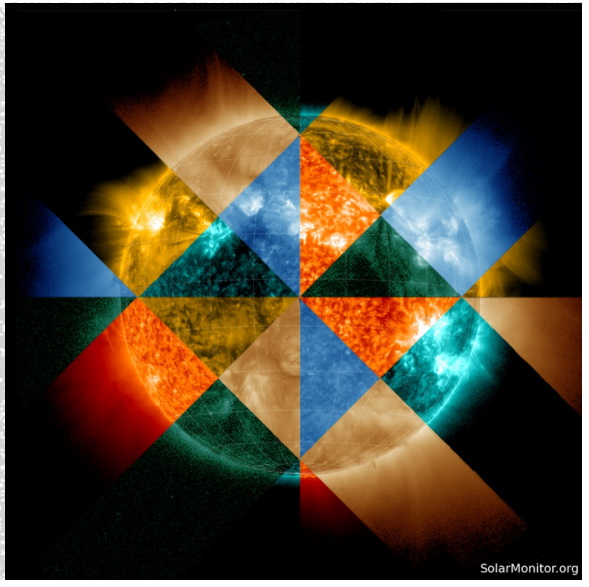
ARCAFF



Active Region Classification and Flare Forecasting

PITHIA-NRF High Profile Meeting 1, Brussels, Mar 14, 2023

Shane Maloney on behalf of ARCAFF project.

European Commission

DIAS
Institiúid Ard-Léinn Bhaile Átha Cliath | Dublin Institute for Advanced Studies

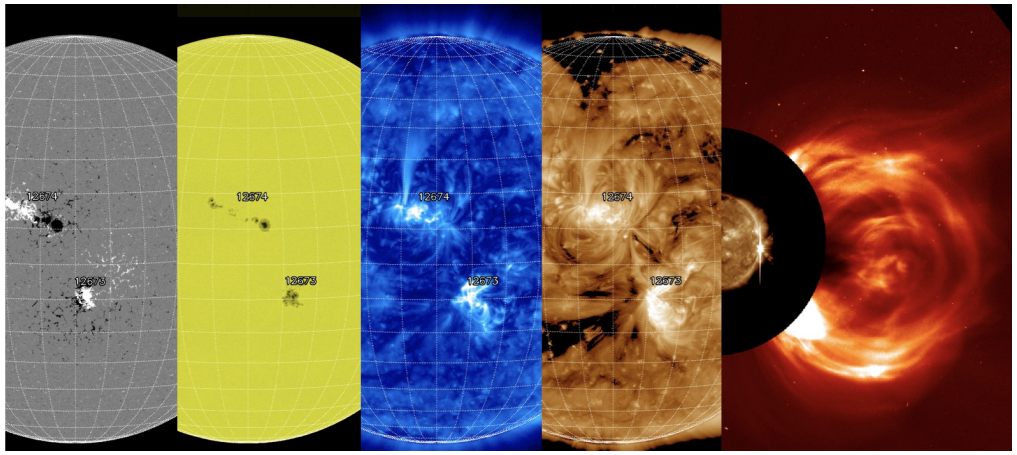
Università di Genova

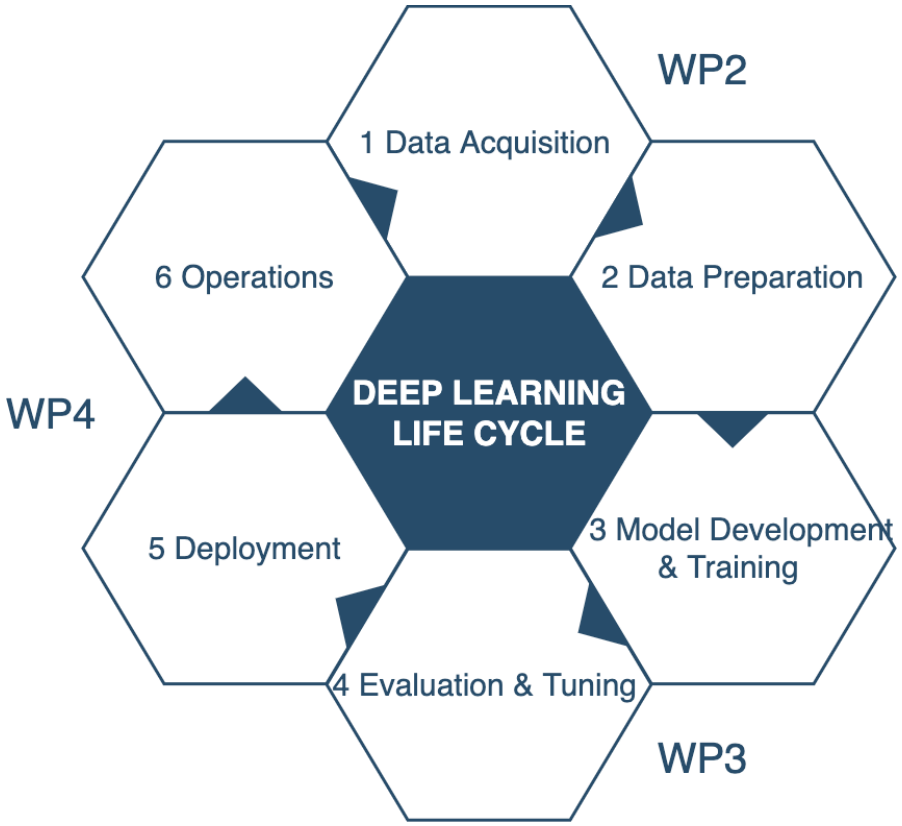
UNIVERSITY OF WESTMINSTER

SZTAKI

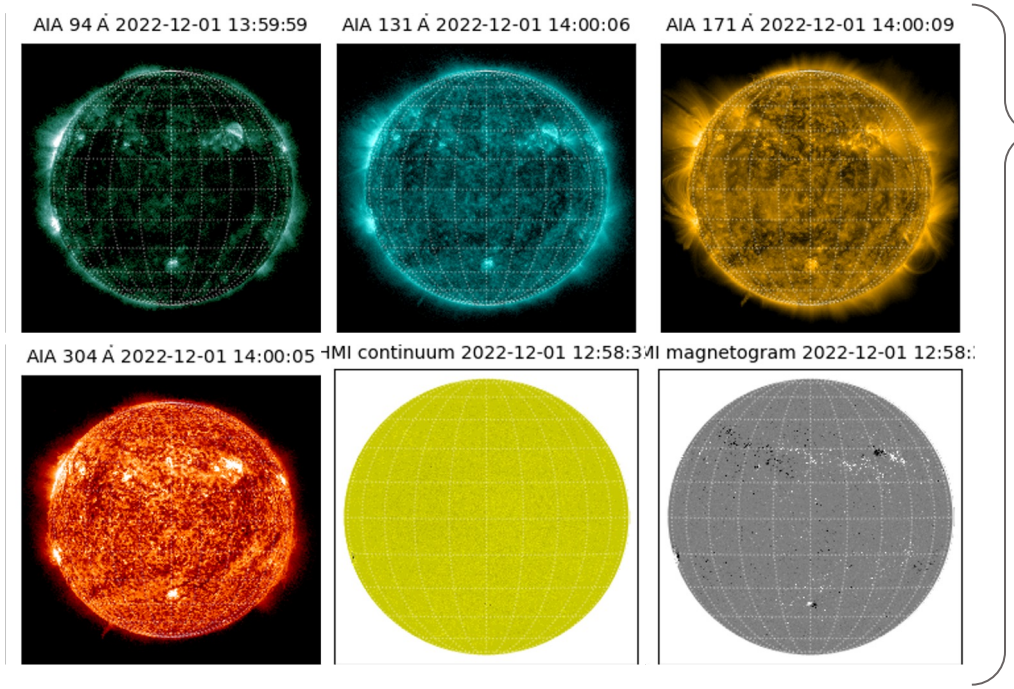
ARCAFF

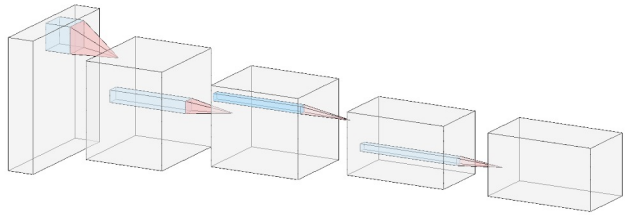
- Horizon Europe HORIZON-CL4-2022-SPACE-01 call (Project ID 101082164)
- 3 Year project Dec 2022 – Dec 2025
- Web: arcaff.eu
- Twitter: @arcaff_eu





