Data Center Outage Notification and Prediction Utilizing Satellite Weather Information

1. Introduction

The contemporary digital world is fundamentally reliant on data centers, which serve as the central nervous systems for a vast array of services. These facilities underpin cloud computing, facilitate online transactions, and support critical infrastructure, making them indispensable to modern society [1]. The uninterrupted operation of data centers is crucial for businesses, governments, and individuals alike, as our dependence on digital services continues to intensify.

However, data center outages can incur substantial financial losses due to downtime, encompassing reduced productivity, potential data loss, and the violation of service level agreements (SLAs) that can lead to financial penalties [2]. Beyond the immediate financial impact, outages can severely tarnish the reputation of data center operators and erode the trust of their clientele [3]. Furthermore, the interconnected nature of digital services means that disruptions in one data center can trigger cascading failures, potentially impacting a wide range of industries and leading to broader economic and societal consequences.

A significant and growing threat to the reliability of data centers is the increasing frequency and intensity of extreme weather events, a trend largely attributed to anthropogenic climate change [5]. Data center infrastructure, despite its robust design, remains vulnerable to various weather phenomena. Heatwaves can place immense strain on cooling systems, potentially leading to equipment failure. Floods can cause direct physical damage and disrupt power supplies. Severe storms can result in both physical damage to facilities and widespread power outages [7]. Recent history provides numerous examples of data center outages directly caused by extreme weather, including shutdowns due to overheating during heatwaves [5].

In this context, the utilization of satellite weather data presents a promising avenue for proactive mitigation of weather-related data center outages. Satellite technology offers unparalleled capabilities for monitoring and forecasting weather patterns across the globe, providing a comprehensive view that extends beyond the limitations of ground-based sensor networks. This is particularly advantageous for wide-area surveillance and for monitoring remote or underserved regions where ground infrastructure may be sparse [13]. The ability to leverage satellite weather data holds the potential to enable the development of early warning systems, enhance the accuracy of predictive analytics for weather-induced outages, and ultimately bolster the resilience of data centers against these growing environmental challenges.

2. The Landscape of Data Center Outages

Data center outages can arise from a multitude of sources, each with the potential to cause significant disruption. Among the primary causes are power failures, which consistently rank as a leading factor in significant downtime incidents [1]. These failures can originate from instability or disruptions in the external utility grid, malfunctions within the data center's on-site power distribution systems, or the failure of backup power mechanisms such as uninterruptible power supplies (UPS) and generators.

Hardware failures in critical components like servers, storage arrays, and networking equipment also contribute significantly to outages, underscoring the necessity of rigorous maintenance and continuous monitoring practices [2]. Data centers generate a substantial amount of heat, and the effective operation of cooling systems is paramount. Issues such as HVAC system malfunctions, insufficient cooling capacity to handle increasing server densities, or impediments to proper airflow can lead to equipment overheating and subsequent failure, resulting in service disruptions [1].

Human error remains a surprisingly prevalent cause of data center outages. Mistakes made by personnel during routine maintenance, system configuration changes, or in response to alerts can have significant consequences, highlighting the importance of comprehensive training, clearly defined operational procedures, and the implementation of automation where feasible [1]. Network-related problems, including failures in network hardware like switches and routers, as well as outages experienced with third-party network service providers, can also sever critical connectivity and disrupt data center operations [1]. Furthermore, the increasing sophistication of software and the persistent threat of cybersecurity attacks, including malware and DDoS attacks, pose ongoing risks to data center stability and can lead to significant outages [1]. While less frequent than other causes, natural disasters such as earthquakes, floods, wildfires, and severe storms represent a high-impact threat, capable of causing widespread damage and prolonged periods of downtime [2].

Amidst these various factors, weather is emerging as an increasingly significant contributor to data center outages. The correlation between extreme weather events and data center downtime is becoming more pronounced, evidenced by a growing number of incidents and analyses within the industry [5]. The escalating global temperatures associated with climate change are placing greater demands on data center cooling infrastructure, increasing the likelihood of system failures during extended periods of high heat [5]. Certain geographic regions face heightened vulnerability to specific weather phenomena; for instance, coastal data centers are susceptible to hurricanes, which can cause widespread power outages and flooding [18]. Consequently, the ability to accurately predict and proactively prepare for weather-related threats is becoming ever more critical for ensuring the continuous operation of data centers and minimizing potential disruptions to the digital services they support.

