

International Workshop on Machine Learning for Space Weather: Fundamentals, Tools and Future Prospects

7-11 November 2022
This is a hybrid meeting
Buenos Aires, Argentina



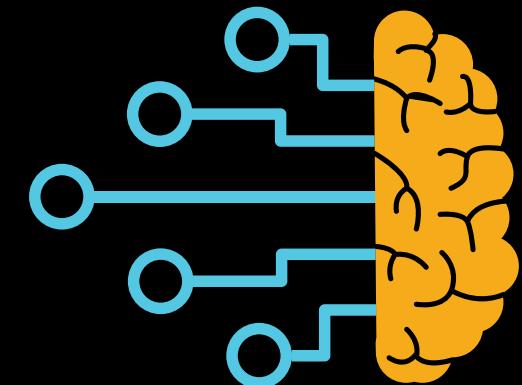
Further information:

<https://indico.ictp.it/event/9840/>
smr3750@ictp.it
+39-040-2240284
Elizabeth Brancaccio

Dra María Graciela Molina
FACET-UNT / CONICET
Tucumán Space Weather Center - TSWC

<https://spaceweather.facet.unt.edu.ar/>
IG -> @spaceweatherargentina

gmolina@herrera.unt.edu.ar



About us ...



Dra. María Graciela Molina
gmolina@herrera.unt.edu.ar

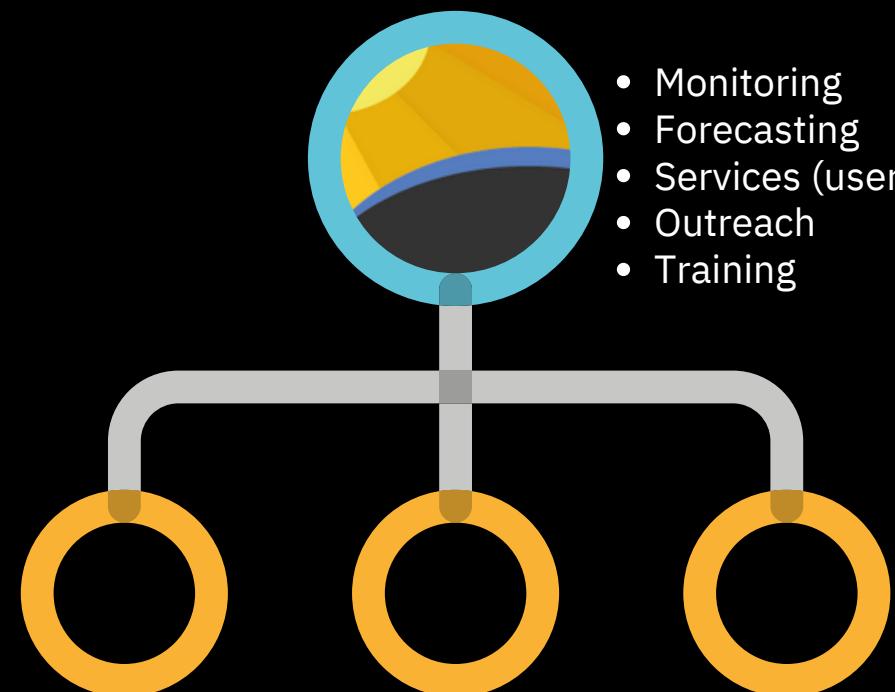


Lic. Jorge H. Namour
jnamour@herrera.unt.edu.ar



Instrumentation

- Deployment
- Design and Development
- Networks
- Radar systems development

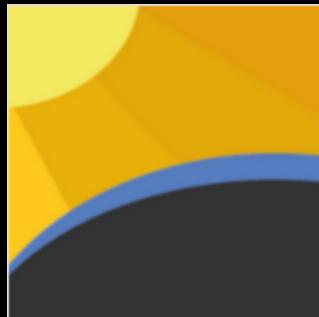


Data Management and Operative tools

- Data infrastructure
- Tailored software development
- DS approach: AI modeling/forecasting, data bases.
- Operative AI
- ML assisted forecasters tools

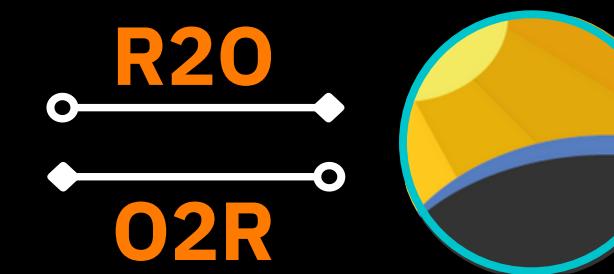
Scientific goals

- Atmospheric physics
- Space Weather chain of events understanding. Sun-Earth connections
- Geomagnetism
- Radiopropagation
- ML and stats methods for SWx
- XAI



Tucuman Space Weather Center FACET-UNT

Canal oficial Tucumán Space Weather Center (TSWC) El TSWC es el centro de monitoreo de meteorología del espacio de la...



<https://spaceweather.facet.unt.edu.ar/>

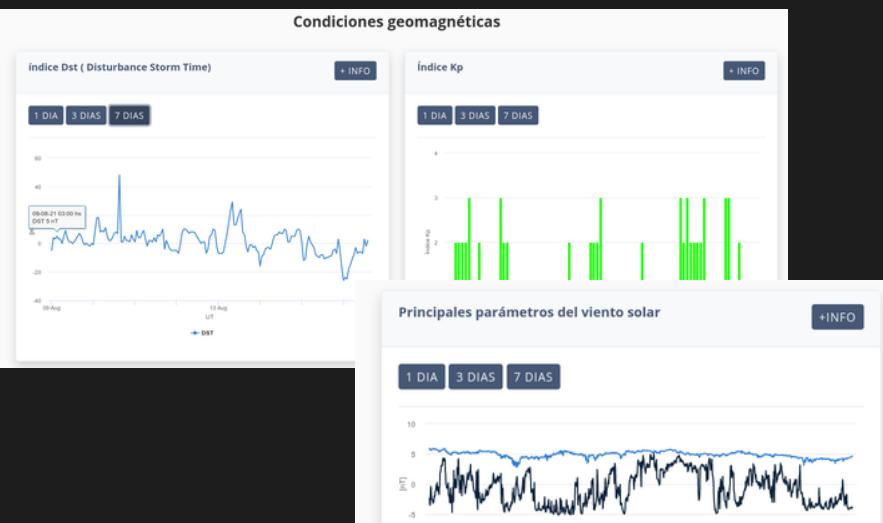
Instagram: /spaceweatherargentina

- Instrumentation development
- Data-driven modeling
- Physics
- Tailored software development
- Operative for ICAO
- Training & Capacity building

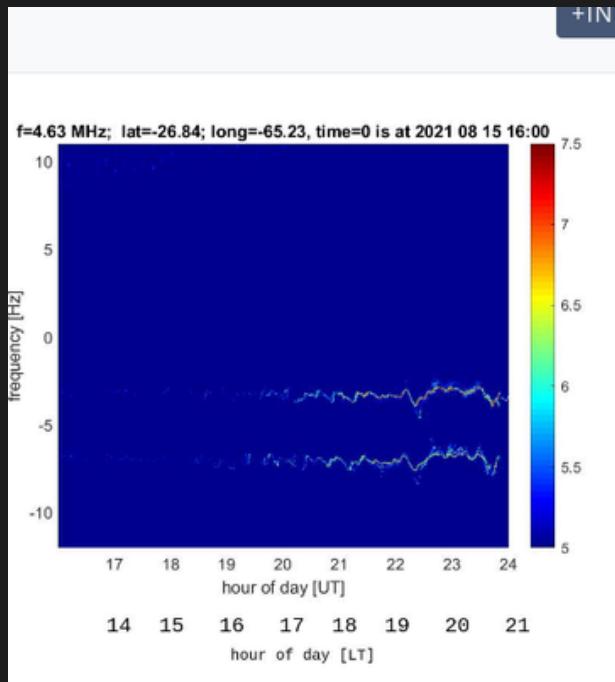
About us ...



Solar wind - magnetosphere coupling monitoring



AGWs automatic detection



Ionosonde Argentine Net

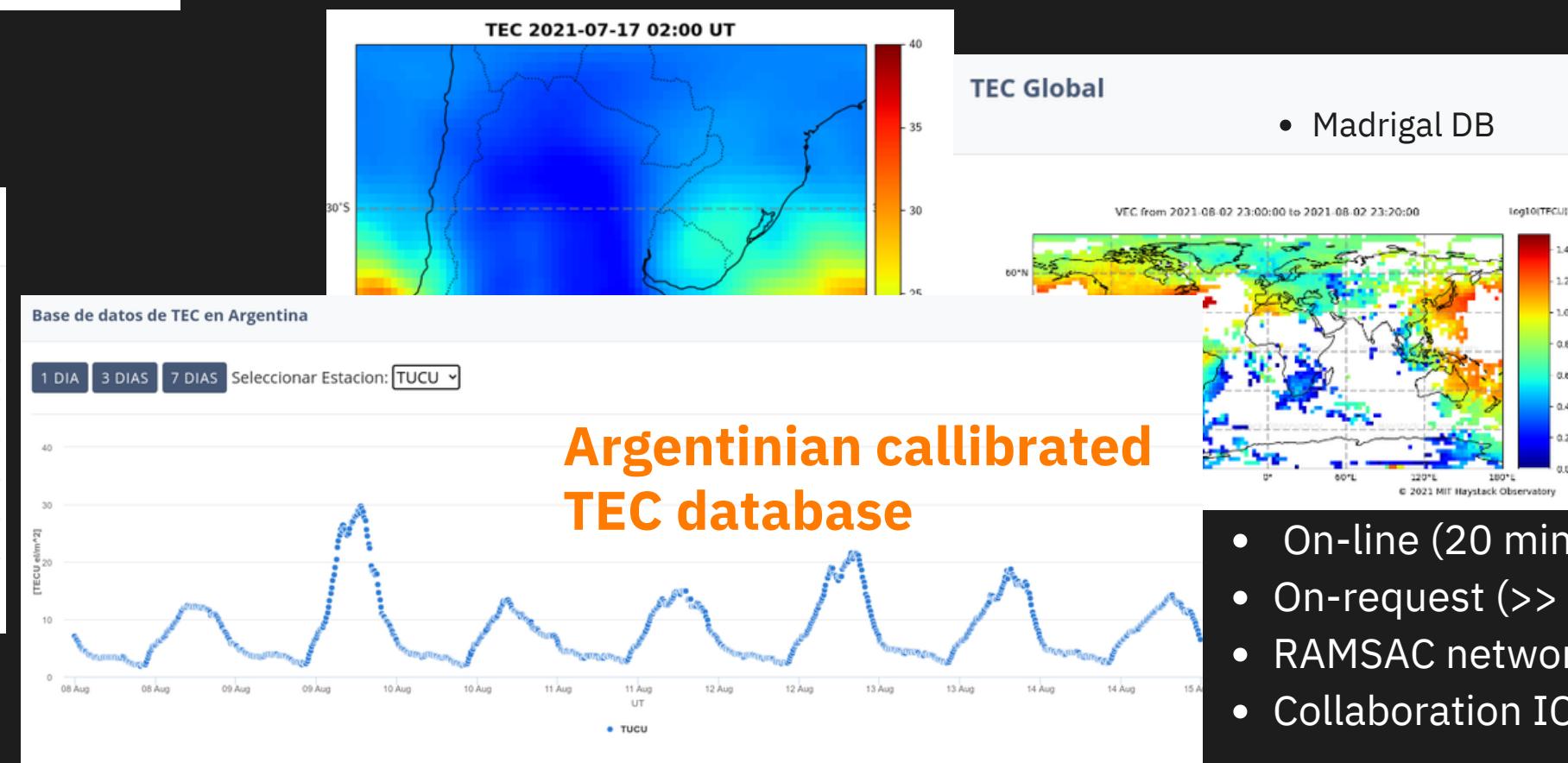
(>> Pegasus Consortium)



Últimos ionogramas registrados en las estaciones ionosféricas de Tucumán (arriba) y Bahía Blanca (abajo)

- Ionogram scaling correction by experts (tool for ionospheric interpreters+ DB)
- Cosmic Ray detector: LAGO collaboration
- Ionospheric conditions forecasting (f0F2 and TEC, single station, regional and global) - AI modelling (status: concept testing)
- NeQuick ingested -> f0F2
- Automatic Flare Analysis Tool (UCR)
- TIDs automatic detection
- TEC calibration service
- New GNSS receiver - New 3D Doppler radar
- ...

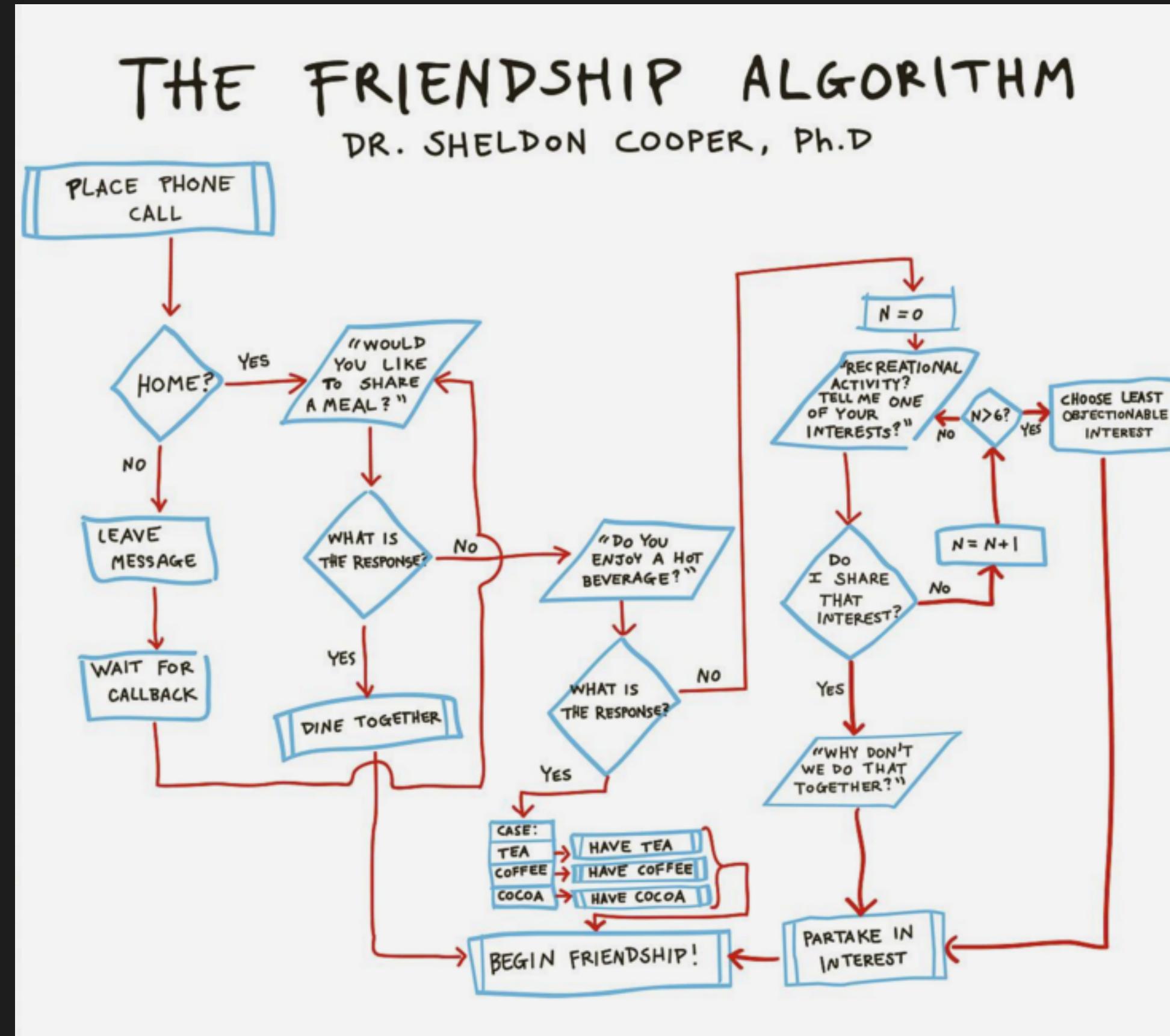
Global and Regional TEC maps



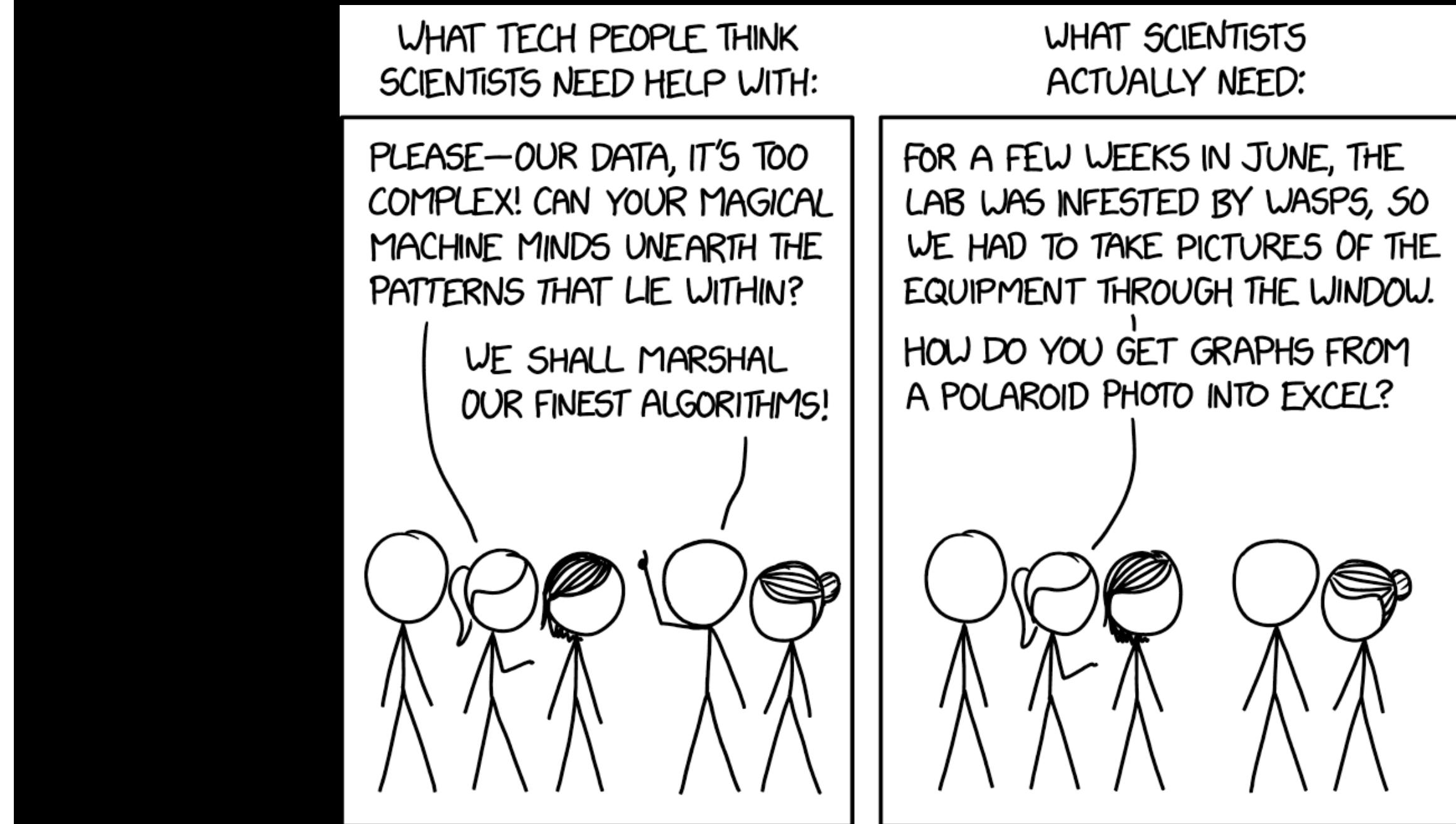
Argentinian calibrated TEC database

- On-line (20 min)
- On-request (>> resol)
- RAMSAC network
- Collaboration ICTP researchers

What about you?



