CII verification using WWLLN data for SADC region

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Introduction

- **SADC region:**
  - Limited number of surface and upper air observations
  - Lightning detection sensors and weather radars not available in most countries
    - Entire region relies on satellite data = high temporal & spatial resolution of entire SADC

- **NEED:** Improve nowcasting & very short range forecasting services in southern Africa

- **South Africa**
  - Has own lightning and radar networks, in addition to satellite data
  - Techniques/products developed in South Africa may be extended to SADC

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Introduction

- In SA, convection usually heat-driven = convective storms expected over summer-rainfall areas from 1200 UTC to late evening (2100 UTC)

- Other southern African countries, convective characteristics not necessarily in these time ranges, but there is convective maximum in late afternoon

- Air instability indices evaluate the potential of atmosphere for convection to occur
  - Convective potential is determined if instability indices exceed thresholds
  - Technique useful for SADC region is Combined Instability Index (CII)

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Introduction

- Due to lack of observation sites in Africa for evaluation of CII, World-Wide Lightning Location Network (WWLLN) data is used
  - Has global coverage of lightning occurrences

- Lightning locations used to evaluate CII values
  - Occurrence of lightning = confirmation of convective activity occurring
  - If convection in same areas as CII values, then CII gives good indication of convection
  - Evaluations done visually and quantitatively

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The CII product

- Is an adaptation of Regional Instability Index (RII) which is localized version of Global Instability Index (GII)
- Run on Unified Model (UM) on 0.1 degree resolution
- Based on satellite fields integrated with model fields into one product
- Indices are possible for entire SADC region – useful since data sparse region
- Only assesses likelihood of convective storms occurring in region in next few hours – used by forecasters to focus attention and monitor

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The CII product

- **<u>Disadvantages of CII:</u>**

➢ Only give values for cloud-free conditions → South Africa generally cloud-free in morning

➢ Cloud-free conditions not necessarily the norm in other SADC countries

- CII values calculated in time-averaged fields to reduce coverage loss due to clouds within single time-instance

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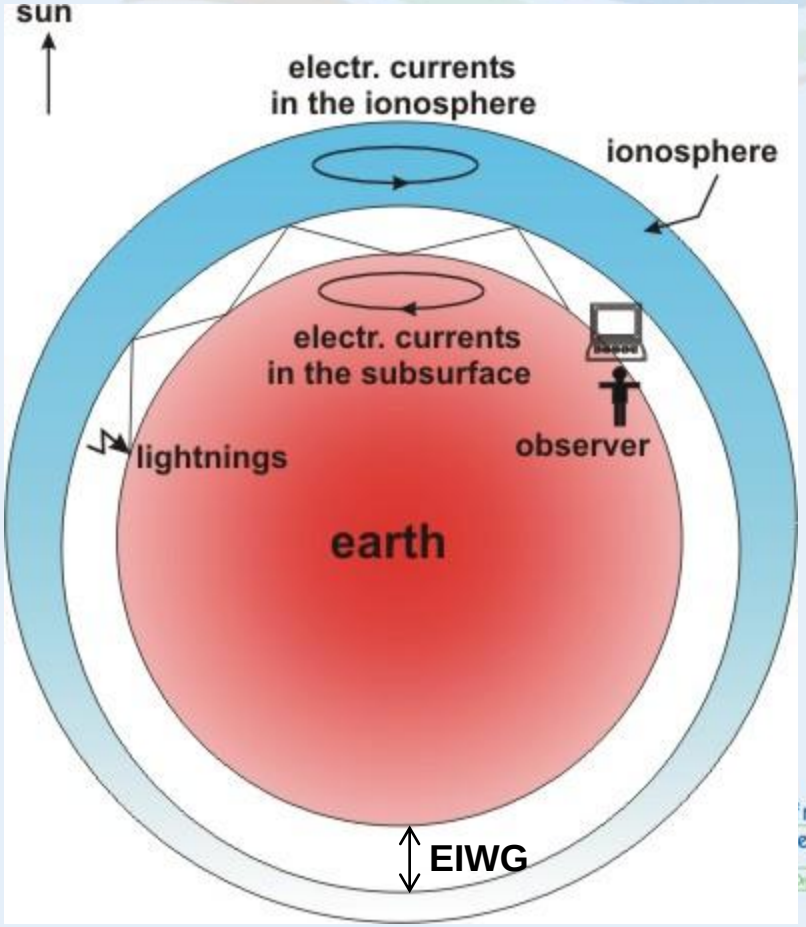
WWLLN lightning

- Lightning discharges are sources of electromagnetic energy over wide bandwidth
- Multi-station lightning location systems detect pulses with high location accuracy and detection efficiency

- Very Low Frequency (VLF) World-Wide Lightning Location Network (WWLLN) used for global lightning monitoring
- Electromagnetic energy propagates inside Earth-Ionosphere Waveguide (EIWG)
- WWLLN sensors conduct very long range remote sensing of lightning – 1000's kms



WWLLN lightning

- WWLLN network = more than 50 sensors around the world
- Location accuracy is 15 to 20km, or even better
- Sensors have intermittent service – detection efficiency and location accuracy of network fluctuates
- “High quality” lightning locations = events where at least 5 WWLLN stations participated

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WWLLN lightning

- Previous studies of WWLLN network to determine detection efficiency:
  - DE is very low – few percent of total lightning
  - DE vastly different for different places

- Reasons for discrepancies:
  - WWLLN receiver distribution = sparse and not uniform
  - Number of sensors increased during different evaluation phases
  - Diversity in networks used as ground truth in different countries – each has own limited DE
  - Each study conducted on different time scales and area sizes

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WWLLN lightning

- Useful to identify if convection is occurring but not necessarily where lightning occurring in individual convective cells

- Biased towards stronger lightning strokes

- Performance in detecting lightning at night and at day is different:
  - Changes in Ionosphere's density throughout day
  - Higher electromagnetic signal attenuation under daytime ionosphere = better detection at midnight than midday
  - 5 sensors required to determine lightning discharges
    - Some sensors triggered on daytime side of world, others triggered on nighttime side

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Data and Methods

- Evaluations of CII for SADC done for 8 case days during 2011/2012 summer period.

