The critical role of space-based observations for Numerical Weather Prediction

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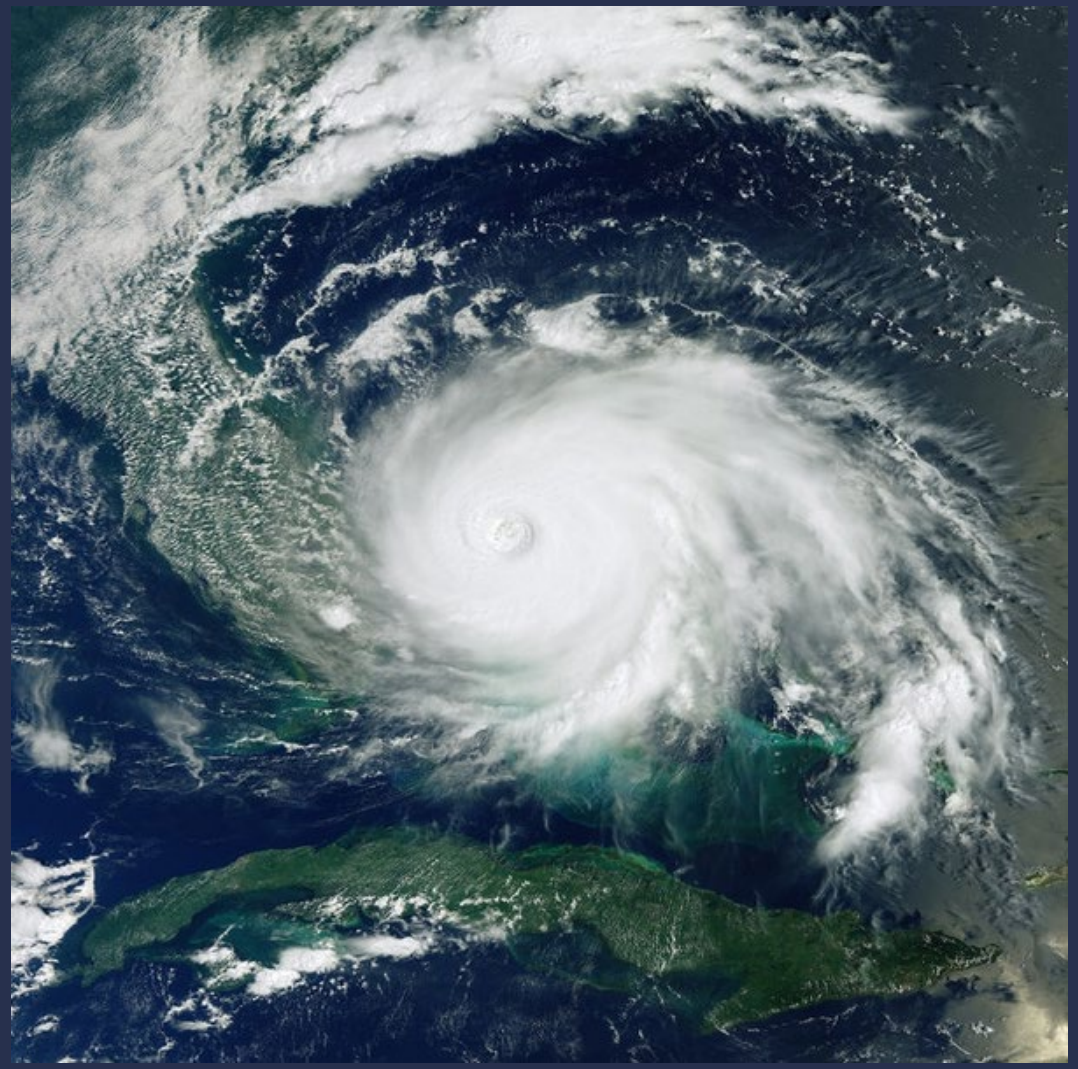
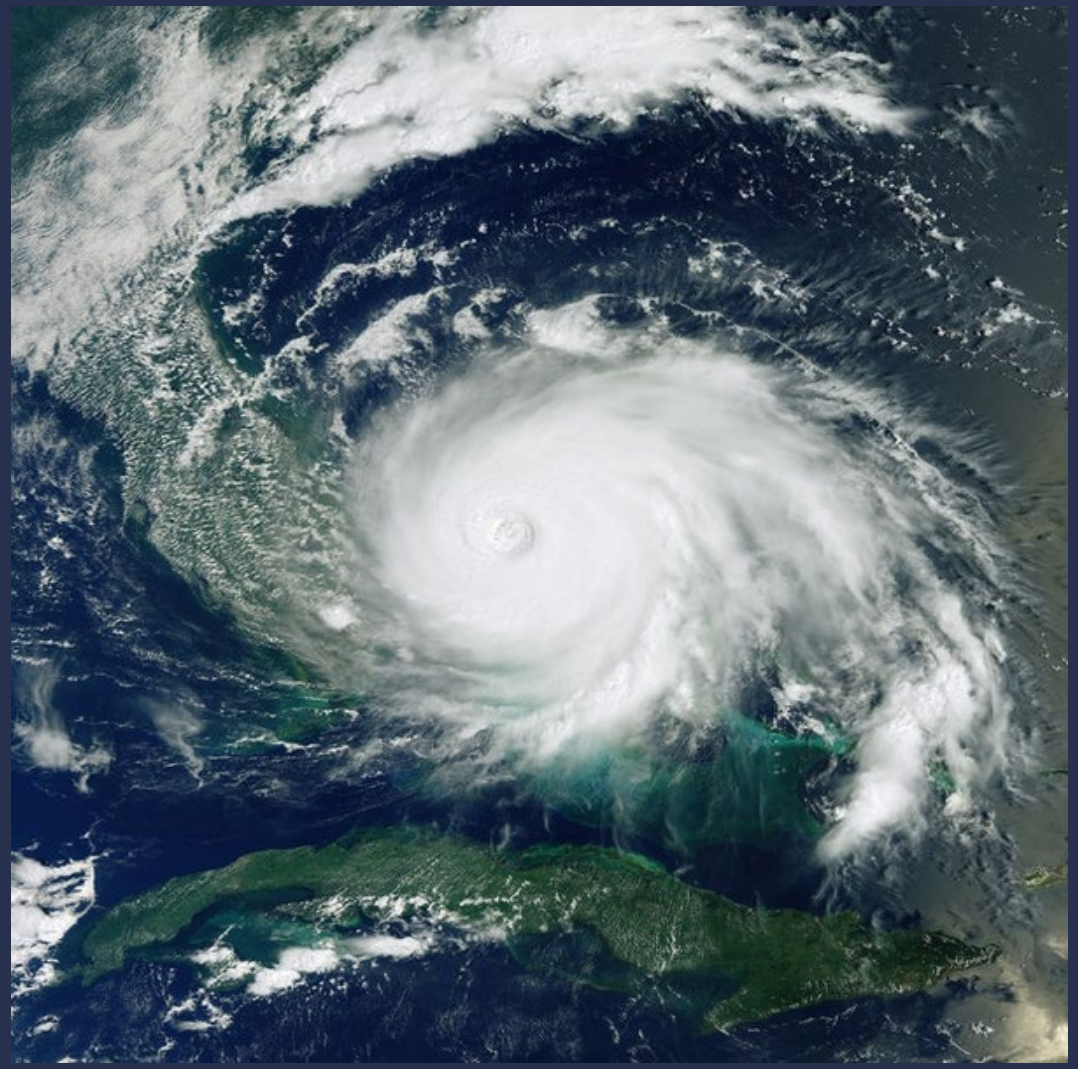
Overview:

- Why do we need space-based observations for NWP ?
- How accurate would weather forecasts be without satellites ?
- The importance of multi-spectral measurements
- Satellite technology innovation improving our knowledge of the atmosphere
- Future satellite sensors and new opportunities with AI

Dorian viewed from the Sentinel-3 satellite



Dorian viewed from the Sentinel-3 satellite



Dorian viewed from the Bahamas

Most deadly event in recent history is Nargis (2008) that claimed ~ 130,000 lives

