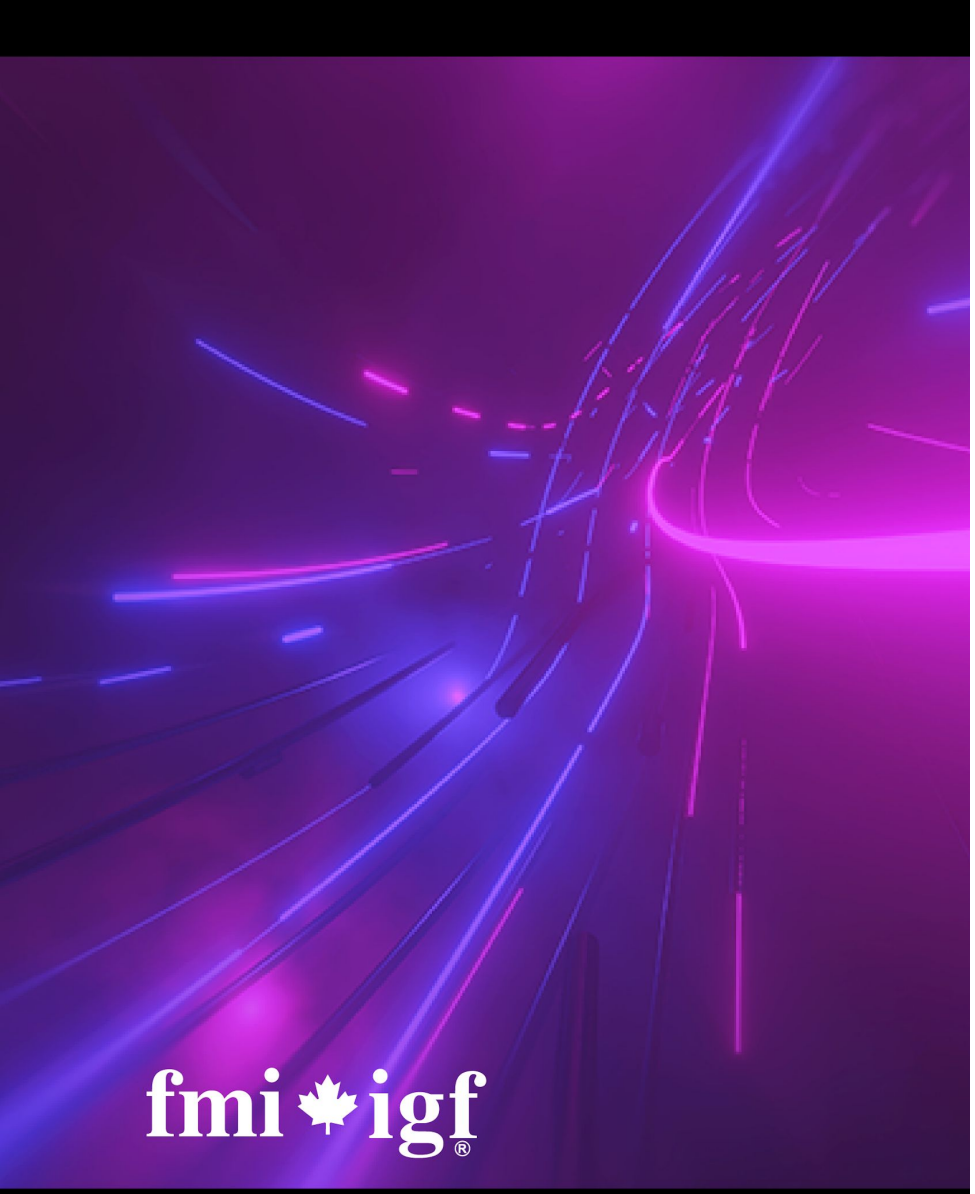
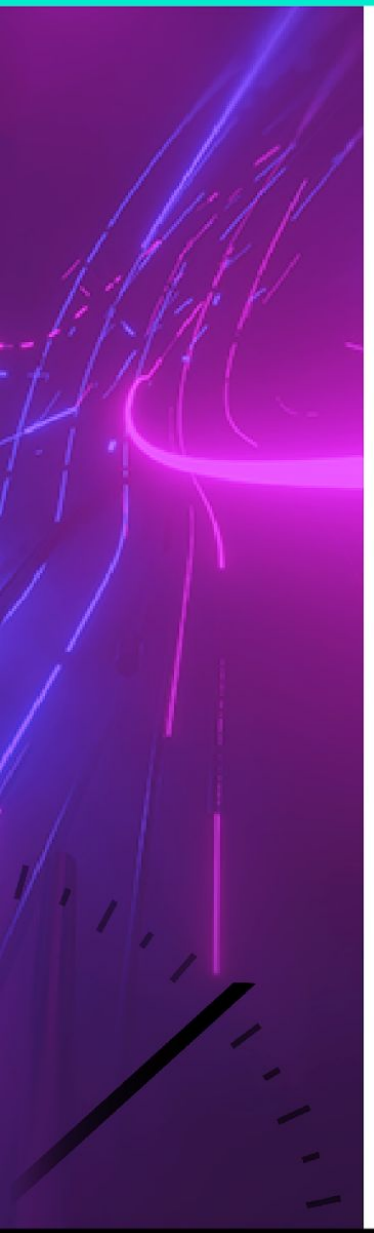


