Severe Weather & Hazards Related Research at CREST

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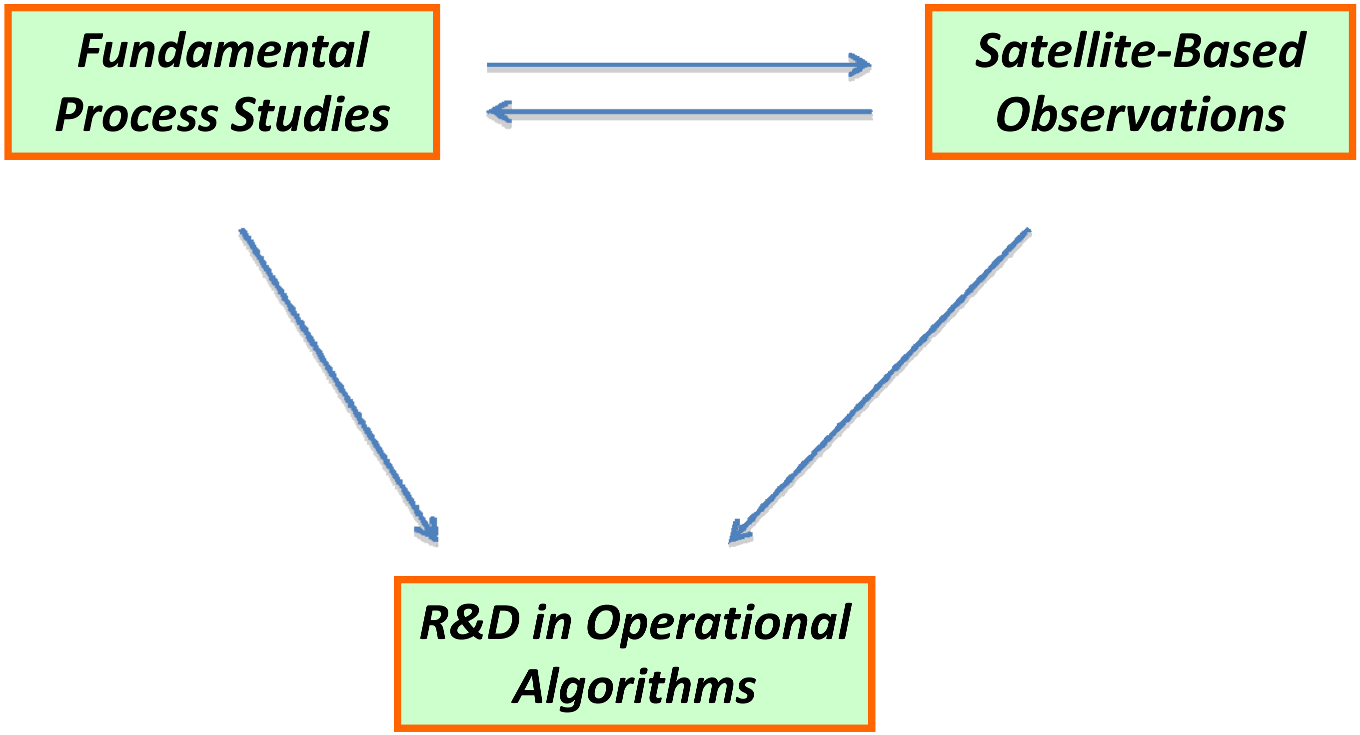
(NOAA Collaborators) Arnold Gruber, Mamoudou Ba, Bob Kuligowski, Valiappa, Lakshmanan, Robert Rabin, Xiwu Zhan


Fundamental Process Studies
Satellite-Based Observations
R&D in Operational Algorithms

The term "***severe weather & hazards***" is not well defined. It can be used to refer to a number of things, depending on who you talk to.

Traditionally, "severe weather" almost always refers to convective storms and related weather phenomena (Houze 2004).

Hazardous Weather Outlook

HAZARDOUS WEATHER OUTLOOK
NATIONAL WEATHER SERVICE PEACHTREE CITY GA
700 AM EST WED DEC 2 2009

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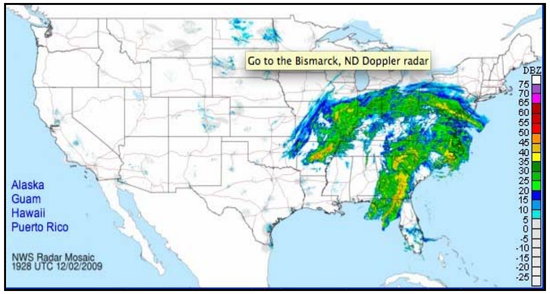
BALDWIN-BANKS-BARROW-BARTOW-BIBB-BLECKLEY-BUTTS-CARROLL-CATOOSA-
CHATTAHOOCHEE-CHATTOOGA-CHEROKEE-CLARKE-CLAYTON-COBB-COWETA-
CRAWFORD-CRISP-DADE-DAWSON-DEKALB-DODGE-DOOLY-DOUGLAS-EMANUEL-
FANNIN-FAYETTE-FLOYD-FORSYTH-GILMER-GLASCOCK-GORDON-GREENE-
GWINNETT-HALL-HANCOCK-HARALSON-HARRIS-HEARD-HENRY-HOUSTON-JACKSON-
JASPER-JEFFERSON-JOHNSON-JONES-LAMAR-LAURENS-LUMPKIN-MACON-
MADISON-MARION-MERIWETHER-MONROE-MONTGOMERY-MORGAN-MURRAY-
MUSCOGEE-NEWTON-NORTH FULTON-OCONEE-OGLETHORPE-PAULDING-PEACH-
PICKENS-PIKE-POLK-PULASKI-PUTNAM-ROCKDALE-SCHLEY-SOUTH FULTON-
SPALDING-STEWART-SUMTER-TALBOT-TALIAFERRO-TAYLOR-TELFAIR-TOOMBS-
TOWNS-TREUTLEN-TROUP-TWIGGS-UNION-UPSON-WALKER-WALTON-WARREN-
WASHINGTON-WEBSTER-WHEELER-WHITE-WHITFIELD-WILCOX-WILKES-
WILKINSON-
700 AM EST WED DEC 2 2009

THIS HAZARDOUS WEATHER OUTLOOK IS FOR NORTH AND CENTRAL GEORGIA.

