OcéanIA
AI, Oceans and Climate Change

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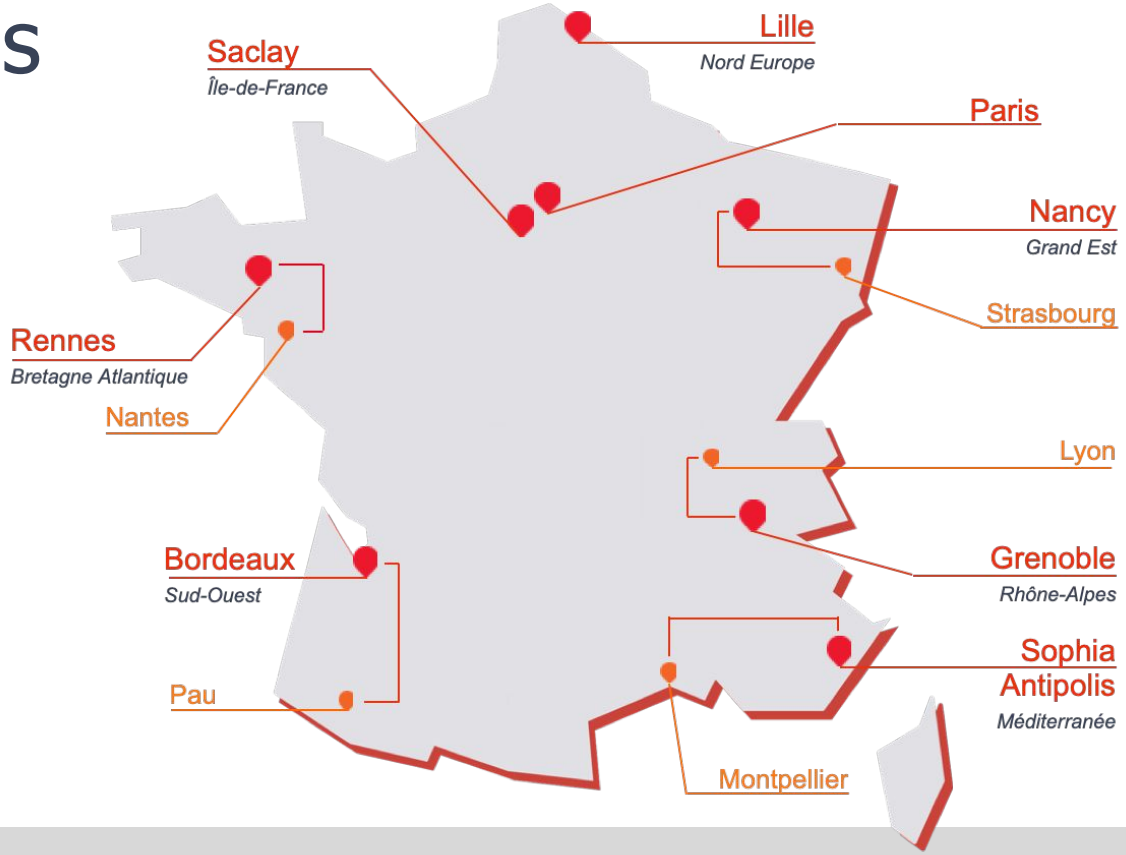
NEURAL INFORMATION PROCESSING SYSTEMS

