STAR Center for Satellite Applications and Research
formerly ORA — Office of Research and Applications

On the Consistency of GRUAN, Satellite Infrared Sounder and GNSS RO in Measuring the Lower Stratospheric Temperature

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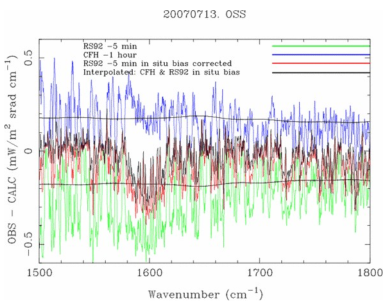
- I gave a presentation at ICM-15 on the same topic but based on a limited data sample. After that meeting, I repeated the analysis by using a large dataset. For this updated analysis:
- **Radiosonde-satellite collocated data of 2018 to 2022 (over 1000 collocations were selected and used)**
  - **RS41 GDP and RS41 EDT** from sites (SGP, ENA, NSA and Beltsville) launching sondes dedicated for NOAA satellites and from Lindenberg, Payerne, and Ny-Alesund where launches happened to match NOAA satellite overpasses.
  - Radiance measurements of the hyperspectral Cross-Track Infrared Sounder (CrIS) on-board NOAA-20 polar orbiting satellite.
  - Tdry from nrt UCAR COSMIC-2 and offline ROM SAF GRAS.
- **Assessment method**
  - Compute radiances using the Community Radiative Transfer Model (CRTM) for radiosonde data and compare the “CAL” radiances with CrIS measurements “OBS” at the CO2 sensitive upper-peaking channels (~100-20 hPa) in the longwave band (LWIR), and further cross-validated using collocated RO Tdry.
- **Summary**
  - Relative to satellite CrIS observations, **for daytime**, RS41 GDP is systematically warm-biased (by 0.1-0.2 K) at ~100-20 hPa, and this is verified by the radiosonde versus RO comparison, suggesting RS41 GDP is under-corrected. In contrast, RS41EDT matches well with both satellite and RO data.
  - **For nighttime**, both RS41 GDP and RS41 EDT are consistent with satellite and RO data.
  - High-ascent radiosondes are needed for satellite cal/val in the stratosphere(Thanks Masatomo for the paper published).

From GRUAN sondes to satellite radiances: uncertainty propagation using the new GRUAN sonde uncertainty

Xavier Calbet
AEMET

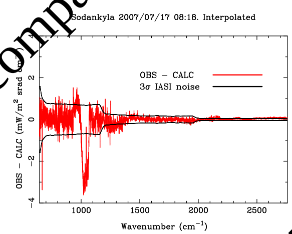
GRUAN ICM-16
17-21 November 2025

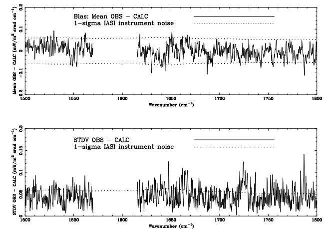
The Long March: radiance comparisons with (proper) uncertainties



