Updates to convective initiation nowcasting, using cloud properties, along with enhancements for early nowcasting of severe storms

John R. Mecikalski[1]

Agostino Manzato[3] and Danny Rosenfeld[4], Christopher P. Jewtt[2], Jason Apke[1]

[1]Atmospheric Science Department, University of Alabama in Huntsville
[2]Earth Systems Science Center, University of Alabama in Huntsville
[3]OSMER (Osservatorio Meteorologico Regionale)
[4]The Hebrew University of Jerusalem, Israel

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Results from:

Mecikalski, J. R., D. Rosenfeld, and A. Manzato, 2016: Evaluation of geostationary satellite observations and the development of a 1–2 hour prediction model for future storm intensity. *J. Geophys. Res. Atmos*., In review.

Hypotheses Motivating Study

- By using satellite–derived cloud parameters and fields that diagnose 0–1 hour convective initiation (Mecikalski et al 2010a,b), the intensity of the newly developed convective storms can also be predicted.

- Clouds that will become intense, and capable of producing severe weather at the ground (≥25 ms^{-1} winds, hail ≥2 cm, tornadoes) possess unique cloud top signatures as compared to neighboring storms that are more benign.

- Conceptual models exist that suggest how the attributes, both kinematically and microphysically, should appear within multi–spectral infrared and visible observations from geostationary satellite for "intense" cumulus clouds.

- Studies to date examine the use of cloud-derived properties for nowcasting, specifically convective nowcasting that demands 1-15 min resolution datasets (e.g., Rosenfeld/Lensky et al. 2006-2010 studies), as well as related to research in weather modification and cloud seeding.

