Optimized multi-sensor application in the ARCHER automated center-fixing algorithm

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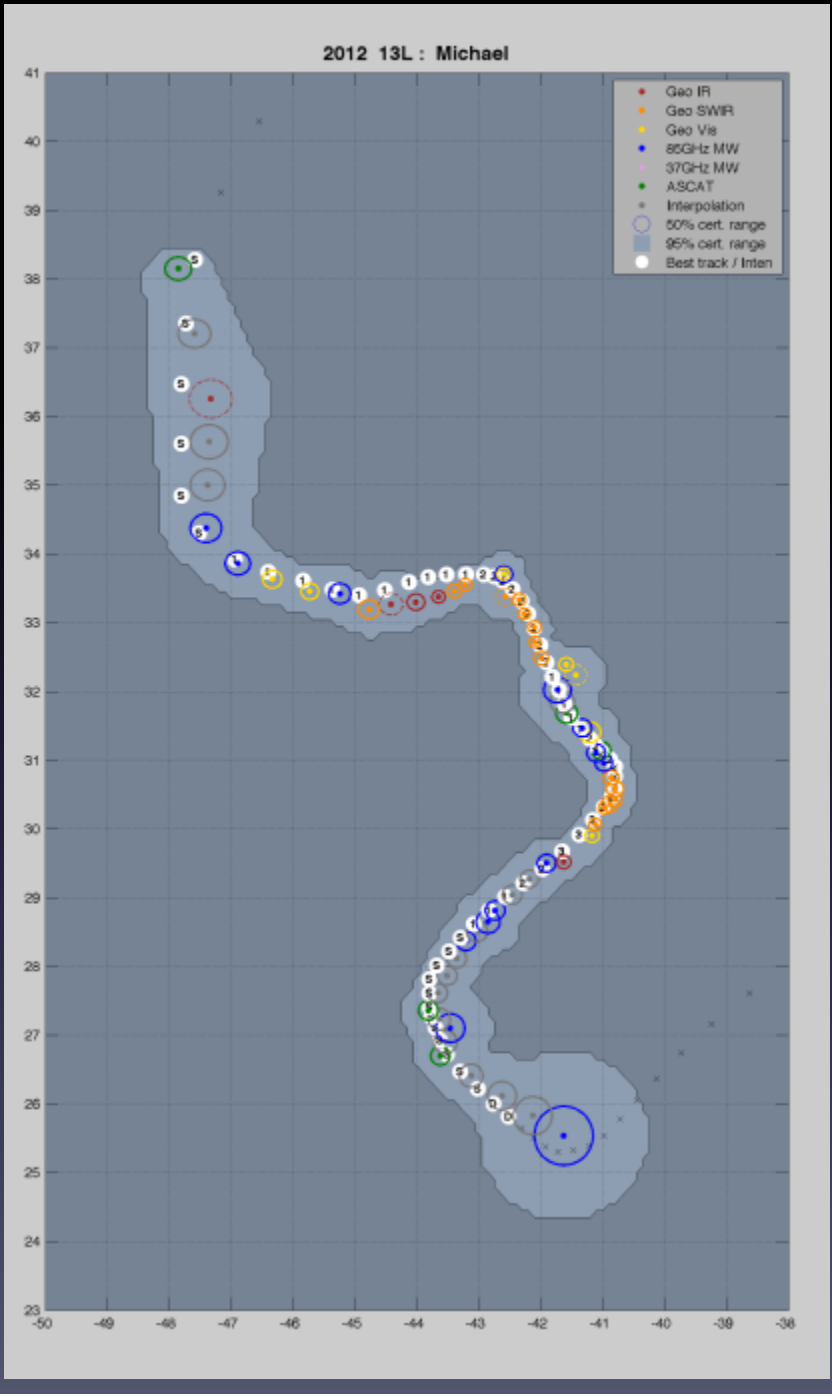
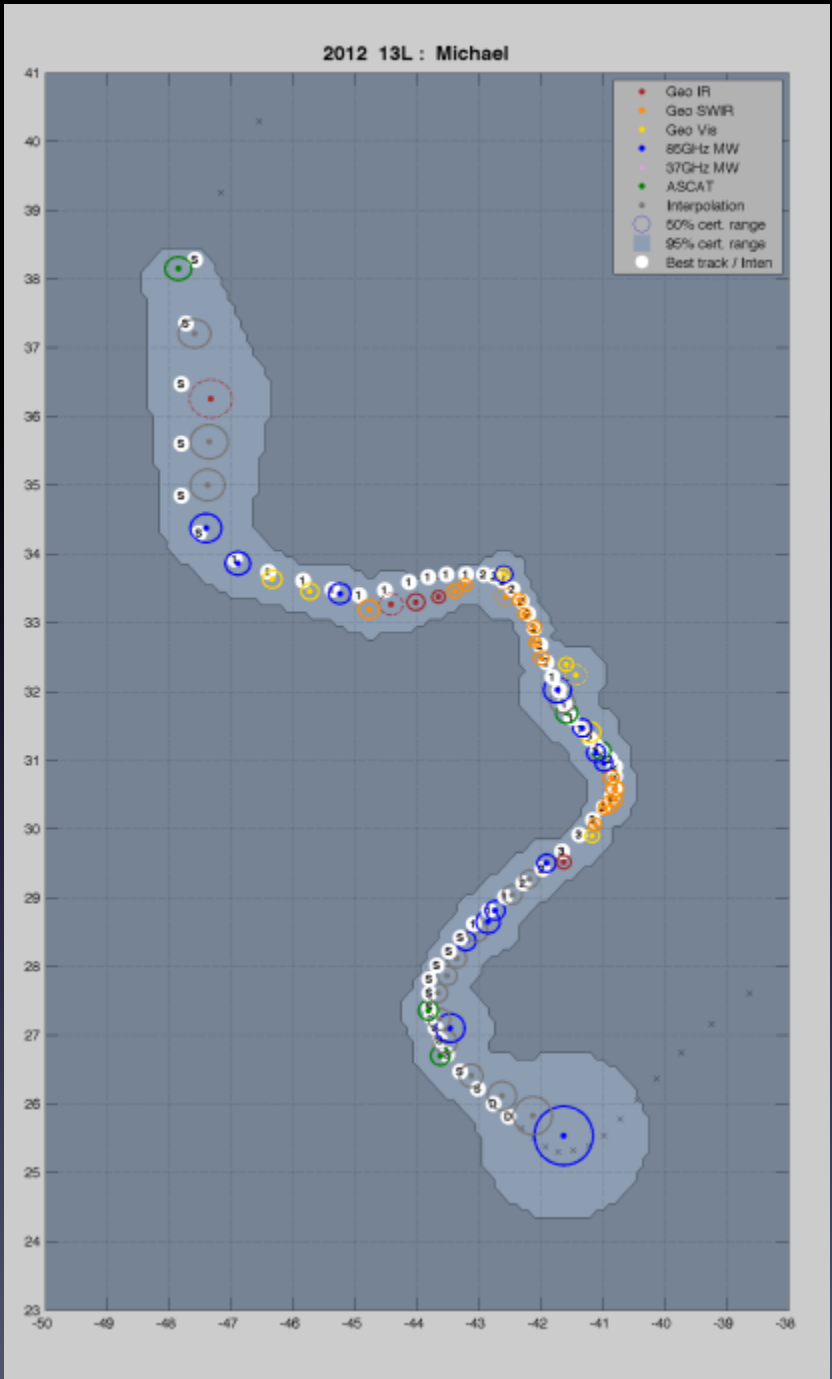
R&D supported by the Naval Research Lab and Office of Naval Research (PE 0602435N)
Operational evaluation by the NOAA Joint Hurricane Testbed



Objectives

- Create an automated, real-time TC center-fixing tool that intelligently employs all available multispectral satellite data.
- Provide objective fix guidance for TC analysts/forecasters based on algorithm results.
- Integrate the output into a track history.

ARCHER: Automated Rotational Center Hurricane Eye Retrieval



Project

- R&D of ARCHER supported by NRL/ONR
- The two-year project with the Joint Hurricane Testbed includes:
  1. Validation of the ARCHER scheme under simulated real-time conditions
  2. If approved, implement an experimental version of ARCHER within JHT framework
  3. Final evaluation and adaptations to provide an operational, real-time algorithm

(This presentation focuses on #1, with a discussion of the impacts on 2 and 3.)

Potential Benefits of ARCHER

To resolve a TC fix, assume an analyst considers all available geostationary images and polar satellite sources. That would include near-infrared, far-infrared, visible, multiple-frequency microwave, and scatterometer observations (plus non-satellite sources…)

All of the above data sources have inherent limitations and strengths based on both sensor type/capability and situation.

ARCHER will integrate all of the above information to provide an **objective** and **quick interpretation** of the TC path as indicated by the available multispectral satellite data, with corresponding information on position confidence and the most reliable satellite sources.

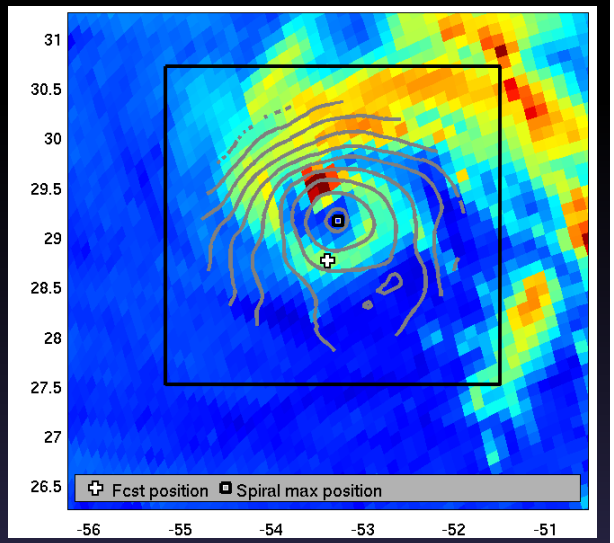
Core Principle

An algorithm cannot replace the expert judgment of human analysts, but that is no reason to deny them the best information an algorithm can compile from a mountain of data.

