Space Weather Impact on GPS: What happened on May 10 and how will it affect farm profitability?

2024 Risk & Profit, Kansas State University
Manhattan, Kansas, 15 August 2024

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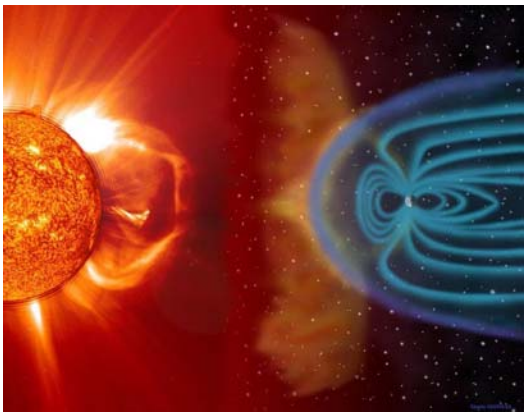
What is space weather?



Activity on the Sun's surface creates a type of weather called **space weather**. The Sun is really far away—about 93 million miles from Earth. However, space weather affects Earth and the rest of the solar system.

https://spaceplace.nasa.gov/spaceweather/en/

Blue lines represent the shield created by Earth's magnetic field. Notice how the solar wind shapes the magnetic field. Credit: SOHO (ESA & NASA)

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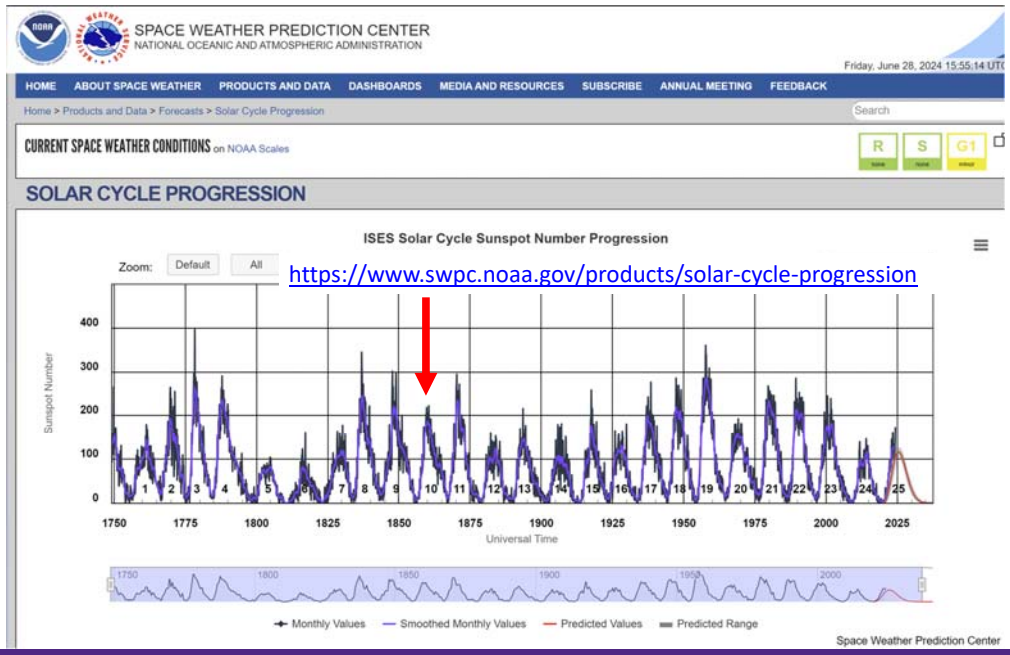


Carrington Event - 1859

September 1, 1859:

