Geo-Hyperspectral Infrared Imaging Sounder – Flash Floods Simulation and Assimilation Study

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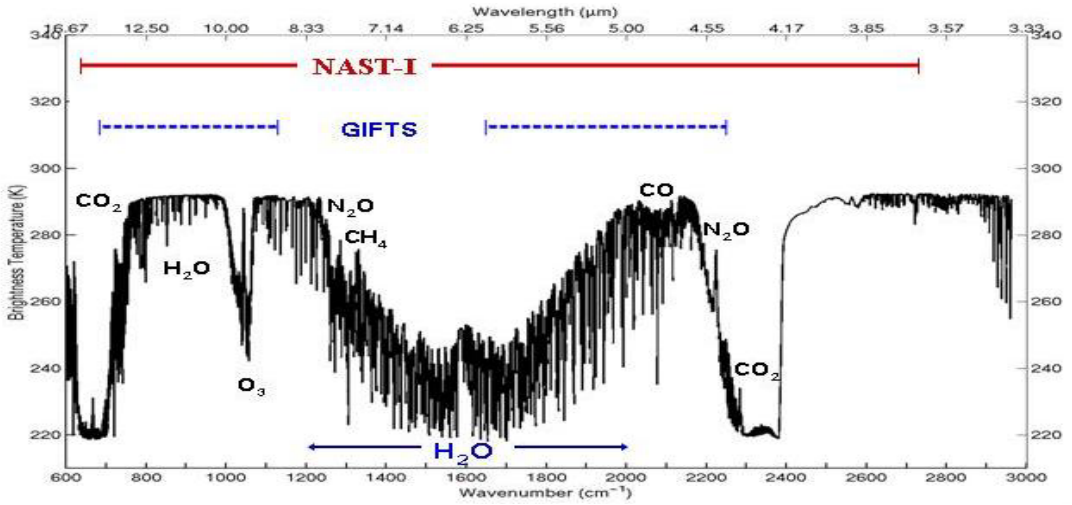
STORM-1 (i.e. GIFTS) Characteristics



(8.8 to 14.6 microns) (4.4 to 6.1 microns)

- Two 128x 128 infrared focal plane detector arrays with 4 km footprint size
- A 512 x 512 visible focal plane detector array with 1 km footprint size
- Array field of view footprint is 512 km x 512 km at satellite sub-point
- 10.9 s full spectral resolution integration time per field of view
- ~ 80000 Atmospheric Soundings every minute

Sounding & Tracking Observatory for Regional Meteorology (STORM)

STORM
SOUNDING & TRACKING OBSERVATORY FOR REGIONAL METEOROLOGY

Top-Level GIFTS / STORM Comparison

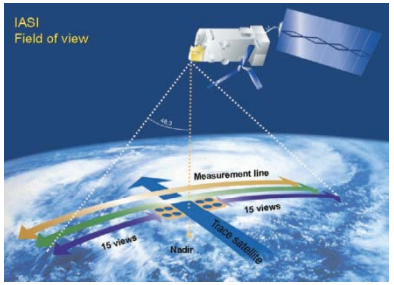
Parameter	GIFTS	STORM
Spectral Bands	LW: ≤685 cm^{-1} to ≥1130 cm^{-1} SMW: ≤1650 cm^{-1} to ≥2250 cm^{-1} VIS: ≥0.725 μm to ≤0.875 μm	same
Spectral Resolution	7 resolutions in range 0.6 - 36.7 cm^{-1}	0.6, 1.2, and 9.6 cm^{-1}
FPA Field-of-view (FOV)	14.3 mrad (0.82°)	same
Field-of-regard (FOR)	≥0.306 rad (17.53°) (pointing mirror design: 0.450 rad)	same
IR FPA format	128 X 128 pixels, 60 μm pixel pitch	same
Noise equivalent spectral radiance (NESR) goal	LW: ≤0.4 $mW/(m^2\text{-}sr\text{-}cm^{-1})$ SMW: ≤0.06 $mW/(m^2\text{-}sr\text{-}cm^{-1})$	same
Calibration accuracy goal	≤ 1K (3σ)	same
Data Rate	Max: 70 – 80 Mb/sec Nom: 58 – 73 Mb/sec	same
Mass*	200 kg	300 kg
Volume	1.8 X 1.0 X 1.4 m^3	same
Power*	535 W	550 W avg, 650 W peak
Thermal Rejection *	Design assumed yaw-flip	≥400 W @ 0 °C

* Mass, power, and thermal rejection change due to expected no-yaw-flip operations

LEO-IASI VS. GEO-STORM

Hyperspectral Sounder Comparison

Specification	IASI/IASI-NG	STORM/STORM-NG
Spectral (cm^{-1})	0.5/0.25	Variable: 0.6-9.6
Temporal (per day)	~ 2 (>>2 @ poles)	Variable: 12 (full disk)
Spatial Sampling @ Nadir (km)	12/12	4/2
Spectral Coverage (cm^{-1})	645-2760	685-1130; 1650-2250
Sampling Rate (#FOV/Sec)	30/8	16384/10



STORM
SOUNDING & TRACKING OBSERVATORY FOR REGIONAL METEOROLOGY

Near Term Geo-Hyperspectral Sounder available in Asia Region

Top Level Sensor Spec. Comparison	GIIRS FY-4A/China R&D	GIIRS FY-4B/China Operational	STORM-1 GeoMetWatch/USA Operational
Spectral Parameter (cm^{-1})	Range Resolution #-Ch LWIR 700-1130 0.8 538 S/MIR 1650-2250 1.6 375	Range Resolution #-Ch LWIR 700-1130 0.625 688 S/MIR 1650-2250 1.2 500	Range Resolution #-Ch LWIR 685 – 1130 0.57 780 S/MIR 1650 – 2250 0.57 1052
Spatial Resolution (km)	At Nadir: 16 IFOV: 448 µrad	At Nadir: 8 IFOV: 224 µrad	At Nadir: 4 IFOV: 112 µrad
Operational Model Coverage (km^2 x km^2)	China Area: 5,000 x 5,000 Mesoscale Area: 1000 x 1000	China Area: 5,000 x 5,000 Mesoscale Area: 1000 x 1000	Full Disk: ~10,000 x ~10,000 CONUS: 5,000 x 5,000 Mesoscale: 1,000 x 1,000
Temporal Resolution (minutes)	China Area: 60 Mesoscale Area : 30	China Area: 60 Mesoscale Area: 30	Full Disk: 40-60 CONUS: 15 Mesoscale: 1-5
Sensitivity (mW/M^2srcm^{-1})	LWIR: 0.5 S/MIR: 0.1	LWIR: 0.3 S/MIR: 0.06	LWIR: 0.4 LWIR: 0.06
Calibration Accuracy Radiation (K at 3σ)	1.5	1.0	1.0
Calibration Accuracy Spectrum (ppm at 3σ)	10	5	2
Quantization (bits)	13	13	14
Planned Launch Date	2015	2017	2016-2017
Life time (years)	5	7	7

GIIRS: Geo Interferometric Infrared Sounder

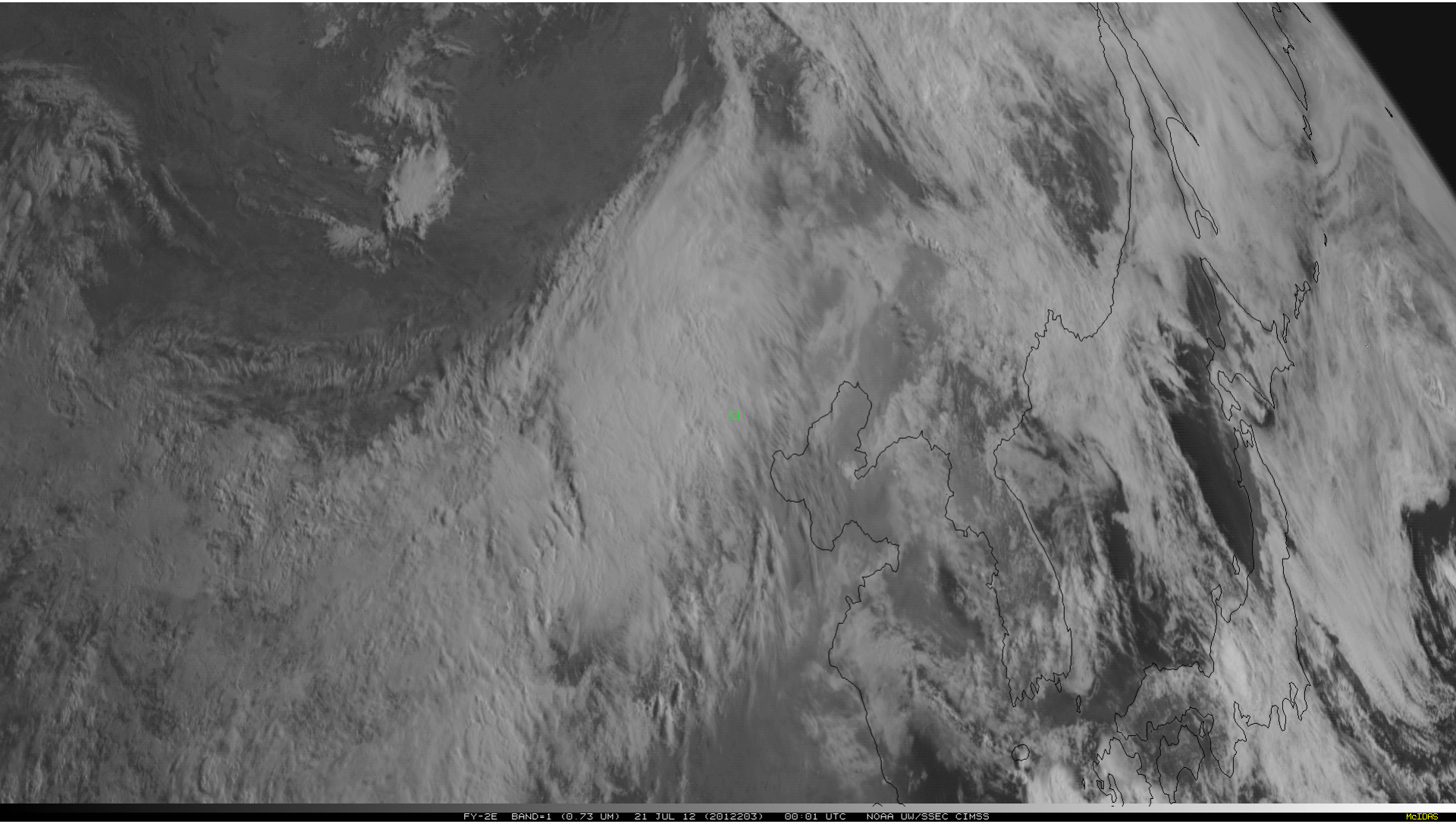
STORM: Sounding and Tracking Observatory for Regional Meteorology

2012 Beijing 721 flooding facts

A major flooding event occurred in the Beijing, China area on 21 July 2012, as the **heaviest rainfall in over 60 years** caused more than**100 fatalities**, **cancelled over 500 airport flights**, and forced **more than 65,000 people to be evacuated.** Much of the city averaged around **7-9 inches of rainfall within a 10 hour period**, with the heaviest total rainfall accumulation being **18.1 inches (460 mm) in the Fangshan District** of Beijing (direct **property loss is** in only Fangshan District is estimated to be **CYN6.1B**).

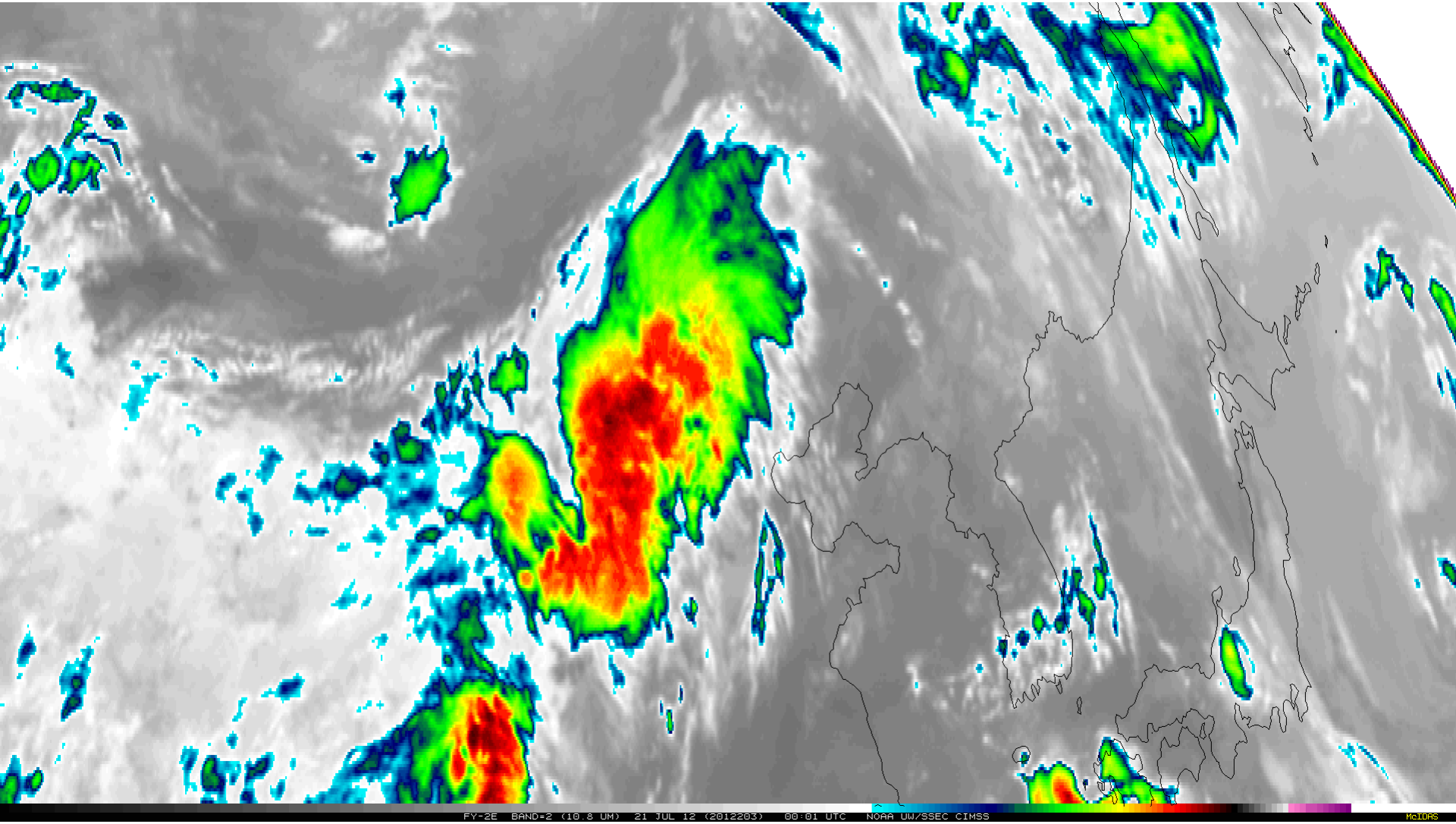
*Rain started at ~03 UTC on 21 July 2012