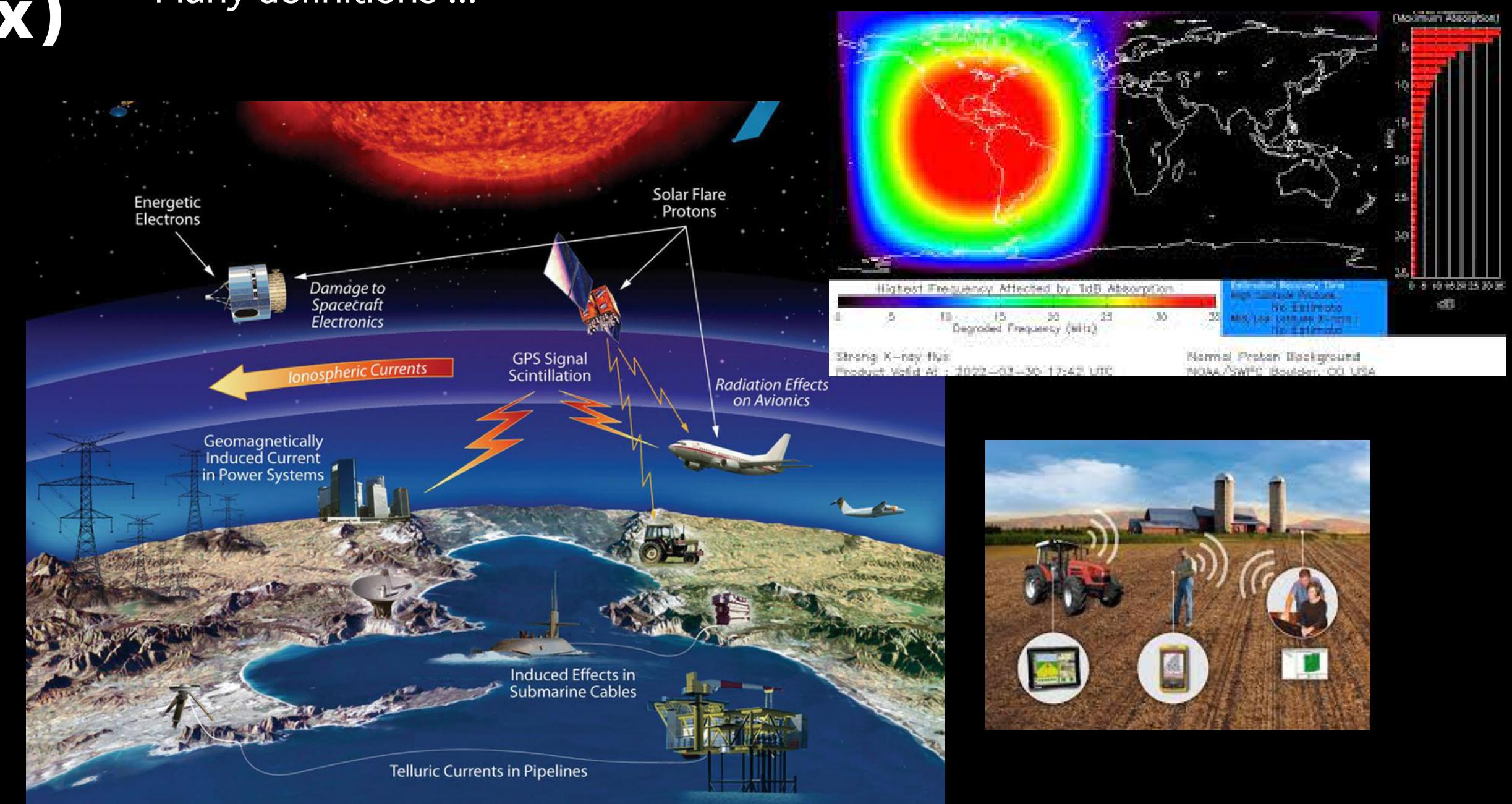
Intro



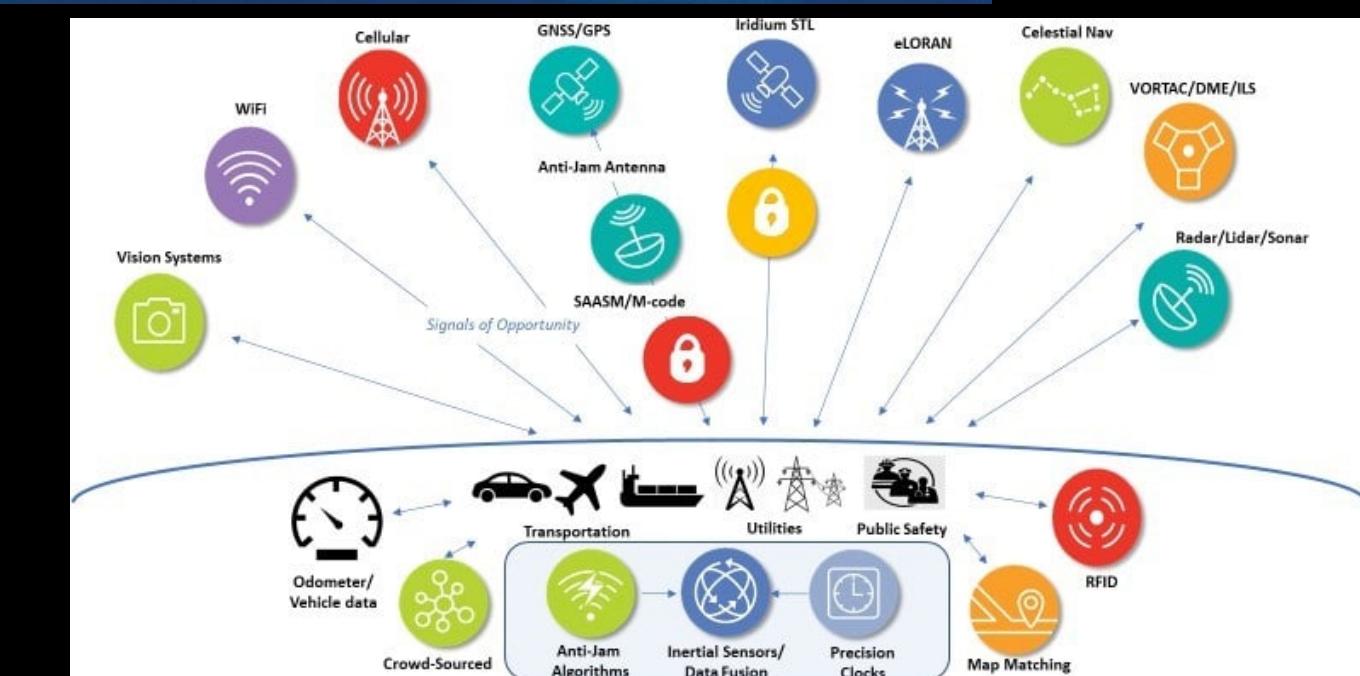
Space Weather (SWx)

Many definitions ...

Space Weather is the physical and phenomenological state of natural space environments. The associated discipline aims, through observation, monitoring, analysis and modelling, at understanding and predicting the state of the Sun, the interplanetary and planetary environments, and the solar and non-solar driven perturbations that affect them, and also at forecasting and nowcasting the potential impacts on biological and technological systems. -COST Action 724 , 2009



COST (European Cooperation in Science and Technology) is a funding organisation for research and innovation networks



TSWC, 2022

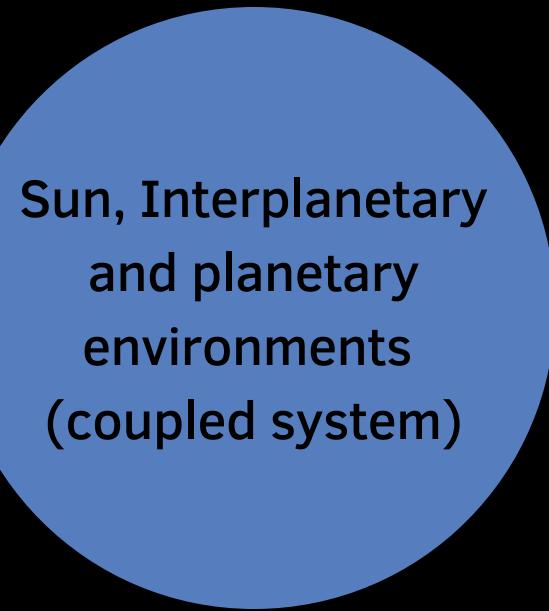
Space Weather (SWx)

COST (European Cooperation in Science and Technology) is a funding organisation for research and innovation networks

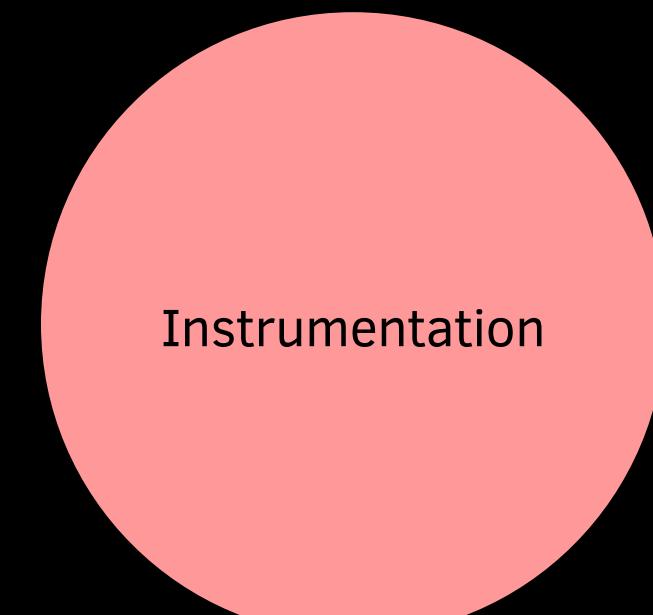
Space Weather is the physical and phenomenological state of natural space environments. The associated discipline aims, through observation, monitoring, analysis and modelling, at understanding and predicting the state of the Sun, the interplanetary and planetary environments, and the solar and non-solar driven perturbations that affect them, and also at forecasting and nowcasting the potential impacts on biological and technological systems. -COST

Action 724 , 2009

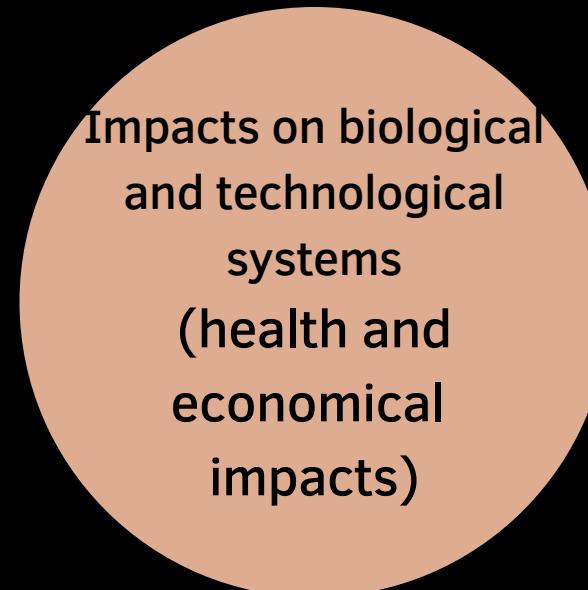
Many definitions ...



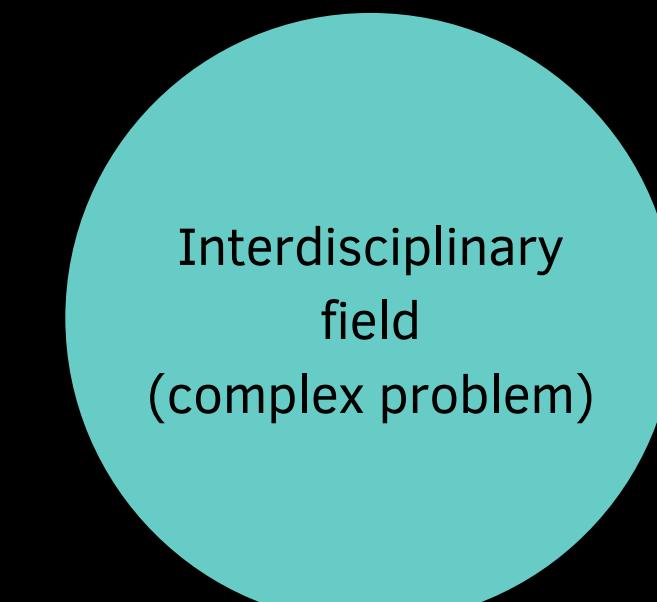
- Science



- Coverage
- Partial observations
- Scientific + military + commercial
- Networks



- Stakeholders
- R2O
- Drives the services (e.g. ICAO - interested in HF)



- Now/Forecasting
- Modelling
- Analysis
- Monitoring
- Observations



TSWC, 2022

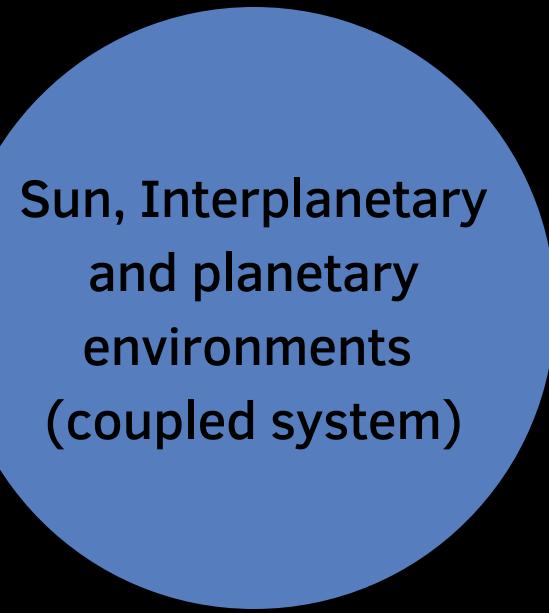
Space Weather (SWx)

COST (European Cooperation in Science and Technology) is a funding organisation for research and innovation networks

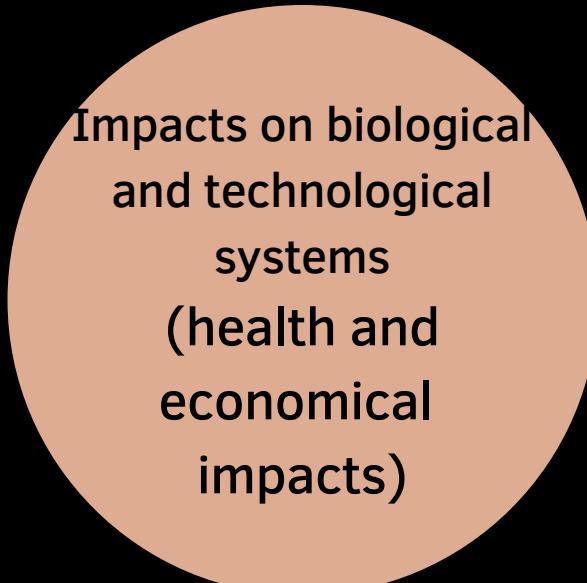
Space Weather is the physical and phenomenological state of natural space environments. The associated discipline aims, through observation, monitoring, analysis and modelling, at understanding and predicting the state of the Sun, the interplanetary and planetary environments, and the solar and non-solar driven perturbations that affect them, and also at forecasting and nowcasting the potential impacts on biological and technological systems. -COST

Action 724 , 2009

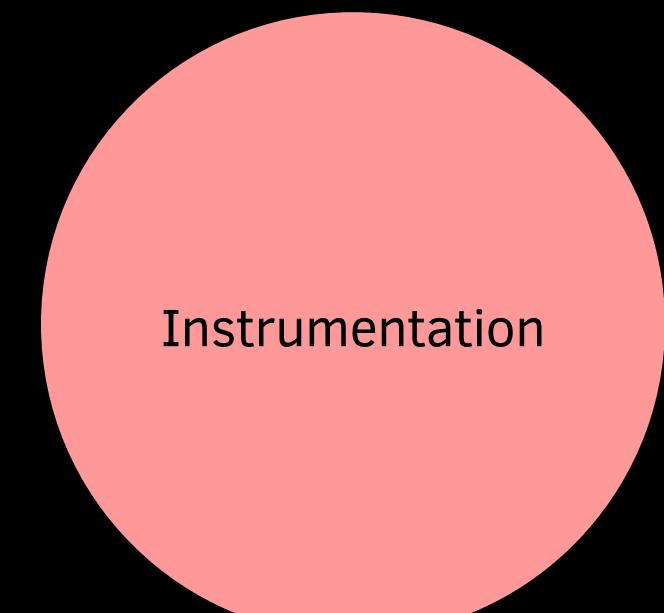
Many definitions ...