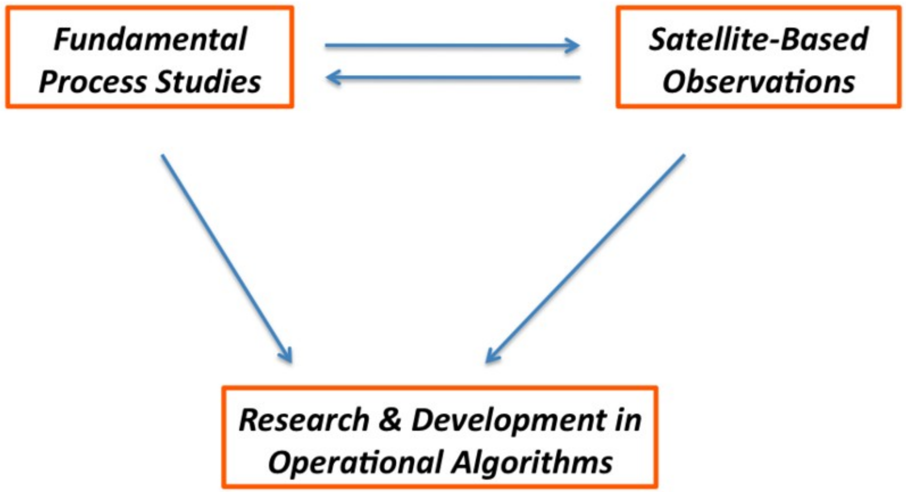
.DAY ONE...TODAY AND TONIGHT
HEAVY RAINFALL AND ISOLATED TO SCATTERED THUNDERSTORMS EXPECTED
TODAY. SOME THUNDERSTORMS COULD BE SEVERE.



The term "***severe weather & hazards***" is not well defined. It can be used to refer to a number of things, depending on who you talk to.

Traditionally, "severe weather" almost always refers to convective storms and related weather phenomena (Houze 2004).

But the definition can be easily expanded to include subjects such as drought, flood, etc.



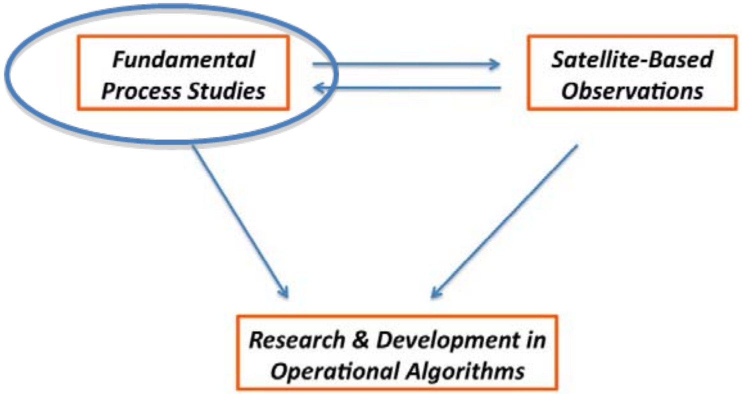
Fundamental Process Studies

Prof. Johnny Luo's group

1. Global surveys of deep convective processes (NASA data):

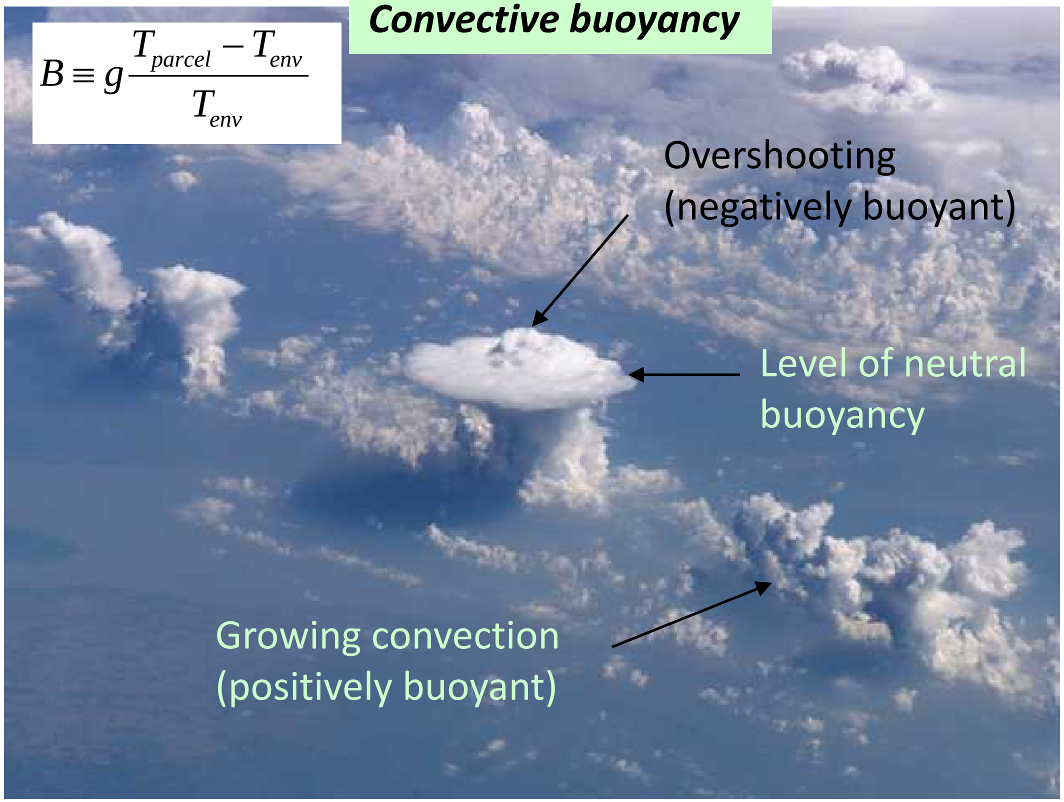
   1) convective buoyancy,
   2) convective entrainment,
   3) hurricane intensity

