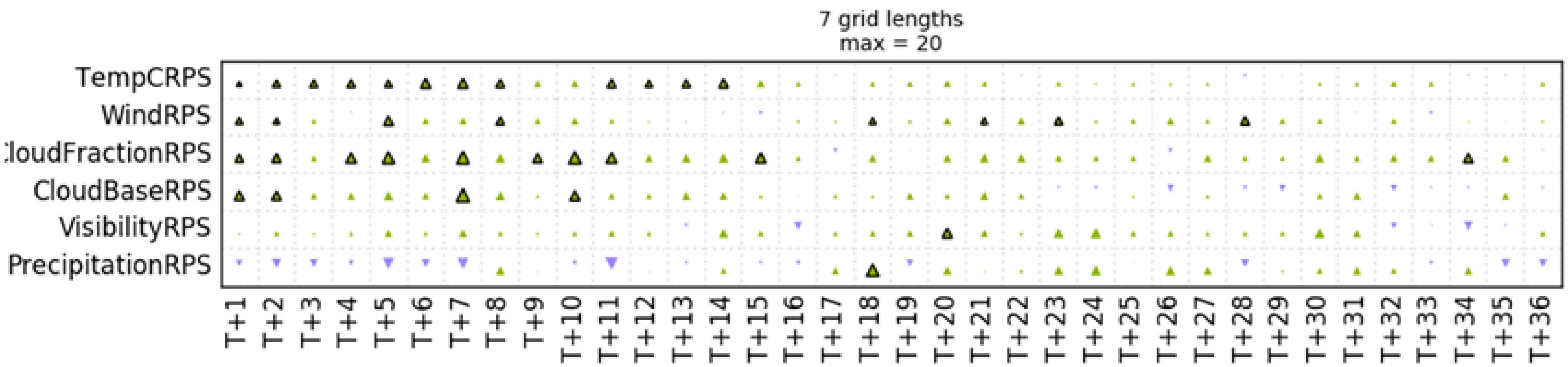
- R the interpolator from host model resolution to regional model resolution.
- LSB increments: $\delta \mathbf{x}^{LSB}(t) = SL(\delta \mathbf{x}^h(t))$.
- The increments are applied to the background fields. We calculate analysis increments to this incremented background.
- The blending of the large-scale information takes place during the forecast from the analysis.
- Set-up : wavelength cut-off at 700km, LSB applied at 03Z, 09Z, 15Z and 21Z, vertical weighting with maximum weight of 75%.

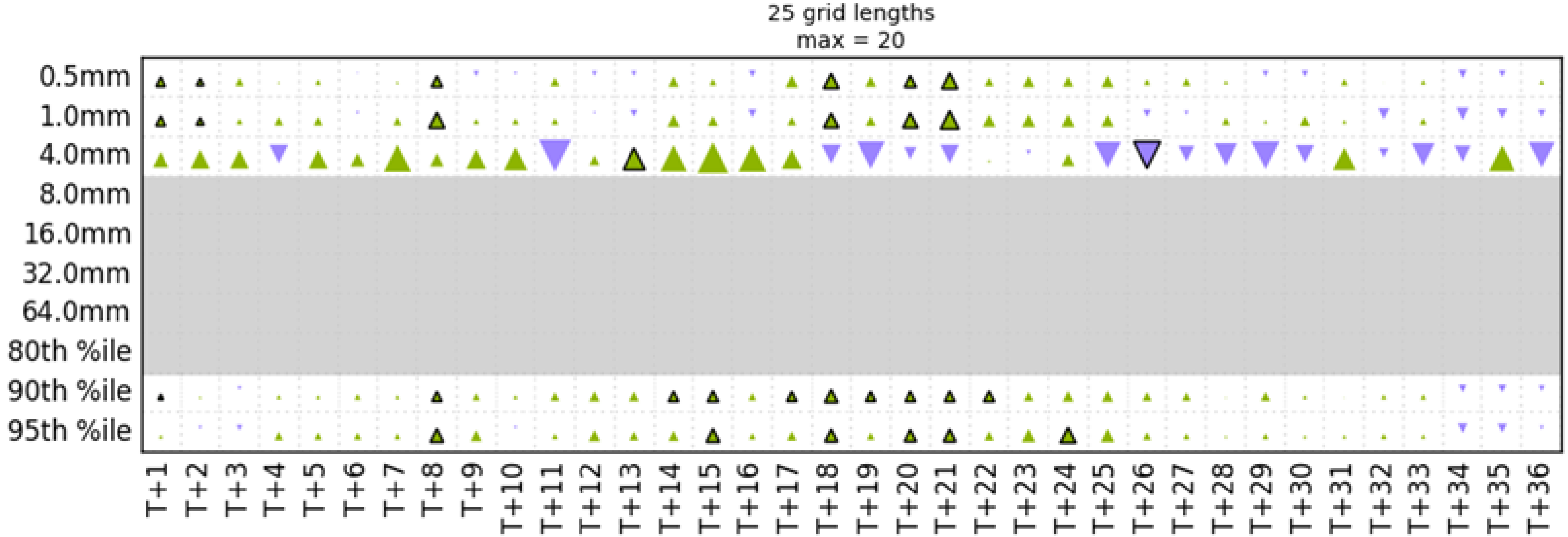
Marco Milan

Met Office

Large-scale blending : some results

WINTER





- Hinton scorecards for run with LSB vs without LSB (control). For different variables and for precipitation FSS for different thresholds.
- Bold triangles: statistically significant improvements.
- Winter: LSB improves the forecast for different variables up to T+14. Improvements for precipitation are visible between T+14 and T+21.
- Summer: LSB has better skill for surface variables up to T+20. For precipitation up to T+12.

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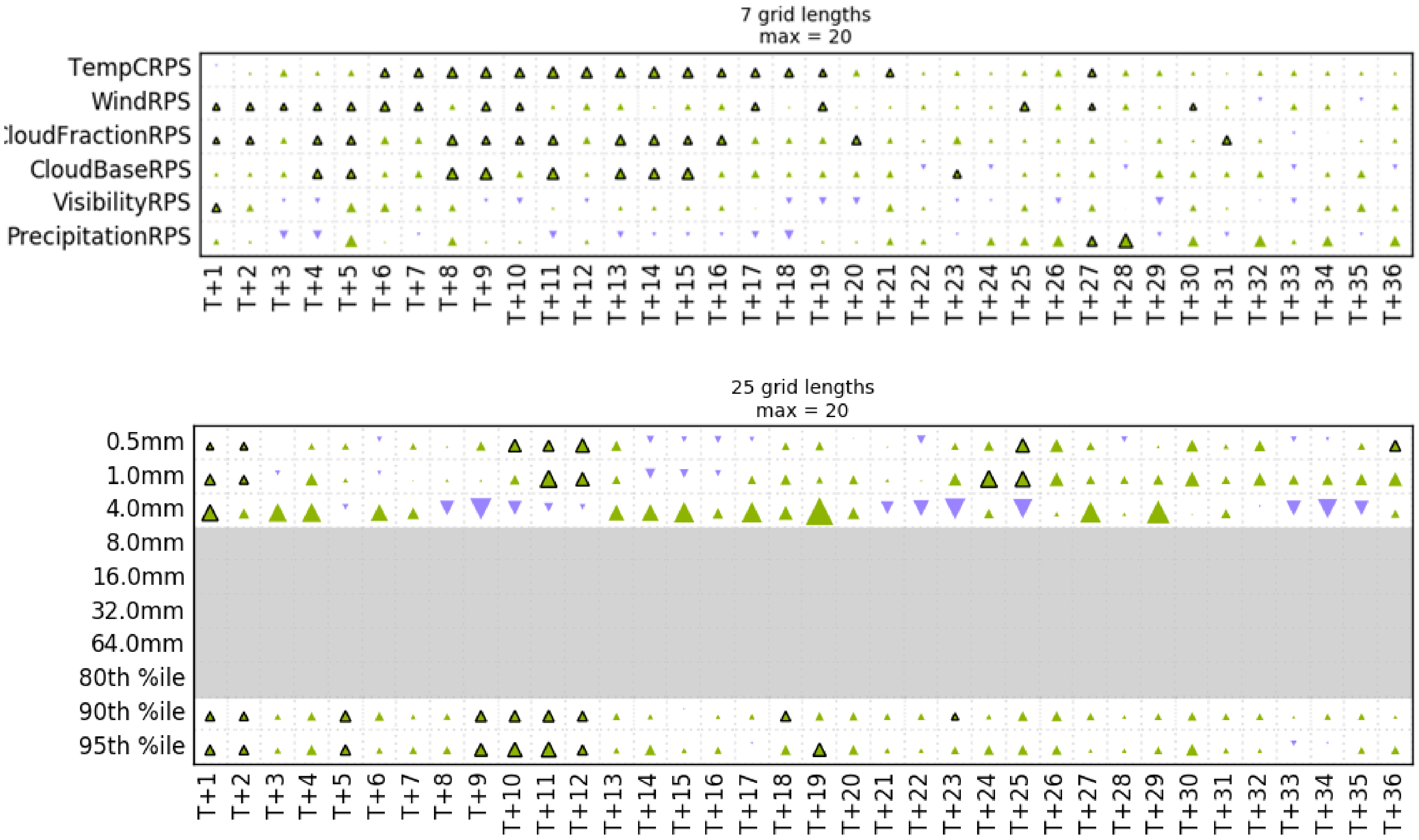
Met Office