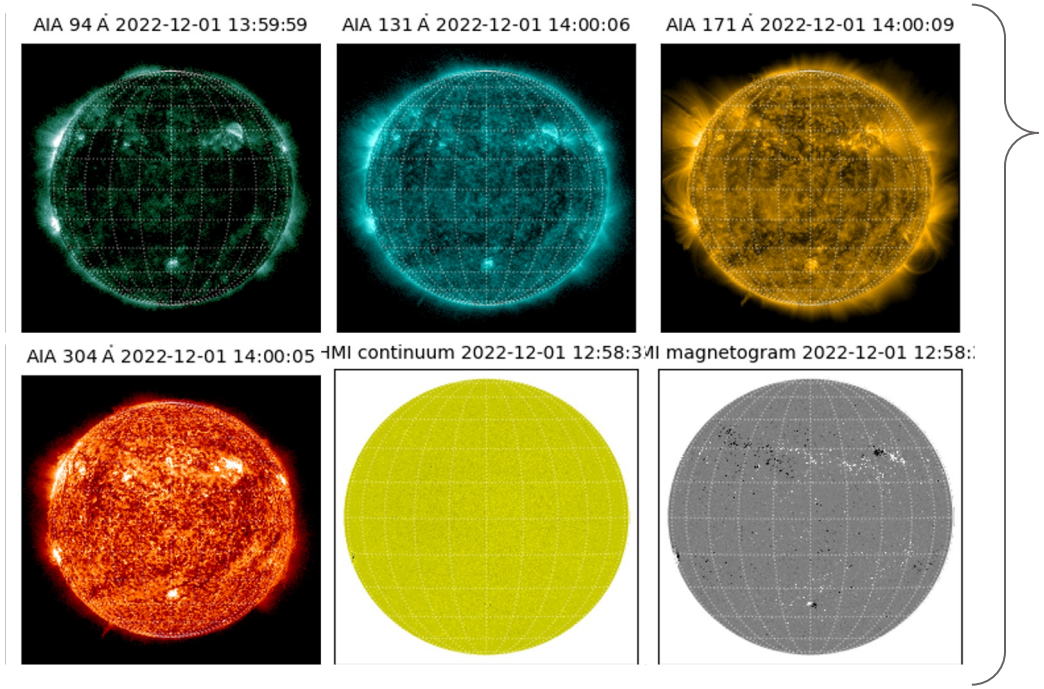
ARCAFF





Flare or no Flare
+6, +12, +24 hours

ARCAFF


AIA 94 Å 2022-12-01 13:59:59
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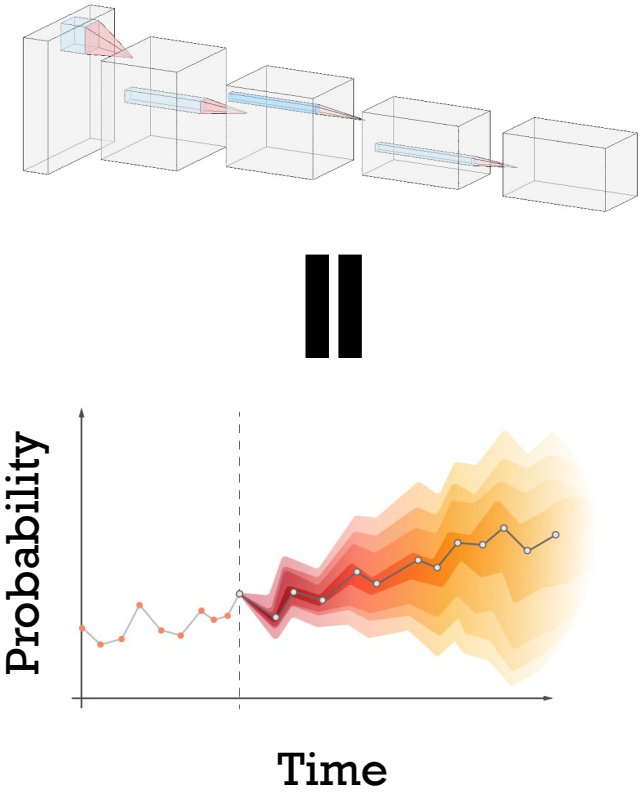
MI magnetogram 2022-12-01 12:58:


Probability
Time

ARCAFF

- Objectives
  - **Objective 1 (O1)** - Active region classifications using magnetogram cutouts
  - **Objective 2 (O2)** - Active region localisation and classification using full disk magnetograms
  - **Objective 3 (O3)** - Point-in-time flare prediction using full disk magnetograms
  - **Objective 4 (O4)** - Point-in-time flare prediction using full disk multimodal observations
  - **Objective 5 (O5)** - Time series flare prediction based on time series of full disk multimodal observation

- Work Packages
  - WP1 Management
    - How the overall project will be managed
  - WP2 Solar Data Sources
    - Preparation of solar image and AR and flare datasets.
  - WP3 Deep Learning
    - Development and training of advanced deep learning models on AR and flare forecasting dataset.
  - WP4 Compute Platform
    - Implement flexible distributed back-end system for data aquisiationand preparation, deep learning development and training, as well as an accessible front-facing interface for users.
  - WP5 D, C & E
    - How the project will engage the scientific and operational space weather community, and the wider public and policy makers.

ARCAFF

- Objectives
  - **Objective 1 (O1)** - Active region classifications using magnetogram cutouts
  - **Objective 2 (O2)** - Active region localisation and classification using full disk magnetograms
  - **Objective 3 (O3)** - Point-in-time flare prediction using full disk magnetograms
  - **Objective 4 (O4)** - Point-in-time flare prediction using full disk multimodal observations
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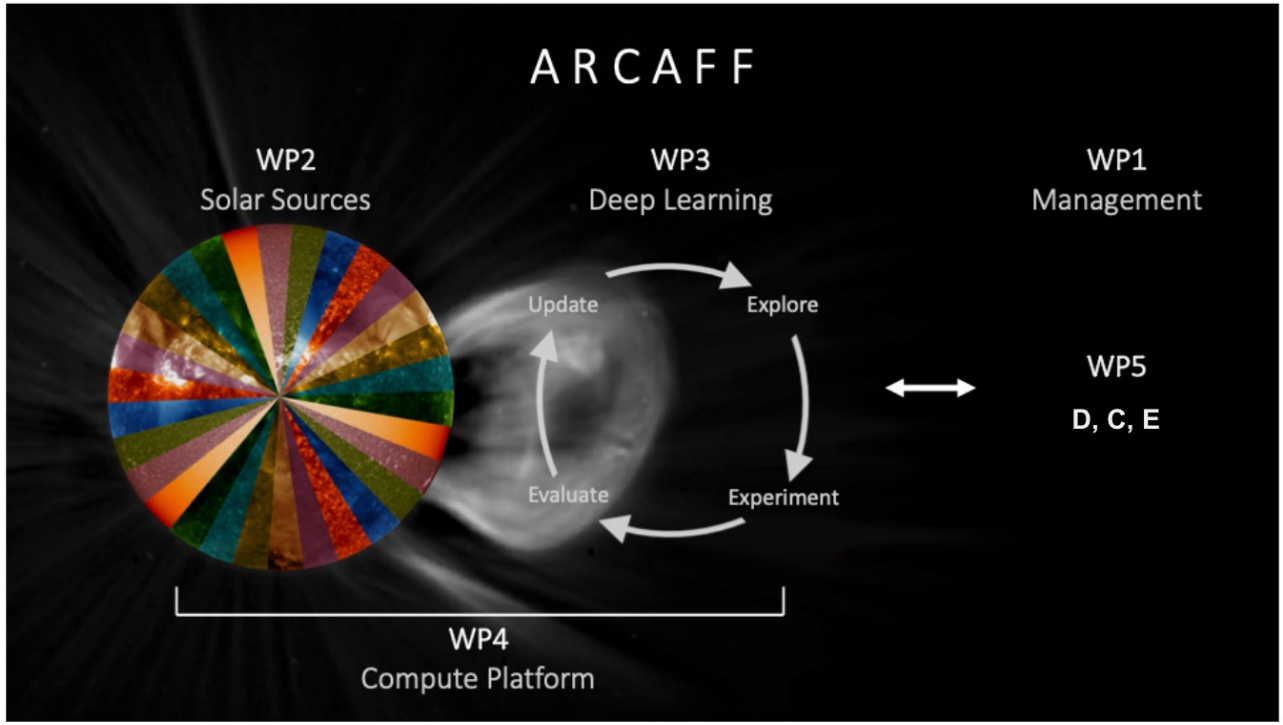
- Work Packages