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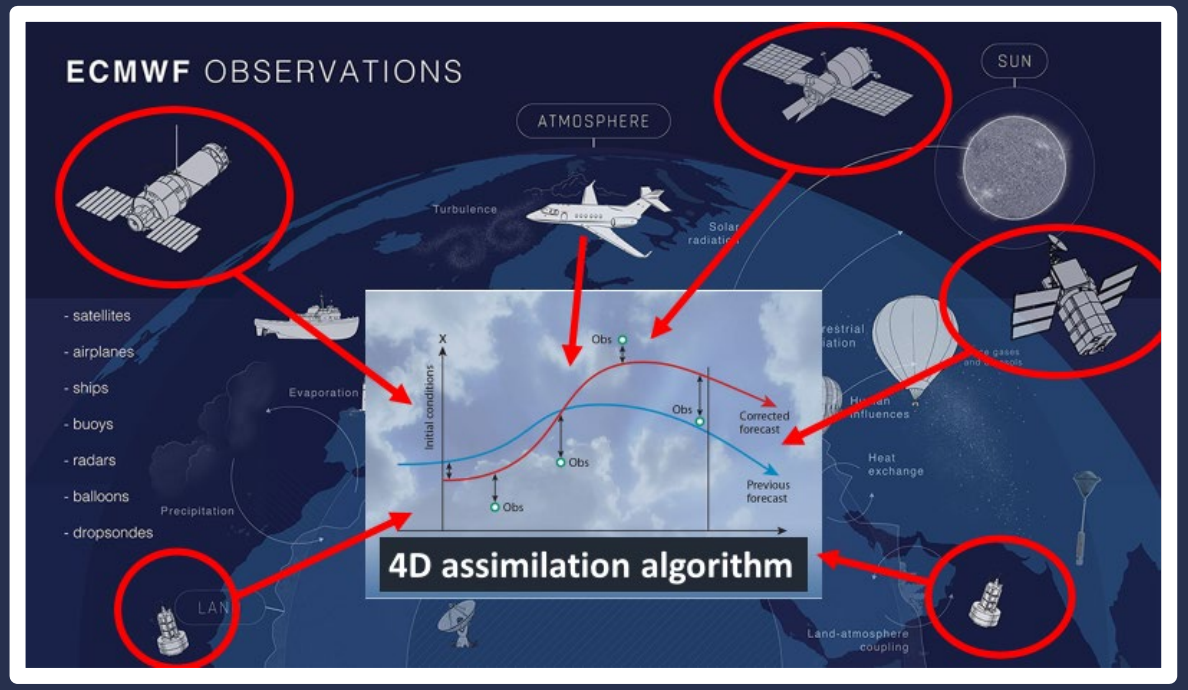
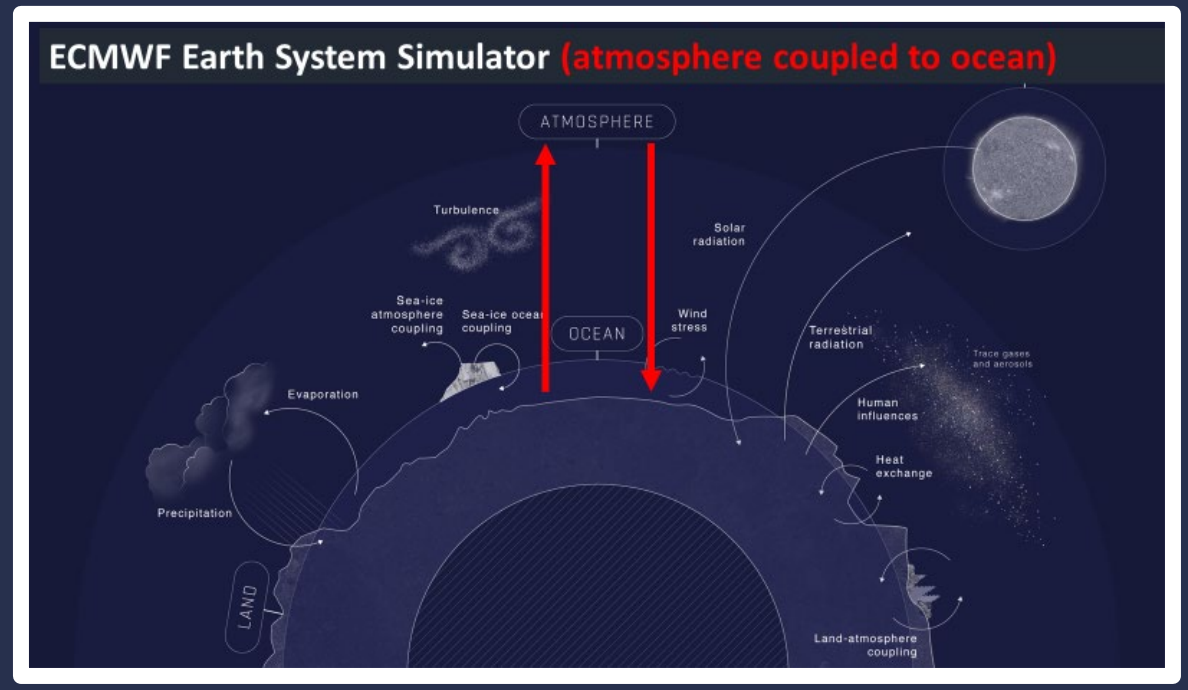
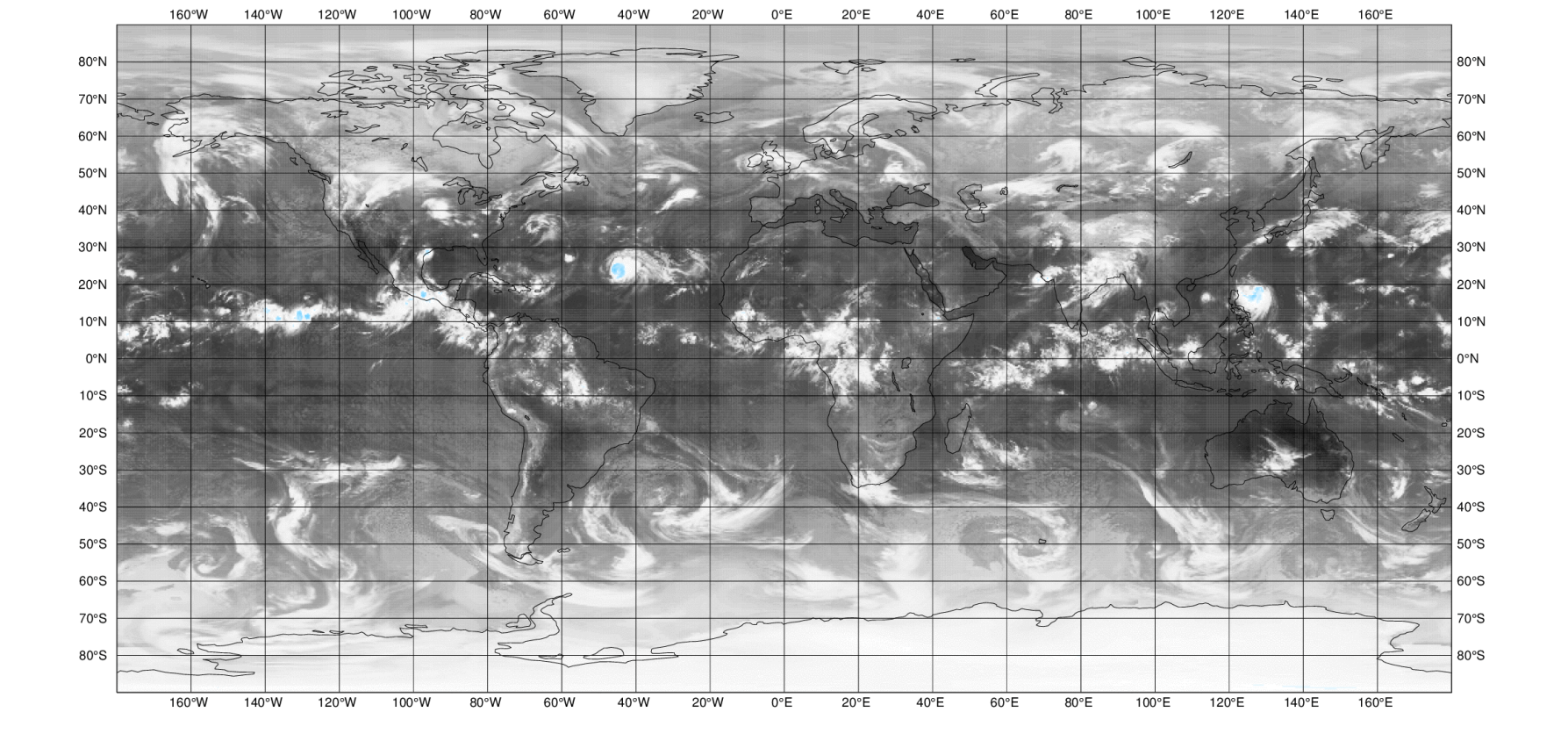
The Satellites provide **initial conditions** (what the atmosphere doing now) from which forecasts are launched





To forecast many days into the future, we need <u>global</u> initial conditions…and only satellites can provide this



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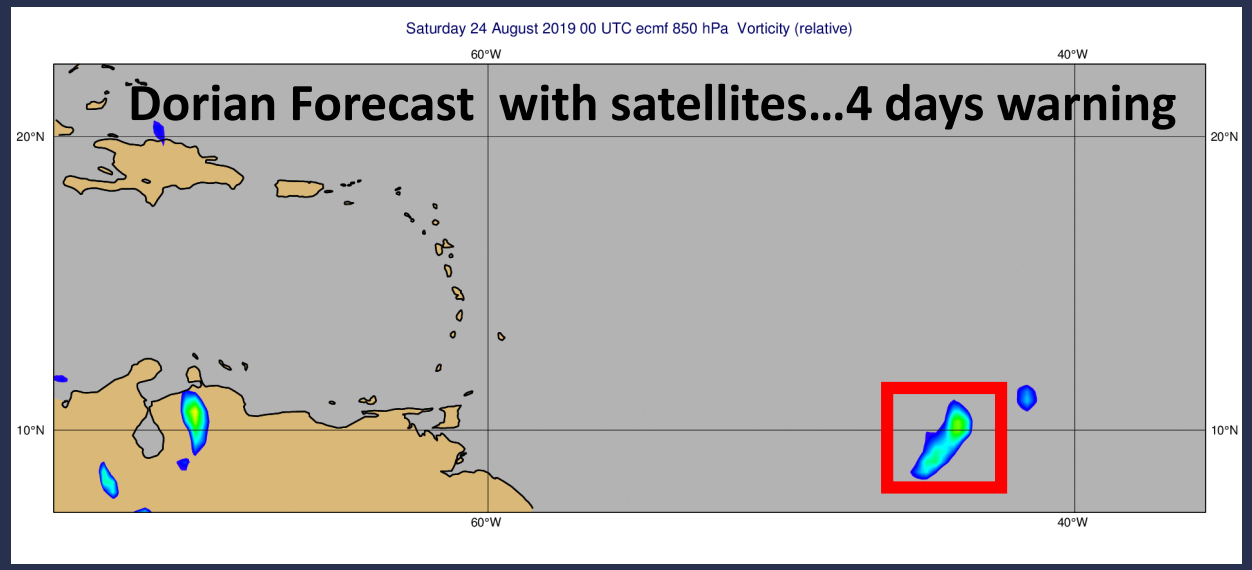
Early identification of storm genesis with satellites saves many thousands of lives

