Assimilation of Geostationary Hyperspectral Infrared Sounders (**GeoHIS**) : progresses, challenges and perspectives

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Virtual meeting

Outline

- What learned from the REAL GeoHIS data?
- What's the opportunity of GeoHIS ?
- What's looking forward?

- **WHY GeoHIS**
  - **HIGH temporal**, 3D temperature and moisture (trace gases)
  - **Targeted Observing** for high impact weather
- **Progress on GIIRS evaluation and assimilation**
  - **NEW methods**
    - **ISSEC**, A fast and accurate spectral bias estimation algorithm
    - **OOPS**, On Orbit Parameter eStimation using data assimilation methodology
  - **NEW findings**
    - Diurnal and seasonal variation
    - Possible root cause: sensor parameter estimation based on NWP
  - Assimilation of GIIRS radiances and *the "4D winds"*
- **Summary and future perspectives**
  - Suggestions for NWP user community
  - Towards assimilation of global ring of Geo. sounders in "active mode" : THORPEX forward

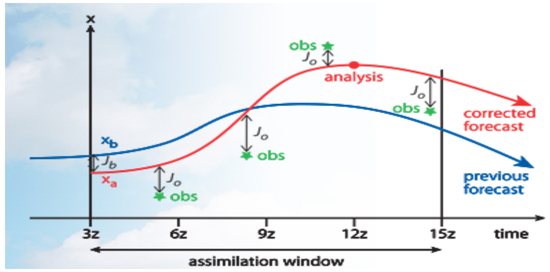
WHY GeoHIS: Opportunities and Challenges

- **Convective scale analysis and forecast**
  - Fast evolving weather
  - Pre-convection monitoring
- **Targeted observing for HIW in geo. orbit (**Han,2019**)**
  - Hurricane
  - Convection
  - Strong precipitation
- **Large detector array challenges in geo. orbit**
  - Calibration (spectral , radiometric)
  - Bias correction
  - Observation error estimation

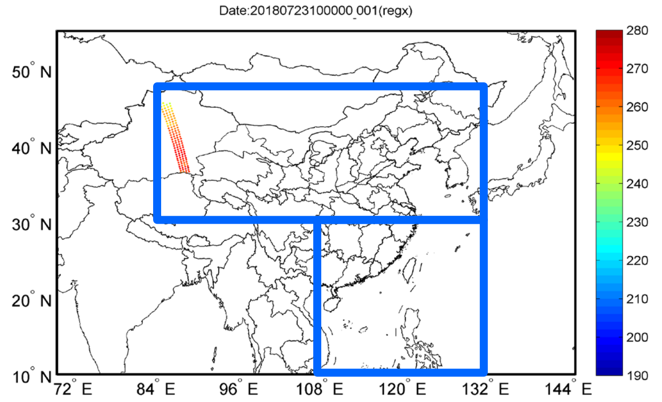
Uniformity of all the detectors: accuracy and stability

FY-4A GIIRS Targeted Observing for Typhoon Forecasts

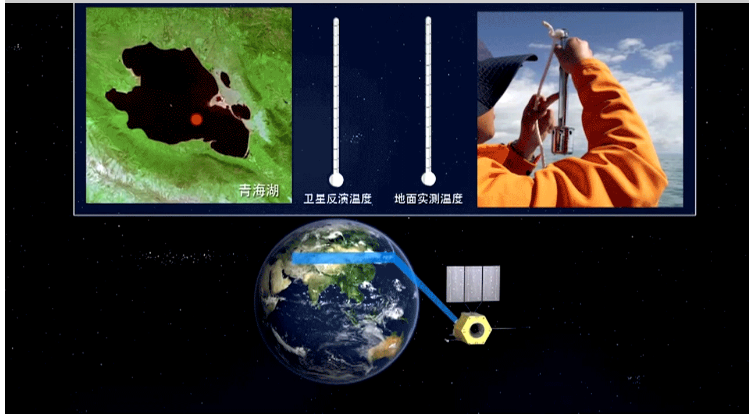
4D-Var



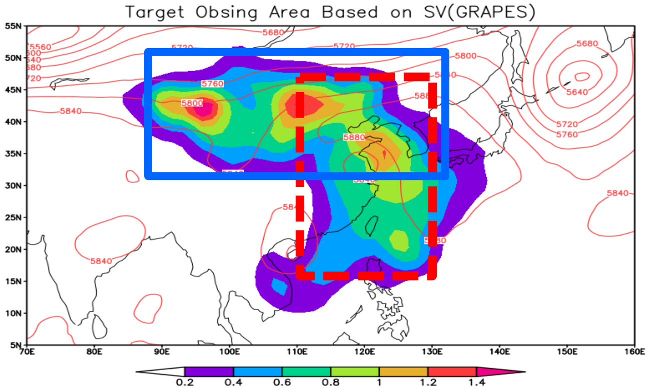
Assimilation of targeted observations



Every 30 minutes sounding in sensitive area



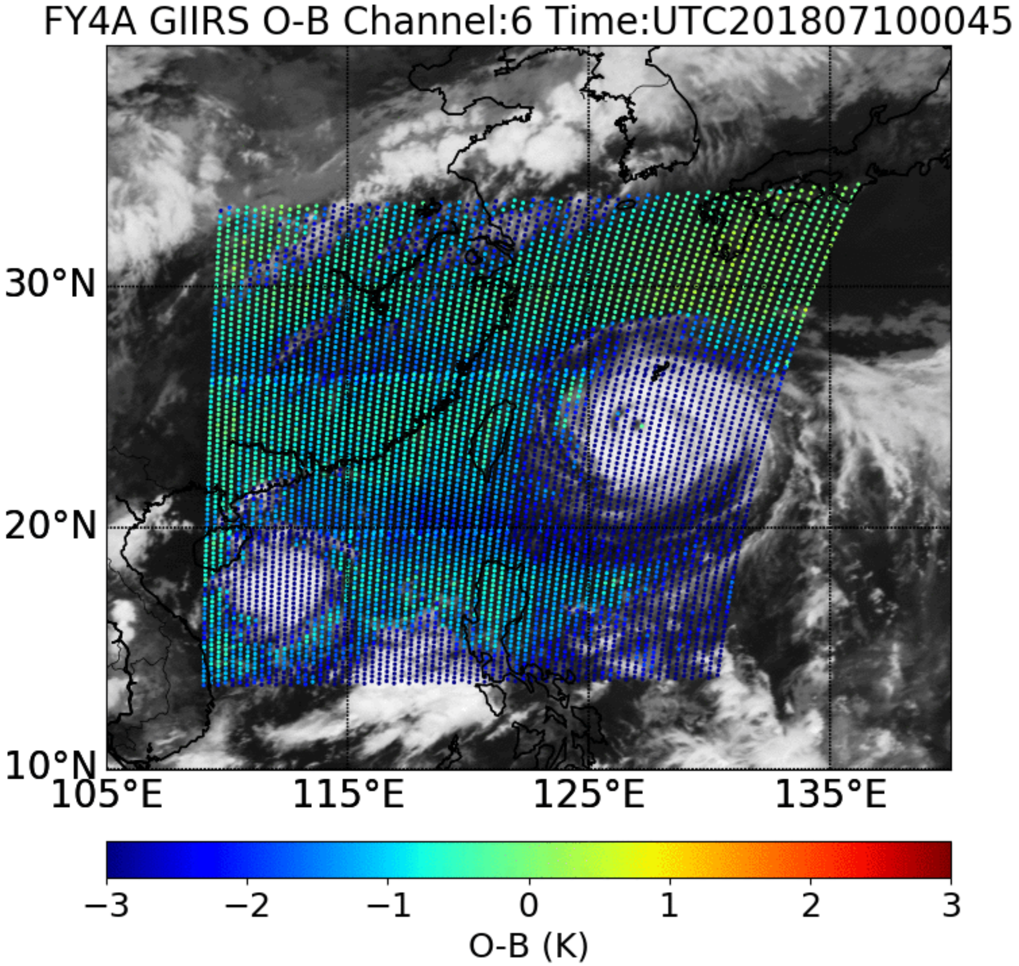
Sensitive area



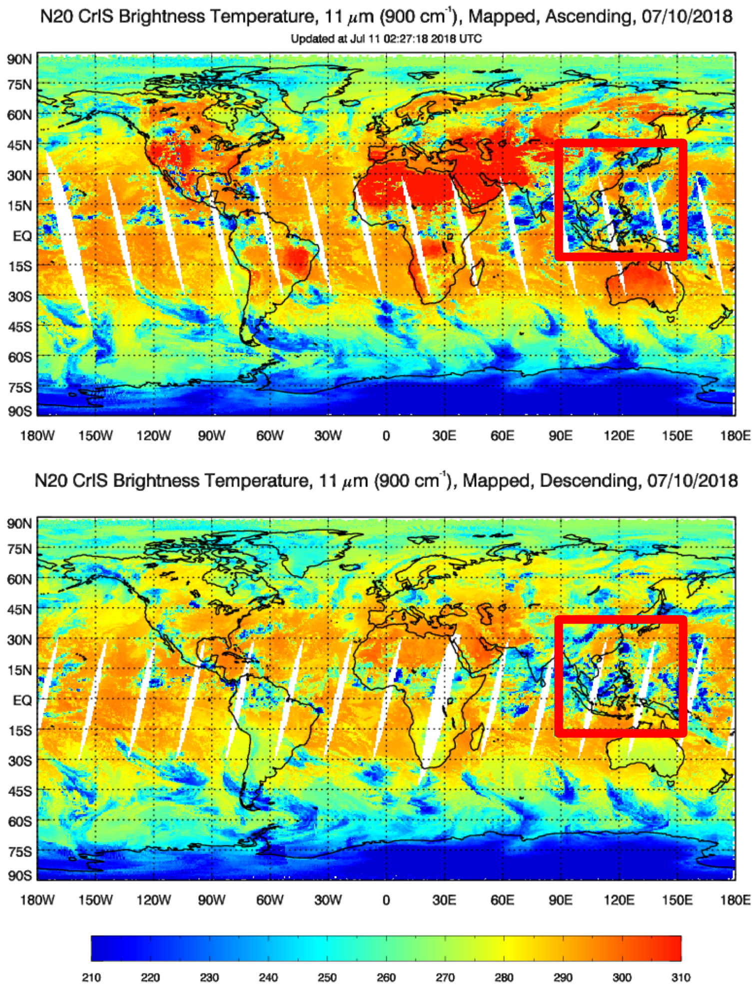
Han W. et al, 2019: Assimilation of high temporal resolution GIIRS in 4D-var , 2019 Joint Satellite Conference, Boston, Sept.28-Oct.4,2019.
https://ams.confex.com/ams/JOINTSATMET/videogateway.cgi/id/505317?recordingid=505317

