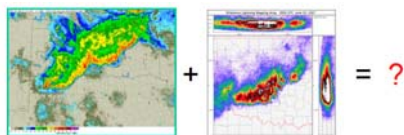




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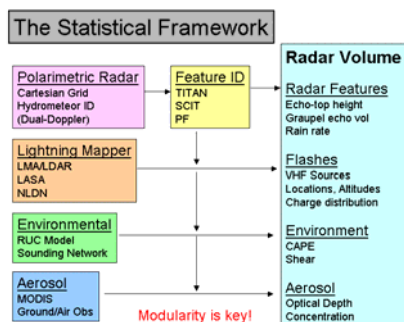


1. Introduction



Computational capabilities, along with objective analysis algorithms, have progressed to the point that true objective statistical analysis of polarimetric Doppler radar and three-dimensional total lightning information is now possible. To that end, a framework for performing statistical analysis has been developed and tested on a number of different radar and lightning datasets. This poster describes the key components of the framework, while a companion poster (Anderson et al. 2009; 4MALD P2.2) discusses the evaluation of the framework using Severe Thunderstorm Electrification and Precipitation Study cases.

2. Framework Overview



The linchpin to the framework is the processing and association of three-dimensional lightning information, environmental parameters, and aerosol observations with defined radar features (e.g., individual cells or fullblown mesoscale systems) in individual Cartesian-gridded NetCDF-format radar volumes. The processing components of the framework currently work in the most recent version of the Interactive Data Language (IDL) software, although the end-result NetCDF volumes can be used by most standard analysis software packages.

Modularity and flexibility are design goals. The final data files can be used either for case studies or fullblown statistical analysis. On the front end, either through objective or subjective analysis, radar features are identified for each gridded radar volume. These features are then (objectively or subjectively) associated with lightning flashes (from any observing network, including 3-D lightning mappers), as well as aerosol and environmental parameters. All of this information is stored in the NetCDF gridded radar volumes.

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3. Data Processing Discussion

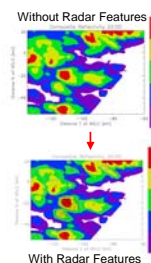
In this section, it is important to note that these are merely examples of how to go from Point A (disparate radar, lightning, environmental, and aerosol datasets) to Point B (fully combined gridded data volumes). Alternative approaches are certainly possible.

Radar Feature Identification

CSU has two algorithms available for taking a 3-D gridded radar field and creating a 2-D field of identification numbers for each radar feature. Plan projections of the 3-D radar data are then used to determine if those data exist within a feature.

1. Hybrid TITAN/SCIT algorithm that works on composite reflectivity field, and with two reflectivity thresholds (default: 35 & 45 dBZ)
2. Nesbitt/Zipser Precipitation Feature algorithm

Could also use SCIT or TITAN, or another algorithm (even subjective definition). The choice of feature ID algorithm is critical, as it determines the scale of precipitating system examined (e.g., convective vs. mesoscale). Feature tracking optional but available



Lightning Data

Standard tabular 2-D lightning data (e.g., NLDN, WWLLN) are straightforward to assign to radar features. If they occur in a feature, they are assigned to it. If they do not, they are assigned to the nearest feature within a specified distance (default: 10 km).

3-D LMA data are assigned via the following methodology:

1. XLMA software classifies flashes following Thomas et al. (2003) algorithm
2. At least 7 stations and $\chi^2 \leq 1$ required for VHF sources
3. Flash data (including all sources) exported to IDL save files
4. Flashes and sources then matched to individual radar features using simple space/time criteria (e.g., > 50% sources contained within feature, closest radar volume)
5. NLDN data matched by XLMA to flashes are carried along when parent flashes are matched to radar features

Environmental Data

2-D or 3-D environmental data (e.g., reanalysis, model output) are matched to features by taking the values (determined via either bilinear interpolation or nearest neighbor) at the 2-D geographic center of the feature. Individual sounding data can be matched to features via nearest neighbor. Interpolation between sounding/analysis times is used if possible.

Aerosol Data

2-D fields from satellite sensors (e.g., MODIS) are matched to features similar to the technique for environmental data. Point measurements, or aircraft measurements, can be matched via nearest neighbor.

4. Example Data File

Here is listed the array design for all data within a file that has been fully processed through the framework. The file, being NetCDF, is very similar to a typical gridded radar file, and actually is not much larger (~10-20%) even if copious amounts of LMA data are added.

```
x,y,zsize=grid size
nfeat=# of radar features in volume
nflash=# of LMA flashes
nsource=# of LMA sources
nnldn=# of nldn flashes
```

Radar Fields (e.g., Reflectivity, Z_{DR}):
ftarr(xsize,ysize,zsize)

Feature/Track ID: lonarr(xsize,ysize)

LMA Flash Feature Number: lonarr(nflash)
LMA Source Flash Num: lonarr(nsource)
LMA Source Data: ftarr(nsource)
(e.g., lat, lon, charge, etc.)

NLDN Flash Data: lon/ftarr(nnldn)

Environmental data: ftarr(nfeat,zsize)

Aerosol data: ftarr(nfeat)

5. Test Results for NASA AMMA Project

To demonstrate the flexibility of the framework, here are shown test results using data from the NAMMA field campaign (August/September 2006). See a talk last conference (Lang and Rutledge 2008; 3MALD) and a companion poster this conference (Anderson et al. 2009; 4MALD P2.2) for more examples.

Data Sources

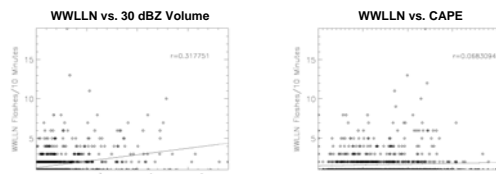
MIT C-Band non-polarimetric Doppler radar (Niamey, Niger)
WWLLN Flashes
ECMWF 0.25° 6-hrly Reanalyses
Daily 0.1° Aerosol Optical Depth maps from MODIS (via Lang and Rutledge 2006/GRL methodology)

Used Hybrid SCIT/TITAN algorithm, so looking at relatively intense convective features.

Variable	Features w/ Lightning	Features w/ No Lightning
No. of Features	1.2k	24k
1000 hPa Vorticity (s^{-1})	-2.1e-6	-2.5e-6
250 hPa Vort	-1.0e-5	-0.8e-5
1000 hPa Divergence (s^{-1})	0.5e-6	2.4e-6
700 hPa Div	-1.4e-6	-3.5e-6
250 hPa Div	2.4e-6	4.0e-6
CAPE ($J kg^{-1}$)	1214	1075
0 dBZ Volume (km^3)	4564	1298
30 dBZ Vol	1944	491
0 dBZ Height (km MSL)	18.1	16.5
30 dBZ Height	9.8	6.4

Note: no significant differences in shear ($\sim 5.7 m s^{-1}$ in 1000-500 hPa layer), aerosol optical depth (~ 0.4), or various moisture parameters

While not advised (low WWLLN detection efficiency), scatterplots and other basic analyses are also made available by the framework. Here are two examples.



6. Conclusions

A framework for the statistical analysis of large radar and lightning datasets has been described. The framework is extremely flexible and fully modular, and can incorporate a variety of different radar, lightning, environmental and aerosol datasets.

Data processed through the framework forms a set of NetCDF files, which can then be analyzed in a rapid and straightforward manner, either as part of a case study or as a full statistical analysis.

The framework is now ready to be applied toward outstanding research problems in atmospheric electricity, especially the influence of the environment and aerosols on storm charge structure and lightning production.