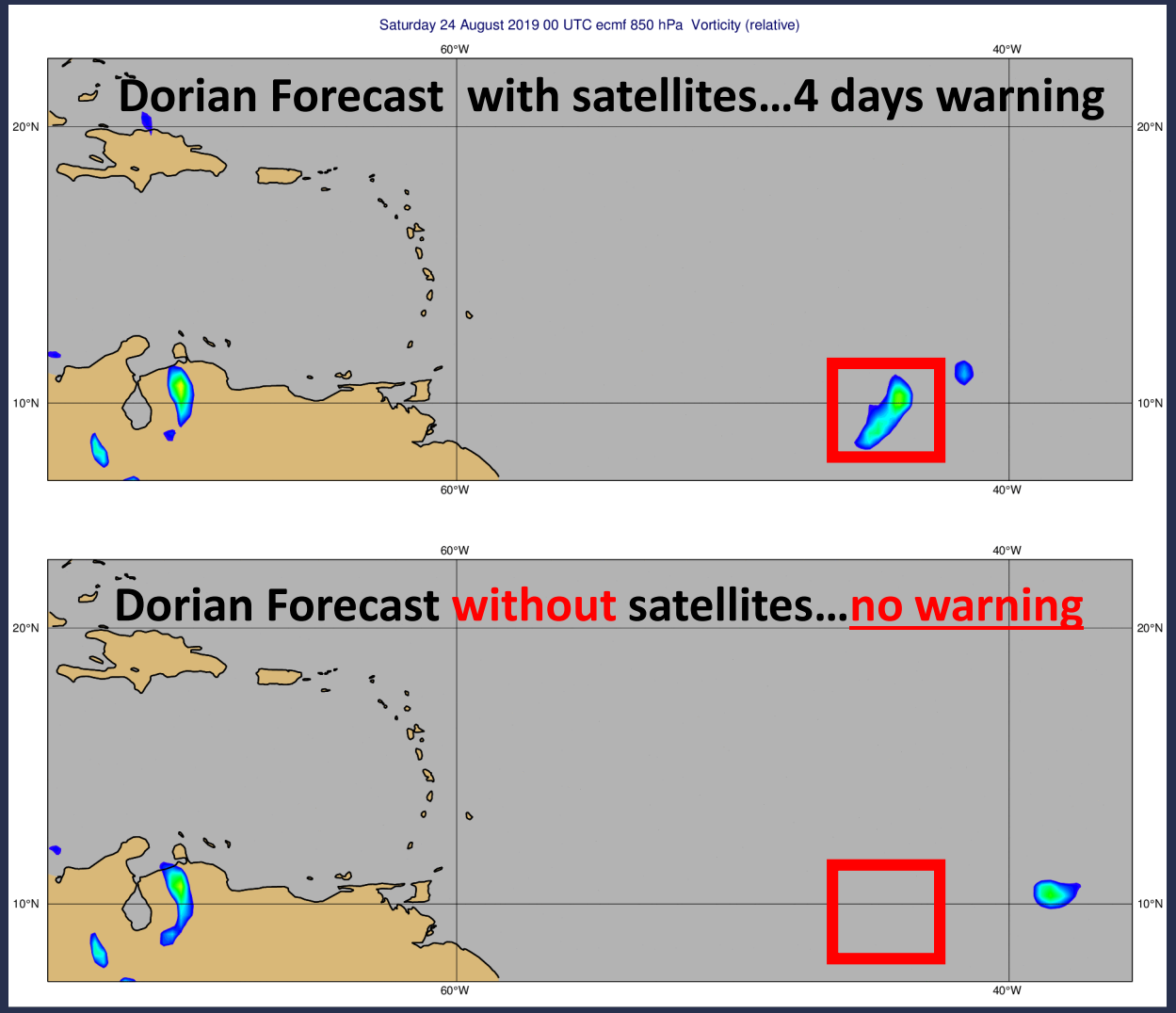


Key information

1. Ocean surface temperature
2. mid level humidity
3. wind sheer

Satellites provide this …

Without satellites we would often give no warning of severe weather!



Key observations

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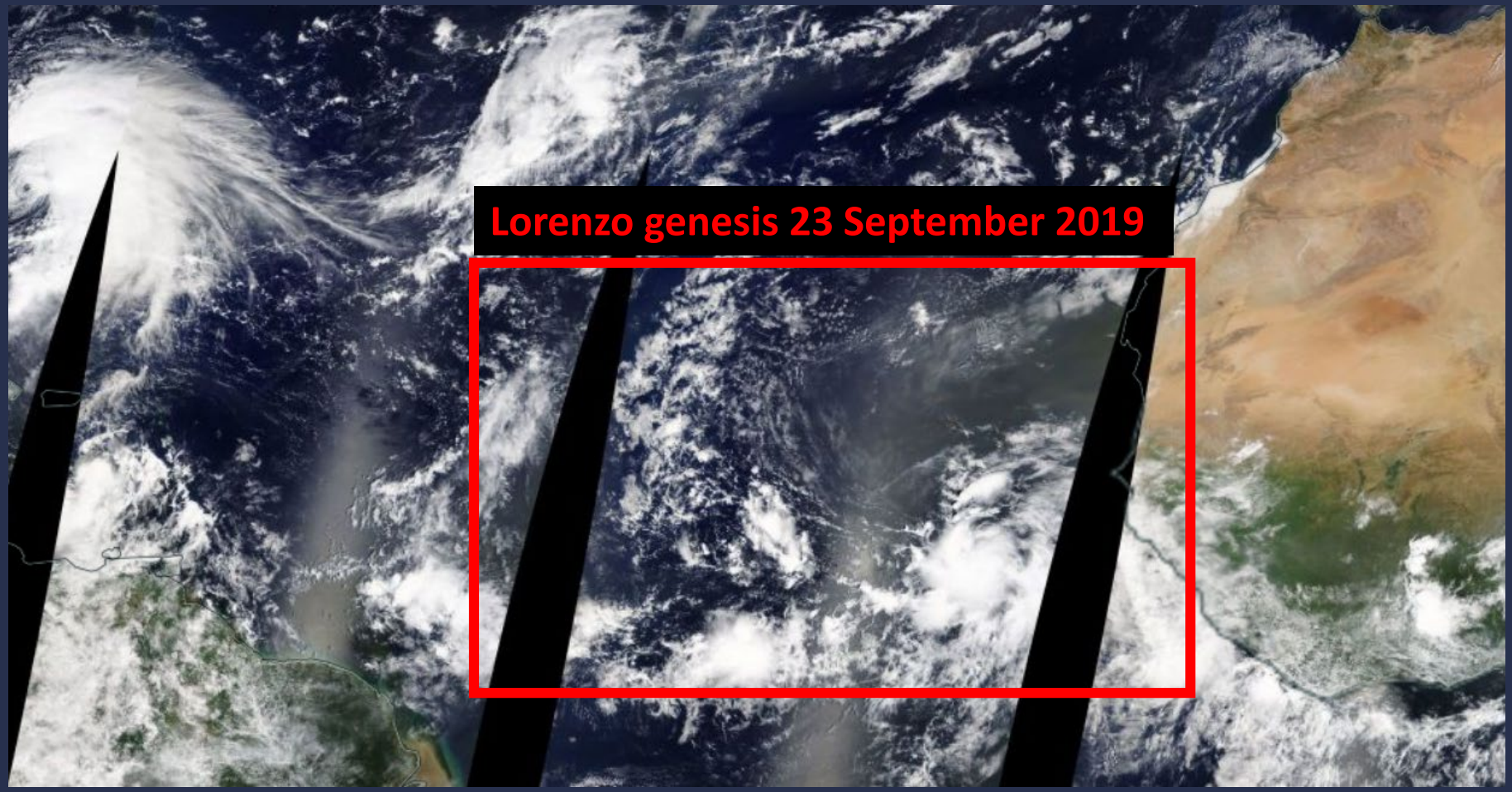
Early identification of storm genesis…Lorenzo

