Statistical Analysis of the Existence of Thundersnow and Snow-to-Liquid Ratios

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Introduction

- Satellite imagery is not traditionally used to anticipate and forecast winter weather, rather reliance on model data and radar imagery is more common
- Subjective thundersnow (TSSN) studies have demonstrated the occurrence of phenomenon with potential maximum snowfall accumulations, relative snowfall rates and even a climatology
- No studies have examined the correlation between TSSN and snow-to-liquid ratio (SLR) values
- Currently, SLR values are determined by daily observations, from weather observers, from Cooperative Summary of the Day (COOP) stations
- Estimating SLR values is crucial in understanding snowfall rates and potential hazardous surface conditions (i.e. low visibility, slick/ice road conditions)
- Objectively understanding the correlation between TSSN, SLR values, snowfall rates and accumulation increases situational awareness for forecasters

Products/Sensors

- **NESDIS merged Snowfall Rate (mSFR) Product:**
  - Developed with AMSU, MHS, ATMS, and SSMIS, GMI microwave measurements
  - Blended with Multi-Radar Multi-Sensor (MRMS) precipitation rate associated with snow flag
  - Detect snowfall rates up to 2 in/hr
  - Spatial/temporal resolution: 1x1 km, 10 min
  - Can be used to track snowfall rate maxima
  - Can be used to anticipate rain to snow transitions or detect cloud seeding before snow reaches the surface
- **Lightning:**
  - Geostationary Lightning Mapper (GLM)
  - Spatial/temporal resolution: ~8km, 2 ms
  - Flash, Group, Event data increments
  - Operationally available for the first time during the 2017-2018 winter
  - Can GLM data be used to anticipate SLR values, snowfall rates, potential snowfall accumulation?

High Resolution Snow-to-Liquid Ratio Values Methodology

- Low spatial resolution SLR values derived from COOP stations using Roebber et al. 2003 method (Fig. 1)
- High spatial resolution SLR value estimates needed to perform analysis
- Utilization/aggregation of mSFR over time provides estimated quantitative precipitation estimate (QPE) for snowfall cases
- Observed snowfall accumulation and mSFR QPE used to created high resolution SLR values (Fig. 2)

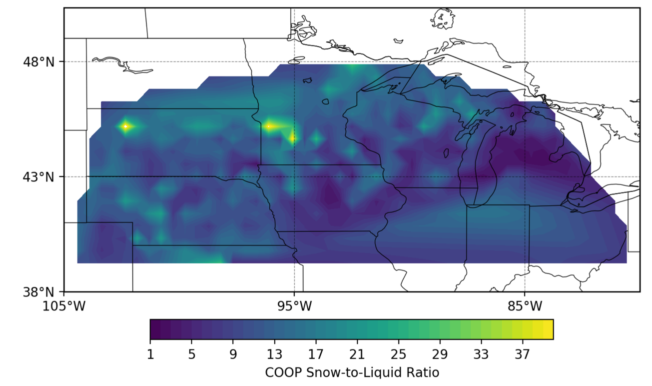

Fig. 1: Linear interpolated COOP SLR values (snowfall accumulation/liquid equivalent) for the 13 April 2018 Midwest Blizzard

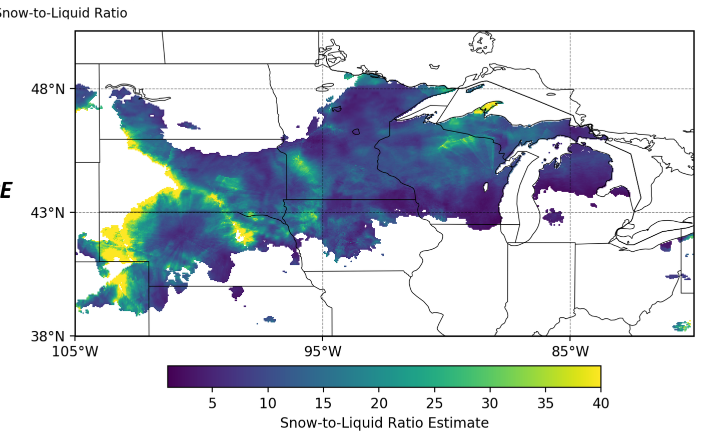

Fig. 2: High resolution SLR estimates utilizing mSFR QPE and snowfall accumulation for the 13 April 2018 Midwest Blizzard

