LA-UR- 11-02042

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Title: Using lightning as an indicator of rapid hurricane intensification

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Intended for: Workshop on Lightning Activities in Tropical Cyclone Beijing, China, 11-15 April 2011

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Using lightning as an indicator of rapid hurricane intensification

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Abstract

The presentation reviews LASA's observations of hurricane lightning activities. Examples reported include hurricanes Katrina, Rita Wilma and Charley. Also included is a conceptual proposal of a similar LASA in East Asia for a collaborative typhoon study.

Using lightning as an indicator of rapid hurricane intensification

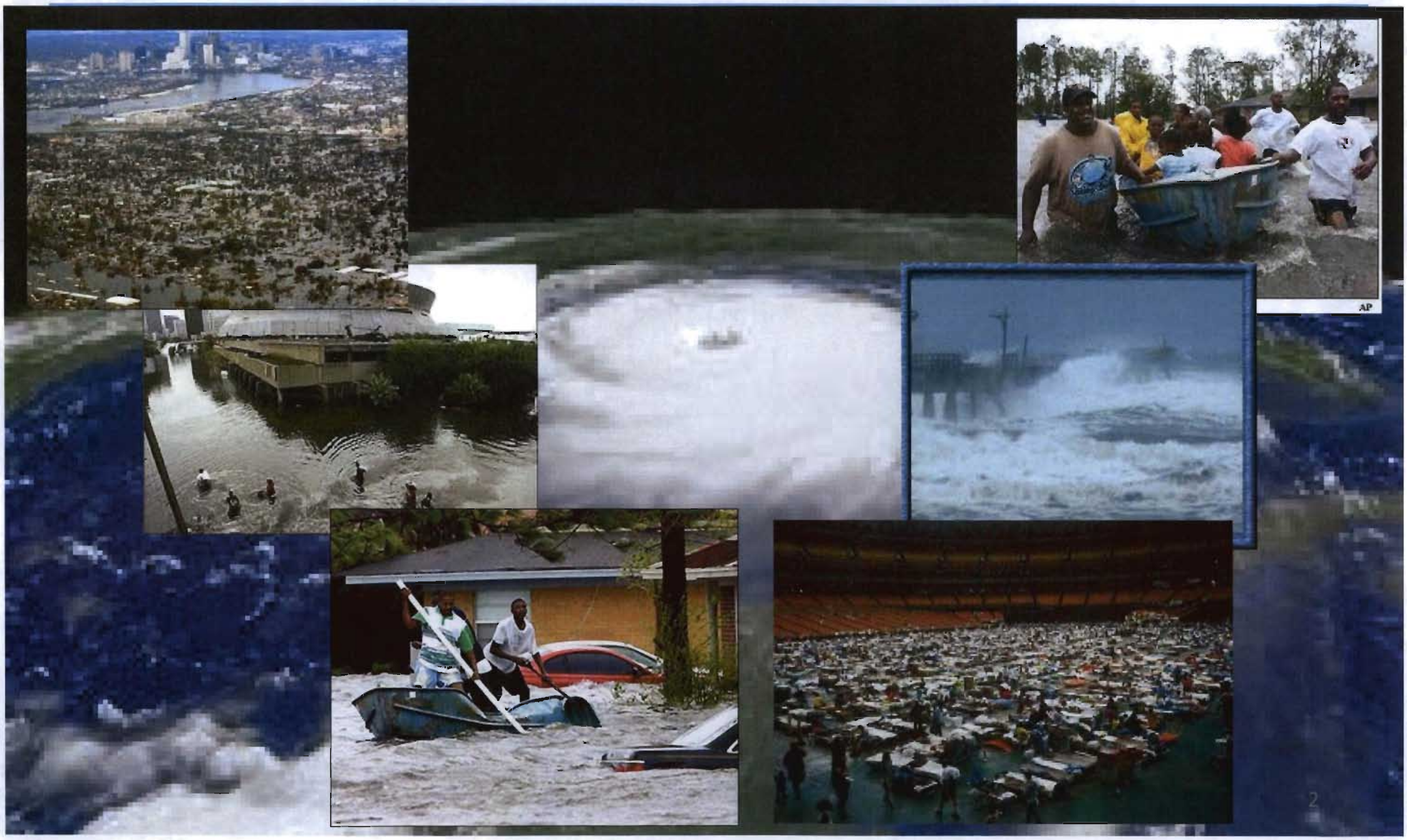
Xuan-Min Shao

Alexandre Fierro, Jon Reisner, Jeremiah Harlin, Timothy Hamlin

Los Alamos National Laboratory

Hurricane Katrina, Aug., 2005

Killed 1836 people, damaged $91 bln properties

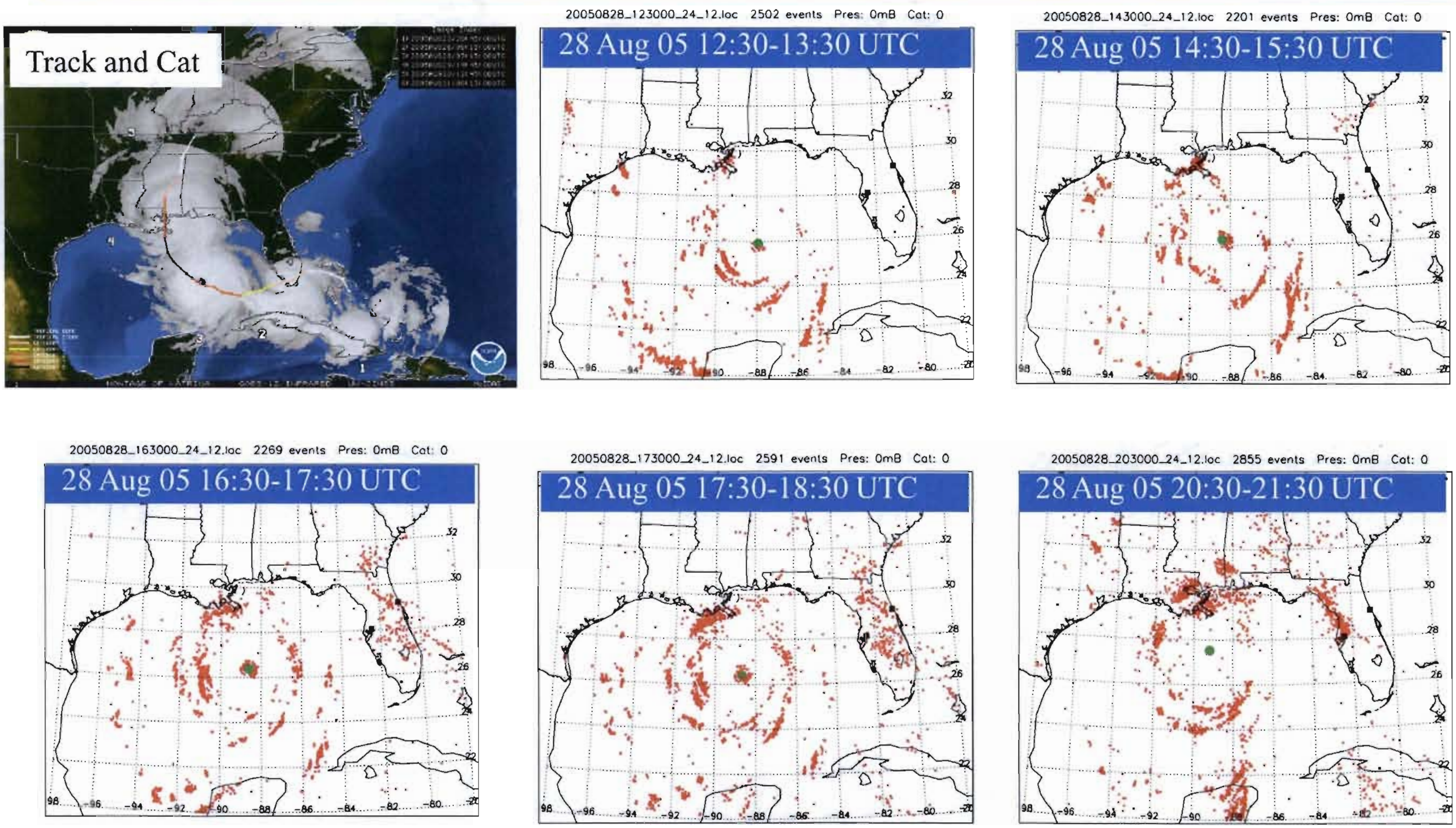


Hurricane Rita, Sept. 2005

Killed 120 people, damaged $11 bln properties

Lightning activities of Hurricane Katrina

(1) Start to see eye-wall lightning at Cat 4. (2) Eye-wall lightning intensifies while Katrina progresses from Cat 4 to 5; eye-wall lightning decreases when Katrina decays. (3) Unusual high rate of rainband lightning; rainband lightning not associated with Katrina intensity.



