Met Office

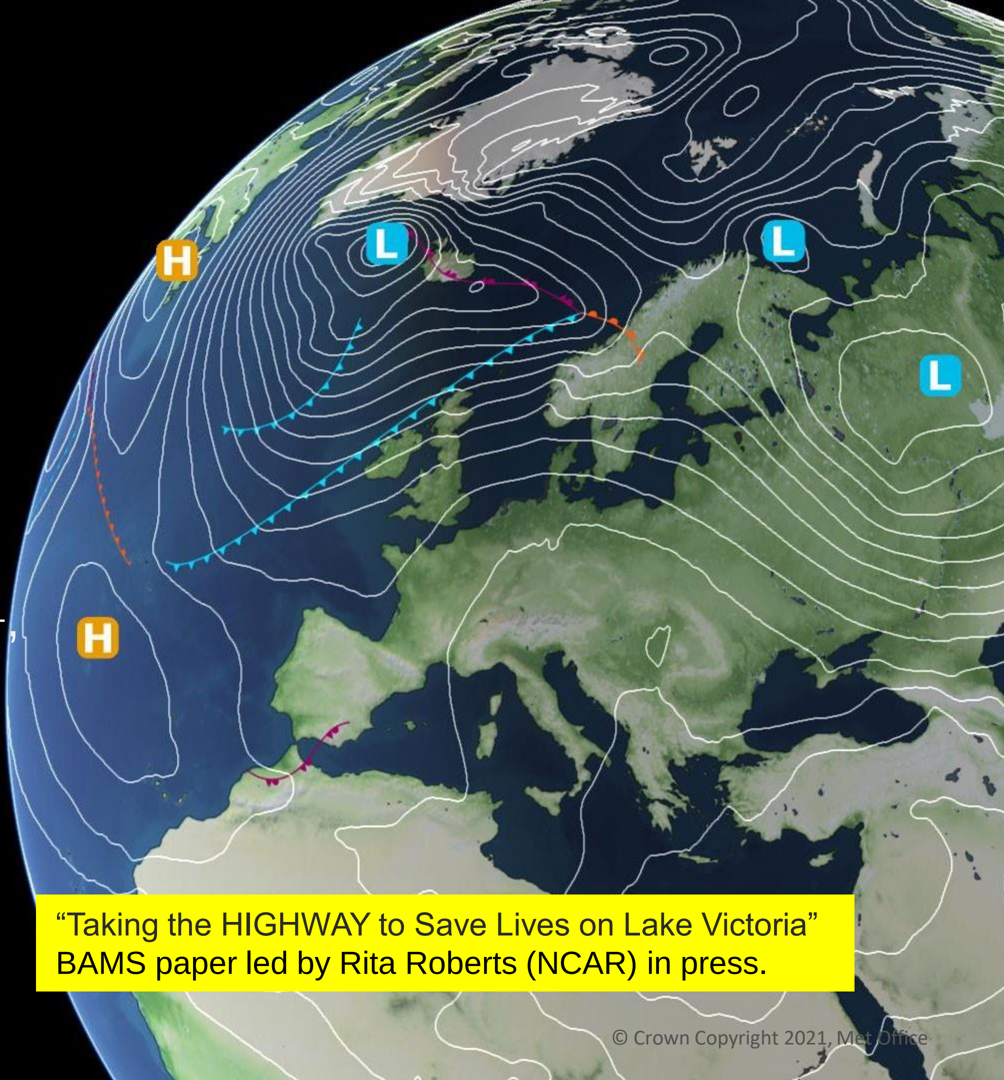
Evaluating a lightning diagnostic: comparing model-oriented and user-oriented outcomes

Marion Mittermaier[1], Jonathan Wilkinson[1], Gabriella Csima[1], Stephanie Landman[2] Katrina Virts[3] and Steve Goodman[4]

[2]South African Weather Service

[3]University of Alabama in Huntsville/NASA, USA

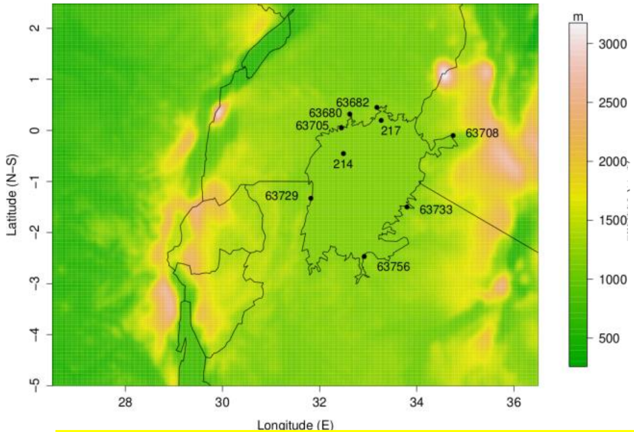
[4]Thunderbolt Global Analytics/NASA, USA

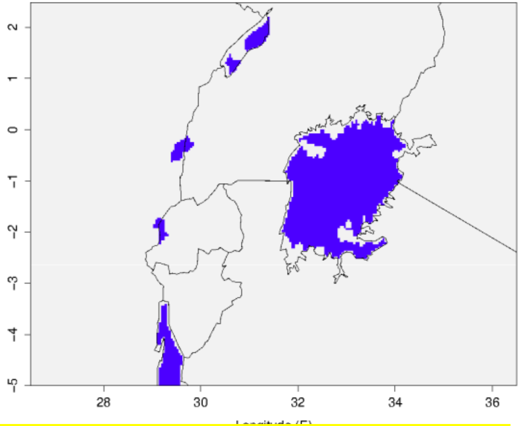


"Taking the HIGHWAY to Save Lives on Lake Victoria" BAMS paper led by Rita Roberts (NCAR) in press.