Large-scale blending : some results

SUMMER



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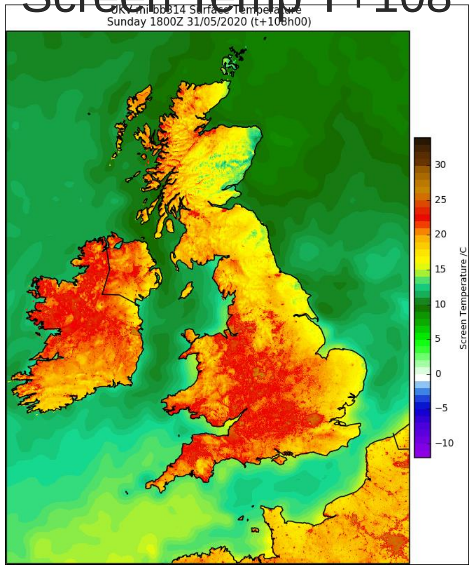
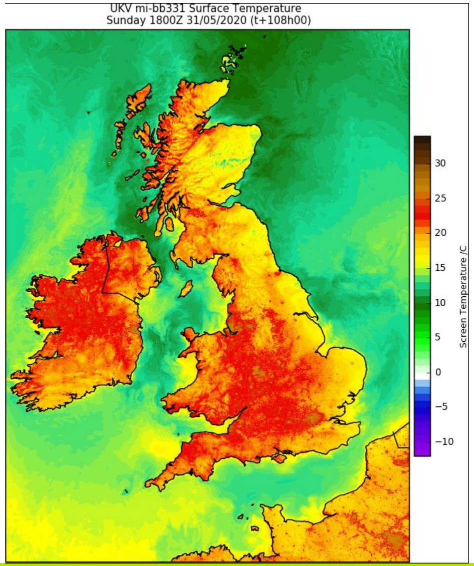
SST updating

Screen Temp T+108



OSTIA

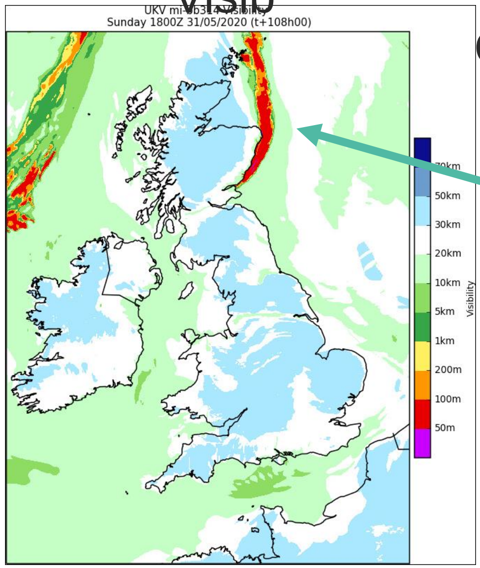


NEW SST

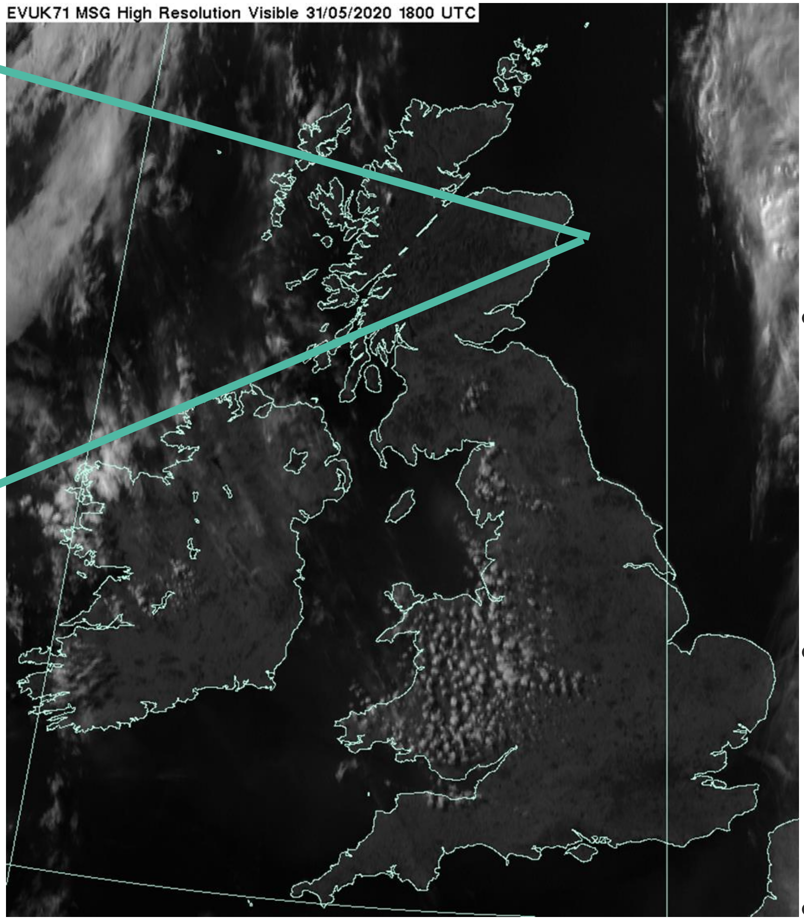
- Currently the UKV uses SST through a forecast out to 5 days from an OSTIA (Operational Sea Surface Temperature and Ice Analysis) analysis updated. In the UKV we update the SST once per day at 09UTC.
- New update: the forecast uses hourly updated SSTs obtained from daily AMM15 (Atlantic Marginal Model, 1.5km) ocean forecasts model.
- From previous results using MOGREPS-UK: Expecting greatest impacts at longest lead times.
- Example spring 2020: T+108 Screen T and visibility.

