EOC Experience
Moving Beacons

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Slowly Moving Beacons and DOA Location Accuracy

- Recent international studies, and *more importantly* real world data collected by the USCG, have identified that location accuracy from MEOSAR data can be significantly degraded when the beacon is in motion

- In the current system, an activated beacon could be moving rapidly (e.g., on an aircraft), but the current concern is with "slow" moving beacons (e.g., < 5 knots) resulting generally from beacons drifting at sea (which happens quite often), but could also apply to a hiker walking with a PLB and other conditions

- MEOLUTs use 406 MHz beacon burst data relayed via multiple satellites to compute a Difference of Arrival (DOA) location using both Time of Arrival (TOA), and Frequency of Arrival (FOA) measurements

- The reason that location accuracy is degraded stems from using Frequency of Arrival (FOA) in the computation, as the relative motion between the beacon and satellites produces a small but detrimental Doppler shift into these frequency measurements

Example Case #1

- LGM data sent to the USCG Control and Command Center in November (prior to EOC) was analyzed by Jack Frost

- Beacon Id AB277_CF8B7_25DD1 was activated 16 November southeast of Hawaii and appeared to be moving roughly east

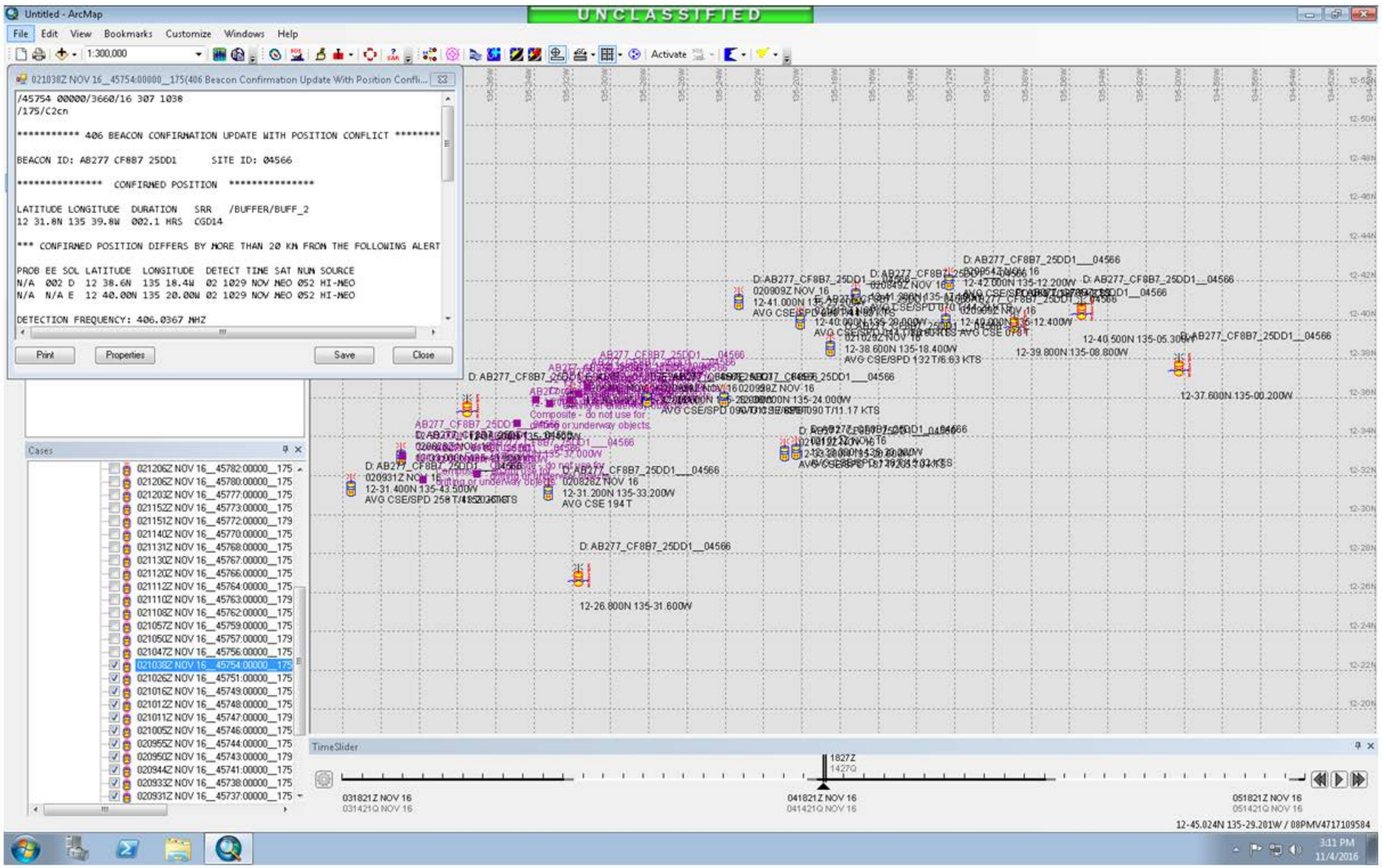
- After the initial stages of processing, the composite positions provided by the USMCC remained static, but the data, in particular the encoded positions, followed the beacon's apparent movement