Geo Sounder and Leo Sounder: Hurricane sounding

Geo Sounder: FY-4A GIIRS

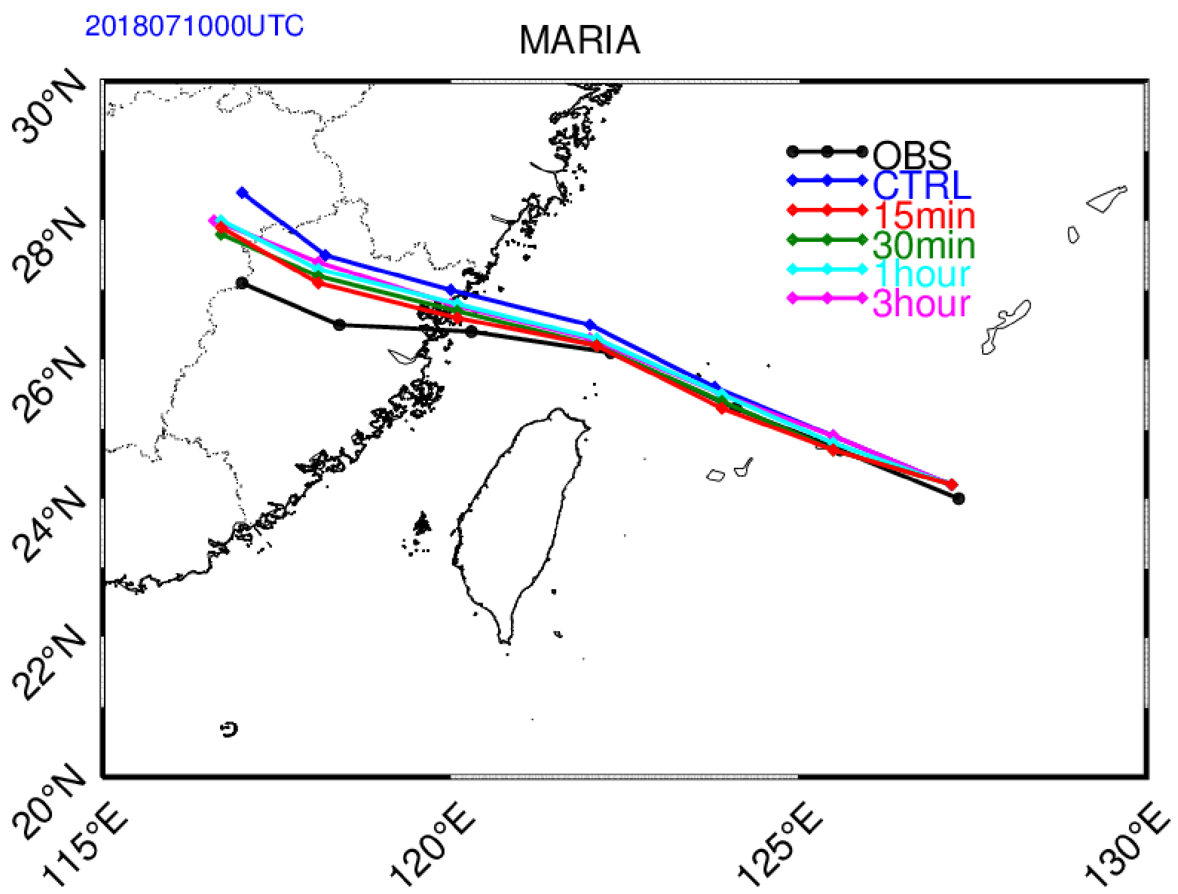


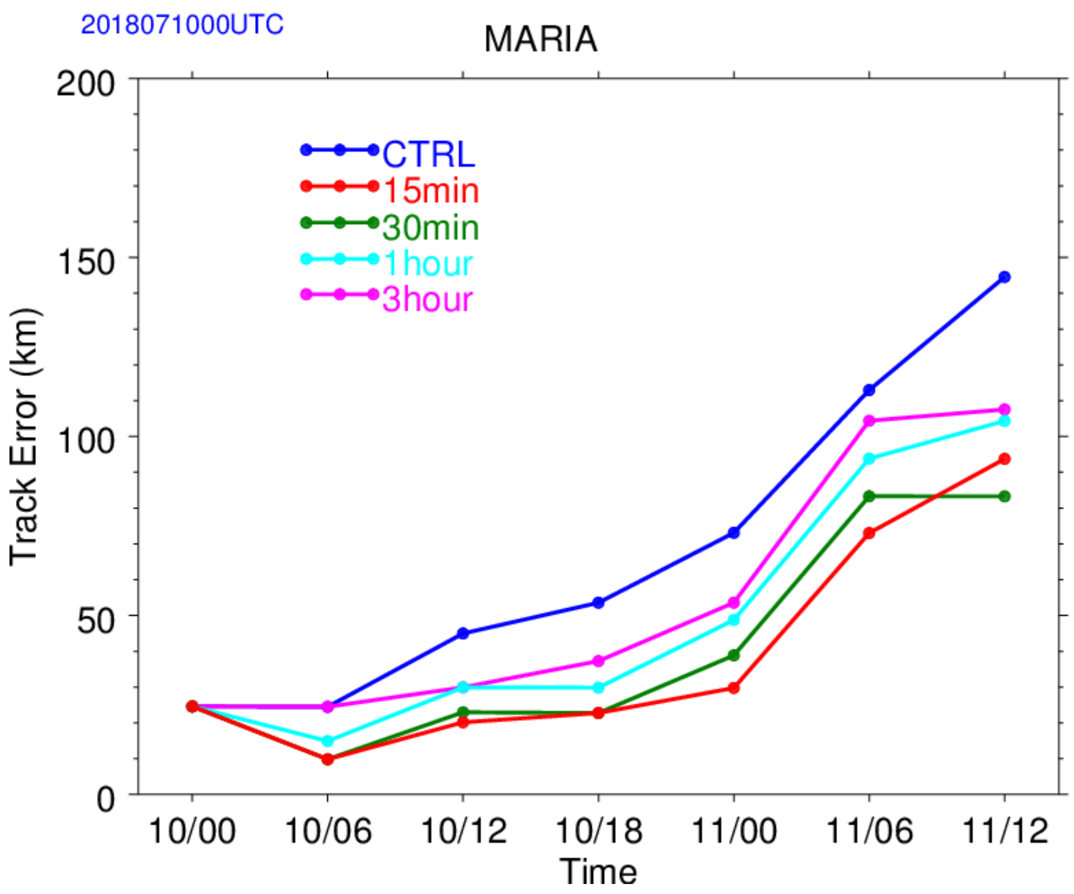
Leo Sounder: N20 CrIS



Typhoon Maria (2018)

Impact of GIIRS targeted observing on Typhoon Maria forecasts

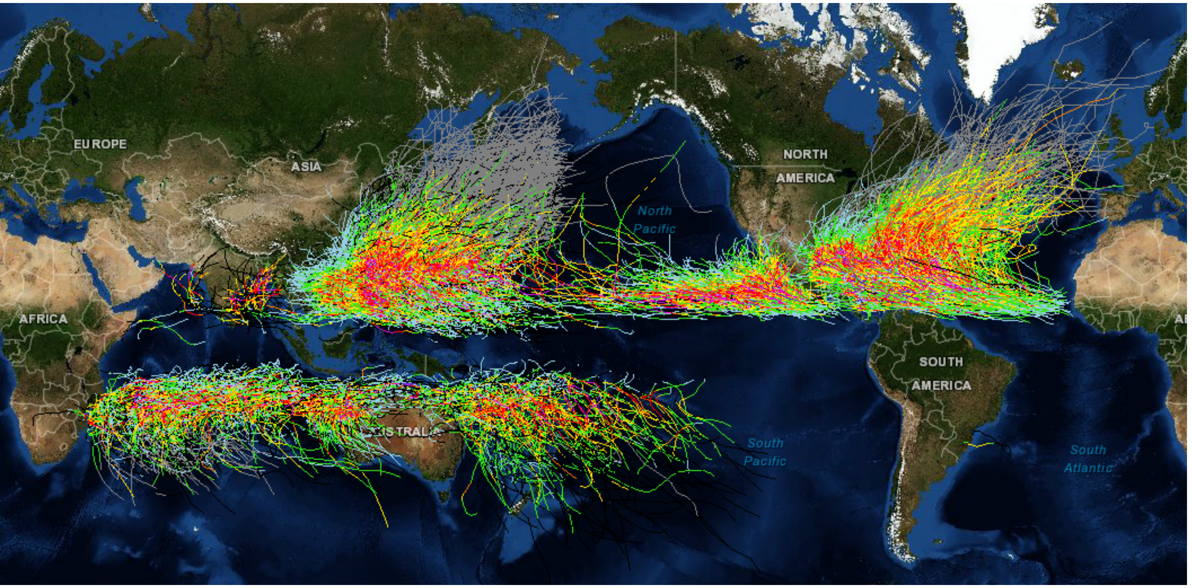


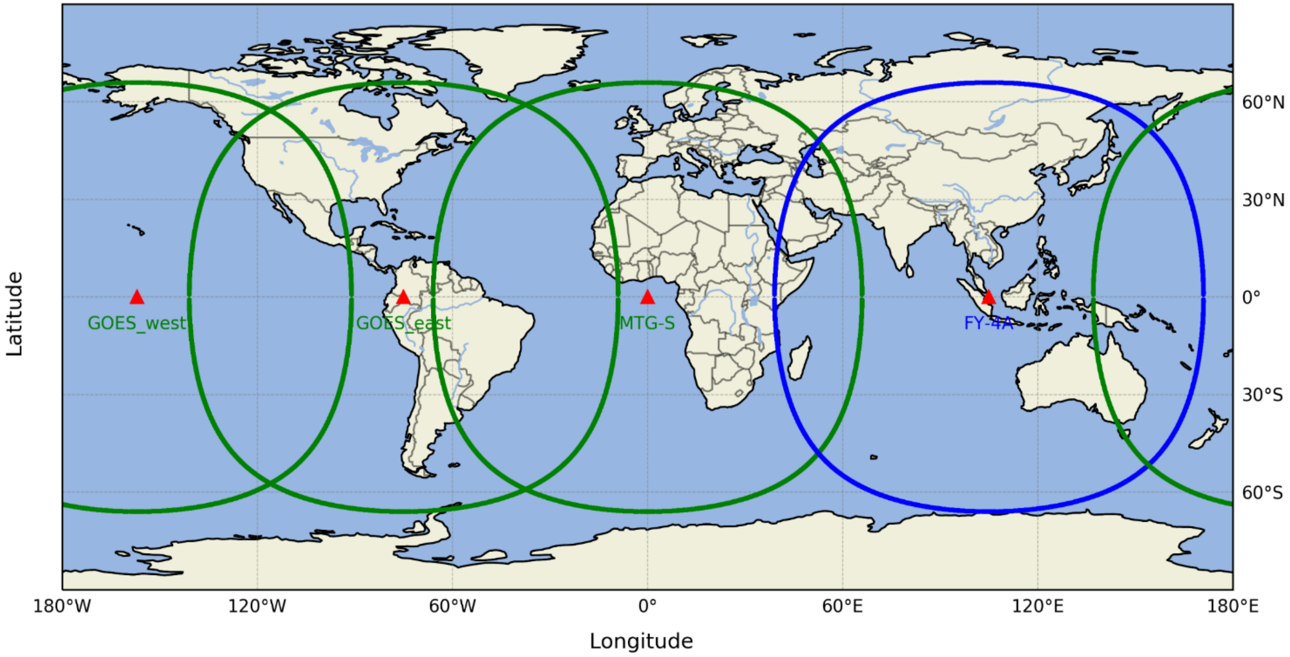


Han W. et. al.,Assimilation of high temporal GIIRS radiance in GRAPES,ITSC22, Québec, Canada, 31 October – 6 November 2019.