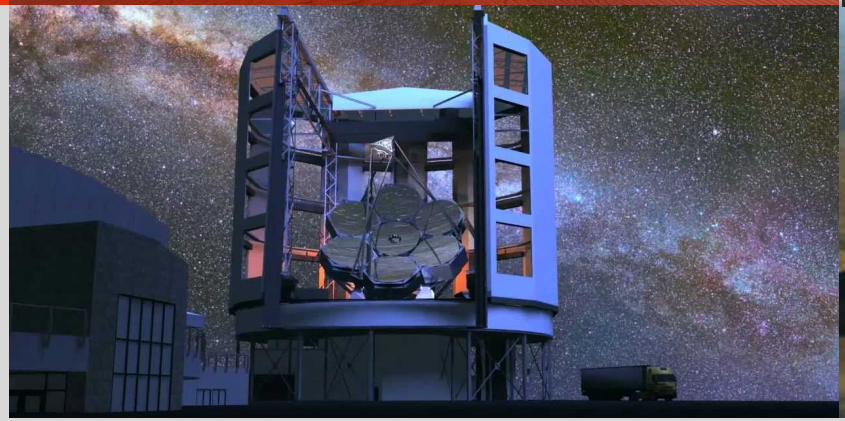
LXAI

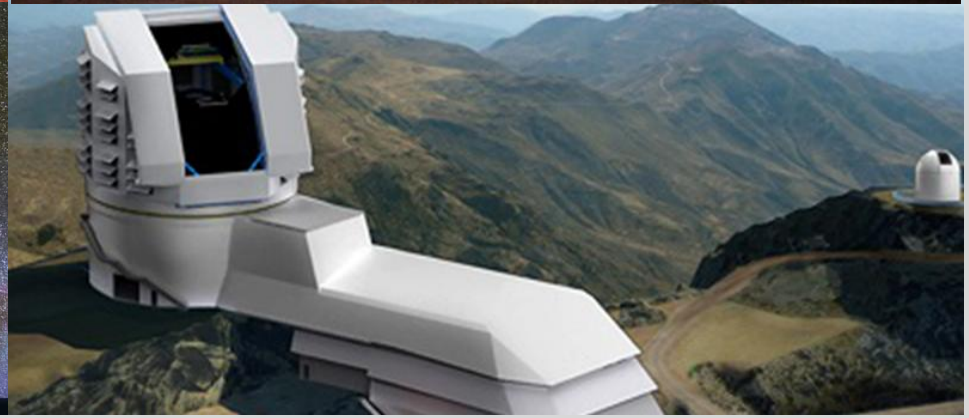
December 7th, 2020

Inria Centres



Diversity in Natural Resources: Atacama desert

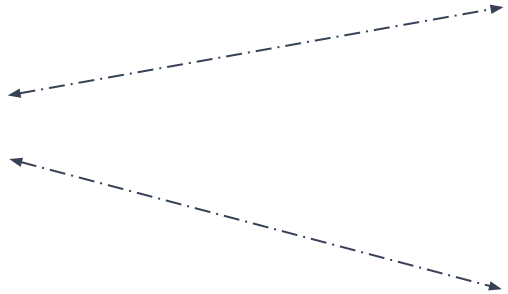




Diversity in Natural Resources: Antarctica

Challenging enough to AI/ML

AI/ML



- ➔ Small, big and/or high dimensional data
- ➔ Transfer learning
- ➔ Causal Learning
- ➔ Active Learning
- ➔ Explainable AI

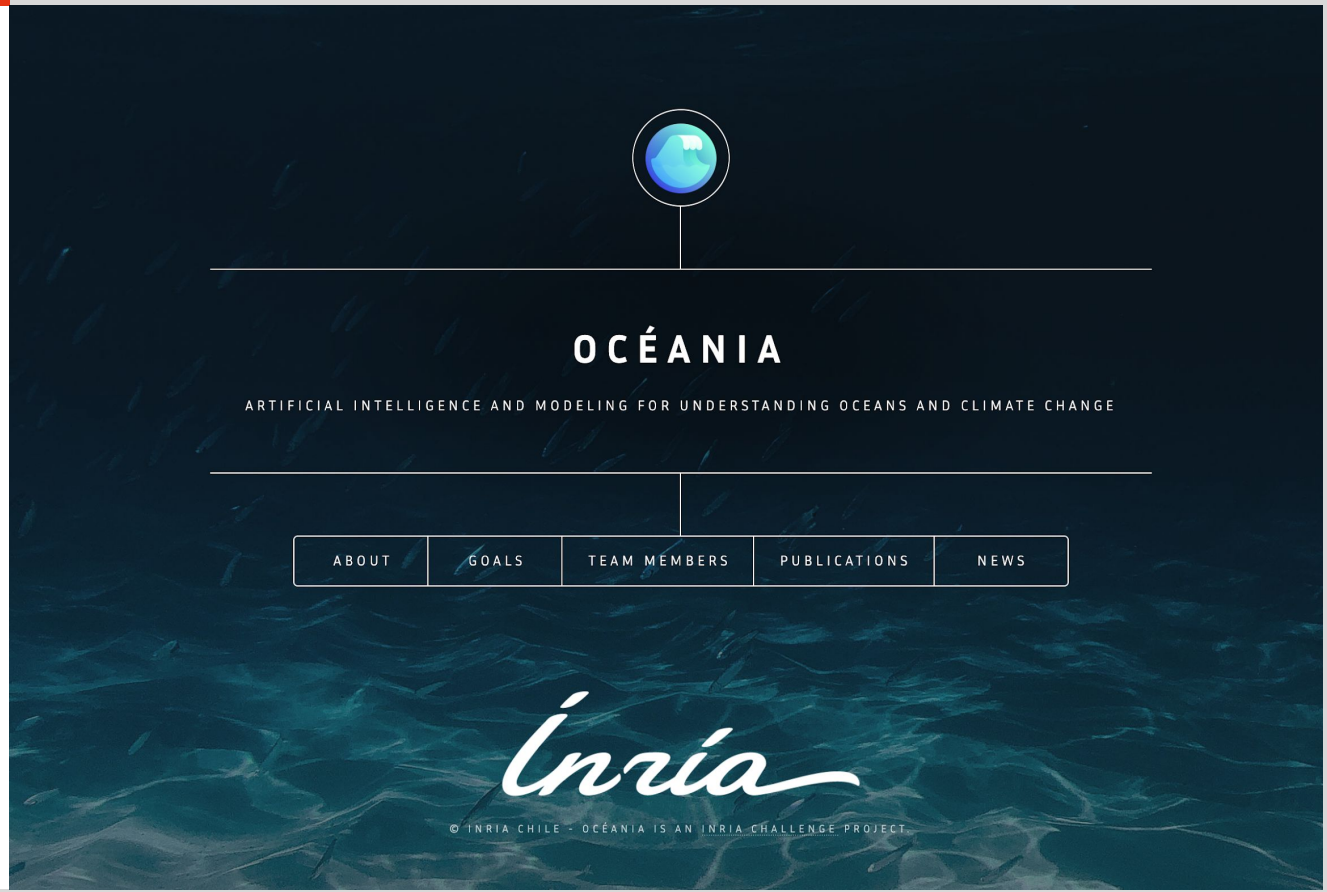
- ➔ Inherent complex context
- ➔ Convergence of physical and life sciences through Big and Data

