



Solar Storms & High Accuracy GPS for Farming

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AMS Solar Storms
Briefing
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DISCLAIMER

The opinions expressed herein are my personal opinions and not necessarily the official position of NavCom Technology or John Deere.

Outline

- **Background – High-Accuracy Positioning for Farming**
 - The StarFire System
 - RTK & RTK Extend
- **Ionospheric Disturbances & Scintillation**
- **Conclusion: Effect on GNSS Precision Navigation**



The StarFire System

Ground Tracking Network

- Tracks all GPS and GLONASS satellites continuously
- Over 50 survey-grade precision reference receivers are located around the world
- Measurements are sent to the Processing centers every second.



Processing Centers

- Two processing centers
 - Moline Illinois
 - Torrance California
- Both centers compute correction streams for each satellite
 - Orbit corrections once per minute
 - Clock corrections once per two sec.



The StarFire System

StarFire Uplink & Space Segment

- StarFire channels on six L-Band communication satellites
- All receivers receive StarFire corrections from at least two geosynchronous satellites
 - Two over Americas, Two over Europe and Two over Asia



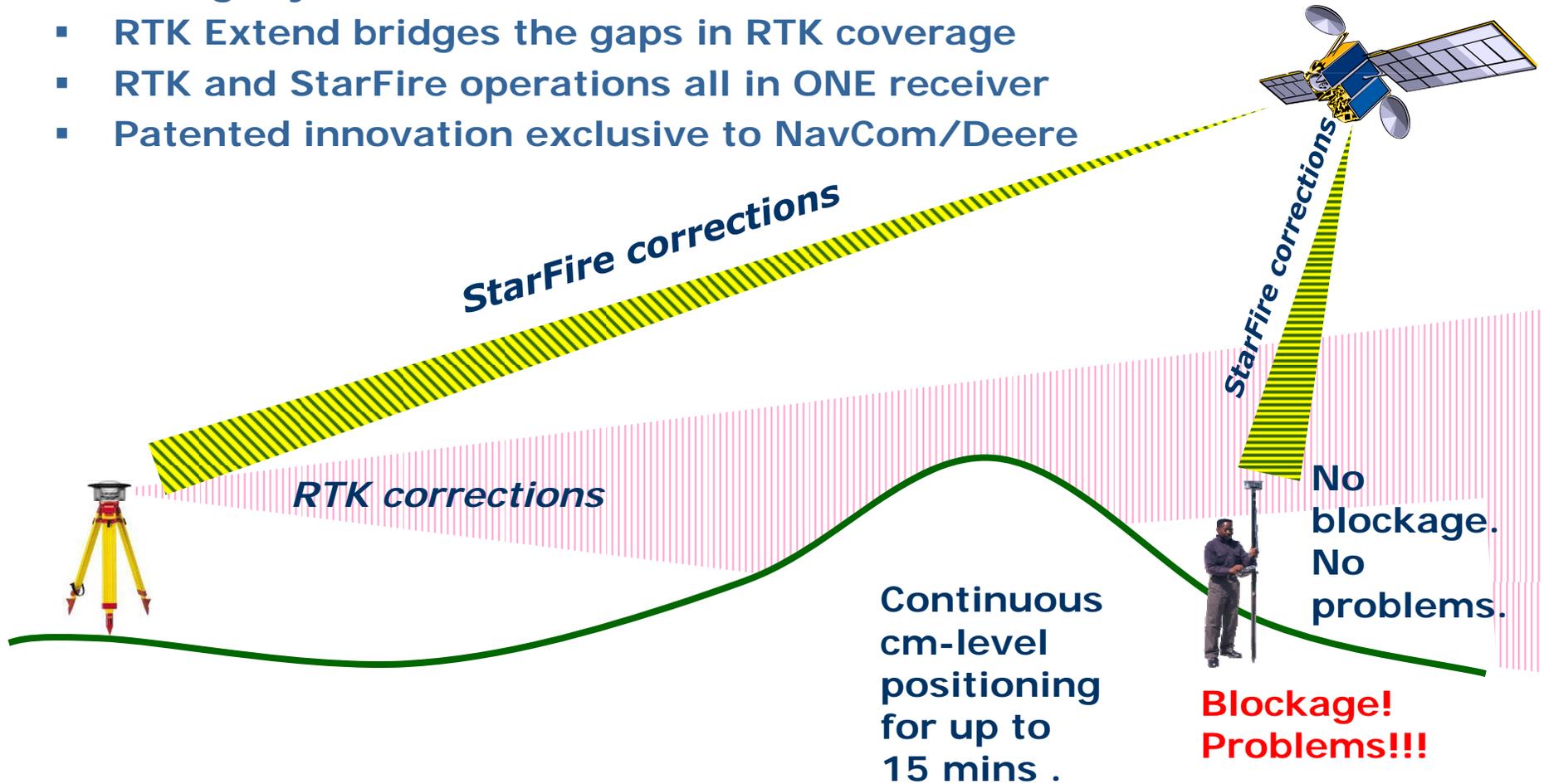
StarFire Receiver Performance

- Real time global accuracy is:
 - 10 cm. horizontal (4 inches)
 - No local base station
 - Built-in communication link
 - 99.999% reliability (< 6 min./year offline)
 - Normal ionospheric refraction effects are removed using dual-frequency corrections



RTK & RTK Extend