Convective intensity nowcasting

Convective intensity monitoring…

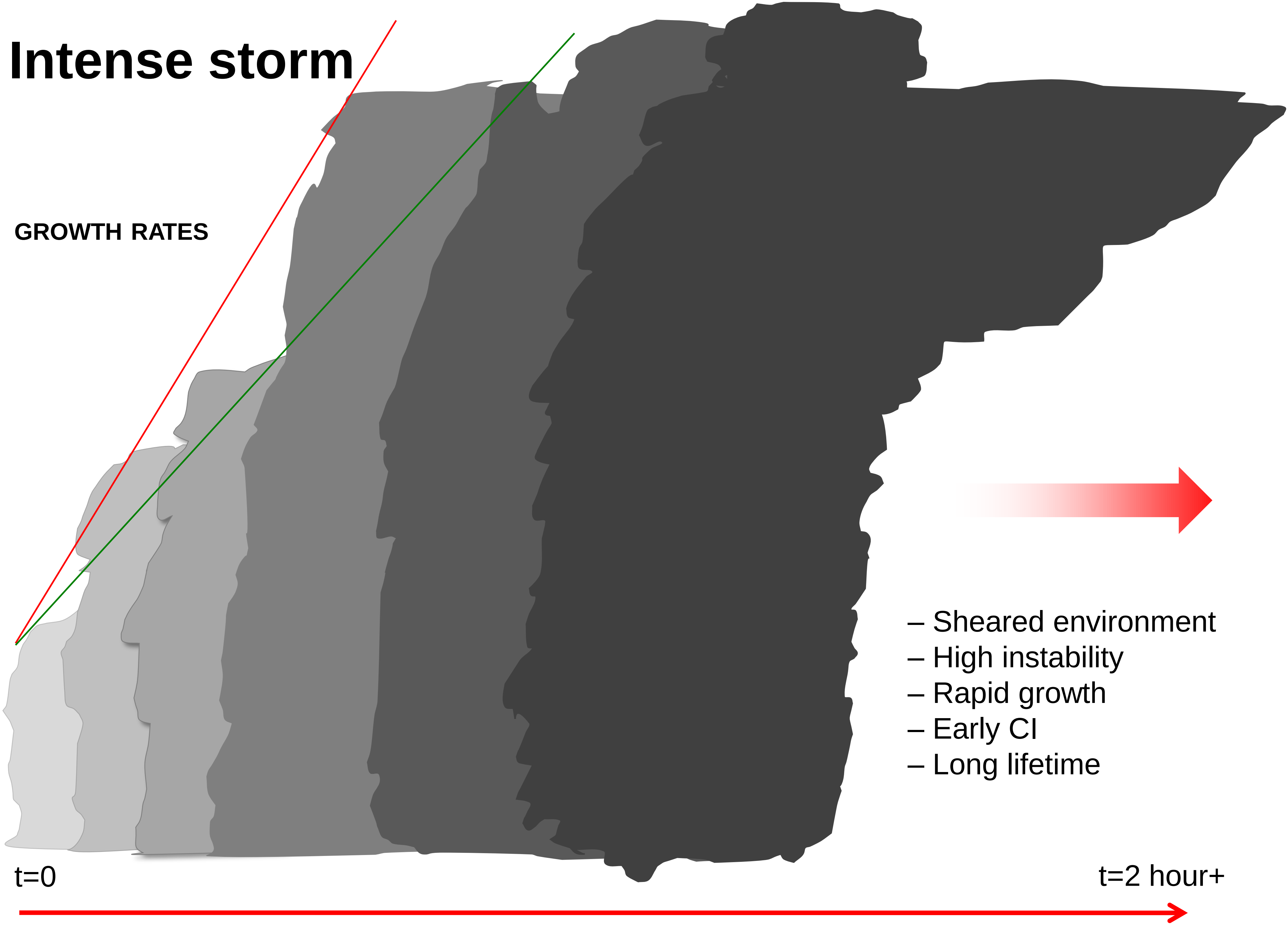
Convective Initiation

t = 0

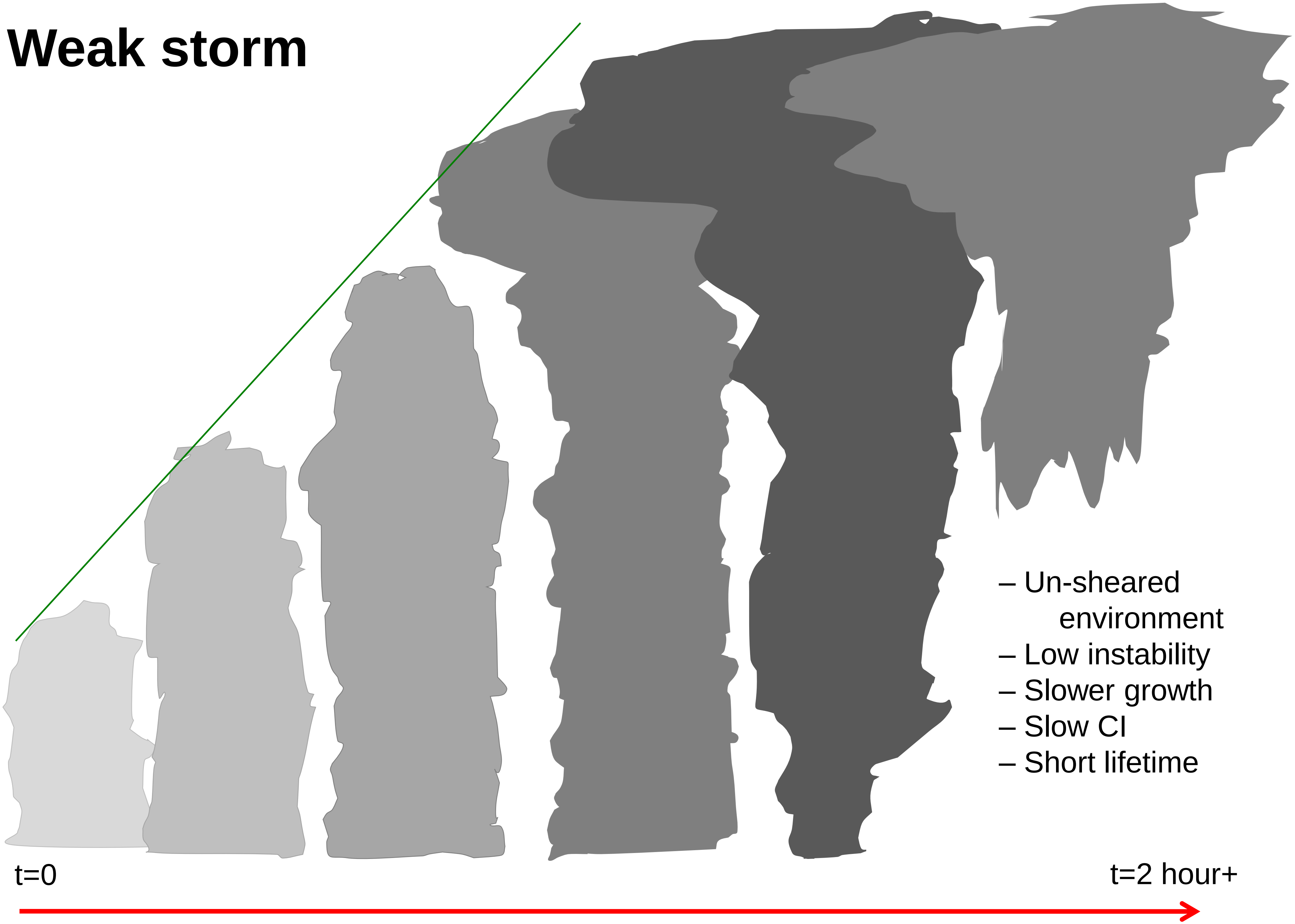
45 min

t = 1 hour

t = 2 hours


Intense storm
GROWTH RATES
– Sheared environment
– High instability
– Rapid growth
– Early CI
– Long lifetime
t=0
t=2 hour+

Weak storm

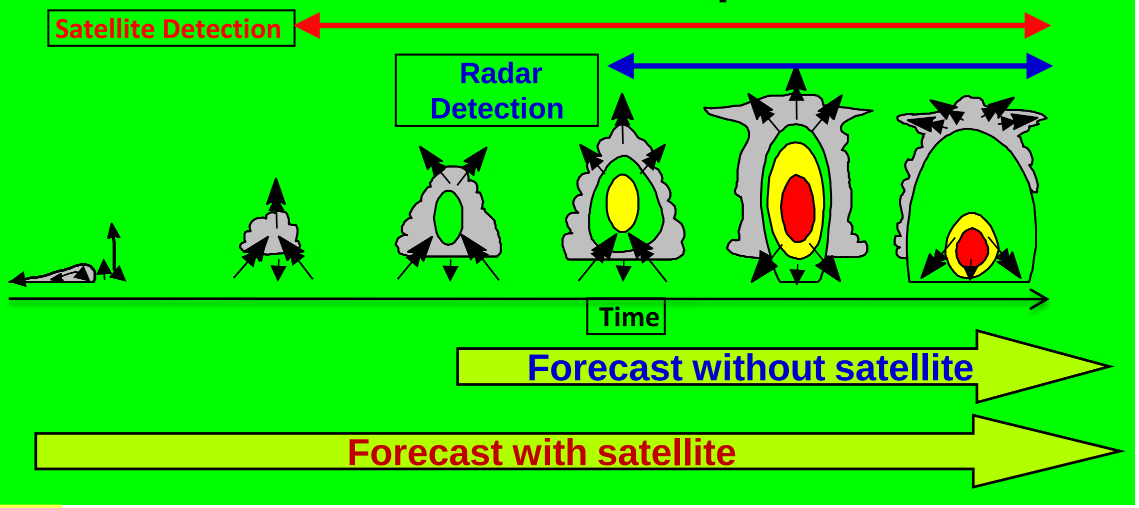


- Un-sheared environment
- Low instability
- Slower growth
- Slow CI
- Short lifetime

Satellite–based Convective Initiation Research

Download latest satellite imagery…

Monitor Cumulus Cloud Development



Make Cloud Mask

Produce MAMVs

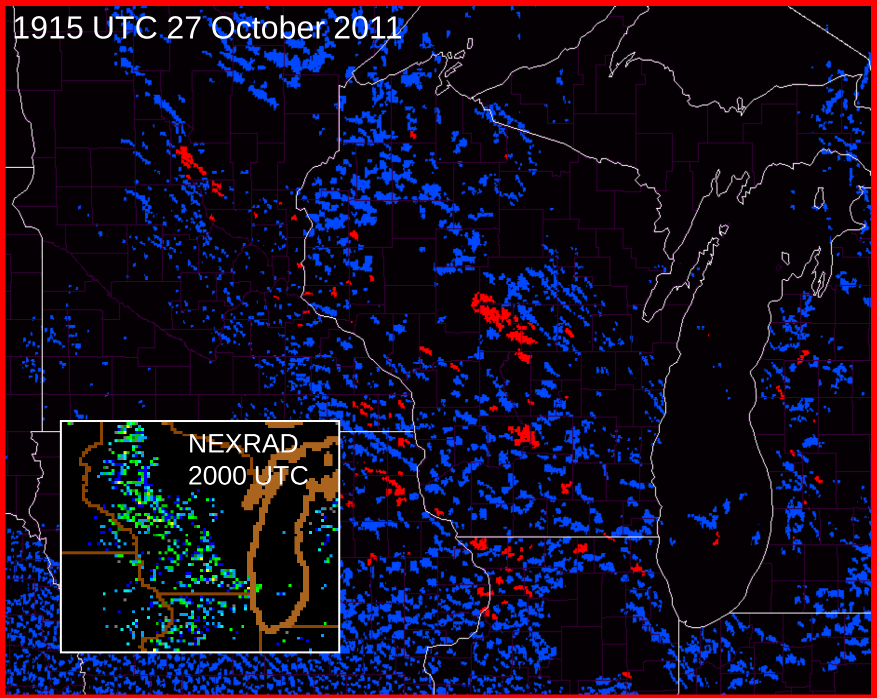
Track "Cloud Objects" from 'T1' to 'T2'

(Similar to "Cb-TRAM" Zinner et al. 2008)