- Validation needed for derived SLR values
  - Validated against Baxter et al. 2005 results (Fig. 3)
  - Justification of using derived SLR instead of COOP SLR values
- Derived SLR climatology, based on 19 snowfall cases, from January-April 2018 (Fig. 4)
  - Events range from Nor'easters, Blizzards, and convective snowfall in Great Plains Region
  - Similar SLR value distribution compared to Baxter et al. 2005
- SLR Climatology:
  - Results in a higher spatial resolution and statistically similar SLR value compared to traditional SLR methodology
  - Mean: 14.52, Median: 12.57, 25^{th}: 9.05, 75^{th}: 17.71 (derived)
  - Mean: 13.53, Median: 12.14, 25^{th}: 9.26, 75^{th}:16.67 (literature)

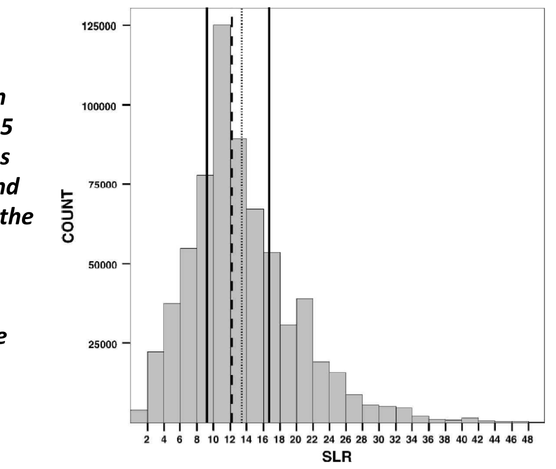

Fig. 3: SLR value climatology from Baxter et al. 2005 (Fig 9). Solid lines represent 25^{th} and 75^{th} percentiles, the long dashed line represents the median, and the short dashed line represents the mean.

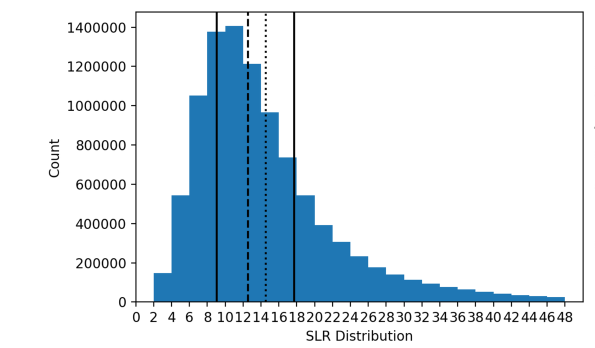

Fig. 4: Derived SLR climatology from snowfall accumulation and mSFR QPE values. Vertical lines same as in Fig. 3.

Snowfall Accumulation and Snow-to-Liquid Ratio Characteristics

- Objectively identified TSSN based on GLM and mSFR overlap rather than using trained weather observer reports (Fig. 5)
- GLM seasonal TSSN similar to Market et al. 2002 TSSN climatology (Fig. 6)
- TSSN characteristics (i.e. SLR, snowfall accumulation) based on highest confidence of GLM data being TSSN

