Lightning observations for NWP forecast verification and quantifying the impact of lightning observation representativeness errors

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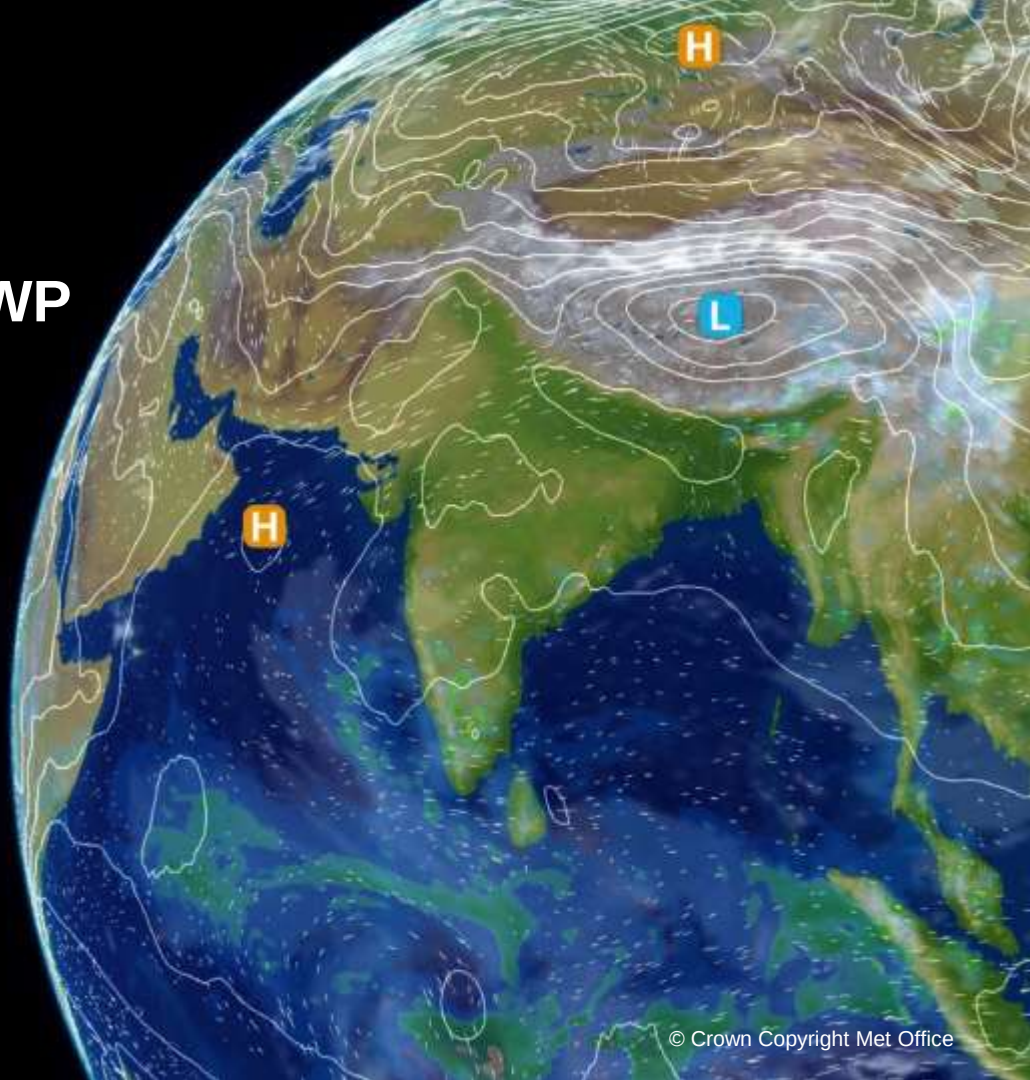
In collaboration with Anupam Hazra, Saji Mohandas and A. Jayakumar



Overview

Model

- 4.4 km forecasts from versions of the Met Office Unified Model over India for the monsoon. The model uses the **McCaul scheme**.