- R.C. Carrington observed white-light flare

18 hours later: aurora observed from the Caribbean

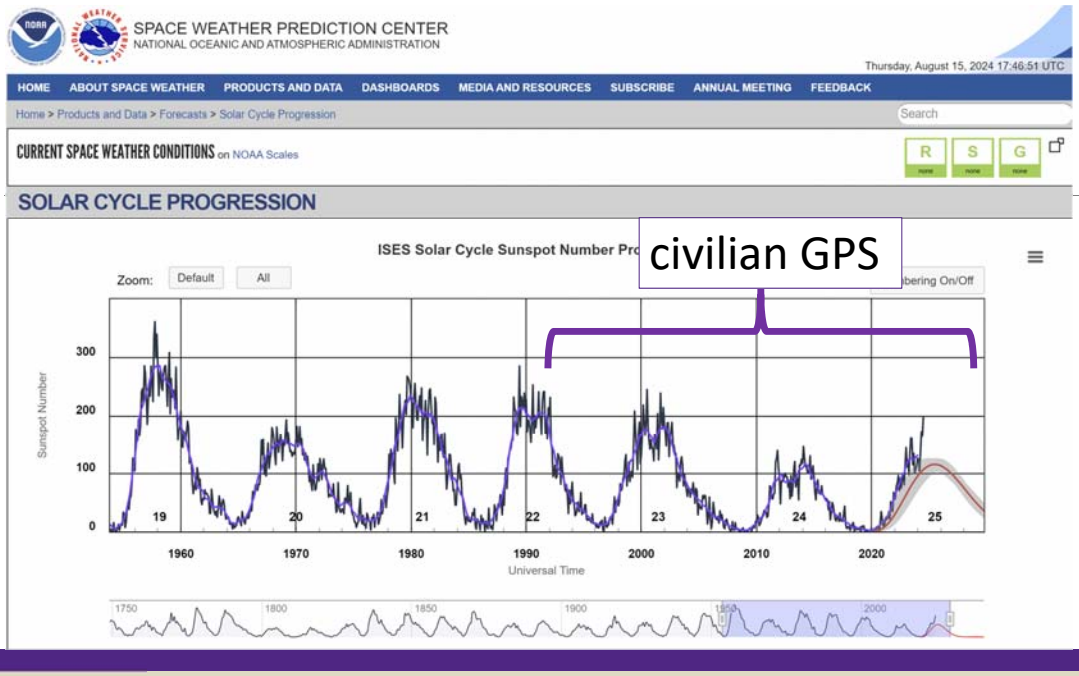
- Telegraphs functioned w/o batteries, caught fire, shocked operators

Estimated to recur every 150-200 years

- 12% chance this decade

Today it would bring down the electrical grid, disable satellites

- Infrastructure repair estimated over 1-10 years



Radio blackouts www.swpc.noaa.gov/noaa-space-weather-scales

Scale	Description	Effect	Physical measure	Average Frequency (1 cycle = 11 years)
R 5	Extreme	**HF Radio:** Complete HF (high frequency) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector. **Navigation:** Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	X20 (2×10^{-3})	Less than 1 per cycle
R 4	Severe	**HF Radio:** HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time. **Navigation:** Outages of low-frequency navigation signals cause increased error in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth.	X10 (10^{-3})	8 per cycle (8 days per cycle)
R 3	Strong	**HF Radio:** Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth. **Navigation:** Low-frequency navigation signals degraded for about an hour.	X1 (10^{-4})	175 per cycle (140 days per cycle)
R 2	Moderate	**HF Radio:** Limited blackout of HF radio communication on sunlit side, loss of radio contact for tens of minutes. **Navigation:** Degradation of low-frequency navigation signals for tens of minutes.	M5 (5×10^{-5})	350 per cycle (300 days per cycle)
R 1	Minor	**HF Radio:** Weak or minor degradation of HF radio communication on sunlit side, occasional loss of radio contact. **Navigation:** Low-frequency navigation signals degraded for brief intervals.	M1 (10^{-5})	2000 per cycle (950 days per cycle)

Ionospheric scintillation

Rapid modification of radio waves caused by small scale structures in the ionosphere. **Severe scintillation** conditions can **prevent a GPS receiver** from locking on to the signal and can make it **impossible to calculate a position**.

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https://www.swpc.noaa.gov/phenomena/ionospheric-scintillation

Space weather implications on agriculture

Aerospace Corporation white paper 2022

- Space Environment Engineering and Science Applications Workshop – Ionospheric Impacts: Precision Applications(Precision Agriculture)
- https://agmanager.info/news/recent-videos/global-cost-assessment-gnss-outage-agricultural-productivity