Satellite View: FY-2E Imagery animation of 2012 Beijing Flood



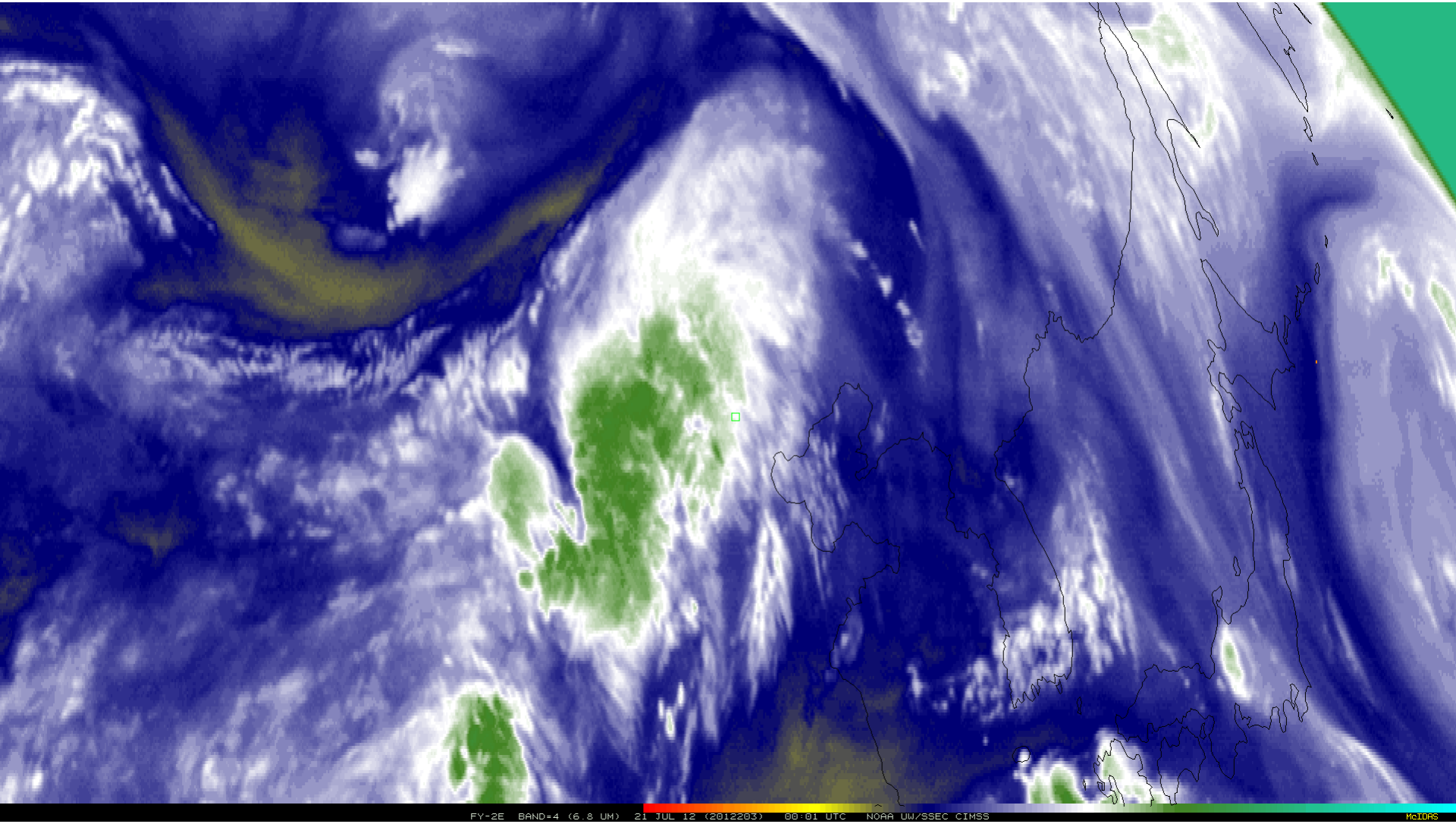
McIDAS images of 1.25 km resolution 0.73 µm visible channel data from the Chinese FY-2E (105ºE) satellite showed an elongated band of clouds with embedded thunderstorms oriented from southwest to northeast across much of northeastern China. The small green box denotes the location of Beijing Capitol Airport.

Satellite View: FY-2E Imagery animation of 2012 Beijing Flood

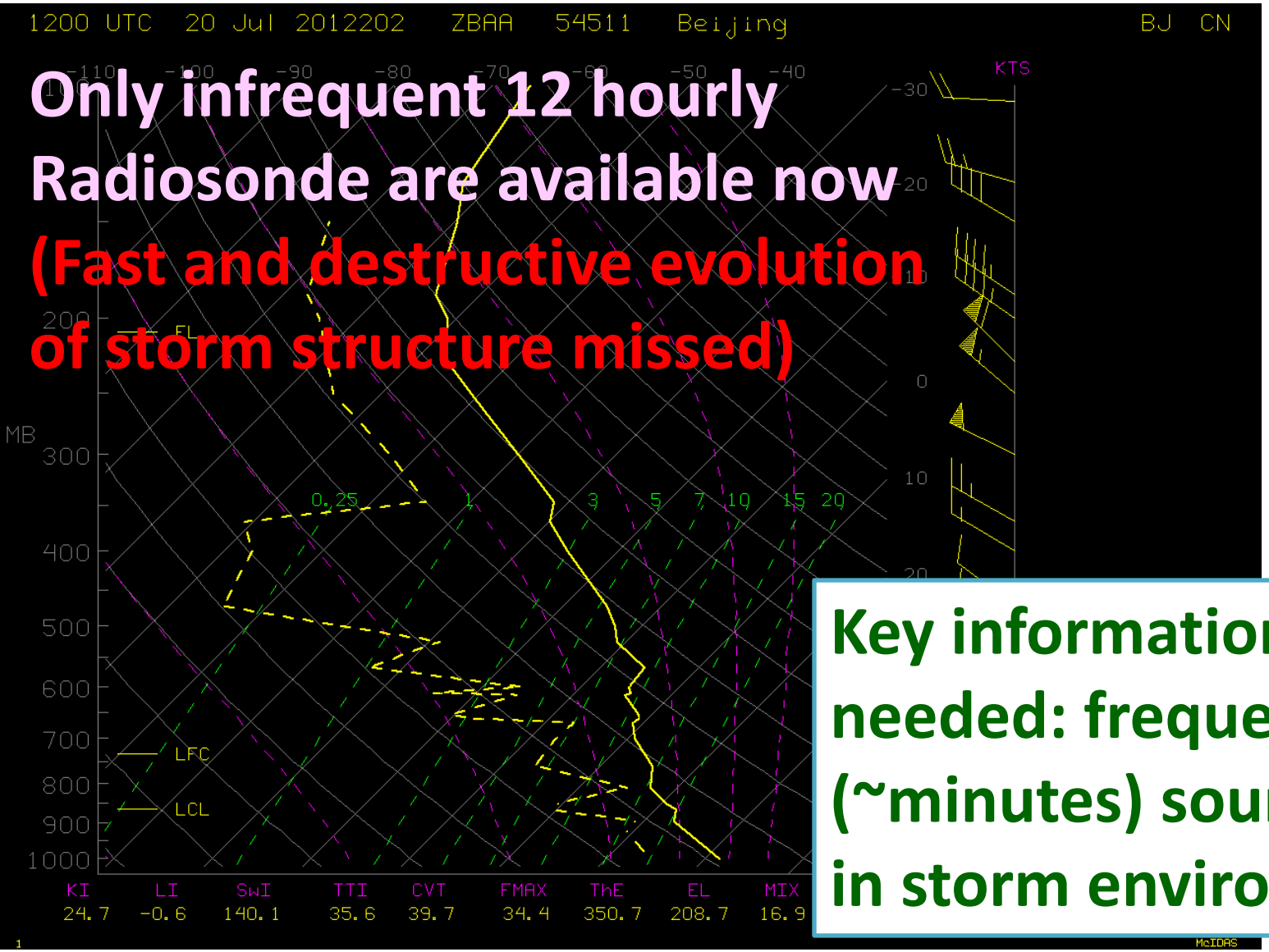


5 km resolution FY-2E 10.8 μm IR channel images revealed the development of very cold cloud top brightness temperatures (-60° C to -75° C, red to black to white color enhancement) with some of these embedded thunderstorms, with evidence of a period of back-building of convection in the vicinity of Beijing after 15 UTC.

Satellite View: FY-2E Imagery animation of 2012 Beijing Flood



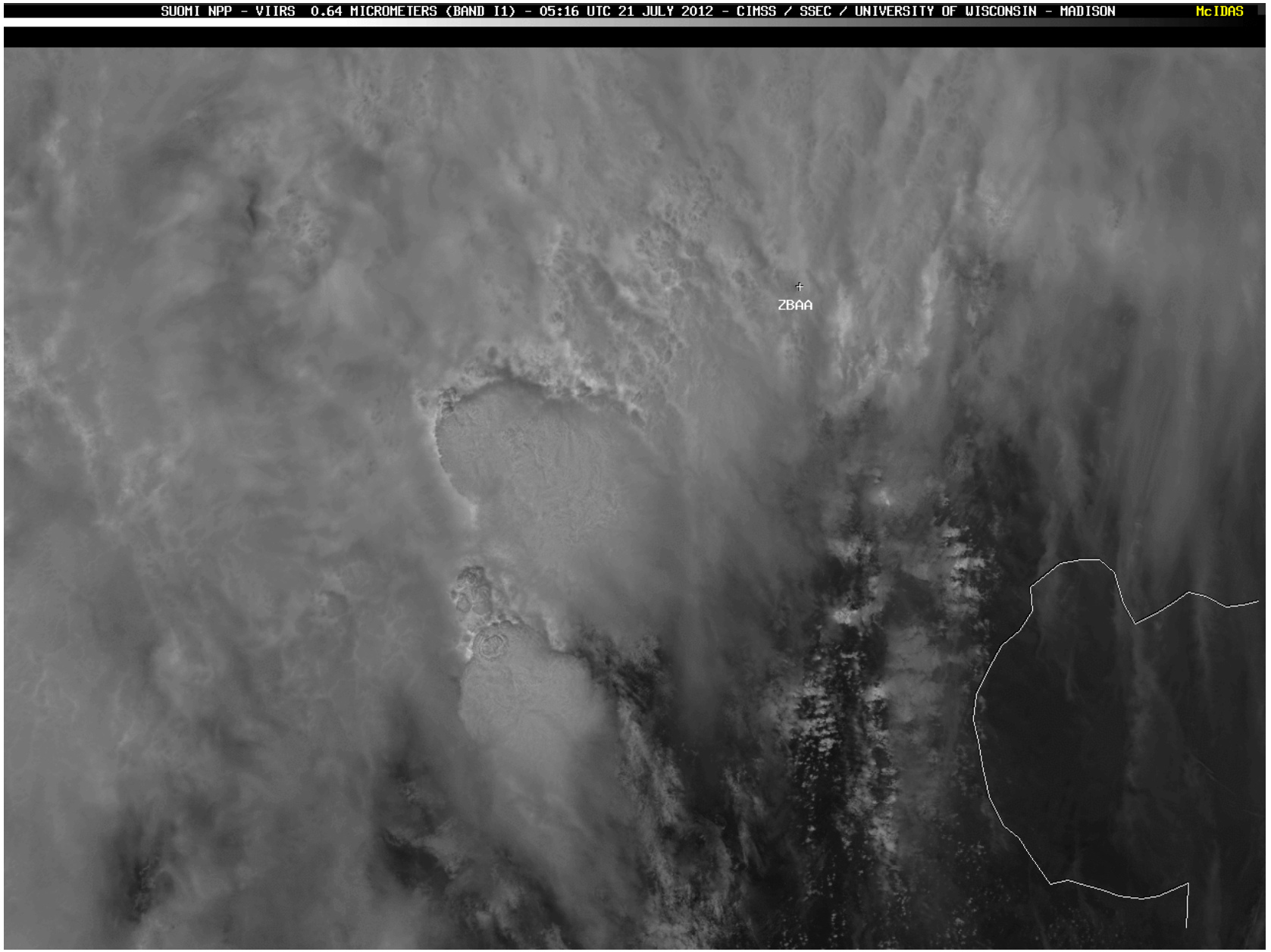
5 km resolution 6.8 µm “water vapor” images indicated a pronounced warming/drying signature (yellow colors) associated with a deepening shortwave trough that was approaching from the northwest. This approaching trough may have played a role in helping to enhance synoptic-scale upward vertical motion across the Beijing region, creating a more favorable environment supporting the formation and maintenance of strong convection.



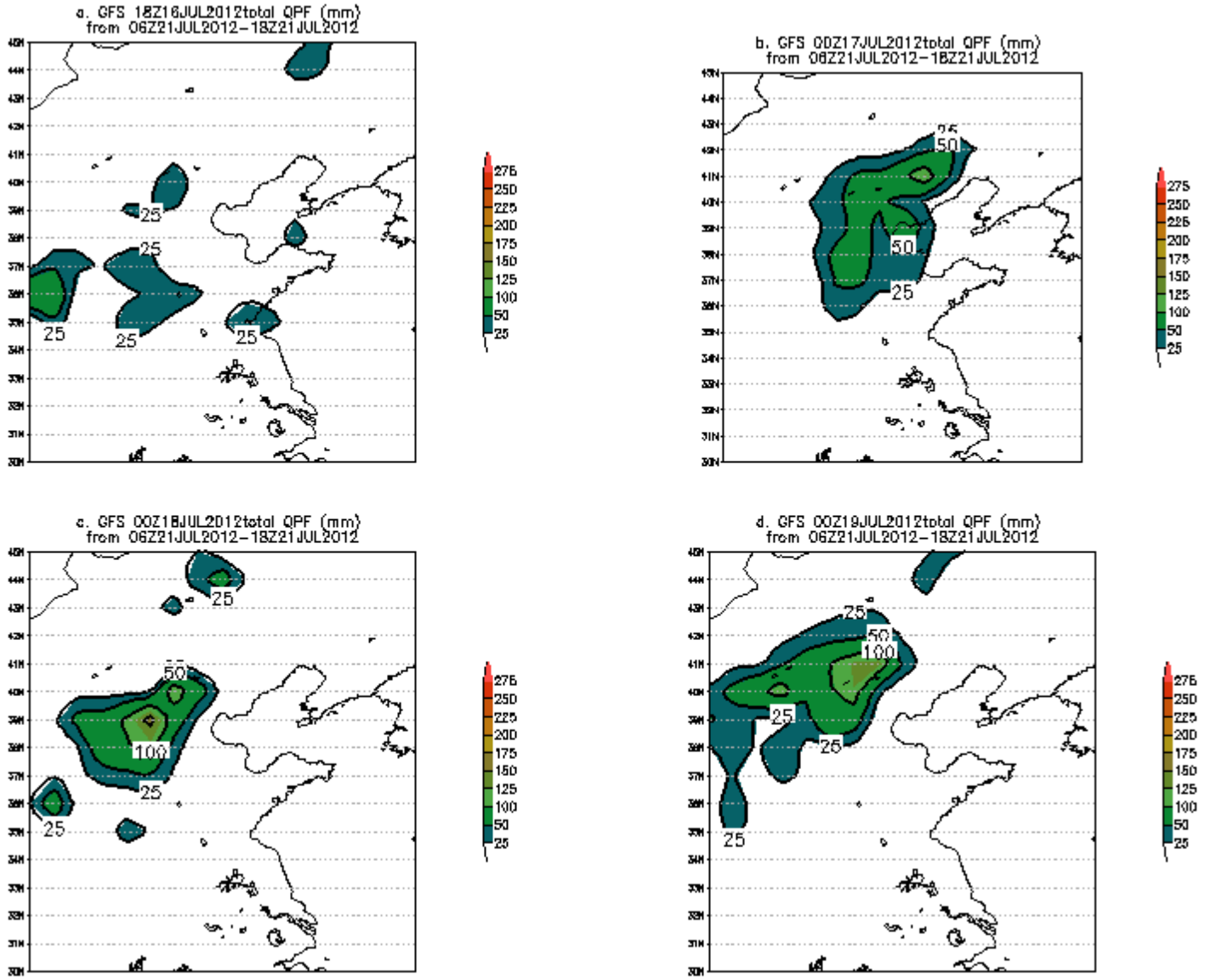
Only infrequent 12 hourly Radiosonde are available now (Fast and destructive evolution of storm structure missed)