PD WEEK 2022

SEMAINE DE PP 2022

Spatial Finance

The integration of geospatial data and analysis into financial research



THE VIEWS EXPRESSED IN THIS PRESENTATION ARE THOSE OF THE SPEAKERS AND DO NOT NECESSARILY REFLECT THE OFFICIAL VIEWS OF THE BANK OF CANADA. NO RESPONSIBILITY FOR THEM SHOULD BE ATTRIBUTED TO THE BANK.

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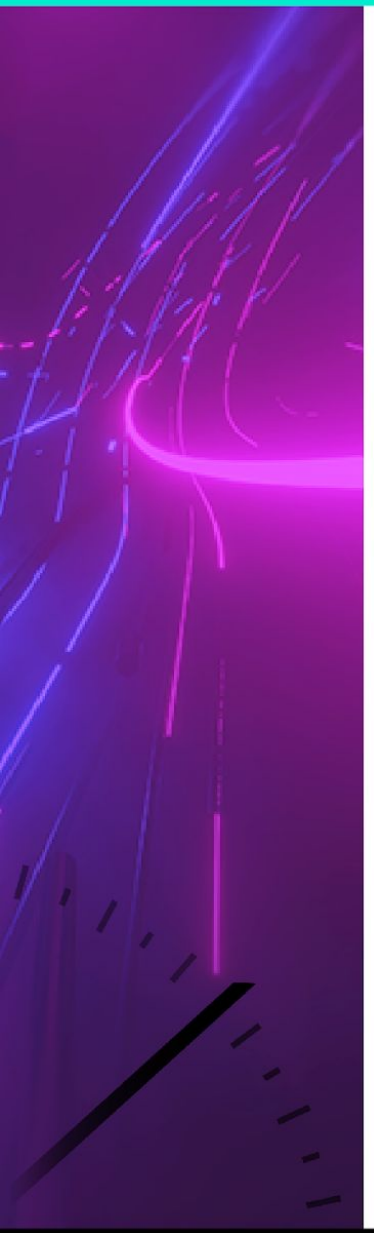
BANK OF CANADA

Caleb White

Chief Operating Officer

Climate Engine®



Why

Climate change will have profound impact on almost every sector of the economy in the decades ahead.

The need to understand these effects and their implications for the economy and financial system places climate change analysis within the scope.

Understanding risks to the economy and the financial system related to climate change

Developing a set of Canada-relevant scenarios and analyses

Through our research and analysis, we are working with partners in Canada and internationally to ensure that our economy and financial system are adequately prepared to handle such risks.

Physical Risks and Transition Risks

Physical Risks

Increasing number and severity of extreme weather events

Potential significant impacts on the financial system

Can adversely affect several parts of the economy

For example: diminish labour productivity, agricultural yields and industrial output.

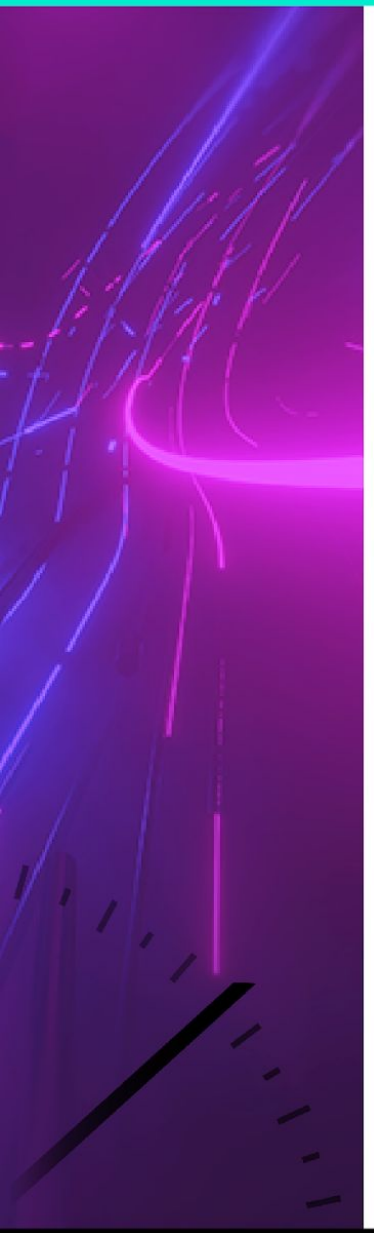
Reducing these physical risks requires global action on climate change policies supported by technological progress and socio-economic change.