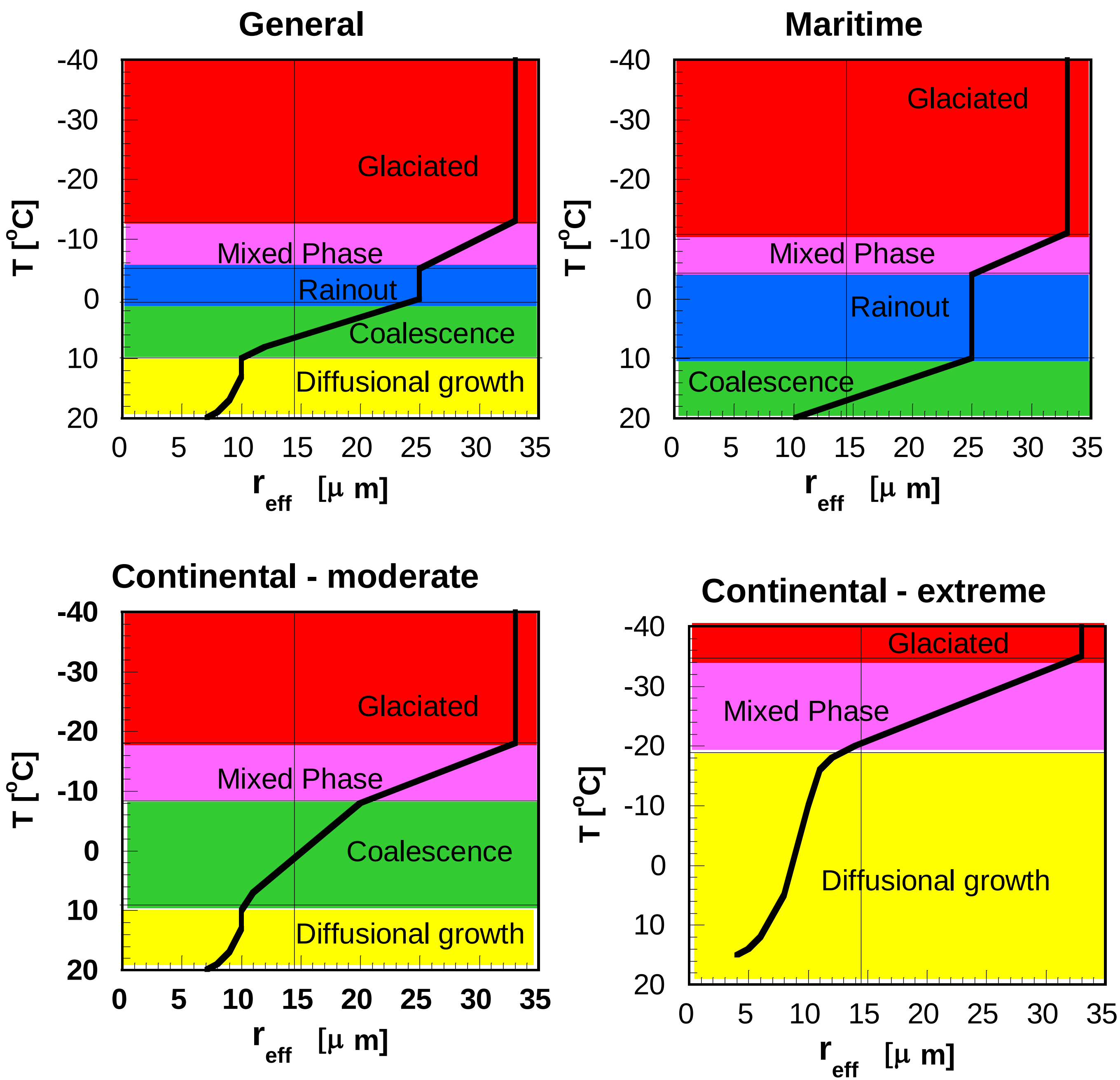
CI Definition:
1st ≥35 dBZ echo at ground, or at –10 °C altitude

Determine CI forecast for each tracked Cloud Object using 6 spectral/temporal differencing tests (aka: "Interest Fields")

Per-Object CI forecast



The classification scheme of convective clouds into microphysical zones according to the shape of the temperature – effective radius relations



Note that in extremely continental clouds r_e at cloud base is very small, the coalescence zone vanishes, mixed phase zone starts at T<-15° C, and the glaciation can occur at the most extreme situation at the height of homogeneous freezing temperature of –39° C. In contrast, maritime clouds start with large r_e at their base, crossing the precipitation threshold of 14 mm short distance above the base. The deep rainout zone is indicative of fully developed warm rain processes in the maritime clouds. The large droplets freeze at relatively high temperatures, resulting in a shallow mixed phase zone and a glaciation temperature reached near –10° C.

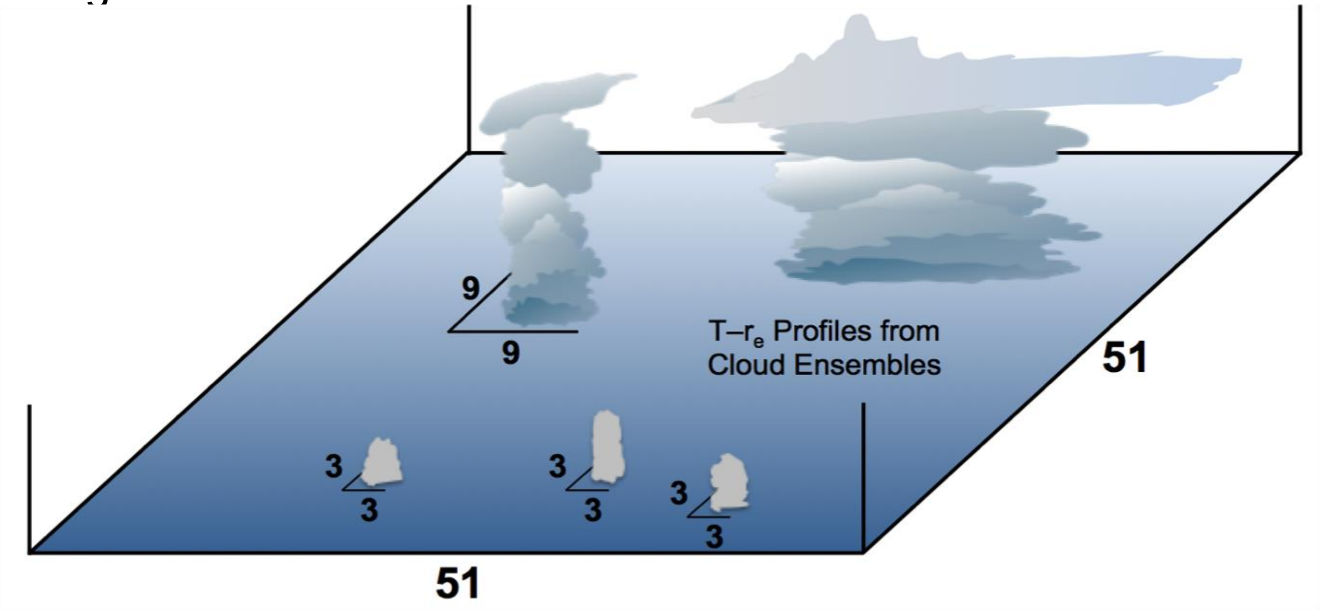
Study Results

1. Case selection (optimal dates, ESWD data)
2. Storm/event database development for analysis
3. Parameter list and derived fields
   - CI fields
   - T–Re fields
   - GII fields
   - Feature expansion (anvil level)
   - Cloud top and overshooting top features

1. Statistical analyses & Inter-relationships between fields, new methods to nowcast storm intensity, and key new findings

Database Development

- 340 storms in the process of initiating were on:
  - 15 August 2010
  - 1 July 2012
  - 7 July 2012
  - 21 July 2012
  - 20 June 2013
  - 29 July 2013



- 34 Intense and 306 non–intense storms were cataloged.

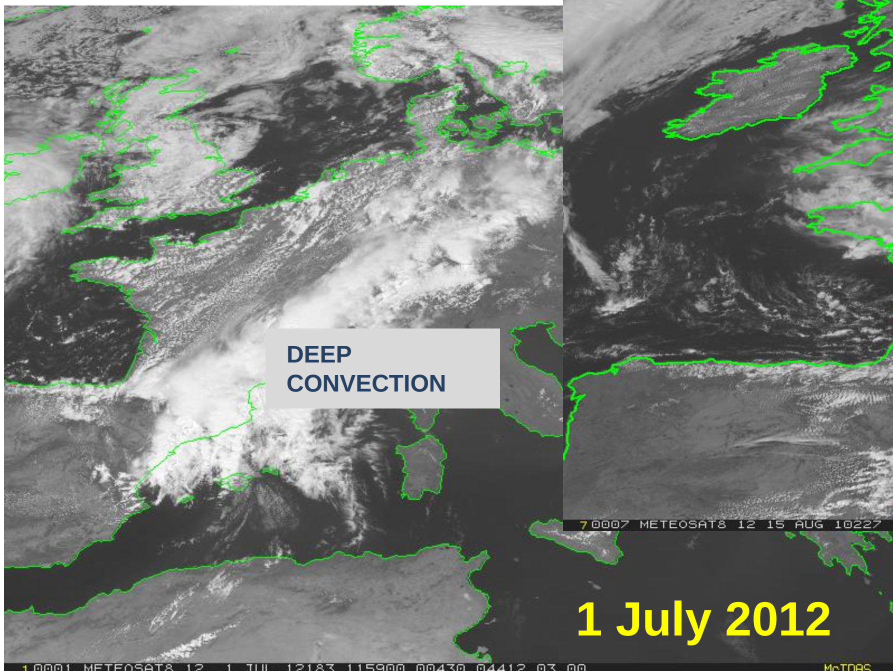
- MSG SEVIRI data (channels 1–11) were collected for events over a 3 x 3 pixel CI domain, a 9 x 9 pixel "storm" domain, and 51 x 51 pixel "environment" domain