Global Ring of geo. sounders in global observing system

- User driven **Target Observing** to improve High Impact Weather (**HIW**)





Large detector array of FY-4A GIIRS: Uniformity (spectral and radiometric)

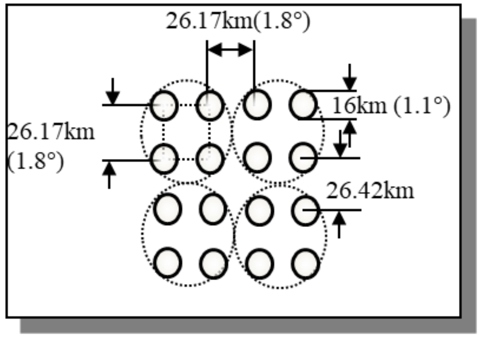
Detector Array:112kmX648km

FOV: 16km

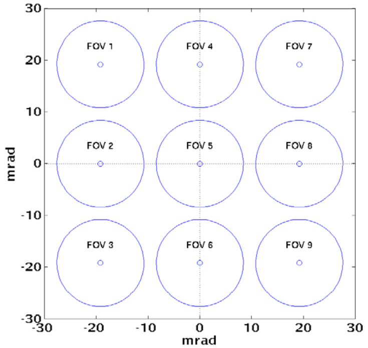
MTG IRS: 160X160

2 hour （15N-65N ,75E-135E）

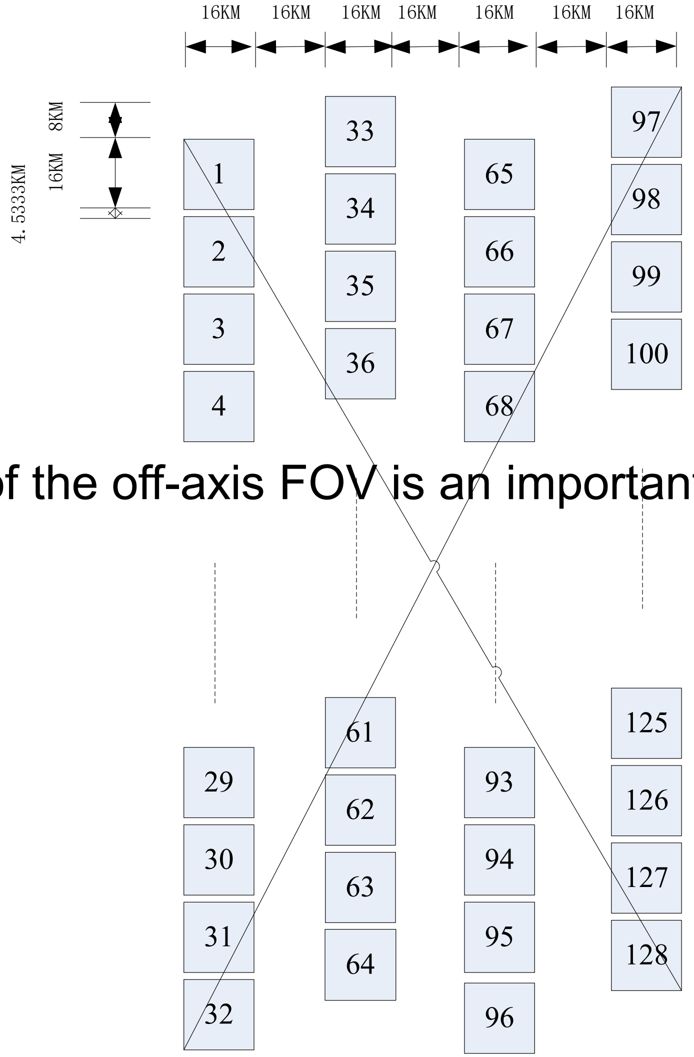
FY-3D HIRAS:2X2



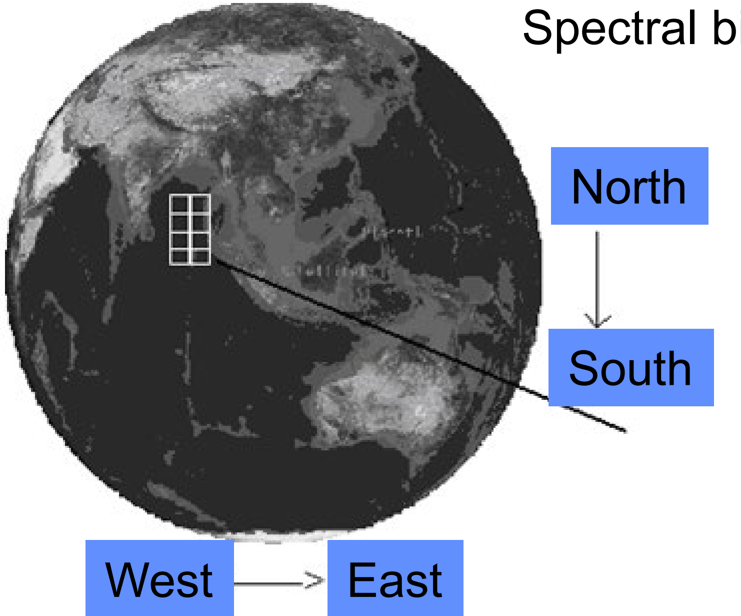
CrIS:3X3



32X4 648km × 112km



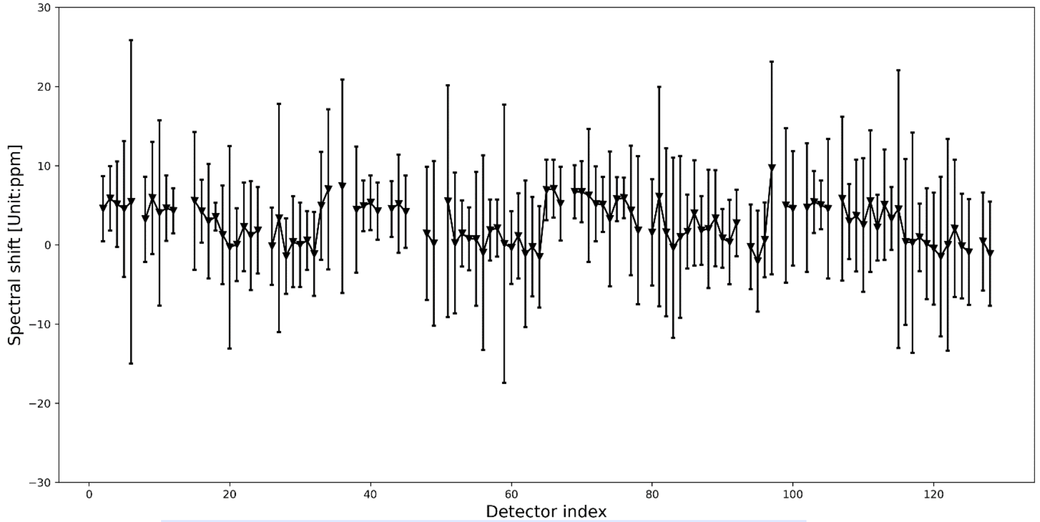
Spectral bias of the off-axis FOV is an important issue

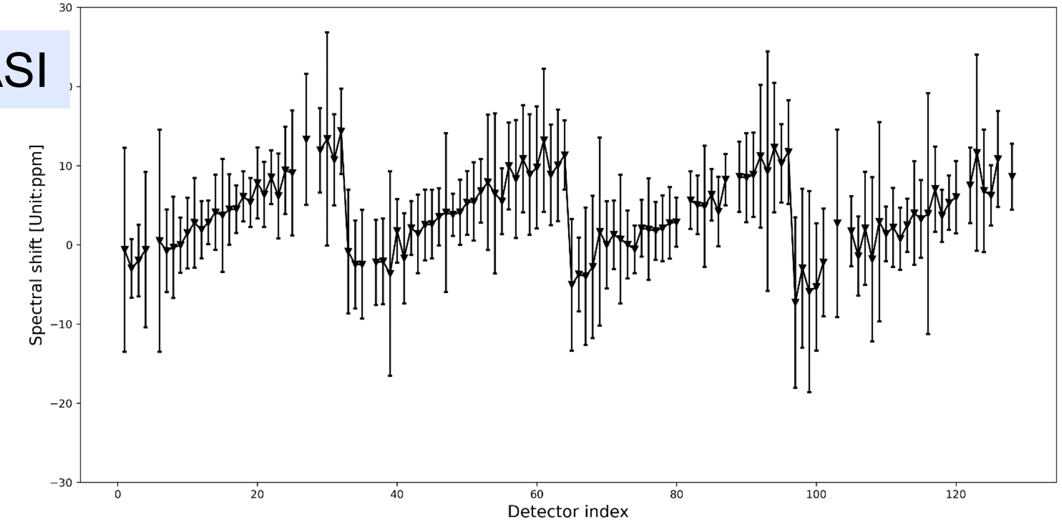


Questions:

WHY the spectral shift are different using GIIRS_IASI and GIIRS_CrIS SNOs?

WHY the pattern change over time?