Met Office

Outline





HIGHWeather impact lAke sYstem” (HIGHWAY) project

Thunderstorms over the lake present a significant hazard to the people using the lake (fishermen, transport).

1. Lightning diagnostic definition
2. Model-oriented verification
   - Domain average
   - *Coverage-Distance-Intensity* (CDI) method (Wilkinson 2017)
   - Gaussian kernel dressing of gridded lightning counts for classical gridded categorical analysis
3. Maximising skill and measuring value for the user for warn-able events
4. Conclusions

Lightning diagnostic in the UM

After McCaul et al 2009.

Provides lightning “origin flash density” to indicate the source of the lightning.

Lightning may travel considerable distance from origin.

Observations are often in strokes, with multiple strokes per flash. Need to convert to flashes. Need to know the conversion multiplicative factor (here 2.1 strokes per flash)

Forecasting Lightning Threat Using Cloud-Resolving Model Simulations

EUGENE W. MCCAUL JR.
Universities Space Research Association, Huntsville, Alabama

STEVEN J. GOODMAN
NOAA/NESDIS/ORA, Camp Springs, Maryland

KATHERINE M. LACASSE AND DANIEL J. CECIL
University of Alabama in Huntsville, Huntsville, Alabama

Met Office

Domain averages

March – October 2019

Split by region:

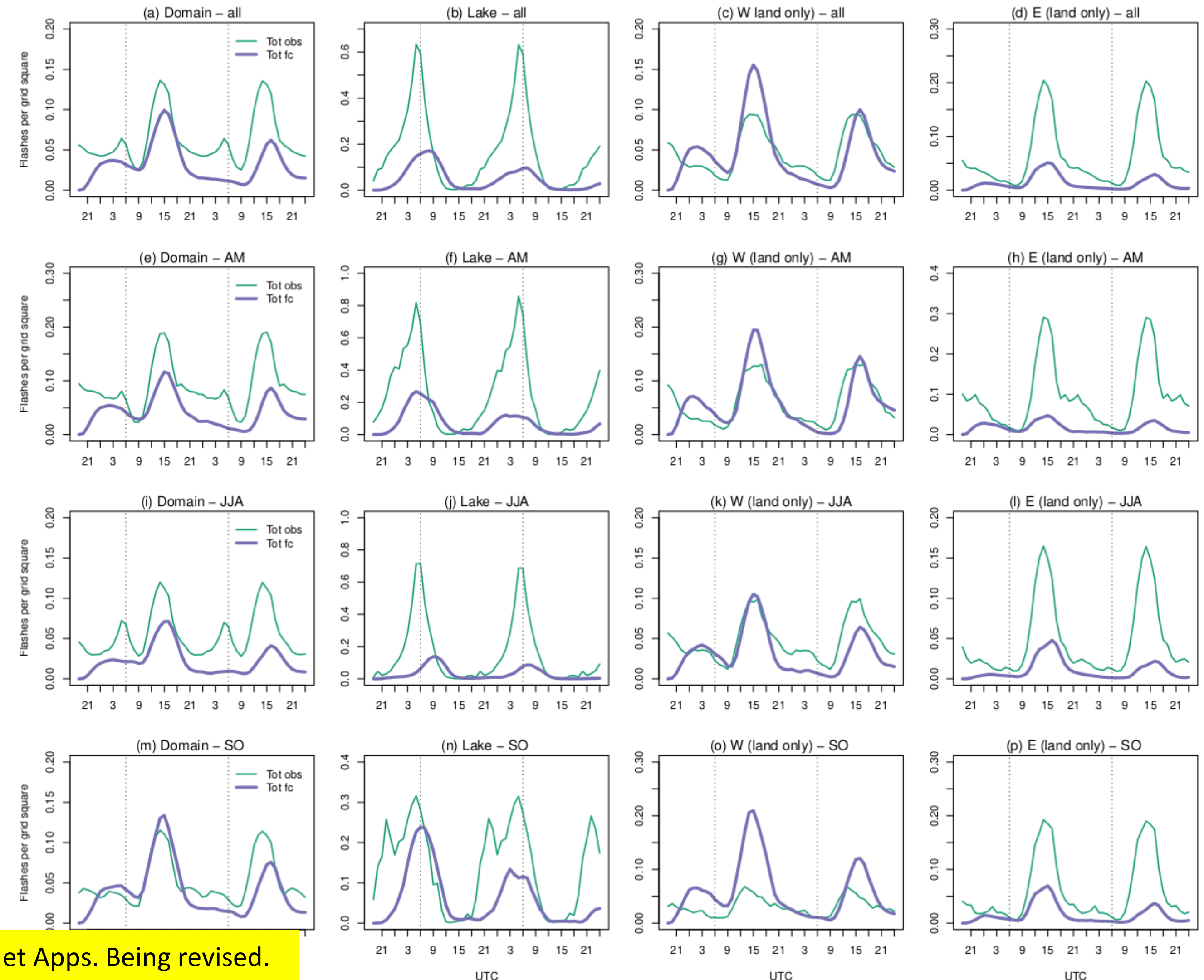
All, W, E and over lake

Split by season:

All, AM, JJA, SO

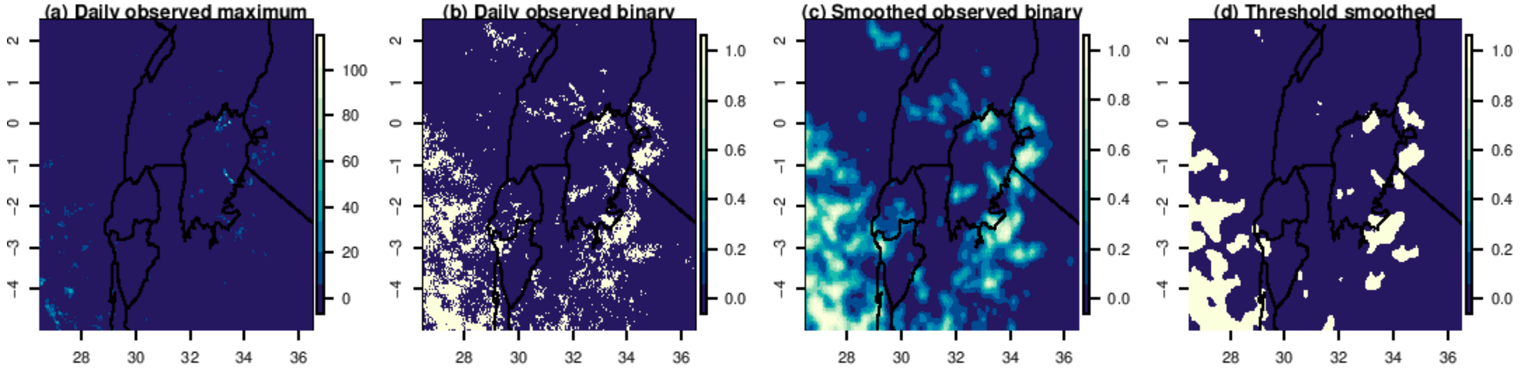
Model does not capture the geographical differences.

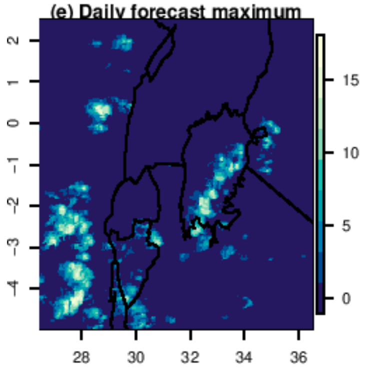
Model too much lightning W of the lake, but way too low over lake.



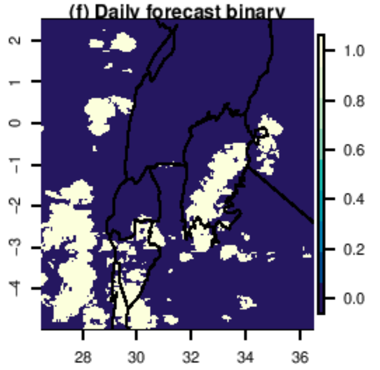
Mittermaier et al. (2021a), submitted to Met Apps. Being revised.