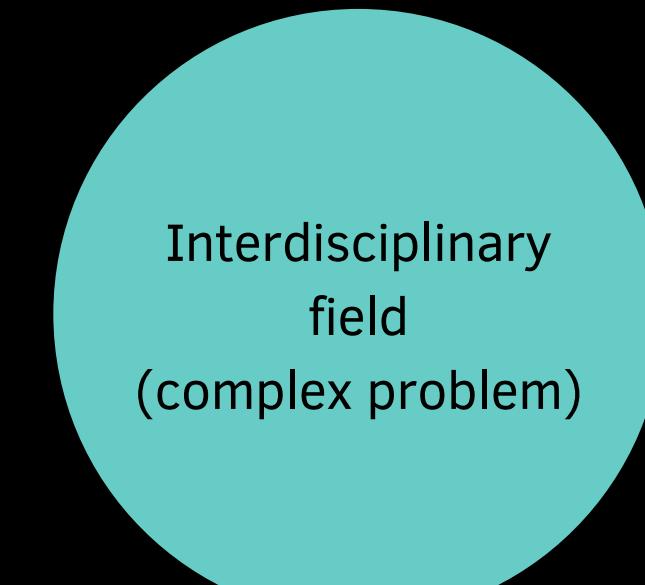
- Science



- Stakeholders
- R2O
- Drives the services (e.g. ICAO - interested in HF)



- Coverage
- Partial observations
- Scientific + military + commercial
- Networks



- Now/Forecasting
- Modelling
- Analysis
- Monitoring
- Observations



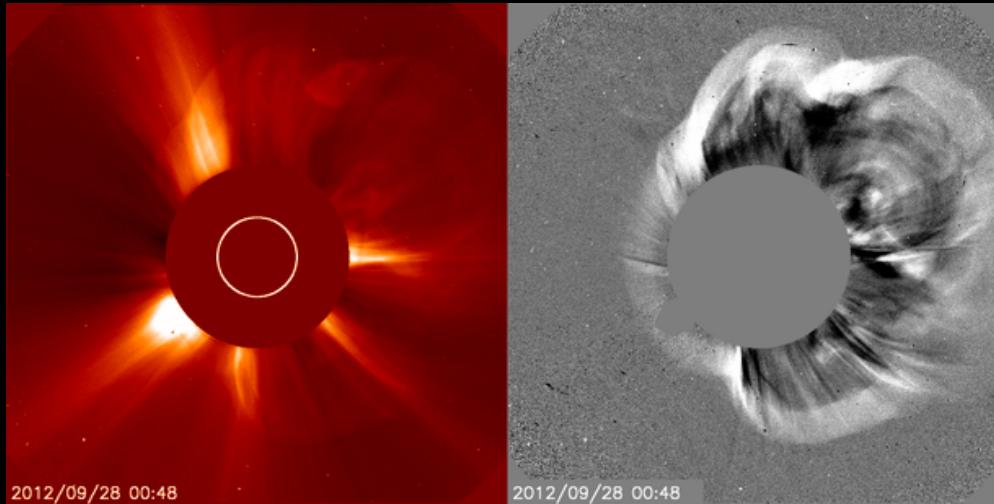
TSWC, 2022

Space Weather (SWx) Main sources & propagation - Observations - Consequences

CMEs: large portions of the corona (outer atmosphere) of the Sun explosively blown (plasma) into space. Sometimes are directed toward the Earth. If CMEs reach the Earth's magnetosphere, CMEs magnetic field can interact with the Earth's magnetic fields and produce (under special conditions) the so-called geomagnetic storms

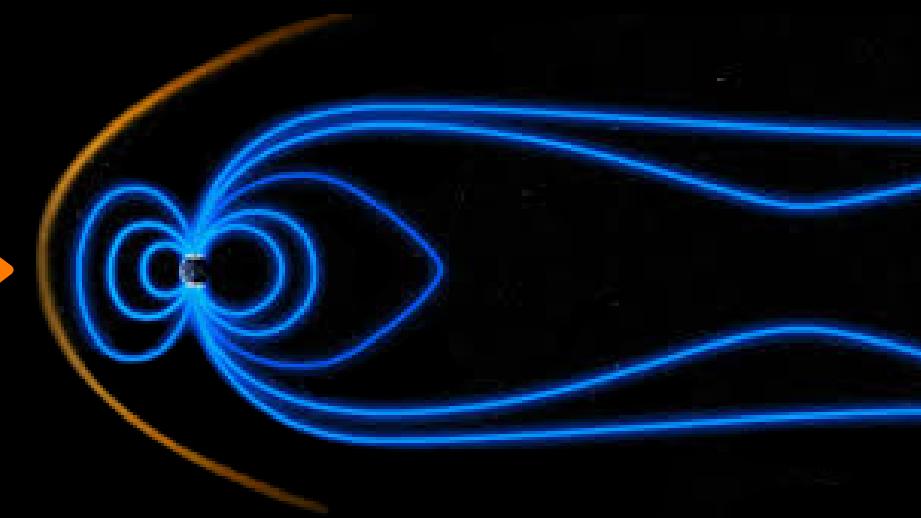


<https://umbra.nascom.nasa.gov/lasco/observations/halo/2012/120928/>



- Can reach the Earth in ~ 1.5 - 3 days (typically)
- SLOW events but difficult to predict

- Solar wind: constant outflow of electrons and protons from the Sun (interacts with Earth Mag field)



Geomagnetic Storms:
Temporary disturbances of the Earth's magnetic field
(coupling solar wind-magnetosphere through magnetic reconnection)



Space Weather (SWx) Main sources & propagation - Observations - Consequences

Solar flares: Energetic bursts of radiation (radio, white light, EUV, soft X-rays, hard X-rays and Gamma-rays) and particles triggered by the release of magnetic energy on the Sun.



Others: e.g. filaments



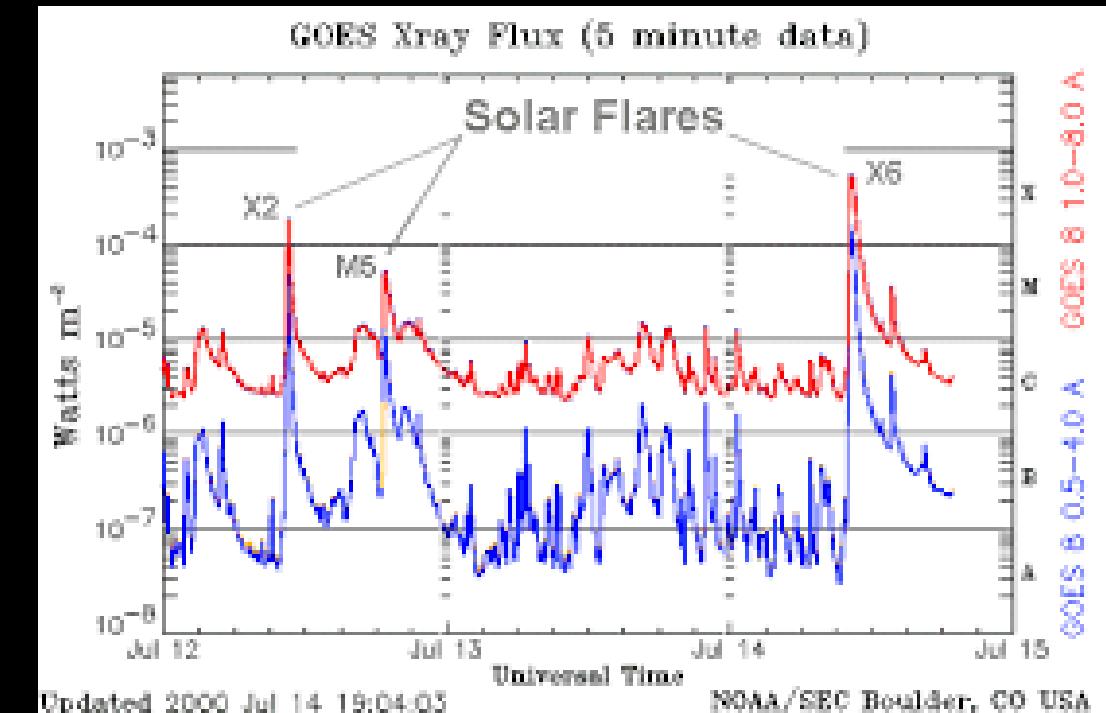
CMEs



- Slow events: ~ 1.5 - 3 days (typically)
- Difficult to predict

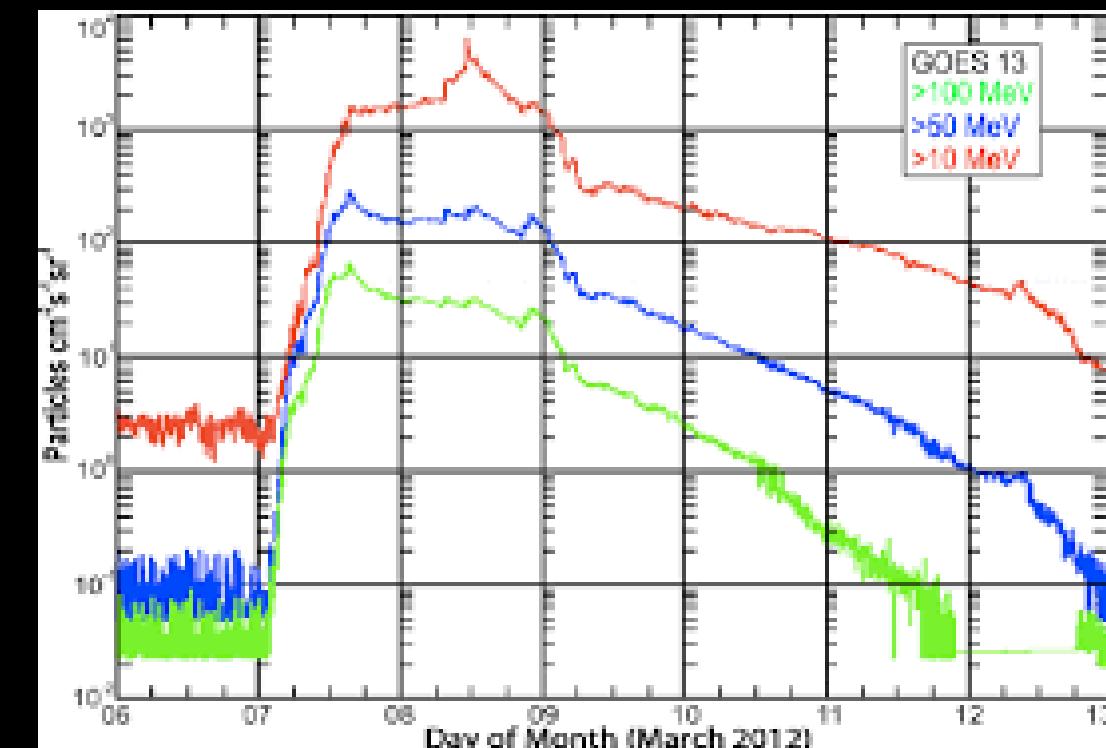
SOFT X-RAY ENHANCEMENT:

- Very Fast events: ~8 m to reach the Earth (dayside)
- Hard to predict (almost instantaneous with the observations)
- X-flares (X-ray radiation emission) classification (Near Earth): A, B, C, M or X [W/m²] of X-rays between 1- 8 Å
- Produces sudden ionization in the ionosphere



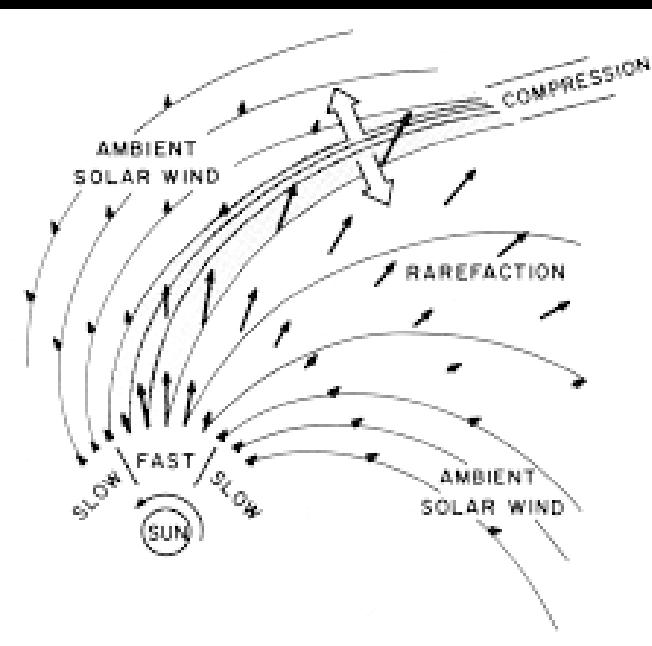
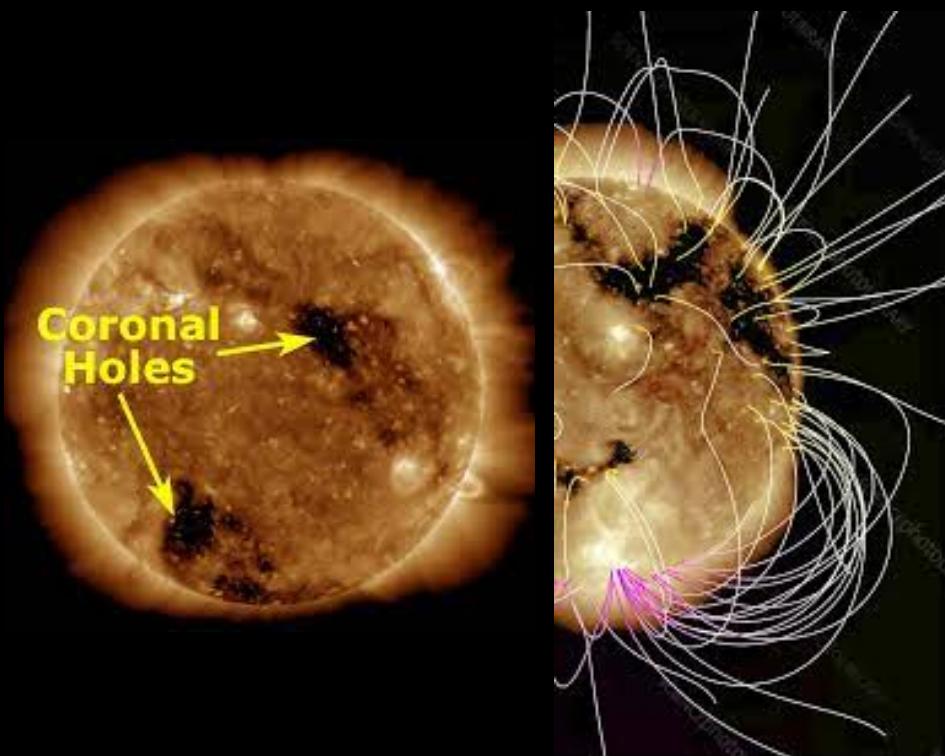
SEPs

- Can reach the Earth in ~ 1.5 - 3 days (typically)
- fast events: ~20 min



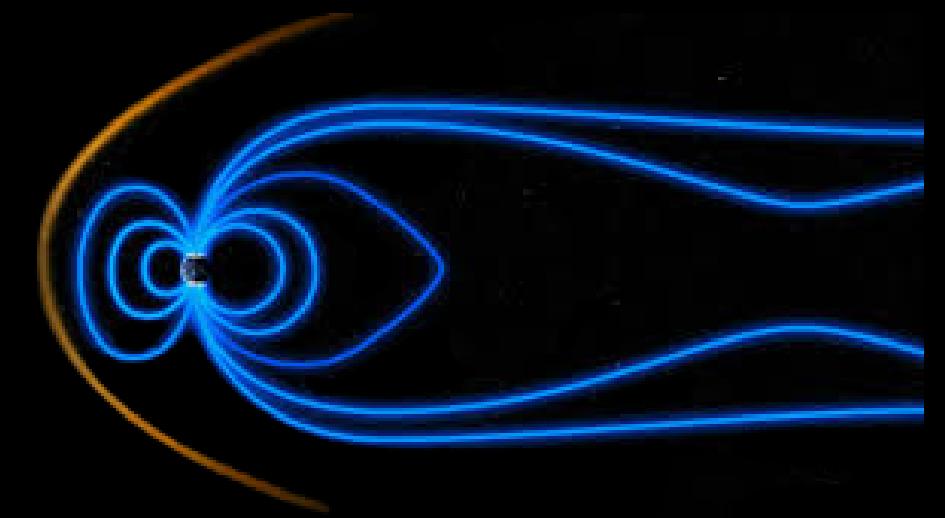
Space Weather (SWx) Main sources & propagation - Observations - Consequences

CHs: Portion of the Sun atmosphere with lower density. These are regions where the Sun magnetic field lines are connected directly with the interplanetary medium, allowing solar material to escape out in a high-speed stream of solar wind.



