APPLICATIONS OF REAL-TIME SATELLITE PRECIPITATION ESTIMATES

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Outline

- Precipitation estimation: status
- The GPM mission
- Potential applications

Precise precipitation estimation is important for:

- NWP models cal/val and verification
- The water cycle problem: closure
- Better understanding of the physics of some processes (e.g. hurricanes)
- Hydrological operations (dams, etc.)
- Response to extreme hydrometeorological events
  - Localised heavy rain
  - Hail
  - Flash floods monitoring
  - Hurricanes

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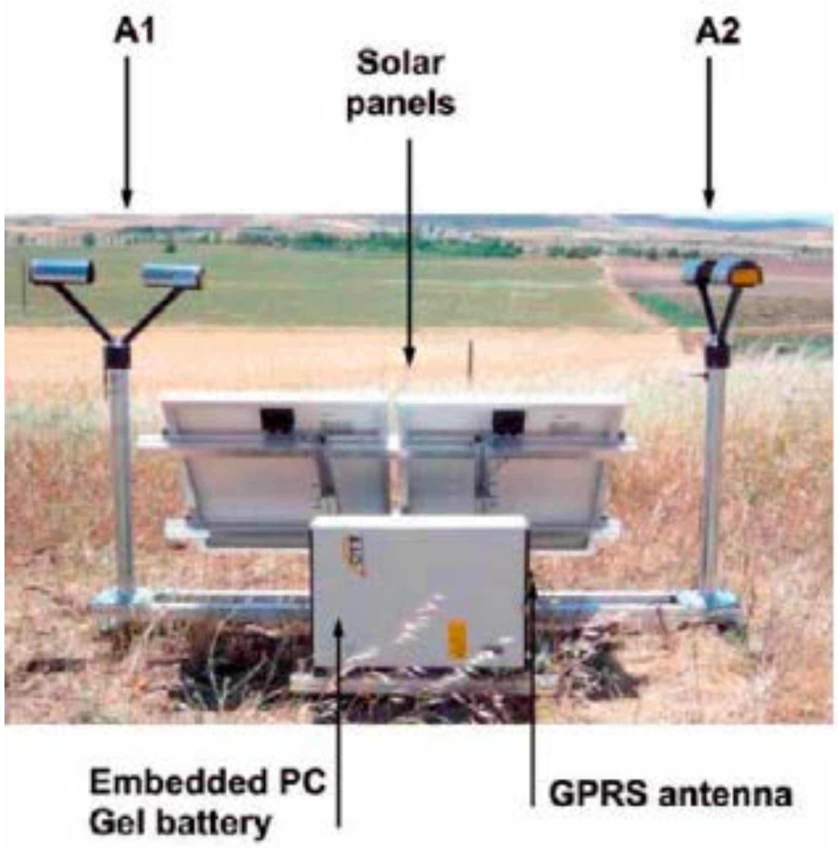
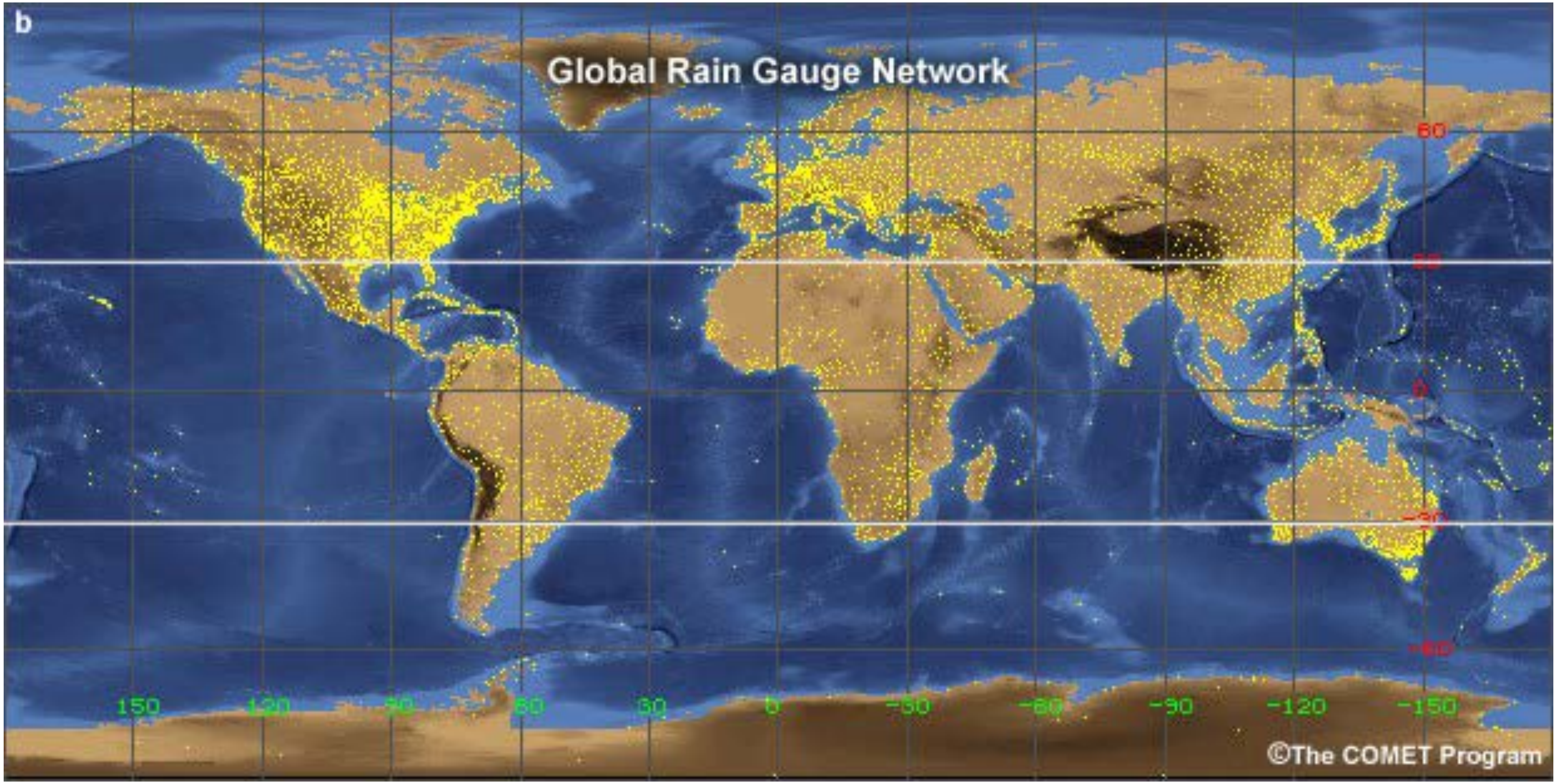


Ground-based estimates of precipitation present several shortcomings


b
Global Rain Gauge Network
60
30
0
-30
-60
150
120
90
60
30
0
-30
-60
-90
-120
-150
©The COMET Program


bwin
Coca-Cola
Mahou

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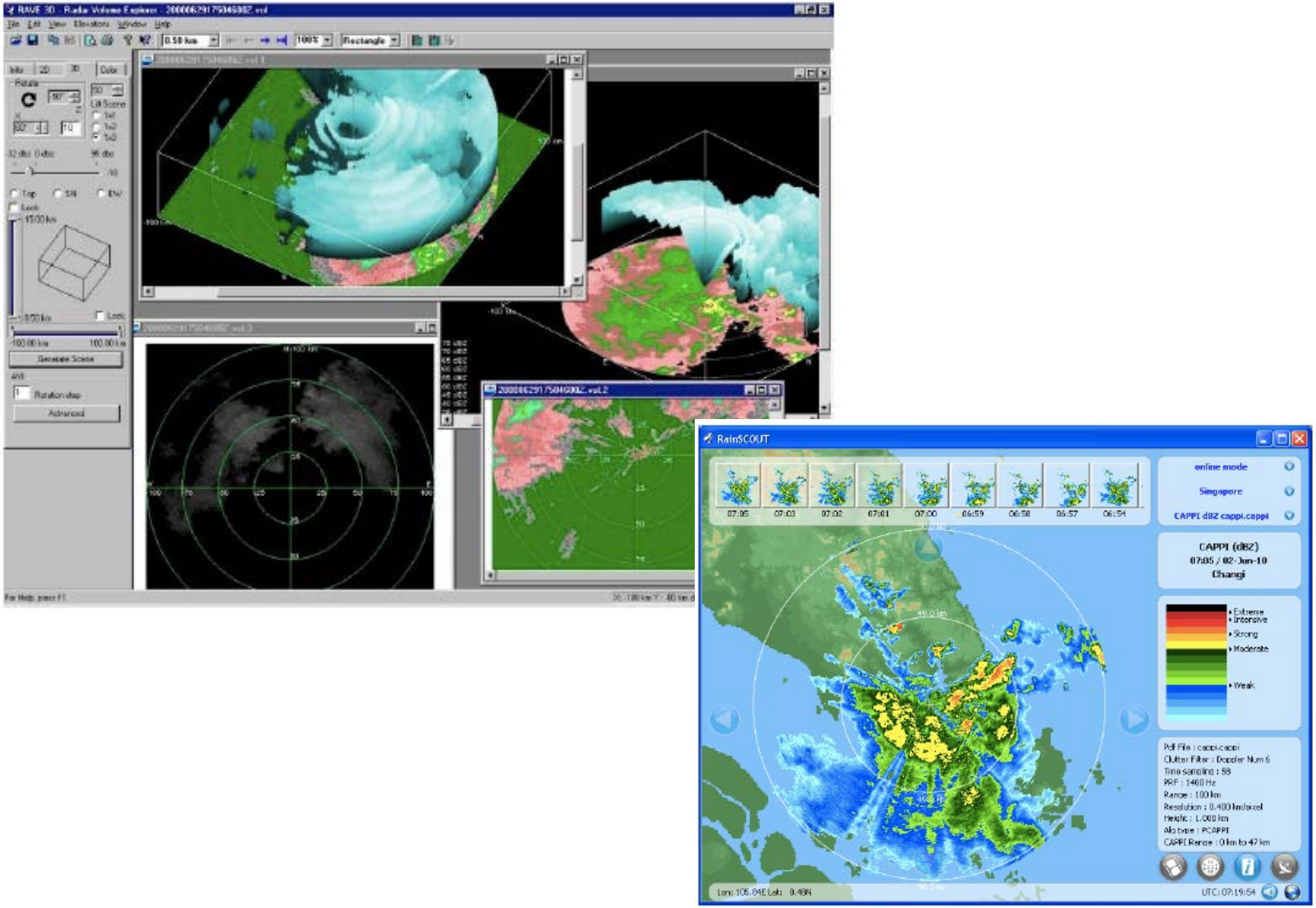

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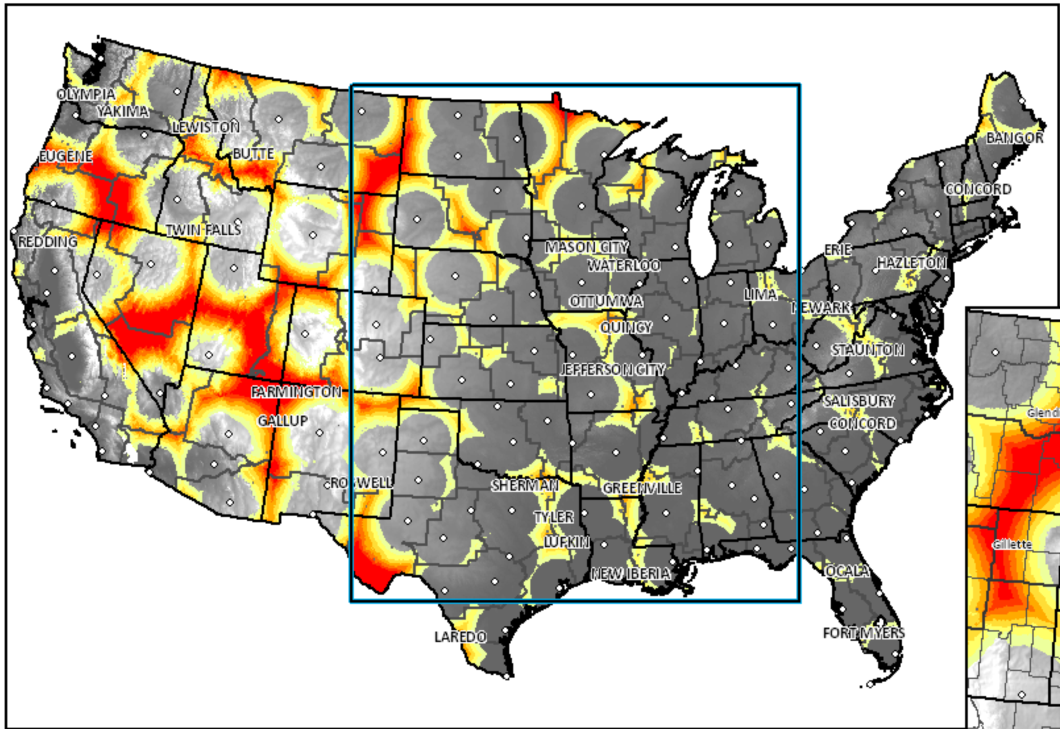
NEXRAD Coverage Deficiencies

and affected communities



NATIONWIDE

Color Fill: Minimum beam height of the 0.5 degree scan under normal atmospheric conditions.

Cities: Labeled cities with population exceeding 25,000 on the national map and 5,000 on the central US map.

LEGEND

- NEXRAD Sites

Min. NEXRAD Beam Height (ft AGL)

<VALUE>

- 8,000 - 10,000
- 10,000.00001 - 12,000
- 12,000.00001 - 14,000
- 14,000.00001 - 16,000
- 16,000.00001 - 18,000
- 18,000.00001 - 20,000
- 20,000.00001 - 40,000

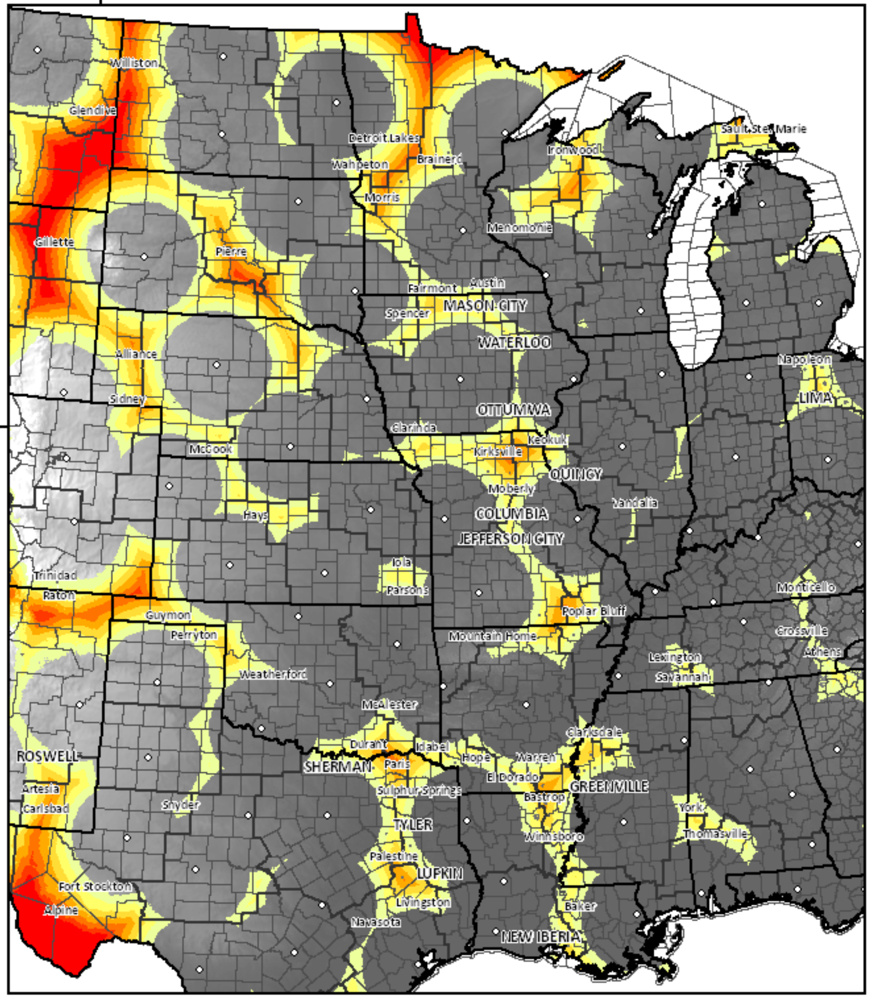
Elevation (ft)