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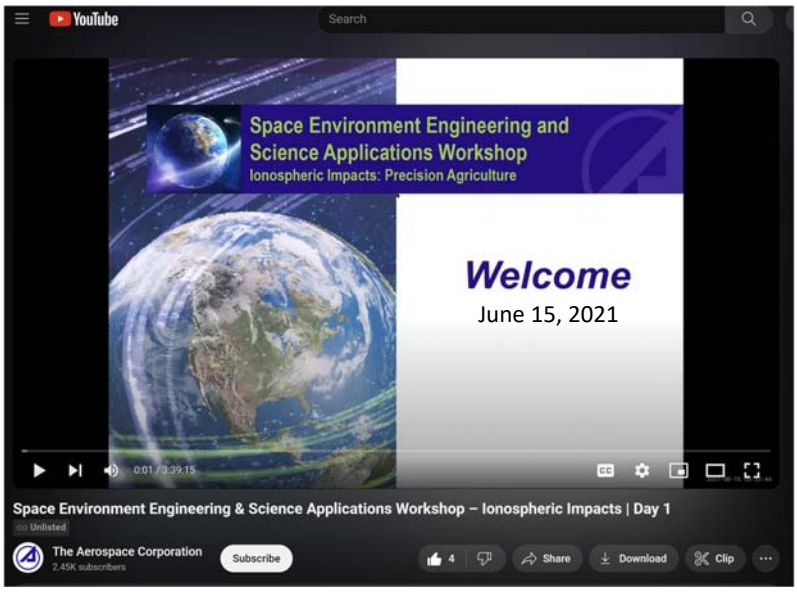


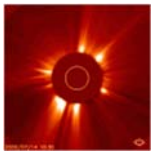
Rebecca Bishop, Aerospace Corp

https://www.youtube.com/watch?v=6C3EMEZk46g

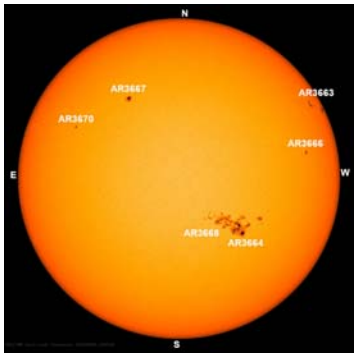
What happened on 10 May 2024? aka Gannon Event

May 7: Active Regions (AR) 3668 and 3664 had new growth emerged

May 8/9: Active regions 3668 and 3664 fused together, AR 3664 dominates, 7 solar storms launched

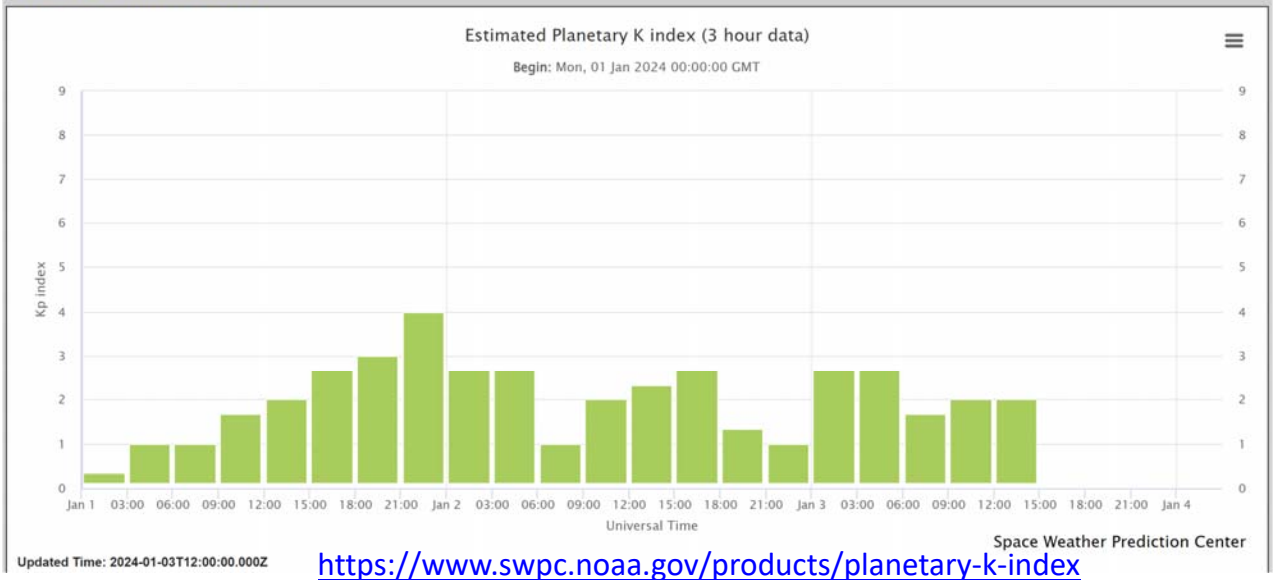


- Storm 1: Launches SW of Earth
- Storm 2: Full halo, very first X-class flare from AR 3664
- Storm 3: 2nd halo, and a direct Earth hit
- Storm 4: Filament Launch – NE
- Storm 5: 3rd halo
- Storm 6: Launched during X4.5 flare, strongest of the bunch and a direct hit
- Storm 7: Asymmetric halo, weaker and moving out of the strike zone



