

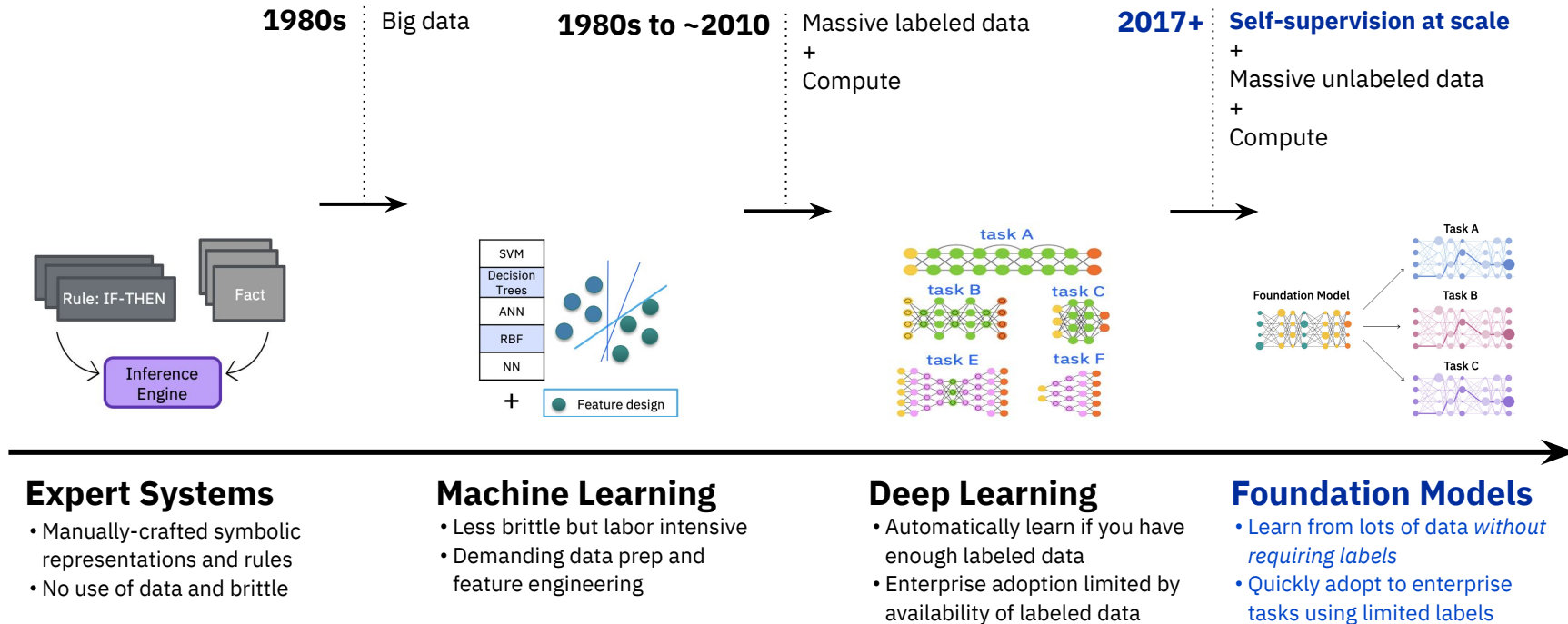
Revolutionizing Earth Science with Generalized AI Models

Dr. Rahul Ramachandran*, NASA/MSFC IMPACT
Tsengdar Lee, NASA/HQ
Raghu Ganti, IBM Research

Contact:
rahul.ramachandran@nasa.gov

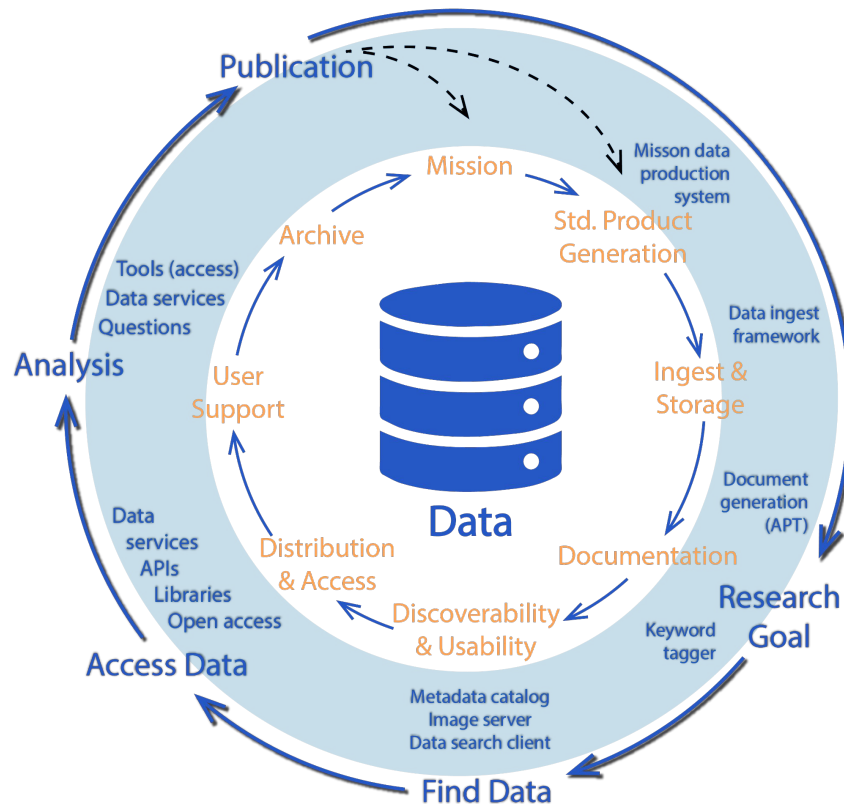
Inflection Point in AI

poised to dramatically accelerate enterprise AI adoption





Building Blocks



Data + Tools/Infrastructure -> Enable Research Lifecycle

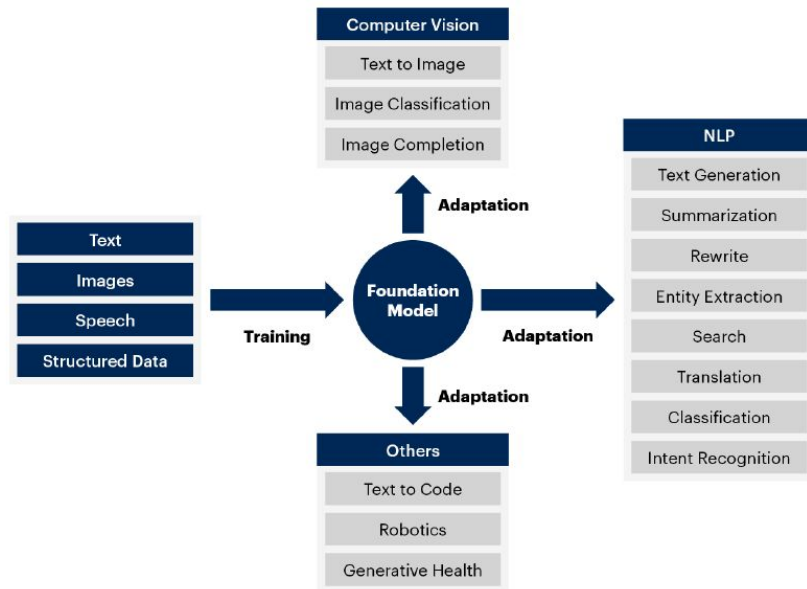


What Are Foundation Models?

