

Thirty-plus (30+) Years of Snowstorm Climatology Obtained from MERRA Reanalysis



Abstract

Thirty-seven (37) years of blizzard-like snowstorms are identified and individually tracked using NASA's Modern Era Retrospective-analysis for Research and Applications (MERRA) reanalysis hourly data with a spatial resolution of half (1/2) degree in latitude by two-thirds (2/3) of a degree in longitude. We have gathered not only summary statistics for all storms, such as frequency distributions of storm duration and cumulative area coverage, but also per-event statistics for each storm, e.g. beginning/ending times, hourly locations, and hourly mean snowfall intensities. This work is greatly benefited by technology projects funded by NASA Advanced Information Systems Technology (AIST) program and facilitated by a Big-Data technology, SciDB. We have constructed a Google Maps application (App) marking the hourly locations of each snowstorm and annotating them with hourly statistics. Moreover, whenever coincident data granules of relevant satellite remote-sensing observations are found within the NASA metadata repository, i.e. EOS Clearing House (ECHO), the FTP URLs of these data granules are also included as annotations to corresponding hourly locations. Since the App runs on the server side and utilizes browser-based visualization, it can be executed on smart phones. With such an App, researchers studying snowstorms will be able to conveniently find the storms matching their research interest and criteria. In addition, they can easily and quickly obtain coincident data granules from NASA's vast satellite remote sensing data holdings. There are other more far-reaching implications with this type of effort, which we will elucidate in our presentation.

Our Innovation

Event-based versus Presence-based approach

- Presence-based approach can tell whether a grid cell satisfies the criteria for a given phenomenon (e.g. blizzard).
 - It **cannot** tell whether two cells satisfying the criteria, but separated by space and time, belong to the same episode of the phenomenon!
- Event-based approach applies connectivity criteria to cells satisfying the criteria and track their development to recognize and form distinct episodes.

MERRA Datasets Used

Resolutions:

- Spatial resolution
 - 1/2° × 2/3° in latitude × longitude (540 × 361 spatial grid)
- Temporal resolution
 - 1 hour, except for **MACONXCNS**, which is time-independent
 - ≥300,000 hours for ~37 years (January 1979 – November 2015)

| Short Name | Name | Brief Description |
|------------|------------------|---|
| MACONXCNS | const_2d_asm_Nx | 2D constants |
| MAT1NXFLX | tavg1_2d_flux_Nx | 2D surface turbulent flux diagnostics |
| MAT1NXLND | tavg1_2d_lnd_Nx | 2D land surface diagnostics |
| MAT1NXSLV | tavg1_2d_slv_Nx | 2D atmospheric single-level diagnostics |

Variables Used

| Dataset | Variable | Description | Study |
|-----------|----------|--|---------|
| MACONXCNS | AREA | Area of grid box | This DY |
| | FRLAND | fraction of land type in grid box | This DY |
| MAT1NXFLX | FRSEAI | Fraction of sea-ice | This DY |
| | PRECSNO | Surface snowfall flux | This DY |
| | PRECTOT | Total surface precipitation flux | This DY |
| MAT1NXLND | SNODP | Snow depth | This DY |
| MAT1NXSLV | U10M | Eastward wind at 10 m above displacement height | This DY |
| | V10M | Northward wind at 10 m above displacement height | This DY |
| | T2M | Temperature at 2 m above displacement height | DY |
| | TS | Surface skin temperature | DY |

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Derived Variables

| Description | Variable | Definition |
|--|----------|---|
| 10-m wind speed | S10M | $(U10M^2 + V10M^2)^{1/2}$ |
| Snowfall rate in mm·hr ⁻¹ | SRATE | PRECSNO × 3.93 × 10 ³ |
| Extinction cross section due to falling snow | FSBETA | 3.912 × SRATE / 10 ³ |
| Extinction cross section due to blowing snow | BSBETA | 10 ⁻⁴ × 1.4428 ^{S10M} |
| Visibility | VIS | 3.912 / (FSBETA + BSBETA) |