May 10/11: G5 storm arrives at Earth, mid-latitude aurora, Kp index reaches level 9

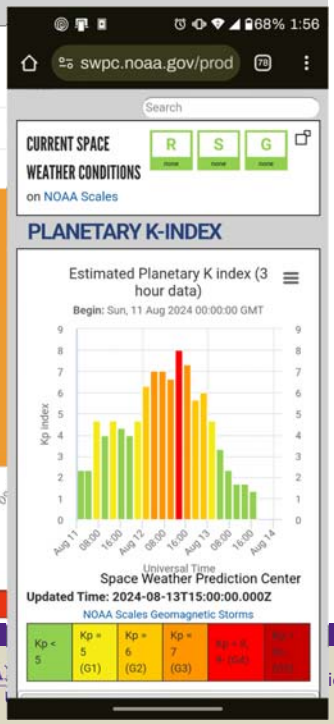
PLANETARY K-INDEX



https://www.swpc.noaa.gov/products/planetary-k-index

PLANETARY K-INDEX

Monday morning 12 August 2024



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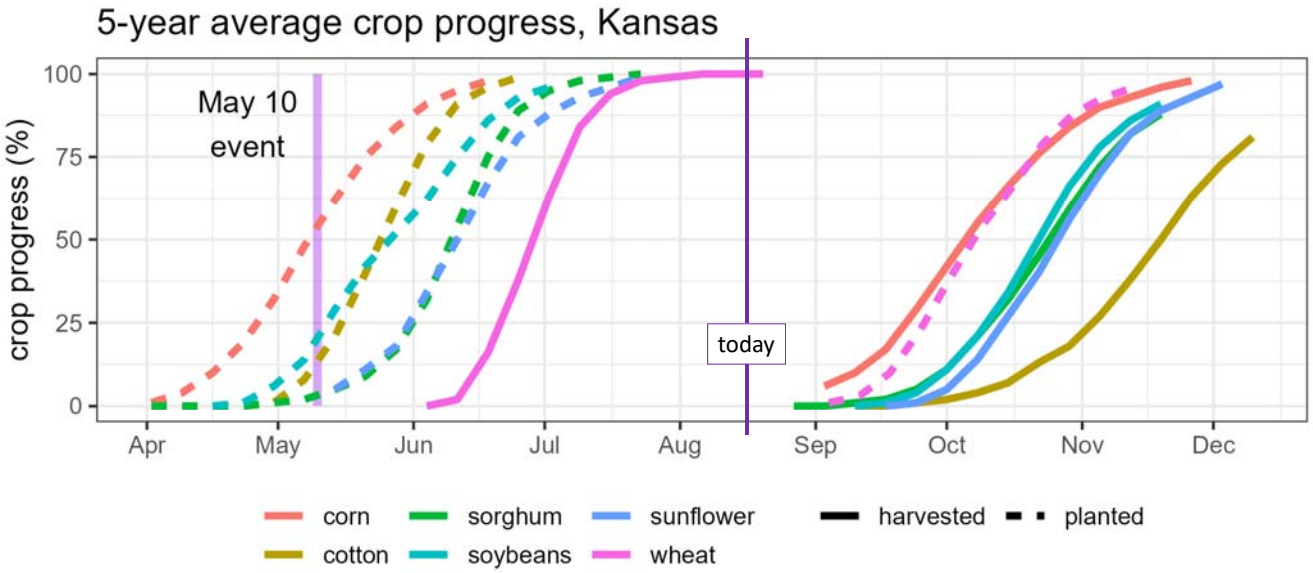
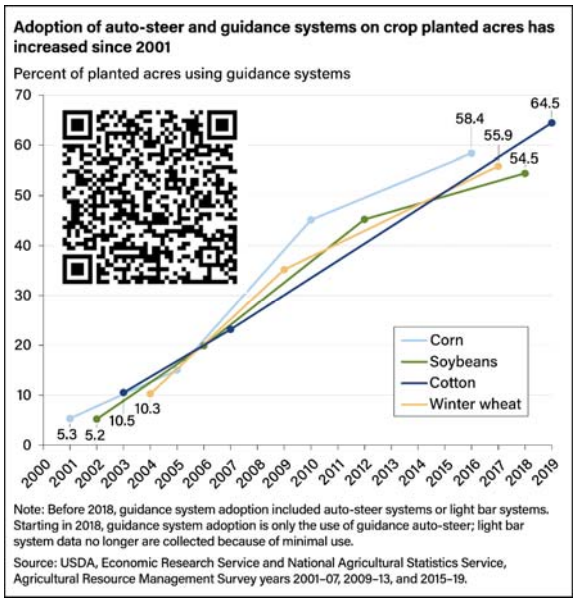
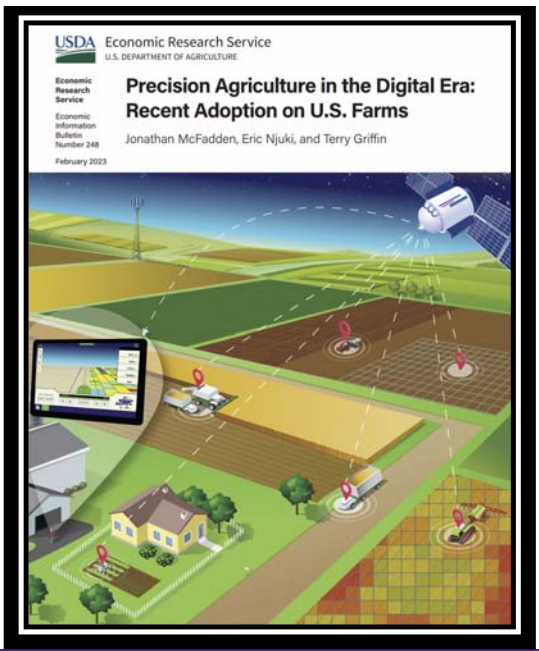