Observations

- **IITM lightning observations (ENGLN)** counts accumulated onto the model grid.
- **ISS-LIS observations** → swath width of ~550 km with several irregularly spaced overpasses a day, sampling a different region every time. The ISS travels at ~28000 km/h, thus these observations should be classed as “near instantaneous” even though they are labelled by the hour.

$$F = 0.95F1 + 0.05F2$$
$$F1 = k1 \times graupel\ flux$$
$$F2 = k2 \times total\ ice\ water\ path$$

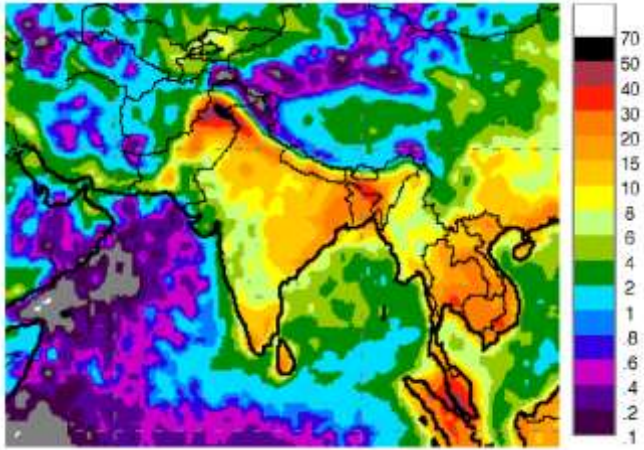
Where F1/F2 are flash rates per 5 minutes, F is the weighted flash rate per 5 minutes and graupel flux is at the -15°C isotherm

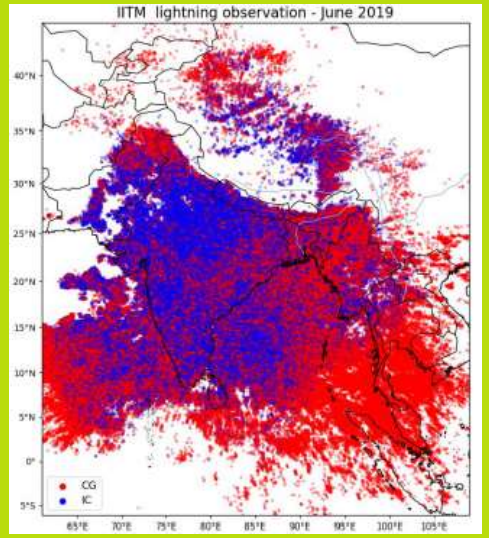
We are intent on **improving the forecasts of lightning flash counts** in the model. India presents a uniquely active environment for development, tuning and testing of model parameterisations and subsequent forecast performance.

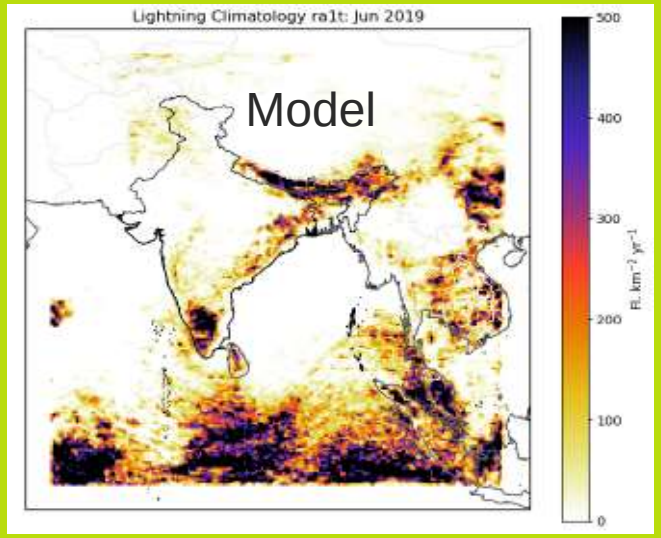
Lightning over India

Is a public safety issue.
More people are killed by lightning than any other weather phenomenon.