2010 IASI Symp.: Rad comparison within IASI noise

2011 AMT: Rad comparison within IASI noise

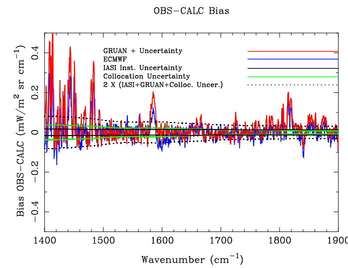




2016 AMT: Rad comparison full spectra

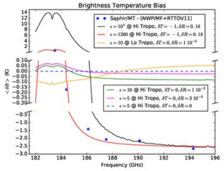
2017 AMT: GRUAN Rad comparison

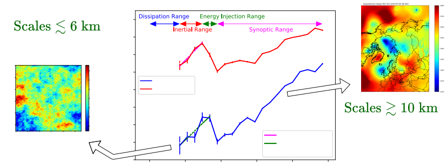
2018 AMT: 183 GHz Turbulence



2022 AMT: WV Inhomogeneity

2025 GRUAN ICM-16





Estimation of the GRUAN Uncertainty Covariance Matrix

- Based on the document «GRUAN Data Product Uncertainty/Covariance Matrix. Calculations and Case Studies» by Rasma Ormane and Tom Gardiner
- This document has been of great help to understand the uncertainties present in the GRUAN sonde data
- But, it has some shortcomings:
    - Figure 4 legends seem inconsistent
    - Some terminology could be further improved
    - It is still not enough for «simple minds» to generate the covariance matrix
- Perhaps some pseudo-code in the document could be useful

Estimation of the GRUAN Uncertainty Covariance Matrix

- Nico to the rescue... with Matlab code for RS41s:

```
C_T.Cucor = diag(temp_uc_uncor.^2);

% Totally correlated (spatial & temporal components)
for i=1:NL
    for j=1:NL
      C_T.Cscor(i,j) = temp_uc_scor(i) * temp_uc_scor(j);
       C_T.Ctcor(i,j) = temp_uc_tcor(i) * temp_uc_tcor(j);
    end
end

% Cov matrix (all components)
C_T.Ctot = C_T.Cucor + C_T.Cscor + C_T.Ctcor;
```

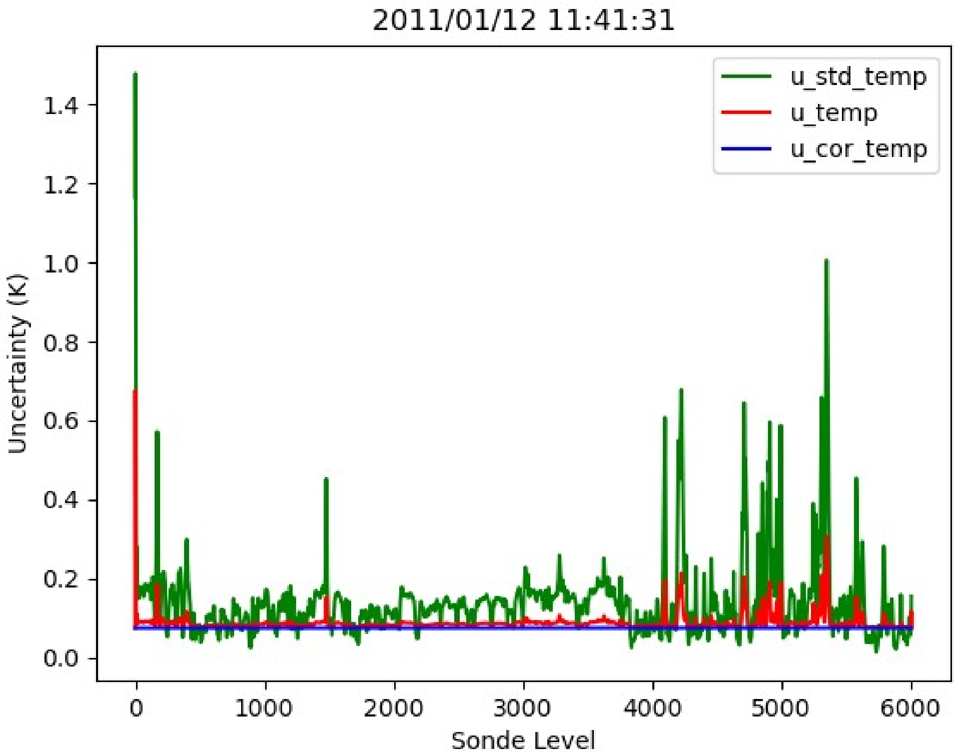
Estimation of the GRUAN Uncertainty Covariance Matrix