3. The Role of Satellite Weather Data in Outage Prediction

Satellite technology has revolutionized weather monitoring and forecasting, offering a diverse array of data that can be instrumental in predicting and mitigating data center outages. Satellites capture imagery across a range of spectral bands, including visible light and infrared, providing crucial information about cloud cover, precipitation, and surface temperatures, all of which are indicators of potential weather hazards [13]. Furthermore, sophisticated satellite instruments can measure key atmospheric variables such as temperature, humidity, and wind speed and direction at various altitudes, contributing significantly to the accuracy of weather forecasts and our understanding of atmospheric dynamics [13]. Satellites equipped with specialized sensors also provide detailed data on precipitation, including rainfall and snowfall rates and accumulation, which is vital for predicting potential flooding and other precipitation-related disruptions [13].

Beyond terrestrial weather, satellites play a crucial role in monitoring solar activity. Geostationary and other satellites continuously observe the Sun for phenomena such as solar flares and coronal mass ejections (CMEs), which can trigger geomagnetic storms. These storms have the potential to induce currents in the Earth's power grid, potentially damaging critical transformers and leading to widespread outages [13]. Notably, a study estimated that NOAA's space weather forecasts and alerts help the electric power industry avoid losses ranging from $111 million for minor geomagnetic disturbances to as much as $27 billion for severe geomagnetic storms [24]. Certain satellites are also equipped to capture nighttime light data. By analyzing changes in the intensity of lights visible from space at night, researchers can detect and assess the extent of power outages following weather events, providing a valuable proxy for direct outage information, especially in areas with limited ground-based reporting [18].

NASA plays a pivotal role in providing open access to a vast amount of satellite-derived weather data through its Open APIs portal [20]. One particularly relevant resource is the Space Weather Database Of Notifications, Knowledge, Information (DONKI). This comprehensive online tool compiles space weather observations, analyses, models, forecasts, and notifications, offering critical data on solar events like coronal mass ejections, solar flares, and geomagnetic storms that can impact terrestrial infrastructure, including power grids [13]. For accessing a broad range of NASA Earth science data, including satellite imagery and atmospheric datasets pertinent to weather monitoring, the Earthdata Search portal serves as an invaluable discovery tool [14]. The POWER (Prediction Of Worldwide Energy Resources) project provides meteorological datasets derived from satellite observations, specifically tailored for applications in renewable energy and other sectors, which include parameters relevant to data center operations such as solar irradiance, temperature, wind speed, and precipitation [19]. Furthermore, the Global Imagery Browse Services (GIBS) APIs offer a highly responsive way to access global, full-resolution satellite imagery, enabling the visualization of current and historical Earth conditions, which can be useful for monitoring weather patterns and their potential impact on data center locations [15].

4. Commercial Solutions for Weather-Aware Outage Management

The increasing need for proactive management of weather-related risks has spurred the development of commercial solutions aimed at integrating weather intelligence into various operational contexts, including data center management. Identifying companies that specialize in data center monitoring and management and are incorporating predictive analytics, particularly through the integration of weather data, is a crucial step in understanding the current landscape [20].

Several prominent weather data providers offer APIs and platforms that can be integrated into data center monitoring systems. The Weather Company, an IBM business, stands out as a major player, providing highly accurate real-time weather APIs and extensive historical weather data [30]. Their Weather Analytics and Insights API is specifically designed to support decision-making across various industries, including the energy and utilities sector, by delivering actionable weather intelligence [30]. IBM's Environmental Intelligence Suite even features an Outage Prediction module that combines weather data with utility-specific information to forecast potential power outages, a capability that could be adapted to predict data center vulnerabilities arising from weather-induced power disruptions [31]. AccuWeather is another globally recognized service, offering highly localized weather forecasts with minute-by-minute updates and a broad spectrum of advanced weather data products, including industry-specific solutions relevant to the energy sector [34]. AerisWeather focuses on delivering high-quality weather data and sophisticated analytics to businesses through weather APIs and customizable solutions, enabling seamless integration of weather information into existing applications and operational workflows [34]. Custom Weather provides tailored weather forecasting services and real-time weather alerts designed to meet the unique needs of businesses across diverse industries, offering localized forecasts and customized weather data feeds [34].