Annual lightning strikes per square km: 1995-2003 average around the India domain (Source: NASA)







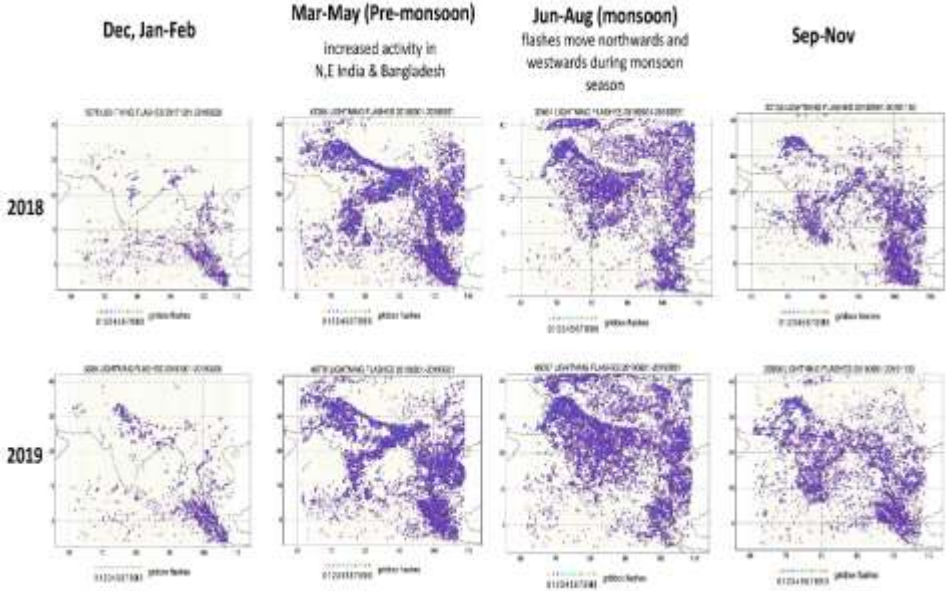
ENGLN strikes for one month and what a model sees

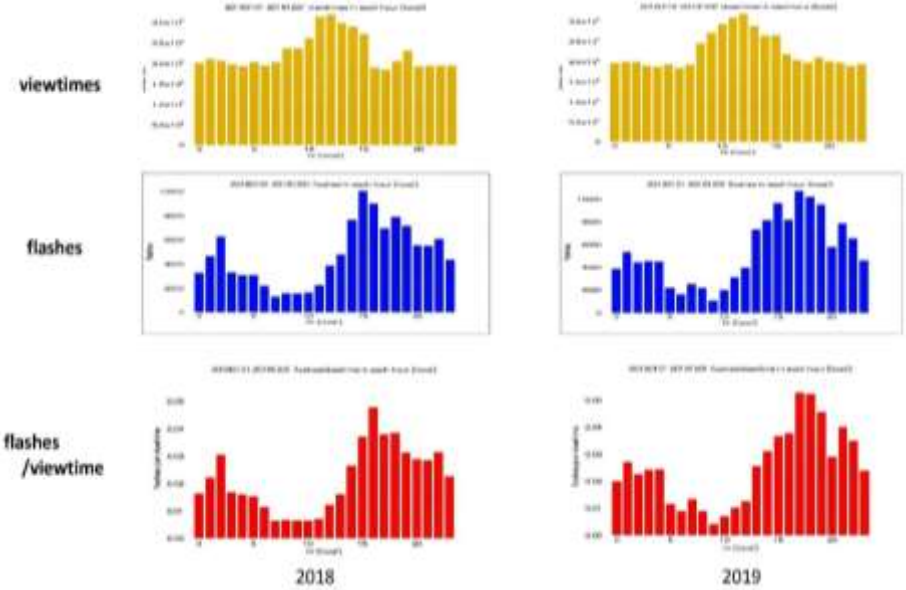
ISS LIS observations

- A gridded LIS dataset on the 4.4 km model grid was created which confirms **a potential climatological use case** of the ISS LIS observations.
- Nature (near-instantaneous, limited & irregular coverage) means they are **not useful on their own for verification of hourly or even daily forecasts.**
- A **simple "merging" of the IITM and LIS observations** (for qualitative validation) was attempted by simply adding the (few) LIS flashes to the appropriate hourly IITM. An example of this, with the smoothing algorithm as the final step is shown next.
- The merged observations were not used for model evaluation.
- There is a lot more work to be done to create a viable merged data set. A **more robust method for merging observations** (especially for model evaluation) would be **desirable** to improve detection.