NWS Blizzard Criteria

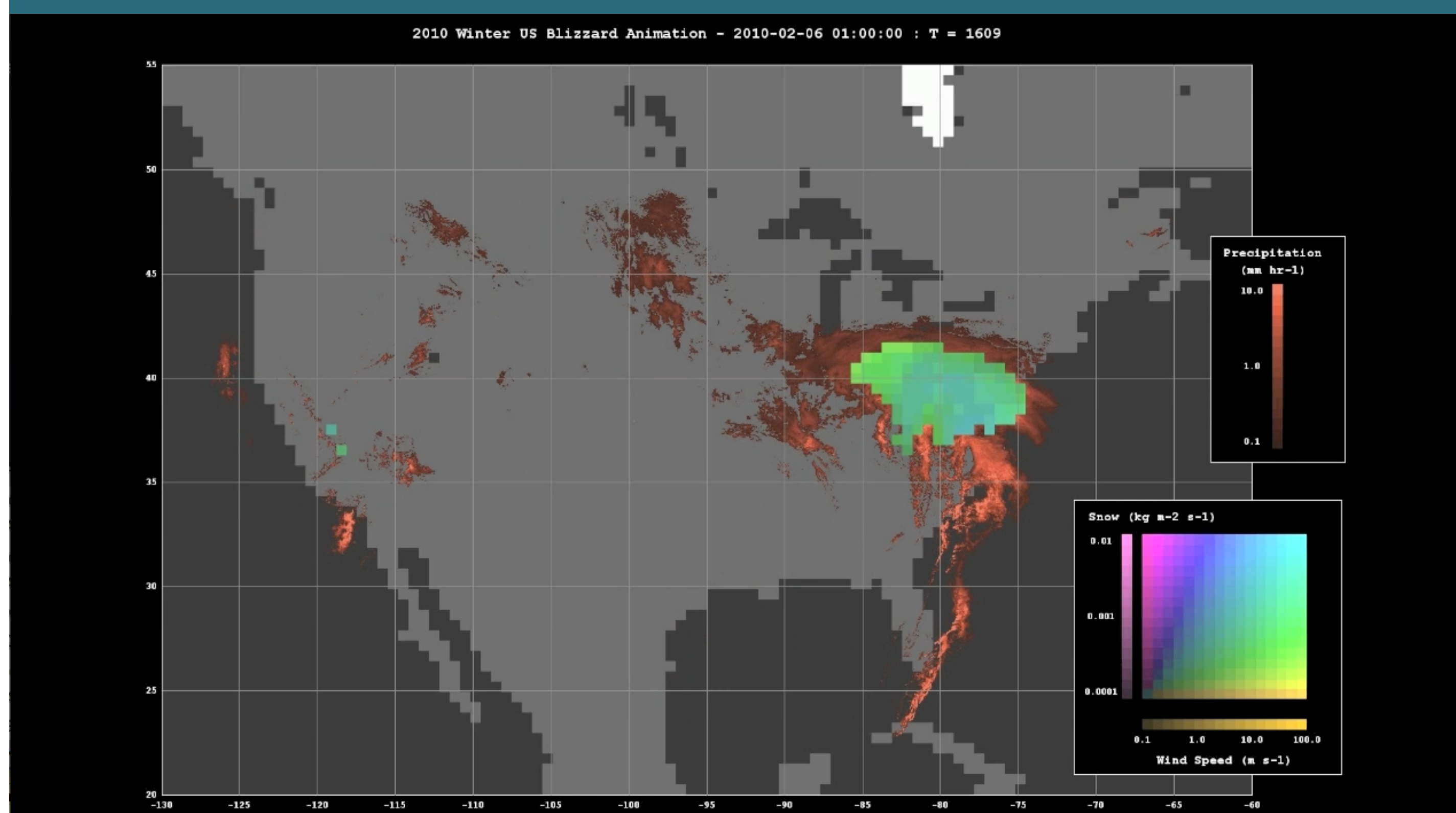
According to NWS, a blizzard means that the following conditions are expected to prevail for a period of 3 hours or longer:

- **Sustained** wind or **frequent** gusts to 15.6 m/s (35 mph) or greater; and
- **Considerable** falling and/or blowing snow, i.e., reducing visibility **frequently** to less than 400 m (1/4 mile)

Numerical Blizzard Criteria Used on MERRA

| Phenomenon | Criterion |
|------------------------|--|
| Blowing snow possible | • (FRLAND > 0.5 or FRSEAI > 0.5) and • SNODP > 0.03 |
| Falling snow condition | • PRECSNO = PRECTOT and PRECSNO > 0 |
| Blizzard | • VIS < 945.36 • Lasting 3 hours or longer |