For more localized monitoring needs, Perry Weather offers comprehensive on-site weather monitoring and alerting systems, including the deployment of weather stations and the provision of real-time alerts for various weather hazards, which could be particularly beneficial for individual data center facilities [35]. OpenWeather provides a free and open-source weather API, including an Alerts API that allows users to pull data on specific weather alerts based on location and other criteria, offering a potential resource for data centers to stay informed about impending weather threats [36]. Finally, EOS Data Analytics (EOSDA) offers a Satellite API providing access to a vast archive of satellite imagery and weather data, including historical records and forecasts, which could be valuable for developing comprehensive weather-aware monitoring solutions [38].

Table 1: Summary of Commercial Weather Data Providers and Their Offerings Relevant to Data Centers

Company Name	Key Weather Data Offered	Relevant APIs/Platforms	Industry Focus (if applicable)
The Weather Company (IBM)	Real-time, Forecasts, Historical, Alerts, Satellite Imagery (indirectly), Analytics	Weather APIs, Environmental Intelligence Suite	Energy, Utilities, Aviation
AccuWeather	Hyper-local, Minute-by-minute forecasts, Global coverage, Severe Weather Alerts	APIs, Enterprise Solutions	Energy, Transportation, Retail
AerisWeather	Real-time, Forecasts, Historical, Radar, Satellite Imagery,	Weather APIs, AerisPulse	Logistics, Energy, Agriculture

	Customizable solutions		
Custom Weather	Global coverage, Real-time, Forecasts, Alerts, Historical, Maps	APIs, Custom Solutions	Retail, Construction, Energy
Perry Weather	On-site data (Temperature, Humidity, Lightning, etc.), Automated Alerts, All-clear notifications	On-Site Weather Stations, Mobile & Desktop App	Athletics, Energy, Construction
OpenWeather	Current, Forecasts, Historical, Alerts	Weather API, Alerts API	General Weather Data
EOS Data Analytics	Satellite Imagery (multi-source), 7-day Forecasts, Historical, Indices (NDVI, etc.)	Satellite API, Weather Data API, EOSDA Crop Monitoring	Agriculture

This table provides a consolidated view of some of the key commercial weather data providers and their relevant offerings, highlighting the diverse options available for data centers seeking to integrate weather intelligence into their operations.

5. Cloud Provider Initiatives

Major cloud service providers, including AWS, Azure, and GCP, offer a range of services designed to help users monitor the health and availability of their cloud-based resources. AWS provides the AWS Health API, which allows programmatic access to information about events that may affect AWS services and resources [39]. The AWS Health Dashboard offers a console-based view of service health [45]. While AWS offers Amazon Forecast for time-series prediction, there is no specific service mentioned in the provided snippets that directly integrates external satellite weather data for predicting outages in user-managed data centers [46].

Similarly, Microsoft Azure offers Azure Service Health, providing personalized insights into the health of Azure services and regions used by a customer [47]. Azure Service Health includes Azure status, the service health service, and Resource Health, offering different perspectives on platform and resource availability [50]. Azure also provides

APIs for programmatically accessing service health events [51]. However, the snippets do not indicate a specific Azure service for integrating external satellite weather data to predict outages in user-defined data centers.

Google Cloud Platform (GCP) offers the Service Health API, enabling programmatic access to real-time and historical data on the operational status of GCP services relevant to a user's projects [53]. The Personalized Service Health dashboard in the Google Cloud Console offers a filtered view of disruptive events affecting specific GCP resources [55]. GCP also provides Google Cloud (WeatherNext), an AI-powered weather forecasting model [46]. Nevertheless, the provided information does not reveal a specific GCP service that allows users to integrate external satellite weather data for outage prediction within their own data center deployments on the platform.

While these cloud providers offer sophisticated monitoring and notification systems for their own infrastructure and possess advanced capabilities in areas like AI and weather forecasting, the current offerings appear to primarily focus on the health of their cloud services. There is no explicit evidence in the provided research material that they currently provide specific, readily available services that enable users to directly integrate external satellite weather data for predicting outages within their own data center deployments hosted on these platforms.