source: USDA NASS



https://www.ers.usda.gov/publications/pub-details/?pubid=105893



Since advent of GPS

Equipment especially planters have become larger, more rows and wider, such that physical row markers may be infeasible, or at least more expensive than guidance systems

Tramlining aka controlled trafficking allow some farm operators to plant without guidance or mechanical row markers

Without georeferencing sensor data, mapping and farm data are hindered, reducing value within farm gates and outside stakeholders

Planter technology has progressed to the point that John Deere is offering a 120-foot machine that can plant 48 rows, each 32 inches apart.

Source: http://www.global-farming.de/Services-in-agricultural-sector_81_en.html

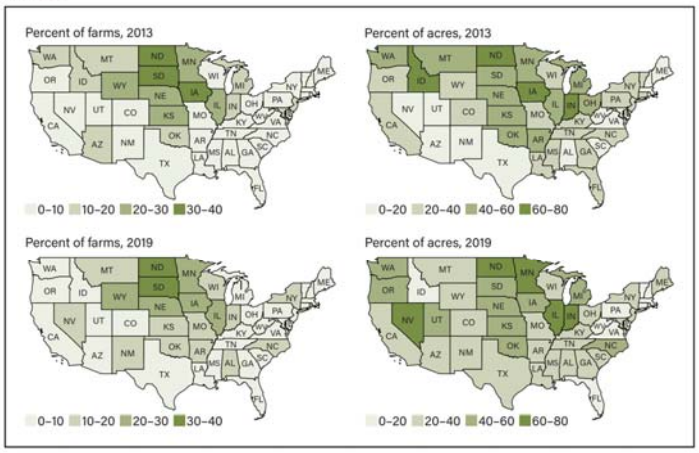
Because of GPS...

1995

2005

2015

Percent of total farms and total farm/ranch acres using GPS for on-farm production activities, 2013 and 2019



Note: The top panels depict the percent of each State's total farms and total farm/ranchland, respectively, in 2013, with operators who indicated they used GPS for on-farm production activities. Similarly, the bottom panel depicts these percentages for year 2019. Data are not available for Alaska and Hawaii.

Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, 2013 and 2019 Agricultural Resource Management Survey (ARMS).