- A screen shot from Jack's analysis is displayed on the following slide

- Two key things can be readily noted
  - The scattering of data around what can be seen as the possible track the beacon was following (west to east)
  - The cluster of composite locations in purple (to the west)

Example Case #1 (cont.)

AB277_CF8B7_25DD1 – screen shot provided by Jack Frost

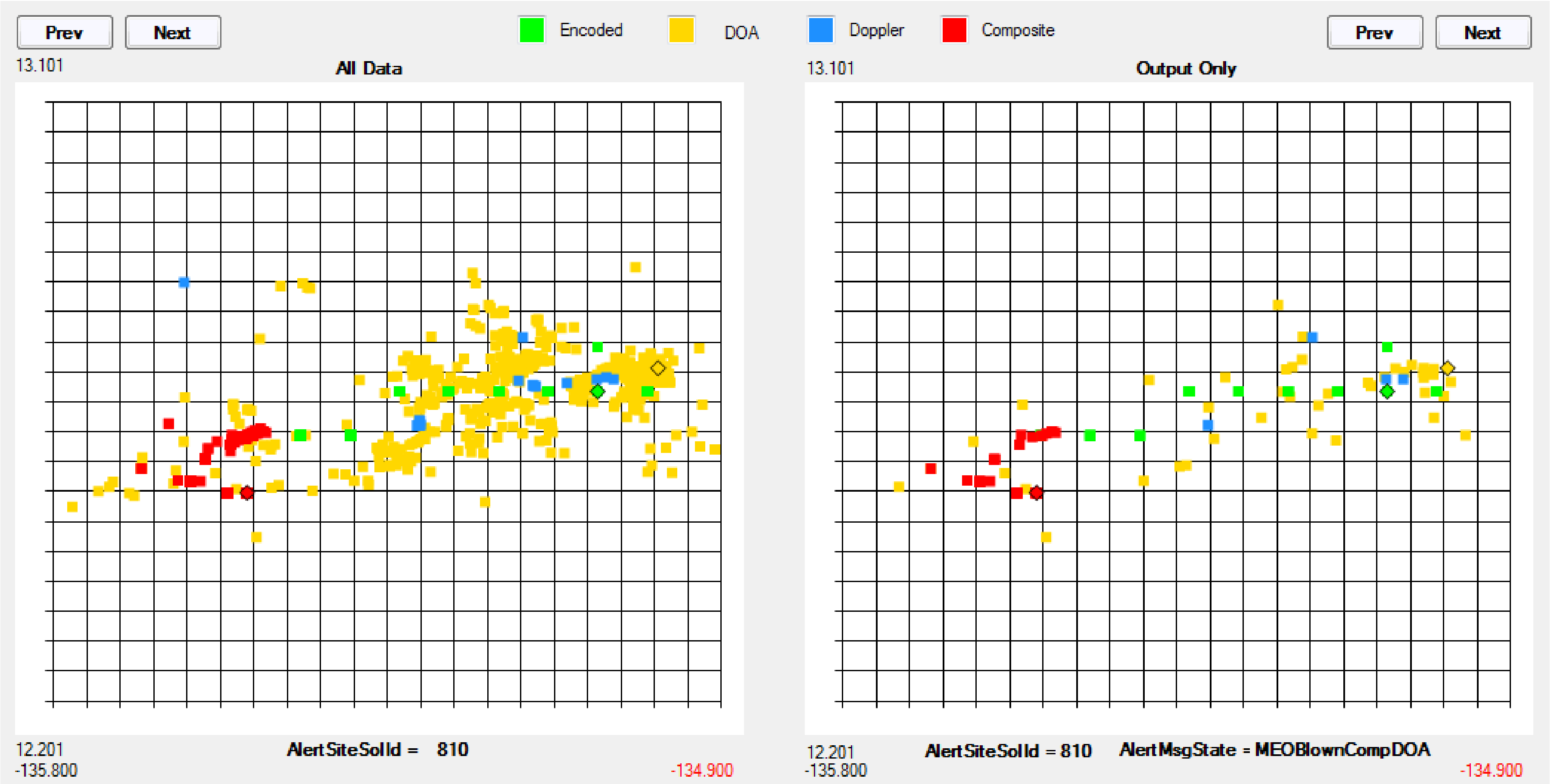


Example Case #1 (cont.)

- The screen shot on the next slide shows data for the same beacon, AB277_CF8B7_25DD1, and was generated from a similar (but more primitive) utility used by the USMCC software developer
- The same key things can be readily noted:
  - The scattering of data around what can be seen as the possible track the beacon was following