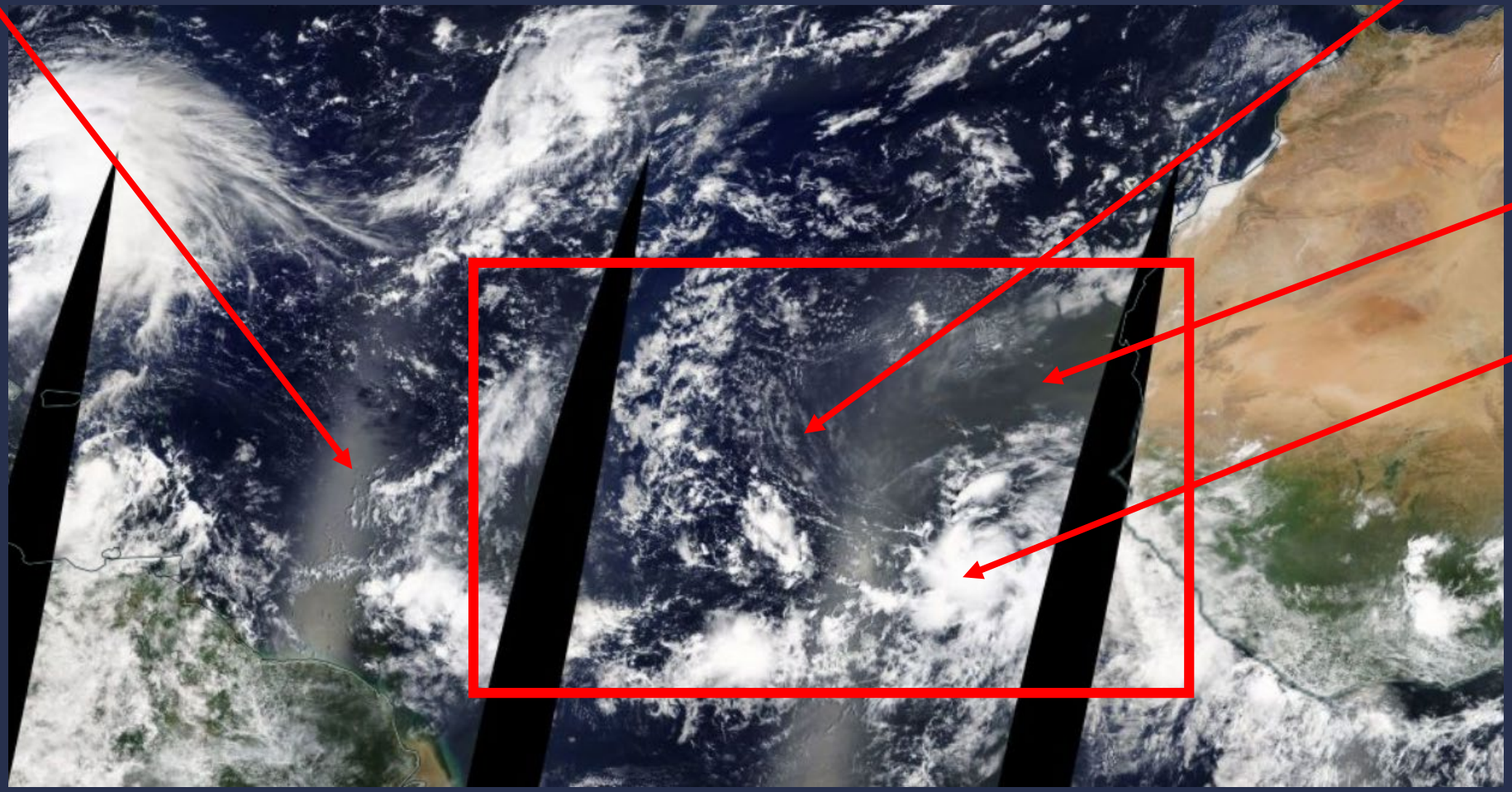
Key observations

- Ocean surface temperature ?
- mid level humidity ?
- wind sheer ?



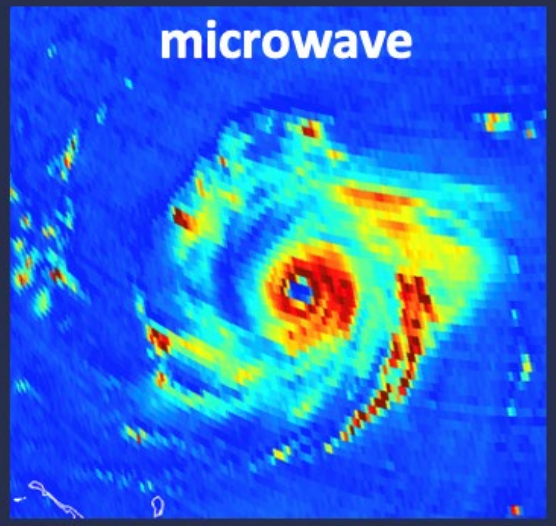
Early identification of storm genesis…in a challenging environment

- Ocean surface temperature ?
- mid level humidity ?
- wind sheer ?



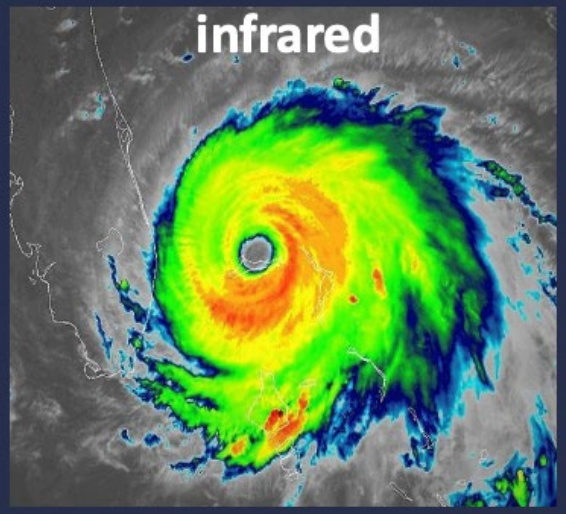
Satellite sensors operating at different frequencies are used to understand the full atmospheric state…

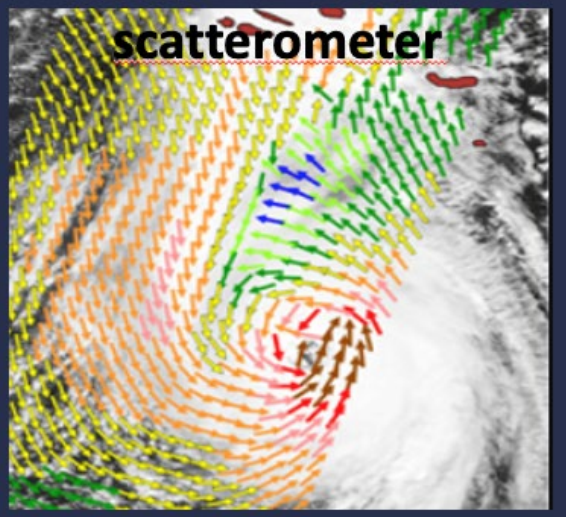
Cloud phase and motion (wind)



Water and rain content within clouds

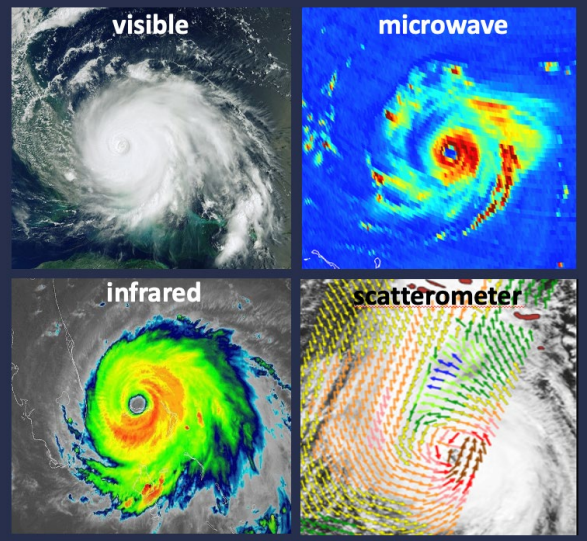
Temperature and height of clouds, humidity in clear sky

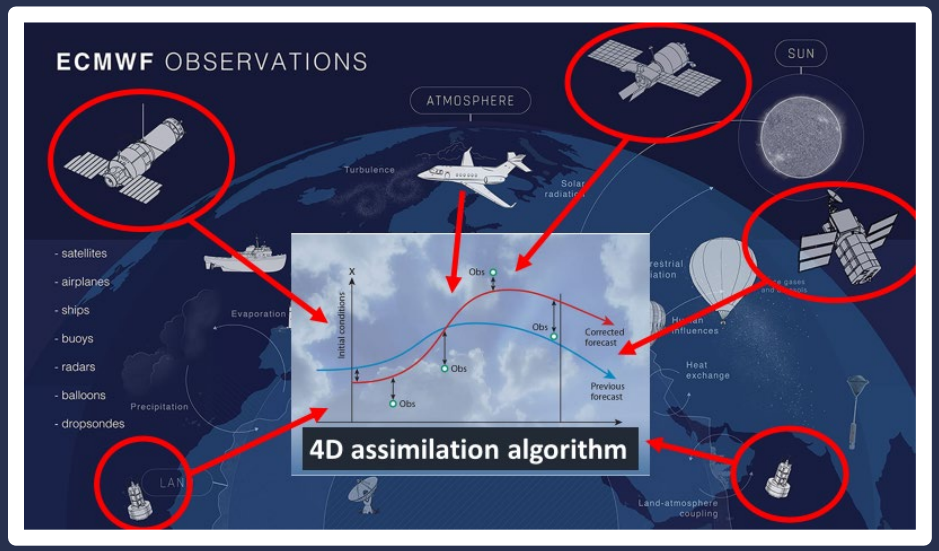


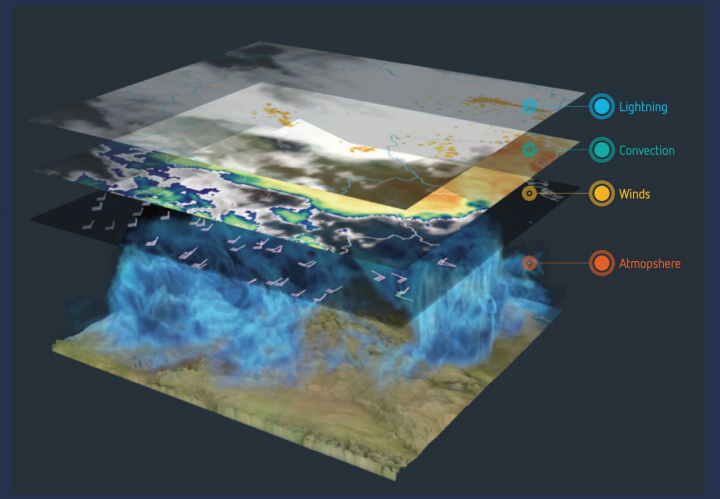


Penetrating the clouds to look at ocean roughness and land state

…But require highly sophisticated Data Assimilation Systems to combine these into a coherent 3D picture