6. Academic Research and Development

Academic research has extensively explored the prediction of power outages using a variety of weather data sources and advanced analytical techniques. Studies have employed machine learning algorithms and statistical models to forecast outages based on weather forecasts and historical data, focusing on various weather events such as severe rain and wind, hurricanes, and thunderstorms [58]. Researchers have developed dynamic and granular outage forecasting models, even utilizing high-resolution radar data in Bayesian prediction algorithms to enhance accuracy [58].

A significant area of innovation lies in the use of satellite nighttime light data as a proxy for power outages, particularly valuable in regions where traditional outage records are scarce. Studies have demonstrated the effectiveness of using data from the Visible Infrared Imaging Radiometer Suite (VIIRS) to predict hurricane-induced power outages by analyzing changes in nighttime illumination [18]. These approaches often involve comparing pre- and post-disaster illumination levels and developing machine learning models that incorporate this satellite data along with geographic and weather variables [18].

Recognizing the critical importance of infrastructure resilience during severe weather, academic work has also addressed the prediction of telecommunication infrastructure outages during hurricanes. Researchers have developed both time-independent models for rapid pre-hurricane assessment and time-dependent models leveraging recurrent neural networks like LSTM for real-time prediction as a storm progresses [64]. This body of research on power and telecommunication outage prediction offers valuable methodologies and insights that could be adapted and applied to the specific challenges of predicting outages in data center environments, especially considering their reliance on stable power and network connectivity.

7. Open-Source Projects and Community Efforts

Exploring open-source platforms like GitHub for projects related to data center outage notification and prediction using weather data reveals a landscape ripe with potential, though perhaps not yet with fully mature, dedicated solutions. A search using keywords such as "data center outage notification weather" or "weather-aware data center monitoring" may yield some relevant projects or components that could be adapted.

The realm of open-source Data Center Infrastructure Management (DCIM) tools presents another promising avenue. Tools like NetBox, RackTables, OpenDCIM, and Ralph offer functionalities for managing and monitoring various aspects of data center infrastructure, including power, cooling, and environmental conditions [65]. These platforms often have modular architectures or APIs that could potentially be leveraged to integrate weather data feeds or to develop custom plugins for weather-aware outage prediction.

The availability of open-source weather data APIs is also a significant enabler for community-driven development. Open-Meteo, for instance, provides a free and open-source weather API that offers access to a wide range of weather data, including forecasts and historical information, which could be readily integrated into data center monitoring systems [36]. Similarly, the NOAA Weather API offers open access to critical weather forecasts, alerts, and observations for the United States, providing a valuable resource for projects focused on data centers within the US [30]. While a specific, end-to-end open-source solution for data center outage prediction using satellite weather data might not yet be widely available, the combination of existing open-source DCIM tools, accessible weather data APIs, and the potential for utilizing open satellite data sources like those provided by NASA creates a strong foundation for community-led innovation in this critical area.

8. Beyond Weather: Other Factors Influencing Data Center

Outages

While the focus of this report is on weather-related outages, it is essential to acknowledge that data centers are susceptible to disruptions from a variety of other factors. Power grid failures, stemming from issues external to the data center such as utility equipment malfunctions or insufficient grid capacity, can lead to significant outages if backup systems are inadequate [1]. The increasing threat of cyberattacks, including sophisticated ransomware and denial-of-service attacks, poses a serious risk to data center operations and can result in service disruptions and outages [1]. Human error during maintenance, system configurations, or emergency responses remains a surprisingly common cause of downtime, underscoring the need for robust training and well-defined operational protocols [1]. Hardware malfunctions in critical components like servers, storage devices, and networking equipment are also a significant contributor to outages, highlighting the importance of proactive maintenance and monitoring [2]. Software failures, whether due to bugs, misconfigurations, or incompatibilities, can also lead to unexpected service interruptions [1]. Finally, issues with both internal network infrastructure and external network connectivity can disrupt data flow and potentially cause outages affecting hosted services and applications [1]. Therefore, a comprehensive approach to ensuring data center uptime requires addressing vulnerabilities across all these potential causes, with weather-aware prediction being an important but integral part of a broader risk management strategy.