But efforts to decarbonize economies carry risks of their own.

Transition Risk

A late and abrupt transition to a low-carbon economy could lead to assets suddenly losing value and a rapid repricing of climate-related risks.

This could negatively affect the balance sheets of financial market participants, with potential consequences for financial stability overall.



Shocks

Identifying the nature, persistence and magnitude of the shocks.

Physical risks will likely imply increases in the frequency and severity of:

- *Negative supply shocks* (e.g., destruction of capital stocks, disruptions to labour supply, disruptions to supply chains)
- *Demand shocks* (e.g., damage to household and corporate balance sheets, reduced consumption and investment).

High degree of uncertainty regarding the future path of climate change, climate-related policies, technological innovation and socio-economic changes.

Climate-economy models should develop a range of plausible macro-financial scenarios:

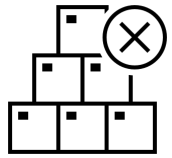
- Impacts of more frequent and severe extreme weather events on short-term forecasting
- Sectoral, regional and macroeconomic effects of the transition to a low-carbon economy
- Long-term structural effects

Risks to the financial system

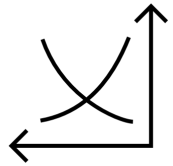
More frequent or severe extreme weather events and/or a late and abrupt transition to a low-carbon economy could have significant impacts on the Canadian financial system.

Damage to physical assets: real estate, capital, infrastructure

Loss of life with consequent property and casualty (P&C) insurance losses



Increases in defaults, and potential financial sector distress



Sudden repricing of climate-related risks and stranded assets negatively affect the balance sheets of financial market participants

Challenging problem

Assessing the impacts of physical and transition risks on the financial system is one of the most prominent issues.

Uncertainties around the course of climate change, the breadth and complexity of the transmission channels, the direct and indirect impacts, and the need to consider some combination of both physical and transition risks make it particularly challenging.

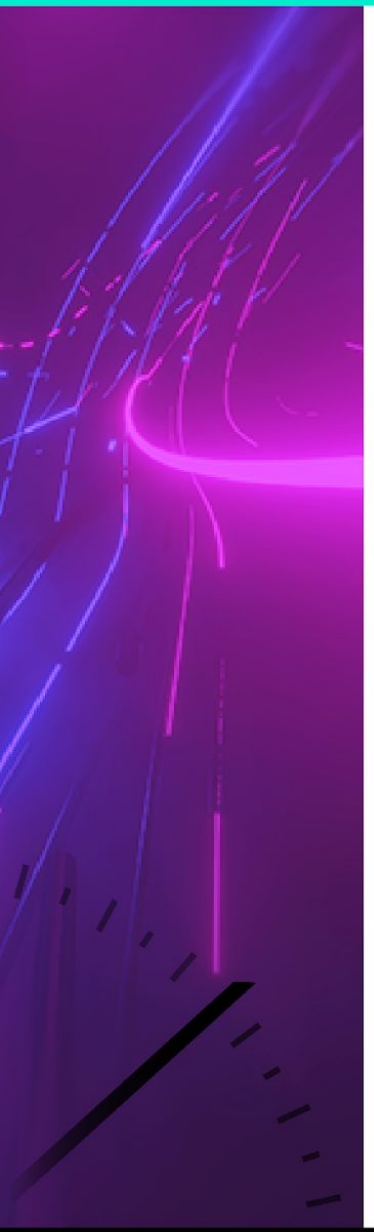
Data-driven scenarios can be used to explore the direction and scale of outcomes.

A data-driven challenge

Climate scenario analysis (particularly physical risk projections) require

- High geographic resolution for data
- Detailed geographic location of assets (e.g. farms, manufacturing etc.)
- Reliable data relationship between spatial data and industrial sectors
- Accurate historical and current data of climate events
- Timely, high frequency, easily accessible climate risk data
- Sophisticated subject-matter expertise to correctly interpret spatial data and perform analysis

Get to Climate Insights Faster with Google Cloud



Google has an ambitious 10-year strategy for climate action that goes far beyond our own operations