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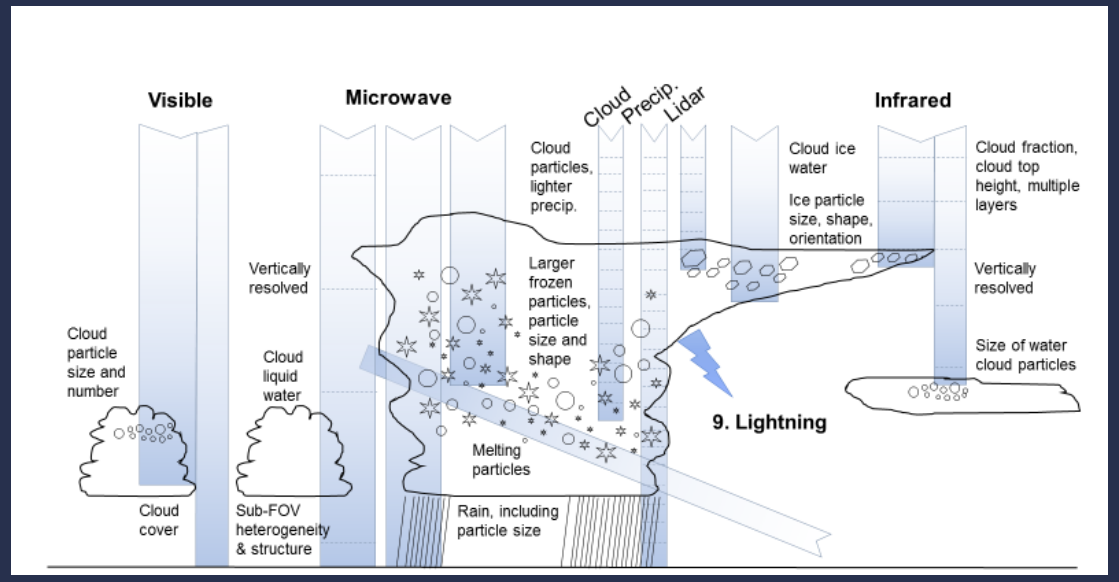
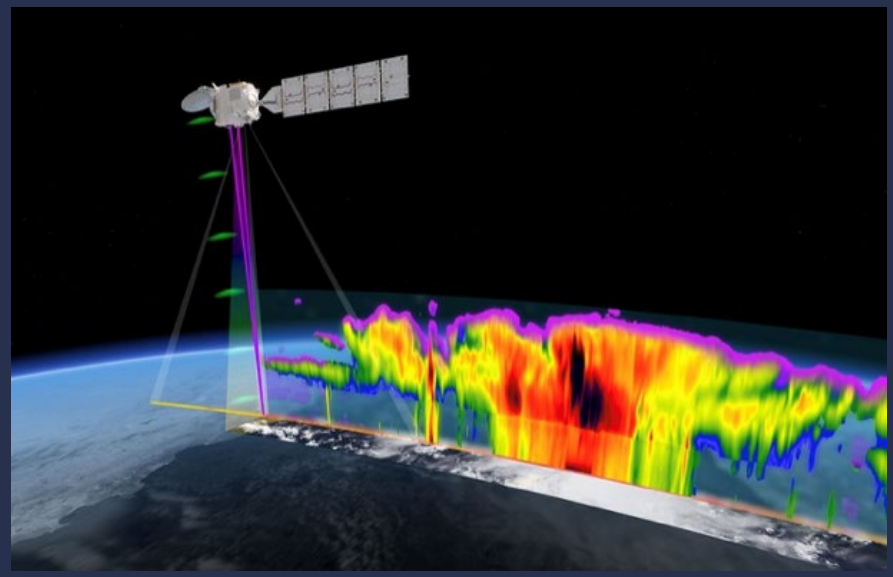
Satellite technology innovation improving our knowledge of the atmosphere…

…ESA EarthCARE

Cloud RADAR and LIDAR



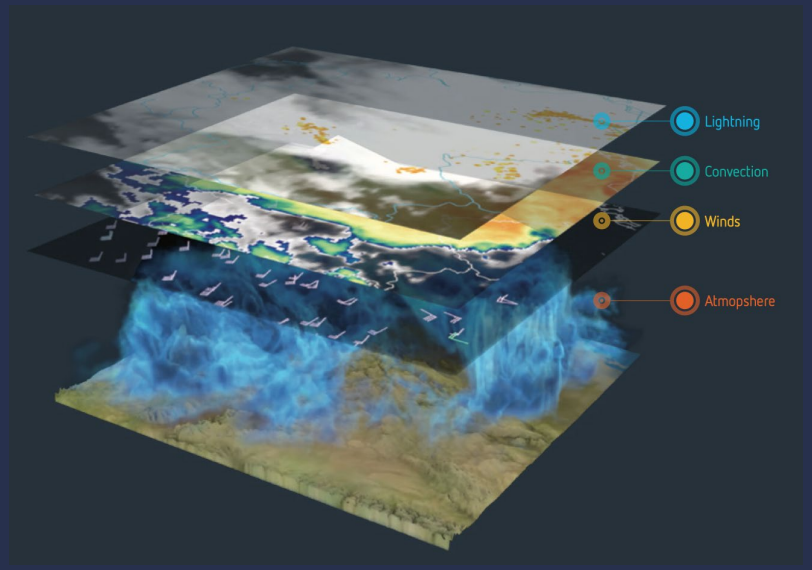


These data will improve initial conditions, but also forecast model physics and the use of other satellite observations

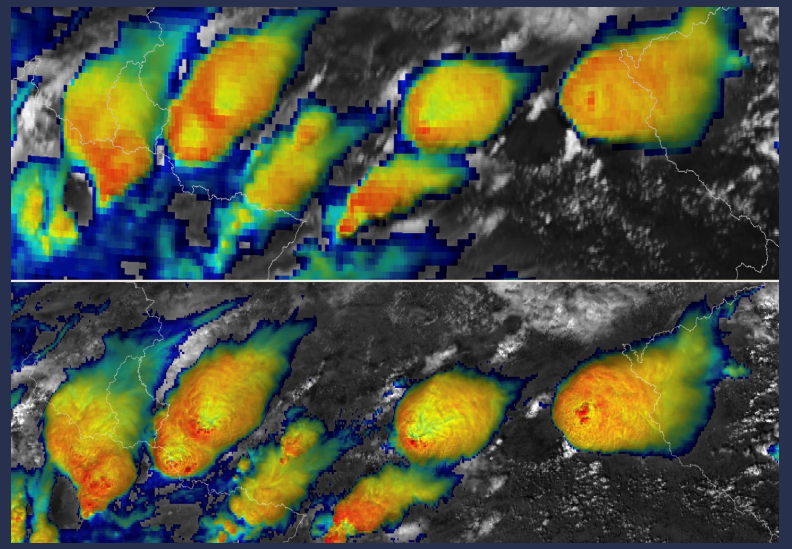
Satellite technology innovation improving our knowledge of the atmosphere…

…EUMETSAT MTG

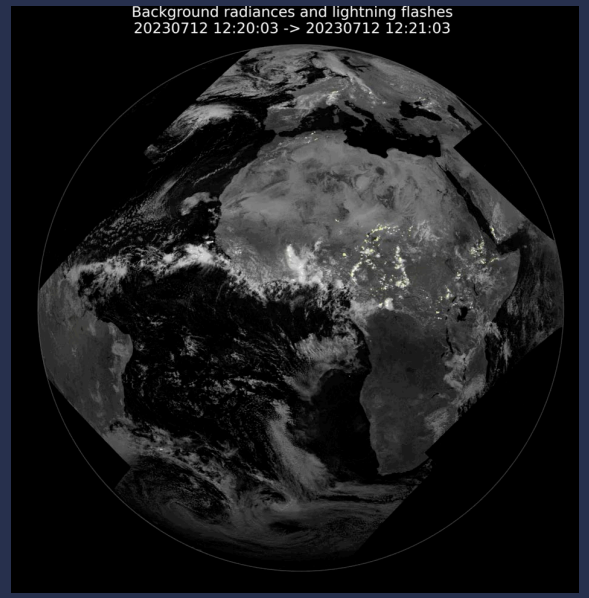
Hyperspectral delivers fine vertical detail