LIS climatologies and diurnal cycle

Gridded dataset containing hourly ISS LIS views and detected flashes on rotated pole 4.4km grid of NCMRWF regional model domain for 2018 and 2019





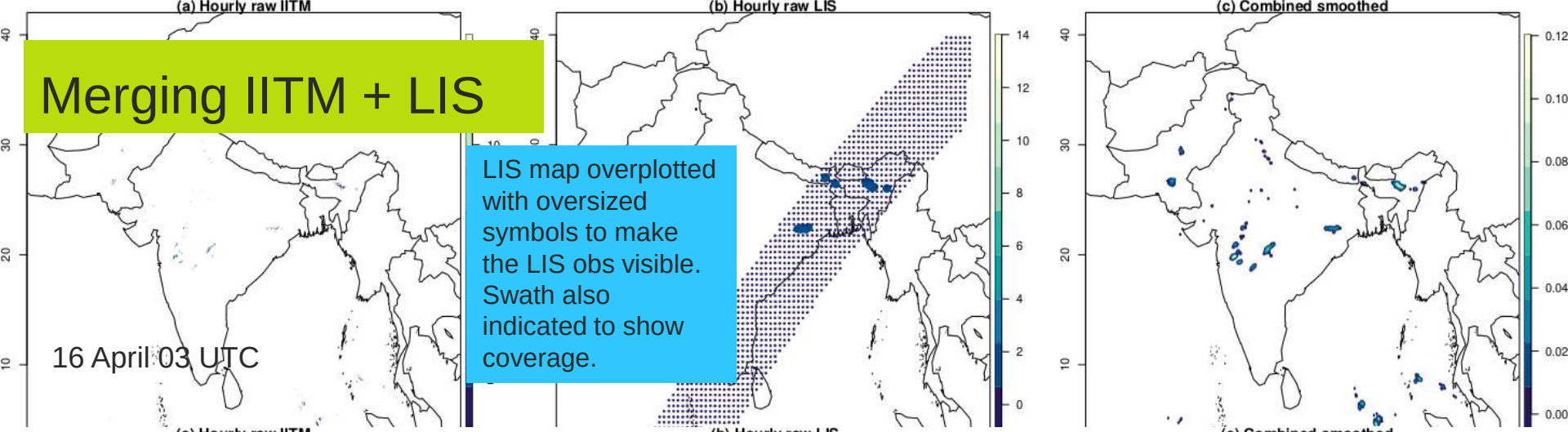
Demonstrates potential of similar lightning imager datasets on geostationary satellites for evaluation and nowcasting applications.