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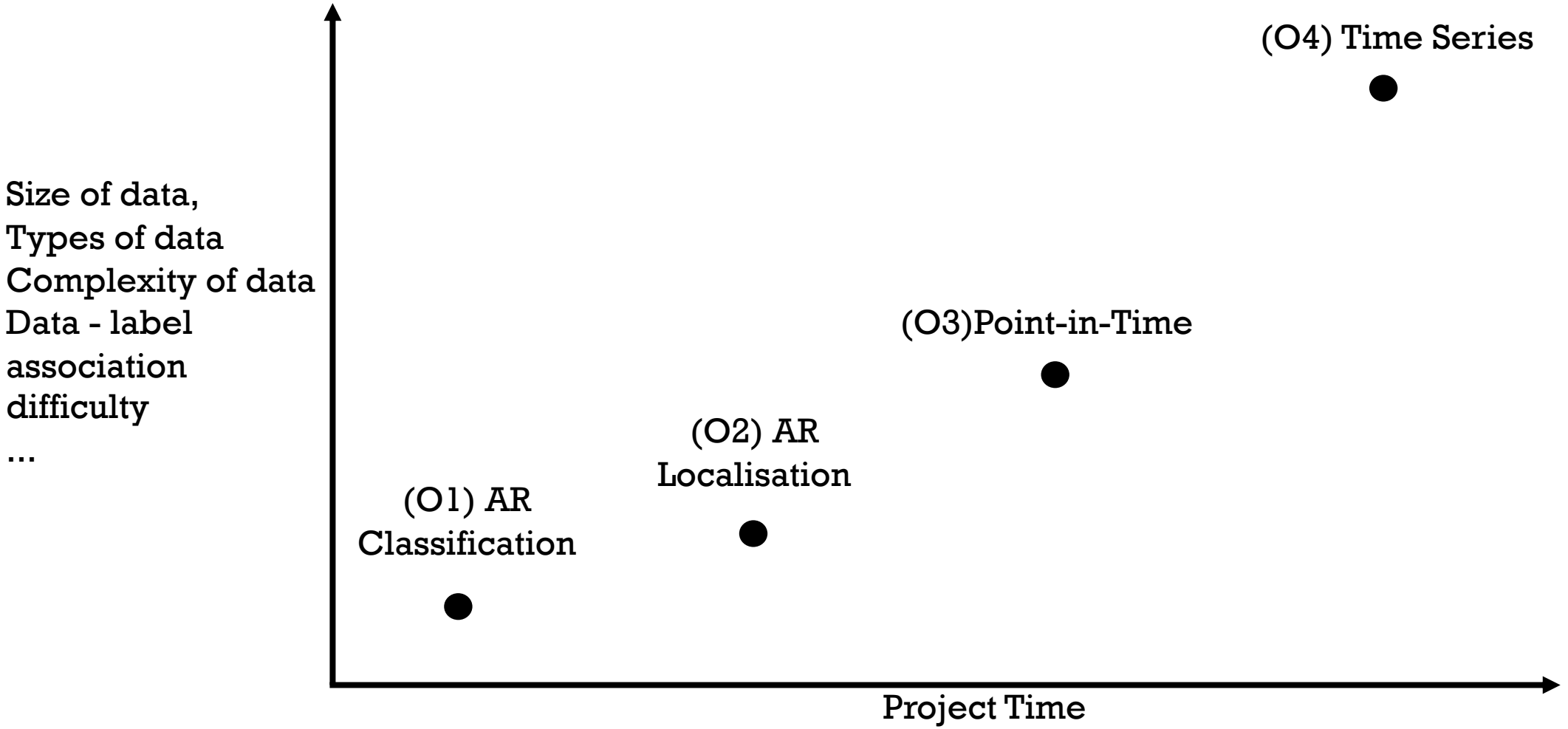

Size of data,
Types of data
Complexity of data
Data - label association difficulty
...
(O1) AR Classification
(O2) AR Localisation
(O3)Point-in-Time
(O4) Time Series
Project Time

ARCAFF

Instrument	Observations	Wavelength	Cadence	Date Range
SOHO/MDI	LoS B field	6768	96 min	1996 - 2011
SOHO/EIT	EUV Intensity	171, 195, 284, 304	12 min – 6 hours	1996 - present
SDO/AIA	EUV Intensity	94, 171, 193, 304, 335	12 sec	2010 – present
SDO/HMI	LoS B field	6768	720 / 45 sec	2010 – present
SDO/HMI	Continuum		720	2010 – present
GOES	XRS	0.1-0.8nm, 0.05-0.4nm	1/3 sec	1970s – present

ARCAFF (01)
AR CLASSIFICATION

Search and download full disk (FD) magnetograms from the SOHO/MDI and SDO/HMI archives (ESA SOHO archive, JSOC for SDO/HMI).

Preprocessing of full-disk (FD) magnetograms - calibration, alignment, scaling, and bad data removal.

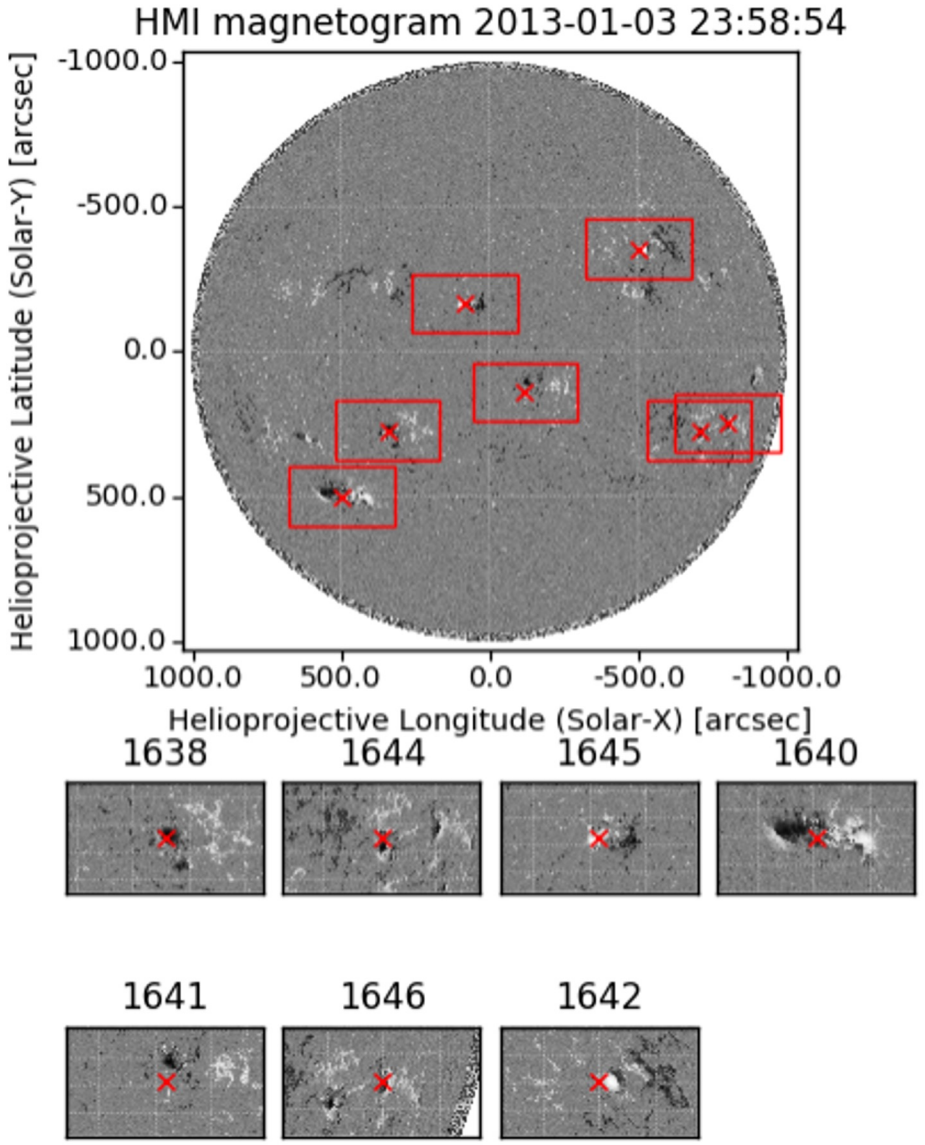
Download of AR properties (locations and classifications in SRS files) from SolarMonitor.org or NOAA/ SWPC.