The ARCHER algorithm

- Processing takes place in two stages:

1. **Image analysis**
   - Determination of center-fix, center-fix confidence, additional statistics



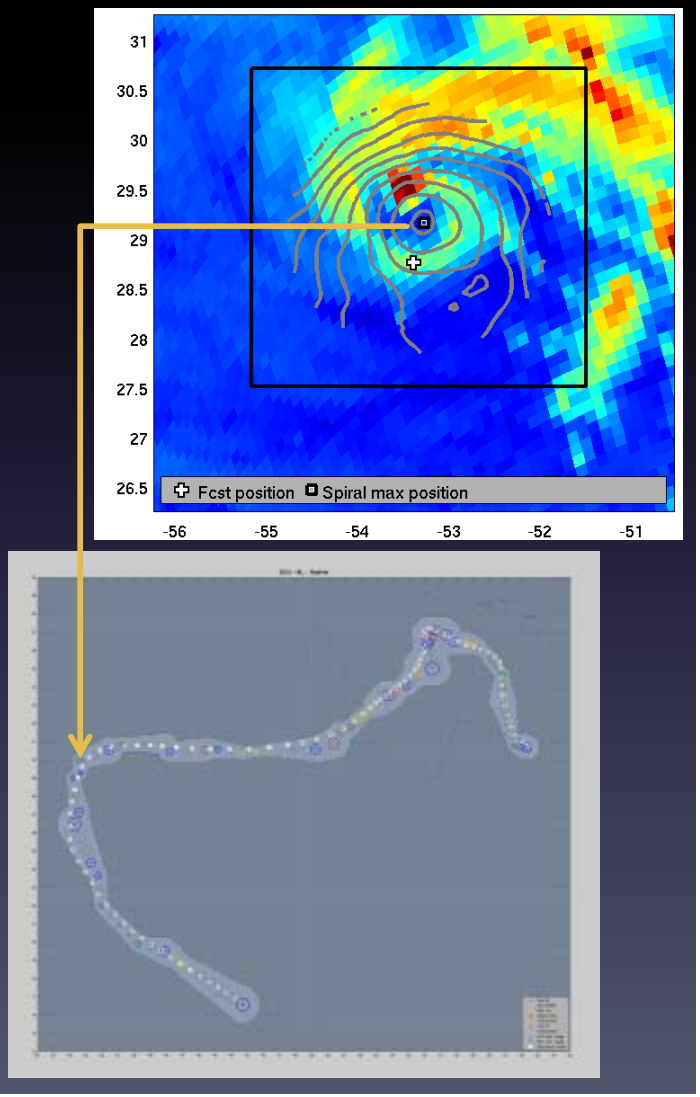
Additional information can be found in Wimmers, A. and C. Velden, 2010: Objectively Determining the Rotational Center of Tropical Cyclones in Passive Microwave Satellite Imagery, *J. Appl. Meteor.*, 49, 2013–2034, 2010.

The ARCHER algorithm

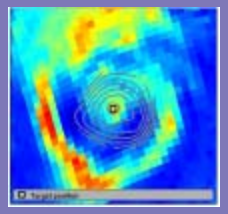
- Processing takes place in two stages:

1. **Image analysis**
   - Determination of center-fix, center-fix confidence, additional statistics

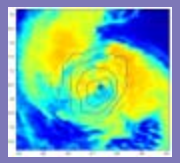
1. **Integration into storm track ("ARCHER-Track")**
   - Selection of the best observation within the time window
   - Clean presentation of output



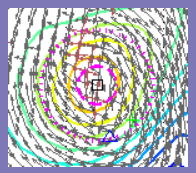
ARCHER: Image analysis ("Stage 1")



Microwave,

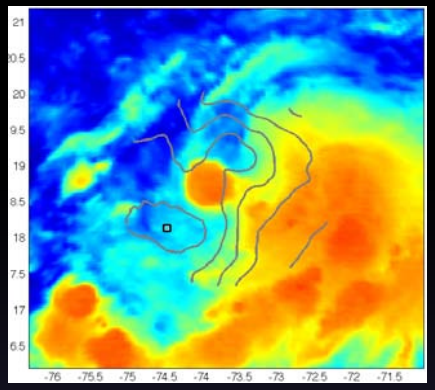


GEO (Visible, Near-IR, IR),



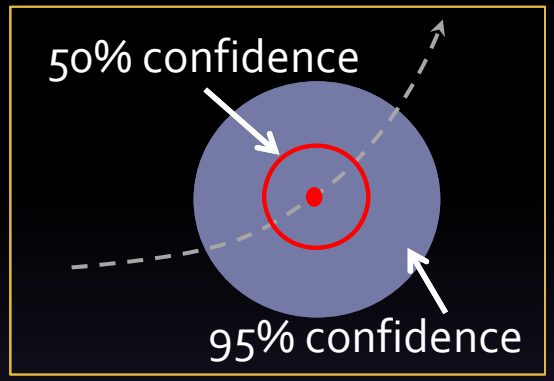
ASCAT

New imagery



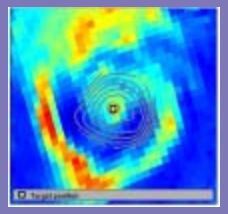
ARCHER score field (contours)

Low confidence score

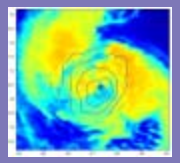


Probabilities of center-fix expected error

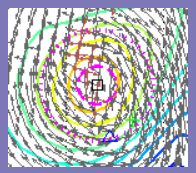
ARCHER: Image analysis ("Stage 1")



Microwave,

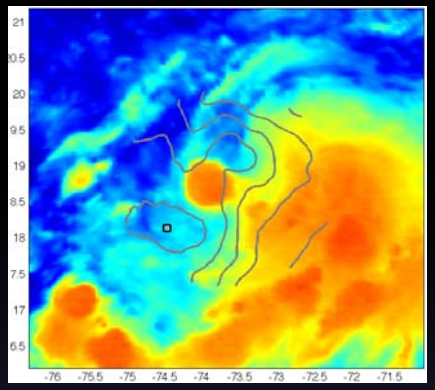


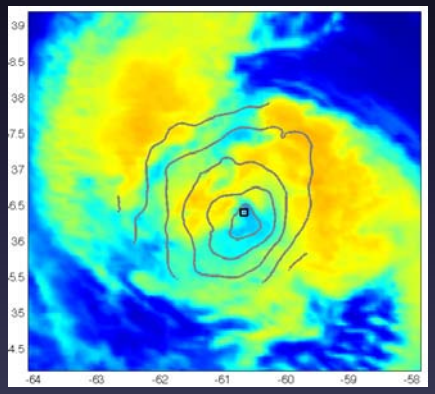
GEO (Visible, Near-IR, IR),



ASCAT

New imagery

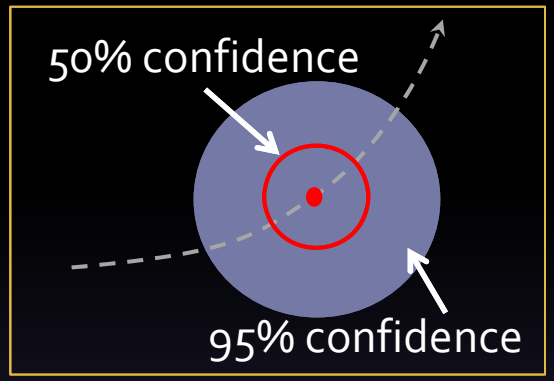


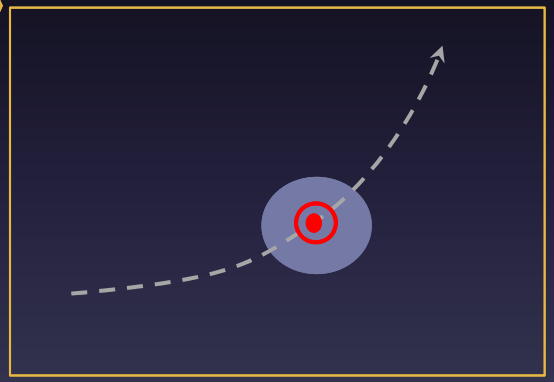


ARCHER score field (contours)