CII data

- Uses satellite, model data, precipitable water and topography in calculations
- Updated every 15 minutes due to high temporal resolution of MSG
- Only calculated in cloud-free conditions

- Three-hourly averages (0600 and 0900 UTC)

Lightning Data

- WWLLN lightning data used to verify CII
- Displayed from 1200 to 2100 UTC for SADC region
- Network detects more lightning at local midnight than noon, so DE could be less than expected

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Data and Methods

- 3 hour average of CII values between 0600 and 0900 UTC verified against number of WWLLN lightning flashes occurring between 1200 to 2100 UTC
  - Time frames consistent with previous verifications of CII in South Africa
  - Allow lead time of 3 – 12 hours for occurrence of convective storms

- Evaluations done visually and quantitatively

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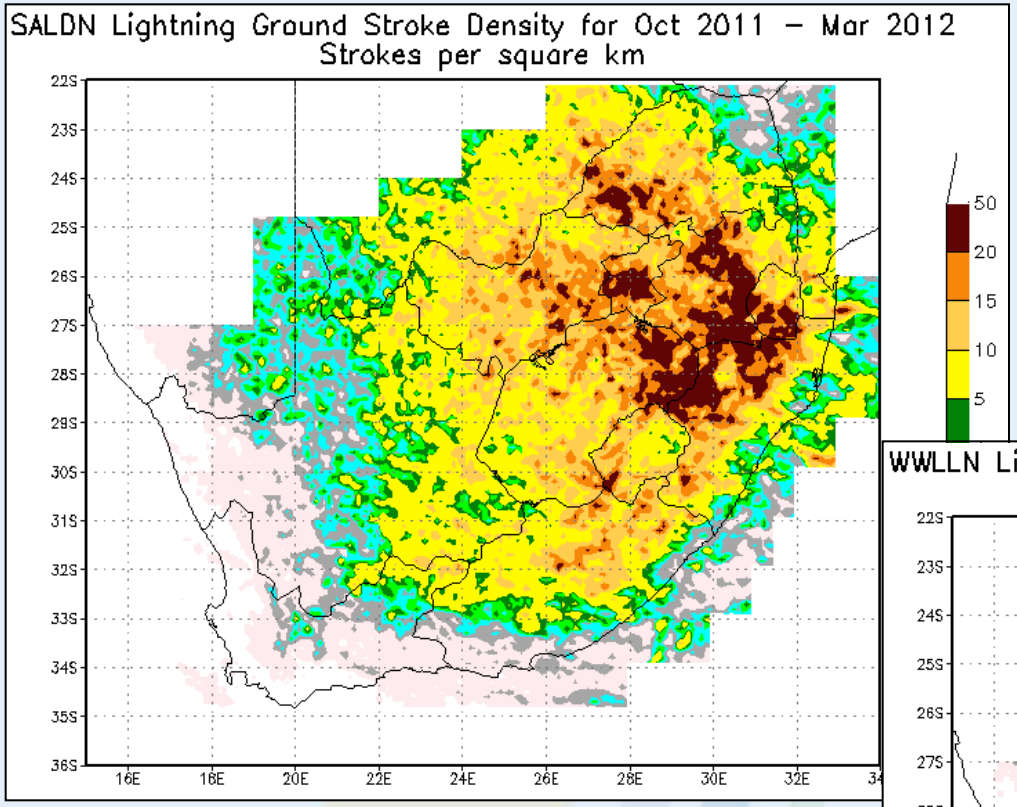
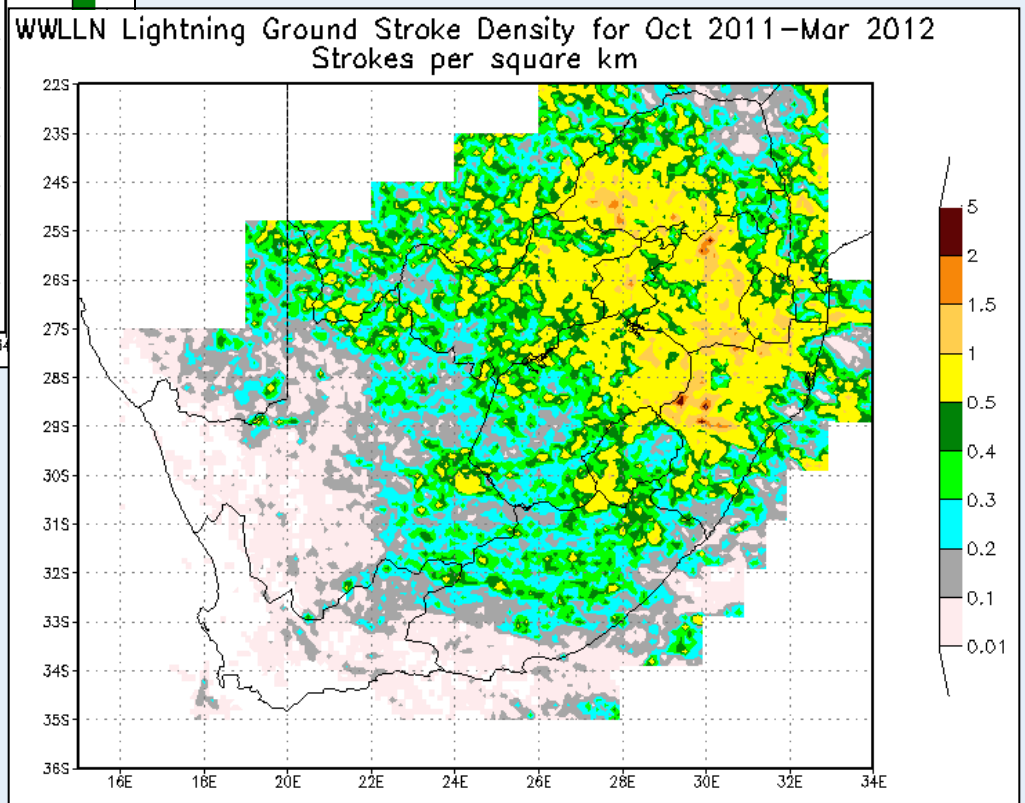
Detection efficiency



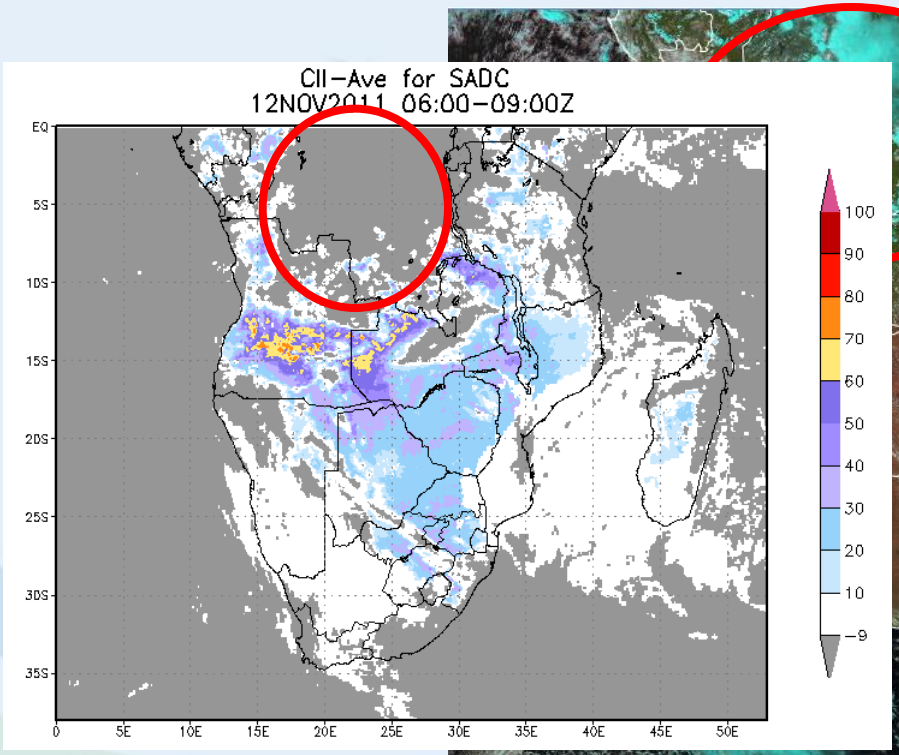
SALDN groundstroke densities:
0.1 to >50 strokes/km^2