Create AR cutouts using processed FD magneograms and AR locations obtained from SRS files.

AR classification

- inputs: AR magneogram cutouts (2D, space × space)
- outputs: classifications (Hale, McIntosh).

Release of datasets, software, and research into AR classification properties.



ARCAFF (01)
AR CLASSIFICATION

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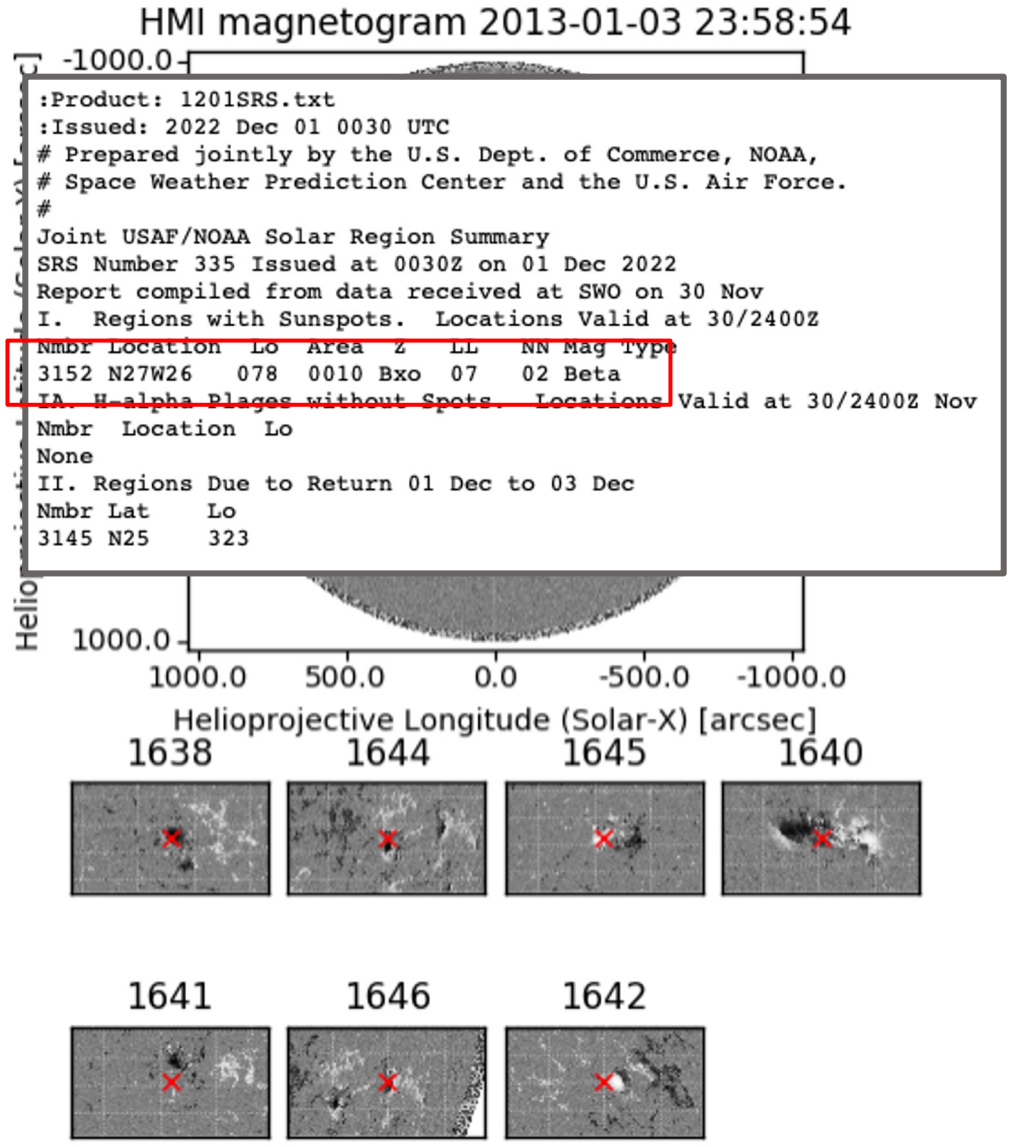


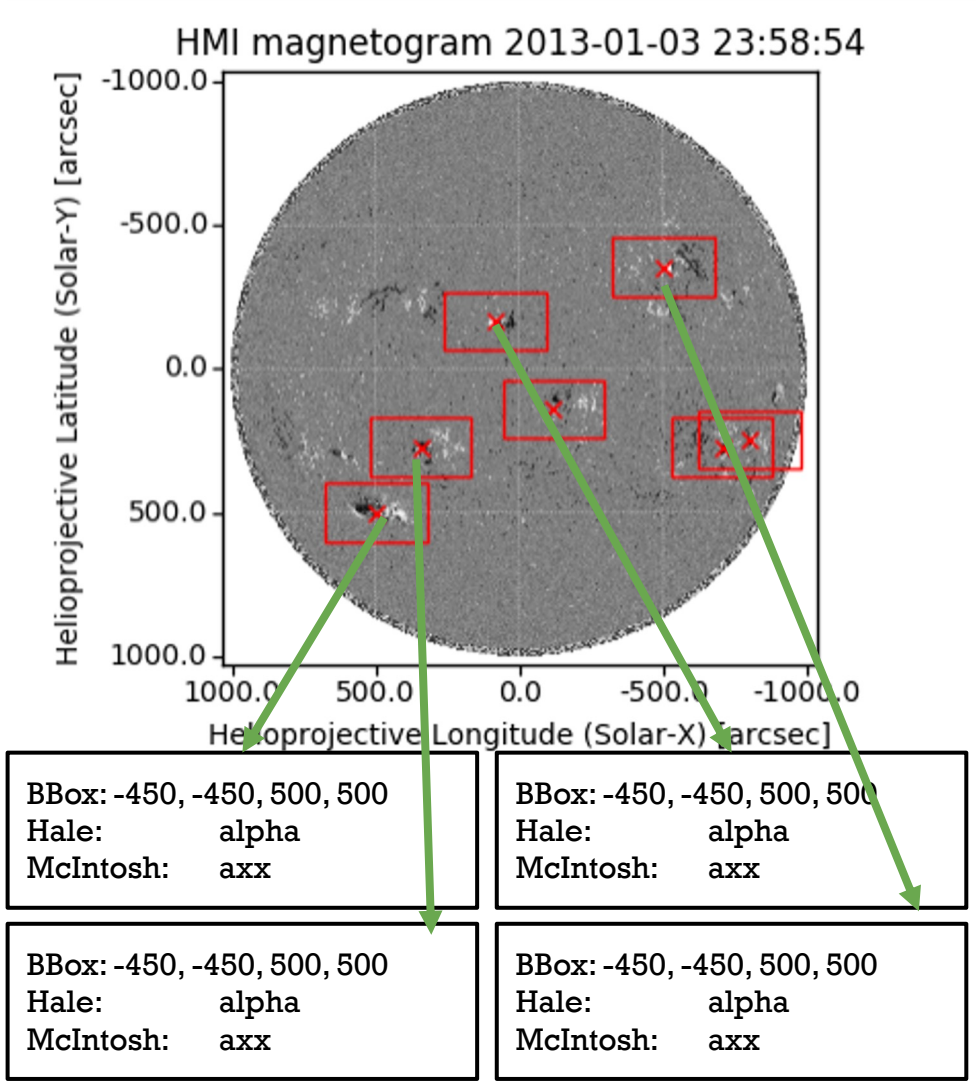
ARCAFF (02)
AR LOCALISATION

Create or obtain AR bounding boxes.

Create data set using previously downloaded and prepared FD images for AR localisation and classification:

- inputs: FD magnetogram (2D - space x space)
- outputs: vector of AR bounding boxes and classifications (Hale, McIntosh) for all ARs in each magnetogram.

Release of datasets, software, and research into AR classification properties.