Low confidence score

High confidence score





Probabilities of center-fix expected error

Calibration of expected error

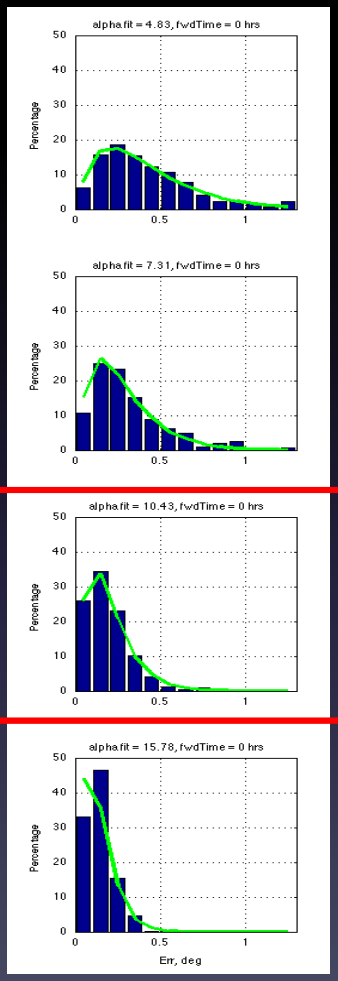
@ image time

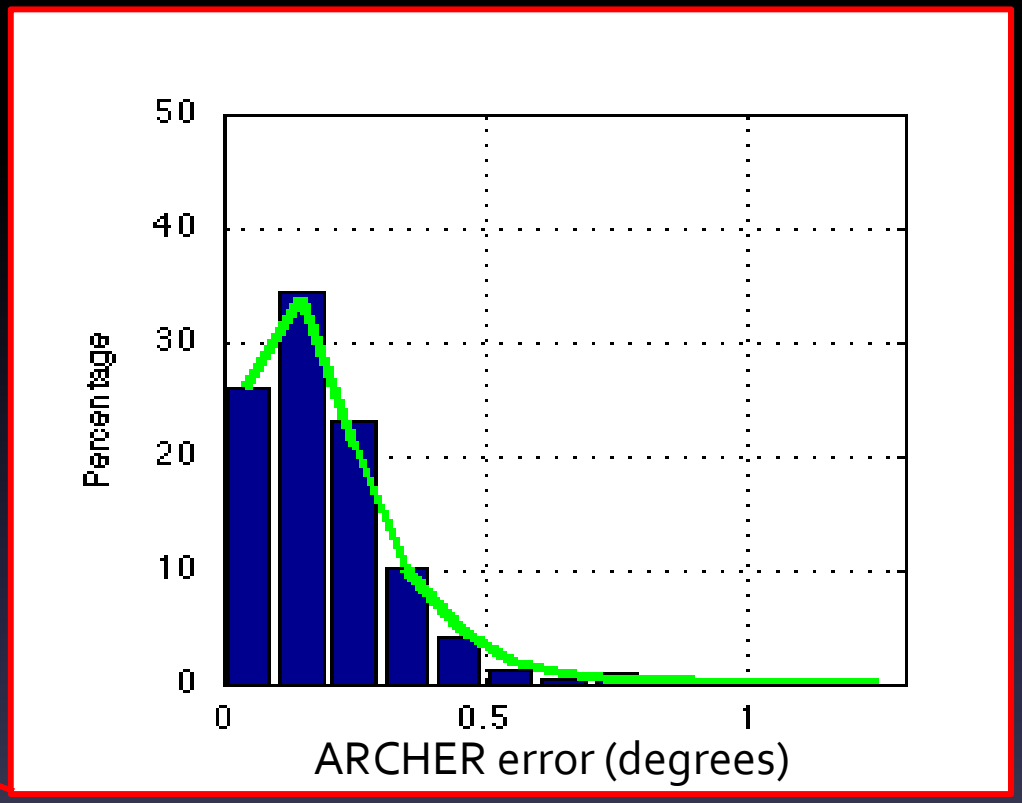
Lowest confidence scores

Second lowest

Second highest

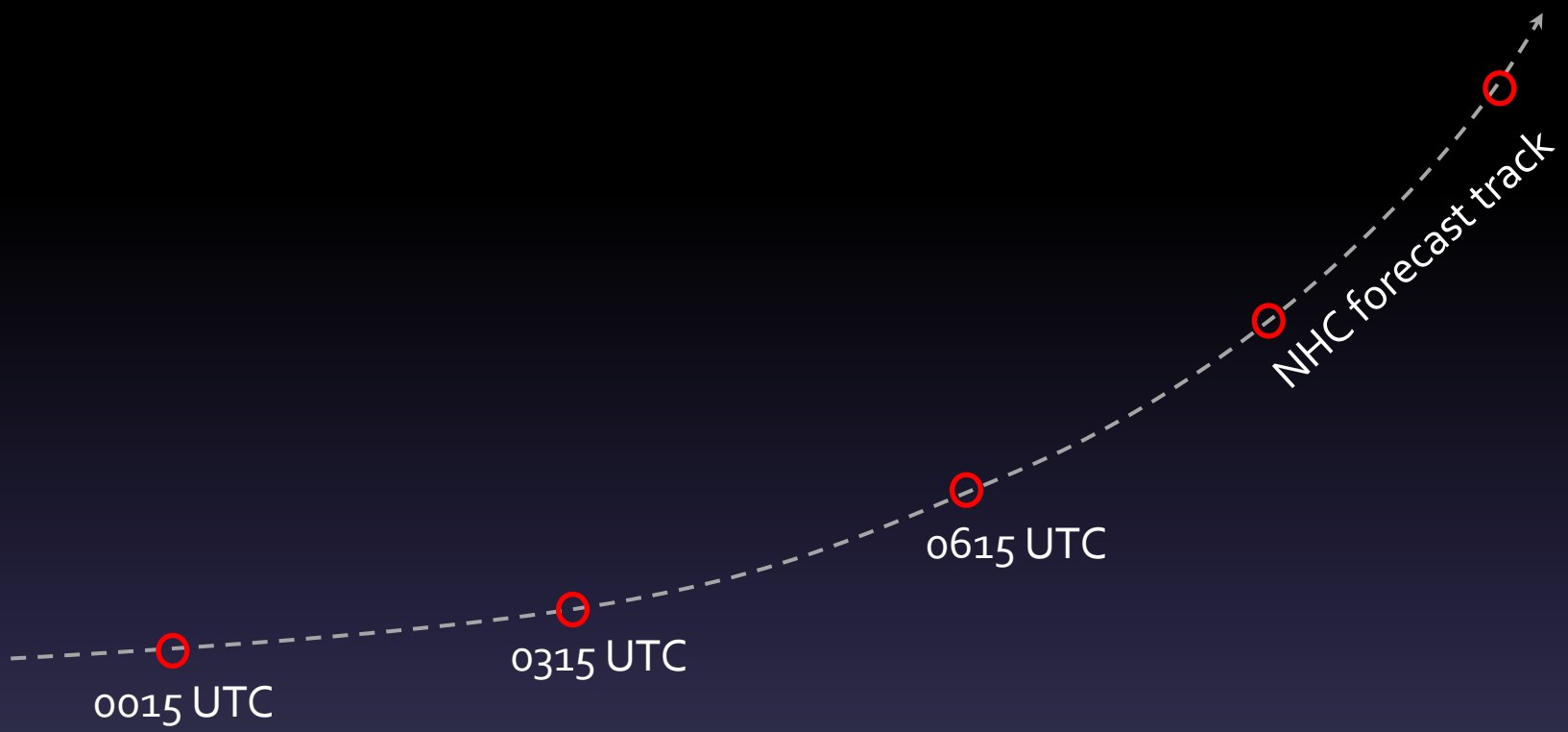
Highest





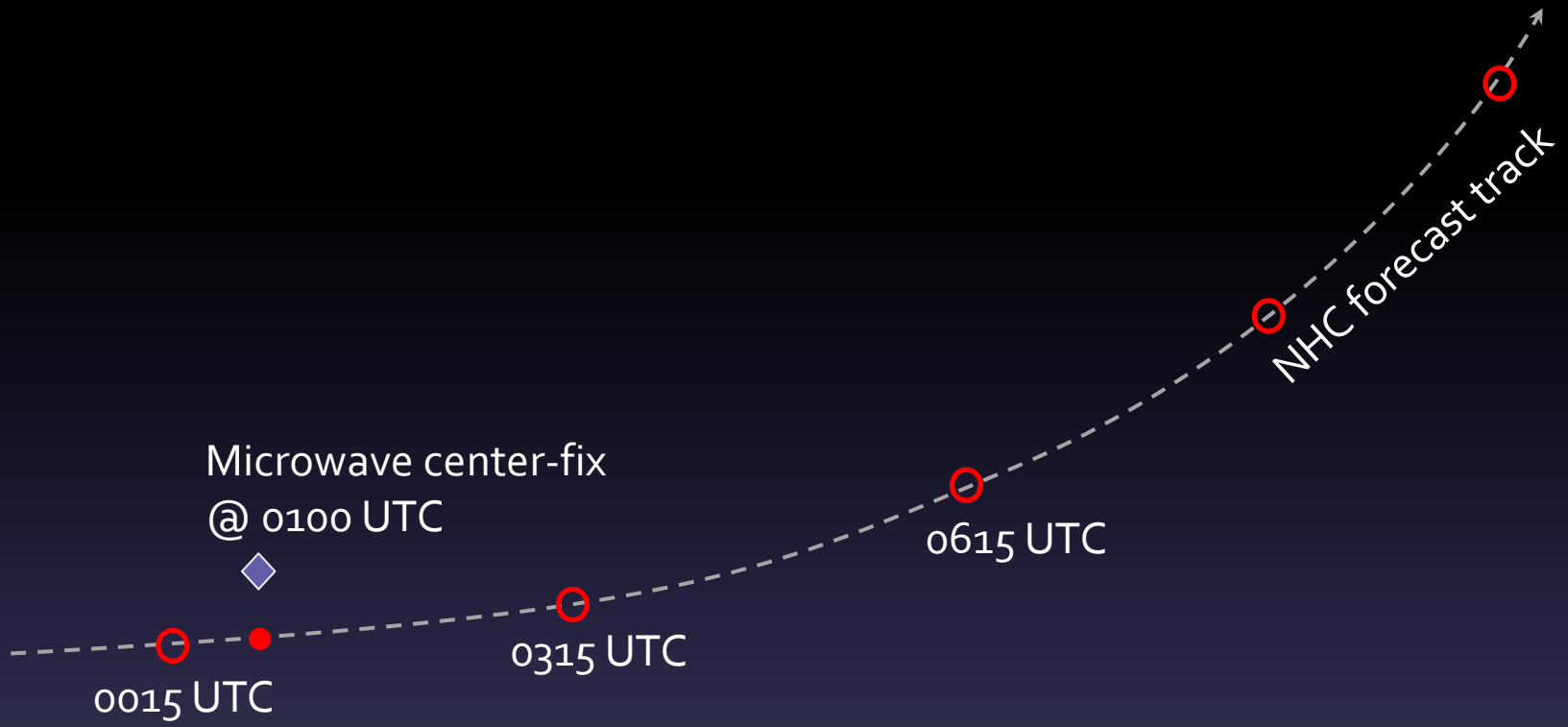
Possion-curve fit of the ARCHER error for 85 GHz (H) imagery (w.r.t. the NHC best track) – 2006-2011 NATL dataset.