Shao et al., Eos, 86, 42, 18 Oct. 2005
Shao et al., AMS meeting, 2006

Lightning activities of Hurricane Rita

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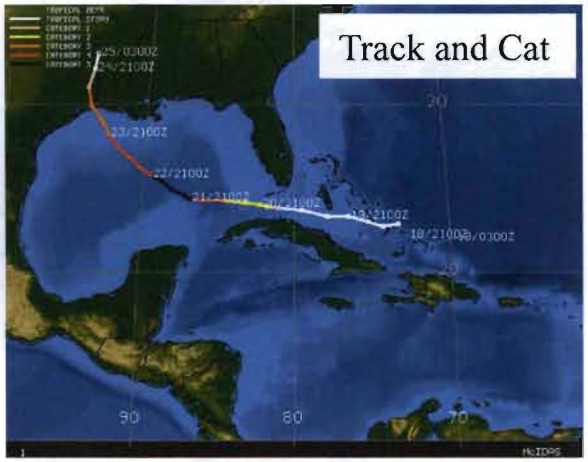
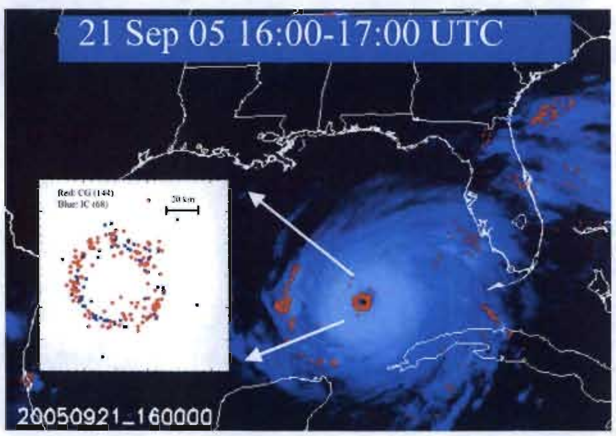
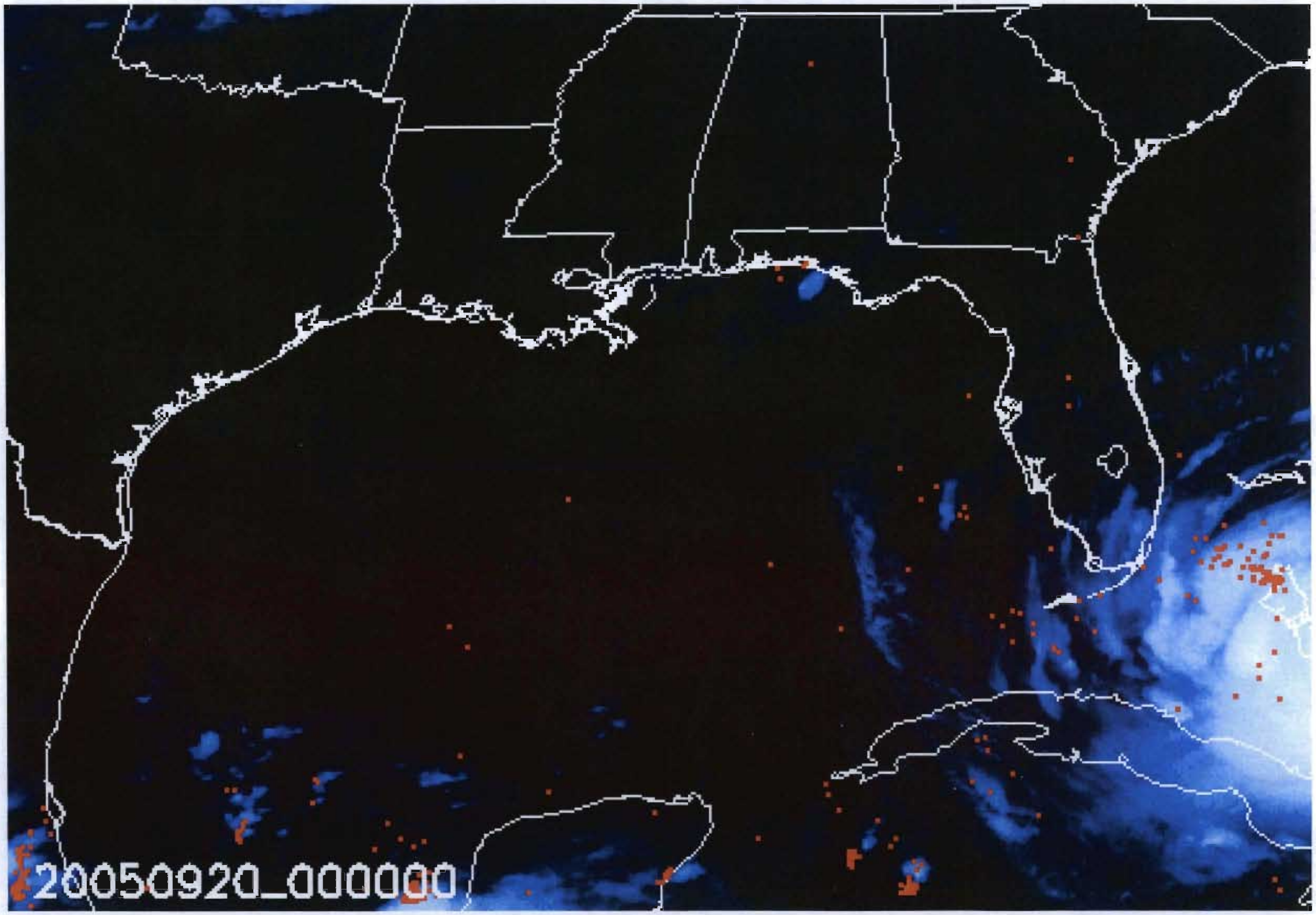
(1) Start to see eye-wall lightning at Cat 3. (2) Eye-wall lightning intensifies while Rita progresses fro
5; eye-wall lightning decreases when Rita decays. (3) Normal rate of rainband lightning; rainband lightning not associated with Rita intensity. (4) Rita intensified from Cat 3 to 5 much faster than Katrina, and produced much more eye-wall lightning.





Shao et al., Eos, 86, 42, 18 Oct. 2005

Rita development Movie



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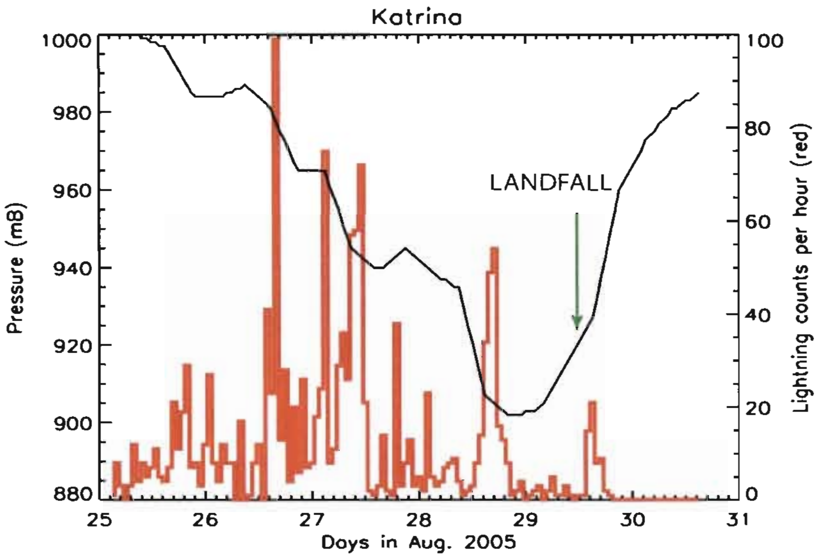
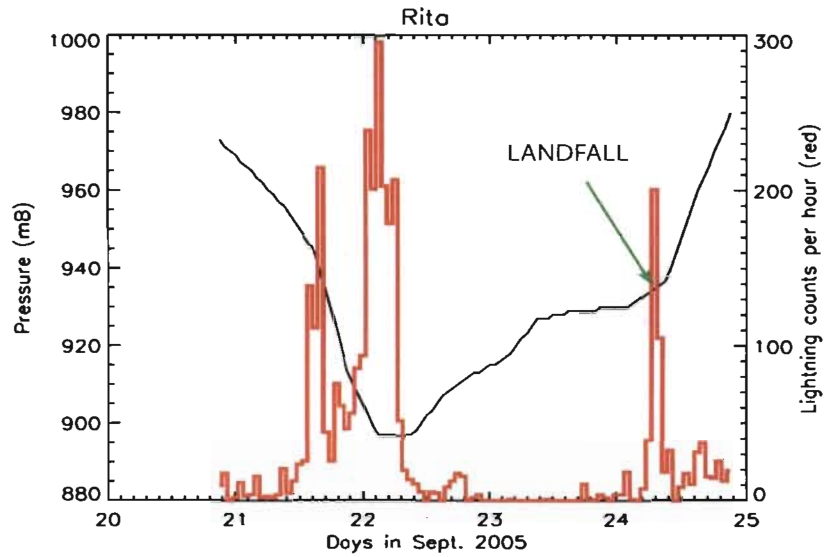
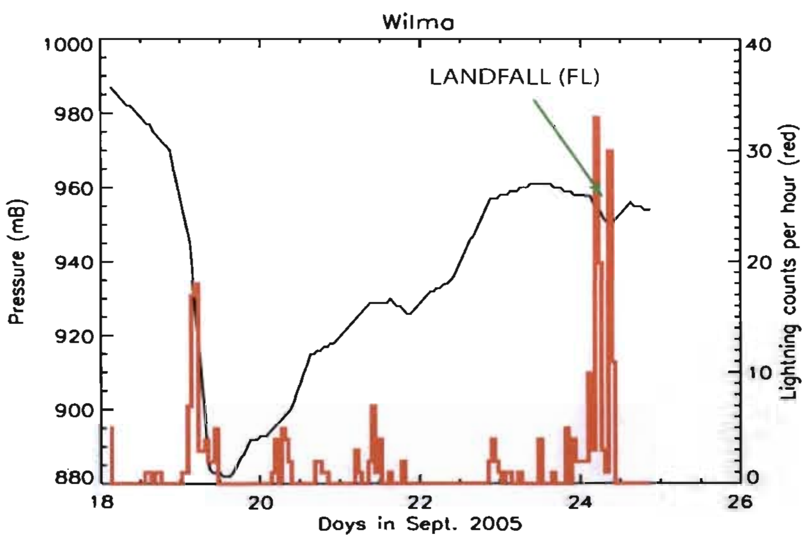
Eye-wall lightning rate positively related to hurricane intensification







Wilma was from Caribbean Sea toward Florida, not ideal for LASA detection.