ARCAFF (03)
POINT-IN-TIME FORECAST

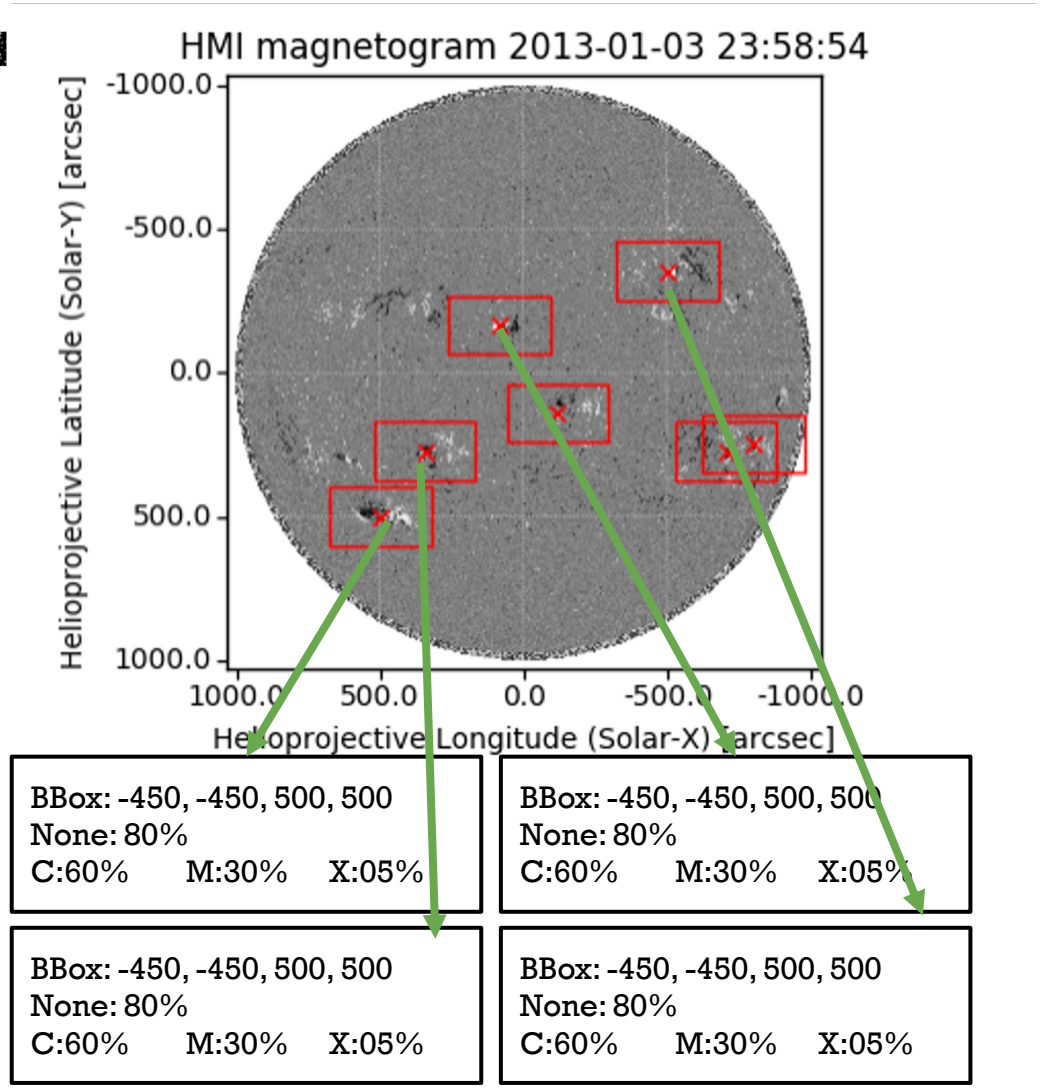
Download flare event data from NOAA/SWPC.

Flare probabilities are calculated from flare events over a rolling interval, e.g. 24 hours, for C, M, and X class flares. The start of this interval is used to find the closest previously downloaded and prepared FD magnetograms, which are then associated with the calculated flare probability.

Use magentogram and derived flare probabilities to create a dataset for training the point-in-time flare forecast:

- inputs (FD magnetograms)
- outputs (vector of bounding boxes and flare probabilities (C, M, X) in time period e.g. 24 hours).

Release of DL dataset and software.



ARCAFF (03)
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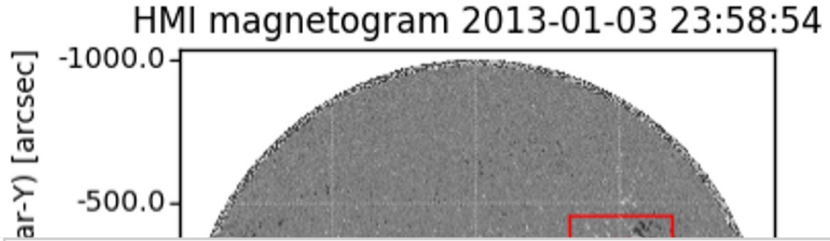
Release of DL dataset and software.



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2	gev_20221130_0534	2022/11/30 05:34:00	05:49:00	05:42:00	C1.3	S19W89
3	gev_20221130_0617	2022/11/30 06:17:00	06:29:00	06:23:00	C2.1	S14W89
4	gev_20221130_1103	2022/11/30 11:03:00	11:18:00	11:13:00	C1.7	S18W89
5	gev_20221130_1106	2022/11/30 11:06:00	11:18:00	11:13:00	C1.6	S17W89
6	gev_20221130_1118	2022/11/30 11:18:00	11:35:00	11:22:00	C1.5	S16E89
7	gev_20221130_1222	2022/11/30 12:22:00	12:35:00	12:31:00	C1.2	N20W63
8	gev_20221130_1400	2022/11/30 14:00:00	14:19:00	14:10:00	C1.2	S19E89
9	gev_20221130_1419	2022/11/30 14:19:00	15:09:00	14:48:00	C2.6	S20E89
10	gev_20221130_1610	2022/11/30 16:10:00	16:24:00	16:17:00	C3.0	S18W84
11	gev_20221130_1701	2022/11/30 17:01:00	17:14:00	17:09:00	C2.8	N20W65
12	gev_20221130_1803	2022/11/30 18:03:00	18:26:00	18:21:00	C1.8	S17E89
13	gev_20221130_1826	2022/11/30 18:26:00	18:36:00	18:30:00	C2.6	S18W89
14	gev_20221130_2223	2022/11/30 22:23:00	22:30:00	22:26:00	B9.1	S16E89
15	gev_20221201_0110	2022/12/01 01:10:00	01:18:00	01:14:00	C1.1	S16E89
16	gev_20221201_0400	2022/12/01 04:00:00	04:23:00	04:09:00	B8.9	N21E89
17	gev_20221201_0511	2022/12/01 05:11:00	05:21:00	05:16:00	B7.2	S16E89
18	gev_20221201_0531	2022/12/01 05:31:00	06:29:00	05:55:00	B9.6	S20E89
19	gev_20221201_0704	2022/12/01 07:04:00	07:36:00	07:21:00	M1.0	N28W32 (3152)

