Exploring Using Artificial Intelligence (AI) to Exploit Big Satellite Data for NowCasting and NWP

- Focus on JPSS-related Applications/Sensors-

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JPSS Meeting, College Park, MD, August 27-30th 2018

Agenda

1 **Why Artificial Intelligence (AI) ? Background and Motivations**

2 **What are we exploring using AI for?**

3 **JPSS-related Examples of AI Applications:**

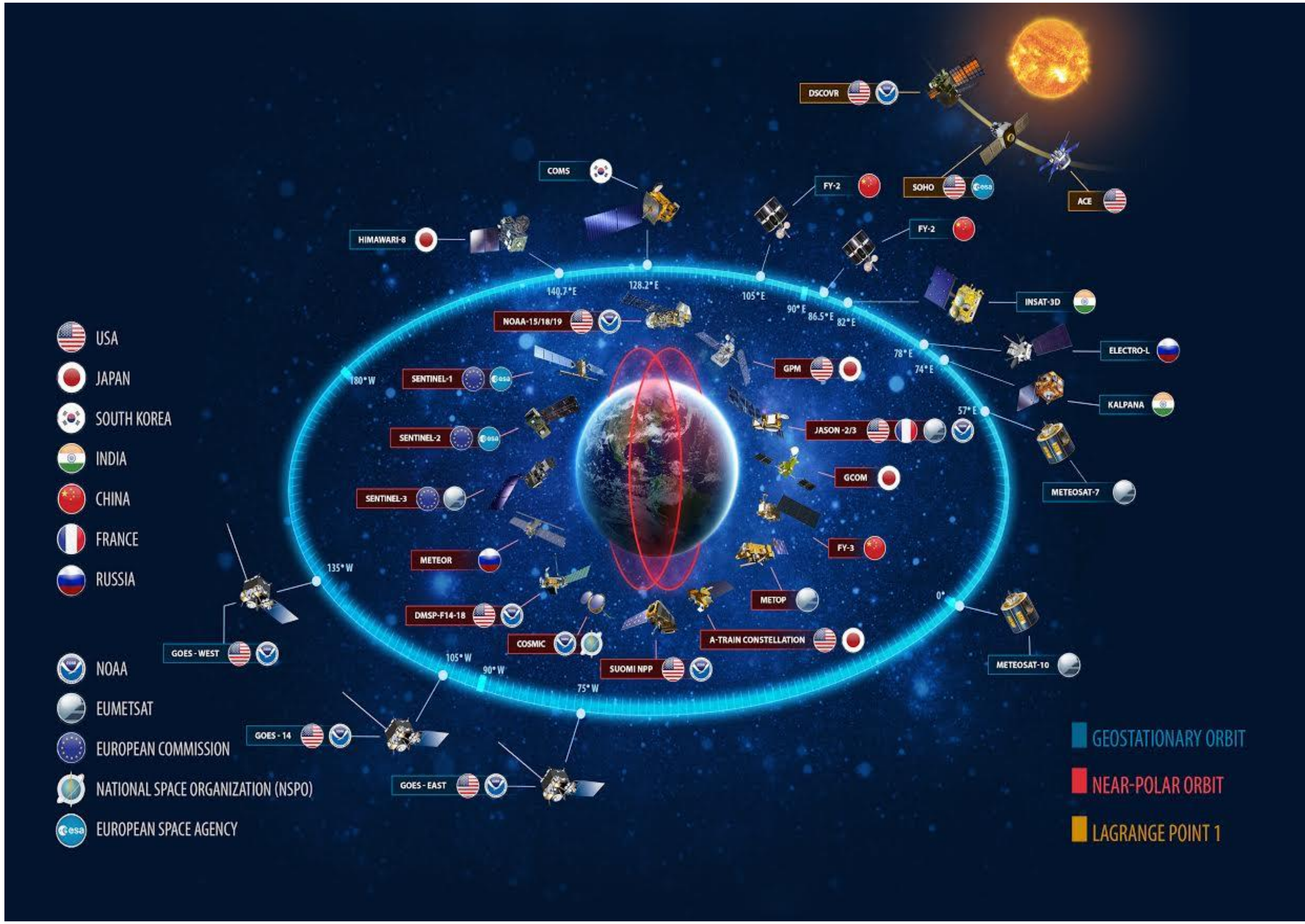
- Remote Sensing Algorithms (next-Gen Algorithms)
- Radiative Transfer
- Data Fusion / Nowcasting & Data Assimilation
- Exploiting Satellite data for Supporting Prediction
- Morphing

4 **Conclusions**

Trends in Global Earth Observation Systems

- **GOS Trends:**
  - New Players in GOS (international, commercial, etc)
  - New Sensors (higher resolutions, etc)
  - New technologies (small sats, etc)
  - Emergence of New GOS (IoT, etc)
  - **Significant Increase in volume and diversity of data**

- **Parallel Trends**
  - Budget, HPC Constraints
  - Higher societal impact and expectations
  - Higher users expectations
  - Demand for Increase in quantity of data assimilated (5% currently assimilated)



Why Consider AI to address these Challenges?

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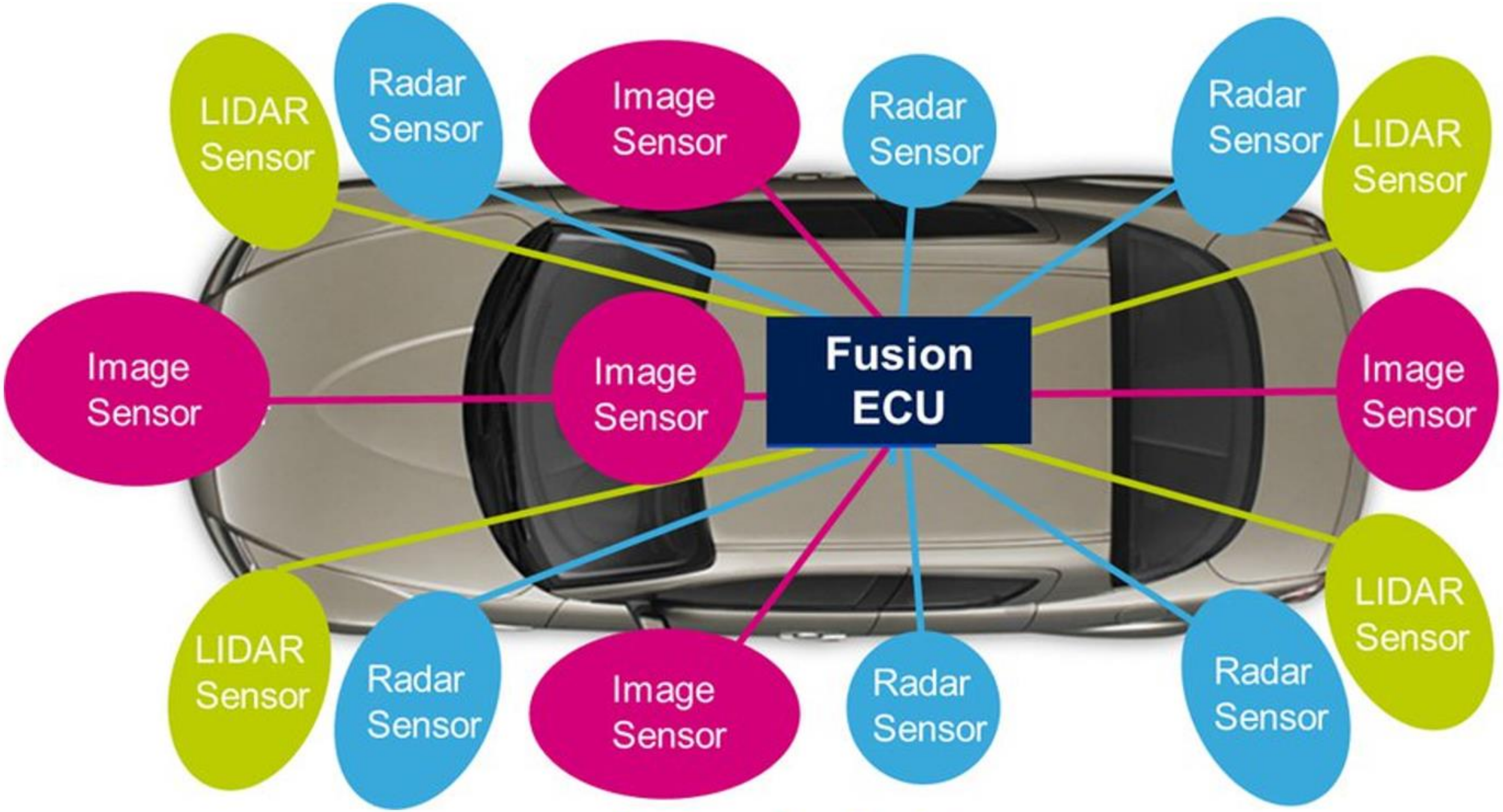
Example of Autonomous Vehicles Using AI