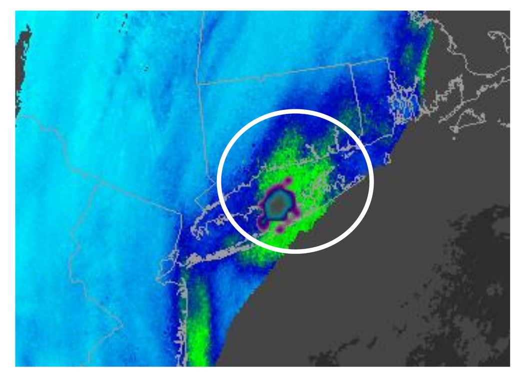

Fig. 5: GLM data overlaid on mSFR product in AWIPS at 2018-01-04 1410 UTC

Probability of Detection
Algorithm: 87.2%
GLM:100%

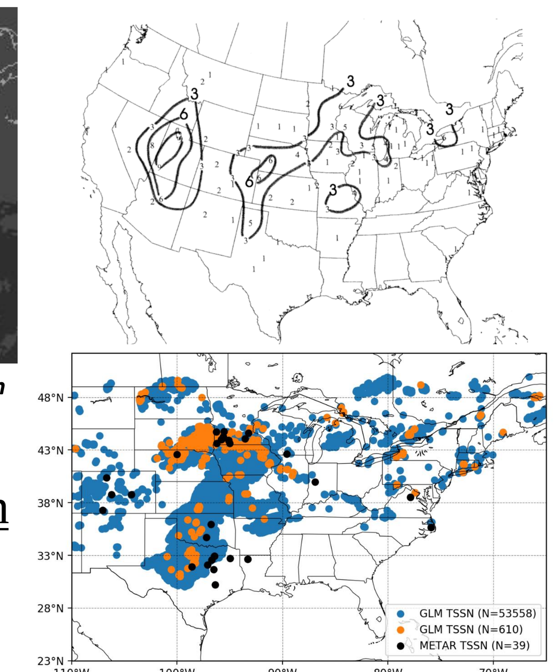

Fig. 6: TSSN climatology comparison

- TSSN Snowfall Accumulation Distribution (Fig. 7)
  - Mean: 10.14, Median: 9.91, 25^{th}: 7.57, 75^{th}: 12.54
  - Approximately Gaussian distributed
- Existence of TSSN suggests that forecasters can expect on average ~10" of snowfall where TSSN occurred
- TSSN SLR distribution (Fig. 8)
  - Mean: 14.17, Median: 11.49, 25^{th}: 8.53, 75^{th}: 16.49
- TSSN occurring in high SLR values compared to lower SLR value (i.e. dendrites vs. needles/bullets)
- Daily SLR values might not be representative of environment in which TSSN occurs given that lightning occurs on several orders of magnitude smaller time scales

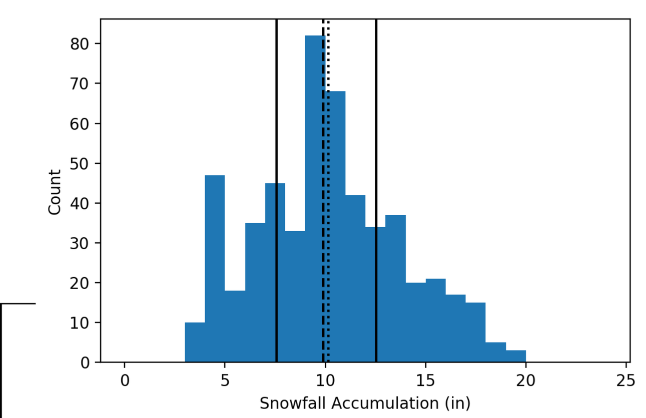

Fig. 7: Snowfall accumulation in areas that experienced TSSN. Vertical lines same as in Fig 3.

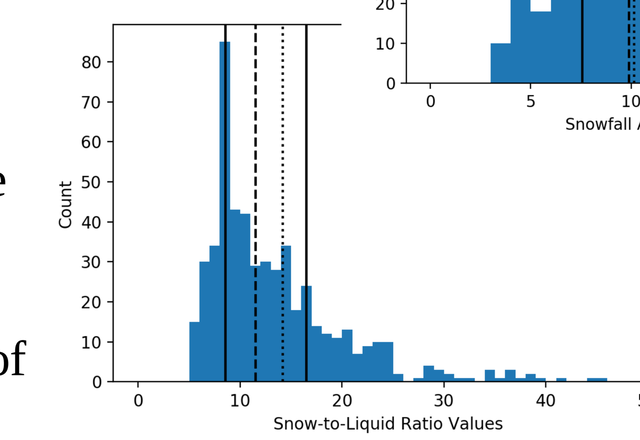

Fig. 8: SLR values in areas that experienced TSSN. Vertical lines same as in Fig 3.

Snowfall Rate and Geostationary Lightning Mapper Characteristics

- Snowfall rates have also been characterized based on the existence of TSSN (Fig. 9)
- Suggests that TSSN is occurring in snowfall rates less than 1 in/hr assuming a 10:1 SLR
- TSSN is also occurring on the south side of the snowbands (Fig. 10) similar to results in Rauber et al. 2014
  - Likely caused by existence of supercooled water in that region