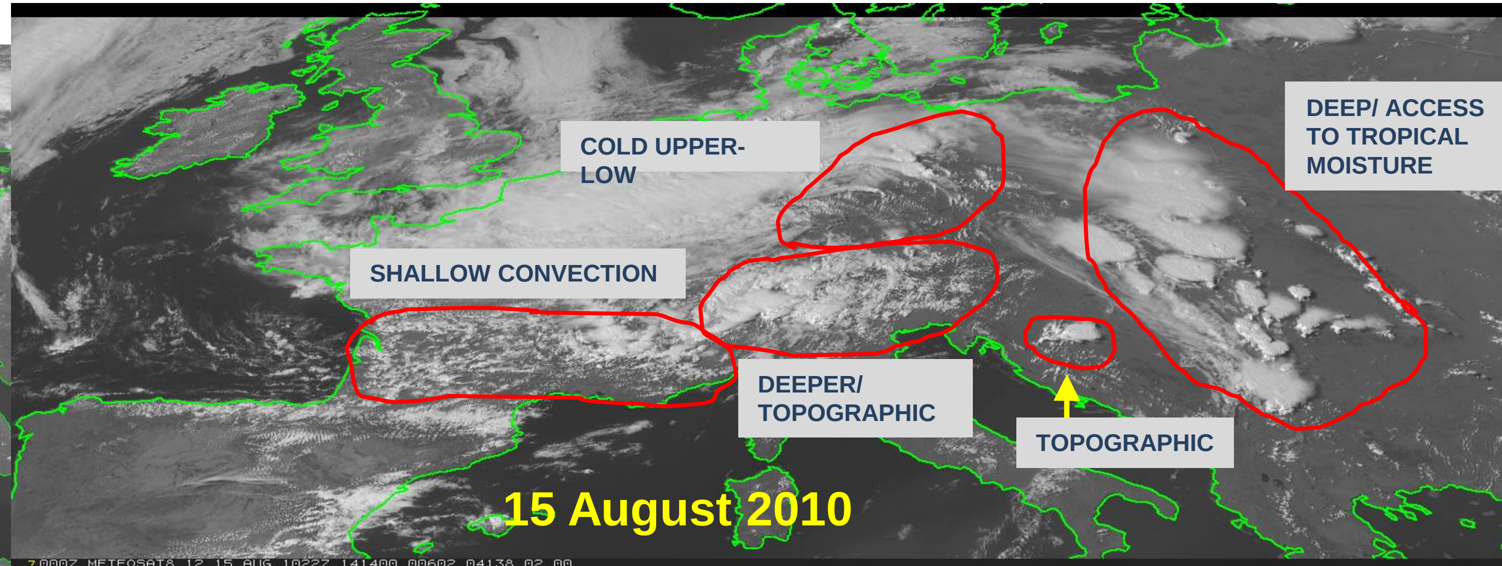
- All domains were analyzed every 5 min to 45 min.

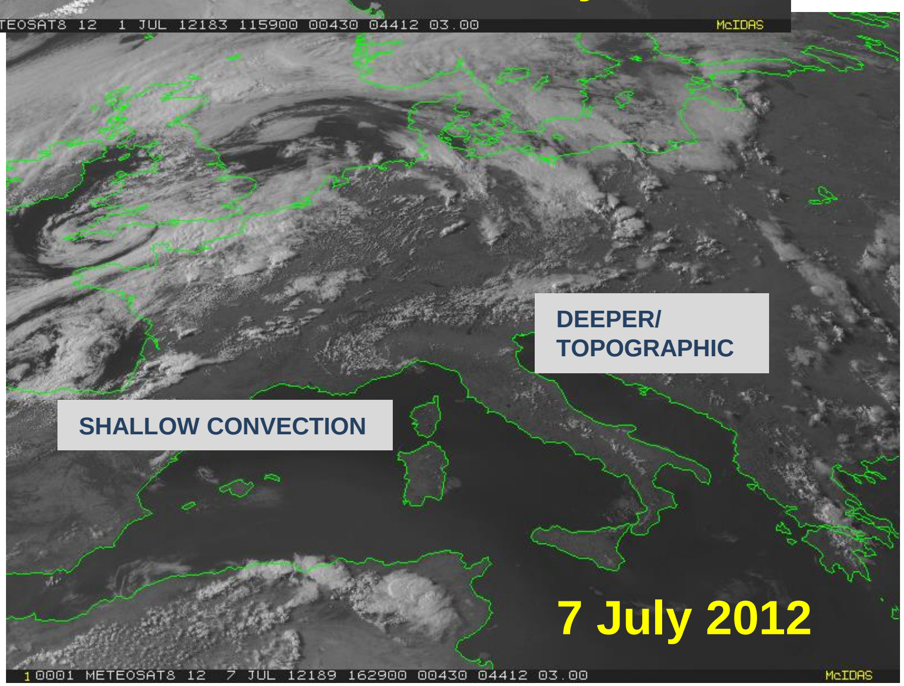
- Storms were tracked by a human expert over a 2 hour timeframe, and associated with severe weather out to 3 hours.

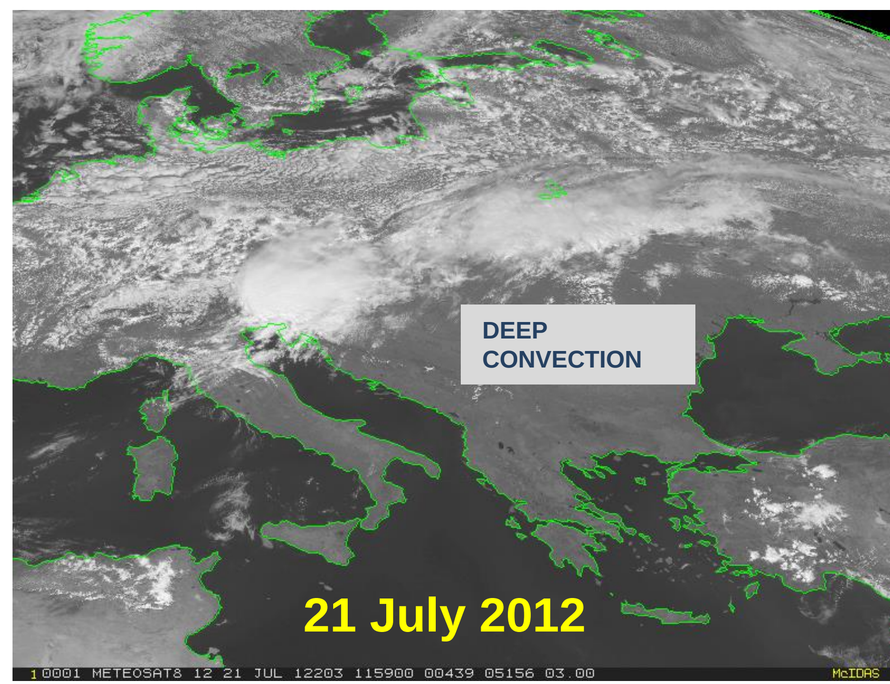
- Numerous CI nowcasting, T–Re procedure, Global Instability Index (GII), and newly derived feature expansion fields were observed per time as clouds grew/evolved.