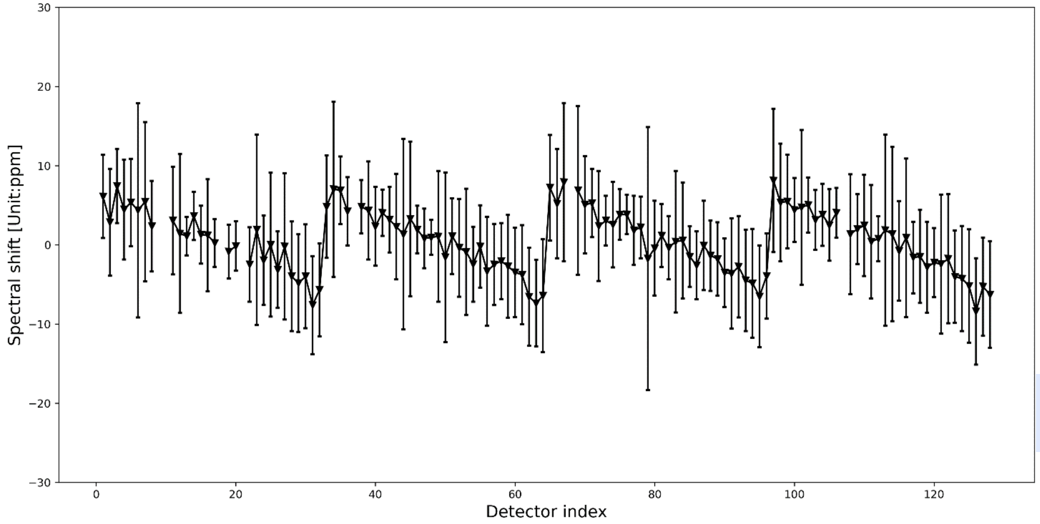


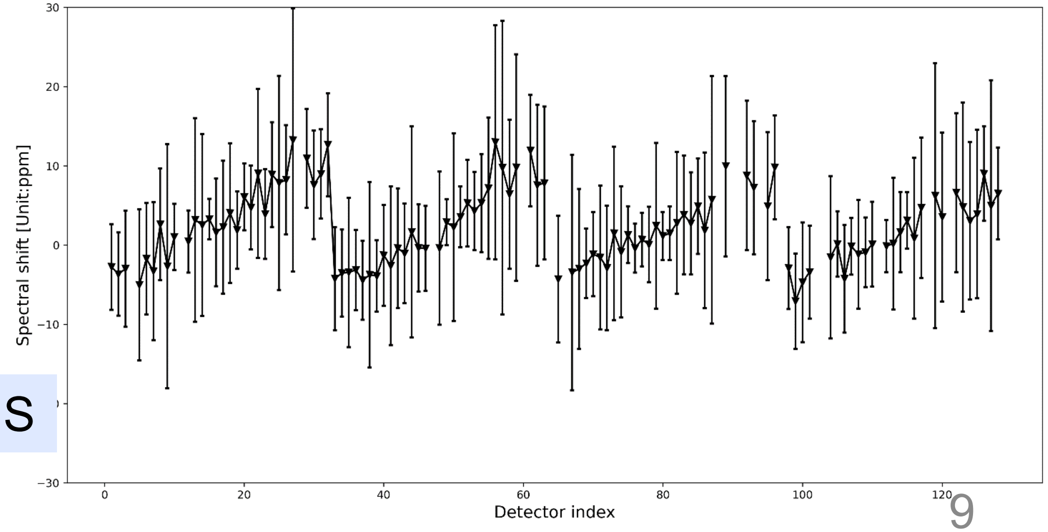


GIIRS-IASI

Period: 20191107-20191130

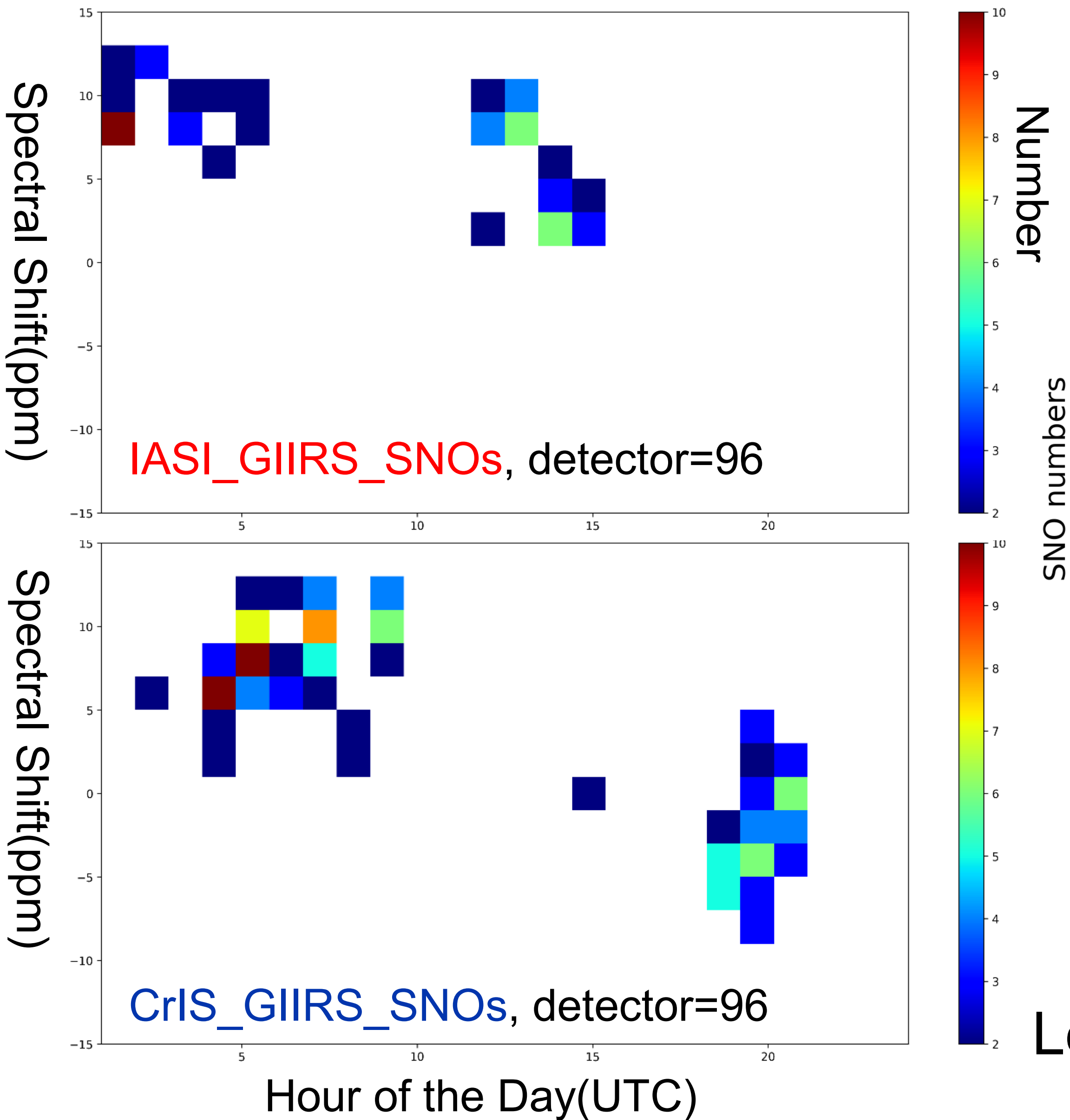
Period: 20200507-200530



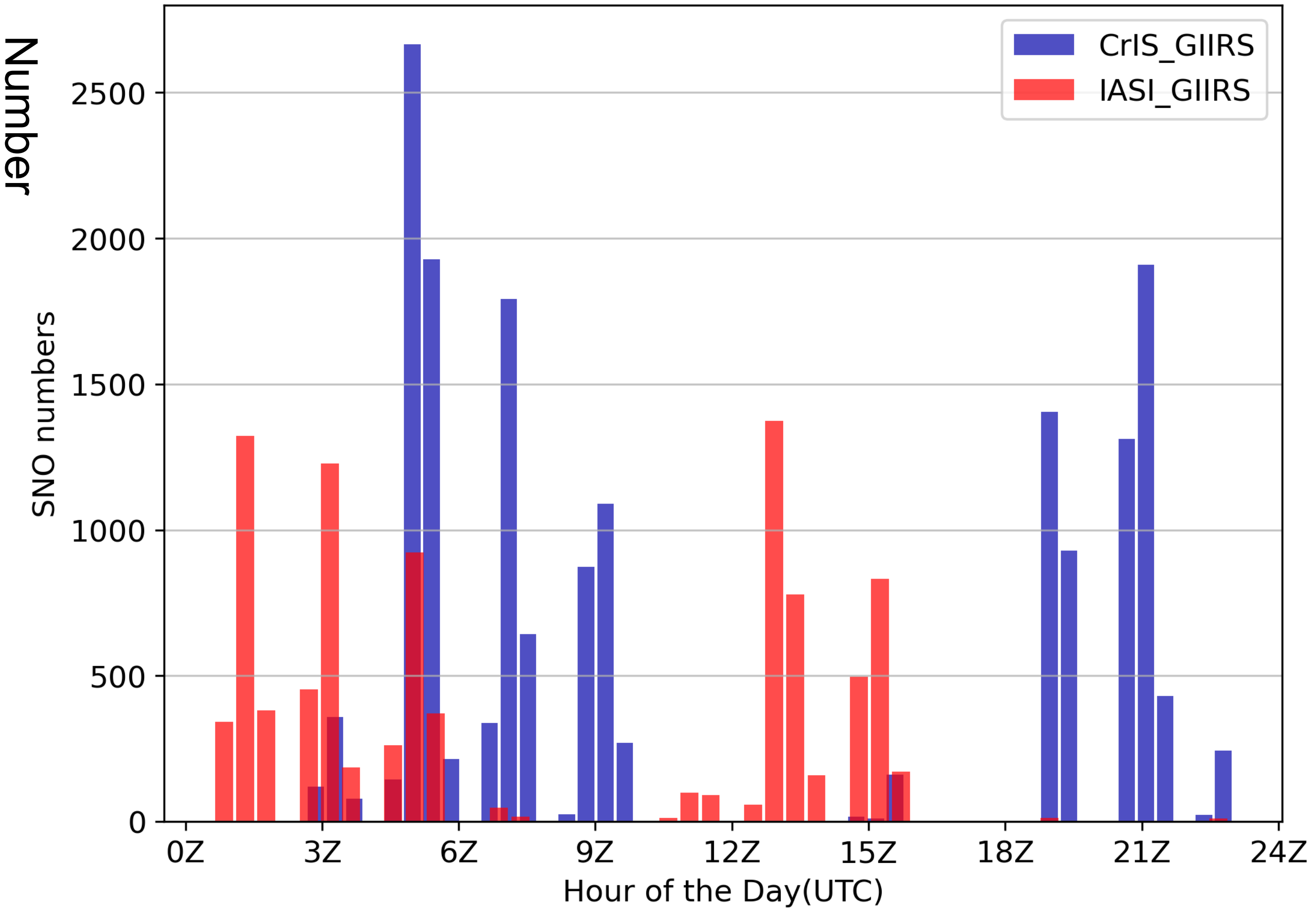


GIIRS-CrIS

CrIS_GIIRS and IASI_GIIRS SNOs : time of the day



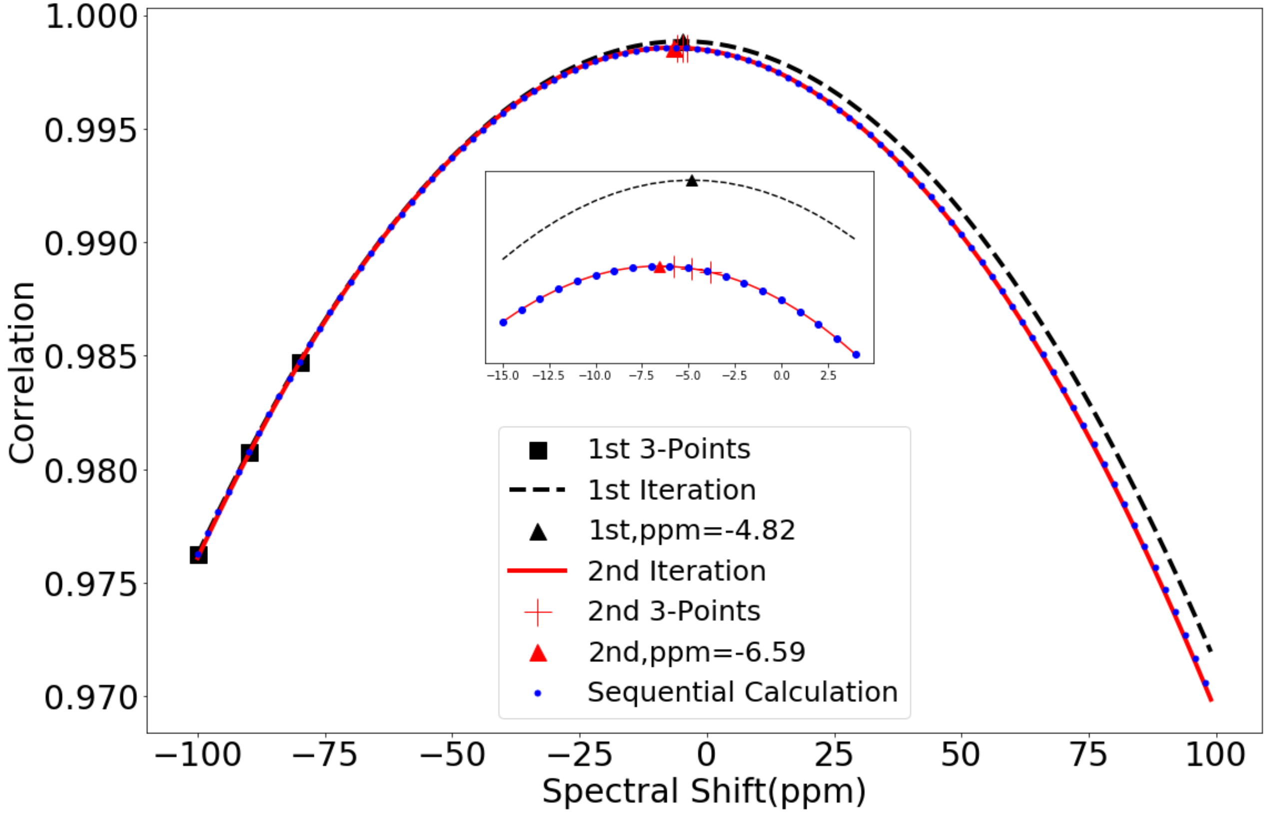
2020050100-20200510, 10 days sample for all the detectors