Adjustment to common timestep

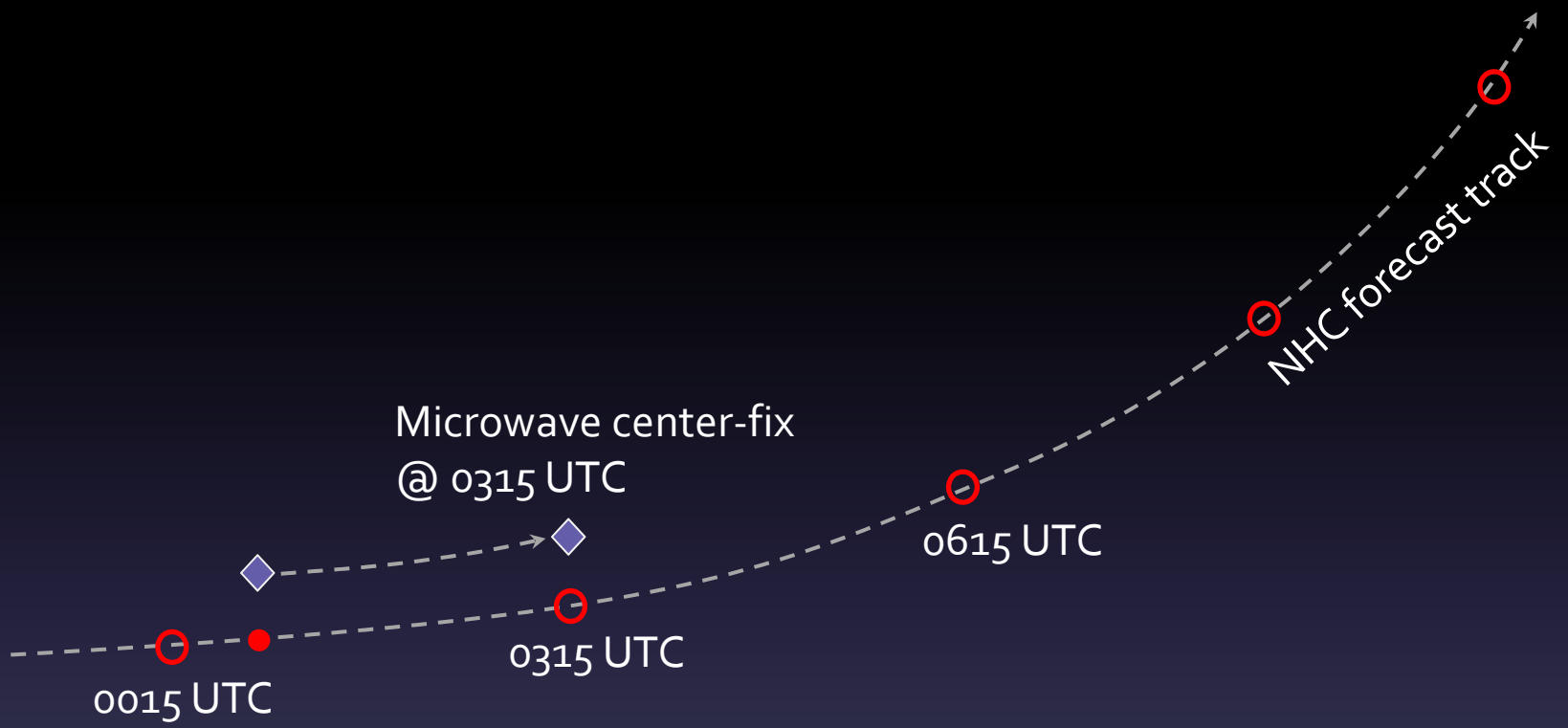


Polar orbiter results are "nudged" to the common timestep using the latest available NHC forecast track.

Adjustment to common timestep

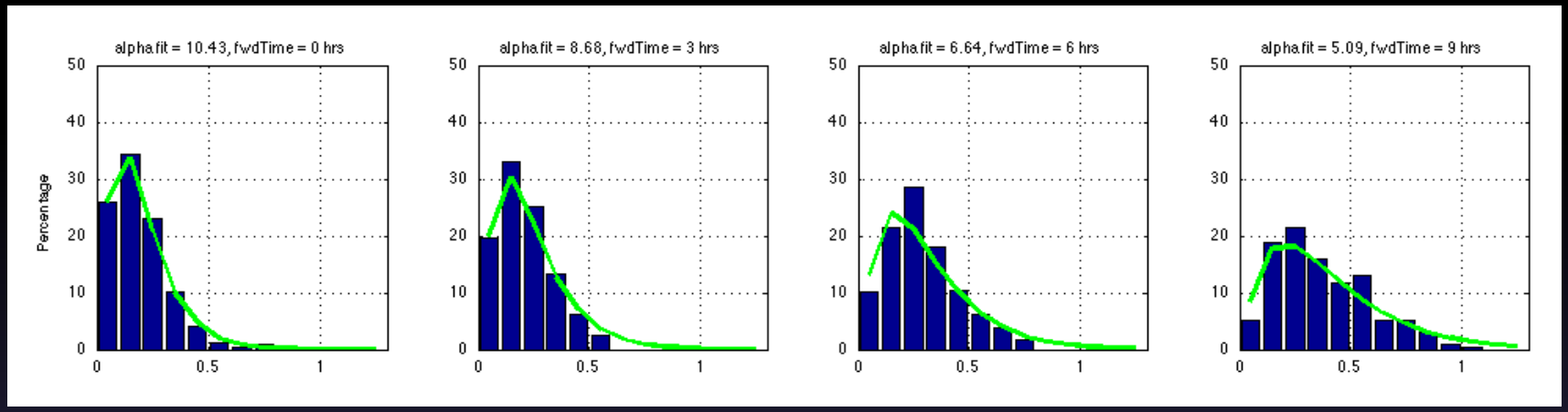


Adjustment to common timestep



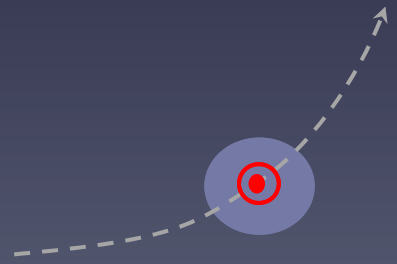
Calibration of expected error

@ image time +3 hrs +6 hrs +9 hrs



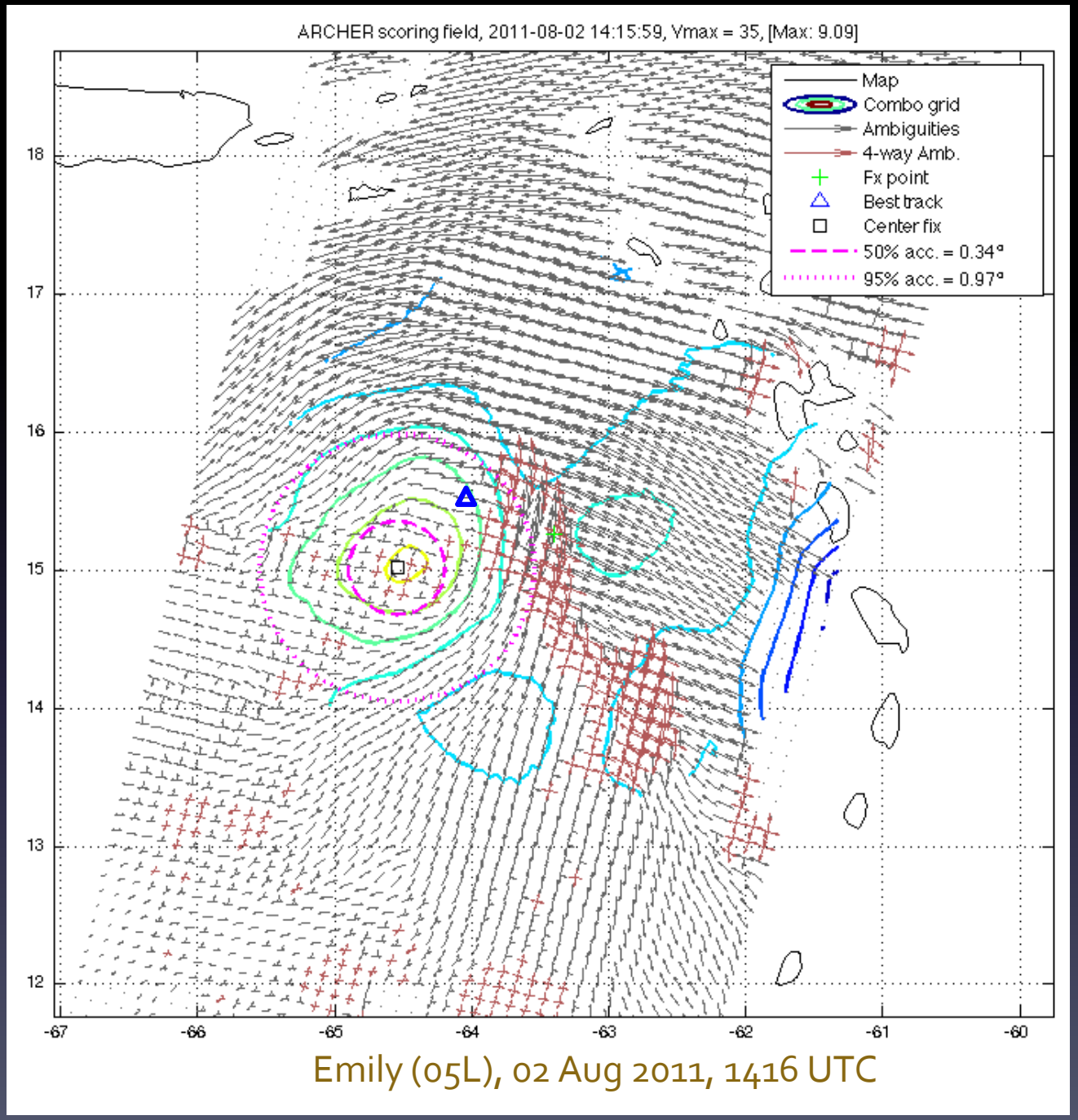
Possion-curve fit of the ARCHER error for 85 GHz (H) imagery , "nudged" by 0, 3, 6, and 9 hours.

