Focus group on data assimilation

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11th Workshop of International Precipitation Working Group (IPWG-11), 15-18 July 2024

Introduction

⇒ In the context of Numerical Weather Prediction, **Data Assimilation aims at** providing the initial conditions which lead to the **best weather forecasts**.

⇒ Assimilating observations within clouds and precipitation has been a long-standing challenge and a lot of progress has been accomplished in the past decades (e.g. routine usage of cloudy microwave passive and active observations for many NWP centers, usage of cloudy observations in the Infrared and visible observations in a few NWP centers).

⇒ Assimilation has **a lot in common with retrievals** in terms of tools (e.g. satellite observations, forward operators, use and development of scattering databases, use of prior information, quality control of observations, etc)

IPWG is a very relevant “cross-expertise” forum of discussions on the subject of clouds and precipitation which complements well the ITWG forum focusing on sounding in general.

Ongoing interests and work in the DA FG

1. **Precipitation-capable observation operators for data assimilation (e.g. CRTM, RTTOV)**
   - Increasing use of **non-spherical snow particle shapes** (e.g. CRTM now using ARTS database) and work **towards non-spherical melting layer** particles (e.g. for CRTM 3.x)
   - **Space-based radar support** (e.g. GPM DPR, Cloudsat CPR) in CRTM from v3.1 and in RTTOV for a while (improved melting layer representation in v13.2)
   - Working towards **cross-frequency capabilities**:
     - RTTOV version 14 (due soon) will allow use of most solvers and cloud overlap models across microwave to visible frequencies - but consistent microphysics and particle scattering databases are still needed across all these frequencies
     - CRTM and RTTOV now support visible reflectance modelling

2. **Precipitation data assimilation developments**

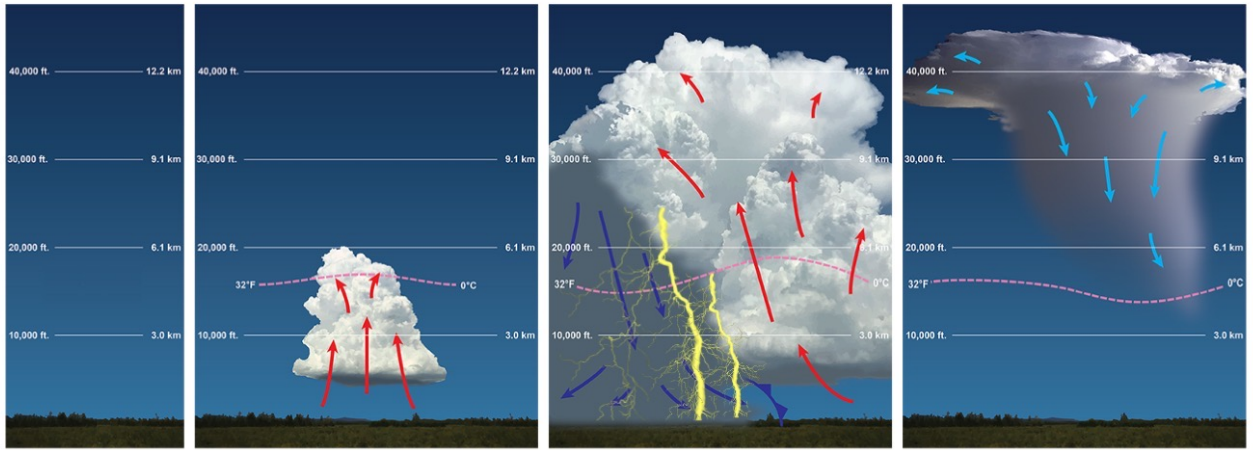
   => See next slides

3. **Machine learning and hybrid data assimilation**

   => See next slides

Precipitation data assimilation developments

In the recent years, a lot of progress has been accomplished on data assimilation of different observing systems, useful at different stages of a cloud life cycle :



Development of favorable thermo-dynamical conditions

Initiation phase

Mature phase

Dissipation phase

(Figure adapted from https://www.weather.gov/spotterguide/life)

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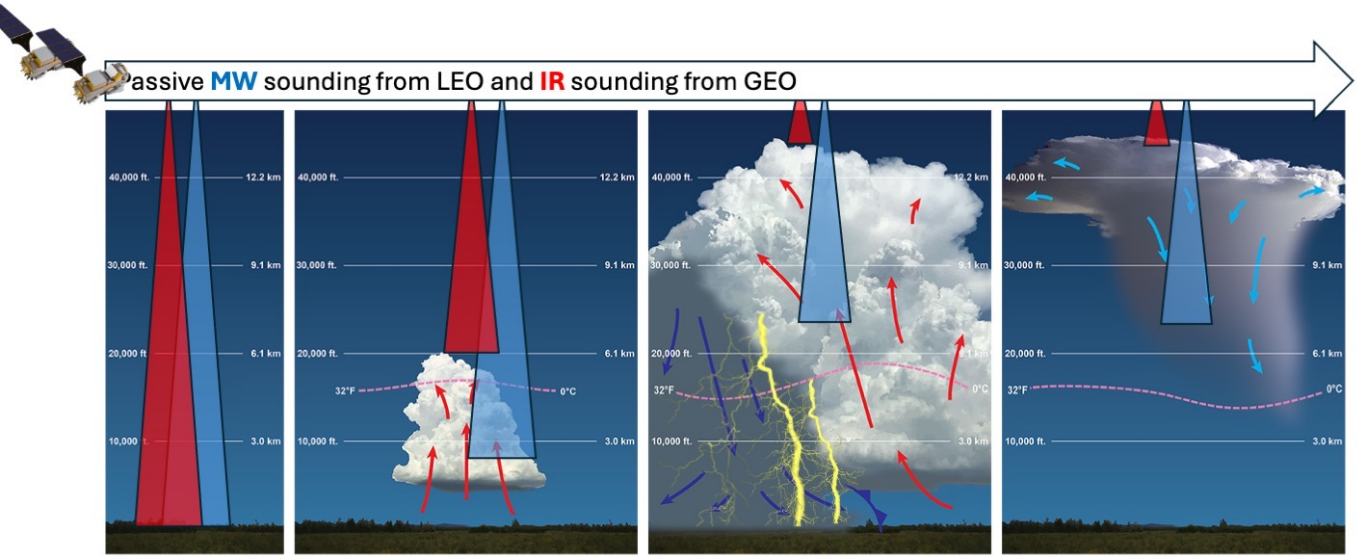
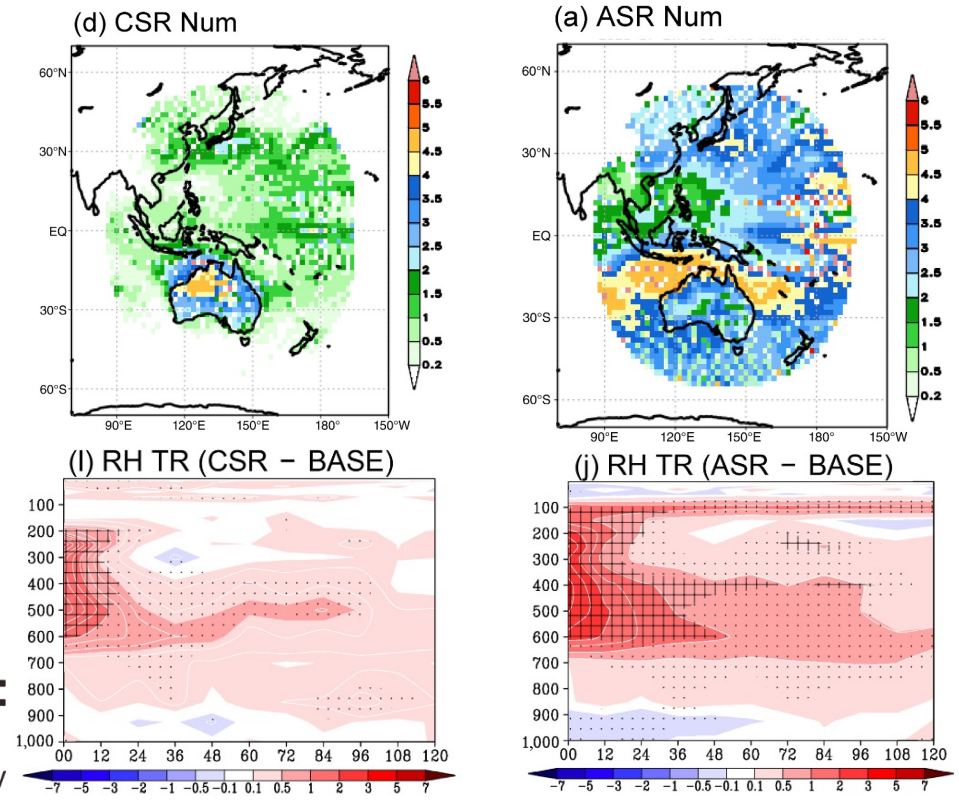


Transition from Clear Sky Radiances to Himawari AllSky Radiances



気象庁
Japan Meteorological Agency

(Okamoto et al., 2023)

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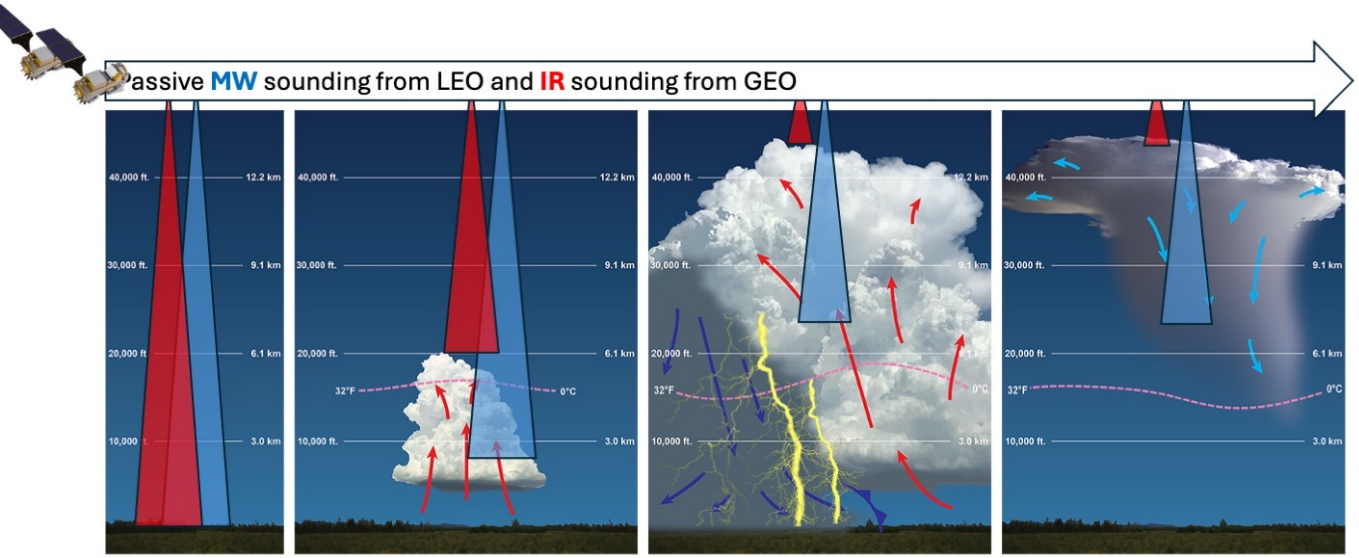
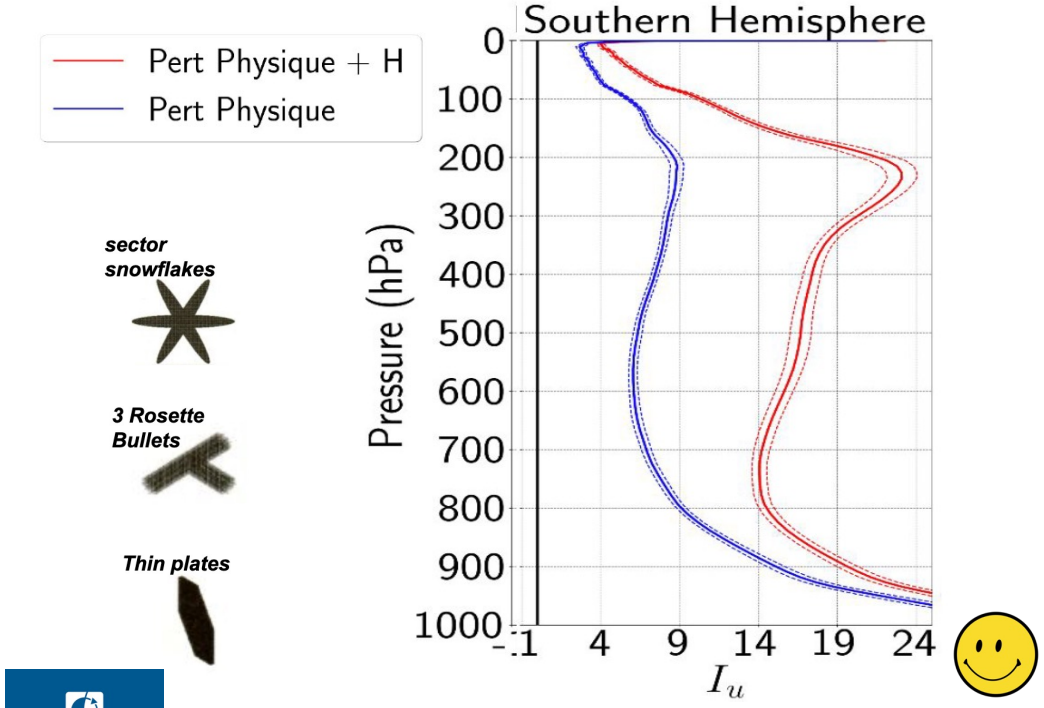