Date Selection









Database Development

28 Instantaneous Storm & Environmental Parameters:

Map	Map number in the storm tracking (1 to 25)
hour	Decimal hour
Ttop9	9x9 Lowest top temperature [° C]
Tg9	9x9 glaciation temperature [° C]
Tbrtg9	9x9 T of break point of the T-r_e line [° C]
T149	9x9 T where r_e exceeds 14 mm [° C].
Tb9	9x9 T of cloud base, or warmest cloudy pixel [° C]
dSlope9*10	9x9 slope of lower part minus slope of upper part of the T-re line [10*mm/° C]
Re_Top9	9x9 effective radius (r_e) at Ttop9 [mm]
ReGlac9	9x9 r_e at Tg9 [mm]
Rebrtg9	9x9 r_e at Tbrtg9 [mm]
Exp9/10	9x9 Expansion rate of the cloud top, as defined by the coldest 10 T ° C [0.1 km2/5 min]
fExp9*10	9x9 Fractional expansion rate, defined by Exp9 cloud top area [unit-less]
Cortbtg9	9x9 correlation of the T-r_e points [unit-less]
8.7-10.8	BTD of 8.7-10.8 mm [° C]
A3.9	3.9 mm reflectance [unit-less]
3BTD	BTD of [(8.7-10.8 um)-(10.8-12.0)] [mm]
12-10.8	BTD of 8.7-10.8 mm [° C]
Ttop51	51x51 Lowest top temperature [° C]
Tg51	51x51 glaciation temperature [° C]
Tbrtg51	51x51 T of break point of the T-r_e line [° C]
T1451	51x51 T where r_e exceeds 14 mm [° C].
Tb51	51x51 T of cloud base, or warmest cloudy pixel [° C]
dSlope51*10	51x51 slope of lower part minus slope of upper part of the T-re line [10*mm/° C]
Re_Top51	51x51 effective radius (r_e) at Ttop9 [mm]
ReGlac51	51x51 r_e at Tg9 [mm]
Rebrtg51	51x51 r_e at Tbrtg9 [mm]
Exp51/10	51x51 Expansion rate of the cloud top, as defined by the coldest 10 T ° C [0.1 km2/5 min]
fExp51*10	51x51 Fractional expansion rate, defined by Exp9 cloud top area [unit-less]
Cortbtg51	51x51 correlation of the T-r_e points [unit-less]

Database Development

49 Storm Lifetime Parameters:

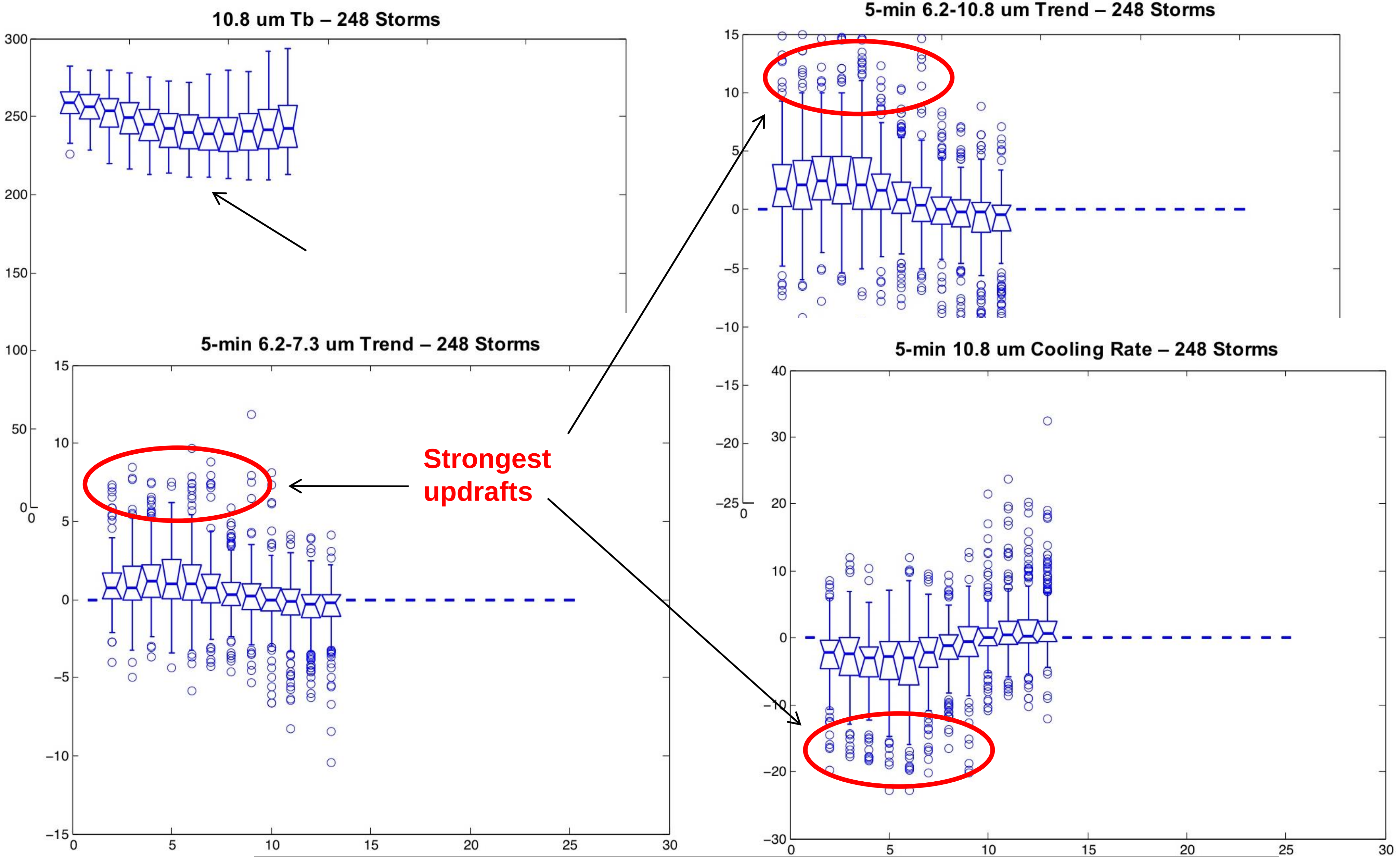
Map	Map number in the storm tracking (1 to 25)
Hour	Decimal hour
K-Index	K-Index [° C]
Lifted	Lifted Index [° C]
PW_tot	Total precipitable water (mm) [GII]
PW>500mb	Precipitable water above 500 hPa (mm) [GII]
PW850-500	Precipitable water between 850 and 500 hPa (mm) [GII]
PW<850	Precipitable water between 850 hPa and surface (mm) [GII]
Ttop_min9	9x9 coldest T [° C]
Ttop_min51	51x51 coldest T [° C]
dtTtop_min9	Time of Ttop_min9 [hours since map 1. Form here on just "hours"]
dtTtop_min51	Time of Ttop_min51 [hours]
Ttop_anvil	T of anvil level, as determined by the first maximum from above in the T histogram T [° C]
TtopAnvil1	9x9 T of cloud to when it first reached or exceeded Ttop_anvil T [° C]
dTovershoot	Overshoot temperature difference: -(TtopAnvil1-Ttop_anvil) T [° C]
dtAnvil1	Time to reach TtopAnvil1 [° C]
CoolingPreAnvil1	9x9 Cooling rate of Ttop9 just before dtAnvil1 [° C/5 min]
CoolingPostAnvil1	9x9 Cooling rate of Ttop9 just after dtAnvil1 [° C/5 min]
CoolingAnvil1	9x9 CoolingPreAnvil1+ CoolingPostAnvil1 [° C/5 min]
TgAnvil1	9x9 r_e of TtopAnvil1 [mm]
ReGlacAnvil1	9x9 r_e of glaciation temperature at dtAnvil1 [mm]
ReTopAnvil1	9x9 r_e of cloud top at dtAnvil1 [mm]
GrowthAnvil1	9x9 fExp9 at dtAnvil1 [unit-less]
Ttop9-40	9x9 Ttop9 when first reaching or exceeding -40° C [° C].
Tg940	9x9 Tg9 when first reaching or exceeding -40° C [° C].
ReGlac9-40	9x9 ReGlac9 when first reaching or exceeding -40° C [mm].
Temp149-40	9x9 T149 when first reaching or exceeding -40° C [° C].
Tlinmin9-40	9x9 Tlinmin9: T of break point of the T-r_e line (old method) when first reaching or exceeding -40° C [° C].