Value

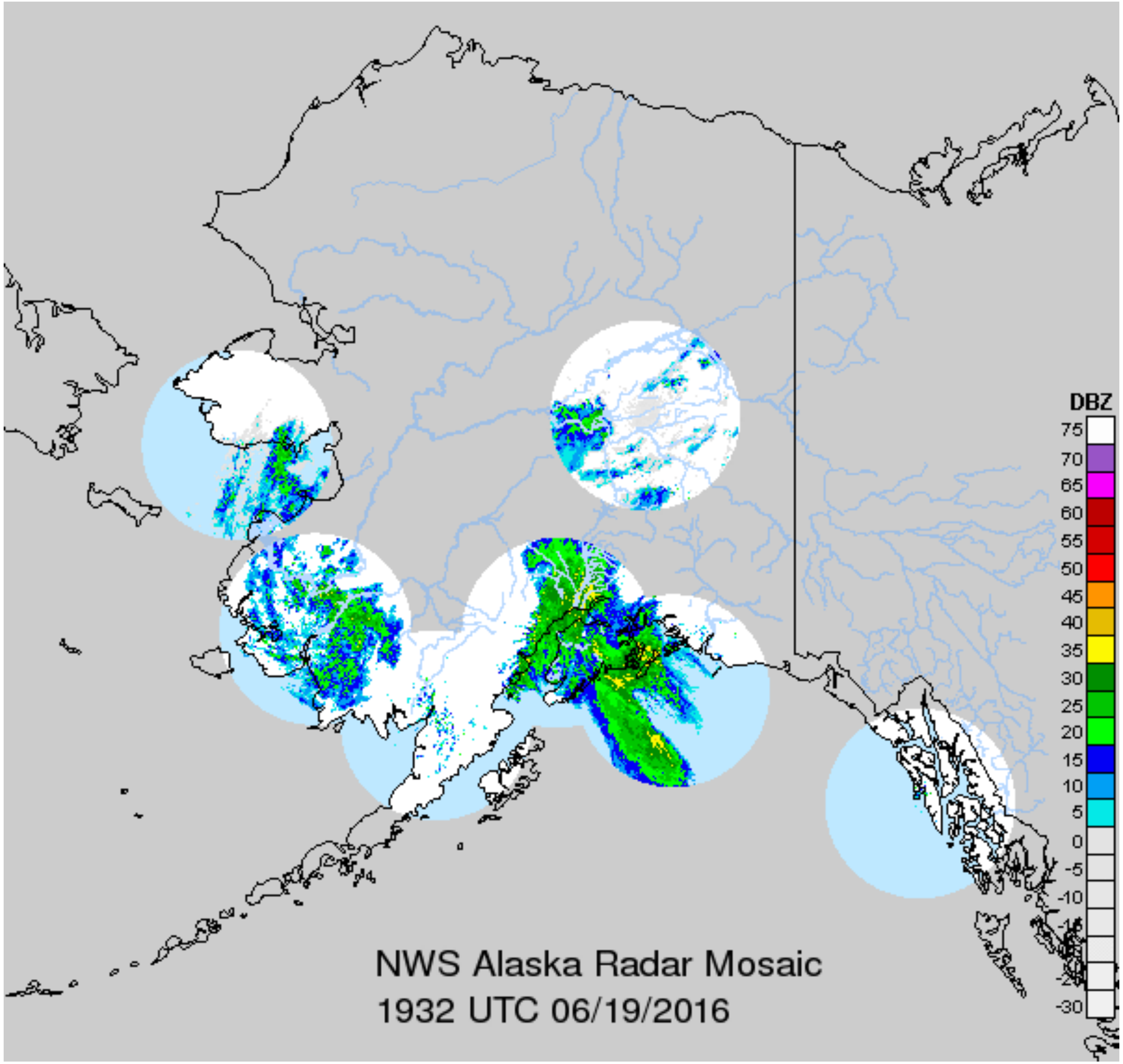
High : 10000

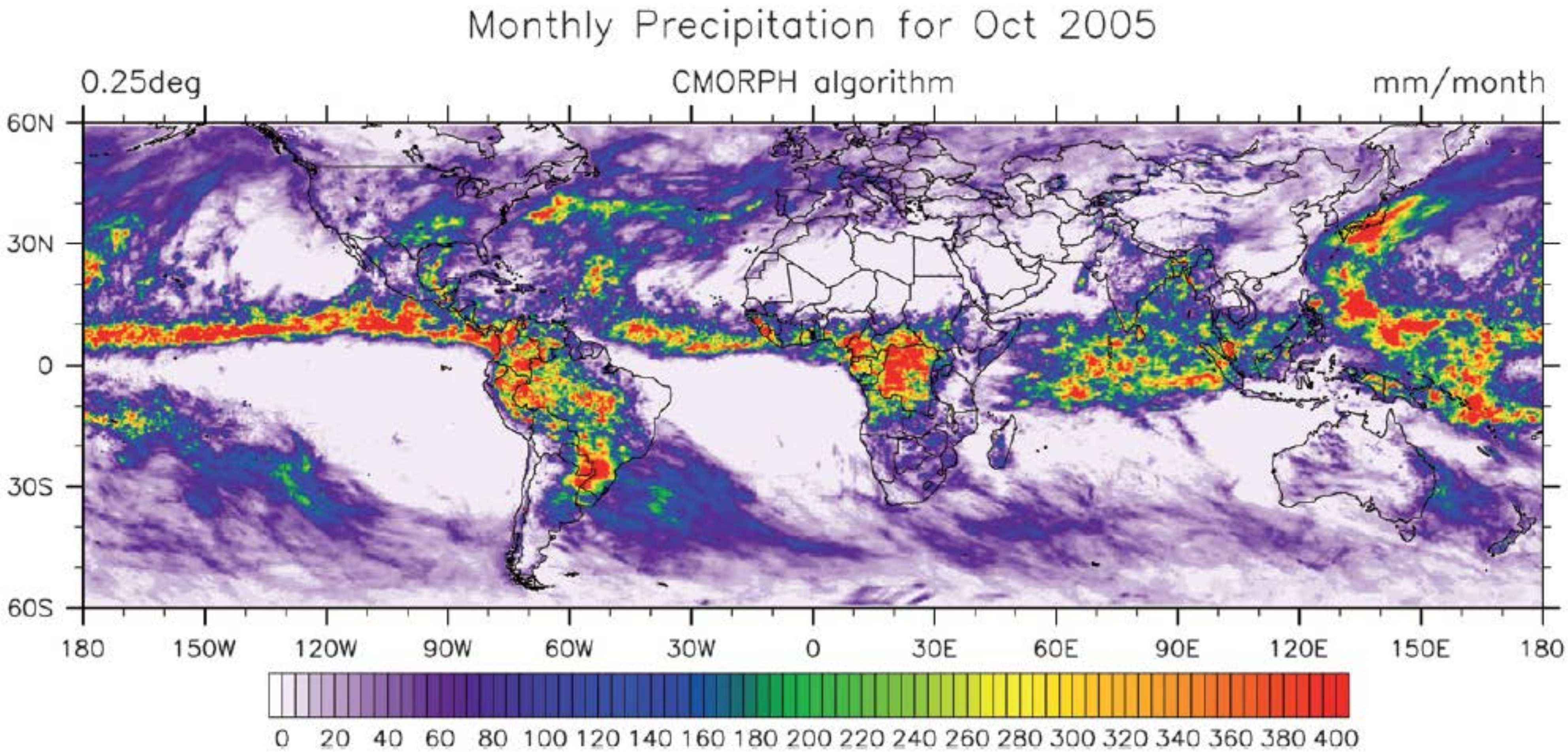
Low : 250

CENTRAL U.S.



Cartographer:
W Scott Lincoln
June 1, 2009


DBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-30
NWS Alaska Radar Mosaic
1932 UTC 06/19/2016



Tapiador et al. 2009, Energy Environ. Sci., 2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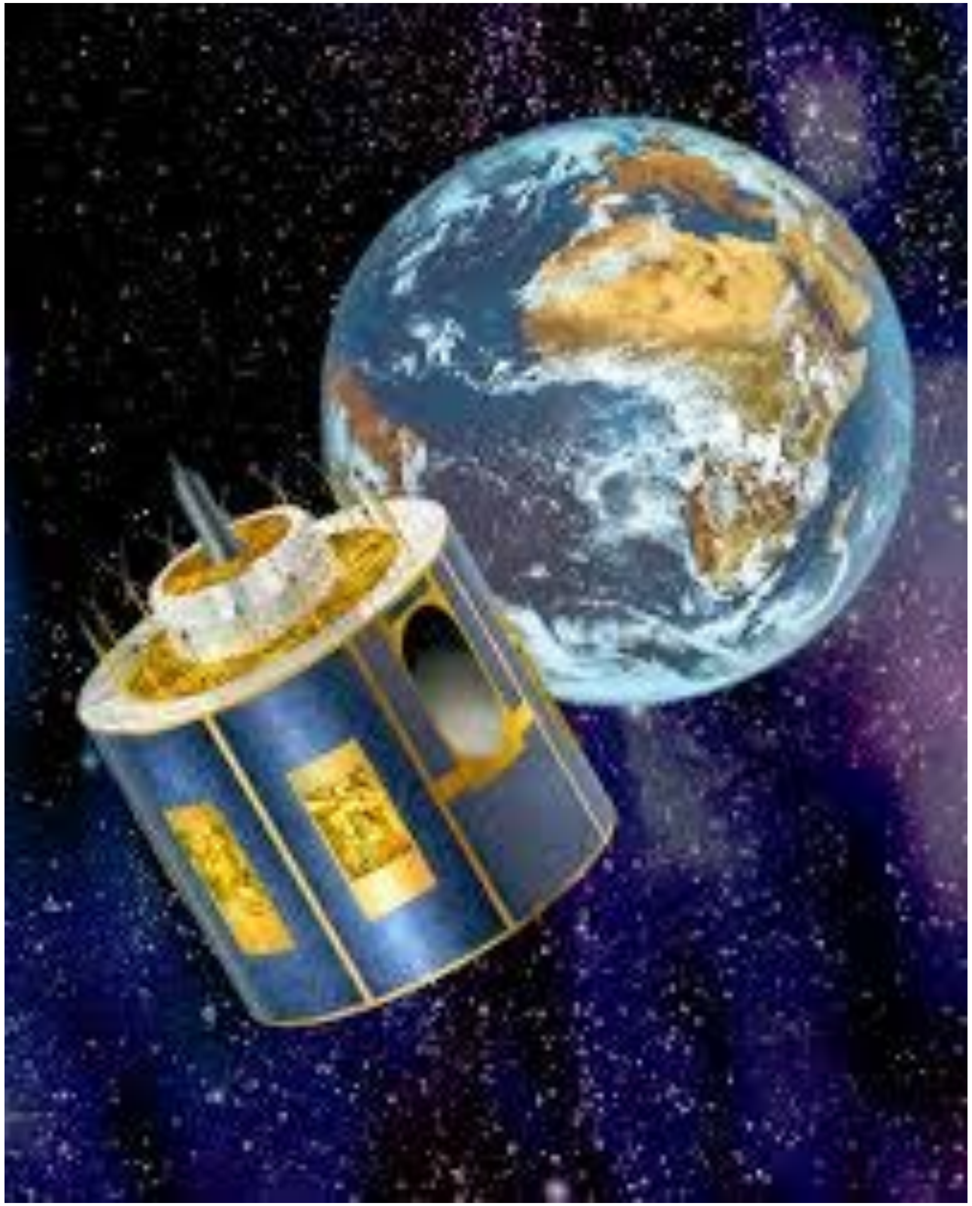
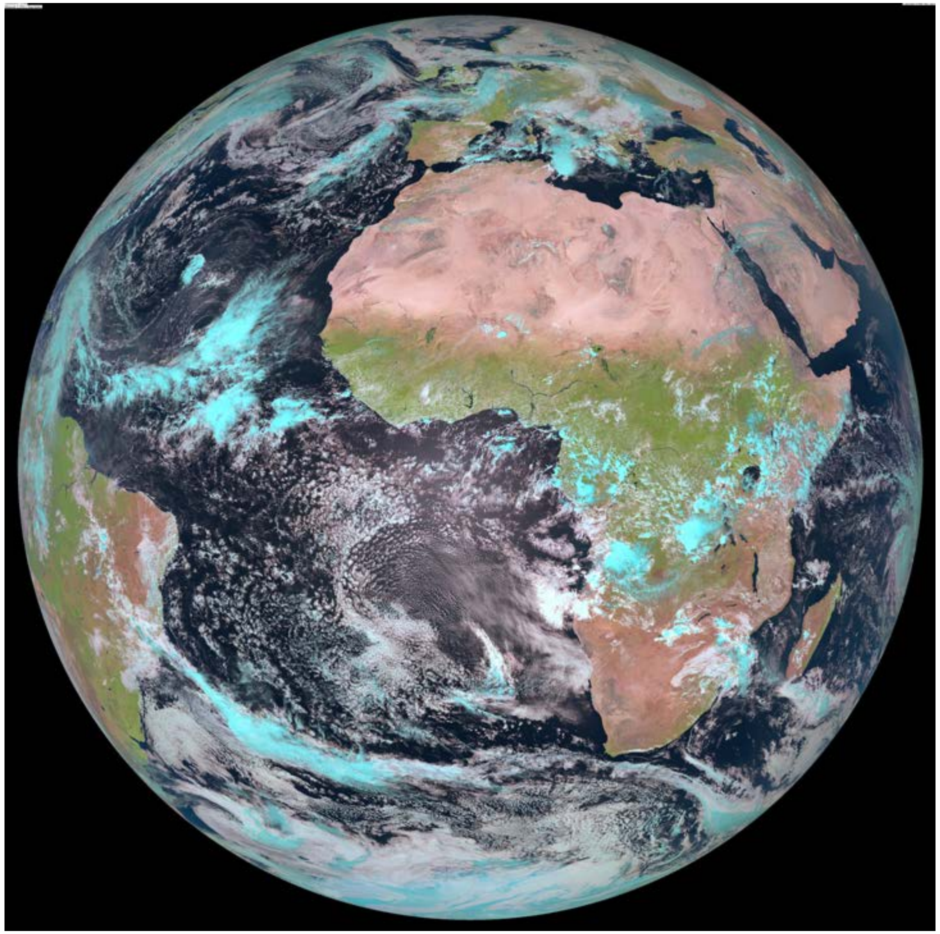
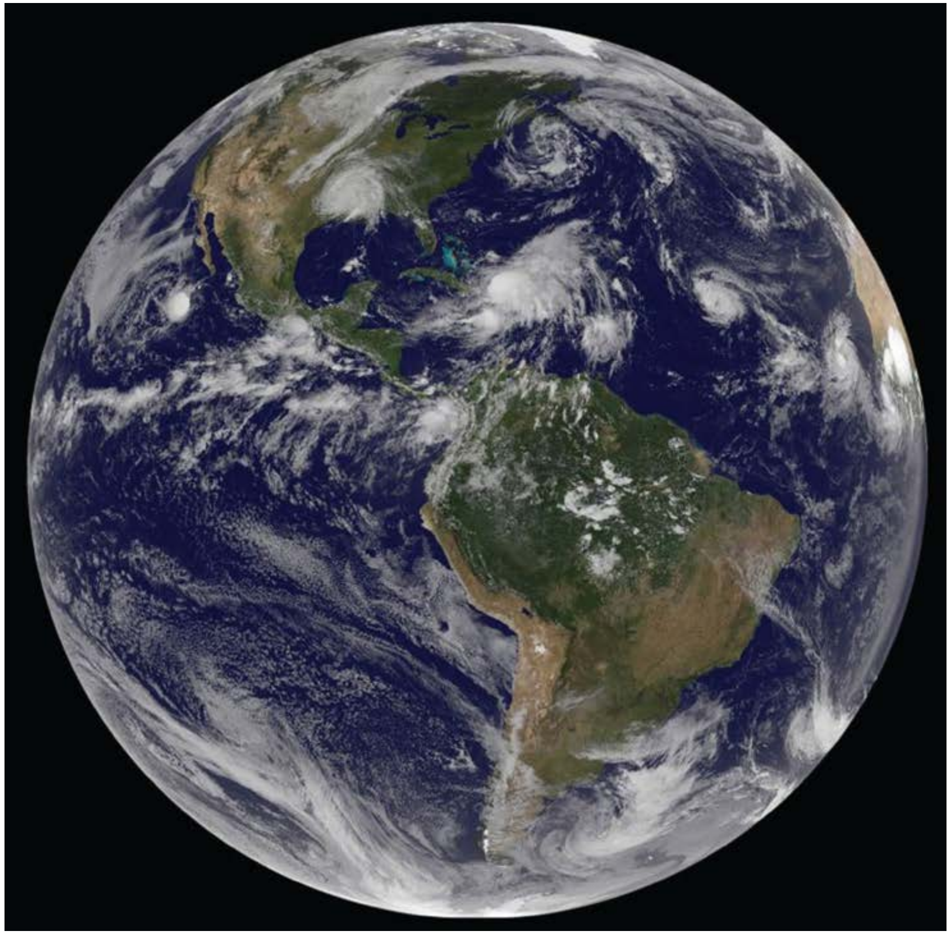
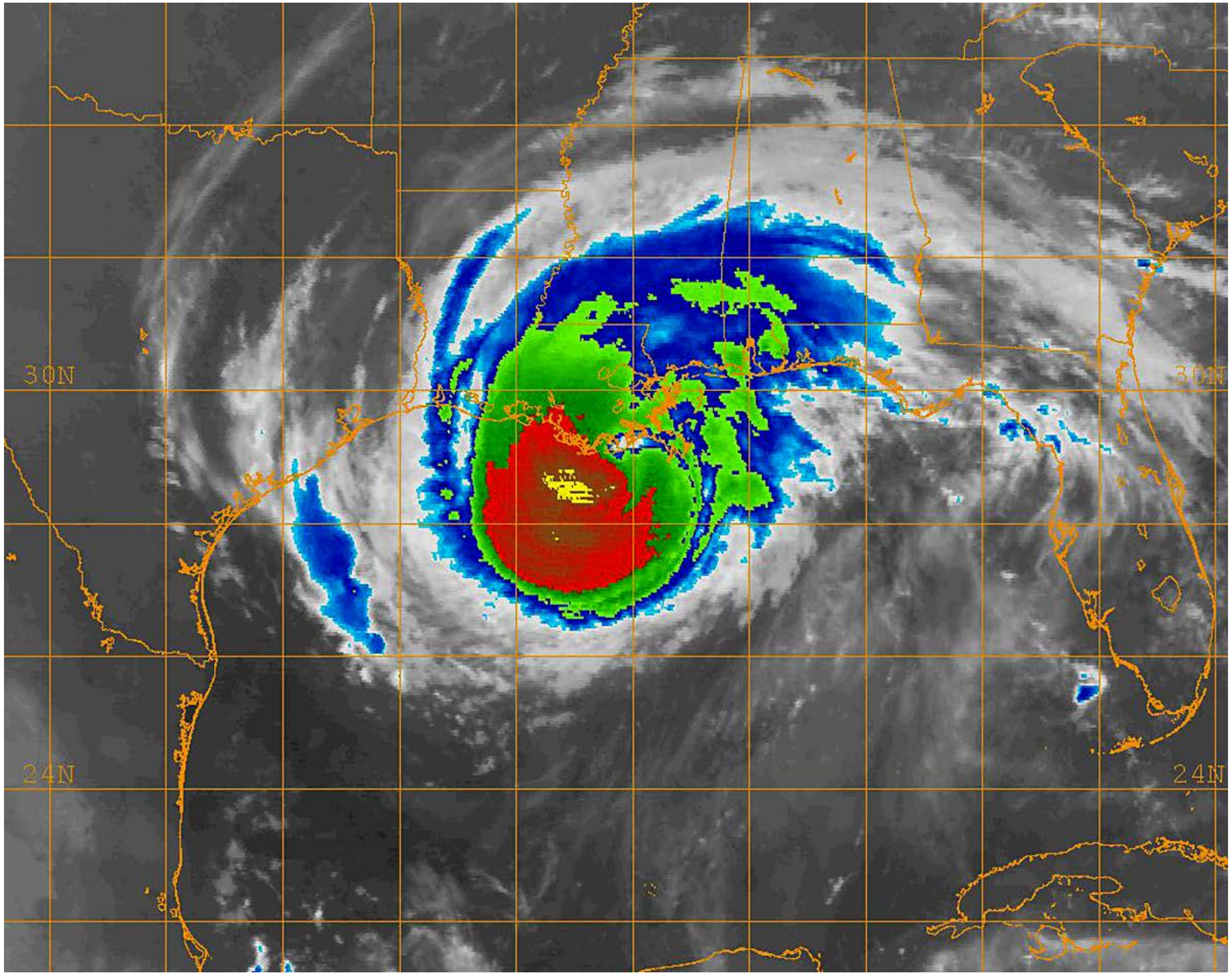