- Foundation models (FM) are AI models that are **designed to replace task-specific models and be applied to many different downstream applications**.
- FM are trained using **self-supervised techniques** and can be built on any type of **sequence data**.
 - Self supervised learning removes the **existing roadblock for developing a large annotated dataset for training**.
- FM can be applied to downstream tasks by **using few shot learning and fine tuning**

- Some have to be **trained at scales** that limits the ability to a handful organizations

Foundation Models - Characteristics and Applications

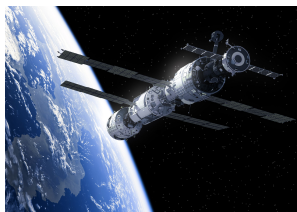


Source: Gartner
769102_C



Language Model for Earth Science

Train a new domain specific foundation model on Earth science literature that improves downstream tasks and enables information retrieval



- Models built using FM stack
- Standard RoBERTa base architecture (125M)
- 120k papers (after data preprocessing and duplicate removals, reduced from 275k papers)
- 64 NVIDIA A100 GPUs
- 10 hrs of training
- 67k words/GPU/sec throughput

NASA RoBERTa model

CAPE increase due to [*anthropogenic greenhouse warming*].

The second most abundant element in the atmosphere is [*oxygen*].

[*Oxygen*] atoms combine to form dioxygen.

An igneous rock is a rock that crystallizes from [*magma*].

An igneous rock is a rock that crystallizes from [*igneous melt*].

Standard English RoBERTa

CAPE increase due to [*weather*].

The second most abundant element in the atmosphere is [*water*].

[*The hydrogen*] atoms combine to form dioxygen.

An igneous rock is a rock that crystallizes from [*ashes*].

An igneous rock is a rock that crystallizes from [*the ground*].



Using the Language Model for Question Answering



Question Answering

What would you like to know?

Is there a dust index that can be used to detect airborne dust over china

Ask

Question

Is there a dust index that can be used to detect airborne dust over china

Found 15 answers matching your question.

Answer

A dust aerosol index (DAI) algorithm based on measurements in deep blue (412 nm), blue (440 nm), and shortwave IR (2130 nm) wavelengths using Moderate Resolution Imaging Spectroradiometer (MODIS) observations has been developed

Confidence: 52%

Was this answer useful?

Evidence

Answer

dust aerosol index (DAI) algorithm based on measurements in deep blue (412 nm), blue (440 nm), and shortwave IR (2130 nm) wavelengths using Moderate Resolution Imaging Spectroradiometer (MODIS) observations has been developed

Confidence: 31%

Was this answer useful?

Evidence

Answer

Infrared Difference Dust Index (IDDI).

Confidence: 39%

Was this answer useful?

Evidence

Answer

Daily aerosol optical thickness (AOT) at 0.55 μm over the desert regions is needed as a source of validation for numerical models such as the United Kingdoms Numerical Weather Prediction Unified Model. We examined the relationship between monthly mean ultraviolet (UV) absorbing aerosol index (AI) from the Ozone Monitoring Instrument (OMI) that is available on a daily basis with the Multiangle Imaging Spectroradiometer (MISR) AOT that is available once every nine days over North Africa

Confidence: 43%

Was this answer useful?

Retriever

ColBERTRetriever

Select a retriever

Retriever Settings

Checkpoint

Maximum number of retrieved documents

1 100 5

Corpus

nasa-corpus

Select a corpus

Reader

ExtractiveReader

Select a reader

Reader Settings

Model

PrimeQA/nq_tydi_sq1-reader-xmlr_large-202211

Maximum number of answers

1 5 3

Maximum answer length

2 2000 100

Proof of concept demo (IBM Research collaboration)

Enhancing Scientific Efficiency through AI (FIRMS Q&A)

The screenshot displays a JupyterLab environment with a dark theme. The top bar includes the 'CO' logo, the notebook title 'NLP-API-trend-analysis', and a star icon. A menu bar with 'File', 'Edit', 'View', 'Insert', 'Runtime', 'Tools', and 'Help' is visible, along with a status message 'All changes saved'. On the right, there are buttons for 'Comment', 'Share', and a settings gear, followed by a green circular profile icon.

The left sidebar contains navigation icons: a hamburger menu, a search icon, a variable icon '{x}', a folder icon, and a code editor icon '<>'. Below these are icons for a terminal and a file explorer.

