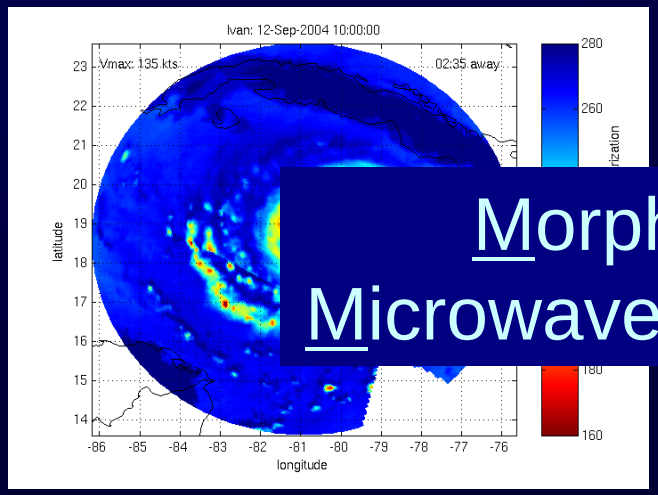
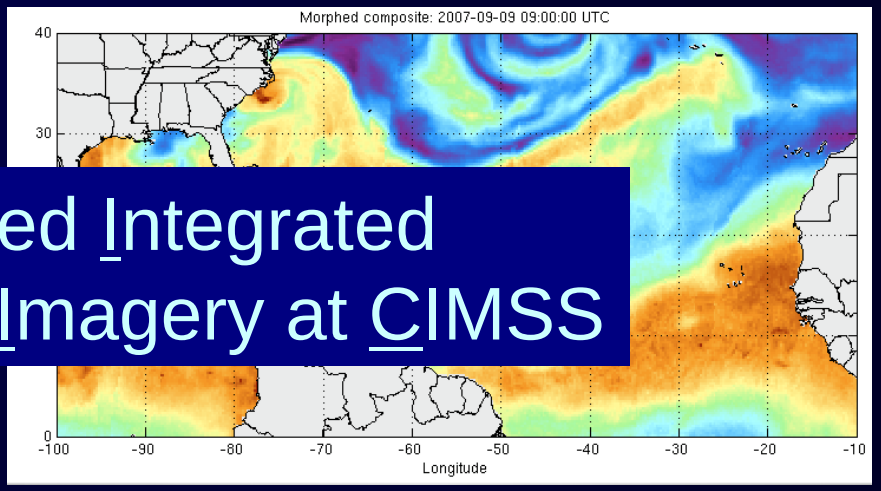
‘MIMIC’: Real time, morphed microwave animations of tropical cyclones

Tony Wimmers, Chris Velden





Morphed Integrated Microwave Imagery at CIMSS

University of Wisconsin - Cooperative Institute for Meteorological Satellite Studies (CIMSS)

Sponsored by The Oceanography of the Navy through the PEO C4I PMW-150 program office and the Naval Research Laboratory

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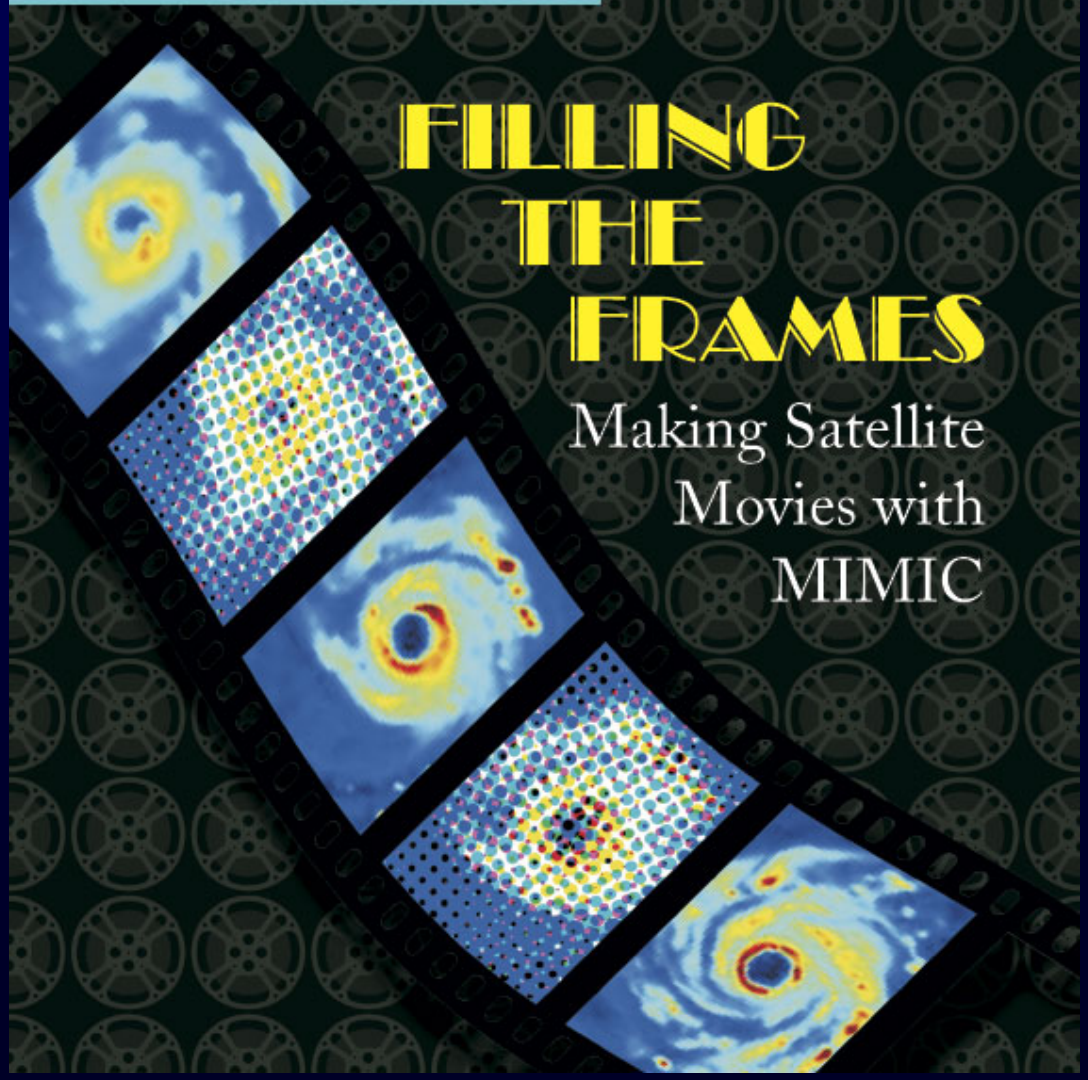
BAMS

Bulletin of the American Meteorological Society

INTRO TO EUMETSAT

A PLAN FOR AEROSOL SCIENCE

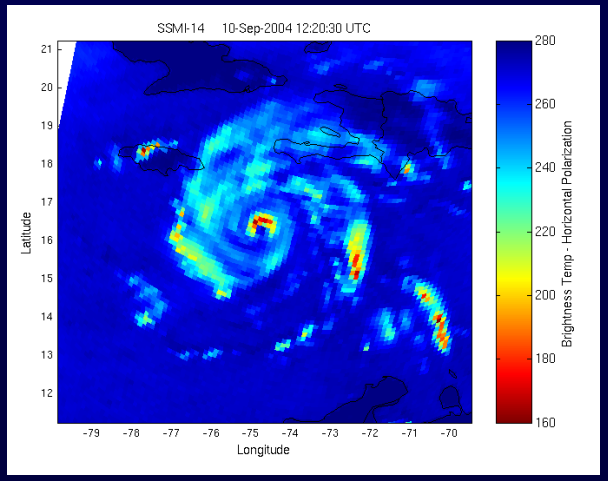
COMMUNICATING FORECASTS



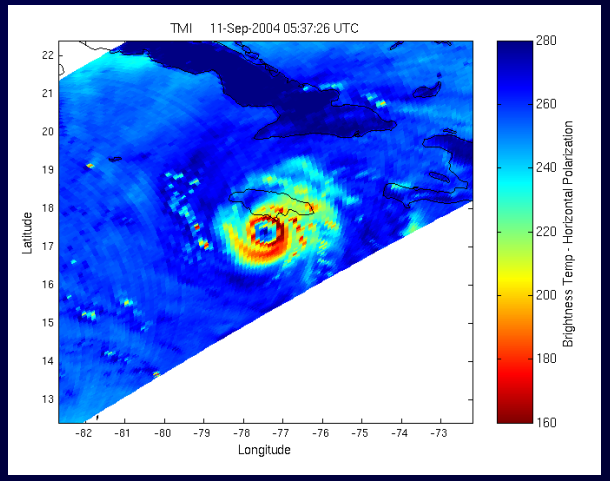
FILLING THE FRAMES

Making Satellite Movies with MIMIC

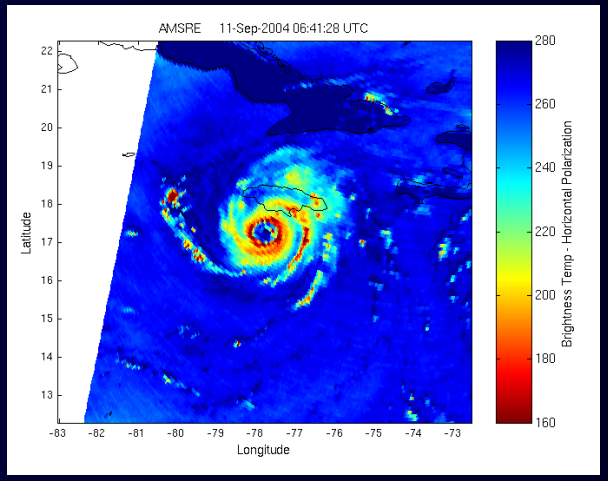
85-92 GHz microwave band



DMSP SSM/I



TRMM TMI



Aqua AMSR-E

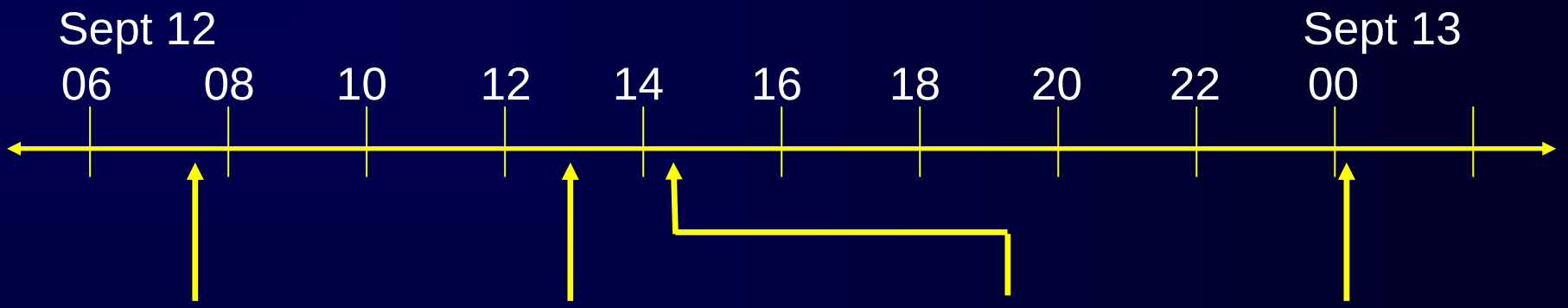
- Signal is strongly attenuated by hydrometeors generated by deep convection, so it can be used as a proxy for precipitation (like radar). Averages ~7km above surface level.

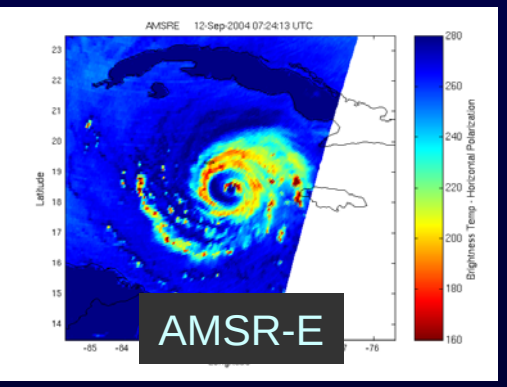
- Unique tool for observing eyewall dynamics (such as eyewall formation, replacement cycles, motion of spiral bands delivering vorticity to the eye)

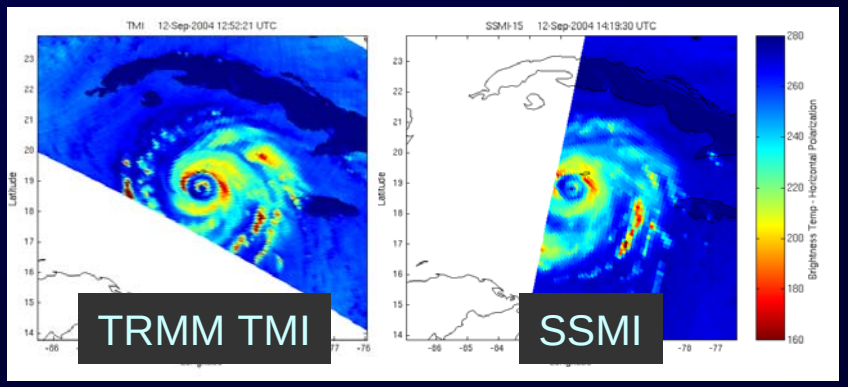
Satellite microwave instruments that contribute to the MIMIC-TC product

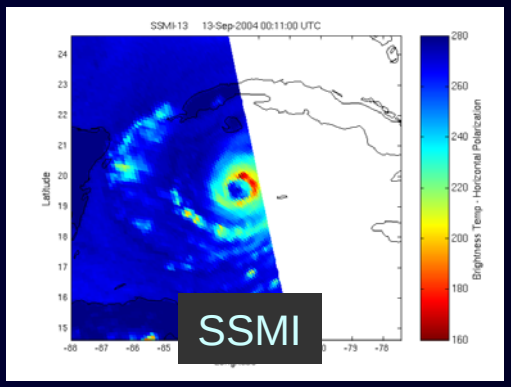
Satellite	Instrument	Frequency (GHz)	Orbit	Footprint (km)
DMSP-13	SSM/I	85.5, H	Polar, sun-synchronous	16 x 14
DMSP-14	SSM/I	85.5, H	Polar, sun-synchronous	16 x 14
DMSP-15	SSM/I	85.5, H	Polar, sun-synchronous	16 x 14
DMSP-16	SSMIS	91.7, H	Polar, sun-synchronous	14 x 13
TRMM	TMI	85.5, H	Equatorial, between 38 S and 38 N	7 x 5
Aqua	AMSR-E	89.0, H	Polar, sun-synchronous	6 x 4

Central visualization problem





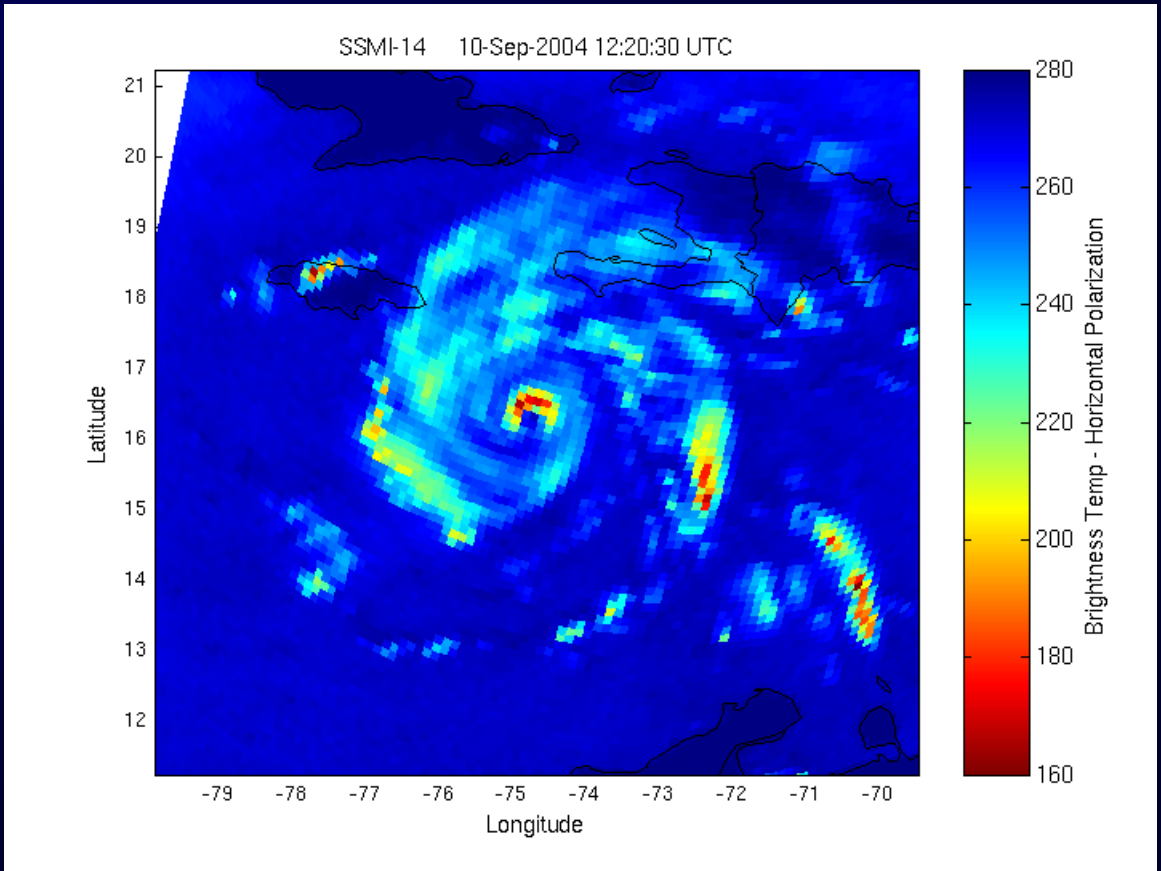




Irregular time gaps are too difficult to piece together mentally.

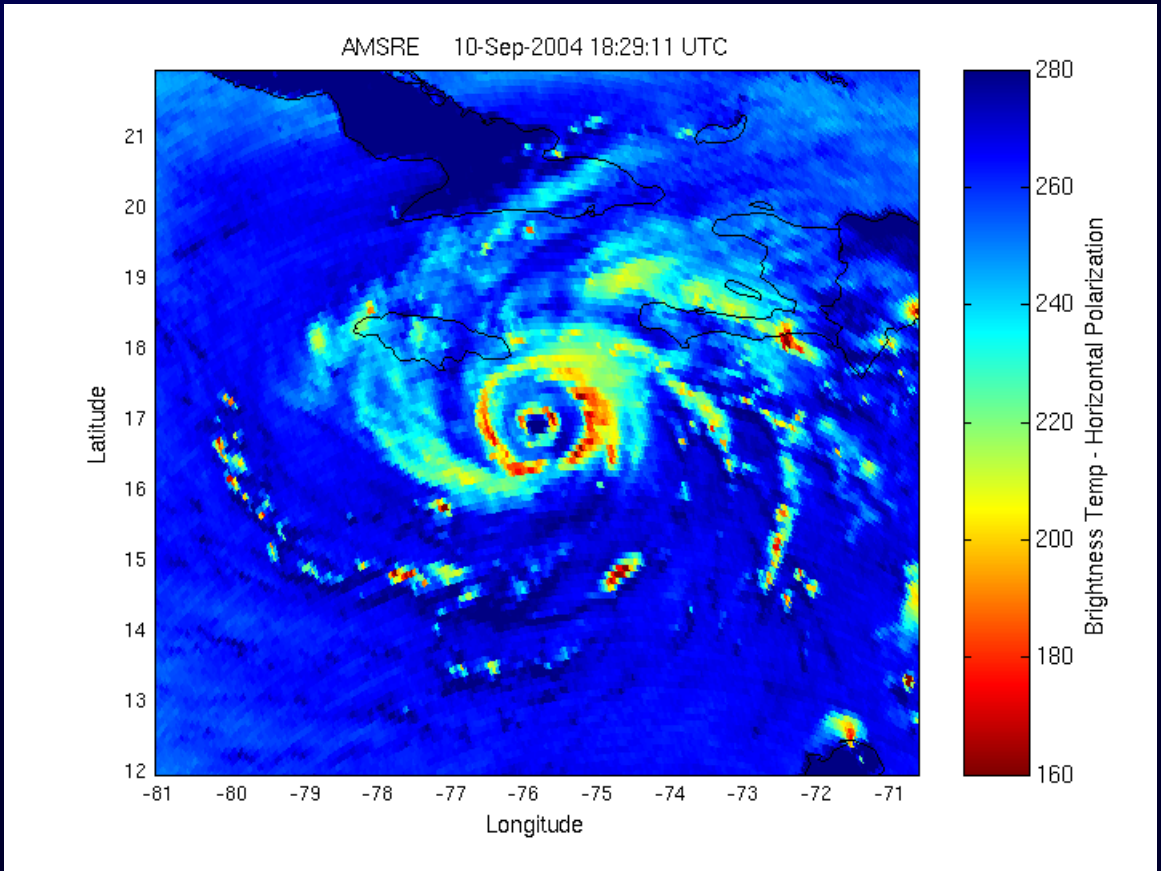
- This is worsened by the fact that most of us think we're smart enough to do it.