(Similarities to Satellite Data Use in Earth Observation and Nowcasting/NWP)



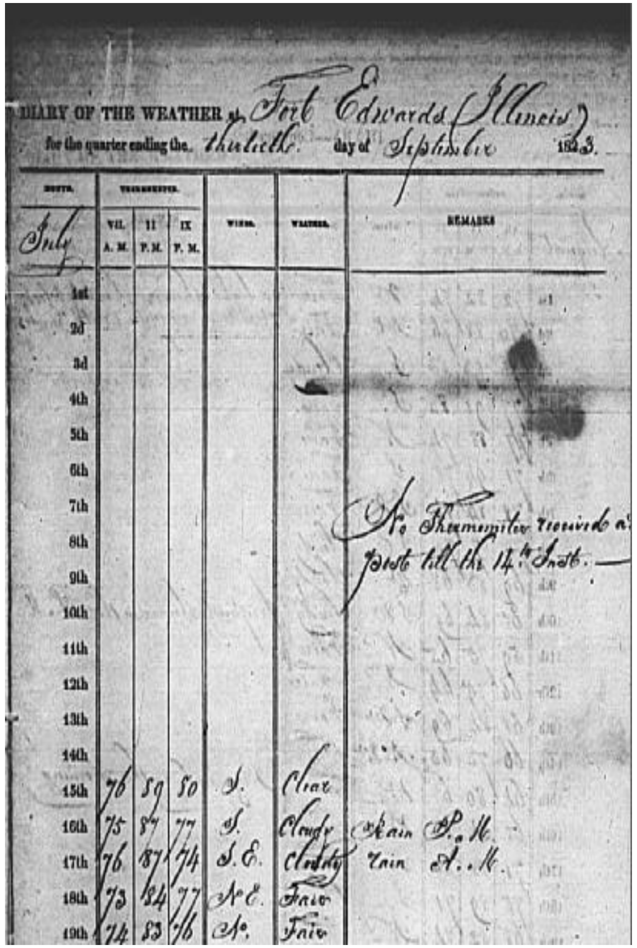
Reference: Sensors Magazine published ST article "Three Sensor Types Drive Autonomous Vehicles" by Gert Rudolph and Uwe Voelzke:

Evolution of Environmental Data Exploitation

This evolution applies to all areas of computing.

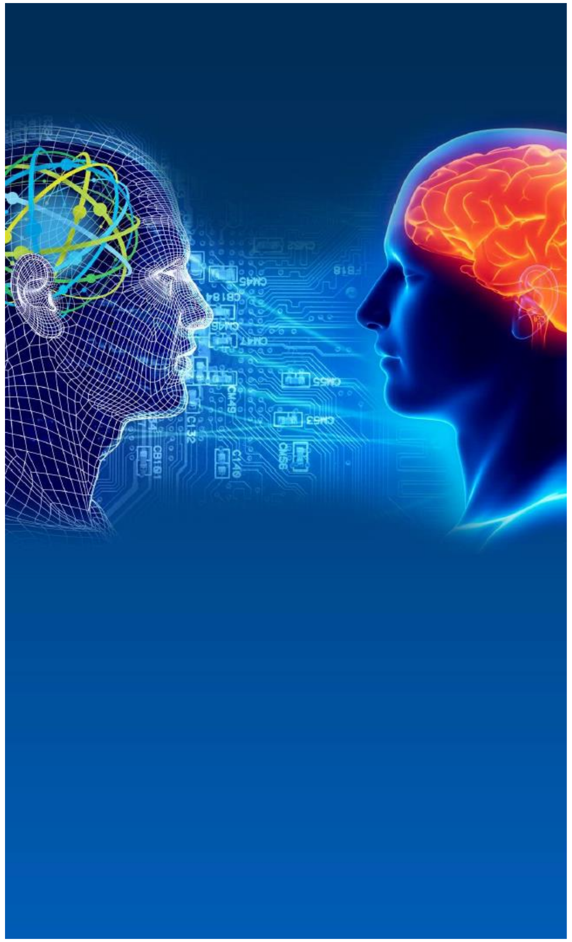
It has led several major companies to adapt their business models to take advantage of AI

Credit: Materials adapted for Environmental Observations specifically, inspired from an IBM presentation by Dr John Kelly, senior vice president, cognitive solutions, to the NOAA Science Advisory Board (SAB) on November 2016



Tabulating Systems Era
(1800-1940s)
Manual Measurement and analysis

Programmable Intelligence Era
(1950-Now)
Transformational efficiency in Applying Human Intelligence