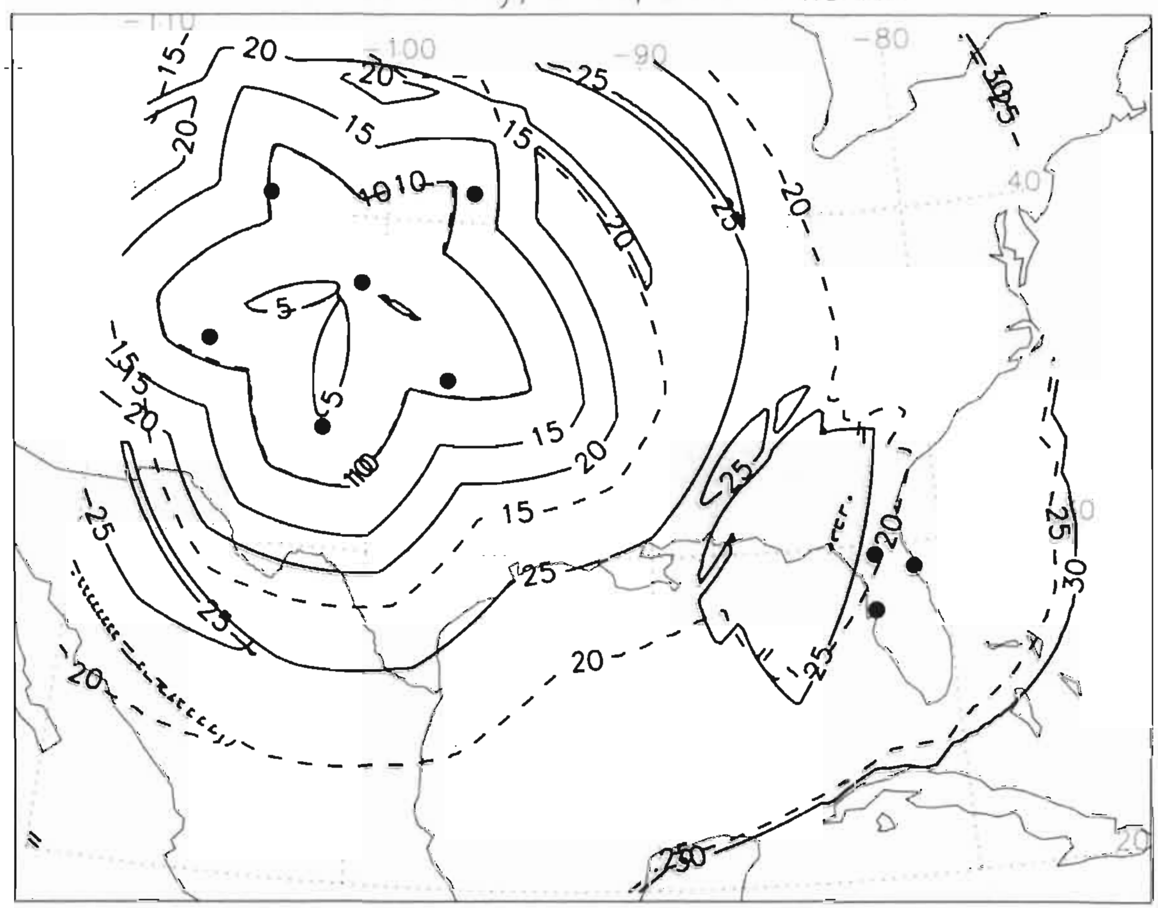
What LASA saw from Katrina and Rita?

About ½ of first return strokes and ½ of NBEs in the Gulf

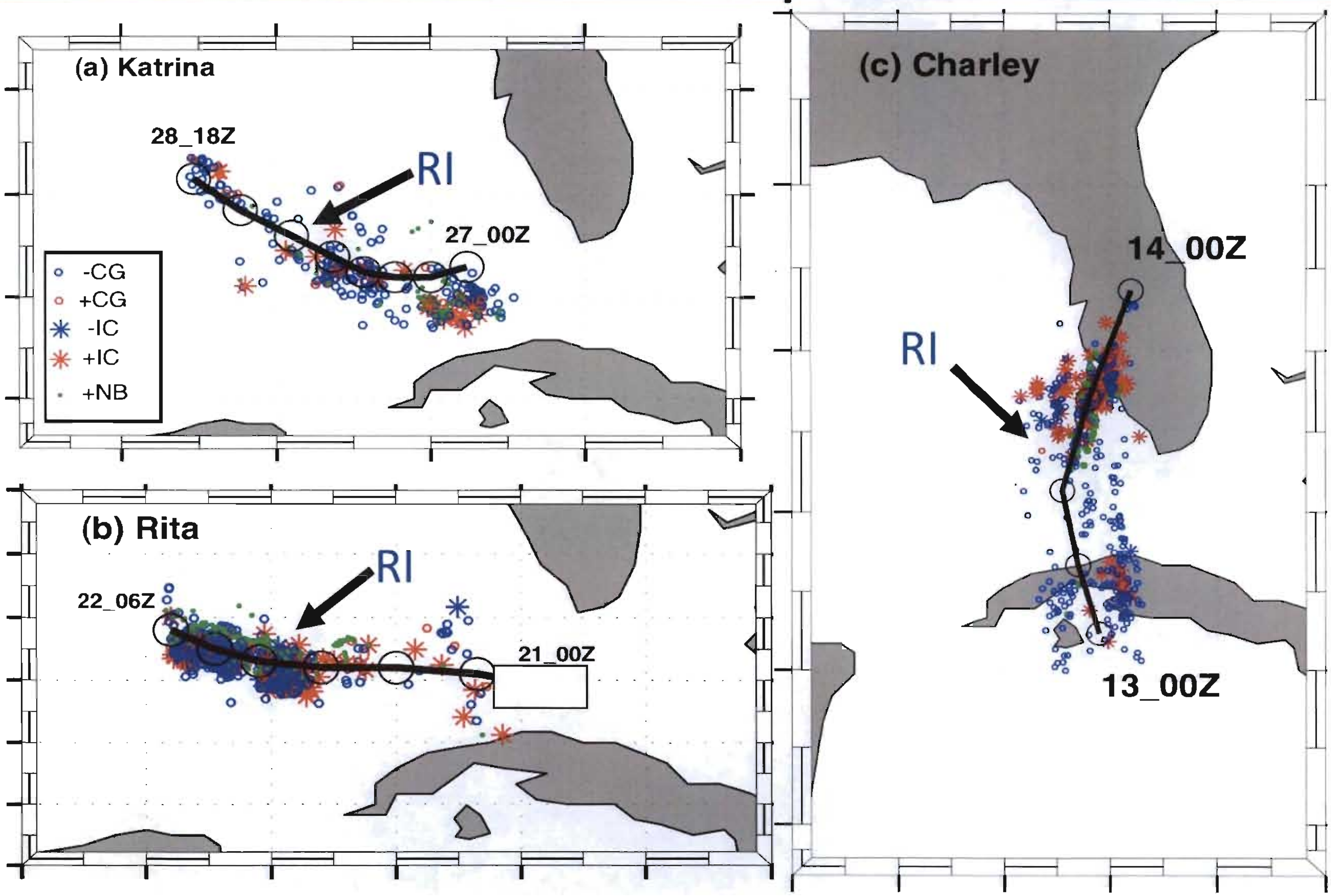
Sensitivity map is based on:

(1) Trigger threshold
(2) VLF/LF propagation model simulation
(3) Conversion of E-field to peak current

LASA sensitivty, 2005, Detectable kA



Detected lightning types along hurricane paths



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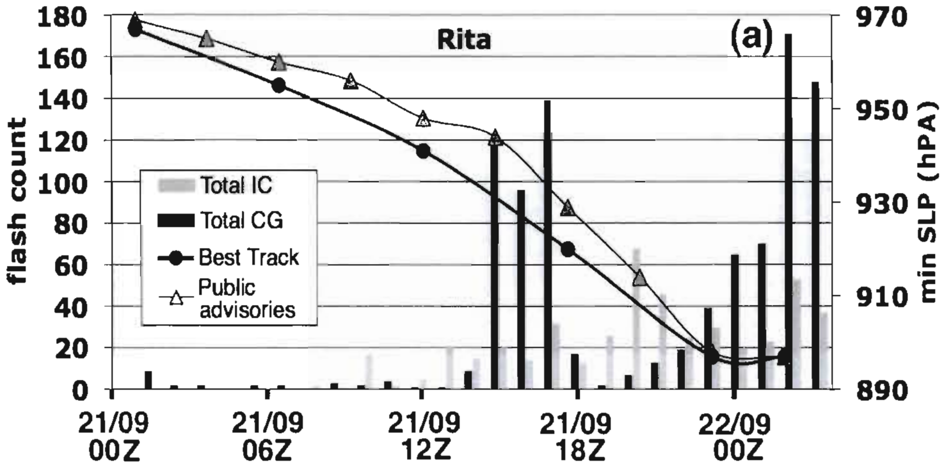
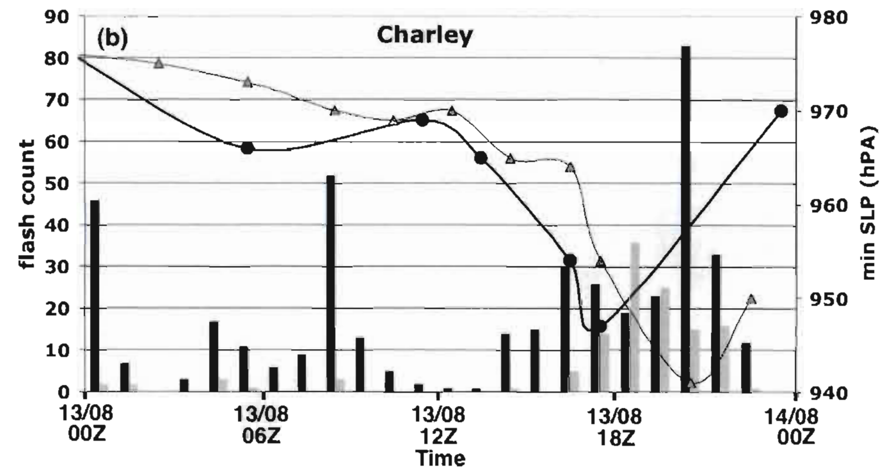
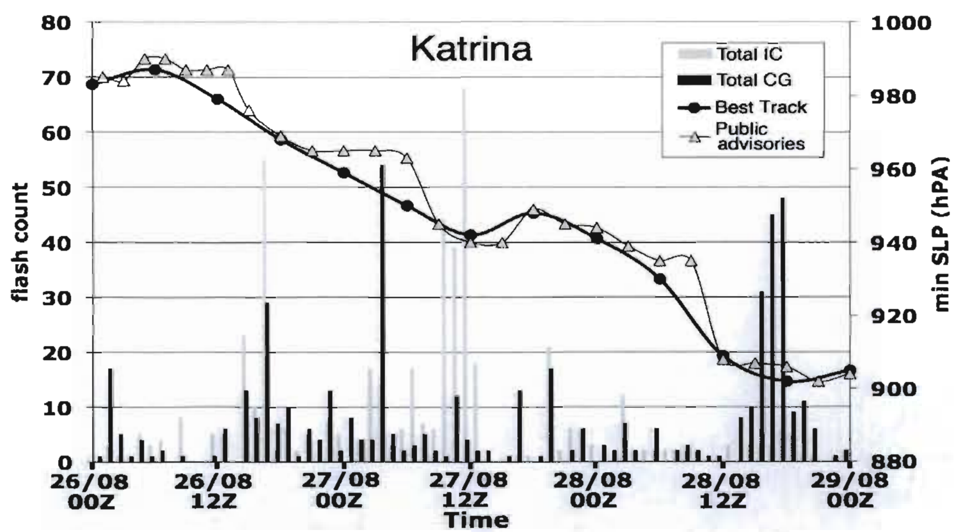
Time series of CG and IC (mostly NBEs)