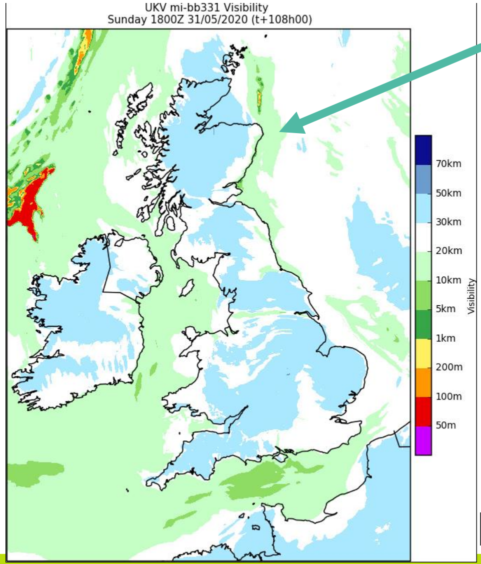
SST updating

Visib



OSTIA





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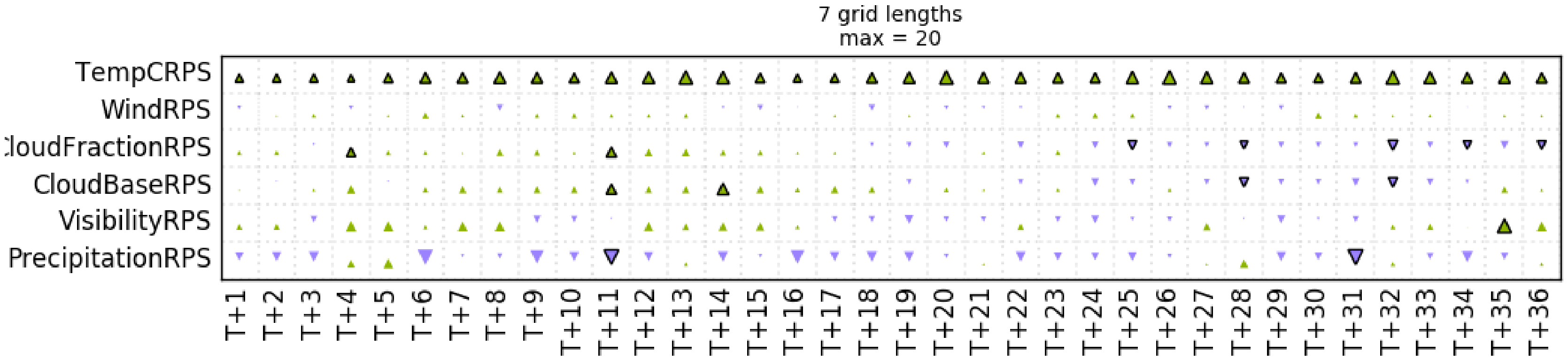
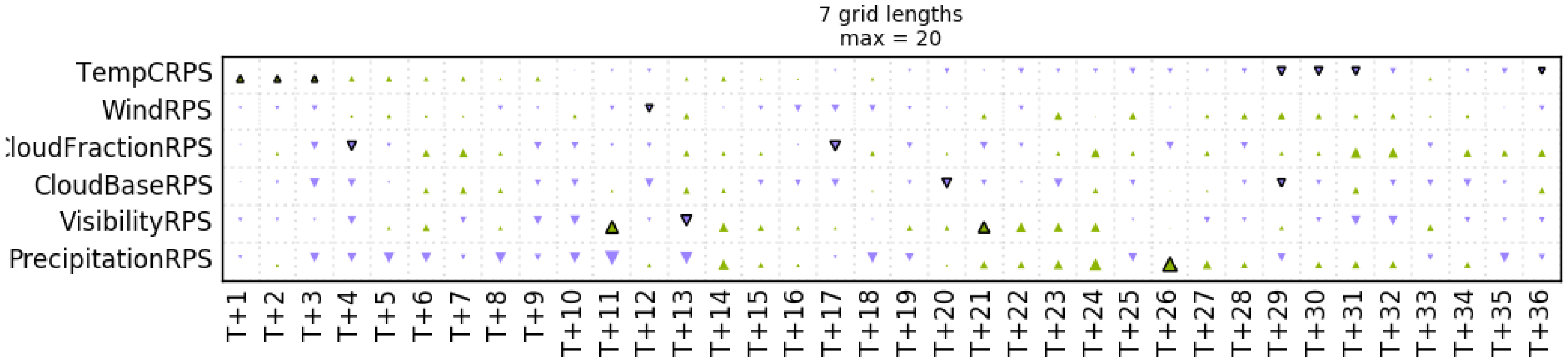
SST updating: some results

SUMMER



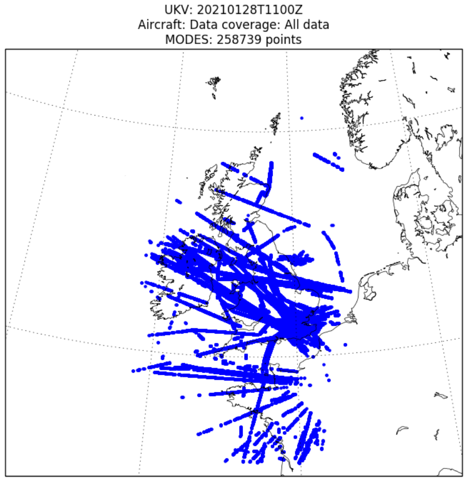
WINTER

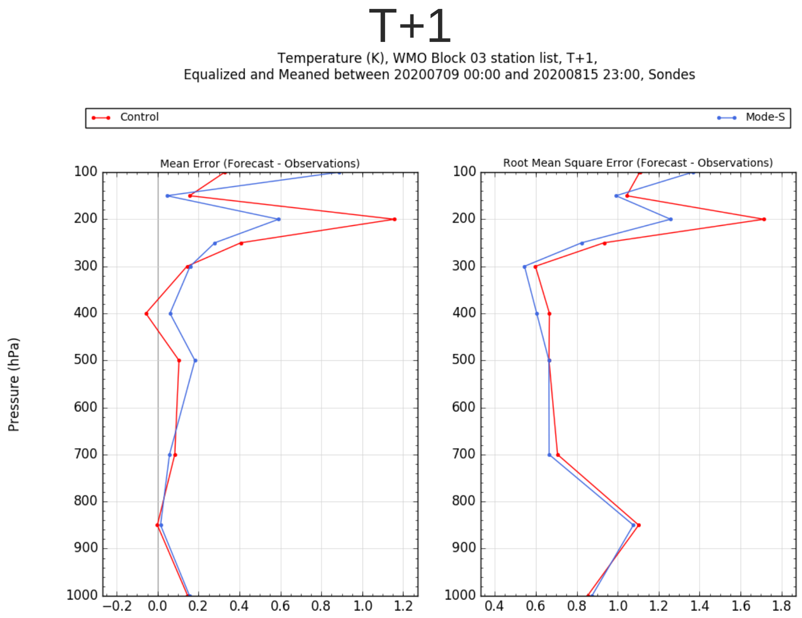


- Test in UKV.
- Largest impacts in Spring/ early Summer periods when SST changes are greatest
- Main land impact is a progressive warming with lead time, greatest at coastal stations.
- Reduction in poor visibilities (mostly at sea but also some coastal locations), mainly as a result of a lifting of cloud bases

Gareth Dow

Assimilation of KNMI Mode-S temperatures



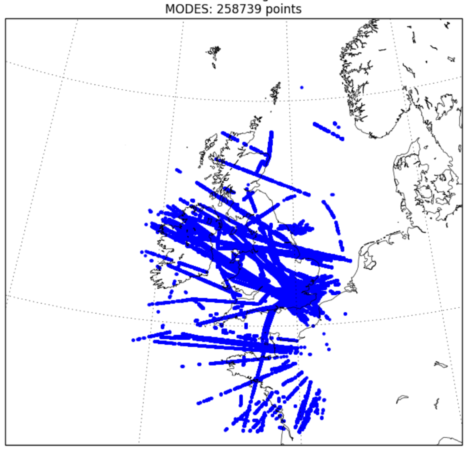


- Mode-S observations of wind and temperature are provided by all aircraft during flights, only wind currently assimilated.
- KNMI now provide good quality temperatures from Mode-S data. Assimilation of temperature under test.
- Temperatures are available up to 12000m (and beyond) with a good coverage over the UK (more flights expected post Covid restrictions).
- Errors in the temperature profile are reduced in both the Summer and Winter trial out to at least T+6, particularly at 200hPa which roughly corresponds to the cruising altitude of the aircraft and is where most observations occur.