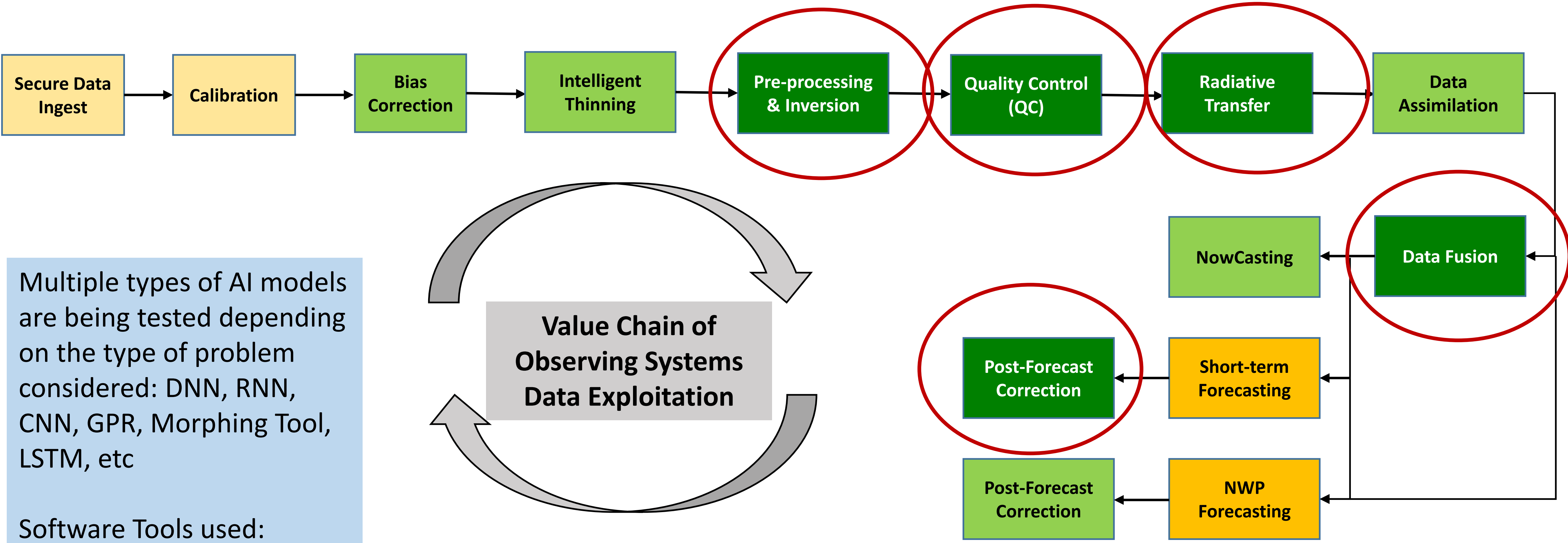


Cognitive Computing –AI Era
(2011- Foreseeable Future)
Enhancement/Augmentation of Human Intelligence

Agenda

1. **Why Artificial Intelligence (AI) ? Background and Motivations**
2. **What are we exploring using AI for?**
3. **JPSS-related Examples of AI Applications:**
   - Remote Sensing Algorithms (next-Gen Algorithms)
   - Radiative Transfer
   - Data Fusion / Nowcasting & Data Assimilation
   - Exploiting Satellite data for Supporting Prediction
   - Morphing
4. **Conclusions**

Exploring AI for Remote Sensing, NWP & Nowcasting/Situational Awareness (SA). Status



Multiple types of AI models are being tested depending on the type of problem considered: DNN, RNN, CNN, GPR, Morphing Tool, LSTM, etc

Software Tools used: TensorFlow and KERAS

Not Tested. Unknown level of confidence	Not tested. Reasonable level of confidence	Tested or not: Moderate level of confidence	Tested. High level of confidence

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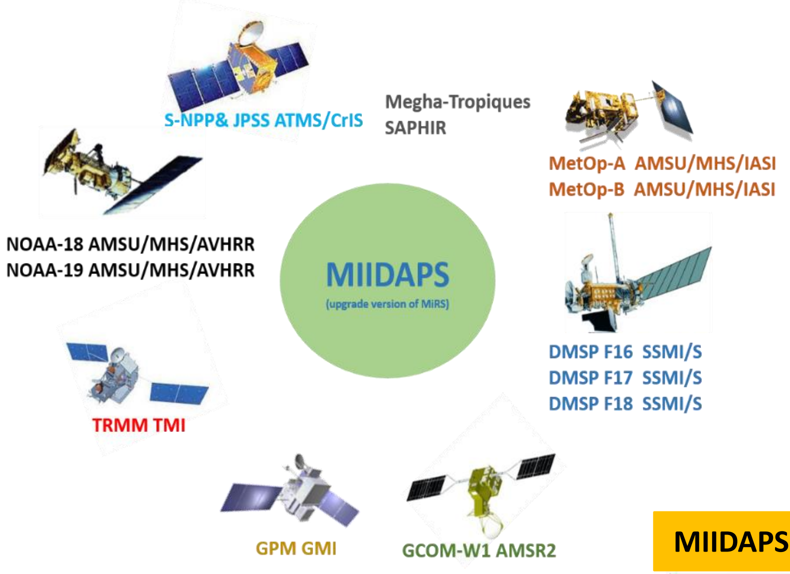
4 **Conclusions**

Pilot Project: MIIDAPS-AI:

Multi-Instrument Inversion and Data Assimilation Preprocessing System

Use of Deep Neural Network (DNN) for Geophysical Retrieval and Quality Control Purposes