Example: Hurricane Ivan (2004)



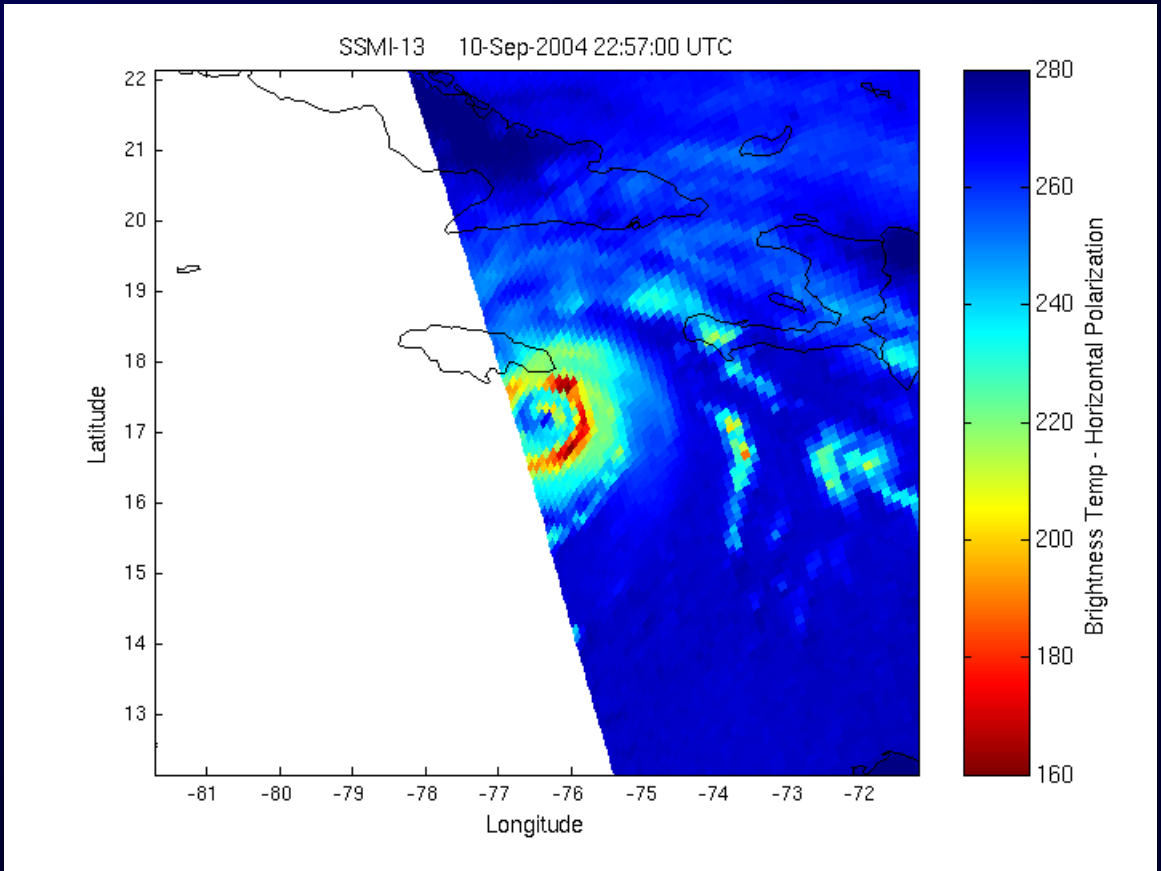
10 Sept, 1220 UTC

Example: Hurricane Ivan (2004)



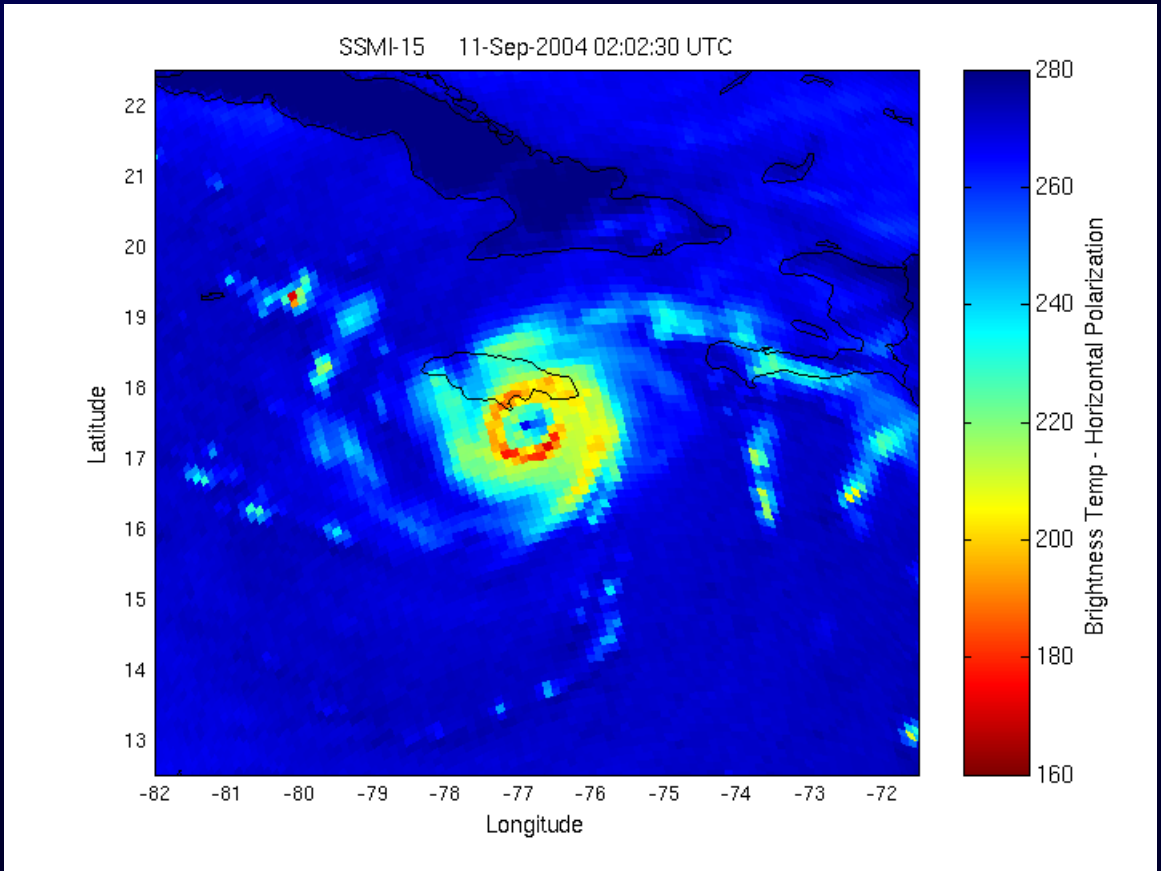
10 Sept, 1829 UTC

Example: Hurricane Ivan (2004)



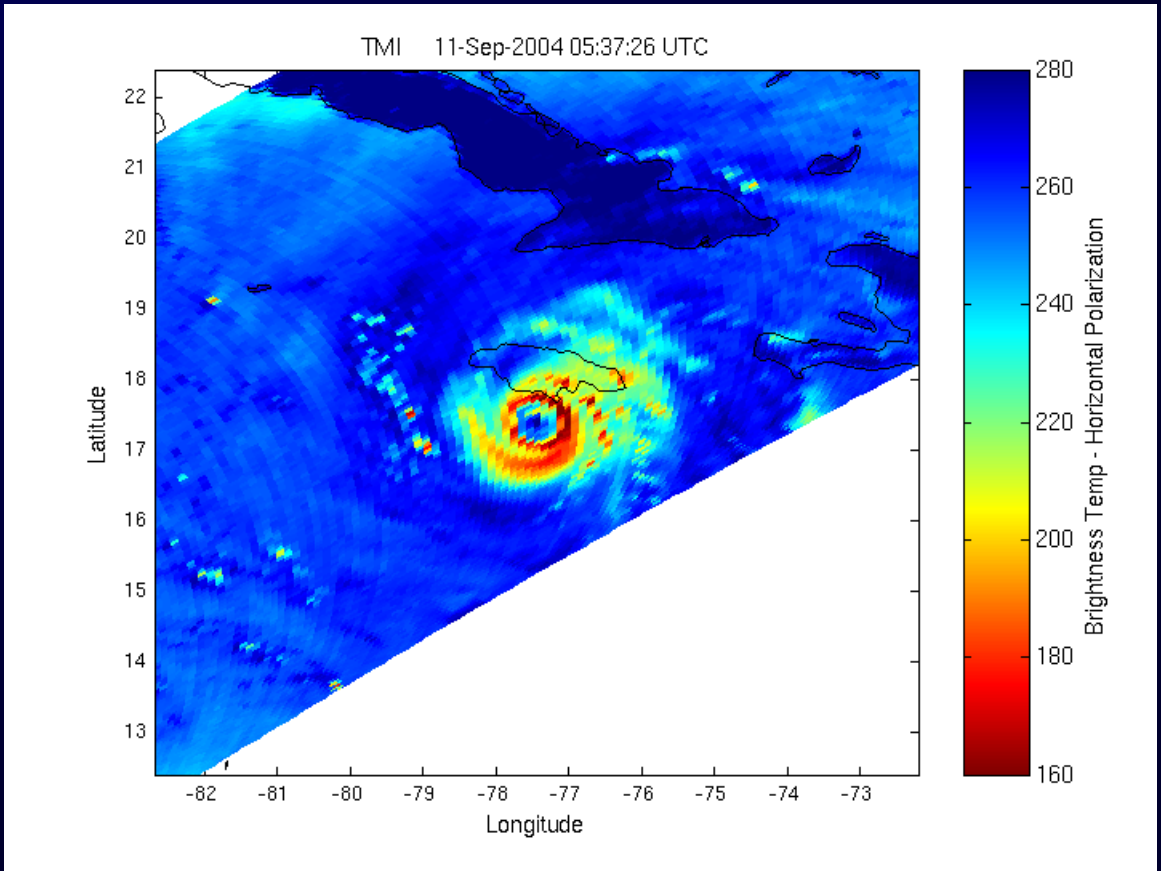
10 Sept, 2257 UTC

Example: Hurricane Ivan (2004)



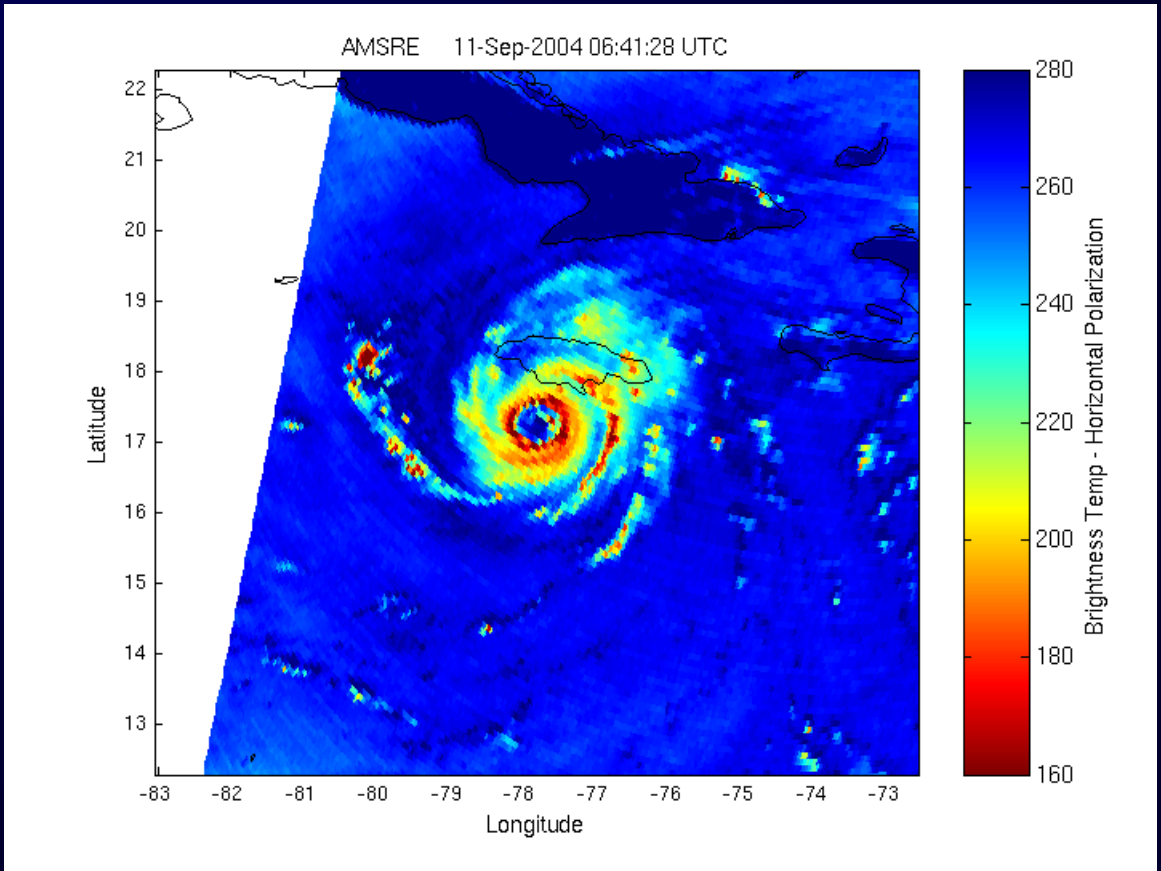
11 Sept, 0202 UTC

Example: Hurricane Ivan (2004)



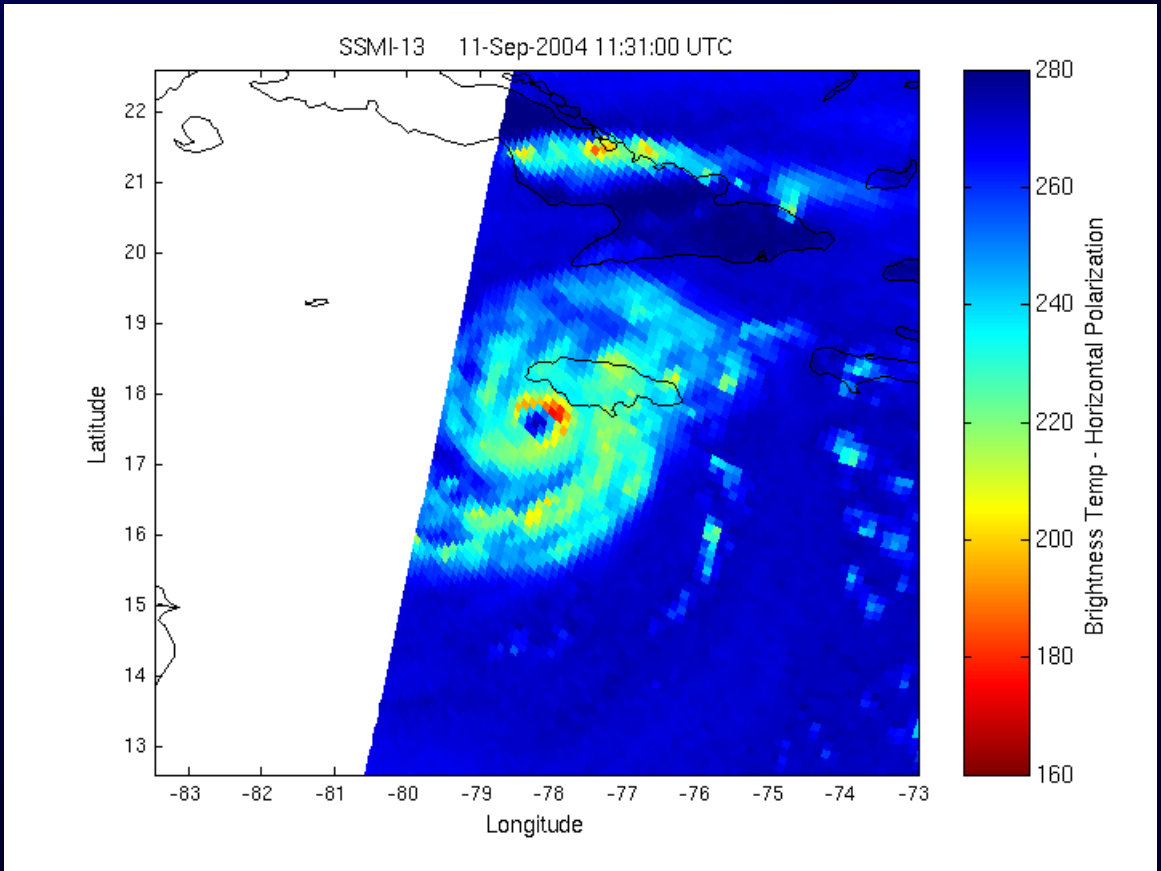
11 Sept, 0537 UTC

Example: Hurricane Ivan (2004)



11 Sept, 0641 UTC

Example: Hurricane Ivan (2004)



11 Sept, 1131 UTC

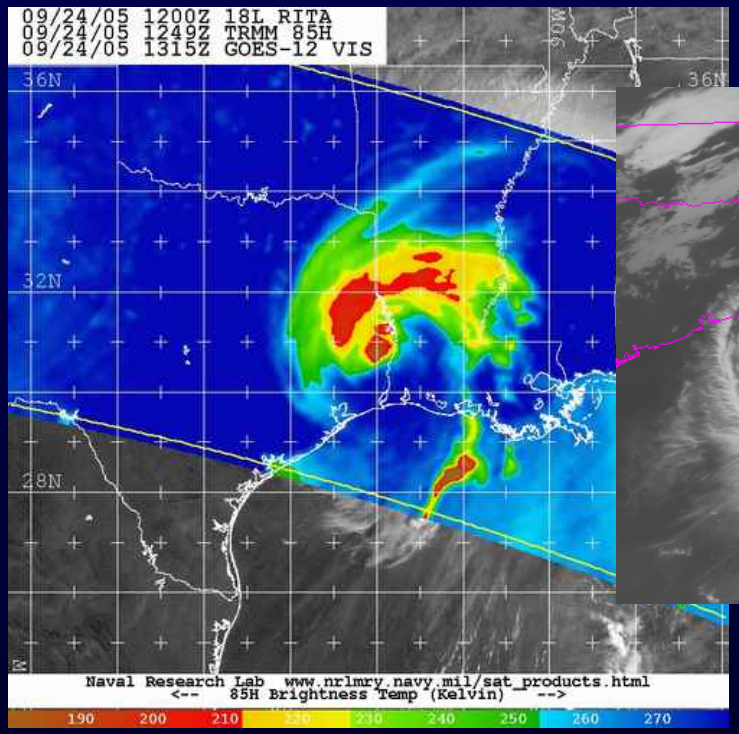
(insert 1-ivanEx avi)

QuickTime™ and a
decompressor
are needed to see this picture.

Hurricane Ivan (2004): 10 Sept 1200 UTC - 11 Sept 1200 UTC

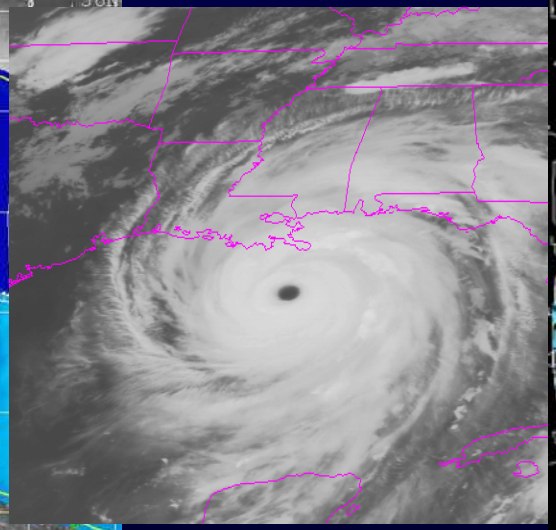
The most common alternatives to visualize tropical cyclones observations:

Microwave



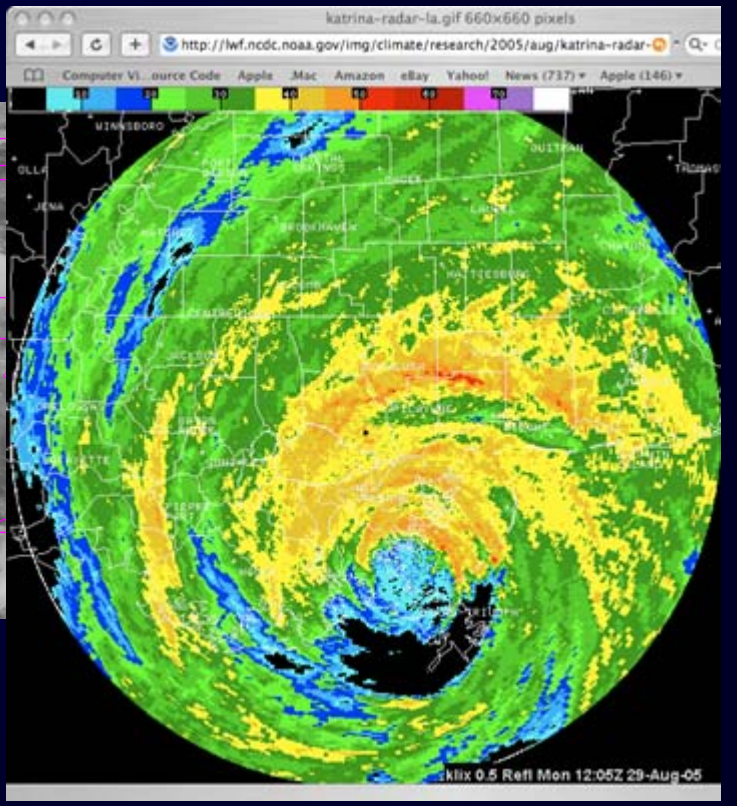
(Irregular time gaps)

Geo



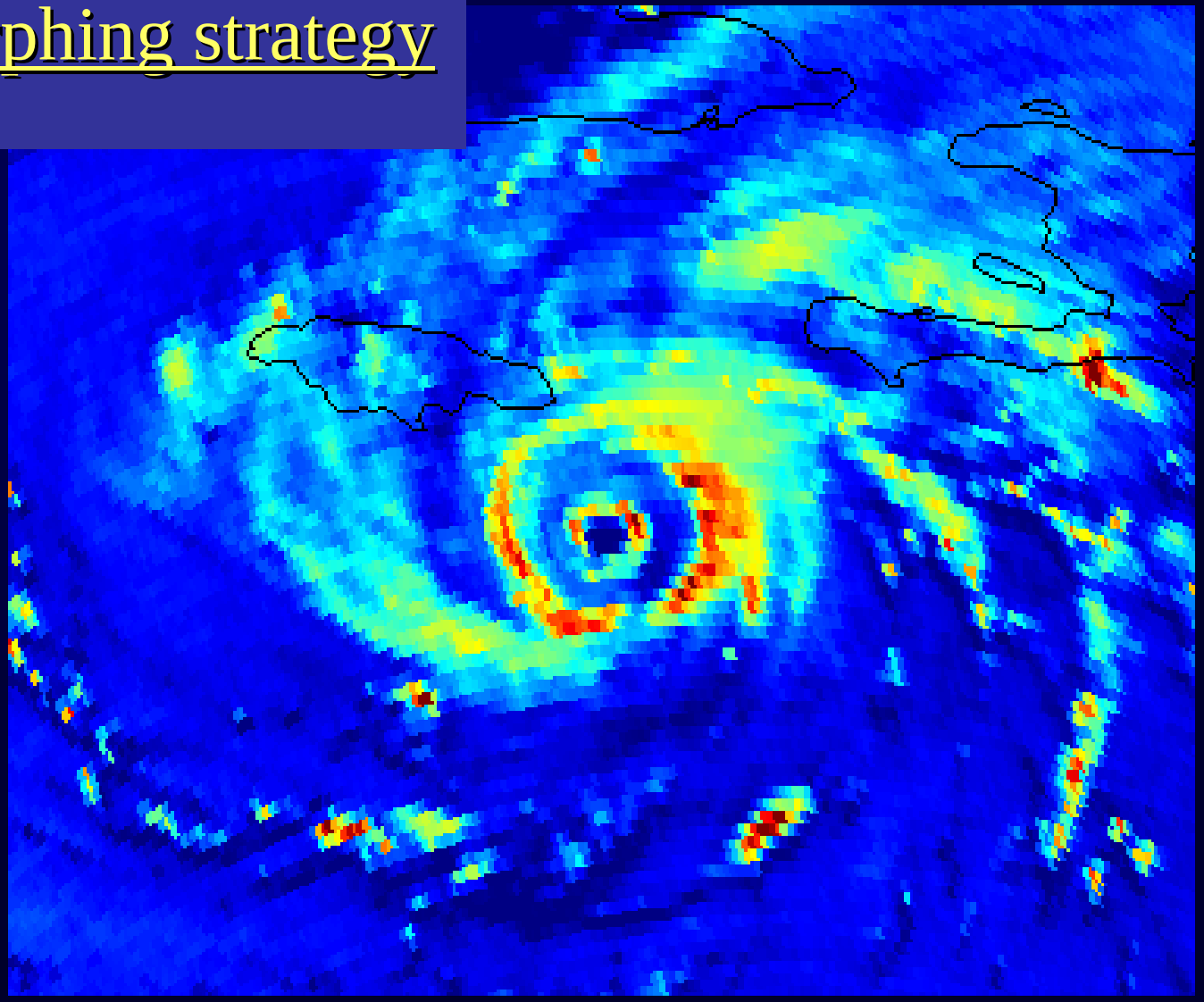
(Cloud cover)

