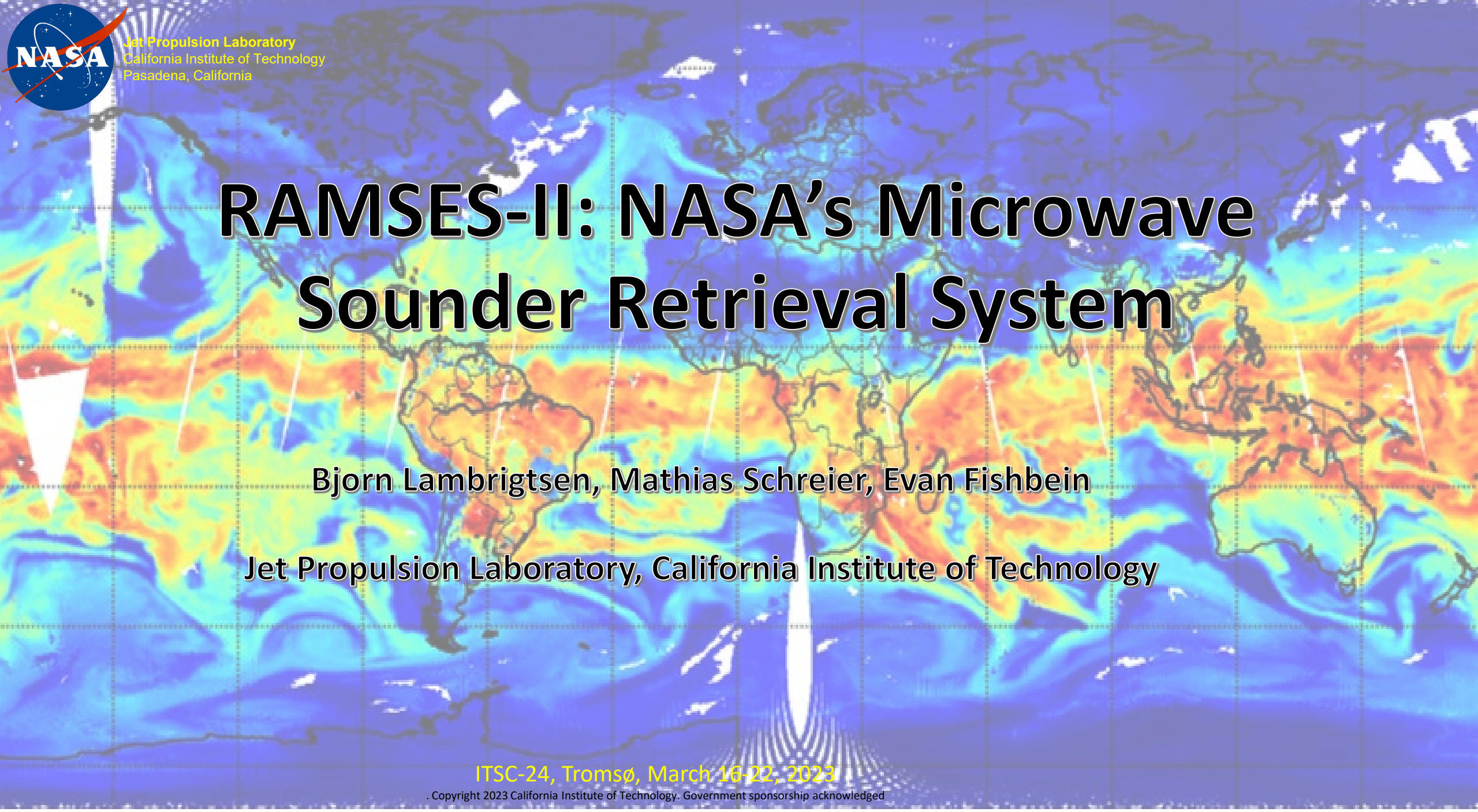

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RAMSES-II: NASA's Microwave Sounder Retrieval System

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ITSC-24, Tromsø, March 16-22, 2023

Post-EOS continuity: Use NOAA sounders for NASA research?

NASA formed science team to address this question

- 2011-2014
- Team analyzed quality of S-NPP instruments and algorithms

Assessment report delivered in 2013

- Conclusion #1: Instrument quality is adequate
- Conclusion #2: NOAA algorithms are *not* adequate
- Conclusion #3: NOAA data processing/handling is *not* adequate

Recommendations formed the basis for ROSES solicitations

- Develop new retrieval algorithms for all S-NPP/JPSS instruments
- Set up NASA data processing and product distribution/archiving

Subsequent sounder science team

- Instrument-level (L1b = SDR) responsibility assigned by NASA
  - CrIS: U. Wisconsin
  - ATMS: JPL
- Two retrieval (L2 = EDR) algorithms “down-select” through ROSES’17
  - One CrIMSS algorithm → “CLIMCAPS” (C. Barnet)
  - One ATMS algorithm → “RAMSES" (B. Lambrigtsen)
- Algorithms are delivered to “Sounder-SIPS” at JPL for assessment
- Operationalized code delivered to GES/DISC DAAC for processing

RAMSES: The NASA MW retrieval system

Retrieval **A**lgorithm for **M**icrowave **S**ounders in **E**arth **S**cience

- Initially funded under ROSES'13/NPP (2014-2017)
- Continued under ROSES'17/TASNPP (2018-2021)

Development path

Two approaches pursued:

- Aqua AMSU/HSB system adapted for S-NPP/ATMS (Fishbein) → RAMSES-I
- New development (Schreier)

Eventual merger:

- Aqua RTM ("MitRTA") + new development for the rest → RAMSES-II

Current status of RAMSES-II

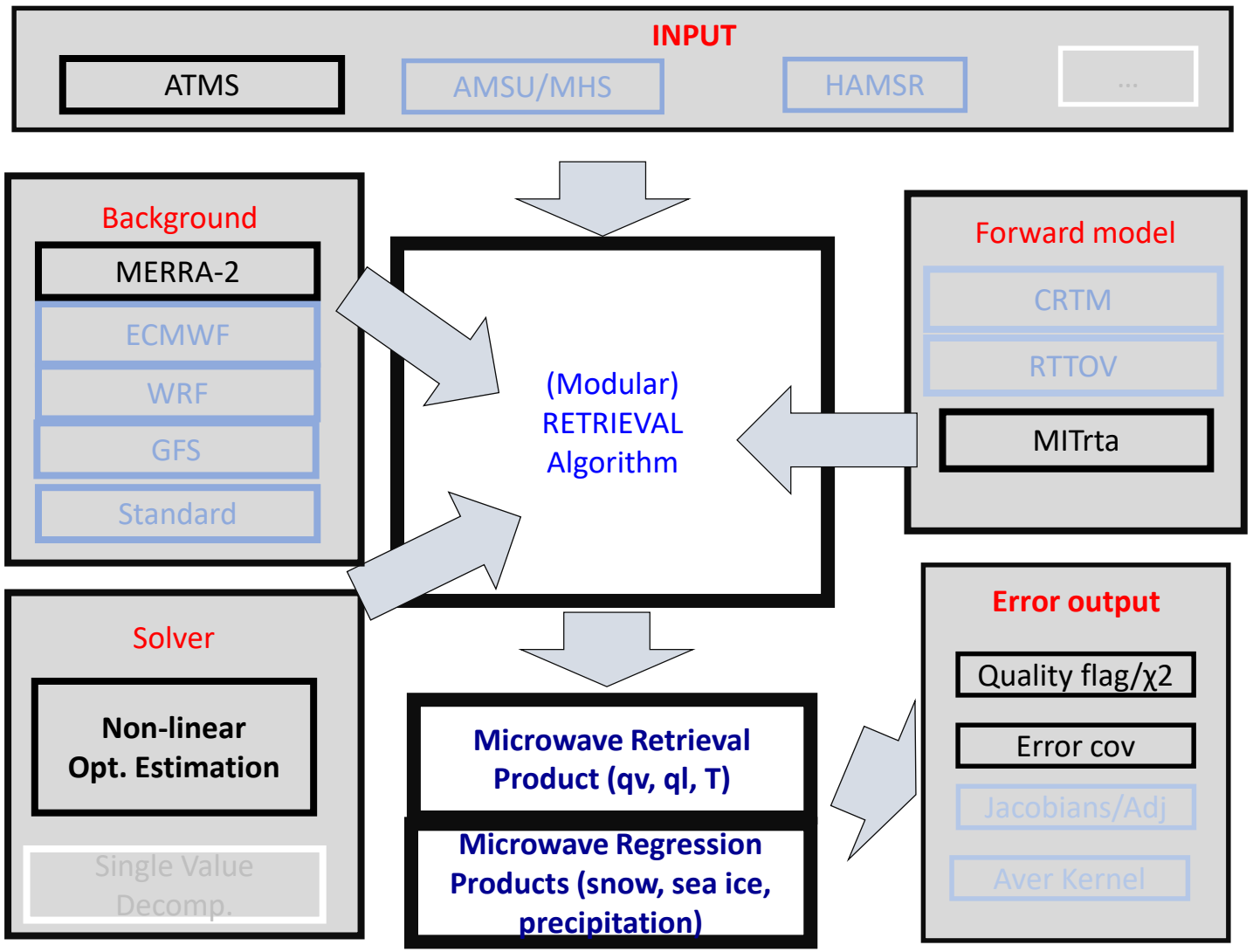
- GES DISC processing of baseline version (V1) in 2021 (limited data set for testing & assessment)
- GES DISC processing of mature version (V3) in 2023 table below)

Description	Collection Name	DOI
Sounder SIPS: Suomi NPP ATMS Level 2 RAMSES2 Standard: Atmosphere, precipitation and surface geophysical state V3	SNDRSNML2RMS_3	10.5067/FT9GRABK1CMK
Sounder SIPS: Suomi NPP ATMS Level 2 RAMSES2 Support V3	SNDRSNML2RMSSUP_3	10.5067/KMEMD53MTTU8
Sounder SIPS: JPSS-1 ATMS Level 2 RAMSES2 Standard: Atmosphere, precipitation and surface geophysical state V3	SNDRJ1ML2RMS_3	10.5067/69Y2R9BJAJS3
Sounder SIPS: JPSS-1 ATMS Level 2 RAMSES2 Support V3	SNDRJ1ML2RMSSUP_3	10.5067/WEO3KIK1GBGT

GES DISC Dataset: Sounder SIPS: Suomi NPP ATMS Le...