- Faster than background solar wind, but less speed than CMEs (typically)
- SLOW events - A CH can be present for more than a Sun rotation (~27 days), still difficult to predict

Geomagnetic Storms:
Temporary disturbances of the Earth's magnetic field (coupling solar wind-magnetosphere through magnetic reconnection)



Consequences of a Solar Wind Stream Interaction Region on the Low Latitude Ionosphere: Event of 7 October 2015

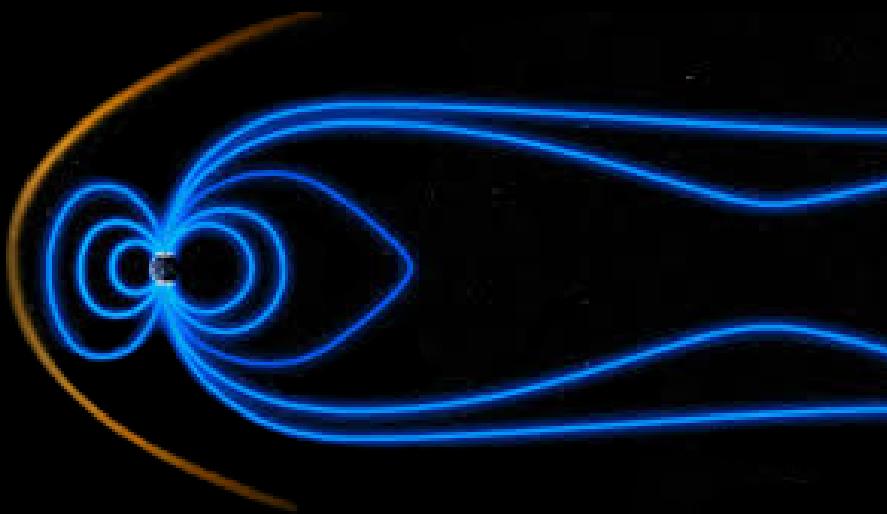
(Molina et al, 2020)



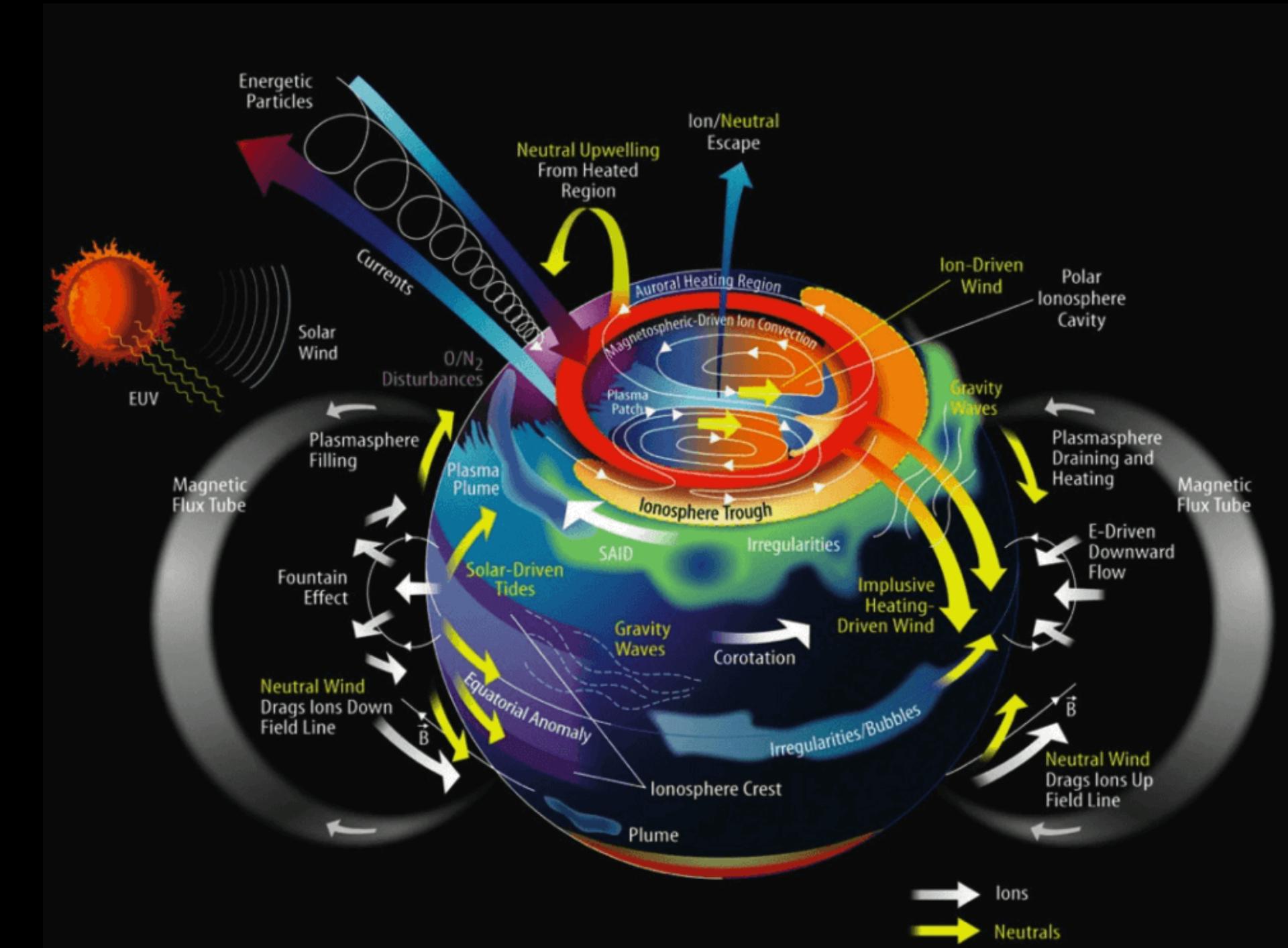
TSWC, 2022

Space Weather (SWx) Main sources & propagation - Observations - Consequences

Geomagnetic Storms:
Temporary disturbances of the
Earth's magnetic field
(coupling solar wind-
magnetosphere through
magnetic reconnection)



Solar Wind - Magnetosphere - Ionosphere
- Thermosphere coupling



TSWC, 2022

Space Weather (SWx) Main sources & propagation - Observations - Consequences

SW-M-I-T

Geomagnetic field perturbations:

- Auroral lat: AU/AL/AE/AO indeces
- Sub-auroral lat: K_p
- Low lat: Dst
- Regional (South America): KSA

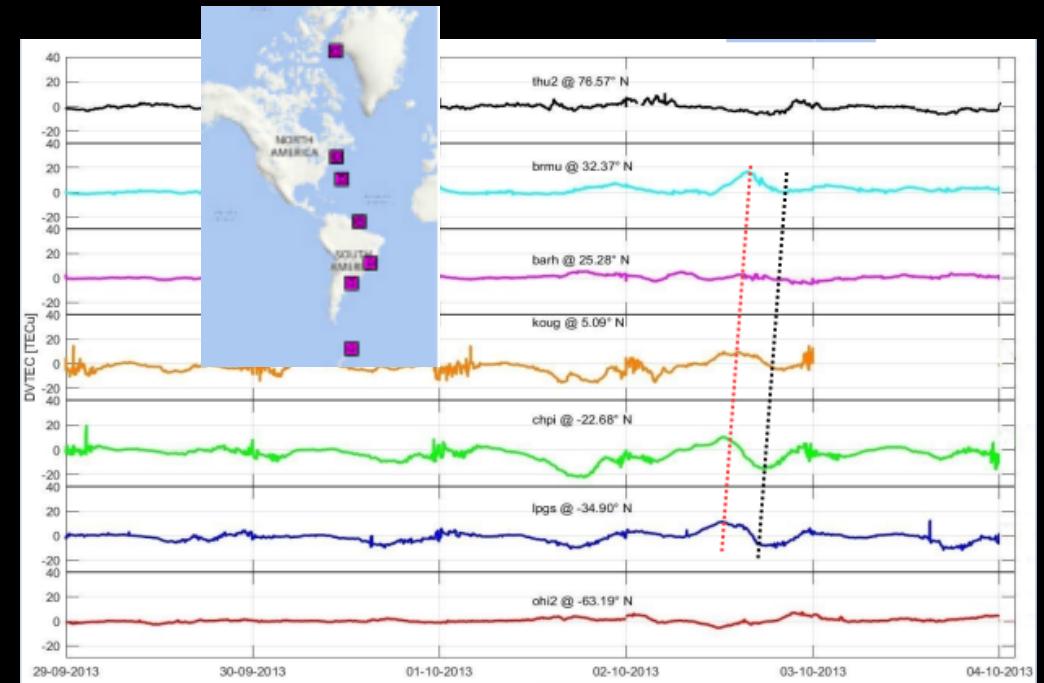
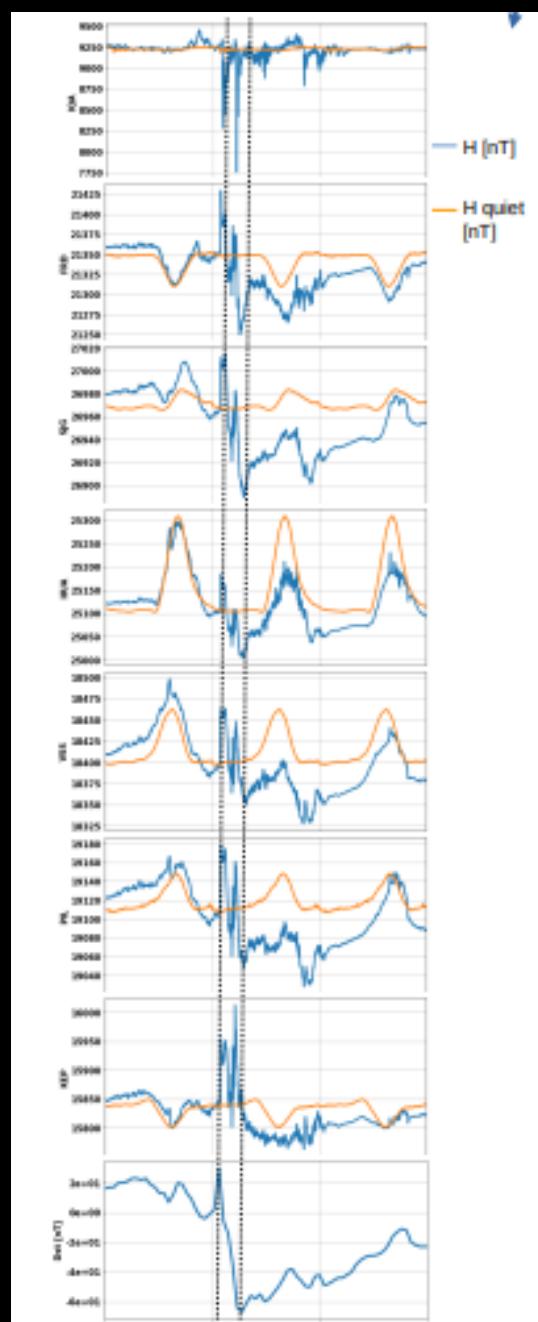
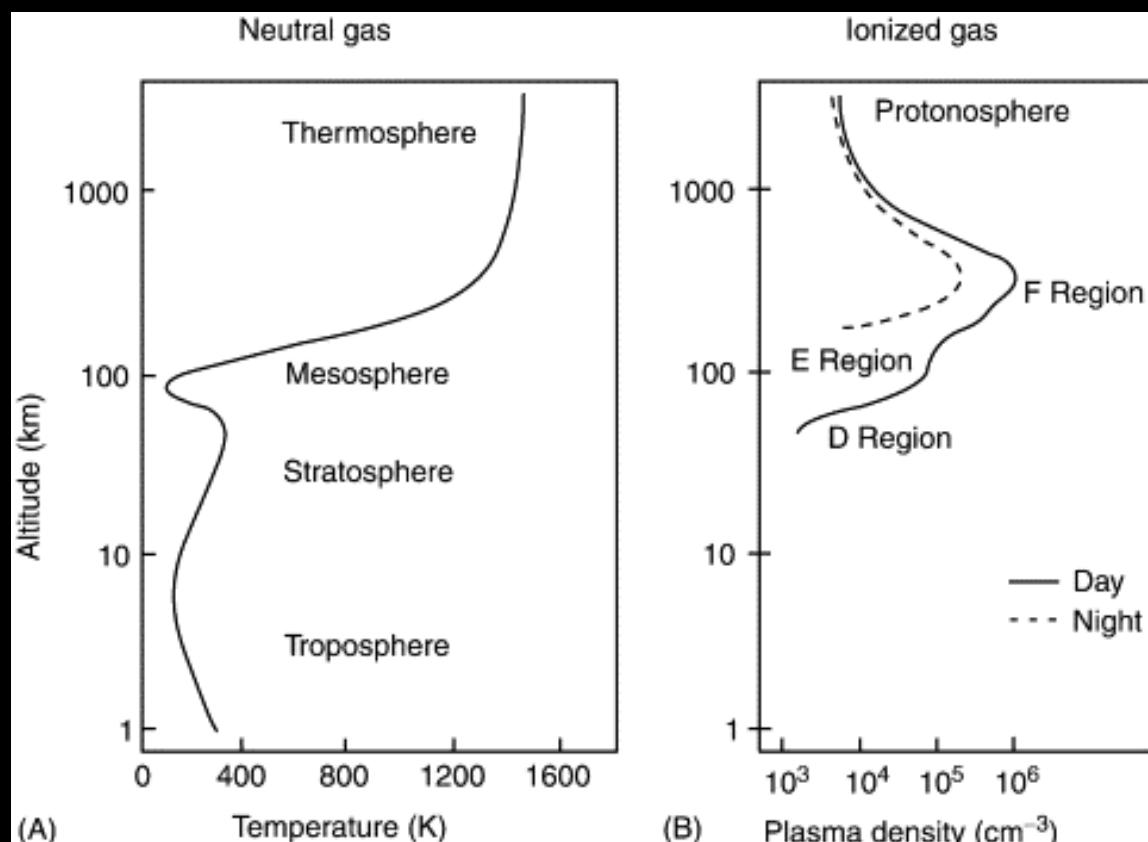
Ionosphere:

- Modification of the ionospheric current system ar high lat (auroral electrojet) - PPEF
- Modification of the ionospheric current system at low lat (equatorial electrojet)
- Ionospheric heating
- Travelling Ionospheric Disturbances
- (and more)



TSWC, 2022

Particle precipitaion: enhancement at auroral latitudes



Ionospheric response to the geomagnetic storm on 2nd October 2013: Longitudinal chain analysis over the American sector. (Molina et al, 2018)

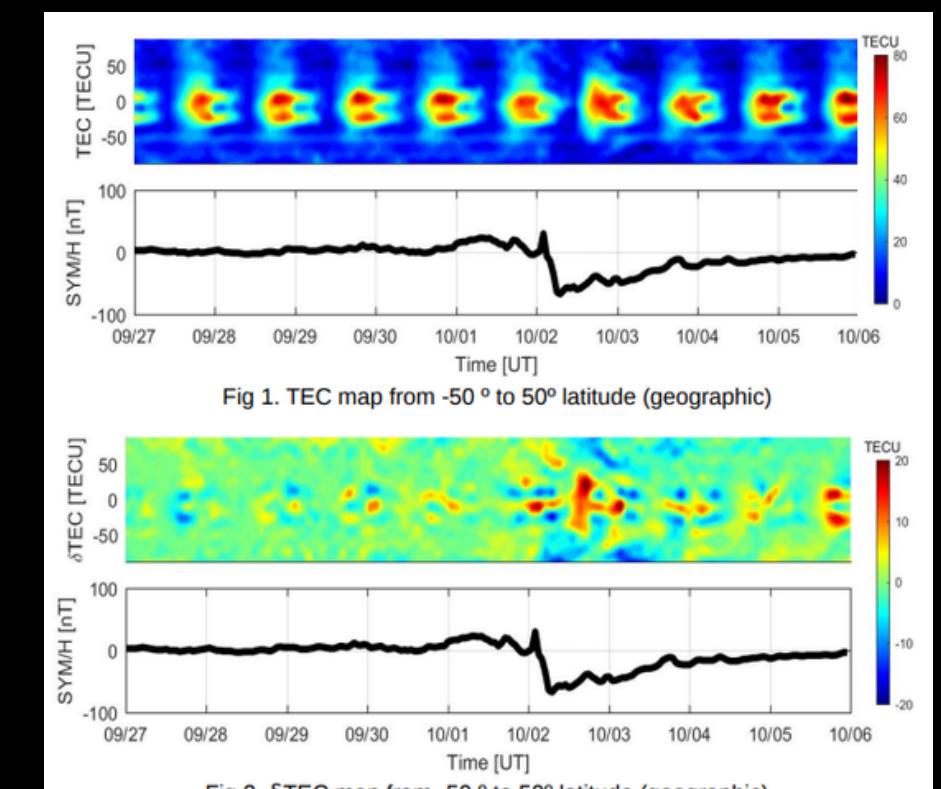


Fig 1. TEC map from -50° to 50° latitude (geographic)

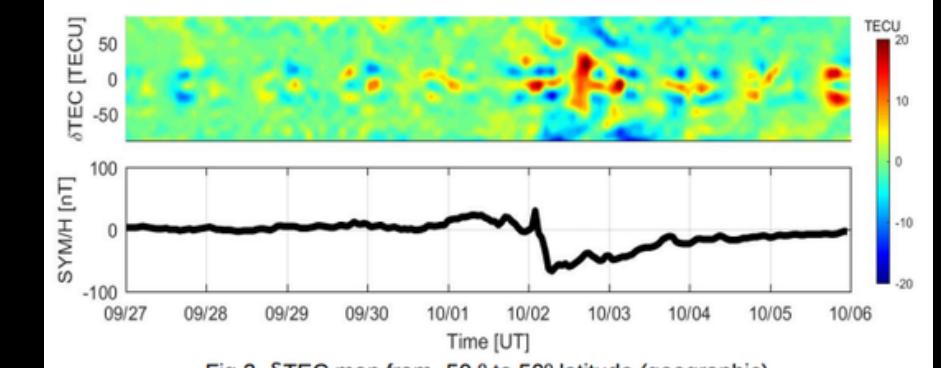
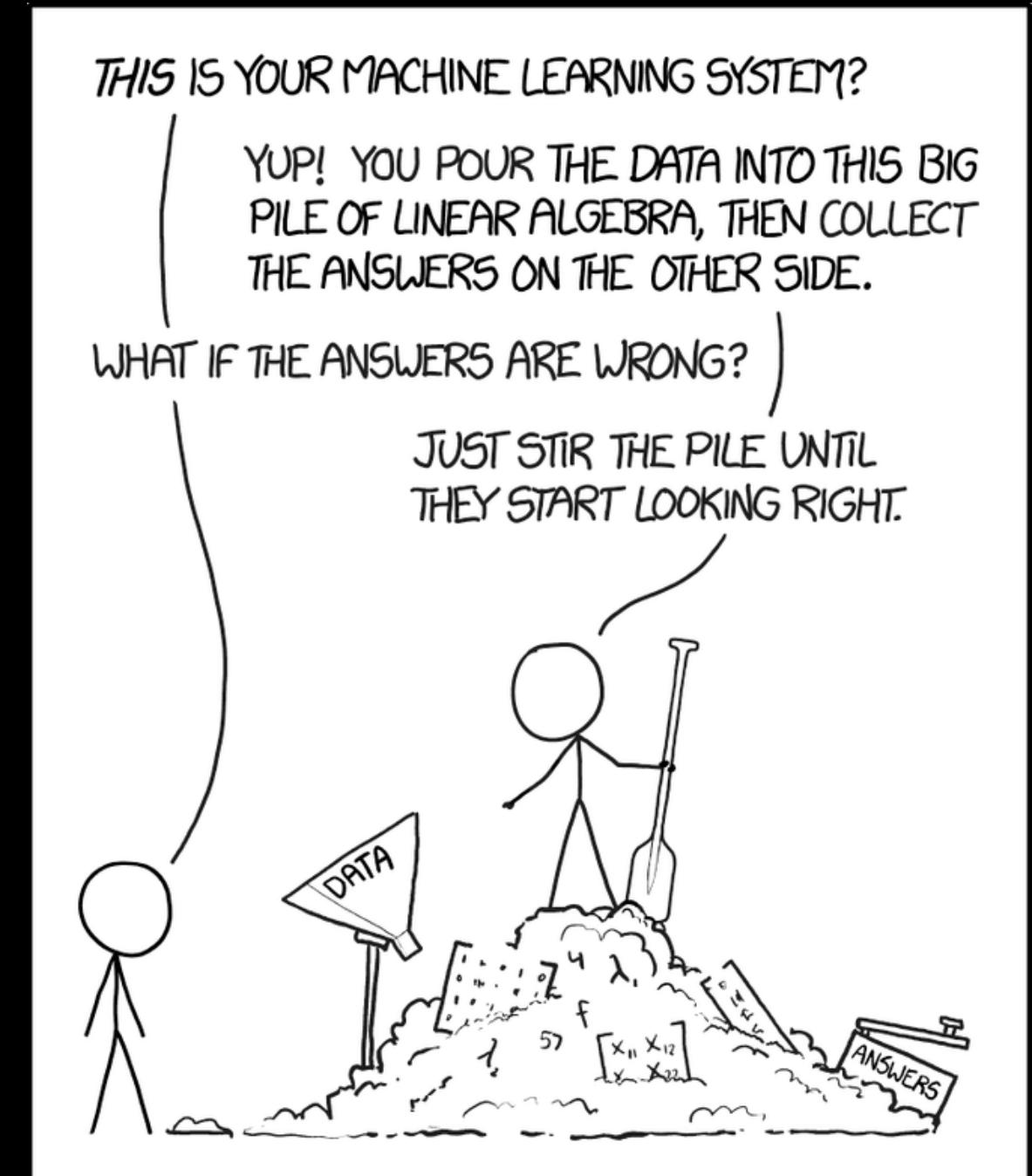


Fig 2. δTEC map from -50° to 50° latitude (geographic)

Space Weather (SWx)

- Heterogenous Data
- Huge amount of data
- Coverage: partially observe a portion of the problem
- Data availability (remote data, military data, etc)
- Data quality: high quality = science; less quality = operations; levels of pre-processing
- Formating madness! resolution madness!
- Not straight-forward to understand
- Produced by instruments, interpreters, simulations or models, metadata
- Storage!
- Complex problems, complex data
- Data infrastructure: data model, a model for data management, hardware
- Intrinsically unbalanced data
- Scales!!!!