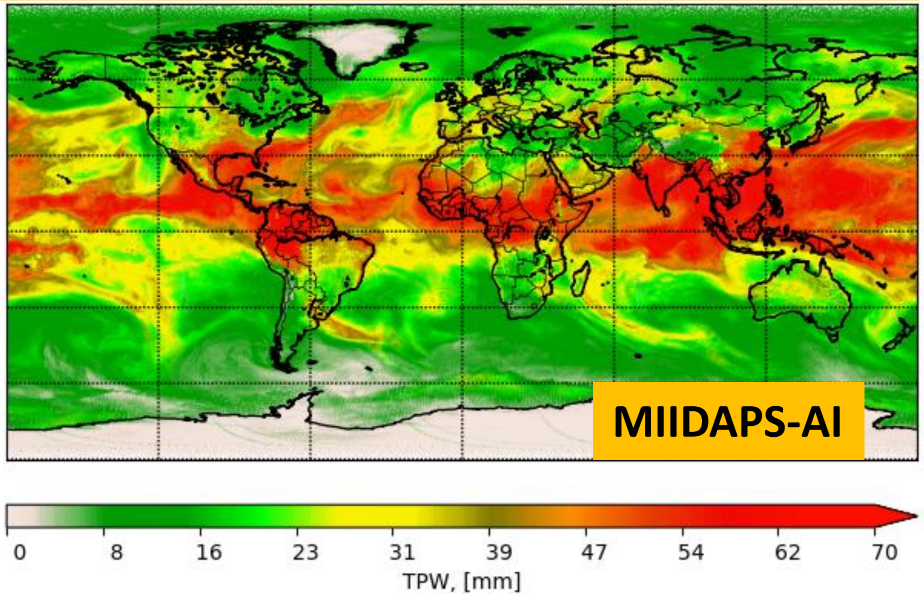


Google TensorFlow Tool used for MIIDAPS-AI

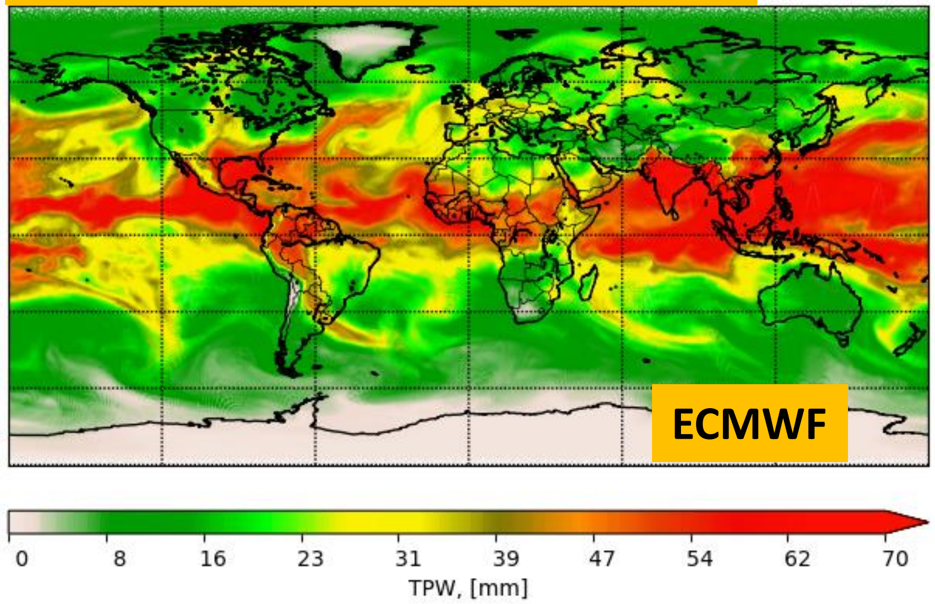
How to assess that AI-based output (Satellite Analysis) is valid?

(1) Assessing quality by comparing against independent analyses
(2) Assessing Radiometric Fitting of Analysis
(3) Assessing analysis spatial coherence
(4) Assessing inter-parameters correlations