9. Strategic Considerations for Data Center Location

The strategic selection of a data center location is a critical decision that can significantly impact its long-term reliability and resilience, particularly in the face of increasing environmental challenges. A primary consideration is the availability of a stable and sufficient power supply, including the reliability of the local power grid and access to robust electrical infrastructure [68]. Proximity to fiber optic networks, internet exchange points (IXPs), and a diverse range of network carriers is essential to ensure high-bandwidth and low-latency connectivity, which is fundamental for data center operations [68]. A thorough assessment of environmental risks is also paramount, including the likelihood of natural disasters such as earthquakes, floods, hurricanes, and extreme weather events. Locations with a lower propensity for these hazards are generally preferred to minimize the risk of disruptions [68]. The availability of resources for cooling, especially water in regions utilizing water-based cooling systems, is another important factor. Furthermore, considering the ambient temperature and humidity of a location can significantly influence the efficiency and cost of data center cooling operations, with cooler climates often offering advantages [6]. Economic factors such as the cost of real estate, the price of electricity, and the presence of tax incentives can also play a crucial role in site selection [68]. Finally, depending on the data center's purpose, proximity to end-users and cloud connectivity hubs can be a strategic advantage for minimizing latency and facilitating access to broader digital ecosystems [69].

10. Conclusion and Future Directions

The analysis indicates a growing recognition of the importance of predicting and mitigating data center outages, particularly those caused by increasingly frequent and intense weather events. While commercial solutions that specifically integrate satellite weather data for this purpose are still emerging, a variety of weather data providers offer APIs and platforms that could be leveraged. Academic research has made significant advancements in predicting power outages using weather data, including innovative approaches utilizing satellite nighttime light imagery. Major cloud providers offer comprehensive service health monitoring for their own infrastructure, but direct integration of external satellite weather data for user-managed data centers appears limited.

Despite the progress, challenges and gaps remain. There is a need for more readily available commercial solutions tailored to the specific needs of data centers for weather-aware outage prediction using satellite data. Further research is required to deepen our understanding of the precise impacts of various weather phenomena, as observed from space, on different data center components. Integrating diverse satellite datasets with existing monitoring systems and a lack of widespread specialized expertise also present potential barriers to adoption.

Looking ahead, several future directions and opportunities emerge. We can anticipate an increased integration of satellite weather data into comprehensive data center monitoring and management platforms. Advancements in AI and machine learning will likely lead to the development of more sophisticated predictive models leveraging satellite data. The open-source community has a significant opportunity to contribute by developing cost-effective solutions using publicly available weather and satellite data. Enhanced collaboration between weather data providers, data center operators, and cloud service providers will be crucial for creating tailored and effective solutions. Finally, continued improvements in the accuracy and granularity of satellite-based weather forecasts will directly enhance the ability to predict and prepare for weather-related data center outages, ultimately bolstering the resilience of our critical digital infrastructure.

Table 2: Overview of NASA's Relevant Space Weather and Earth Observation APIs

API Name	Description of Data Provided	Key Parameters/Endpoints Relevant to Weather and Outages	Link to Documentation
DONKI (Space Weather Database Of Notifications, Knowledge, and Information)	Chronicles space weather observations, analysis, models, forecasts, and notifications, primarily from the Space Weather Research Center (SWRC).	Coronal Mass Ejections (CME), Geomagnetic Storms (GST), Solar Flares (FLR), Notifications (including type filtering).	[13]
Earthdata Search	Discovery portal for NASA Earth science data, including satellite imagery and atmospheric datasets.	Search by keyword, date range, spatial coordinates, dataset short name (e.g., MODIS, VIIRS).	[14]
POWER (Prediction Of Worldwide Energy Resources)	Meteorological datasets derived from satellite observations, focused on renewable energy applications.	Surface meteorology and solar energy parameters (temperature, precipitation, wind speed, solar irradiance).	[19]
GIBS (Global Imagery Browse Services)	Global, full-resolution satellite imagery in a highly responsive manner.	Web Map Tile Service (WMTS), Web Map Service (WMS) for accessing imagery products.	[15]