disc.gsfc.nasa.gov

RAMSES-II: Basic concept



The Foundation is a Testbed Concept	
Language	Fortran 2003
Input	HAMSR, ATMS, AMSU/MHS
RTMs	CRTM, RTTOV, MITrta
Background	ECMWF, WRF, MERRA-2
Advantage	- Modular, extendable - Good for comparisons
Disadvantage	- Difficult to create uncertainty and quality control - Slow processing

RAMSES-II Approach	
Select specific components	• Input: ATMS L1B (NASA SIPS) • RTA: MITrta • Background : MERRA-2 • Solver: LMBM (Karmitsa)
Focus on	• Speed and Reprocessing • Uncertainty estimates • Good quality control

Radiative transfer model

MITrta	
Language	Fortran77
Version	Developed for AMSU/HSB
Author	P. Rosenkranz
Advantage	- Reliable (used for EOS AMSU/HSB) - Source code available - Reliable spectroscopy - Fast semi-analytical Derivatives - ***Fast !!!***

Evan Fishbein upgraded code with help from Phil Rosenkranz	
Language	Upgrade to Fortran 2003
Version	Upgrade to ATMS (Coefficient upgrade)
Author	P. Rosenkranz with E. Fishbein

Main Changes	- Code more modular
	- Upgrade readability of the entire system
	- Easier switch between instruments
	- Extended surface module
	  - (added selection of subroutines, e.g. FASTEM)
	- Upgraded matrix multiplication
	- Extensive validation with CRTM and RTTOV
	- Upgraded I/O-interfaces
	  ➢ Easier subroutine access to RTA and Jacobians
	  ➢ netCDF I/O
	  ➢ Library compilation (easier plug-in-and-play)

Retrieval system and postprocessor

RAMSES-II : Basic retrieval

- Basic product in netcdf
- Non-standardized, often legacy
- Sigma-pressure levels (72)

Profile parameters
- Specific humidity
- Temperature
- Ice/Liquid water

Other observables:
- Rain rate
- Land/Ice/Snow coverage

Additional information:
- Error/Quality
- Convergence
- Surface height
- Lat/Lon/scan angle

RAMSES-II Post processor

- Retrieval and support product in netcdf
- Standardized by NASA Sounder SIPS for easier comparison
- Constant pressure levels (standard 27, support: 100)

Basic Profile parameters
- Specific humidity
- Temperature
- Ice/Liquid water

Additional Derived Parameters (selection)
- Relative humidity
- Saturation over water/ice
- Tropopause information (height, strength,…)
- Near surface information (t,qv, relative hum.)

Other Observables:
- Rain rate
- Land/ice/snow coverage

Auxiliary information:
- Basic retrieval on sigma levels
- Background

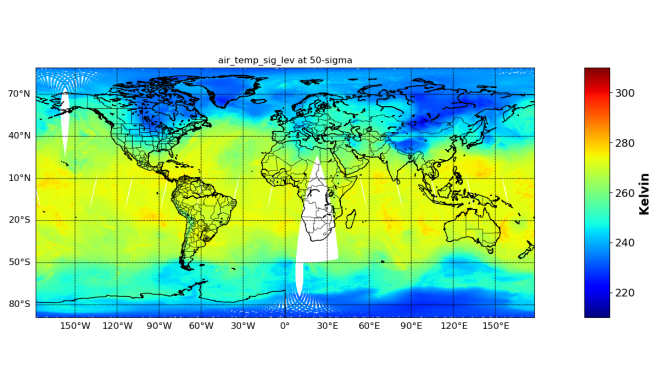
Additional information (selection):
- Error/Quality
- Convergence
- Surface height
- Geopotential height and uncertainty
- Global attributes (version, L1B-files, contact, processing date, …)

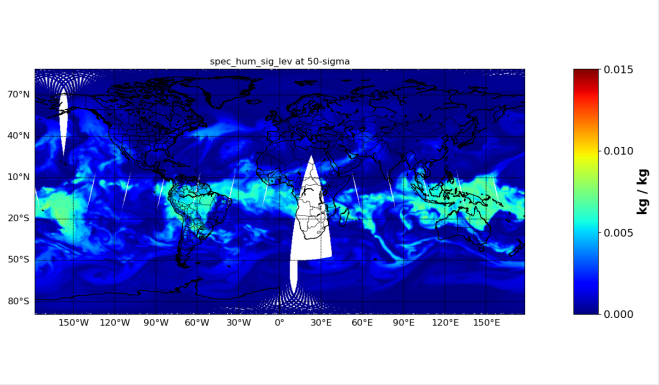
Satellite-information (selection):
- Scan angle/azimuth/zenith
- Satellite position/velocity
- Lat/lon
- Ascending/descending node
- Field of View-Polygon
- Time (local/UTC/TAI)

Product examples

RAMSES-II : Basic examples

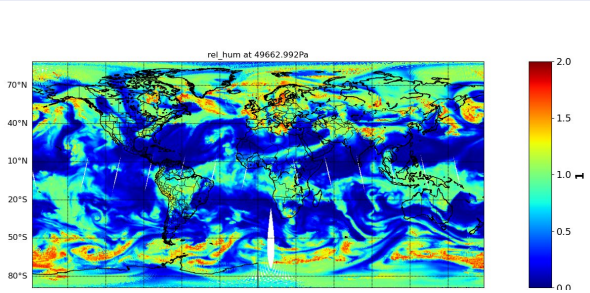
- T at sigma level = 50
- qv at sigma level =50