Snapshot of "Snowmageddon"

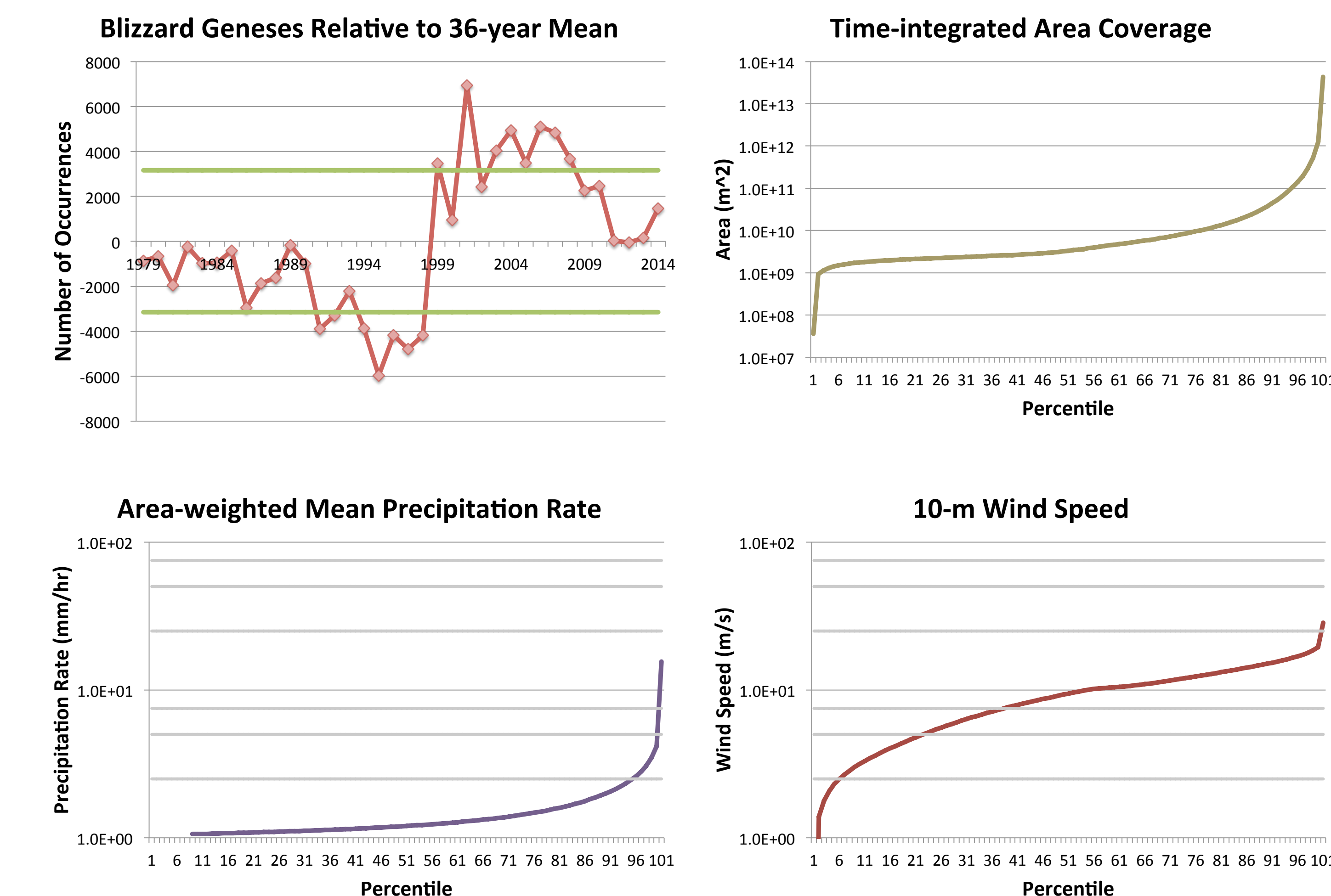


The image is generated for a time slice during the "Snowmageddon" event on the East coast of the United States in February 2010.