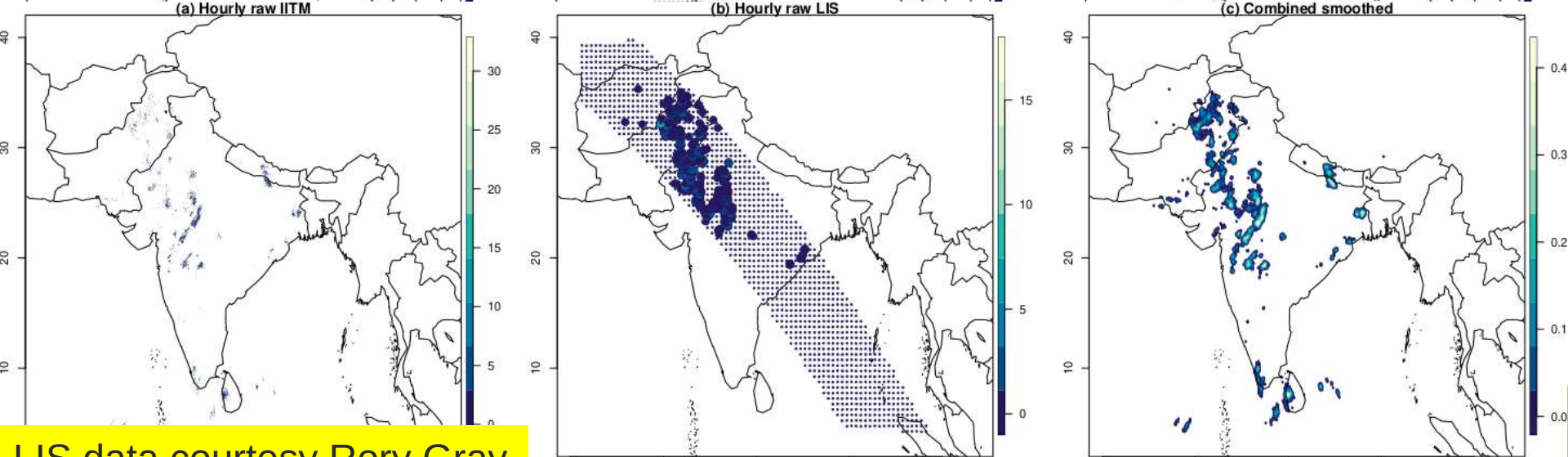
Rory Gray

Merging IITM + LIS

LIS map overplotted with oversized symbols to make the LIS obs visible. Swath also indicated to show coverage.