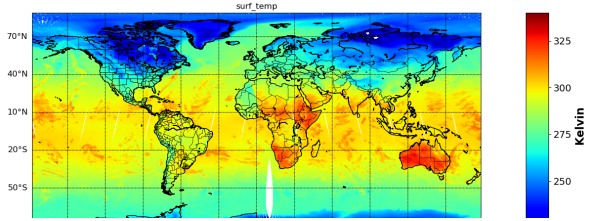


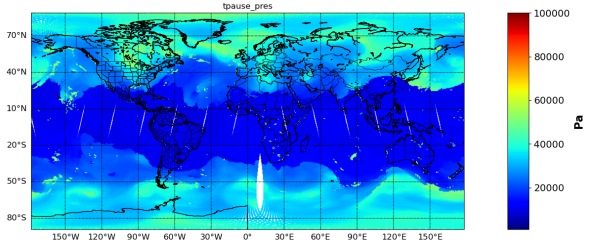


RAMSES-II Post processor examples

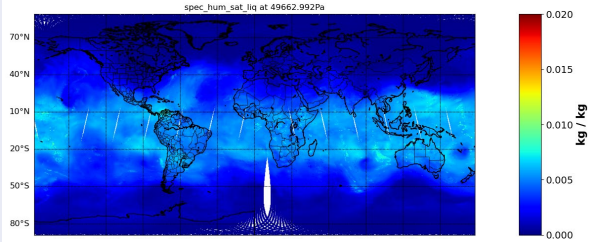
- relative humidity at 500 hPa
- Near surface temp
- Tropopause pressure height

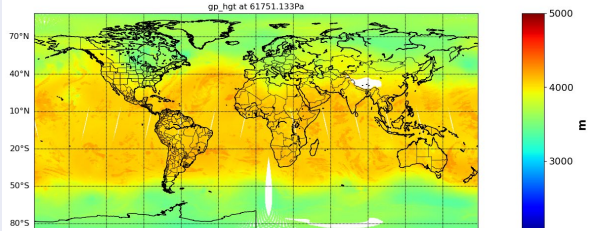


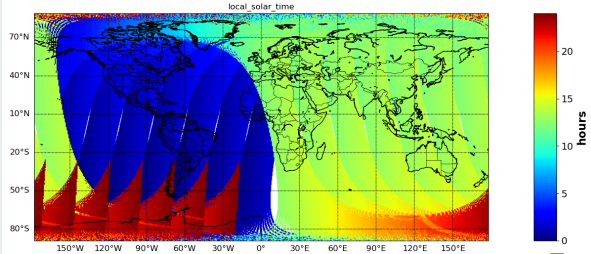




- Saturation over liquid at 500 hPa
- Geopotential height at 600 hPa
- Satellite local time

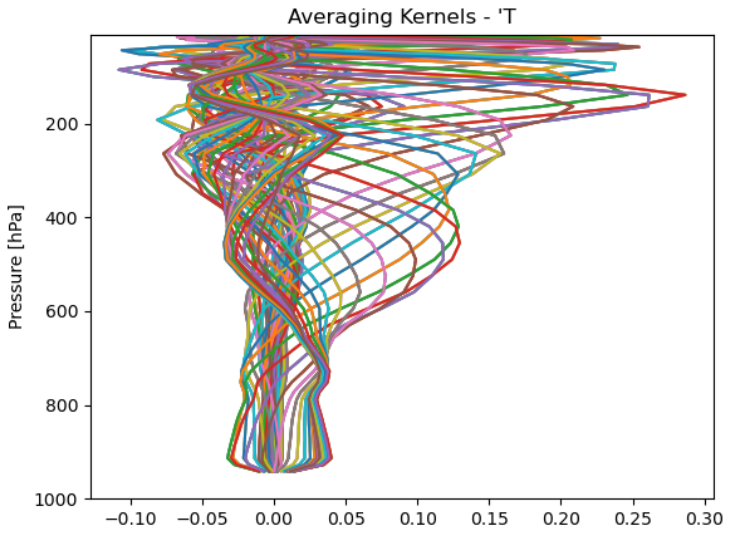


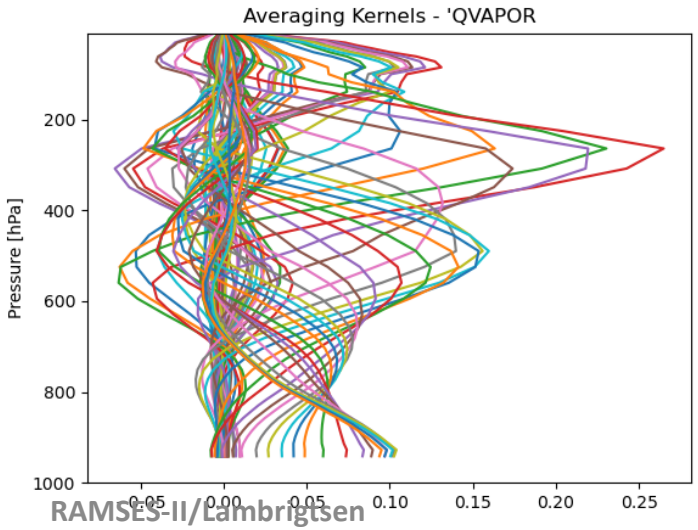




Available information content

Averaging Kernel Examples





Averaging Kernels - Example

- For ATMS and MITrta
- Most information in the upper troposphere
- Taken from random spot in California in Winter