Inria Challenge

OcéanIA:

Artificial Intelligence and Modelling for Understanding Climate Change

https://oceania.inria.cl/



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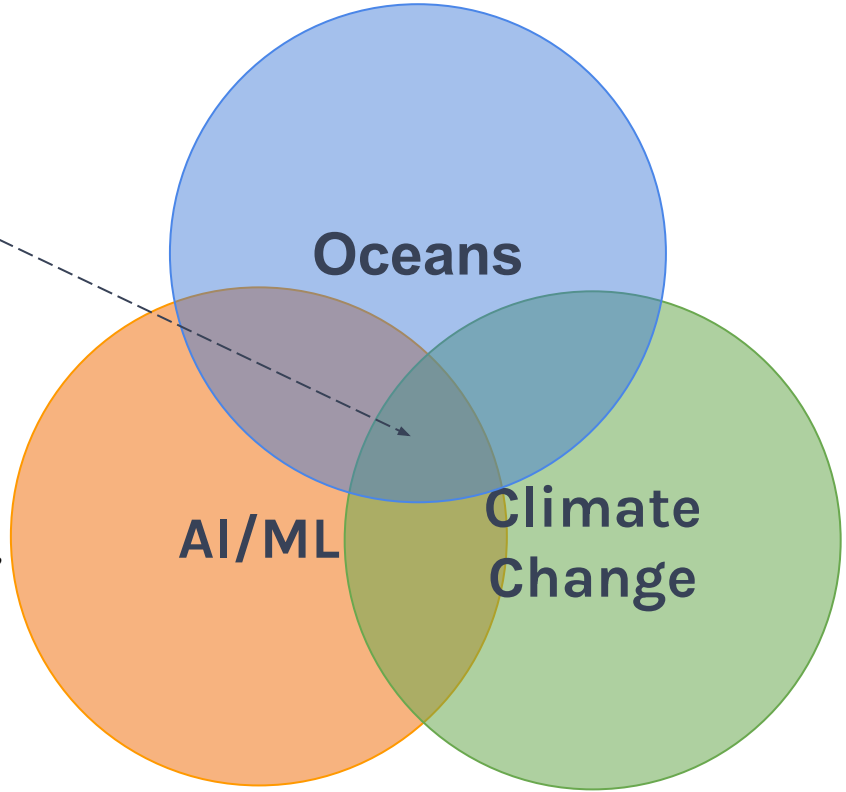


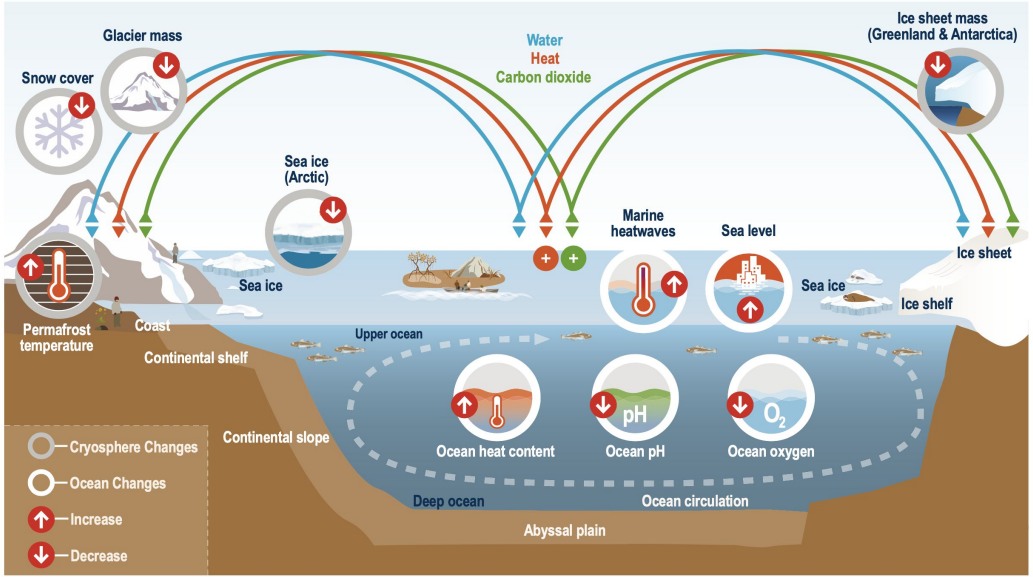
ENVIRONMENT

Nature has provided a lot of inspiration for the AI/ML area:

- ↳ neural networks,
- ↳ learning theories,
- ↳ evolutionary computing, etc.