The data! just few thing to think about ...



DATA
SCIENCE



TSWC, 2022



Data Science

- Interdisciplinary field
- Extract knowledge from data
- Transform data into knowledge/information
- Aids decision making

DATA

Data Scientist: The Sexiest Job of the 21st Century

by Thomas H. Davenport and D.J. Patil

FROM THE OCTOBER 2012 ISSUE

[SUMMARY](#) [SAVE](#) [SHARE](#) [13 COMMENT](#) [TEXT SIZE](#) [PRINT](#) **\$8.95** BUY COPIES

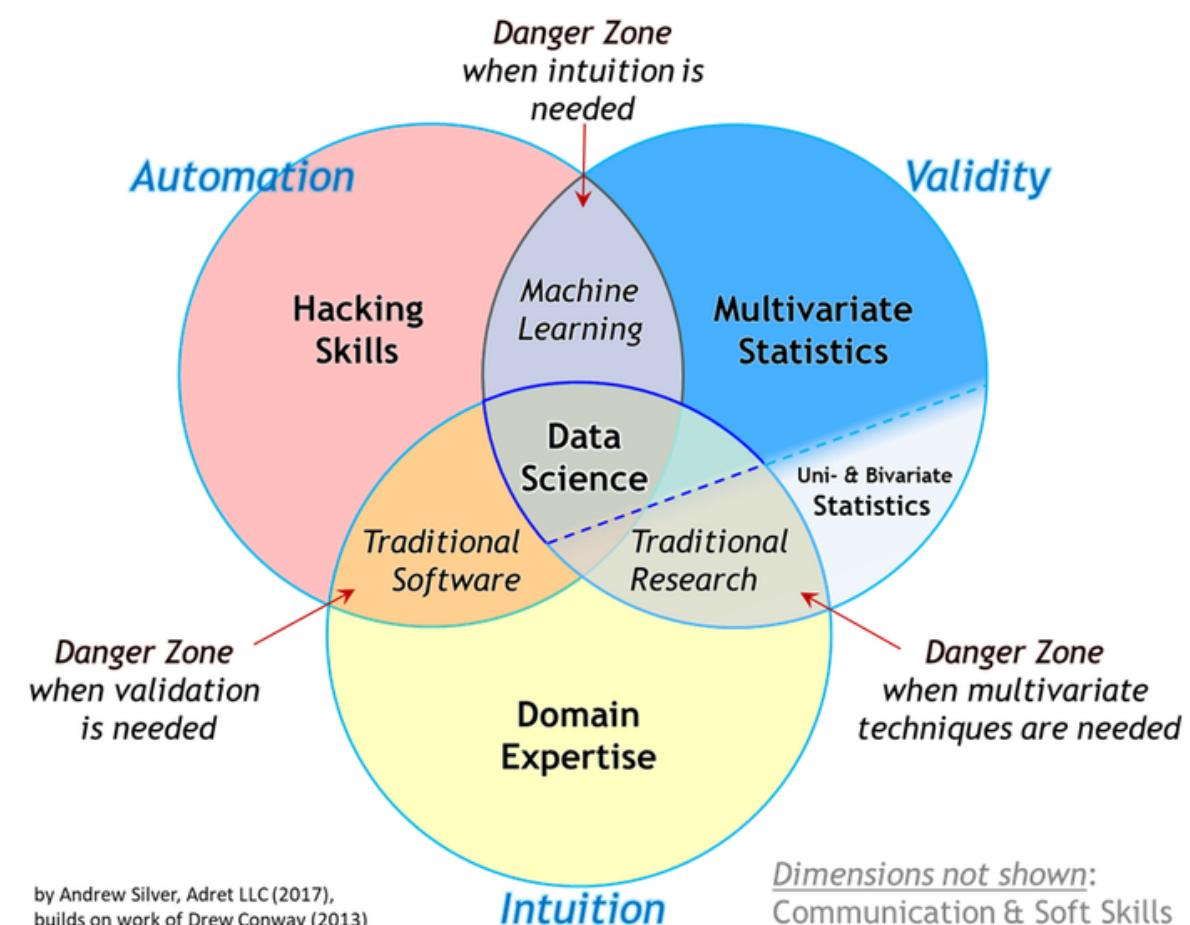
When Jonathan Goldman arrived for work in June 2006 at LinkedIn, the business networking site, the place still felt like a start-up. The company had just under 8 million accounts,

and the number was growing quickly as existing members invited their

1/3 FREE ARTICLES LEFT > REGISTER FOR MORE | SUBSCRIBE + SAVE!

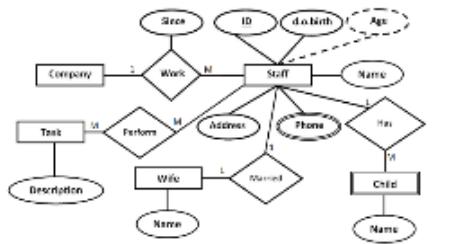


TSWC, 2022



KNOWLEDGE & SKILLS

- Experience (domain)
- Methods (e.g. ML)
- Programming Language + tools + libraries + data formats
- Data access / transformation
- Data storage
- Visualization tools
- Google skills!



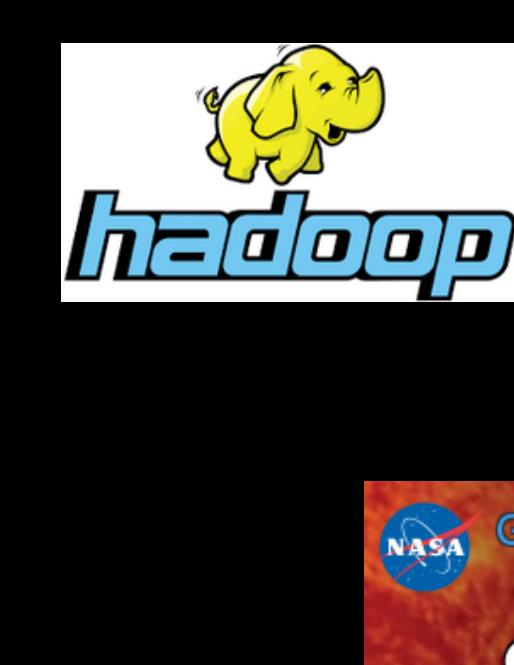
SQL

```
<?xml version="1.0"?>
<qanda seq="1">
<question>
Who was the forty-second president of the U.S.A.?
</question>
<answer>
William Jefferson Clinton
</answer>
<!-- Note: We need to add more questions later.-->
</qanda>
```