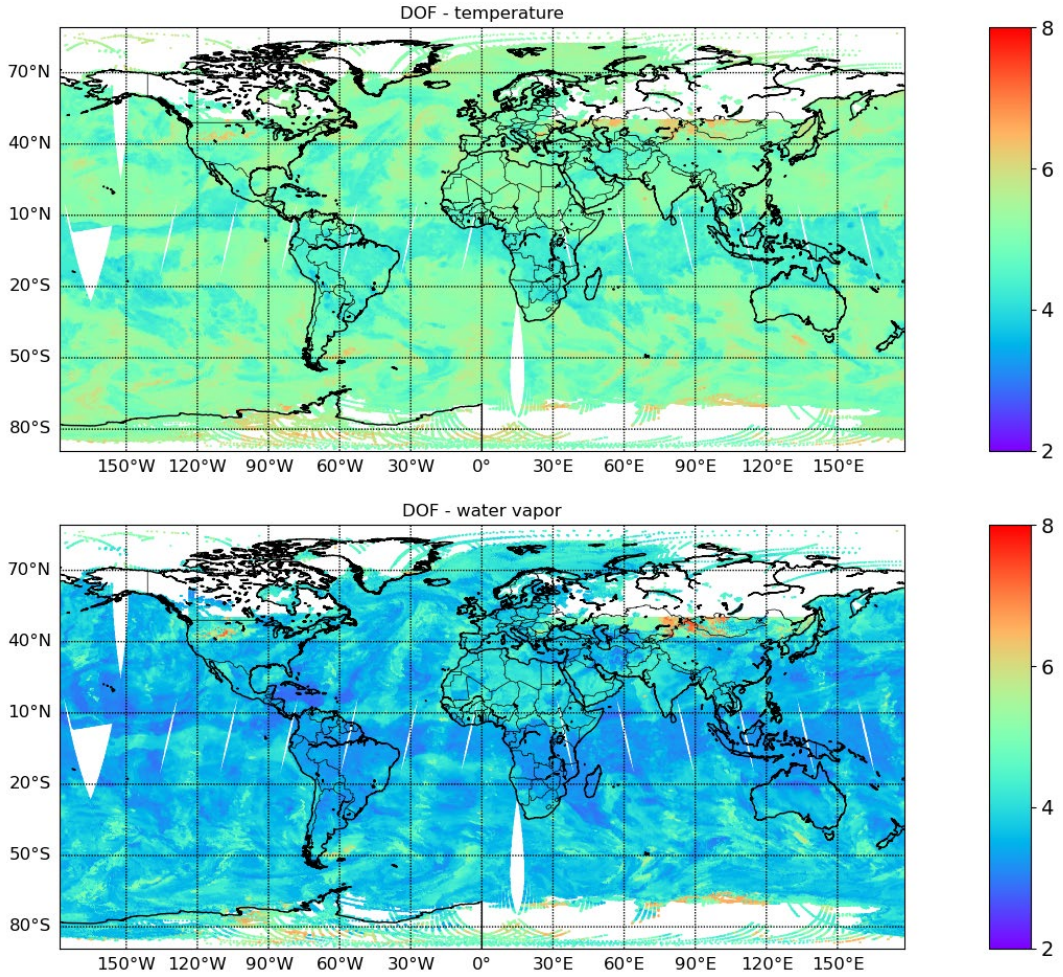
Upper panel :

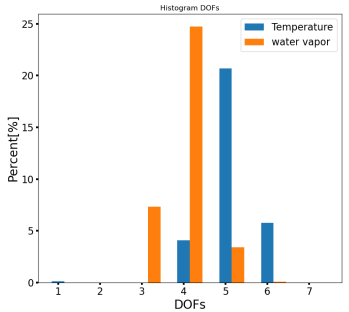
- Temperature Kernel
- Most information in the upper troposphere and beyond
- Total DoF ~6.2
- Information in PBL available, but limited (1000-800 hPa: DoF ~0.2)

Lowe Panel:

- Water vapor kernel
- Most information in the upper troposphere
- Total DoF ~4.4
- Information in PBL available, but limited (1000-800hPa: DoF ~0.3)

Global information content





Degrees of Freedom around the Globe – Statistical Variation

Current retrieval : no scattering

- Calculate degrees of freedom
- Calculate retrieval without scattering
- Measure of “success “ convergence

Left panels:

- DOFs for Temperature (top) and water vapor (lower)
- Filtered by snow/ice and rain

Right panel :

- Histograms of DOFs (Filtered by good quality)