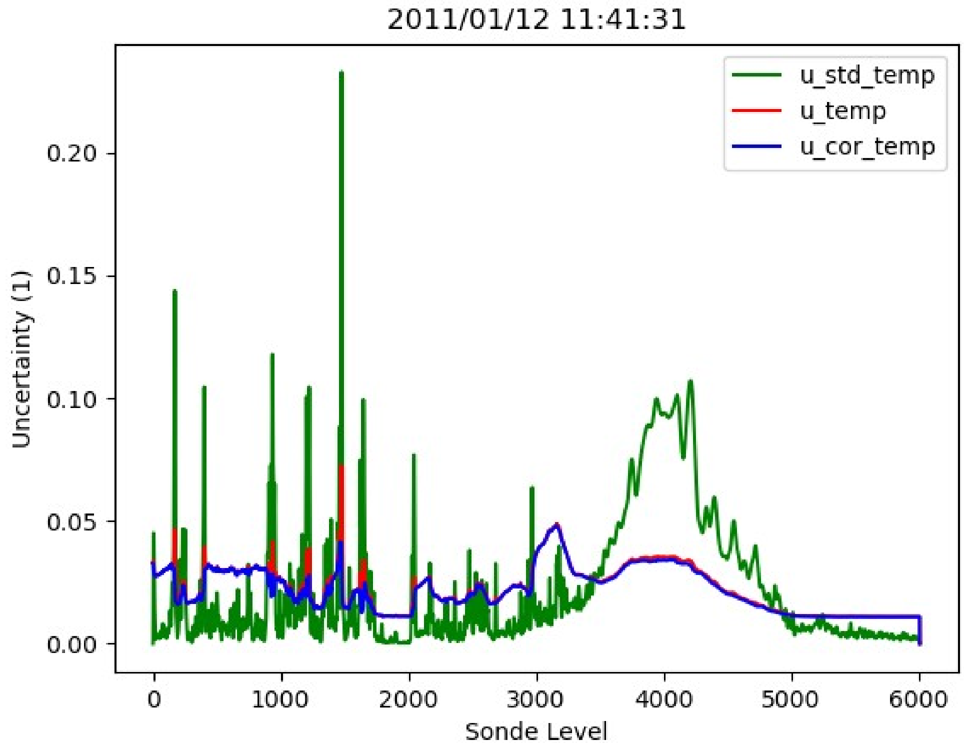
- But... I am processing RS92!!!
- Only TWO uncertainties in RS92 files:

u_temp = total uncertainty

u_cor_temp = correlated uncertainty

u_std_temp = standard deviation





Estimation of the GRUAN Uncertainty Covariance Matrix

- But... I am processing RS92!!!
- Is this code correct? :