It is about time that we return the favor!

Climate Change and the Ocean



Source: H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, E. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.- O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.).

Environment

- **TARA ARCTIC (2006-2008) :** First Arctic drift since Nansen (1893)
- **TARA OCEANS (2009-2013) :** First global study of the planktonic ecosystem
- **TARA MEDITERRANEAN (2014) :** Study of the impact of plastic on the marine ecosystem in the Mediterranean
- **TARA PACIFIC (2016-2018) :** Study of the adaptive capacity of coral reefs to climate change
- **MICROPLASTICS (2019) :** First study of river sources of microplastics on a European scale

11 missions including 5 major expeditions
100,000 microscopic marine species discovered
Over 150 million marine genes discovered
Almost 200,000 viruses characterized
Over 150,000 samples collected

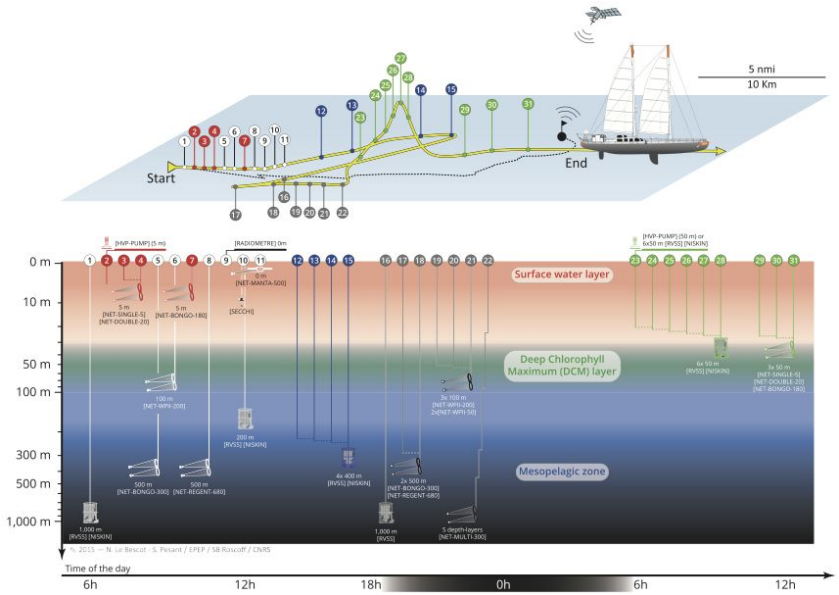
TARA OCEANS

Expedition
Feb - May 2021

Mission Microbiome
-CEODOS

Understand the ocean environment, climate change, its impact and mitigation.

Why Tara?



Source: Pesant, S., Not, F., Picheral, M., Kandels-Lewis, S., Le Bescot, N., Gorsky, G., Iudicone, D., Karsenti, E., Speich, S., Trouble, R., Dimier, C., & Searson, S. (2015). Open science resources for the discovery and analysis of Tara Oceans data. *Scientific Data*, 2(Lmd), 1–16. https://doi.org/10.1038/sdata.2015.23

Schooner Tara:

- ↳ >40,000 plankton samples collected
- ↳ 210 sampling stations at three depths
- ↳ >60 terabases of DNA and RNA sequenced
- ↳ ~7 million images captured

➜ Tara Oceans adopts the principle of **open access** and **early release** of raw and validated data sets.

➜ Solid, diverse and international scientific community.

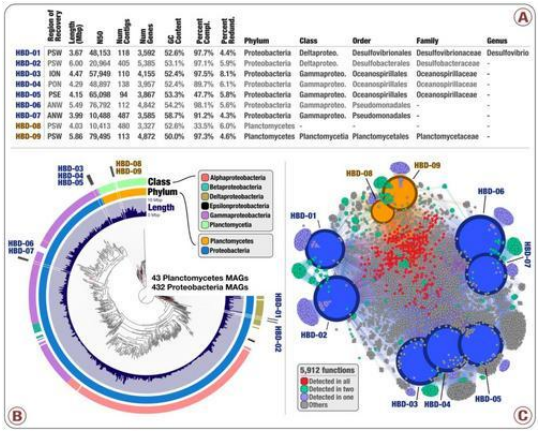
OcéanIA

An opportunity and a challenge to state-of-the-art AI/ML

CHALLENGES

- Small & high dimensional data
- Data Engineering & HPC
- Transfer Learning
- Multiobjective decision making
- Data & AI Governance
- Interpretability Explainable AI
- Causal inference
- Structure and graph-based NN
- Energy-aware Green AI/ML