MIIDAPS-AI outputs (TPW) Using SNPP/ATMS Real Data

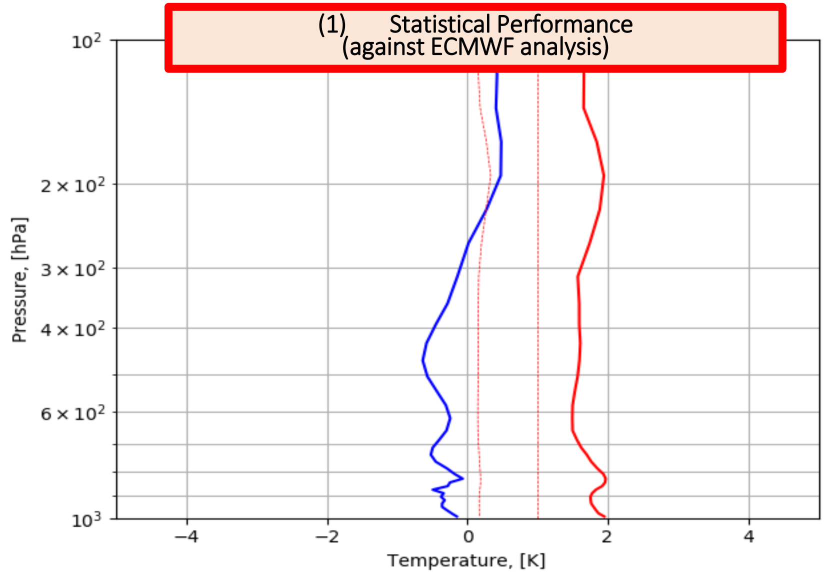


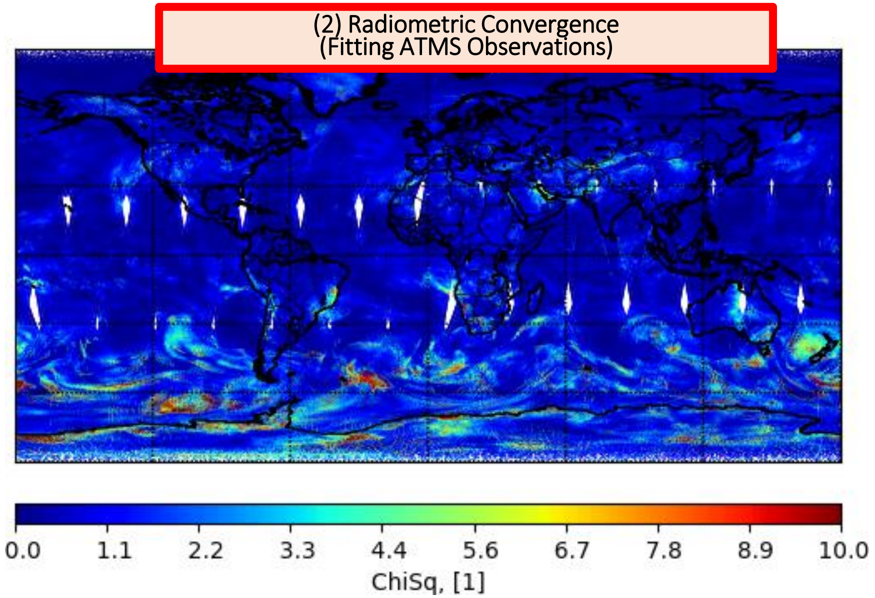
Reference source of TPW: ECMWF Analysis

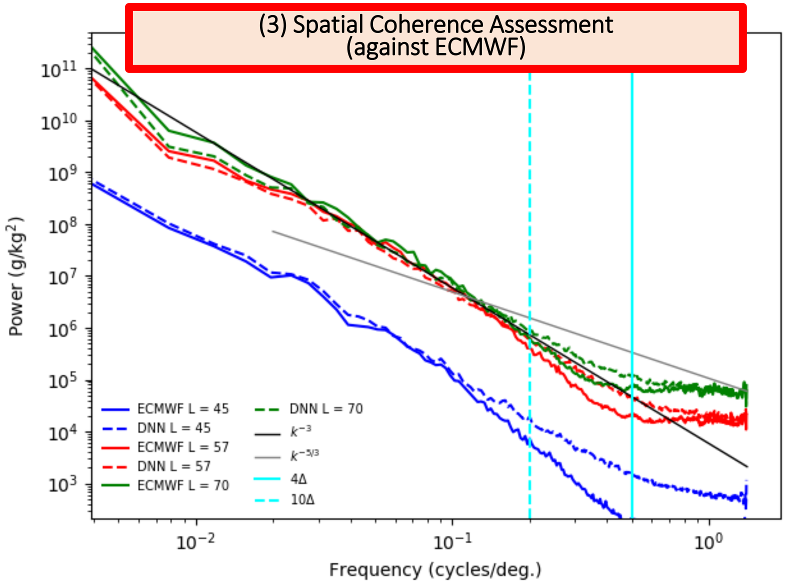


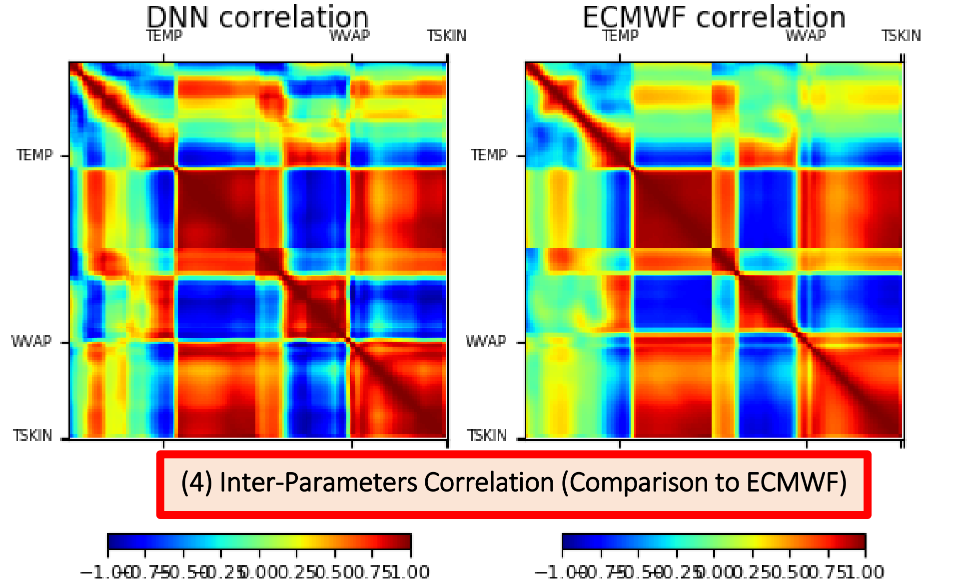
	MIIDAPS-AI	MIIDAPS
Processing Time for a full day data. A single sensor (ATMS). Excluding I/O	~5 seconds	~ 2 hours

How do we know if this AI-based satellite-analysis is scientifically valid?



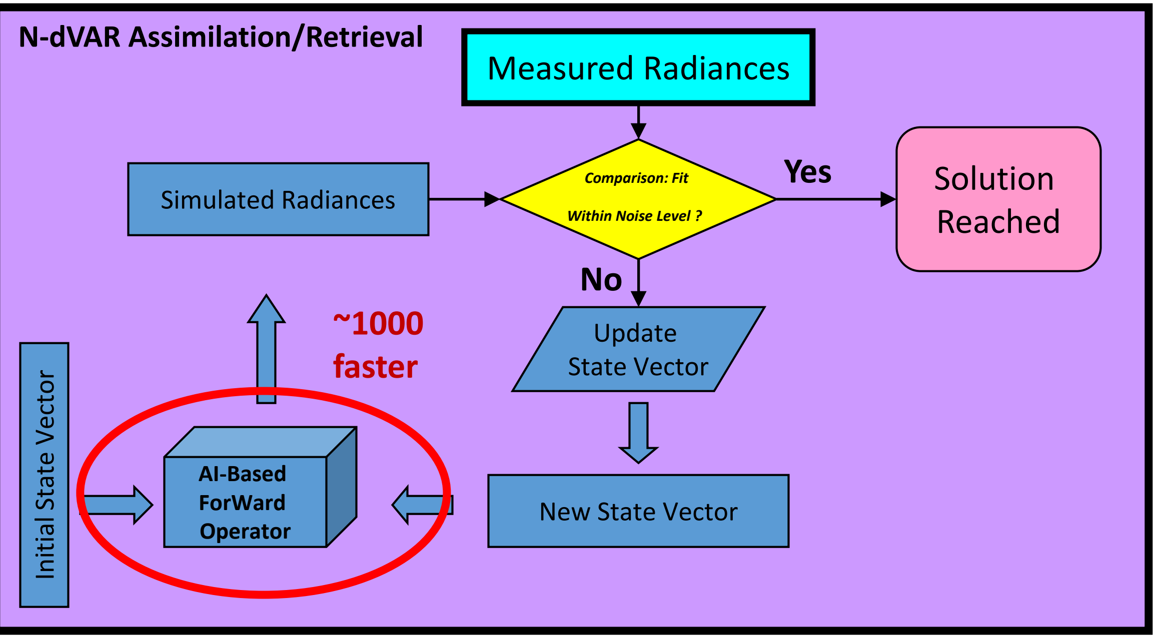


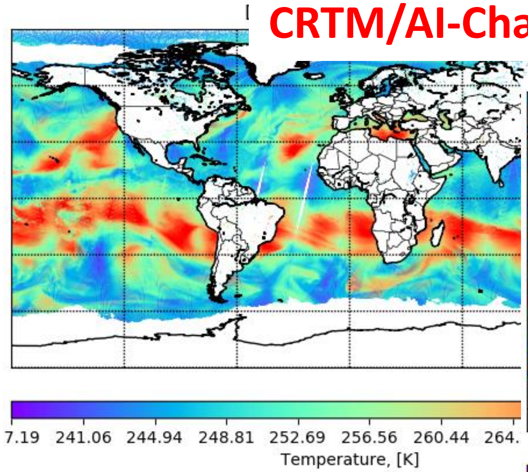


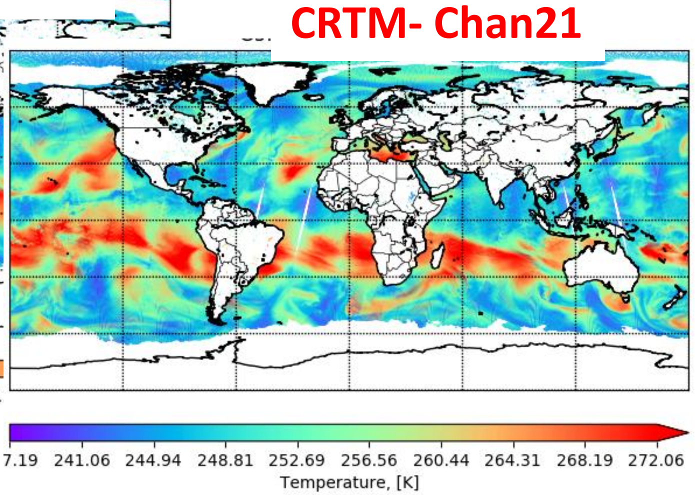


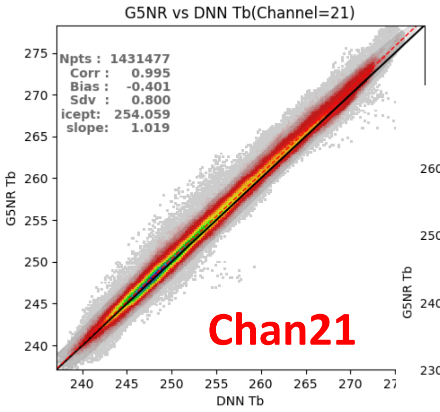
Can AI Be Used as Forward Operator?