  - The cluster of composite locations "stuck" to the west, in red this time
- The plot on the left is "all data", on the right is what was sent out to the RCC, and key observations (seen best on the right) are:
  - The encoded positions (green) appear to follow the suspected track
  - The few Doppler positions (purple) in this set also follow, but not perfectly
  - The multitude of DOA positions (gold) follow, but are widely scattered

Example Case #1 (cont.)

AB277_CF8B7_25DD1 – LGM USMCC software in November



Notes: all data pertaining to the site on the left, outputs to the RCC are on right, grid is at 5 km

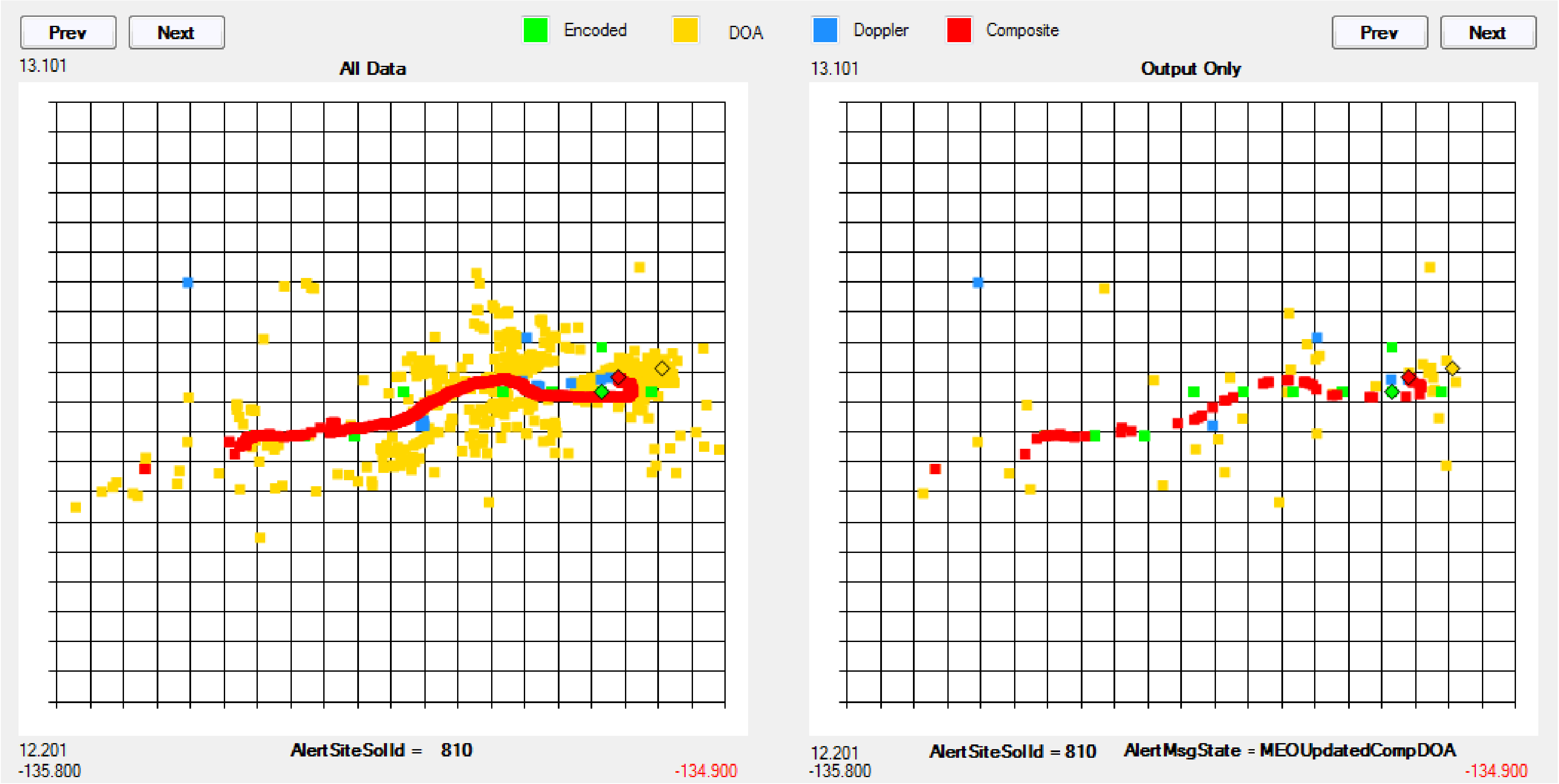
Example Case #1 (cont.)