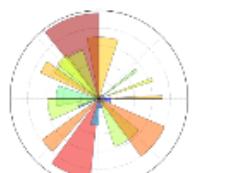
XML



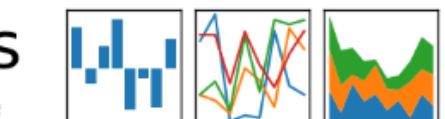
mongoDB®



TensorFlow



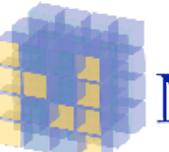
pandas



Refine^{OPEN}



scikit
learn



NumPy



Keras



theano



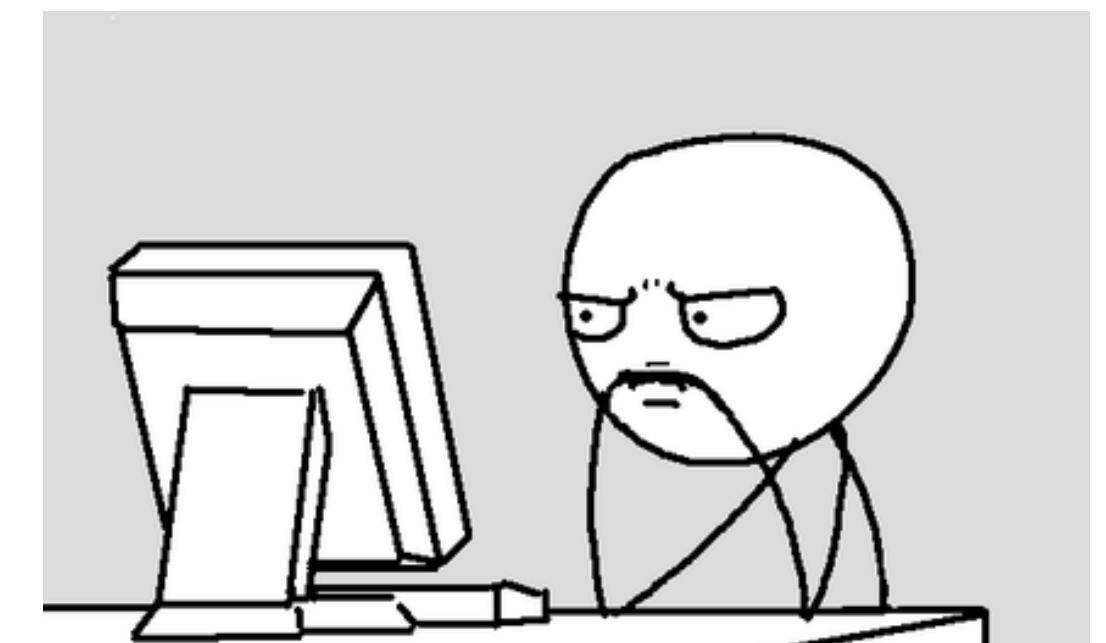
PyMC3

tableau^{OPEN}

Data Science



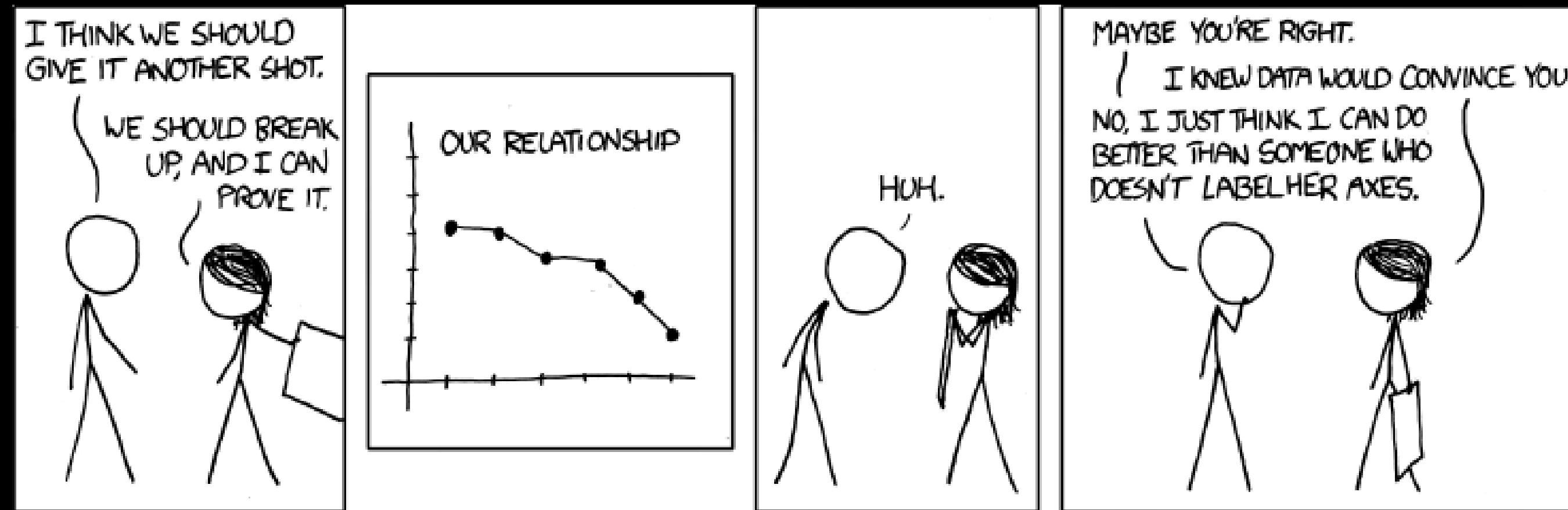
<https://spase-group.org/data/>



TSWC, 2022

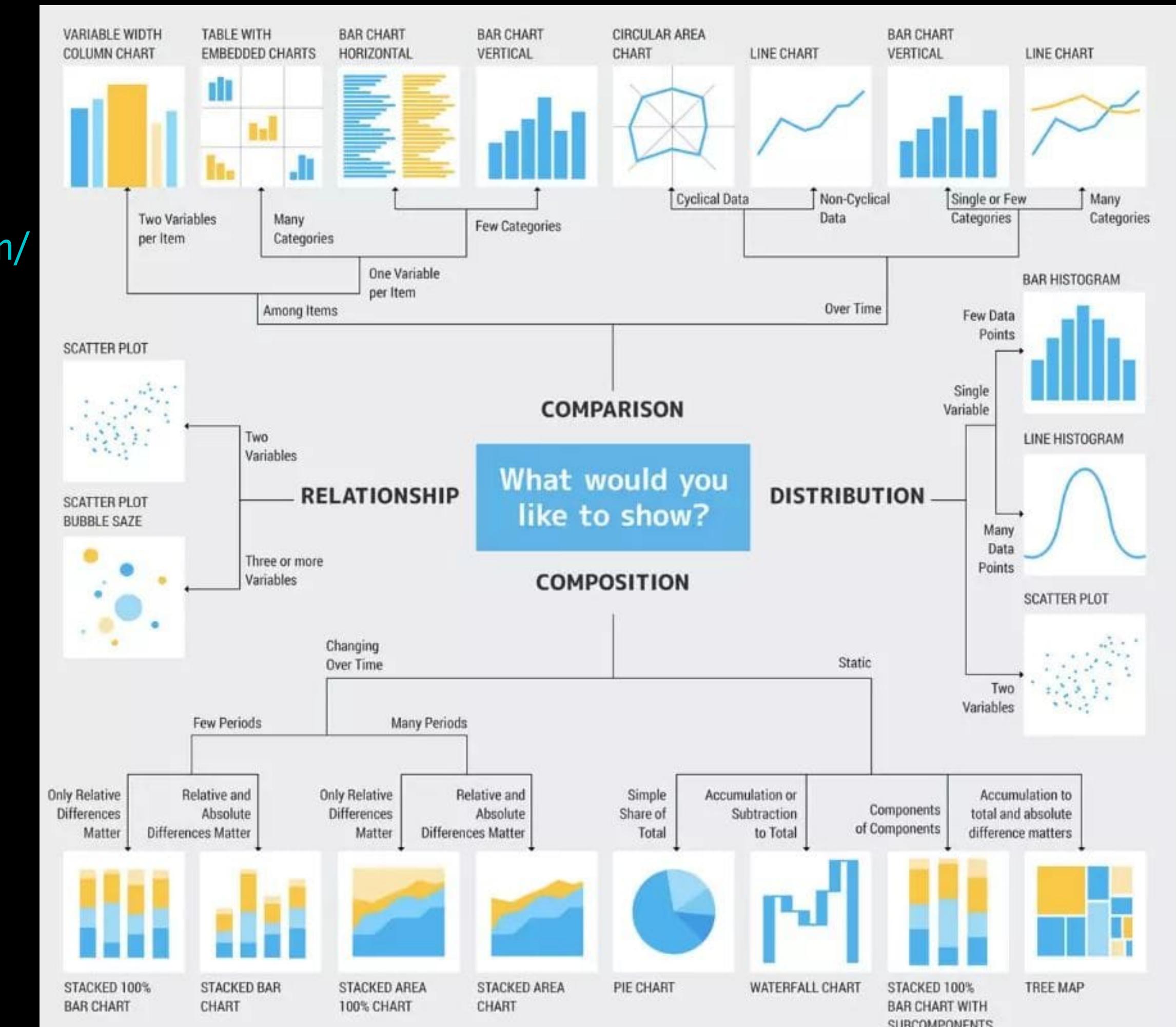
KNOWLEDGE & SKILLS

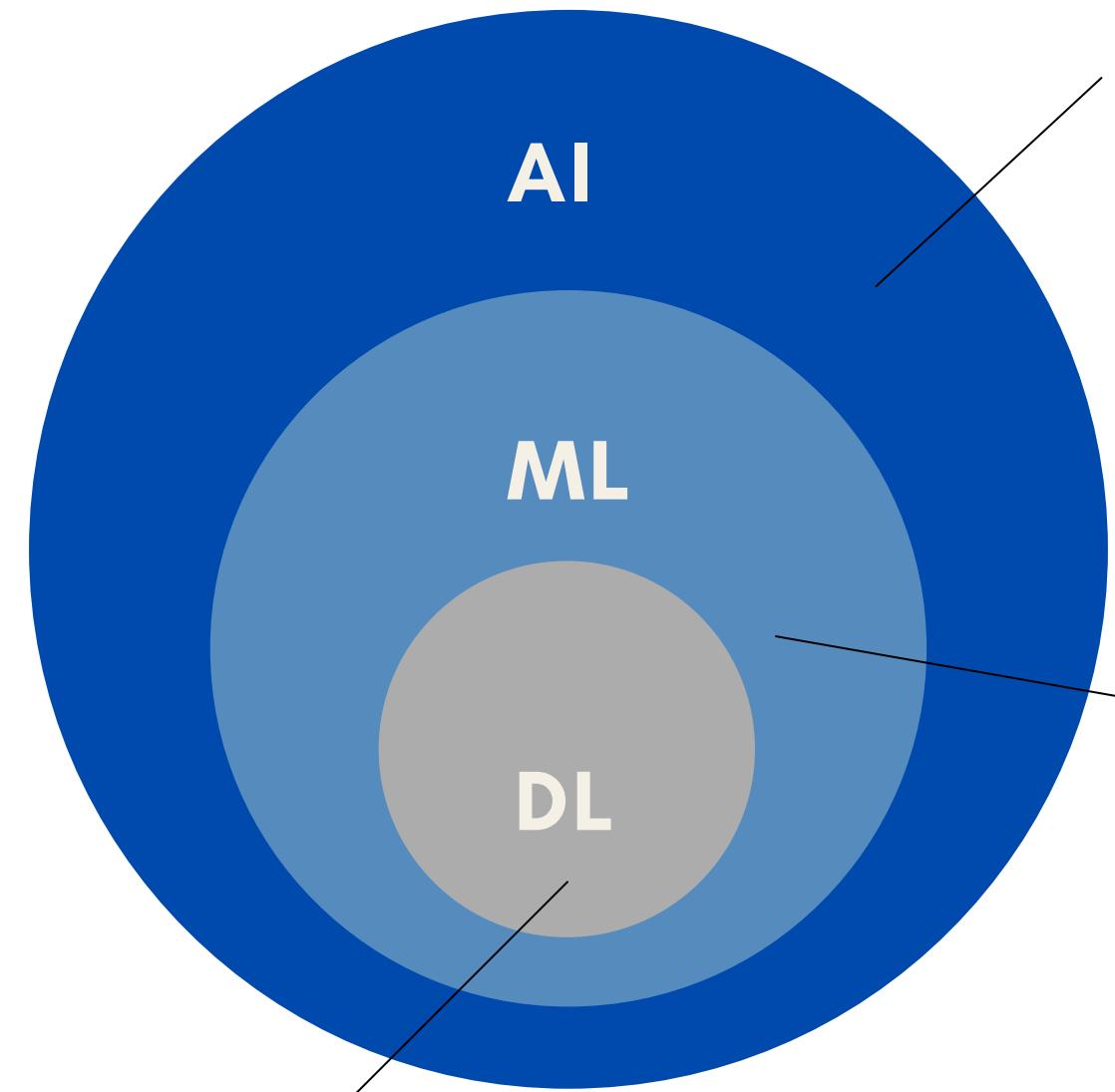
- Visualization tools
- Google skills!
 - <https://www.kaggle.com/>
 - <https://es.stackoverflow.com/>



KNOWLEDGE & SKILLS

- **Visualization tools**
- **Google skills!**
 - <https://www.kaggle.com/>
 - <https://es.stackoverflow.com/>

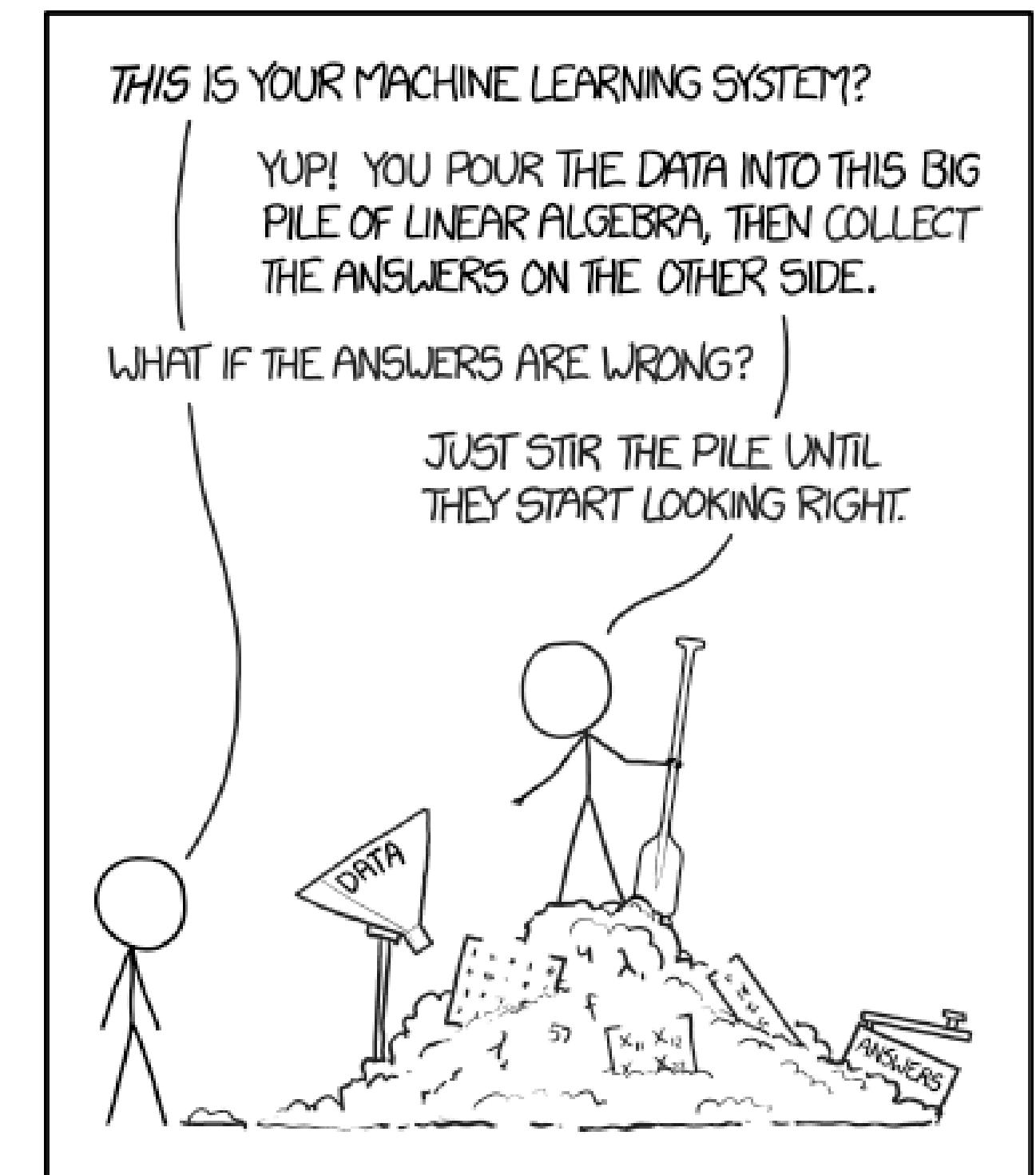




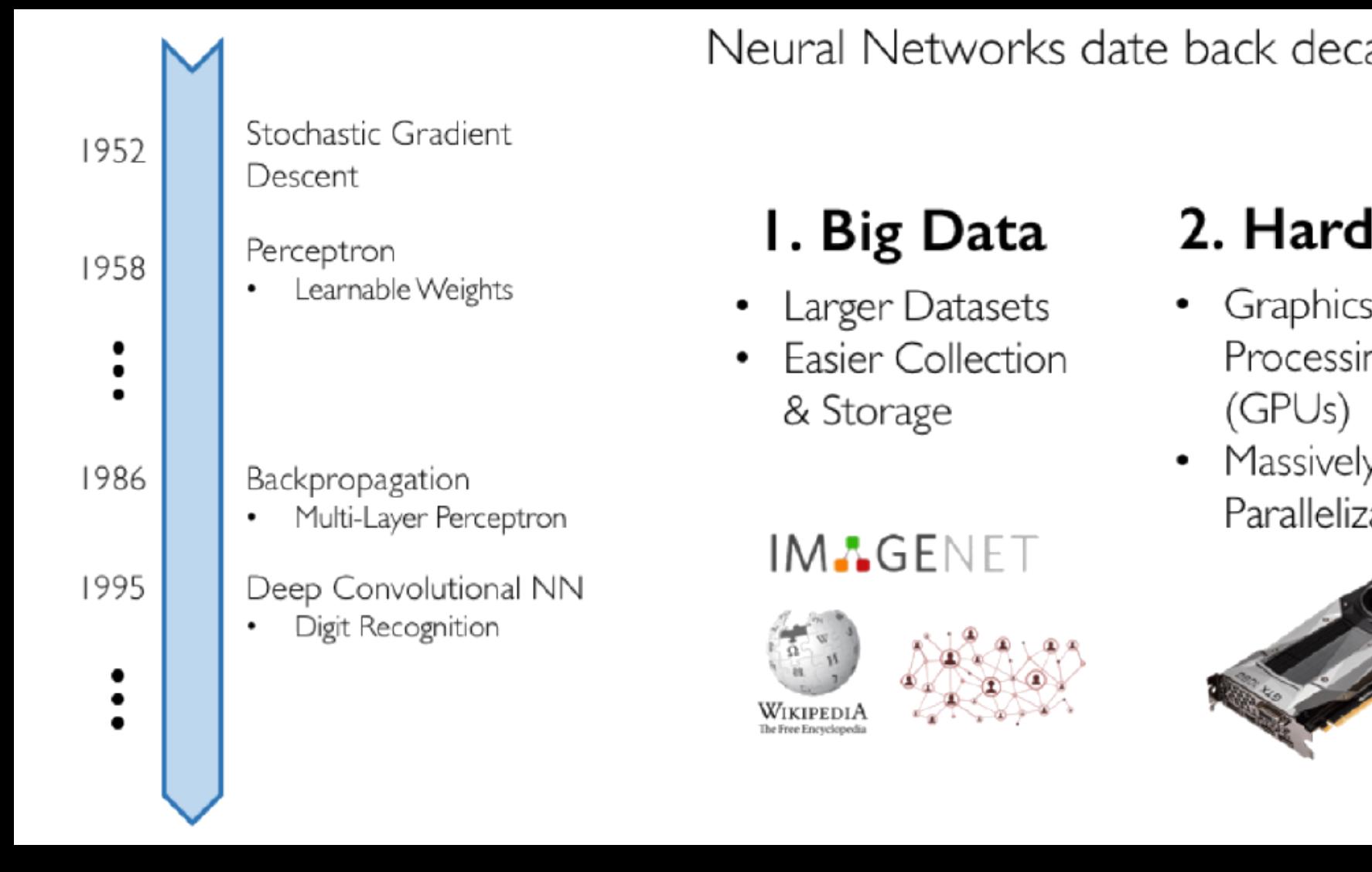
DL = a subset of ML and refers to artificial neural networks that are composed of many layers.

AI = area of computer science that emphasizes the creation of intelligent machines that work and react like humans.

ML = method of data analysis that automates data model building. ML uses algorithms that learn from data and can find insights without explicit programming.



ML (DL) WHY NOW?



Neural Networks date back decades, so why the resurgence?



+ more mature algorithms
+ applications
+ bigger community

DOI: 10.1214/AOMS/1177729586 • Corpus ID: 16945044

A Stochastic Approximation Method

H. Robbins • Published 1 September 1951 • Mathematics • Annals of Mathematical Statistics

Let $M(x)$ denote the expected value at level x of the response to a certain experiment. $M(x)$ is assumed to be a monotone function of x but is unknown to the experiment, and it is desired to find the solution $x=0$ of the equation $M(x) = a$, where x is a given constant. we give a method for making successive experiments at levels x_1, x_2, \dots in such a way that x will tend to 0 in probability.

View via Publisher PDF projecteuclid.org Save to Library Create Alert Cite

Share This Paper

6,527 Citations

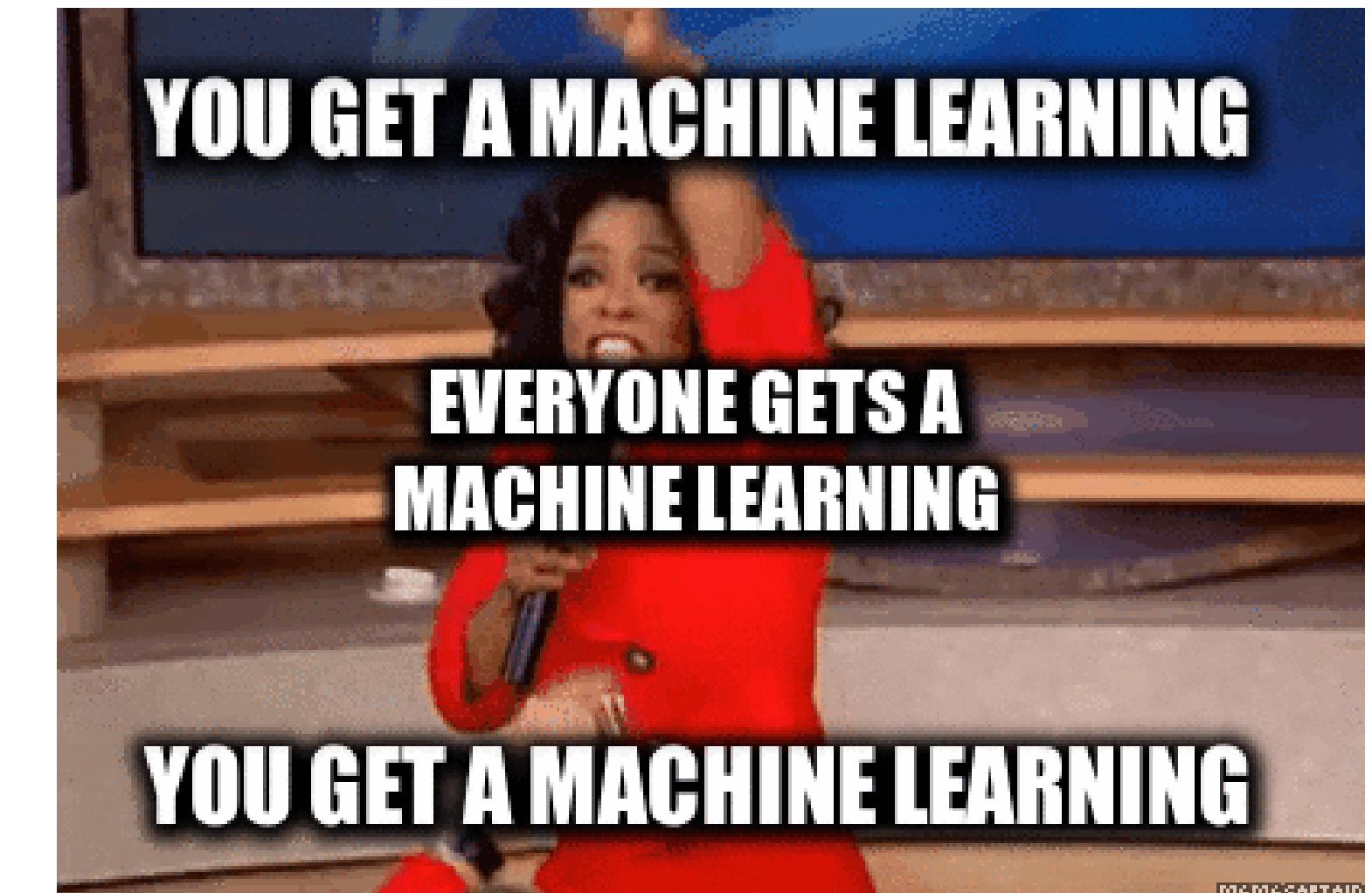
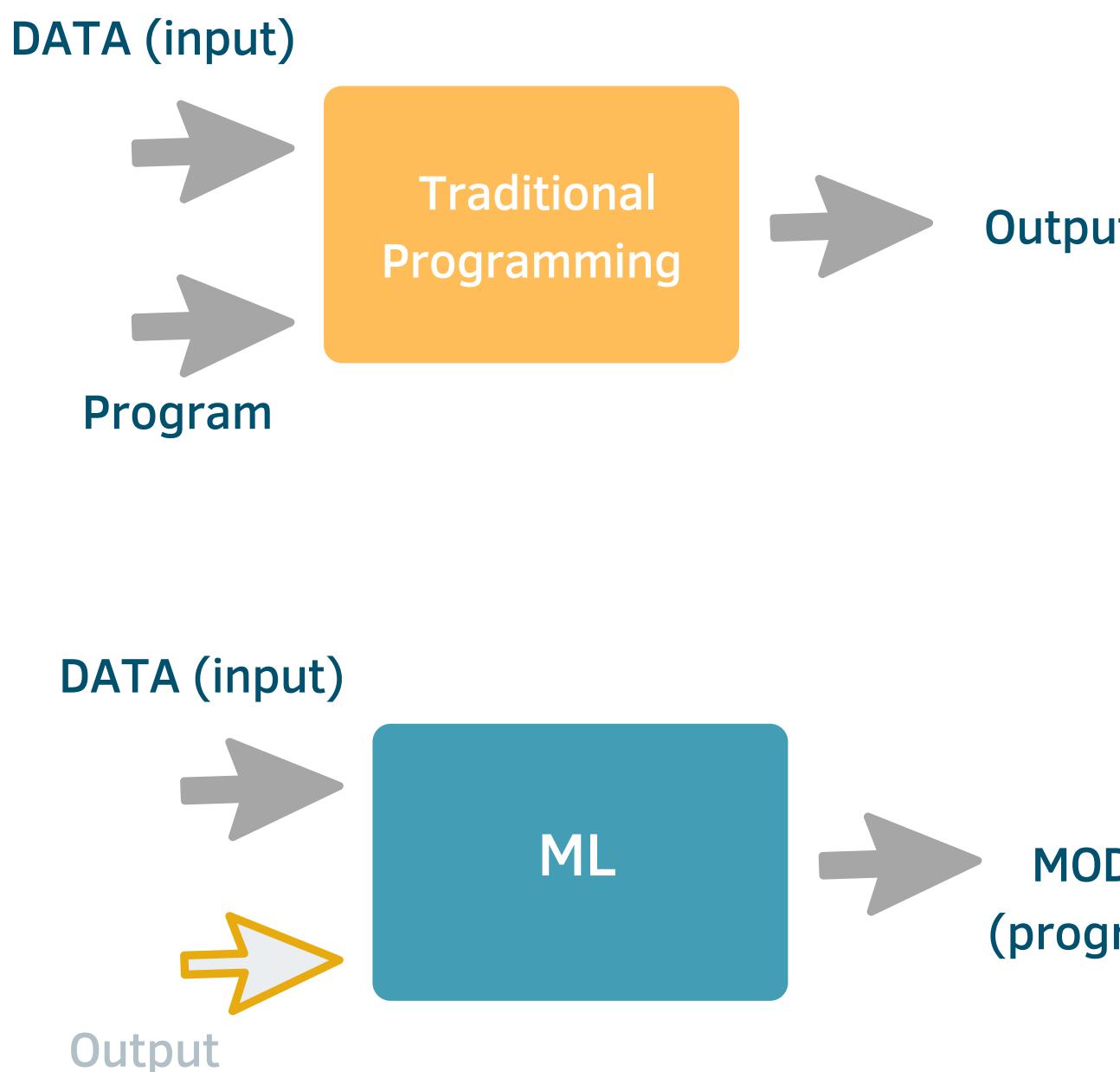
Citation Type	Count
Highly Influential Citations	764
Background Citations	1,848
Methods Citations	2,663
Results Citations	45

[View All](#)



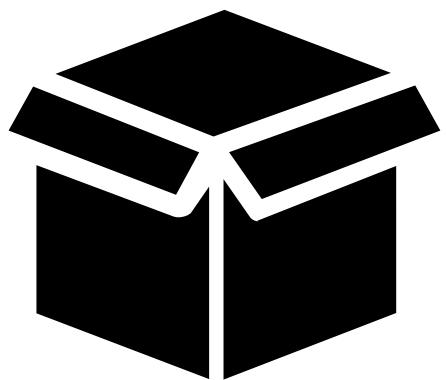
TSWC, 2022

ML (DL) WHY NOW?