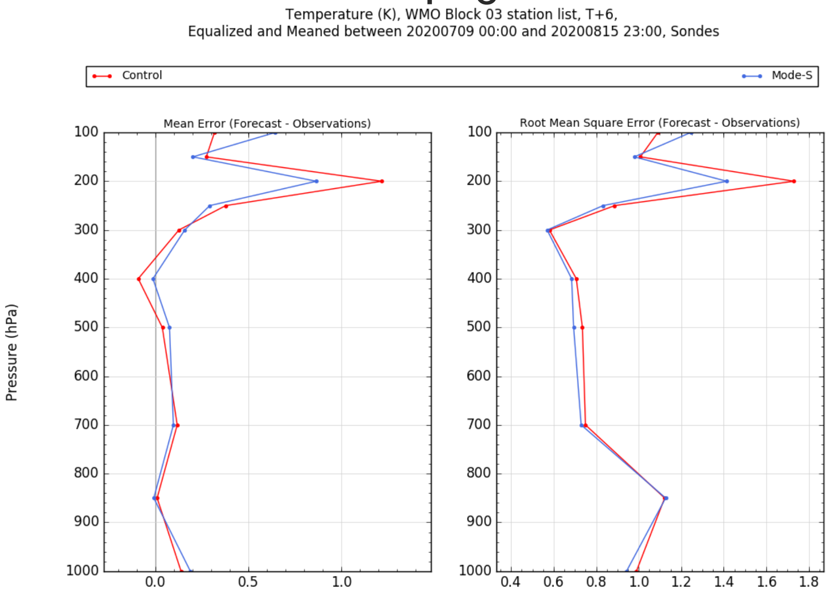
Helen Buttery

Assimilation of KNMI Mode-S temperatures

UKV: 20210128T1100Z
Aircraft: Data coverage: All data
MODES: 258739 points



T+6



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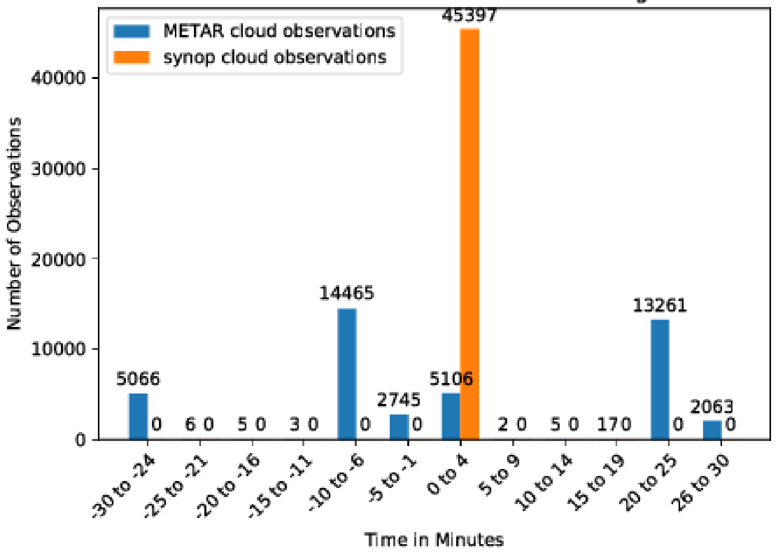
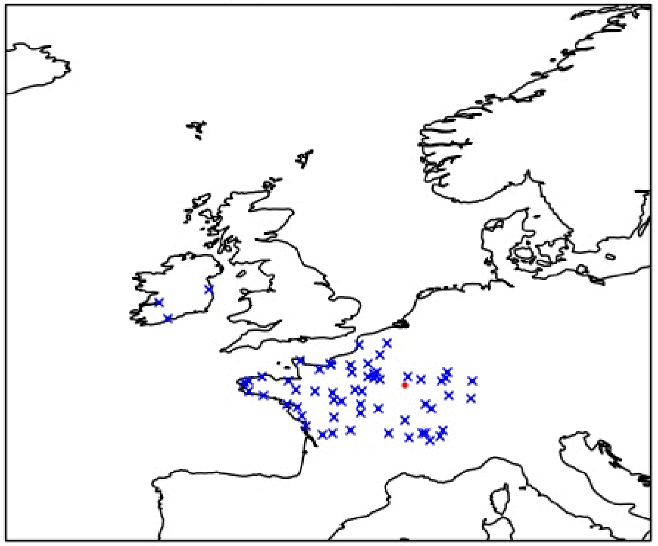
Assimilation of METAR cloud data





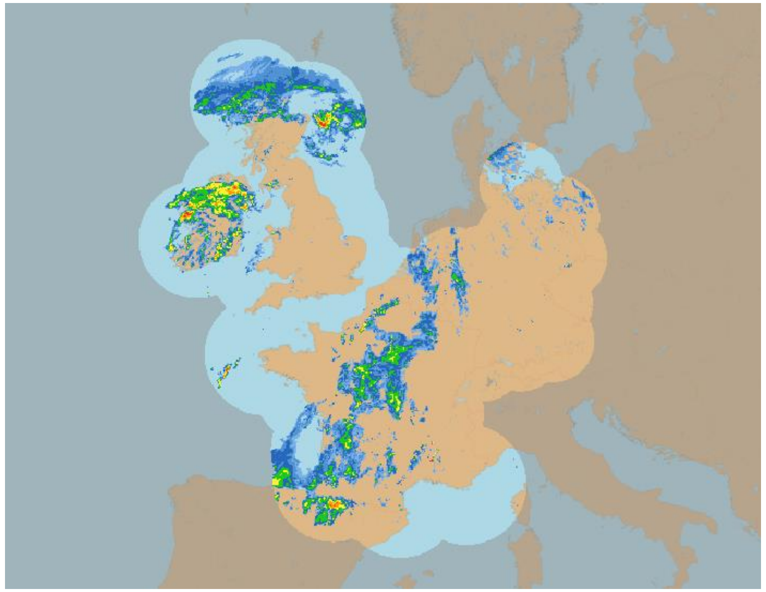
METAR

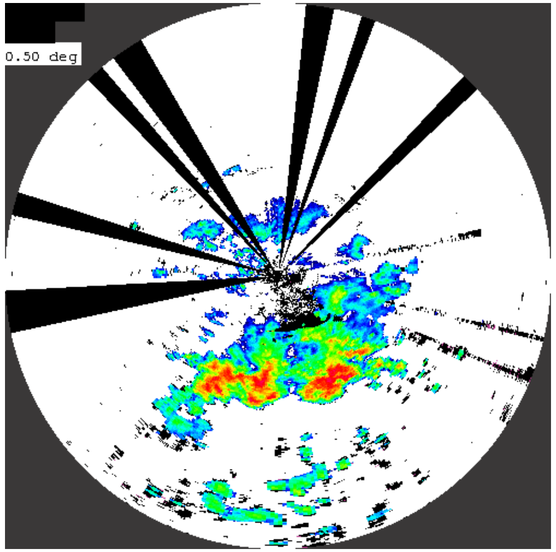
SYNOP

- METAR: METeorological Aerodrome Reports. Observations at small airport similar to SYNOP.
- Assimilate the METAR cloud data in the same way as the SYNOP cloud data.
- METAR cloud data increases the number of cloud observations by 50%.
- METAR cloud data is available distributed during the assimilation window and may therefore provide some time-evolution information.
- Some additional locations.
- Up to 6 layers of METAR cloud data assimilated. SYNOP data are assimilated only for the lowest cloud layer.
- We are not assimilating data above 500 hPa and in the lowest level.
- At the moment, we are not using cloud type.

Helen Buttery

Reflectivity assimilation





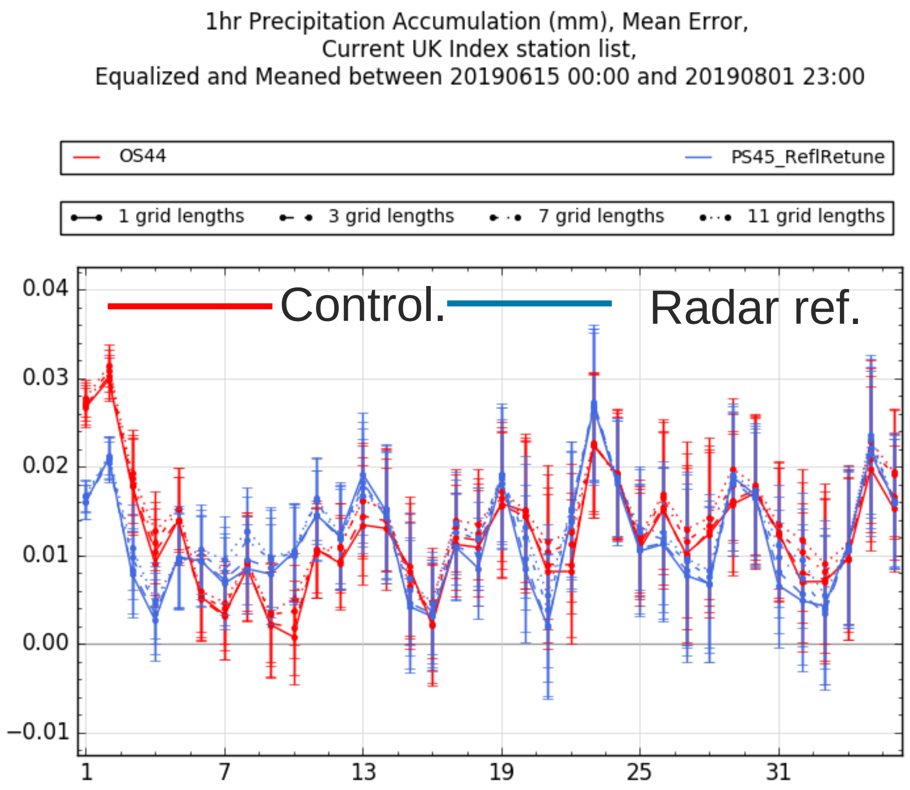
- European surface rain rates assimilated by latent heat nudging (LHN) every 15 minutes.
- Direct assimilation of UK and Irish reflectivity data in 4D-Var.
- Use of empirical Z-R relation tuned to reduce O-B bias.
- Assimilate dry and rainy obs.
- Reject data when model T < 3 ^{o}C. Issue for ice and brightband.
- If no cloud in background, we can't add increments.
- We don't take into account evaporation.