Key information needed: frequent (~minutes) soundings in storm environment

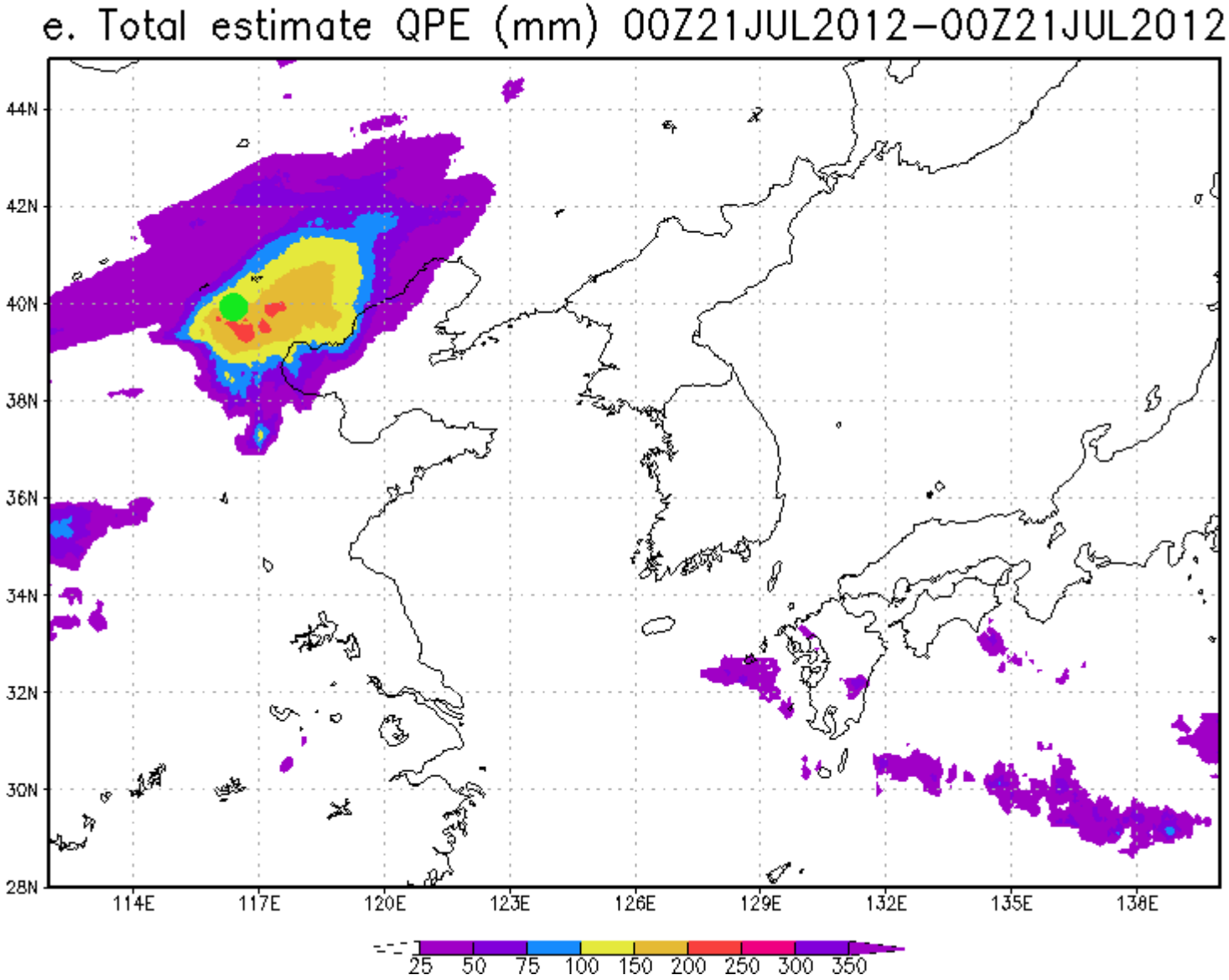
A time series of Beijing rawinsonde data Skew-T plots (below) showed the moistening of the atmosphere on 21 July, with the total precipitable water peaking at 50.4 mm (1.98 inches) at 12 UTC. The subsequent arrival of dry middle-tropospheric air associated with the approaching shortwave trough can be seen after 00 UTC on 22 July, as Precipitable Water (PW) values dropped to 26.4 mm or 1.04 inch by 12 UTC.



A comparison of 375 m resolution Suomi NPP VIIRS 0.64 µm visible channel and 11.45 µm IR channel imagery at 05:16 UTC (below) showed the development of some of the initial areas of embedded deep convective elements just to the southwest (upstream) of Beijing (station identifier ZBAA).



NCEP GFS quantitative precipitation forecasts (mm) over eastern China showing total accumulated precipitation for the 12 hour period of 0600-1800 UTC 21 July 2012 from the GFS initialized at a) 18:00 UTC 16 July, b) 00:00 UTC 17 July, c) 00:00 UTC 18 July and d) 0000 UTC 19 July 2012. Shading as in the color bar to the right of each image and contours are 25,50,100, 150 and 200 mm.



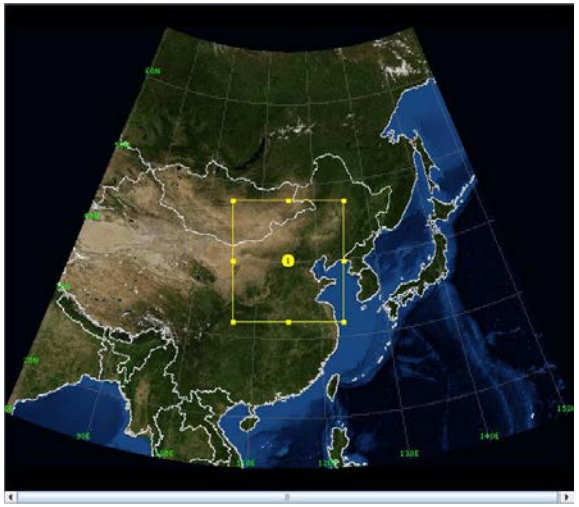
Satellite estimated rainfall (mm) for 21 July 2012 from the CMORPH satellite data set.

NOAA CPC Morphing Technique ("CMORPH")

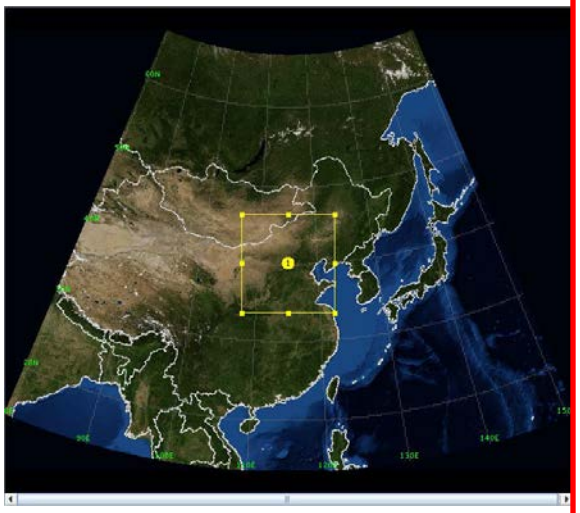
Beijing Flood 21 July 2012 04z-12z Assimilation

13 Jan 2013

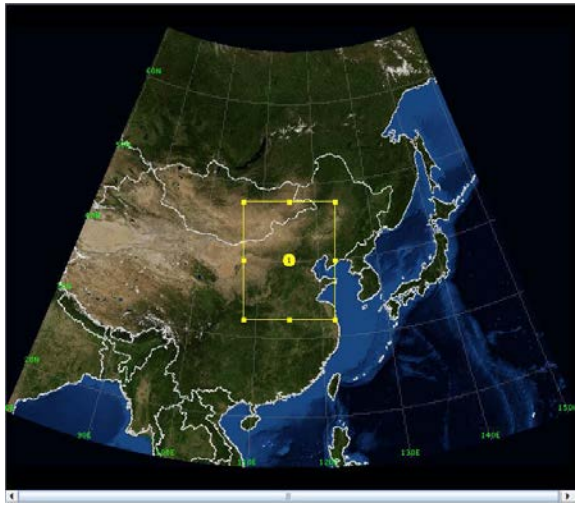
Domains



Resolution : 4 km
Size : 392 by 427 by 75



Resolution : 6 km
Size : 220 by 232 by 75



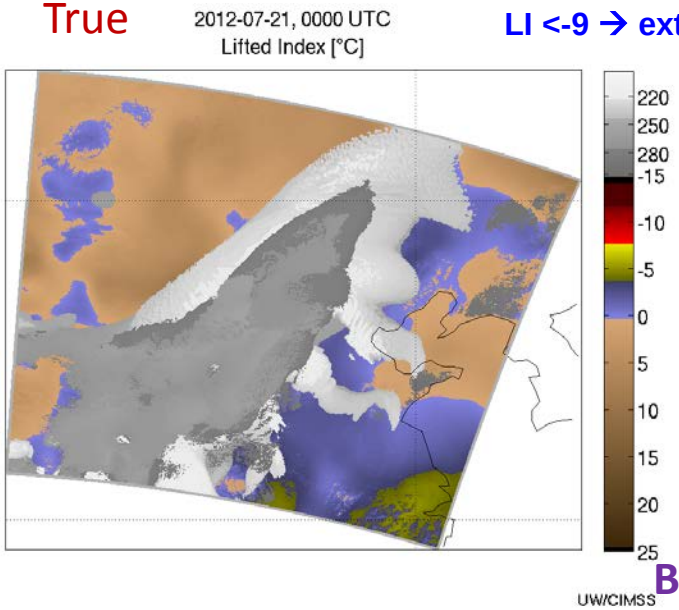
Resolution : 8 km
Size : 162 by 208 7 by 75

Lifted Index (LI = T500 - Taa)

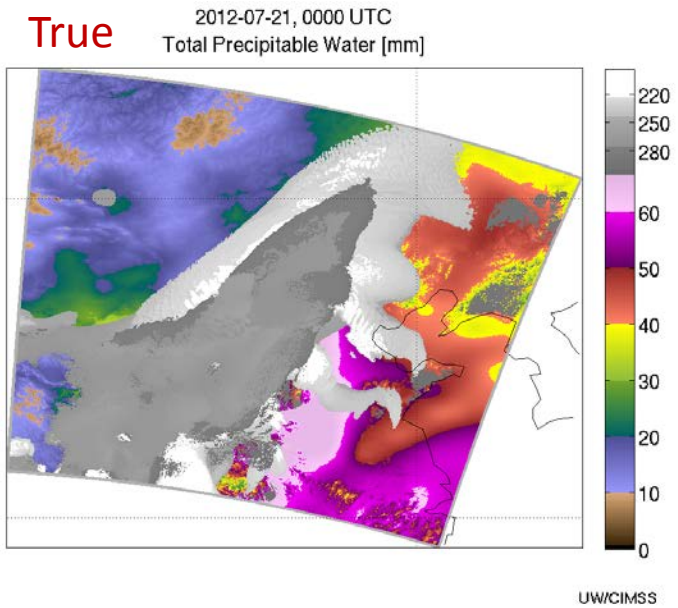
0< LI → stable
-3< LI <0 → marginally unstable
-6< LI <-3 → moderately unstable
-9< LI <-6 → very unstable
LI <-9 → extreme instability