- In early February the LGM USMCC software was upgraded to generate better composite positions (i.e., the "Confirmed Position" on the message sent to the RCC)
- The essential improvements in this case were largely corrective, fixing errant logic in the algorithms designed to generate composites using a moving time window (configured to 1 hour)
- Now, the composites (in red) very nicely follow not only the encoded positions*, but provide a very convincing track for the moving beacon
- The DOA locations themselves (in gold) are still scattered, and improvements in the MEOLUT processing are needed

*Note: encoded positions may also be inaccurate for moving beacons due to gaps in the beacon's schedule for updating the encoded position

Example Case #1 (cont.)

LGM USMCC Software – after upgrades in early February

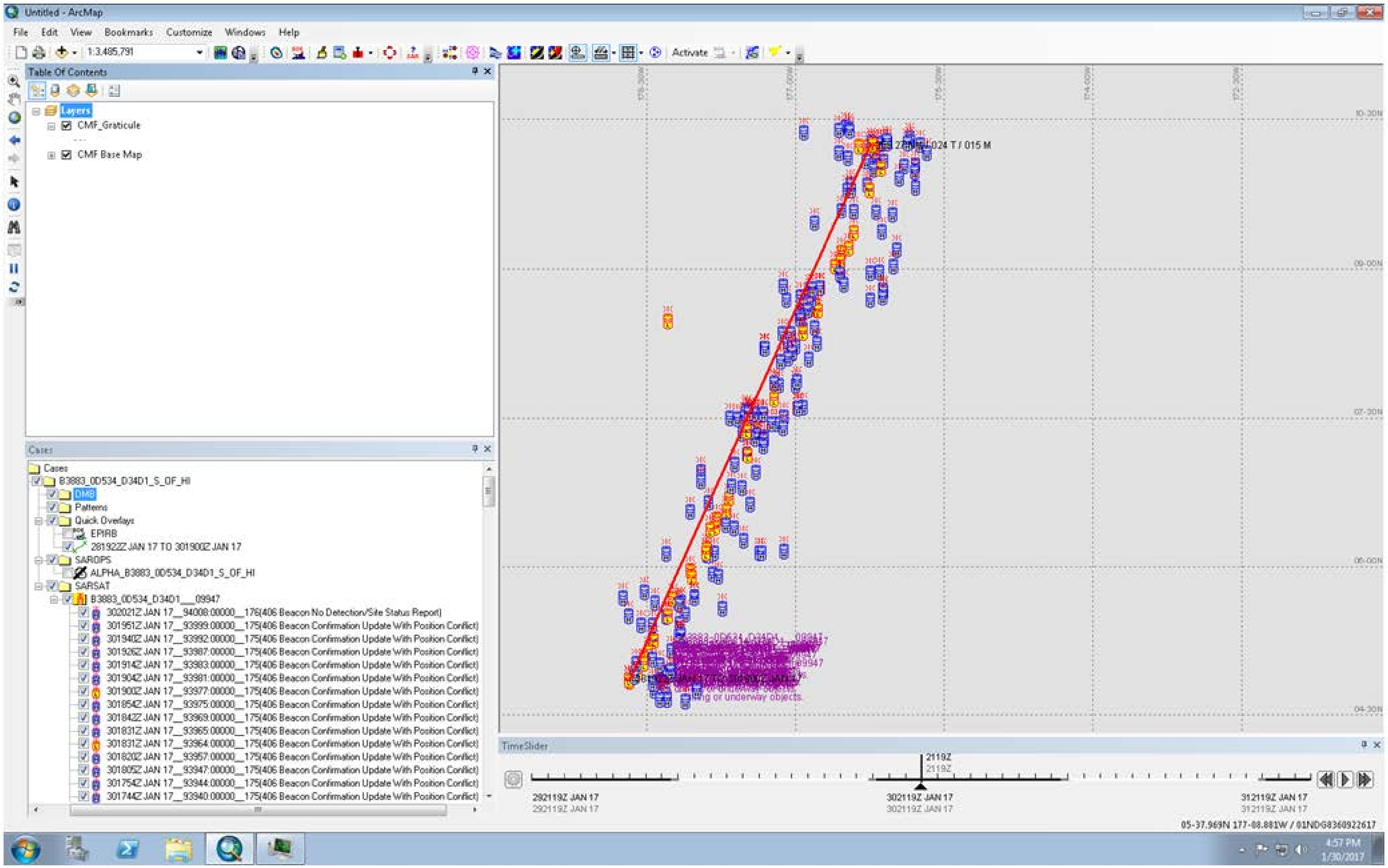


Example Case #2

- In January, Jack Frost again provided analysis regarding LGM data sent to the USCG that showed similar behavior