Taking into account uncertainties of the forward model within DA => perturbing the observation operator



MF EDA spread increase perturbing Physics and H

Precipitation data assimilation developments

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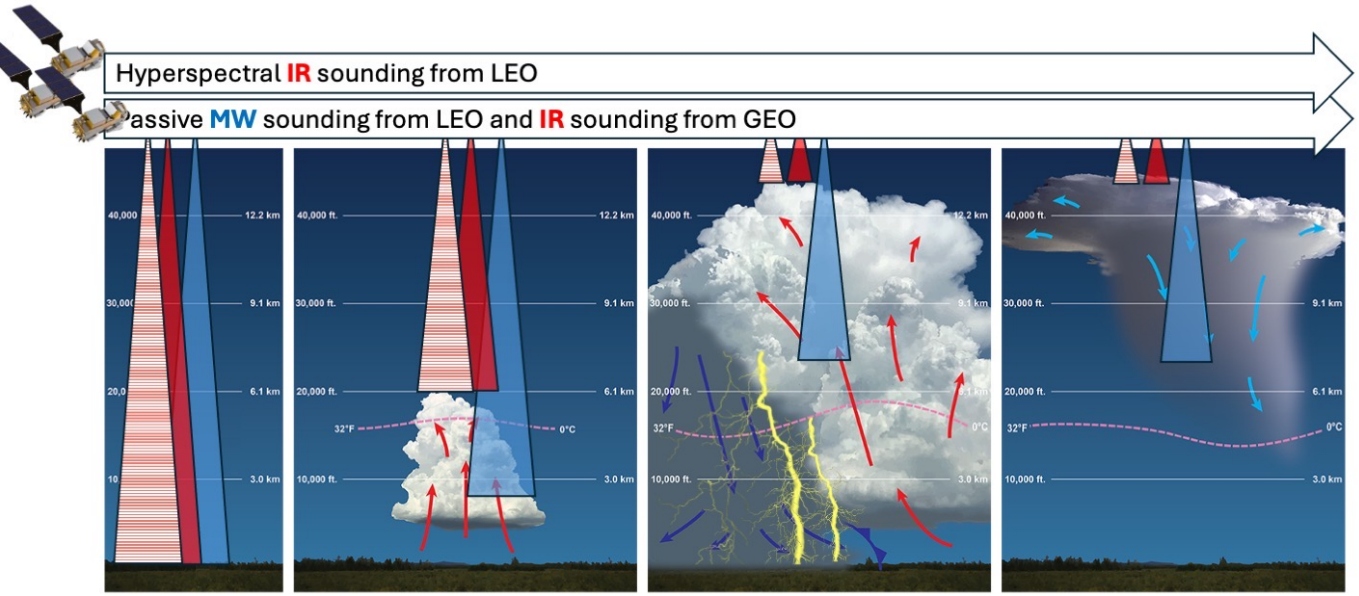
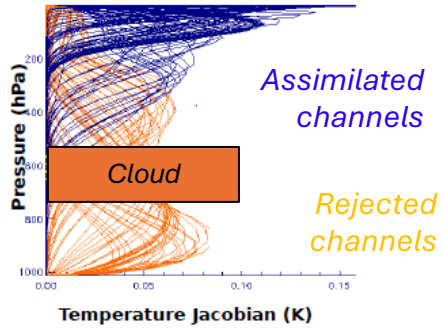
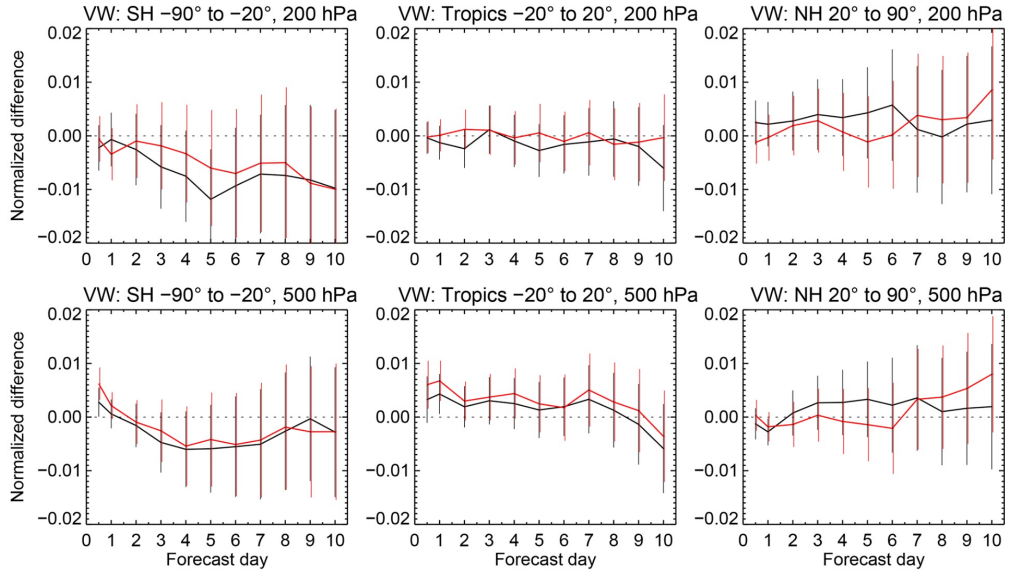


Toward the all-sky assimilation of hyperspectral IR data: Impact of 7 WV channels in allsky in the IFS

McNally & Watts cloud detection





ECMWF

(Geer et al., 2019)

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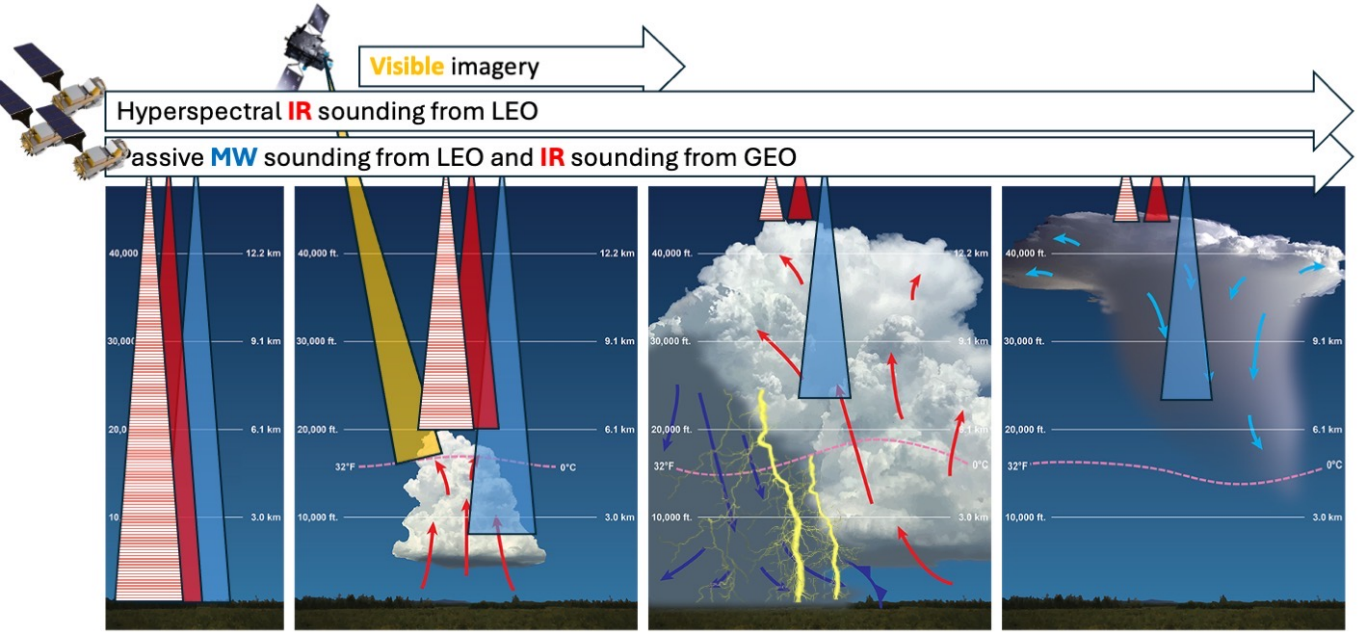
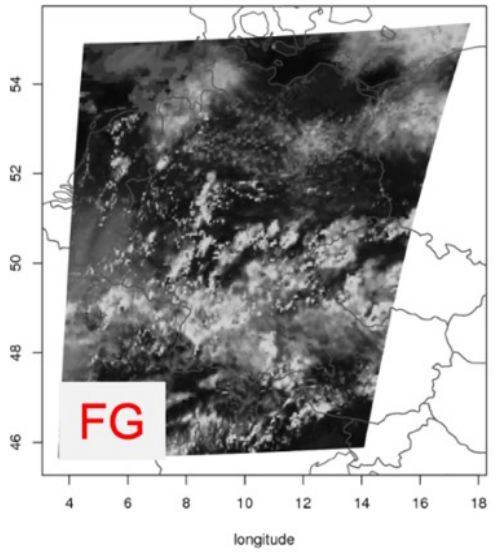
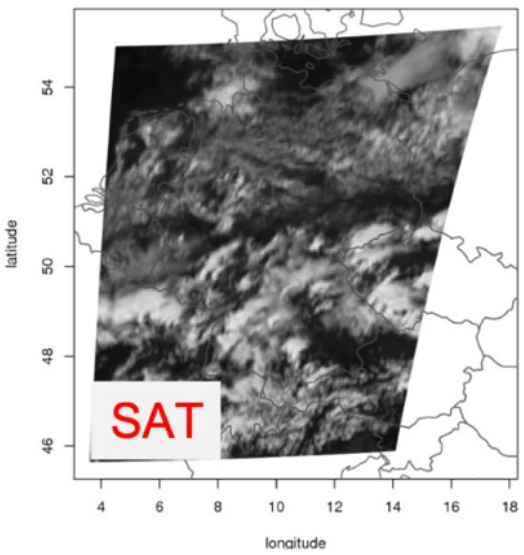
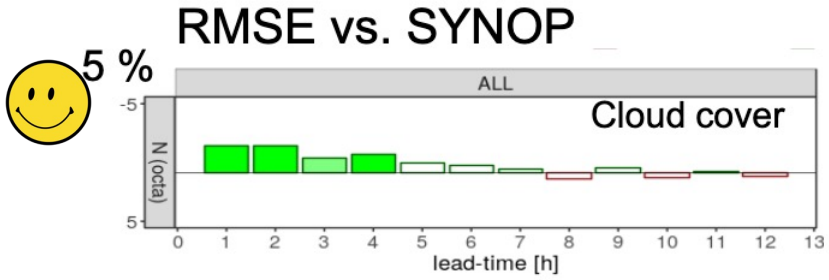