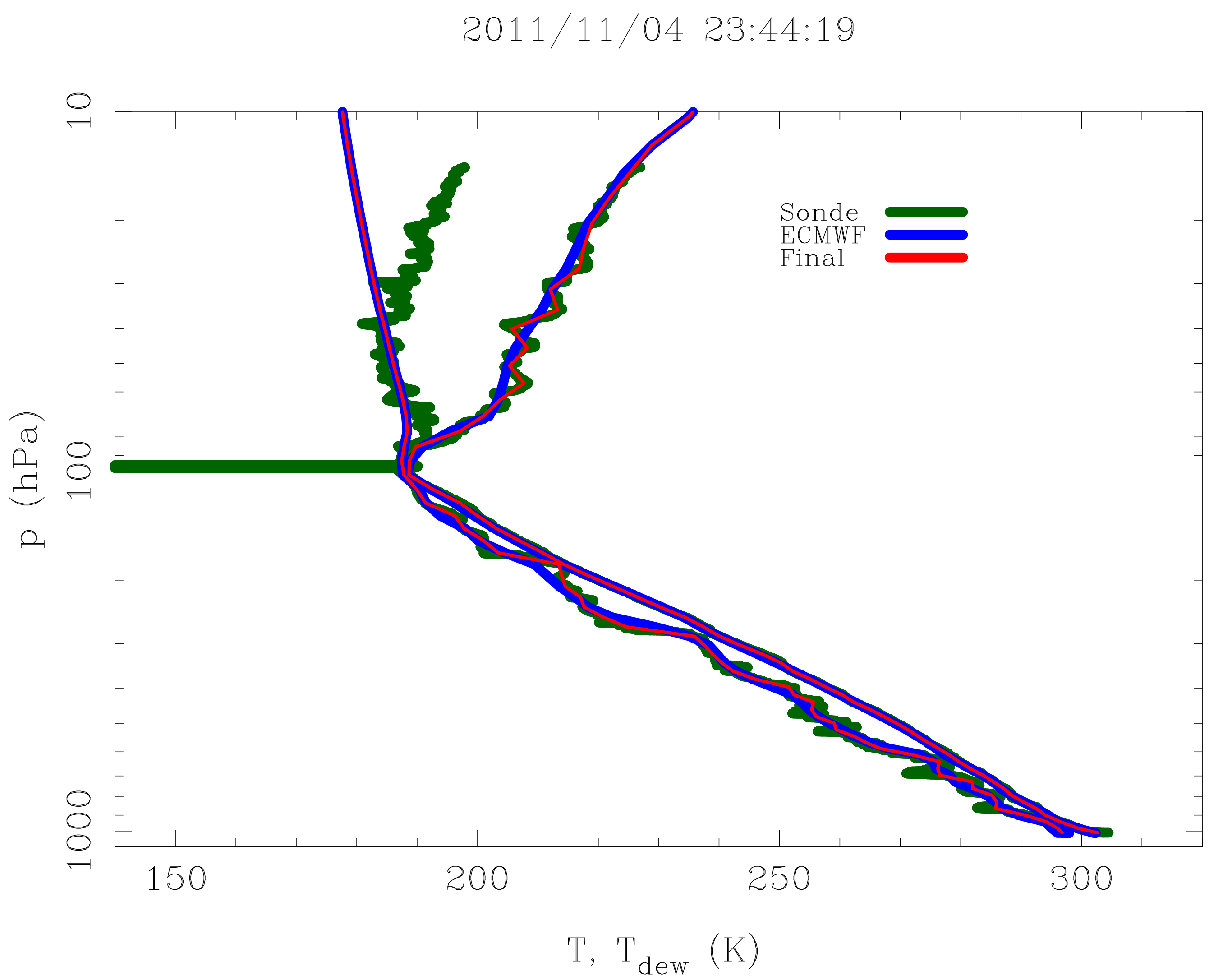
```
u_temp = total uncertainty
u_cor_temp = correlated uncertainty
Then Uncorrelated Uncertainty →
u_uncor_temp = sqrt(u_temp**2 - u_cor_temp**2)
C_T.Cucor = diag(u_uncor_temp^2);

% Totally correlated (spatial & temporal components)
for i=1:NL
    for j=1:NL
      C_T.Ccor(i,j) = u_cor_temp(i) * u_cor_temp(j);
    end
end
% Cov matrix (all components)
C_T.Ctot = C_T.Cucor + C_T.Ccor;
```