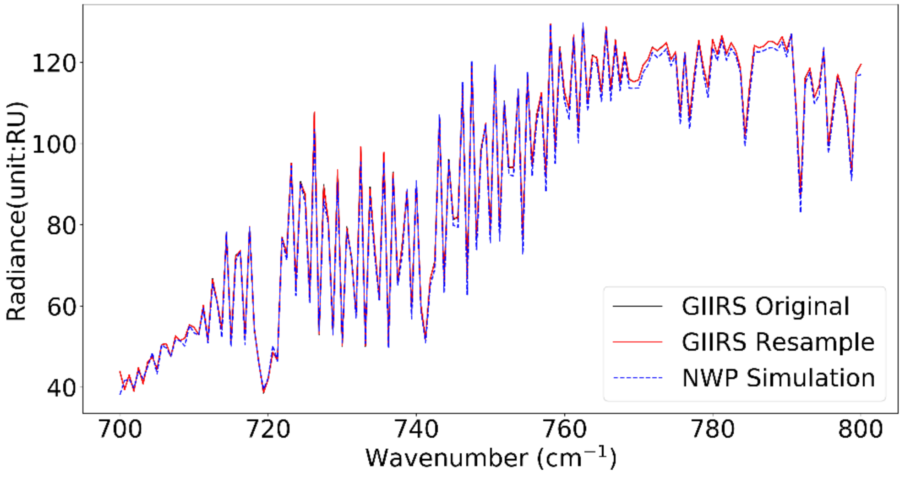


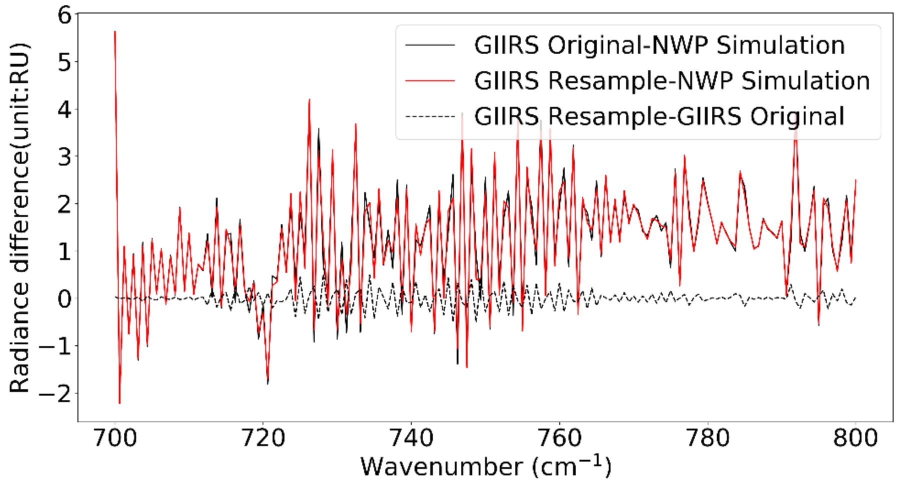
Lessons learned: consider time of the day!

Iterative **S**pectral **S**hift **E**stimation and **C**orrection using local quadratic approximation (**ISSEC**)

Resample calculation: $\frac{ISSEC}{SEQUENTIAL} = \frac{6}{200} \approx \frac{1}{30}$

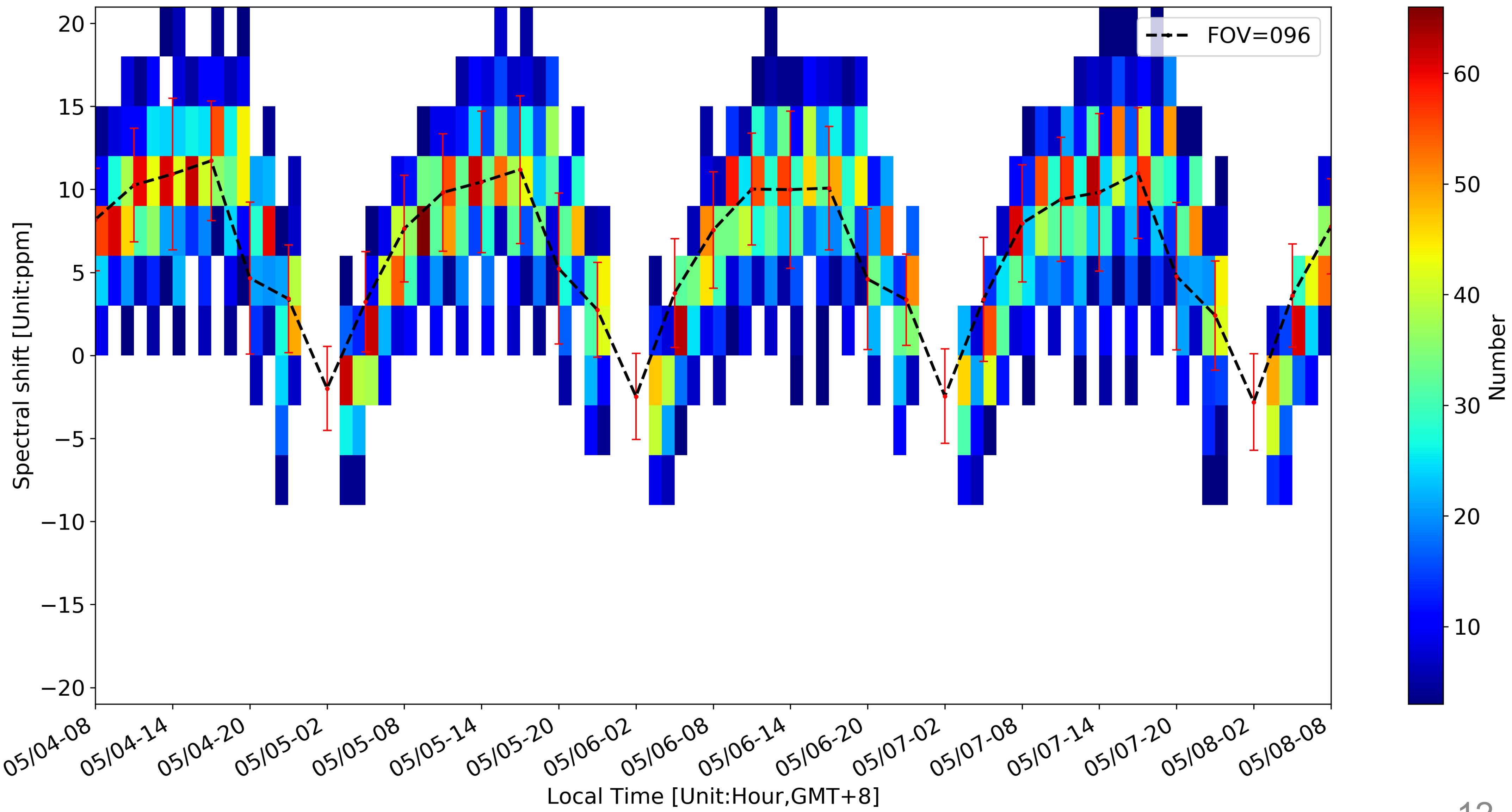




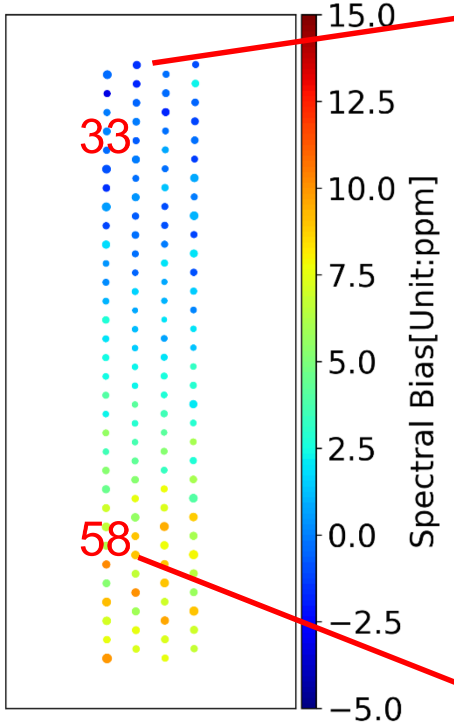


Han W. et. al., ISSEC: An fast and accurate algorithm for hyperspectral infrared sounder spectral shift estimation and correction with application on FY-4A GIIRS, to be submitted.

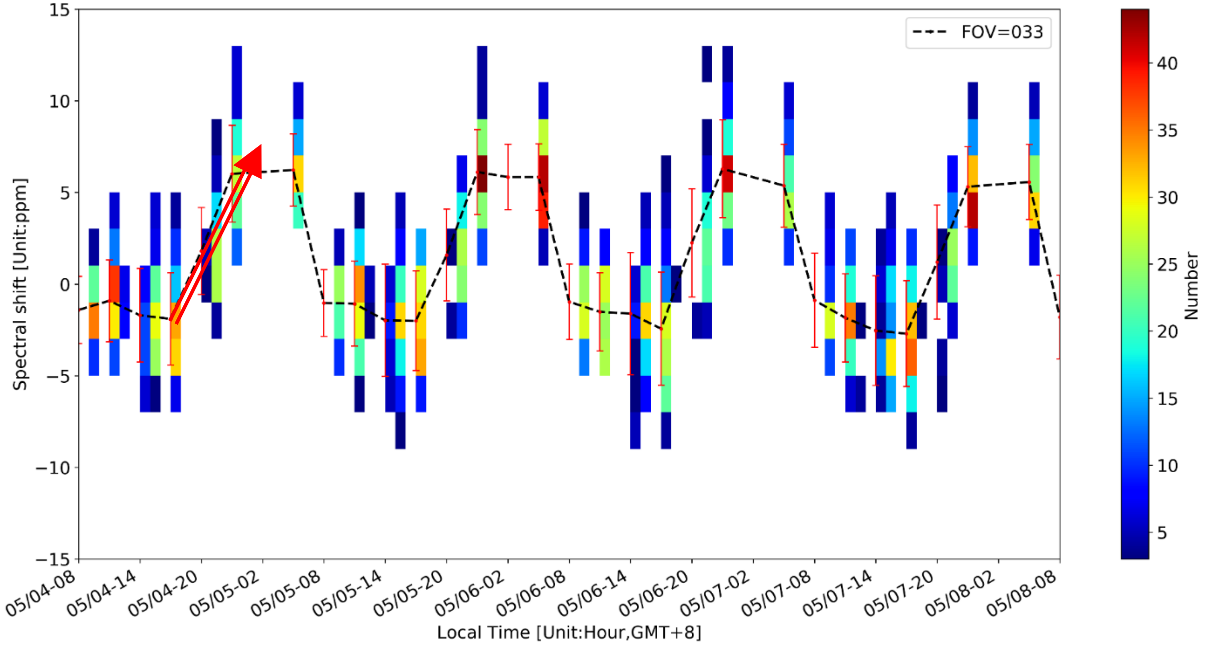
Spectral diurnal variation estimation using NWP simulation as reference