Total Precipitable Water

True

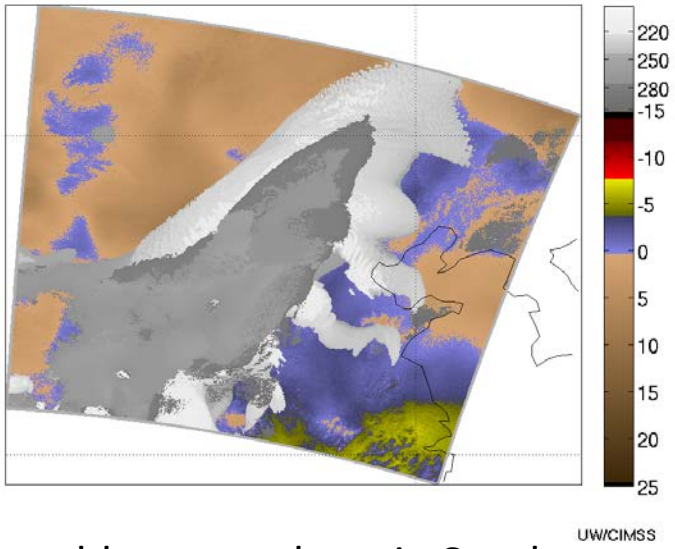


True

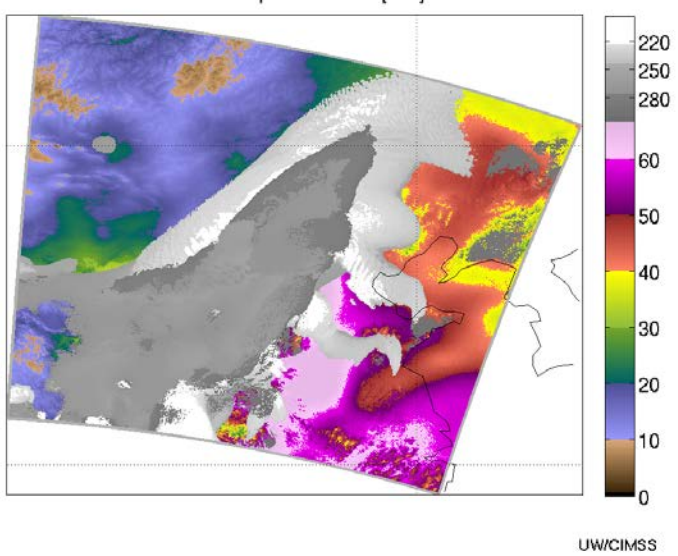


July 21, 2012
Beijing Flood Event

GEO-STORM

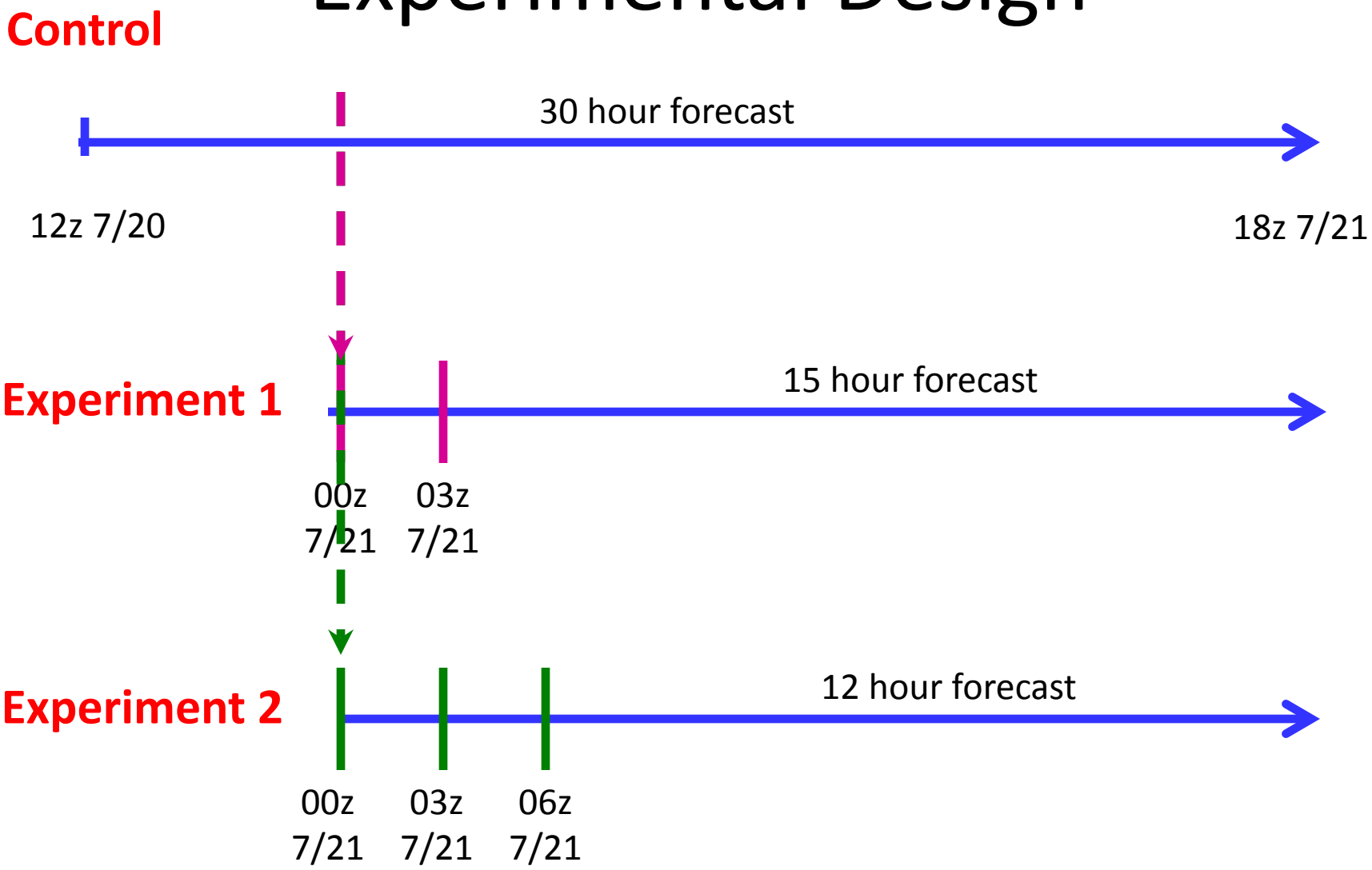


GEO-STORM



Unstable atmosphere in Southeast of Beijing

Experimental Design

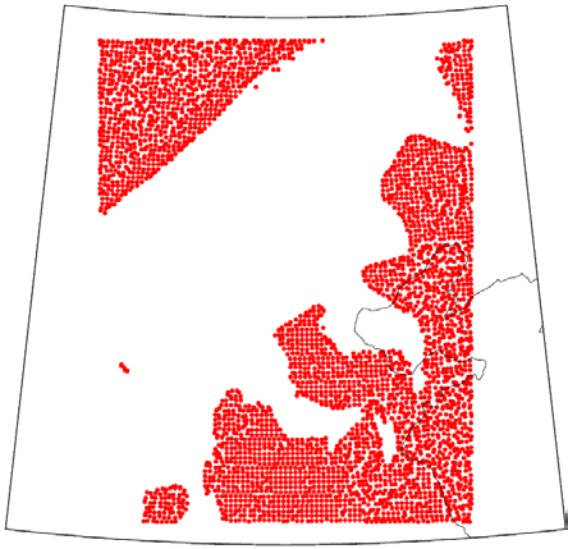


Data coverage that gets assimilated

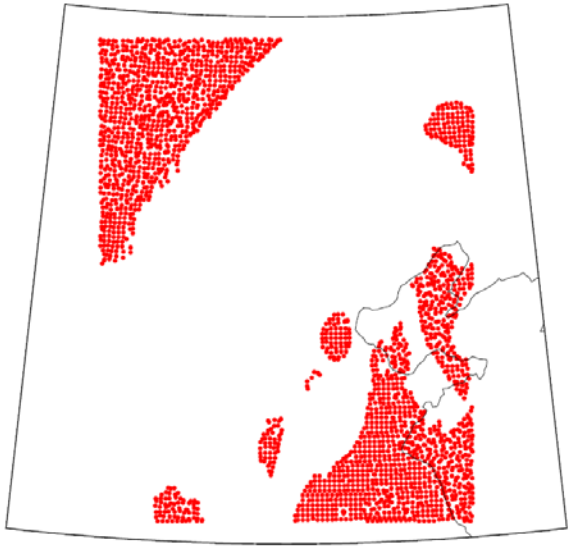
Assimilation Time	Number Clear	Total	% Clear
00z	830901	1475180	56.33
03z	653161	1475180	44.28
06z	576368	1475180	39.07

Satellite Radiance Data thinning : 16 km
Time window = +/- 15 min of analysis time
Biases are corrected using the nadir pixel, following that use for the GOES data in GSI.

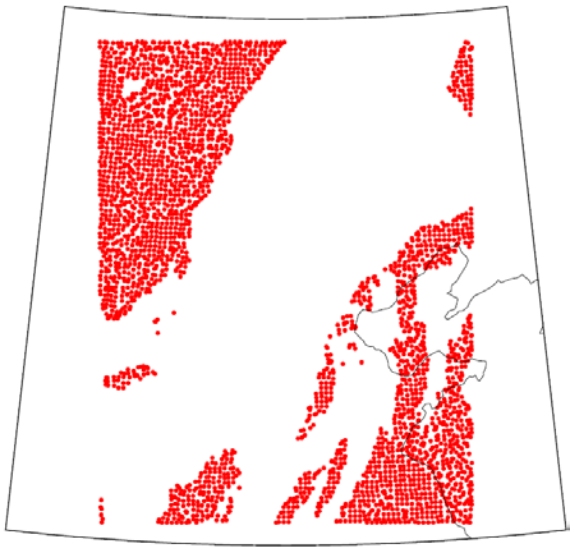
2012-07-21 00z

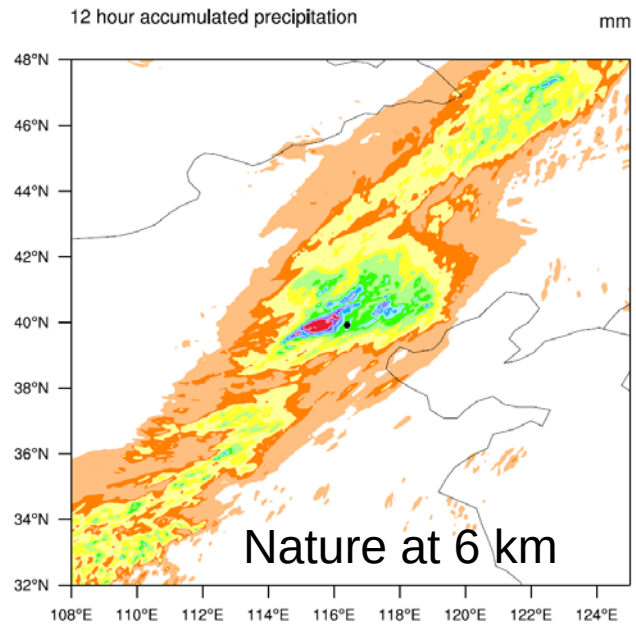


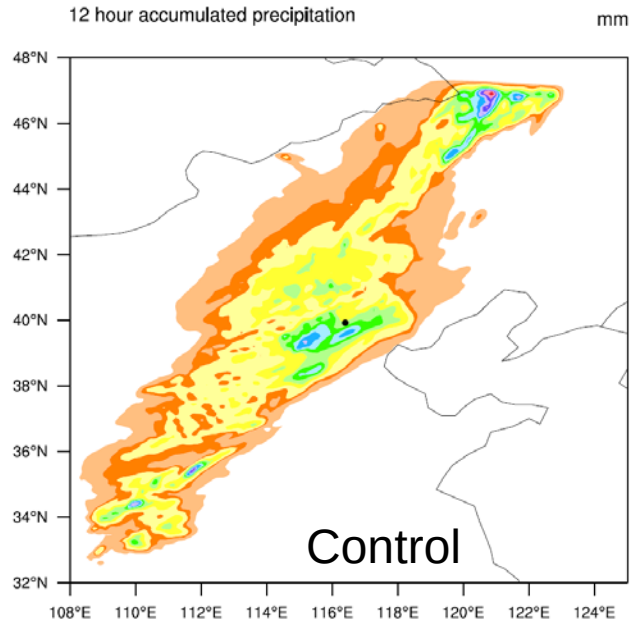
2012-07-21 03z

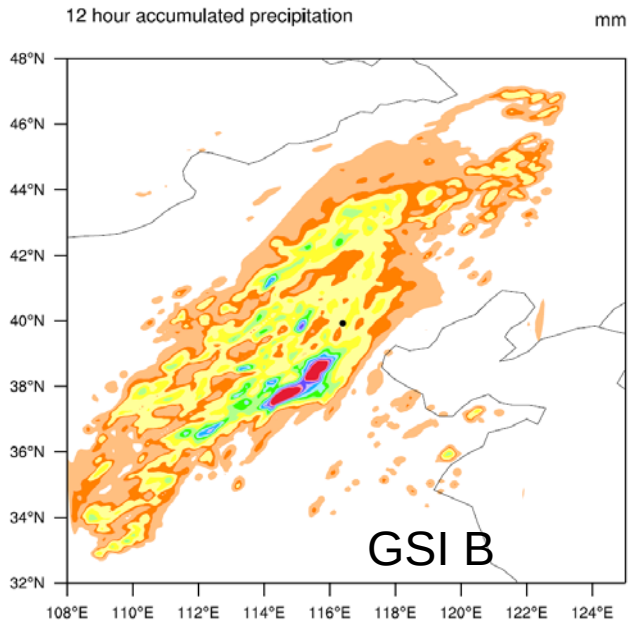


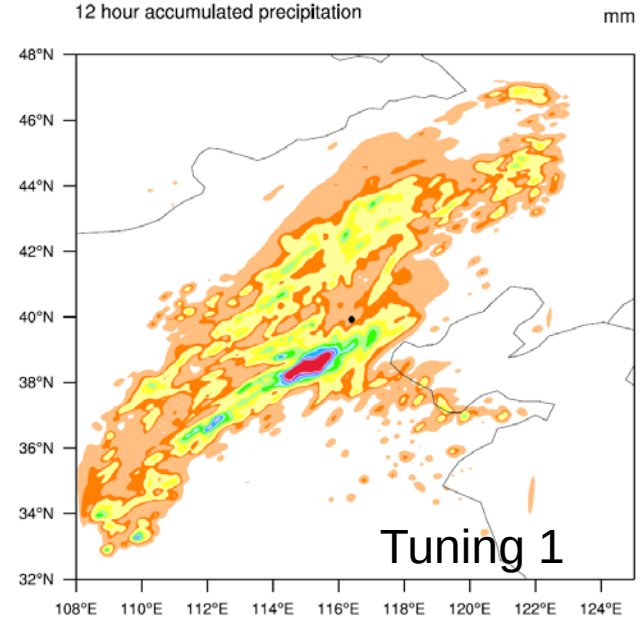
2012-07-21 06z

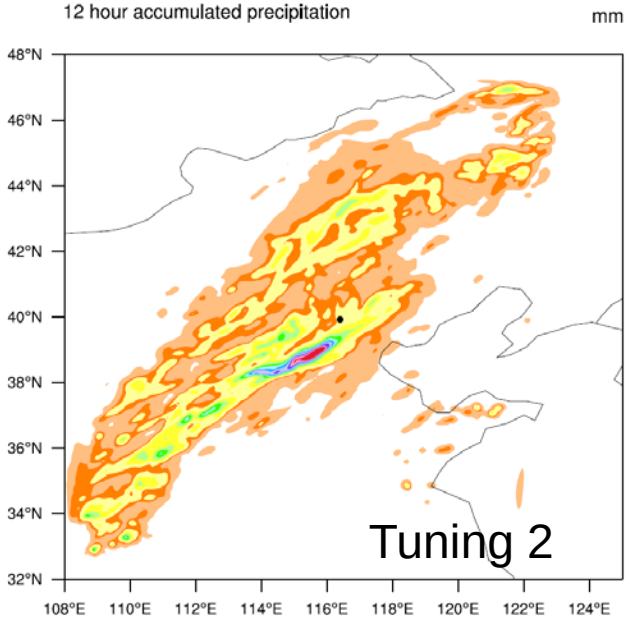


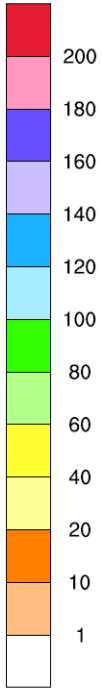

12 hour accumulated precipitation
mm
Nature at 6 km


12 hour accumulated precipitation
mm
Control

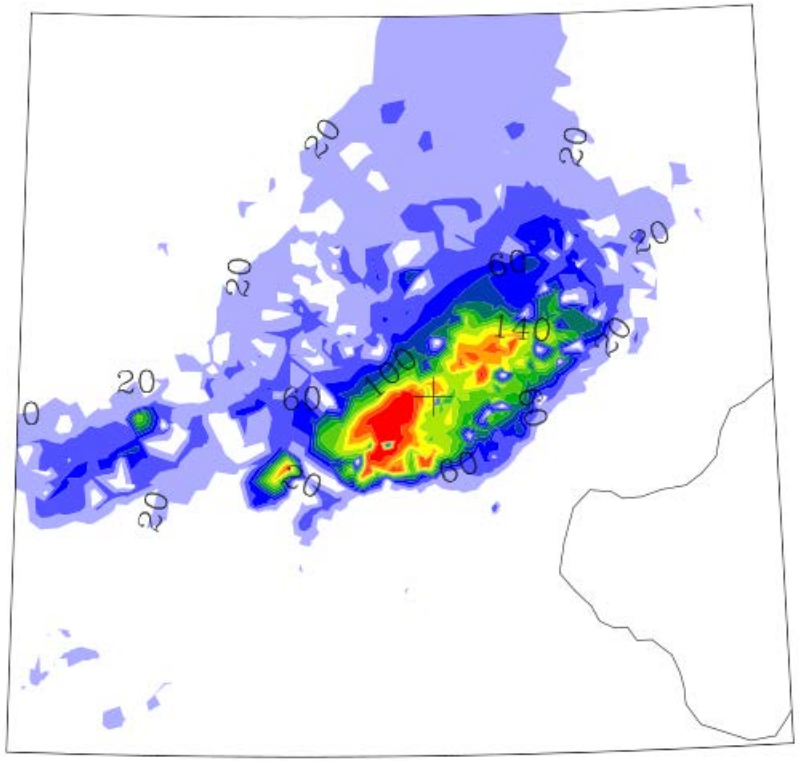

12 hour accumulated precipitation
mm
GSI B

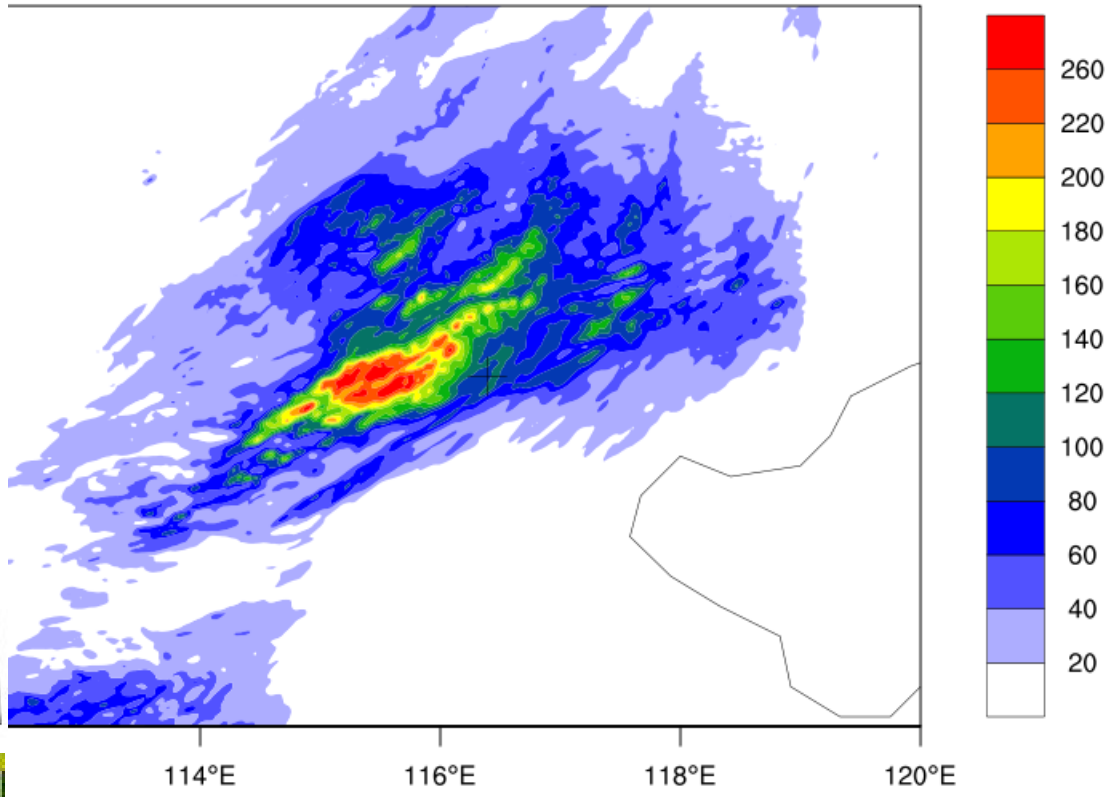

12 hour accumulated precipitation
mm
Tuning 1


12 hour accumulated precipitation
mm
Tuning 2


200
180
160
140
120
100
80
60
40
20
10
1

High resolution WRF run for Beijing 721 storm simulation (21 July 2012 Beijing Storm)





Spatial coverage of domains 1 and 2 in WRF model

Observed (upper left) and WRF simulated (upper right) 12 hour accumulated precipitation (mm)