Database Development

49 Storm Lifetime Parameters (cont…):

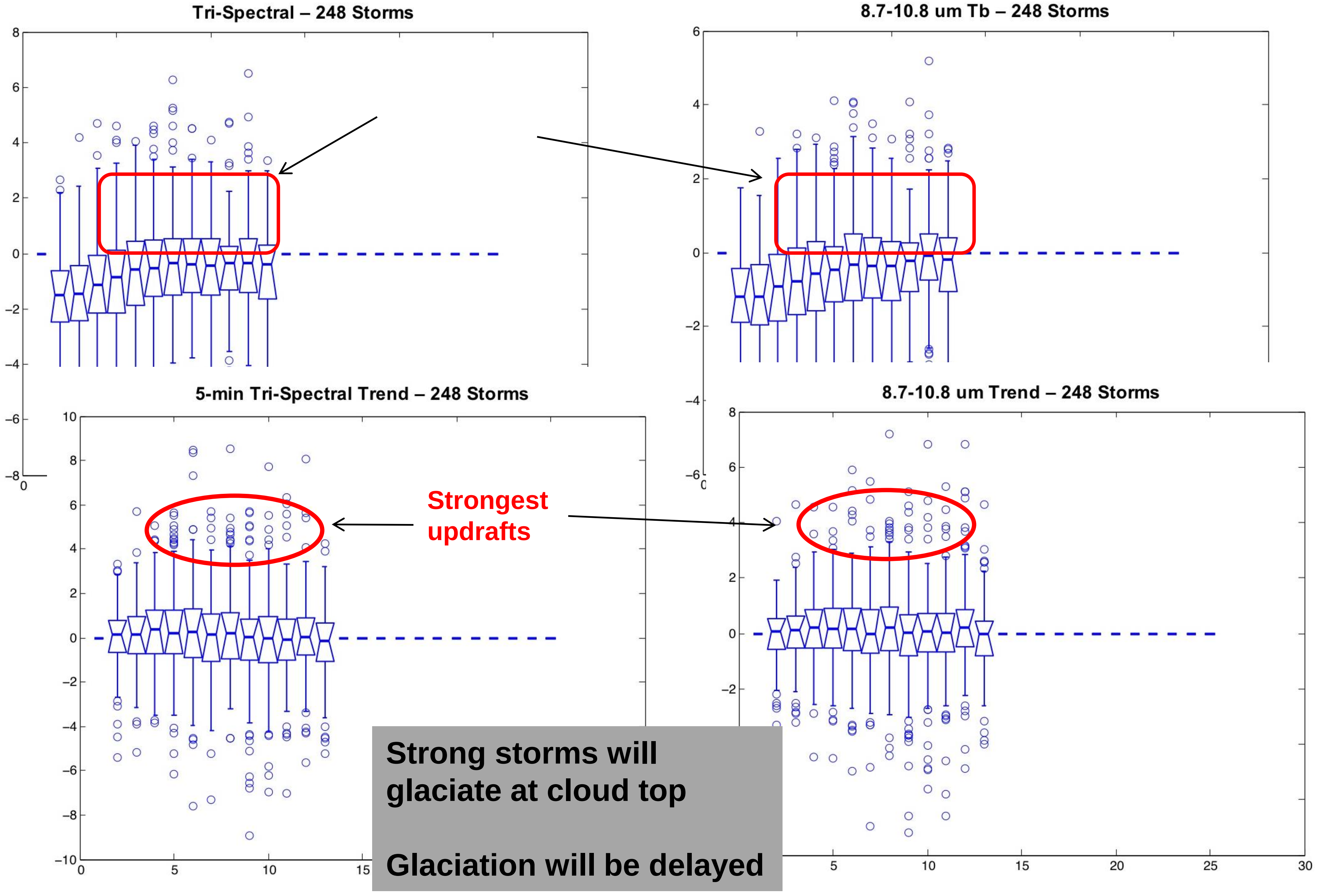
dSlope_Tlinmin9-40	9x9 slope of lower part minus slope of upper part of the T-re line (old method) when first reaching or exceeding -40° C [10*mm/° C].
dSlope_TBcormin9-40	9x9 slope of lower part minus slope of upper part of the T-re line (new method) when first reaching or exceeding -40° C [10*mm/° C].
re_Ttop9-40	9x9 r_e of Ttop9 when first reaching or exceeding -40° C [mm]
Ttop51-40	51x51 Ttop51 when first reaching or exceeding -40° C [° C].
Tg25-40	51x51 Tg51 when first reaching or exceeding -40° C [° C].
ReGlac51-40	51x51 ReGlac51 when first reaching or exceeding -40° C [mm].
Temp1451-40	51x51 T1451 when first reaching or exceeding -40° C [° C].
Tlinmin51-40	51x51 Tlinmin51: T of break point of the T-r_e line (old method) when first reaching or exceeding -40° C [° C].
dSlope_Tlinmin51-40	51x51 slope of lower part minus slope of upper part of the T-r_e line (old method) when first reaching or exceeding -40° C [10*mm/° C].
dSlope_TBcormin51-40	51x51 slope of lower part minus slope of upper part of the T-r_e line (new method) when first reaching or exceeding -40° C [10*mm/° C].
re_Ttop51-40	51x51 r_e of Ttop51 when first reaching or exceeding -40° C [mm]
CI1	10.8 mm TB 5-min
CI2	10.8 mm cooling rate
CI3	5-min 6.2-10.8 mm trend
CI4	8.7-10.8 mm
CI5	5-min 8.7-10.8 mm trend
CI6	3.9 mm reflectance
CI7	5-min 3.9 um reflectance trend
CI8	[(8.7-10.8 mm)-(10.8-12.0 mm)]
CI9	5-min tri-spectral trend
CI10	5 min 6.2-7.3 mm trend
CI11	5-min 3.9-10.8 mm trend
CI12	12.0-10.8 mm