- While this behavior was due in small part to the same issues, the new software still failed to move the composite position which remained stationary starting about 3 hours after the initial detection
- B3883_0D534_D34D1, Site ID 09947 from 281807Z JAN 17 to 301949Z JAN 17, appeared to be moving NNE at about 7.4 knots (starting near the Marshall Island area moving toward Hawaii)
- The essential difference here was that the beacon was apparently moving faster, and once the gap was large enough, no matches to the old composite position occurred
- Two key points are again noted on Jack's screen shot on the next slide:
  - The scattering of data around the apparent beacon track (NNE)
  - The cluster of composite locations in purple (all at the start of the track)

Example Case #2 (cont.)

B3883_0D534_D34D1 – screen shot provided by Jack Frost



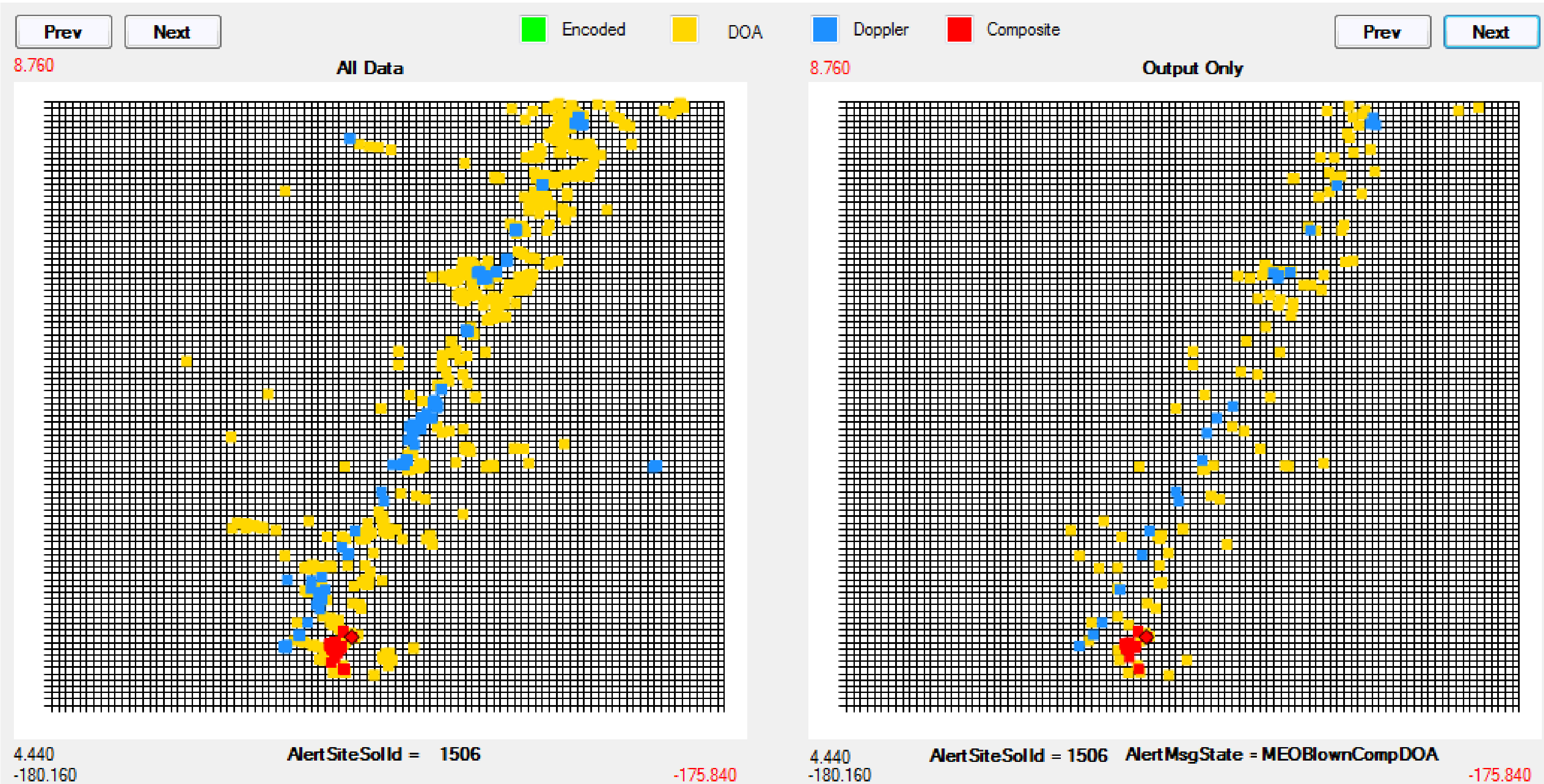
Example Case #2 (cont.)