Leading at Google

Go beyond carbon neutrality for our operations

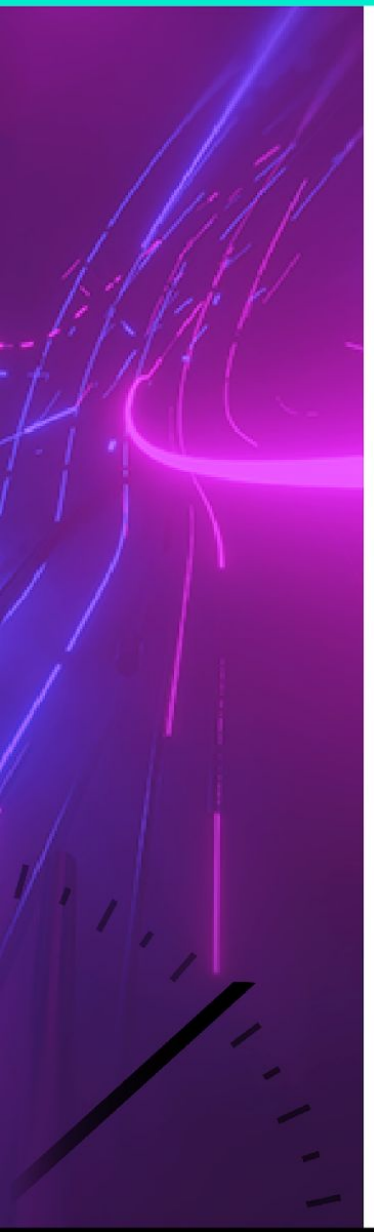
Supporting Partners

Empower partners (companies, nonprofits, researchers, policymakers, etc.) with the tech they need to scale up climate solutions

Enabling Everyone

Through our products (core products, consumer hardware), we offer helpful ways for everyone to be part of the solution

Watch more about Google's sustainability mission



By partnering with Google Cloud, you can deliver innovation that benefits the environment and your business

01

Digital Sustainability

Google data centers are **twice as energy efficient** as a typical enterprise data center and compared to 5 years ago we deliver **7x the compute power** for the same amount of electricity.[1]

02

Sustainable Value Chains

Minimize your footprint no matter where your supply chain operates in.

Improve decision-making and **lower your TCO by 26% to 34%** with BigQuery, while **cutting analyst workload by 70%** using a centralized data model with Looker.[2]

03

ESG Process Transformation

Enable faster speed to value with accessible AI/ML that anyone who works with data can use

High-quality, automated, and accurate AI/ML results, with **benchmarks in the top 8% and higher.**[3]

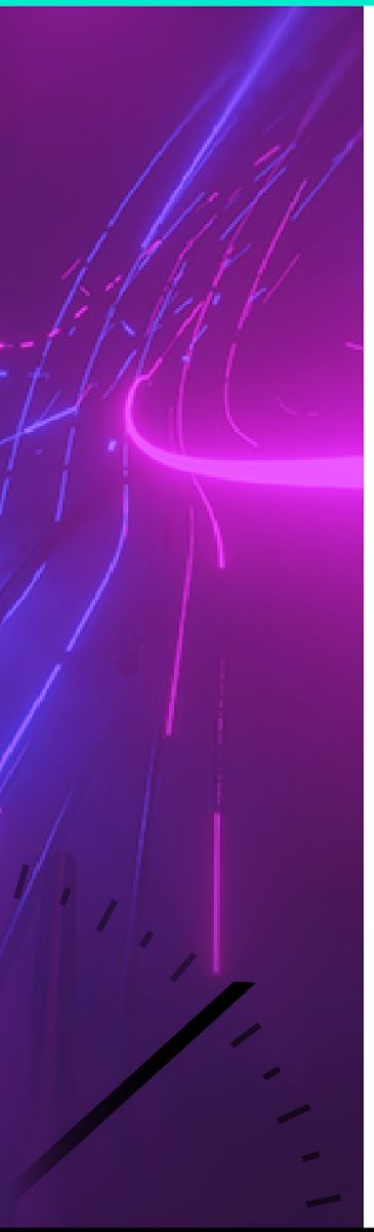
04

Climate Risk & Resilience

Understand the impact on the Earth from **40+ years of satellite imagery** in Google Earth.

Access **over forty petabytes of geospatial data** instantly available for analysis.[4]

1) Google Cloud Sustainability 2) Quantifying the performance of the TPU, our first machine learning chip, 3) Google AI Blog Using AutoML for Time Series Forecasting 4)Google Earth Engine



Get to climate insights faster

01

Data

Integrate and access climate related datasets along with a rich catalog of relevant data sets

- Public Data
- Google Earth Engine
- Commercial Data
- Agency Data

02

Smart Analytics

Geospatial analytics & AI to assess climate impact and rapidly surface insights

- BigQuery
- Looker
- Compute Engine
- Vertex AI

03

Google Ecosystem

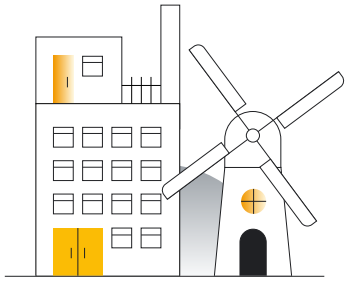
Partnerships that enable deeper insights and easy to use interfaces