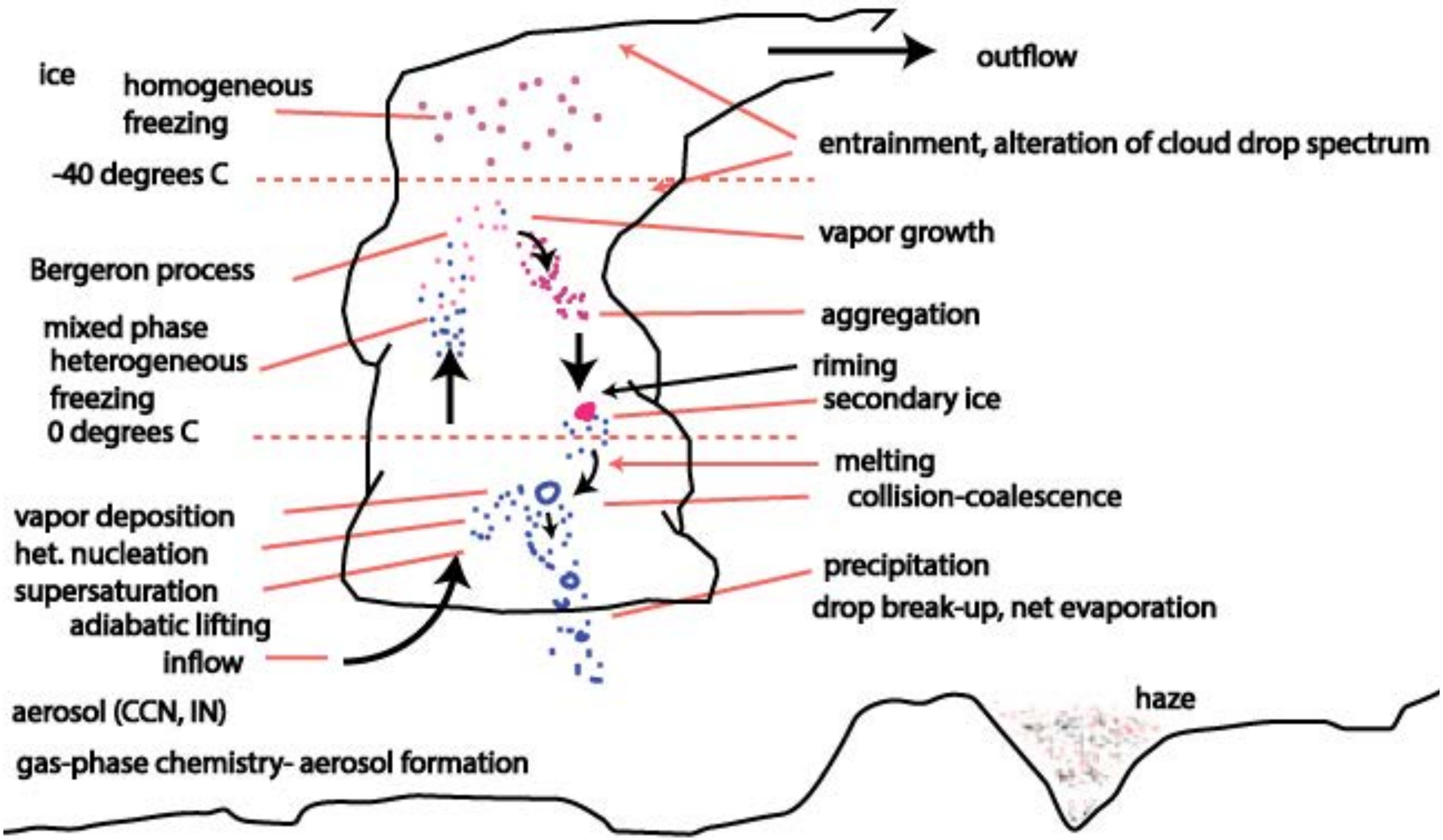
VIS/IR/WV sensors

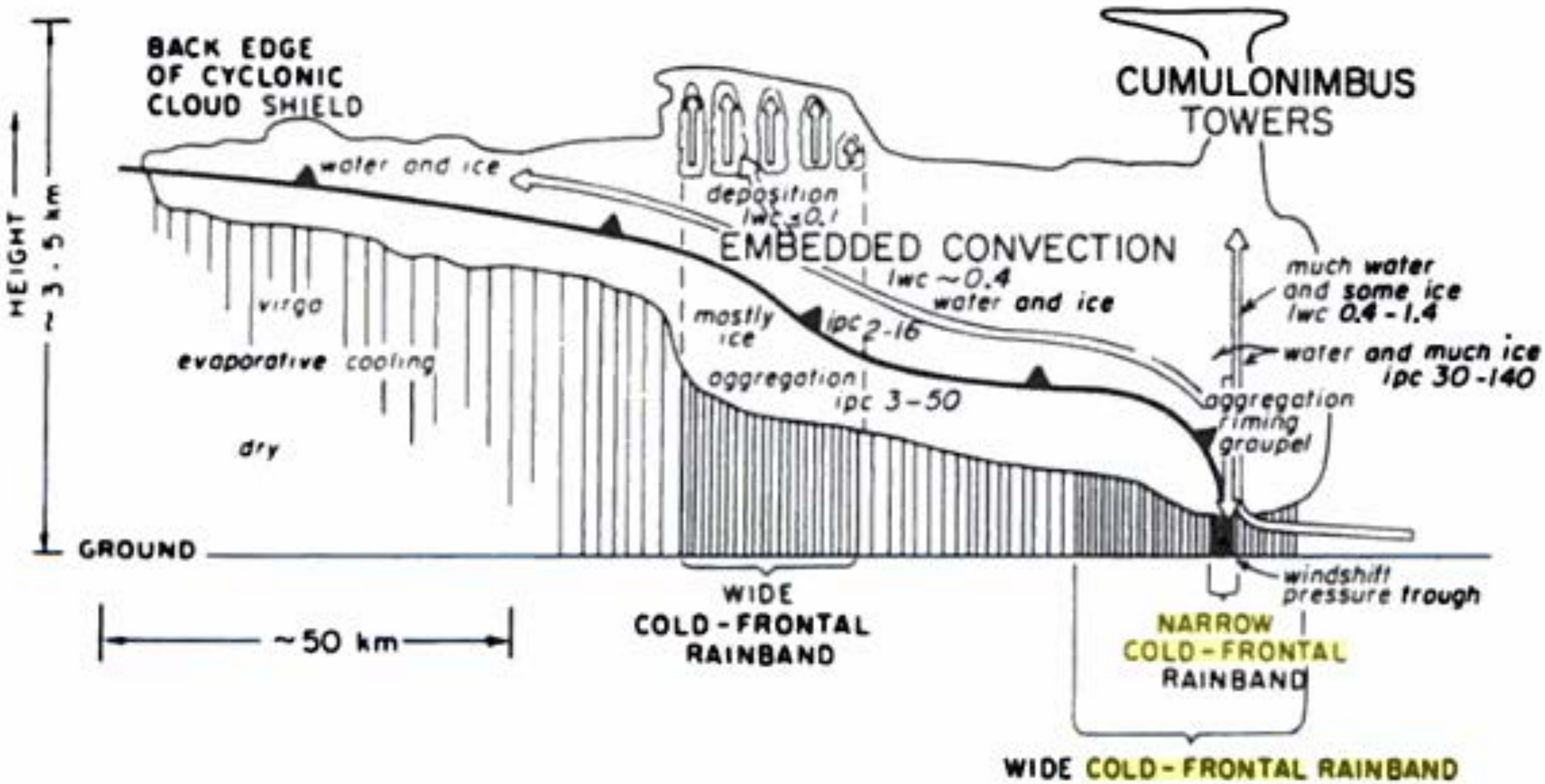




IR methods: based on cloud top temperature




ice
homogeneous freezing
-40 degrees C
Bergeron process
mixed phase heterogeneous freezing
0 degrees C
vapor deposition
het. nucleation
supersaturation
adiabatic lifting
inflow
aerosol (CCN, IN)
gas-phase chemistry- aerosol formation
outflow
entrainment, alteration of cloud drop spectrum
vapor growth
aggregation
riming
secondary ice
melting
collision-coalescence
precipitation
drop break-up, net evaporation
haze


BACK EDGE OF CYCLONIC CLOUD SHIELD
CUMULONIMBUS TOWERS
HEIGHT ~3.5 km
water and ice
deposition
lwc <0.1
EMBEDDED CONVECTION
lwc ~0.4
water and ice
much water and some ice
lwc 0.4 - 1.4
water and much ice
ipc 30 -140
virga
mostly ice
ipc 2-16
evaporative cooling
aggregation
ipc 3-50
aggregation
riming
graupel
dry
GROUND
windshift
pressure trough
~50 km
WIDE COLD-FRONTAL RAINBAND
NARROW COLD-FRONTAL RAINBAND
WIDE COLD-FRONTAL RAINBAND

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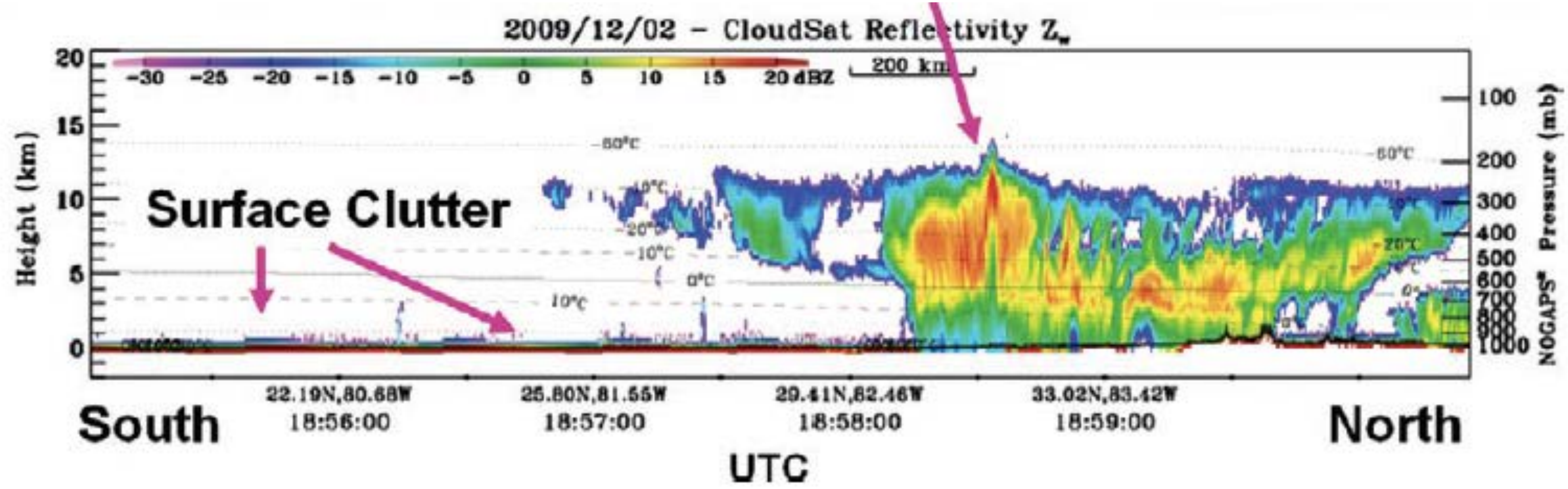

Lee et al. 2012, BAMS

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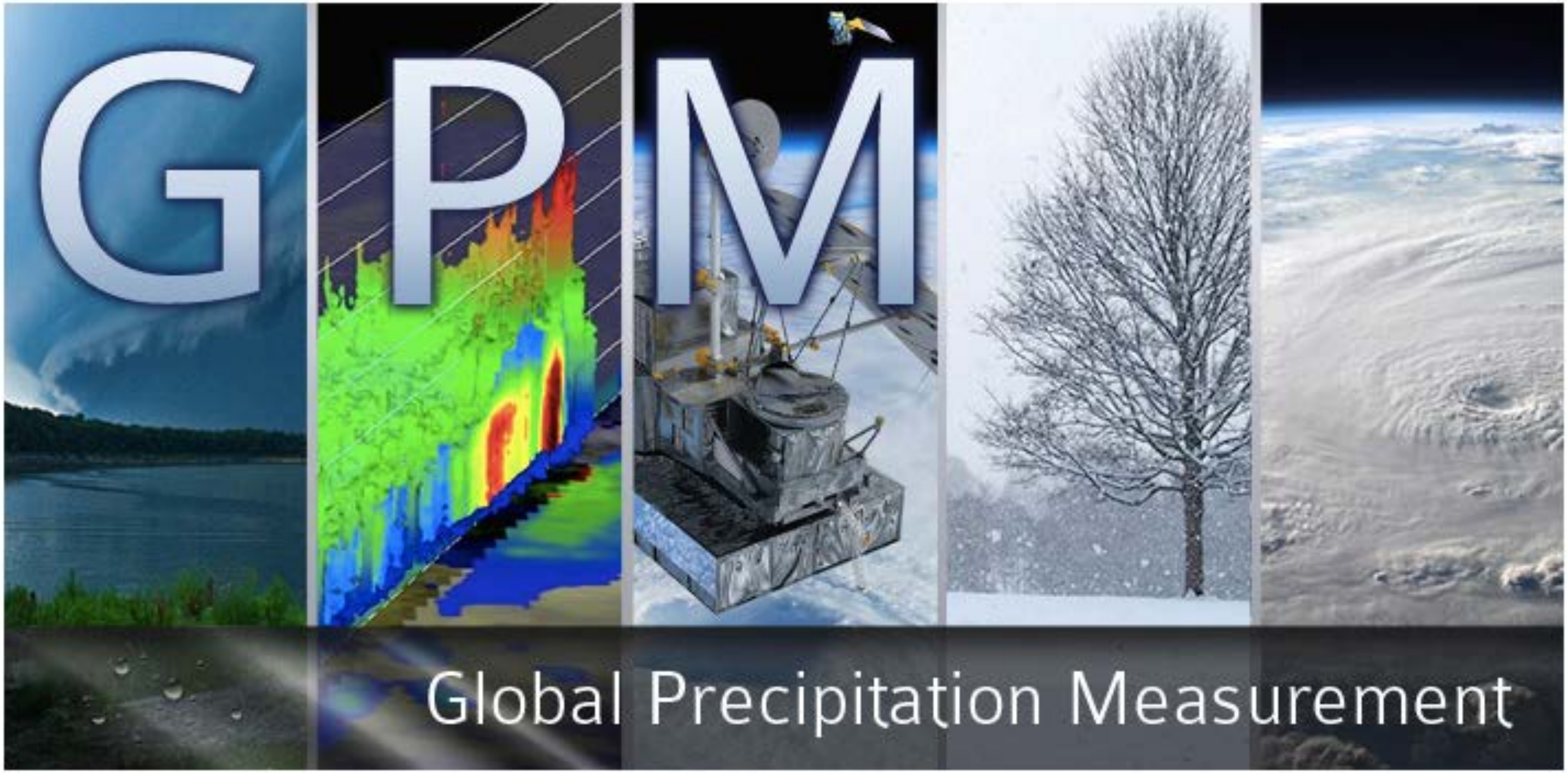
- Potential applications


GPM
Global Precipitation Measurement

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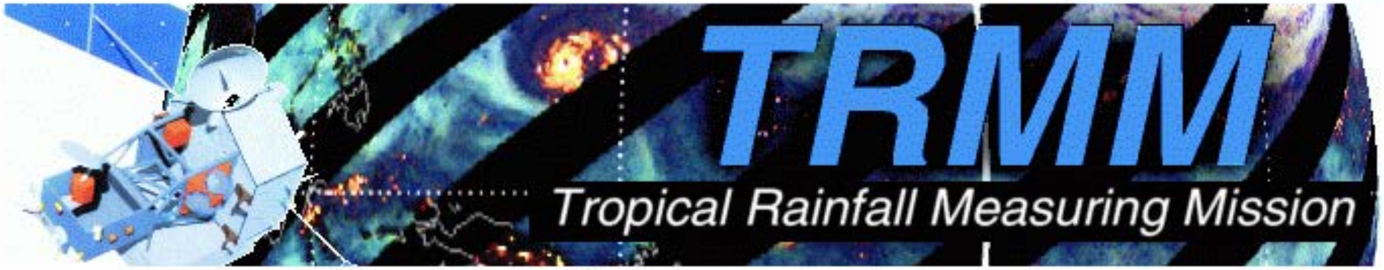
GODDARD SPACE FLIGHT CENTER | + NASA Homepage



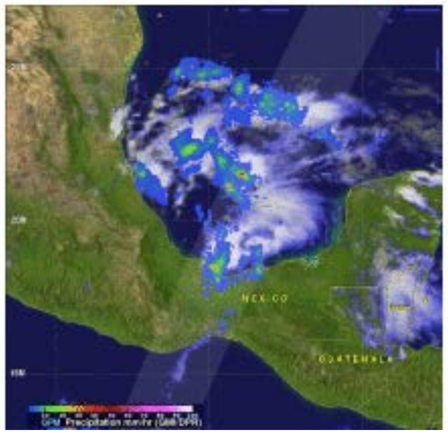
+ ABOUT TRMM | + NEWS | + PUBLICATIONS | + SEARCH | + CONTACTS | + DATA | + IMAGE POLICY

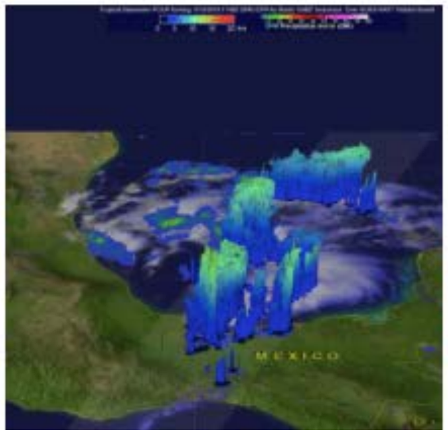
The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between NASA and the Japan Aerospace Exploration (JAXA) Agency to study rainfall for weather and climate research. The TRMM satellite ended collecting data on April 15, 2015 (see http://pmm.nasa.gov/trmm/mission-end). Launched in late November 1997, with a design lifetime of 3 years, the TRMM satellite produced over 17 years of valuable scientific data. TRMM carried 5 instruments: a 3-sensor rainfall suite (PR, TMI, VIRS) and 2 related instruments (LIS and CERES). TRMM delivered a unique 17-year dataset of global tropical rainfall and lightning. The TRMM dataset became the space standard for measuring precipitation, and led to research that improved our understanding of tropical cyclone structure and evolution, convective system properties, lightning-storm relationships, climate and weather modeling, and human impacts on rainfall. The data also supported operational applications such as flood and drought monitoring and weather forecasting.