- Expected error function (green line) is a well-defined function of ARCHER confidence score and adjustment time. That means that the expected error regions are *very* robust.



ARCHER: Image analysis

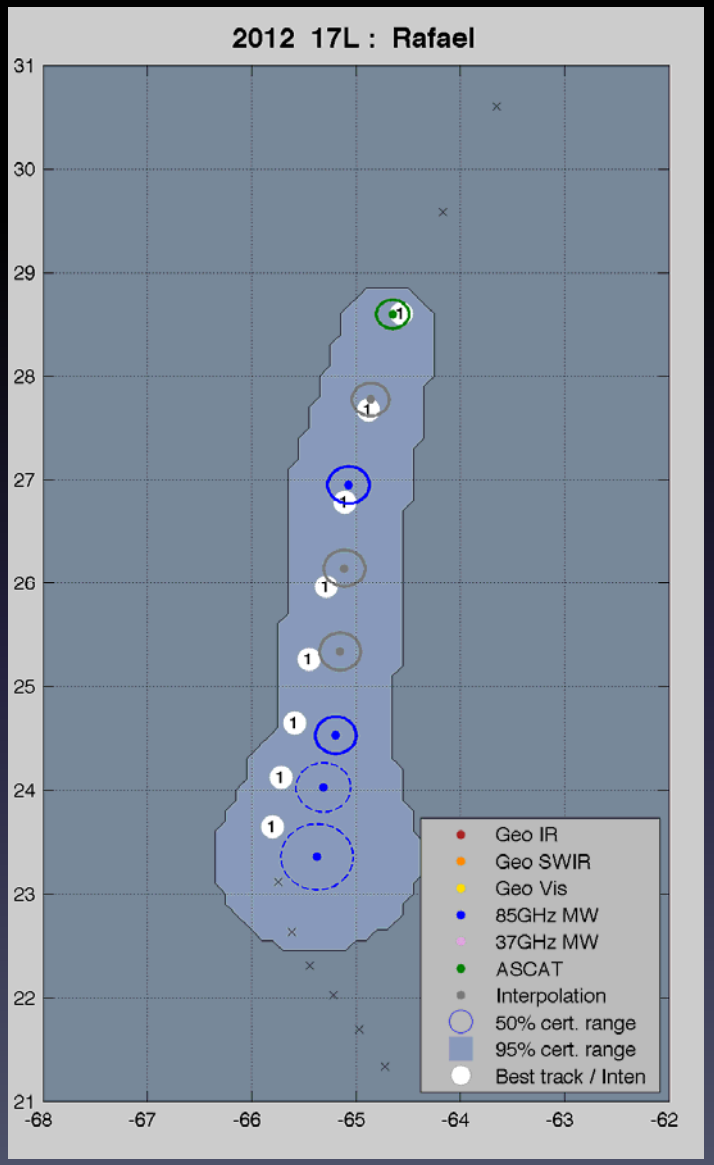
Scatterometer ambiguity data: ASCAT (Metop), 1-2 updates / day.



Emily (05L), 02 Aug 2011, 1416 UTC

ARCHER: Integration into storm track ("Stage 2")

- The algorithm picks the highest-confidence center-fix for each timestep
  - For older data, the algorithm can use interpolations as well

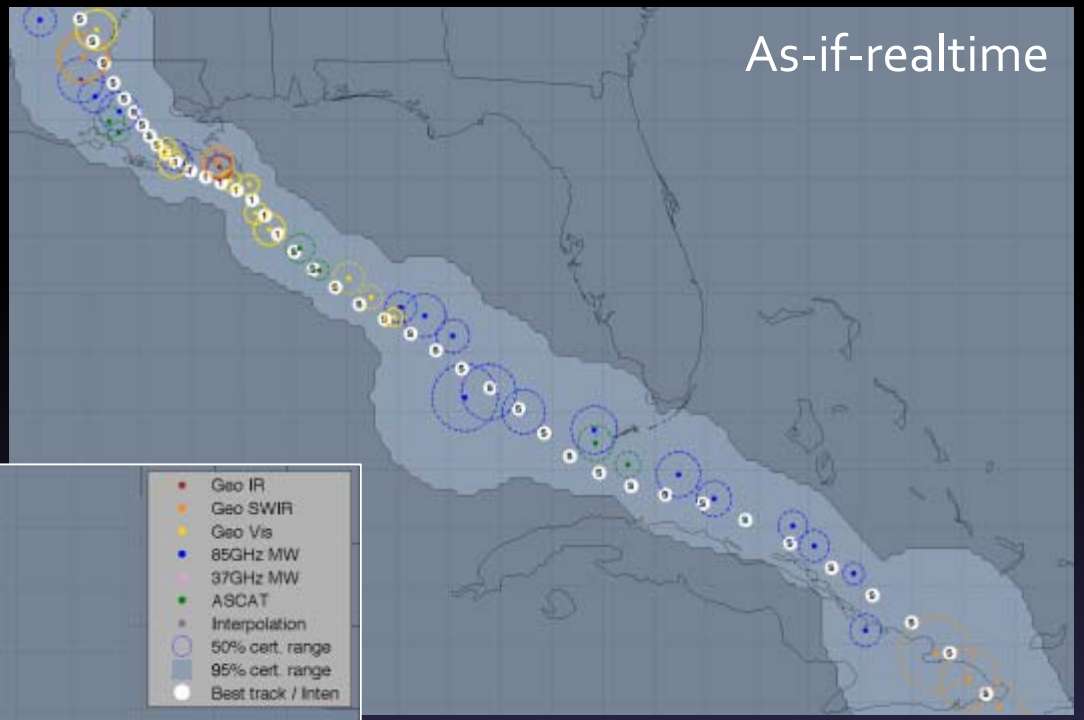


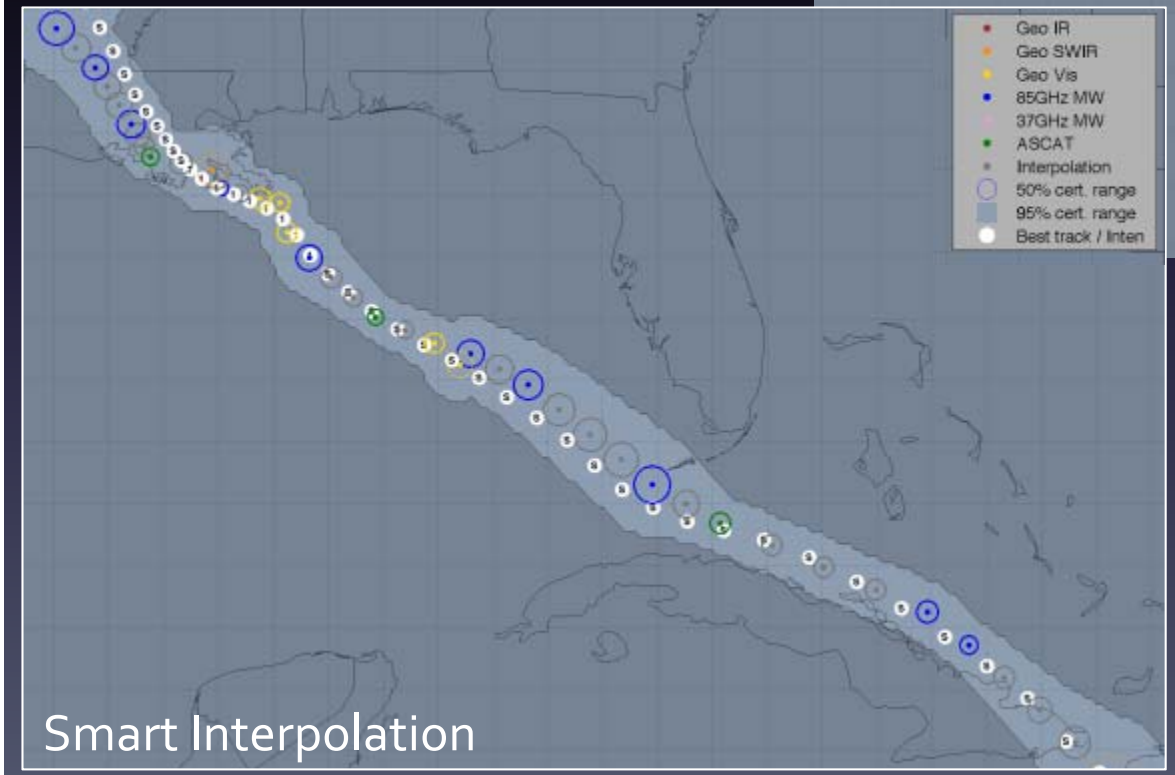
Validation

- Dataset: 2012 season in NATL (only 2011 and 2012 had valid ASCAT archives)
  - GOES-East Visible, Near-IR, IR window
  - 85-92 GHz Microwave: SSMI, SSMIS, TMI
  - Scatterometer: ASCAT
  - NHC records of 6-hourly forecast tracks
- Applies track positions every three hours (0015, 0315, etc.)
- Two output datasets produced:
  - "As-if-realtime": Every position is calculated only with data available at the valid time, assuming polar data latency of 2 hours.
  - "Smart Interpolation": Uses best data before and after, and also interpolates where interpolation is likely to be better. This simulates performance of track at ~6+ hours before present.