Unprecedented spatial and time resolution



Lightening mapper informing on storms



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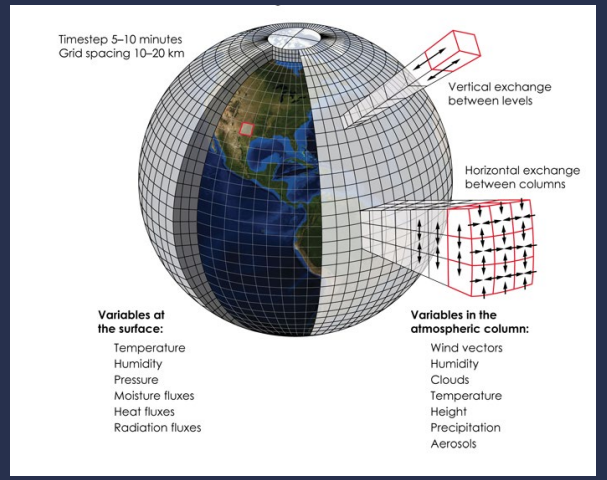
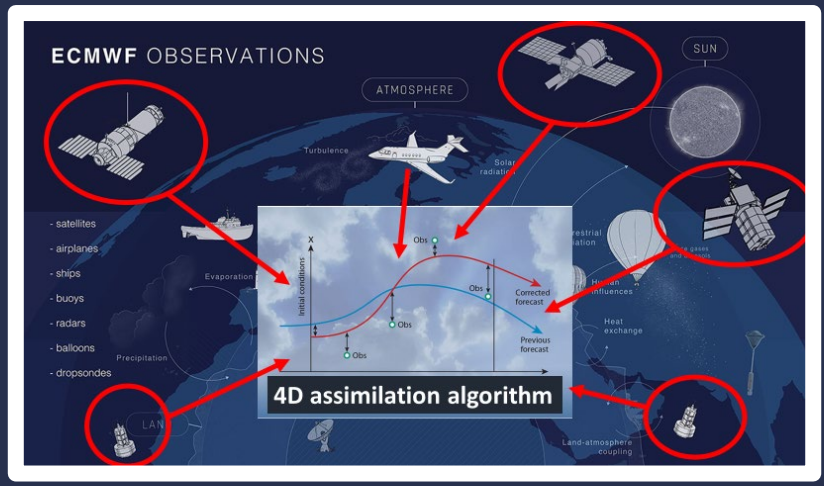
Enhanced exploitation of satellite observations using Artificial Intelligence

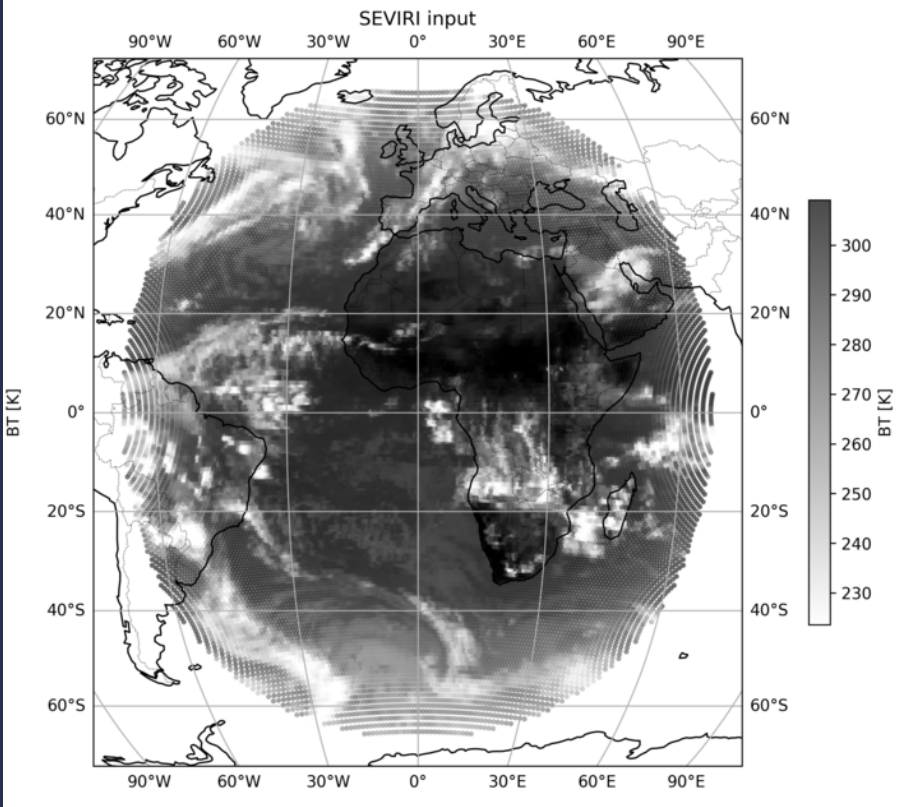
- Physics-based global NWP models have evolved to ever higher spatial resolution (km scale) and levels of complexity (i.e. full Earth system).

- This presents extreme challenges for data assimilation to combine observations and provide initial conditions of the required accuracy.



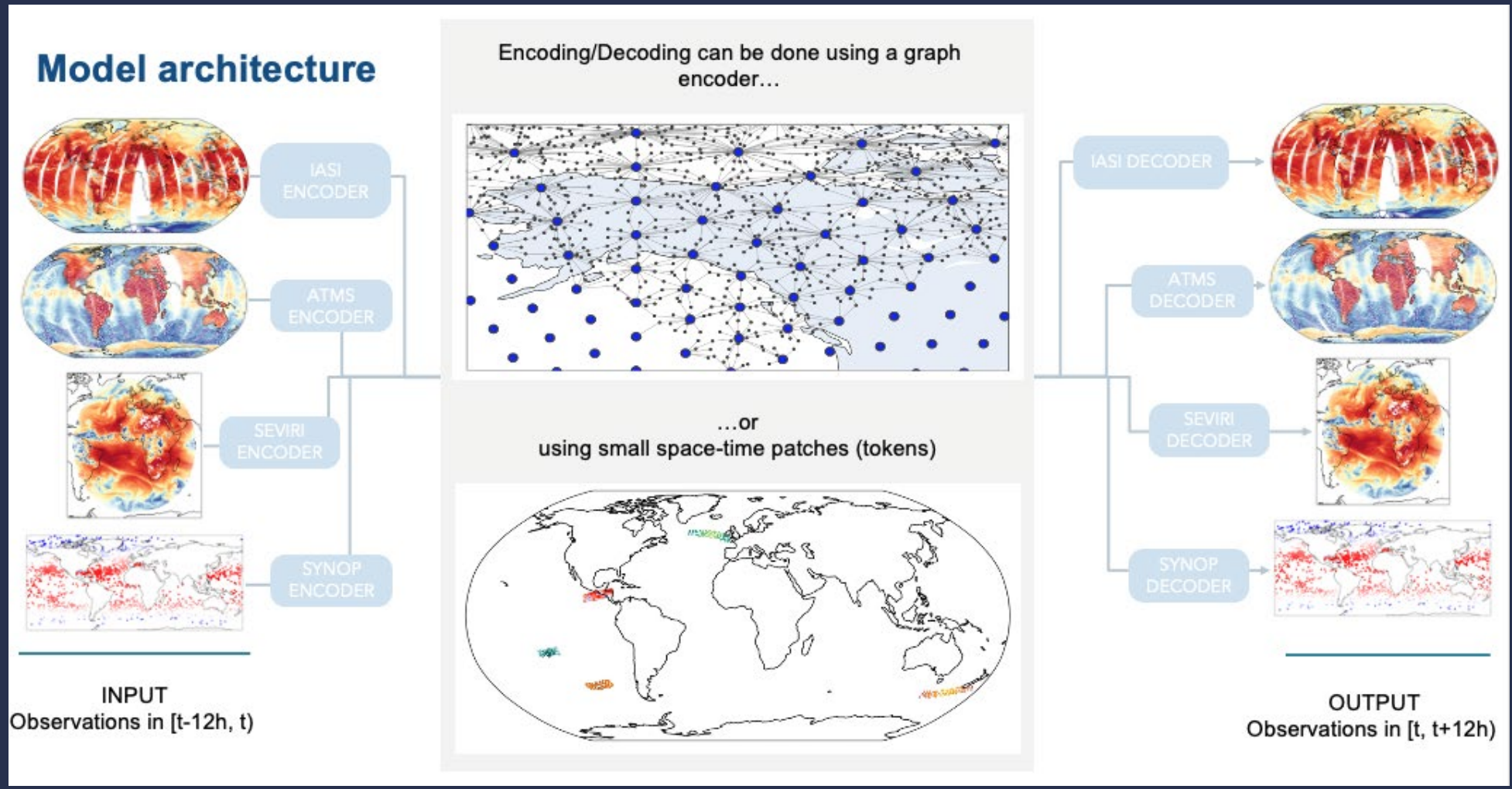


Enhanced exploitation of satellite observations using Artificial Intelligence…Direct Observation Prediction



- We use historical observations to train a Neural Network (NN) to forecast future observations
- Include observations of the full Earth system (atmosphere, ocean, land) simultaneously
- Use all observations, without demanding a detailed physical model of the measurement
- Once trained, we initialize the model directly with the observations themselves, allowing much faster access to forecast warnings