Radar



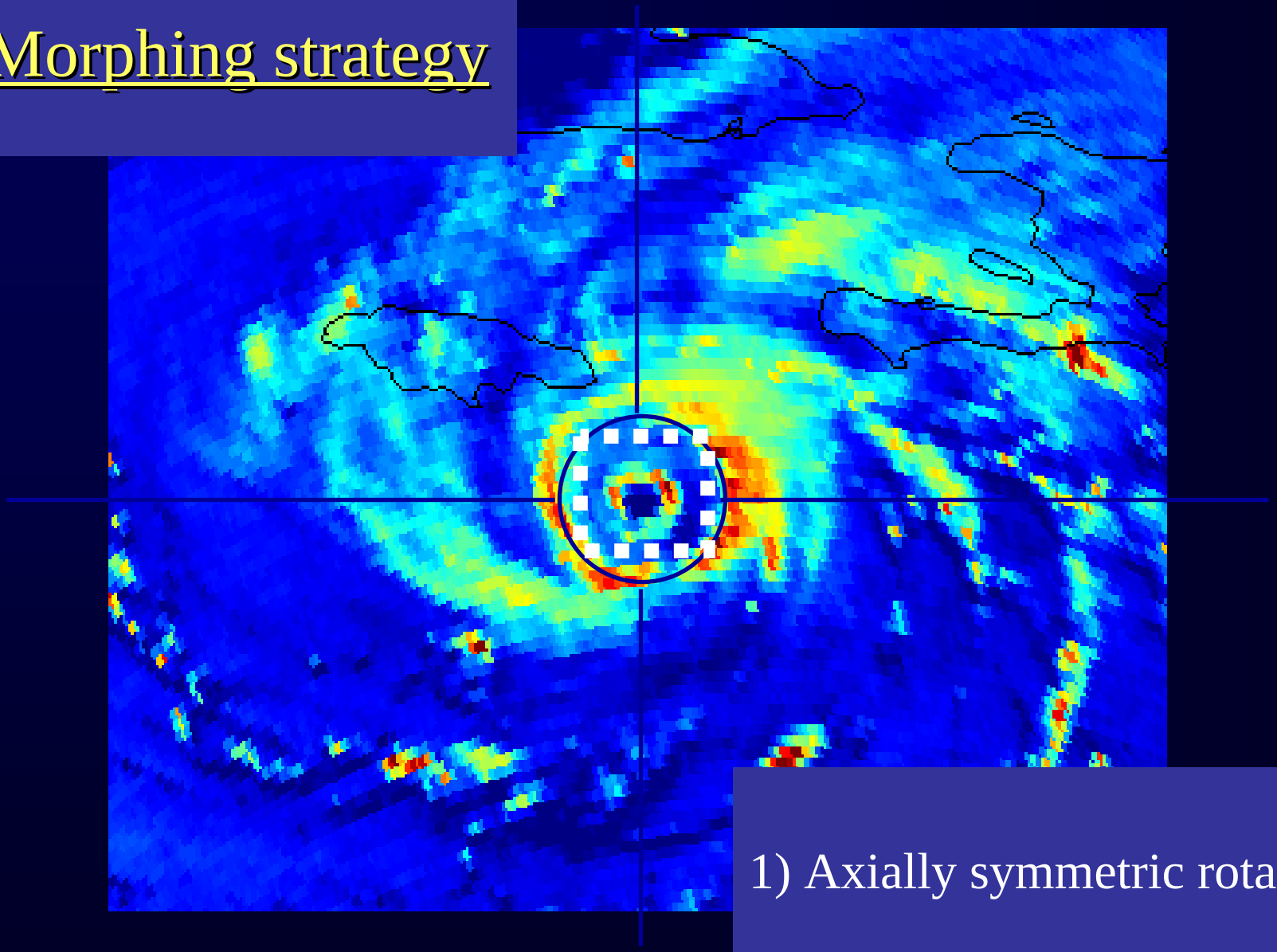
(Only available at coast)

Morphing strategy



10 Sept, 1829 UTC

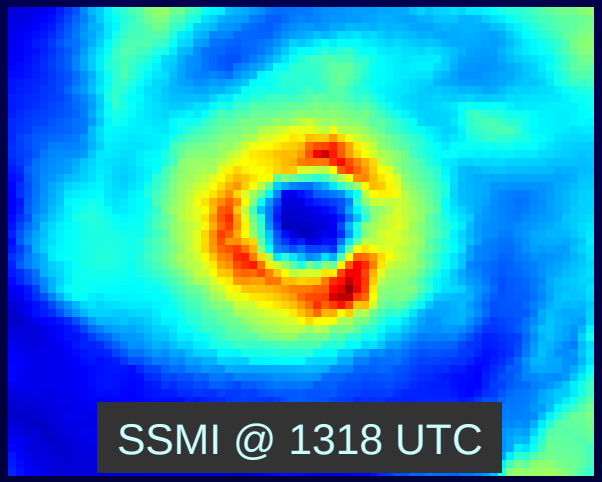
Morphing strategy

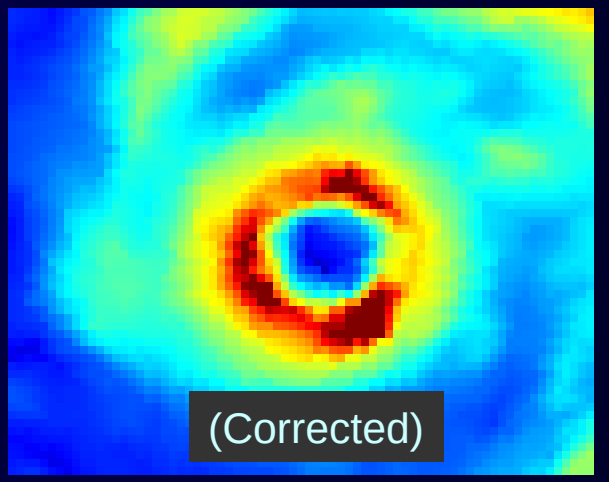


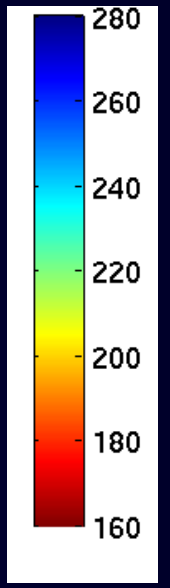
1) Axially symmetric rotation

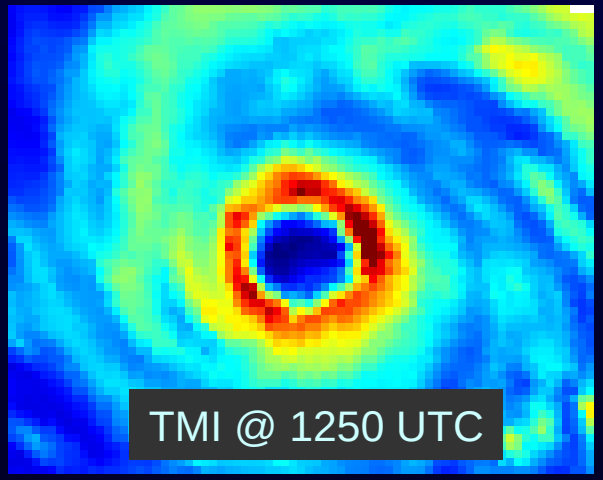
10 Sept, 1829 UTC

Morphing strategy



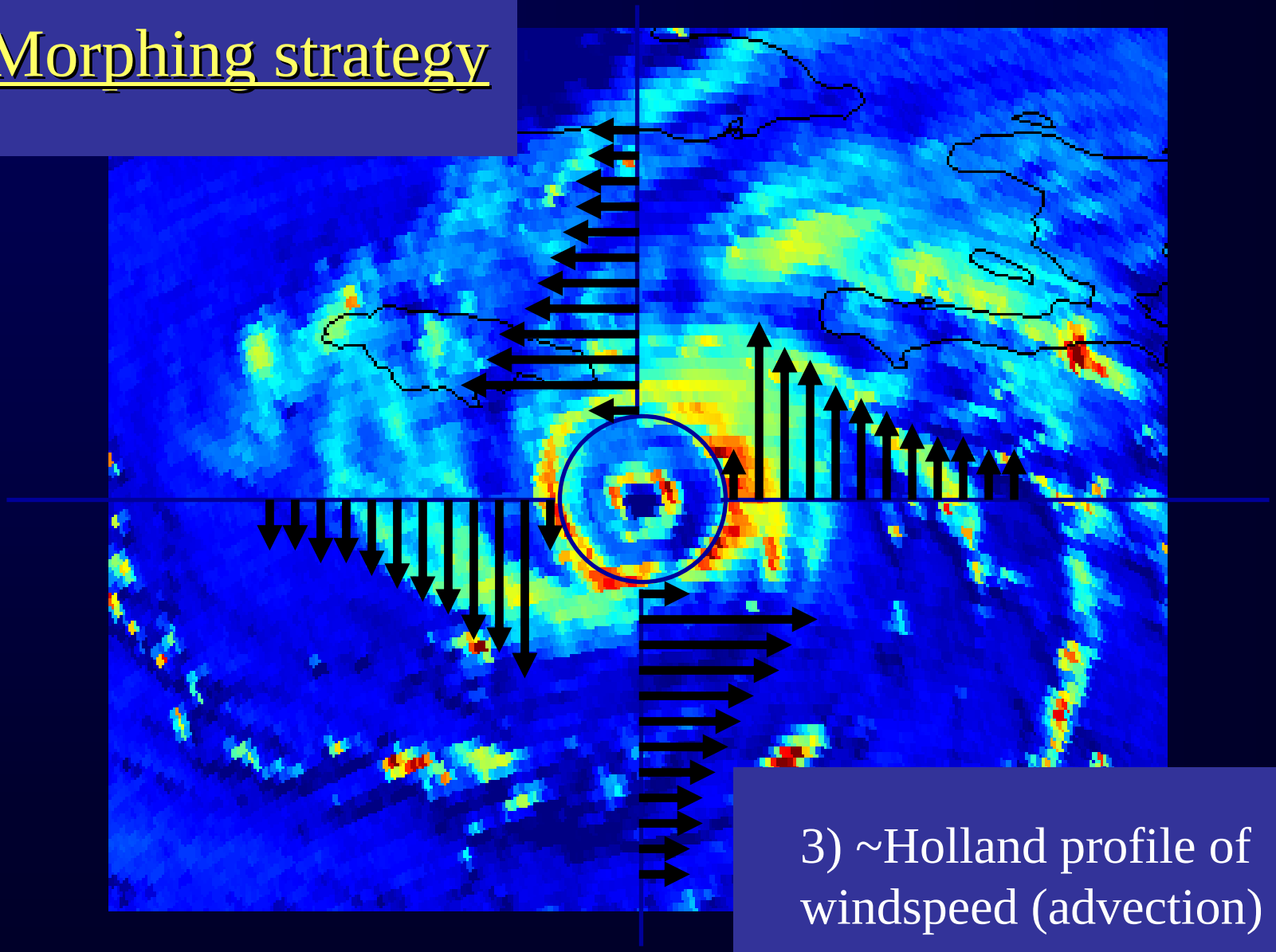






2) Brightness temp calibration

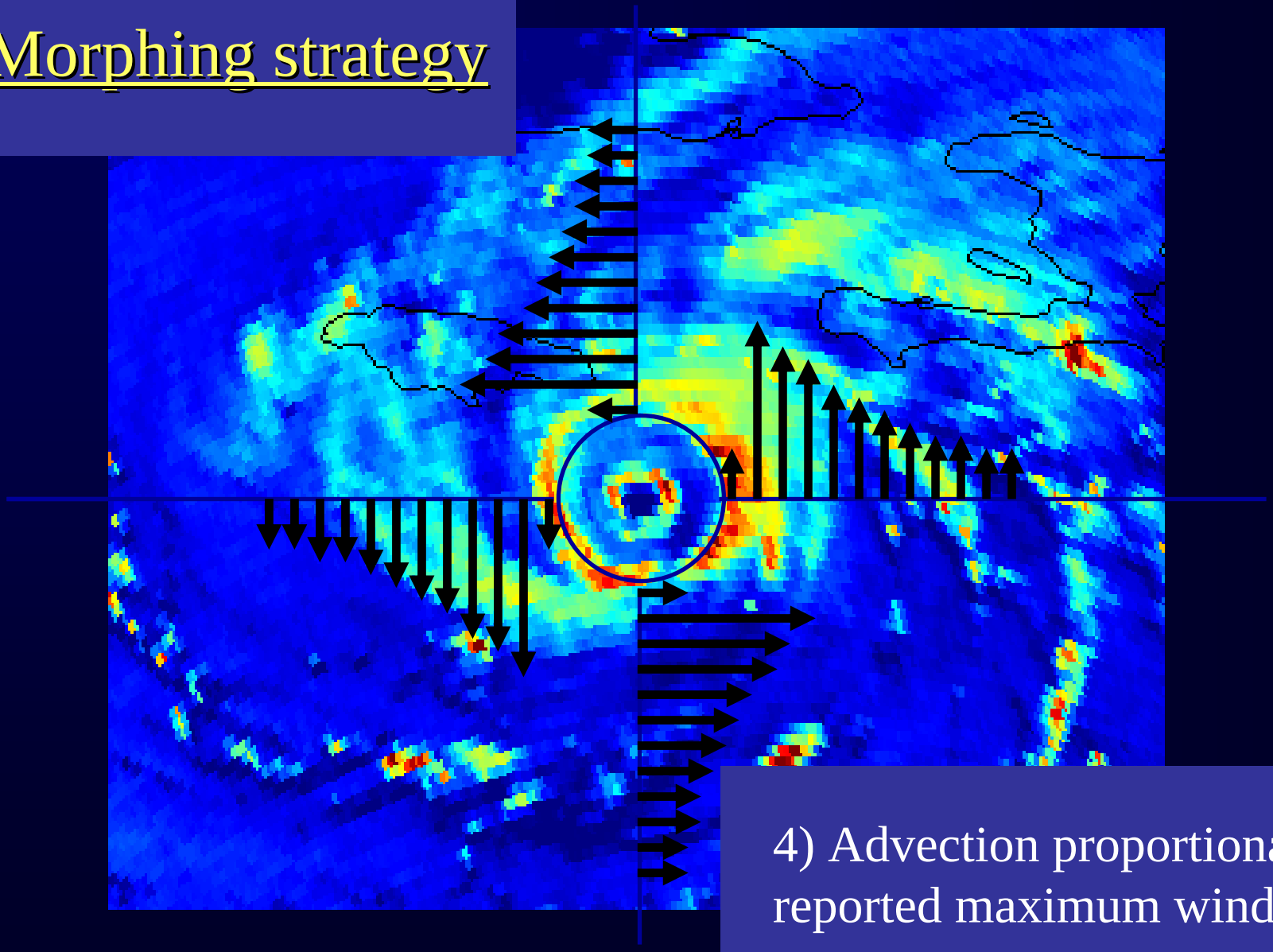
Morphing strategy



3) ~Holland profile of windspeed (advection)

10 Sept, 1829 UTC

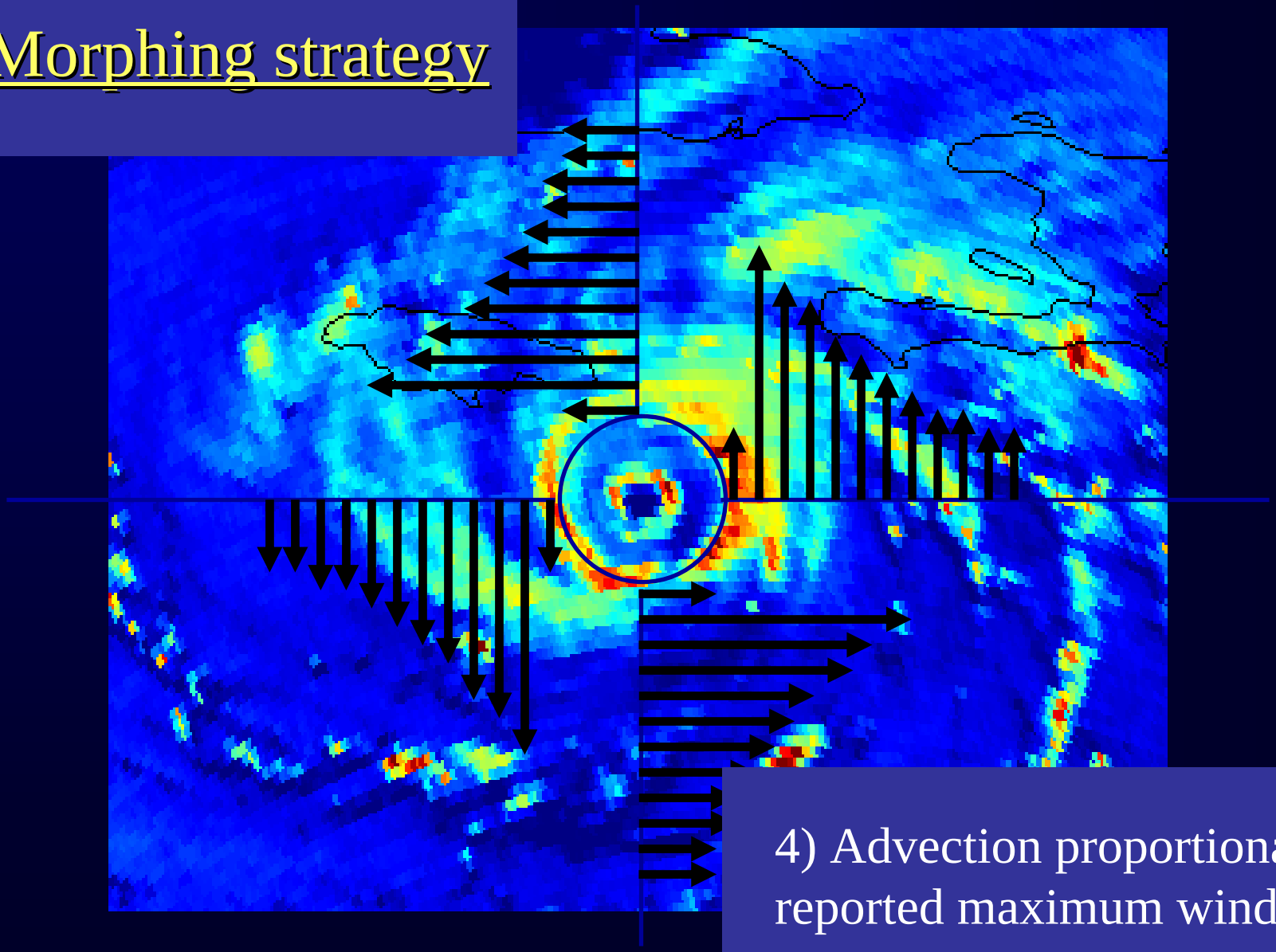
Morphing strategy



4) Advection proportional to reported maximum winds

10 Sept, 1829 UTC

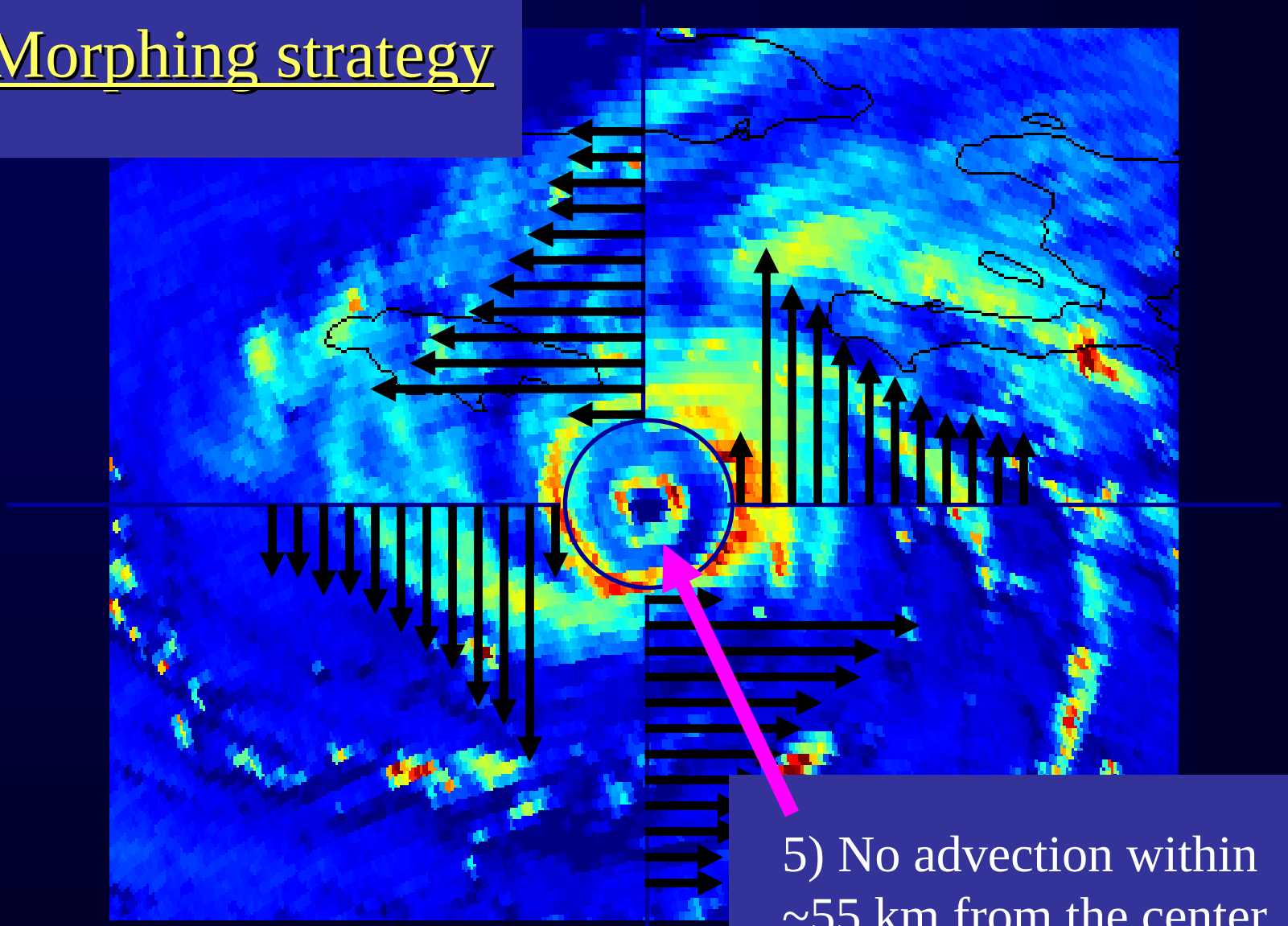
Morphing strategy



4) Advection proportional to reported maximum winds

10 Sept, 1829 UTC

Morphing strategy



5) No advection within ~55 km from the center

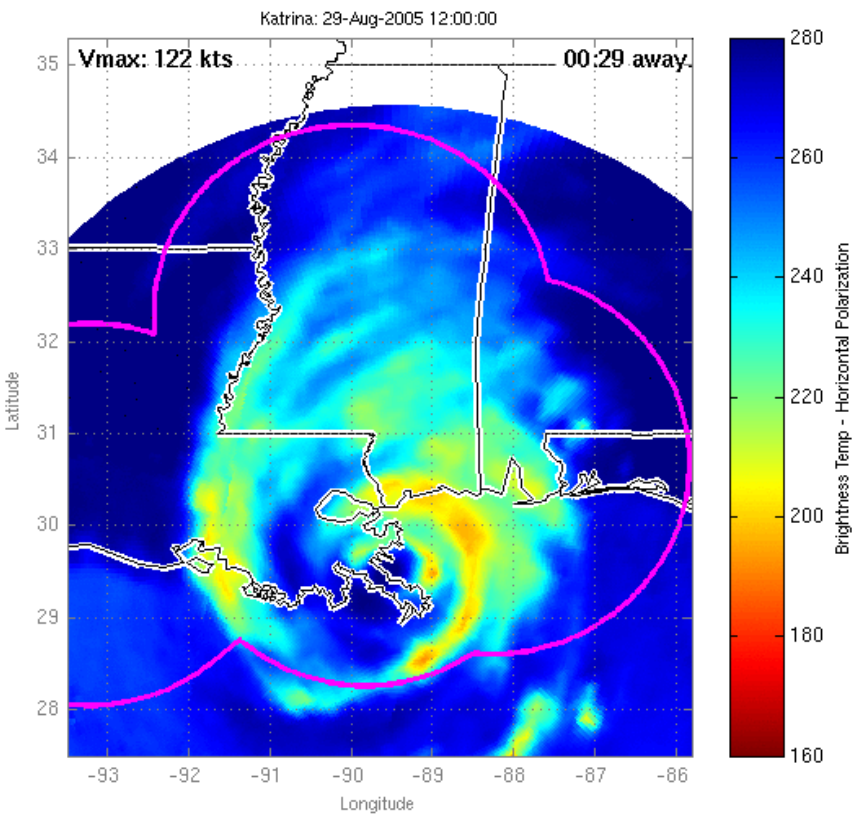
10 Sept, 1829 UTC

QuickTime™ and a
decompressor
are needed to see this picture.