This Presentation

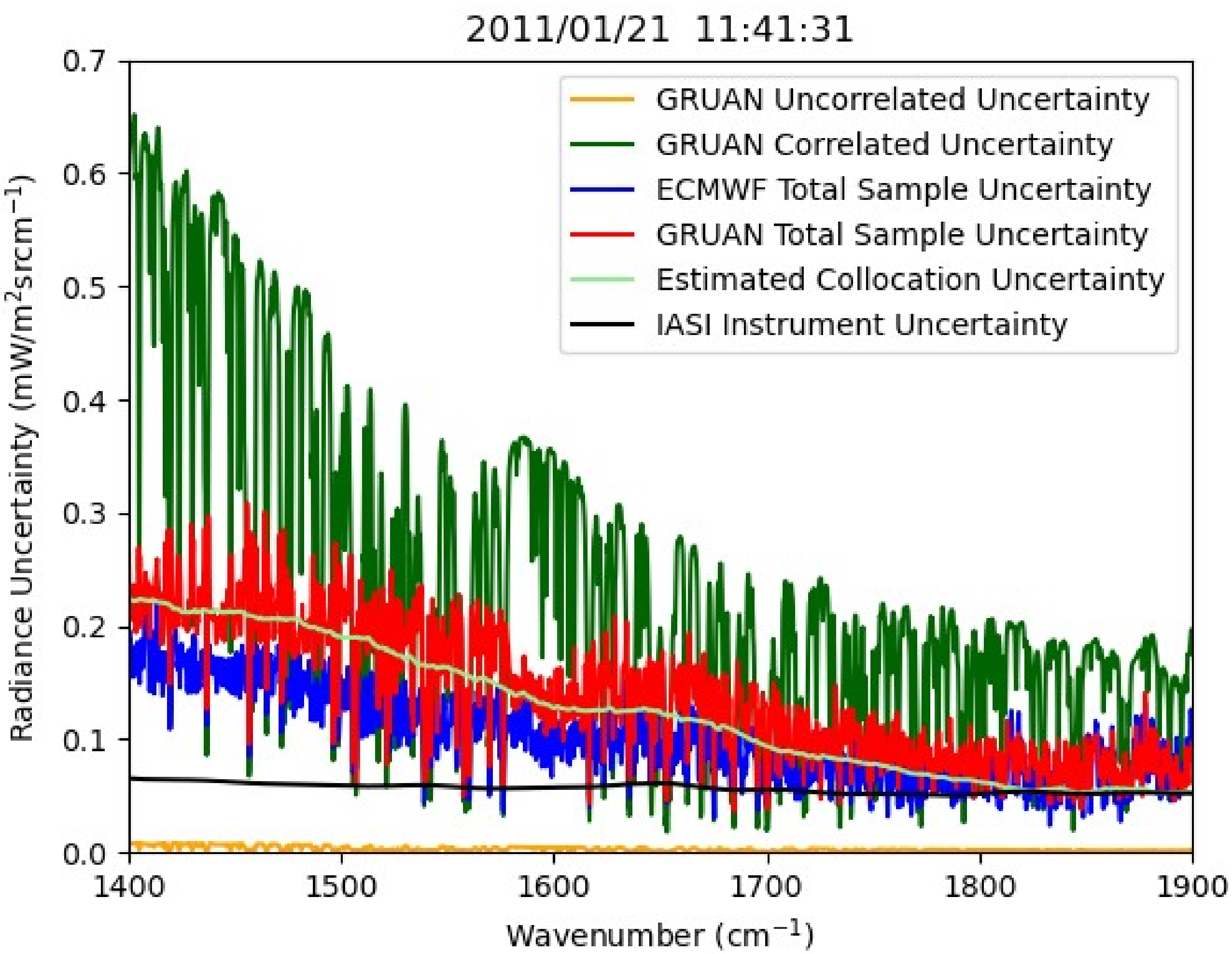
- Based on the GRUAN – IASI radiance intercomparison AMT-2017
- 76 GRUAN sondes over Manus island
- From 2011 to 2013
- Collocated with IASI less than 25 km and 30 min
- To transform sonde uncertainties into radiance uncertainties the full sonde vertical uncertainty covariance is needed
- Now using the «new» uncertainty covariance matrix