- Climate Engine
- Carto
- Aclima
- RS Metrics

Cleanest cloud in the industry

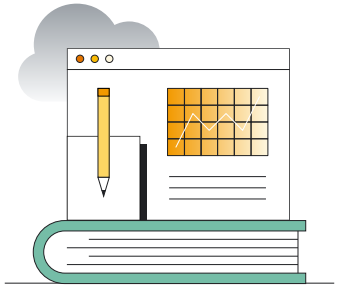
Earth observation data and analysis is critical for making sustainability decisions with accuracy, speed and scale

Collate business' physical locations prone to sustainability risk (land, forestry, biodiversity, water, etc)

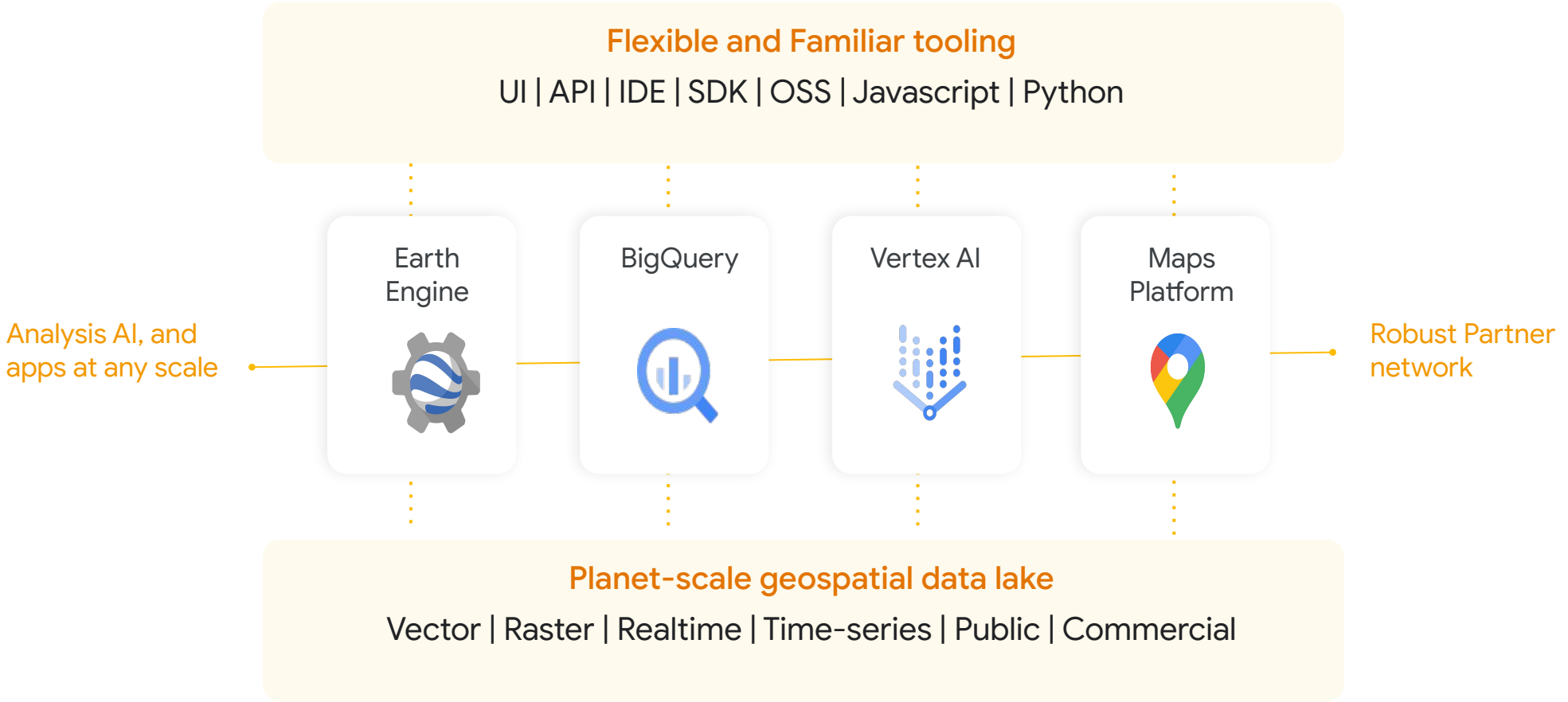


Link them to observable data about the Earth's surface globally and in near real-time

Analyze and evaluate how to reduce impact and improve business operations



Google Cloud's comprehensive platform helps you solve for common geospatial use cases at scale

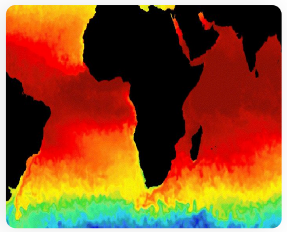


Gain relevant insights leveraging public and commercial datasets available through Google Cloud and its partners