TRMM Reentry Assessment (pdf file)

(6/3/2015) Frequently Asked Questions about TRMM Spacecraft Re-Entry .

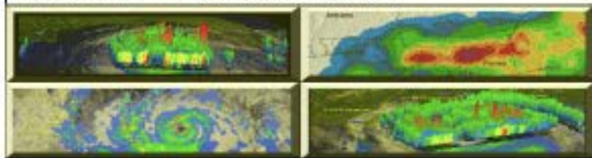
TOP STORY



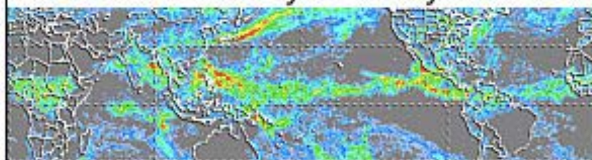


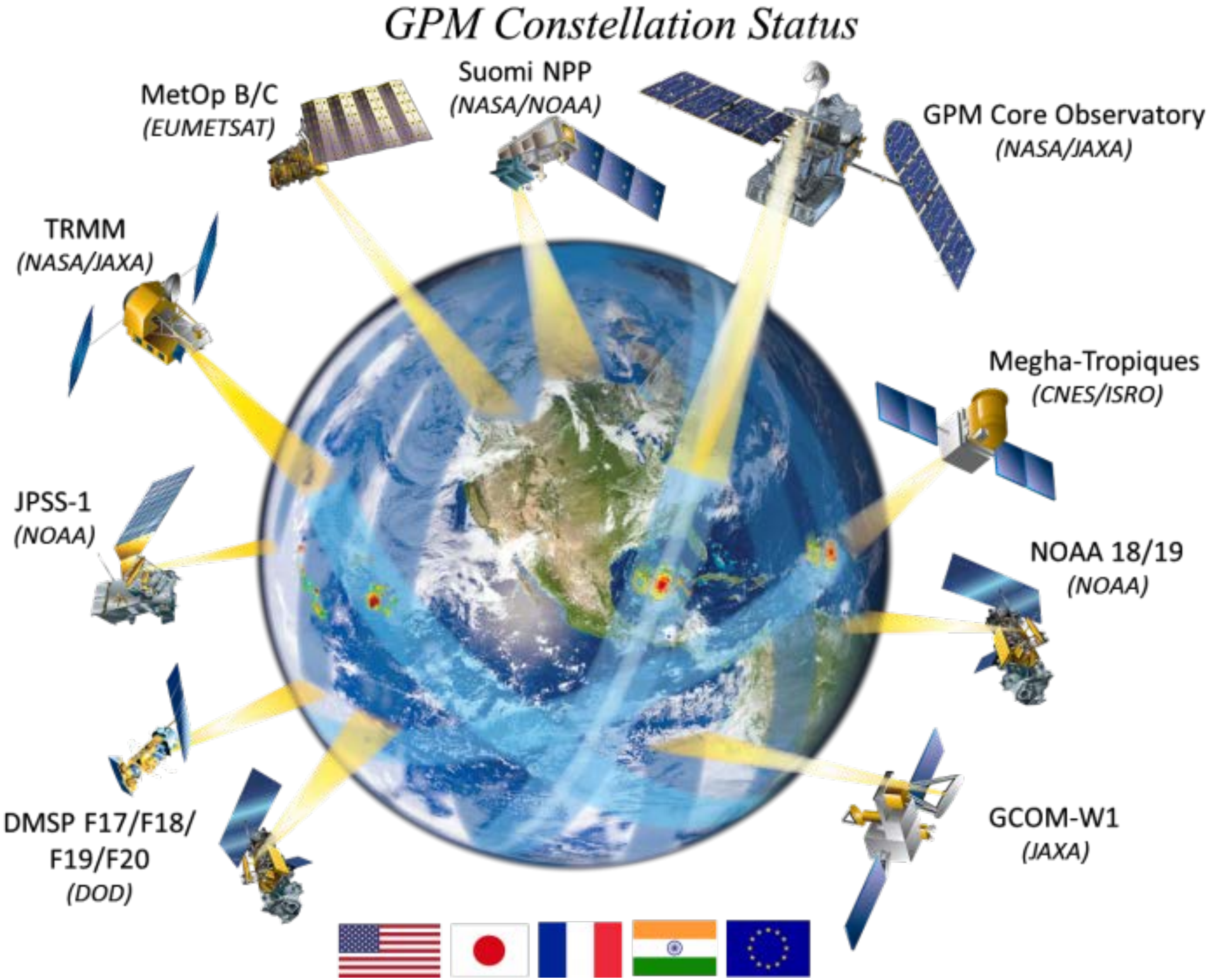
RESOURCES

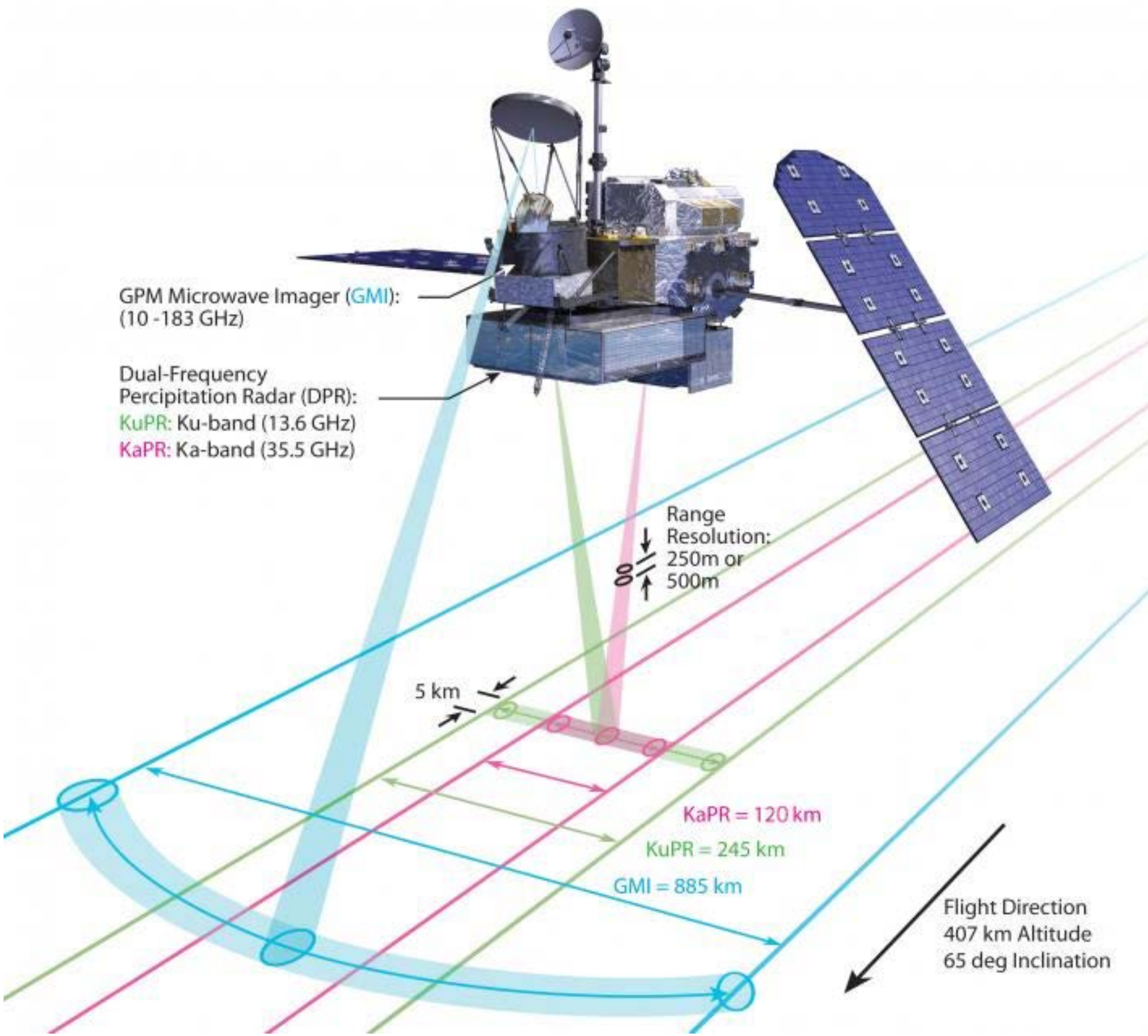
Extreme Event Archives

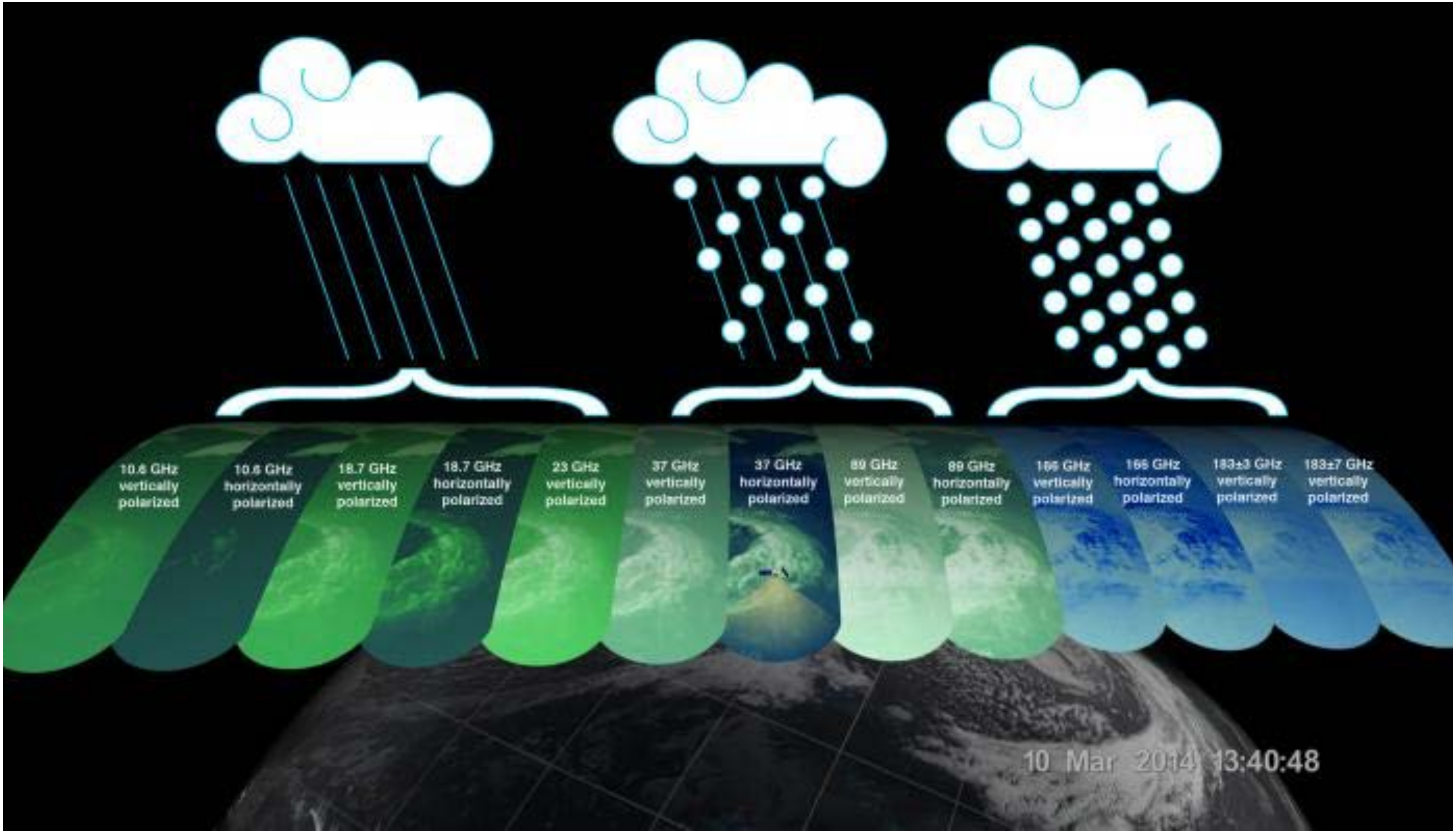


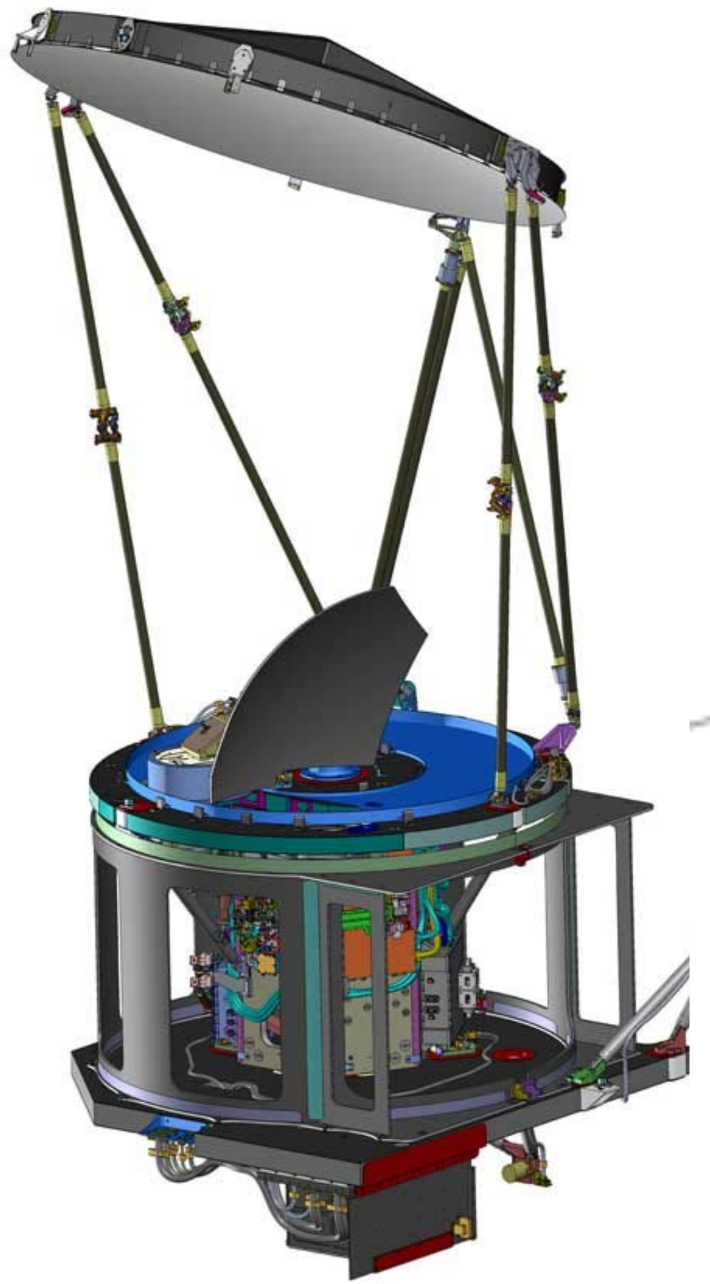
Realtime 3 Hourly & 7 Day Rainfall

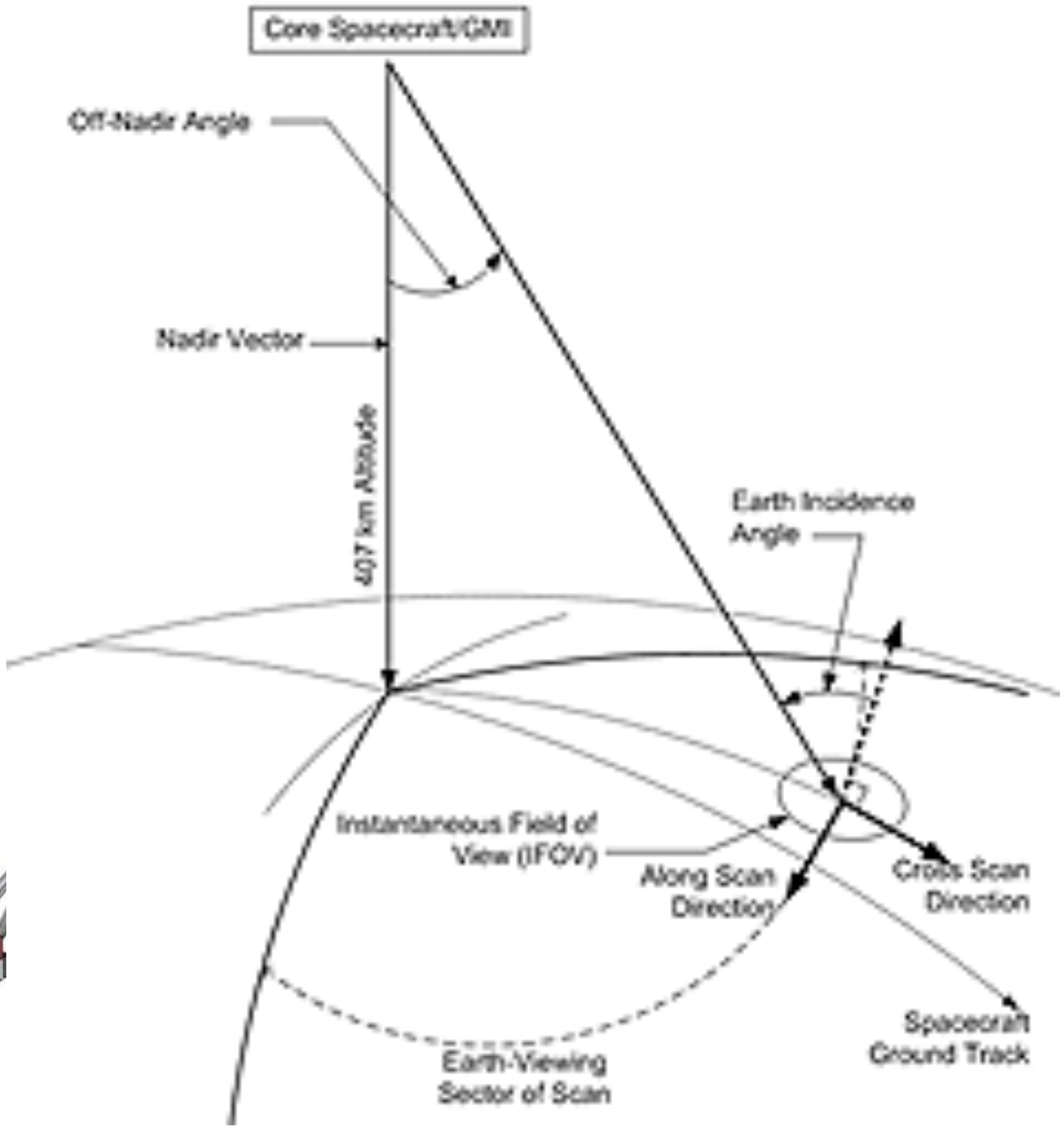



GPM Constellation Status
MetOp B/C
(EUMETSAT)
Suomi NPP
(NASA/NOAA)
GPM Core Observatory
(NASA/JAXA)
TRMM
(NASA/JAXA)
Megha-Tropiques
(CNES/ISRO)
JPSS-1
(NOAA)
NOAA 18/19
(NOAA)
DMSP F17/F18/
F19/F20
(DOD)
GCOM-W1
(JAXA)