04 - 16 UTC， 21 July 2012

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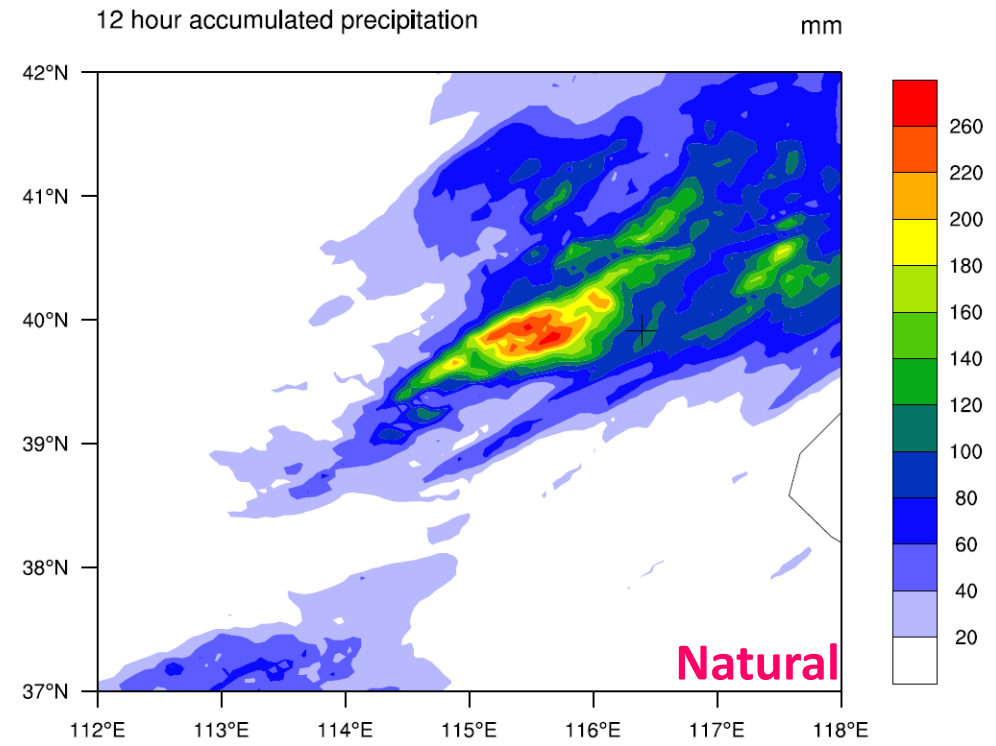

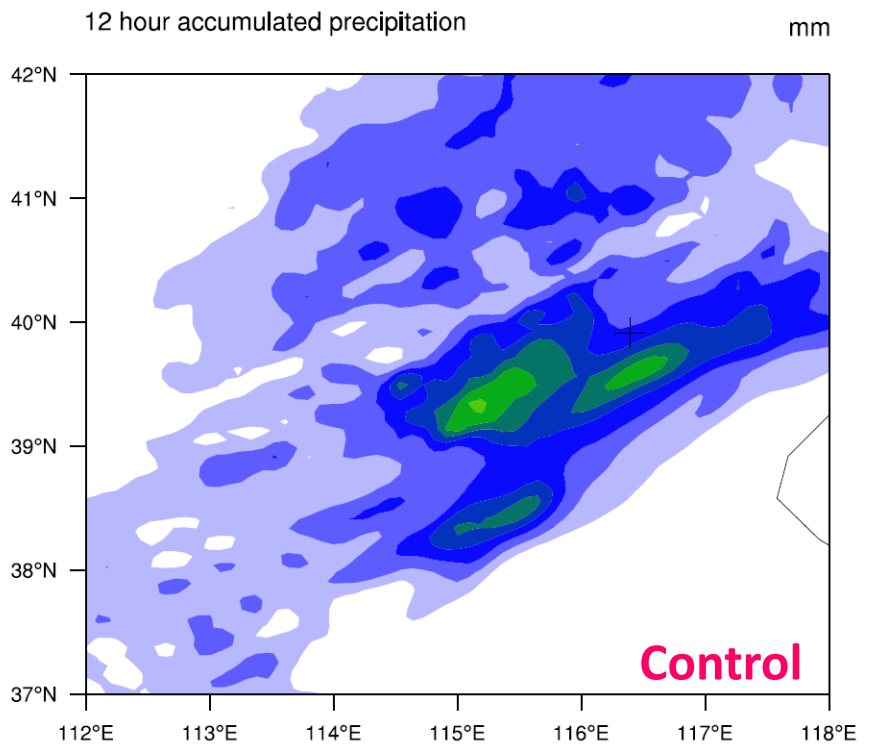

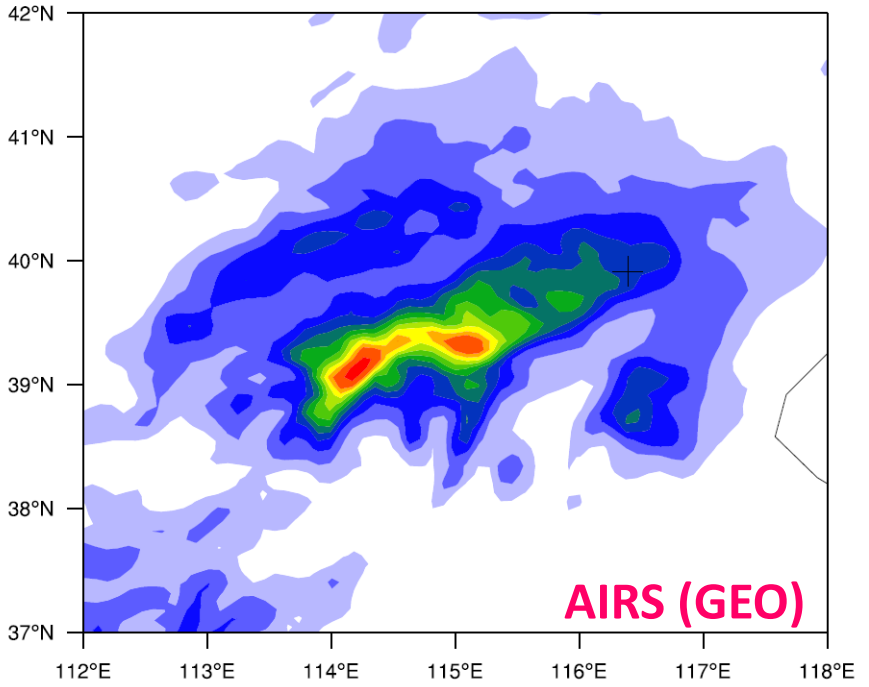

12 hour accumulated precipitation from natural run (upper left), control (upper right) and assimilating GEO AIRS (lower right). GEO AIRS data are assimilated at 00 UTC, 03 UTC and 06 UTC 21 July 2012, forecasts valid for 06 UTC to 18 UTC 21 July 2012.

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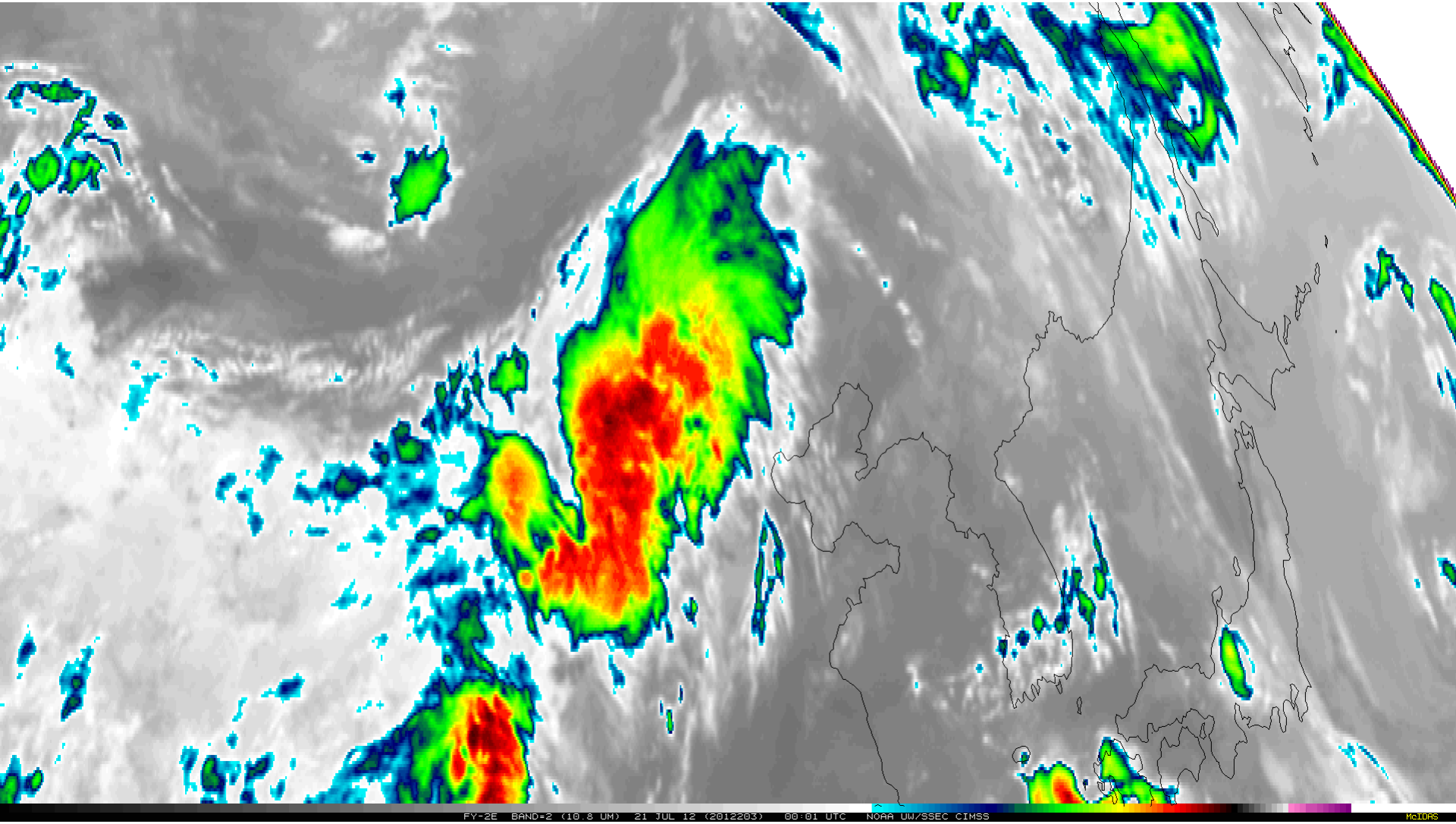
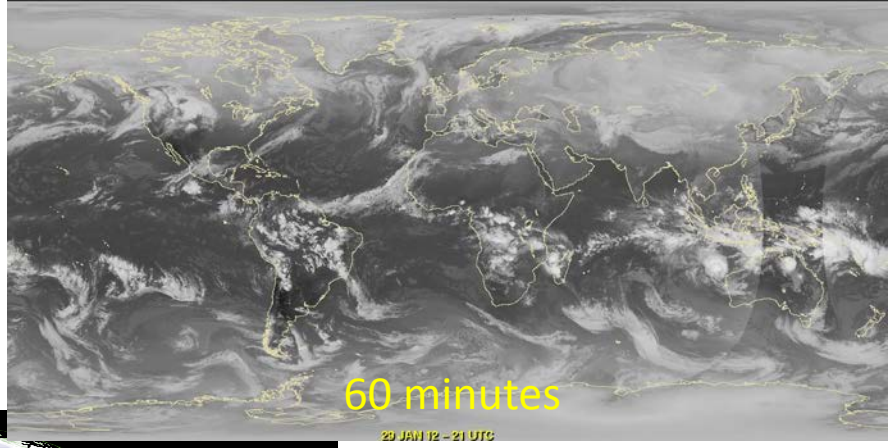
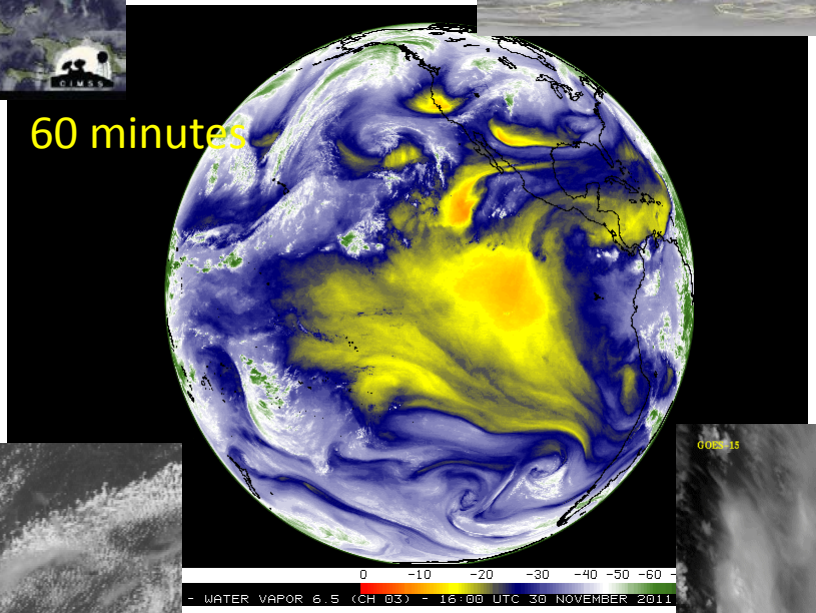
Satellite View: FY-2E Imagery animation of 2012 Beijing Flood



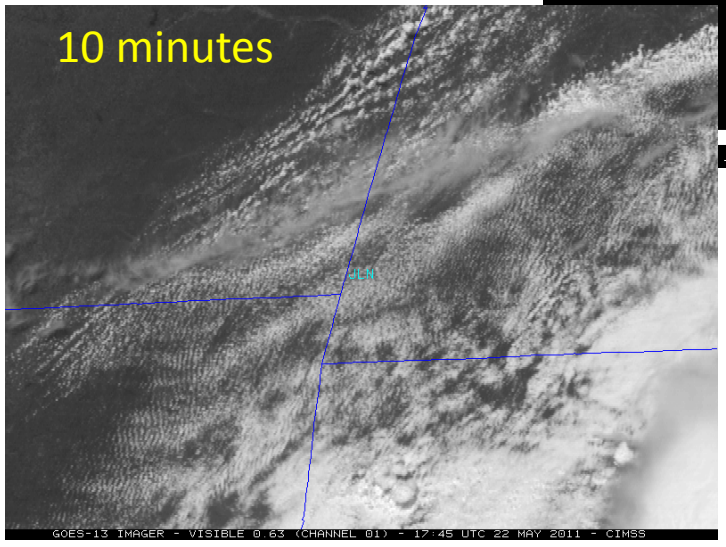
5 km resolution FY-2E 10.8 μm IR channel images revealed the development of very cold cloud top brightness temperatures (-60° C to -75° C, red to black to white color enhancement) with some of these embedded thunderstorms, with evidence of a period of back-building of convection in the vicinity of Beijing after 15 UTC.