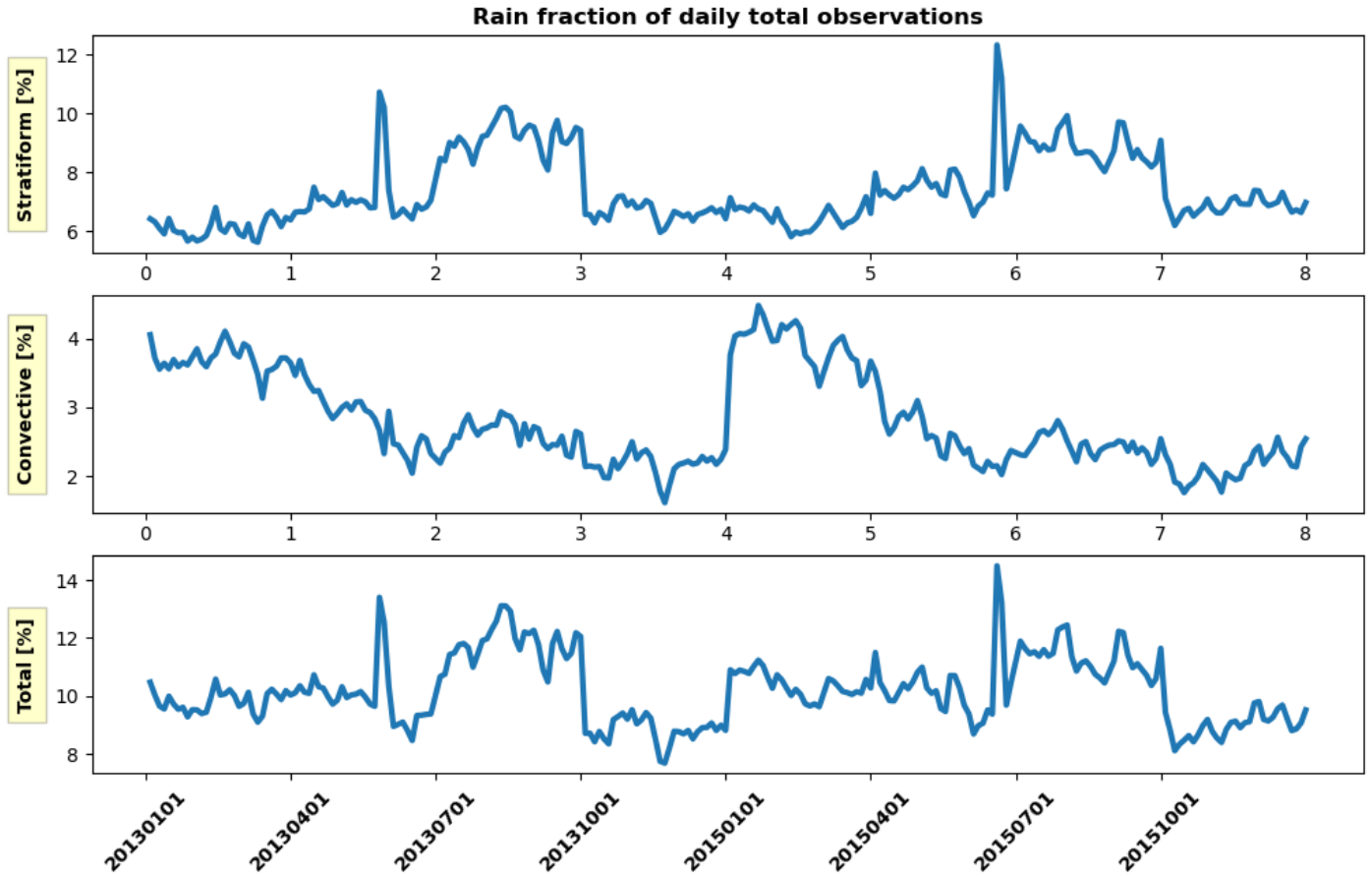
- Summary:
- Range for temperature is 4-6, for water vapor it is 3-5
- Quality control drops useable observations by half (polar observations get filtered)
- But quality filtering has no big effect on distribution

Not very different from IR sounders!

See, e.g., Smith, N. and Barnet, C.D., 2020. CLIMCAPS observing capability for temperature, moisture, and trace gases from AIRS/AMSU and CrIS/ATMS. Atmospheric Measurement Techniques, 13(8), pp.4437-4459.

Rain and unusable profiles

How many rainy cases are there statistically?



Note. Precipitation is derived from a "borrowed" regression algorithm.
Laviola, S., & Levizzani, V. (2011). The 183-WSL fast rain rate retrieval algorithm: Part I: Retrieval design. Atmospheric Research, 99(3-4), 443-461.

Rain fraction: Global (upper set), ±65° (lower set)

Upper panel:
- Fraction of Stratiform rain

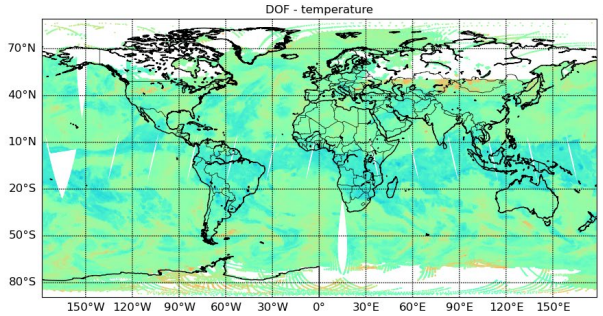
Middle panel :
- Fraction of Convective rain

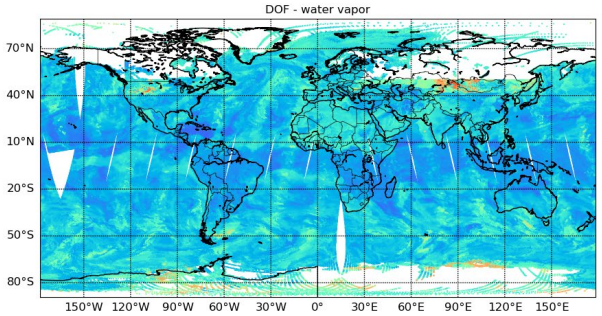
Lower panel :
- Total sum

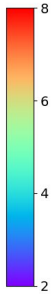
- Timeline :
  - January, April, July, October 2013 and 2015
- Rain fraction makes up around ~ 10% of the data
- Slight variation with season, highest in July
- Reason seems to be stratiform cases
- Stratiform cases are ~ 6-8%