Observations SEVIRI



Simulations ICON





Precipitation data assimilation developments

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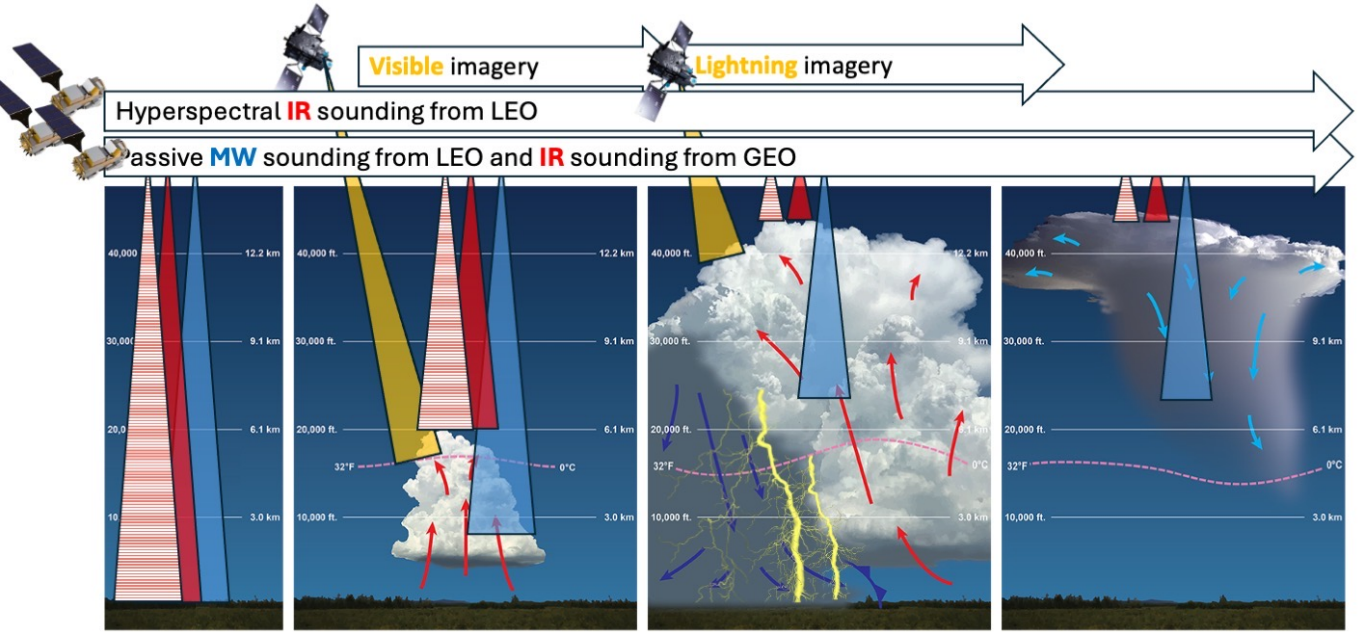
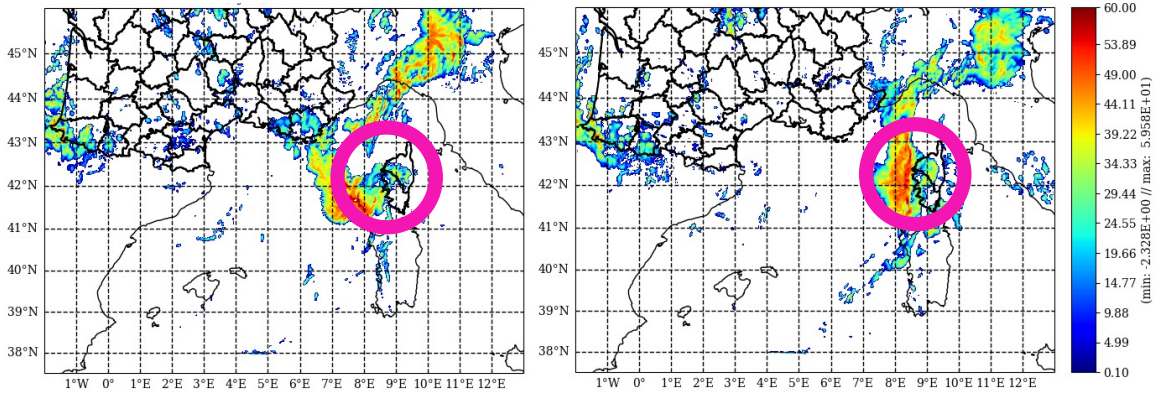


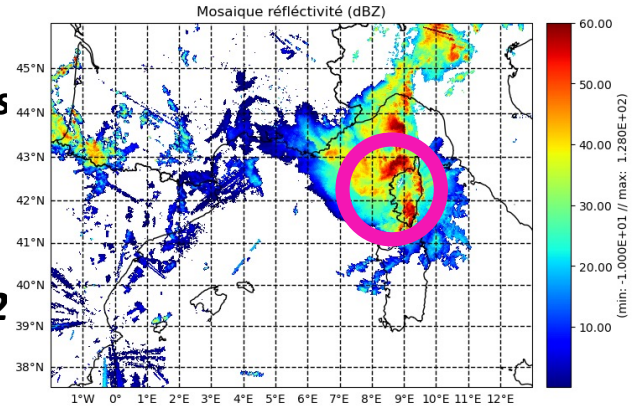
Preparing Lightning data assimilation from MTG/LI

AROME Cy48t1 (3DEnVar)

+ MTG-LI simulated with Météorage



Reflectivities observed at 7h UTC on 08/18/22



METEO FRANCE
À VOS CÔTÉS, DANS UN CLIMAT QUI CHANGE

気象庁 Japan Meteorological Agency

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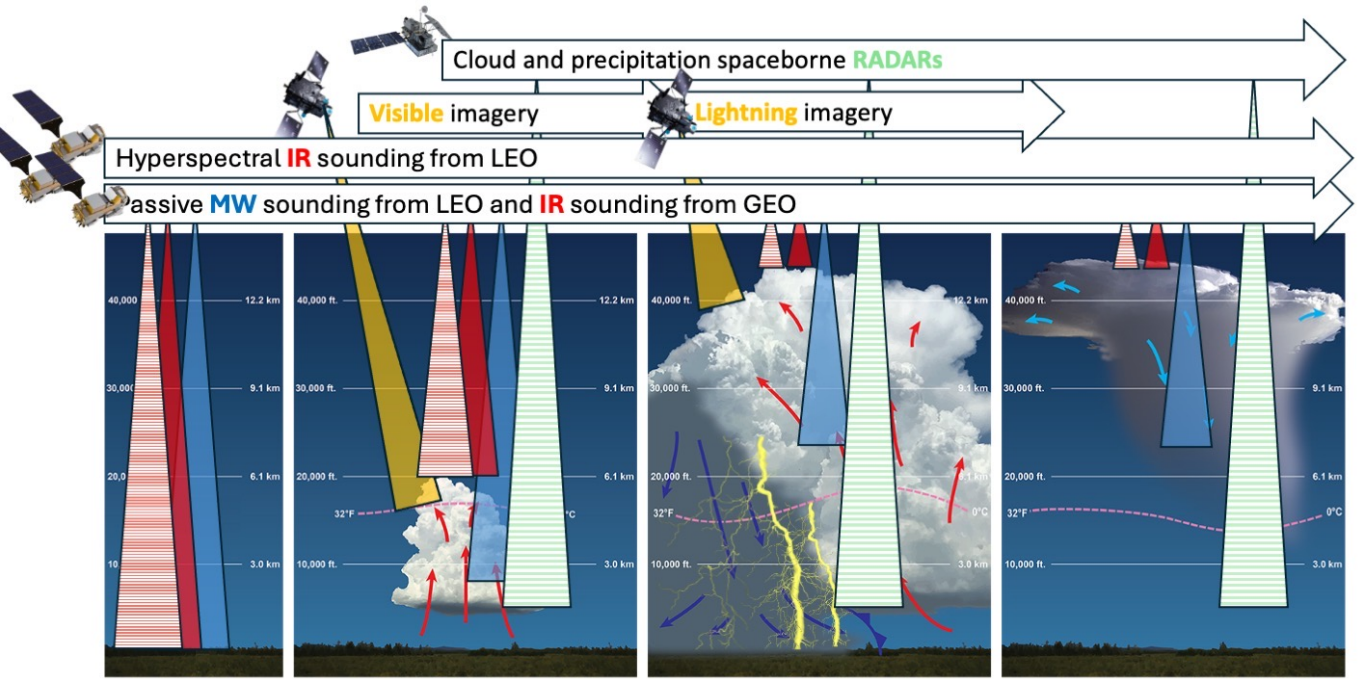
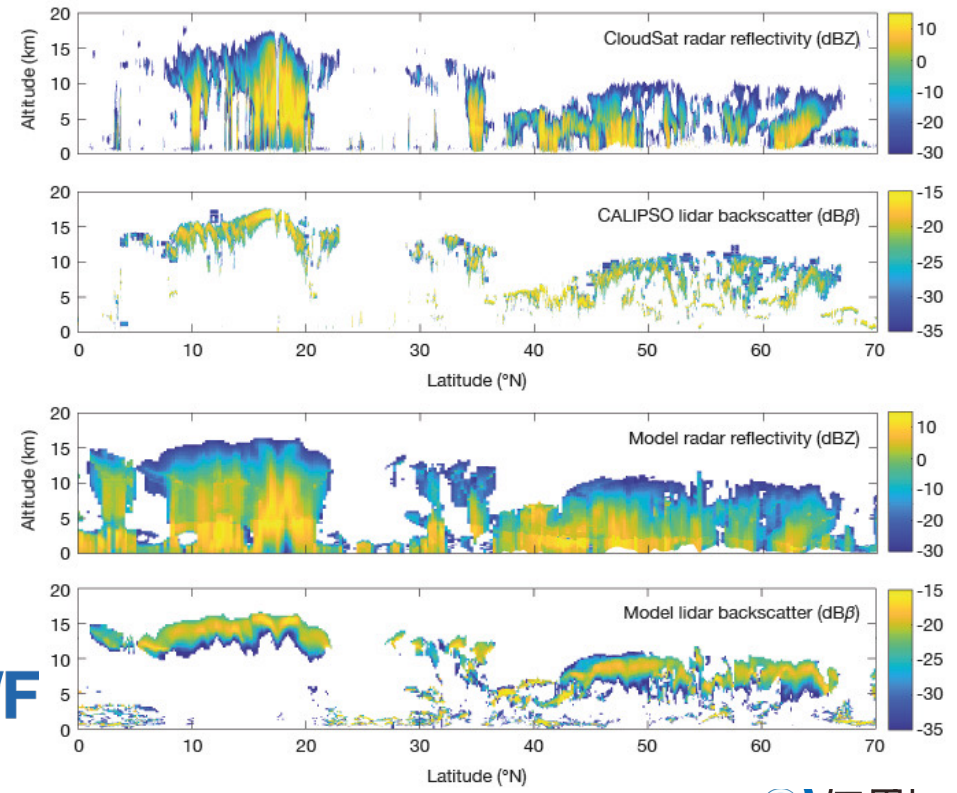


Preparing EarthCARE assimilation with Cloudsat/Calipso data



ECMWF

Japan Meteorological Agency

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Precipitation data assimilation developments