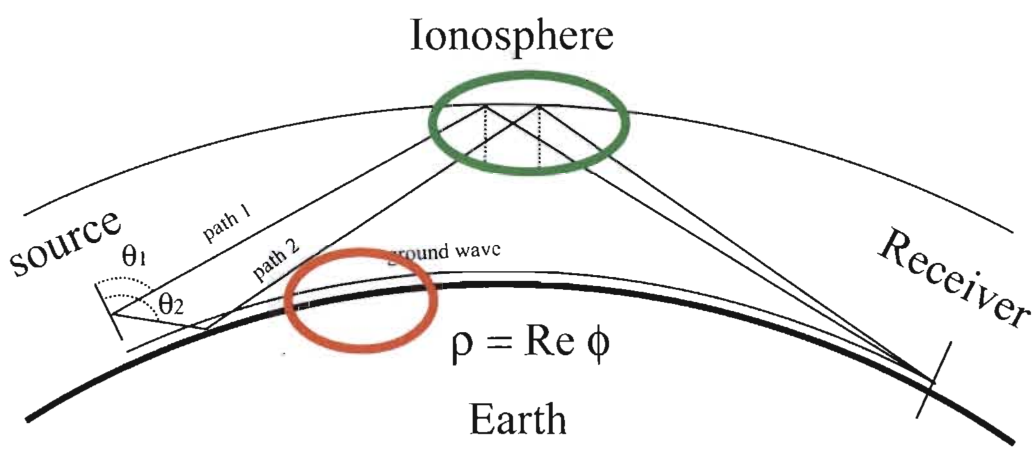
1. Increase in both cloud-to-ground (CG) and intra-cloud (IC) flash rate during onset of RI
2. Large CG flash burst observed during period of max intensity

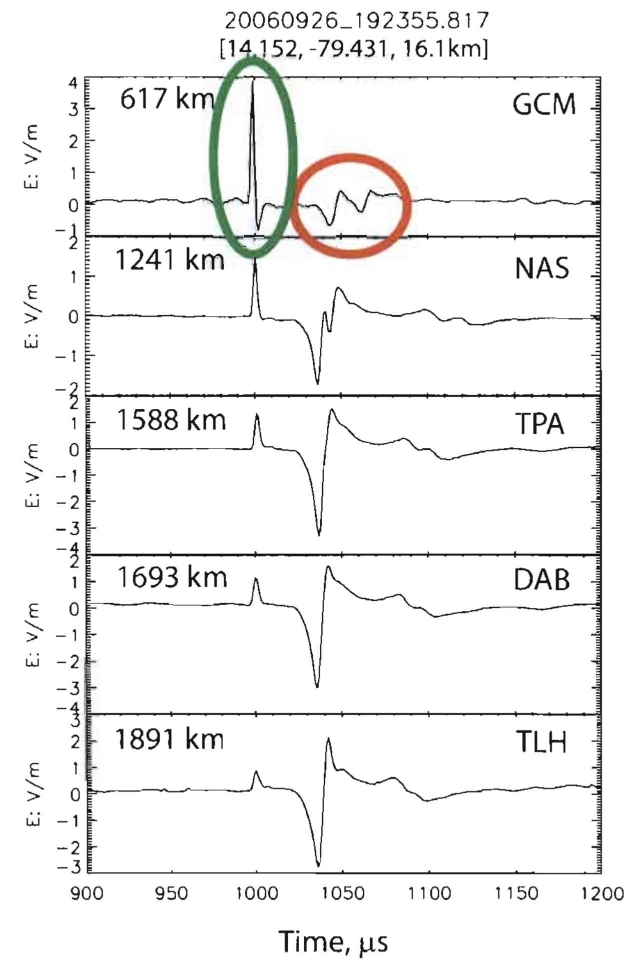
NBEs provide valuable convection height (and strength) information

LASA records full waveforms, and has unique capability of determine source height from distance.

(1) Need to know geolocation

(2) Pair of reflections can be identified for NBEs up to 1000 km.