GPM Microwave Imager (GMI):
(10 -183 GHz)
Dual-Frequency
Percipitation Radar (DPR):
KuPR: Ku-band (13.6 GHz)
KaPR: Ka-band (35.5 GHz)
Range
Resolution:
250m or
500m
5 km
KaPR = 120 km
KuPR = 245 km
GMI = 885 km
Flight Direction
407 km Altitude
65 deg Inclination

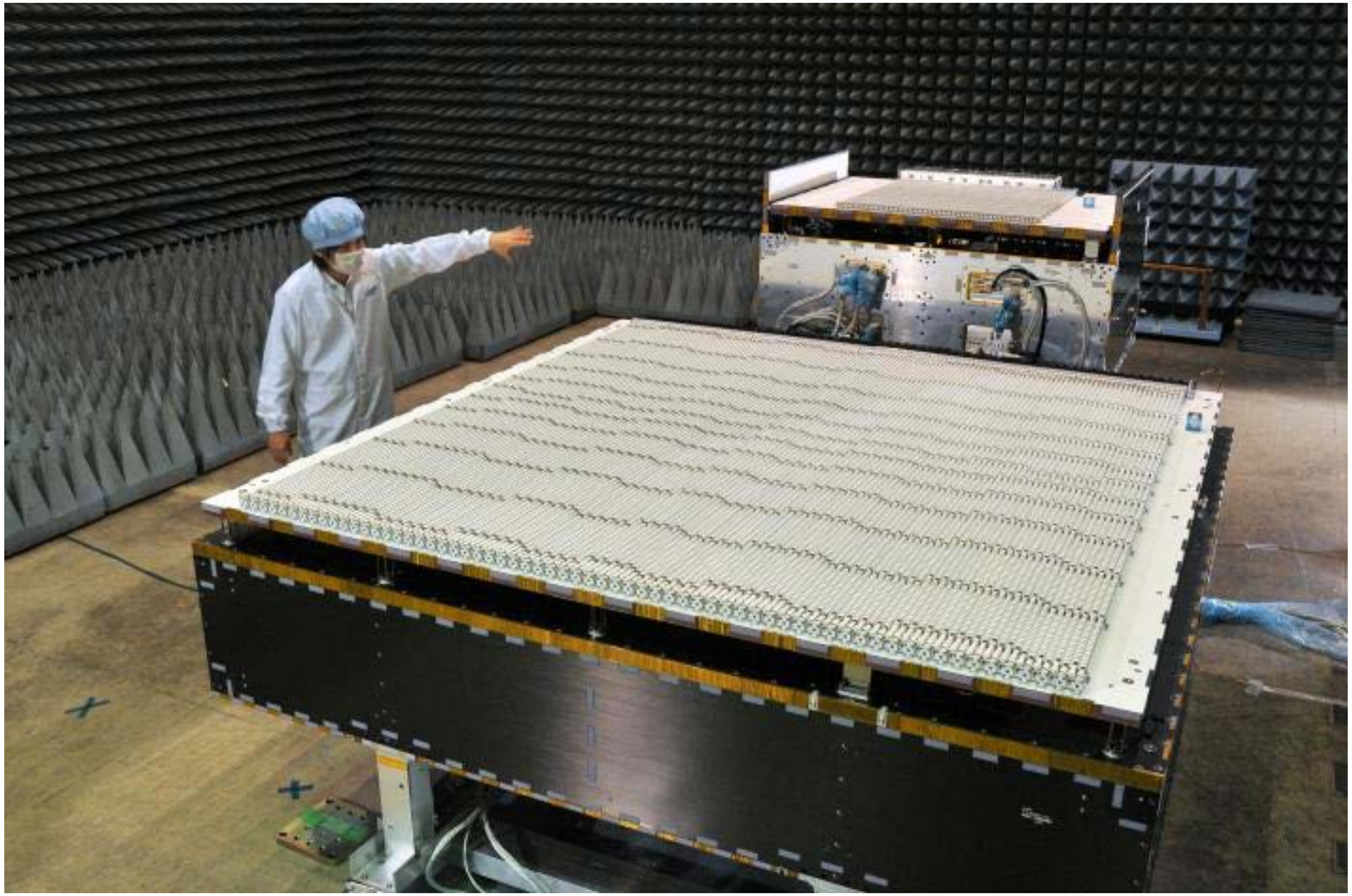

10.6 GHz vertically polarized
10.6 GHz horizontally polarized
18.7 GHz vertically polarized
18.7 GHz horizontally polarized
23 GHz vertically polarized
37 GHz vertically polarized
37 GHz horizontally polarized
89 GHz vertically polarized
89 GHz horizontally polarized
166 GHz vertically polarized
166 GHz horizontally polarized
183±3 GHz vertically polarized
183±7 GHz vertically polarized
10 Mar 2014 13:40:48

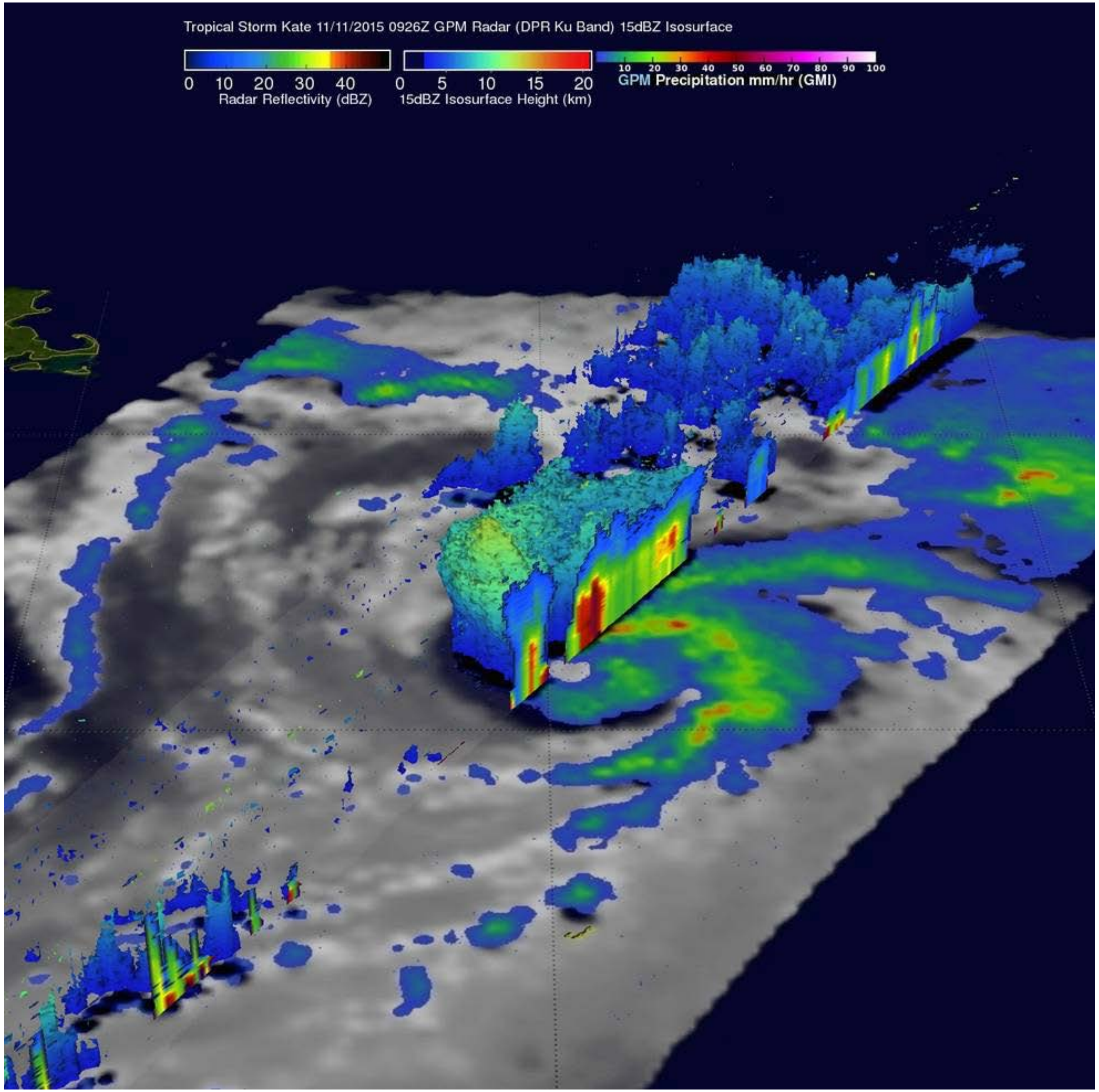



Core Spacecraft/GMI
Off-Nadir Angle
Nadir Vector
407 km Altitude
Earth Incidence
Angle
Instantaneous Field of
View (IFOV)
Along Scan
Direction
Cross Scan
Direction
Spacecraft
Ground Track
Earth-Viewing
Sector of Scan

First space-borne Ku/Ka-band Dual-frequency Precipitation Radar (DPR)

- 120 and 245 km swaths
- Ka-band precipitation radar (KaPR, 35.5 GHz)
- Ku-band precipitation radar (KuPR, 13.6 GHz)




Tropical Storm Kate 11/11/2015 0926Z GPM Radar (DPR Ku Band) 15dBZ Isosurface
0 10 20 30 40
Radar Reflectivity (dBZ)
0 5 10 15 20
15dBZ Isosurface Height (km)
10 20 30 40 50 60 70 80 90 100
GPM Precipitation mm/hr (GMI)

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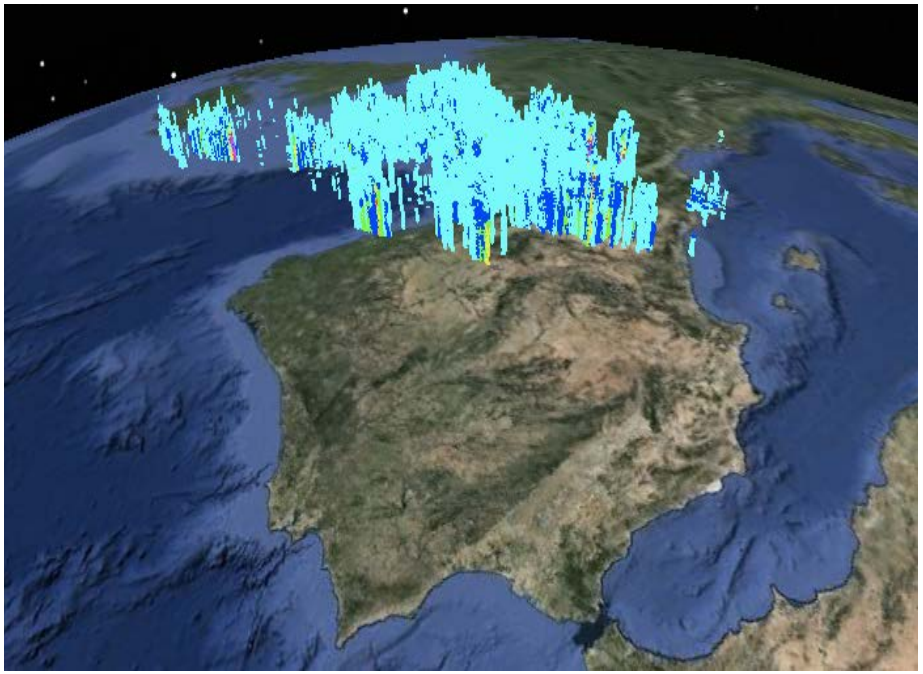
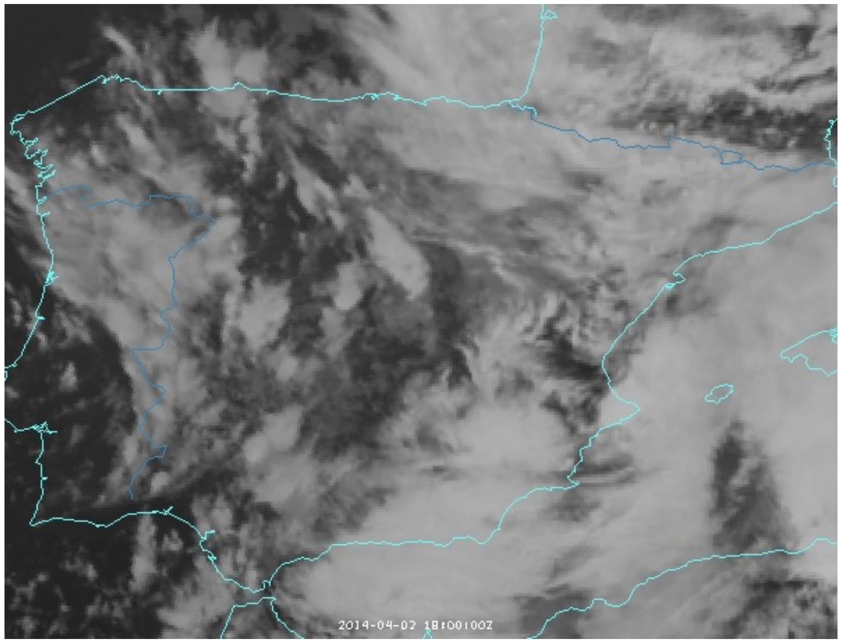
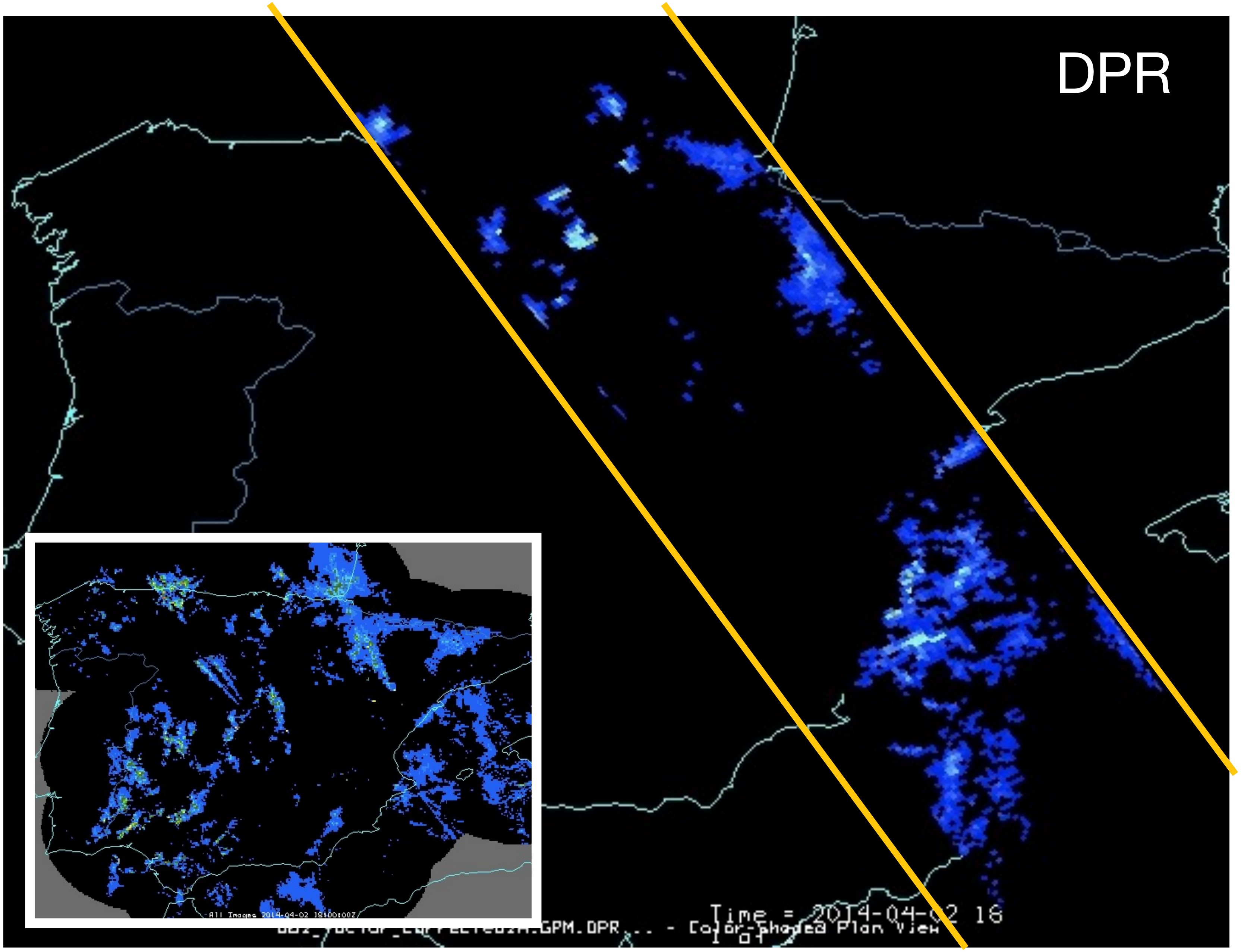
GPM: beyond the Tropics (TRMM)