ARCAFF (04)
POINT-IN-TIME MULTIMODAL FORECAST

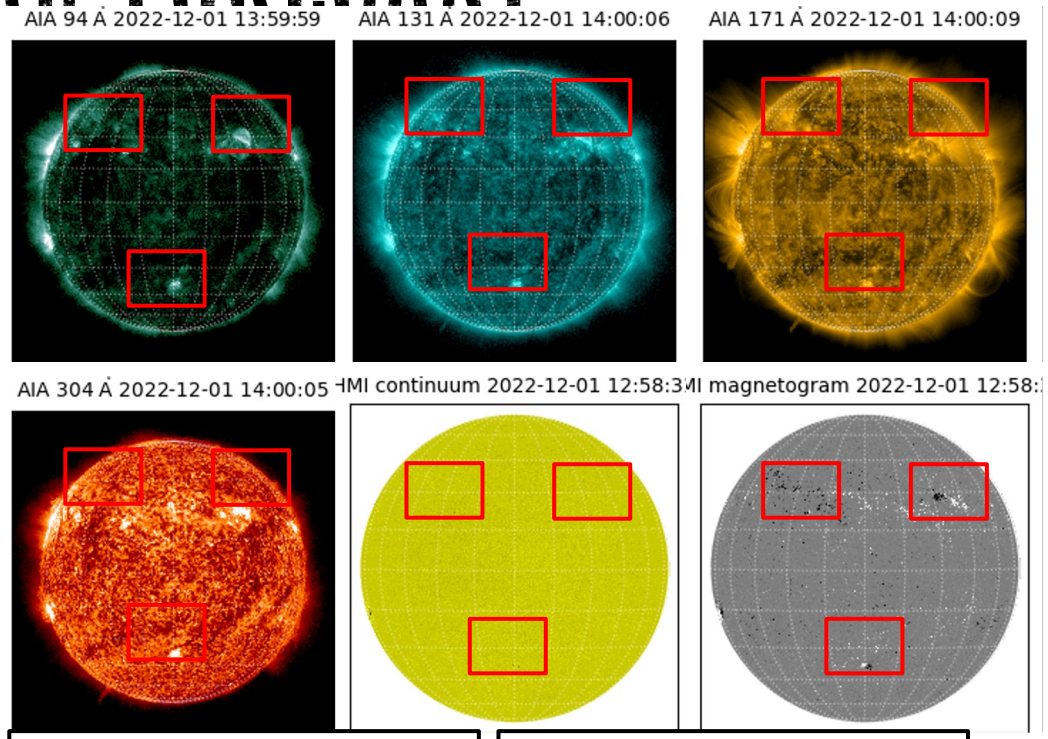
Search and download corresponding EUV data from SOHO/EIT and SDO/AIA for previously obtained and prepared magnetograms (T2.2).

Preprocessing of EUV data, calibration, alignment, scaling and bad data removal. Co-alignment of MDI with EIT, and HMI with AIA, and reprojection to common pixel grids for SOHO and SDO.

Use co-aligned image and flare events to create a data set for training the point in time flare forecast:

- inputs (FD image cube; space × space × wave)
- outputs (vector of bounding boxes and flare probabilities calculated in task T2.4).

Release of DL dataset and software.



ARCAFF (05)
TIME SERIES MULTIMODAL FORECAST

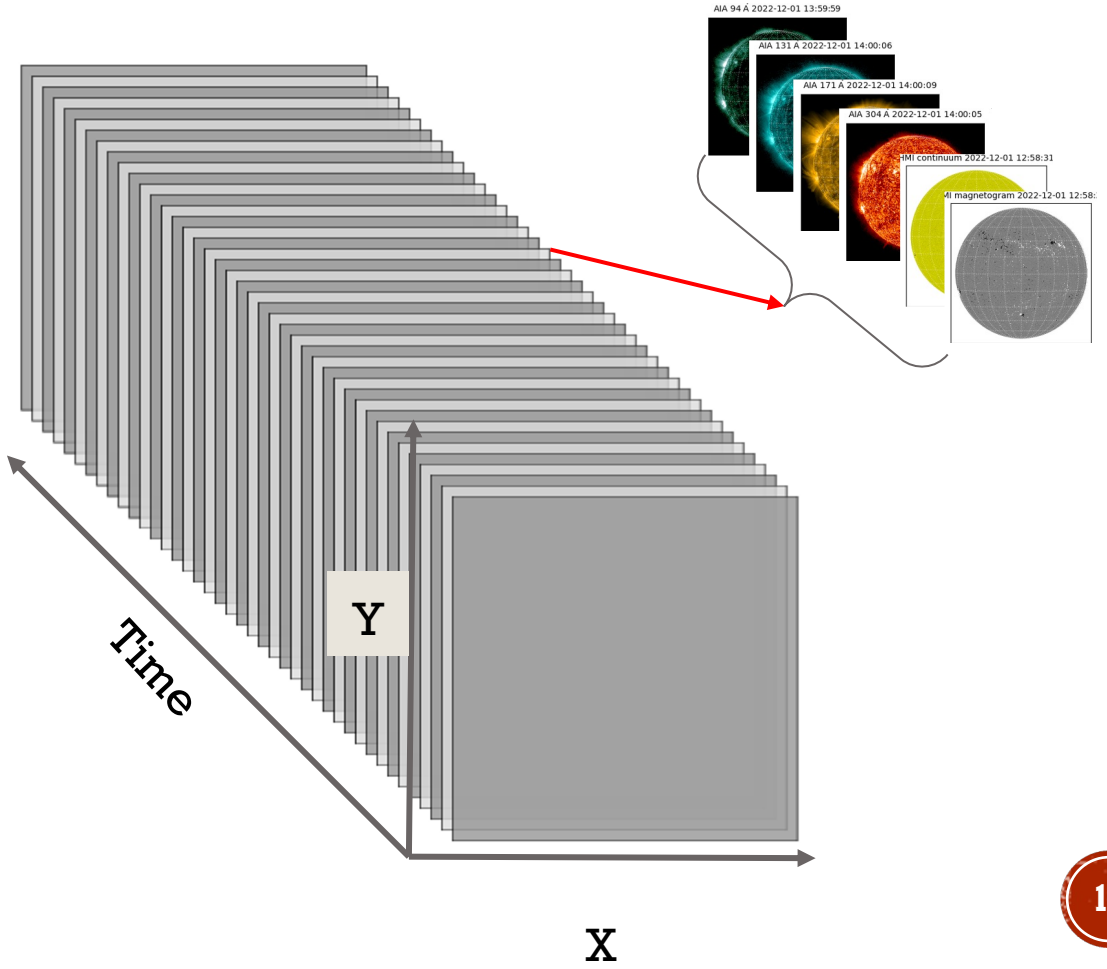
Using a similar approach to T2.4 but instead of a single time interval a sequence or time series of flare probabilities is created, for example every hour from a time t to t+24 hours.

The input data is a time series or 4D cube of past observations, for example every hour from a time t to t-24 hours. The exact number and size of the time intervals for both input and output data will be analysed as part of this task.

Create a dataset for training the time series multimodal flare forecasts:

- inputs (4D co-aligned and reprojected image cubes; space × space × wave × time)
- output (derived sequences of flare probabilities).

Release of DL dataset and software.

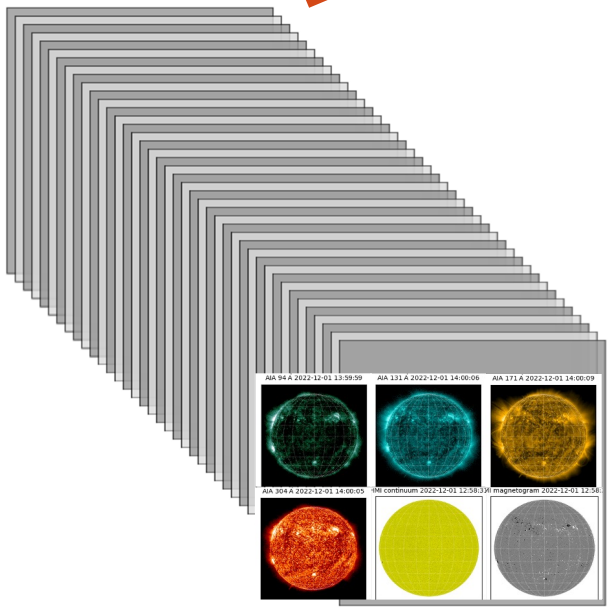


ARCAFF MODELS

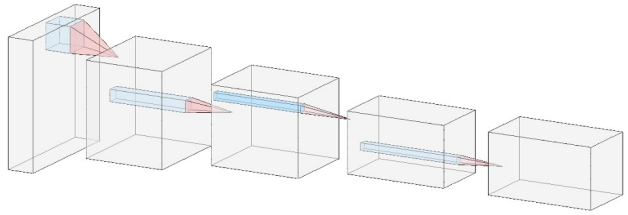
Objectives	Relevant DL Models	Comment
AR Classification (O1)	AlexNet, VGG, GoogleNet/Inception, RESNET	Replace input with solar image cutouts and outputs with AR classifications
AR Localisation and Classification (O2)	R-CNN, Fast-RCNN and Faster-RCN, YOLOv1-v3	Replace input with solar images and outputs with AR classifications and bounding boxes
Point-in-time flare forecast using full disk magnetograms (O3)	R-CNN, Fast-RCNN and Faster-RCN, YOLOv1-v3	Modify output layers and activations to model C, M and X flare probabilities
Point-in-time flare forecast using full disk multimodal observations (O4)	R-CNN, Fast-RCNN and Faster-RCN, YOLOv1-v3	Modify output layers and activation to model C, M and X flare probabilities
Time series flare forecasts using full disk multimodal observations (O5)	DeepSpeech2, LAS	Add additional feature encoder to create featuregrams and modify output layers and activation to output sequence of flare probabilities