FUTURE DEVELOPMENT

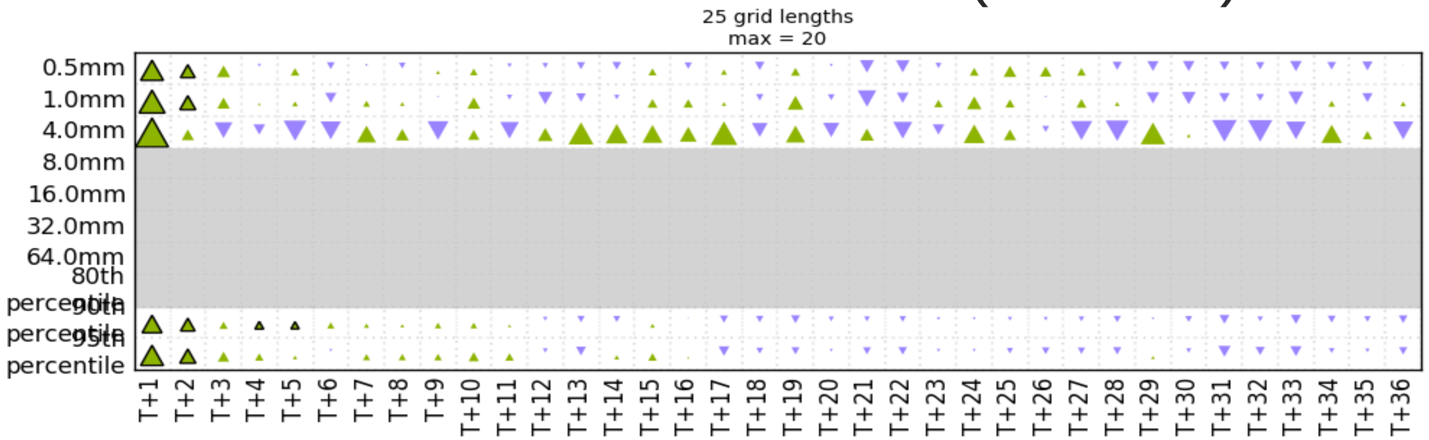
- Implement correlated observation errors for radar reflectivity (autocorrelation).
- Use of ice observations.
- Switch off LHN.

Lee Hawkness-Smith

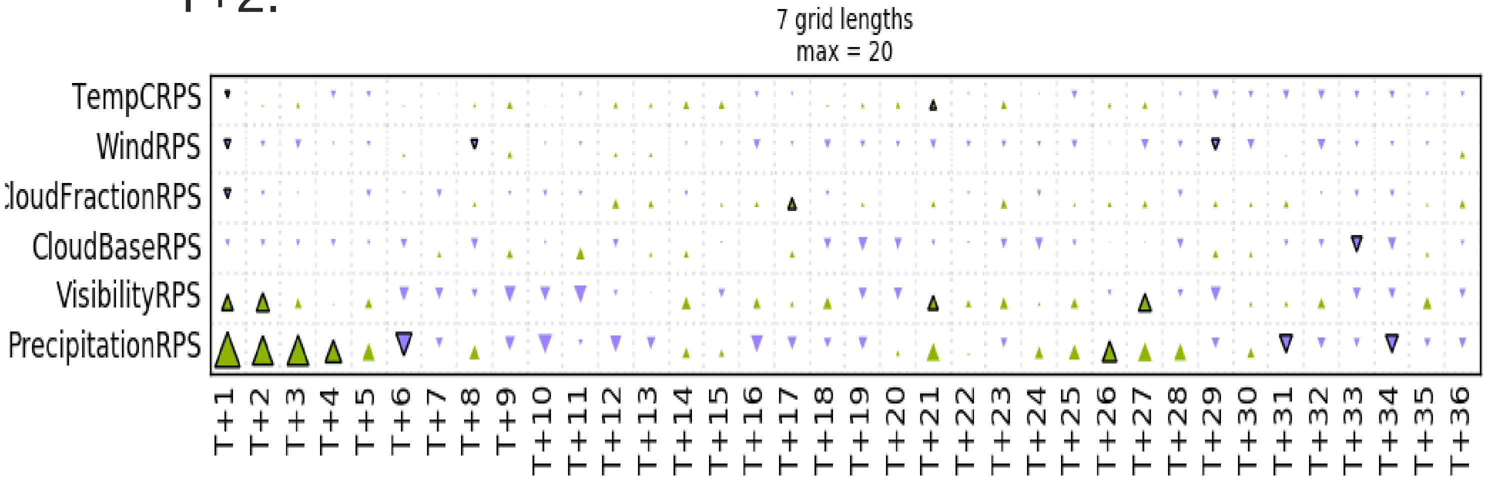
Met Office Reflectivity assimilation: results combined with LHN (summer)



- Reduced 'spin-down' bias at model initialization



- Improved Fractions Skill score at all thresholds up to T+2.

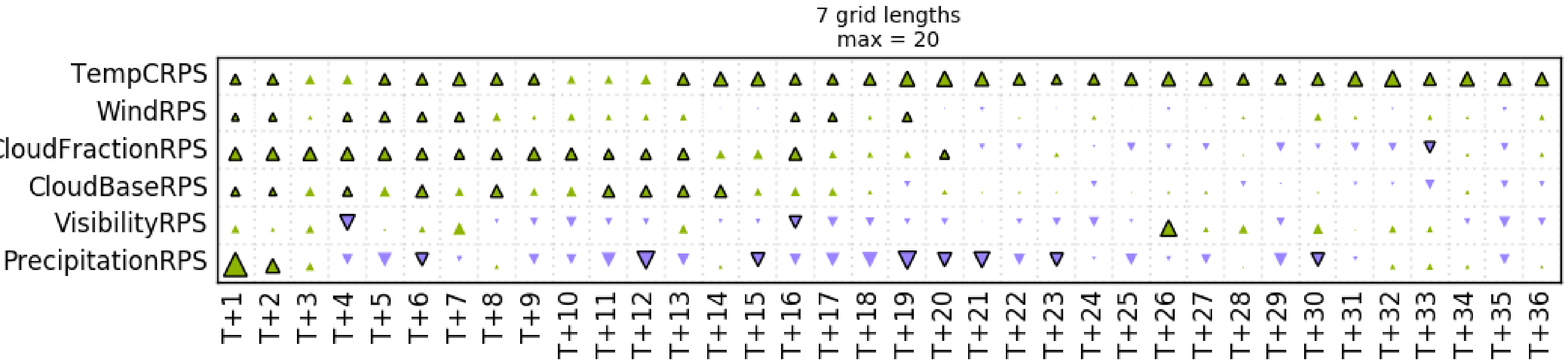


- Improved Precipitation RPS, and neutral impact on other scores.

Lee Hawkness-Smith

Results using the full system

SUMMER



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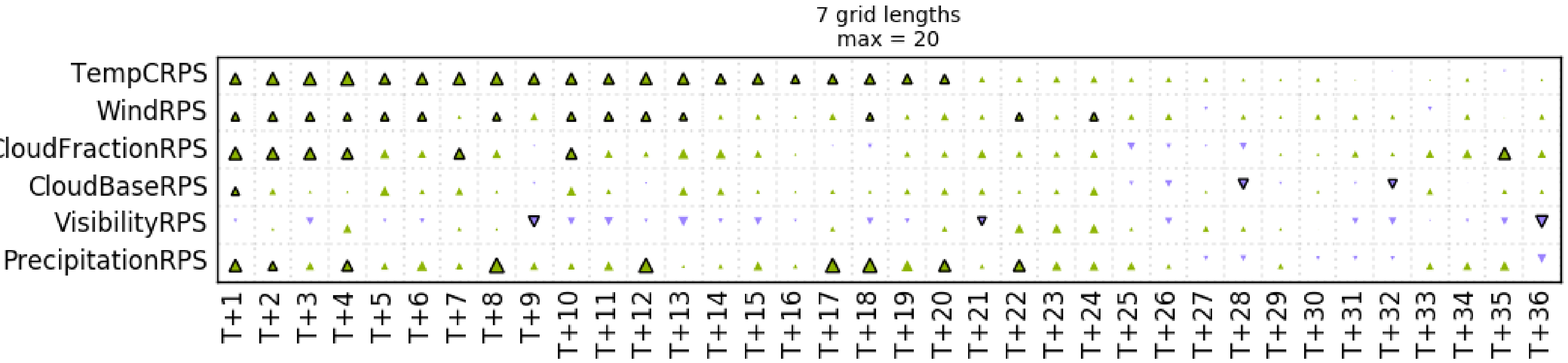
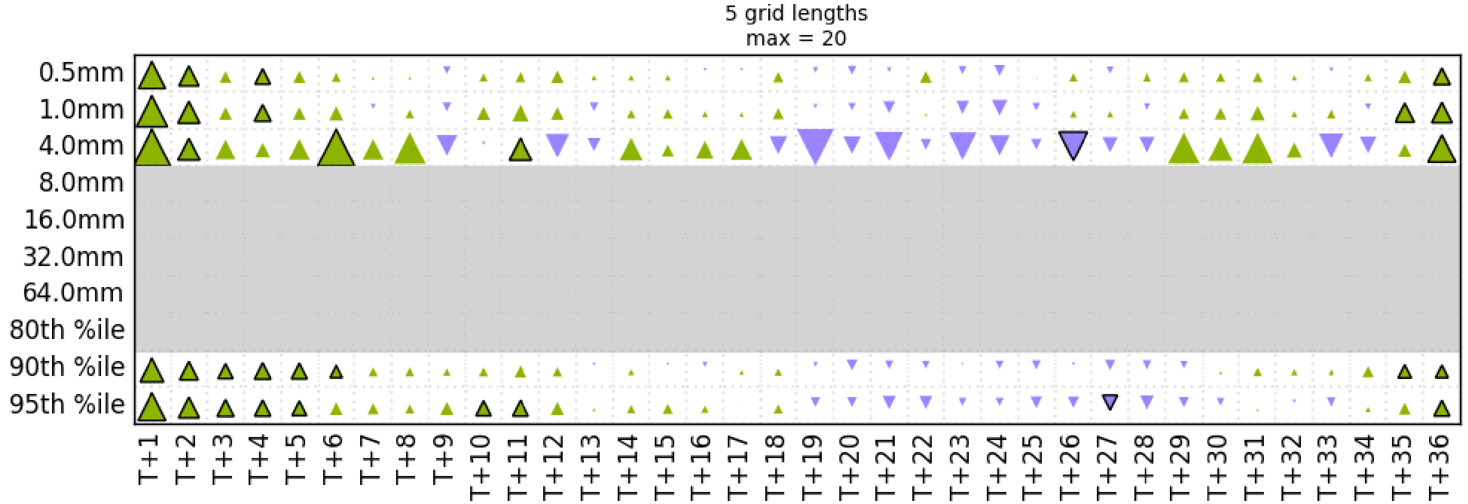