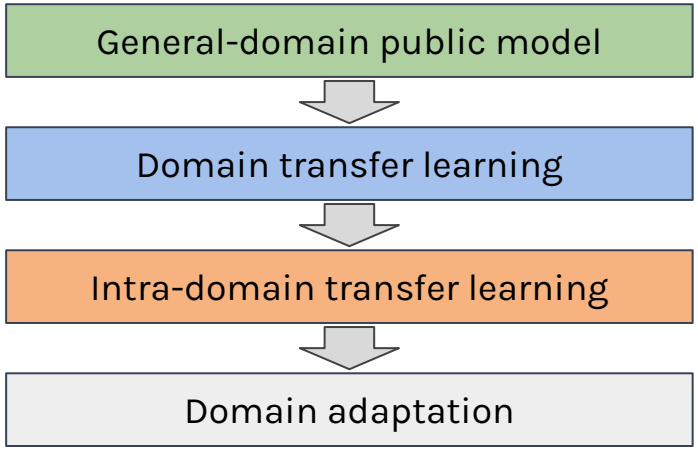
Small but high-dimensional heterogeneous data



- ➜ Tara expeditions gather lots of data - from a marine biology point of view.
- ➜ Highly heterogeneous: DNA barcodes, images, environment variables.
- ➜ Samples includes many species at the same time.
- ➜ Grouped by sample location, interested in networks and graph-based information.
- ➜ In spite of efforts it is not always consistent and it is always evolving: i.e. new hardware.
- ➜ Data from Tara allows exploration of the relationship between marine ecosystem functioning and biodiversity.

Source: Delmont, T. O., Quince, C., Shaiber, A., Esen, Ö. C., Lee, S. T., Rappé, M. S., MacLellan, S. L., Lücker, S., & Eren, A. M. (2018). Nitrogen-fixing populations of Planctomycetes and Proteobacteria are abundant in surface ocean metagenomes. Nature Microbiology, 3(7), 804–813. https://doi.org/10.1038/s41564-018-0176-9

Model reuse, transfer learning and domain adaptation

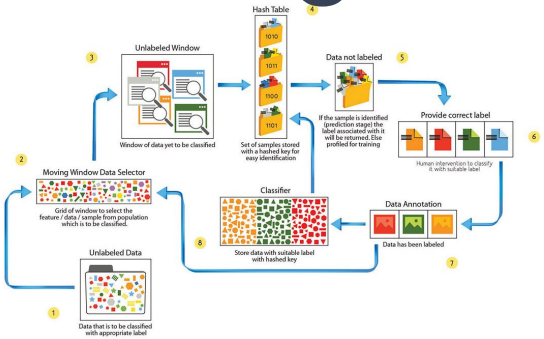


A three-step work hypothesis:

- ↳ Is it possible to adapt existing (computer vision or graph) models to out domain?
- ↳ How to transfer a domain model to other biomes, locations or across species?
- ↳ How to cope with variations across species and sensing hardware?

- **Transfer learning** addresses the issue of how to adapt and re-purpose the internal representations of a model that has been trained on a similar problem.
- **Domain adaptation** is the capacity to cope with changes in the environment because of the evolution of the system and/or the need to particularize a general model to a particular instance.

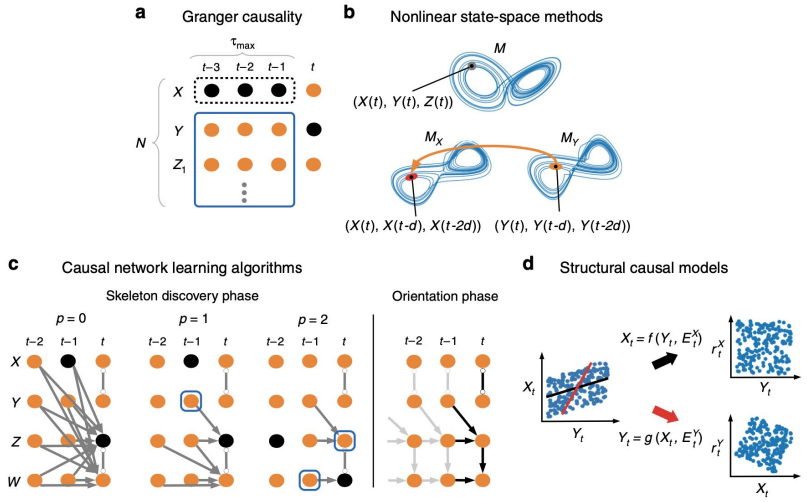
Active, few-shot and multi-task learning



Source: https://brandidea.ai/activeLearning.html

- ➜ Limited data and/or high uncertainty,
- ➜ Direct sampling to the areas of the domain where they are most necessary.
- ➜ Guiding sampling using **active learning.**
- ➜ **Few-shot learning** methods to produce actionable products with minimal data.
- ➜ **multi-source** or **multi-task learning** ensembles training signals of related tasks.
  - ↳ enables the model to generalize better on the main task.
  - ↳ effectively increases the sample size that is being used for training.
  - ↳ biases the model to prefer representations that are useful for other tasks -> transfer learning!