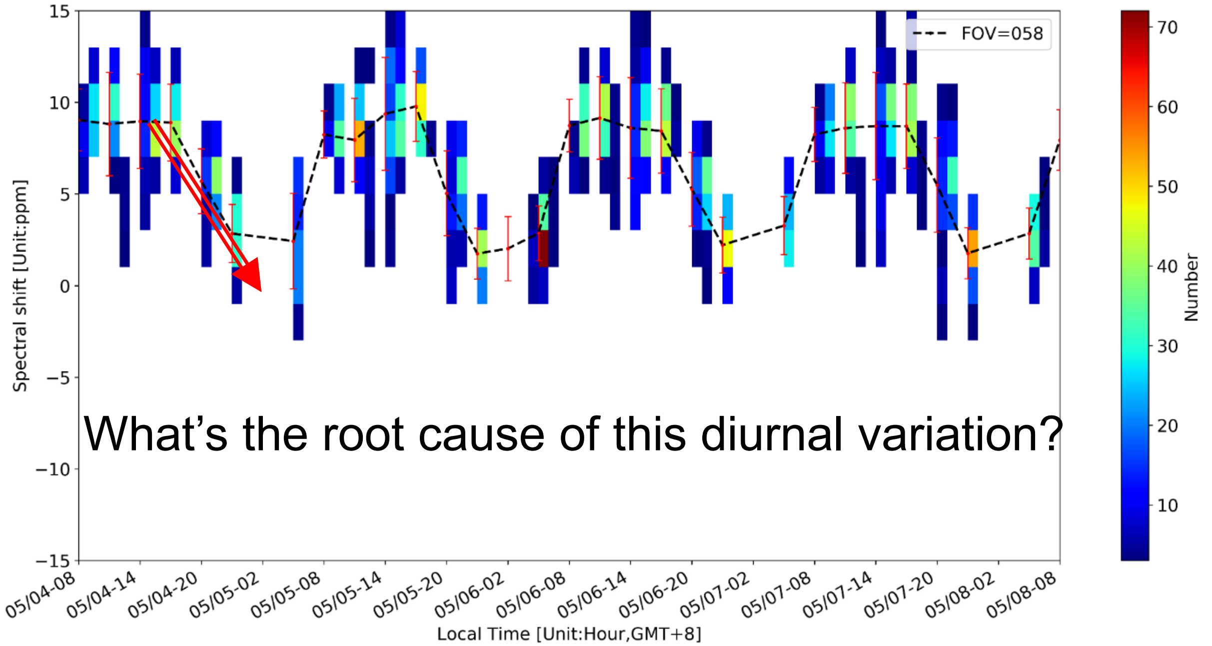


Spectral bias diurnal variation (using JEDI UFO)
FOV33 and 58



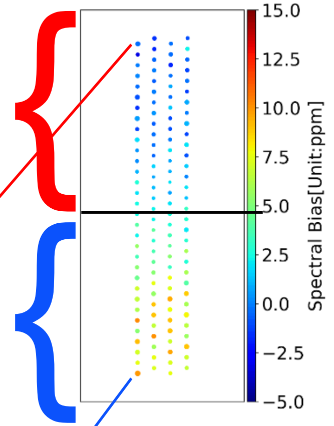
32x4=128 detectors

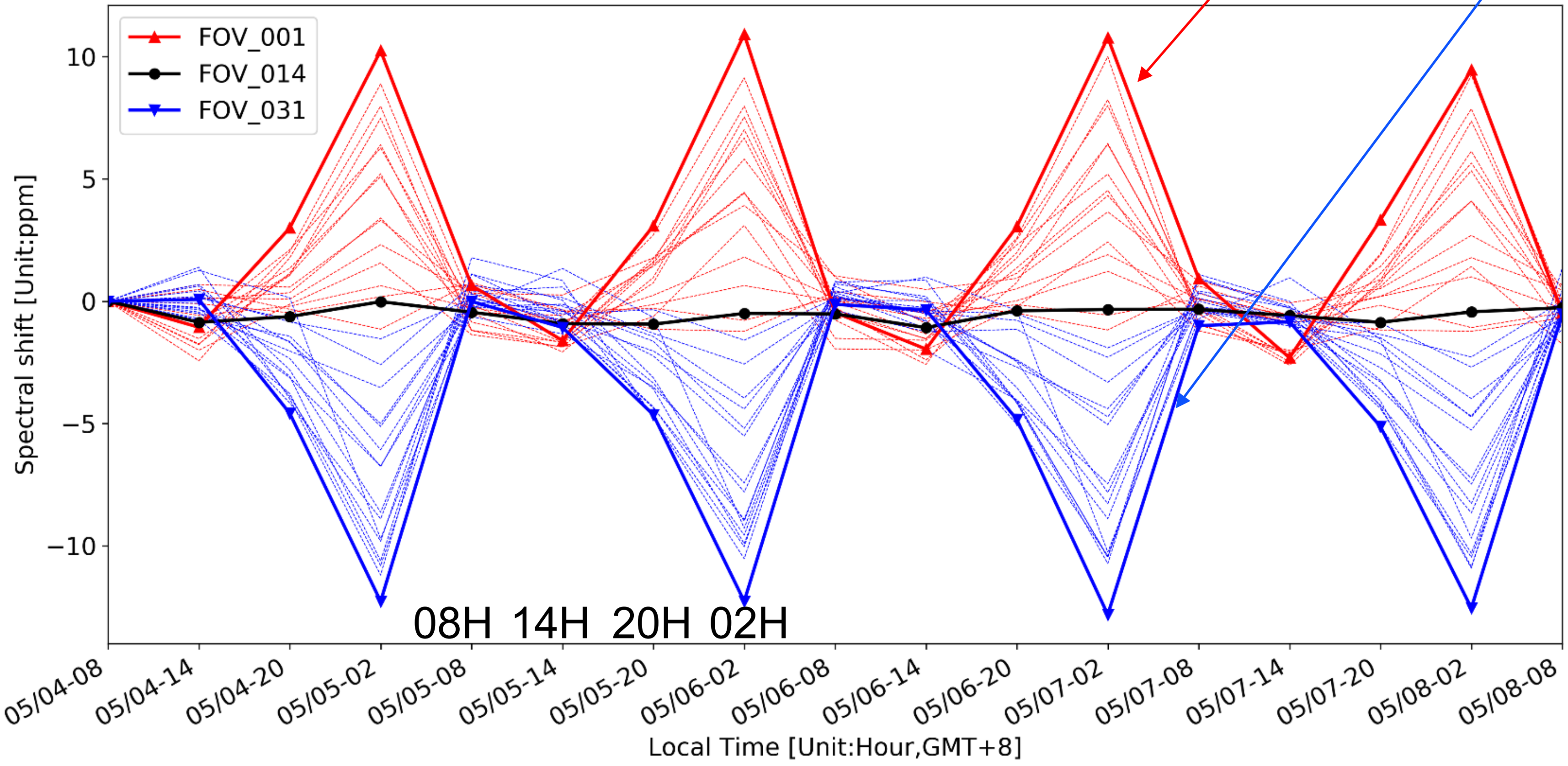




Spectral shift relative change (difference to 00z)

The spectral shifts are predicable and could be corrected.

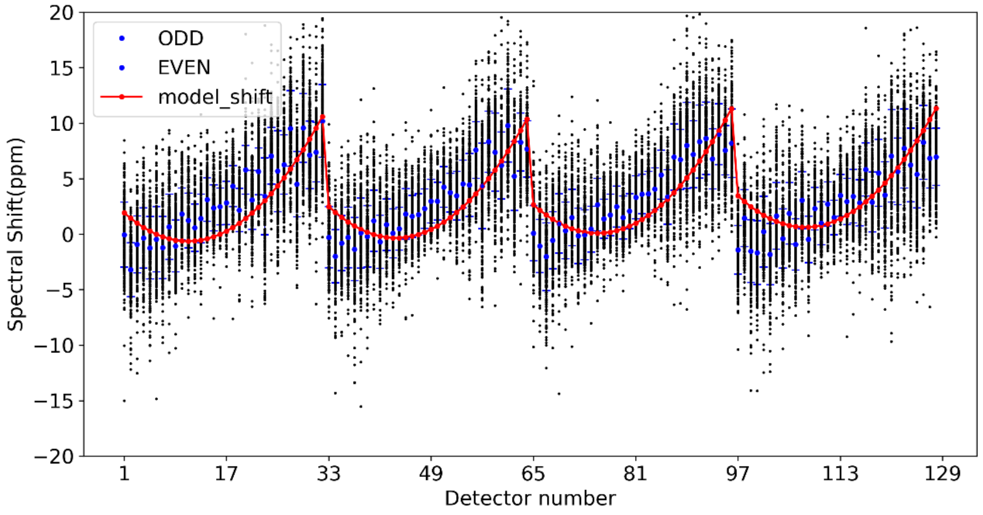




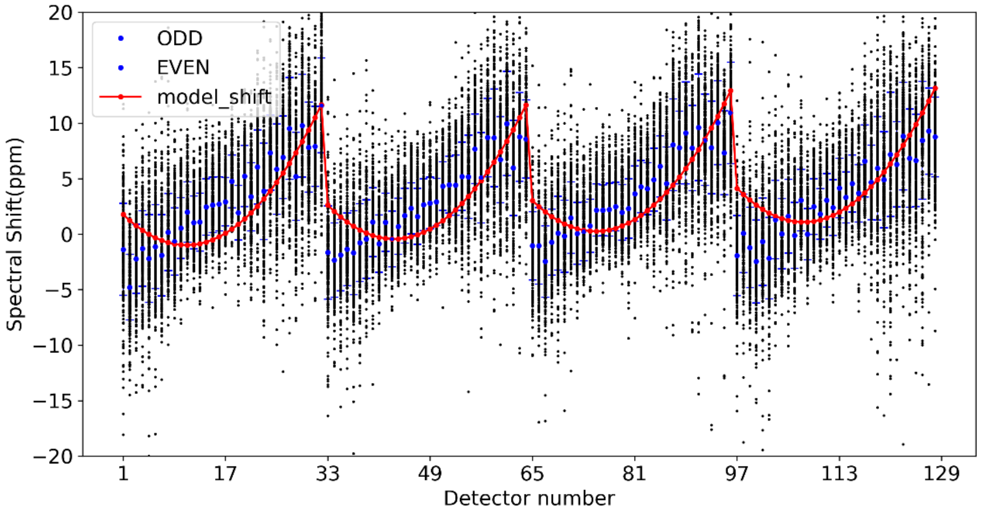
Local time

Spectral shift diurnal variation estimated using JEDI

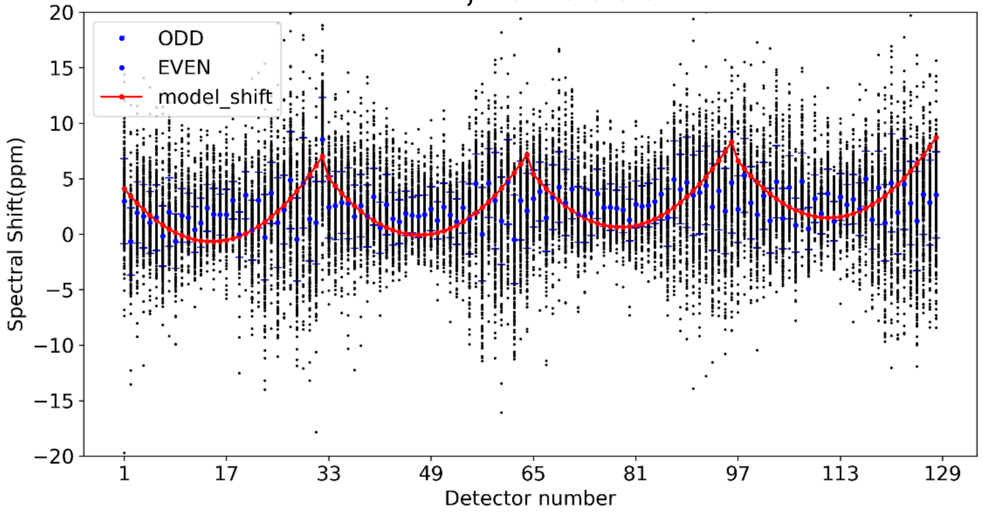
00Z,2020050400



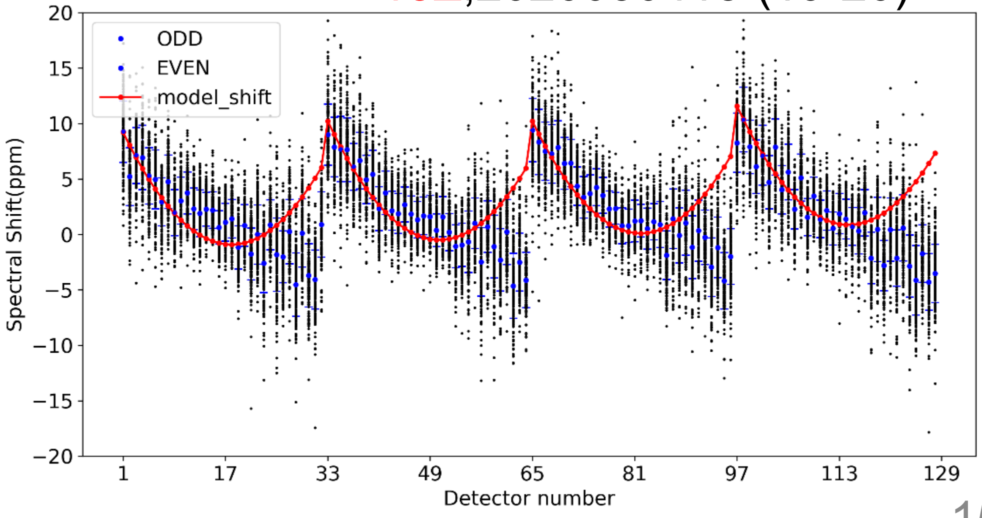
06Z,2020050406



12Z,2020050412



18Z,2020050418 (19-20)