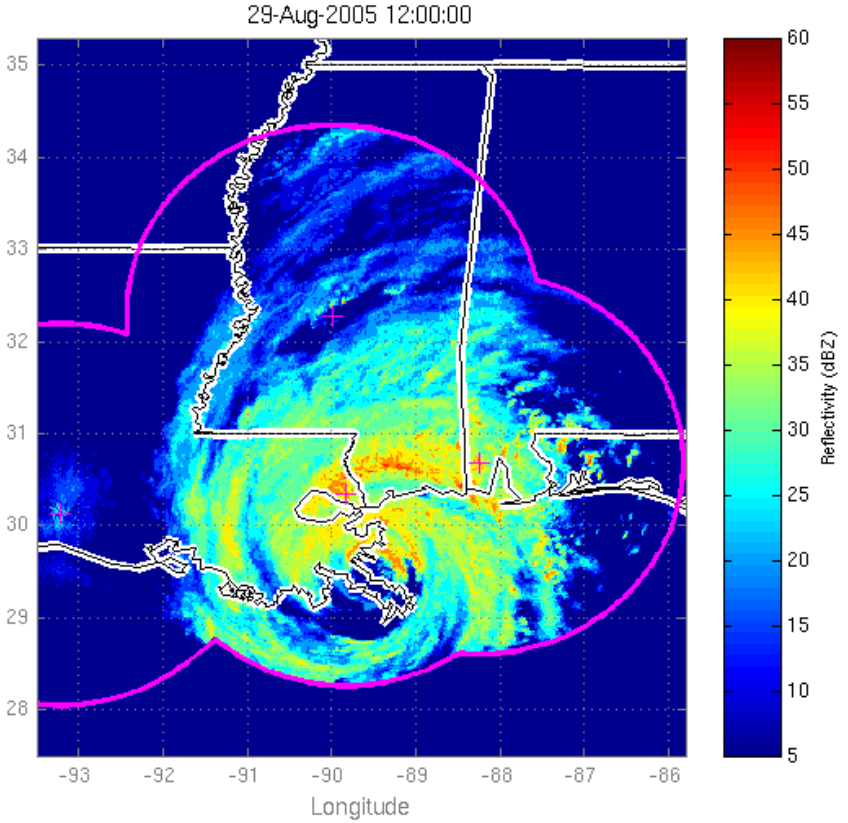
(insert 2-katMI avi)

Example: Katrina, 27-29 August, 2005

Comparison to radar reflectivity



MIMIC brightness temperature
29 August 1200 UTC



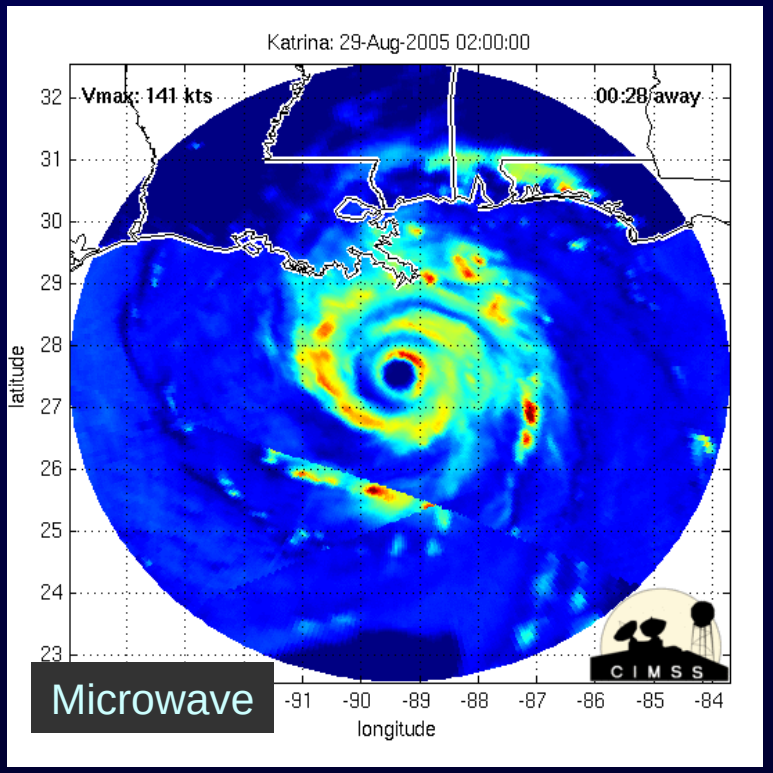
NEXRAD composite base reflectivity
29 August 1200 UTC

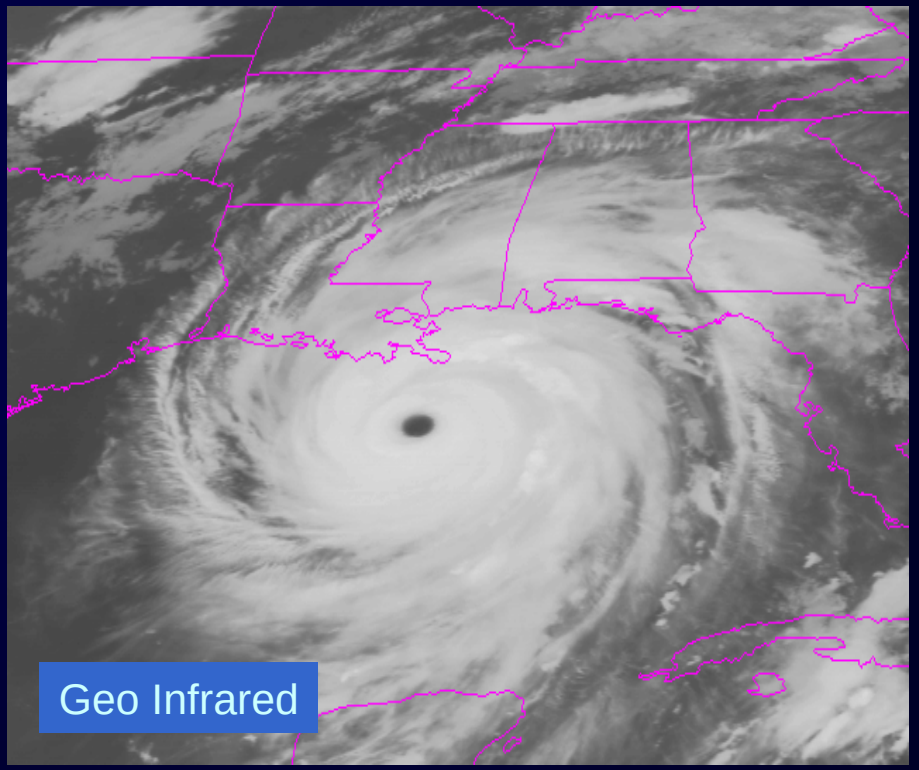
QuickTime™ and a
decompressor
are needed to see this picture.

(insert 3-wilMI avi)

Example: Wilma, 19-22 October 2005

New visualization problem:

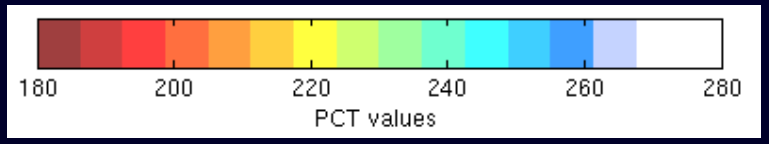




Intercomparison between different types of images (microwave and infrared) should be straightforward, but it rarely is

QuickTime™ and a
decompressor
are needed to see this picture.

(insert 5-wilIR avi)

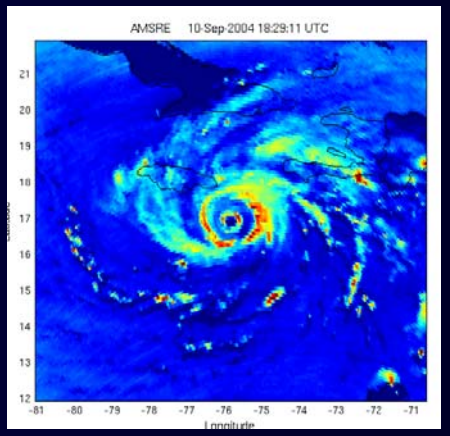


‘MIMIC-IR’: Wilma, 19-22 Oct 2005

Geostationary satellites that contribute to the MIMIC-IR product

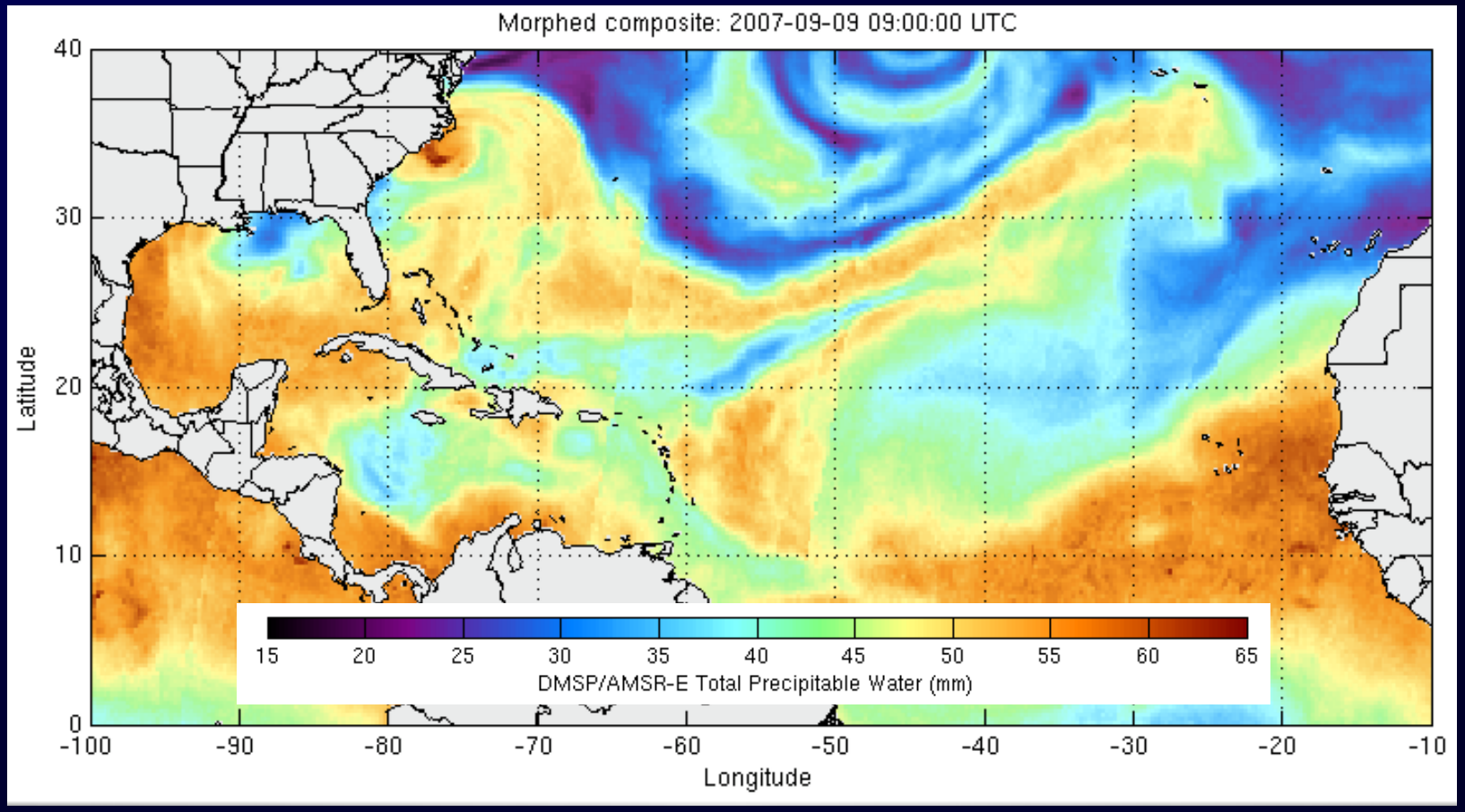
Satellite	Nadir Longitude	Basin
GOES-East	75 W	North Atlantic
GOES-West	135 W	West Pacific, Central Pacific
MTSAT	140 E	East Pacific, Central Pacific
Indoex	63 E	Indian Ocean

Comments: MIMIC-TC and MIMIC-IR



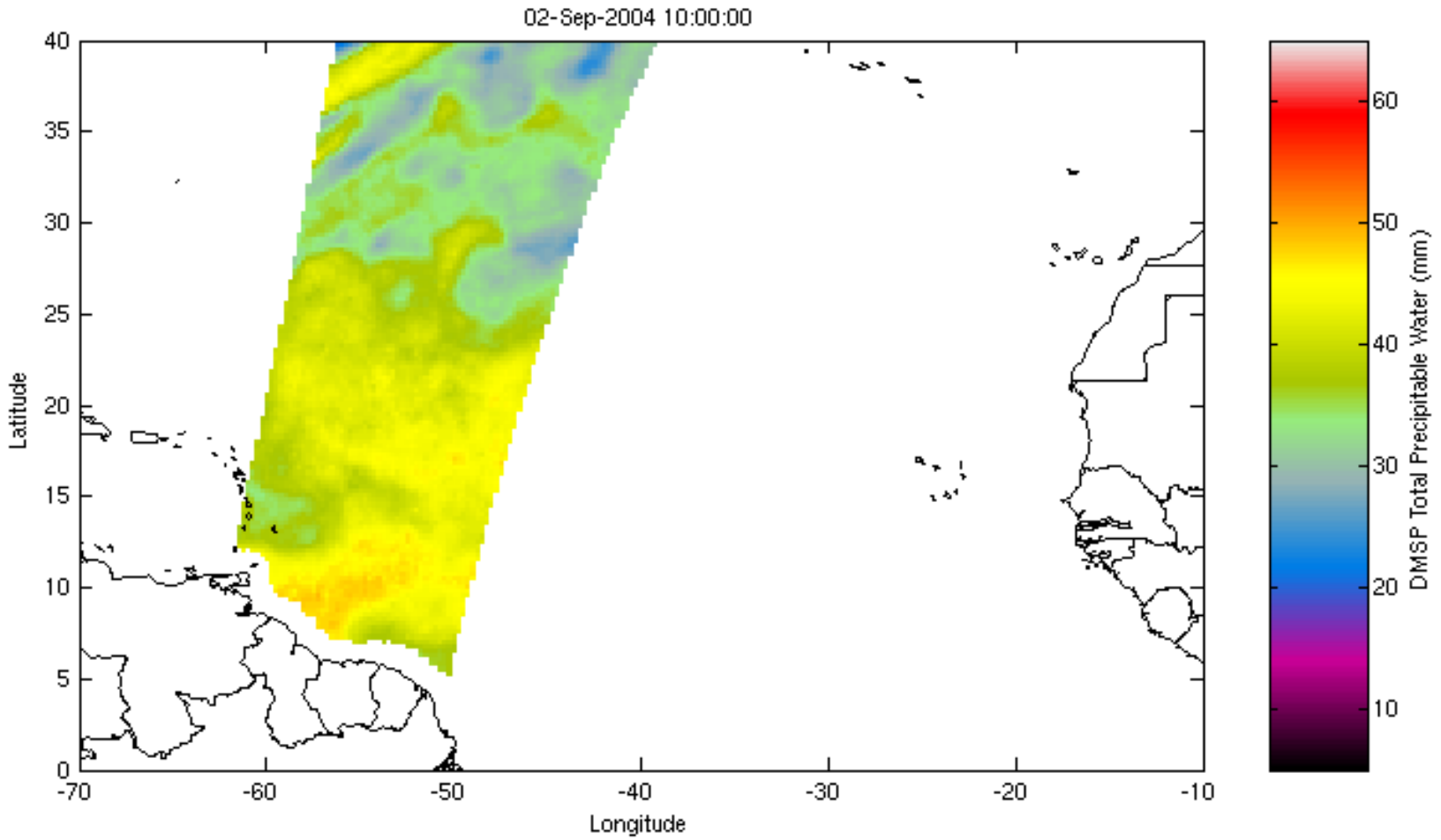
- Does not contain new data, but is easier to visualize
- Artifacts (esp. over time gaps of >6 hours)
- MIMIC-TC and -IR have better visualization of convective structure than ground-based radar
- New satellite platforms will become increasingly important as the current group end their periods of service

MIMIC-TPW



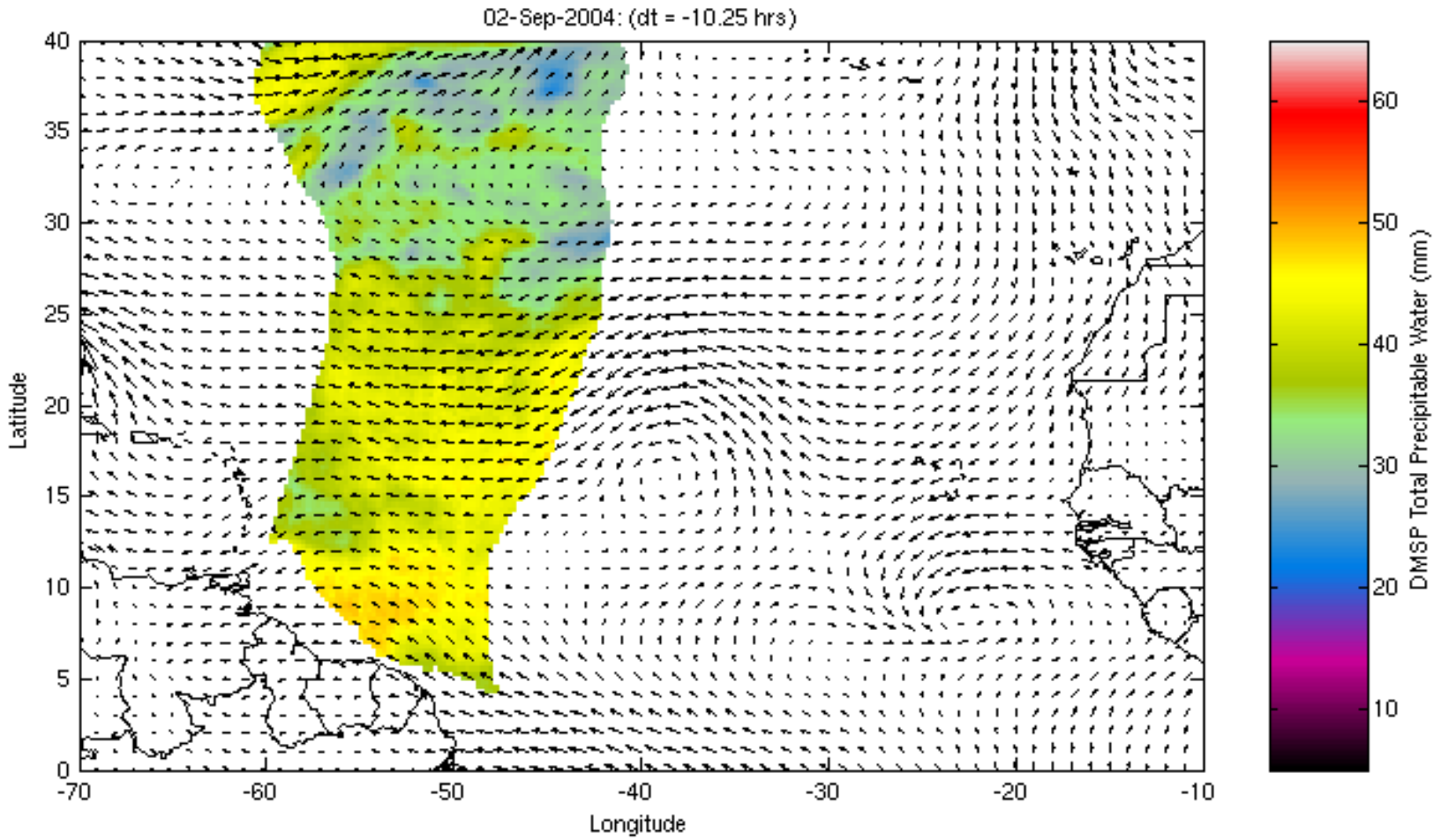
- Basin-wide
- TPW from SSMI (F-13 and F-14) and Aqua AMSR-E
- Uses GFS model winds near the surface