- Follwing results from an indivual sondes AND statistics from all 76 sondes

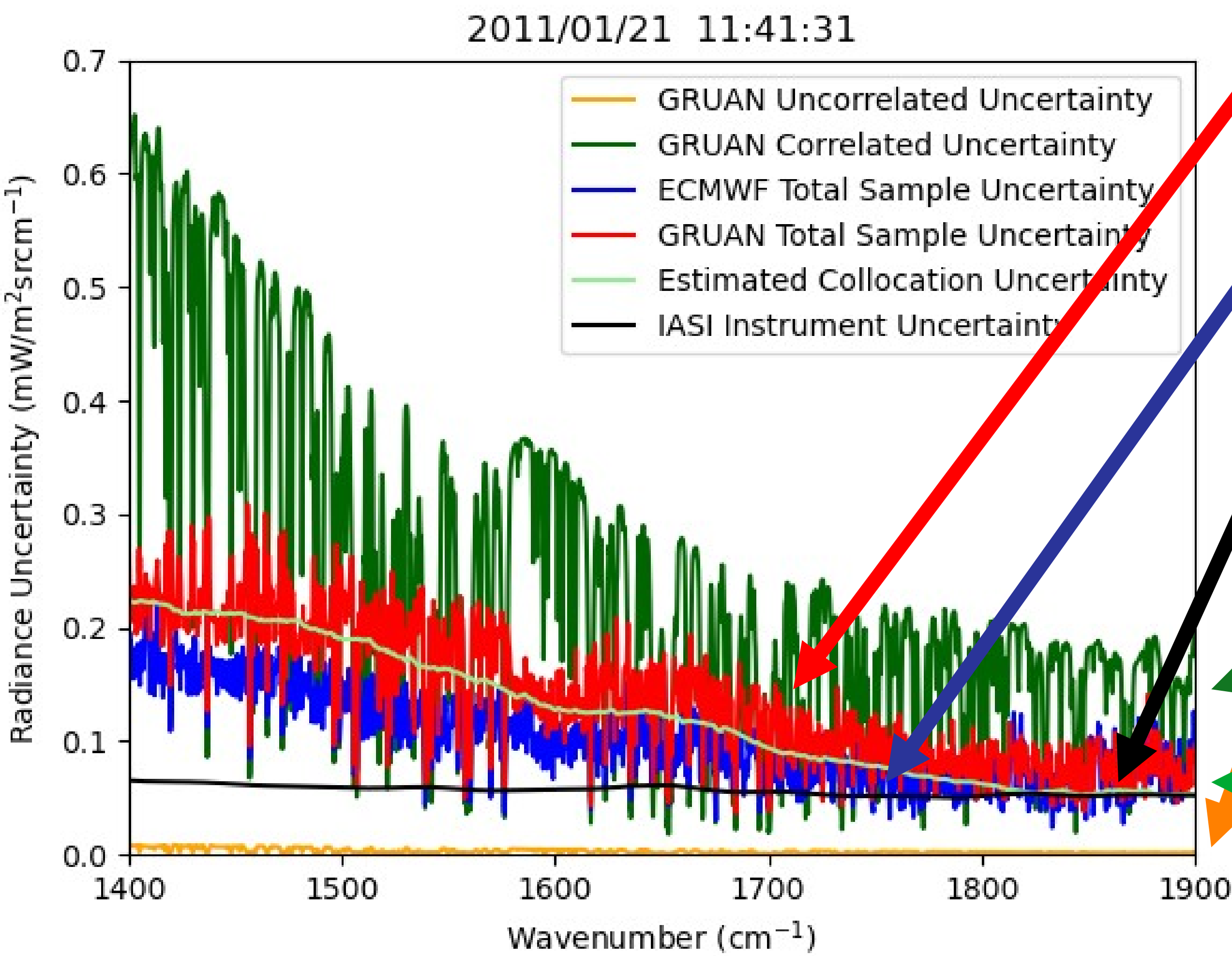
2017 Results: Sonde Example



2017 Results



2017 Results



Standard Deviation of IASI Observed minus GRUAN Calculated radiances

Standard Deviation of IASI Observed minus ECMWF Calculated radiances

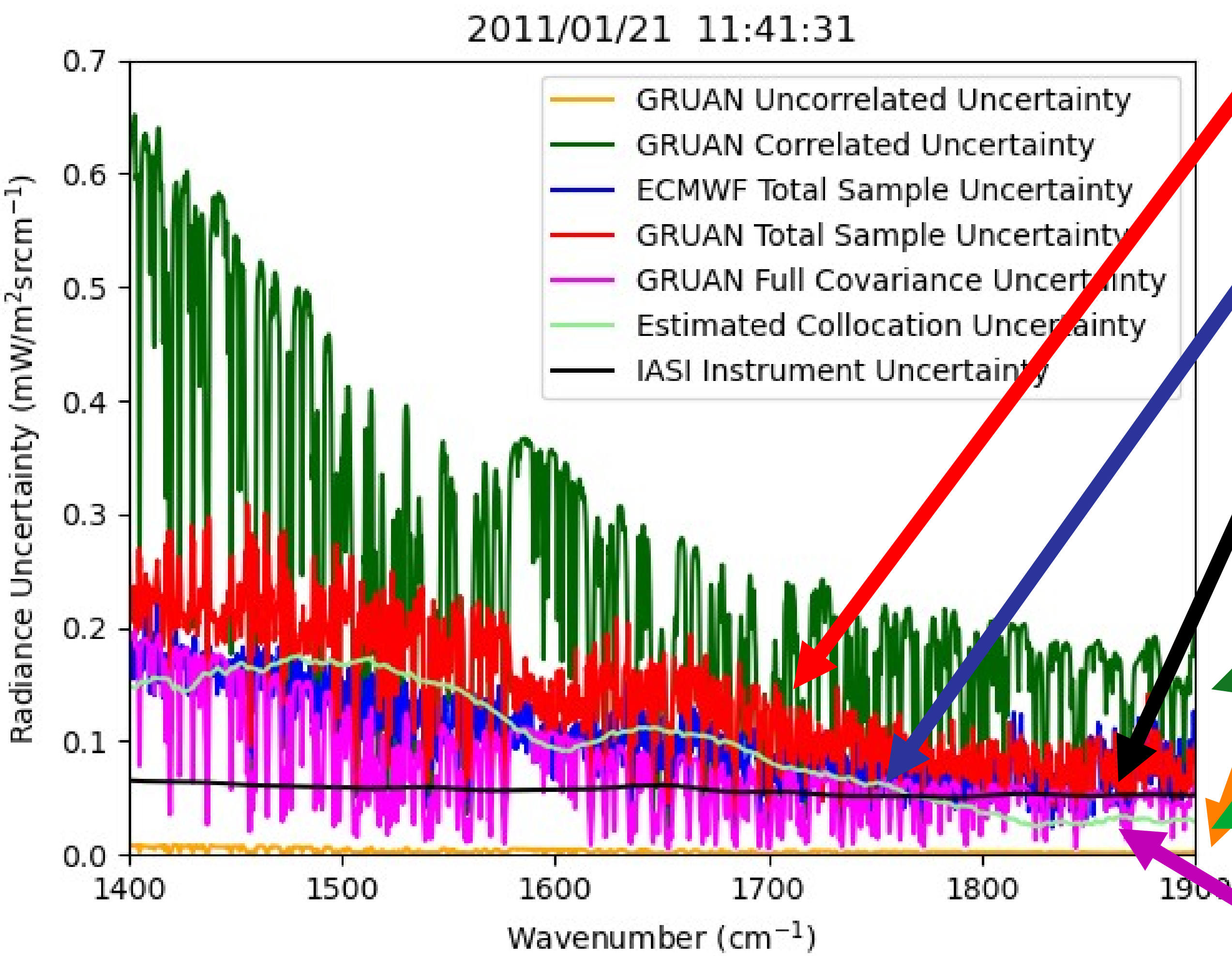
IASI Instrument Noise

GRUAN Uncertainty assuming no vertical uncertainty correlation