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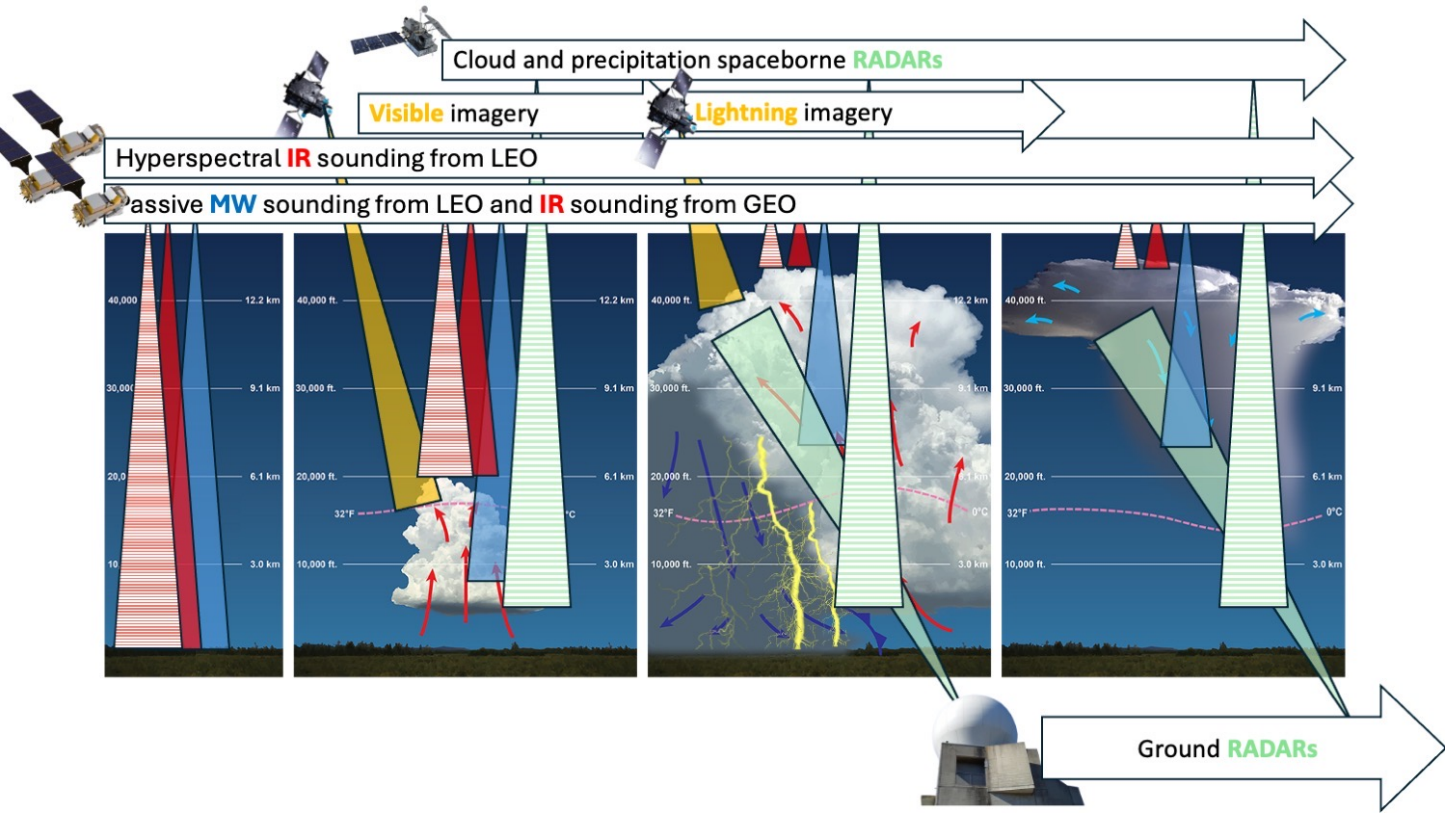
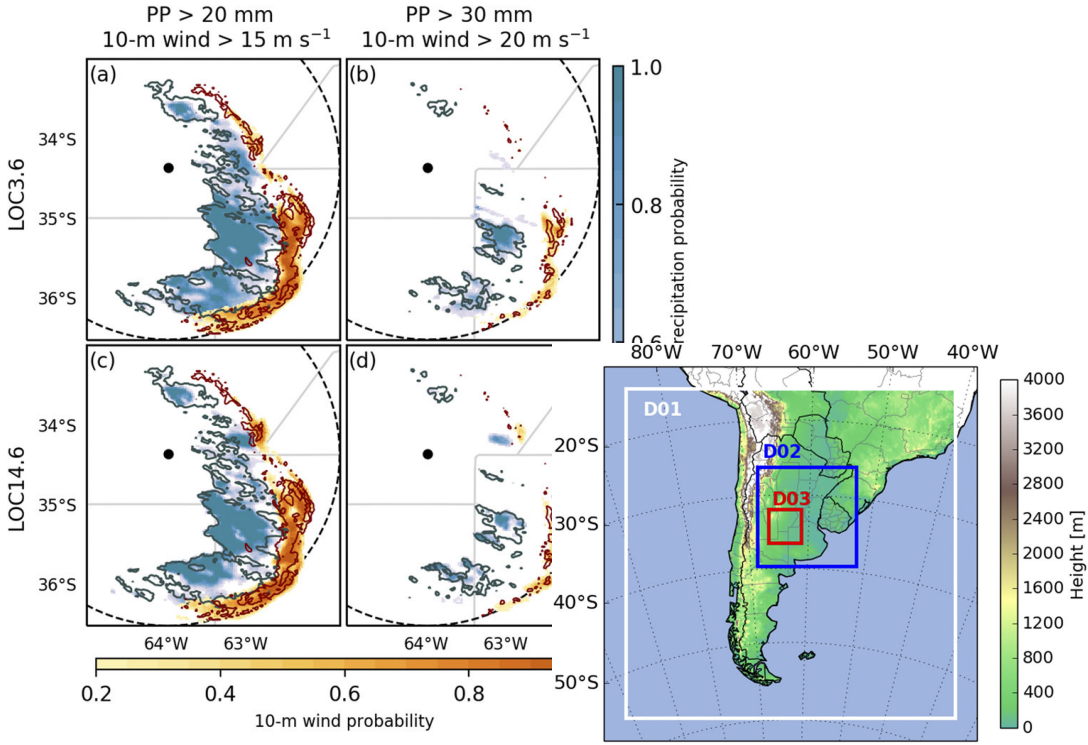


Optimizing the assimilation of ground radar data by experimenting different localization schemes



(Maldonado, Ruiz, Saulo, 2020)

UBA Universidad de Buenos Aires

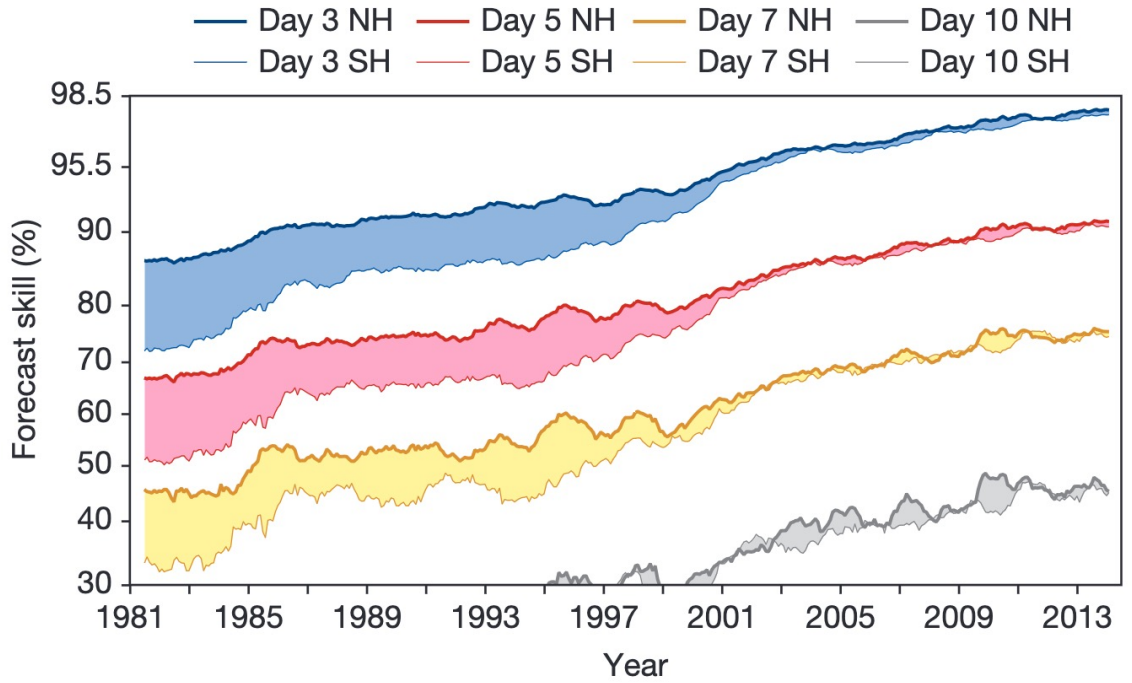
気象庁 Japan Meteorological Agency

METEO FRANCE

Upcoming evolutions in NWP

⇒ Future evolutions foreseen and research to be performed in data assimilation are strongly linked to future evolutions of Numerical forecast models.

⇒ Until recently, this field of research was performing a **"quiet revolution"** (Bauer et al., 2015), with NWP systems gaining in forecast skills of about ~1day/decade, considering improvements in model physics, data assimilation algorithms, usage of new observations, …

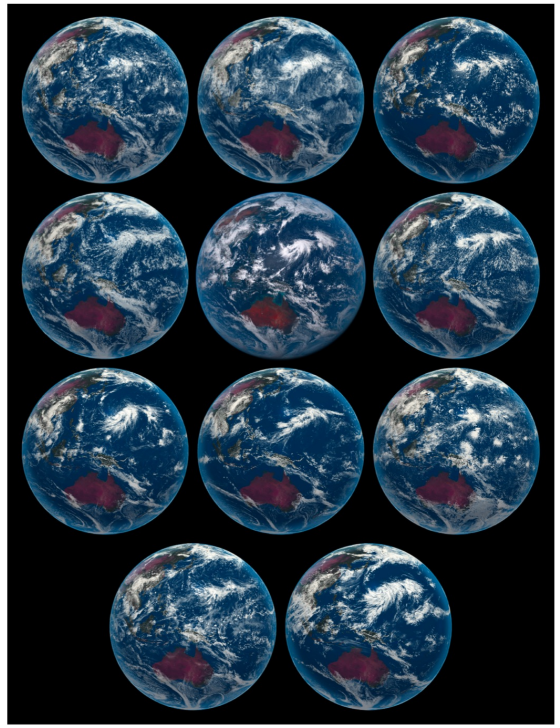


(Bauer et al., 2025)

Upcoming evolutions in NWP

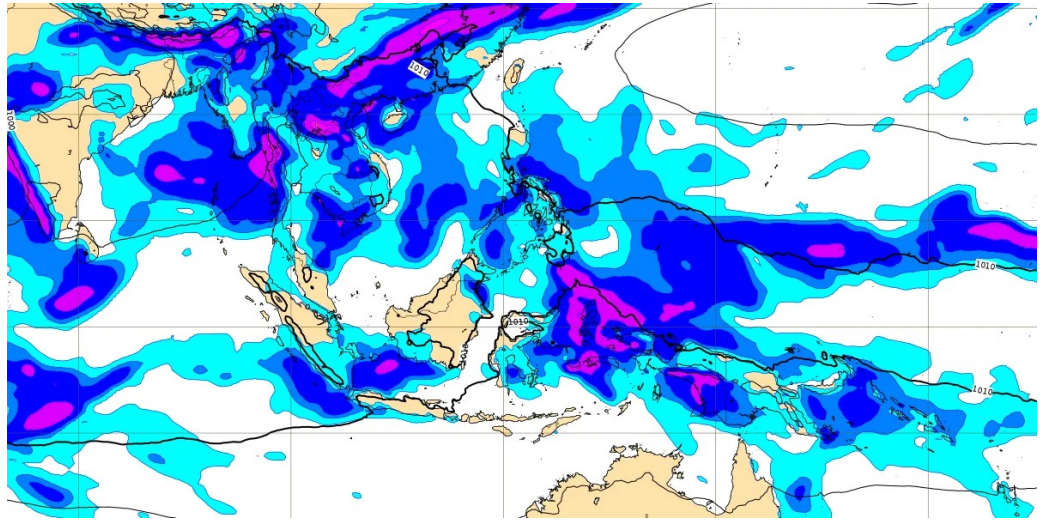
Research on two major evolutions is ongoing with very different upcoming challenges for data assimilation :

Kilometric scale modeling of the Earth system



(Source : Stevens et al. 2019)

Numerical forecasts with AI-based models

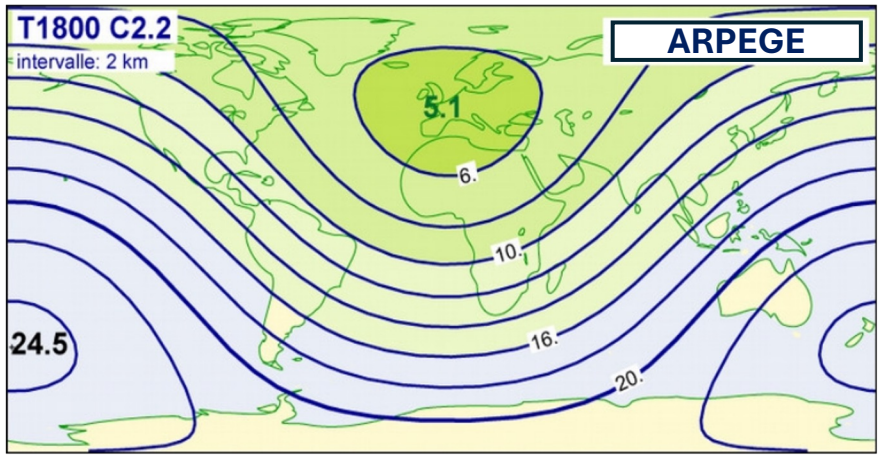


(Source : ECMWF, AIFS ML model)

Upcoming evolutions in NWP

Challenges related to the initialization of Kilometric scale modeling of the Earth system

The current generation of NWP systems already suffer from a lack of constrain on its initial conditions with the current observing system.