Validation: Examples

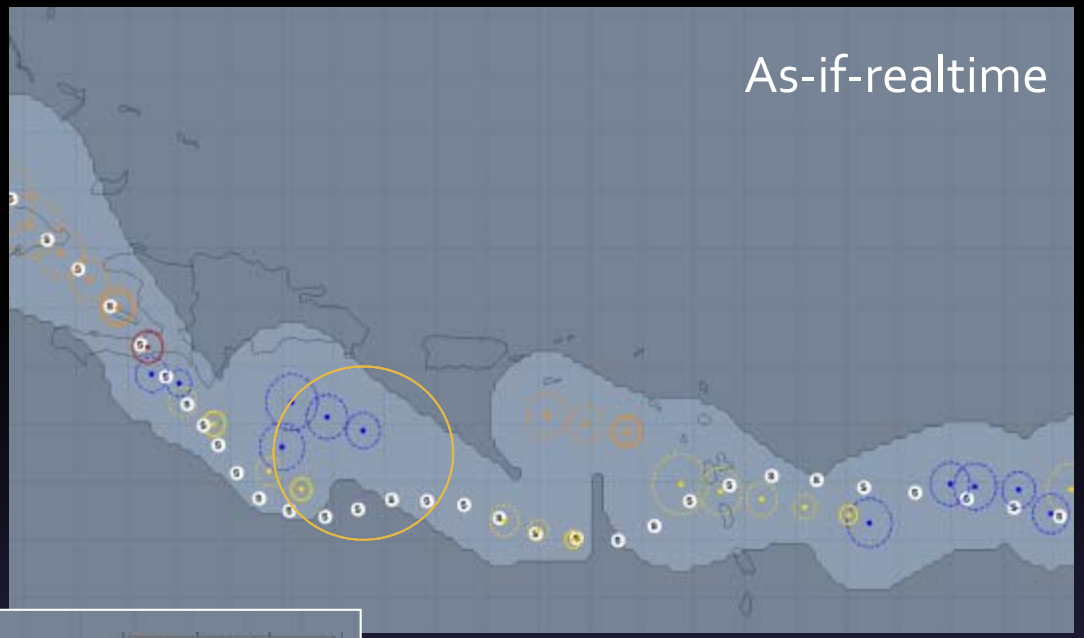
Good performance
Isaac (2012)

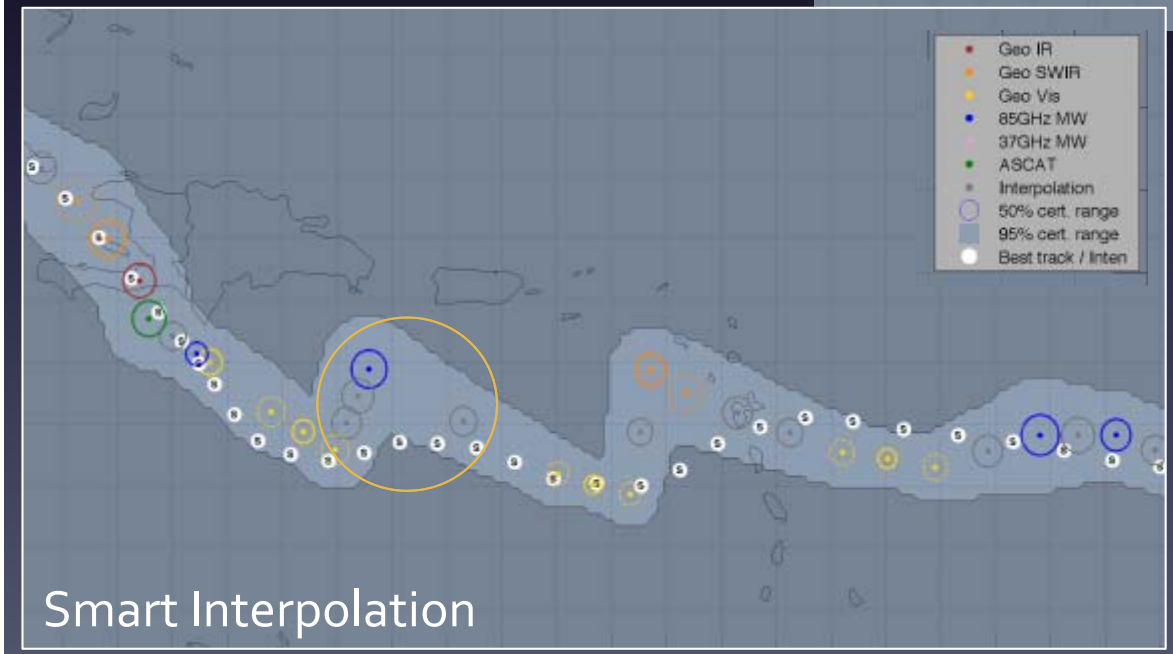




Validation: Examples

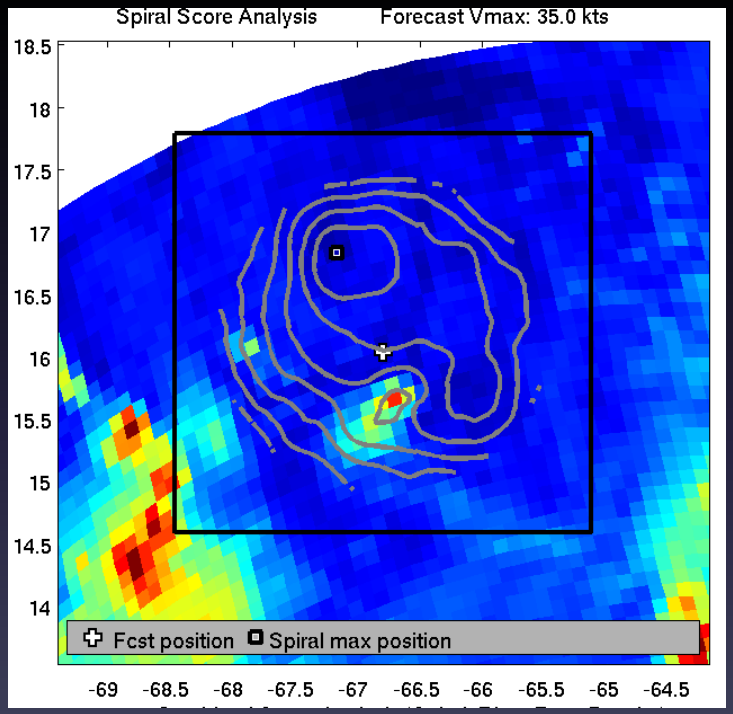
Poorer performance
Isaac (2012), earlier on





Validation: Examples

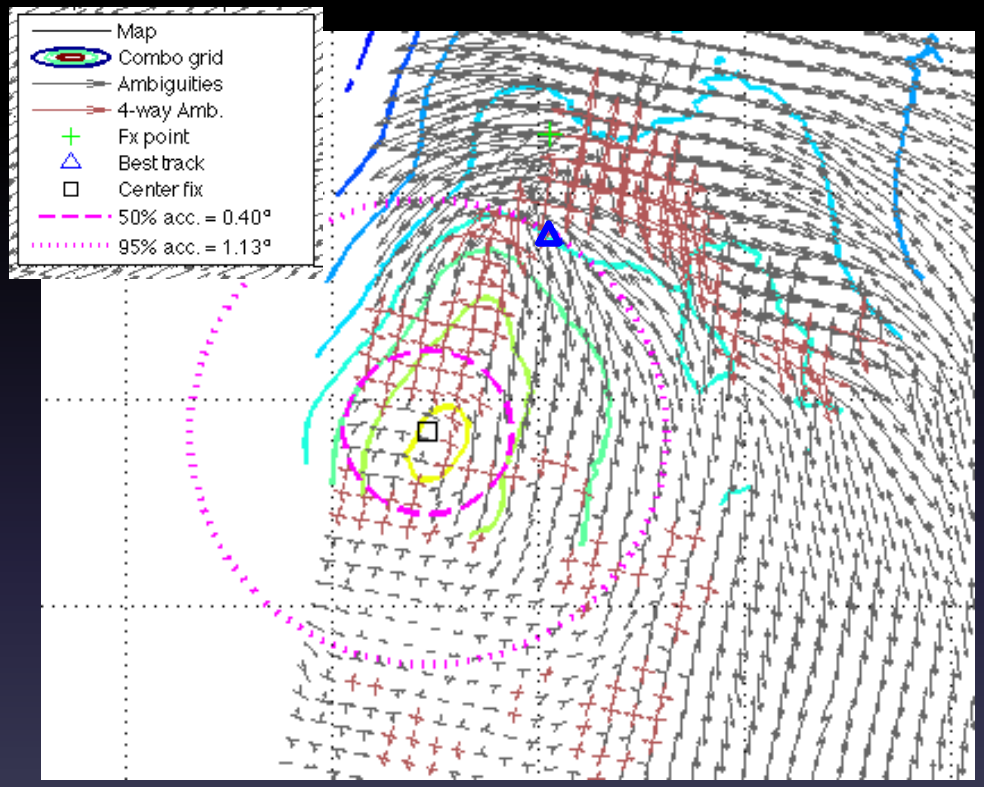
Poorer performance
Isaac (2012)