- General positive impact (statistically significant) in all variables until T+12.
- Cloud benefit better in summer.
- Summer, better screen temperature all over the forecast time. Winter until T+20.
- Strong impact in precipitation forecast in summer. Until T+10.
- Winter precipitation positive until T+2. After slightly positive until T+10.

Results using the full system

SUMMER



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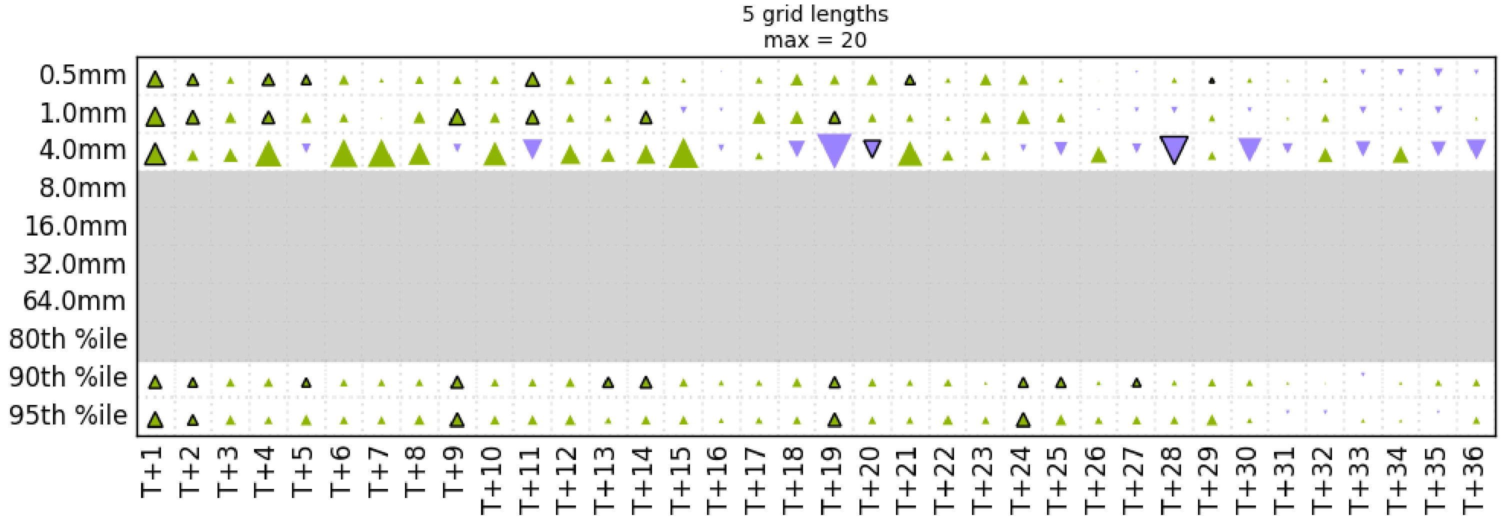

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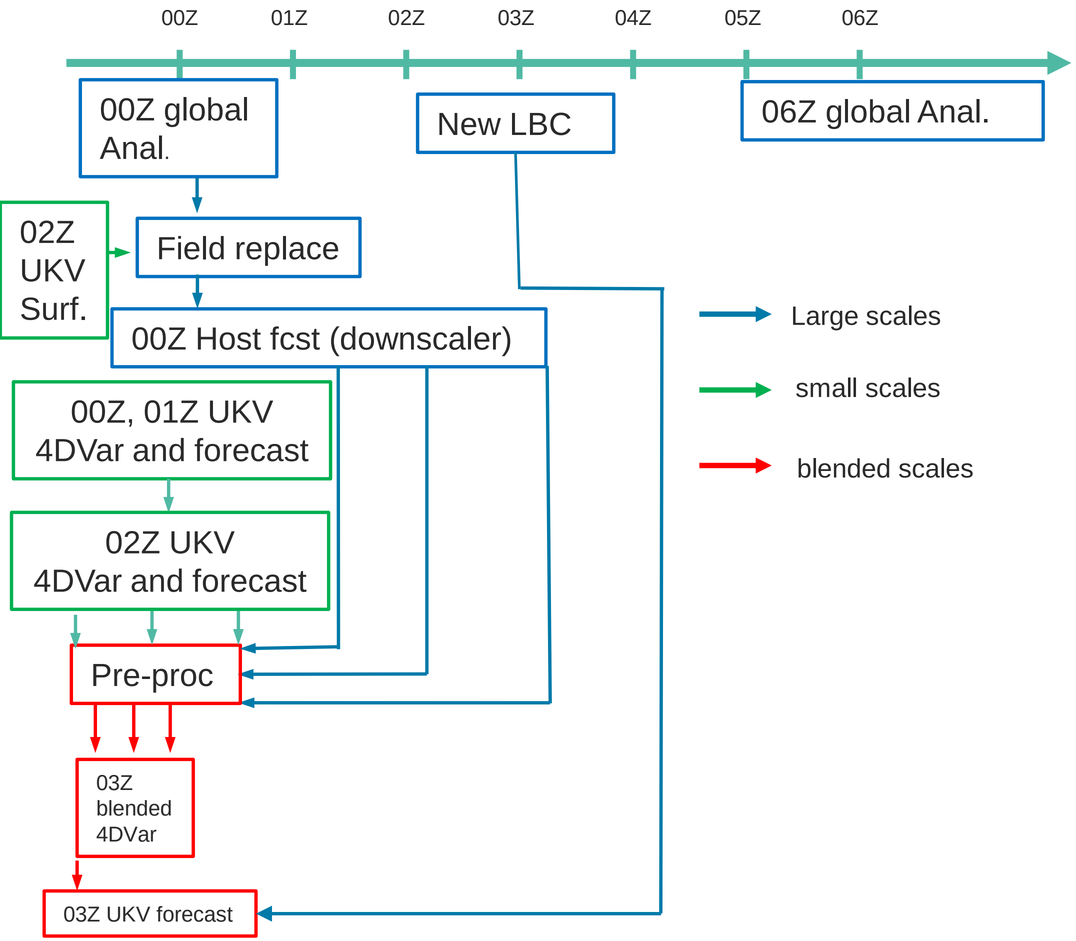
THANK YOU
QUESTIONS?

QUESTIONS

- Large-scale blending at the Met Office.
- Large-scale blending fit to observation.
- Large-scale blending setup.
- Reflectivity assimilation: a case study.