Table 3: Common Causes of Data Center Outages and Associated Weather Triggers

Cause of Outage	**Potential Weather Triggers**	**Relevant Research Snippets**
Power Failures	Severe storms (lightning, high winds), geomagnetic storms (solar flares, CMEs), extreme heat (increased demand leading to grid instability), flooding (substation damage).	[1]
Cooling System Issues	Prolonged heatwaves, high humidity, extreme cold (freezing of cooling systems).	[1]
Network Issues	Severe storms (damage to terrestrial infrastructure), extreme weather affecting satellite communication.	[1]
Natural Disasters	Hurricanes (high winds, flooding), floods (inundation of facilities), wildfires (smoke and heat damage, power outages), extreme cold (freezing).	[2]
Human Error	Stress on personnel during severe weather events potentially leading to mistakes.	[1]

Works cited

1. Data Center Outage: Common Causes and Proven Prevention Methods, accessed March 27, 2025, https://andcable.com/cable-management/data-center-outage-causes-prevention/
2. Causes of Data Center Outages and Solutions to Prevent Them - Motadata, accessed March 27, 2025, https://www.motadata.com/blog/causes-of-data-center-outages/
3. Causes of Data Center Outages and How to Prevent Them | Park Place Technologies, accessed March 27, 2025, https://www.parkplacetechnologies.com/blog/causes-of-data-center-outages-h

ow-to-prevent-them/
4. Most Common Causes of Data Center Outages - Newtech Group, accessed March 27, 2025, https://www.newtechapac.com/most-common-causes-of-data-center-outages/
5. Ask the Experts – How Are Data Centers Impacted by Climate Change? - Boston University, accessed March 23, 2025, https://www.bu.edu/hic/2022/10/12/ask-the-experts-how-are-data-centers-impacted-by-climate-change/
6. How Do Data Centers Adapt to Climate Change - FS.com, accessed March 23, 2025, https://www.fs.com/blog/how-do-data-centers-adapt-to-climate-change-13625.html
7. Extreme Weather | Cybersecurity and Infrastructure Security Agency CISA, accessed March 23, 2025, https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience/extreme-weather
8. The Climate Change-Ready Data Center - Accelsius, accessed March 23, 2025, https://accelsius.com/the-climate-change-ready-data-center/
9. The Effects of Climate Change on Data Centers - Dataspan, accessed March 23, 2025, https://dataspan.com/blog/effects-of-climate-change-on-data-centers/
10. Data centers at 'Vulnerability' to Climate Change - Veritis, accessed March 23, 2025, https://www.veritis.com/blog/datacenters-at-the-vulnerability-to-climate-change/
11. Data Centers At Risk From Climate Change - Computer Futures, accessed March 23, 2025, https://www.computerfutures.com/en-us/knowledge-hub/ai-machine-learning/data-centers-facing-the-threat-of-the-climate-crisis/
12. How to Protect Your Data Center in Extreme Weather | Fuller Engineering LLC, accessed March 23, 2025, https://fullerengr.com/how-to-protect-your-data-center-in-extreme-weather/
13. API Reference — nasapy 0.2.3 documentation, accessed March 23, 2025, https://nasapy.readthedocs.io/en/latest/api.html
14. Earthdata Search - NASA, accessed March 23, 2025, https://search.earthdata.nasa.gov/
15. Global Imagery Browse Services APIs | NASA Earthdata, accessed March 23, 2025, https://www.earthdata.nasa.gov/engage/open-data-services-software/earthdata-developer-portal/gibs-api
16. NOAA Satellite-Based Climate and Weather Data, accessed March 23, 2025, https://coast.noaa.gov/digitalcoast/data/satellite.html
17. Reducing the Risks of Power Outages in Data Centers | Volico, accessed March 27, 2025, https://www.volico.com/reducing-the-risks-of-power-outages-in-data-centers/
18. On the Use of Satellite Nightlights for Power Outages Prediction - Brookhaven