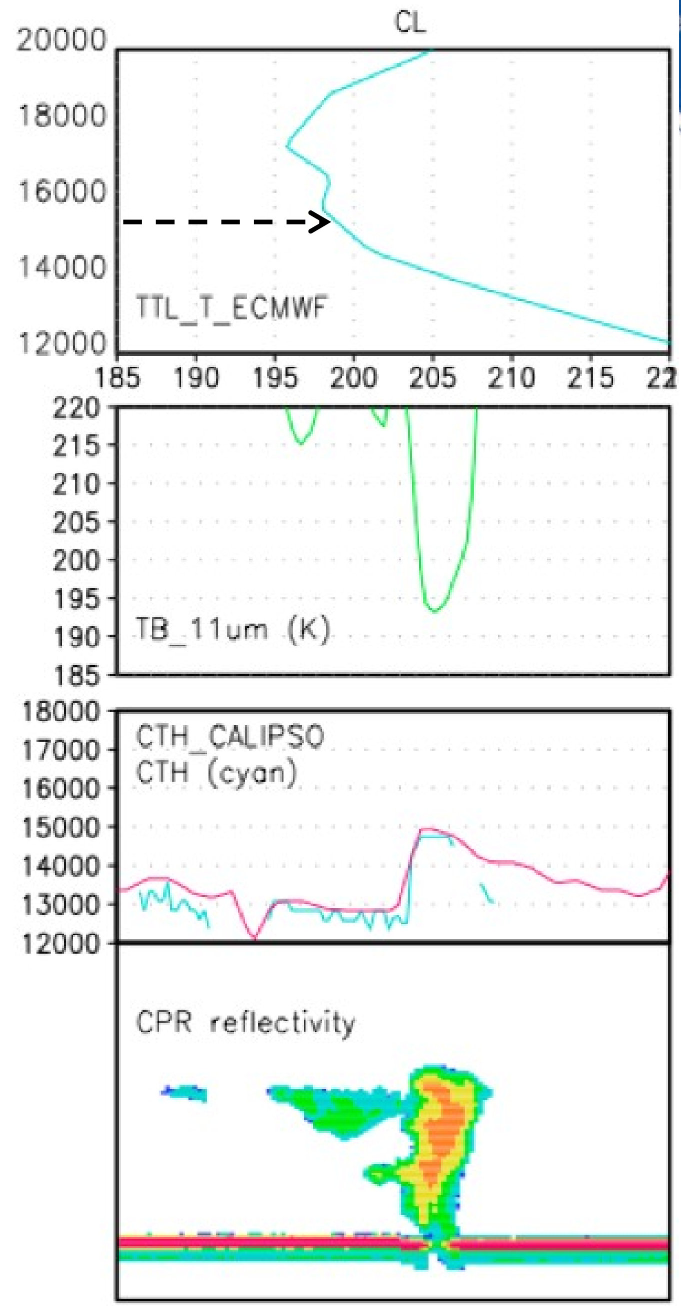
2. How transitions can be made from NASA experimental satellites to NOAA operational satellites



Convective buoyancy

$$B \equiv g\frac{T_{parcel} - T_{env}}{T_{env}}$$



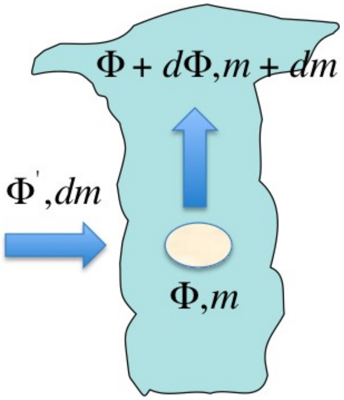


T_{parcel}=193 K; T_{env}=198 K

Negatively buoyant!

Measurement requirements: independent measurements of 1) cloud-top height & 2) cloud-top temperature, and 3) nearby sounding.

Convective entrainment



$$\frac{d\Phi}{dz} = \lambda(\Phi' - \Phi)$$

$$where \;\; \lambda \equiv \frac{d \ln m}{dz} = \frac{1}{m}\frac{dm}{dz}$$

Φ is any conserved quantity. For this application, we use moist static energy (MSE).

Moist static energy (MSE) of the convective top:

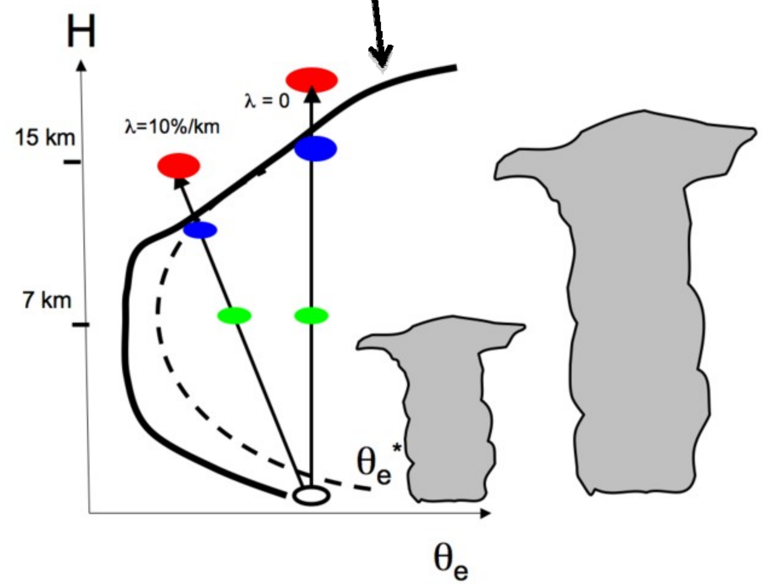
$$MSE = c_pT + gz + L_vq$$

Cloud-top temperature

Cloud-top height

Function of temperature

Environmental sounding

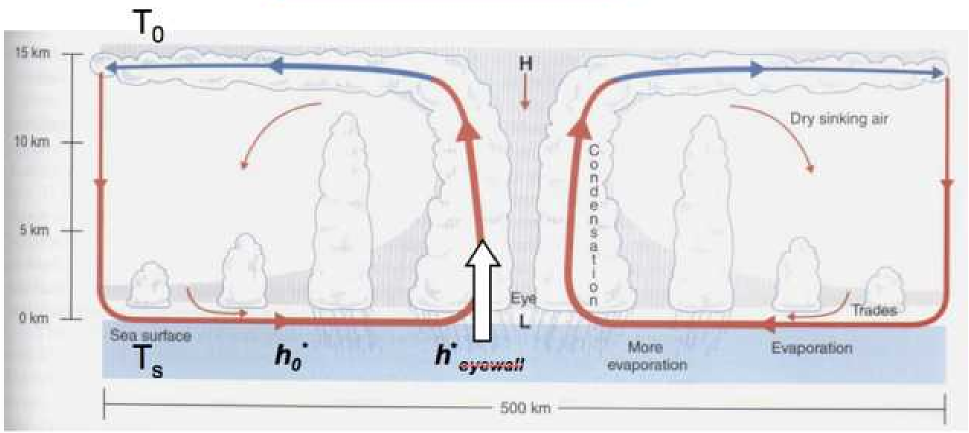


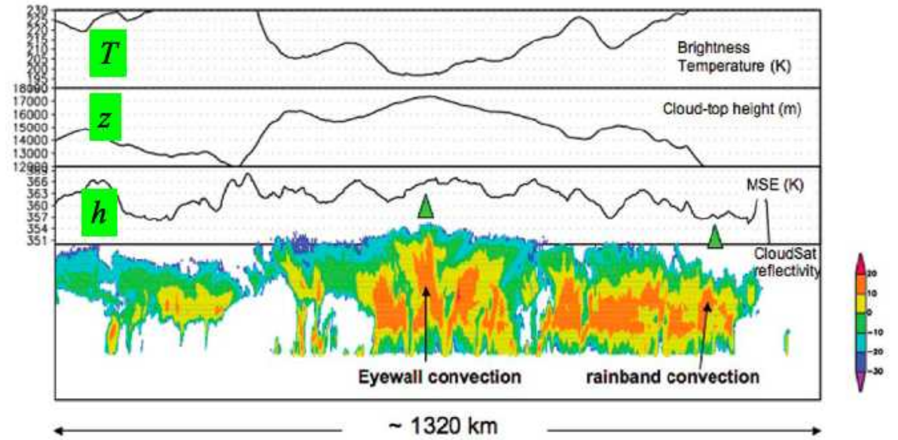
Knowledge of λ is important to determining the final fate of convection (e.g., deep Vs intermediate).

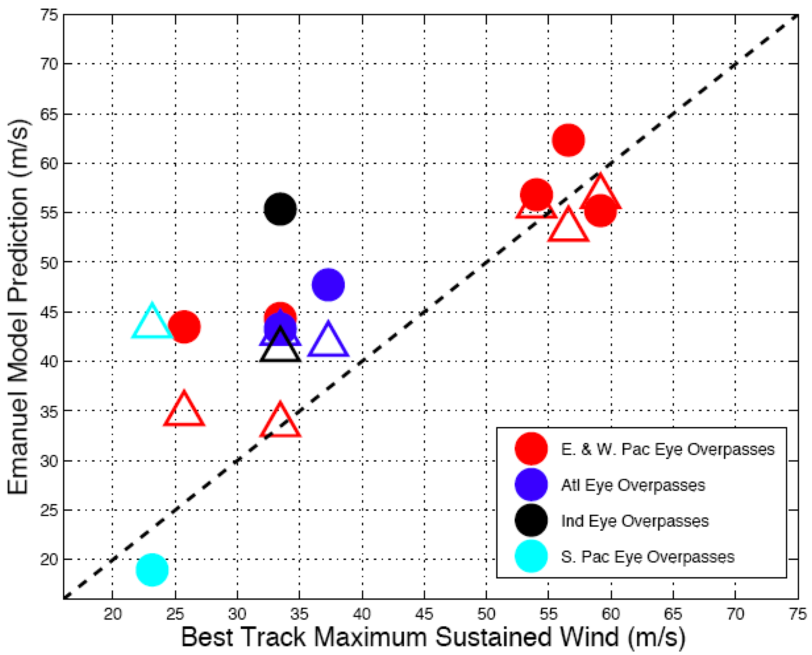
Hurricane Intensity

Emanuel (1986) modeled the hurricane as a balanced, convectively neutral vortex (analogous to a Carnot heat engine) and provided a physically-based approach for determining the storm intensity.

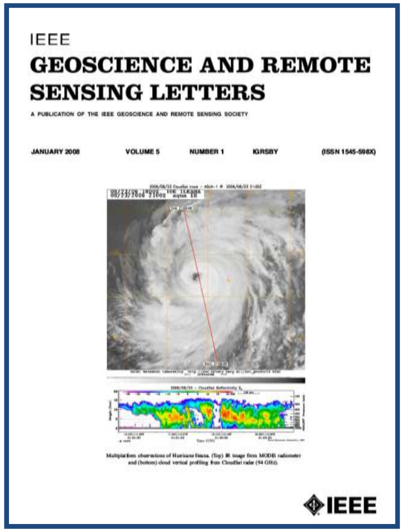
$$V_m^2 \approx \frac{T_s - T_0}{T_0}\left(h^*_{eyewall} - h^*_0\right) \qquad \text{where } h \equiv C_p T + gz + L_v q$$



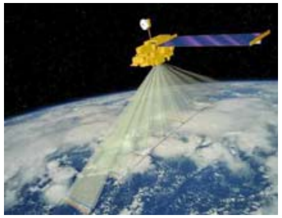




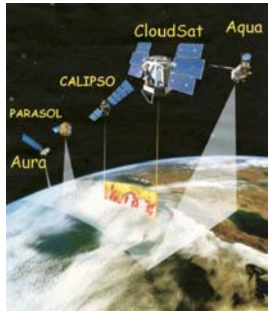
Measurement requirements: independent measurements of
1) cloud-top height &
2) cloud-top temperature



Luo et al. 2008

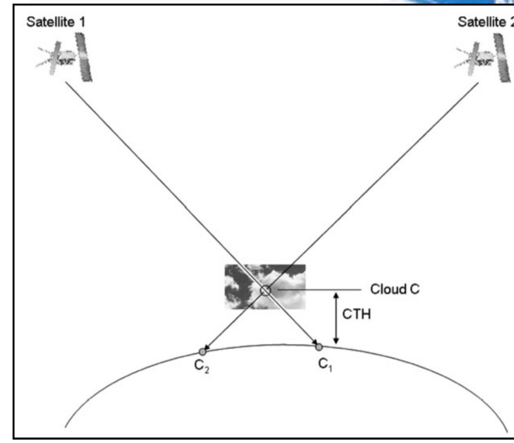


MISR



CloudSat/CALIPSO

Transition to operational



Stereoscopic cloud-top height (need two GEOs)

Measurement requirements

1. Cloud-top height;
2. Cloud-top temperature;
3. Identification of convective towers

So far

MISR, CloudSat, CALIPSO

Any IR radiometer (e.g., GEO, MODIS, etc.)