Hourly synthetic swaths

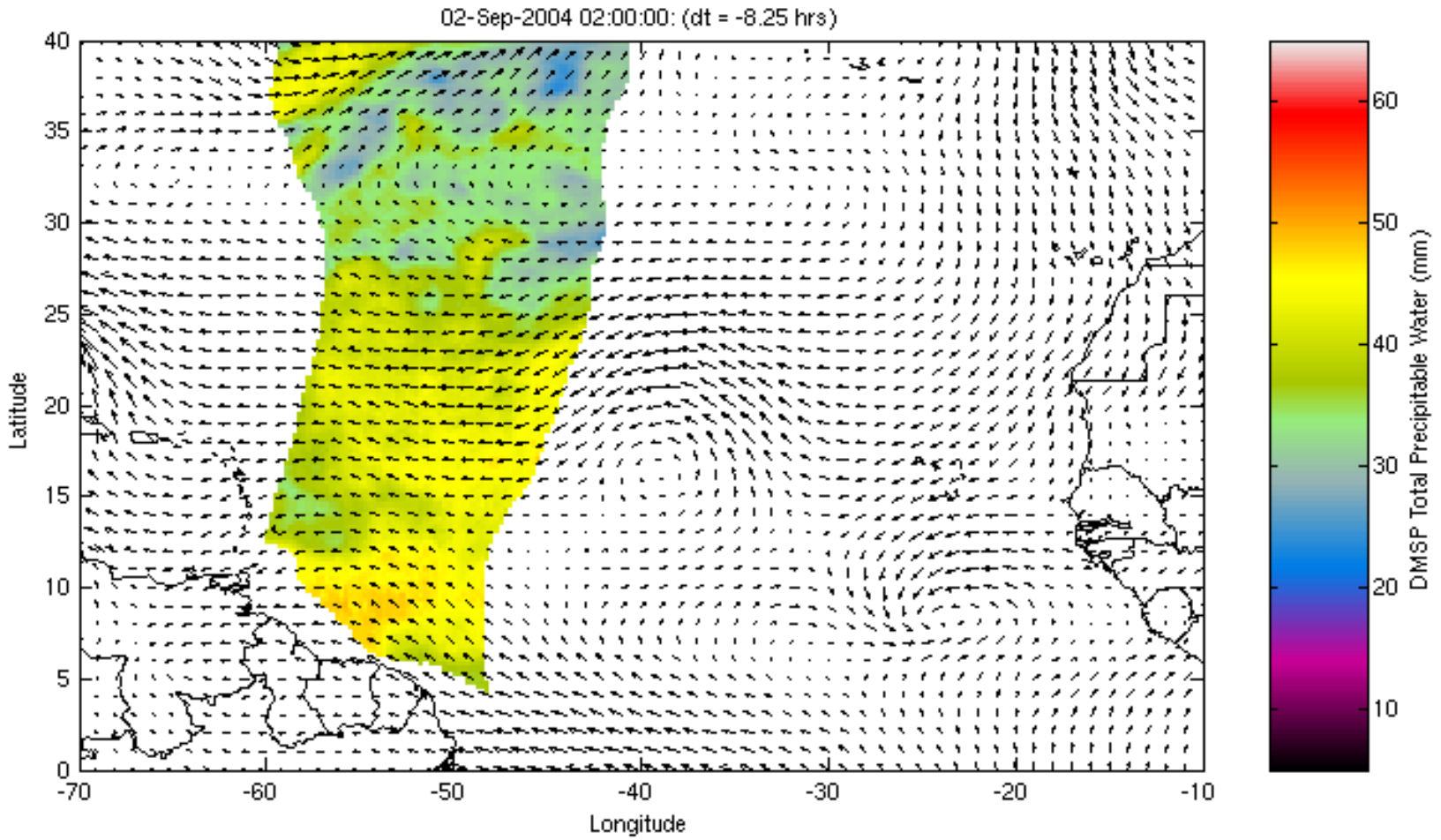


Original Swath

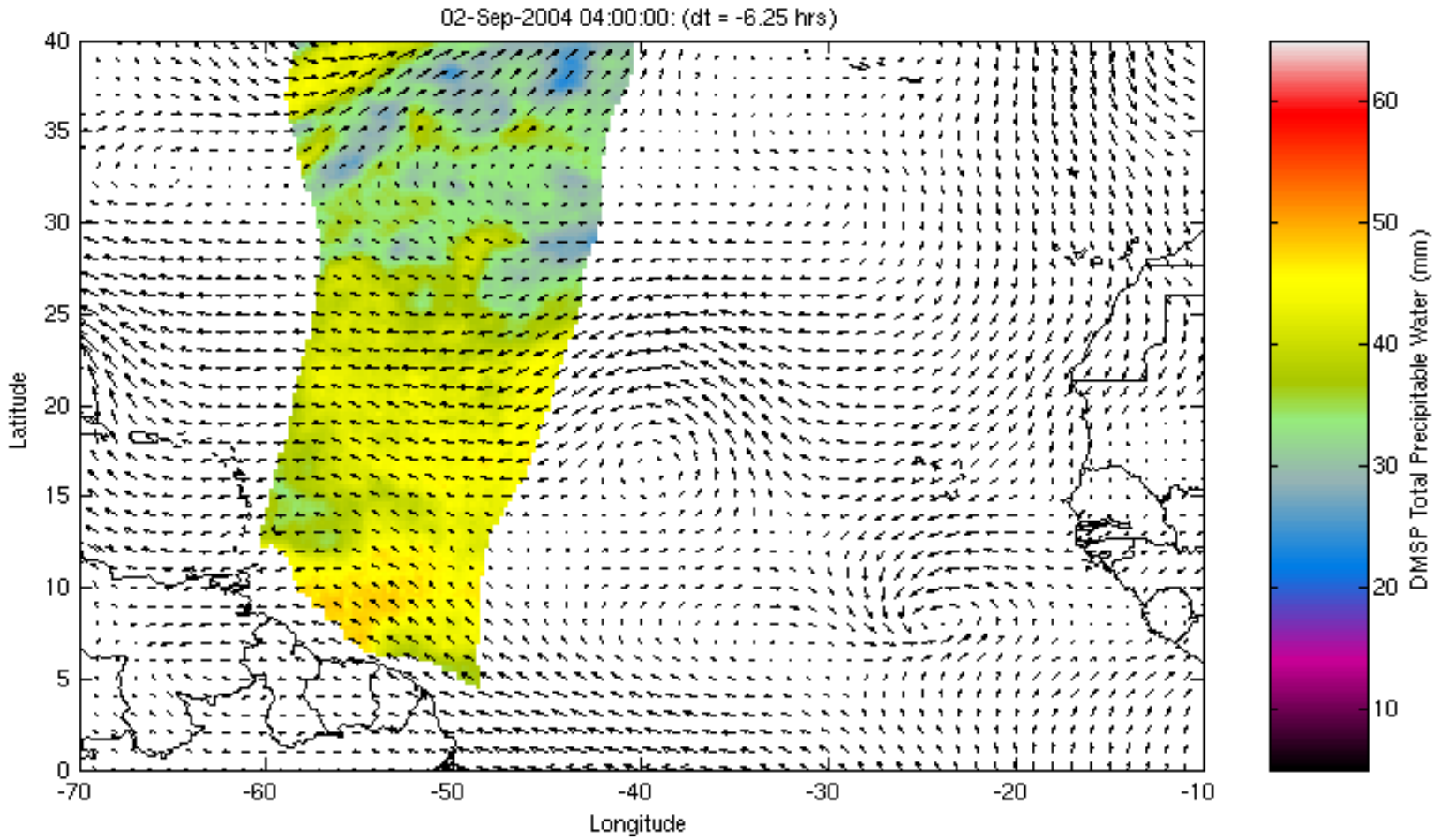
Hourly synthetic swaths



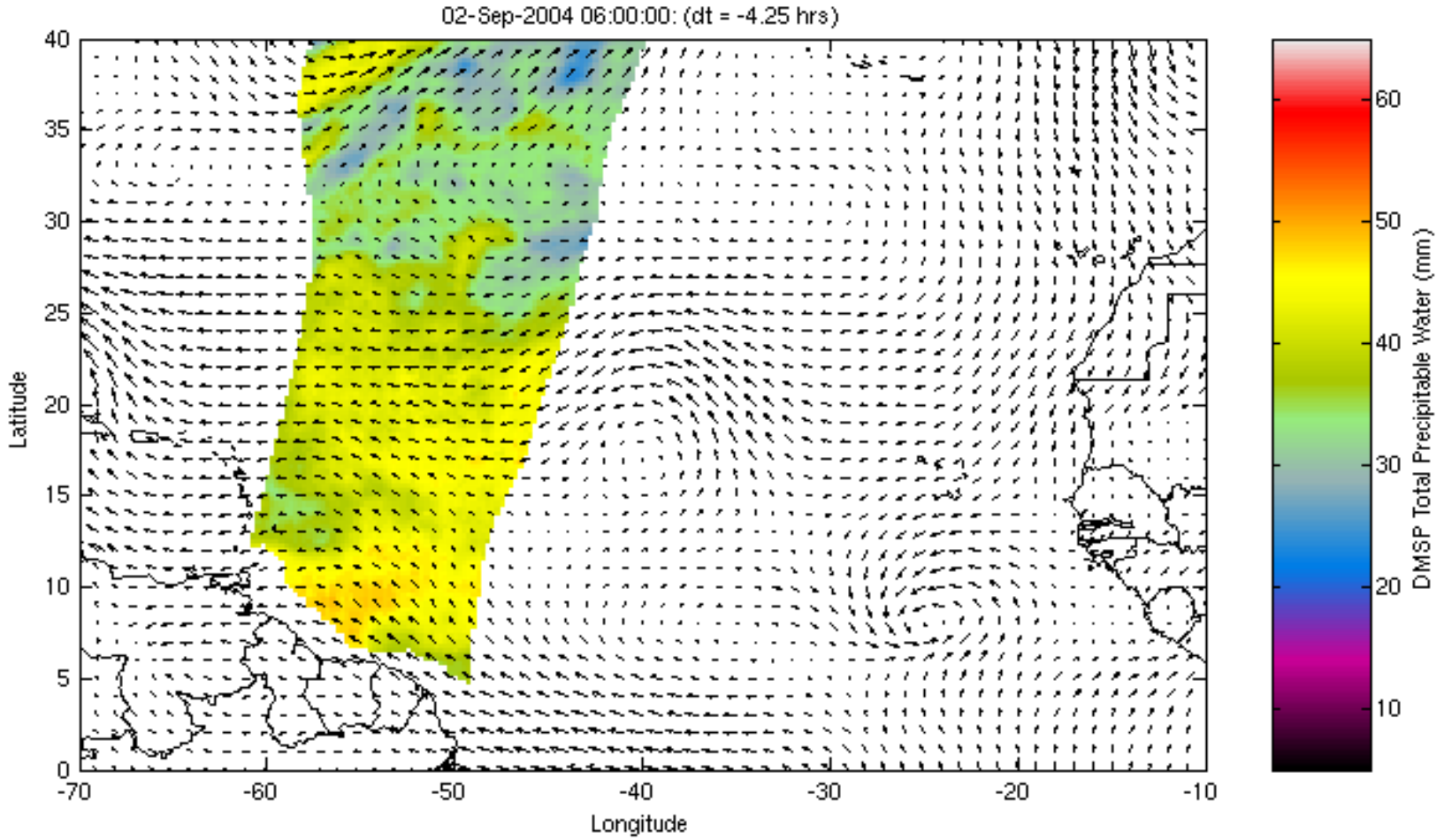
Hourly synthetic swaths



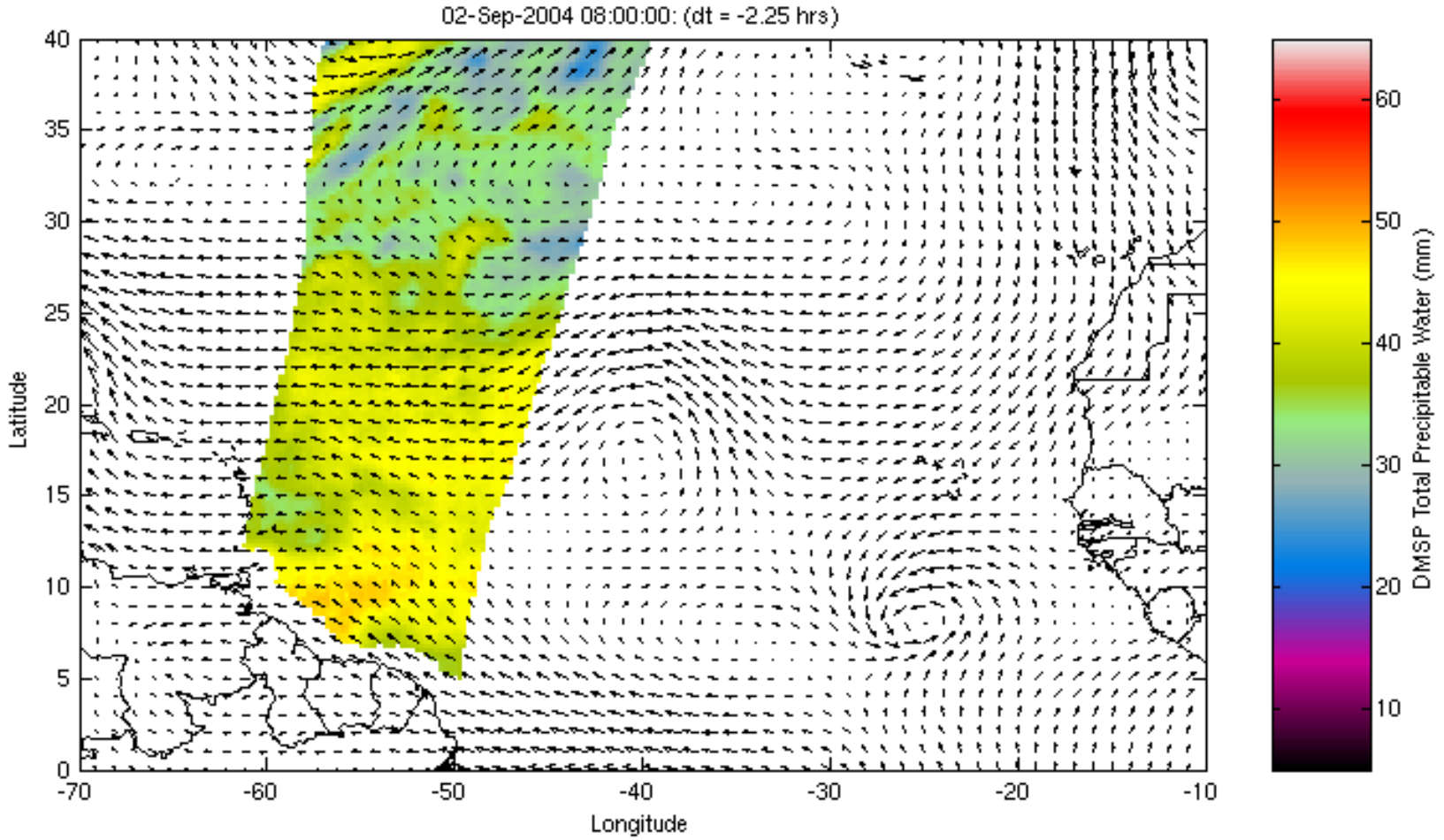
Hourly synthetic swaths



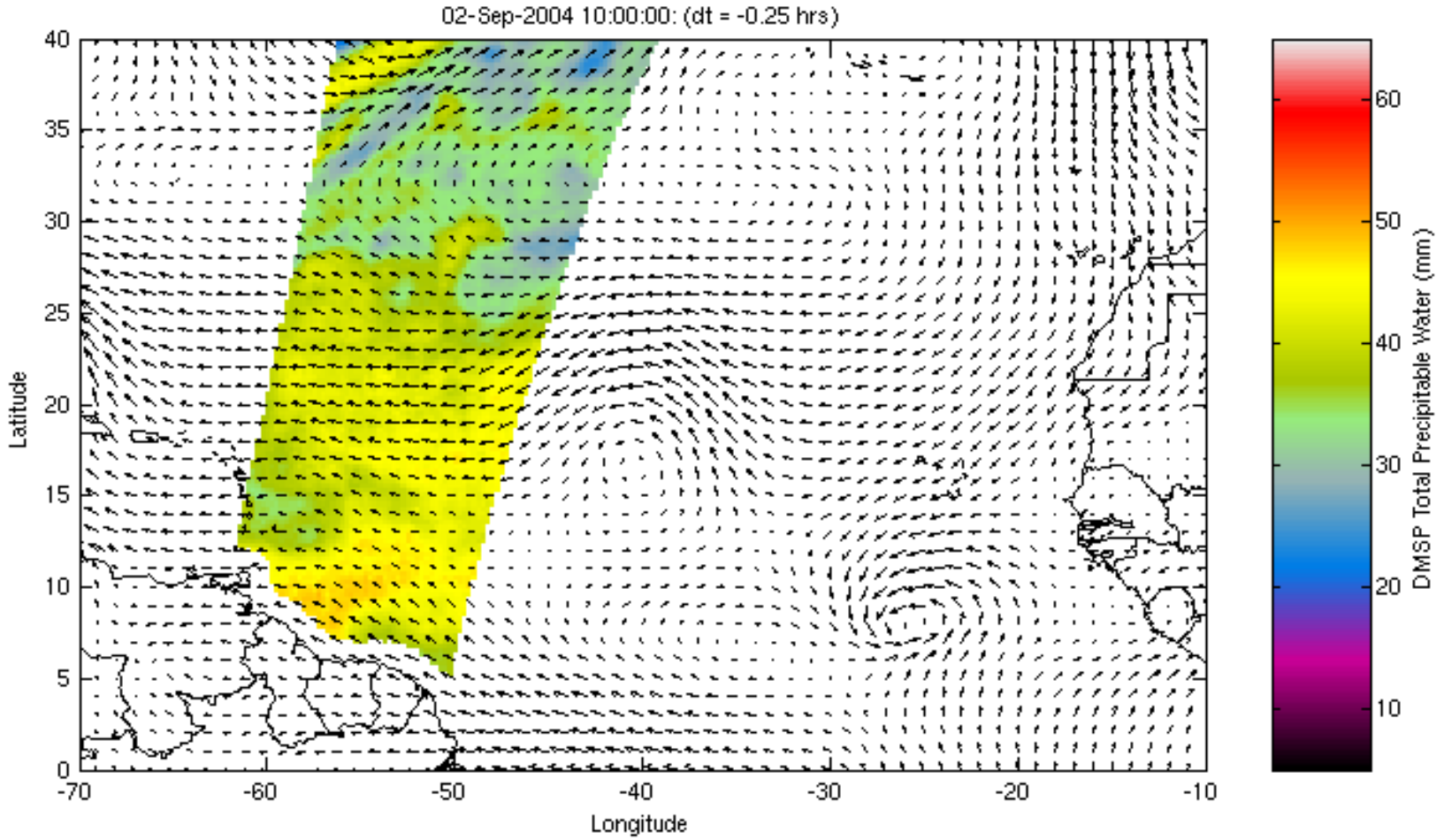
Hourly synthetic swaths



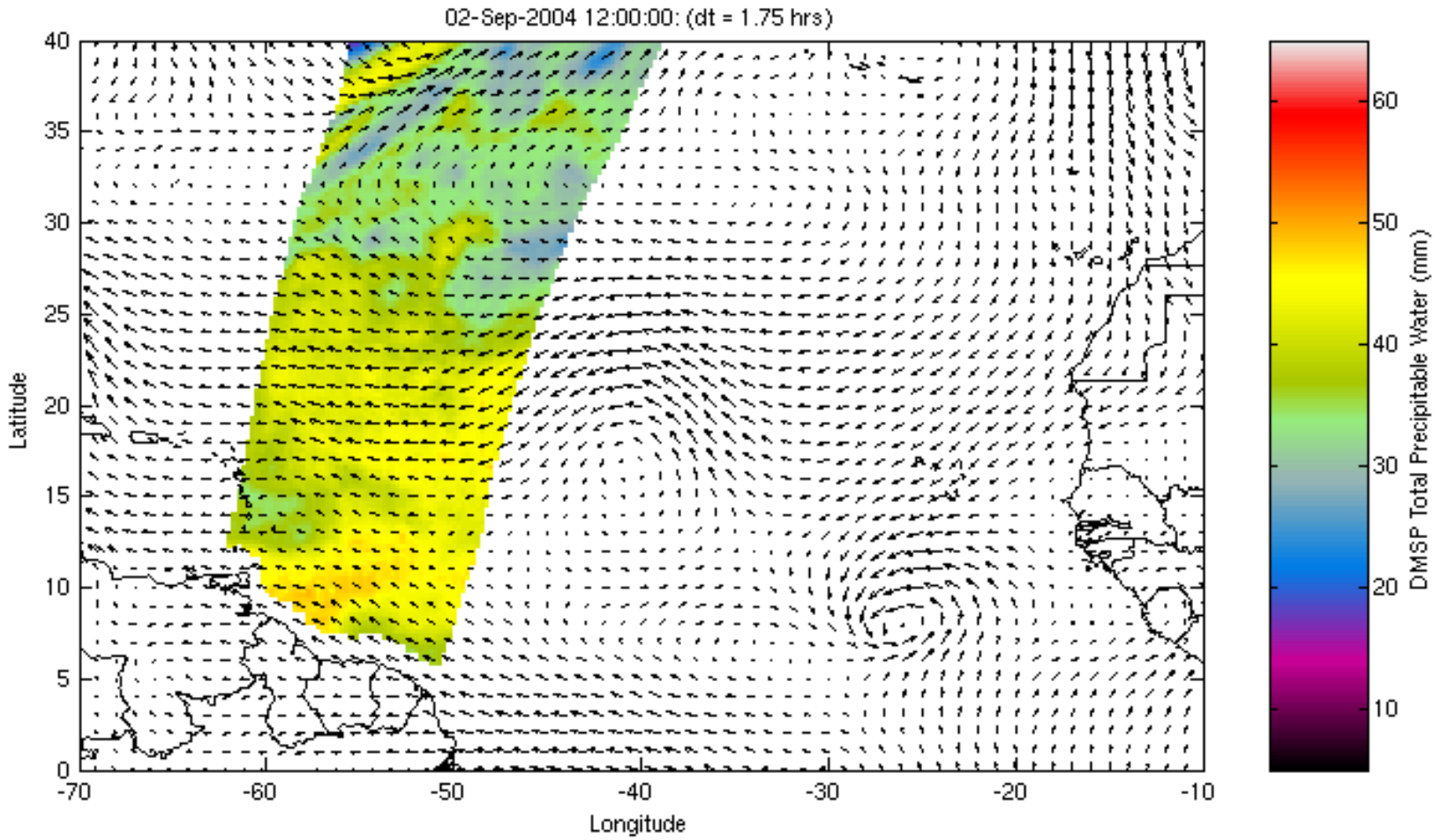
Hourly synthetic swaths



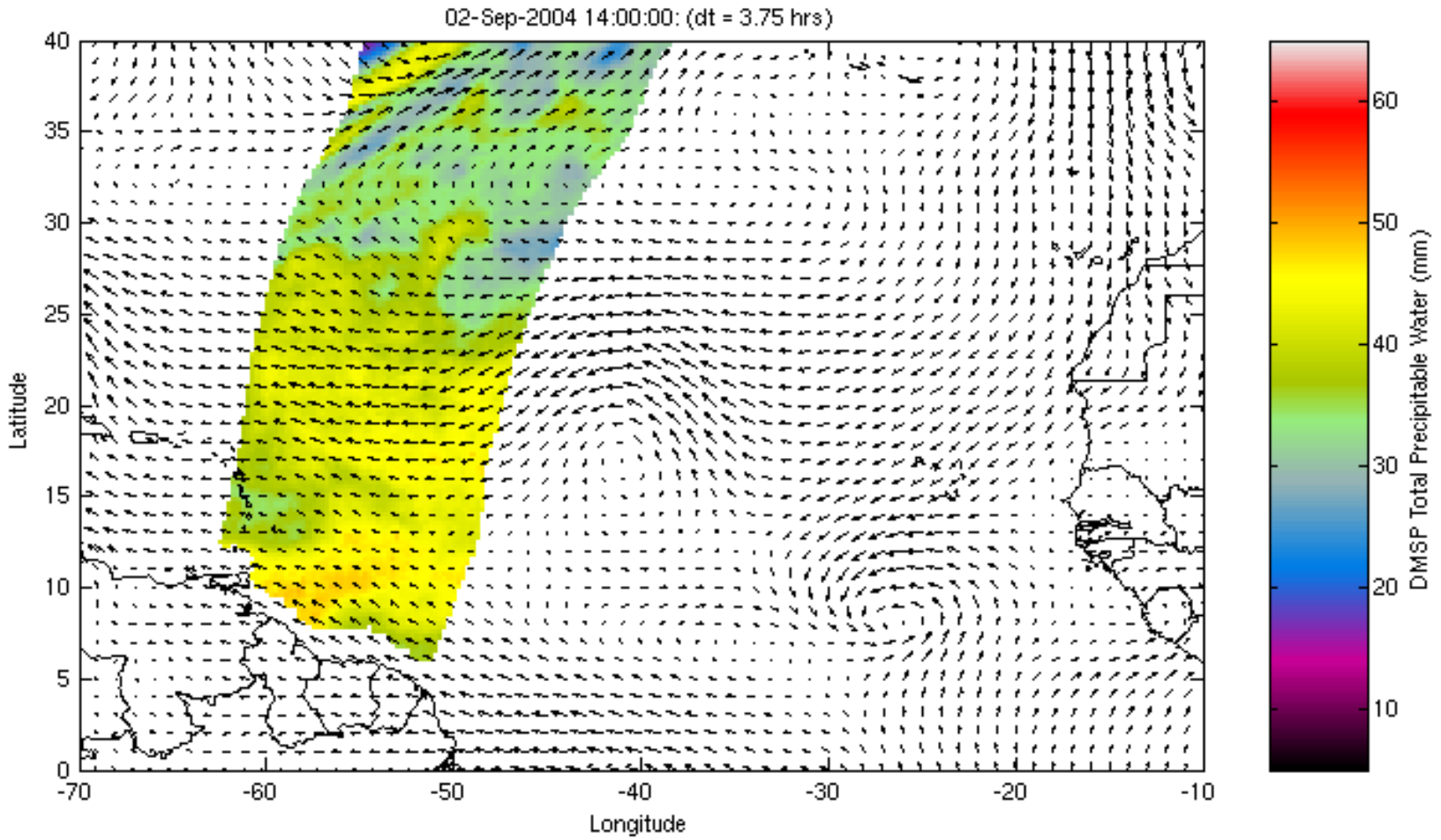
Hourly synthetic swaths



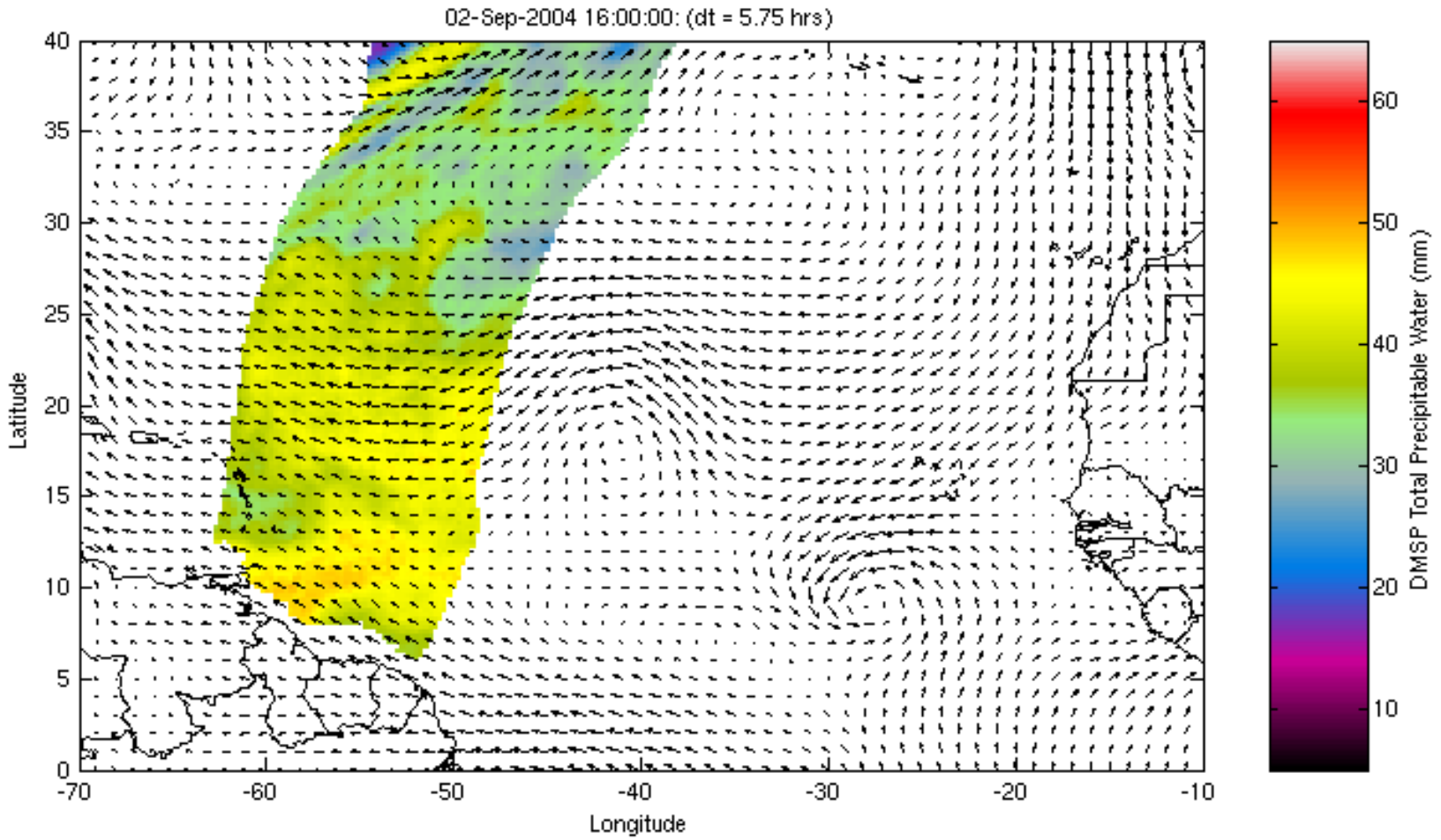
Hourly synthetic swaths



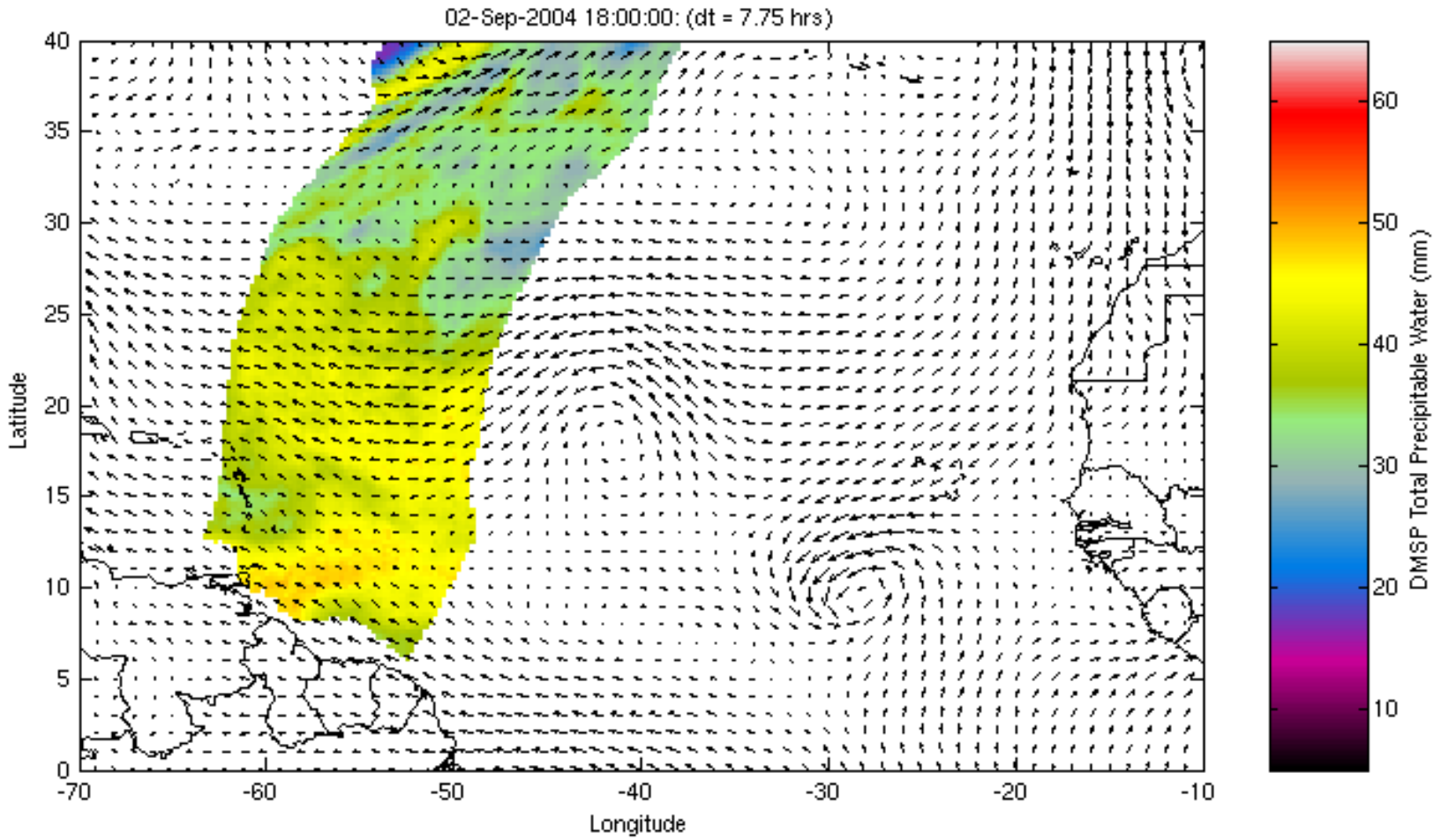
Hourly synthetic swaths



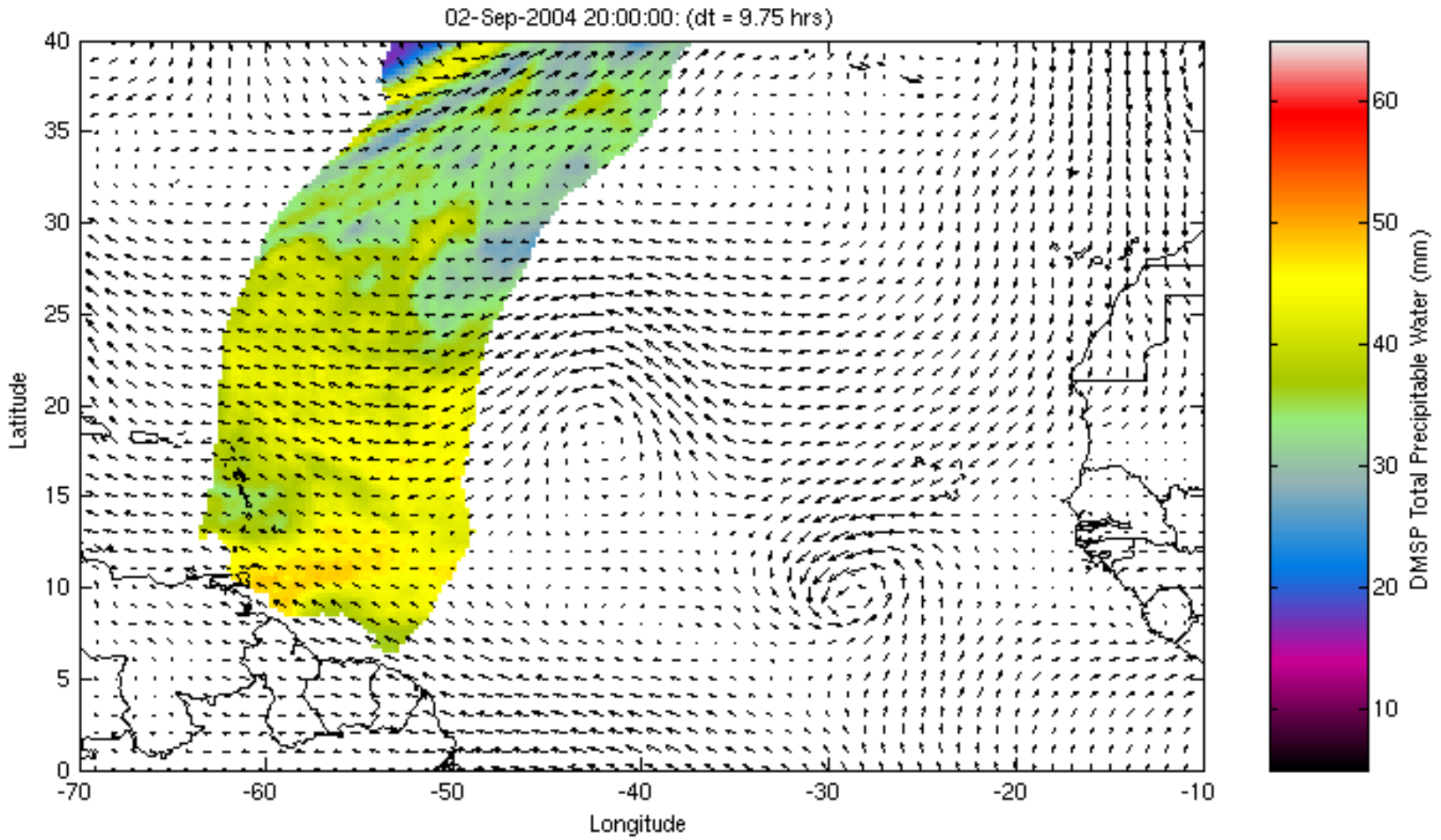
Hourly synthetic swaths



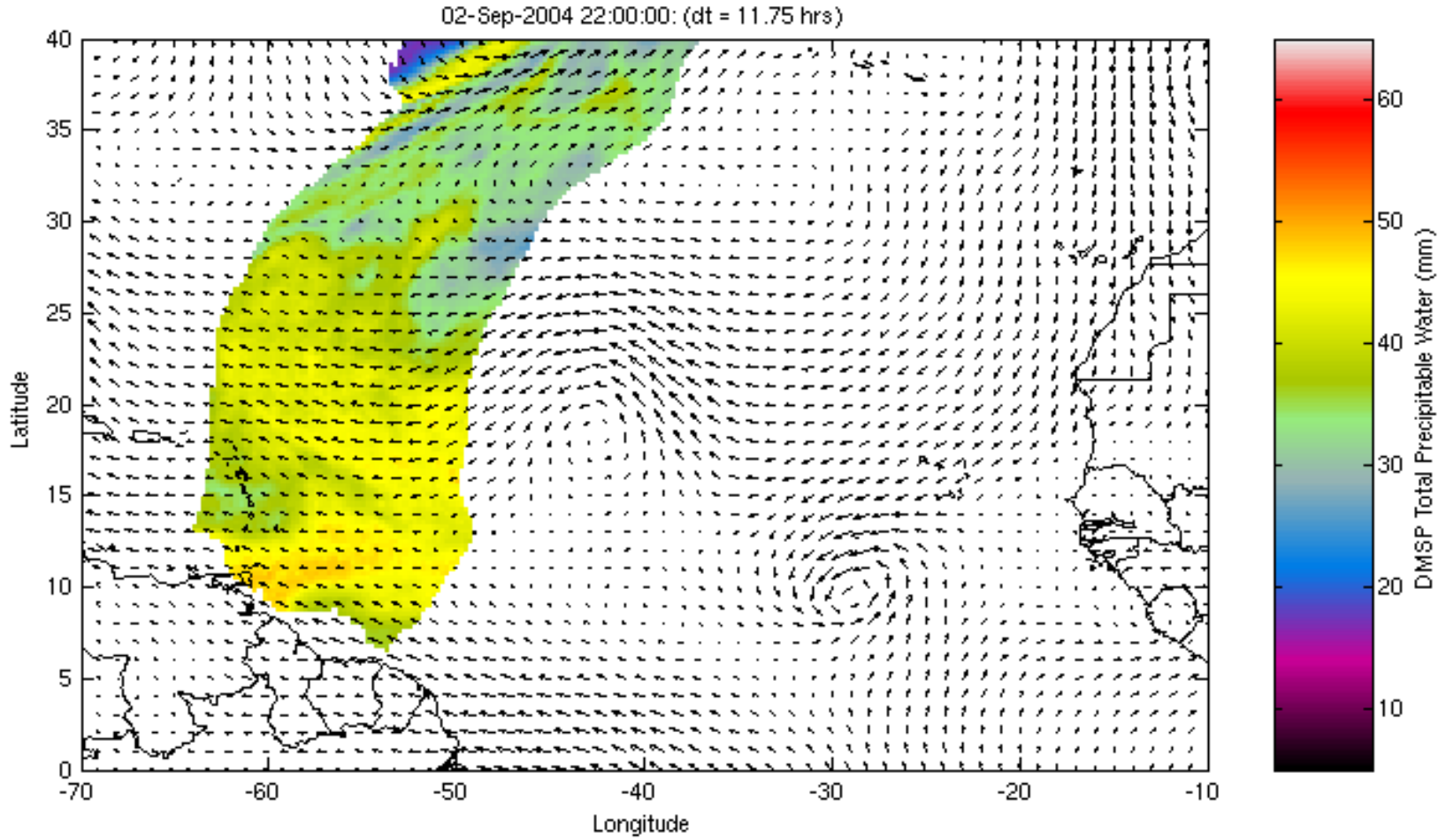