- Real Time Kinematic (RTK) yields centimeter level relative accuracy—after carrier phase ambiguity resolution
- RTK Extend bridges the gaps in RTK coverage
- RTK and StarFire operations all in ONE receiver
- Patented innovation exclusive to NavCom/Deere



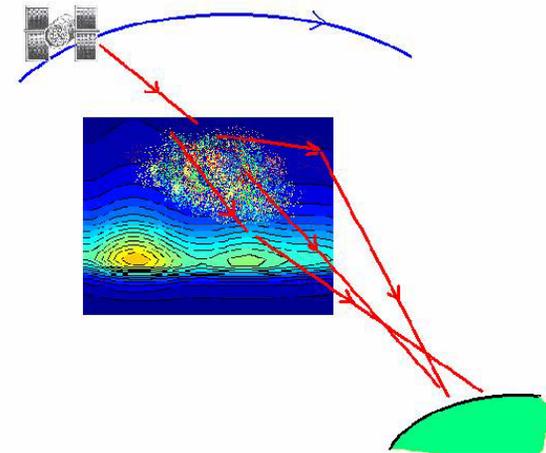
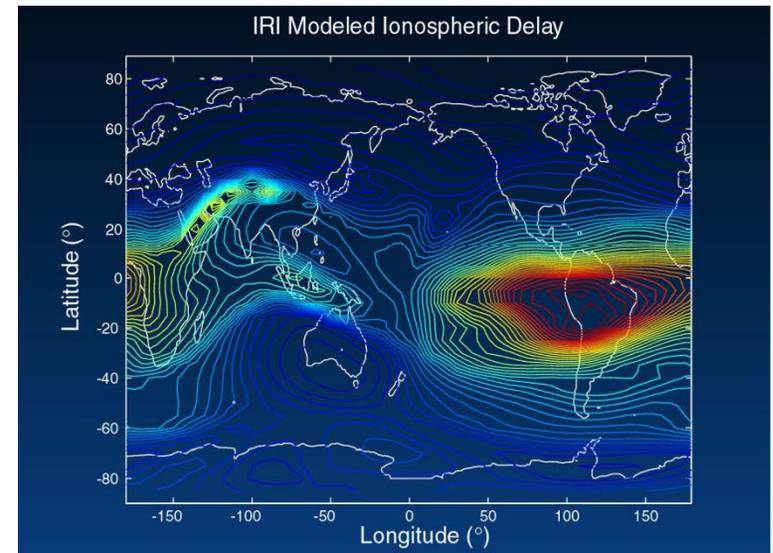
Ionospheric Disturbances and Scintillation

- **Ionospheric Disturbances**

- Tracks the 11 year solar cycle
- Strong in Brazil
- Largest effects in Nov and Dec
- Most pronounced around 10 PM local time

- **Scintillation:**

- Rapid change of ionosphere delay via multiple path interaction
- 1m / few seconds
- Lose ability to track GNSS signals
- Most often occurs at low & high magnetic latitudes



Conclusion: Ionospheric Effect upon Precise GNSS Navigation

Real Time Kinematic (RTK) Navigation

- Strong ionospheric activity reduces the RTK performance and limits the baseline length to as little as 10 Kilometers (6 miles).
- Network RTK (50 to 100 Km baseline separations) is seriously impacted by solar storms

StarFire Navigation

- Scintillation can affect tracking capability on both frequencies and thereby make the system unusable. In Brazil scintillation has limited agricultural operations by as much as four hours per day

Economic Impact on Farming

- Assume \$3 Billion in annual productivity gain with GPS. Assume RTK & StarFire affected for 10 days (out of 360) for 4 hours (out of 12). Impact would be about \$30 Million annually.

Further research needed to understand and predict scintillation and mitigate impacts

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Thank You



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