Parameter Statistics – CI Fields



Threshold test based on known locations of strongest updrafts

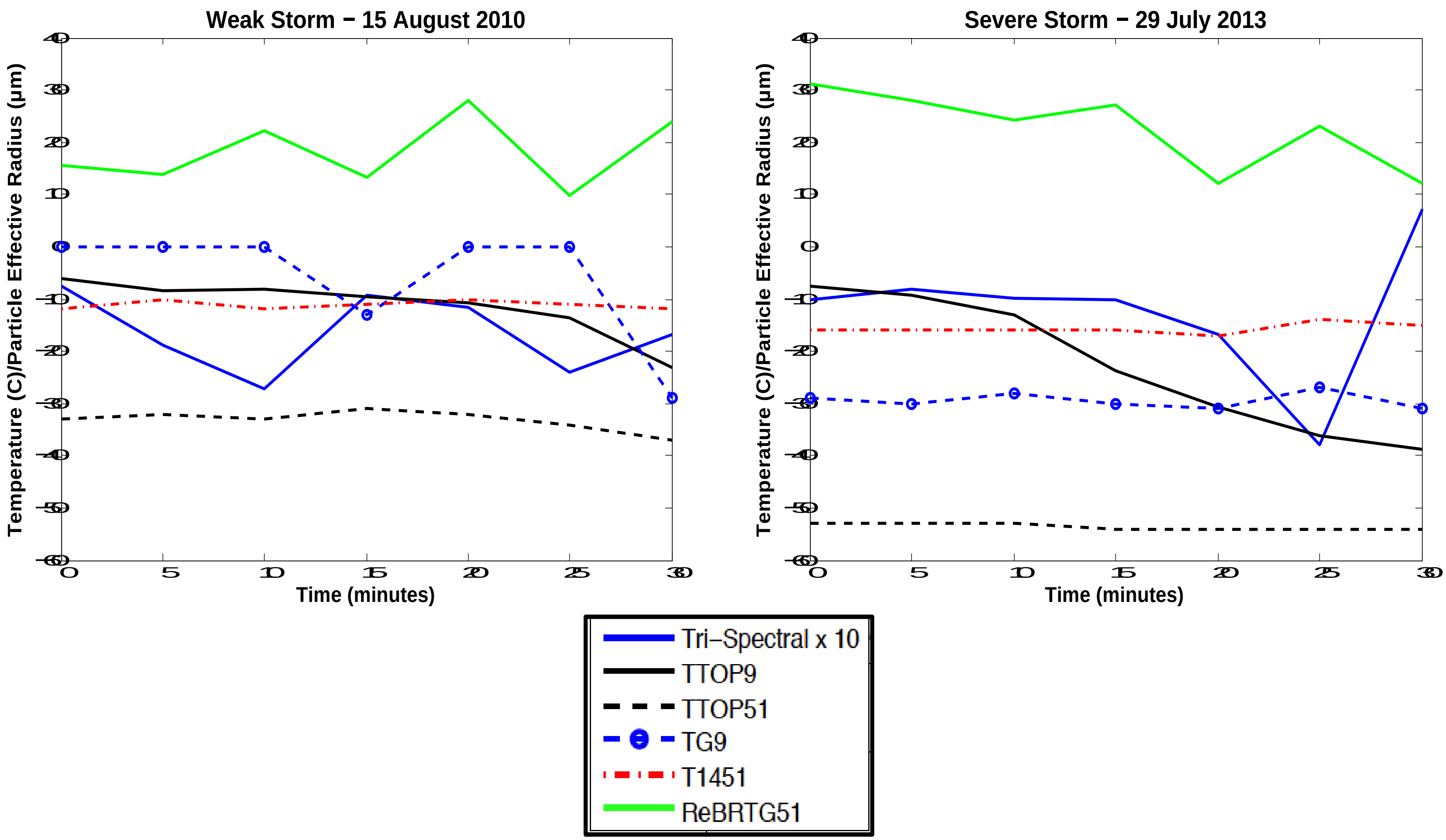
Parameter Statistics – CI Fields



Strong storms will glaciate at cloud top

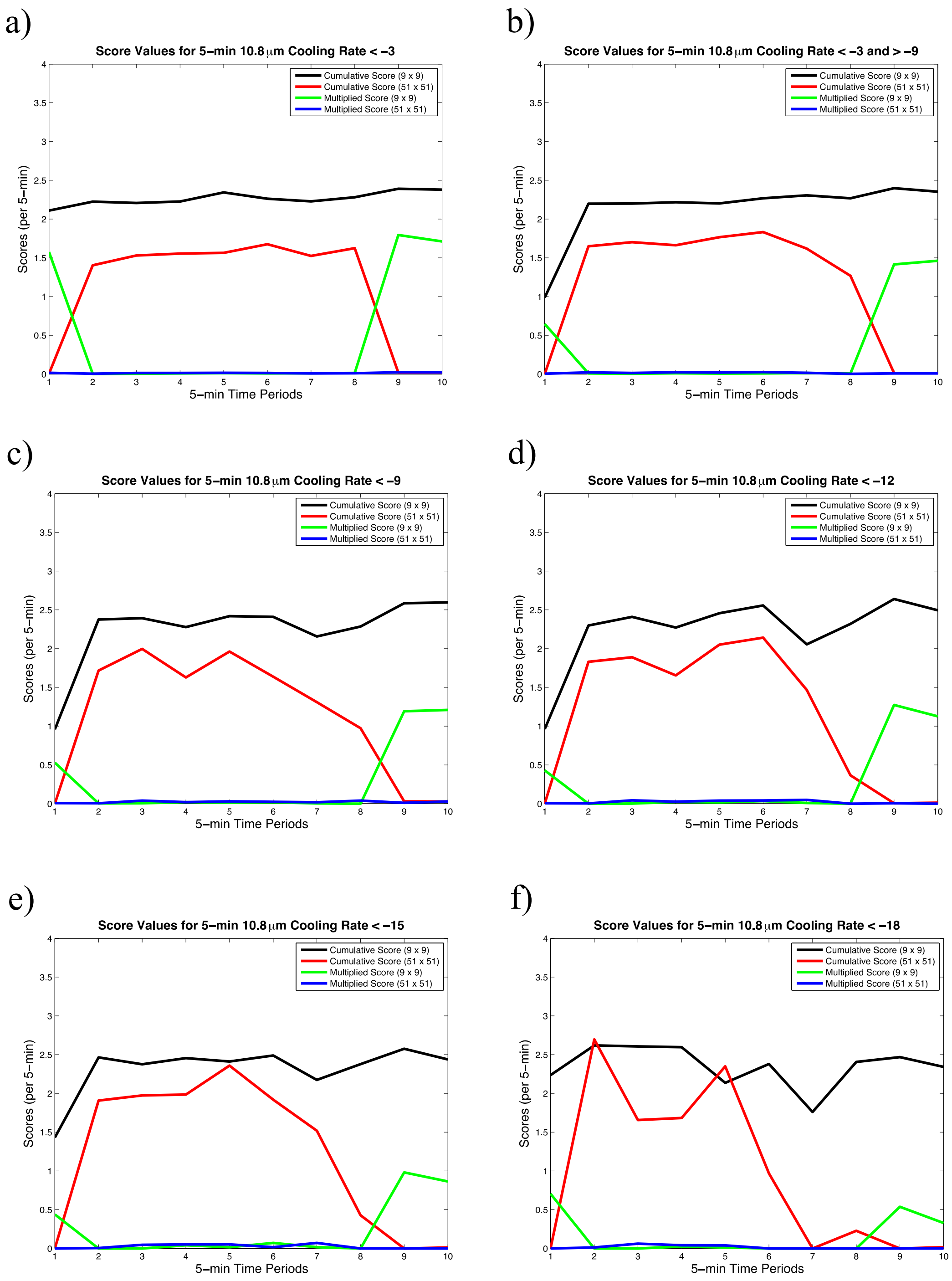
Glaciation will be delayed

Parameter Statistics – Time Trends



T-r_e Score values for clouds with varying 5–min cloud-top cooling rates, from:
(a) < –3 °C to (f) < –18 °C.

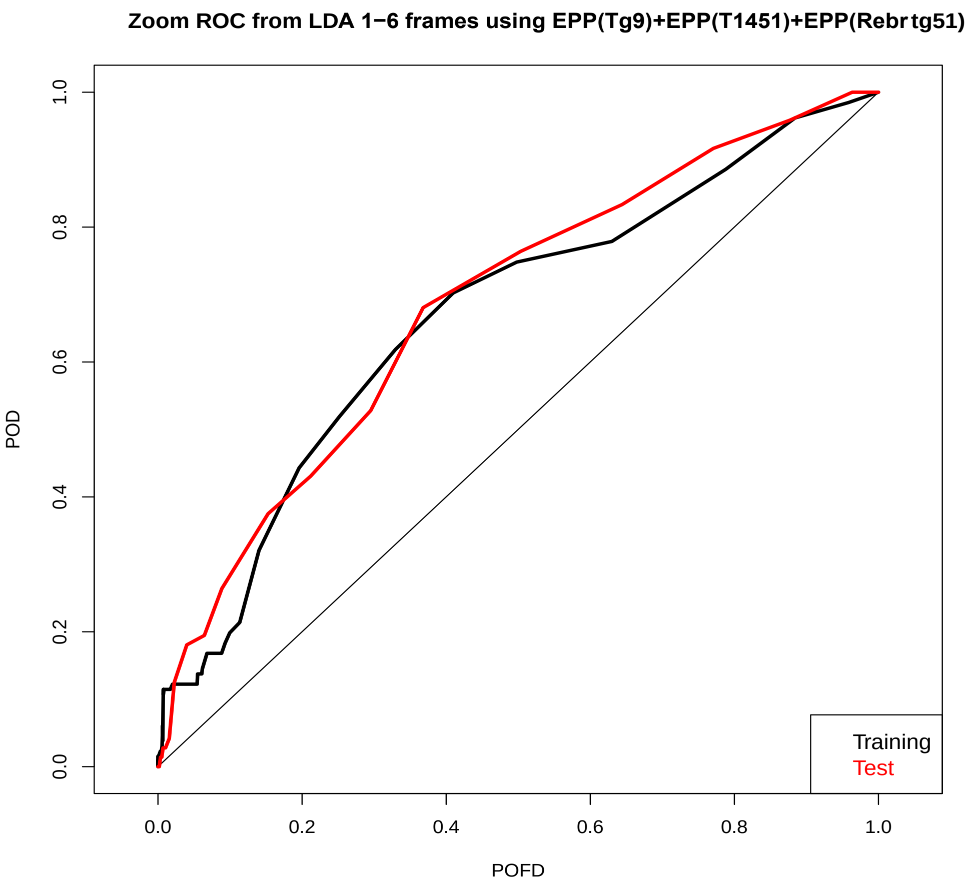
(a) “cumulative on the 9 x 9 pixel domain”
(b) “cumulative on the 51 x 51 pixel domain”
(c) “multiplied scores on the 9 x 9 pixel domain”
(d) “multiplied scores on the 51 x 51 pixel domain”