- In this case, there are no good circulation signatures to work with, and the 85 GHz Tb is slightly "warmer" to the north.
- Other "traps":
  - Central dense overcast, without microwave or scatterometer overpasses to compensate
  - "Sucker holes" (false eyes) in GEO imagery (rare for ARCHER)

Validation: Examples

Poorer performance - Maria (2011)



7 Sept 2011, 1150 UTC

- In other cases, there <u>is no clear, conventional center of low-level closed circulation</u>. In these events, a large area of uncertainty can actually be a useful indicator.

- In both instances (no distinct signatures of circulation and poorly-organized structures), the best mitigation is the human in the loop.

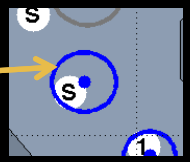
Validation: Quantitative results

- What is the mean error with respect to the best track?

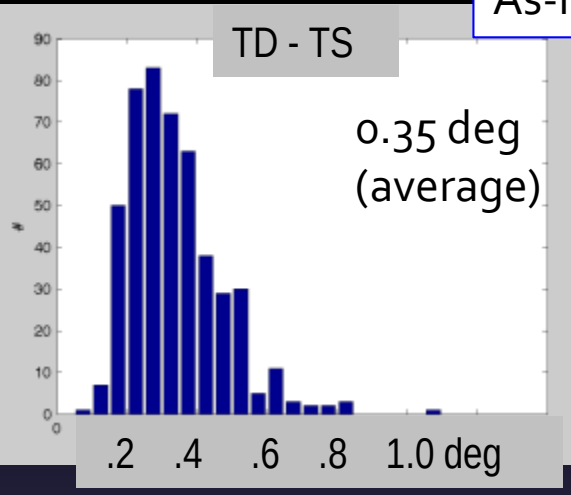
	TD - TS	Cat 1	Cat 2-5
As-if-realtime	0.47 deg (51 km)	0.29 deg (32 km)	0.17 deg (19 km)
Smart interpolation	0.38 deg (42 km)	0.27 deg (30 km)	0.16 deg (17 km)

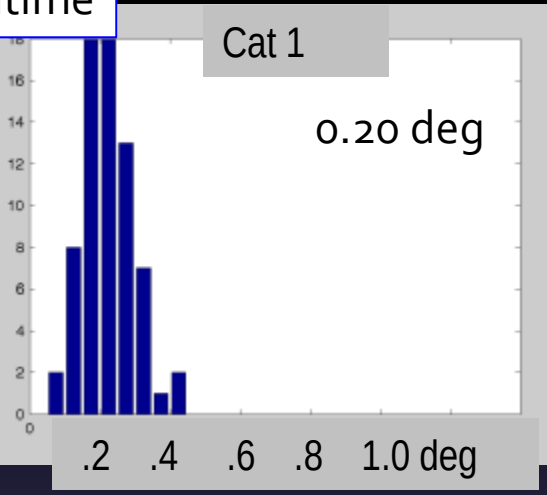
Validation: Quantitative results

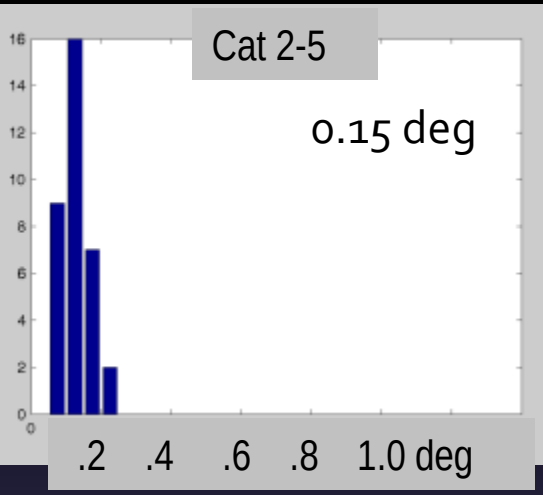
- What size is the 50% confidence radius?



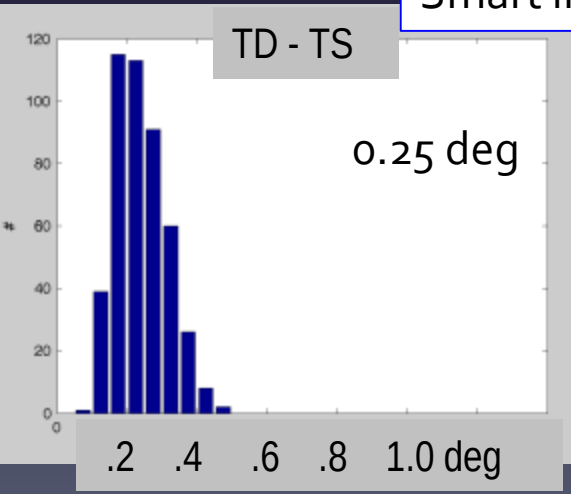
As-if-realtime

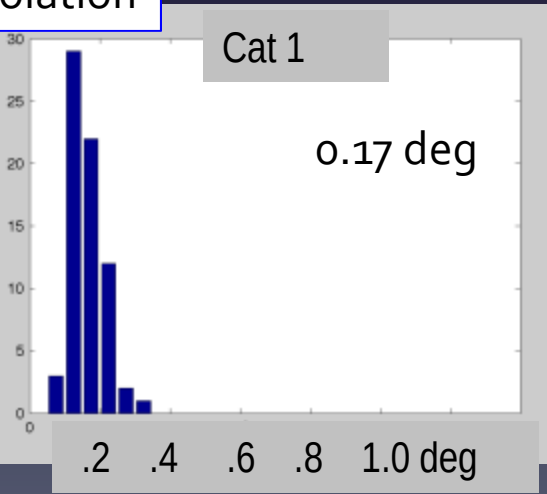


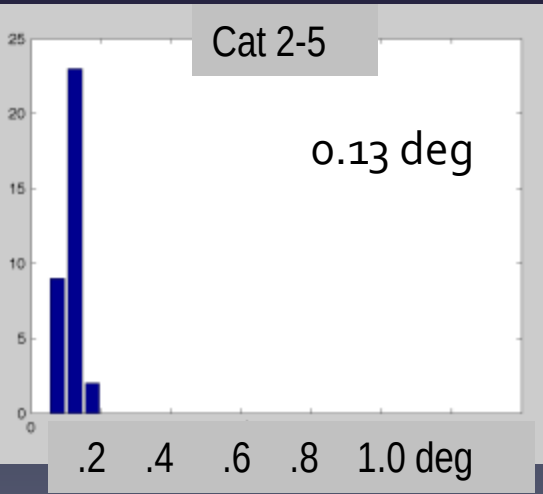




Smart interpolation

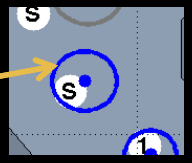






Validation: Quantitative results

- What is the bias of the 50% confidence radius?



	TD - TS	Cat 1	Cat 2-5
As-if-realtime	-6.1%	-8.0%	-8.8%
Smart interpolation	-13.7%	-16.7%	-11.7%

(-10% means that the 50th percentile validates as the 40th percentile.)

Validation: Quantitative results

- What percentage of cases improve on the NHC real-time analysis position (lower error w.r.t. the best track)?

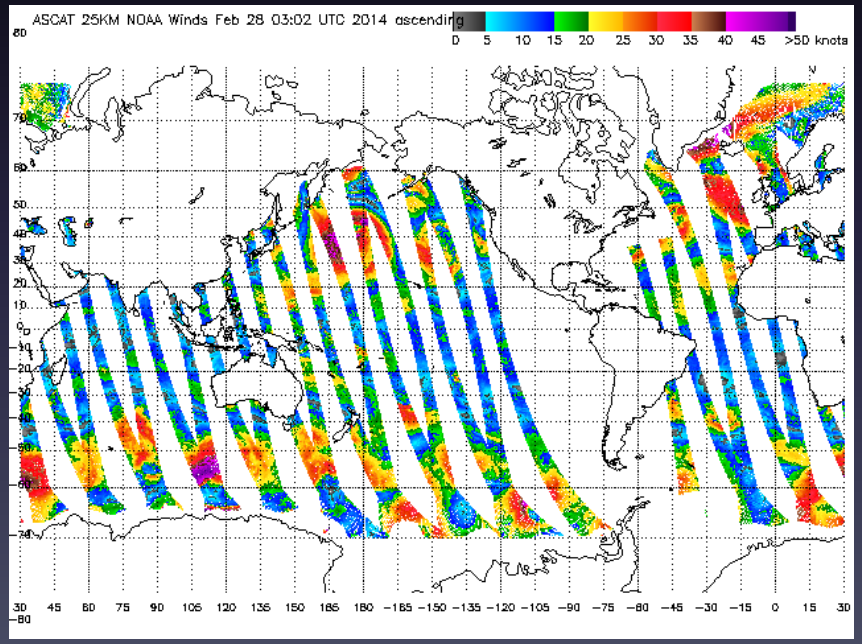
	TD - TS	Cat 1	Cat 2-5
As-if-realtime	29%	28%	25%
Smart interpolation	36%	36%	39%

- Results for Cat 2-5 reveal that data-smoothing in the best track distorts this result much lower than in reality.