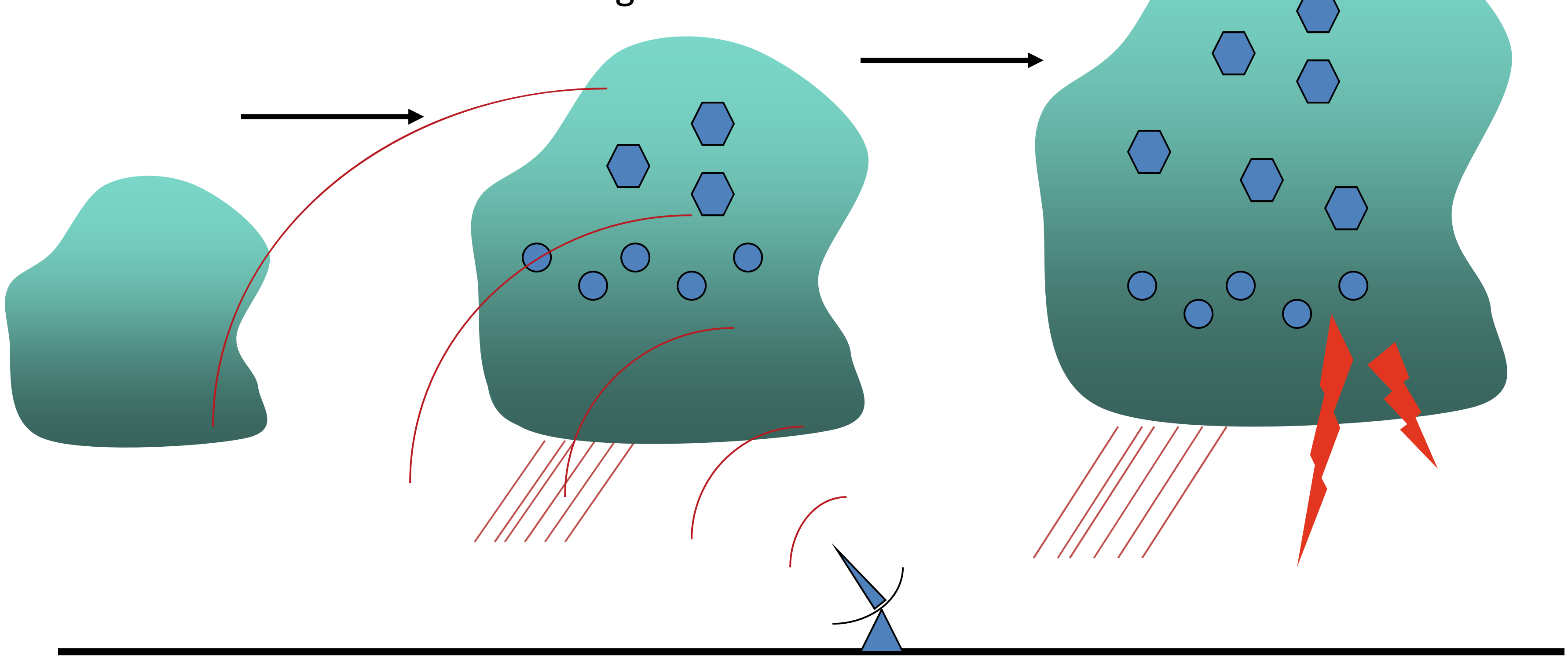
TRMM, CloudSat

R&D in Operational Algorithms

Satellite Thunderstorm Nowcasting: any advantage over radar?

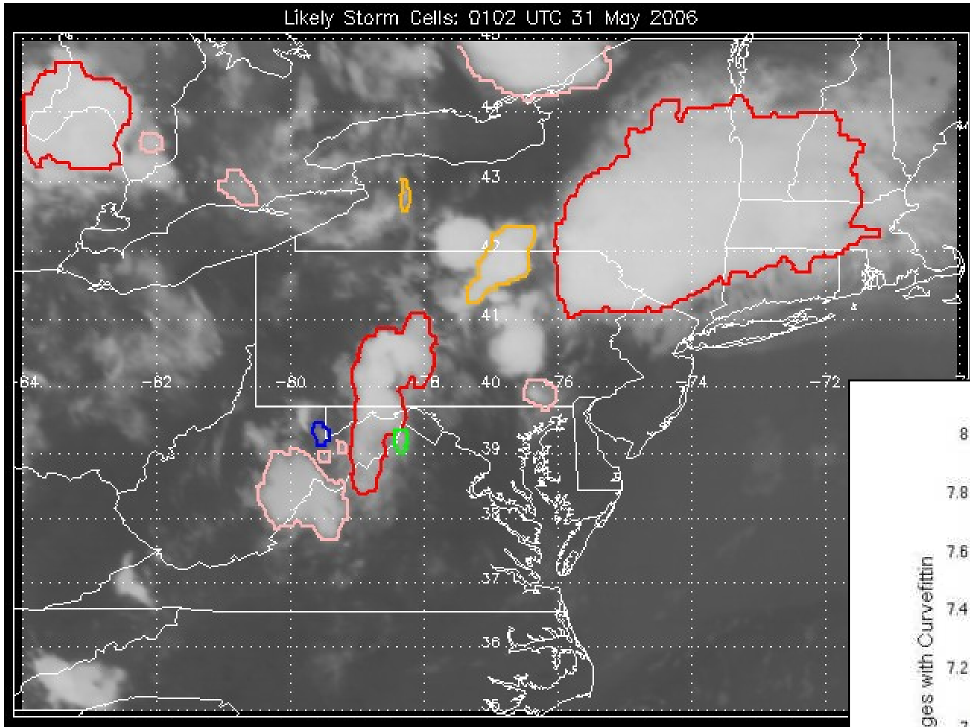
Currently most operational nowcasting is based on weather radar, but geostationary satellite could detect systems before precipitation sized drops develop. It can also detect and track in areas with no radar.