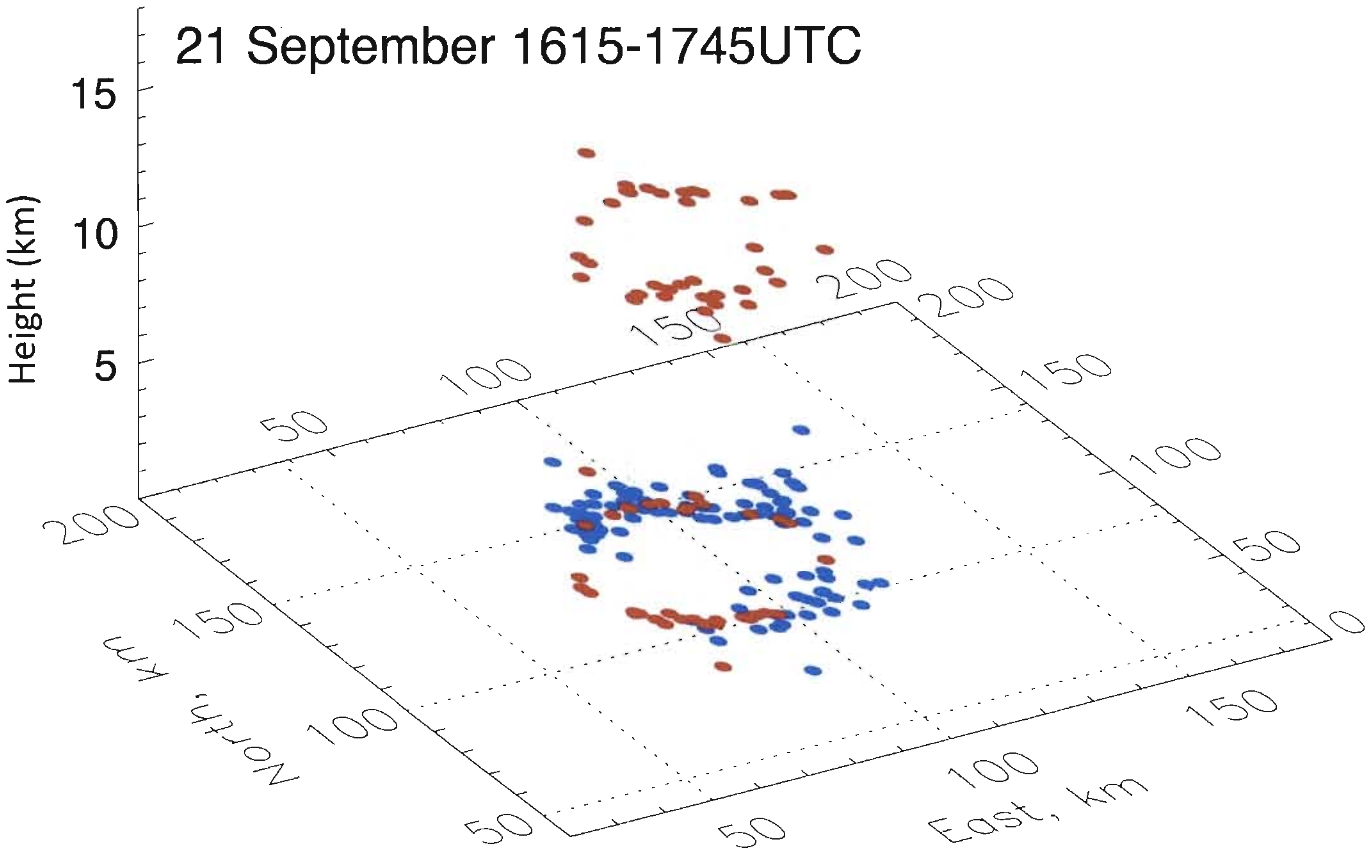




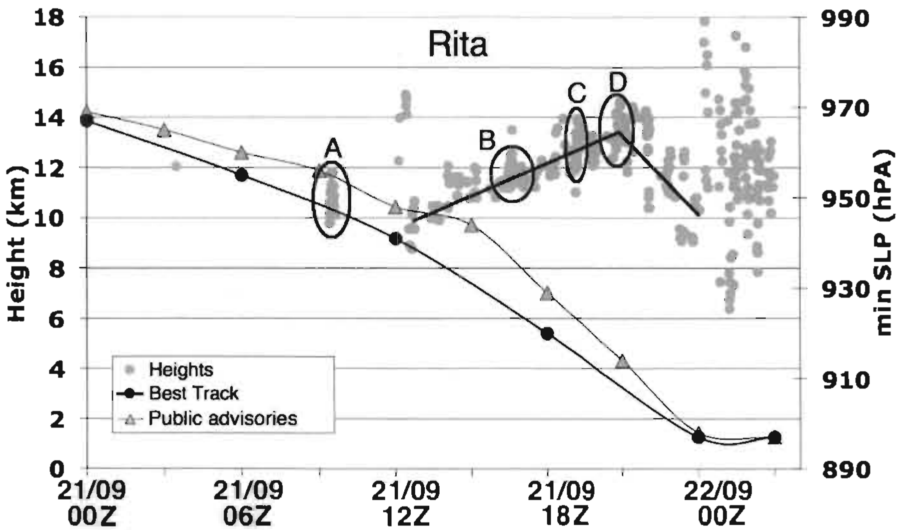
A snapshot of Rita lightning in 3-D

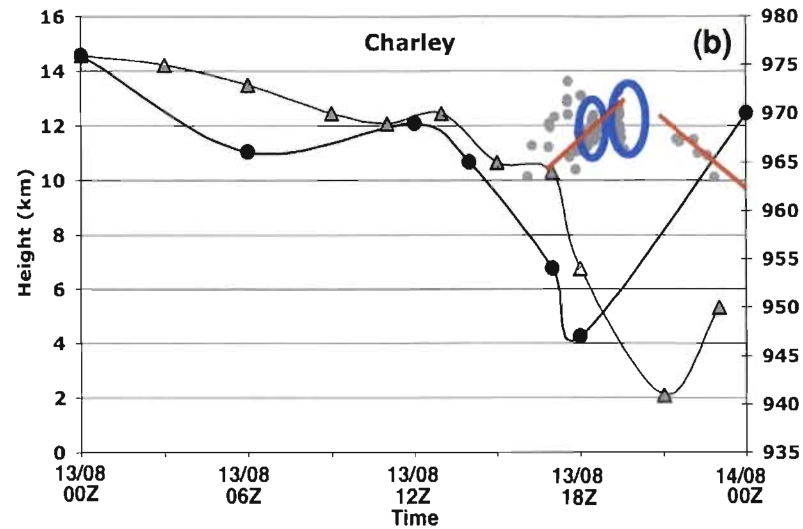
Little-no vertical tilt of CG and IC

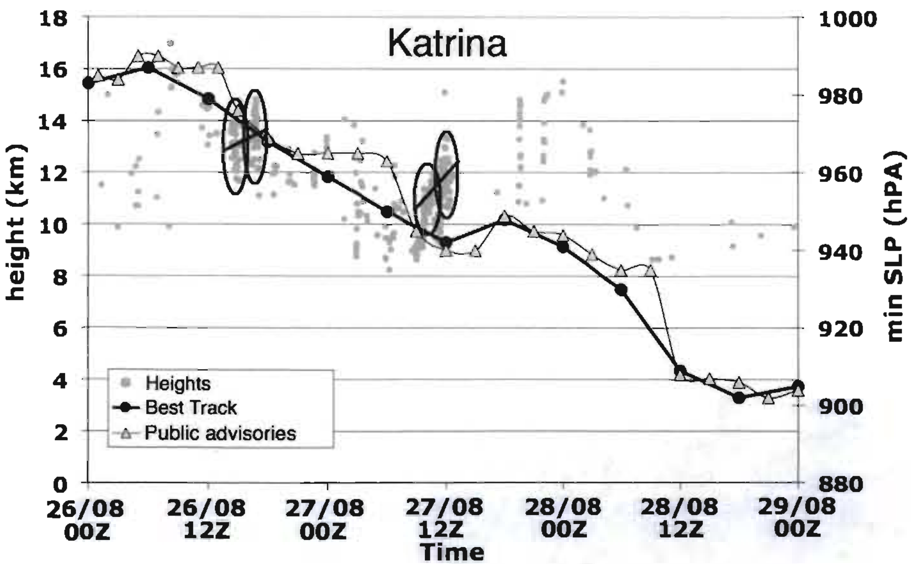
→ Little displacement of charge layers in eyewall convection



Compare NBE height with storm intensification

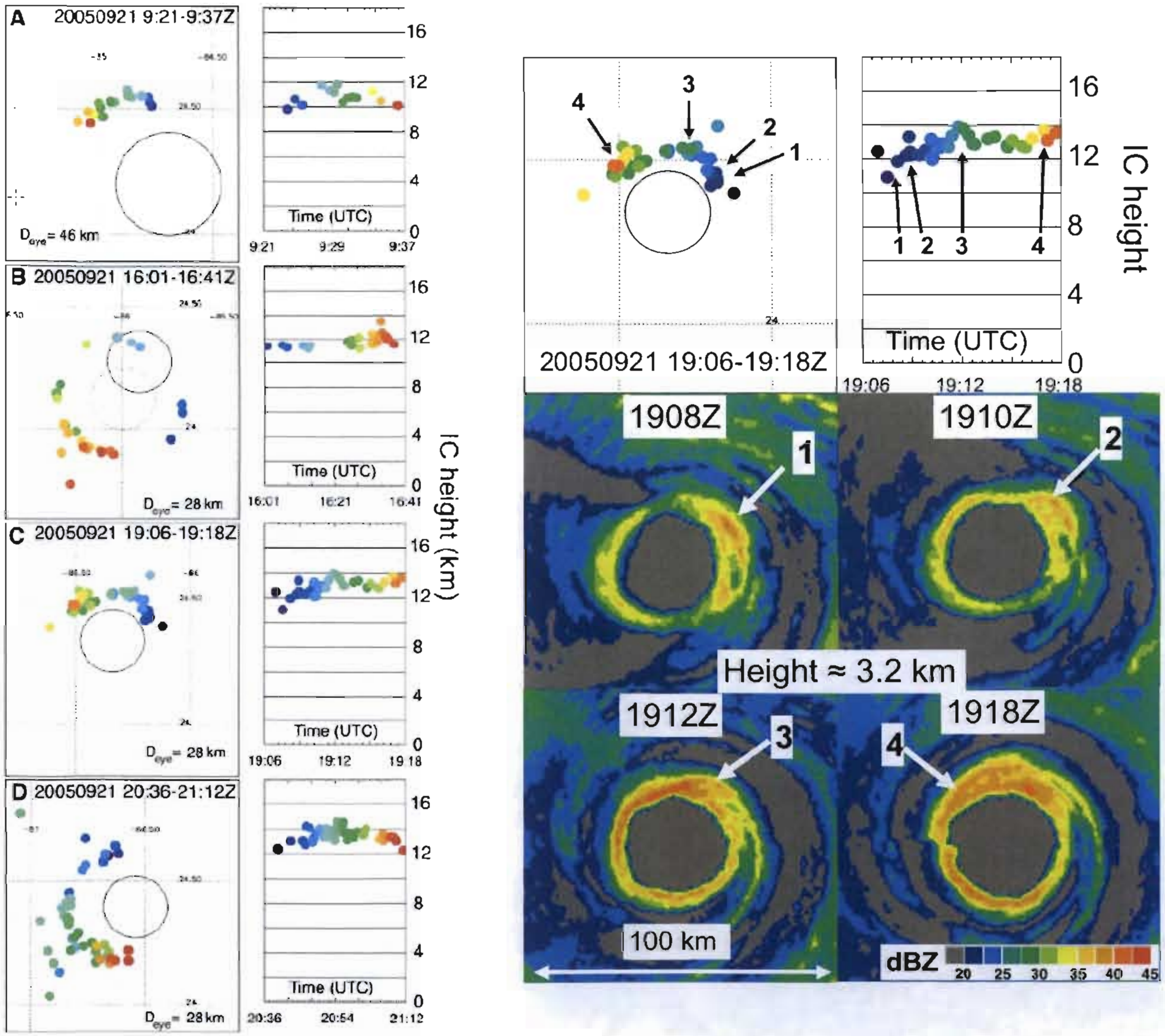






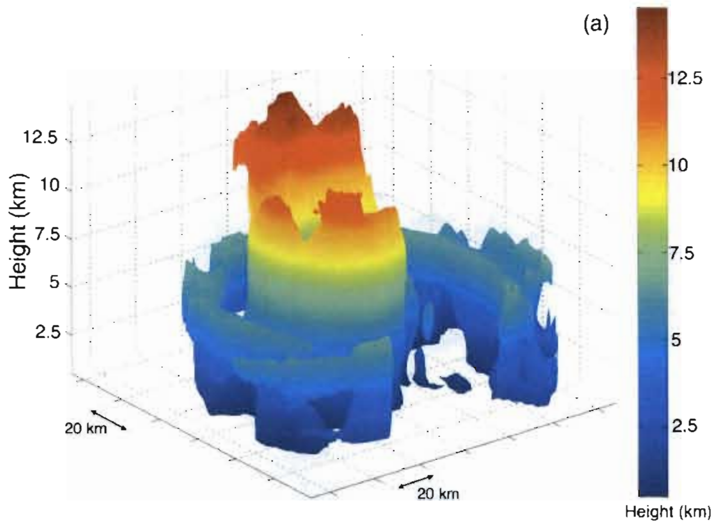
- storms experience NB increase in height during RI, especially Rita by ~ 4 km
- Indicative of charge lofting during convective hot tower burst
- For Rita heights decrease quickly ~3 h before steady state → Indicative of collapse of hot towers

IC (NBE) follows "hot tower" around eye-wall



- IC flashes are found to rotate around the eye
- IC flashes collocated with highest radar reflectivity at z=3 km
- → IC flashes can be use to map individual hot towers during RI
- → IC give crucial information on core internal convective structure/state during RI

Rita: 3D view reflectivity at 1915 (burst C)