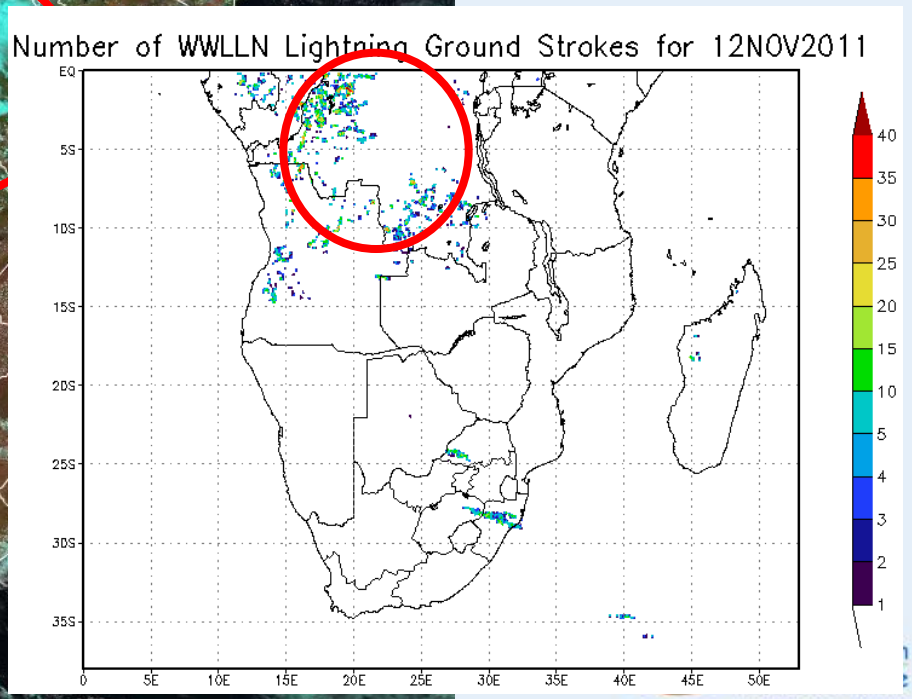


WWLLN ground stroke densities:
0.01 to >5 strokes/km^2

Case 1: 12 November 2011

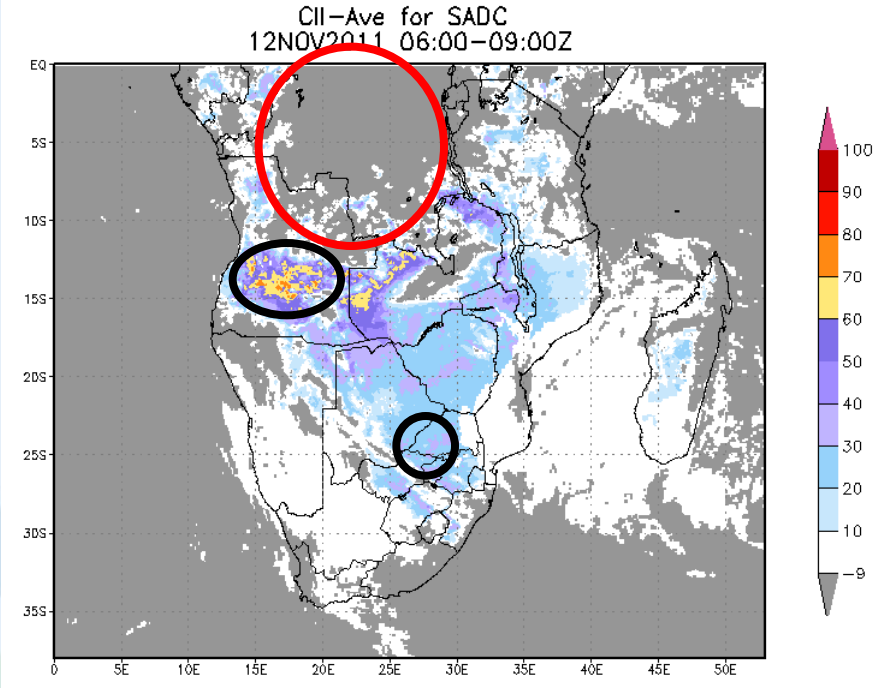
- Much cloud over equatorial regions = no CII values
- Lightning occurring in region of cloud cover – need satellite images to complement CII