- The screen shot on the next slide from the USMCC software developer utility shows the same data for B3883_0D534_D34D1

- Again, the plot on the left is “all data”, on the right is what was sent out to the RCC, and key observations (seen best on the right) are:
  - The scattering of data around the apparent track for the beacon
  - The cluster of composite locations (again in red)
  - This is a Maritime User protocol beacon, and there are no encoded positions
  - The Doppler positions (purple) in this set follow the apparent track well (outliers on the left are “B” solutions)
  - The multitude of DOA positions (gold) follow, but are widely scattered, and even very widely scattered at some points

Example Case #2 (cont.)

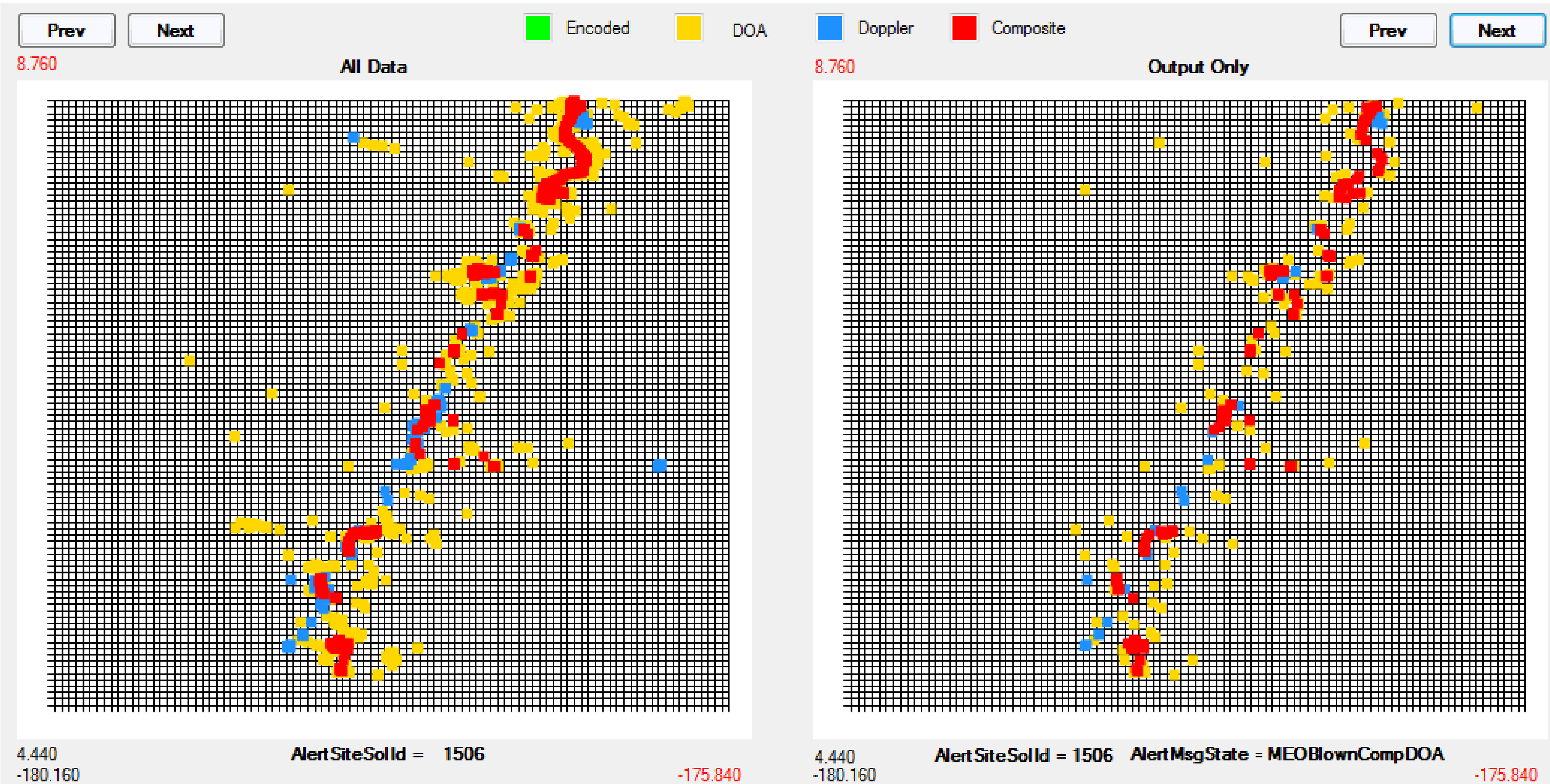
B3883_0D534_D34D1– LGM USMCC software in January



Notes: grid is at 5 km, and the beacon has traveled nearly 500 km at this point

Example Case #2 (cont.)

LGM USMCC Software – after second upgrade in mid February



Example Case #2 (cont.)

- The solution here includes new logic to detect a “stuck” composite position and recover using the most recent data

- The RCC will continue to receive position conflict messages throughout the life of the case but these will be mixed with position update messages as USMCC software repeatedly compensates with a new composite, and then the beacon continues to move away

- Another side effect of this type of algorithm is a sensitivity to very bad data, causing some composites locations to “jump” off the apparent track in sync with a cluster of recent data that has poor locations

- A more sophisticated algorithm would determine the velocity and heading of the beacon, and then include predicted positions in the logic to avoid generating “bad” composite positions (as time allows, such efforts will be considered)

Slowly Moving Beacons: Existing Remediation