Hourly synthetic swaths

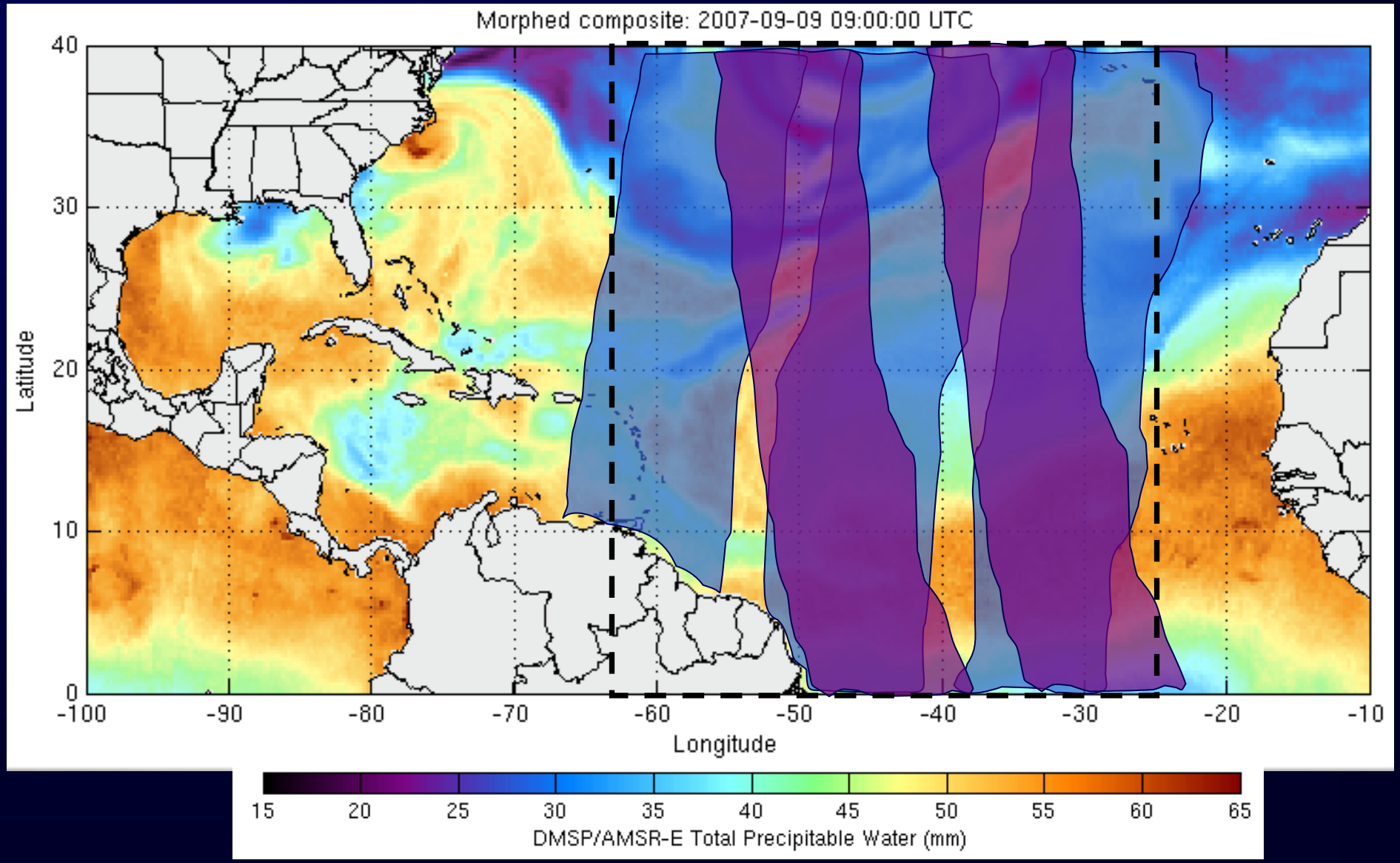


Hourly synthetic swaths



Hourly synthetic swaths

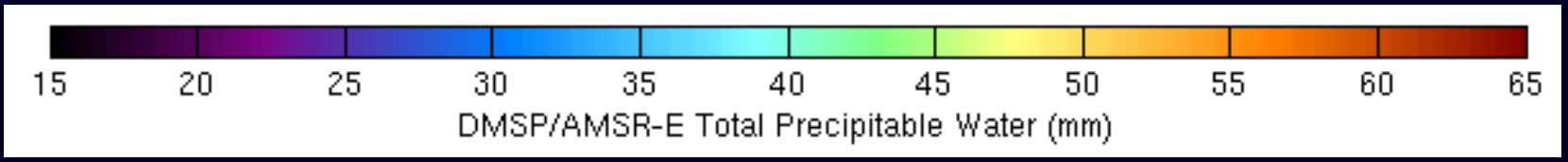




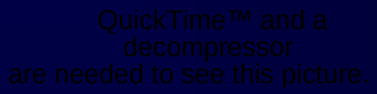
Satellite swaths → synthetic data → hourly basin composites

MIMIC-TPW North Atlantic

QuickTime™ and a
decompressor
are needed to see this picture.



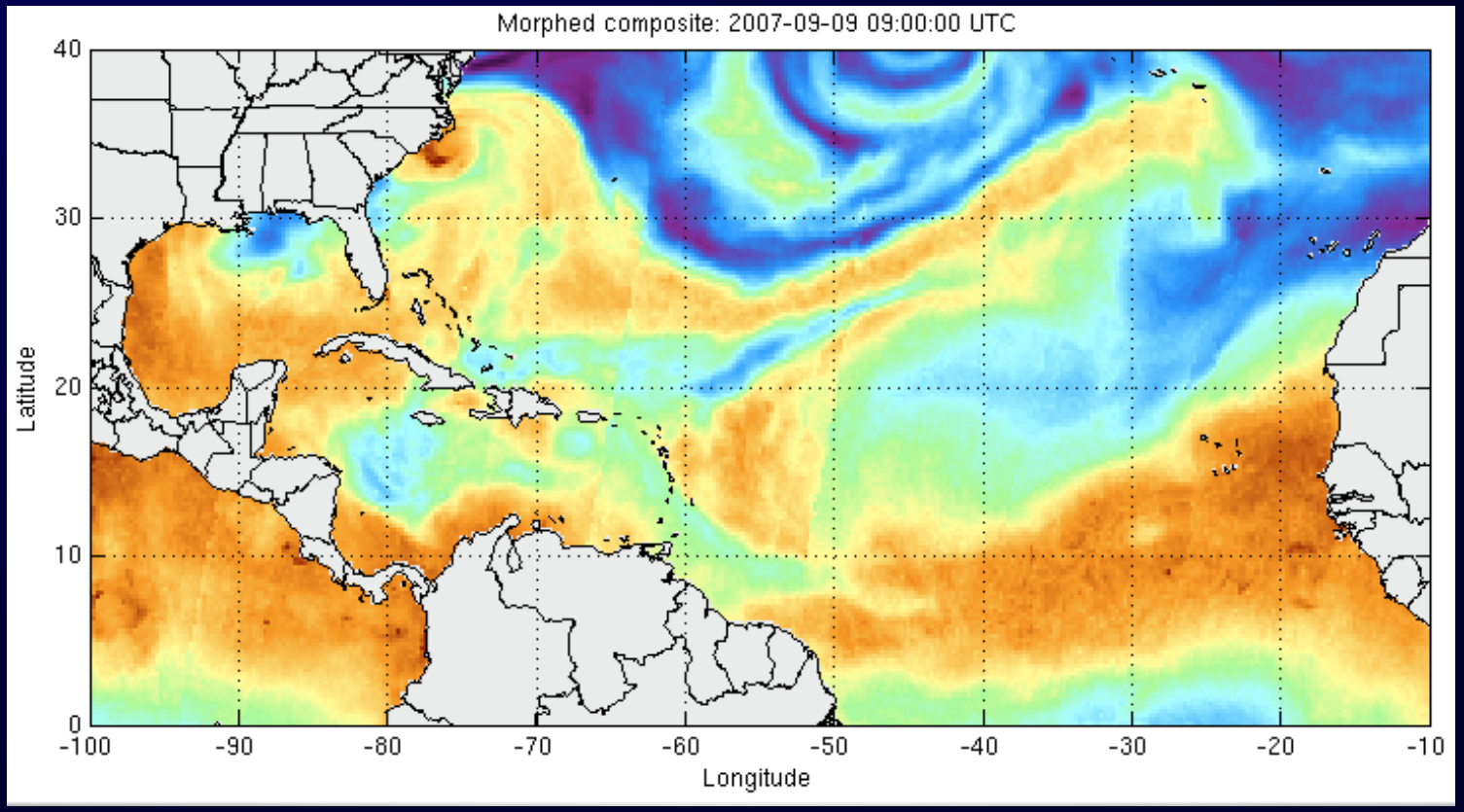
MIMIC-TPW West Pacific



Contrast: MIMIC-TC and MIMIC-TPW

	MIMIC-TC	MIMIC-TPW
Lifetime of features	Convection: ~3 hours	TPW: ~36 hours
Number of satellites	6 (barely enough)	3 (very good coverage)

Future work



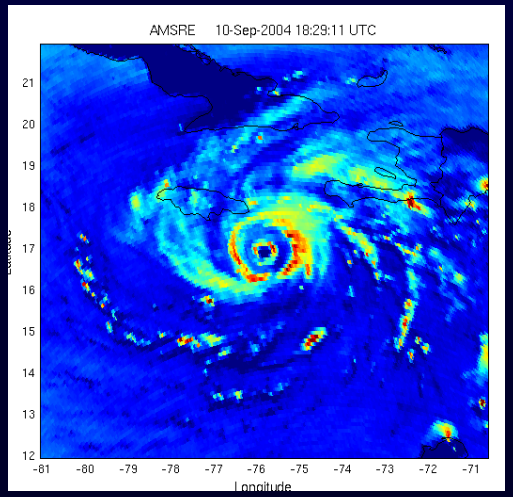
- Extend MIMIC-TPW to all TC basins (1 month)
- Extend to other long-lived tracers (aerosols?)