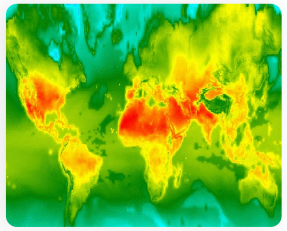
Google Earth Engine provides more than 40 years of historical imagery and scientific datasets, updated and expanded daily

- Climate & Weather
- Imagery
- Geophysical

Climate and Weather



Surface Temperature



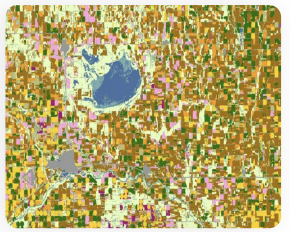
Climate

Imagery

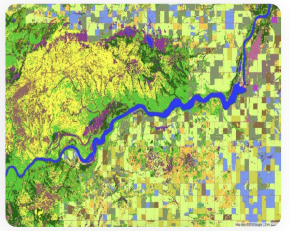
Landsat

Sentinel

Geophysical



Crop land



Land cover

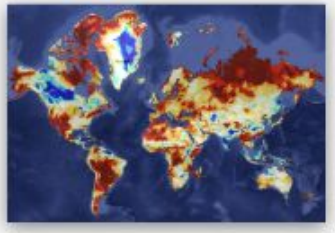
Full data catalog at:
https://developers.google.com/earth-engine/datasets

From Science to Finance: Earth Insights for Climate Resilience with Climate Engine

Data-driven decision making: Dynamic Earth insights, across space & time

Historical

Historical analyses provide baselines for what is 'normal' in order to identify anomalies.



Use Cases

Establish average conditions

Identify extremes and resilience based on real observations

Real-Time

Satellite data provides near-real time status to monitor current conditions.

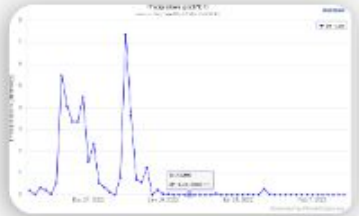
Use Cases

Assess impacts of shock events

Gain visibility into the continuity of critical operations; alerts for environmental impacts

Forecasts

Forecasts provide predictions and early warnings of the impacts of physical hazards with 1 to 90 days notice.



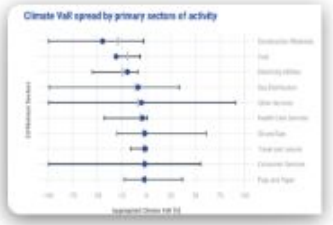
Use Cases

Predict financial impacts of extreme events

Supply chain management

Long-Term

Climate scenarios provide long-term trends (1975-2100) based on various future greenhouse gas emissions.