Gaussian kernel-dressing of gridded lightning observations

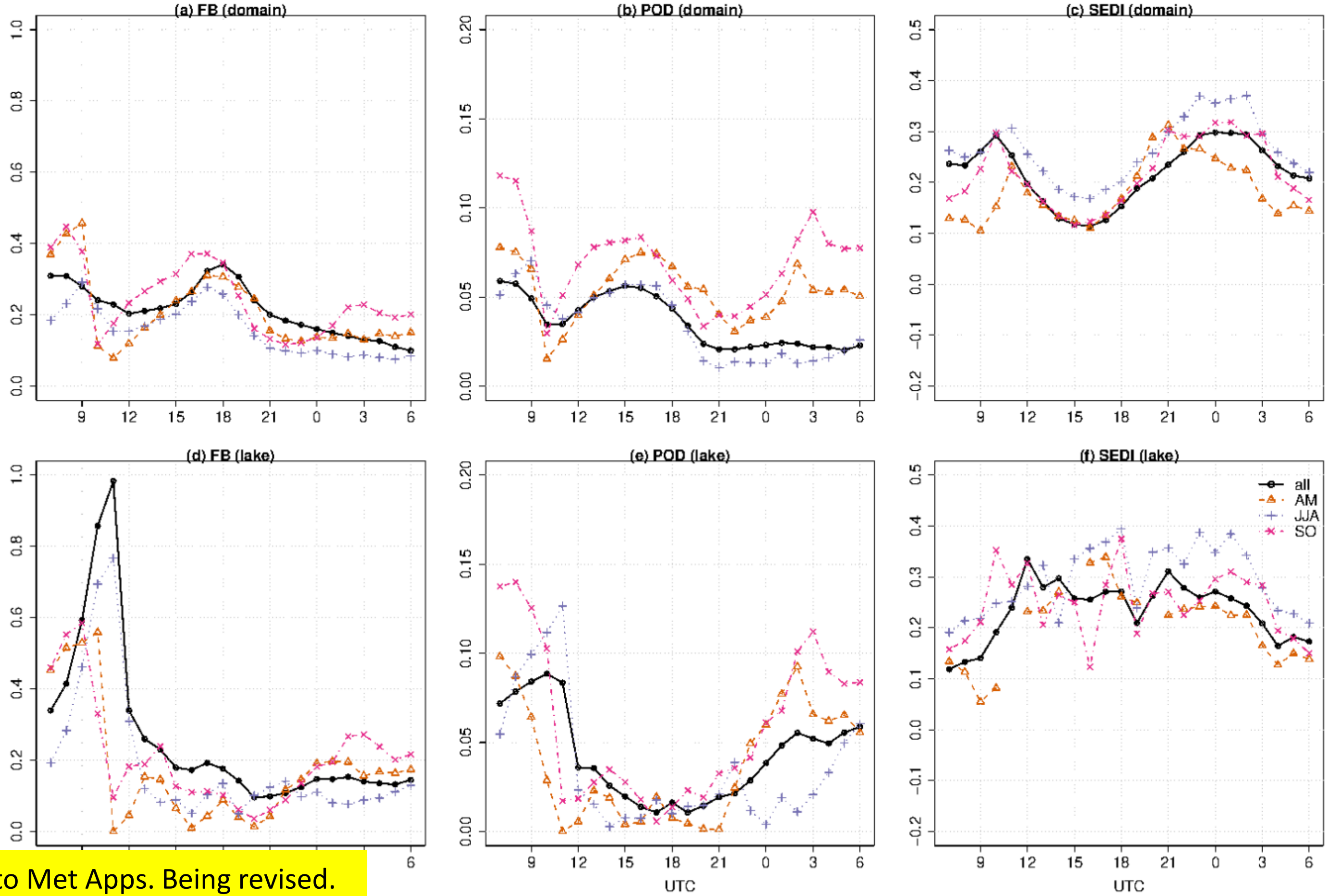




Gridded binary field is Gaussian kernel dressed to find a binary field that is a better match to the forecast field texture



Mittermaier et al. (2021a), submitted to Met Apps. Being revised.



Diurnal cycle in the classical sense

Against Gaussian kernel dressed gridded observations

“any” lightning threshold (>0)

Too little lightning (in terms of FB), over the lake get close but this POD is very low, with some seasonal variations.

SEDI includes the POFD and shows anti-correlated behaviour to POD alone.

Lake is very different to land.

Mittermaier et al. (2021a), submitted to Met Apps. Being revised.