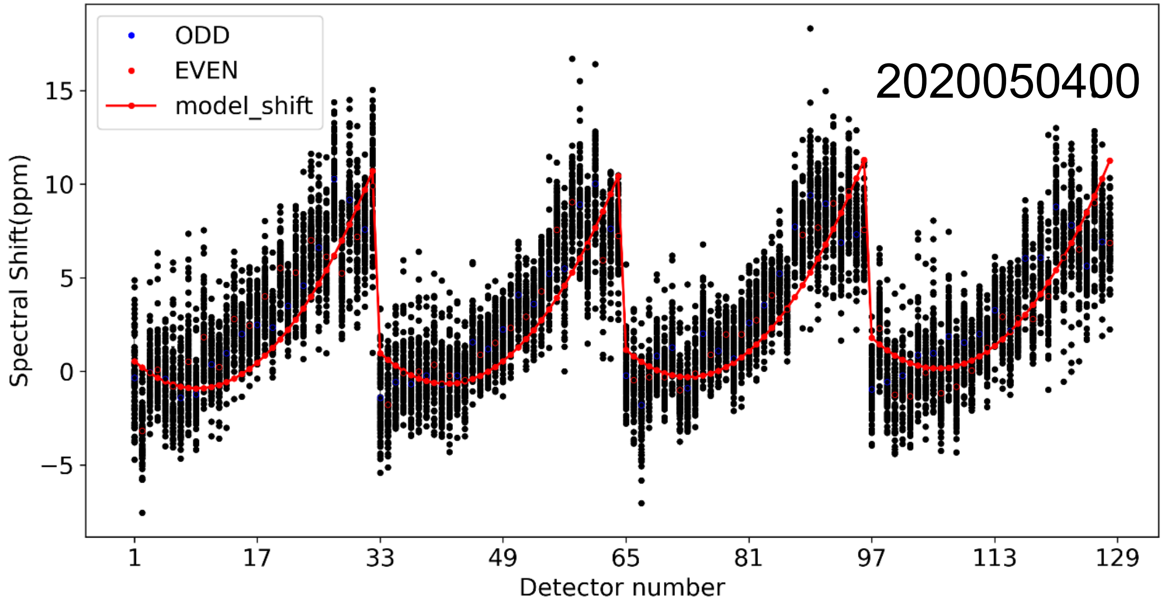
QUESTIONS:

- What's the root cause of the diurnal variation?
- Is there a physical model with limited unknown parameters ?
- How to estimate the unknown parameters?
- How to do the correction?

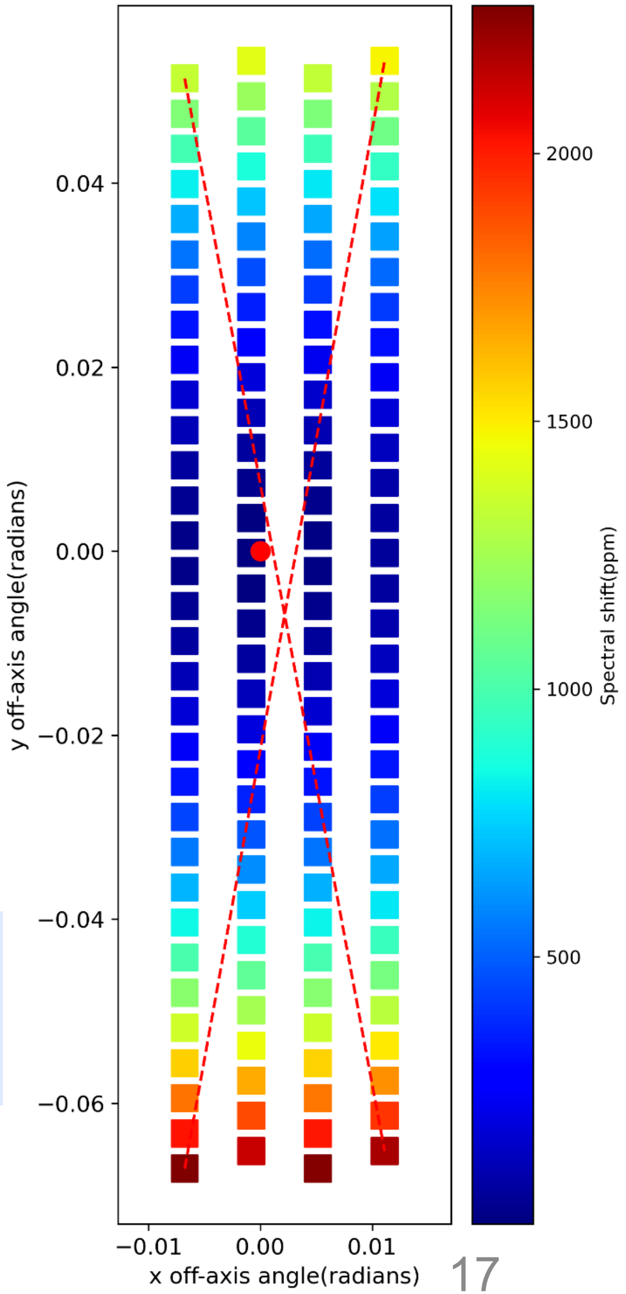
OOPS: On Orbit Parameter eStimation of satellite sensor using data dssimilation methodology

Parameters: focal center (Xc,Yc), afocal ratio, and others
Model: Optical geometry model and its perturbed model
Observations: Spectral shift estimation using NWP or SNOs

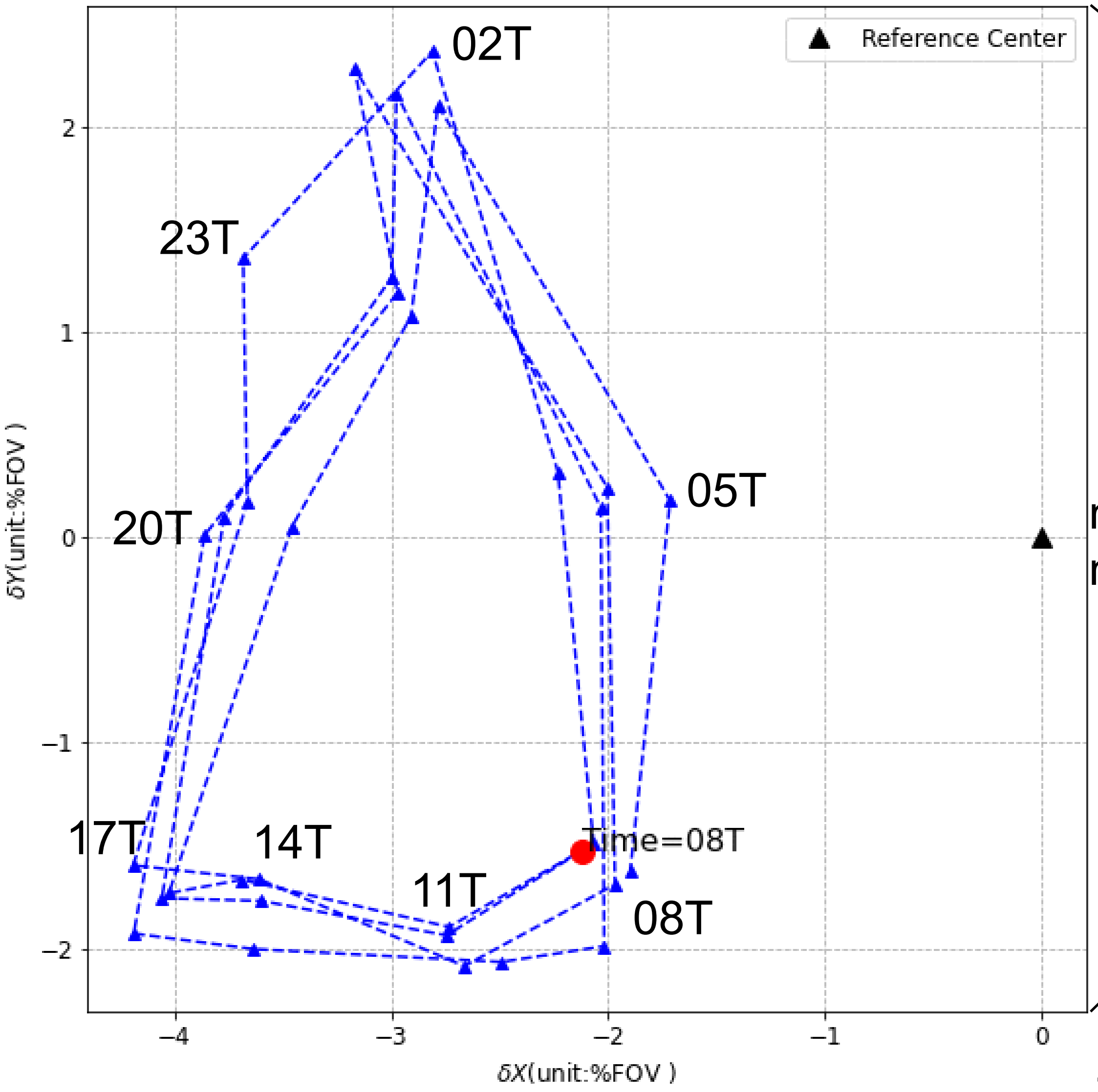
$$J(\delta\mathbf{x}, \delta\mathbf{x}_c) = \frac{1}{2}\delta\mathbf{x}^T\mathbf{B}^{-1}\delta\mathbf{x} + \frac{1}{2}\delta\mathbf{x}_c^{\ T}\mathbf{B}_c^{-1}\delta\mathbf{x}_c + \frac{1}{2}[\mathbf{S}(\mathbf{x}, \delta\mathbf{x}, \delta\mathbf{x}_c) - \mathbf{S}^{obs}(\mathbf{x})]^T\mathbf{R}_{obs}^{-1}[\mathbf{S}(\mathbf{x}, \delta\mathbf{x}, \delta\mathbf{x}_c) - \mathbf{S}^{obs}(\mathbf{x})]$$