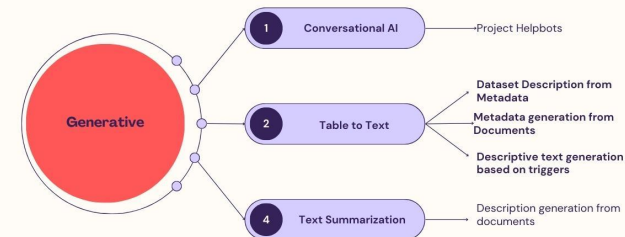
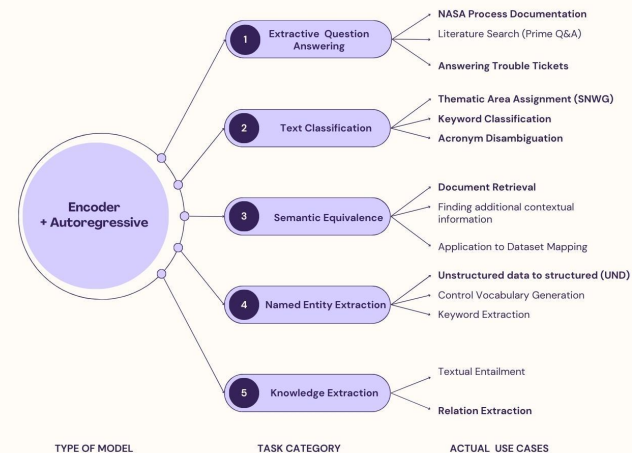
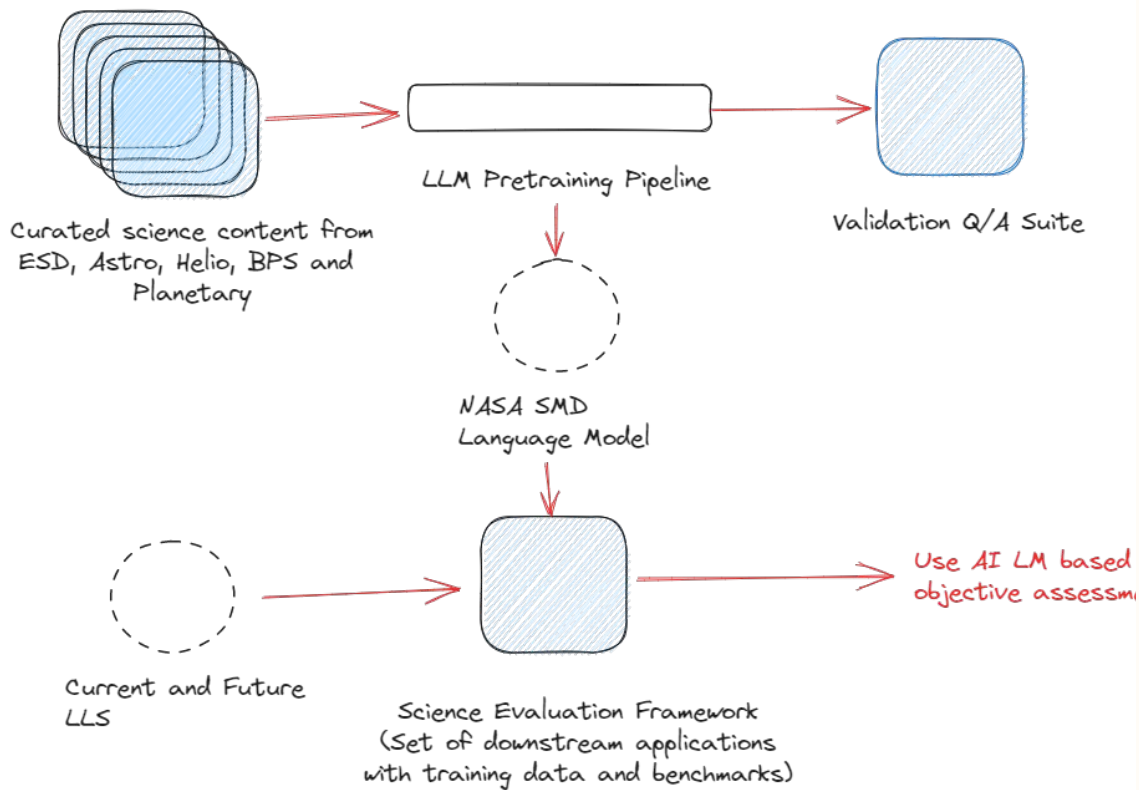
The main workspace shows a code cell with the following Python code:

```
[139] answer, result = query("how many active fires were there in canada yesterday?")
```

Below the code cell, there are two output areas. The first is a text output labeled '[140] answer'. The second is a variable output for 'result', which includes a play button icon and a toolbar with icons for up, down, link, comment, settings, copy, delete, and a menu.

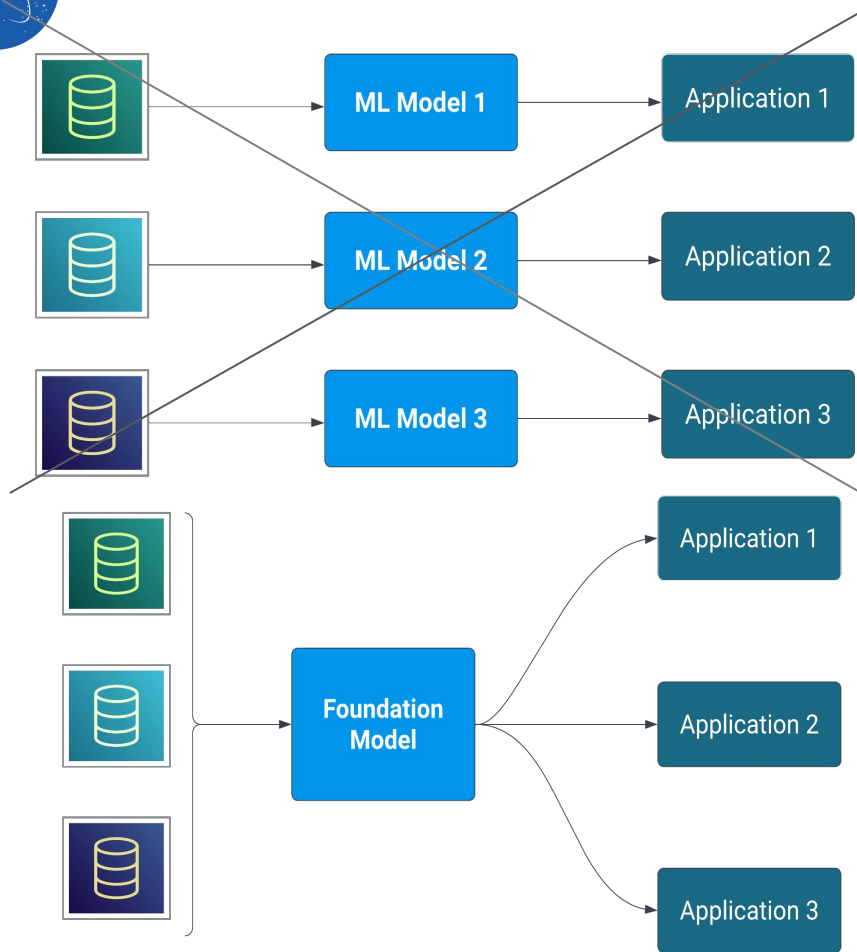
At the bottom of the interface, a status bar indicates '0s completed at 10:14AM'.

Foundation Language Model for Science





Foundation AI Models for Earth Science Data



- Can we build foundation AI models for domains or representative types of data?
 - Optical remote sensing data, SAR, climate simulations
- Can these models capture underlying physical processes?