16 April 03 UTC





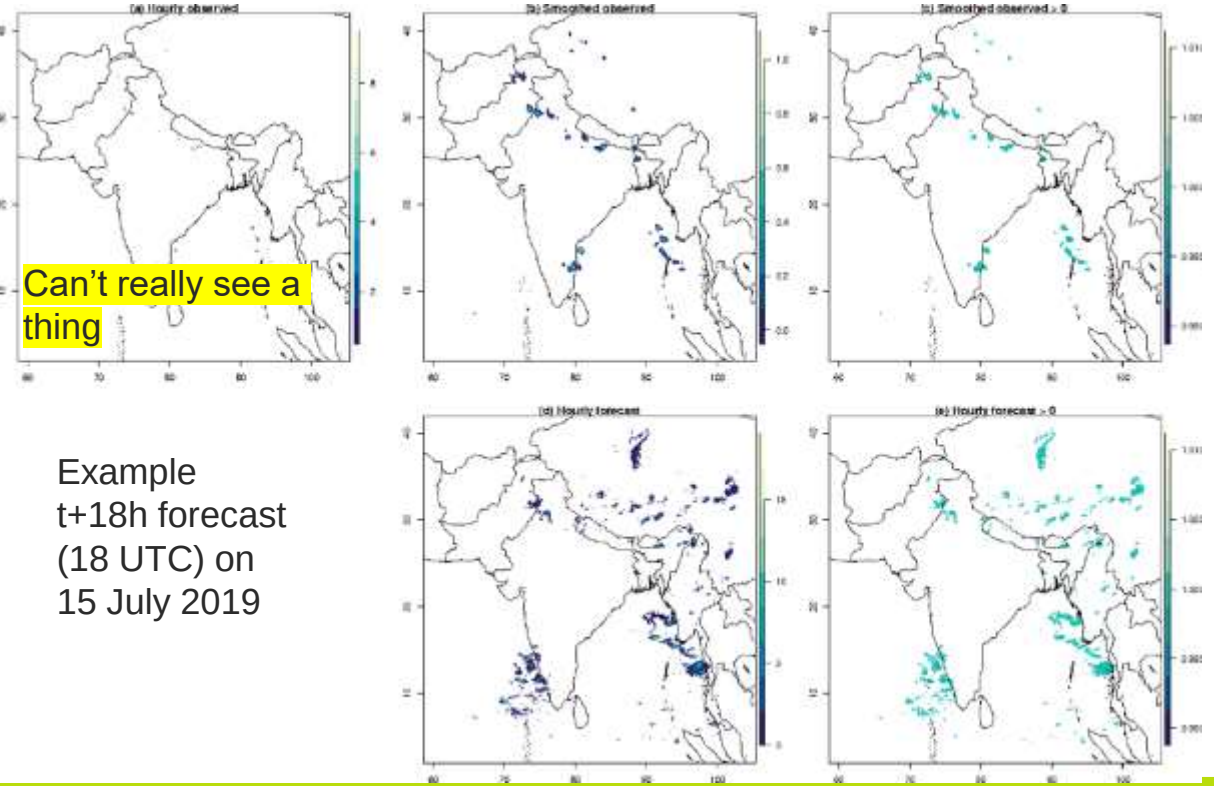
LIS data courtesy Rory Gray

Observation representativeness mismatch

- **Lightning "flash" essentially treated as a point**, but a flash tends to consist of many strokes which can travel up to ~20 km in the horizontal. This spatial dimension is not reflected.
- This leads to a potentially **large representativeness mismatch** even between the 4.4 km model and aggregated lightning flashes onto the same grid.
- **Gaussian kernel smoothing** was added to categorical analysis of elements to mitigate against the impact this mismatch has on the metrics.
- **Recently, the intensity has been re-imputed into the smoothed field but scaled such that total lightning over the domain is conserved**. This implies that the observed peaks are reduced in preference to spreading the lightning out in space.

Addressing representativeness of the lightning observations

Hourly



Can't really see a thing

Example t+18h forecast (18 UTC) on 15 July 2019

Gaussian kernel dressing applied to hourly gridded lightning observations. (a) Gridded lightning flash counts; (b) kernel dressed and mass conserved flash counts; (c) binary field created from (b). (d) Hourly model flash counts and (e) binary field produced from (d).

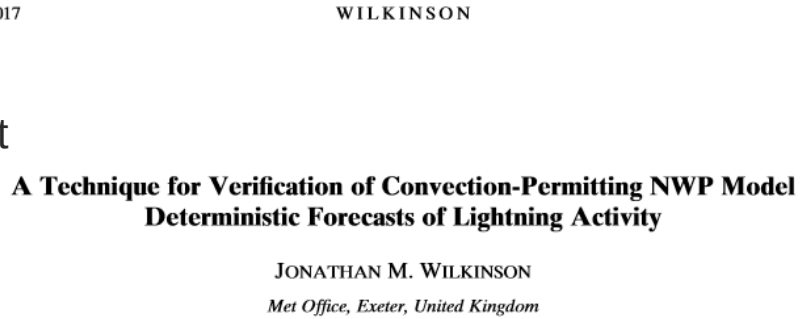
Representativeness mismatch reduced

Used a ~12 km kernel to acknowledge that lightning can travel ~20 km in the horizontal, i.e. the location that the strike is registered to is not necessarily representative of the physical extent.

Mittermaier et al. (2022a, Meteorol. Apps.)

Coverage-Distance-Intensity (CDI)

- **Spatial method specifically developed for evaluating lightning forecasts.**
- The method uses observed lightning flash counts put on the model grid.
- **Treats each grid point separately without doing precise matching.**
- Could be **classed as a hybrid method** with some commonalities with SAL combined with a distance metric.
- Here the **modified coverage component** is used, introduced in Mittermaier et al (2022a, the original paper used SEDS). Both will be shown here to demonstrate why the new coverage component is preferred.


FEBRUARY 2017 WILKINSON

A Technique for Verification of Convection-Permitting NWP Model Deterministic Forecasts of Lightning Activity

JONATHAN M. WILKINSON

Met Office, Exeter, United Kingdom

Wilkinson, J. M. (2017). A Technique for Verification of Convection-Permitting NWP Model Deterministic Forecasts of Lightning Activity, *Weather and Forecasting*, *32*(1), 97-115.

(Mittermaier and Wilkinson, 2023, submitted, WAF)

CDI method II

- **Coverage:** Do the forecasts cover too large/small an area? **Dominated by storm structure [-1,1]**