Use of Deep Neural Network (DNN) for Radiative Transfer Modeling Purposes

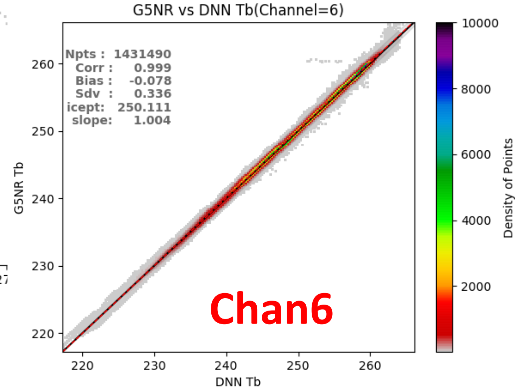








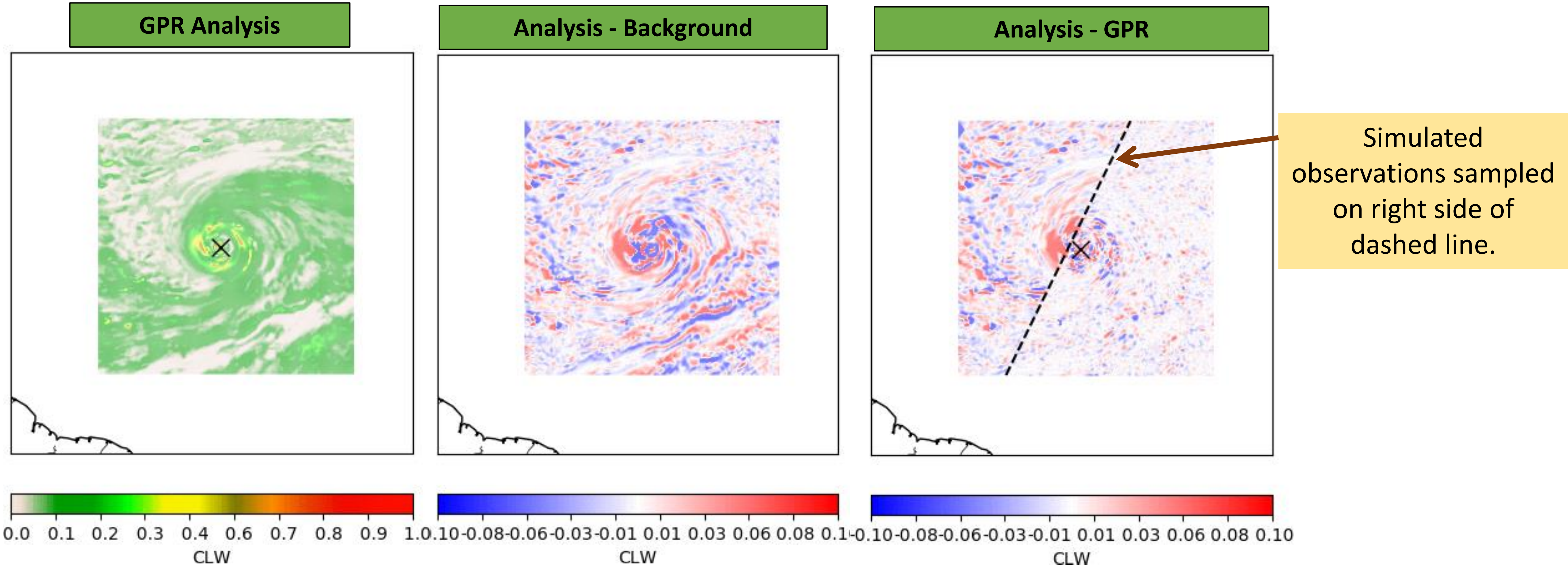
AI vs CRTM



	CRTM-AI	CRTM
Processing Time for a full day data. A single sensor channel(ATMS). Excluding I/O	<1 second	~ 1.3 hours

Can AI Tools Be Used for Data Fusion & Data Assimilation?

Use of GPR (Gaussian Process Regression) AI Model for Data Fusion/Assimilation (Case of Hydrometeors/Clouds)



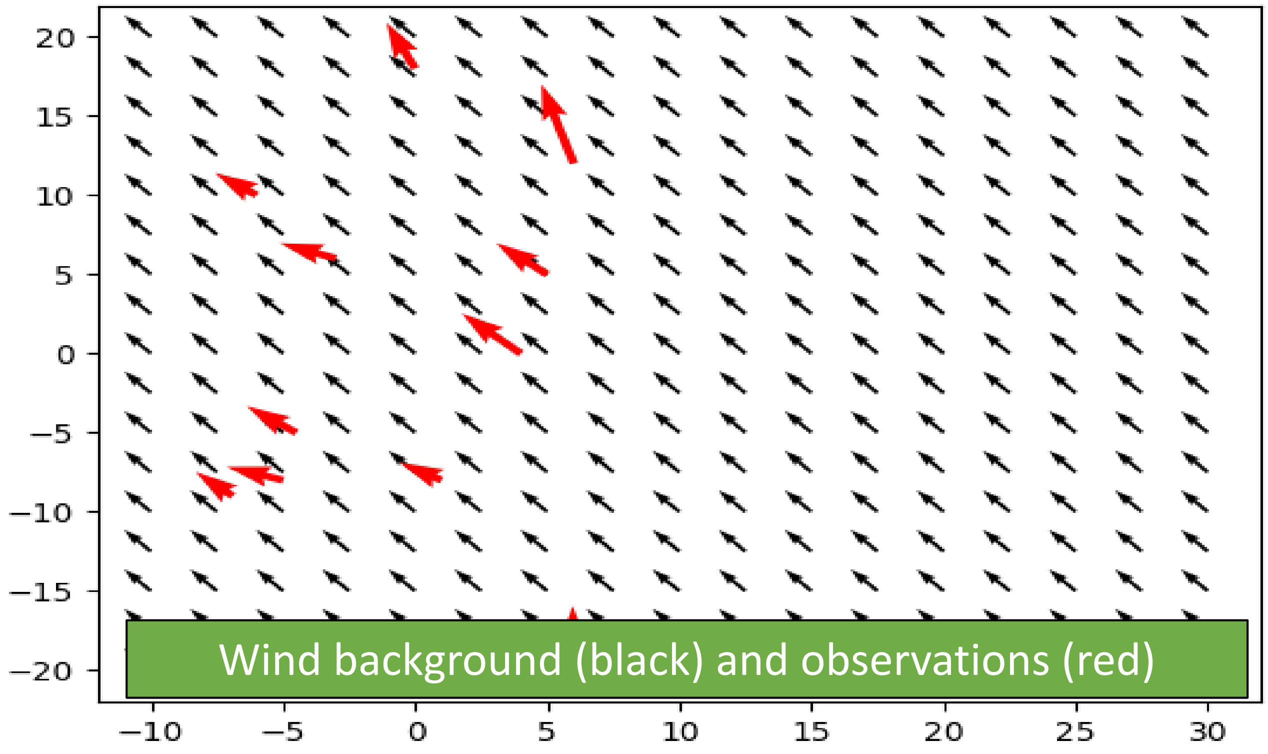
- Fused GPR analysis of total cloud water matches analysis where observations are dense and relaxes to the background field where they are sparse.
- Some distortion near the center of the hurricane is evident in the GPR fields and is due to the sampling.

Can AI Tools Be Used for Data Fusion & Data Assimilation?