Online

MIMIC-TC

- Real time TCs
- Product description
- FAQ
- Archives: 2004-present

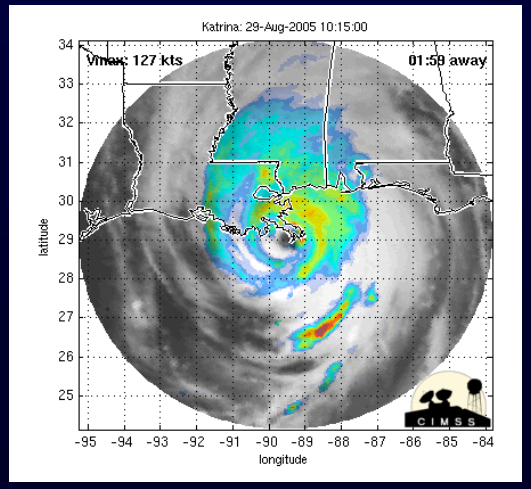
tinyurl.com/pec9s



MIMIC-IR

- Real-time TCs
- Product description
- FAQ
- Archives: 2005-present

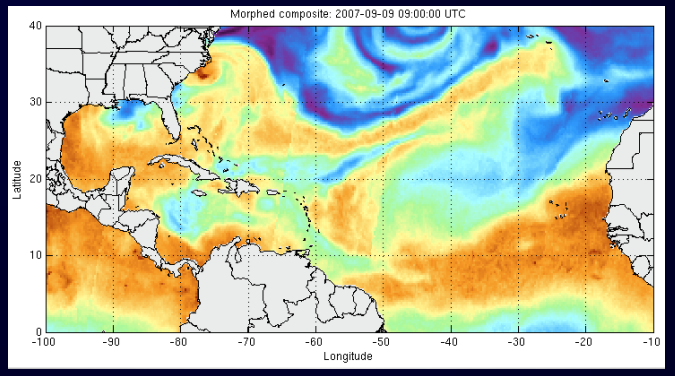
tinyurl.com/pzxlo



MIMIC-TPW

- N. Atl and W. Pac
- Product description
- Archives: from July 2007

tinyurl.com/ywoofu

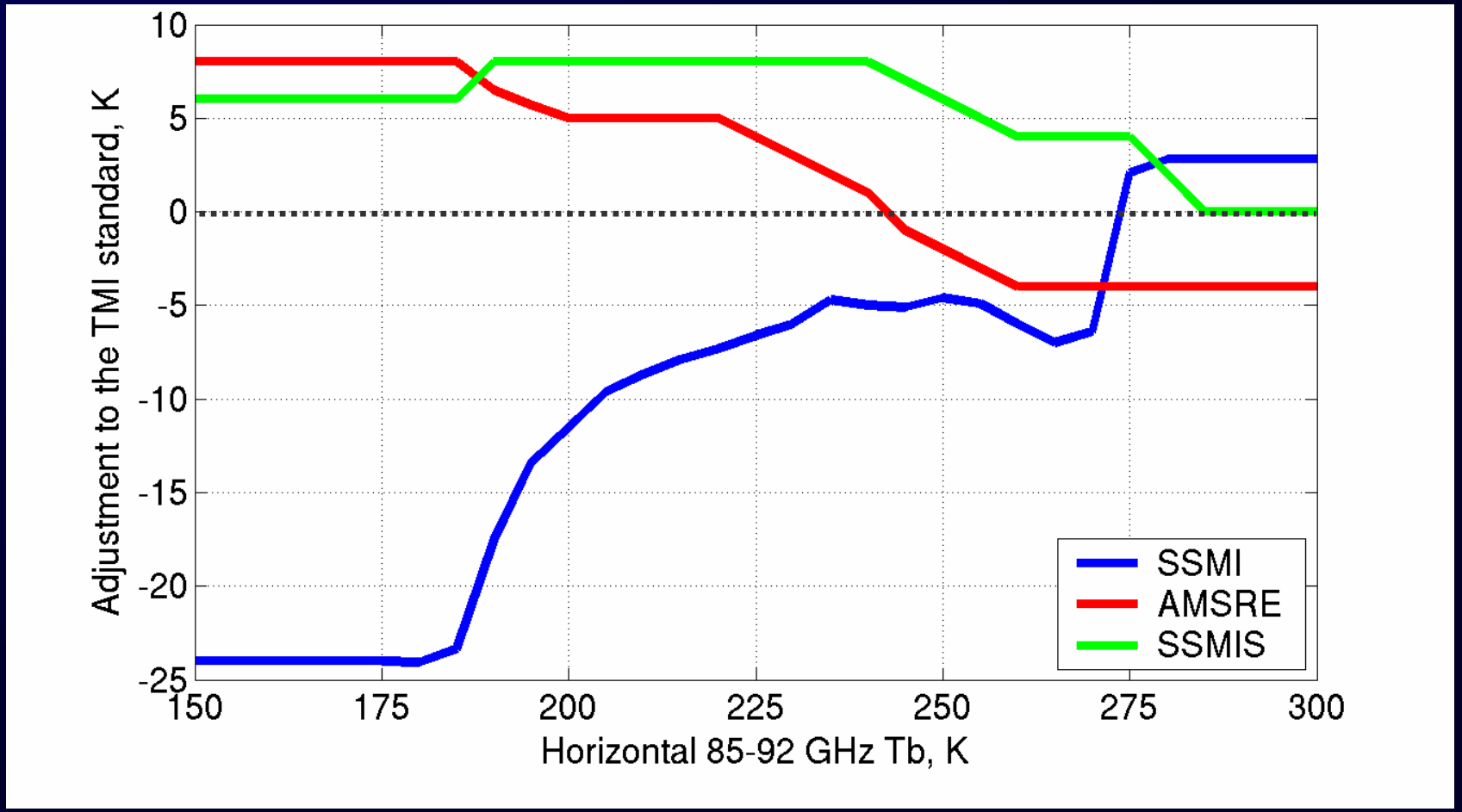


(insert 1-ivanEx avi)

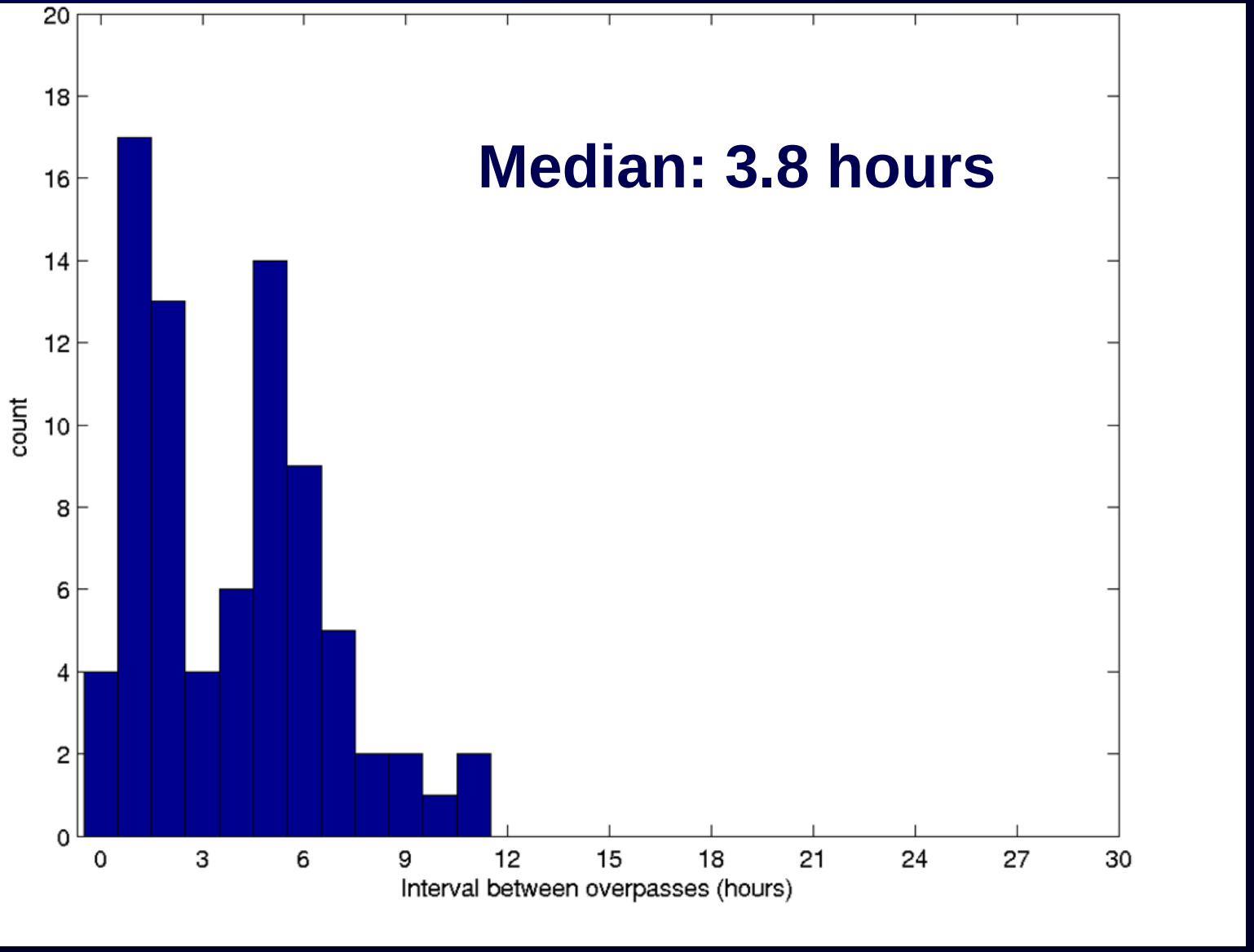
QuickTime™ and a
decompressor
are needed to see this picture.

6) Blended images regenerate once per hour

Calibrating SSMI, AMSRE and SSMIS to the ‘TMI standard’



Overpass interval for Isabel (2003)



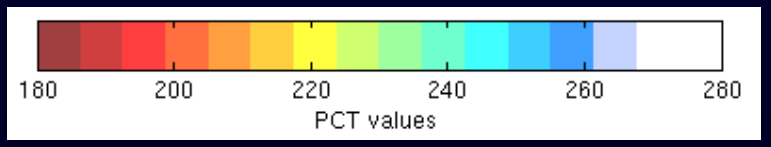
MIMIC-IR persistence forecast

All data

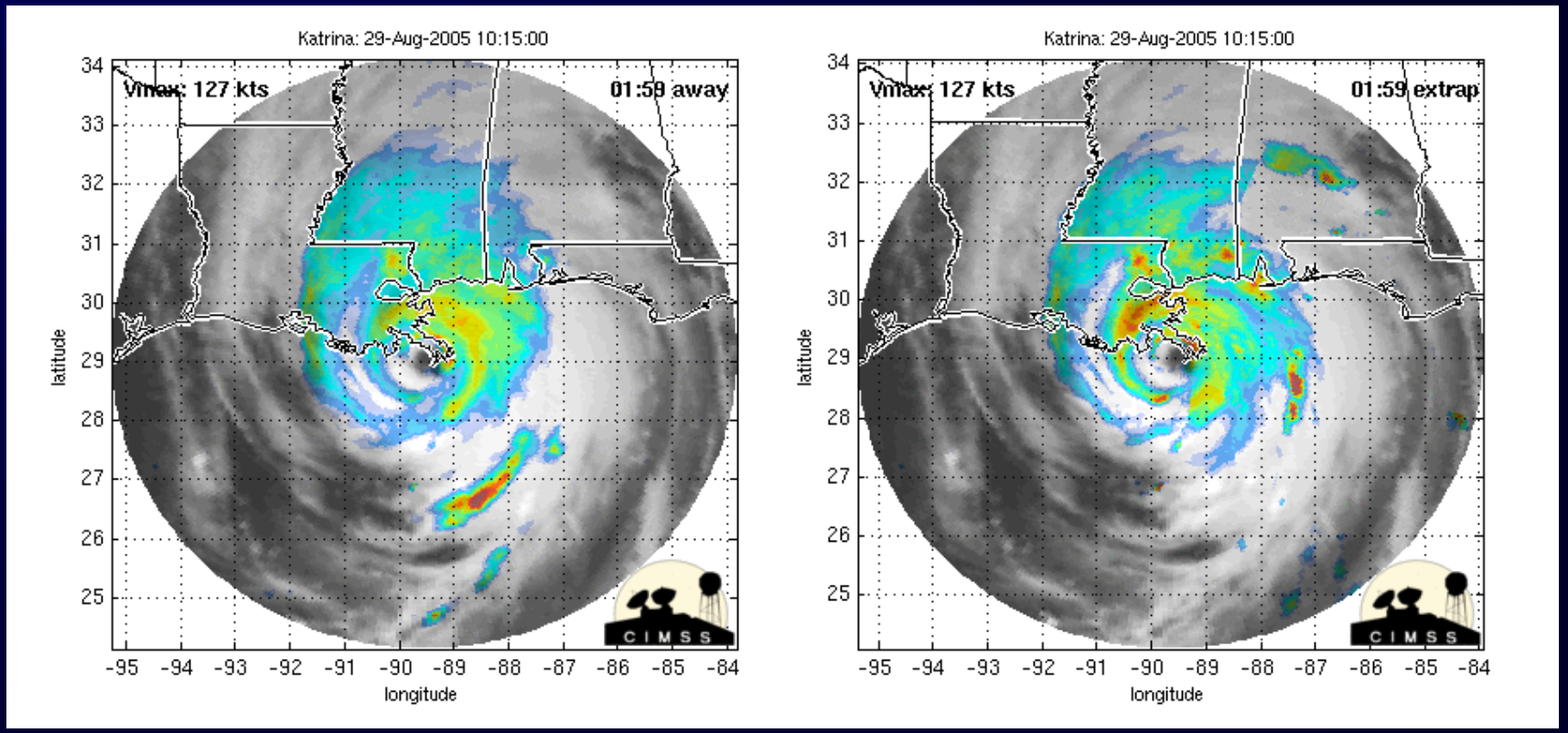
Forecast (beginning at 0800 UTC)

QuickTime™ and a
decompressor
are needed to see this picture.

(insert 6-comp avi)

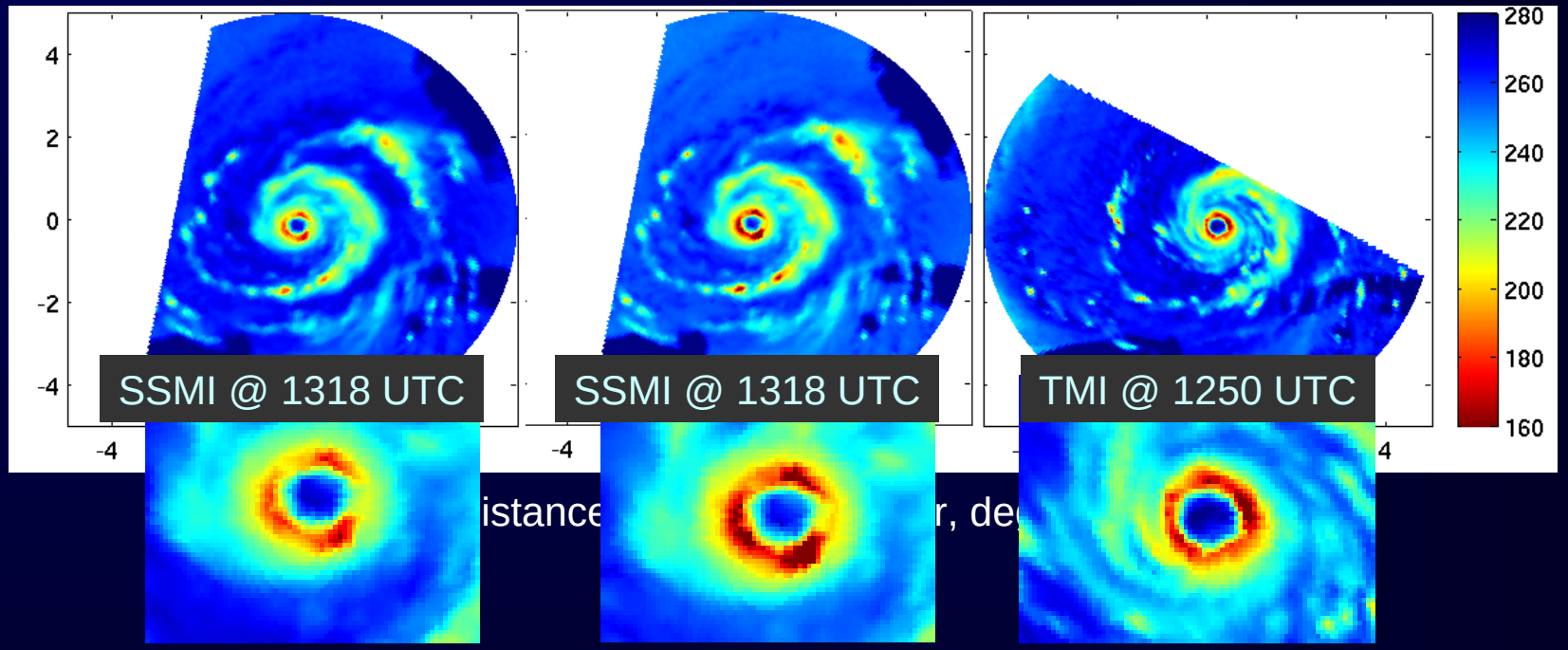


Persistence forecast: Lessons from experience



- 3-6 hours is the optimal length of a persistence forecast
- 50% of the time, this strategy yields a well-developed nowcast of the TC precipitation structure

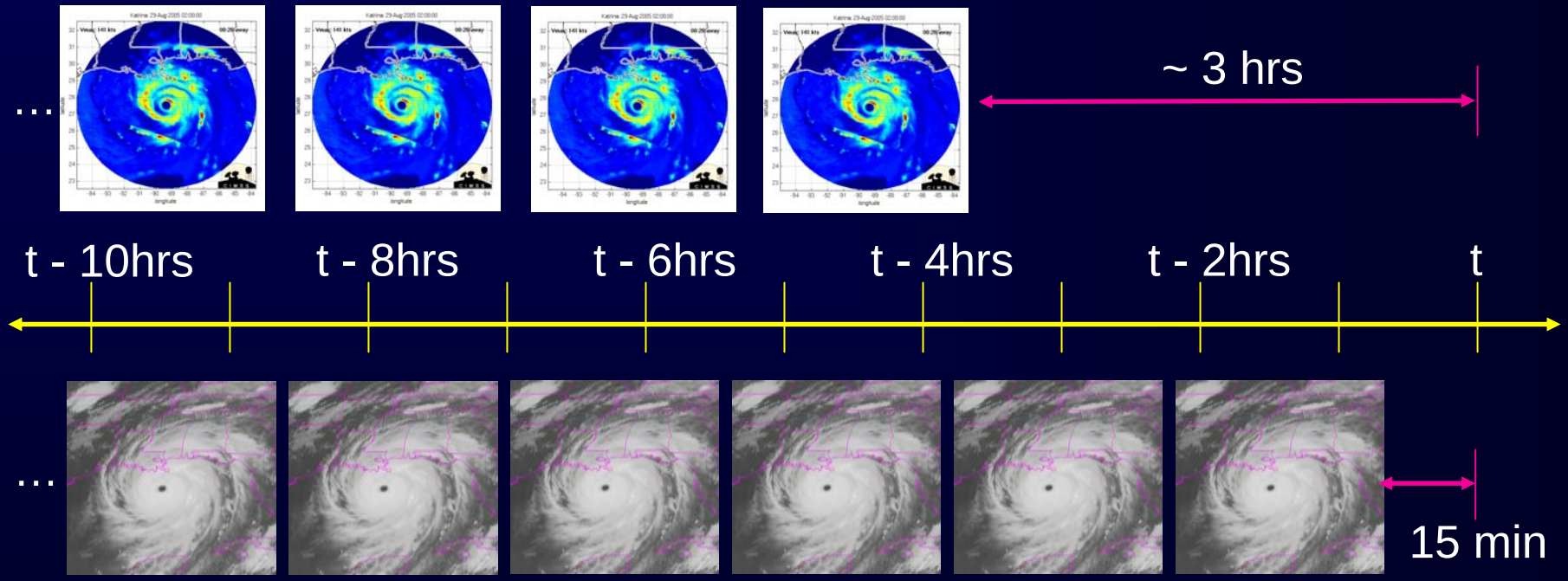
Morphing strategy



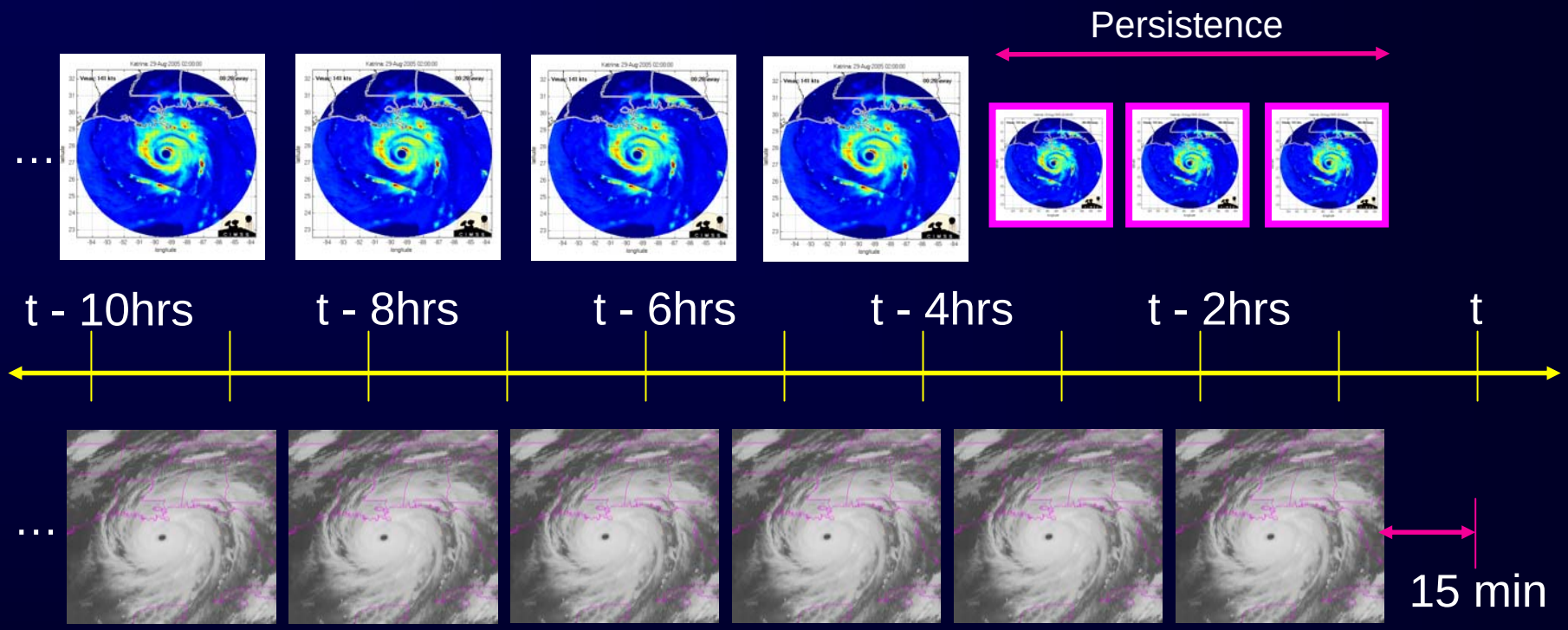
2) Brightness temp calibration

Example: Hurricane R

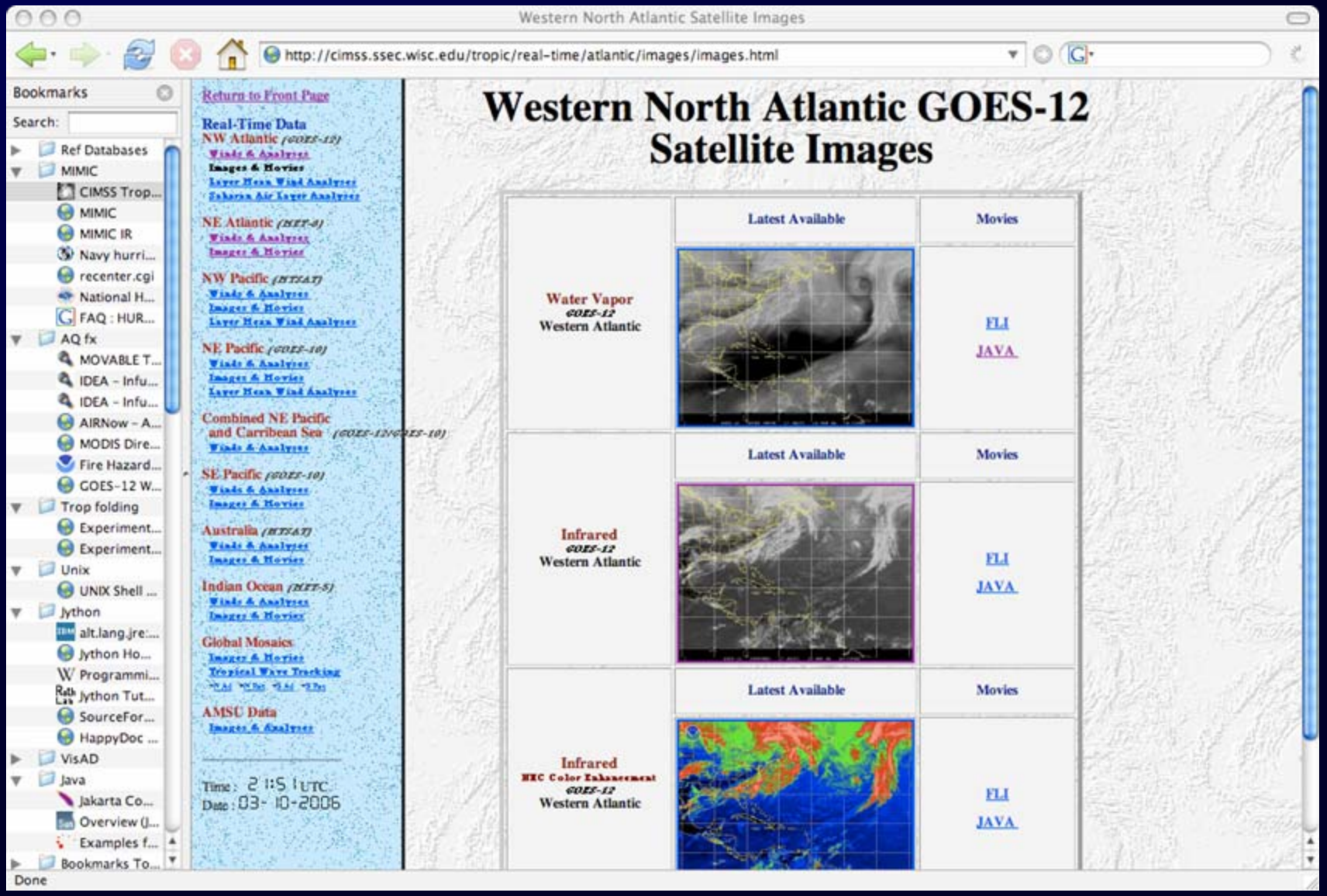
Latency issues with LEO microwave and geo IR