DRP on GOOGLE EARTH



METEOSAT IR10.8




DPR
Time = 2014-04-02 18
GPM.DPR ... - Color-Shaded Plan View

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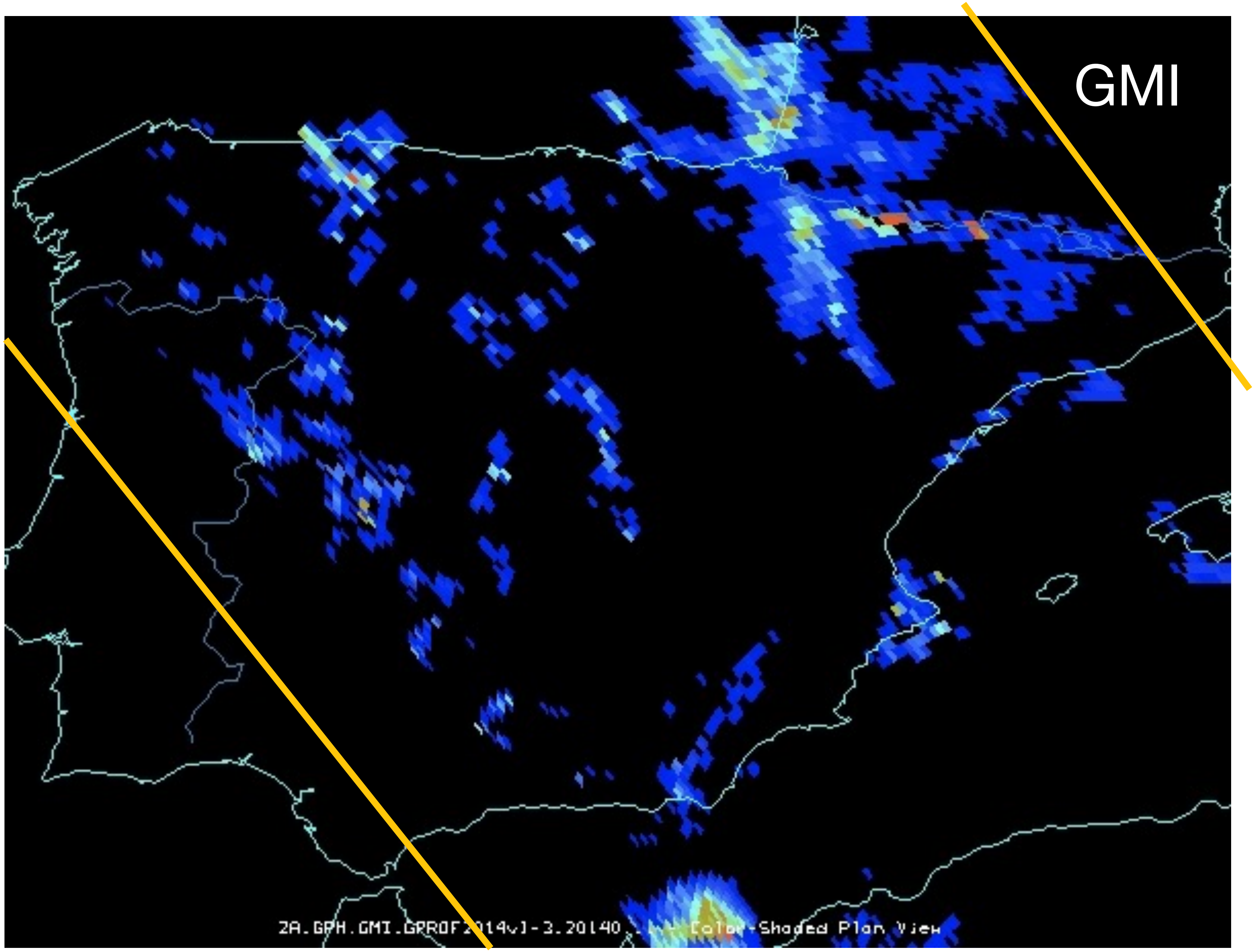
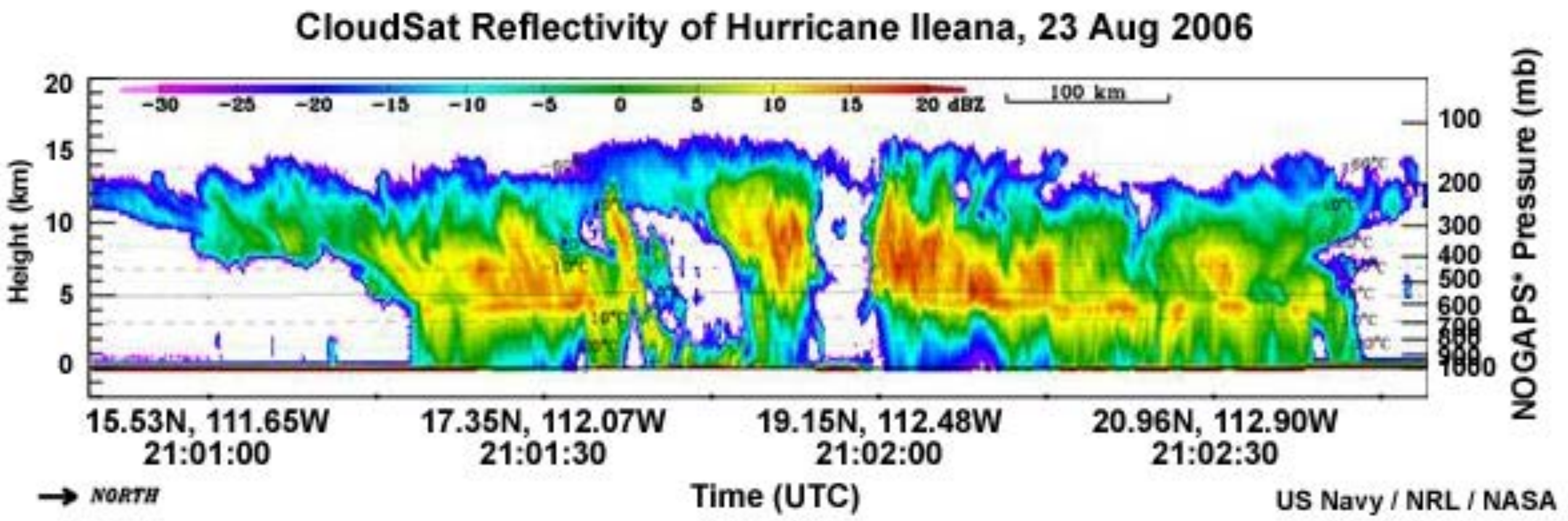
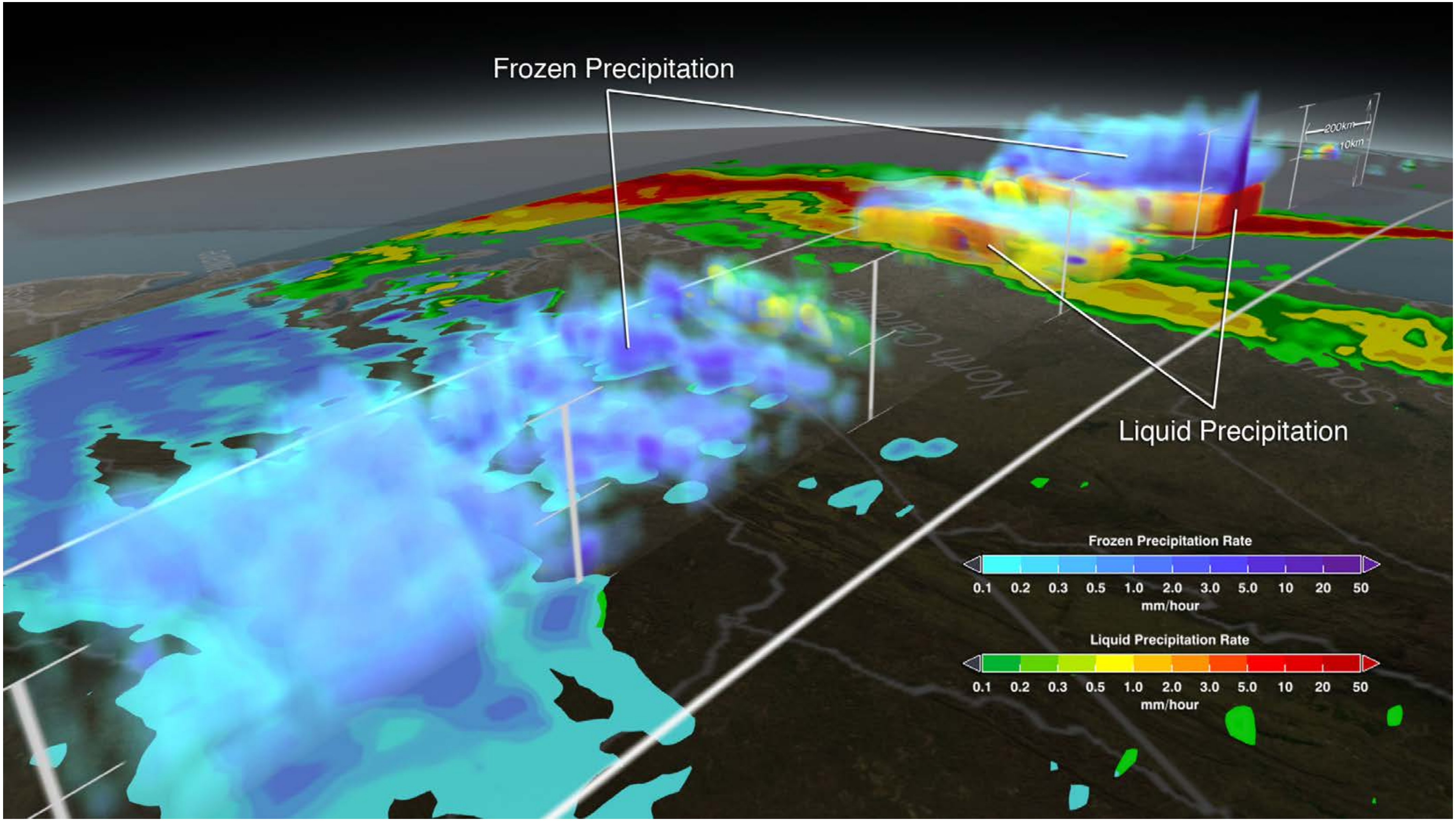
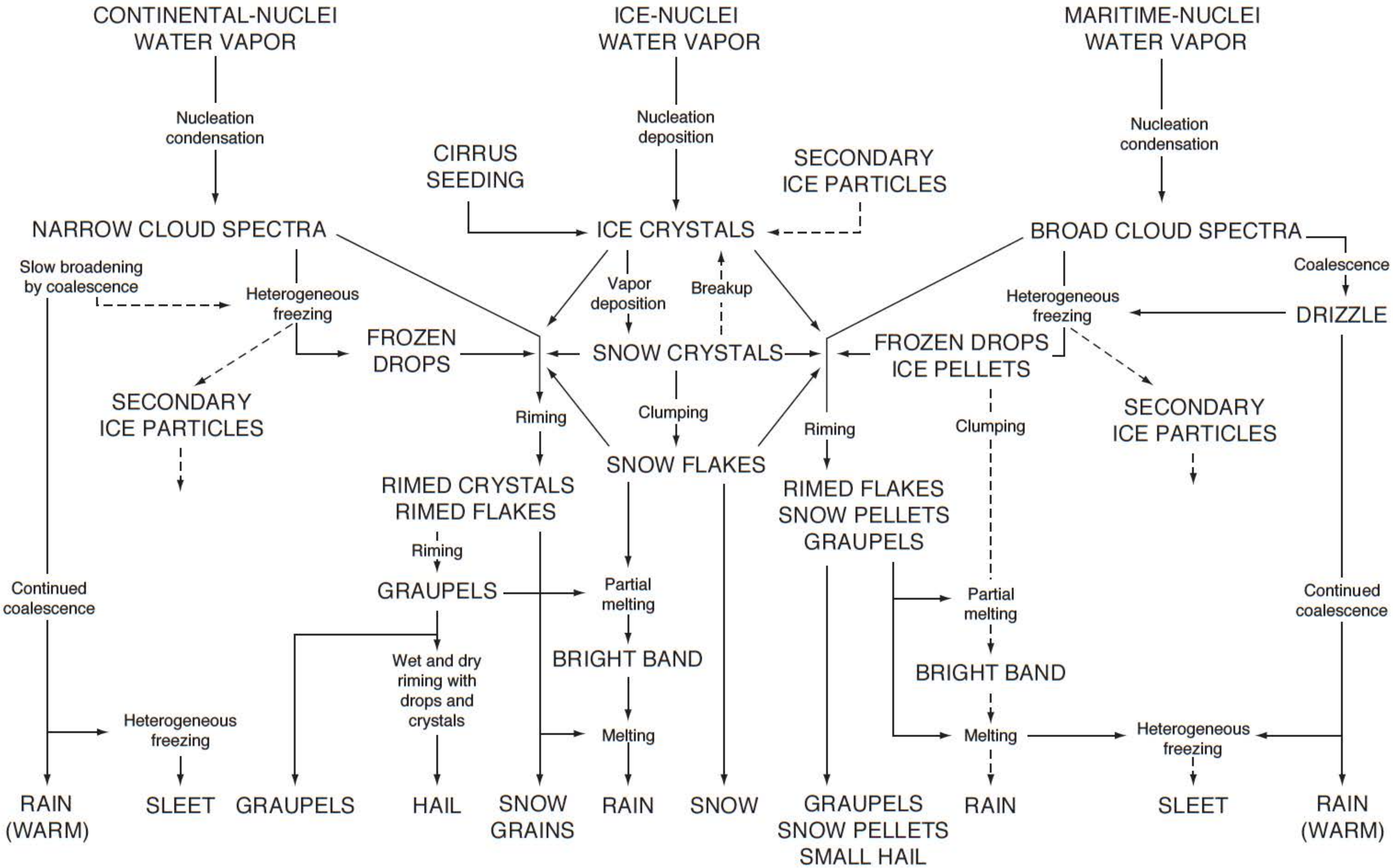



CloudSat Reflectivity of Hurricane Ileana, 23 Aug 2006
Height (km)
NOGAPS* Pressure (mb)
-30 -25 -20 -15 -10 -5 0 5 10 15 20 dBZ
100 km
15.53N, 111.65W
21:01:00
17.35N, 112.07W
21:01:30
19.15N, 112.48W
21:02:00
20.96N, 112.90W
21:02:30
NORTH
Time (UTC)
US Navy / NRL / NASA


Frozen Precipitation
Liquid Precipitation
200km
10km
North Carolina
Frozen Precipitation Rate
0.1 0.2 0.3 0.5 1.0 2.0 3.0 5.0 10 20 50
mm/hour
Liquid Precipitation Rate
0.1 0.2 0.3 0.5 1.0 2.0 3.0 5.0 10 20 50
mm/hour


CONTINENTAL-NUCLEI WATER VAPOR
Nucleation condensation
ICE-NUCLEI WATER VAPOR
Nucleation deposition
MARITIME-NUCLEI WATER VAPOR
Nucleation condensation
CIRRUS SEEDING
SECONDARY ICE PARTICLES
NARROW CLOUD SPECTRA
ICE CRYSTALS
BROAD CLOUD SPECTRA
Coalescence
Slow broadening by coalescence
Heterogeneous freezing
Vapor deposition
Breakup
Heterogeneous freezing
DRIZZLE
FROZEN DROPS
SNOW CRYSTALS
FROZEN DROPS ICE PELLETS
SECONDARY ICE PARTICLES
Riming
Clumping
Riming
Clumping
SECONDARY ICE PARTICLES
SNOW FLAKES
RIMED CRYSTALS RIMED FLAKES
RIMED FLAKES SNOW PELLETS GRAUPELS
Riming
Continued coalescence
GRAUPELS
Partial melting
Partial melting
Continued coalescence
BRIGHT BAND
BRIGHT BAND
Wet and dry riming with drops and crystals
Heterogeneous freezing
Melting
Melting
Heterogeneous freezing
RAIN (WARM)
SLEET
GRAUPELS
HAIL
SNOW GRAINS
RAIN
SNOW
GRAUPELS SNOW PELLETS SMALL HAIL
RAIN
SLEET
RAIN (WARM)