National Laboratory, accessed March 27, 2025, https://www.bnl.gov/tcp/uploads/files/2023-007j.pdf
19. nasa power | dav, accessed March 23, 2025, https://power.larc.nasa.gov/data-access-viewer/
20. NASA Open APIs, accessed March 23, 2025, https://api.nasa.gov/
21. DONKI | Documentation | Postman API Network, accessed March 23, 2025, https://www.postman.com/miguelolave/workspace/nasa-open-apis/documentation/3419756-c07cfadb-8b45-4441-9483-95b61d99a1c6
22. Space Weather Database Of Notifications, Knowledge, Information (DONKI) | T2 Portal, accessed March 23, 2025, https://technology.nasa.gov/patent/GSC-TOPS-223
23. DONKI - NASA CCMC, accessed March 23, 2025, https://ccmc.gsfc.nasa.gov/tools/DONKI/
24. Safeguarding Satellites: How NOAA Monitors Space Weather to Prevent Disruptions, accessed March 27, 2025, https://www.nesdis.noaa.gov/news/safeguarding-satellites-how-noaa-monitors-space-weather-prevent-disruptions
25. The electricity scene from above: Exploring power grid inconsistencies using satellite data in Accra, Ghana, accessed March 23, 2025, https://nline.io/docs/klugman22satellite.pdf
26. NASA Open Data Portal, accessed March 23, 2025, https://data.nasa.gov/
27. NASA Open APIs - Postman, accessed March 23, 2025, https://www.postman.com/miguelolave/nasa-open-apis/overview
28. How To Use NASA API: A Comprehensive Guide - Apidog, accessed March 23, 2025, https://apidog.com/blog/how-to-use-nasa-api/
29. NASA POWER | Prediction Of Worldwide Energy Resources, accessed March 27, 2025, https://power.larc.nasa.gov/
30. Weather Data APIs: Real-time & historical weather intelligence, accessed March 23, 2025, https://www.weathercompany.com/weather-data-apis/
31. Outage Prediction - IBM, accessed March 27, 2025, https://www.ibm.com/docs/en/environmental-intel-suite?topic=solutions-outage-prediction
32. Monitoring Services - IBM Environmental Intelligence, accessed March 27, 2025, https://www.ibm.com/products/environmental-intelligence/solutions/monitoring
33. How utilities can prepare for extreme weather with data and AI | IBM, accessed March 27, 2025, https://www.ibm.com/think/topics/weather-data-for-utilities
34. Top 10 Weather Forecasting Services Companies: Leaders in Weather Prediction and Climate Insights - TechSci Research, accessed March 27, 2025, https://www.techsciresearch.com/blog/top-weather-forecasting-services-companies-leaders-in-weather-prediction-and-climate-insights/4601.html
35. Perry Weather: On-Site Weather Monitoring and Alerting, accessed March 27, 2025, https://perryweather.com/
36. Open-Meteo.com: 🌤️ Free Open-Source Weather API, accessed March 23, 2025, https://open-meteo.com/
37. OpenWeather alerts API, accessed March 27, 2025,

https://docs.openweather.co.uk/openweather-alerts
38. API Access To Satellite Data: Imagery, Statistics, Weather, accessed March 23, 2025, https://eos.com/products/crop-monitoring/satellite-data-api/
39. Integrating AWS Health with other systems using the AWS Health API, accessed March 23, 2025, https://docs.aws.amazon.com/health/latest/ug/health-api.html
40. Welcome - AWS Health, accessed March 23, 2025, https://docs.aws.amazon.com/health/latest/APIReference/Welcome.html
41. aws health - Fig.io, accessed March 23, 2025, https://fig.io/manual/aws/health
42. Health — Boto3 Docs 1.26.93 documentation - AWS, accessed March 23, 2025, https://boto3.amazonaws.com/v1/documentation/api/1.26.93/reference/services/health.html
43. health — AWS CLI 2.0.33 Command Reference, accessed March 23, 2025, https://awscli.amazonaws.com/v2/documentation/api/2.0.33/reference/health/index.html
44. Concepts for AWS Health, accessed March 23, 2025, https://docs.aws.amazon.com/health/latest/ug/aws-health-concepts-and-terms.html
45. AWS Health Dashboard - AWS Documentation, accessed March 23, 2025, https://docs.aws.amazon.com/health/latest/ug/aws-health-dashboard-status.html
46. The Integration of AI-Powered Weather Predictions into Cloud Services: Transforming Industry Forecasting - CloudThat Resources, accessed March 27, 2025, https://www.cloudthat.com/resources/blog/the-integration-of-ai-powered-weather-predictions-into-cloud-services-transforming-industry-forecasting
47. Azure Health Data Services documentation - Microsoft Learn, accessed March 23, 2025, https://learn.microsoft.com/en-us/azure/healthcare-apis/
48. Azure Health Data Services, accessed March 23, 2025, https://azure.microsoft.com/en-us/products/health-data-services
49. Azure Service Health documentation - Learn Microsoft, accessed March 23, 2025, https://learn.microsoft.com/en-us/azure/service-health/
50. Azure Service Health - Learn Microsoft, accessed March 23, 2025, https://learn.microsoft.com/en-us/azure/service-health/overview
51. Azure - API - Lists current service health events in the tenant - Stack Overflow, accessed March 23, 2025, https://stackoverflow.com/questions/78991560/azure-api-lists-current-service-health-events-in-the-tenant
52. Elevated access for viewing Security Advisories - Azure Service Health, accessed March 23, 2025, https://docs.azure.cn/en-us/service-health/security-advisories-elevated-access
53. Service Health API - Google Cloud, accessed March 23, 2025, https://cloud.google.com/service-health/docs/reference/rest
54. Stay Ahead of the Curve with Google Cloud's Service Health API - Medium, accessed March 23, 2025, https://medium.com/google-cloud/stay-ahead-of-the-curve-with-google-clouds-service-health-api-aa1490df1cab