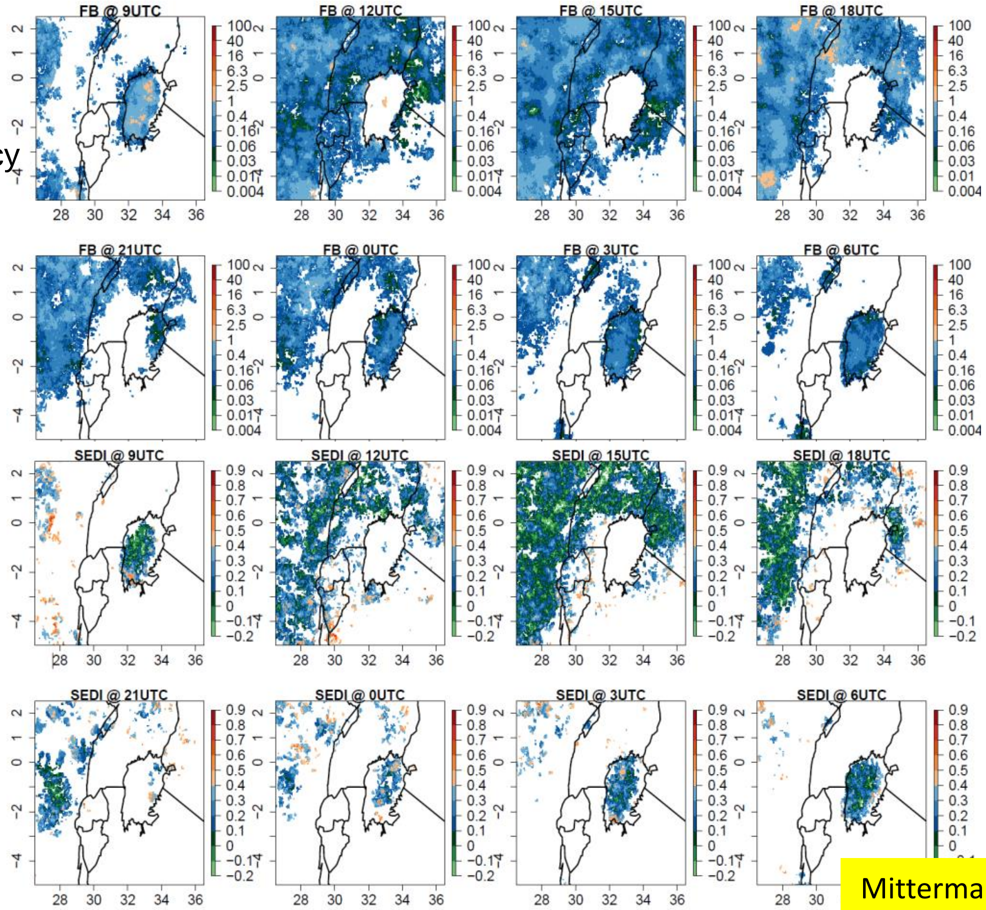
Met Office

Diurnal cycle: spatial view

LT = UTC + 3h

Frequency bias

Skill



Lake a strong driver for diurnal evolution with lightning more prevalent at night over the lake.

Storms traverse domain from E to W.

Hourly FB is generally much less than 1.

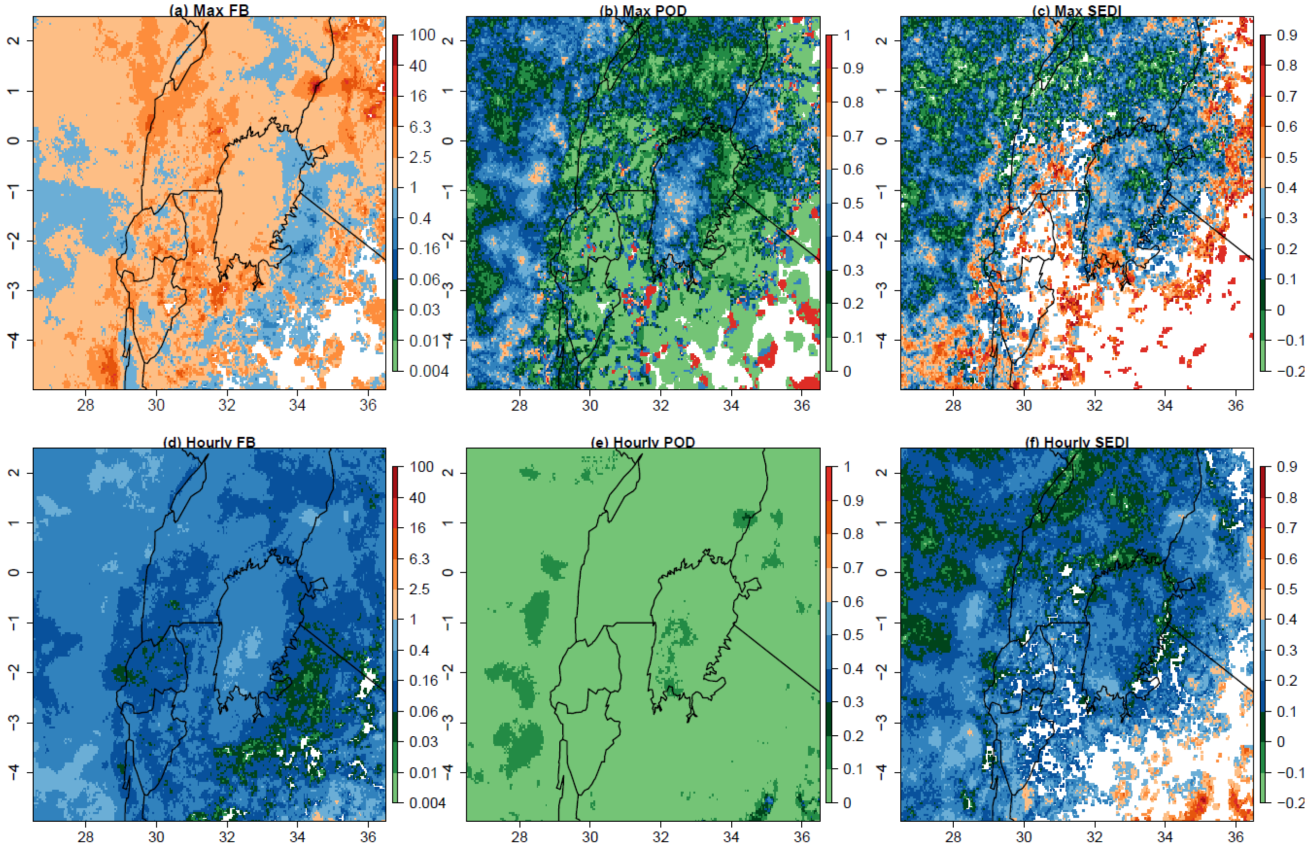
Hourly SEDI shows some moderate amounts of skill.

[Note: SEDI is undefined when the denominator is 0.]

Mittermaier et al. (2021a), submitted to Met Apps. Being revised.

Met Office

Spatial aggregate scores



Top: aggregate computed on the max-in-24h at each grid point every day

Bottom: aggregate computed from hourly contingency tables

Using max-in-24h less biased and possibly slight over-forecast bias.