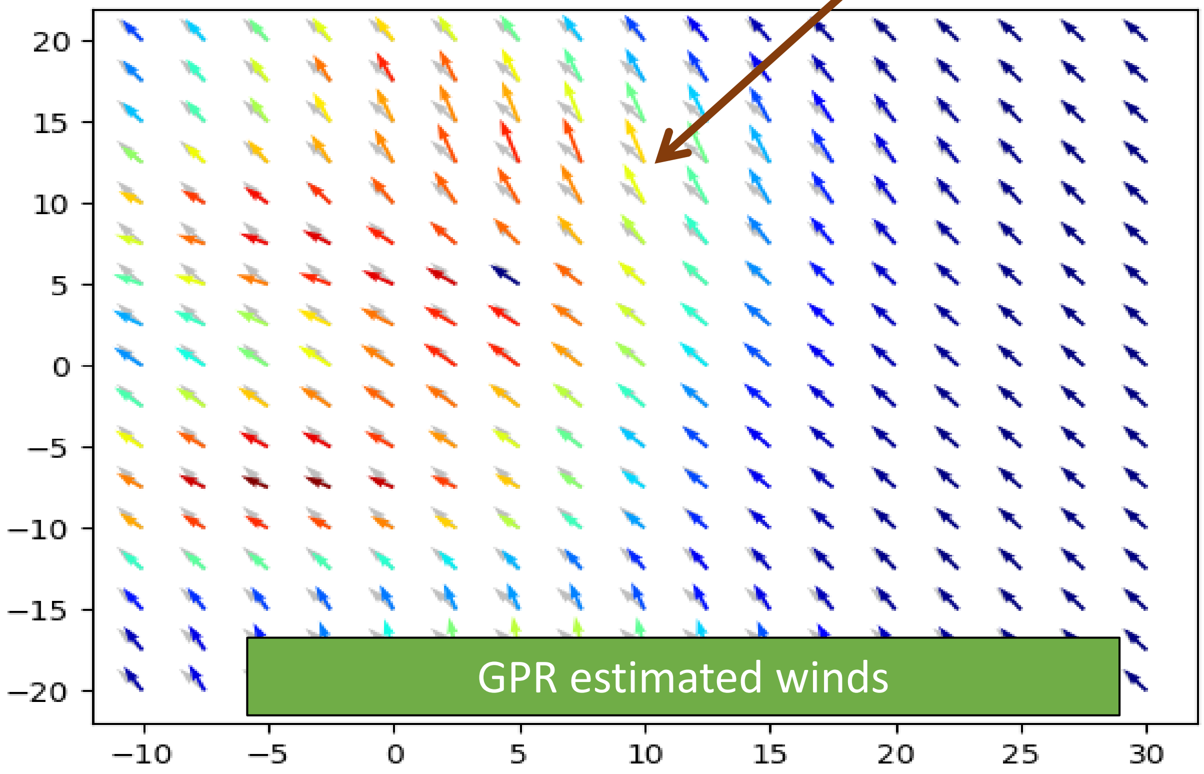
Use of GPR (Gaussian Process Regression) AI Model for Data Fusion/Assimilation (Case of AMV)

Color confidence/error estimates

Background and Measurements



GPR-Based Analysis



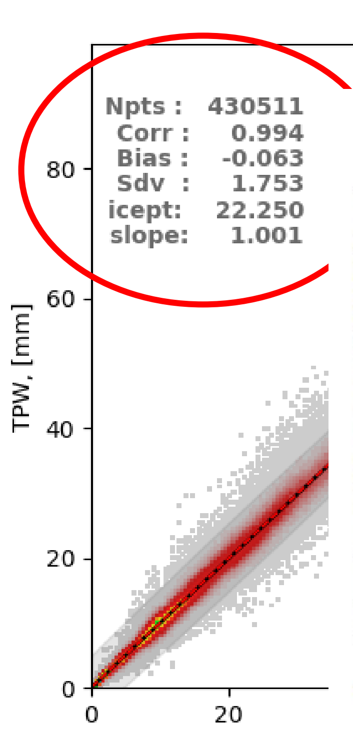
- Synthetic wind observations (red) are injected onto background (black) fields and GPR used to “fuse” the two.
- Color code corresponds GPR confidence – warmer colors reflect high confidence, while colder colors reflect low confidence estimates – and are consistent with observation locations.

Correcting TPW Forecasting with AI?

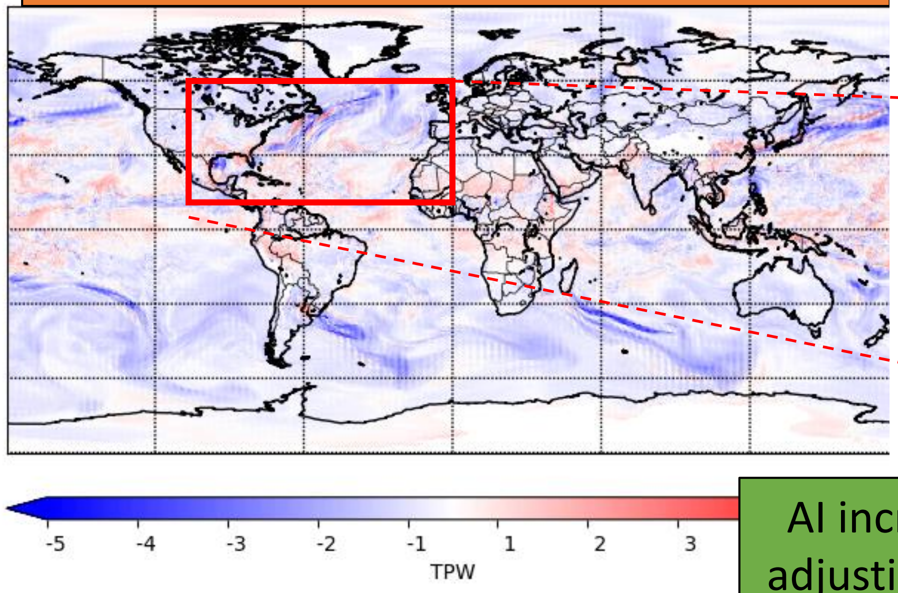
ECMWF vs AI-corrected 6h fcst valid @ECMWF analysis time

ECMWF vs 6 hr frcst valid @ECMWF analysis time.

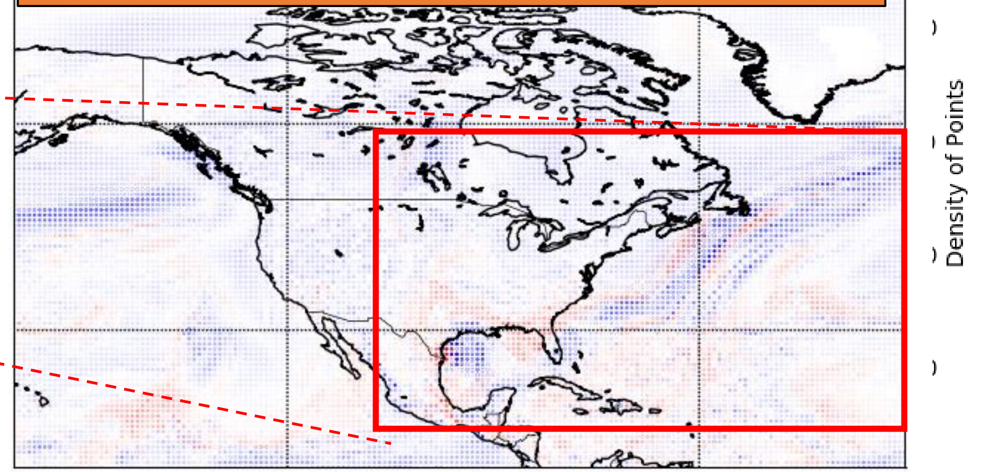
One day - all 4 cycles concatenated together.