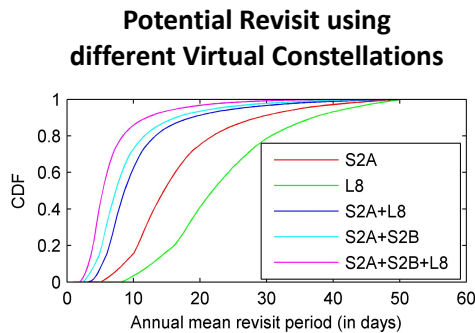
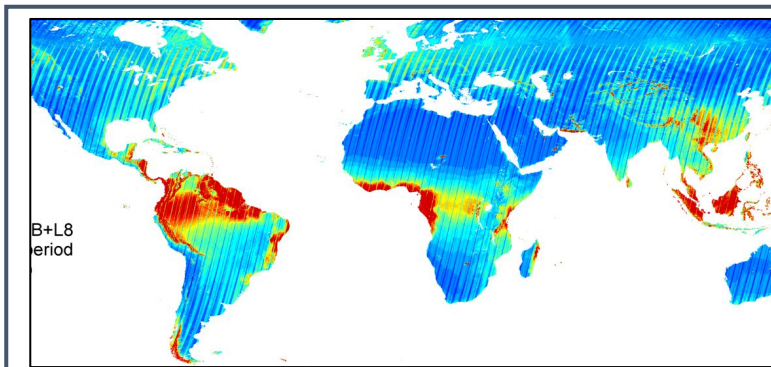
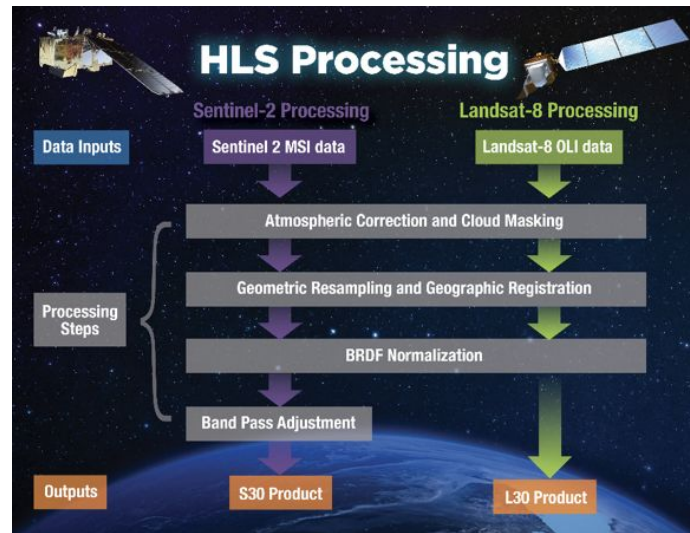


Foundation AI Model for Optical Remote Sensing Data



Harmonized Landsat Sentinel (HLS)

- “Seamless” near-daily 30m surface reflectance record including atmospheric corrections, spectral and BRDF adjustments, regridding
- Merges Sentinel-2 and Landsat data streams and can provide **2-4 day global coverage**