- MEOLUTs combine data from multiple bursts to improve location accuracy, which works very well for static beacons

- Noting the potential that a beacon could be moving, there is no precise requirement, but MEOLUTs will generally reset the processing of multiple bursts at some practical interval (e.g., 10 or 20 minutes), which provides the benefit of improved location accuracy while limiting inaccuracy due to beacon motion over time

- Also, MEOLUTs are required to reset processing if a beacon is not detected for 10 minutes, which again can help with motion especially in the presence of blockage as well

- As indicated above, the USMCC has recently deployed two software updates that significantly improve the generation of composite locations, and although position conflicts will still inevitably occur, the composite (confirmed) positions provided will better follow the elemental data

Slowly Moving Beacons: Future Remediation

- In the future, due to significantly better Time of Arrival (TOA) measurements, second generation beacons will allow MEOLUTs to use algorithms that employ TOA only, eliminating poor frequency measurements as the source of degradation in location accuracy

- However, for current beacons (first generation) more sophisticated processing and algorithms are needed at the MEOLUT, which in general terms involve the computation of a "velocity vector", in effect a 4th dimension in the linear regression algorithm

- Solving for the velocity not only should force a more accurate 2D location (all dimensions will converge better), but the velocity can provide additional information for the MEOLUT to consider in a more sophisticated manner such as reprocessing with a predicted trajectory

- Improved MEOLUT software to locate moving beacons is expected to be ready for field testing by summer of 2017. We'll keep you posted!