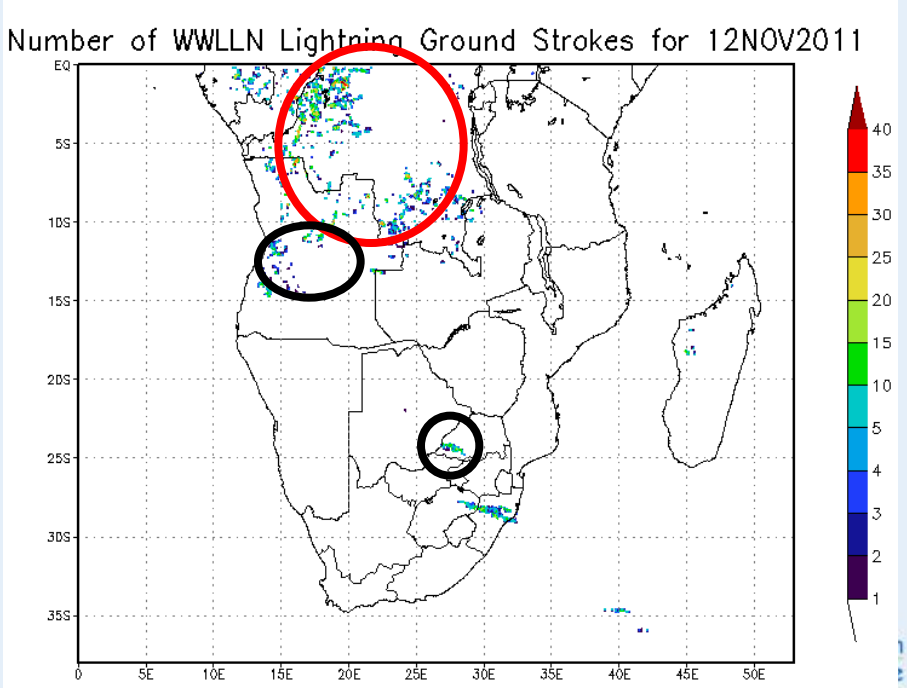




Case 1: 12 November 2011

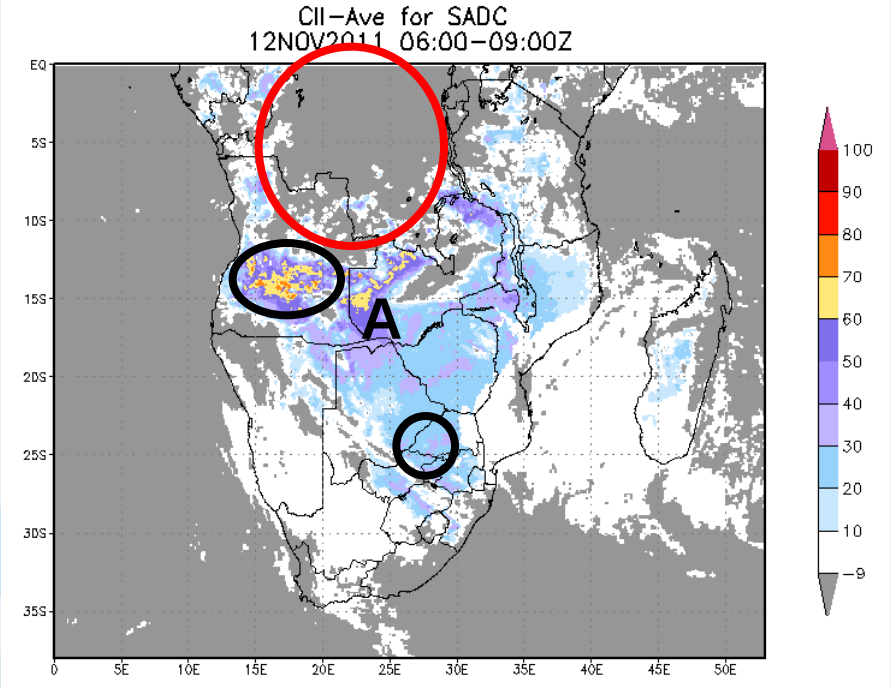
- Highest CII values indicated, locations correspond quite well with WWLLN lightning occurrences at those same locations

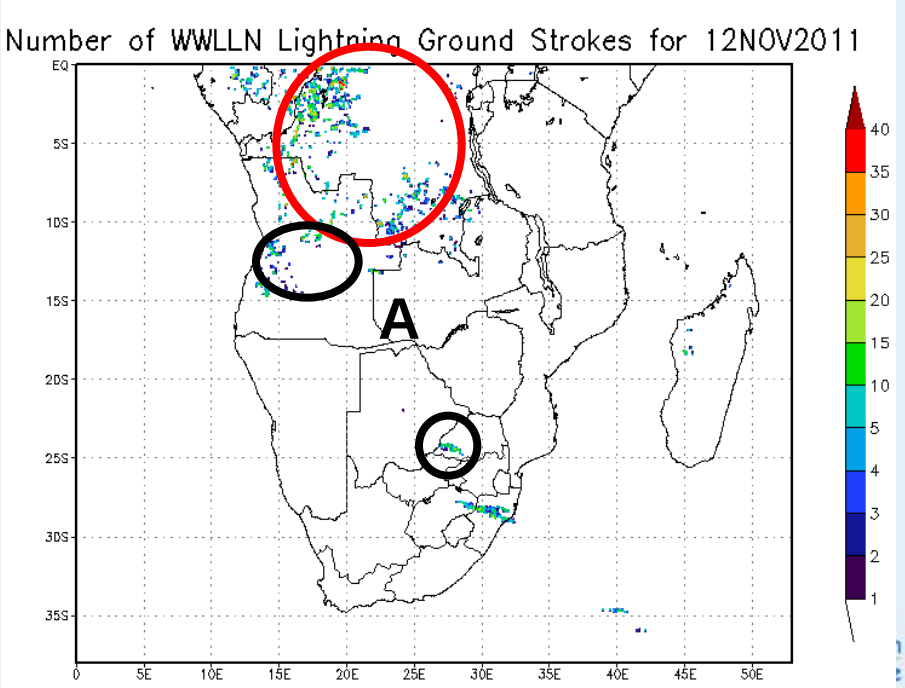




Case 1: 12 November 2011

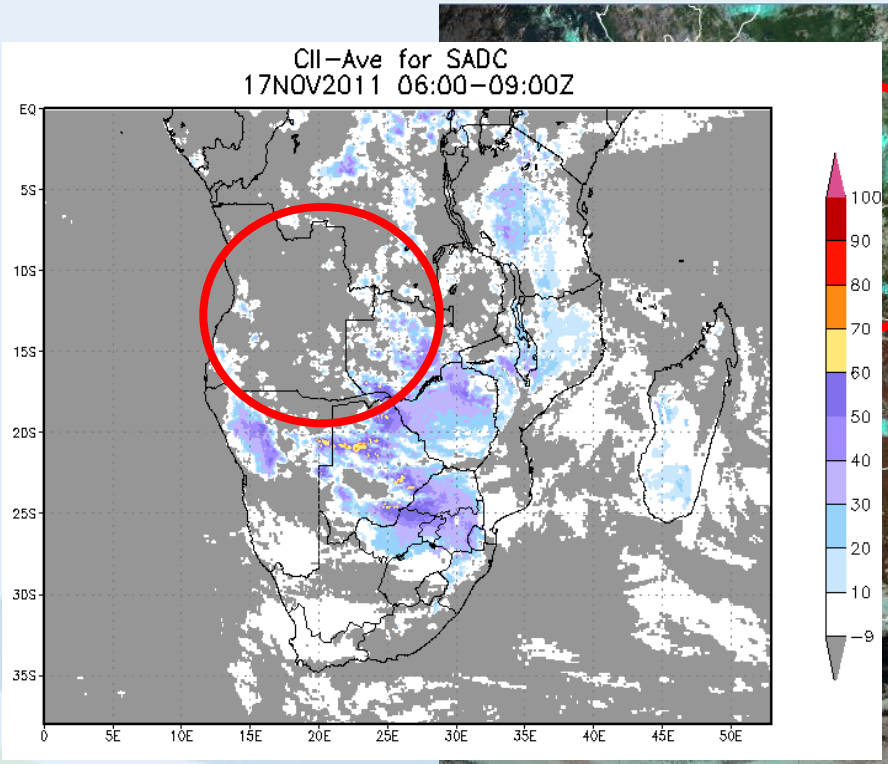
- Some locations with CII values 40% or higher, but did not correspond with lightning locations
  - WWLLN lightning network only picks up 10% of actual lightning in particular location
  - CII values only used to give forecasters indication where convection likely = where they should focus attention