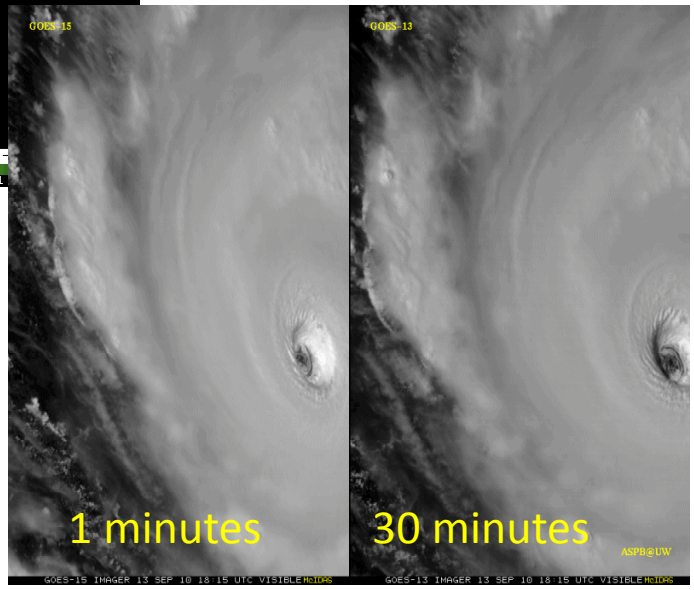




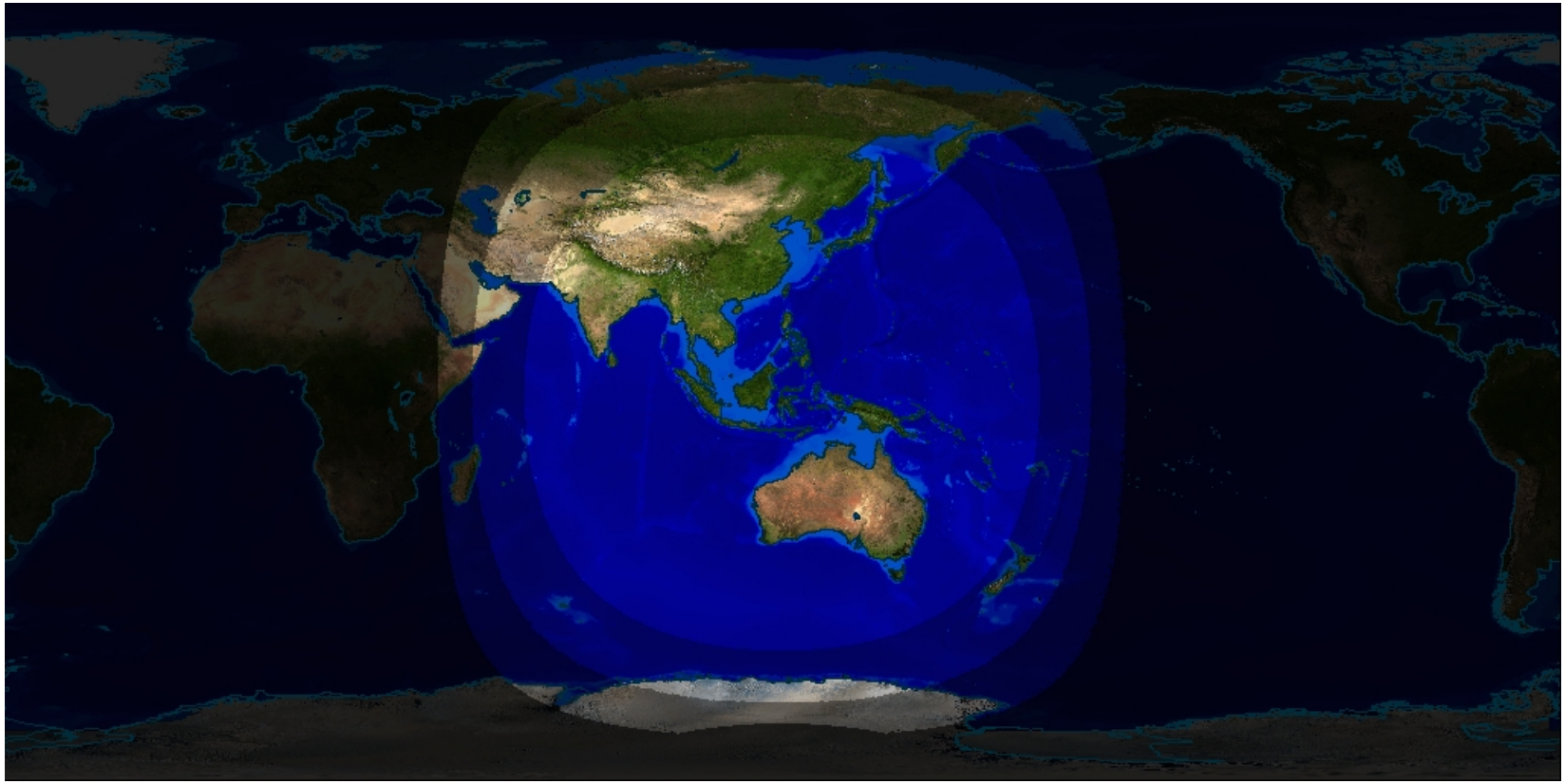
GEO's Programmable Targeting Measurement

GEO Offers High Temporal on Demand



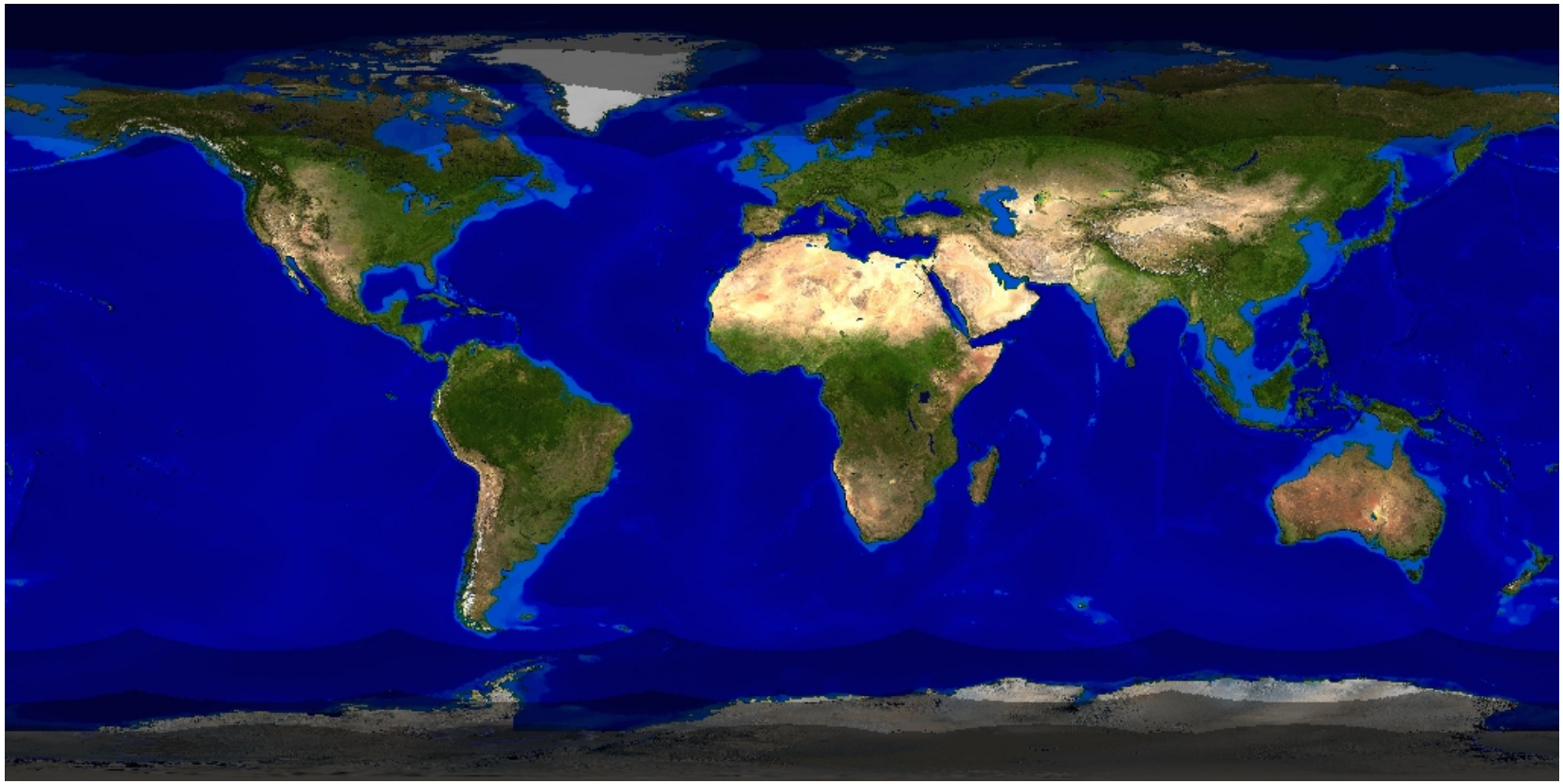


1st STORM Satellite (120^{0}E) will cover >70% of World Population



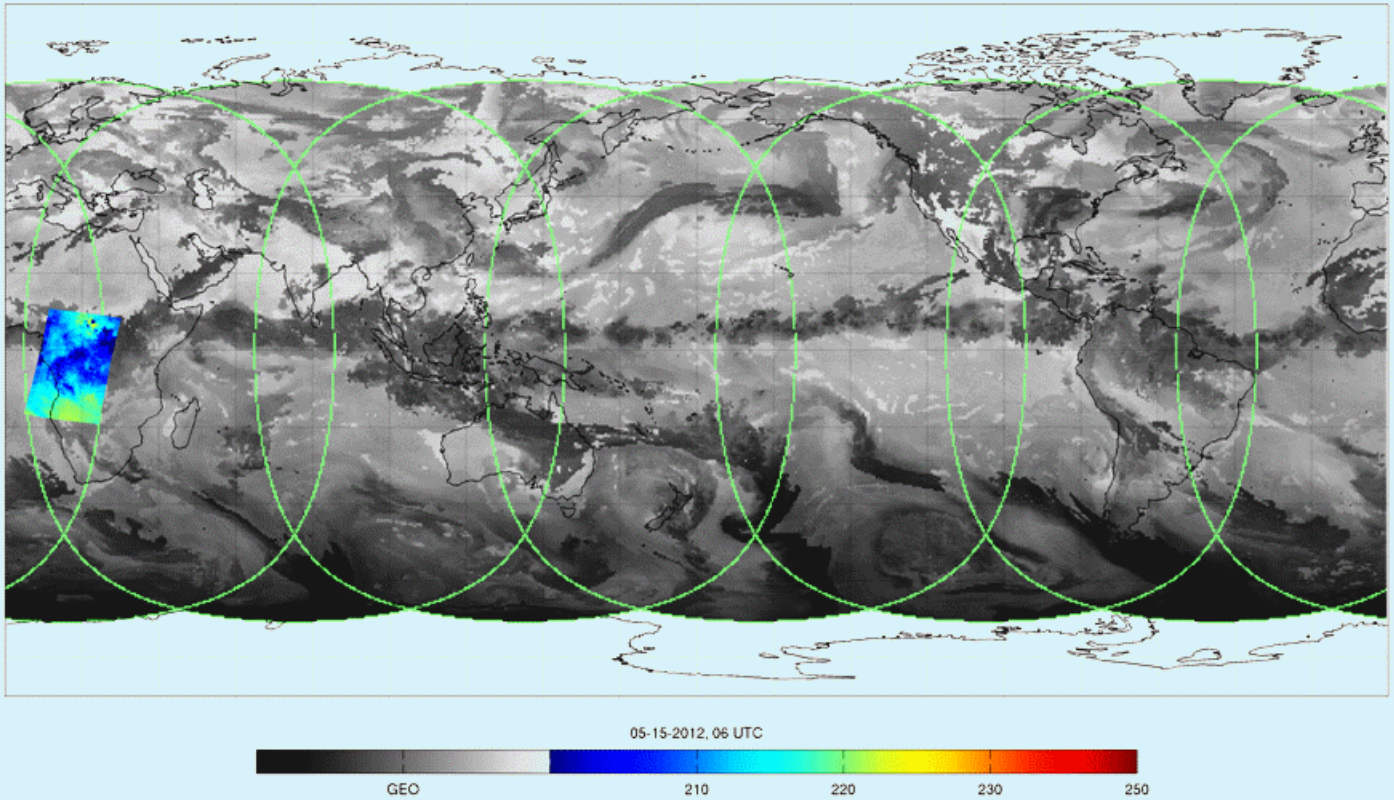
Inner Circle (light blue shade): SVA=67.5^0
Mid Circle (mid blue shade): SVA=80^0
Outer Circle (dark blue shade): SVA=90^0

Six (6) STORM Satellite System (S4) Constellation
will cover >98% of World Population



Inner Circle (light blue shade): SVA=67.5^0
Mid Circle (mid blue shade): SVA=80^0
Outer Circle (dark blue shade): SVA=90^0