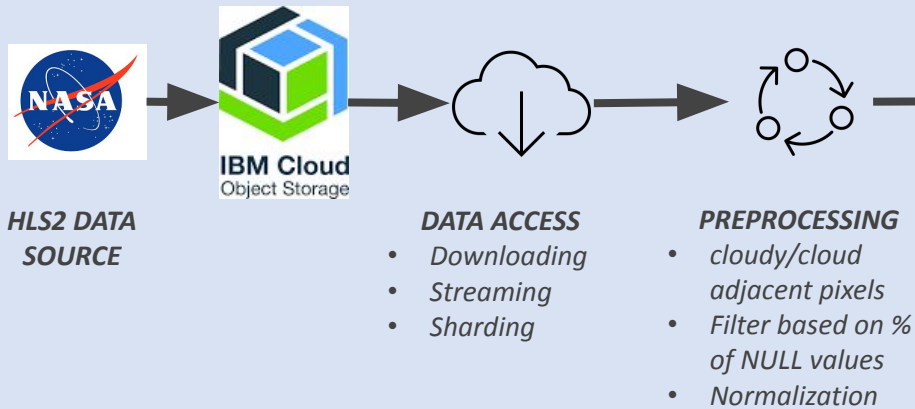


HLS FM Training Pipeline

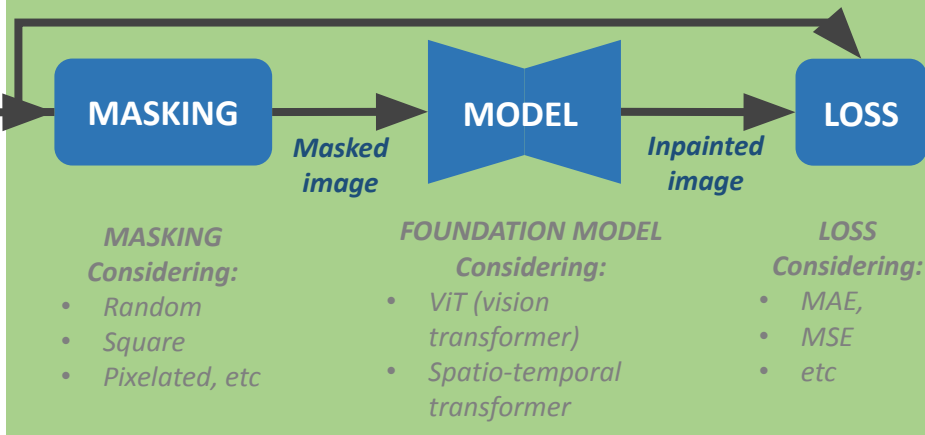


DATALOADING

For multiple GPUS

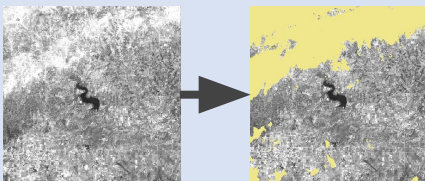


TRAINING



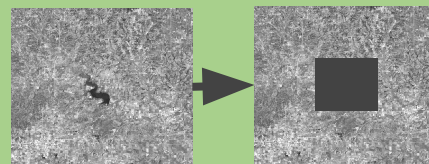
PREPROCESSING

converts cloudy/cloud adjacent pixels to null values

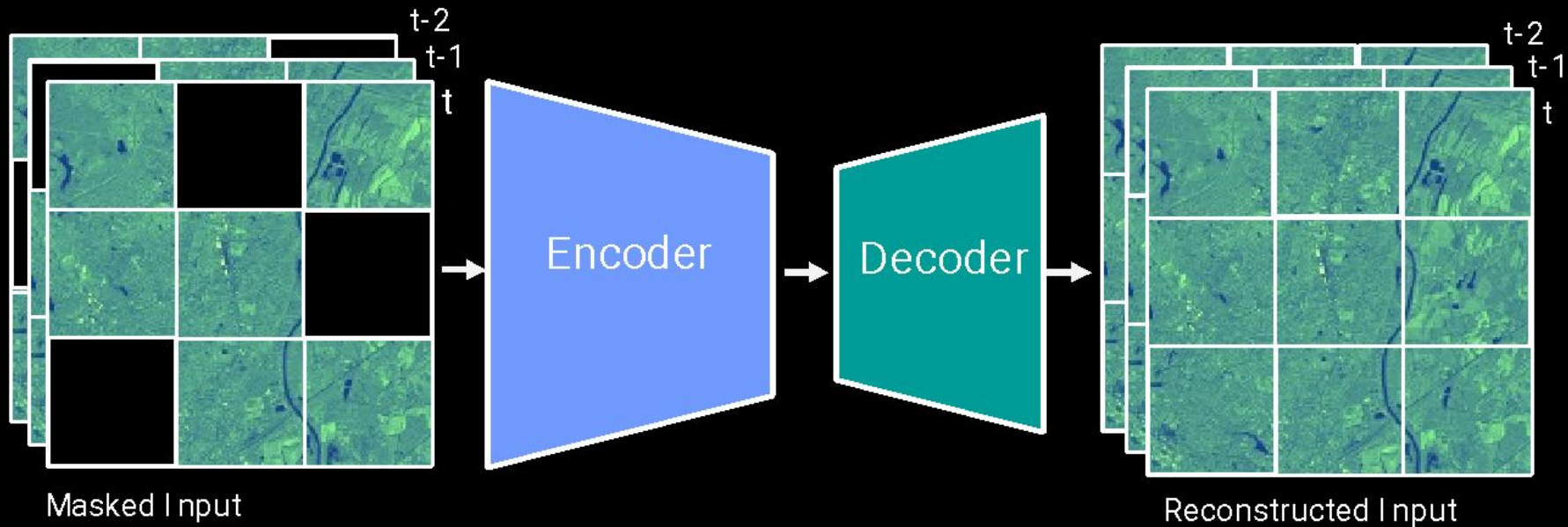


MASKING

Removing portion of image which will be inpainted by foundation model

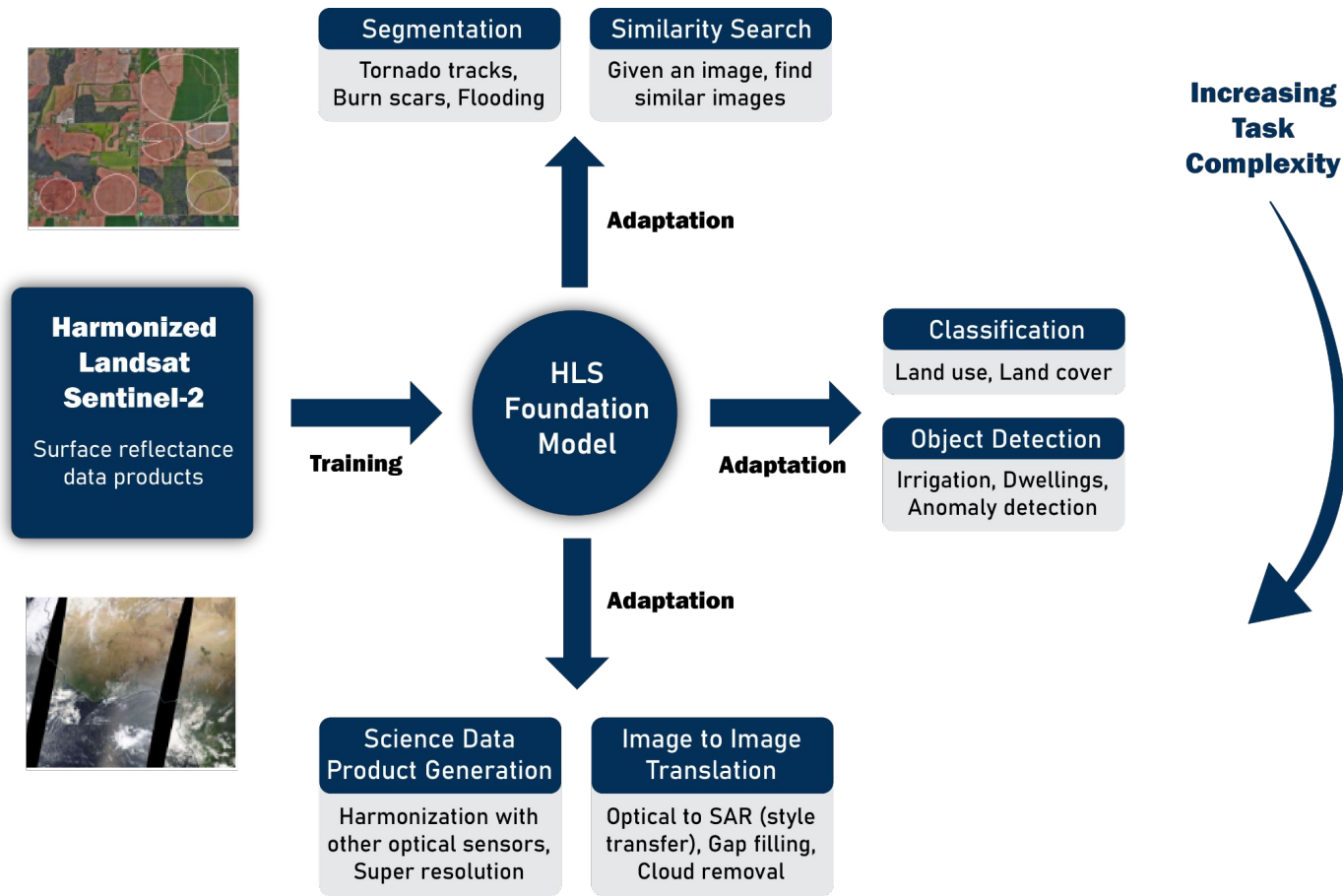


HLS Model – Pretraining (Masked Modeling)