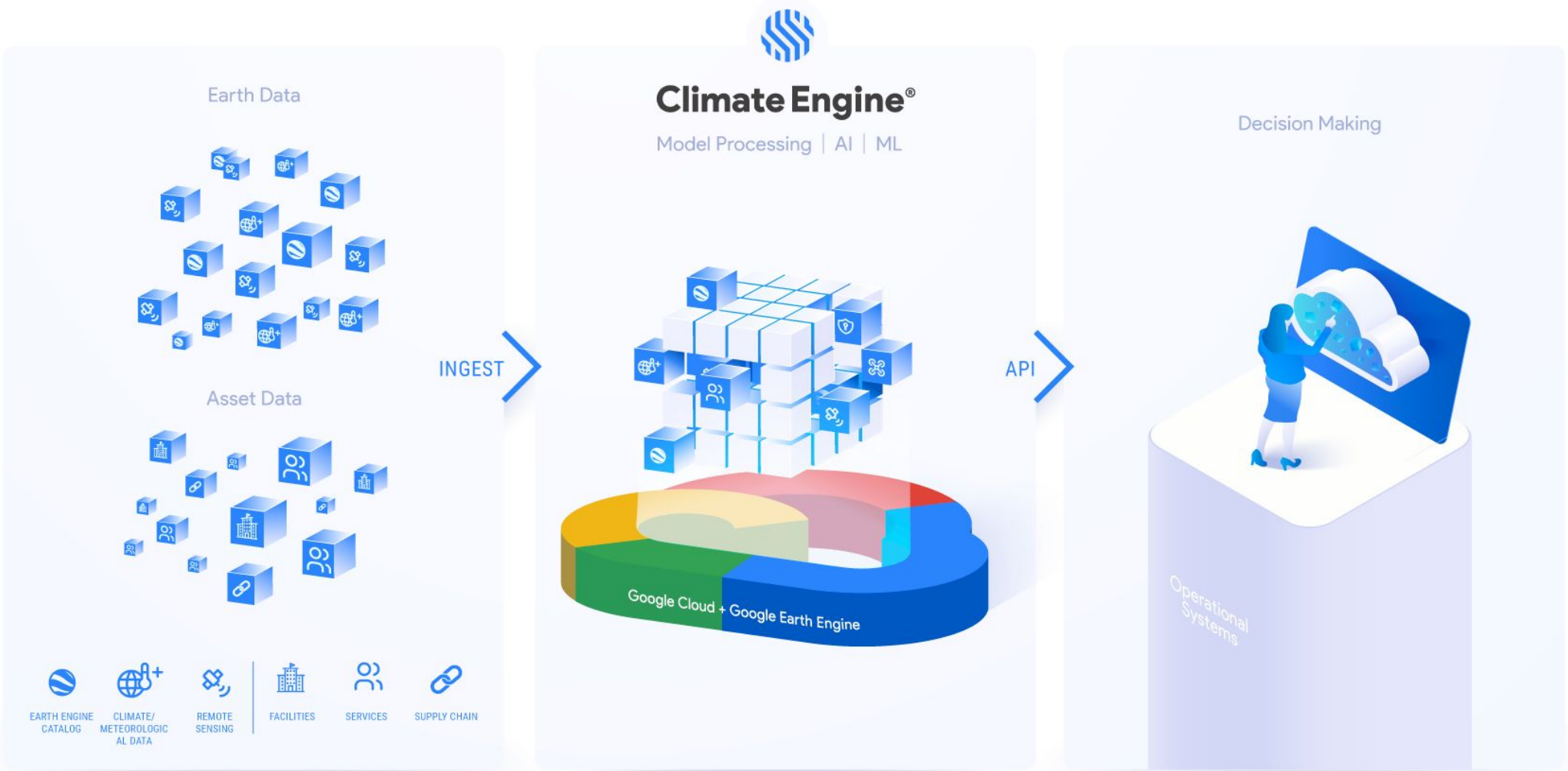


Use Cases

Asses risks to long-term investments

Corporate climate reporting & disclosures

Climate Engine: Merging Earth Insights + Asset Data



Earth Data: Climat Engine + 3rd Party Data Integration

Climate Engine Data

Environmental Factors	Historical	Real Time & Forecast	Long-Term
Wildfire Wildfire danger based on weather and fuel load	>20 Year	Next 90 Days	2100
	10 Year	Remainder of Quarter	2050
Drought State-of-the-art meteorological and hydrological drought indices at multiple time scales	5 Year	Next Month	2040
	2 Year	Next Week	2030
	1 Year	Current	2025
Extreme Heat Weather and heat indices	Last 90 Days		
Flood/Hydrology Precipitation, evaporation, runoff, soil moisture, surface water extents, flood depths	Current Quarter		
	Last Month		
Biodiversity/Vegetation Vegetative productivity, water use, ecological stress, ecosystem monitoring, deforestation	Last Week		
	Single Day		

+

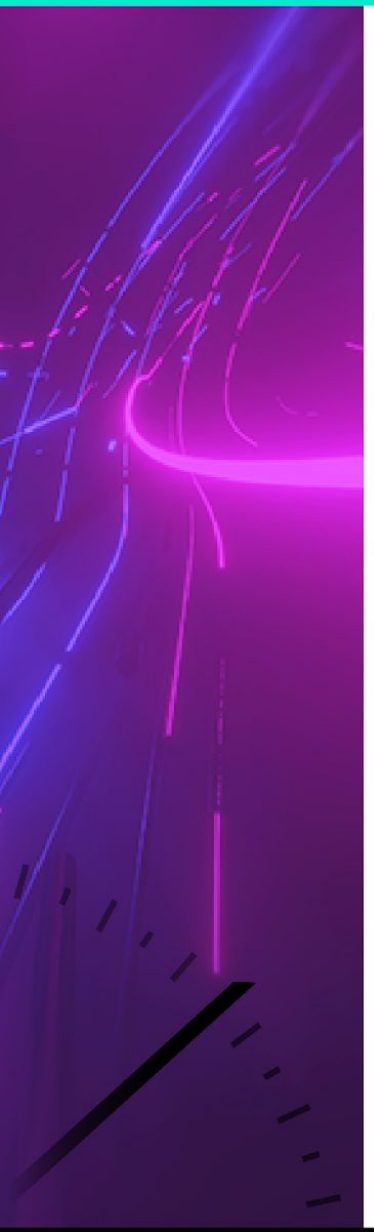
Custom Calculations:

- Values, Anomalies, Trends, Counts, Percentiles, Exceedances, Statistical significance

Batch Processing & Job Scheduling:

- Billion+ asset location processing, Automatic query staging and queue management

Research Project at the Bank of Canada



In 2022, BoC, Climate Engine and Google Cloud initiated a research proof-of-concept project together to see how earth observation data can be leveraged to better understand and perform climate risk analysis.