~8.10^6 observations assimilated every 6 hours for ~200.10^6 variables to initialize


Radiosondes

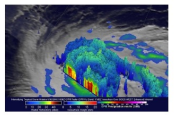

Surface stations

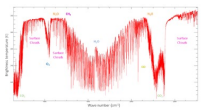

Aircraft data

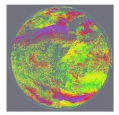

GNSS ground receivers


Wind lidar


Ground radar

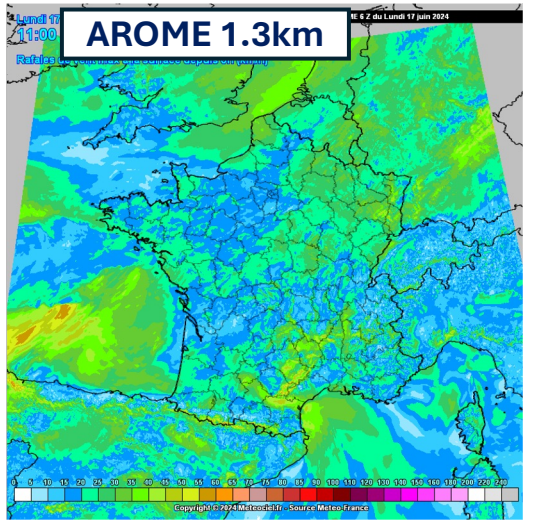

Microwave sounding from space


Infrared sounding from space


Winds derived from imagery


Scatterometer


GNSS Radio-occultation



~100 000 observations assimilated every hours for ~800.10^6 variables to initialize

Upcoming evolutions in NWP

Challenges related to the initialization of Kilometric scale modeling of the Earth system

On the quality of the rain forecasts :

⇒ With its expertise on validation, can IPWG support the validation of precipitation forecasts of these high-resolution global forecasts ?

On the initialization methods and tools :

=> Continued exchange on radiative transfer and scattering and specific needs at km scale

On the observational needs :

⇒ With its expertise on precipitation science, can IPWG help identifying the physical processes which need an observational constraint at high resolution to make sure this new generation of model will provide forecasts at their full potential ?

⇒ Thanks to its strong links with CGMS, can IPWG provide guidance to CGMS members on the future observing system needed to provide appropriate high resolution initial conditions of clouds and precipitation ?

Example of Rain and mean sea level pressure

Tue 25 Jun 2024 00 UTC (T+12)

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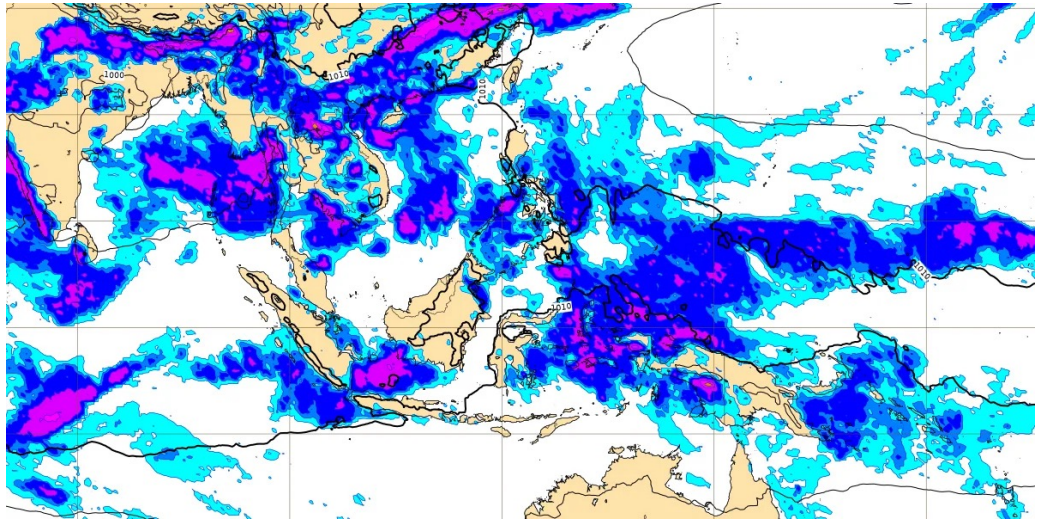
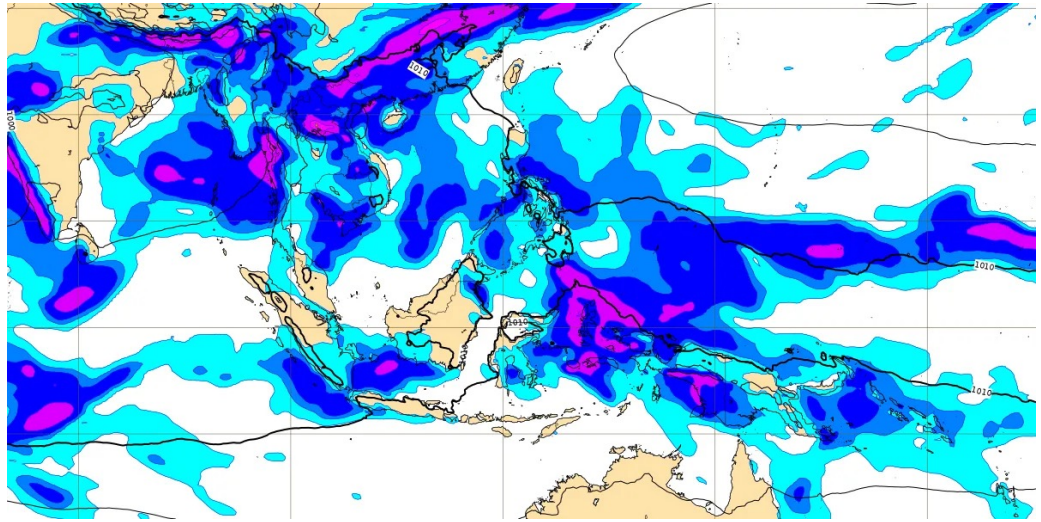
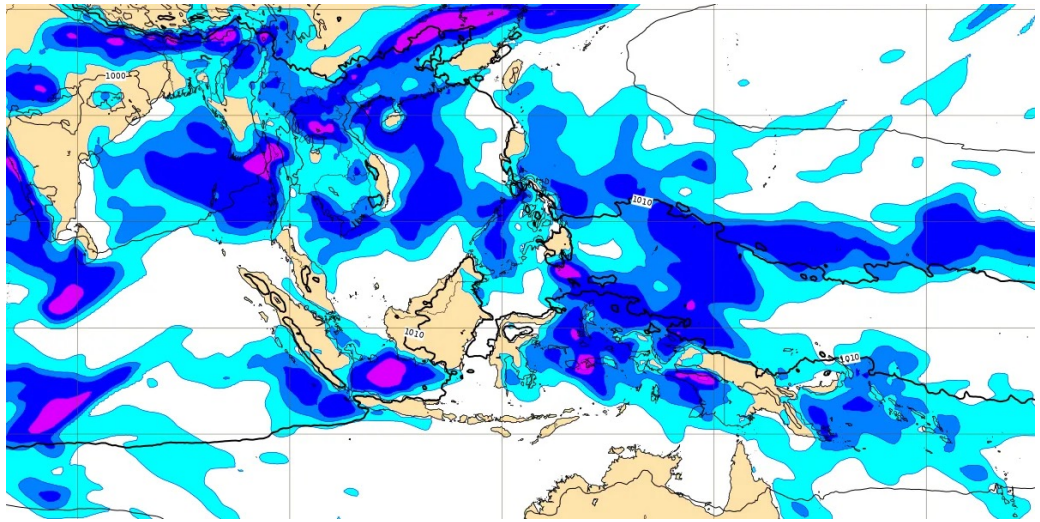
IFS High resolution forecast



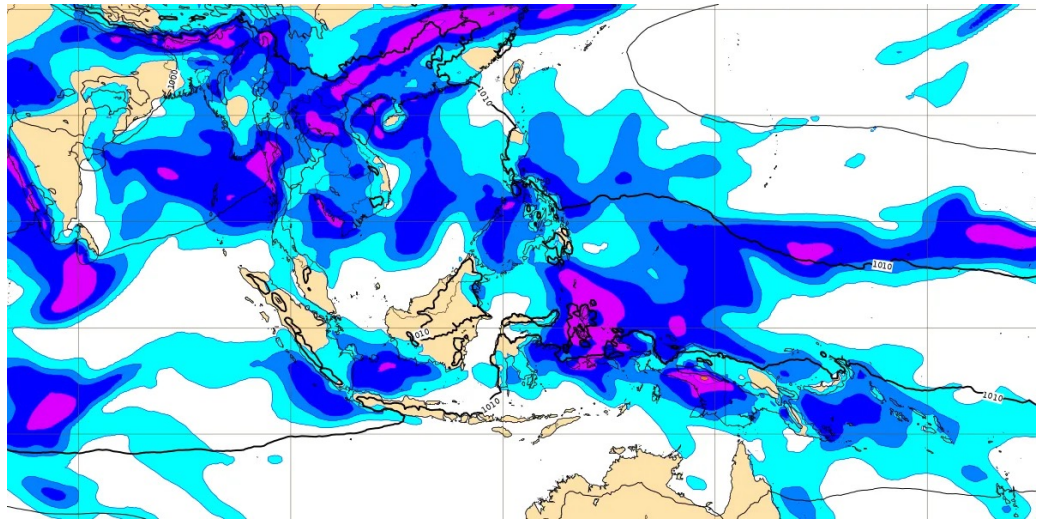
AIFS (ECMWF) ML model



FuXi ML model



GraphCast ML model



Runs of different AI-based models performed at ECMWF, initialized with the same analysis

ECMWF

Example of Rain and mean sea level pressure

Tue 25 Jun 2024 00 UTC (T+24)

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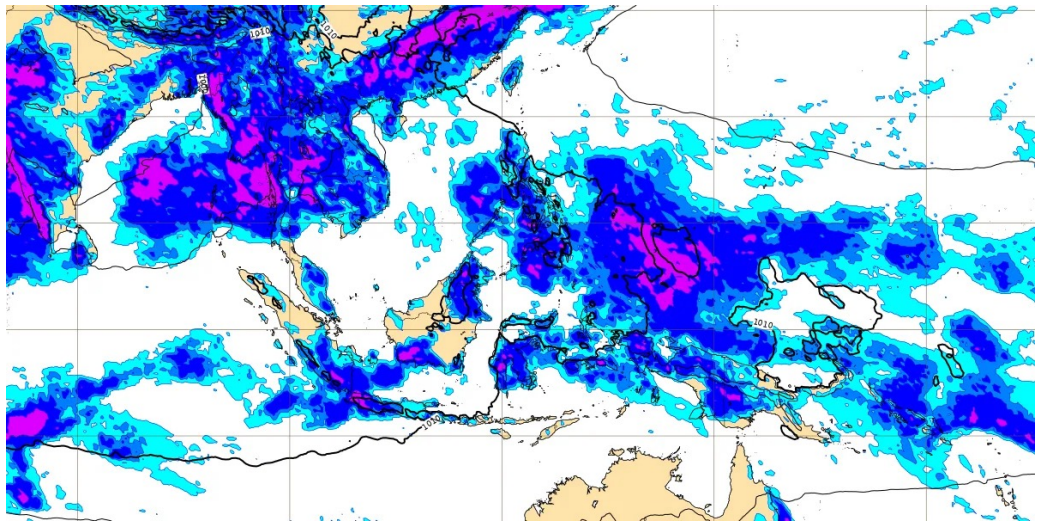
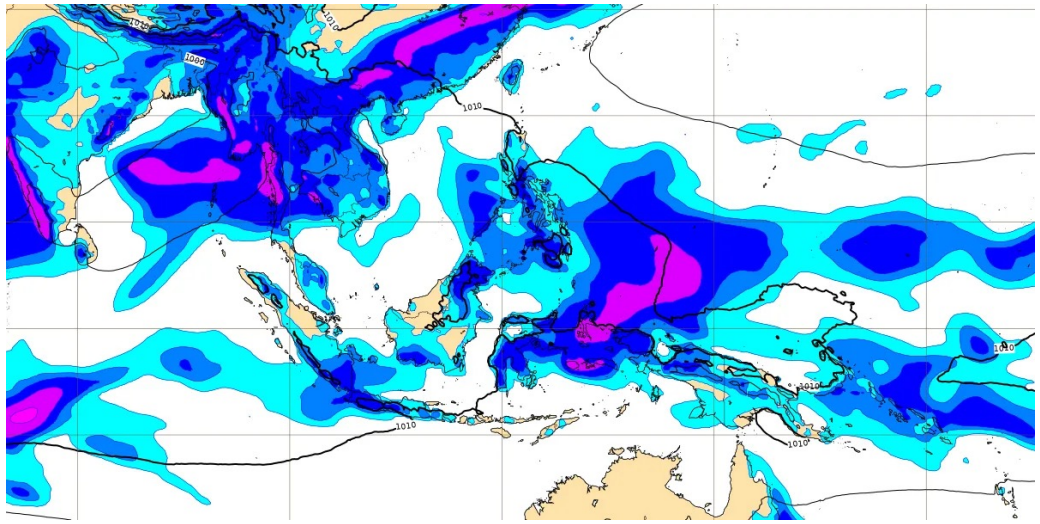
IFS High resolution forecast