ARCAFF MODELS

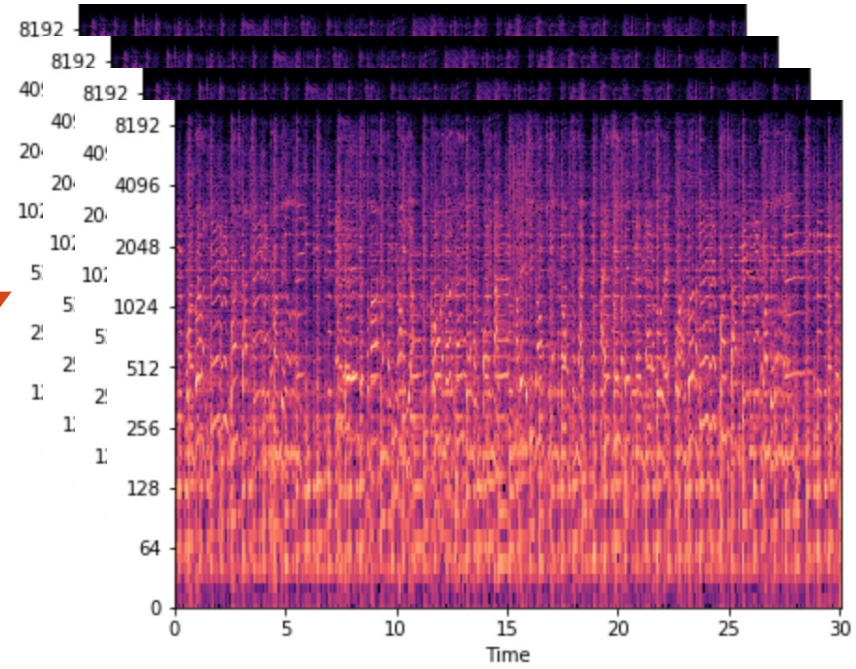
4D Cube
space x space x
wave x time



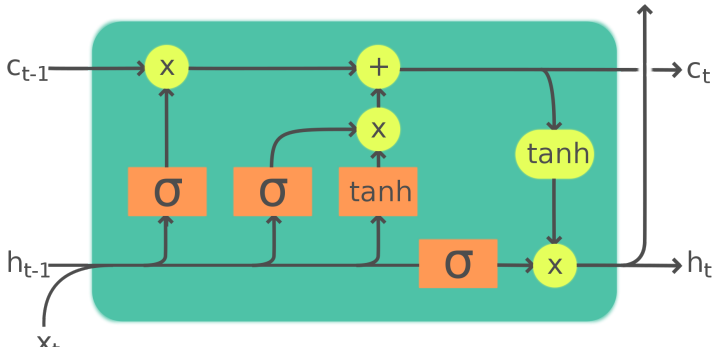
Convolution Layers 4D -> 3D
Feature x time x no. ARs



3D Feature-grams
feature x time x no. ARs



Recurrent Layers
2D Predictions
Prediction x no. ARs



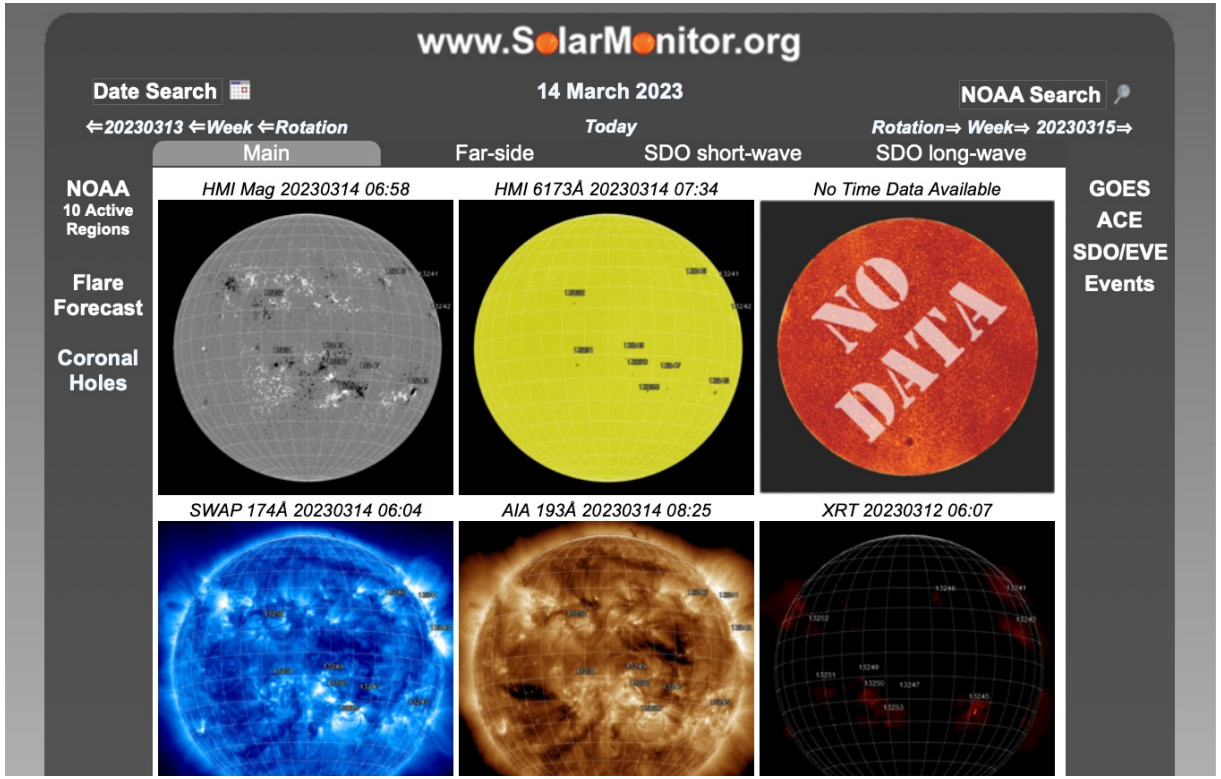
ARCAFF
OPEN SCIENCE

- Open Science, Useability, Reproducibly, and Reusability
  - Core project goals
  - Requirements of Horizon Europe (FAIR, DMP, …)
  - Deploy on solarmonitor.org
  - PITHA-NRF key aspect of this for ARCAFF to promote open science - search, share, access and understand
    - Datasets
    - Models
    - APIs
    - Documentation

ARCAFF
CONNECTION WITH PITHIA

- Publish ARCAFF models and related datasets through the PITHIA e-Science Centre
- ARCAFF models will be provided via APIs and published in the PITHIA eSC
- First prototyping to start soon
- Facilitation: UoW to support integration and even modification of the eSC if needed
  - Partners in both projects
- Benefits for both projects
  - External users for the eSC
  - Further cases studies to validate PITHIA technology
  - Higher visibility, technical robustness and better sustainability for ARCAFF services