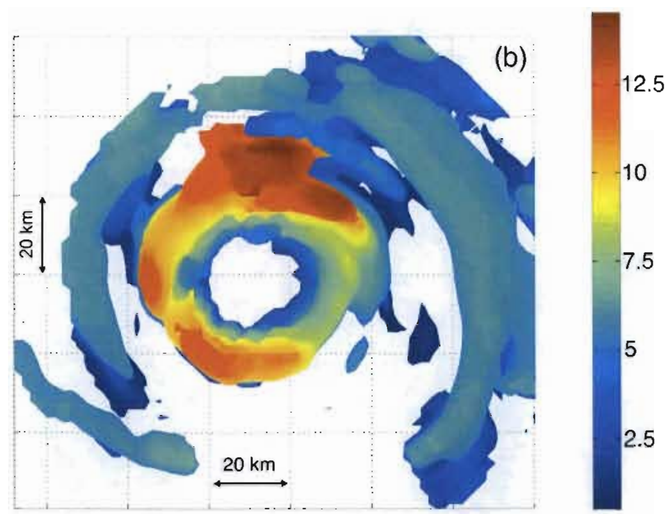


Side View

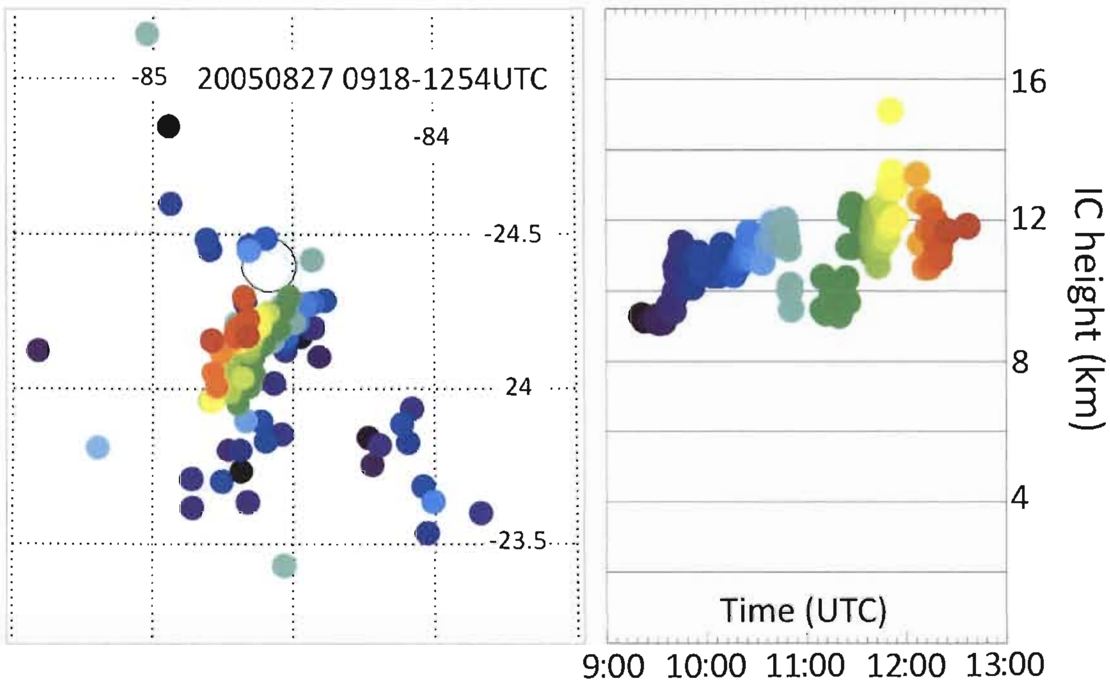
•Northern portion of the eye-wall as suggested by IC flash has deeper hydrometeor cores and thus updrafts

•30 dBZ echo isosurface of lower fuselage aircraft in situ data

Top view

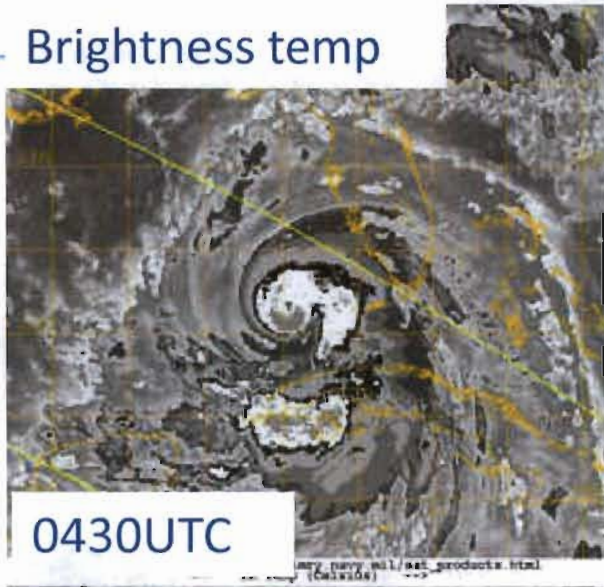


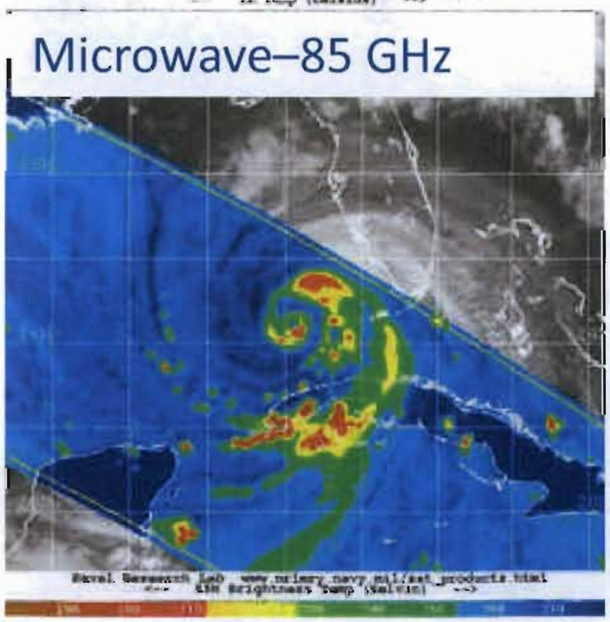
Katrina: second set of NBE bursts

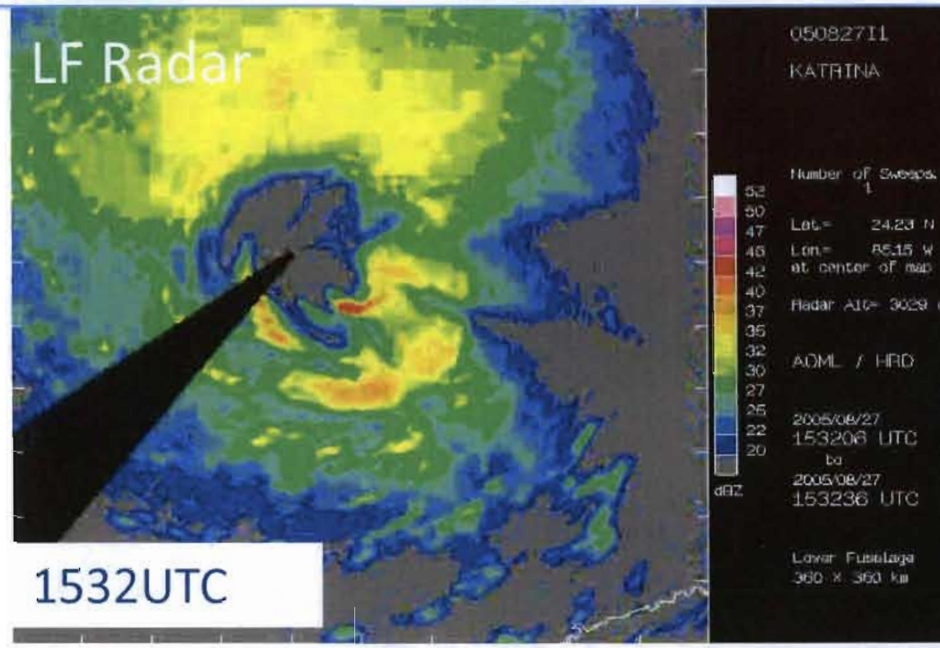


- Convection remains on the south side of the storm and follows storm track. Heights shows net 3 km rise.
- IC lightning helps in also highlighting difference in convective regimes

Katrina: NRL satellte-NOAA Doppler radar images



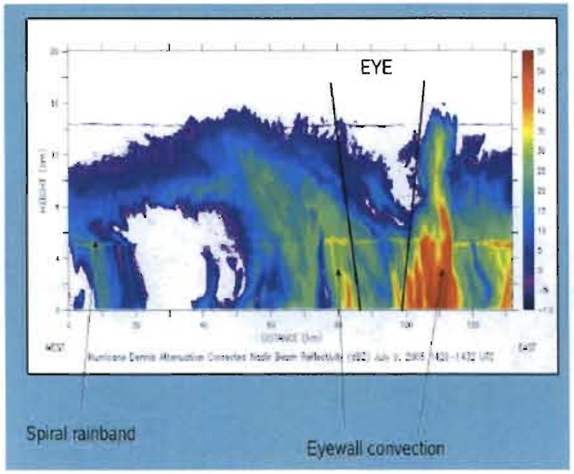


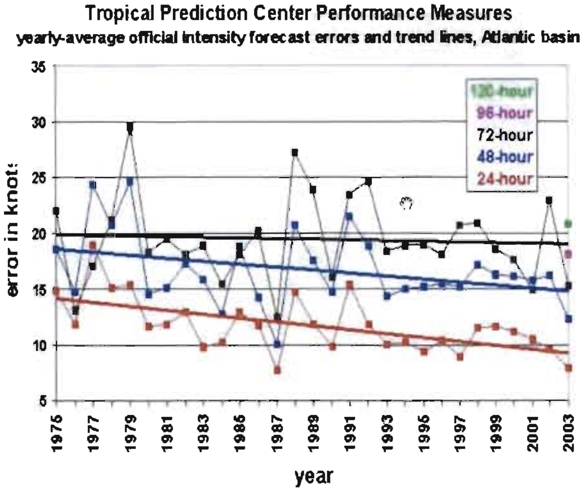


Deep convection present on the southern portion of the eyewall 4h before and 5h after observations.