AIFS (ECMWF) ML model



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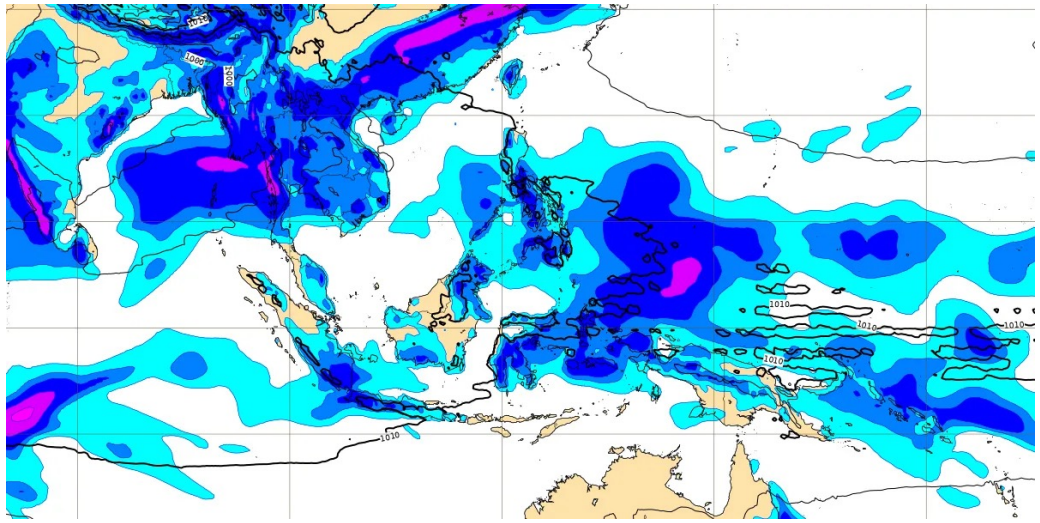

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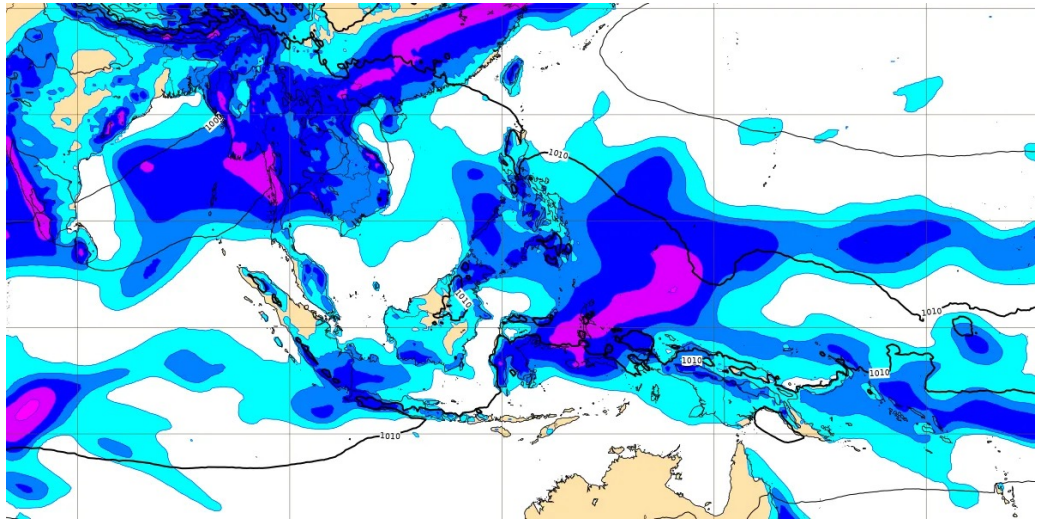

Runs of different AI-based models performed at ECMWF, initialized with the same analysis

ECMWF

Example of Rain and mean sea level pressure

Tue 25 Jun 2024 00 UTC (T+36)

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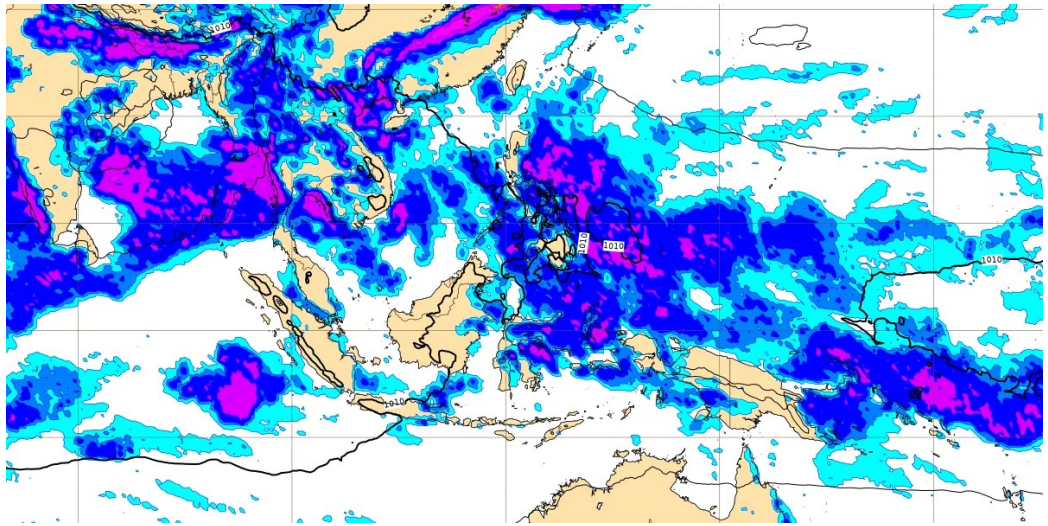
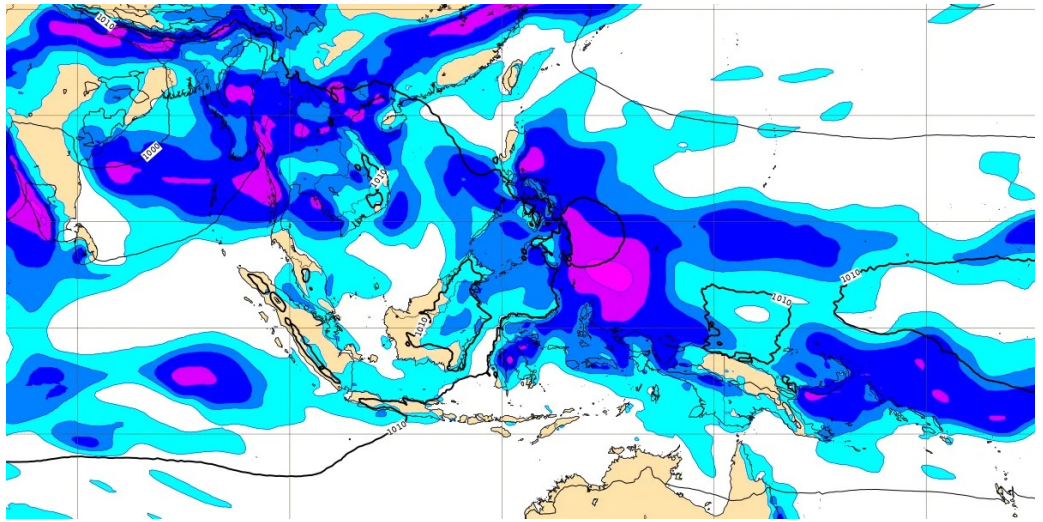
IFS High resolution forecast



AIFS (ECMWF) ML model



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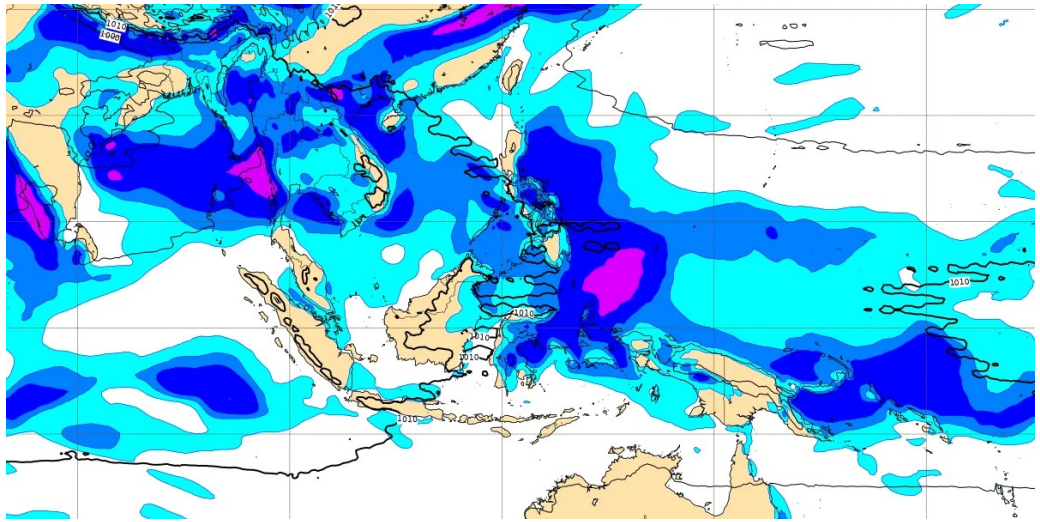

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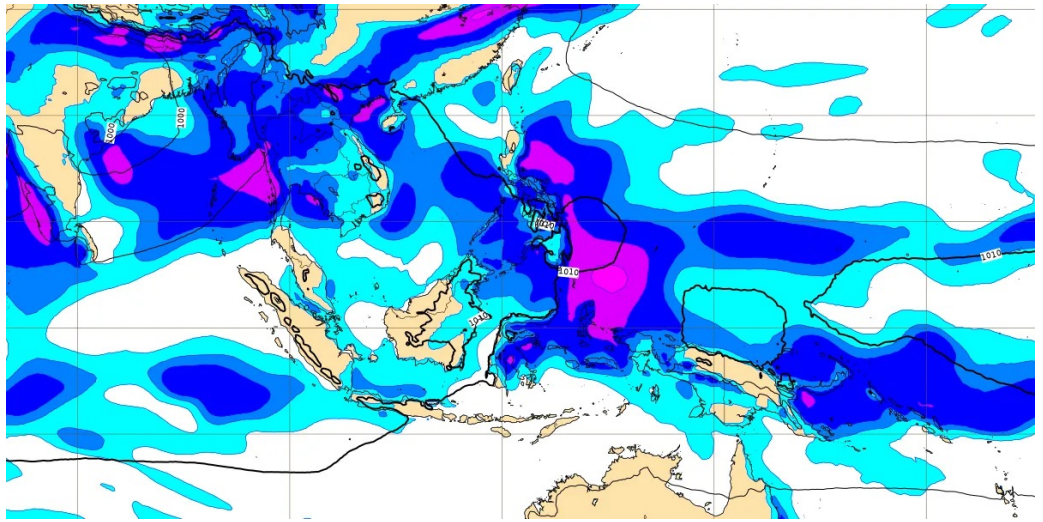

Runs of different AI-based models performed at ECMWF, initialized with the same analysis

ECMWF

Example of Rain and mean sea level pressure

Tue 25 Jun 2024 00 UTC (T+48)