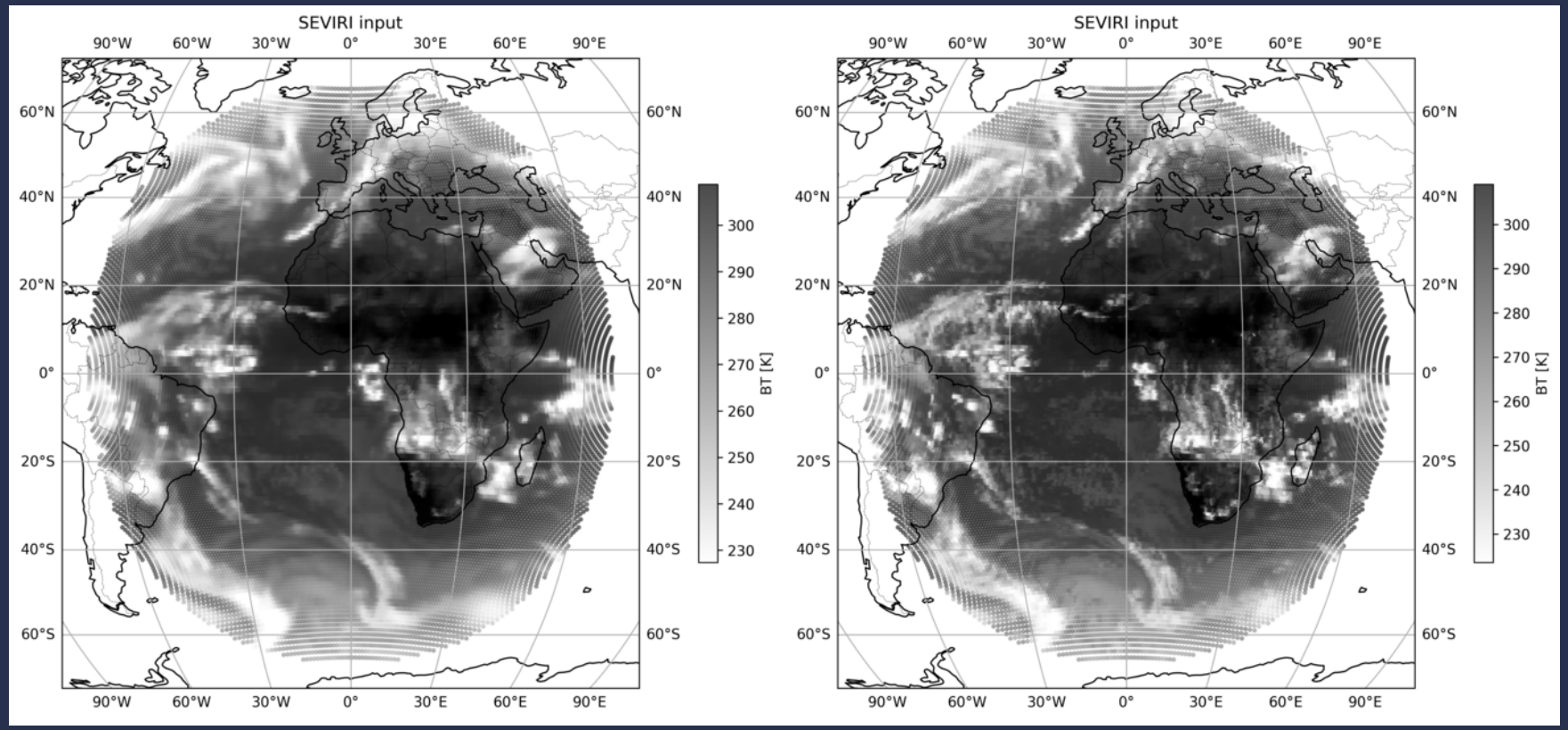
Artificial Intelligence…Direct Observation Prediction (AI-DOP)



First medium-range forecasts made directly from observations:

AI-DOP model

Target real observations



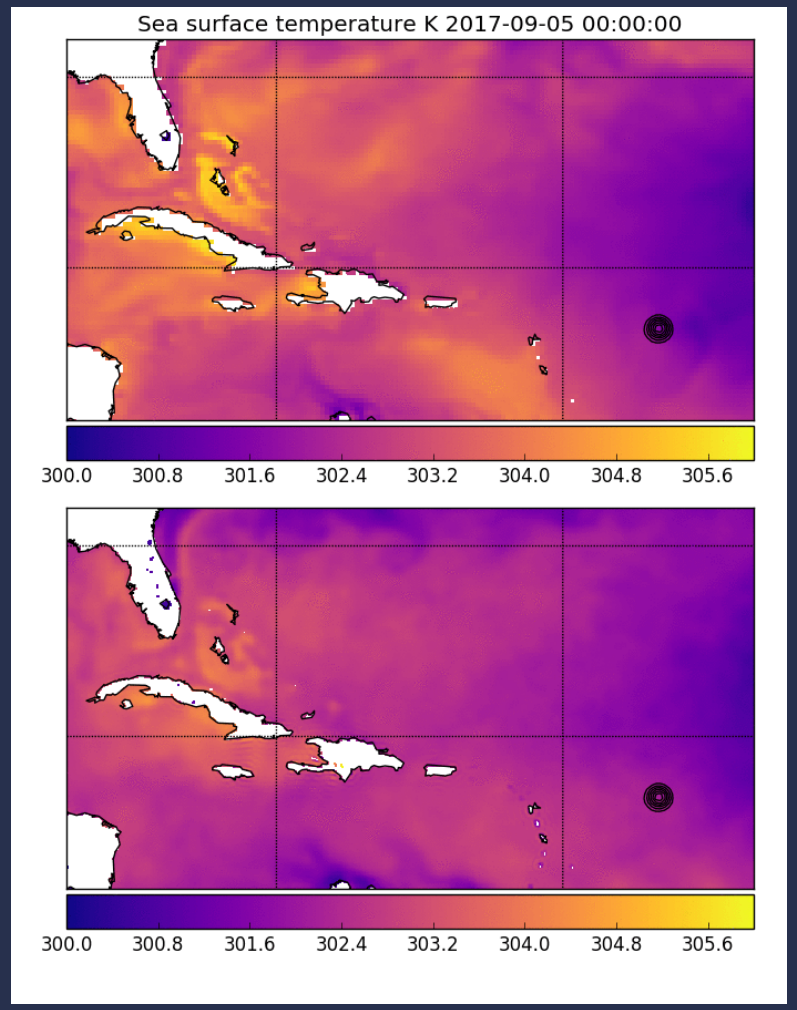
Summary:

- Space-based observations are absolutely critical to allow accurate forecasts and provide advanced weather warnings which undoubtedly save many thousands of lives every year.

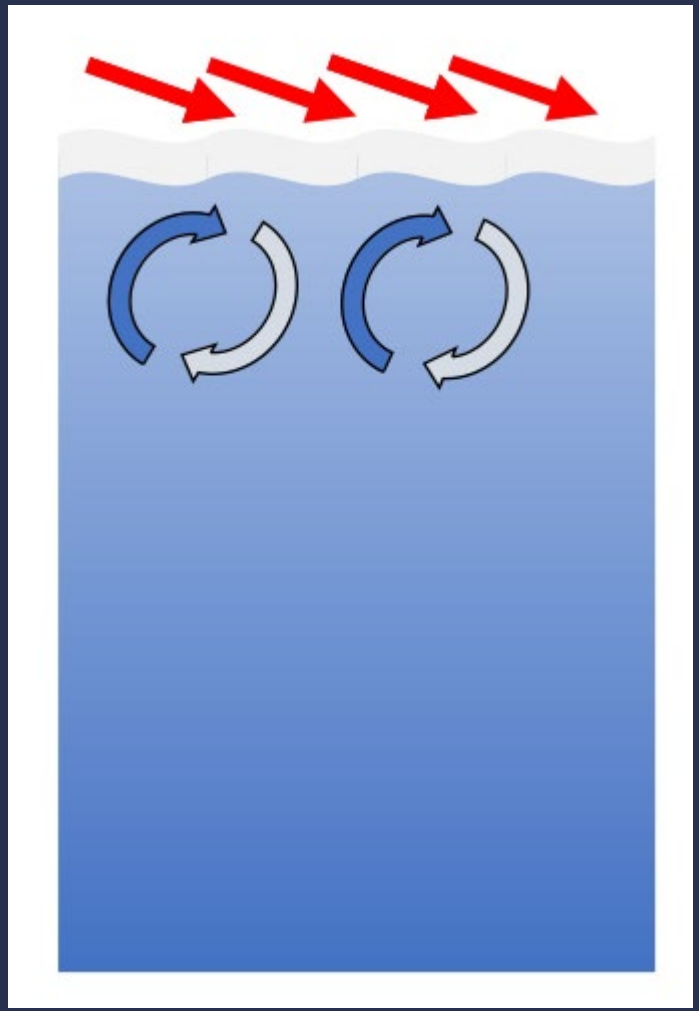
- European satellite constellations are unparalleled, with different space-based sensors providing complementary multi-spectral real-time observations of the atmosphere.