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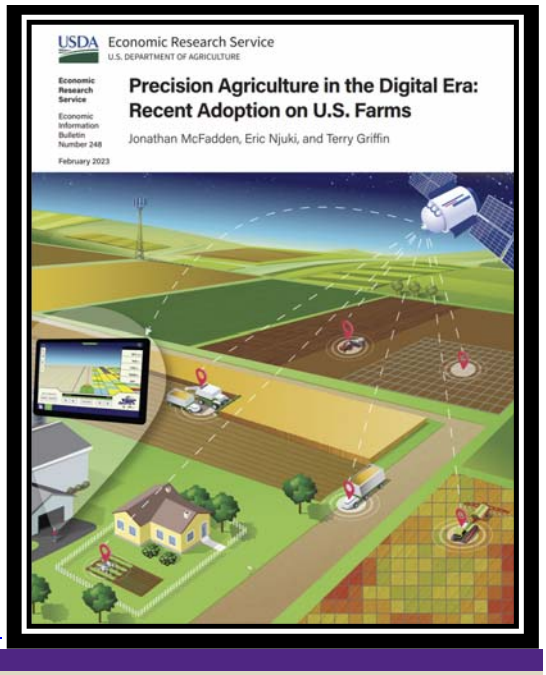
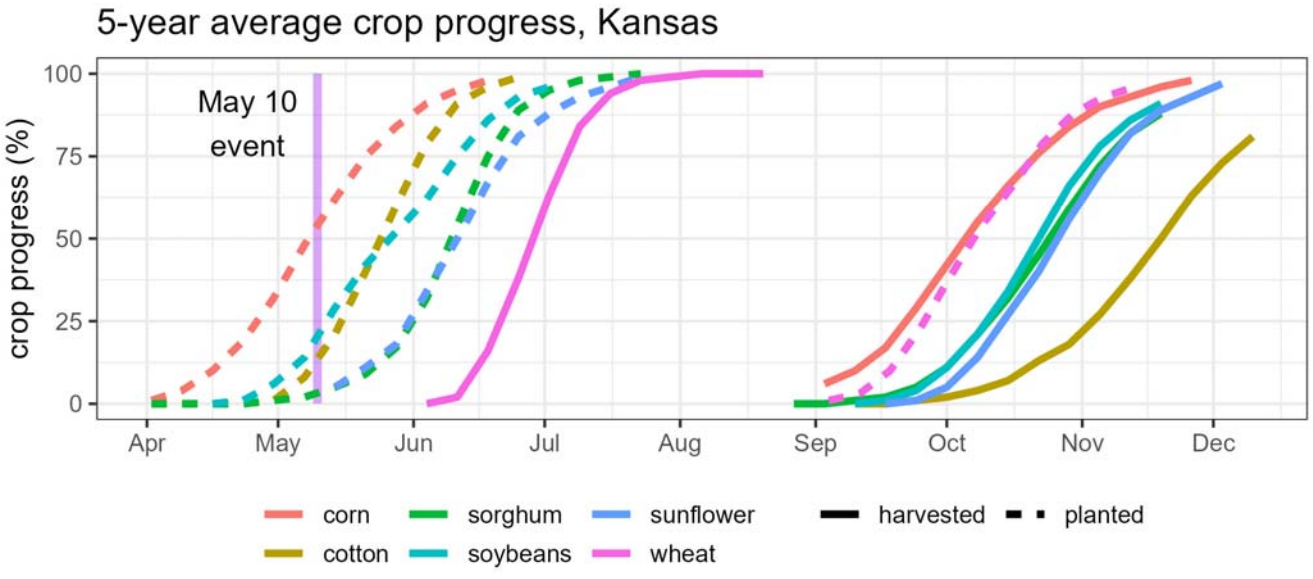
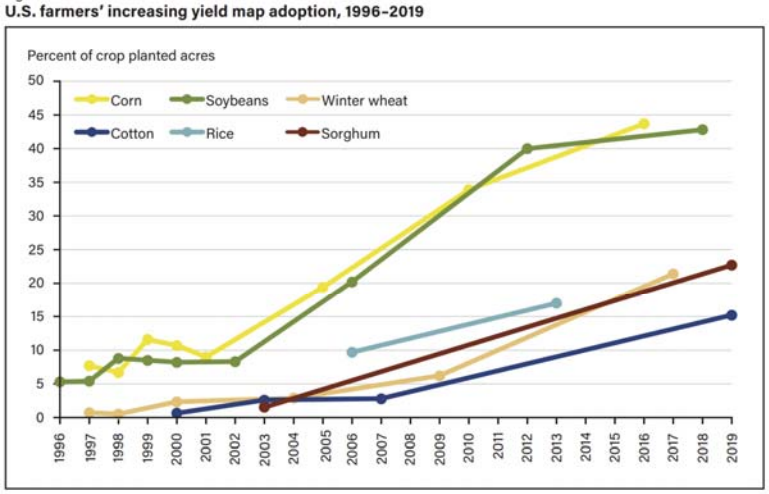