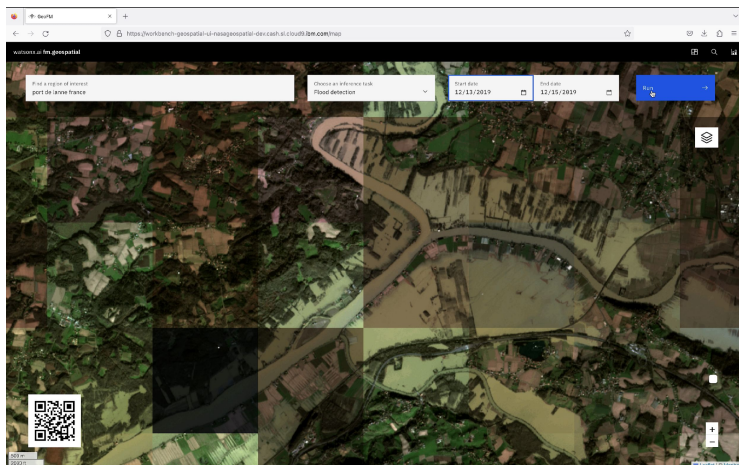


HLS FM Downstream Adaptation



Inference by HLS GeoSpatial FM

Flood Mapping

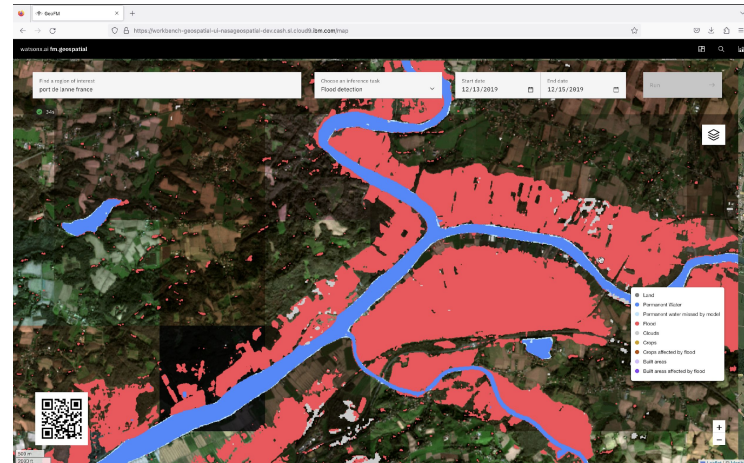


Insights: Flood
detection

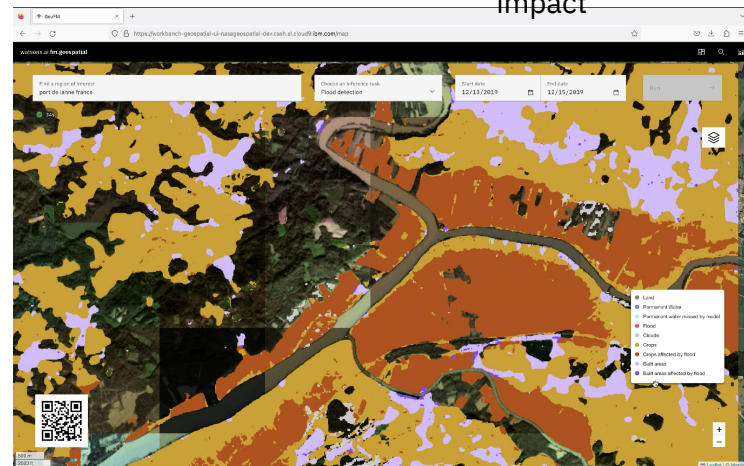
<< Inference >>
(e.g., flood task)

“Prompt”: Image(s) (spatial + temporal domains)

	IoU (water class)	F1 (water class)	IoU	F1 score	Accuracy
Baseline [44]	24.21	—	—	—	—
U-Net-based SOTA [43]	69.12	81.74	93.85	96.65	96.44
ViT-base [19]	66.52	79.89	90.92	94.97	94.97
Swin [46]	74.75	85.55	92.38	95.90	94.73
Prithvi (not pretrained)	79.23	88.41	94.52	97.09	97.07
Prithvi (pretrained)	80.10	88.95	94.78	97.23	97.23