55. Personalized Service Health | Google Cloud, accessed March 23, 2025, https://cloud.google.com/service-health
56. Service Health API - Google Cloud, accessed March 23, 2025, https://cloud.google.com/service-health/docs/reference
57. Google Cloud Service Health, accessed March 23, 2025, https://status.cloud.google.com/
58. On Learning-Based Model for Dynamic Granular Prediction of Power Outages Under Extreme Events - OSTI, accessed March 27, 2025, https://www.osti.gov/servlets/purl/2440516
59. Outage Prediction: Using Big Data to Solve Big Problems - ThinkGrid, accessed March 27, 2025, https://thinkgrid.grid.gevernova.com/articles/outage-prediction-using-big-data-to-solve-big-problems
60. Machine Learning Model Development to Predict Power Outage Duration (POD): A Case Study for Electric Utilities - MDPI, accessed March 27, 2025, https://www.mdpi.com/1424-8220/24/13/4313
61. Study shows power outage predictions in windstorms improved when accounting for multi-hazard effects - Met Office, accessed March 27, 2025, https://www.metoffice.gov.uk/about-us/news-and-media/media-centre/weather-and-climate-news/2025/study-shows-power-outage-predictions-in-windstorms-improved-when-accounting-for-multi-hazard-effects
62. 6. Weather and Impact Modeling for Outage Prediction, Management, and Restoration, accessed March 27, 2025, https://wiser-iucrc.com/2024-research/weather-and-impact-modeling-for-outage-prediction-management-and-restoration
63. A Bayesian Approach Based Outage Prediction in Electric Utility Systems Using Radar Measurement Data | Request PDF - ResearchGate, accessed March 27, 2025, https://www.researchgate.net/publication/317071730_A_Bayesian_Approach_Based_Outage_Prediction_in_Electric_Utility_Systems_Using_Radar_Measurement_Data
64. Data-Driven Telecommunication Outage Prediction during Hurricane Events | ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A, accessed March 27, 2025, https://ascelibrary.org/doi/10.1061/AJRUA6.RUENG-1285
65. 8 Open-Source DCIM Tools - NetBox Labs, accessed March 23, 2025, https://netboxlabs.com/blog/open-source-dcim-tools/
66. API Web Service - National Weather Service, accessed March 27, 2025, https://www.weather.gov/documentation/services-web-api
67. Severe Weather Awareness - Weather Alerts, accessed March 27, 2025, https://www.weather.gov/mob/Severe_Alert
68. United States Data Centers: Top 10 Locations in the USA - Dgtl Infra, accessed March 27, 2025, https://dgtlinfra.com/united-states-data-centers/
69. 5 Considerations for Choosing Data Center Locations - Interconnections - The Equinix Blog, accessed March 27, 2025, https://blog.equinix.com/blog/2024/08/06/5-considerations-for-choosing-data-c

enter-locations/
70. Cities and regions with the highest concentration of data centers, accessed March 27, 2025, https://irei.com/publications/article/cities-regions-highest-concentration-data-centers/
71. Top 10 U.S. Data Center Markets and Why They Are Hot - CoreSite, accessed March 27, 2025, https://www.coresite.com/blog/top-10-u-s-data-center-markets-and-why-they-are-hot