POD of hourly very low but considerably better for maximum fields (helped by over-forecast bias)

SEDI suggests areas of residual skill when taking the POFD into account.

Maximum daily field is of much more use to the user trying to issue warnings on a daily time scale.

Mittermaier et al. (2021a), submitted to Met Apps. Being revised.

Coverage-Distance-Intensity method

February 2017 WILKINSON 97

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

Jonathan M. Wilkinson
Met Office, Exeter, United Kingdom

Specifically developed for evaluating lightning forecasts.

Used here with a modified intensity component (the paper used the SEDS for the intensity part).

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

$$QSDS = \begin{cases} 1, & D_{dis} = 0 \\ 1 - \frac{1}{2}\left[\frac{D_{dis}}{D_h} + \frac{ln(D_{dis})}{ln(D_h)}\right], & D_h > D_{dis} > 0 \\ 0, & D_{dis} = D_h \\ \frac{1}{2}\left[\frac{D_{dis} - D_m}{D_h - D_m} + \frac{ln(D_m - D_{dis})}{ln(D_m - D_h)}\right] - 1, & D_m > D_{dis} > D_h \\ -1, & D_{dis} = D_m \end{cases}$$

$$I = \frac{T_m - T_o}{T_m + T_o}.$$

Components > 0 over-forecasting

Components < 0 under-forecasting

Mittermaier et al. (2021a), submitted to Met Apps. Being revised.

Met Office

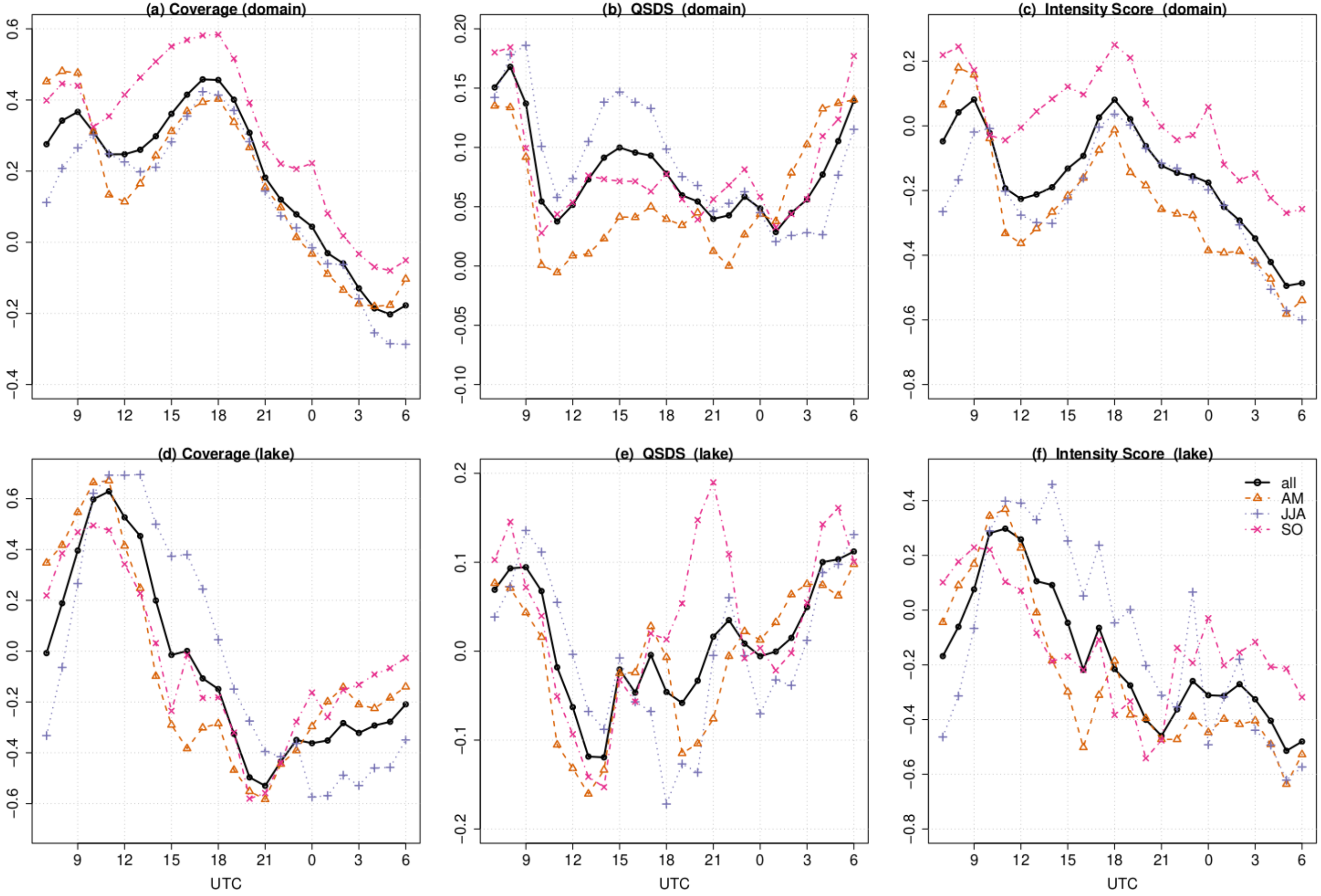
CDI diurnal cycle

Coverage is over-forecast, i.e. model area with lightning is too large

Location of lightning in the domain is slightly positive most of the time.