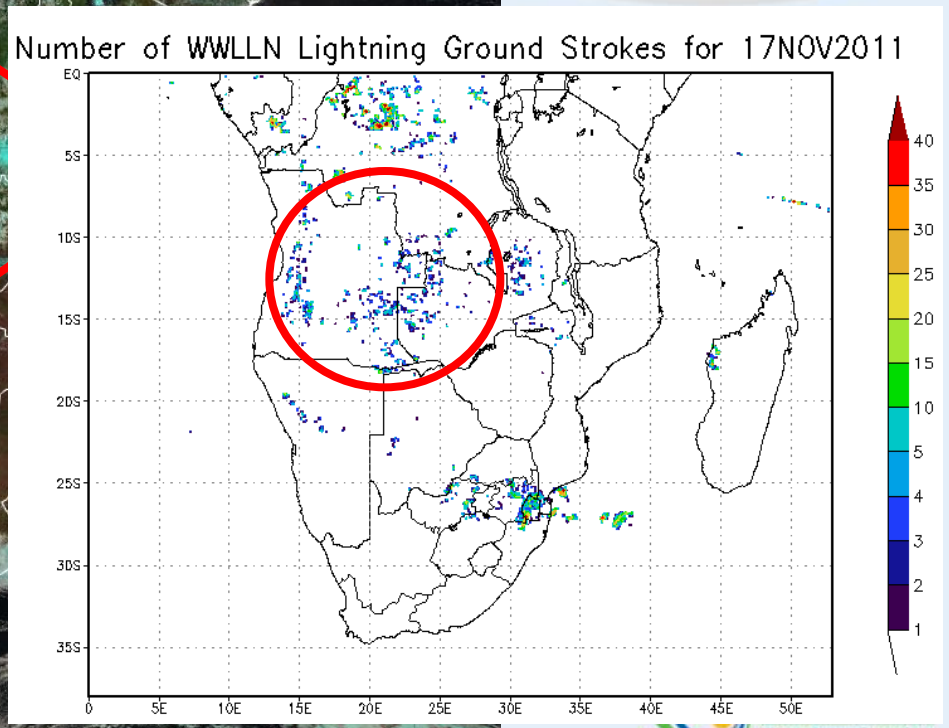




Case 2: 17 November 2011

- Cloud cover over Angola and into surrounding countries
- CII values only for cloud-free conditions





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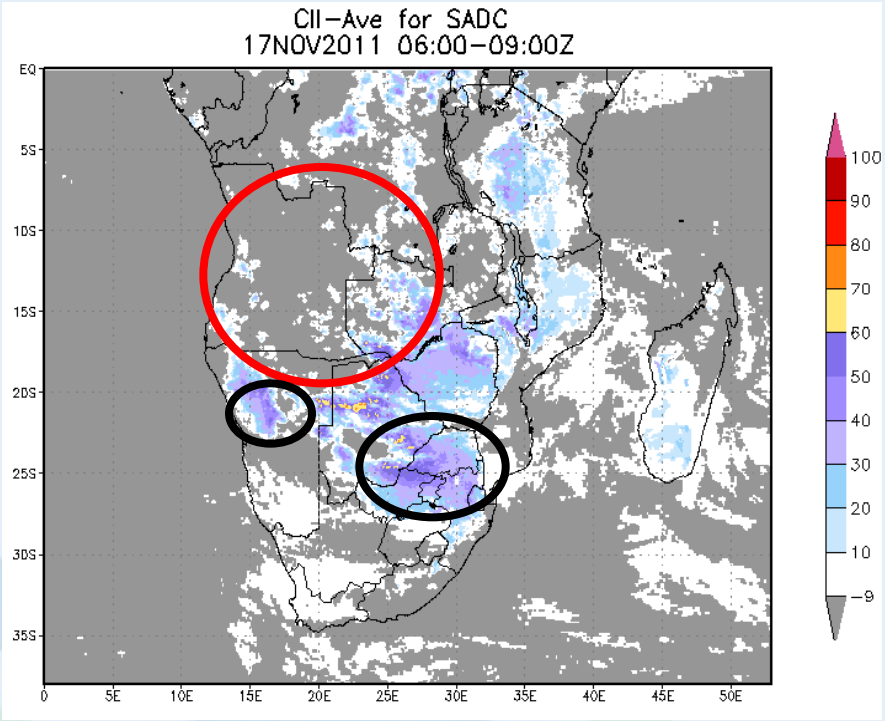
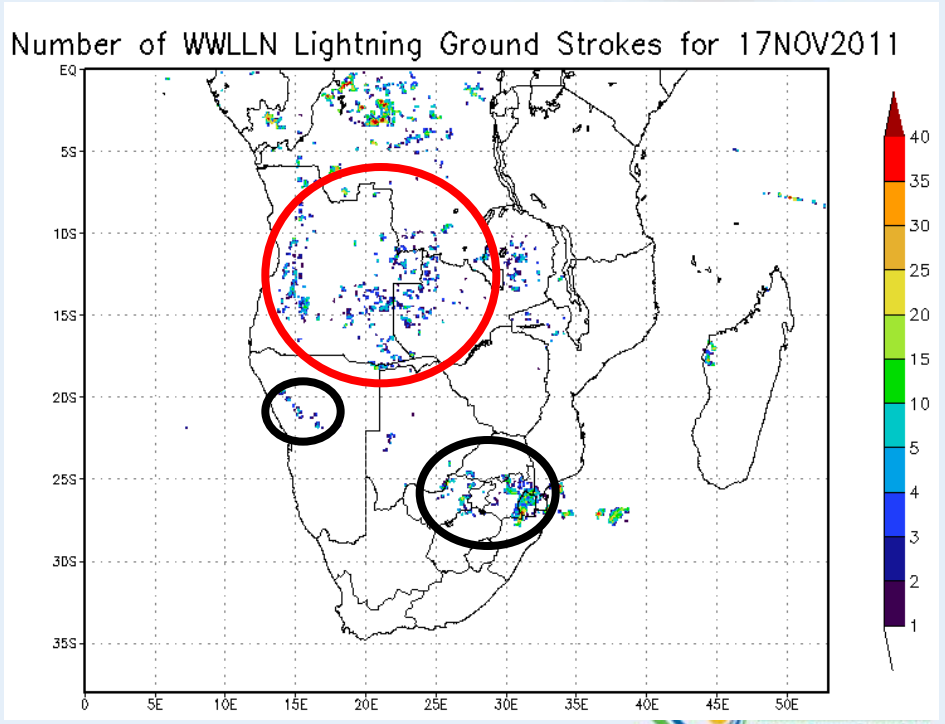
Case 2: 17 November 2011

- Significant CII values (40% and larger) correspond well with WWLLN lightning locations