Marco Milan

Large-scale blending at the Met Office

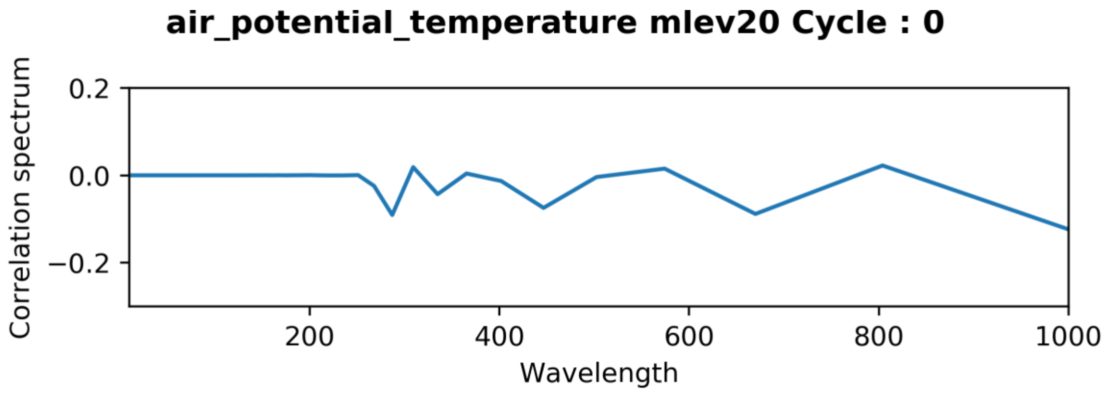


- 00Z Global analysis.
- From 00Z UKV we use surface, soil and aerosol fields
- Use of a downscaler, with a forecast of 150 minutes. The use of a reconfigured global field would lead to a technical issue in our system (different orography with respect to UKV).
- UKV assimilation and forecast at 00Z, 01Z and 02Z. The last one provide the fields for the blending.
- Large scale increments applied 3 times in the hourly assimilation window: T-30min, T+0, T+30min

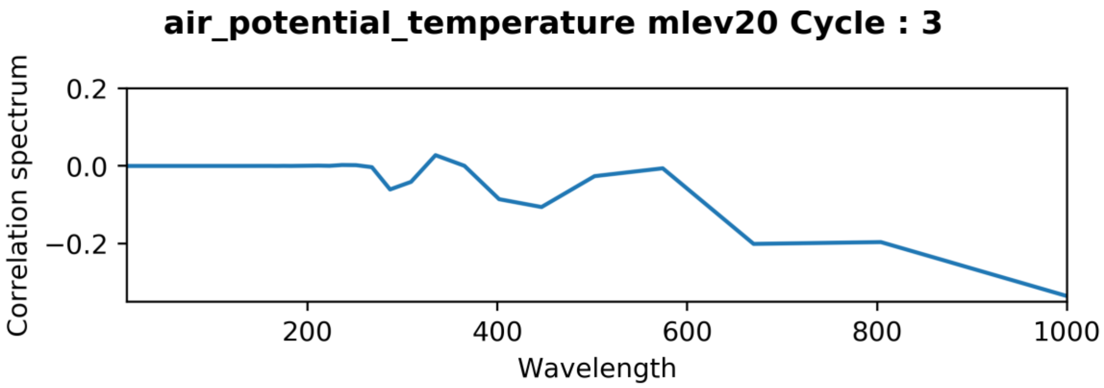
Marco Milan

Large-scale blending : set-up

LBC



noLBC

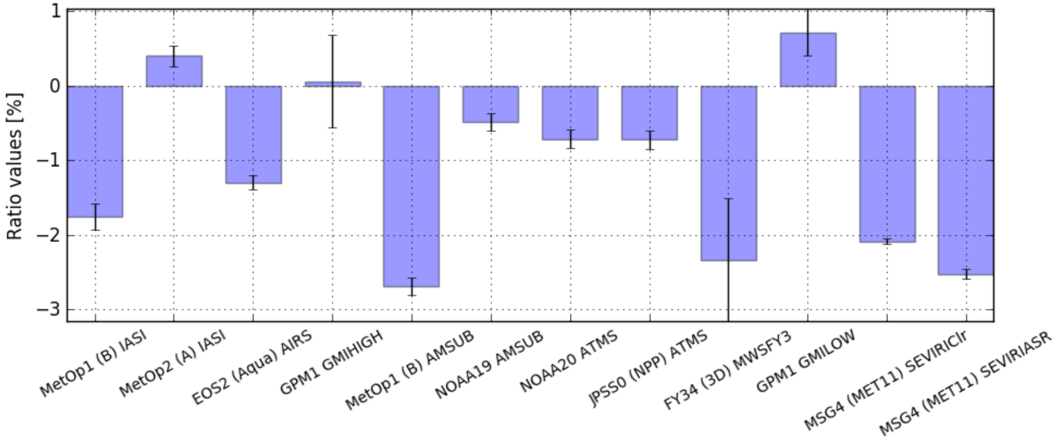


- Wavelength cut-off, from power spectra diagnostic: 700km
- The analysis increments are negatively correlated with the large-scale ones in the cycles where the LBCs were not updated (noLBC).
- We are now applying LSB only at 03Z, 09Z, 15Z and 21Z, where the correlation between the two types of increments is near to 0
- Following the literature, we scale the increment with height. Weight equal to 0 at the surface where the influence of the small-scale dynamics is likely to be more important. We use scaling weights at the top of the model to minimise imbalances.
- Maximum weight of 75%.

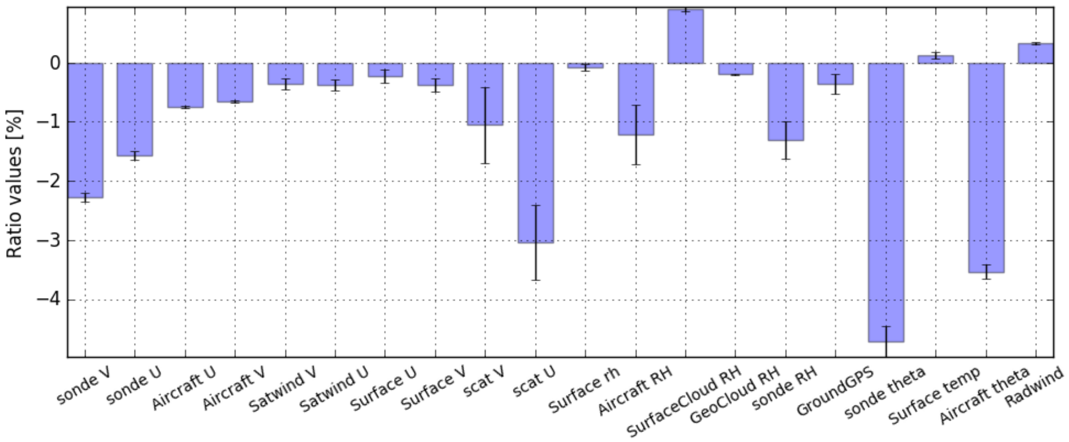
Large-scale blending : Comparison at analysis time

Winter

Satellites



Conventional



- Use of std of O-B departure at analysis time. Percentage of difference between LSB and Control. The 0% line indicate no change in the skills between the experiments.

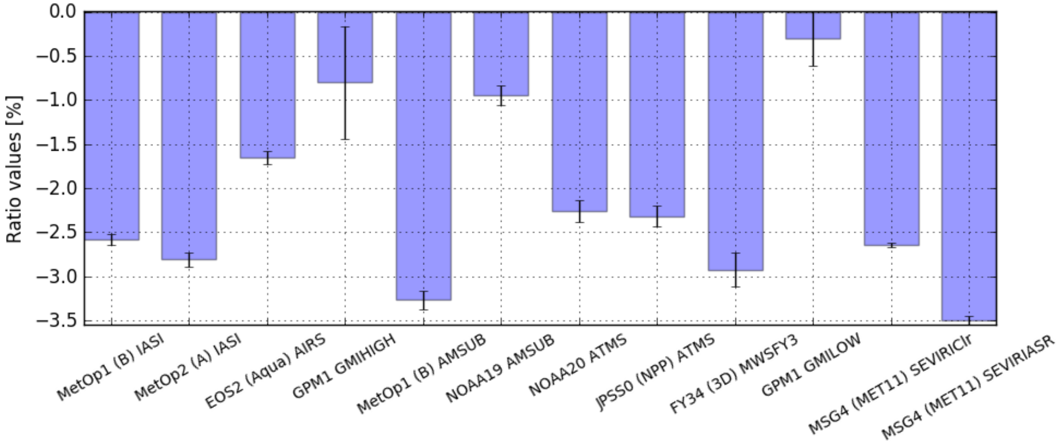
$$\frac{\sigma_{LSB} - \sigma_{CONTROL}}{\sigma_{CONTROL}}$$

- Winter: For most satellite instruments LSB improves the fit to observations. The improvement is even larger for conventional observations.
- Summer: For all satellite instruments LSB improves the fit to observations. Strong improvements also for the conventional observations.