Over the lake the location is negative for part of the day.

Intensity is too low except over the lake during the day/afternoon.



Mittermaier et al. (2021a), submitted to Met Apps. Being revised.

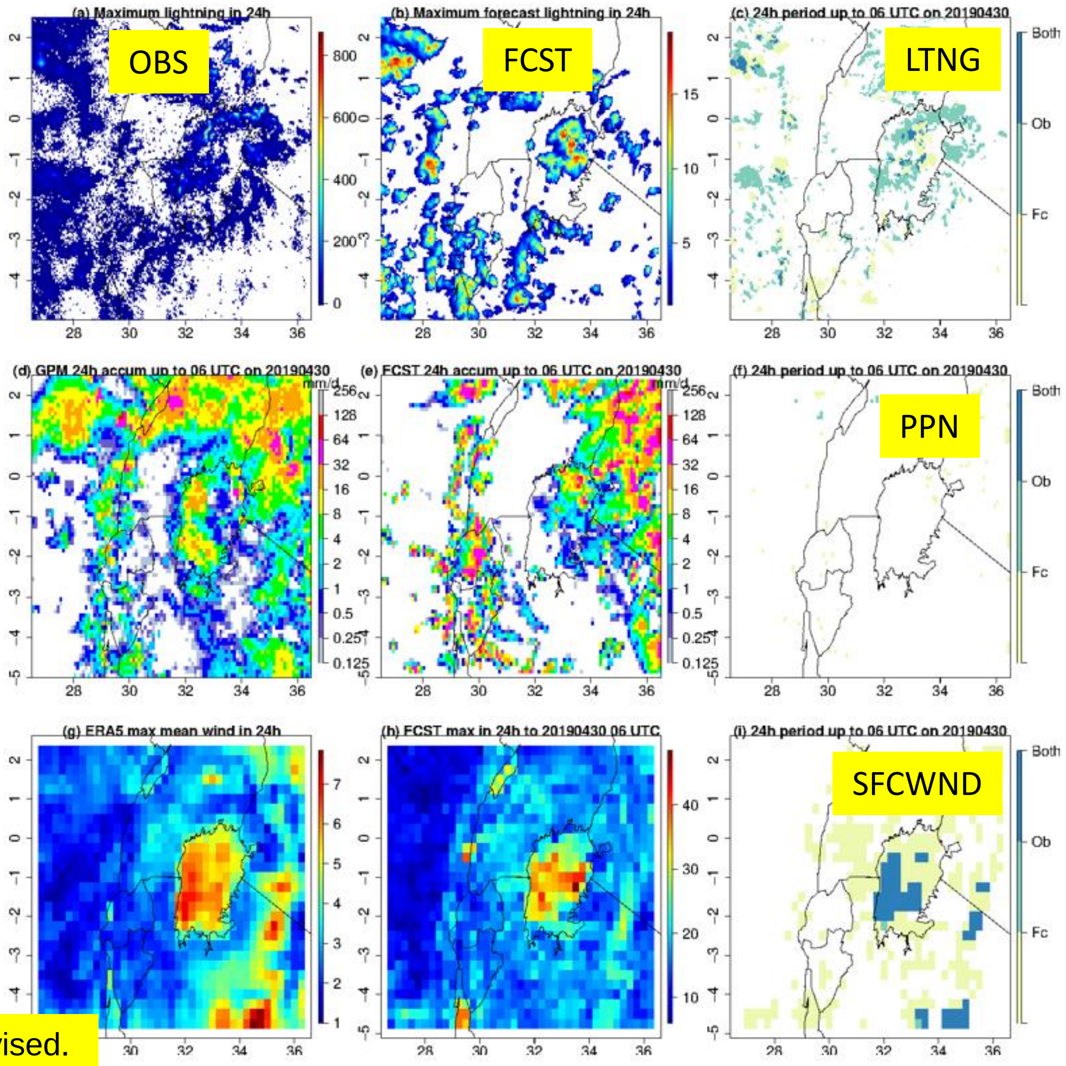
Met Office

Maximising model guidance for warnings

Look at the maximum-in-the-day to identify a signal.

Use a multi-parameter approach to identify the possibility of thunderstorm as a hazard: 10 m wind (ERA5), precipitation (GPM) and lightning (ENGLN).

Use m+2s threshold (based on daily field) to identify “warn-able” (aka strongest on the day) events to eliminate biases and to make all quantities unitless/comparable.