$$C = \frac{P_m - P_o}{P_m + P_o}$$

> 0 over-forecast
= 0 unbiased
< 0 under-forecast

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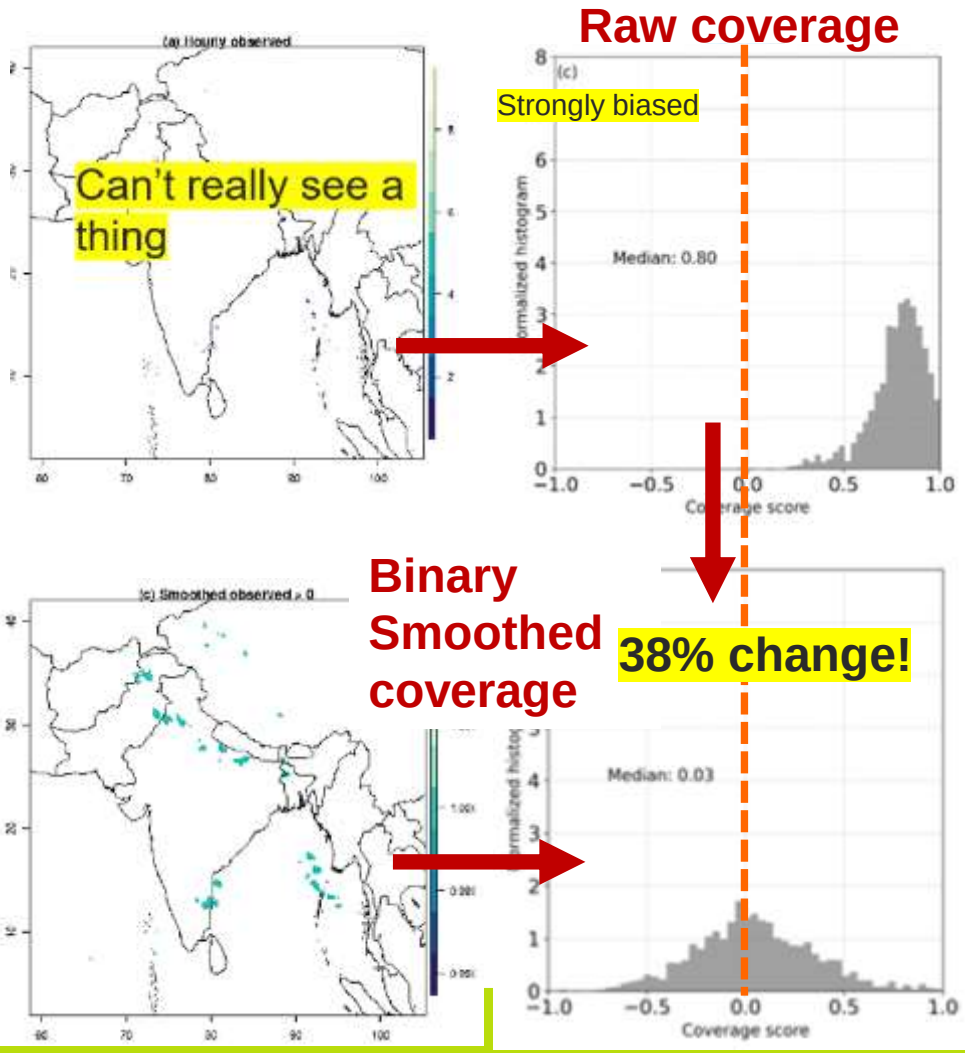
Quantifying the representativeness impact

March to June 2019 and all lead times in the 24h forecast.

Increasing the observation footprint has a significant impact on how model performance is viewed.



Conclusions

- **Spatial representativeness** mismatches are influential. There is a **38% change in the median coverage component for the period March-June 2019** when the mismatch is mitigated against.
- Lightning data are sparse. **Gaussian kernel dressing used in conjunction with a spatial verification method provides a means of dealing with such observations by enlarging their footprint**. In doing so the representativeness mismatch between what an NWP model can resolve and what the observation represents, is reduced and the method is more likely to correctly diagnose forecast behaviour.
- ISS-LIS is/was not suitable for NWP verification. Having **LIS-based spatial lightning data from geostationary platforms on the other hand *should* provide greater spatial coverage and uniformity and will help in being able to assess lightning forecasts across larger areas**, e.g. to complement new Met Office surface-based system (LEELA).
- **Detection limits can be as low as 50%.** This will continue to hamper a better quantification and tuning of model lightning parameterisations. **Some estimates of the observation uncertainty, in terms the (total) flash counts**, would be highly desirable.

Mittermaier, M.P. and J. Wilkinson, 2023, under revision for WAF.

Met Office

Thank you for listening! Questions?

Newton Fund

India partners