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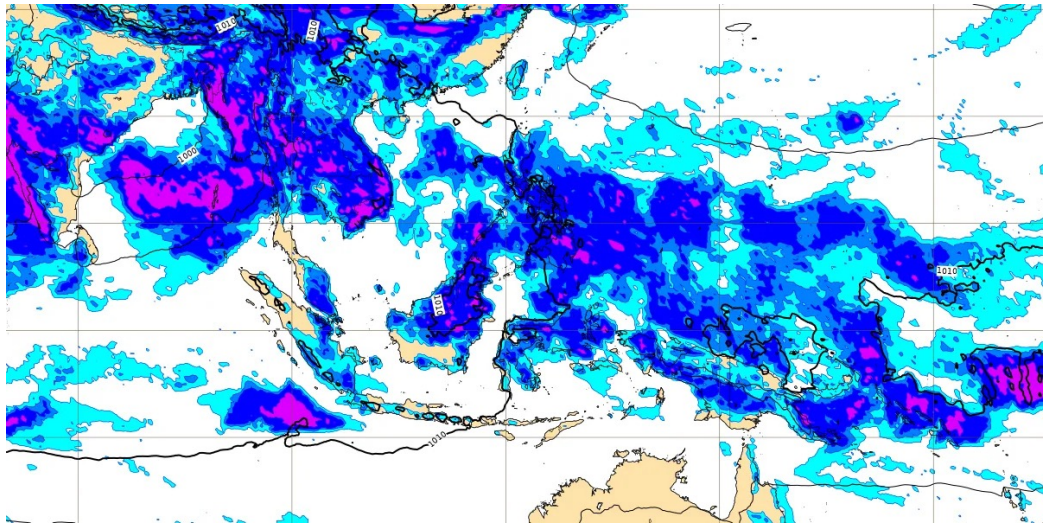
IFS High resolution forecast



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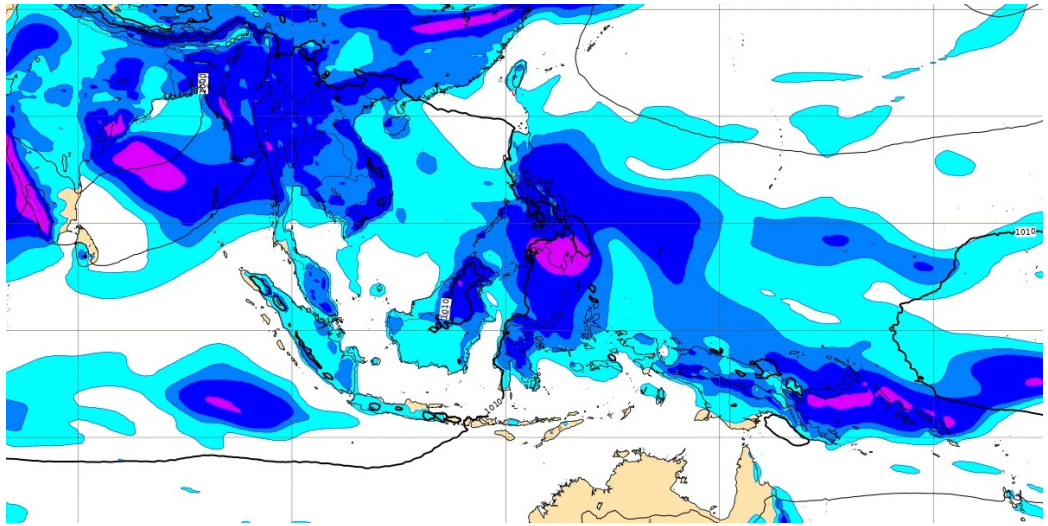

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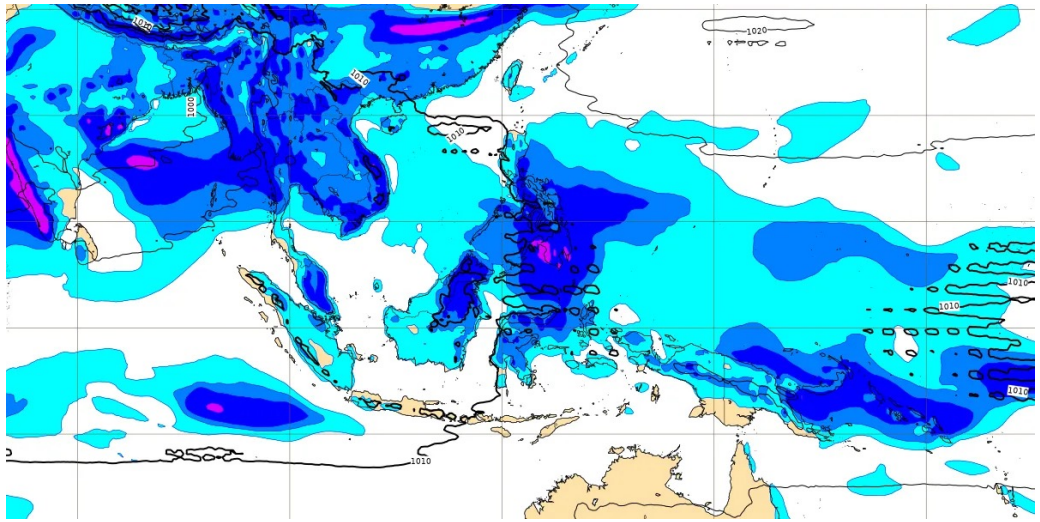

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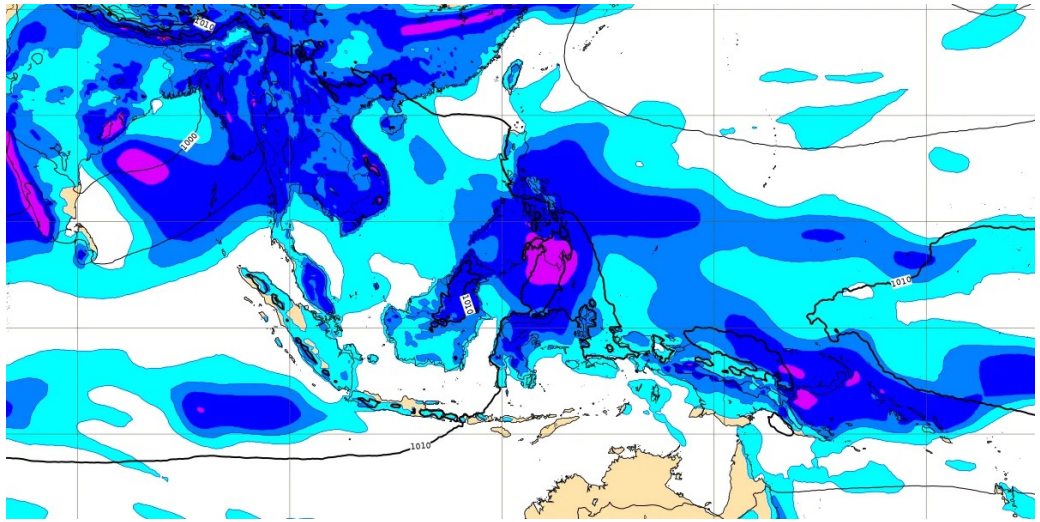

Runs of different AI-based models performed at ECMWF, initialized with the same analysis

ECMWF

Example of Rain and mean sea level pressure

Tue 25 Jun 2024 00 UTC (T+240)

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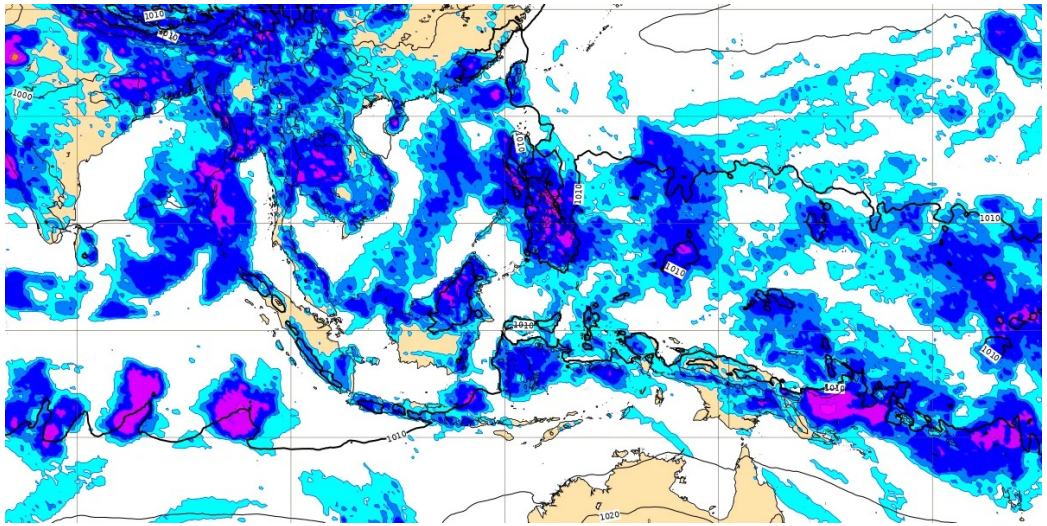

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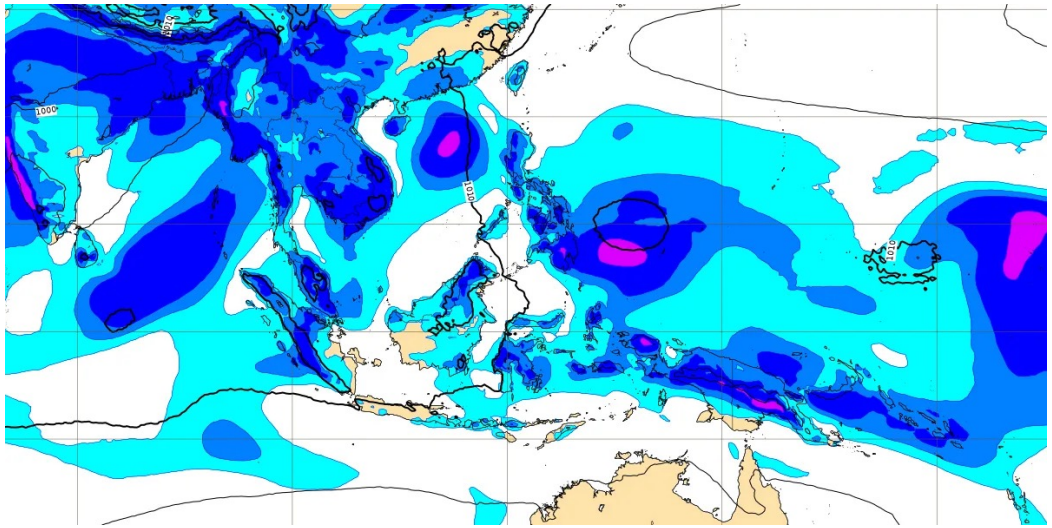
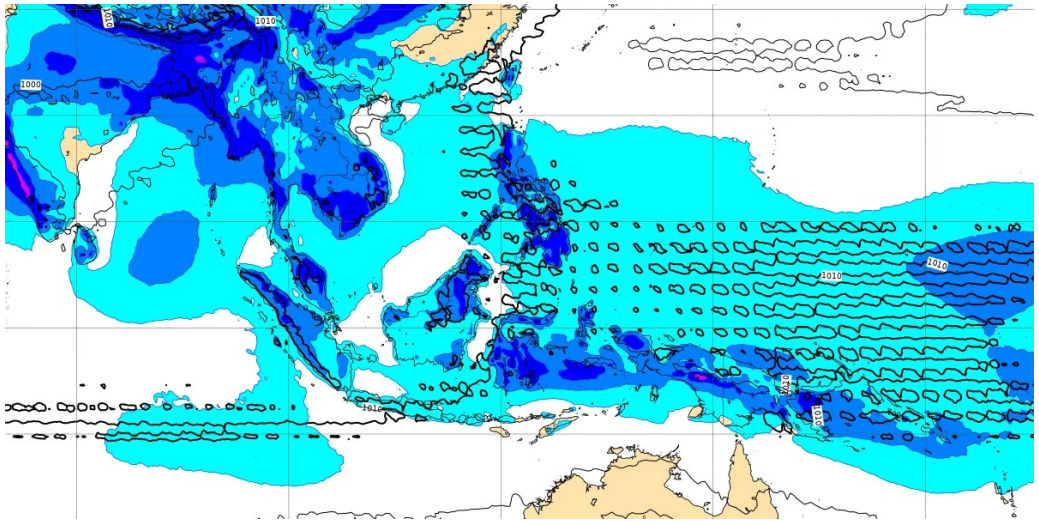
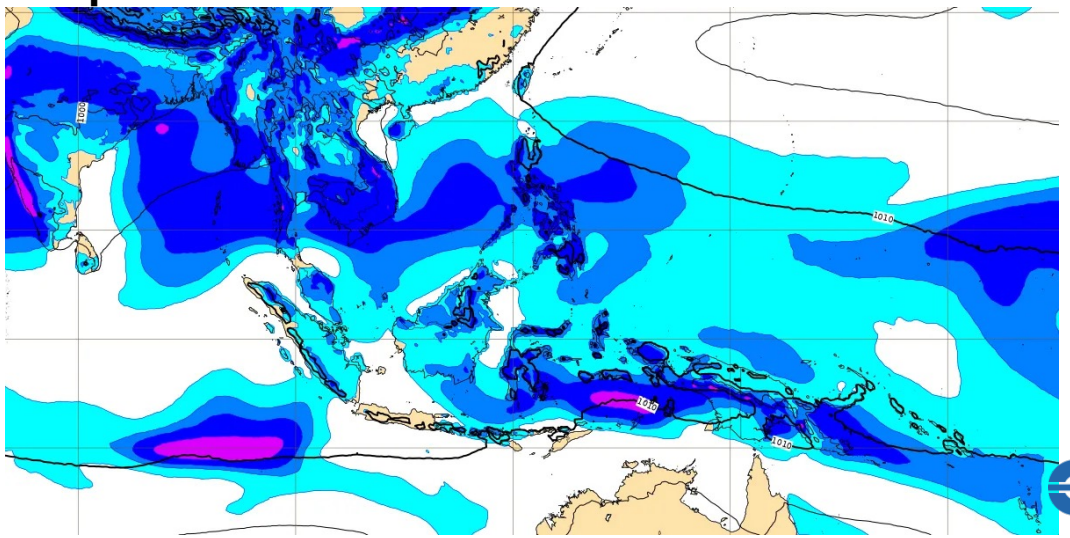