Data-driven modeling

data
+
hyperparameters



model (parameters)



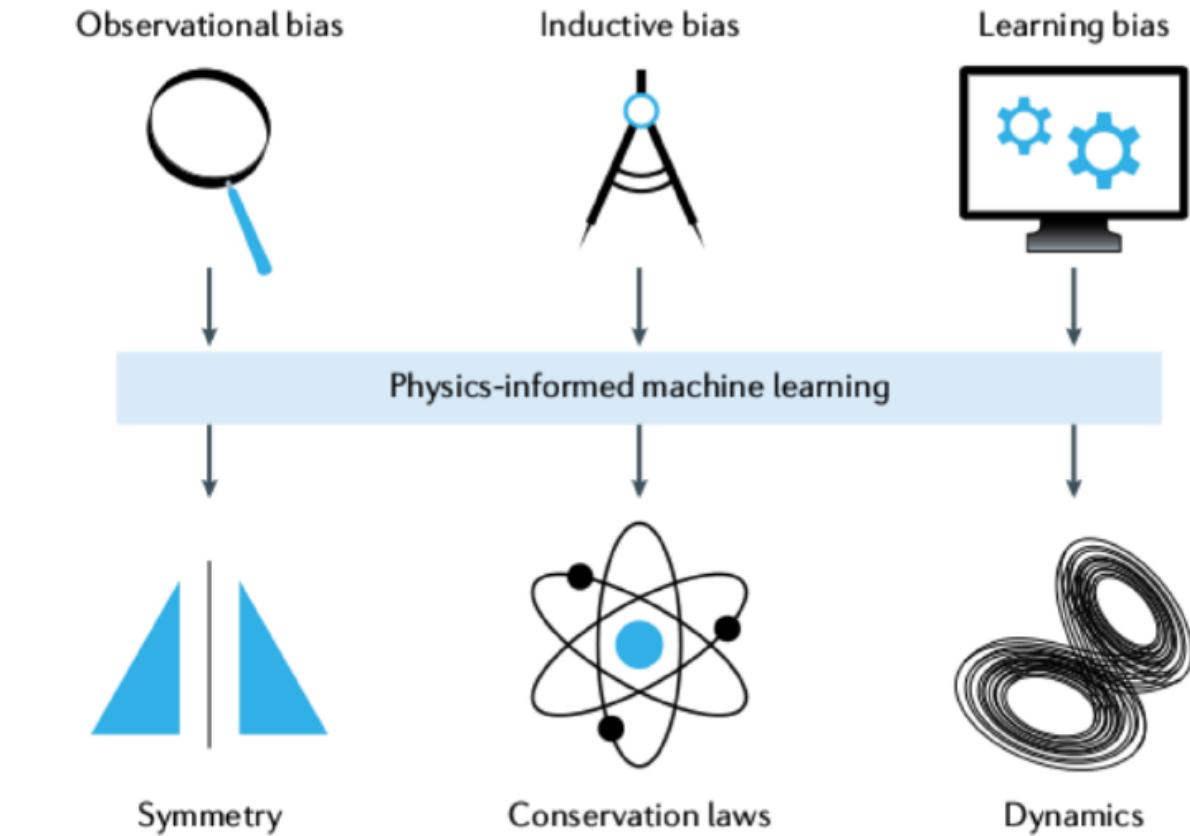
TSWC, 2022

data
+
hyperparameters
+
physics/constraints/do
main knowledge



model
(parameters)

- Physical consistency (definitions, conservation laws...)
- Ability to generalize outside of the training set
- Interpretability
- Stability
- Data limitations



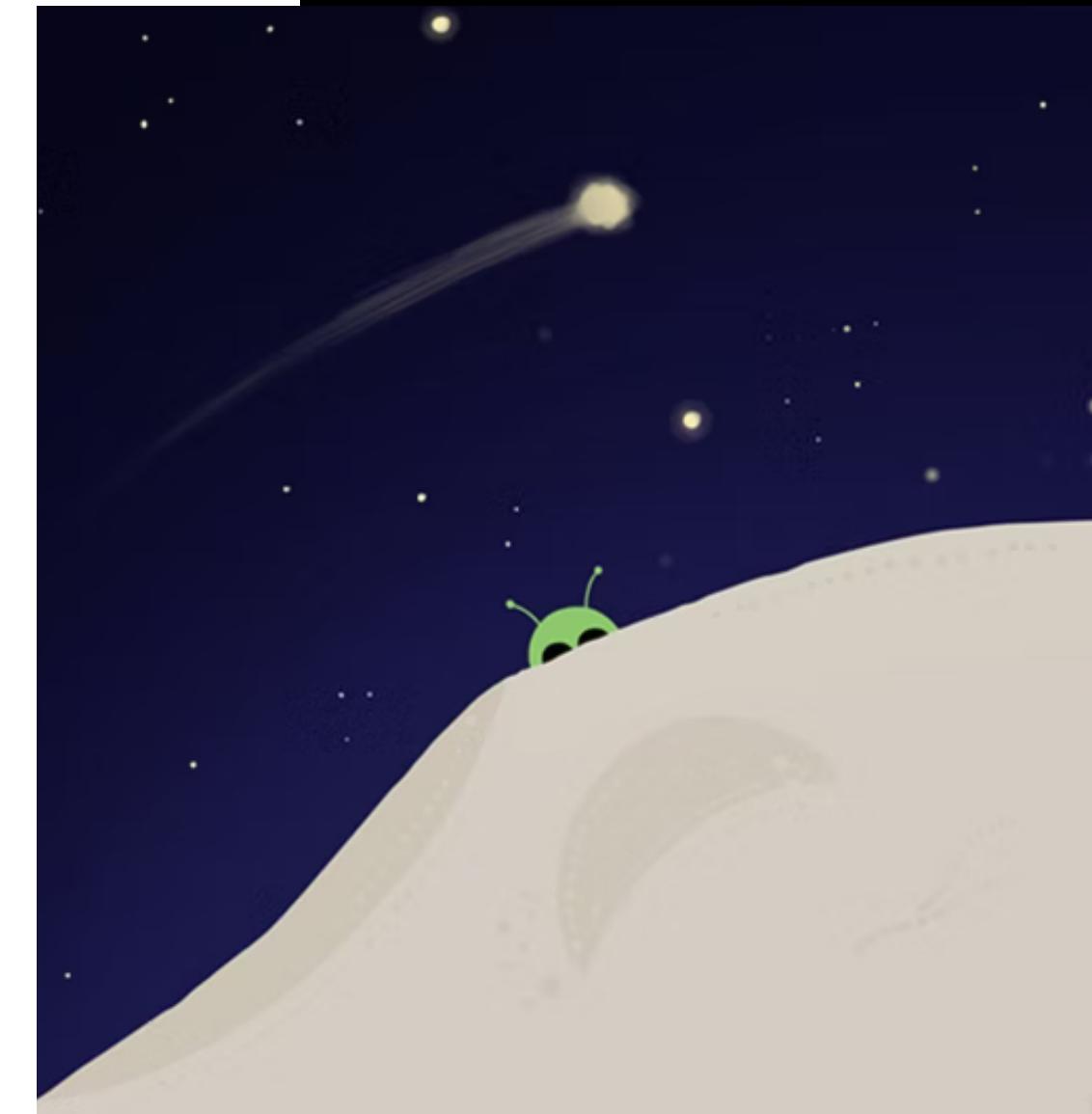
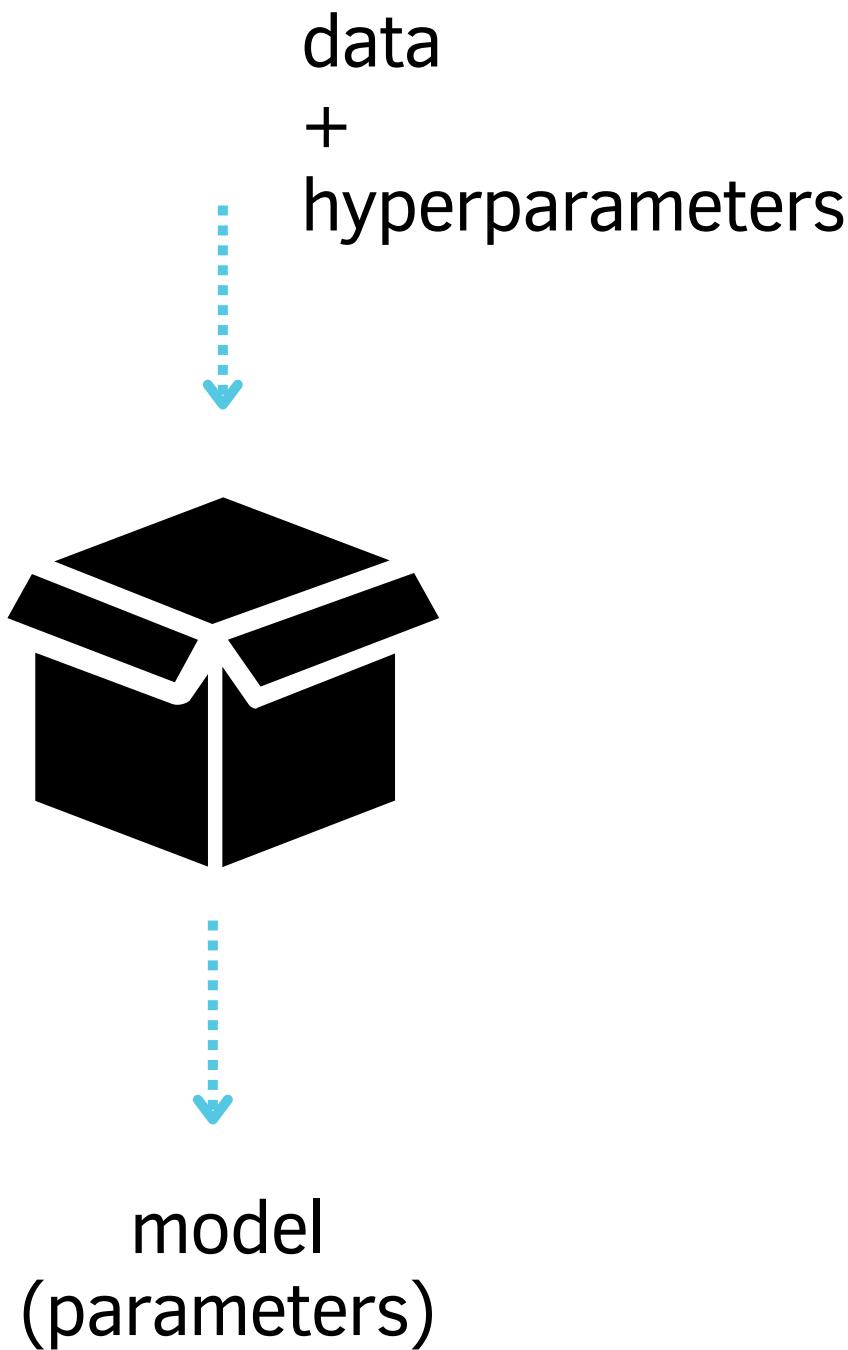
goal = enhance generalization

Physics-informed learning = process by which prior knowledge stemming from our observational, empirical, physical or mathematical understanding of the world can be leveraged to improve the performance of a learning algorithm

Karniadakis et al. Physics-informed
machine learning. Nat Rev Phys (2021).

Data-driven modeling

- Should we give a chance to the black box?