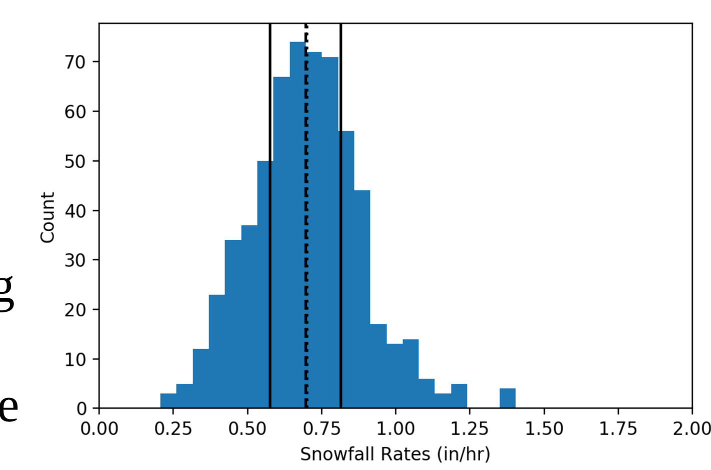

Fig. 9: Snowfall rate distribution of areas that experienced TSSN. Vertical lines same as in Fig 3. Data is approximately Gaussian Distributed.

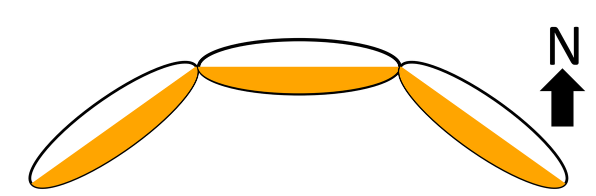

Fig. 10: Simply diagram to highlight were TSSN is more likely to occur in snowband (i.e. orange area)

- No significant correlation between GLM Flash Energy/Area and physical TSSN characteristics (i.e. snowfall rates, etc.)
- Distinct pattern between GLM Flash Energy and Flash Area and TSSN has less variability between the two variables (Fig. 11)
- Potential ability to separate TSSN and non-TSSN lightning, based purely on GLM observations, if more GLM variables are incorporated
- More analysis needs to be done regarding the connection between GLM variables and physical process associated with heavy-banded snowfall

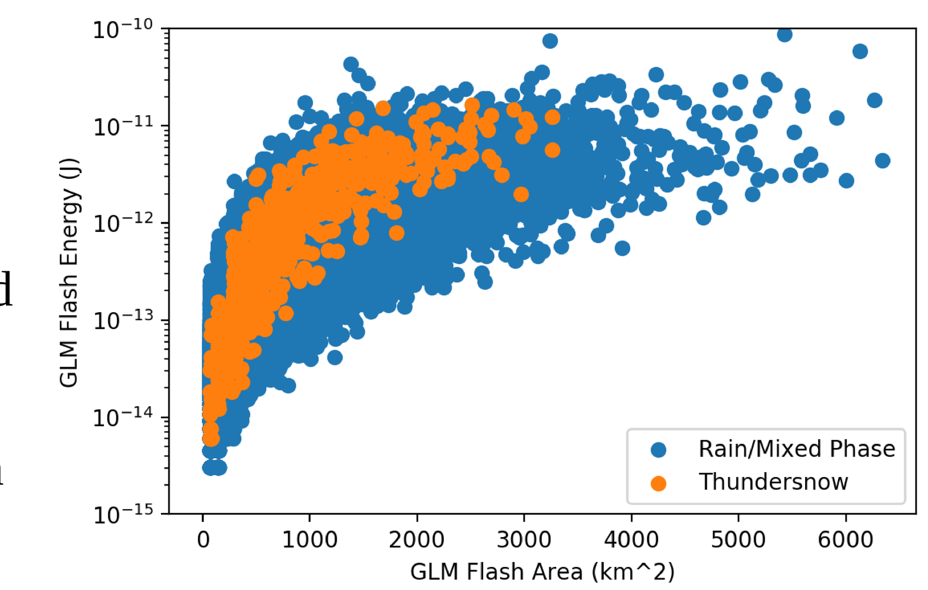

Fig. 11: GLM Flash Area vs Flash Energy. Less variability in high confidence TSSN compared to low confidence TSSN/non-TSSN lightning

Summary and Future Work

- TSSN occurring in high SLR values compared to lower SLR values
  - i.e. dendrites vs. needles/bullets
- Forecasters can expect an area to receive at least 5" of snowfall with an average of ~10" of snowfall accumulation when and where TSSN occurs
- TSSN more likely to occur in lower snowfall rates and on the southern facet of the synoptic banded snowfall regardless of band orientation
- GLM seasonal TSSN matches well with TSSN climatology from Market et al. 2002
- Understanding how next-generation satellite instruments can be used to identify TSSN characteristics will lead to further development of innovative products tailored to increasing situational awareness of high impact events
- Continue investigating connections between physical process in heavy-snowfall and GLM as part of Master and PhD work

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