source: USDA NASS

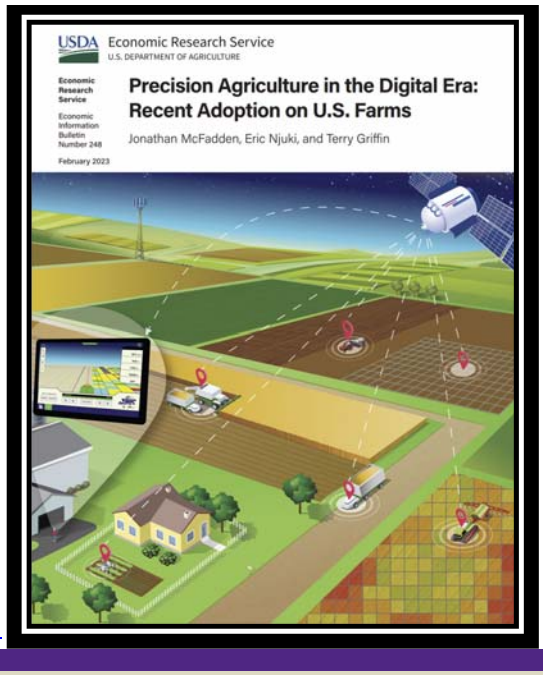
U.S. farmers' increasing yield map adoption, 1996–2019

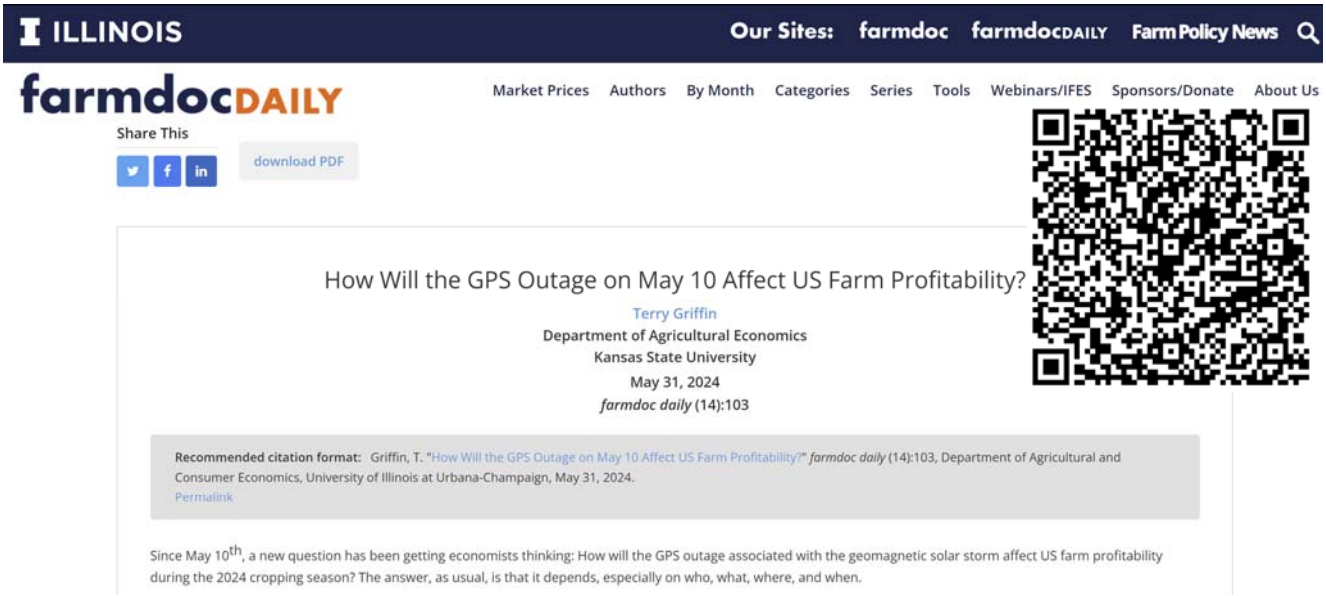


Note: Starting in 2015, the adoption of a yield map is considered to be the use of yield monitor data that were/will be used to create a map.

Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, Years 1996–2007, 2009–13, 2015–19.

https://www.ers.usda.gov/publications/pub-details/?pubid=105893





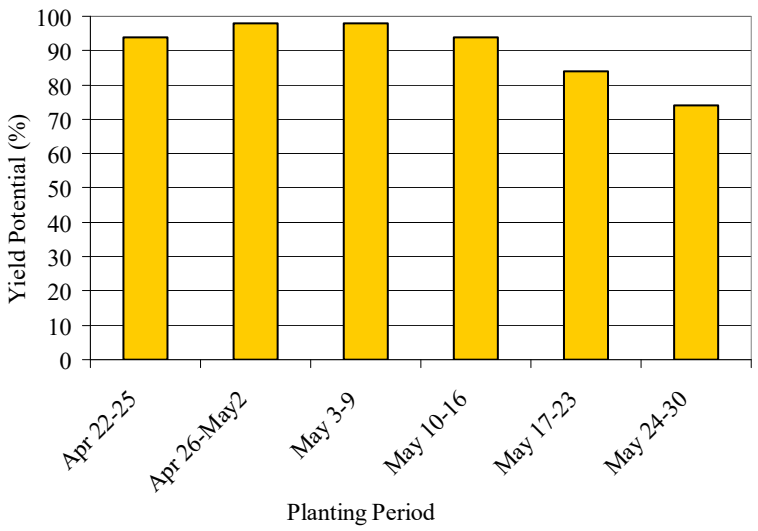
https://farmdocdaily.illinois.edu/2024/05/how-will-the-gps-outage-on-may-10-affect-us-farm-profitability.html

Corn Yield Penalties
Planting Time
eastern corn belt

Assuming harvest October 11-31

from Purdue PCLP aka B-21 farm plan

3000-acre corn & soybean farm
4-hour downtime early May
> **$3000 whole-farm penalty**



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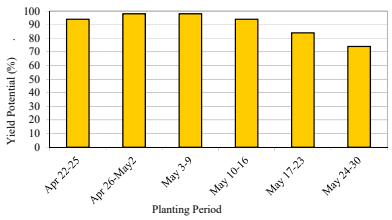

planter	acres per hour	acres in 4 hours	yield penalty		
			5 bu	10 bu	30 bu
4 row - 30	4.9	20	98	196	588
6 row - 30	7.4	30	148	296	888
8 row - 30	9.8	39	196	392	1176
12 row - 30	**14.8**	**59**	**296**	**592**	**1776**
16 row - 30	19.7	79	394	788	2364
24 row - 30	29.5	118	590	1180	3540
48 row - 30	59.0	236	1180	2360	7080

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Kansas State University Department Of Agricultural Economics Extension Publication 07/09/2024

Cost Of Reliance On GNSS For Autonomous Cotton Harvest: Assessing Potential Vulnerability Of Autonomous Navigation Systems To A GNSS Outage

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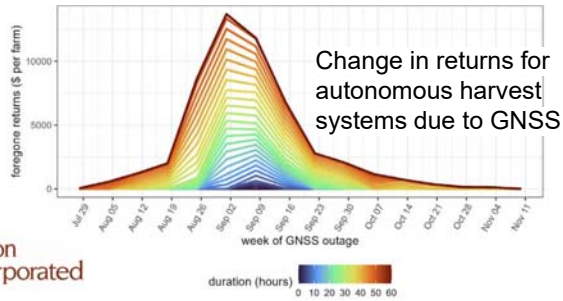

Change in returns for autonomous harvest systems due to GNSS outage

Cotton Incorporated

https://agmanager.info/management-finance/precision-agriculture/cost-reliance-gnss-autonomous-cotton-harvest-assessing

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Space weather impacts on agriculture

Check Planetary K-index

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- https://www.swpc.noaa.gov/

Wait, outage likely only a few hours (if R4)

- R2 or R3 ~ 1 hour

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Resources

If GPS issue is noticed, look at the NOAA alerts or the Navigation Centers civilian GPS outage reports to determine if environmental or hardware problem

https://www.navcen.uscg.gov/guide-tool

If there is elevated space weather, and local hardware issues have been ruled out, report the outage to the Navigation Center through online reporting:

https://www.navcen.uscg.gov/contact/gps-problem-report

Global Positioning System (GPS) Community Dashboard

https://www.swpc.noaa.gov/communities/global-positioning-system-gps-community-dashboard

SXSW 2025 panel proposal

NASA's Favorite Frenemy: The Sun's Explosi

Joseph Westlake, Heliophysics Division Director, NASA
Elizabeth MacDonald, Heliophysics Citizen Science Lead, NASA
Abbey Interrante, Editorial Lead, Heliophysics, NASA
Terry Griffin, Professor, Kansas State University

Upvote our proposal at:

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Acknowledgements

Rebecca L. Bishop, PhD, Research Scientist
Space Science and Applications Laboratory, The Aerospace Corporation

Janelle Shank, Geospatial Technology, MSISA Graduate, Millersville University

Anthony Williams, Weather Intelligence and Risk Management, Millersville University

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