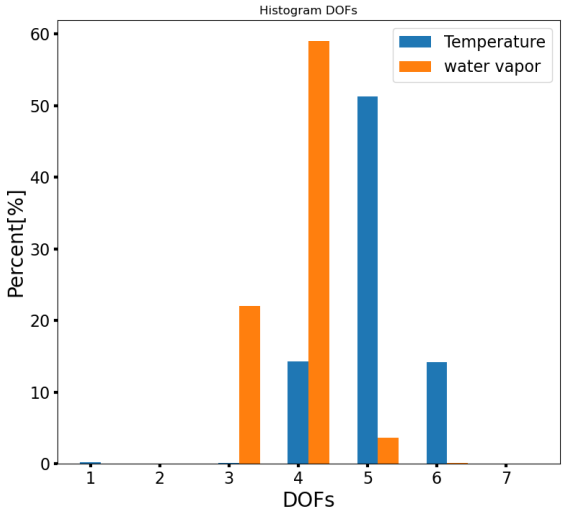
Next version: Add scattering

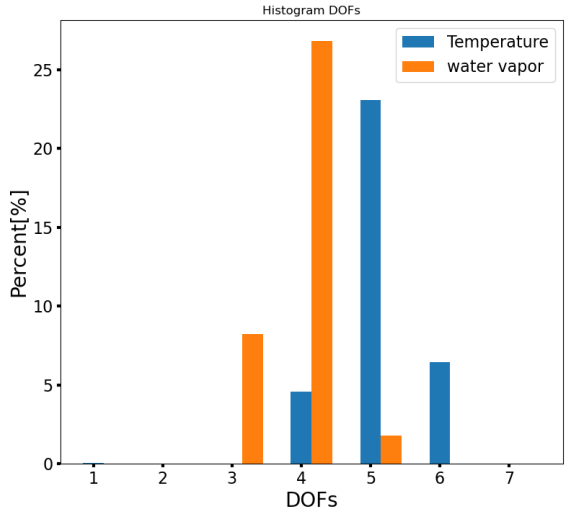
Global and statistical changes











Switch code, when rain is in scene

- Calculate degrees of freedom
- If stratiform, use scattering
- Measure success of convergence

Upper panel:

- DOFs for Temperature and water vapor
- Some gaps filled

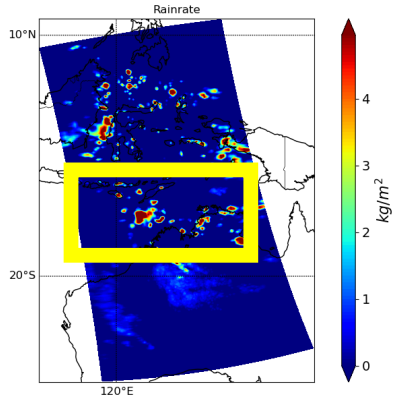
Lower panel :

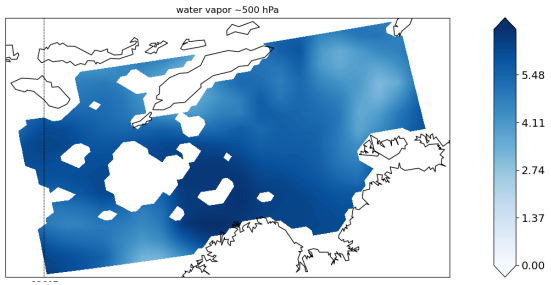
- Histograms of DOFs (lat +/- 65)
- Left side : all DOFs after filtering for snow/ice
- Right side : Filtered by quality

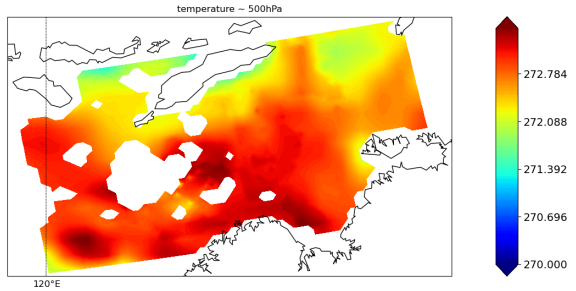
➢ Summary:
➢ Small effect, but visible: more 3-DOFs, especially for water vapor
➢ slightly diminished by quality control

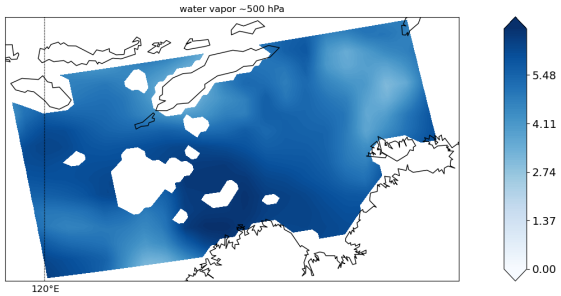
Experimental performance with scattering