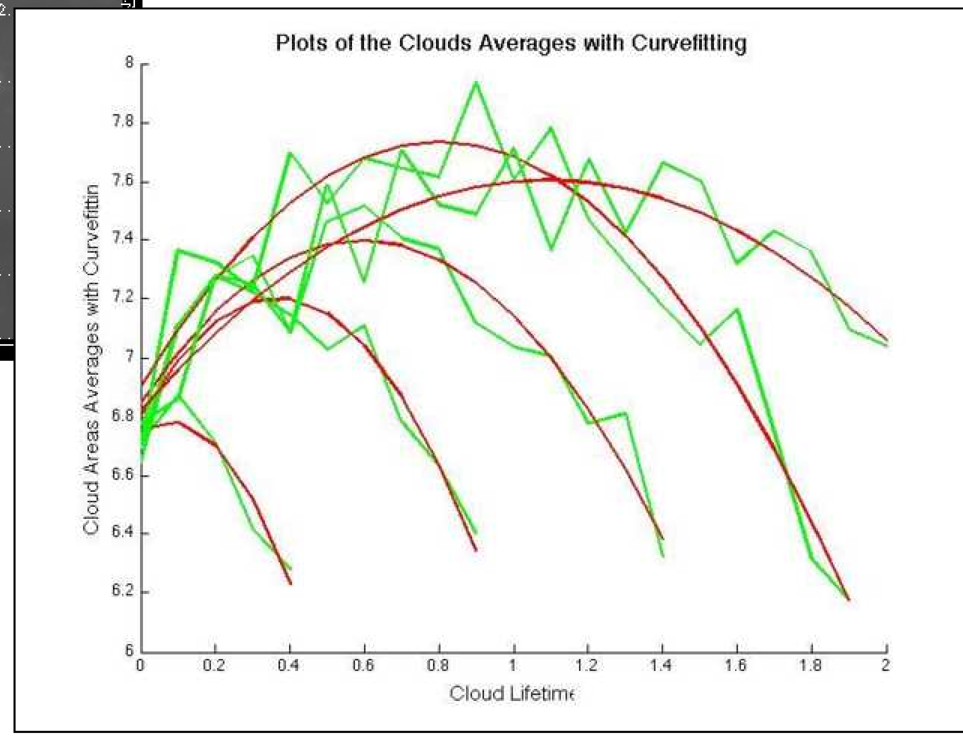
CREST: Brian Vant-Hull, Shayesteh Mahani, Arnold Gruber
NSSL: Robert Rabin STAR: Bob Kuligowski MDL: Mamoudou Ba



R&D in Operational Algorithms

Thunderstorm Nowcasting





RDT is an IR satellite storm detection and tracking algorithm modified from the operational version used by EuMetSat.

We plan to use the lifecycle studies currently underway to provide extrapolation of storm cells into the future.

Flood and discharge monitoring during the 2008 Iowa flood using AMSR-E data

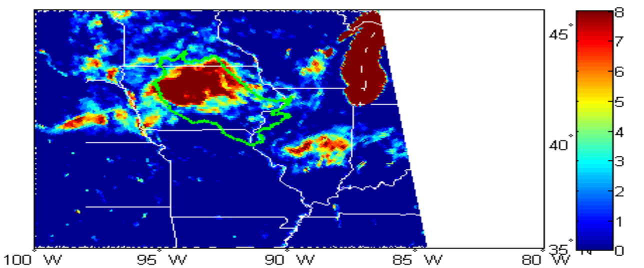
(Drs Temimi, Khanbilvardi and Lakhankar with the collaboration of Dr Xiwu Zhan (NOAA/NESDIS)

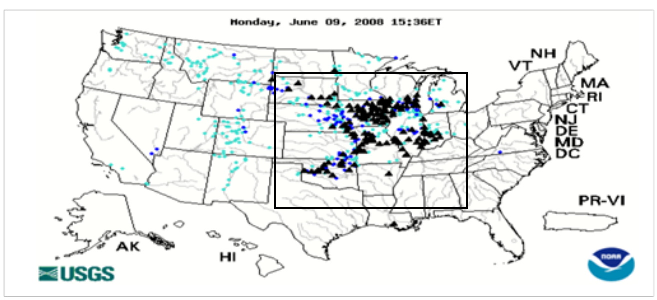
R&D in Operational Algorithms

Polarization Ratio Variation Index (PRVI)

$$PRVI = \frac{PR - \mu_i}{\sigma_i}$$

Where, μi and σi are average and standard deviation of the PR (PR=Tbv-Tbh/Tbv+Tbh) respectively for a given month i. Average and standard deviation were estimated on a monthly basis to account for changes in surface conditions





PRVI values obtained on June 9th, 2008 compared with observed water levels above flood stage as provide by the USGS (http://water.usgs.gov/osw/)

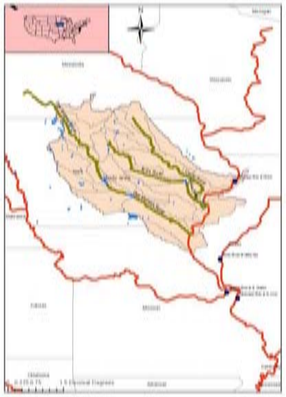
$$\text{Log}(Q(t)) = \log(a) + b \log(FA(t + d.\Delta t))$$

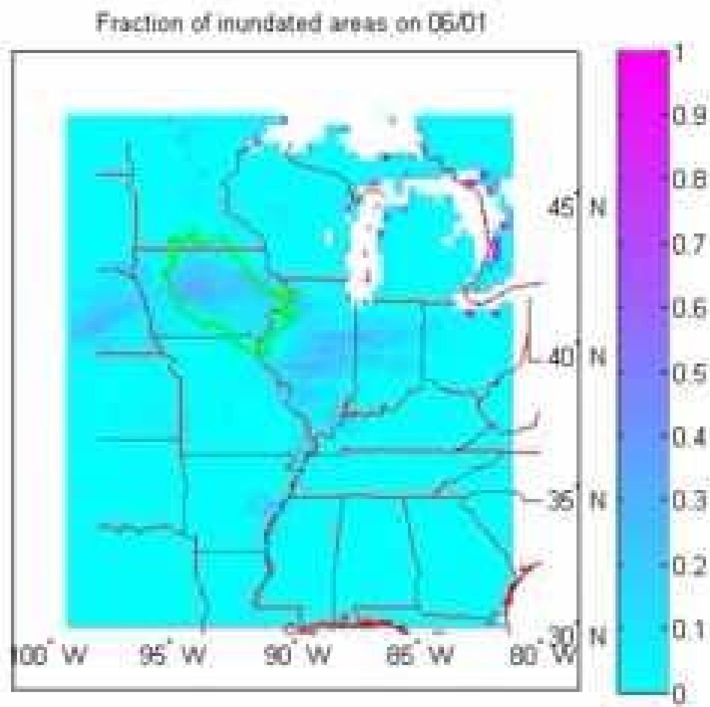
$$Y = A X + B$$

$$Yt = Ht.\ At \qquad \text{where } Yt = Y \qquad A_t = \begin{bmatrix} A \\ B \end{bmatrix} \qquad H_t = \begin{bmatrix} X & 1 \end{bmatrix}$$