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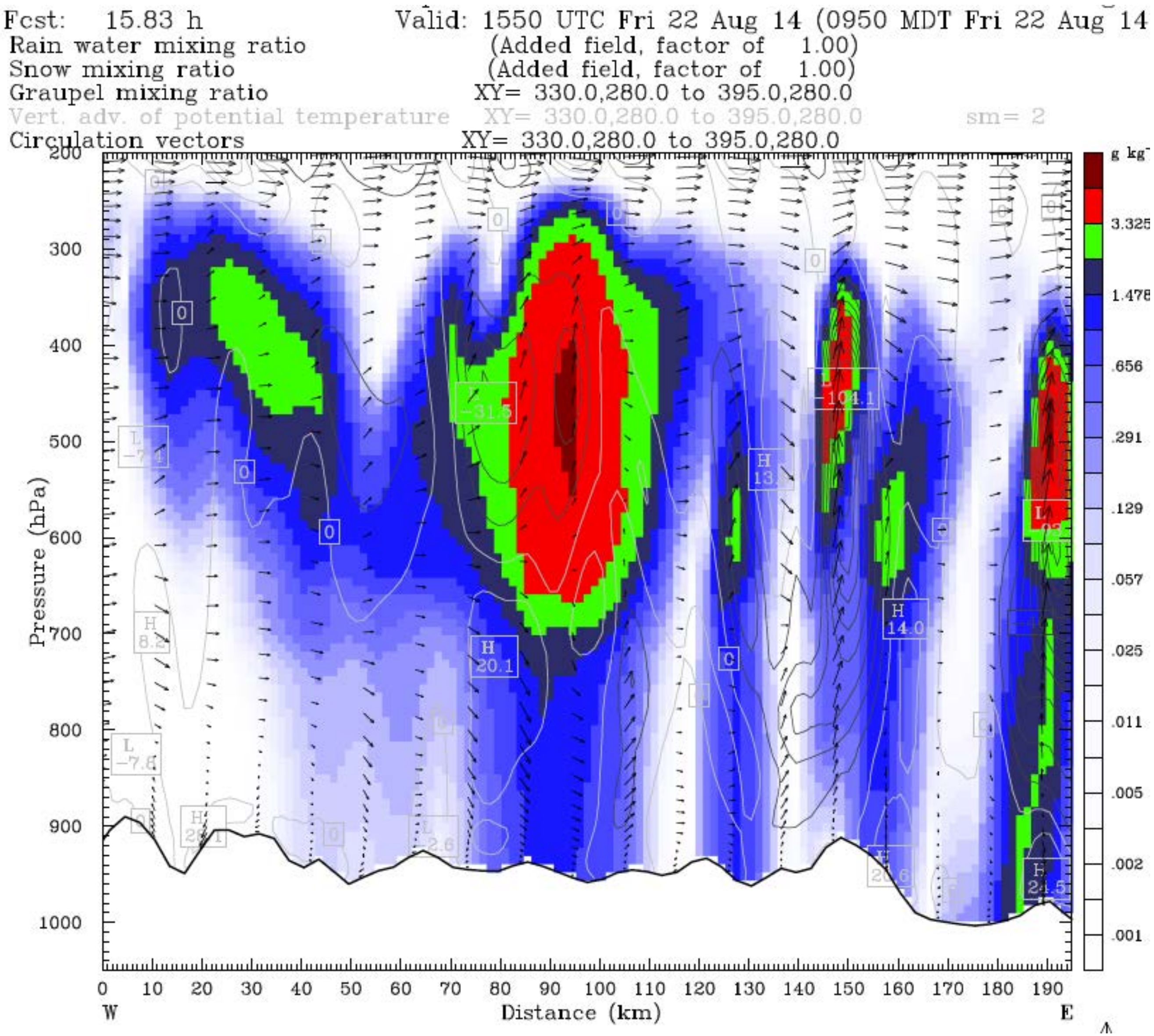
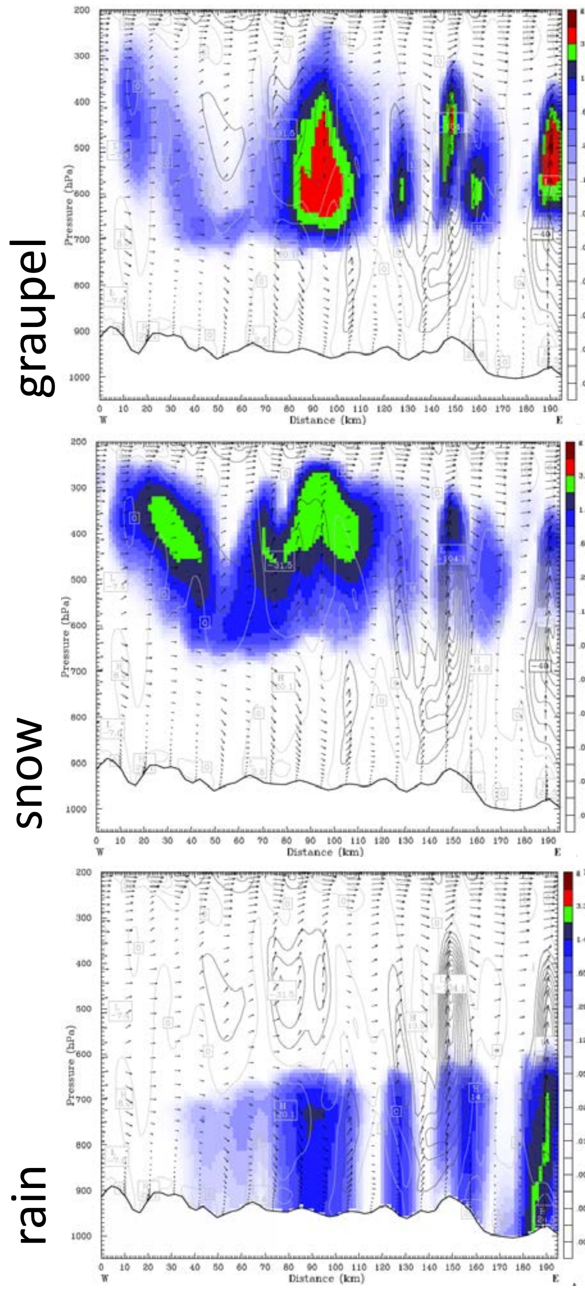
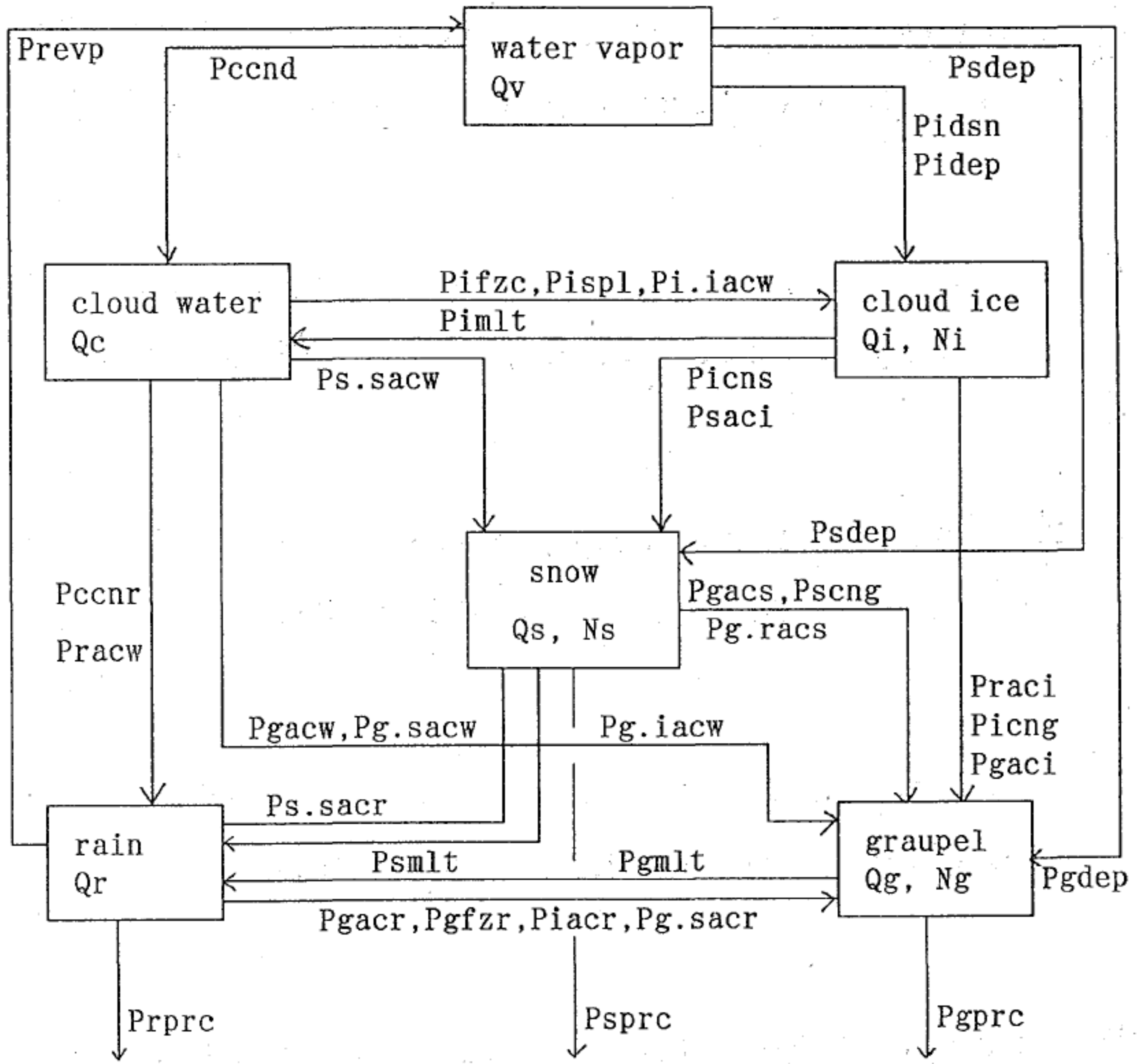
Modeling at 3 km resolution






water vapor
Qv
Prevp
Pccnd
Psdep
Pidsn
Pidep
cloud water
Qc
Pifzc,Pispl,Pi.iacw
Pimlt
cloud ice
Qi, Ni
Ps.sacw
Picns
Psaci
Psdep
snow
Qs, Ns
Pgacs,Pscng
Pg.racs
Pccnr
Pracw
Praci
Picng
Pgaci
Pgacw,Pg.sacw
Pg.iacw
Ps.sacr
rain
Qr
Psmlt
Pgmlt
graupel
Qg, Ng
Pgdep
Pgacr,Pgfzr,Piacr,Pg.sacr
Prprc
Psprc
Pgprc

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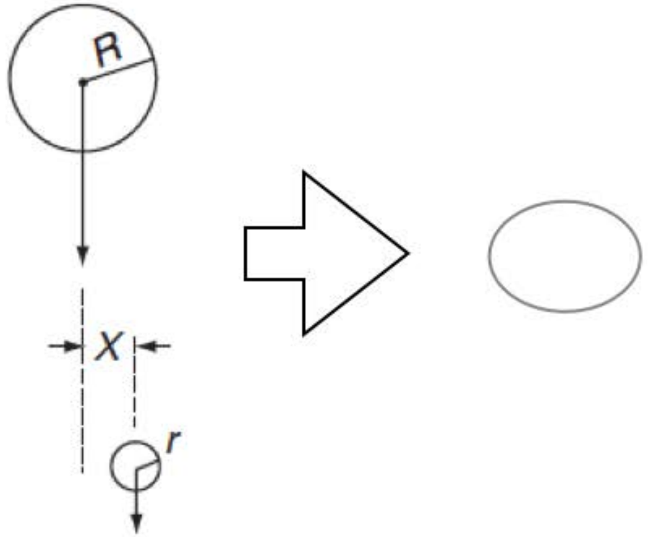
PRacR $(\partial\{N_R, q_R\}/\partial t)_{RacR}$

Pictorial representation



Assumptions

- Spherical drops
- Fall at terminal v
- Spaced in the vertical
- Calm, laminar flux
- Large efficiency in collision and coalescence (=1)

Effects on N and gamma pdf

$N_V =$	$m_V =$	$s_V =$
$N_R \downarrow$	$m_R \uparrow$	$s_R \downarrow$
$N_S =$	$m_S =$	$s_S =$
$N_I =$	$m_I =$	$s_I =$
$N_G =$	$m_G =$	$s_G =$

Parameterizations

Beheng (1994)

$$(\partial N_R/\partial t)_{accRR} = -8.0 \cdot 10^3 \cdot N_R \cdot q_R$$

$$(\partial q_R/\partial t)_{accRR} = 0$$

```
!.......................................................................
! SELF-COLLECTION OF RAIN DROPS
! FROM BEHENG(1994)
! FROM NUMERICAL SIMULATION OF THE STOCHASTIC COLLECTION EQUATION
! AS DESCRINED ABOVE FOR AUTOCONVERSION

         IF (QR3D(K).GE.1.E-8) THEN
! include breakup add 10/09/09
            dum1=300.e-6
            if (1./lamr(k).lt.dum1) then
            dum=1.
            else if (1./lamr(k).ge.dum1) then
            dum=2.-exp(2300.*(1./lamr(k)-dum1))
            end if
!            NRAGG(K) = -8.*NR3D(K)*QR3D(K)*RHO(K)
            NRAGG(K) = -5.78*dum*NR3D(K)*QR3D(K)*RHO(K)
         END IF
```

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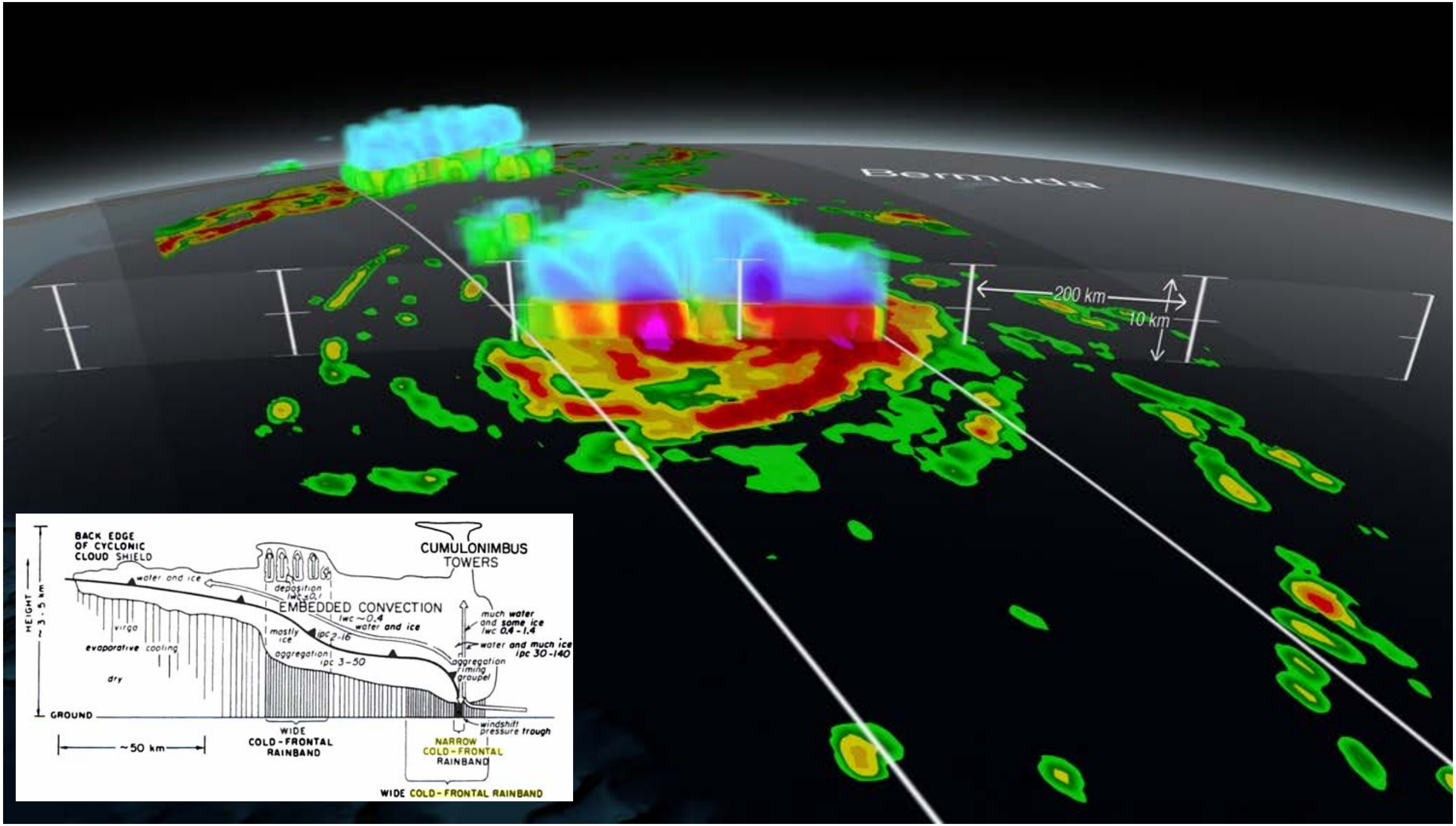

Outline

- Precipitation estimation: status
- The GPM mission
- Potential applications

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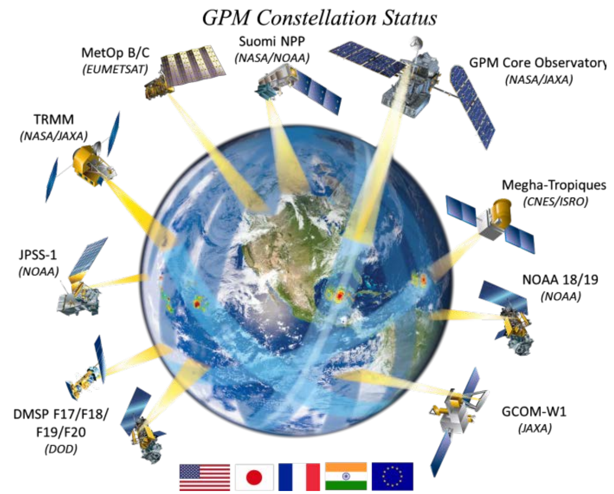
Relative to TRMM, the enhanced measurement and sampling capabilities of GPM offers many advanced science contributions and societal benefits:

- Improved knowledge of the Earth's water cycle and its link to climate change
- New insights into storm structures and large-scale atmospheric processes
- New insights into precipitation microphysics
- Advanced understanding of climate sensitivity and feedback processes
- Extended capabilities in monitoring and predicting hurricanes and other extreme weather events
- Improved forecasting abilities for natural hazards, including floods, droughts and landslides.
- Enhanced numerical prediction skills
- Improved agricultural crop forecasting and monitoring of freshwater resources

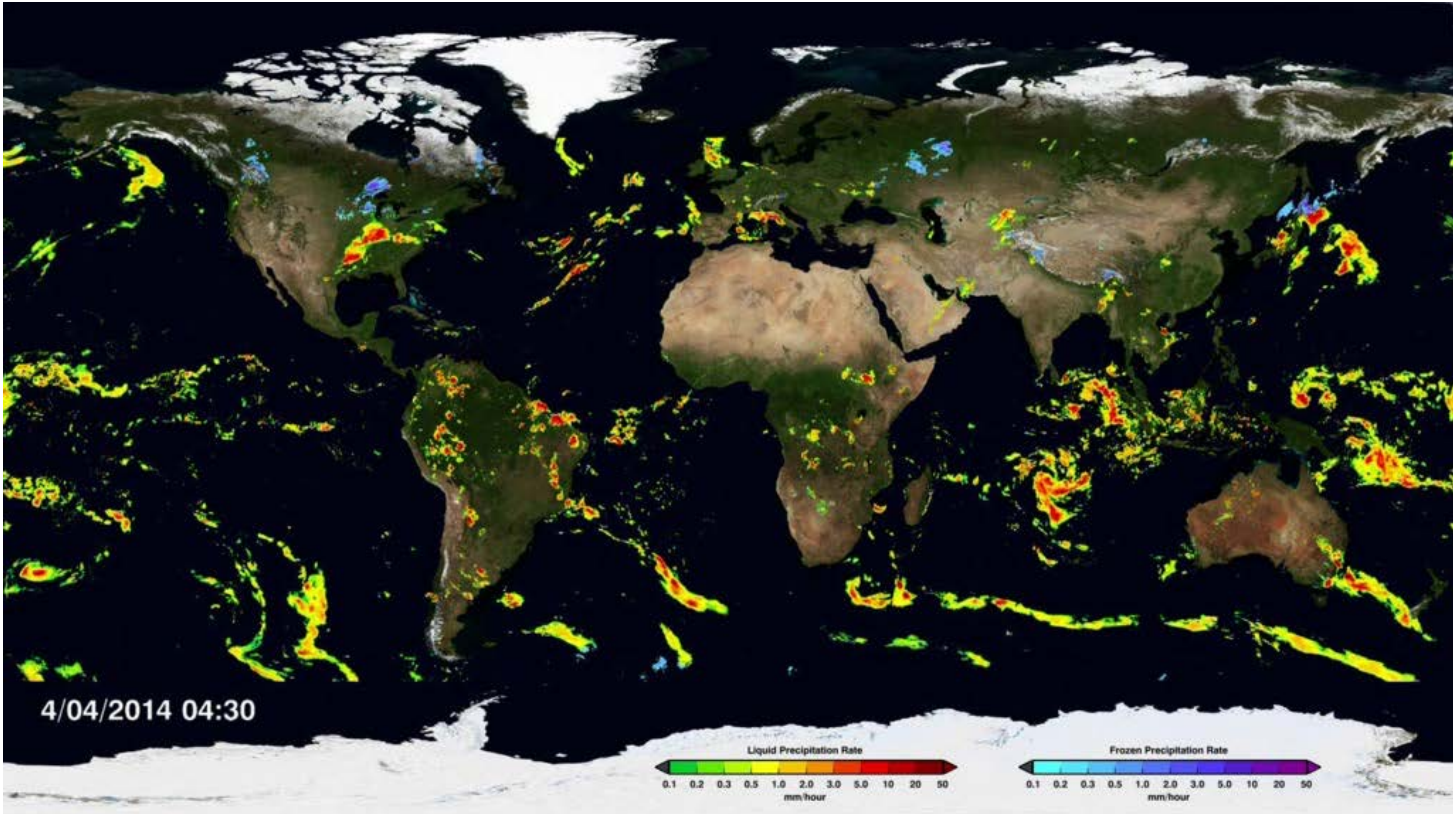


Source: GPM

There are 4 major algorithms associated with the GPM constellation:

1 Radar Algorithms
2 Radiometer Algorithms
3 Combined Radar+Radiometer Algorithms
4 Multi-Satellite Algorithms

iMERG


4/04/2014 04:30
Liquid Precipitation Rate
0.1 0.2 0.3 0.5 1.0 2.0 3.0 5.0 10 20 50
mm/hour
Frozen Precipitation Rate
0.1 0.2 0.3 0.5 1.0 2.0 3.0 5.0 10 20 50
mm/hour

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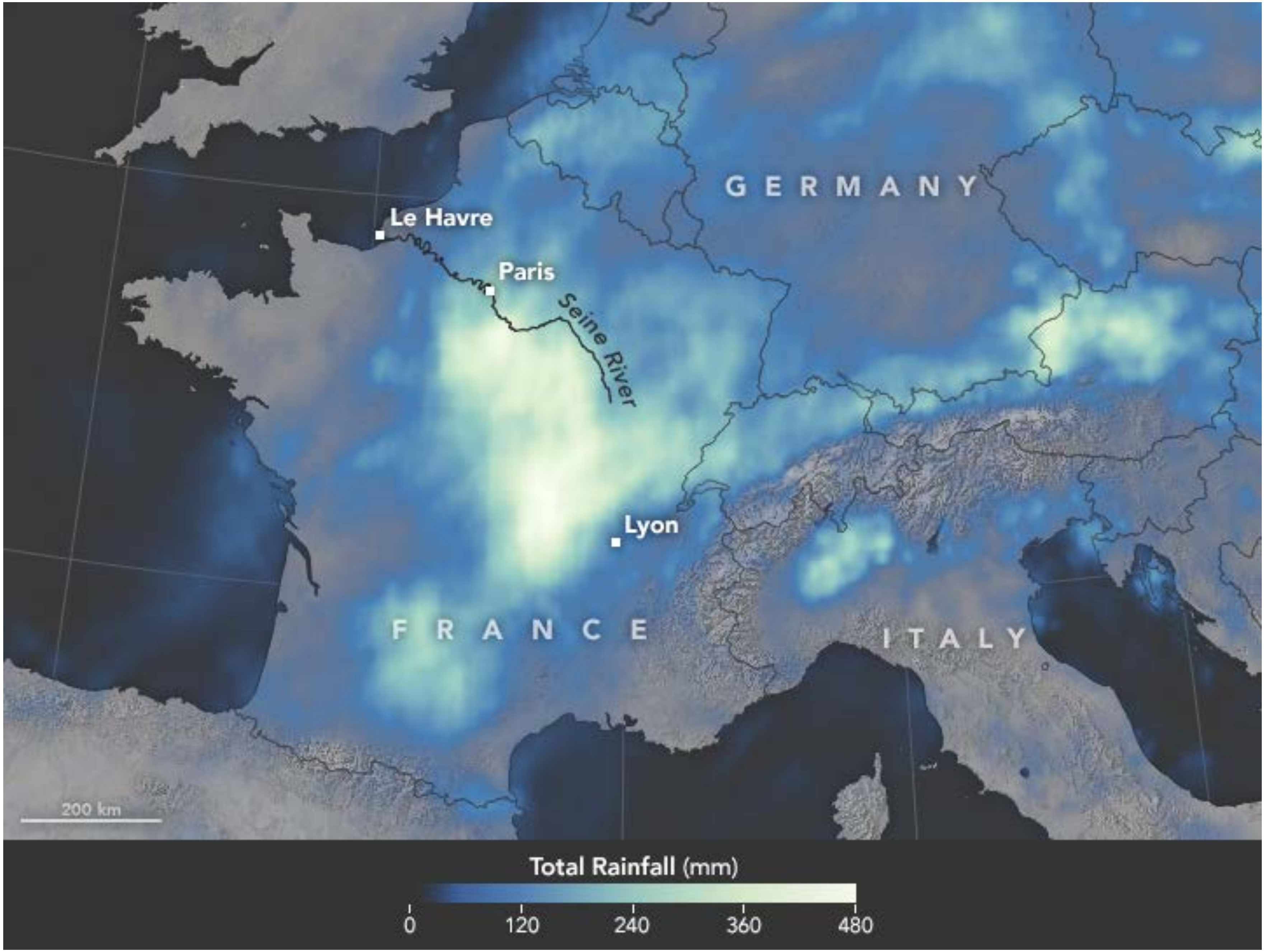
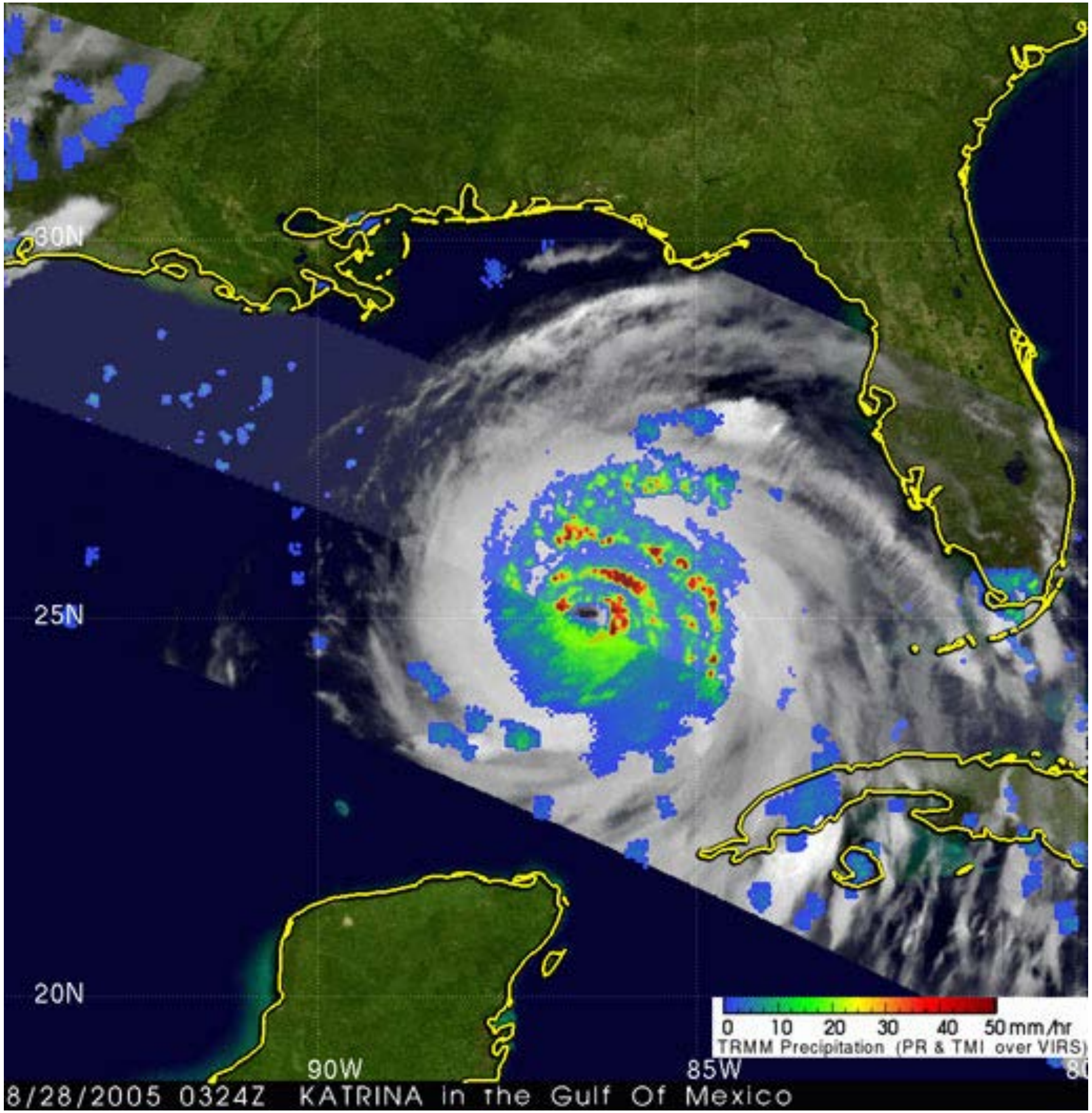
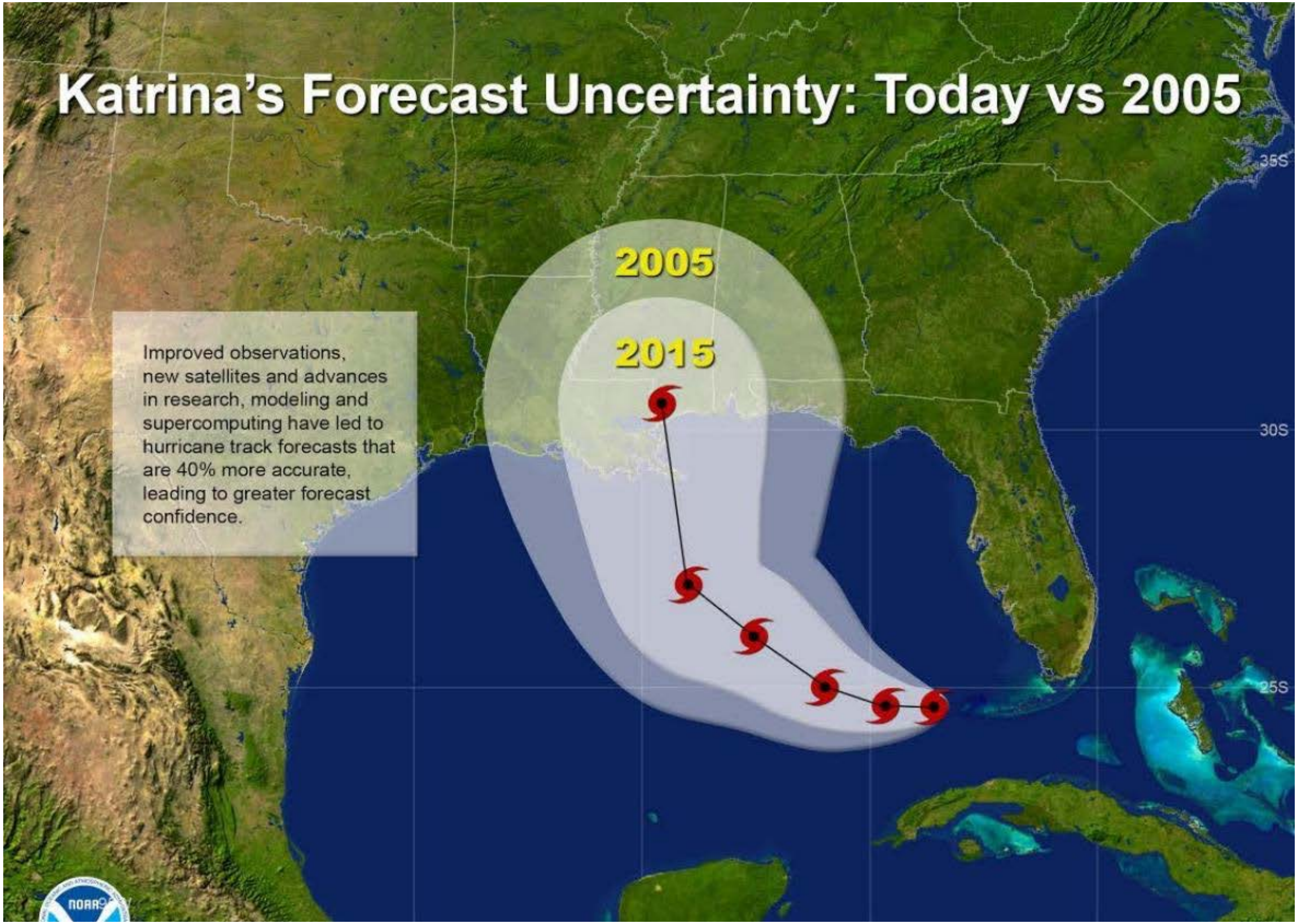
#NEWS
LOUVRE SHUTS DOORS
AS FLOOD WATERS RISE


© AFP/Getty Images


Le Havre
Paris
Seine River
GERMANY
Lyon
FRANCE
ITALY
200 km
Total Rainfall (mm)
0
120
240
360
480

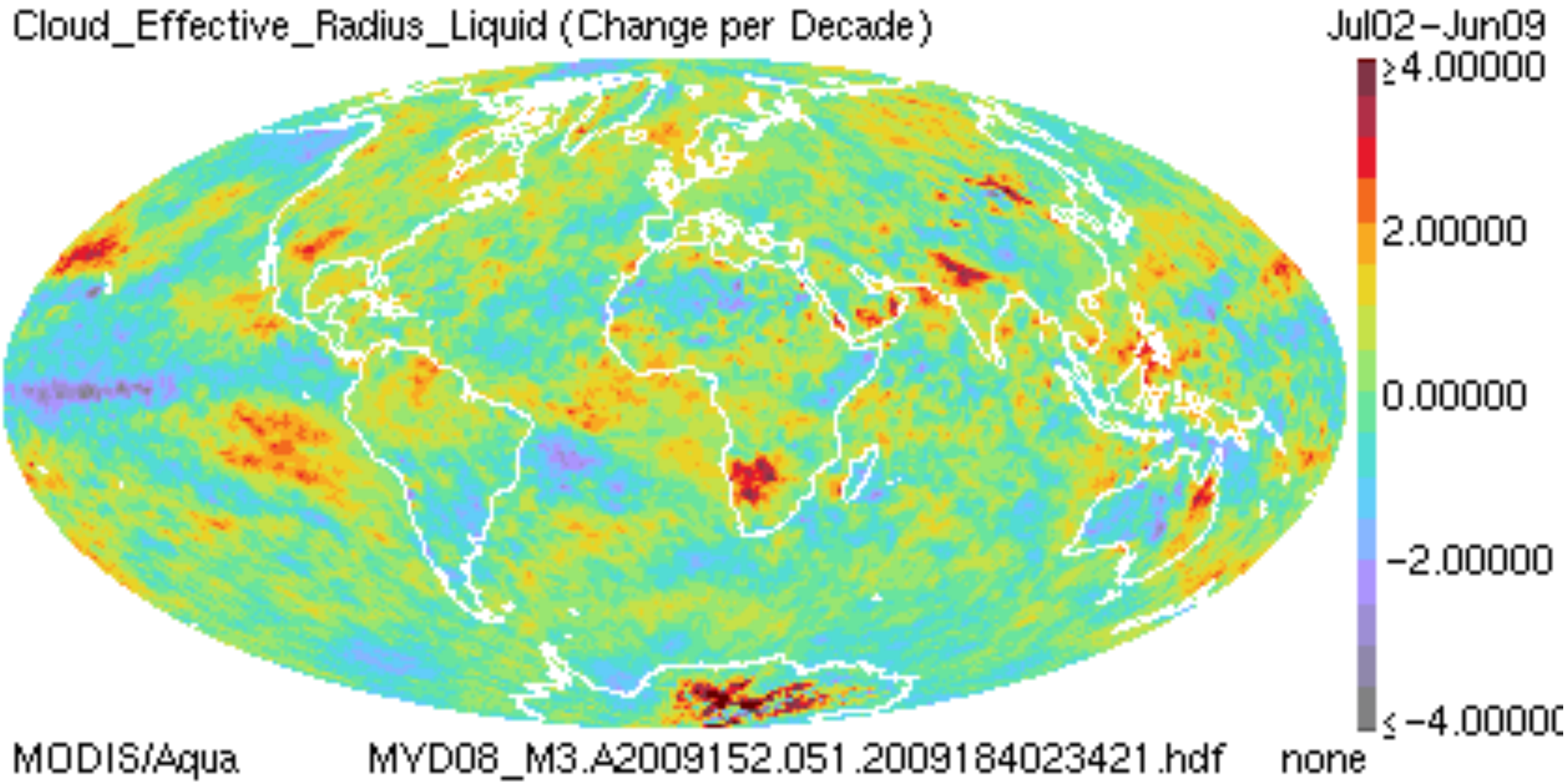

30N
25N
20N
90W
85W
80
0 10 20 30 40 50 mm/hr
TRMM Precipitation (PR & TMI over VIRS)
8/28/2005 0324Z KATRINA in the Gulf Of Mexico


Katrina's Forecast Uncertainty: Today vs 2005
2005
2015
Improved observations, new satellites and advances in research, modeling and supercomputing have led to hurricane track forecasts that are 40% more accurate, leading to greater forecast confidence.
35S
30S
25S
NOAA

Synergisms with Direct Readout Systems

1. Data fusion
2. Expand coverage of individual satellites
3. Provide key geophysical parameters in both directions
4. Cross-disciplinary endeavours

Synergisms with MODIS



Thanks

Disclaimers:

[All pics in the presentation are from public sources unless otherwise stated]
[All resources used for research&education purposes only]
[I'm not representing GPM in any way]

Discussion

- What kinds of applications are you interested in seeing developed?

- What types of data/algorithms are needed for your potential and/or existing application and information needs?

- Provide information on the actual or potential use of the presented algorithms/product/application in the context of your organization's needs.

- Are there particular challenges/shortcomings/unmet needs? Where can things be made better?

- Are there opportunities for collaboration with other attendees and workshop leads? (regional applications, data sharing, etc.)

- Discuss scenarios with the broader group to identify innovative ideas, potential improvements, etc.