T–r_e based CI Intensity Model

Multi-Step Process

- Leaps (*R*) linear regression
- Linear Discriminant Analysis (LDA) classification
- Bivariate LDA was used with Empirical Posterior Probability (EPP) transform
- Maximize Peirce Skill Score ("maxPSS") (Manzato (2007).



$$LDA_{STORM} = 18.205\ EPP(T_{G9}) + 8.293\ EPP(T_{1451}) + 21.164\ EPP(Re_{BRTG51}).$$

$$EPP(T_{G9}) = 0.058 - 0.00175 \times T_{G9}$$

$$EPP(T_{1451}) = 0.069 + 0.00030 \times (T_{1451} + 8)^2$$

$$EPP(Re_{BRTG51}) = 0.087 + 0.01220 \times ATAN(1.005 + 0.970 \times Re_{BRTG51})$$

Severe weather is expected if $LDA_{STORM} \geq 4.755$

Follow–on Work & Immediate Plans

- In the process of developing a similar framework in U.S. GOES-R CI algorithm.

- Develop training database to compute skill scores using many more Storm Prediction Center (SPC) severe weather reports as “truth” in our training database.

- Begin using Severe CI model in Spring 2016 (i.e. now).

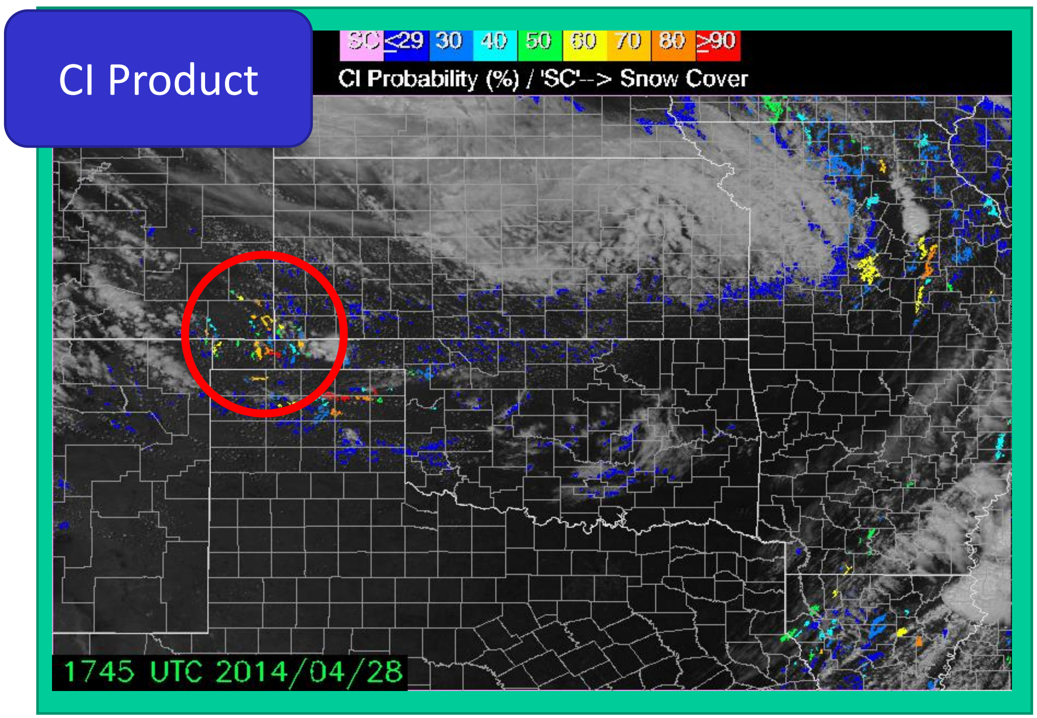
- **Ralph Petersen’s talk... Monday April 4th**. Focus on coupling GOES-R CI/Severe CI with NearCast to enhance forecaster awareness of high-impact events.

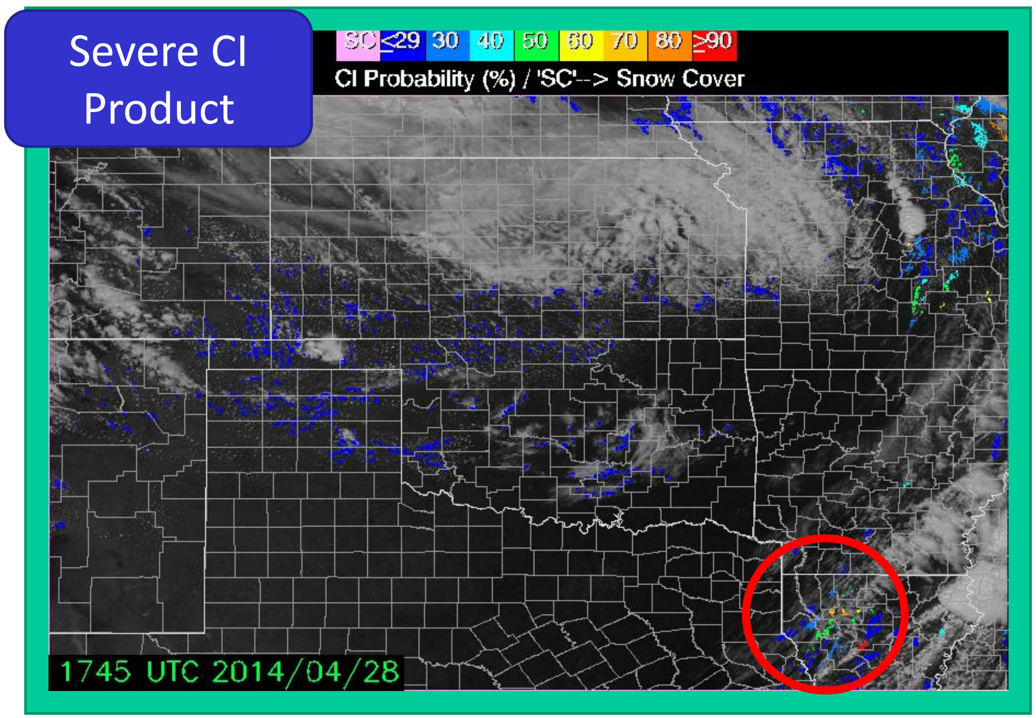
- Move to combine GOES-R CI and T–Re procedures (re: NASA A.25 project with Kris Bedka), and prepare for more robust testing within forecast setting.

Updates: Severe CI Product

Identifies CI cells associated with severe threats

Similar to the standard CI product but uses a “severe cell” database for training purposes→ produces probability of severe weather





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