Causality and Explainable AI

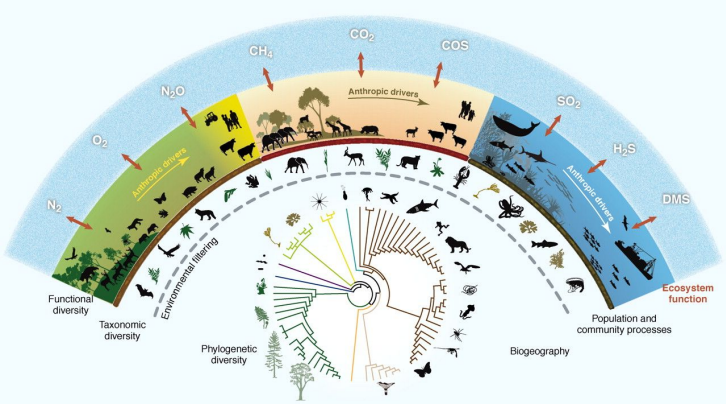


Source: Runge, J., Bathiany, S., Bollt, E. et al. Inferring causation from time series in Earth system sciences. Nat Commun 10, 2553 (2019). https://doi.org/10.1038/s41467-019-10105-3.

- ➜ Produce explainable models, while maintaining performance (prediction accuracy),
- ➜ research support tools that combine explainability and causality for new scientific discoveries and theories by making surrogate human-readable models, and
- ➜ enable human users to understand, appropriately trust, and effectively manage the emerging generation of artificially intelligent partners.

Essential for policy making.

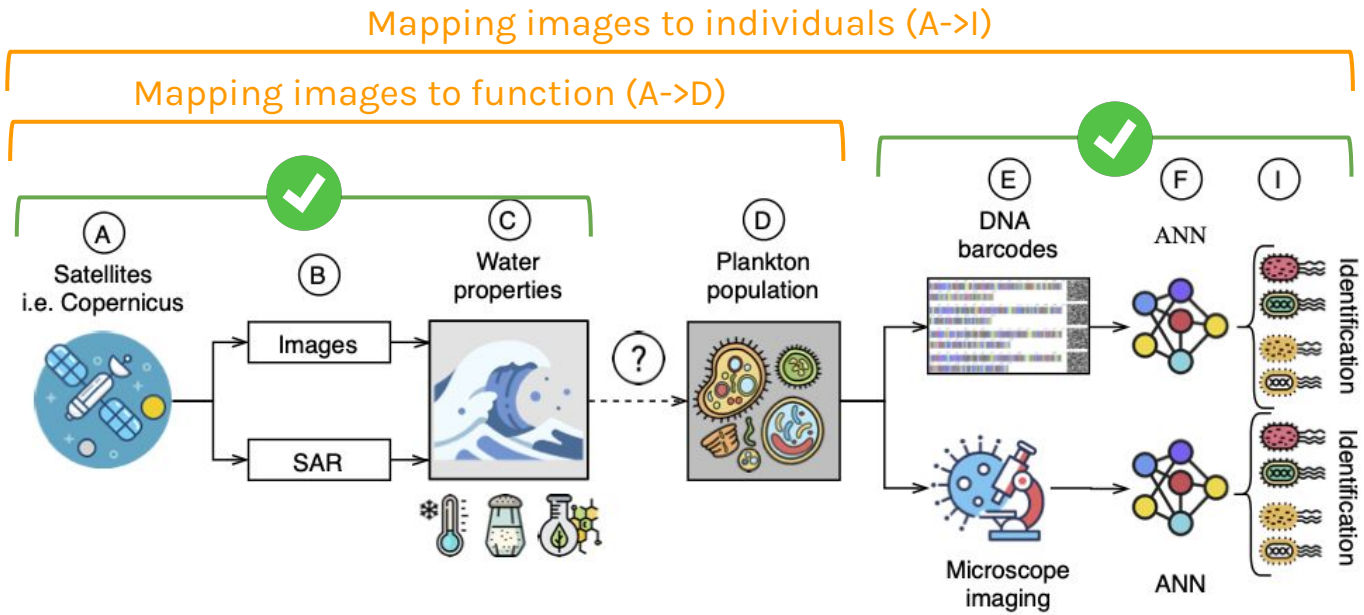
Biodiversity and ecosystem functioning



Source: Naeem, S., Duffy, J. E., & Zavaleta, E. (2012). The Functions of Biological Diversity in an Age of Extinction. *Science*, 336(6087), 1401 LP – 1406. https://doi.org/10.1126/science.1215855

- ➜ Biodiversity supports functions like primary productivity and carbon fixation and sequestration, etc.
- ➜ Understanding this is fundamental: science and policy making.
- ➜ Data from Tara allows exploration of the relationship between marine ecosystem functioning and biodiversity.
- ➜ How variations on biodiversity impact those functions?
- ➜ How changes in temperature (or other variables) impact biodiversity and functions?
- ➜ Understand causality and circular causality among different levels of biodiversity, ecosystem functioning.