GRUAN Uncertainty assuming full vertical uncertainty correlation

What is left is mainly the collocation uncertainty

New Results



Standard Deviation of IASI Observed minus GRUAN Calculated radiances

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IASI Instrument Noise

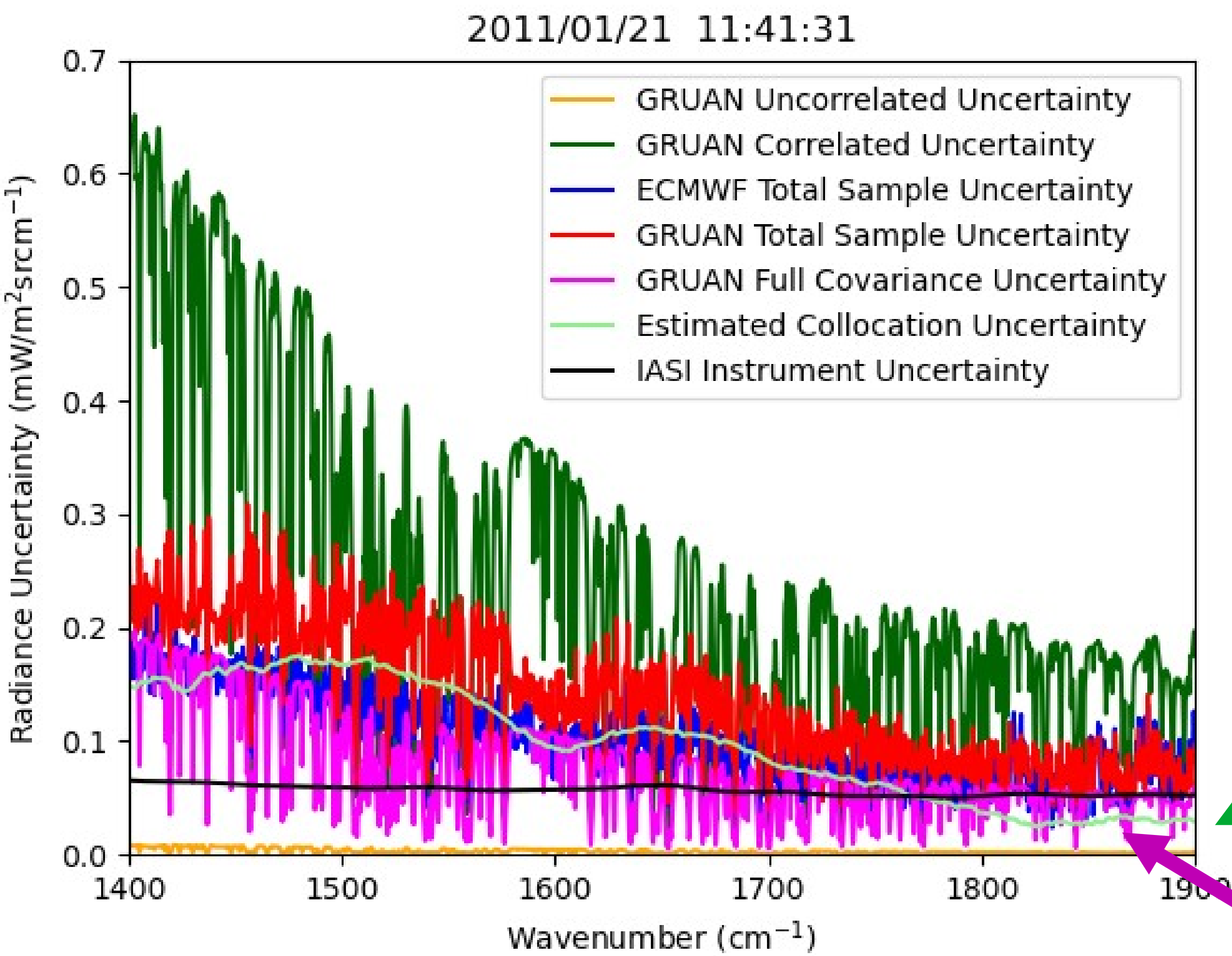
GRUAN Uncertainty assuming no vertical uncertainty correlation

GRUAN Uncertainty assuming full vertical uncertainty correlation

What is left is mainly the collocation uncertainty

GRUAN Uncertainty using full vertical uncertainty covariance matrix

New Results



Collocation Uncertainty below IASI instrument noise!!!!!!!

GRUAN Uncertainty of same order as IASI instrument noise

Conclusions

- More work needed

- But, after 15 years, we are about to complete the full circle!!

- GRUAN uncertainty in radiance space comparable to IASI instrument noise → Comparisons are meaningful and useful!!!!

- Many new conclusions can be derived in the future!!