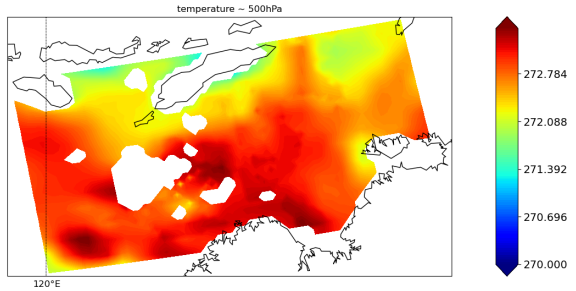
Local changes when adding scattering











Justification, based on examples on a random day

Upper left panel:

- Random observation of rain rate
- Some Stratiform rain
- Mainly Convective rain

Lower right panels :

- Zoom into significant rain area
- Temperature retrieval at 500 hPa
- Upper panel : no scattering
- Lower panel : with scattering

Lower left panel :

- Same, but for water vapor

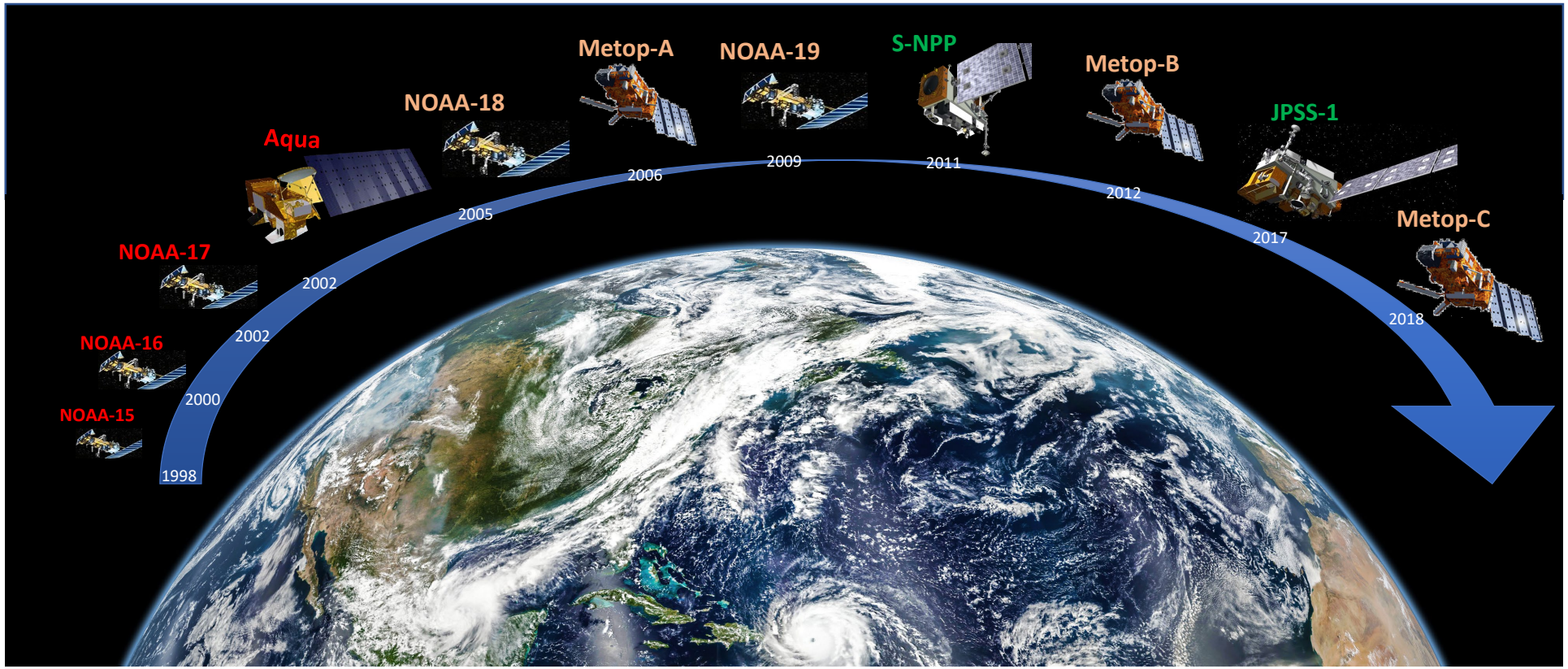
- Summary:
- Strong convective rain still flagged as bad
- However: observations around cells get “closer to center” with scattering
- May seem small, but means an improvement of 30-50 km

Current status and future plans

Microwave Retrieval RAMSES-II

- **Current Release : Version 3**
  - Based on MITrta
  - Mainly profile information (temperature and water vapor)
  - Also regression info (rain rate, snow cover)
  - Full SNPP and JPSS1 data sets, JPSS2 when available
- **Available information content:**
  - Averaging Kernels available on Demand (large size)
  - DoF analysis shows a narrow Gaussian variation with regional dependent information content
  - Temperature-DoF peaks at 5 (~50%), water vapor peaks at 4 DoF (55%)
  - Current DoF in PBL (between 1000-800 hPa) :
    - ~0.2 for temperature, ~0.3 for water vapor
- **Outlook: Fill the gap - getting rainy cases**
  - Currently testing, if it makes sense to add scattering code to increase sample size
  - Preliminary results:
  - Change in global information is content low
  - Mainly reasonable for case study interests

Eventually…



Our goal is to configure RAMSES-II to process all MW sounder data from 1998 onwards:

NOAA-15 to -17: AMSU-A + AMSU-B

NOAA-18 and -19: AMSU-A + MHS

Aqua: AMSU-A + HSB

Metop-A to –C: AMSU-A + MHS

SNPP and JPSS: ATMS