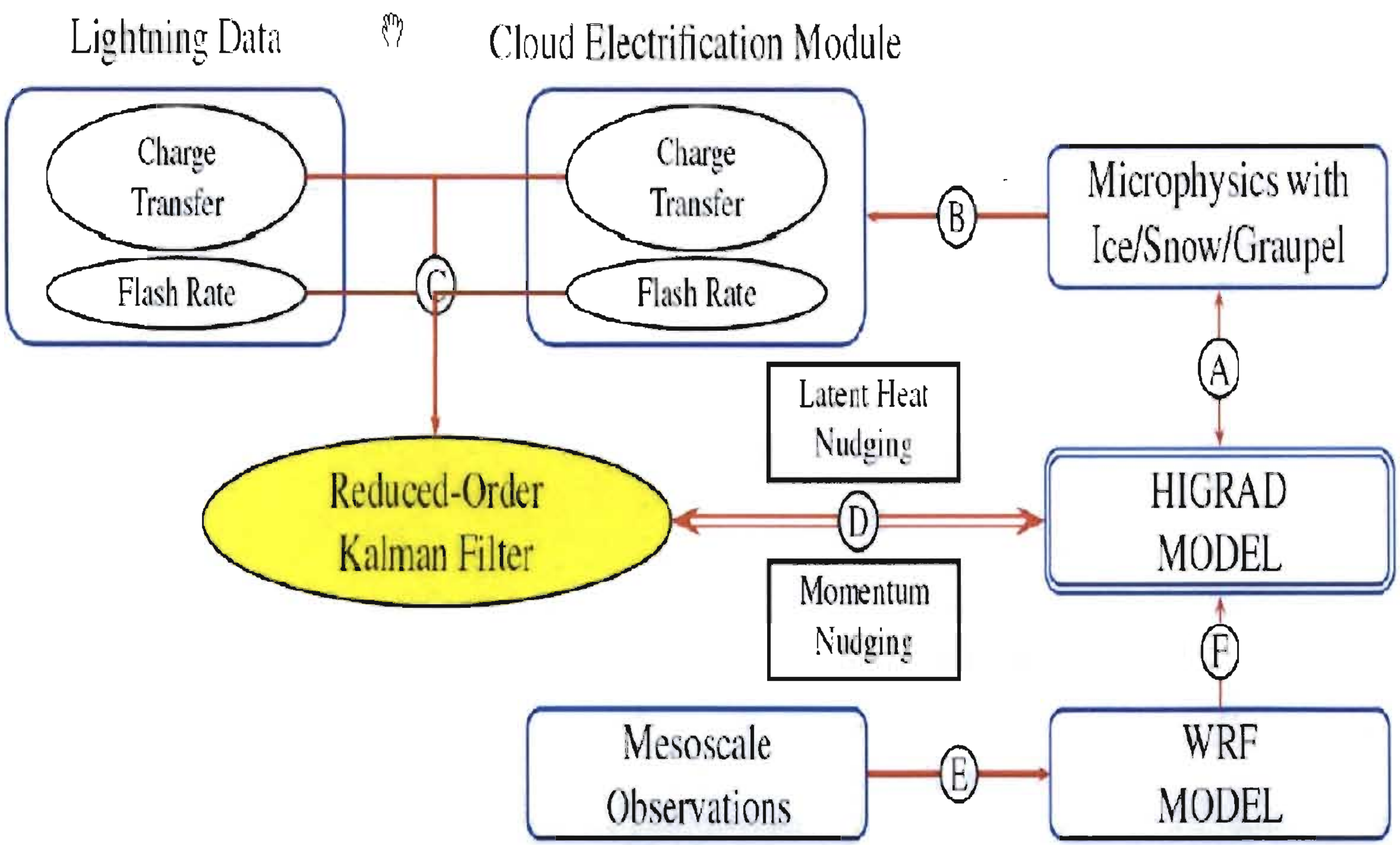
Why lightning? Why LASA?

- Hurricane tracking prediction has been improved significantly in past decades
- But intensification predication has not
  - RI believed related to eye-wall convection dynamics
  - But continuous in-situ observation not possible
  - Land-based radar can only reach a limited range
- Lightning observations are continuous and remote
- LASA provides critical IC and convection height (and strength) information





Feed lightning data into advanced model

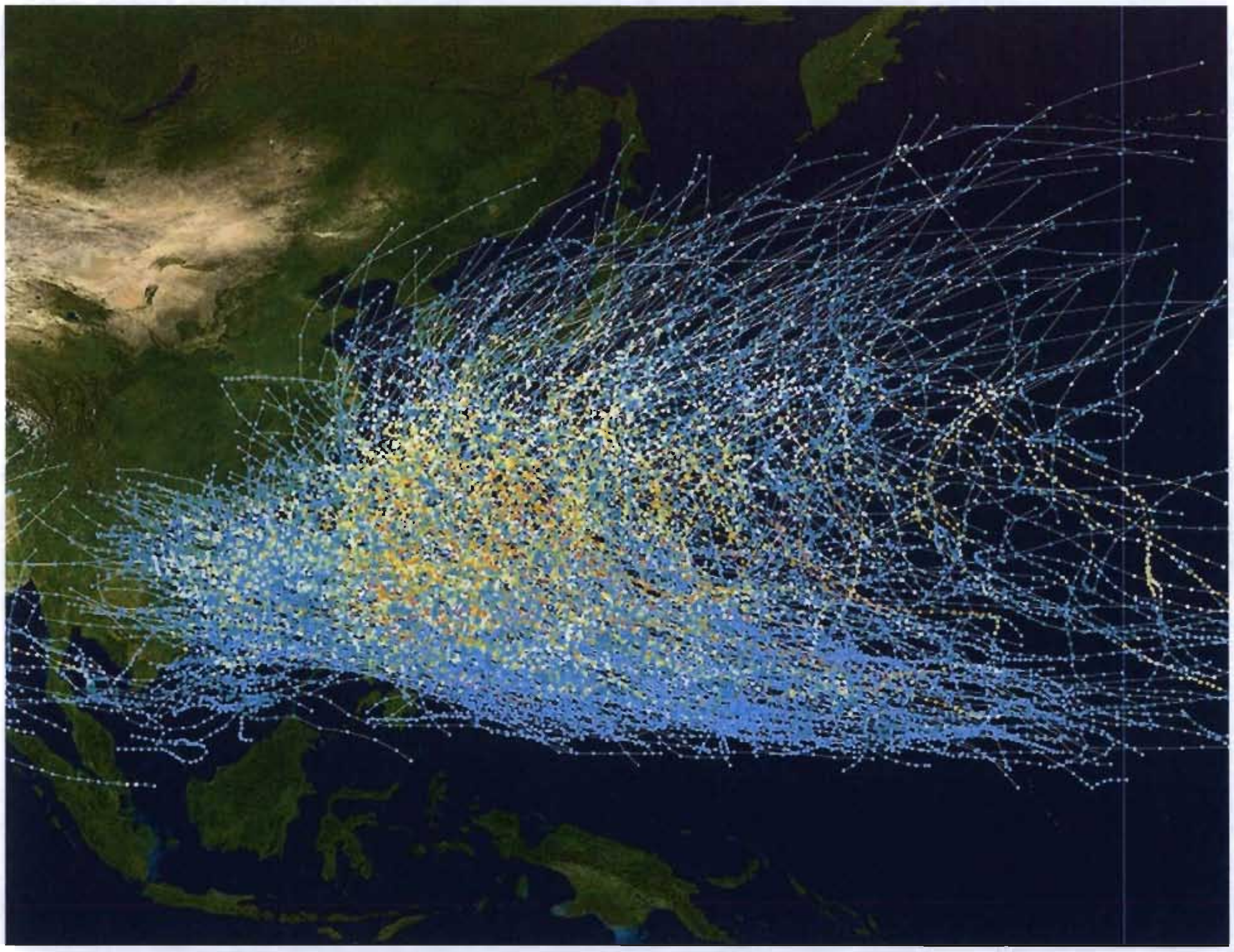


Summary

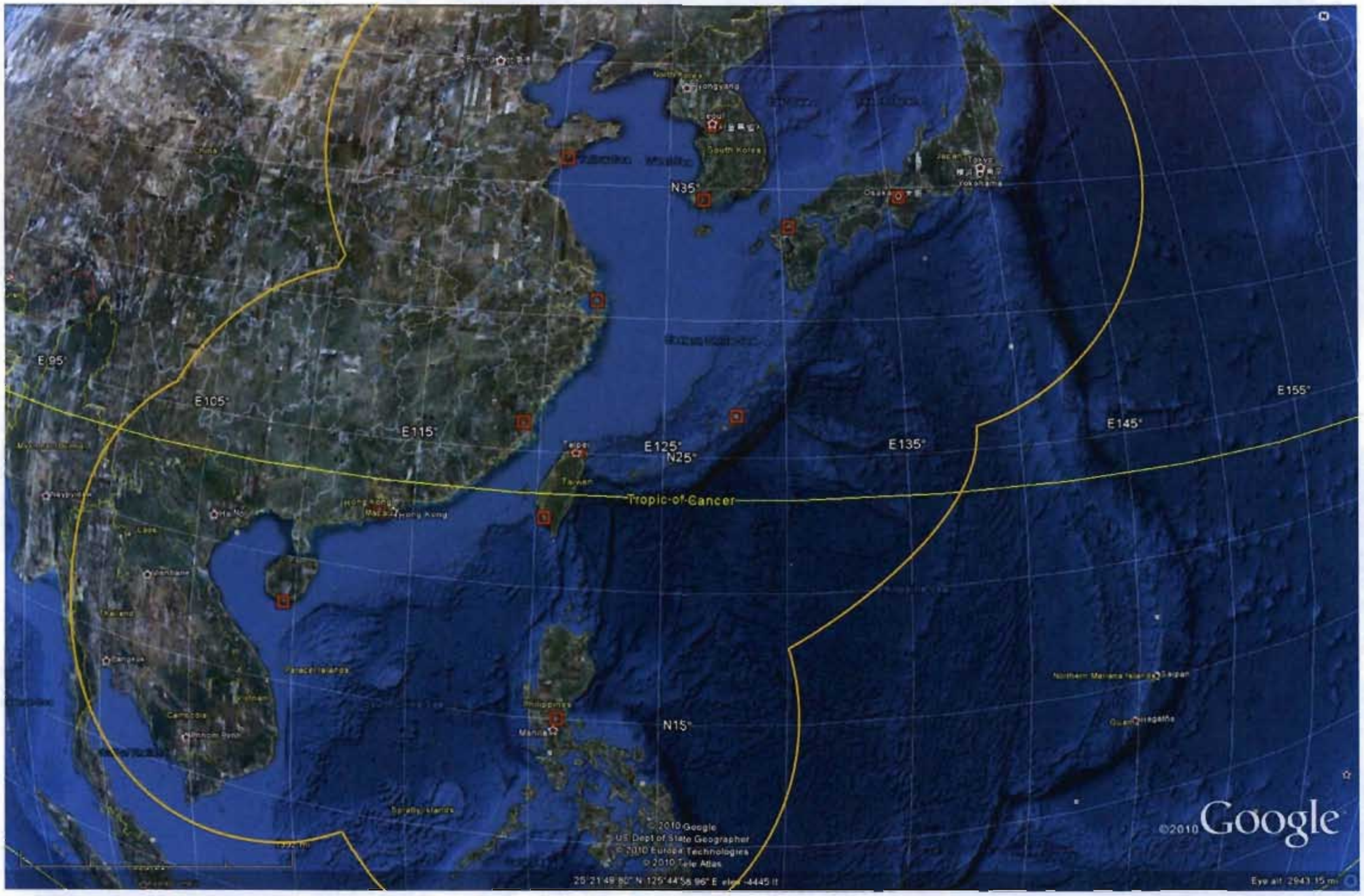
- An increase in CG *and* IC flash rate during the onset of RI
- A large increase in CG flash rate during period of max intensity
- An increase in NBE discharge heights during onset of RI or intensification
- IC flash along with radar data allows one to track individual convective events (or hot tower bursts) as they rotate around the eye-wall.
- $\rightarrow$ Lightning (particularly IC flashes) can be used to fill in the voids of radar data for a better representation of storm core internal structure for data assimilation (EnKF, 4DVAR etc..).