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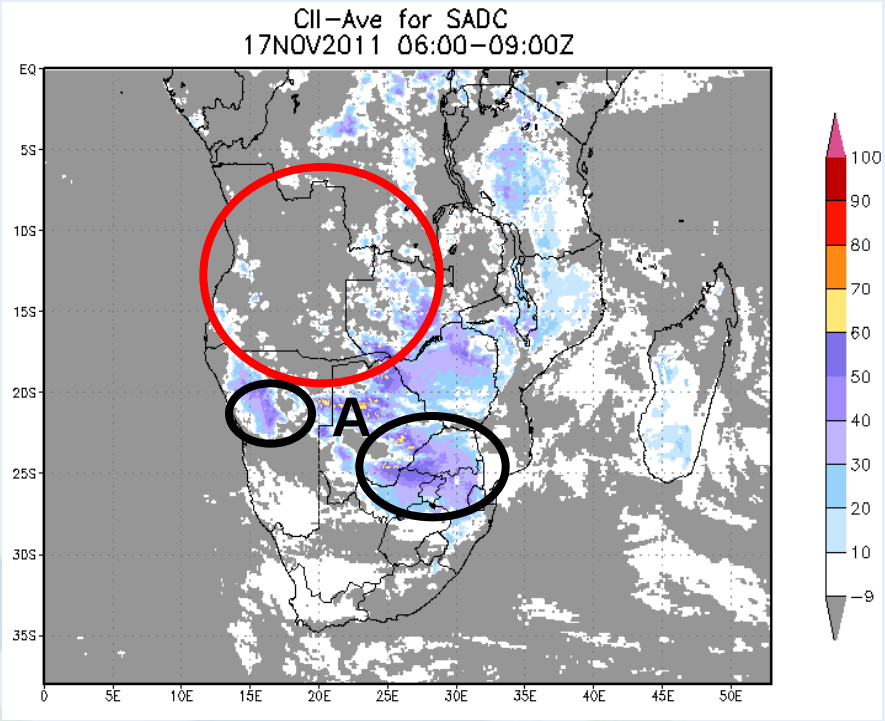
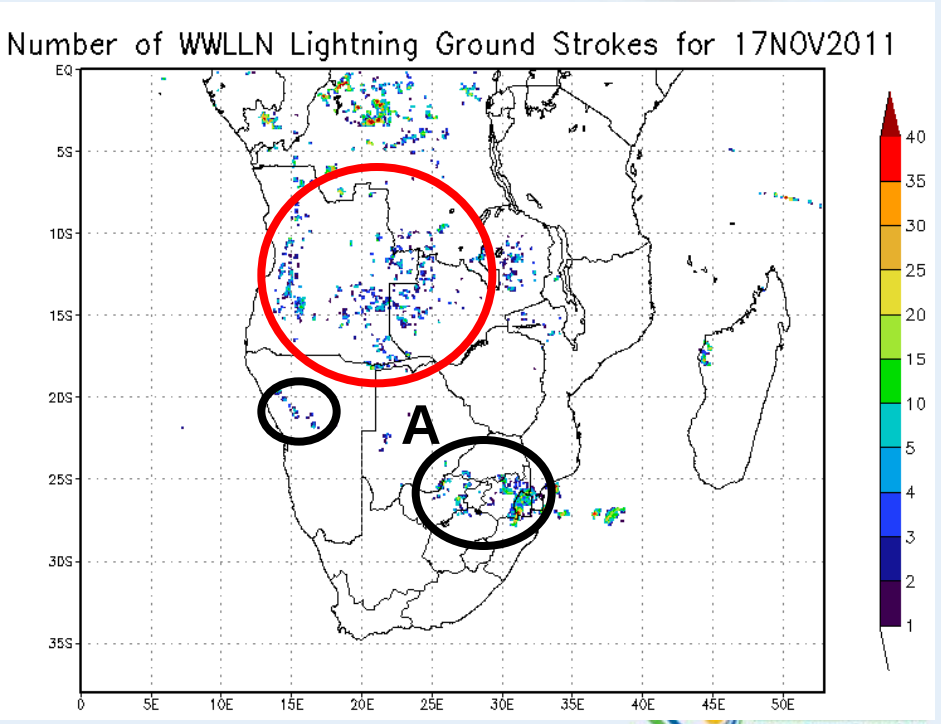
Case 2: 17 November 2011

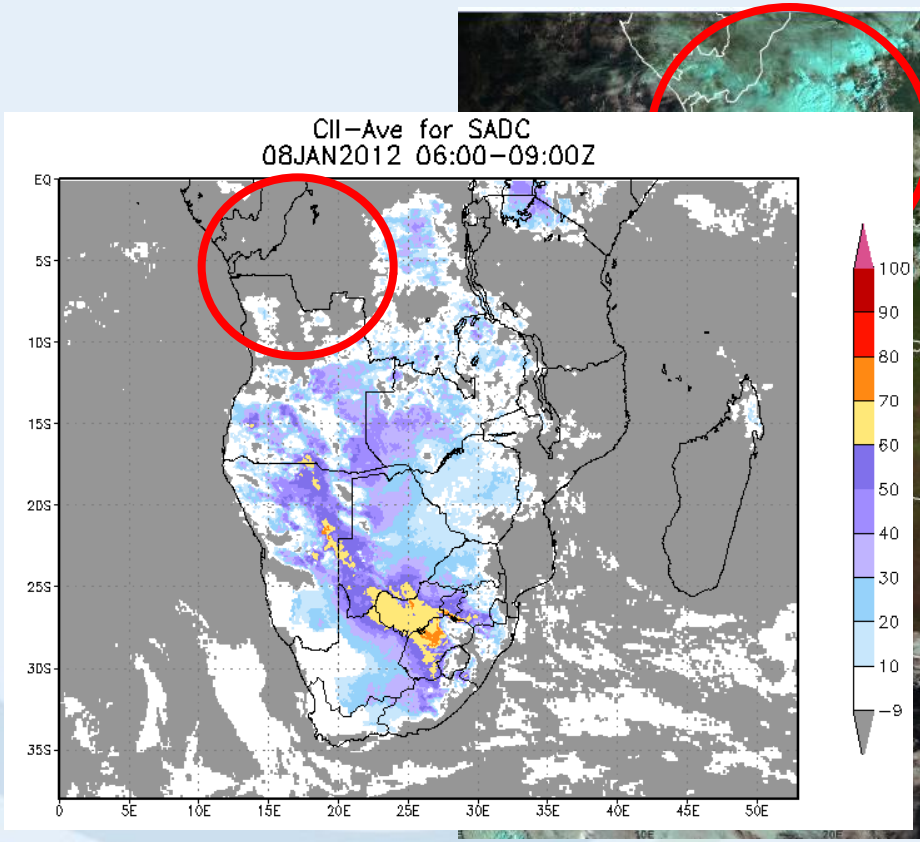
- Some CII locations do not correspond with any lightning locations. This is due to:
  - Small detection efficiency of WWLLN lightning network
  - CII product is only an indicator of possible convection occurring.