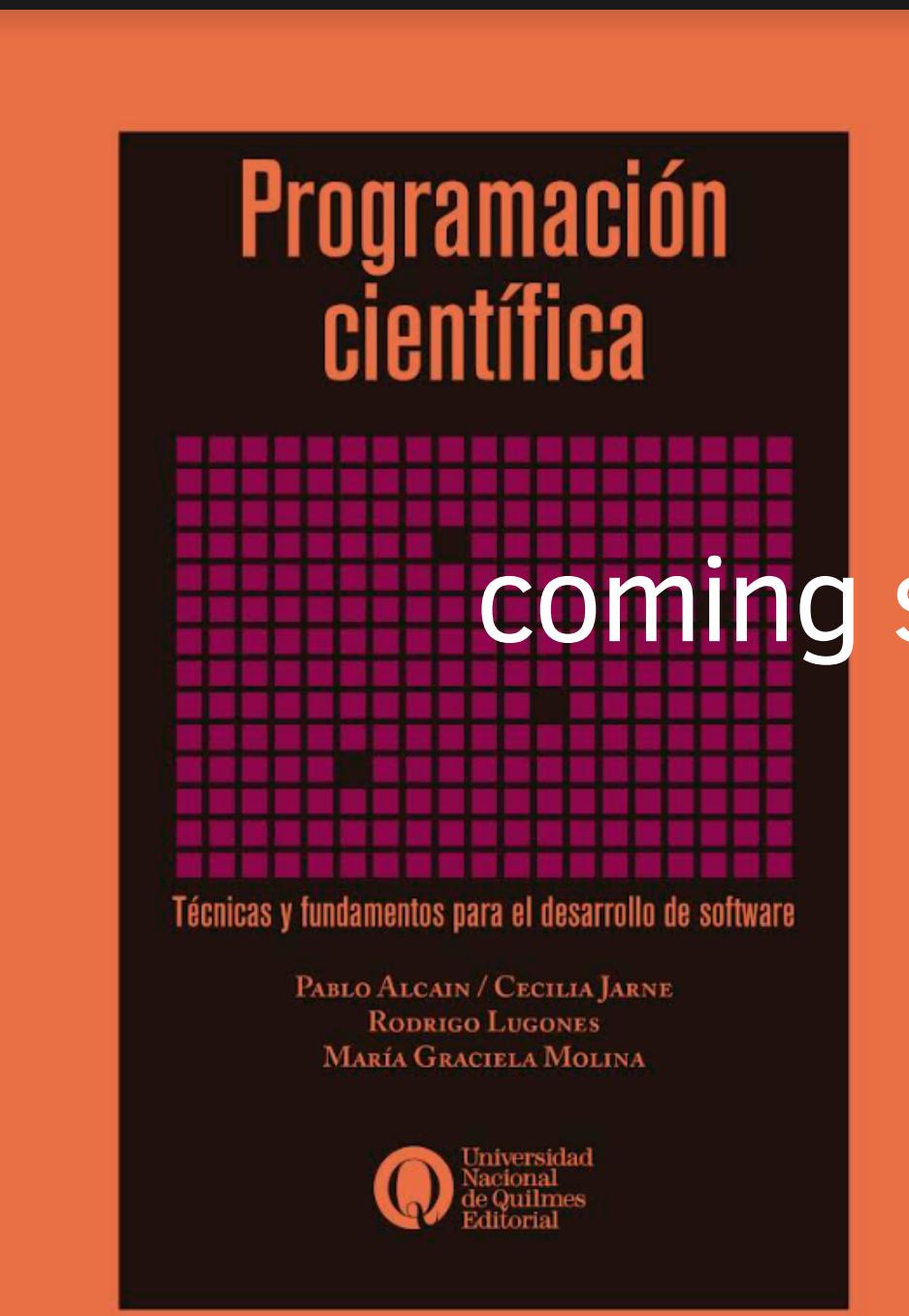
TSWC, 2022

TSWC, 2022

Scientific programming

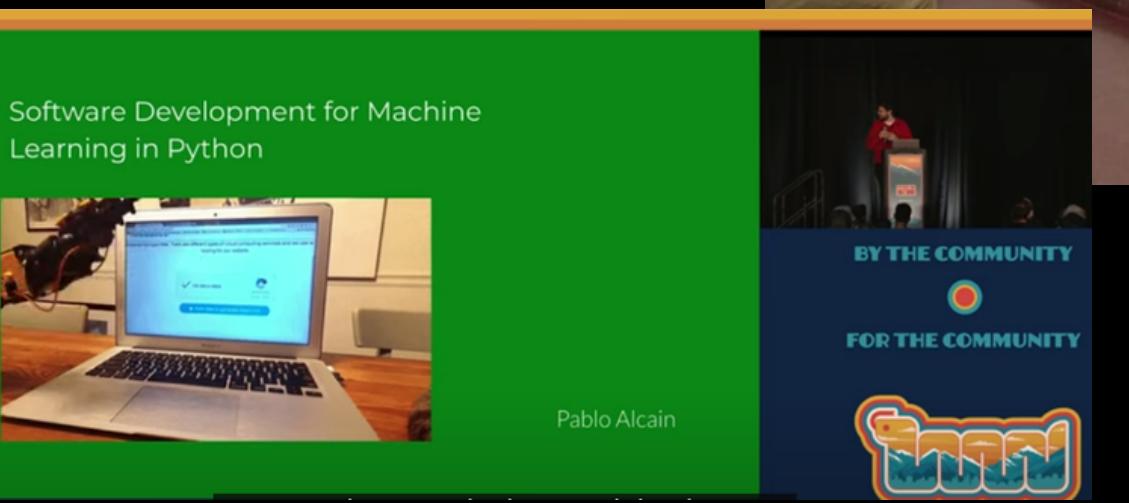
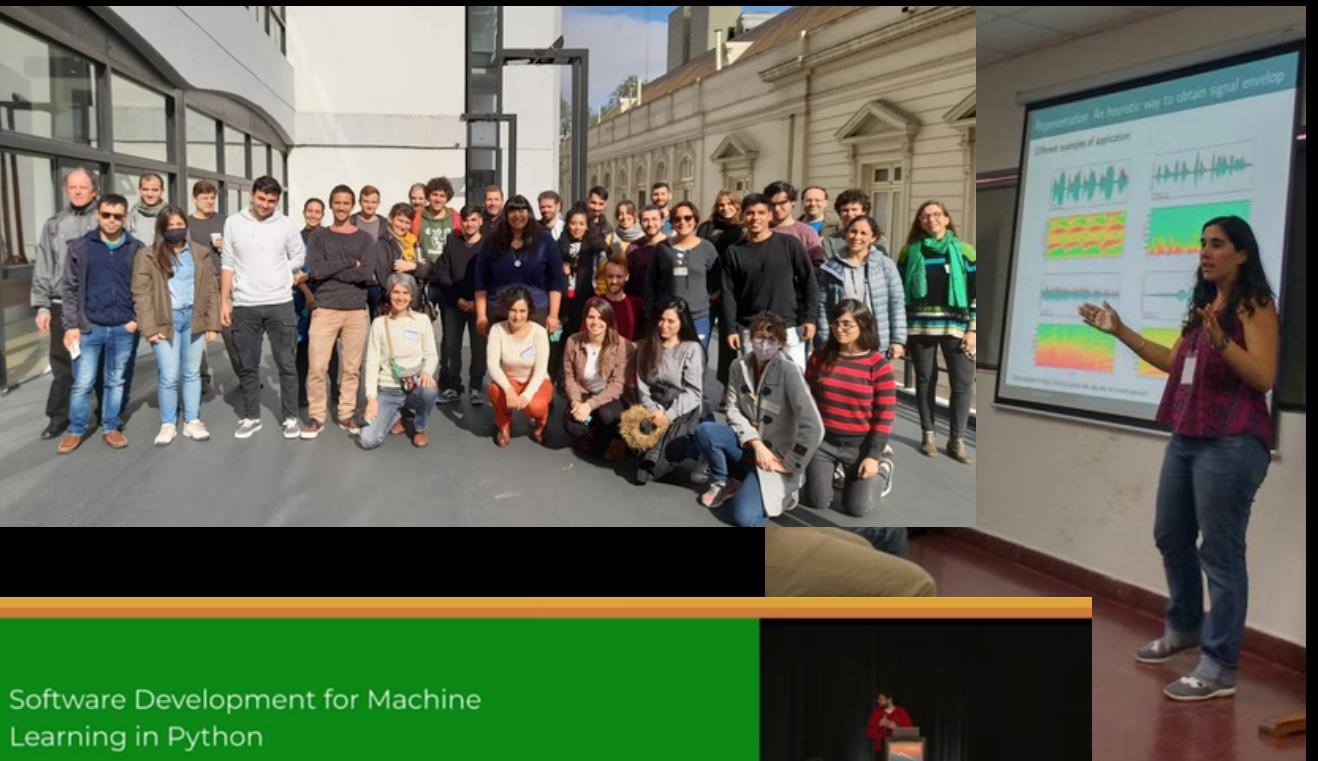
WTPC

WORKSHOP EN TÉCNICAS DE
PROGRAMACIÓN
CIENTÍFICA



coming soon!

<https://wtpc.github.io/>



Python ?)

Programming Language Hall of Fame

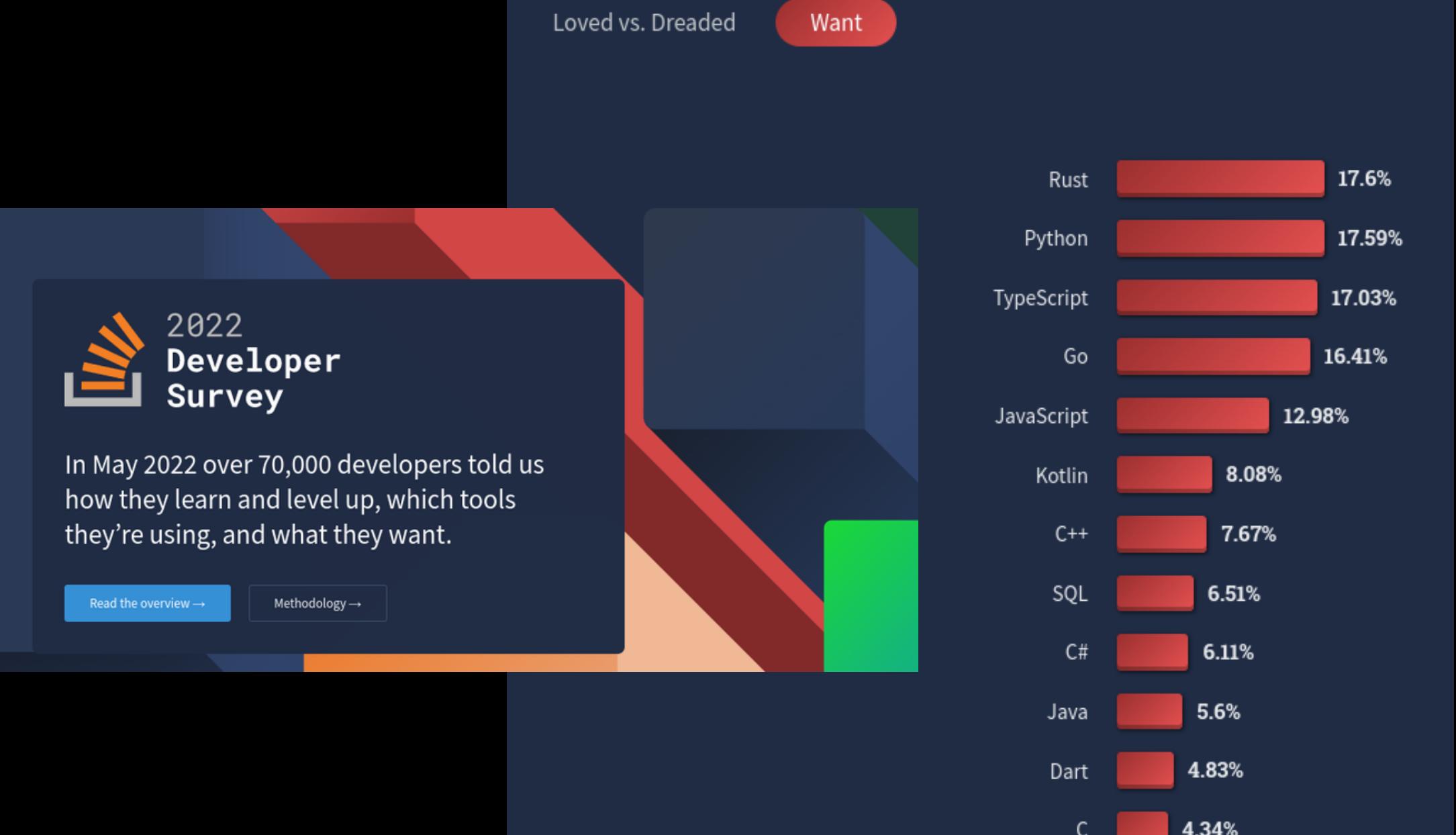
Year	Winner
2021	⭐ Python
2020	⭐ Python
2019	⭐ C
2018	⭐ Python
2017	⭐ C
2016	⭐ Go
2015	⭐ Java
2014	⭐ JavaScript
2013	⭐ Transact-SQL
2012	⭐ Objective-C
2011	⭐ Objective-C
2010	⭐ Python

<https://www.tiobe.com/tiobe-index/>
(July 2022)

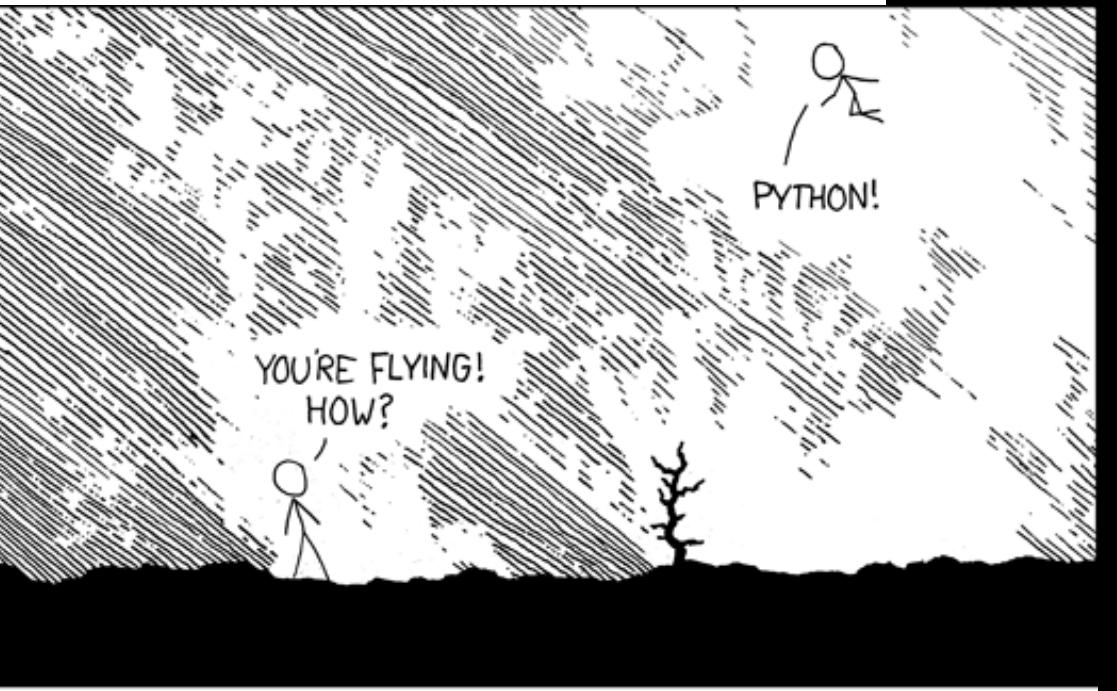
Programming, scripting, and markup languages

Rust is on its seventh year as the most loved language with 87% of developers saying they want to continue using it.

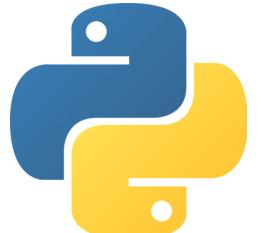
Rust also ties with Python as the most wanted technology with TypeScript running a close second.



TSWC, 2022



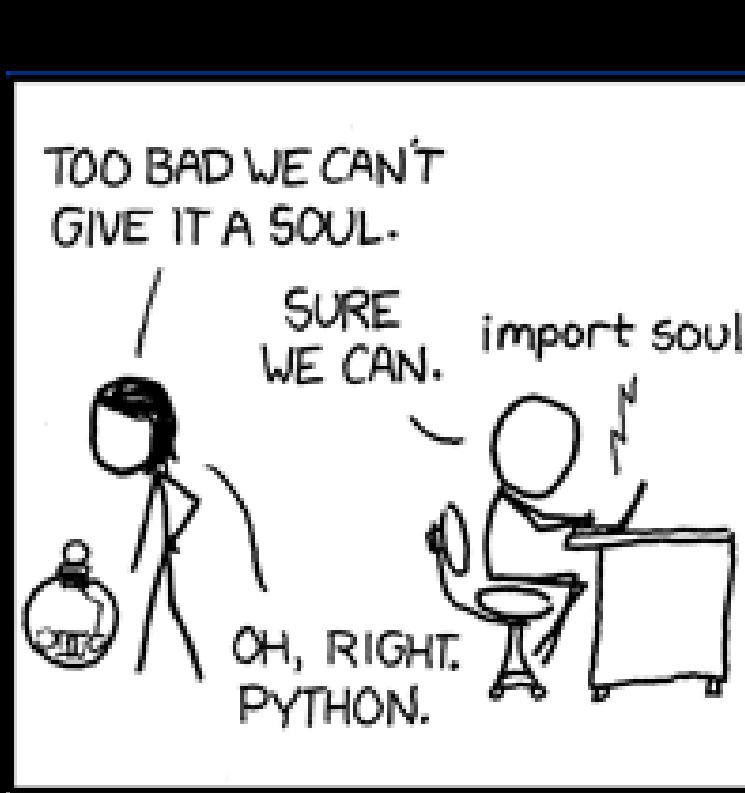
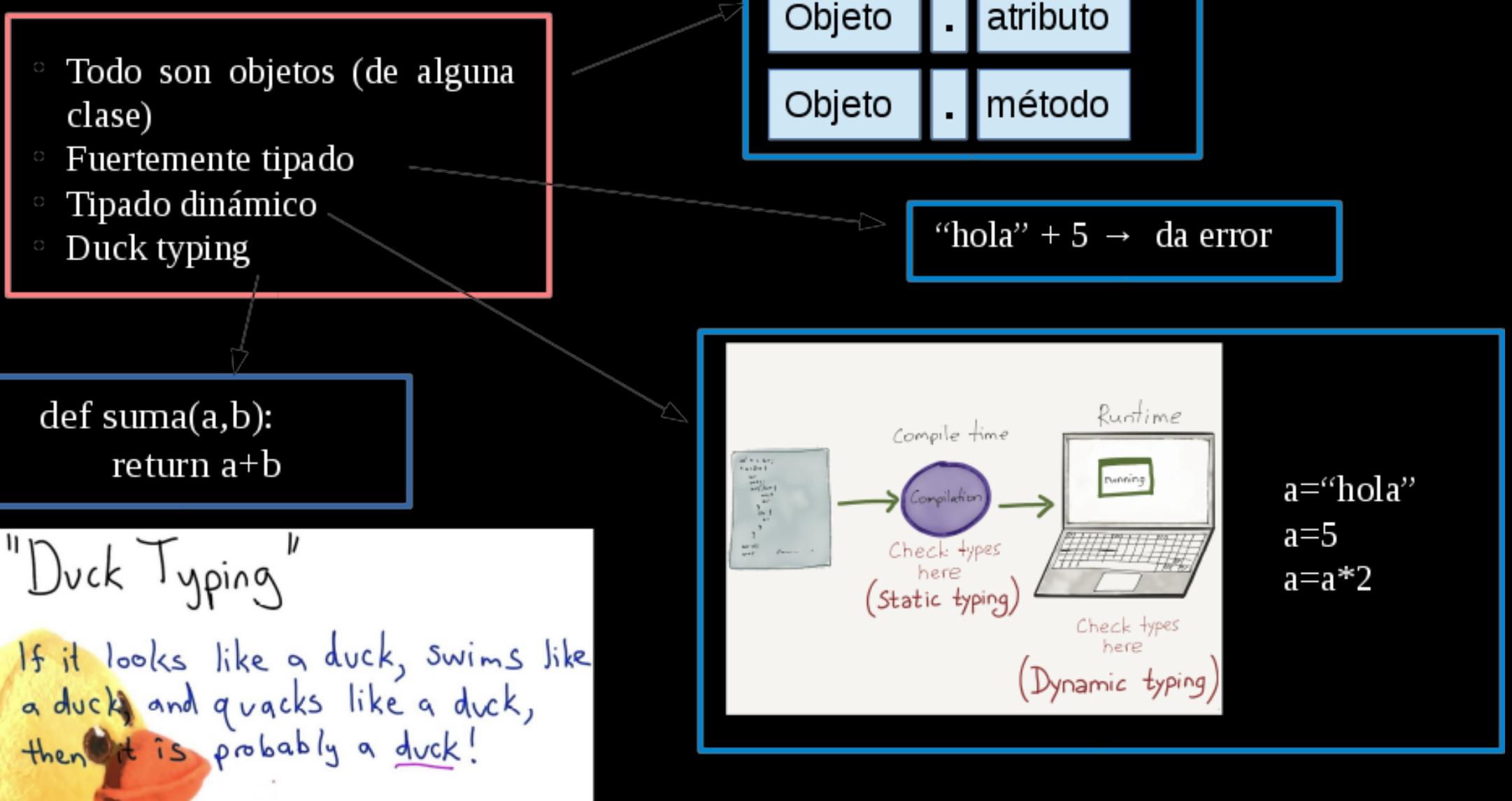
Python



NumPy

pandas

Espacios de nombres (namespaces) y Módulos



TSWC, 2022

HANDS-ON LAB

TP - 0

- Google Colabs - Jupyter Notebooks
- Codes & Data access
- Python refresh (numpy + Pandas)
- sklearn - Playing with a dataset (splitting and modeling)



TSWC, 2022

```
31 self.file = None
32 self.fingerprints = {}
33 self.logopen = True
34 self.debug = False
35 self.logger = logging.getLogger('fingerprint')
36 if path:
37     self.file = open(path, 'w')
38 self.file.write('')
39 self.fingerprints = {}
40
41 @classmethod
42 def tree_settingscls(settings):
43     debug = settings.getboolean('logger.debug')
44     return cls(debug=settings.debug)
45
46 def request_genuine(self, request):
47     fp = self.request_fingerprint(request)
48     if fp in self.fingerprints:
49         return True
50     self.fingerprints[fp] = []
51     if self.file:
52         self.file.write(fp + '\n')
53
54 def request_fingerprint(self, request):
55     return self.request_genuine(request)
```

International Workshop on Machine Learning for Space Weather: Fundamentals, Tools and Future Prospects

7-11 November 2022
This is a hybrid meeting
Buenos Aires, Argentina



Further information:

<https://indico.ictp.it/event/9840/>

smr3750@ictp.it

+39-040-2240284

Elizabeth Brancaccio

Dra María Graciela Molina
FACET-UNT / CONICET
Tucumán Space Weather Center - TSWC

<https://spaceweather.facet.unt.edu.ar/>
IG -> @spaceweatherargentina

gmolina@herrera.unt.edu.ar