- Investment in new observing systems, but also in advanced (AI) utilisation systems is critical for Europe to continue to lead the world in NWP

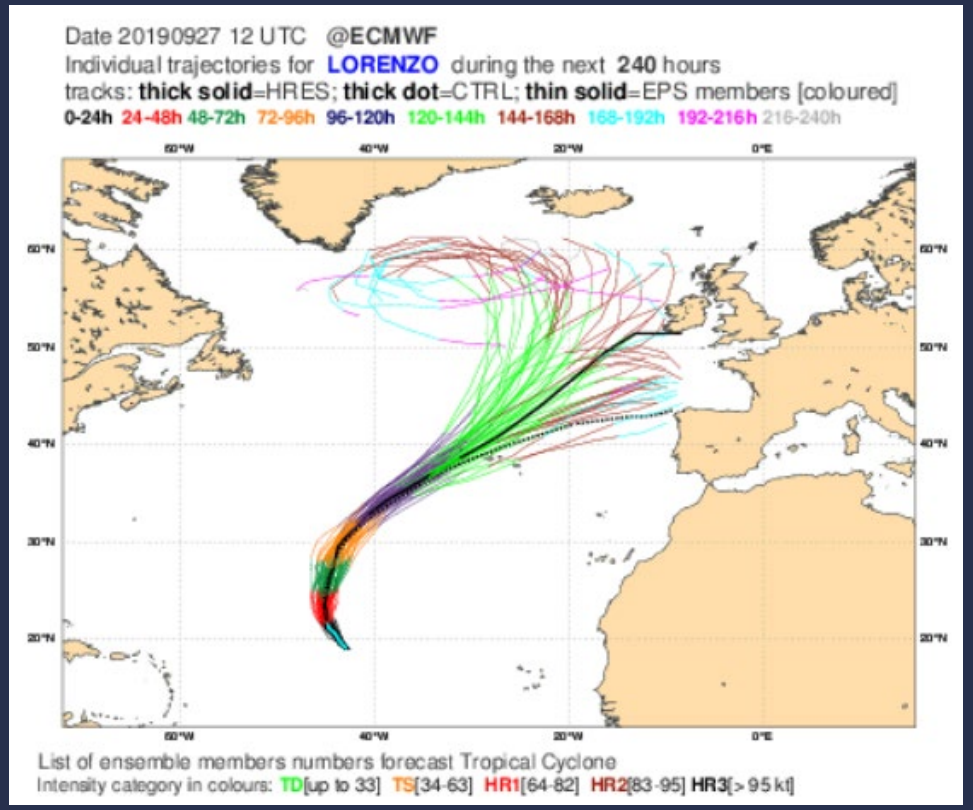
Modelling atmosphere-ocean interaction…mixing

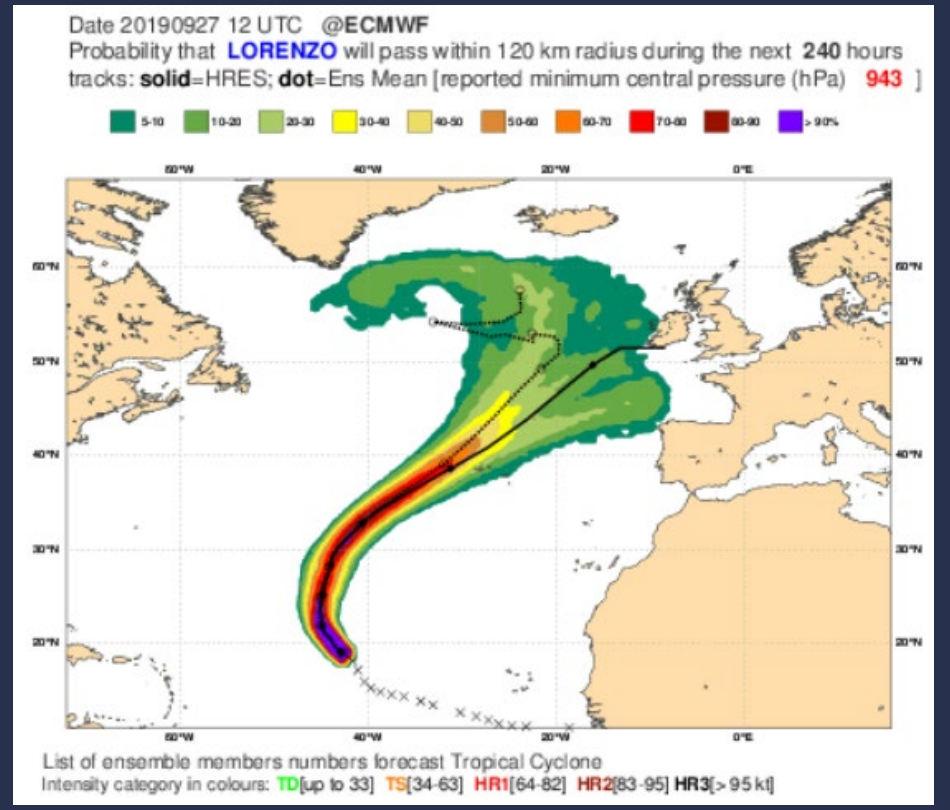


- Wind stress at the surface causes mixing of cold water from below
- Cooling of the ocean surface can suppress the cyclone intensity
- Modelling this important feedback requires an accurate coupling between the atmospheric model and the ocean model
- In practice these have very different grids, time steps and data assimilation



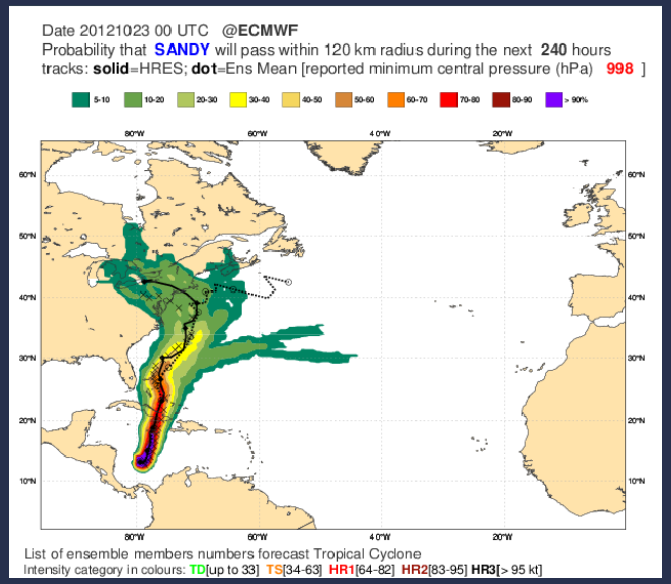
Forecast guidance …ensemble forecasts of Tropical Cyclones produce strike probabilities…



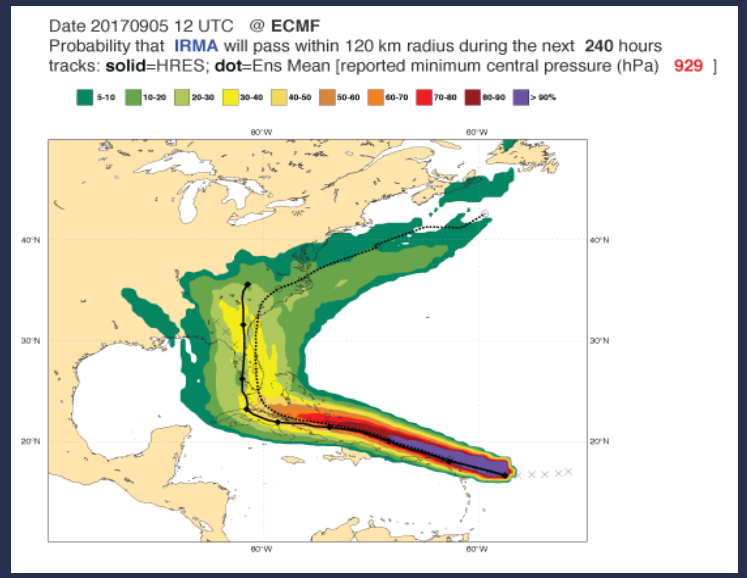


Forecast guidance …how do we act on this information ?

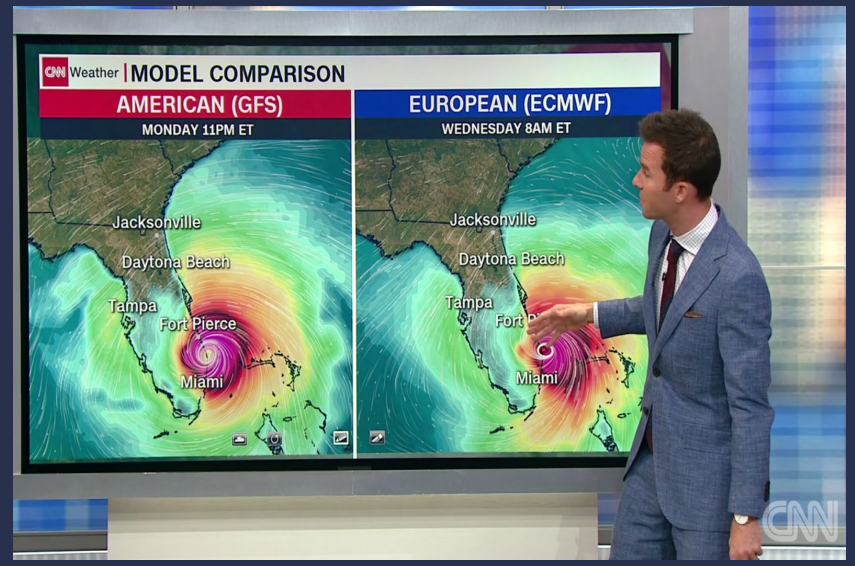
Sandy…evacuate Manhattan ??



Irma…evacuate E or W Florida ?



Dorian…stalling over the Bahamas ?



Are ensemble forecasts the best tool ? (ML / AI alternatives ?)

Can we assist with better decision making on the ground ?

Are traditional statistical approaches optimal with so few cases ?