Acknowledgement

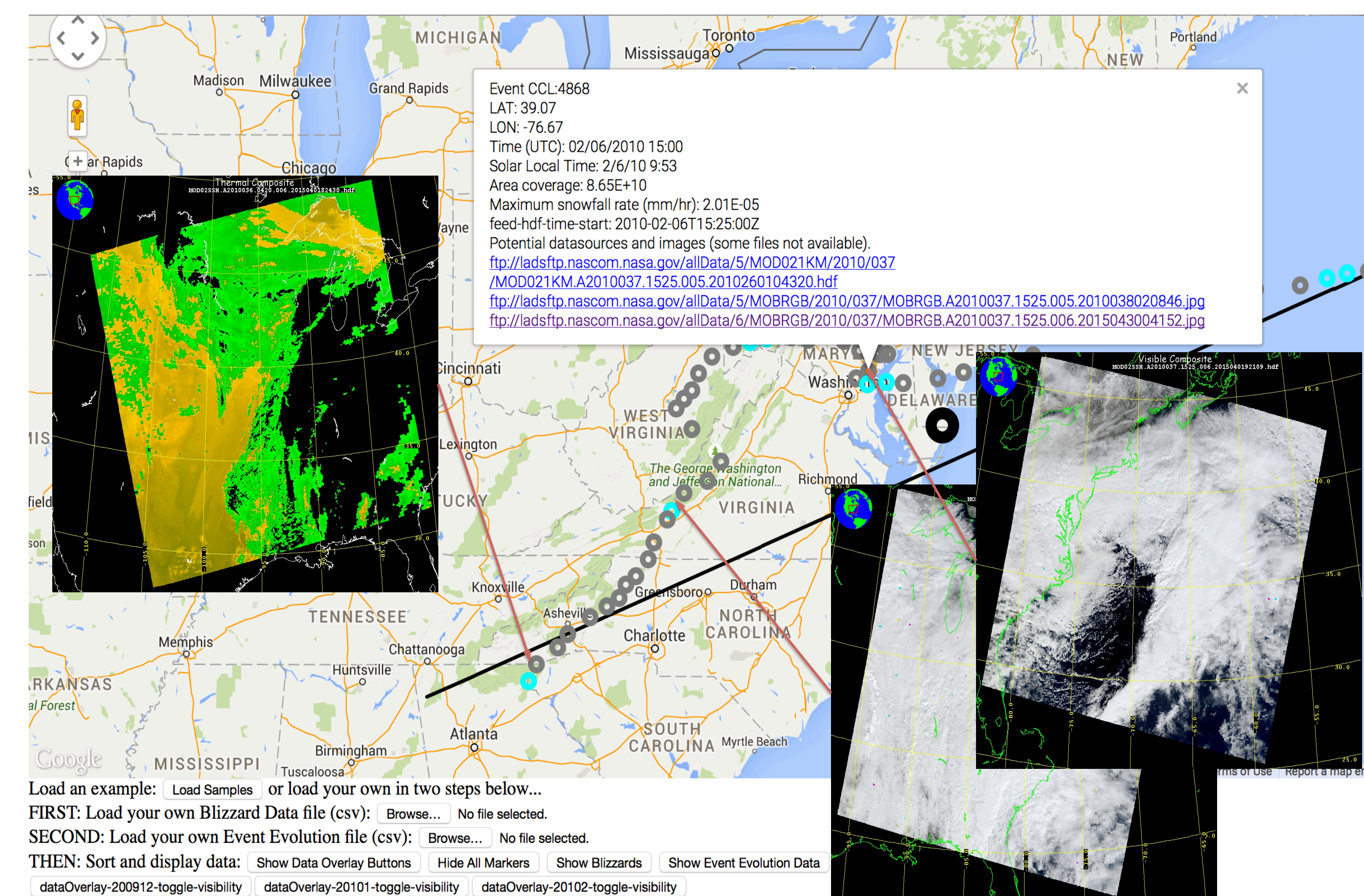
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Some Event-based Climatological Statistics



Event-based Data Discovery

Event time and location enable us to find other relevant datasets for more detailed analysis.



Conclusion

- The Big Data technology employed, i.e. SciDB, demonstrates a far more efficient data analysis operation than the currently prevalent practice.
 - No data needs to be downloaded.
 - Filtering by criteria is efficient (pleasingly parallel).
 - Much faster turnaround time for comprehensive studies.
- Connected component labeling (CCL) tracks episodes of blizzards, enabling the obtainment of event-based statistics.
 - Obtaining number of occurrences per year become possible.
 - Per event (episode) statistics have the potential to serve as bases for refined classification.
 - Per event (episode) statistics may detect climatological changes in related processes.