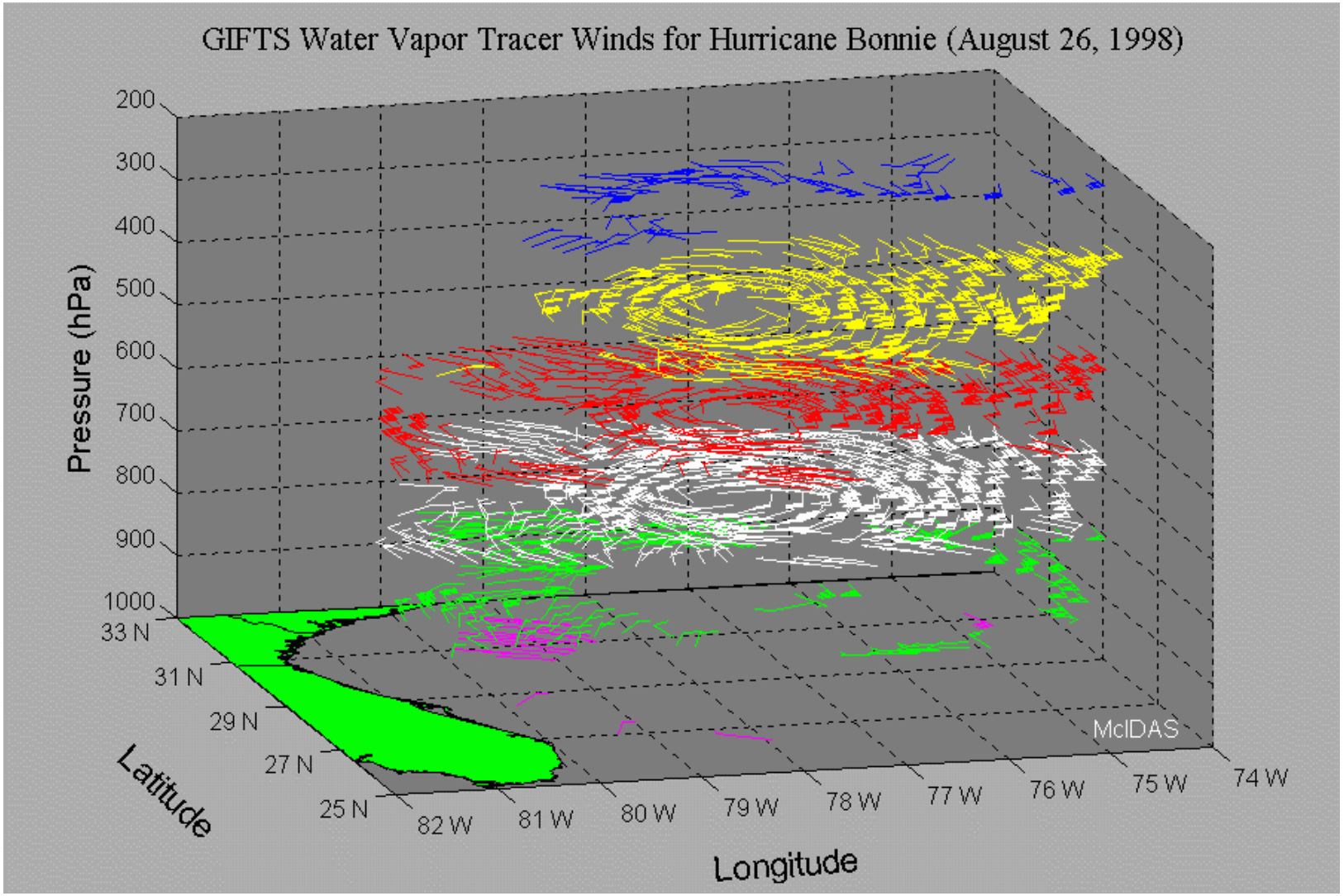
STORM Constellation *vs* LEO



LEO in color

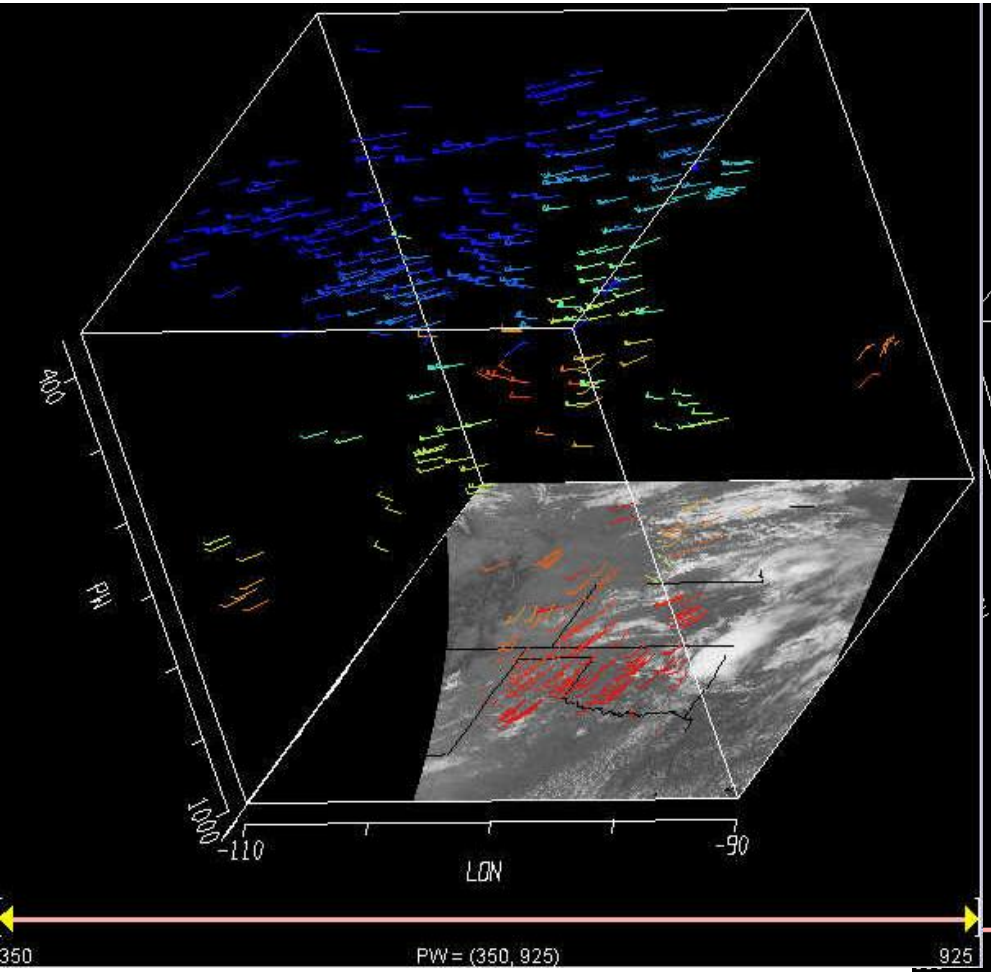
GEO in gray color

GIFTS Simulation of Hurricane Bonnie:
Winds from Water Vapor Retrieval Tracking

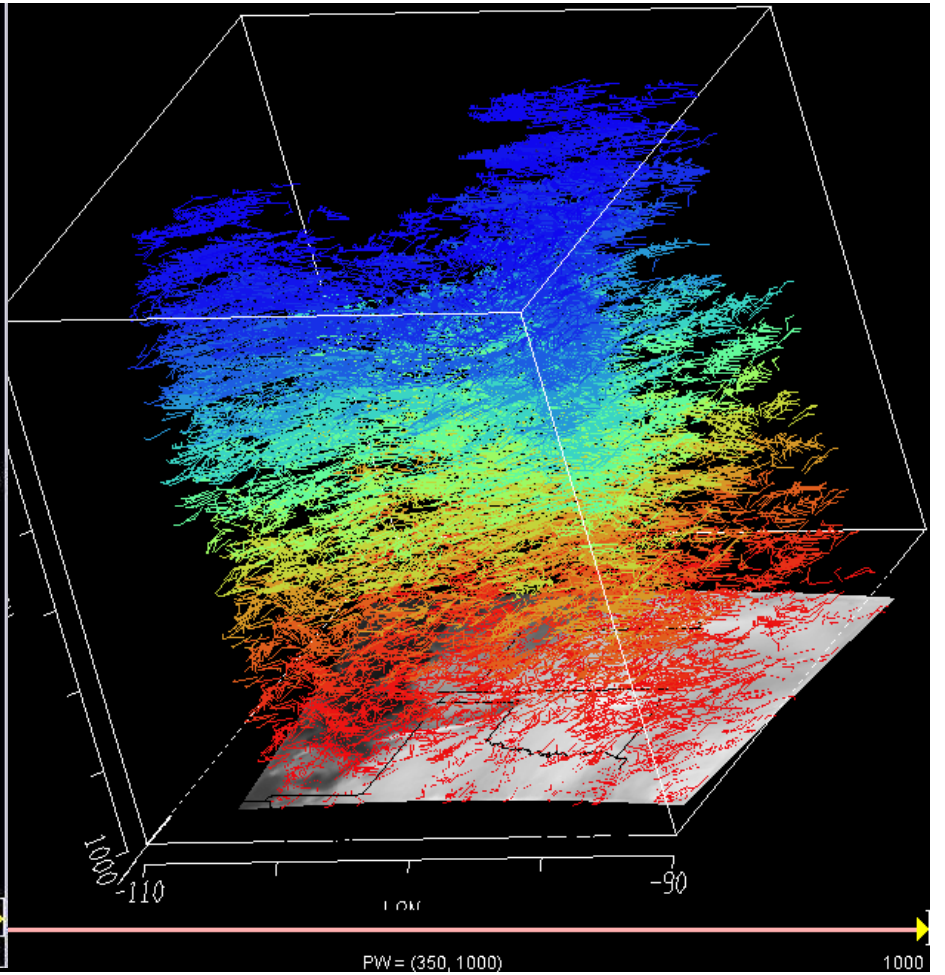


Simulated 3-D Water Vapor Wind

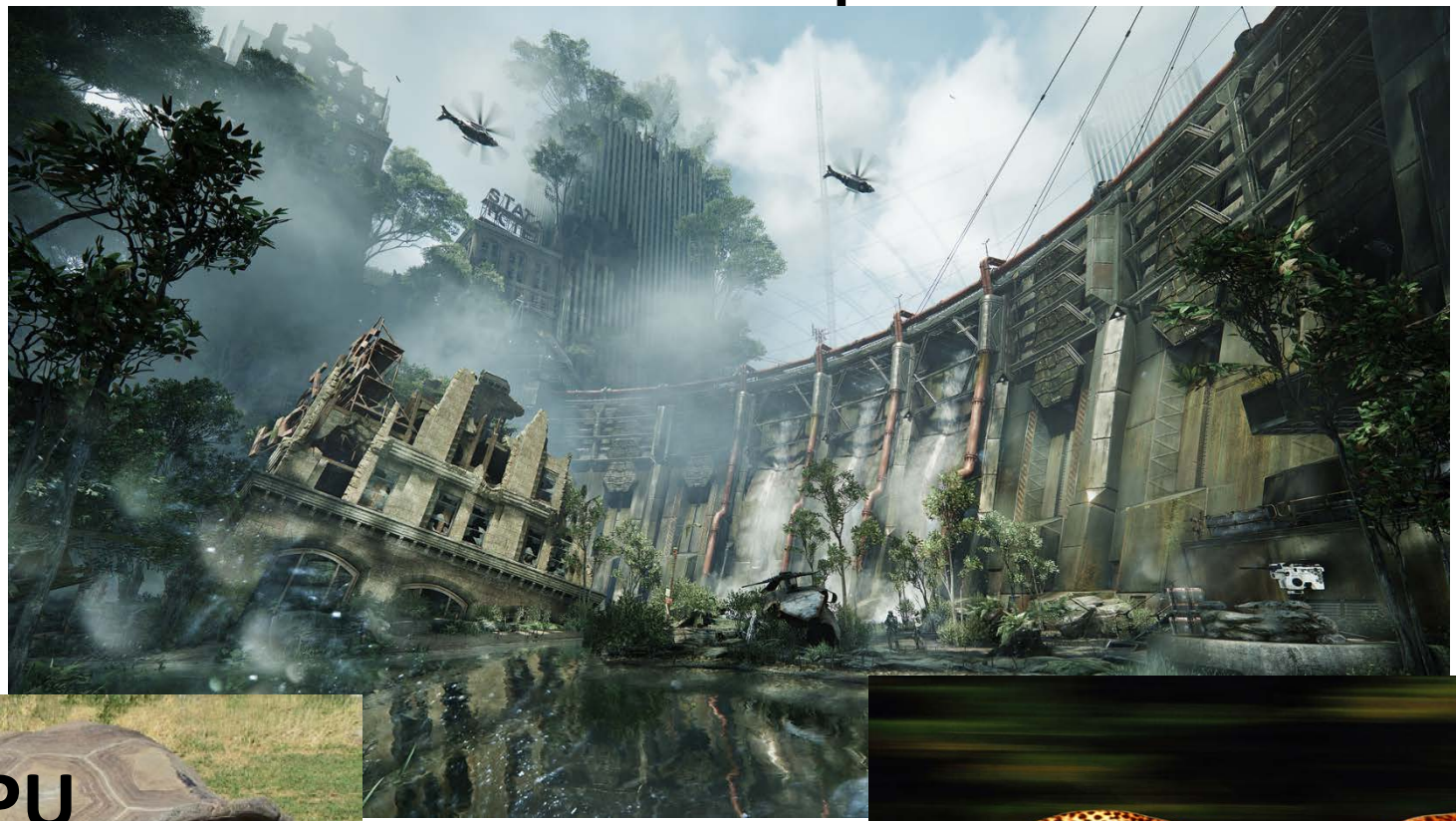
GOES (18 ch)

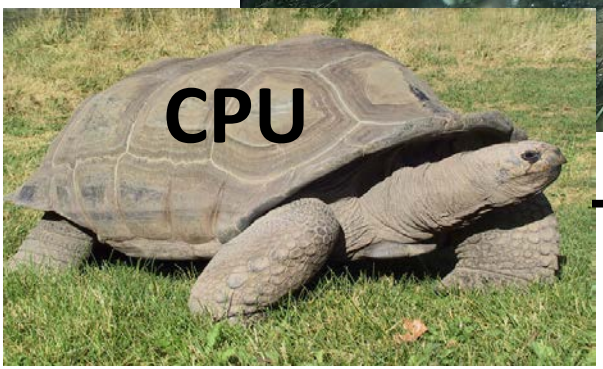


GIFTS/STORM (1800 ch)

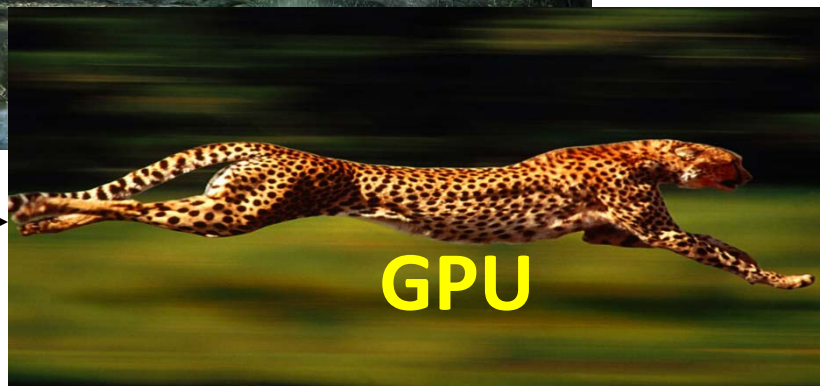


Driver for GPU Technology: Games - Speed





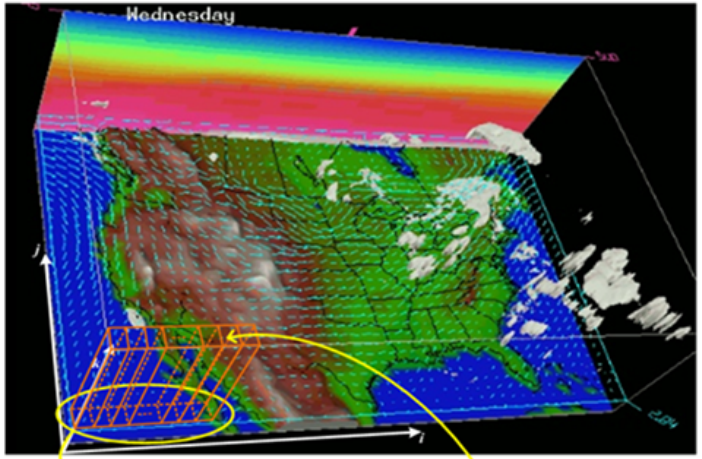
CPU to GPU



Crysis 3

GeoMetWatch is to use GPU-based High-Performance Computing technology to assimilate high spatial and high temporal resolution STORM data to make much improved regional forecast

High-Performance GPU NWP Model Infrastructure >100 Speedup



WRF Module name	Speedup
Single moment 6-class microphysics	500x
Eta microphysics	272x
Purdue Lin microphysics	692x
Stony-Brook University 5-class microphysics	896x
Betts-Miller-Janjic convection	105x
Kessler microphysics	816x
New Goddard shortwave radiance	134x
Single moment 3-class microphysics	331x
New Thompson microphysics	153x
Double moment 6-class microphysics	206x
Dudhia shortwave radiance	409x
Goddard microphysics	1311x
Double moment 5-class microphysics	206x
Total Energy Mass Flux surface layer	214x
Mellor-Yamada Nakanishi Niino surface layer	113x
Single moment 5-class microphysics	350x
Pleim-Xiu surface layer	665x

Next generation satellite sounding data needs to be evolved to keep up with NWP model progress

Year	NWP Model Evolution and Satellite Sounder Observation Availability/Potential			
	NWP Model Resolution (ECMWF)		Satellite Sounder Data Resolution (Hyperspectral)	
	Grid Spacing (km)	Time Step (seconds)	IFOV (km)	Temporal
2012	16	600 (10 min)	AIRS - 14 CrIS/IASI – 12	12 hours
2015/16	10	450 (7.5 min)	CrIS/IASI – 12 CrIS NG - ?? IASI NG – 12 STORM-1 - 4	12 hours 12 hours 12 hours 0.5-1 hour
2020	5	240 (4 min)	CrIS NG - ?? IASI NG – 12 IRS/STORM – 4/2	12 hours?? 12 hours?? 0.5-1 hour
2025	2.5	30-120 (0.5-2 min)	CrIS NG - ?? IASI NG – 12 IRS/STORM – 4/2	12 hours?? 12 hours?? 0.5-1 hour

NWP model resolution is planned to be improved significantly overtime

Satellite sounding data heavily used by NWP model and contributed greatly to forecast accuracy also need to be improved in spatial and temporal resolution to keep up with their much needed contribution…….