ARCAFF


www.SolarMonitor.org
Date Search
14 March 2023
NOAA Search
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Today
Rotation⇒ Week⇒ 20230315⇒
Main
Far-side
SDO short-wave
SDO long-wave
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Flare
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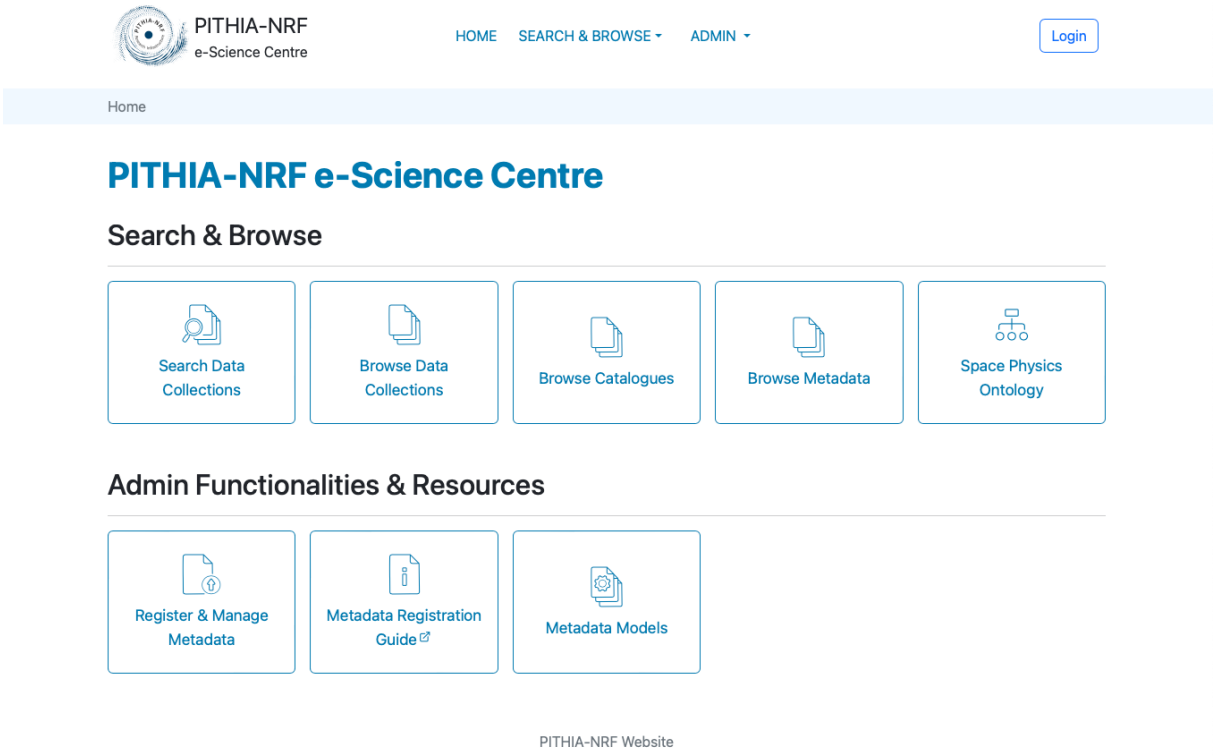
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Register & Manage Metadata
Metadata Registration Guide
Metadata Models
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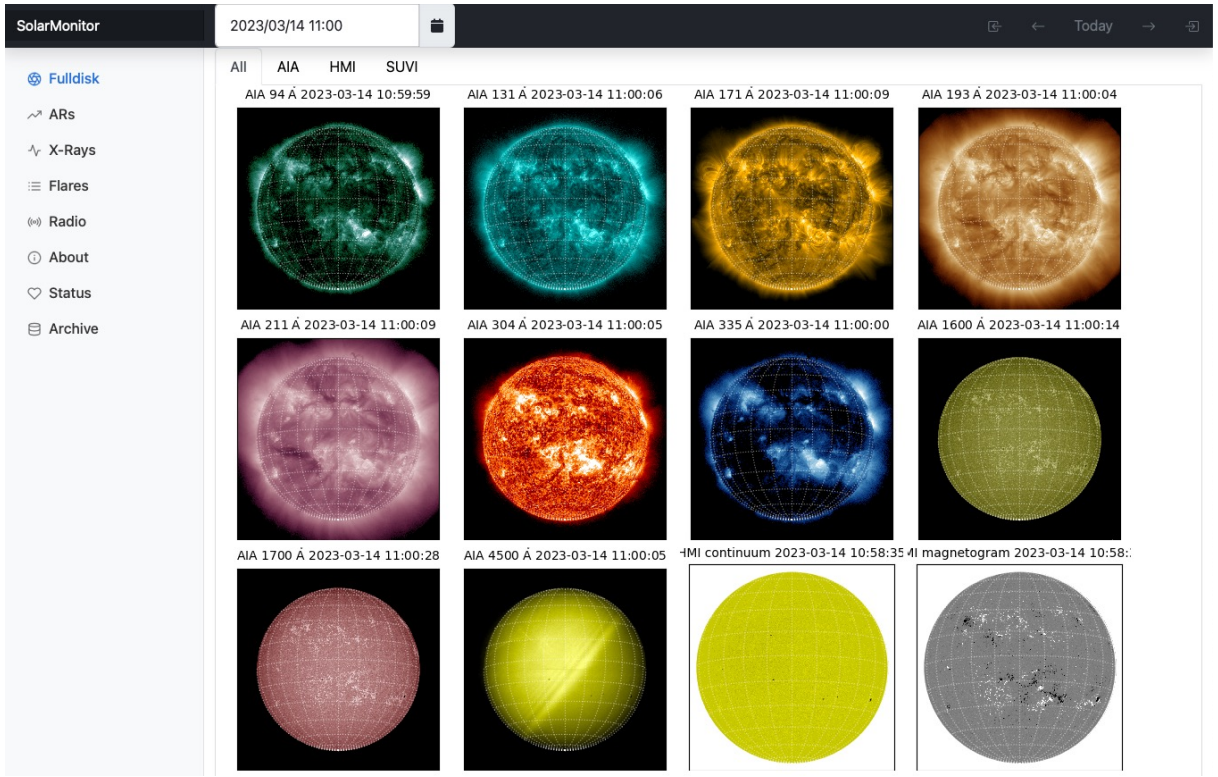
SolarMonitor
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All
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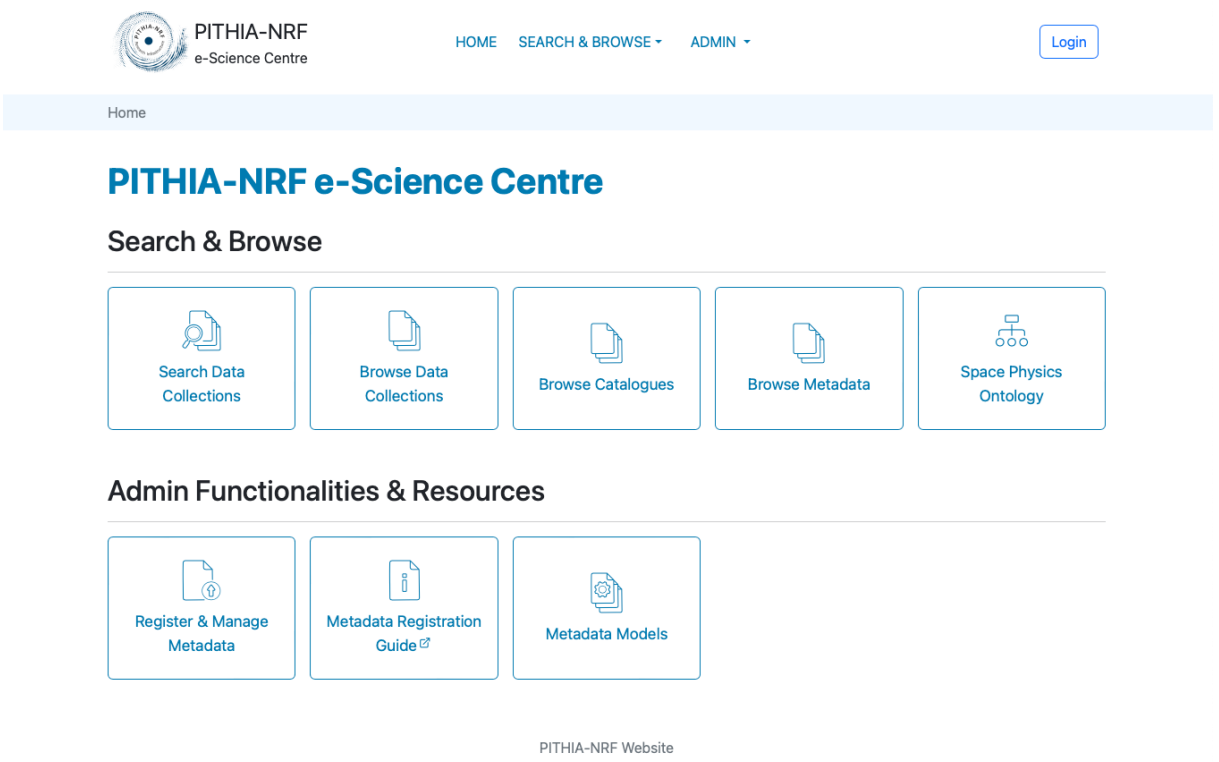
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Register & Manage Metadata
Metadata Registration Guide
Metadata Models
PITHIA-NRF Website

ARCAFF

Jobs

- ~~DIAS Postdoc Position (Deadline May 8)~~
  - ~~http://dias.ie/arcaff-postdoc~~
- UNIGE Postdoc Position (Opens)
  - https://mida.unige.it/form/open-positions

Information

- arcaff.eu

Questions?