Large-scale blending : Comparison at analysis time

Summer

Satellites



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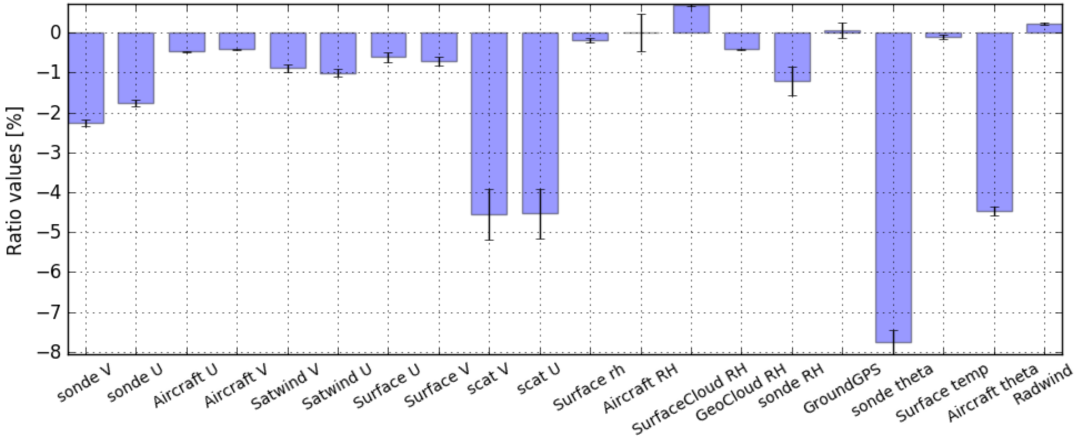

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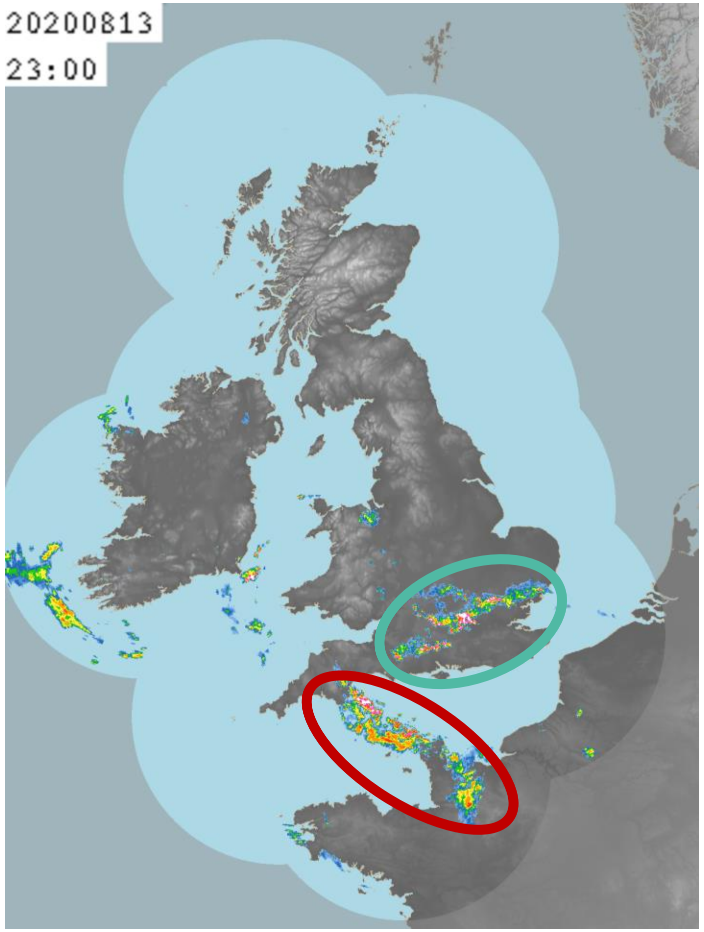
RETURN

Marco Milan

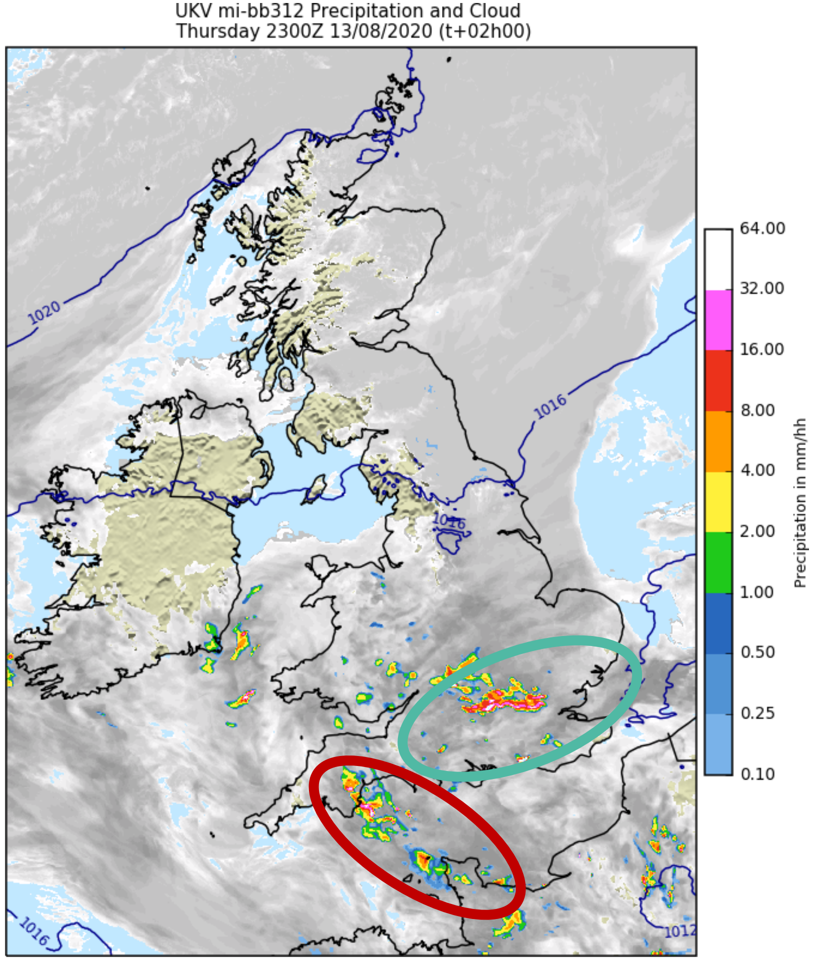
Met Office

Reflectivity assimilation Case study

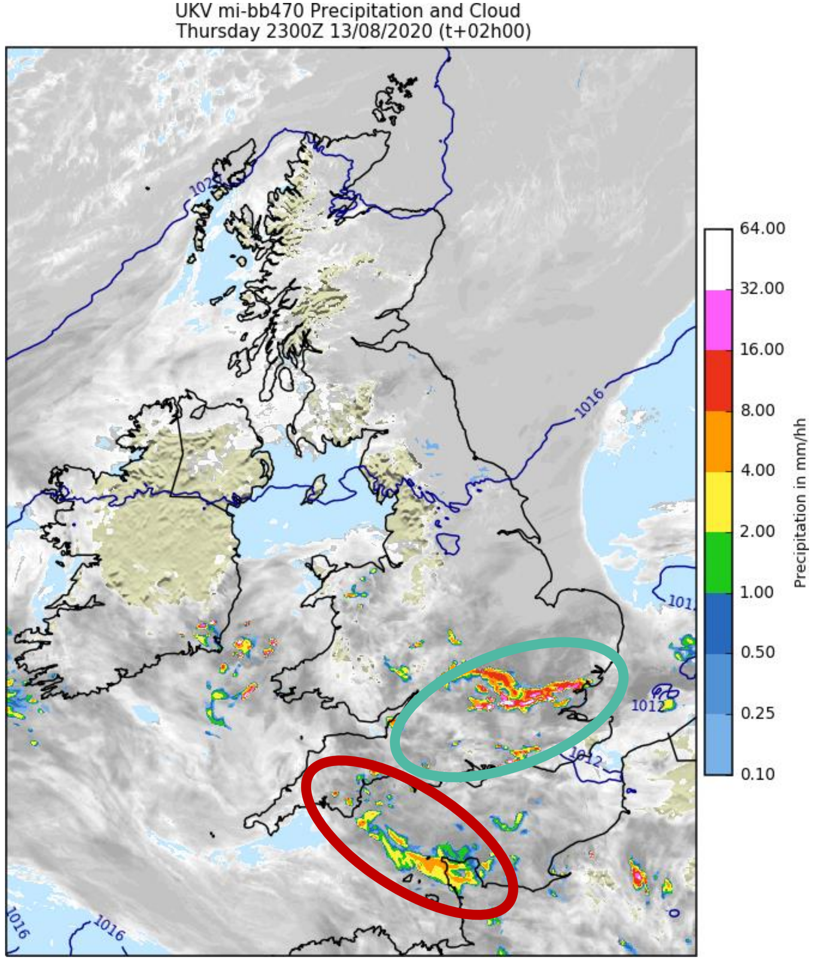
13 Aug 2020, T+2 2300



Obs



Control



Reflectivity Assimilation

Lee Hawkness-Smith