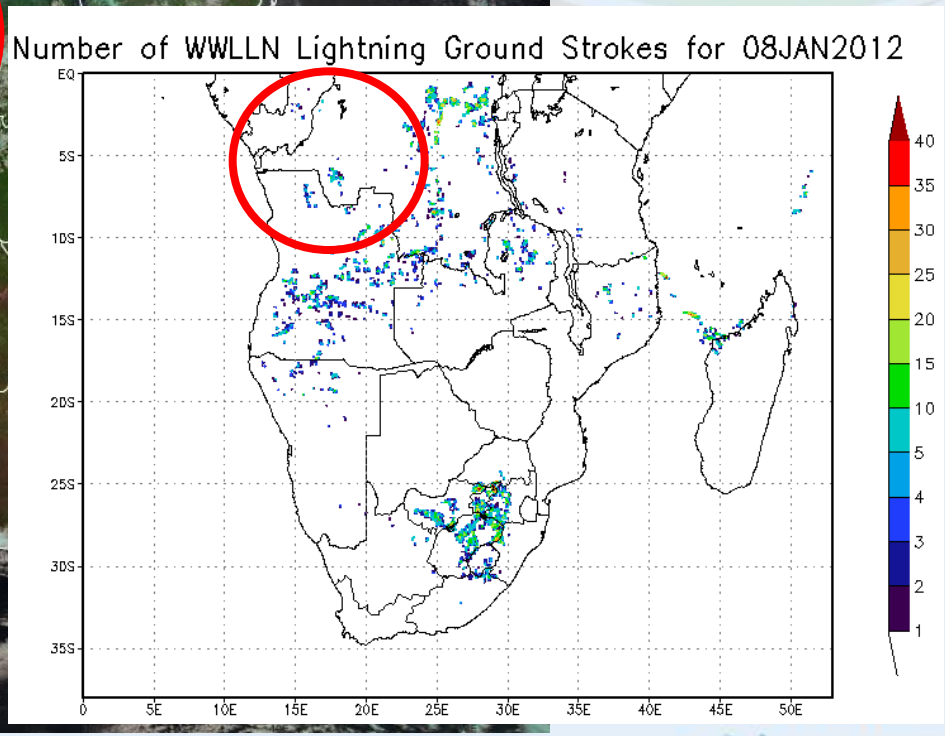




Case 3: 8 January 2012

- Much cloud in equatorial regions
- No CII values in cloudy areas, but convection is occurring according to WWLLN





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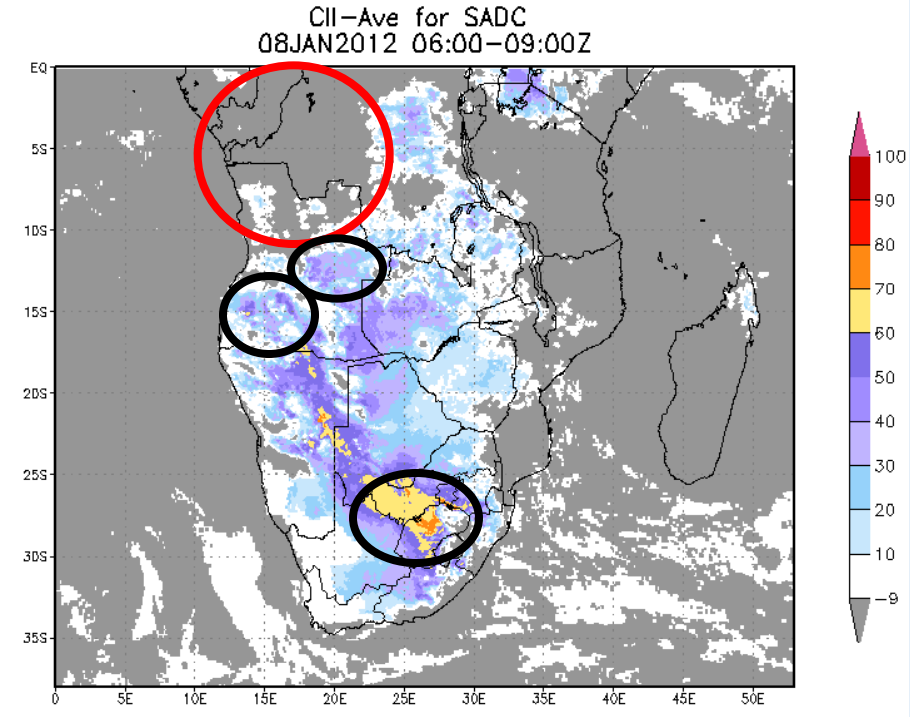
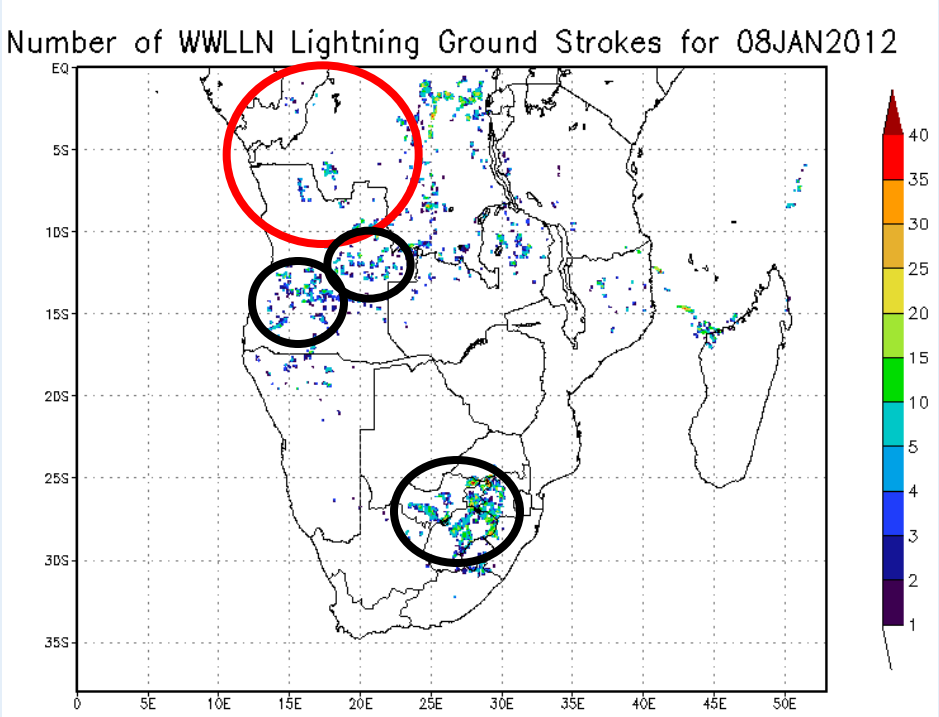
Case 3: 8 January 2012

- Still fairly good correlation between CII areas and lightning observations
- Much value to CII product for SADC region.