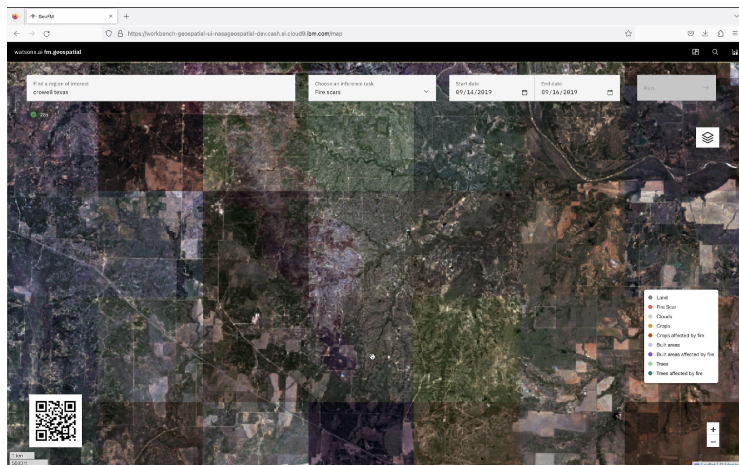


Insights: Flood
impact



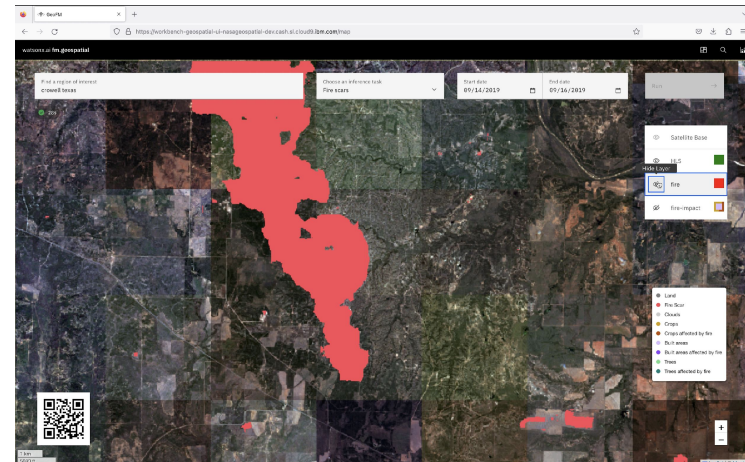
Inference by HLS GeoSpatial FM

Fire Scar Mapping



<< Inference >>

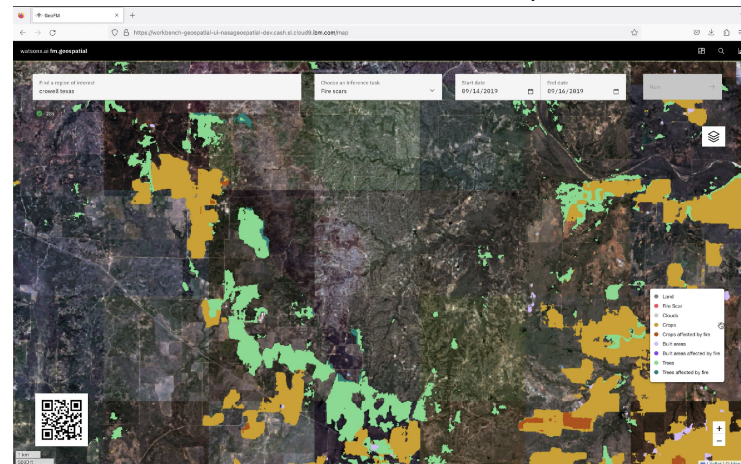
Insights: fire scar
detection



Insights: Fire
impact

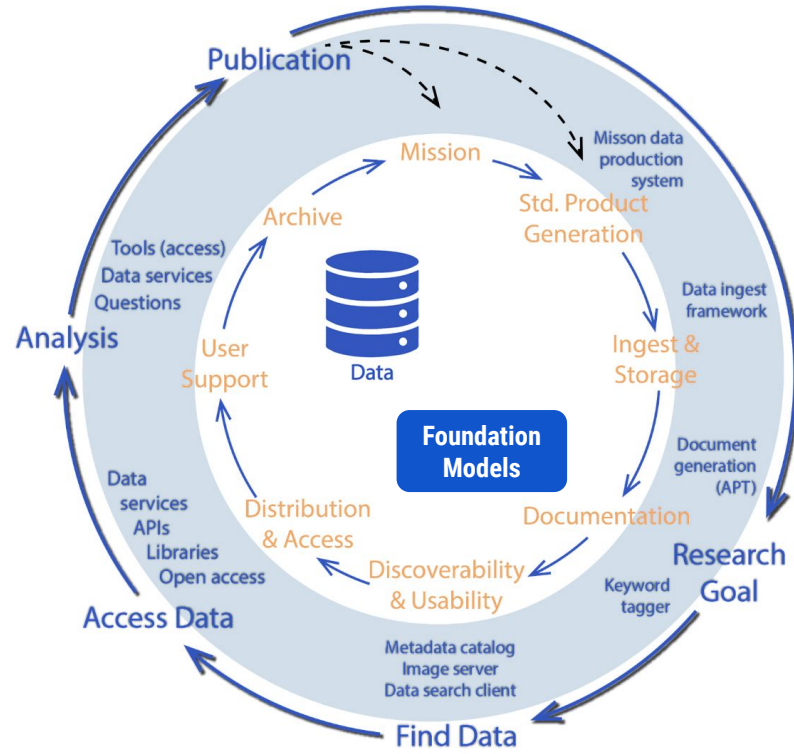
“Prompt”: Image(s) (spatial + temporal domains)

	IoU (fire scar class)	F1 (fire scar class)	IoU	F1 score	Accuracy
U-Net (DeepLabV3) [43]	45.96	62.98	93.38	96.11	96.22
ViT-base [19]	51.87	68.31	94.01	96.56	96.56
Swin [46]	56.04	71.83	94.16	96.71	96.50
Prithvi (not pretrained)	59.31	74.46	94.62	97.0	96.80
Prithvi (pretrained)	61.55	76.20	95.04	97.25	97.10





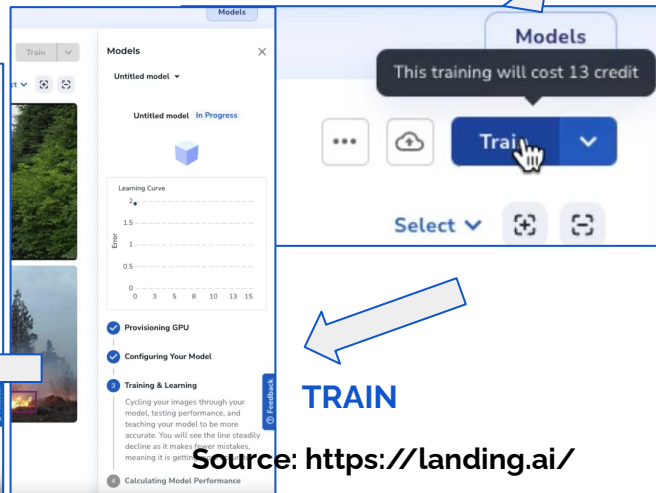
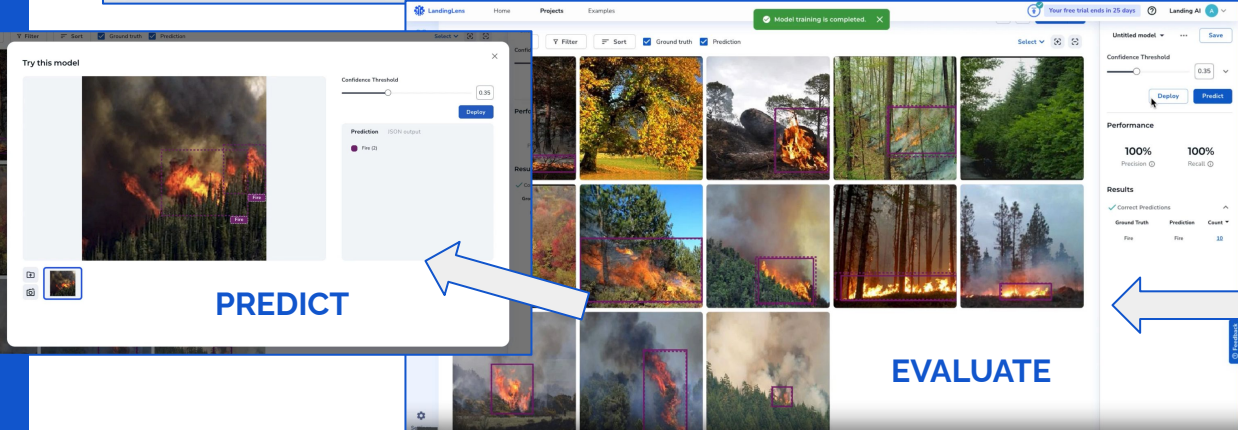
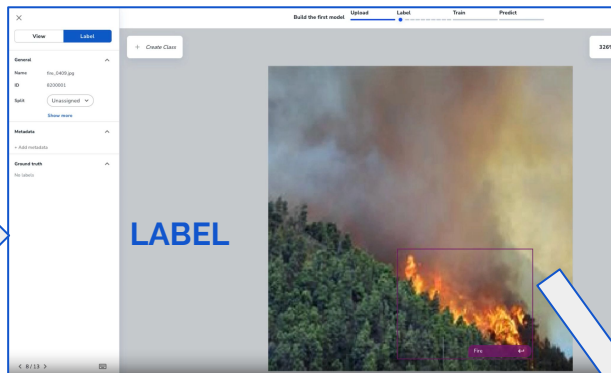
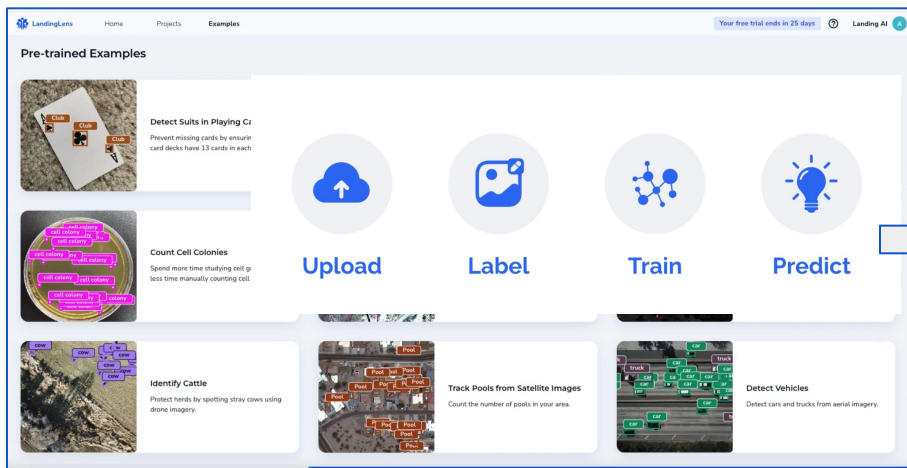
Building Blocks: Future State