GeoMetWatch

Advanced Weather Systems Laboratory
Utah State University

Space Science & Engineering Center
University of Wisconsin

STORM SENSOR

DATA PROCESSING

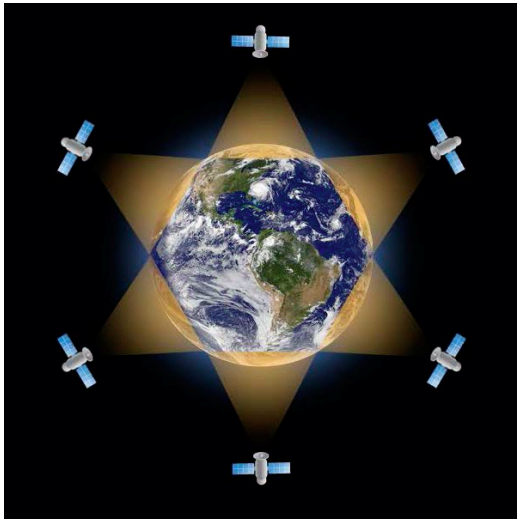
Unprecedented Weather Forecast;
Environmental Monitoring; &
Disaster Mitigation Capability

http://geometwatch.com/

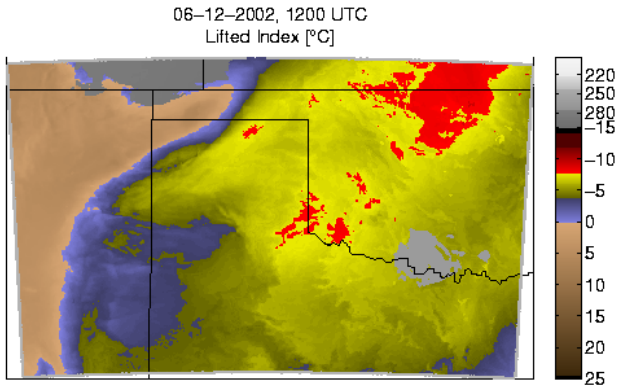
STORM Brings the Science & Technology Together to Further Advance the Remote Sensing & Modeling Capability

Cutting Edge Sensor

Global Coverage

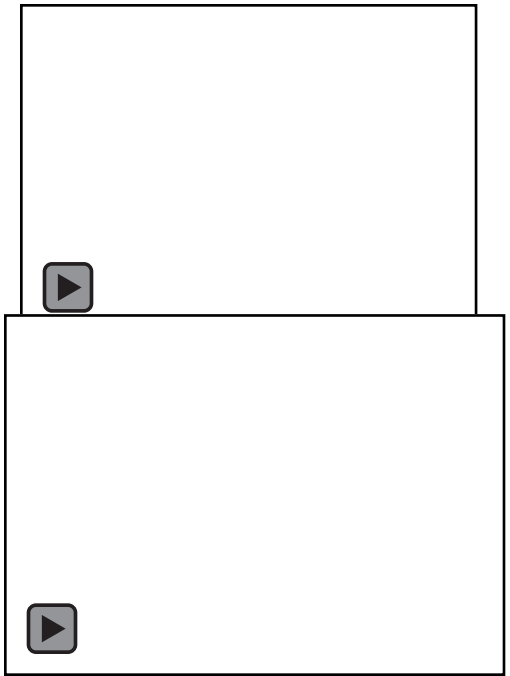


Early Monitoring & Warning

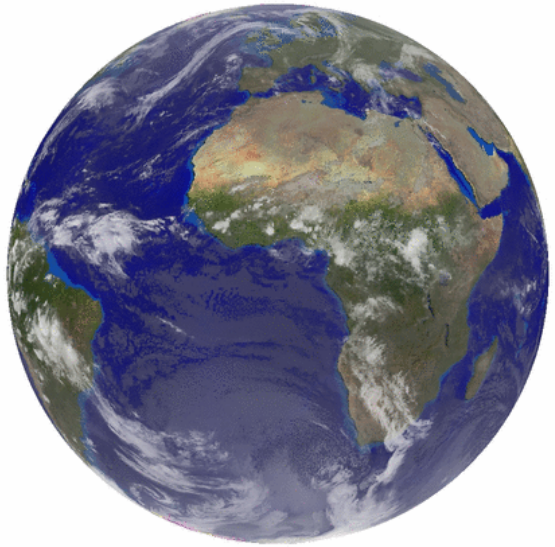


GPU High-Performance Forecasting Technology

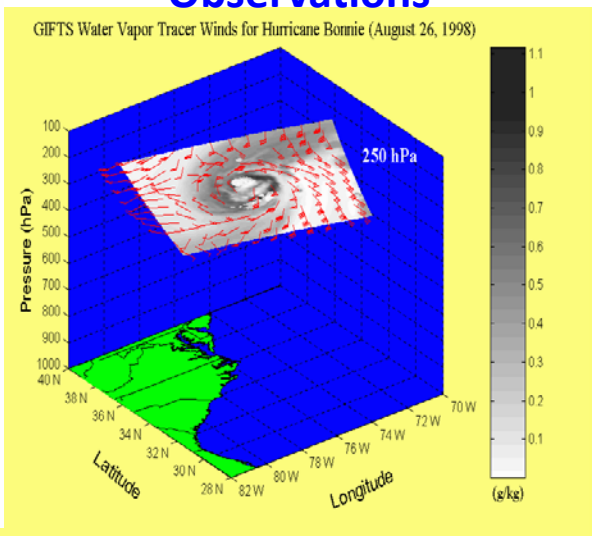
UW/CIMSS



Large Domain High Temporal Observations



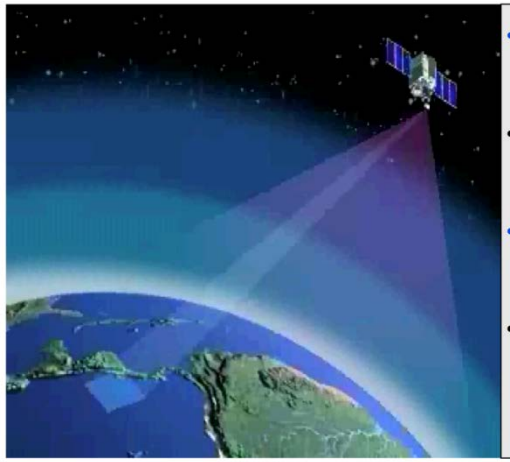
High Vertical Resolving Observations



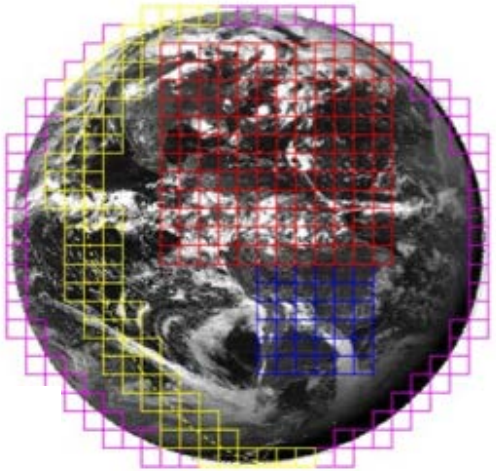
Backups

ABSTRACT:
In a twenty-hour period on July 21, 2012, the city of Beijing, China experienced a major flash flood. Within a day of the flooding more than 60 thousand people were evacuated, whilst floodwaters took many lives, destroyed many homes, and ultimately caused at least 10 billion Yuan in damages. This extreme event was a fresh reminder that a severe weather event of this kind is very difficult to predict, in terms of location, intensity and timing. The reason for this unpredictability is due in large part to the lack of coupled spatial, temporal and spectral observations at the required resolutions.
GeoMetWatch (GMW) is the first, and currently only, commercial company licensed by the US Government to operate a global geostationary Hyper-spectral infrared imaging sounding system. This commercial project is to leverage technology developed by NASA and NOAA in the form of a GMW six-satellite constellation of next-generation hyper/ultra-spectral (spectral sampling < 1.0 cm^{-1}) sensors. This constellation of space-borne geostationary sensors will provide frequent, global infrared/visible measurements for weather forecasting, climate studies, environmental uses, and most importantly, for the type of time-critical weather forecasting required for disaster risk management and rapid-response decision making.
In this presentation, we will unveil the exciting and challenging GMW project and report on the simulation and assimilation of GMW's Sounding and Tracking Observatory for Regional Meteorology (STORM) sensor measurements, and the subsequent forecast verification study of the Beijing 721 intense precipitation episode using Weather Research Forecast (WRF) Model.

GIFTS/STORM Scan Configuration

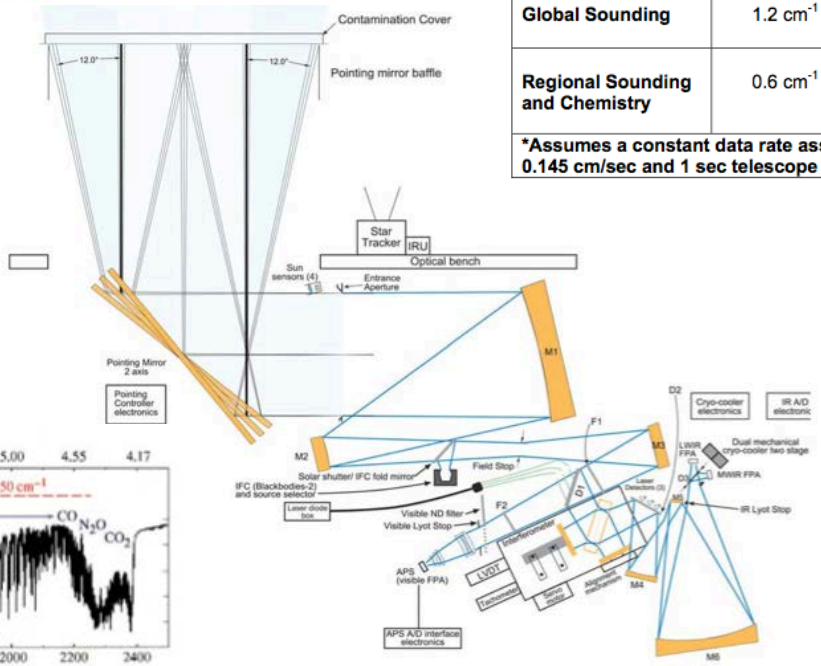


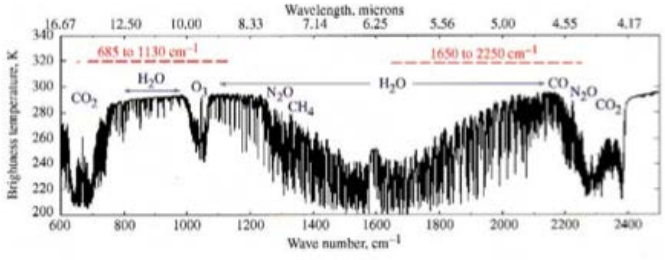
- Two 128 x 128 pixel IR detector arrays with 4 km footprint size
- One 512 x 512 pixel visible detector array with 1 km footprint size
- Views 512 km x 512 km region with all three arrays in < 10 seconds
- 10 second observation provides 16,380 vertical profiles



Mode	Resolution		Coverage	
	Spectral	OPD	Area	Time*
Stare Mode	0.3–36cm^{-1}	0.014–1.744 cm	512 km	<1–11 sec
Regional Imaging	36 cm^{-1}	0.014 cm	6,000 km	3 min
Global Sounding	1.2 cm^{-1}	0.4 cm	10,000 km	< 1 hr
Regional Sounding and Chemistry	0.6 cm^{-1}	0.872 km	6000 km	< 20 min

*Assumes a constant data rate associated with Michelson mirror scan velocity of 0.145 cm/sec and 1 sec telescope pointing step time.





Views:

Earth (12 s)
Coastlines (<1 hr)
Space (~20 min)
CBB (~20 min)
HBB (~20 min)
FAB (~2 weeks)

GeoMetWatch-STORM Product List (Preliminary)

Three levels of products

Level 1

- IR Radiances
- Visible Radiances
- Images (i.e. Clouds; Water Vapor, …)
- Animations

Level 2

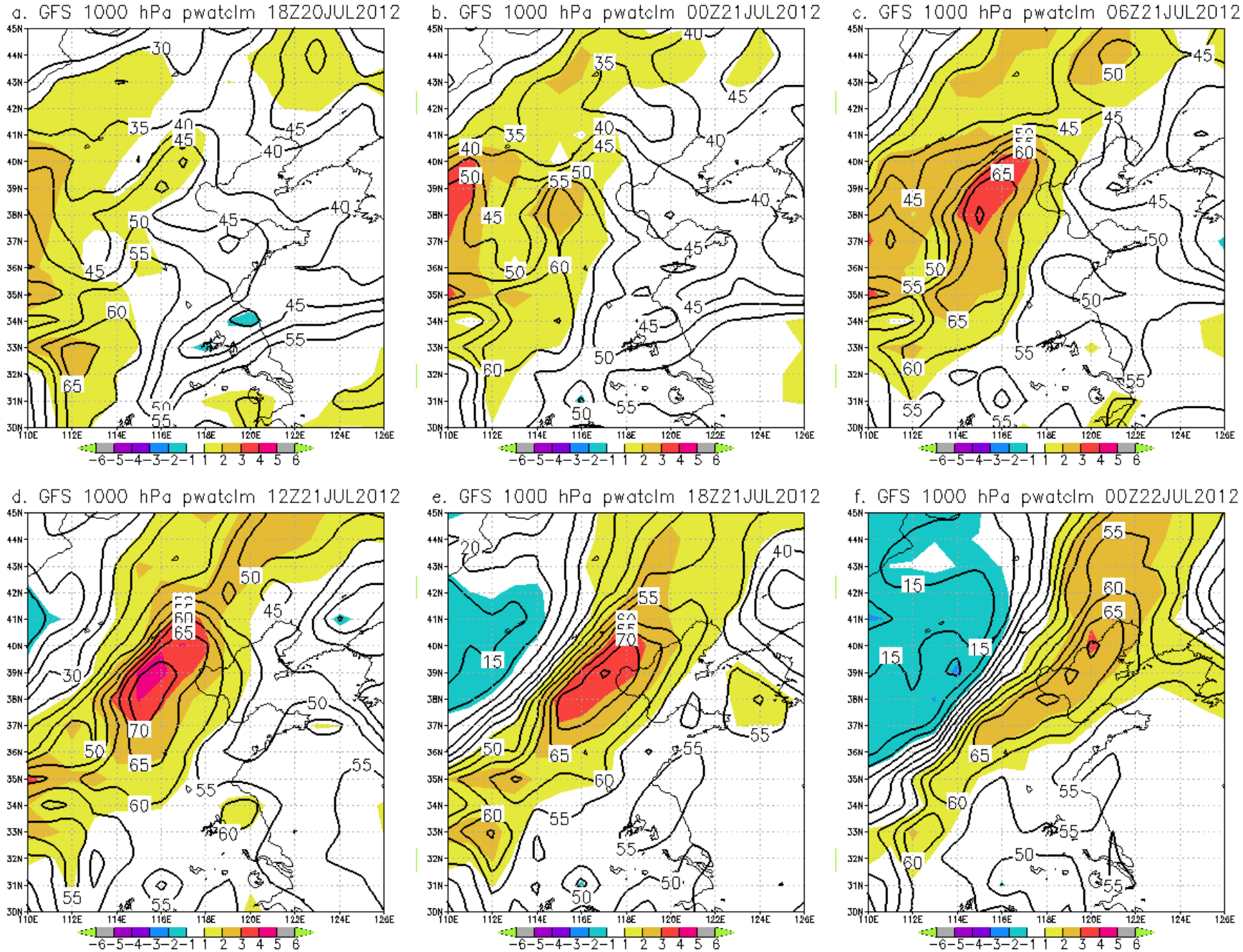
- Vertical Moisture Profile
- Legacy Vertical Temperature Profile
- Aerosol Detection (including Smoke & Dust)
- Aerosol Particle Size
- Suspended Matter / Optical Depth
- Volcanic Ash: Detection and Height
- Aircraft Icing Threat
- Cloud Layers / Heights & Thickness
- Cloud Ice Water Path
- Cloud Liquid Water
- Cloud Optical Depth
- Cloud Particle Size Distribution
- Cloud Top Phase
- Cloud Top Height
- Cloud Top Pressure
- Cloud Top Temperature
- Cloud Type
- Clear Sky Masks
- Low Cloud & Fog

Level 2

- Land Surface (Skin) Temperature
- Sea Surface Temps
- Surface Albedo
- Surface Emissivity
- Vegetation Index
- Currents
- Currents: Offshore
- Sea & Lake Ice: Age
- Sea & Lake Ice: Concentration
- Sea & Lake Ice: Extent
- Sea & Lake Ice: Motion
- Ice Cover
- Snow Cover
- Absorbed Shortwave Radiation: Surface
- Downward Longwave Radiation: Surface
- Downward Solar Insolation: Surface
- Reflected Solar Insolation: TOA
- Upward Longwave Radiation: Surface
- Upward Longwave Radiation: TOA
- Ozone Total
- SO_2 Detection
- Derived Motion Winds
- Fire / Hot Spot Characterization
- Carbon Monoxide

Level 3

- Convective Initiation
- Enhanced “V” / Overshooting Top Detection
- Hurricane Intensity
- Probability of Rainfall
- Rainfall Potential
- Rainfall Rate / QPE
- Flood / Standing Water
- Derived Stability Indices (LI, Total Total)
- Total Precipitable Water
- Wind Shear
- PBL Height
- Turbulence
- Icing
- Solar Insolation
- Cloud Transient
- Cloud Base
- Theta-E Boundary
- Convective Available Potential Energy (CAPE)



GFS 00 UTC forecasts of precipitable water (mm) and precipitable water anomalies in 6 hr increments from a) 00:00 UTC 21 July 2012 through f) 06:00 UTC 2012.