FuXi ML model



GraphCast ML model



Runs of different AI-based models performed at ECMWF, initialized with the same analysis

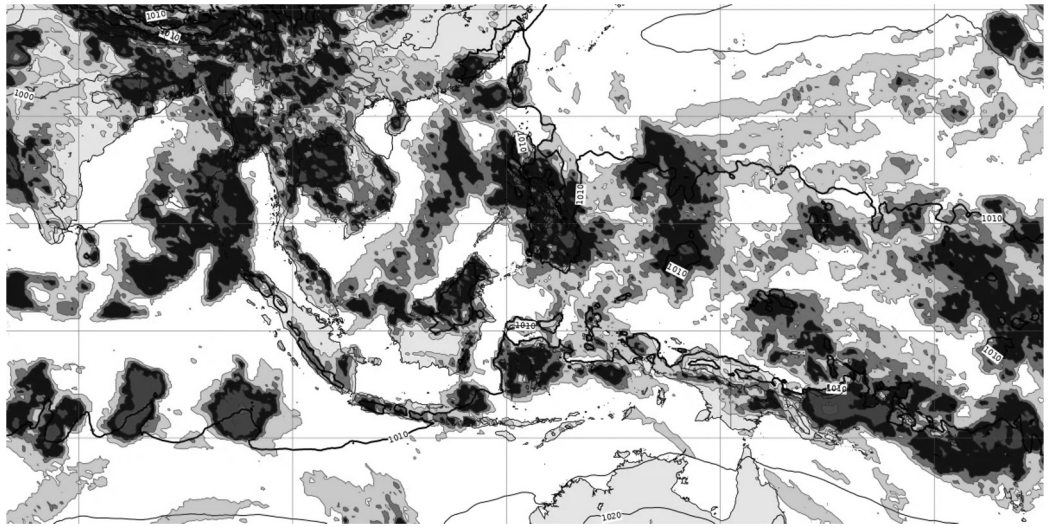
ECMWF

Example of Rain and mean sea level pressure

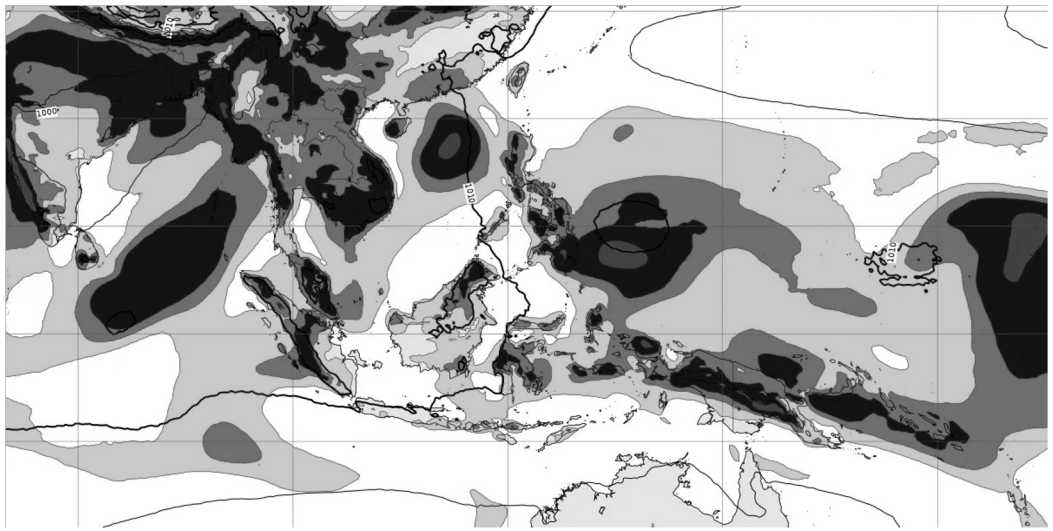
Tue 25 Jun 2024 00 UTC (T+240)

IPWG International Precipitation Working Group

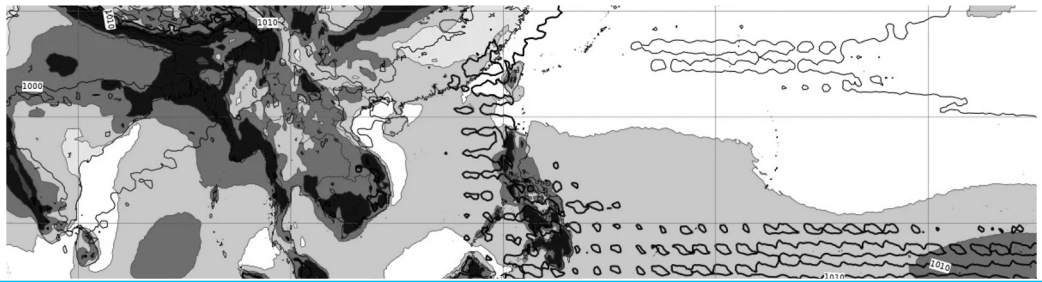
IFS High resolution forecast



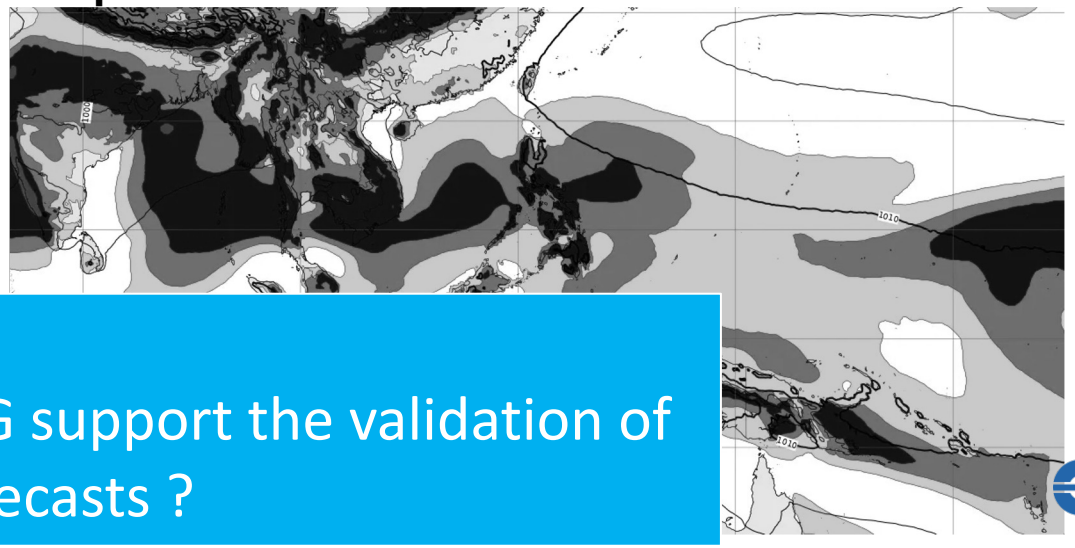
AIFS (ECMWF) ML model



FuXi ML model



GraphCast ML model



Runs of different AI-based models performed at ECMWF, initialized with the same analysis

On the quality of the rain forecasts :

⇒ With its expertise on validation, can IPWG support the validation of precipitation forecasts of these global forecasts ?

ECMWF

Upcoming evolutions in NWP

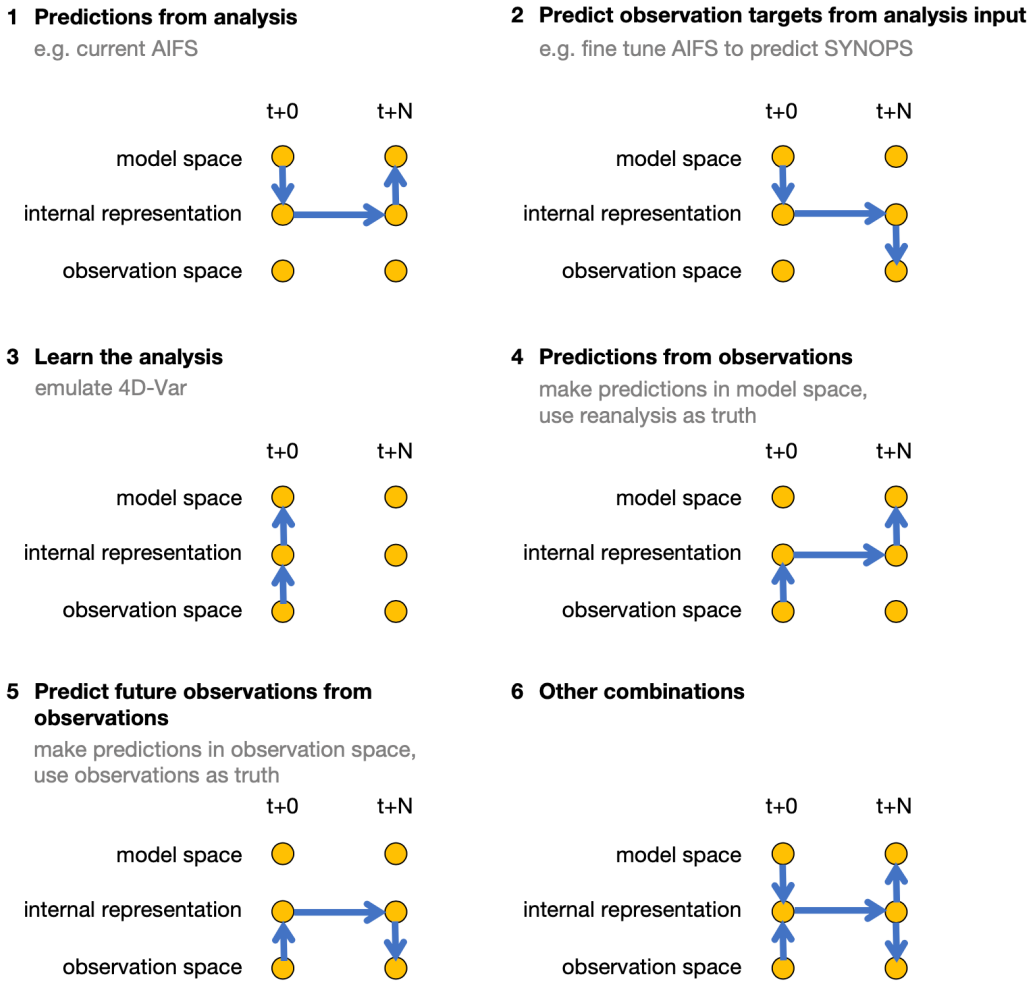
Challenges related to the initialization of AI-based models

On the initialization techniques :

⇒ will AI be more used within the current initialization DA systems (e.g. replacement of an observation operator, a scattering database, a given quality control),

⇒ or by emulating fully a DA systems ?

⇒ can forecasts be initialized directly from observations ?



(Source : McNally et al. ECMWF Newsletter Number 178 – Winter 2023/24)

Proposed organization of the discussion:

1. Discussion on the immediate needs/latest findings for data assimilation in cloudy and precipitating areas with current NWP systems

2. Discussion on the challenges related to the initialization of Kilometric scale modeling of the Earth system

3. Discussion on the challenges related to the initialization of AI-based models