Data + Tools/Infrastructure + AI Foundational Models -> Accelerate Research and Applications



What does the future look like?



Source: <https://landing.ai/>



Future Plans and Attributions

HLS FM

Early August Release

- Hugging Face
 - Pretrained HLS FM
 - Fine Tuned Flooding, Burn Scar Models
- Github
 - Flooding, Burnscar code, data

Late August Release

- Github
 - Pretraining source code
 - Other Fine Tuning examples

Science LLM - December Release (AGU)

Watch this space:

[Earthdata | Earthdata \(nasa.gov\)](#)

[IMPACT Unofficial – Medium](#)

NASA MSFC/IMPACT

Sujit Roy, Ankur Kumar, Chris Phillips, Iksha Gurung, Kumar,
Rahul Ramachandran, **Manil Maskey**

IBM Research

Johannes Jakubik, Linsong Chu, Paolo Fraccaro, Ranjini, Kamal Das, Daiki Kimura, Naomi Simumba, Daniela Szwarcman, Michal Muszynski, Carlos Gomes, **Kommy Weldemariam**, Bianca Zadrozny, **Raghu Ganti**

Clark University

Hamed Alemohammad, Michael Cecil, Steve Li, Sam Khallaghi, Denys Godwin, Maryam Ahmadi, Fatemeh Kordi

NASA HQ

Tsengdar Lee, **Kevin Murphy**

NASA GSFC

Dan Duffy, Mike Little

Using the Language Model for Question Answering

Proof of concept demo

The screenshot displays the PrimeQA web application interface. The browser address bar shows the URL `primeqa.nasa-impact.net/qa`. The application header includes the PrimeQA logo and navigation links for IMPACT and Model Data. The main content area is titled "Question Answering" and contains the instruction "Find answers to question from retrieved evidence blocks". Below this, a text input field prompts "What would you like to know?" with a placeholder text "What would you like to know?". A blue "Ask" button is positioned to the right of the input field. On the right side, a settings sidebar is open, showing configurations for the Retriever and Reader components.

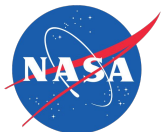
Retriever Settings

- Retriever: ColBERTRetriever
- Select a retriever: [Dropdown]
- Checkpoint: [Text field]
- Maximum number of retrieved documents: 1 (Slider) 100 (Slider) 5 (Input)
- Corpus: nasa-corpus
- Select a corpus: [Dropdown]

Reader Settings

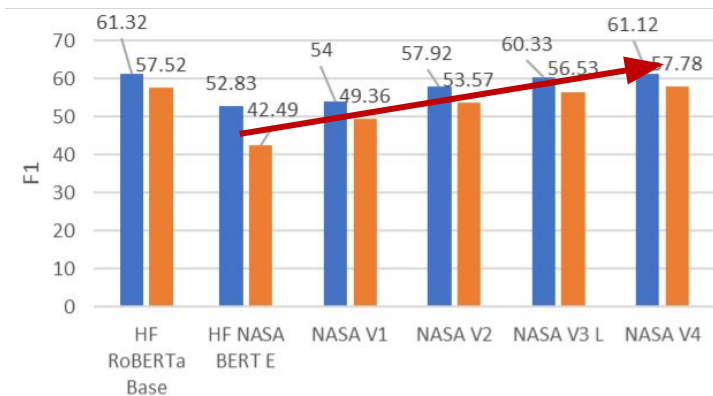
- Reader: ExtractiveReader
- Select a reader: [Dropdown]
- Model: PrimeQA/nq_tydi_sq1-reader-xlmr_large-2022111
- Maximum number of answers: 1 (Slider) 5 (Slider) 3 (Input)
- Maximum answer length: 2 (Slider) 2000 (Slider) 1000 (Input)
- Minimum score threshold: [Text field]

[Try live version trained on NASA ATBD and dataset description](#)



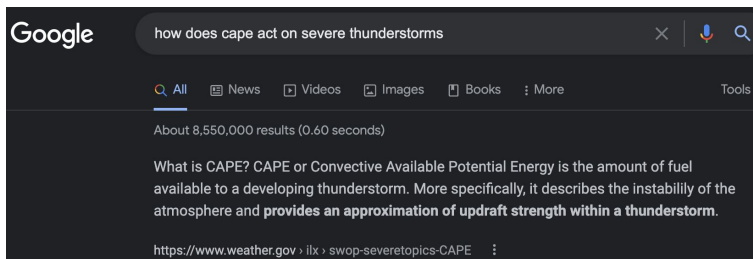
Language Model for Earth Science: Q&A

Integrate trained model with IBM's PrimeQA technology for natural language Q&A with provenance



Next steps

- Improve model by adding relevant data
- Validation of Q&A responses underway by NASA
- Open-source model with Q&A service
- Expand to SMD wide Language Model



NASA abstracts 122111

122111 Articles Wed May 18 2022

Q What would you like to know?

Ask a question

Question

How does CAPE act on severe thunderstorms?

3 answers from articles

Answer

may increase the likelihood of severe storms

60049.txt 1,000

Show answer in context

Increases in convective available potential energy (CAPE)—the energy available to a parcel of air rising through a cloud—may increase the likelihood of severe storms. Model simulations have shown that global warming will increase CAPE in the tropics, but scientists do not fully understand why this occurs or what the implications may be for future precipitation intensity.