- Focus area of this PoC: **drought**
    - Water is central to the Canadian economic system, in agriculture and beyond.
    - Currently, there are no granular high-resolution data readily available with respect to drought linked to Canadian economic indicators.
    - This PoC provides us with an opportunity to how such indicators can be developed in a reliable, scientifically accurate manner with clearly defined connections between climate analysis and economic analysis.

- This innovative work is designed as a partnership where researchers collaborate (as opposed to a service providing model) and each participant brings their perspectives.

- The research is still underway, and we are aiming to publish the results of the first phase very soon, accessible to all.

The research project aims to correlate multiple Earth insights (across space and time) with physical ‘assets’, to assess economic correlations and impacts.

Earth Insights

Soil Moisture

Vegetation (NDVI)

Palmer Drought Severity Index (PDSI)

Evaporative Stress Index (ESI)

North American Drought Monitor

Snow Pack

Water Deficit

Water Runoff

Max Temperature

Precipitation

Statistics:

- Percentile by distribution
- Difference from average
- Values, Trends, Counts
- Percentiles, Exceedances, Statistical significance

Physical ‘Assets’

Census Subdivision Level

Provinces Level

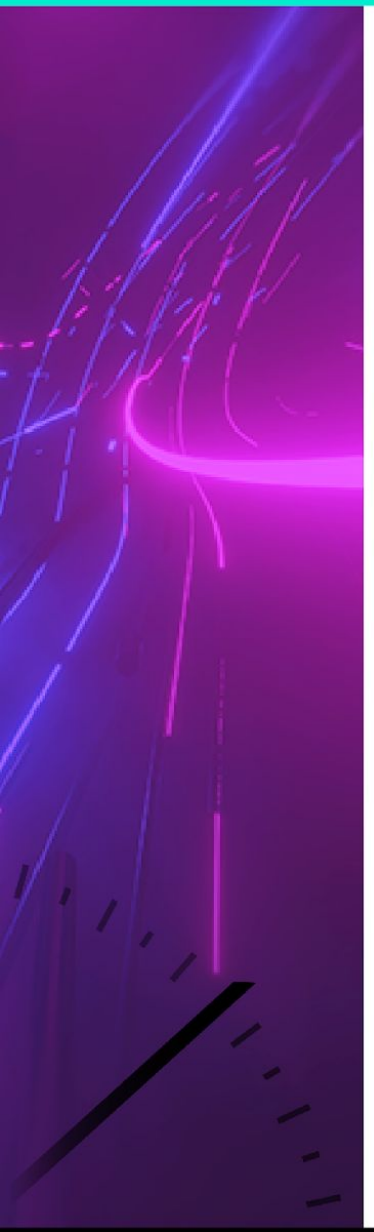
Industrial Subdivisions

Sector Levels:

- Public Administration
- Accommodation & Food Services
- Arts, Entertainment & Recreation
- Healthcare & Social Assistance
- Educational Service
- Professional, Scientific & Technical
- Real estate, Rental & Lease
- Finance & Insurance
- Information & Cultural Industries
- Transportation & Warehousing
- Retail & Wholesale Trade
- Manufacturing & Construction
- Utilities
- Mining
- Agriculture, Forestry, Fishing & Hunting

Impact Study Areas

The economic impacts caused by drought and various other water cycle attributes on regions in Canada.



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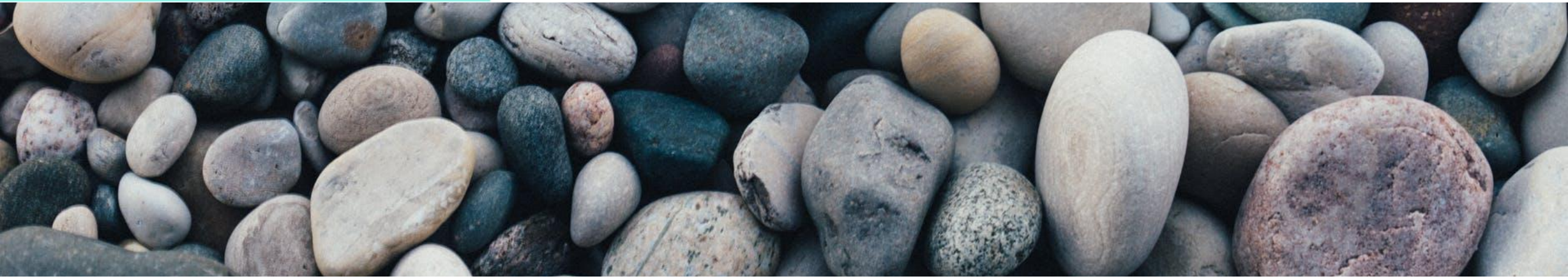

Thank you!

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