Understanding plankton communities using AI, ML, and vision



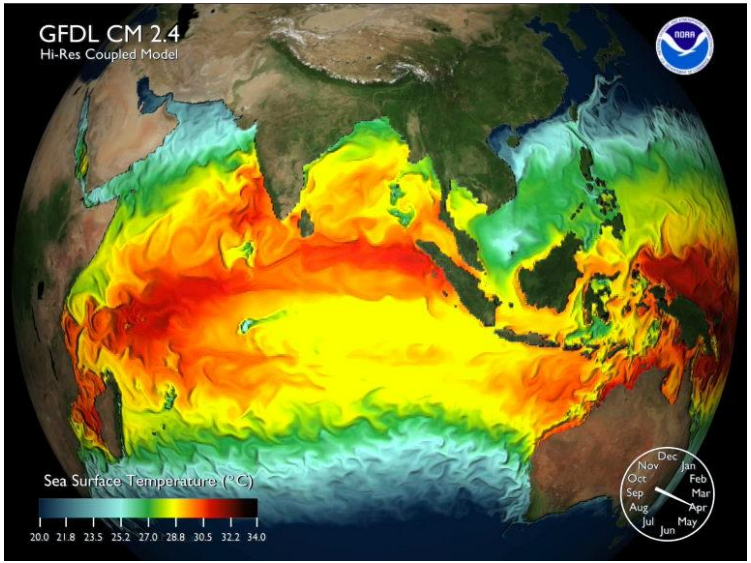
Anomaly detection and explainable AI for automatic plankton ID

Source: Wikipedia

- ➜ Identifying plankton as a supervised problem: already addressed.
- ➜ Estimated that more than 70,000 species unknown.
  - ↳ unsupervised or active learning approaches.
- ➜ Tara sampling includes high-res microscope.
- ➜ Identify **unknown** or **out of context** species.
- ➜ Why an organism represents an interesting specimen?
- ➜ Methods involved:
  - ↳ **transfer learning** and **domain adaptation**,
  - ↳ **(un/self)supervised object detection** and **segmentation**
  - ↳ **causal inference** to understand context.
  - ↳ **explainable AI**: i. e. hint what parts of the organism that determining its selection.

Field experts want a research tool not a black-box.

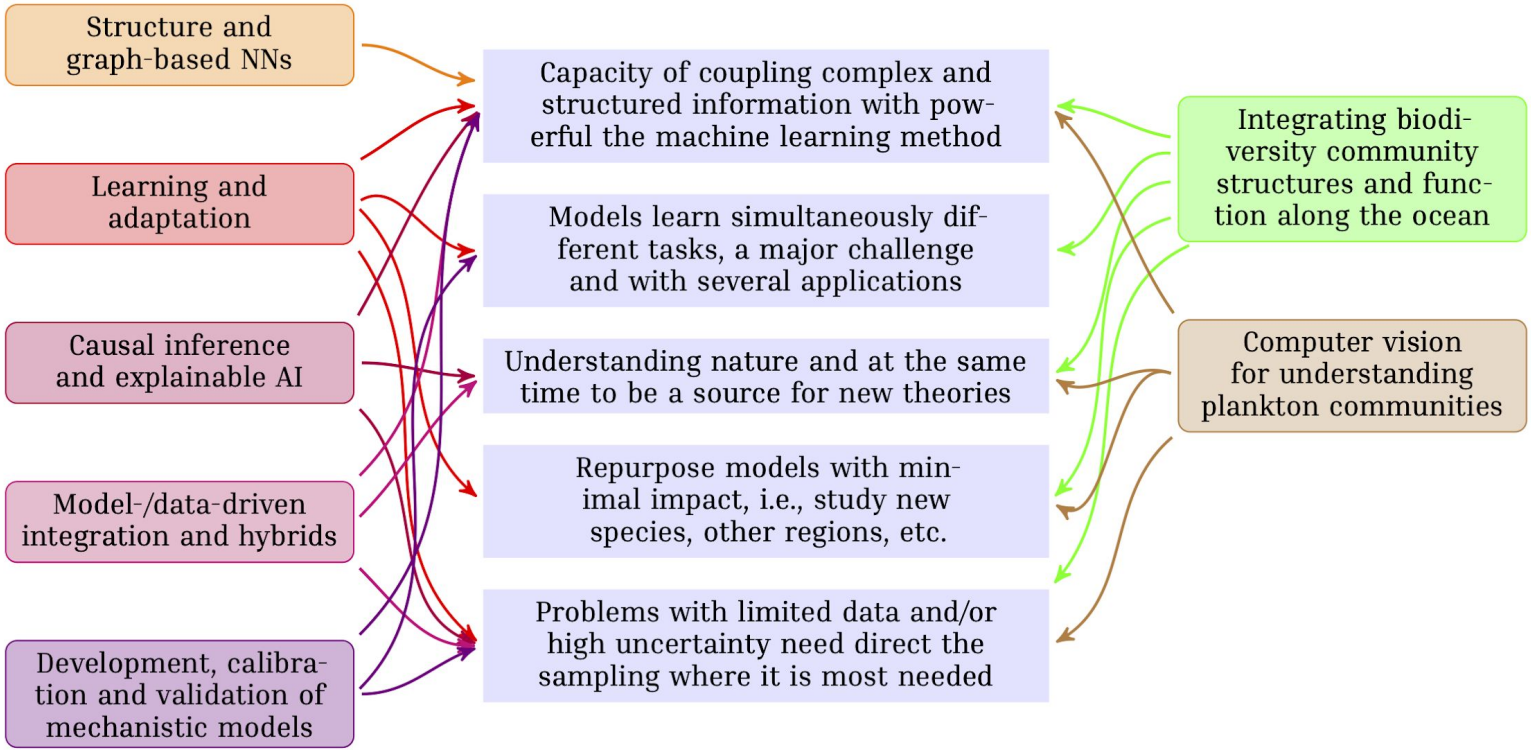
Integrating model-based (i.e. PDEs) and data-based (i.e. ML) approaches