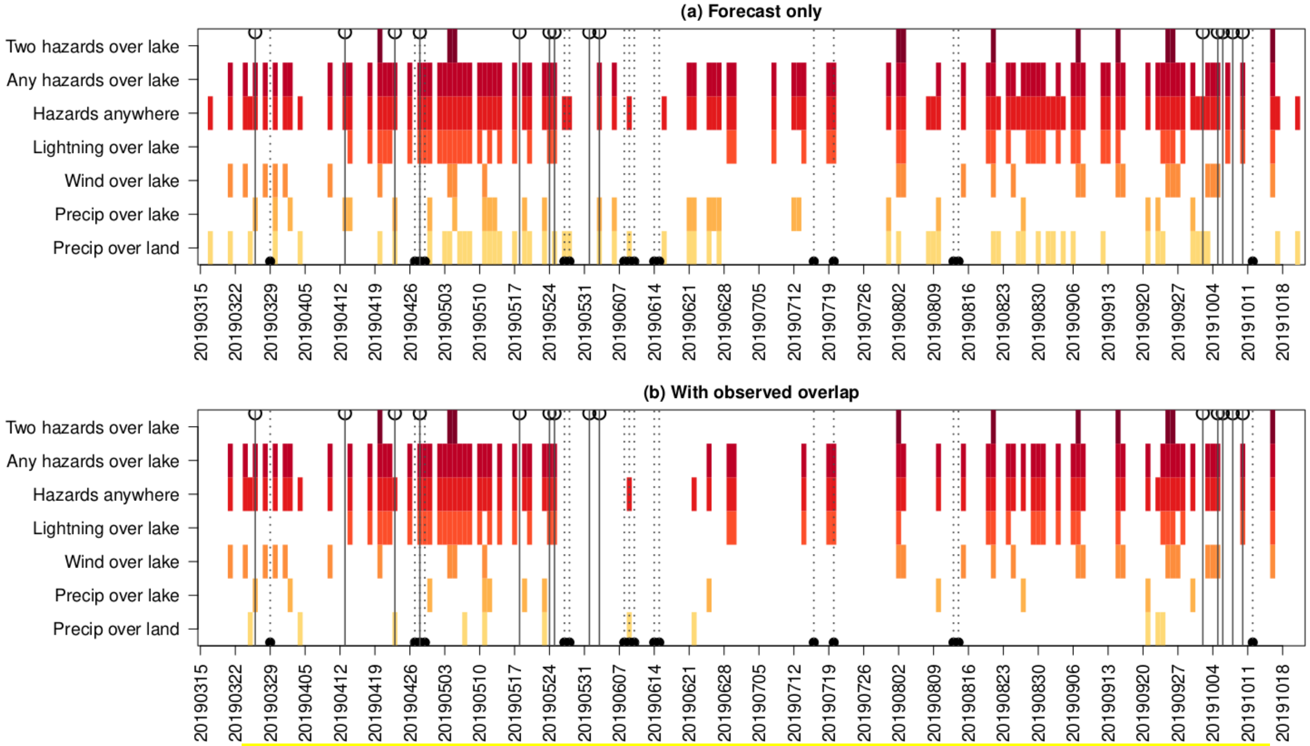
Mittermaier et al. (2021b) submitted to Met Apps. Being revised.

Ability of first-guess warnings to identify events

Coloured squares indicate days where a warn-able event is identified based on the specific criteria listed down the left.

(a) Provides the view for forecasts only

(b) Provides the view of considering only those days where there is an overlap (in normalised space) between the forecast and observed exceedances (verification)



Issued warnings (dotted), reported impacts (solid)

Mittermaier et al. (2021b) submitted to Met Apps. Being revised.

Mittermaier et al. (2021b) submitted to Met Apps. Being revised.

Ability of first-guess warnings to identify events

Table 5 Summary of identified first-guess warning days using a single variable or a combination. Also given (in brackets) is the number of the specified days where the event, as defined by exceeding the daily $m+2s$ threshold, occurred. There were 16 SWFDP warnings issued between March and October 2019 and 14 days with recorded impacts.

Variable	*NWP first-guess warning days identified (event occurred)*	*NWP first guess on SWFDP warning days (event occurred)*	*NWP first guess compared to reported impacts (event occurred)*
Precipitation over lake	28 (11)	0 (0)	4 (1)
Precipitation over land	56 (12)	3 (1)	4 (1)
Lightning over lake	51 (45)	3 (3)	4 (4)
Wind over lake	26 (26)	0 (0)	1 (1)
Any hazard over lake	88 (70)	3 (3)	9 (6)
At least two hazards over lake	11 (10)	0 (0)	0 (0)
Any hazard anywhere	106 (76)	6 (11)	10 (7)

Precip alone least useful for identifying sev. wx.

Lightning better than precip

Mean wind identified all occurred events.

Requiring more than one parameter reduces events.

NWP will provide more events (over-forecast)

Not enough warnings issued

Non-specificity in NWP FG parameters may provide useful guidance for identifying events related to impacts

Met Office

Concluding remarks

1. Lightning does not behave like precipitation and can be considered complementary to the verification of precipitation
2. Lightning observations need some pre-processing to make the representativeness mismatches less severe. Gaussian kernel dressing for such highly localised observations shows some promise in retaining the important information about location (important in this instance).
3. In a highly persistent and repetitive convective regime like over Lake Victoria there NWP can provide some useful guidance for creating first-guess warnings using a maximum-in-the-day.
4. Exploring the diurnal cycle in space and time shows there are significant errors/offsets which need to be improved before the forecast is useful at the sub-daily scale.