Microwave “persistence forecast” (for up to 3 hr latency)

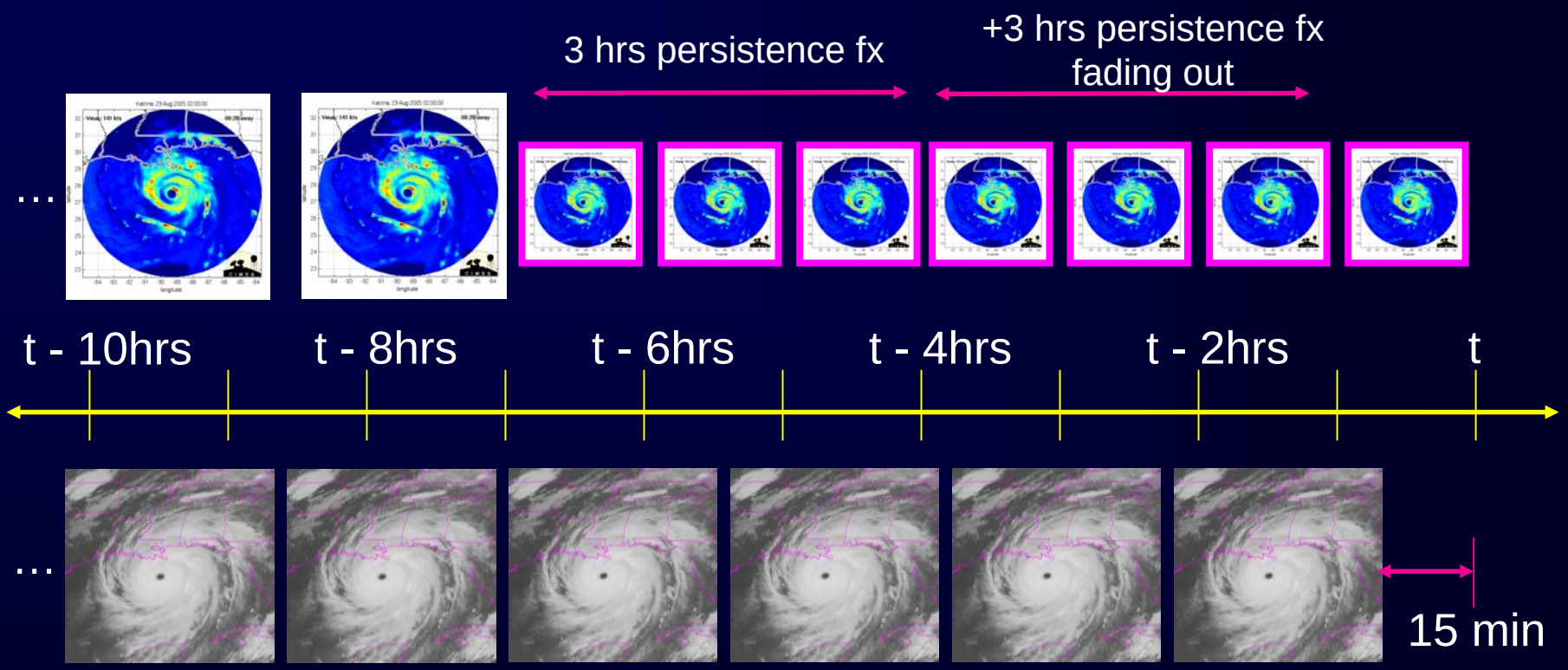


What do we do about it now?



What do we do about it now?

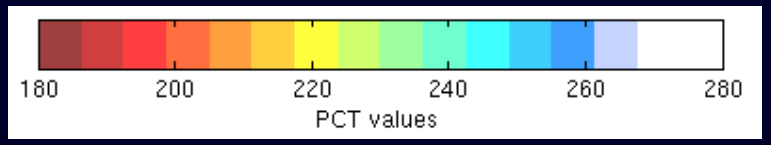
Microwave “persistence forecast” (7 hr latency)



QuickTime™ and a
decompressor
are needed to see this picture.

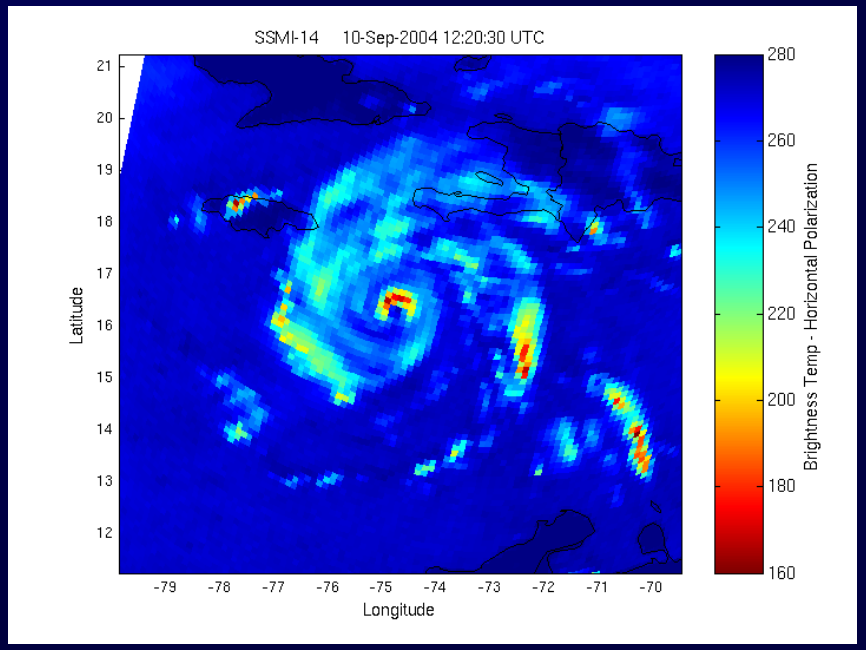
(insert 4-katIR avi)

- Microwave component uses the Polarization Corrected Temperature (PCT) - a proxy for precipitation
- The microwave layer is semitransparent
- Yellow areas are ‘no data’

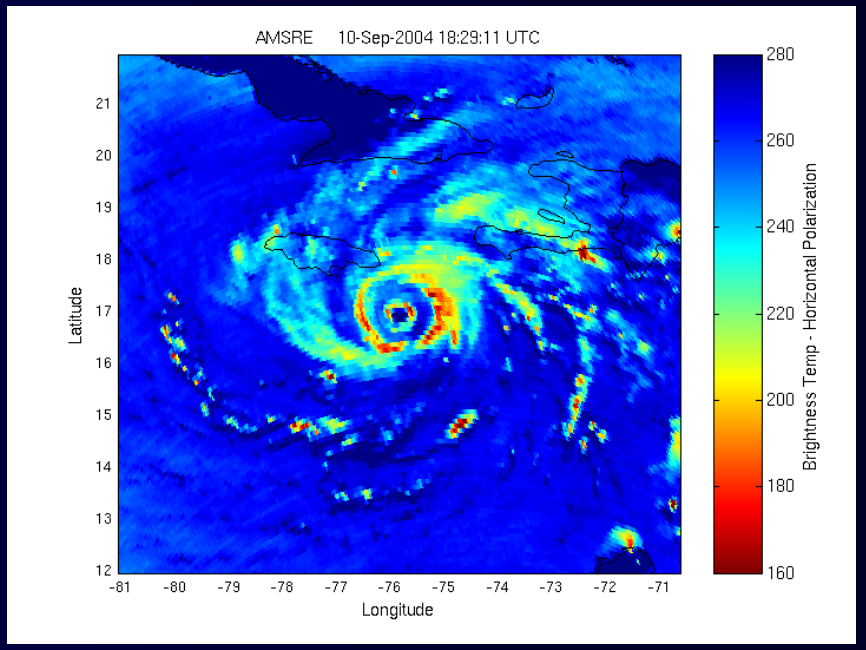


‘MIMIC-IR’: Katrina, 27-29 Aug 2005

10 Sept, 1220 UTC



10 Sept, 1829 UTC



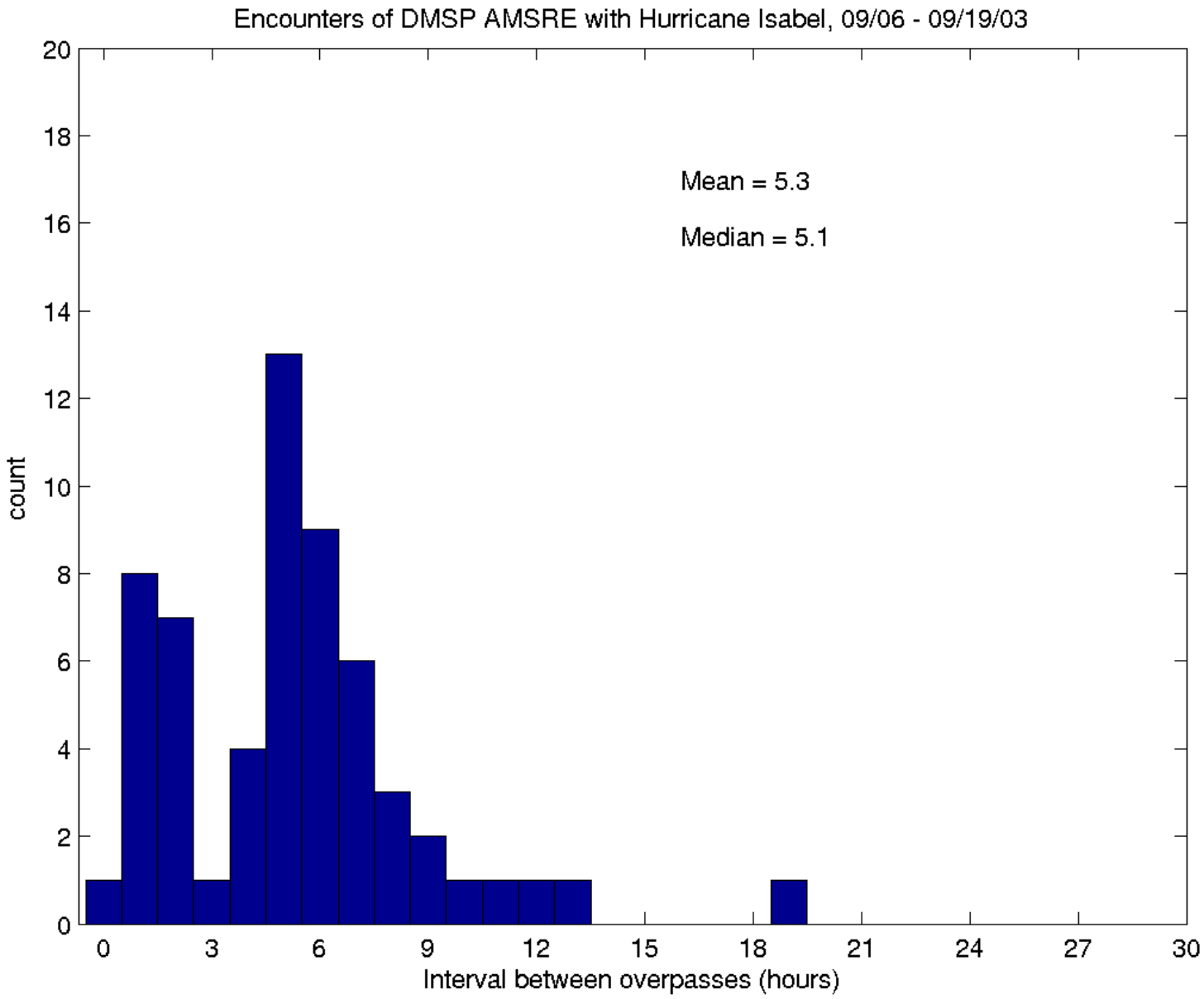
How do you deal with these obstacles to morphing?

- Average temporal spacing between images is 4-5 hours, but the lifetime of most features is shorter than that
- Smaller features advect cyclonically with the windspeed, but larger areas of convection remain quasi-stationary
- Many convective features regenerate repeatedly in the same location

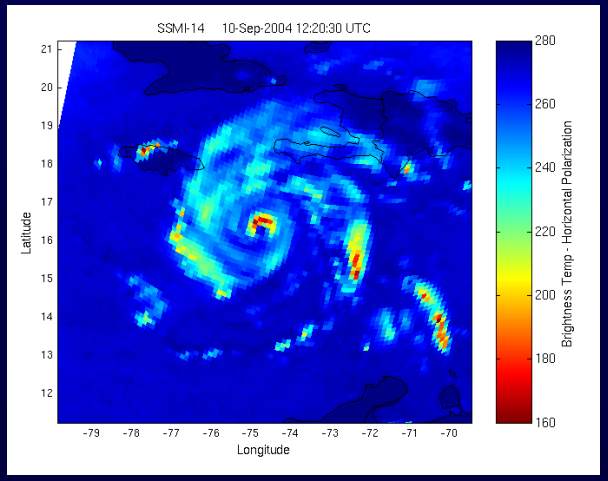
QuickTime™ and a
decompressor
are needed to see this picture.

(insert MIMIC-IR Katrina avi)

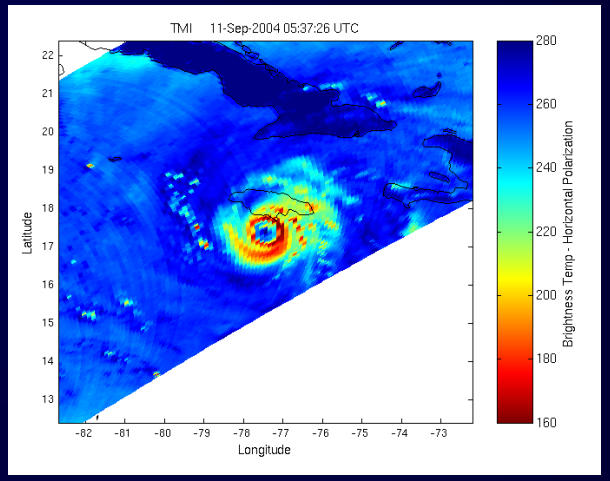
MIMIC: Morphed Integrated Microwave Imagery at CIMSS


Encounters of DMSP AMSRE with Hurricane Isabel, 09/06 - 09/19/03
Mean = 5.3
Median = 5.1
count
Interval between overpasses (hours)
0
2
4
6
8
10
12
14
16
18
20
0
3
6
9
12
15
18
21
24
27
30

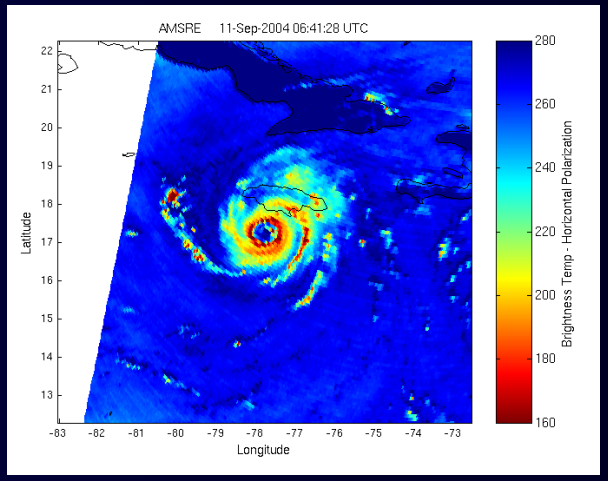
85-91 GHz microwave band



DMSP SSM/I



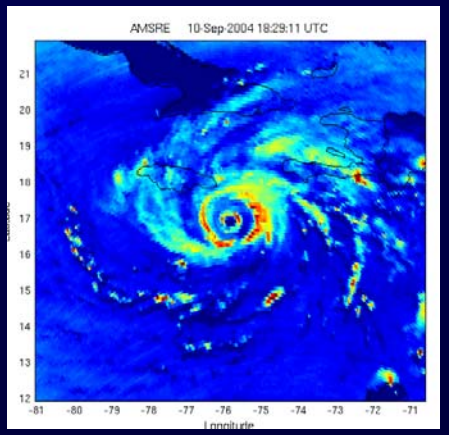
TRMM TMI

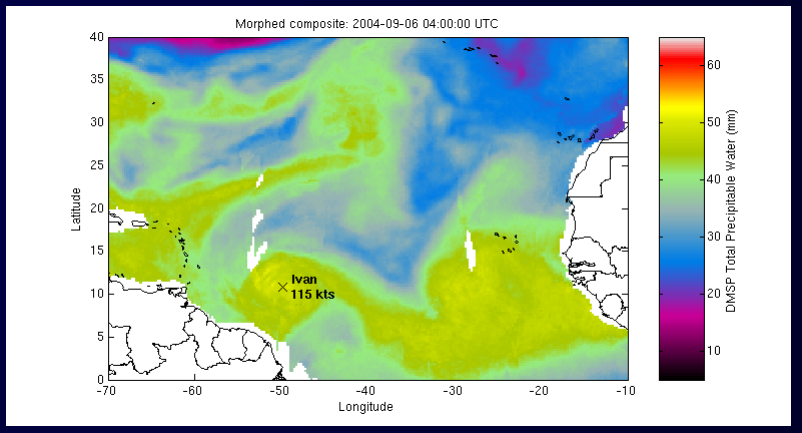


Aqua AMSR-E

- 85-91 GHz channels of the: DMSP 13/14/15 SSM/I, DMSP 16 SSMIS, TRMM Thematic Mapping Imager (TMI) and Aqua AMSR-E
- Global coverage

Main conclusion





Morphing does not add information to the image sequence from which it is built, but it can make the image sequence incredibly easier to visualize

Tradeoffs of morphing

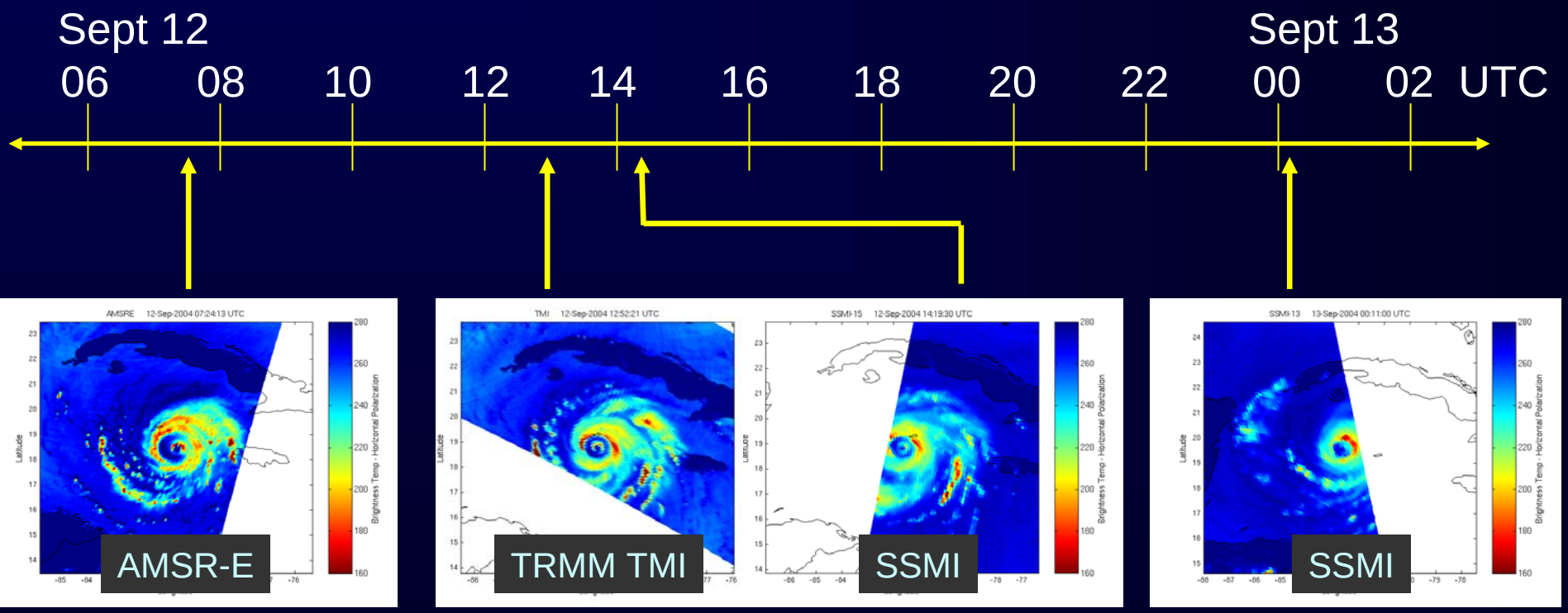
Advantages

- Easier to interpret than irregularly-spaced image sequences (makes the most of the original imagery)
- Can be calculated quickly on a desktop computer (on the order of minutes) without an atmospheric model or radiative transfer model

Disadvantages

- Still smoothes out the spatial detail somewhat
- Not sufficient for capturing transitions in rapidly developing events (cumulus development, rotation inside eyewall)
- Morphing can be deceptively convincing, even when it's done wrong

Problem: Irregular time gaps in LEO microwave imagery



Example: Hurricane Ivan (2004)