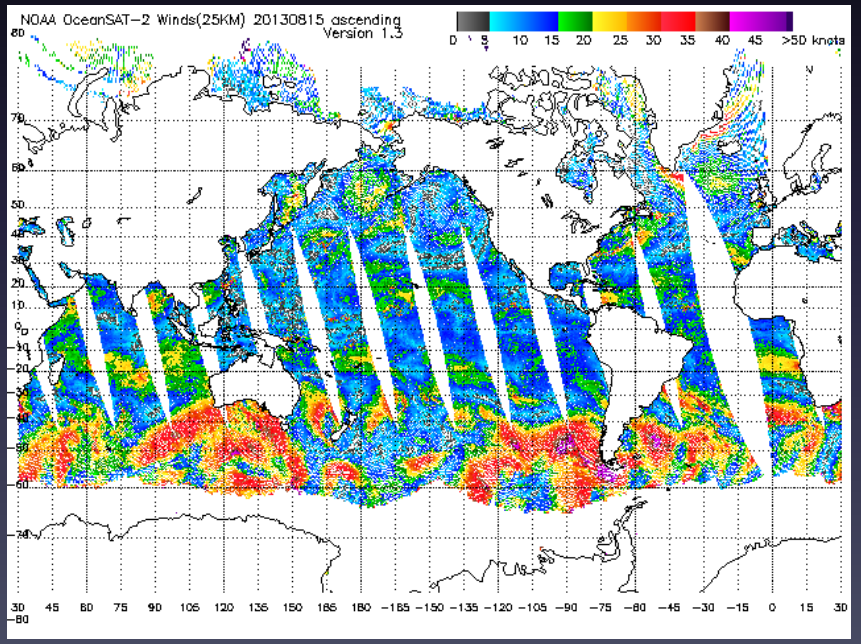
Other data sources

- ASCAT was our only scatterometer data source, because NHC rated it the most reliable. For storms in the TD-TS range, ASCAT was clearly the most important data source, but the narrow swath width caused coverage gaps of >36 hours at times.

- Based on the current results, adding other sources of scatterometer data (OSCAT, Windsat) could still *significantly* improve the TD-TS center fixes.



ASCAT coverage, ascending node



OSCAT coverage, ascending node

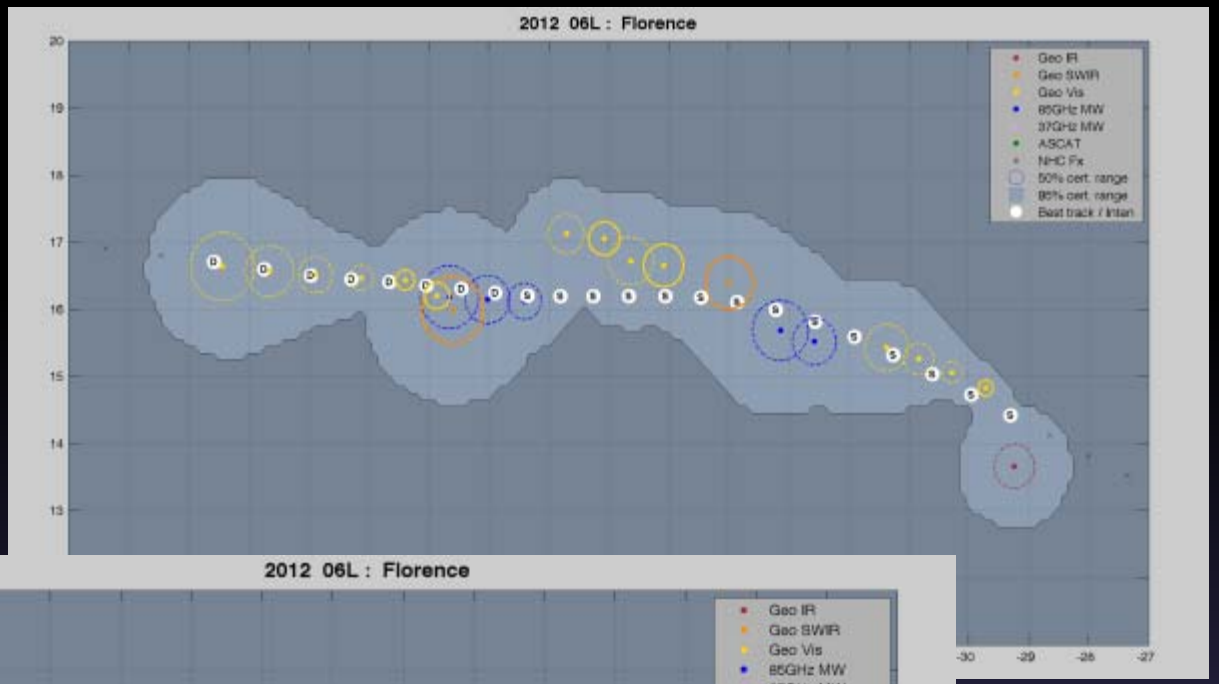
Project plans

- March – June 2014: Complete the current version of the ARCHER algorithm and recode into an online tool
  - Host at JHT and/or CIMSS
  - Following from the experimental ARCHER version that runs at CIMSS
- July – Nov 2014: ARCHER will run in real-time for evaluation and troubleshooting
- Dec 2014 – June 2015: Validate performance during 2014 season, revise algorithm based on feedback, prepare for 2015 season trial

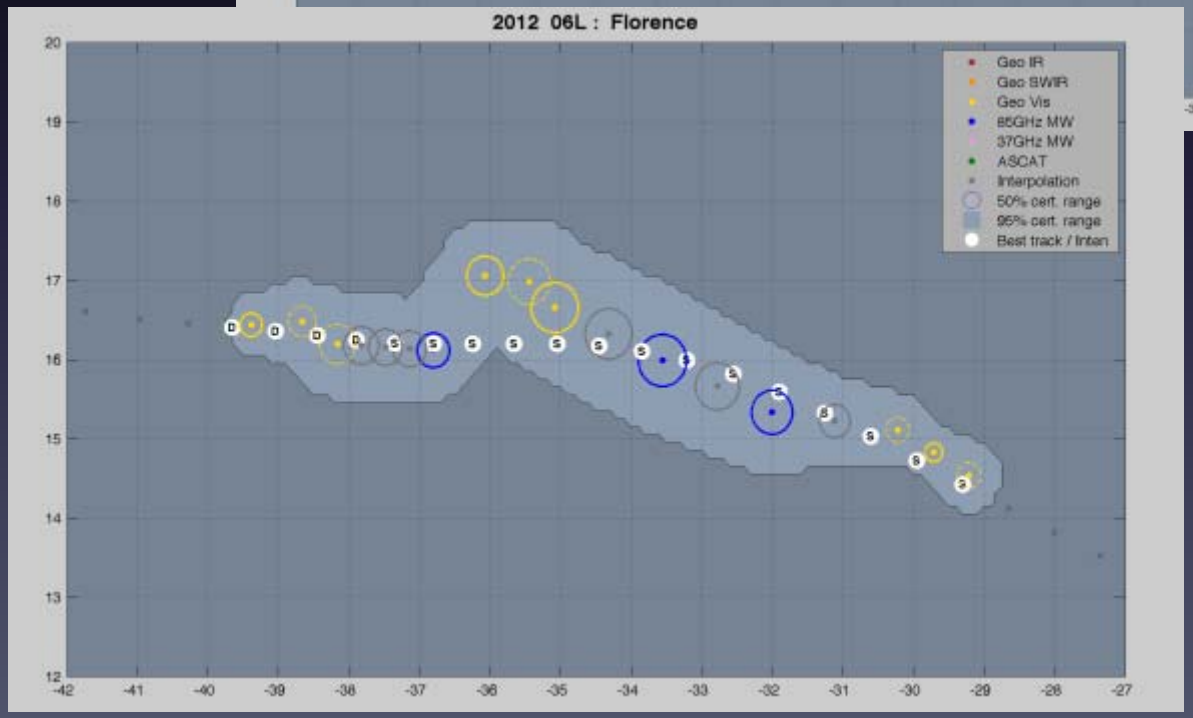
Extras

Validation: Examples

"As-if-realtime"



"Smart Interpolation"



Potential Benefits of using ARCHER

1. **Improved timeliness in NHC's real-time center-fix. This leads to:**
    - Faster incorporation of information to forecast process
    - Better reporting of the storm track to the public
    - More opportunities to apply manual and automated TC-analysis algorithms (Dvorak, Automated Dvorak Technique, ARCHER-based intensity estimates)

Potential Benefits of using ARCHER

2. **Added knowledge of high/low certainties in the center-fix. This leads to:**

   - Aid to fix decision-making and potentially to TC-Vitals output
   - Objective understandings of when a TC circulation is well organized or poorly organized

Potential Benefits of using ARCHER

3. **Decision support , in the form of:**

   - Objective/quantitative guidance on the best source of satellite data at any given time, and the reliability of that data

   - Automated processing of all available satellite information to reduce the time-load for forecasters