$$At{+}1 = \Phi t\ At + Wt \quad \text{(State equation)}$$

$$Yt = Ht\ At + Vt \quad \text{(Observation equation)}$$

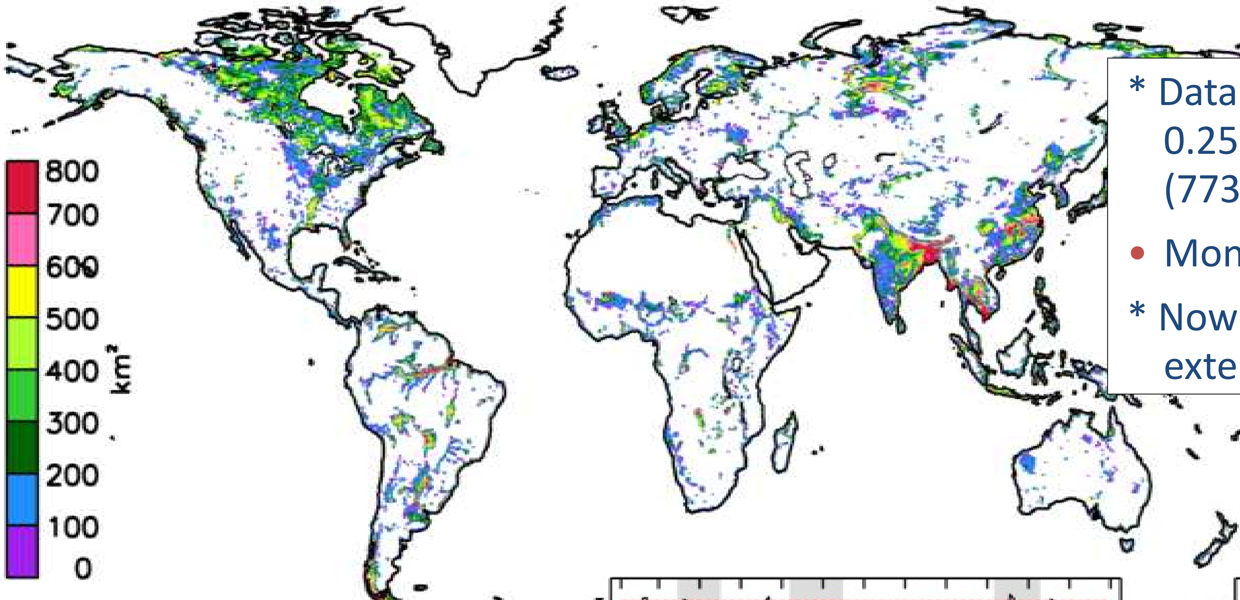




Dynamic of global surface water from multi-satellite observations (Papa, Rossow, Prigent)

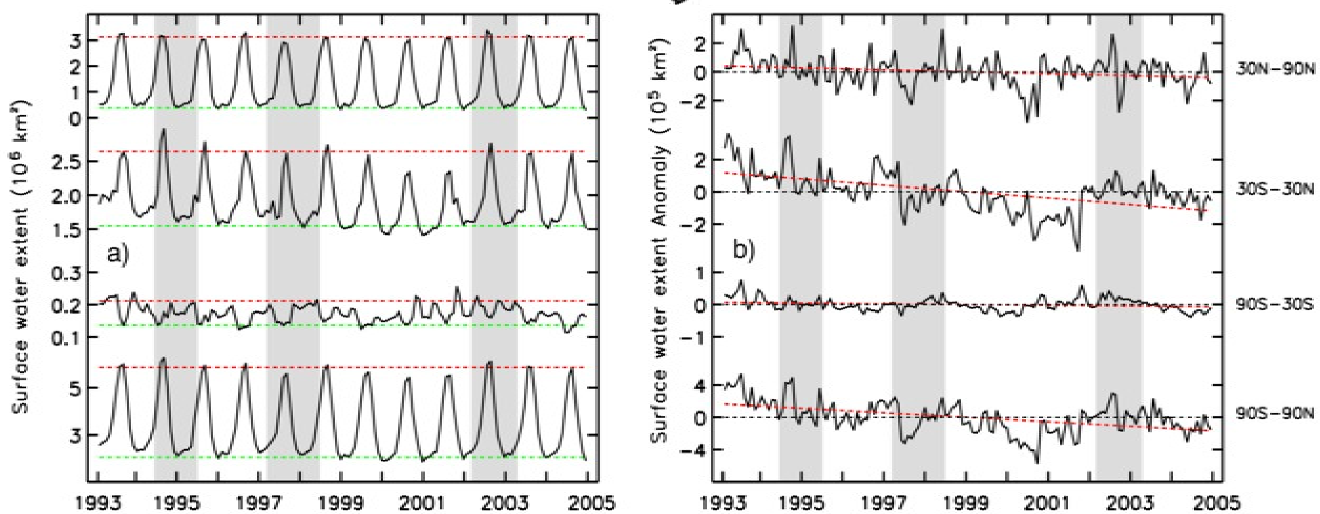
Satellite-Based Observations

Mean surface water extent (km^2) at annual maximum



* Data mapped on equal-area grid with 0.25°x0.25° resolution at equator (773 km^2)
- Monthly resolution, soon daily
* Now for 1993-2004 and at least to be extended to 2012 and longer

1993-2004, monthly surface water extent variations by latitude zones: decrease of ~6% in the Tropics



Satellite-Based Observations

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Fundamental Process Studies

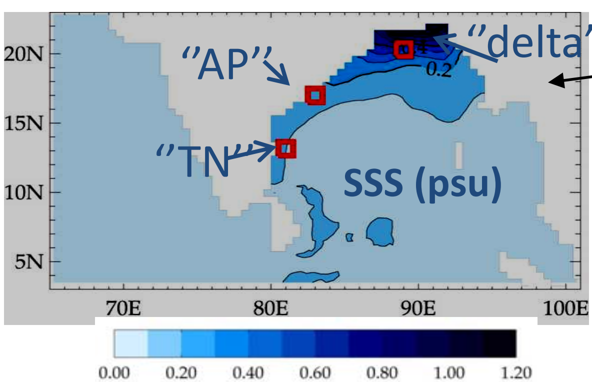
Applications directly related to severe and extreme events:

- → Understanding hydrological processes and floods dynamic for severe events
- → Validation/ Improvement of hydrological models

Combining this dataset with other observations:

- → With radar altimetry and DEM, it provides land surface water volume change
- → +GRACE+precipitation+SM: decomposition of water falling on land into the different components of the water balance equation
  - → Contribution of terrestrial surface water to sea level change
- → Impact of terrestrial hydrology to other climatic components:

Ex: Impact of river discharge on ocean circulation, sea surface salinity….:



Large impact of fresh water fluxes from rivers into the Bay of Bengal in terms of salinity and ocean stratification

→ Impact on SST, cyclogenesis, monsoon variability

Satellite-Based Observations

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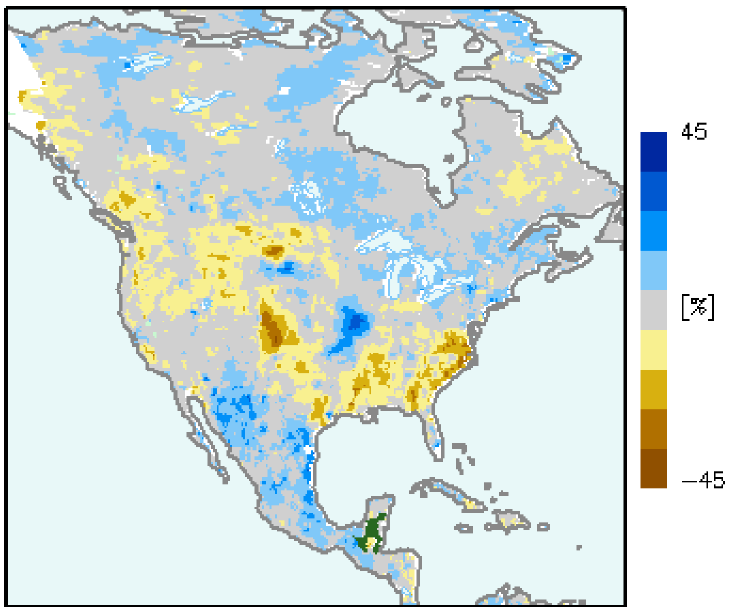
Fundamental Process Studies

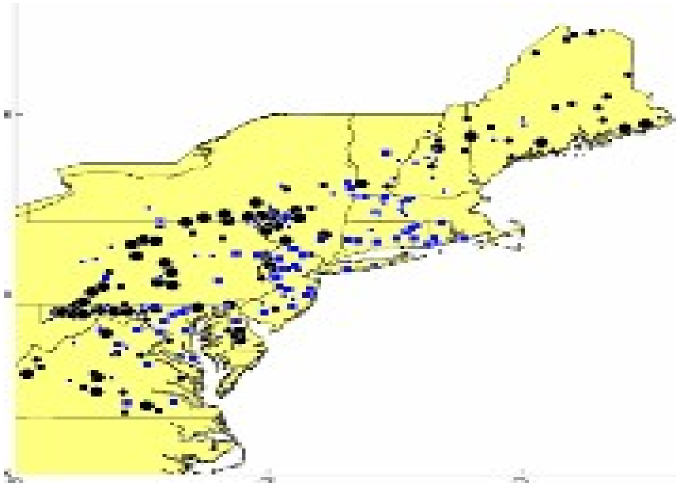
Nir Krakauer:
Drought and water resources



Soil moisture excess/deficit, July 2008, derived from satellite microwave scatterometer (Vienna Institute of Technology)

- Research questions:
  - How do the atmosphere,vegetation, and soil interact to begin and end droughts?
  - Can remote sensing soil moisture and snow products help predict droughts?
  - How should water be used and stored for adequate supply under greenhouse warming and climate variability?

Current projects



• Warming is inducing earlier peak flow in mountain stream in the Northeast (purple markers), lower summer flow.

With J. Jimenez-Vargas (CREST student).

• Soil moisture feedback increases the spatial scale of drought (green-blue: increase in summer T spatial correlation length with soil moisture feedback)

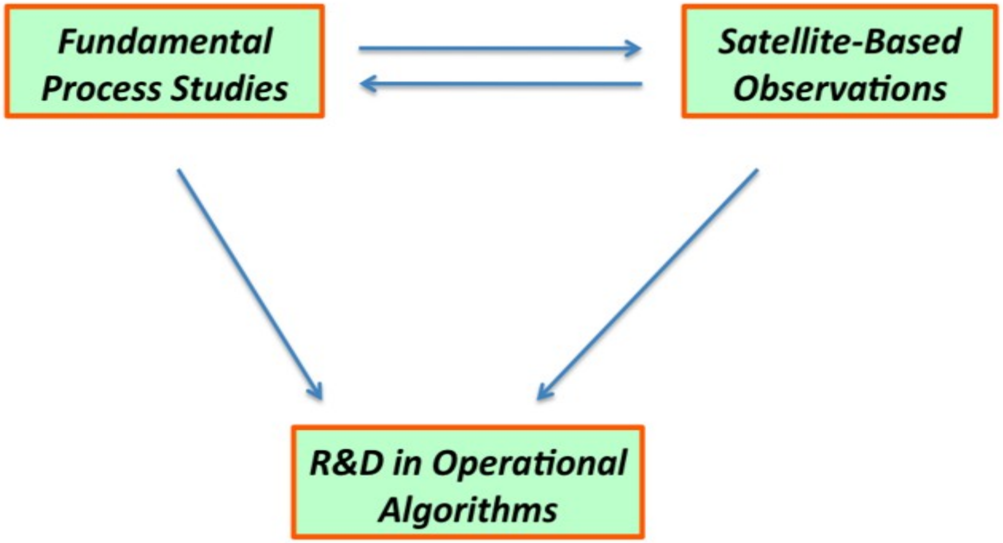
(HESS, in discussion)

Summary

Global survey of convective buoyancy/entrainment, hurricane intensity (Luo)

Drought & water resource monitoring & research (Krakauer)

Global surface water from multi-satellite observations (Papa)



Flood/discharge monitoring (Temimi)

Thunderstorm nowcasting (vant-Hull & Mahani)