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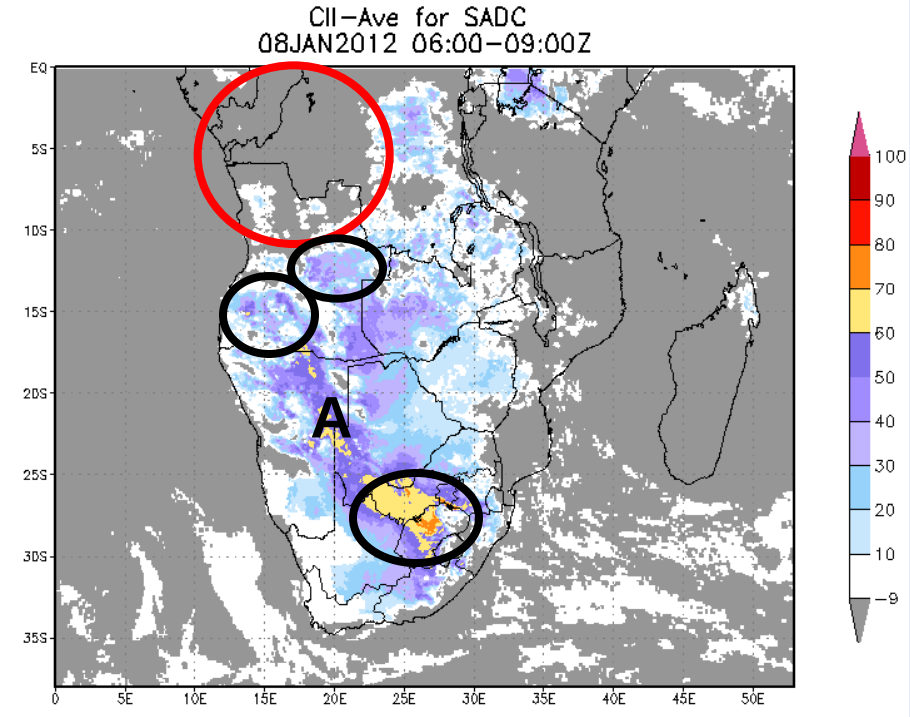
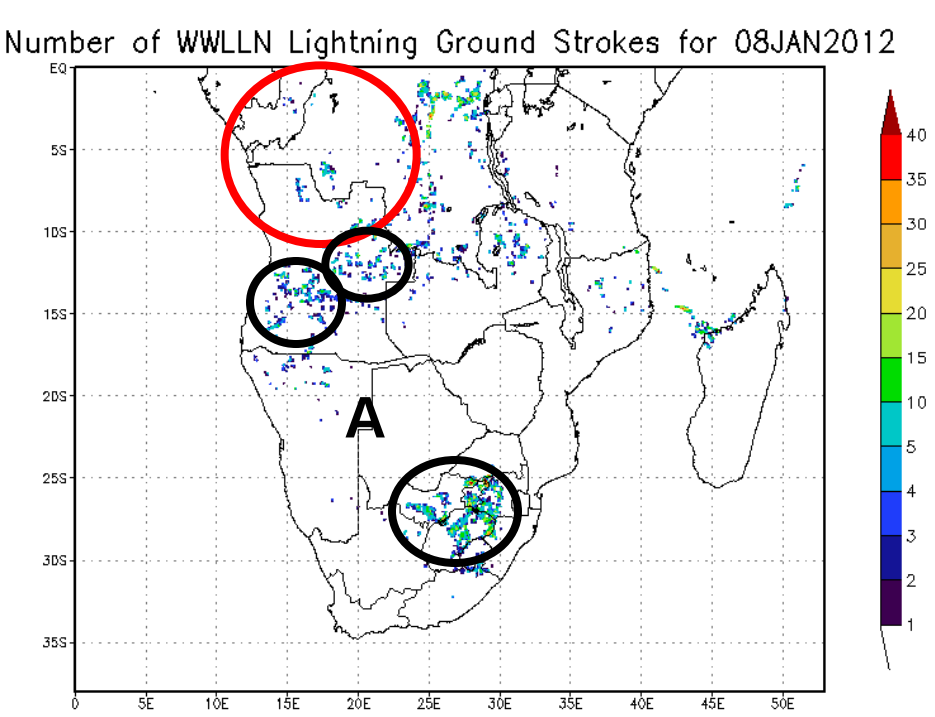
Case 3: 8 January 2012

- Areas of significant CII with no corresponding lightning





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Statistical evaluations

- CII maps evaluated pixel-by-pixel against WWLLN lightning data maps
- With each successive increase in CII threshold values:
  - Hits decrease
  - false alarms decrease
  - correct non-events increase
  - misses increase
- Confirms the visual analyses

TABLE: Statistical scores for different CII thresholds for 12 November 2011

Threshold	Hits	Correct non-events	False Alarm	Misses
10	600	8290	24035	496
20	439	14777	17548	657
30	241	25020	7305	855
40	144	29018	3307	952
50	86	30460	1865	1010
60	43	31587	738	1053
70	7	32240	85	1089

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Statistics

- Each successive increase of CII threshold values:
  - POD decreases
  - POFD improves
  - FAR remains high (greater than 90%)
  - Bias improves

TABLE: Statistical scores for different CII thresholds for 12 November 2011

Threshold	POD	POFD	FAR	BIAS
10	0.55	0.74	0.98	22.5
20	0.4	0.54	0.98	16.4
30	0.22	0.23	0.97	6.89
40	0.13	0.1	0.96	3.15
50	0.08	0.06	0.96	1.78
60	0.04	0.02	0.94	0.71
70	0.01	0	0.92	0.08

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Statistics

- All case studies for 40% CII threshold:
  - POD between 10% and 30%
  - FAR more than 87%
  - Positive bias and larger than 1
- Statistics indicate CII performed poorly

- Grid-point by grid-point statistical evaluation method is strict and not ideal for evaluating CII maps

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Statistics

- Factors that affect statistics:
  - CII data affected by cloud cover → large amount of cloud cover = less forecasted areas
  - WWLLN lightning data is only 10% of actual lightning occurring = significant reduction in number of observations that could be possible, thus large FAR and low POD

- Visual evaluation is best evaluation method as allows for human discretion when analyzing CII locations

Conclusions

- Number of limitations of CII product
- Is only a tool to get indication of areas where convection is likely to occur

- WWLLN data has many limitations as well
- Useful in identifying where convection is occurring
- Using WWLLN data to evaluate CII for SADC region is suitable
- However, WWLLN network only detects 10% of lightning = limited observations = affects grid-point by grid-point evaluations

- Visual evaluations are best = allows human discretion
- CII performs quite well across SADC region in predicting convective locations with lead time between 3 and 12 hours

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