Slides for discussion

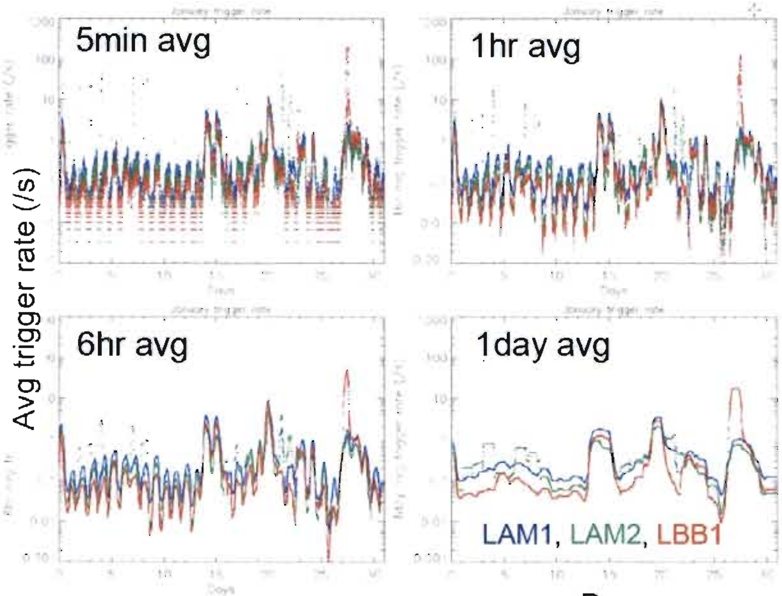
Typhoon tracks in West Pacific 1980-2005



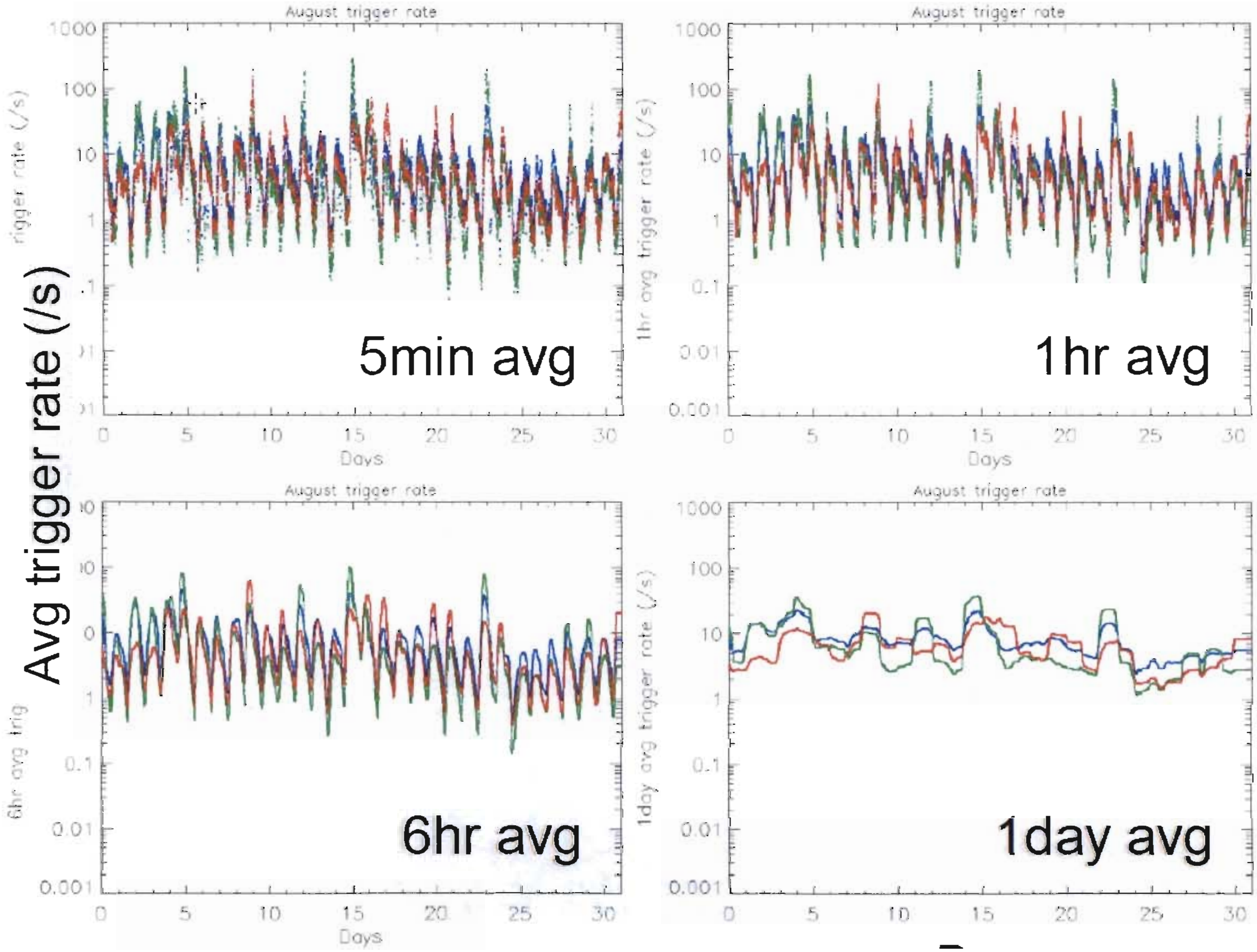
Possible LASA stations



LASA trigger rate in winter



LASA trigger rate in summer



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LASA data rate

- Average data volume over a long period of time is 1-10 GB/day/station. (these are compressed numbers.)
- Raw data are compressed with tar/gzip down to ~65%.
- At the moment, data are grouped into 5 minutes files. A tgz tar ball is made every 10 minutes. Thus we have a minimum data latency of 10 minutes. These can of course be changed.
- We calculate the checksum for each 10-min tgz file in the field.
- Data are pulled from a central system using rsync on top of ssh2.
- Our experience of using infrastructural/academic internet is that we can achieve 100-1000 Kbytes/s within the US.
- We perform data integrity check by comparing of data files in the local archive with respect to the field calculated values.
- > n days old data are purged from the field system once the checksum is confirmed. Currently n=5. Typically this keep the remote system's 200 GB disk at 5-20% usage.

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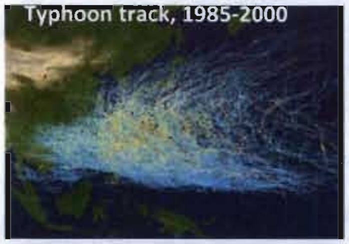
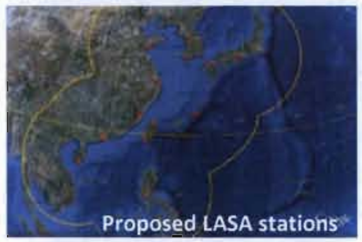
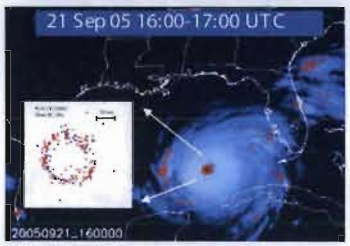
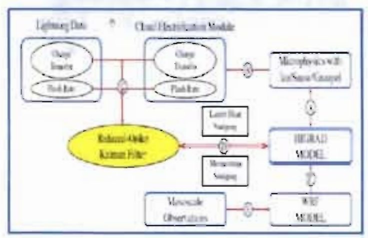
Proposed International Study on Typhoon Intensification with Lightning Observation and Model Assimilation









Objective:

To investigate typhoon intensification process in west Pacific with LASA-like observation and LANL's TC model simulation

Approach:

•Deploy LASA-like lightning sensors in China's coast and Taiwan, Japan, South Korea, and Philippines.

•Each party will provide and deploy LASA-like sensors in its region, and provide data communication facilities. The participated parties will have full access to all the data for process.

•Processed data will be fed into LANL's TC model for forecasting simulation study.

• Research will be conducted through close scientific collaborations among the participating countries.

Background:

•Predication of hurricane/typhoon (tropical cyclone, TC) movement has been significantly improved, but little progress on intensity predication

•Recent studies show temporal correlation between lightning rate and TC intensification (Shao et al. 2005, Price et al. 2009).

•Observation with LASA further showed that incloud lightning (IC) could be a better indicator for TC convection strength, and with LASA's unique capability it was showed that the lightning height starts to increase prior to and during the hurricane intensification period (Fierro, Shao, et al. 2010)

• Assimilated lightning data with LANL's microphysics and HIGRAD model showed substantial improvement on forecasting of hurricane development

Challenges:

No significant technical challenges are expected for lightning sensor development and deployment, data communication, and data processing.

Political and logistic al supports might be needed from the host countries and areas.

Short-term Plans:

A multi-national workshop in Beijing in April 2011 to start the technical discussion.