Source: https://www.gfdl.noaa.gov/hires_indian_sst/

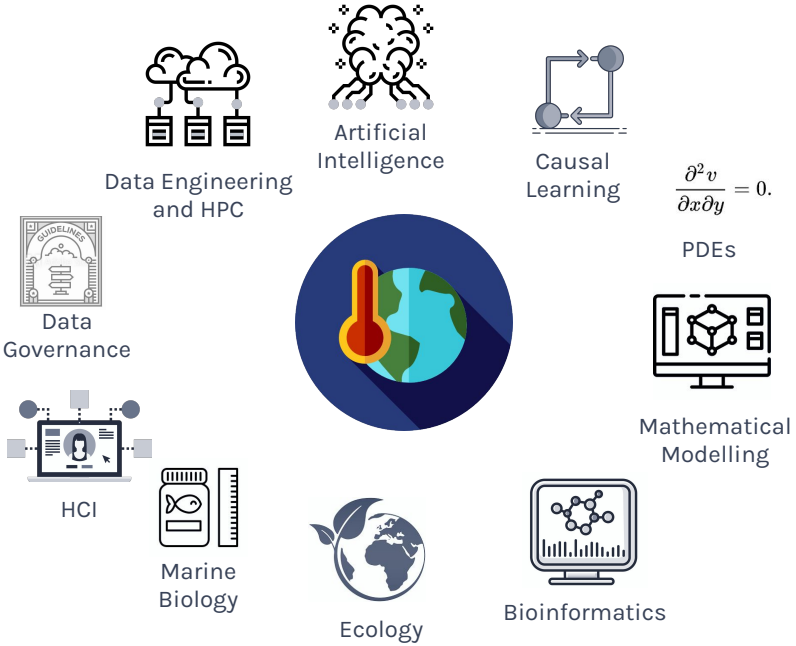
Ocean Circulation Models studying dynamics:

- ➜ high-res models are computationally inviable,
- ➜ current resolution of models is not sufficient,
- ➜ requiere large viscosity and diffusion coefficients smooths out features such as jets and mesoscale eddies.
- ➜ oceanic turbulence at small scales, which play an important role.
- ➜ Planned actions:
  - ↳ Learning PDEs from Data
  - ↳ Understanding learning dynamics
  - ↳ Hybrid models: Combining PDE solvers and DNNs (improved explicability).


Structure and graph-based NNs
Learning and adaptation
Causal inference and explainable AI
Model-/data-driven integration and hybrids
Development, calibration and validation of mechanistic models
Capacity of coupling complex and structured information with powerful the machine learning method
Models learn simultaneously different tasks, a major challenge and with several applications
Understanding nature and at the same time to be a source for new theories
Repurpose models with minimal impact, i.e., study new species, other regions, etc.
Problems with limited data and/or high uncertainty need direct the sampling where it is most needed
Integrating biodiversity community structures and function along the ocean
Computer vision for understanding plankton communities

The OcéanIA team

https://oceania.inria.cl/



Inria Challenge

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CMM Center for Mathematical Modeling

Pontificia Universidad Católica de Chile

Others

TARA OCEANS

Copernicus

Support

Cooperación Regional Francesa para América del Sur

Summary

- Oceans and climate change are intimately related:
  - Carbon capture, impact of change of temperatures, etc.
- Oceans are the last 'unknown':
  - Understanding the role of oceans in climate change is not only important but also challenging for modern AI, ML and applied math.
- A way to address current hot topics like explainability, bias, etc. on a different domain.
- Tara as source of data that can be crossed with other sources.
- I have described the approaches we are to follow in the next 4 years.
- OcéanIA has just started!
  - **We are hiring!**

Thank you! Merci !
Obrigada! ¡Gracias!

Follow us: www.inria.cl and oceania.inria.cl