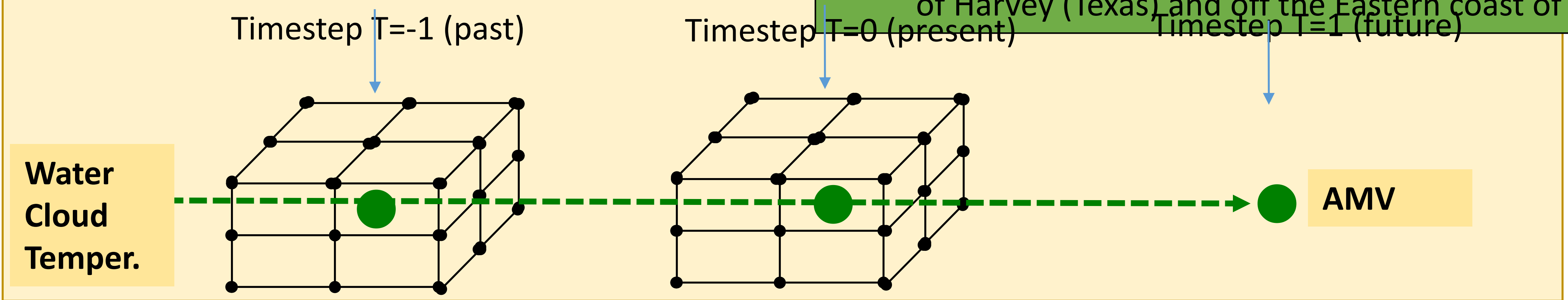
AI Increment



AI Increment – N. America

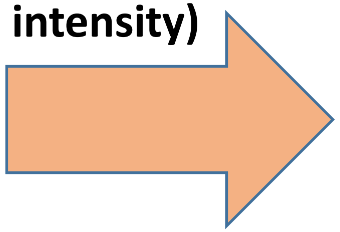


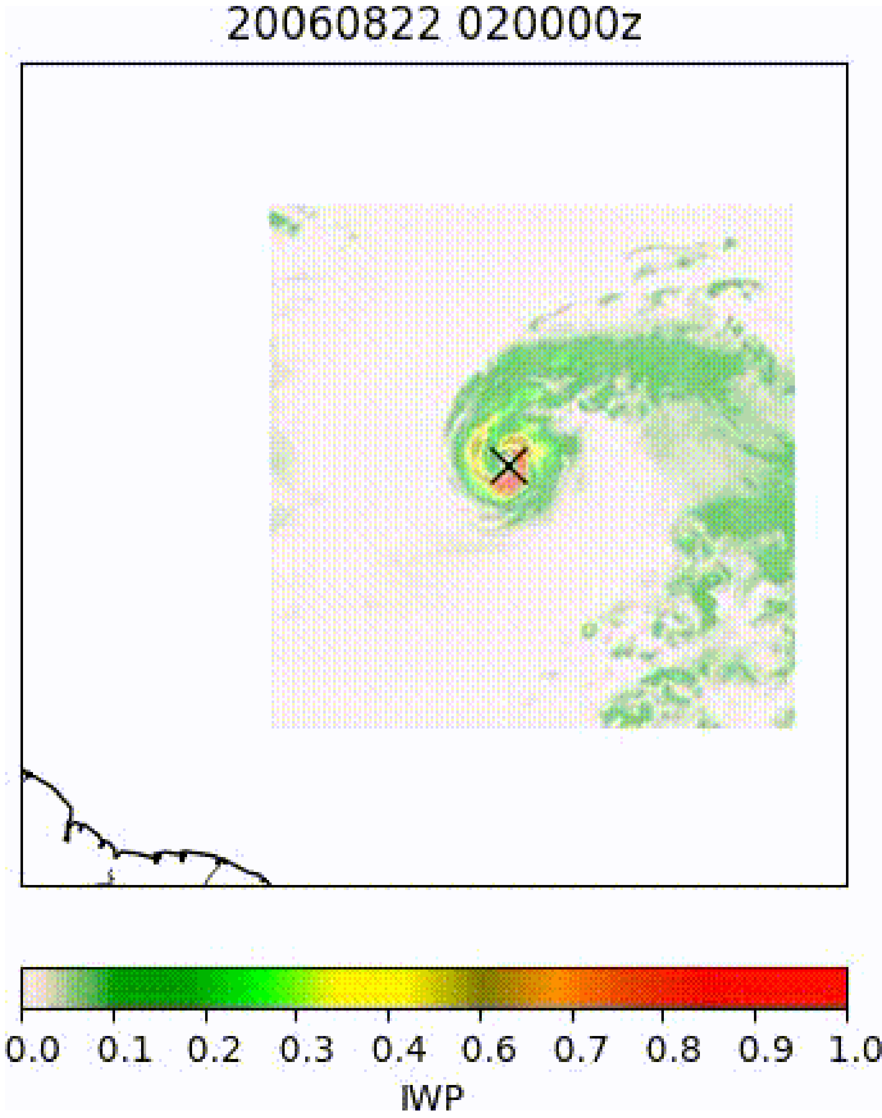
AI increment shows some dipoles indicating that the correction is adjusting the position of some features – Most notably the position of Harvey (Texas) and off the Eastern coast of N.America



Use of "morphing" AI Tool ("dogs" video morphing software) for Cloud/Precip morphing

Note the potential for morphing both the shape and color (i.e. equivalent of track and intensity)





- Used total integrated cloud ice from NASA GEOS-5 Nature Run (G5NR) "AL01" tropical cyclone at two time-steps (0200z and 0600z).
- Morphing software applied as a black box with some hand tuning of transformations between the two images.
  - Image at right sampled using 20 transformations between images

Credit: Example output and software from:
http://andrew.gibiansky.com/blog/image-processing/image-morphing/

Conclusions

- Big Data Challenge already here

- AI/ML approach is a natural evolution of how to exploit data

(think evolution of Programming languages: Assembler, Basic, Pascal, F66, C++, F00, Java, Python, …to TensorFlow, Keras, ….)

- Goal of this study is not to show AI/ML approach can do better, but that it can provide at least similar quality, much faster, therefore it can process more data.

- Significant potential to leverage AI tools and models developed in other fields, to our field: for remote sensing, radiative transfer, data fusion, morphing, etc.

- AI has the potential to be a transformational new approach in our exploitation of Big Environmental data

For More Information….

Upcoming Workshop on use of AI in Earth Observation and NWP

	Tuesday, 23 April	Wednesday, 24 April	Thursday, 25 April
0830 - 0900	Check-in at NCWCP Conference Center	Check-in at NCWCP Conference Center	Check-in at NCWCP Conference Center
0900 - 0930	Opening Remarks	Opening Remarks	Opening Remarks
0930 - 1030	Session I	Session I	Session I
1030 - 1050	Break	Break	Break
1050 - 1200	Session II	Session II	Session II
1200 - 1300	Lunch	Lunch	Lunch
1300 - 1530	Session III	Session III Session IV	Session III Session IV
1530 - 1550	Break	Break	Break
1550 - 1700	Session IV	Session V	Session V