Application of data assimilation ideas in calibration



Focal center diurnal micro variation

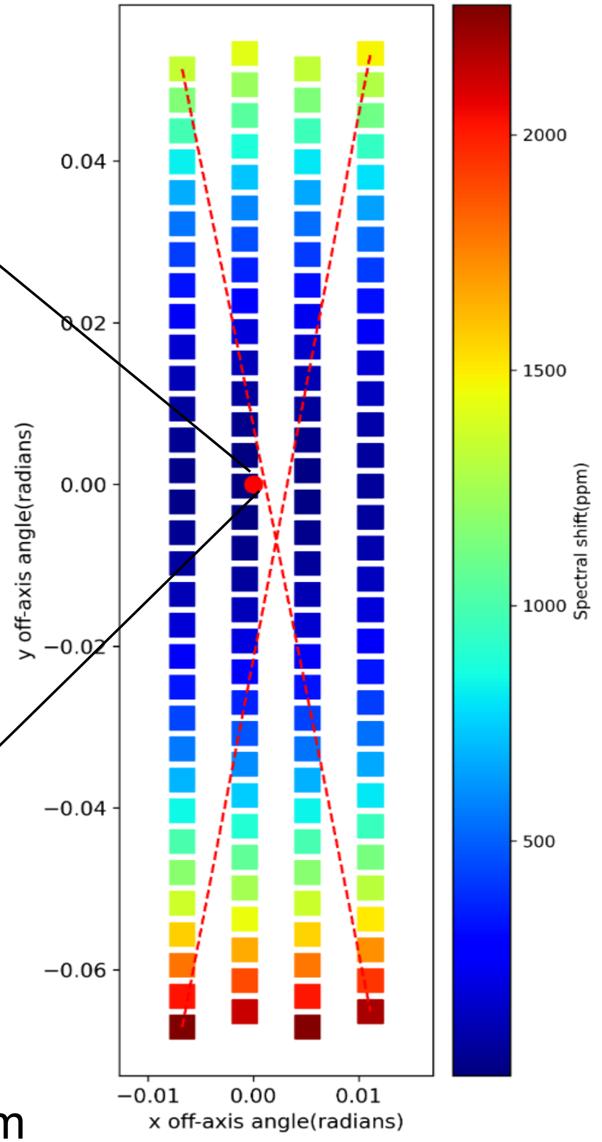


Percent of detector size

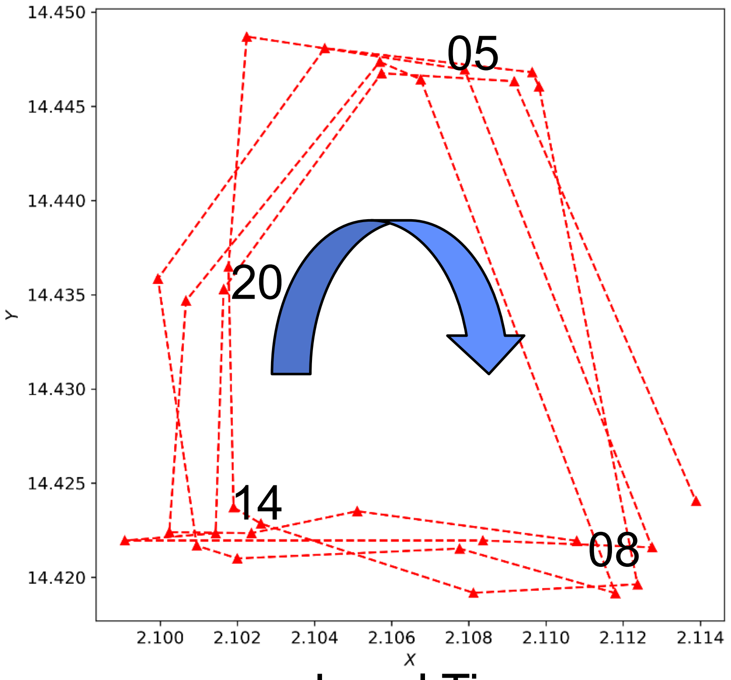
nvc0 = 14.438
nhc0 = 2.134

1%FOV=1.2um

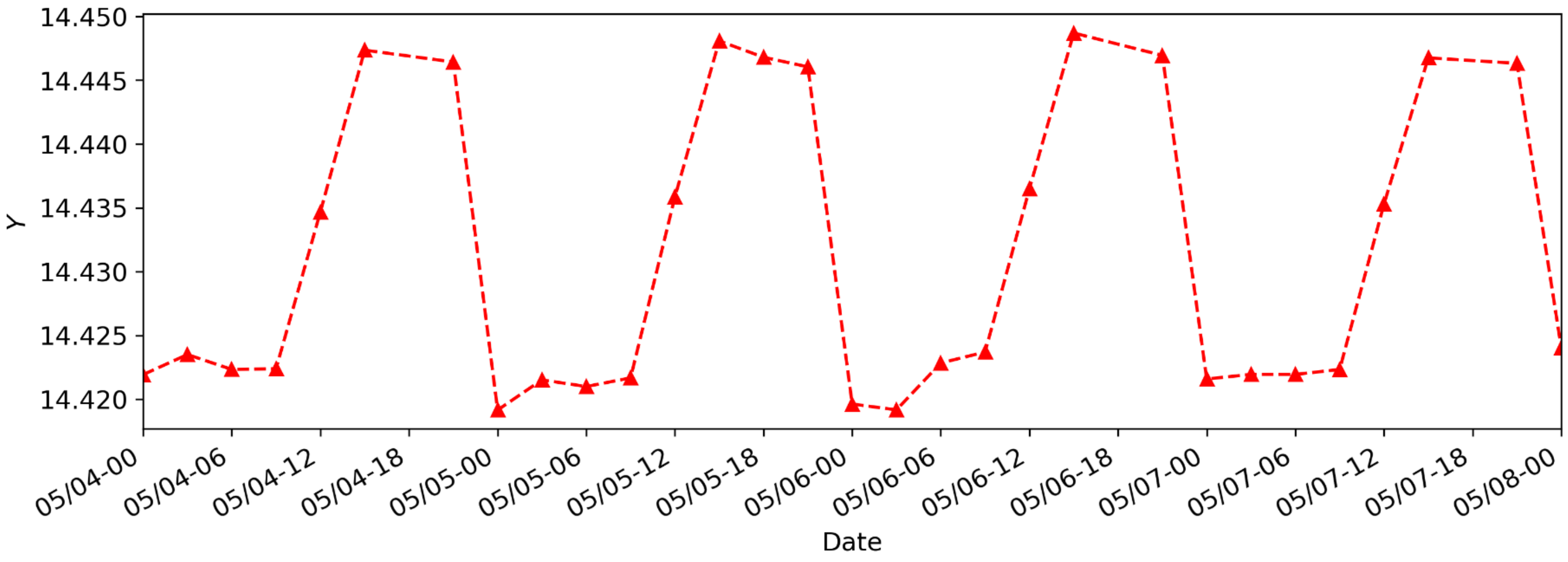
Optical Geometry Model

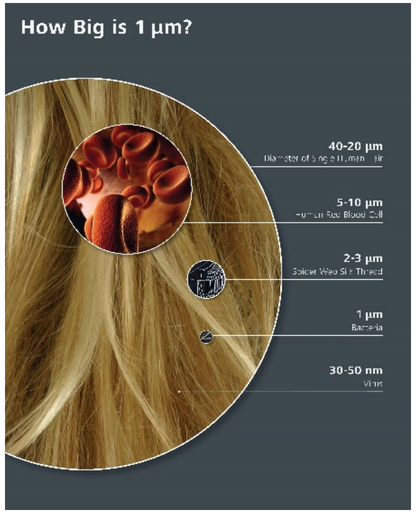


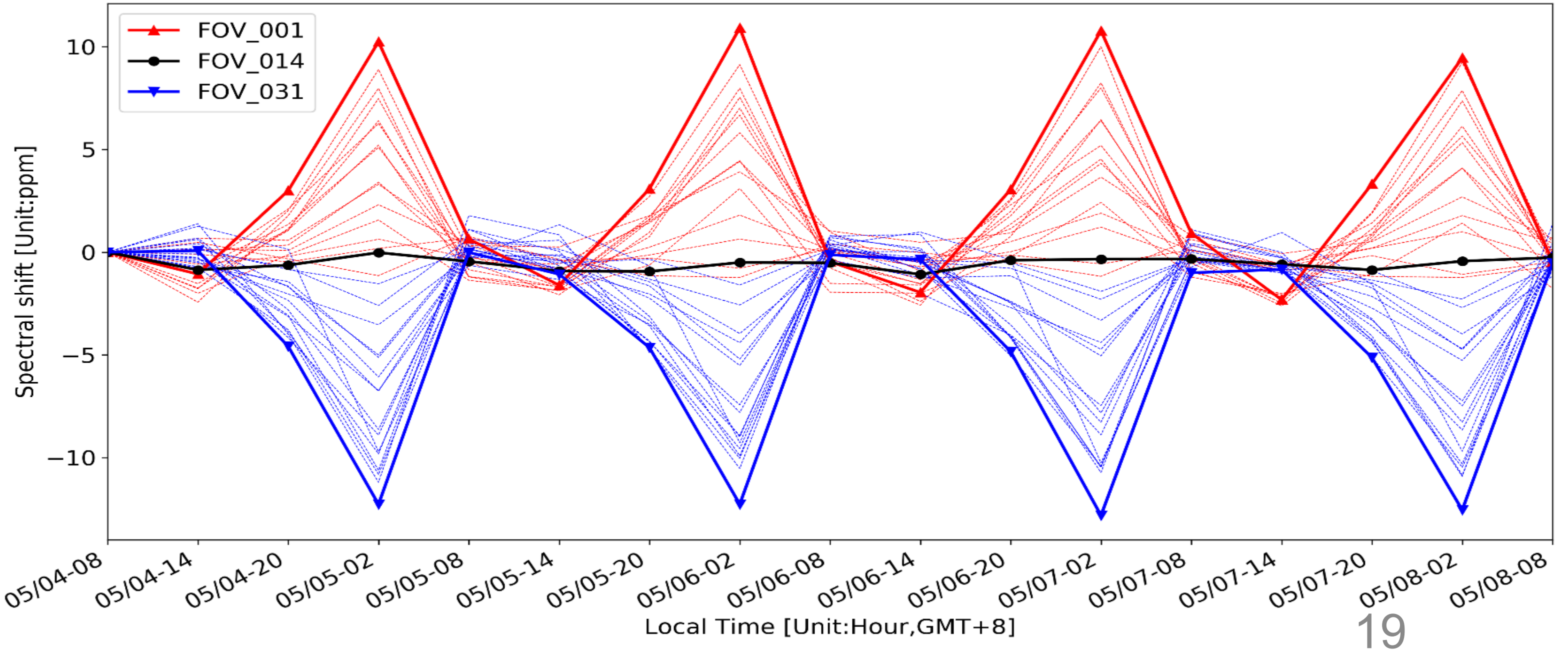
SOLVE Mysteries: tidy variations of the optical center (4% FOV,5um)



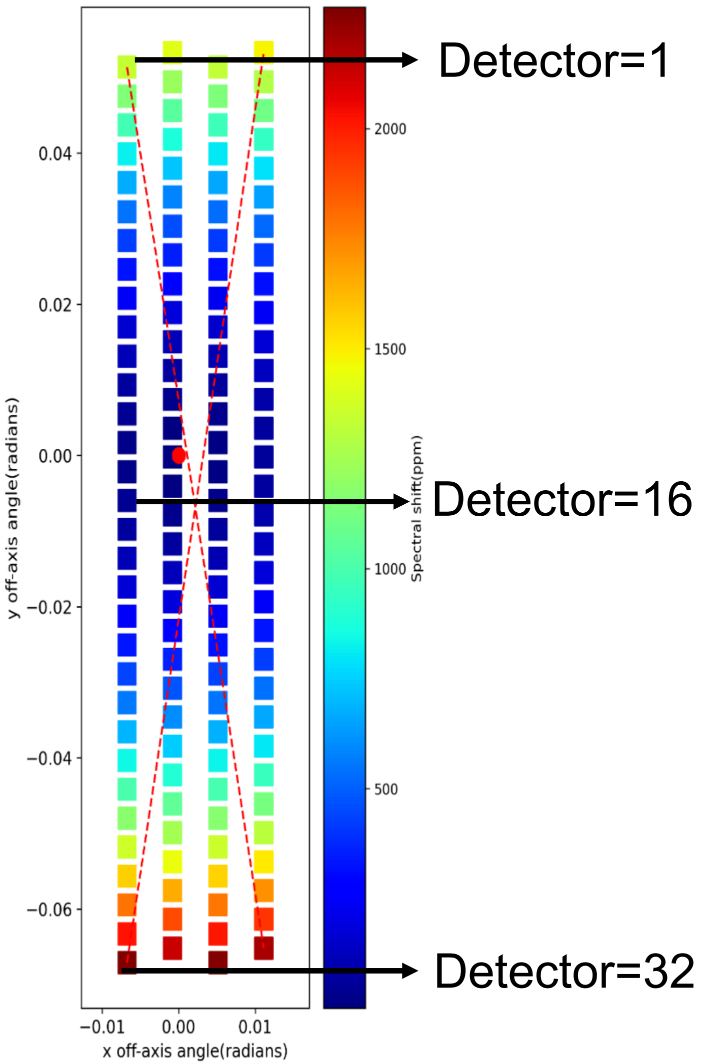
Local Time

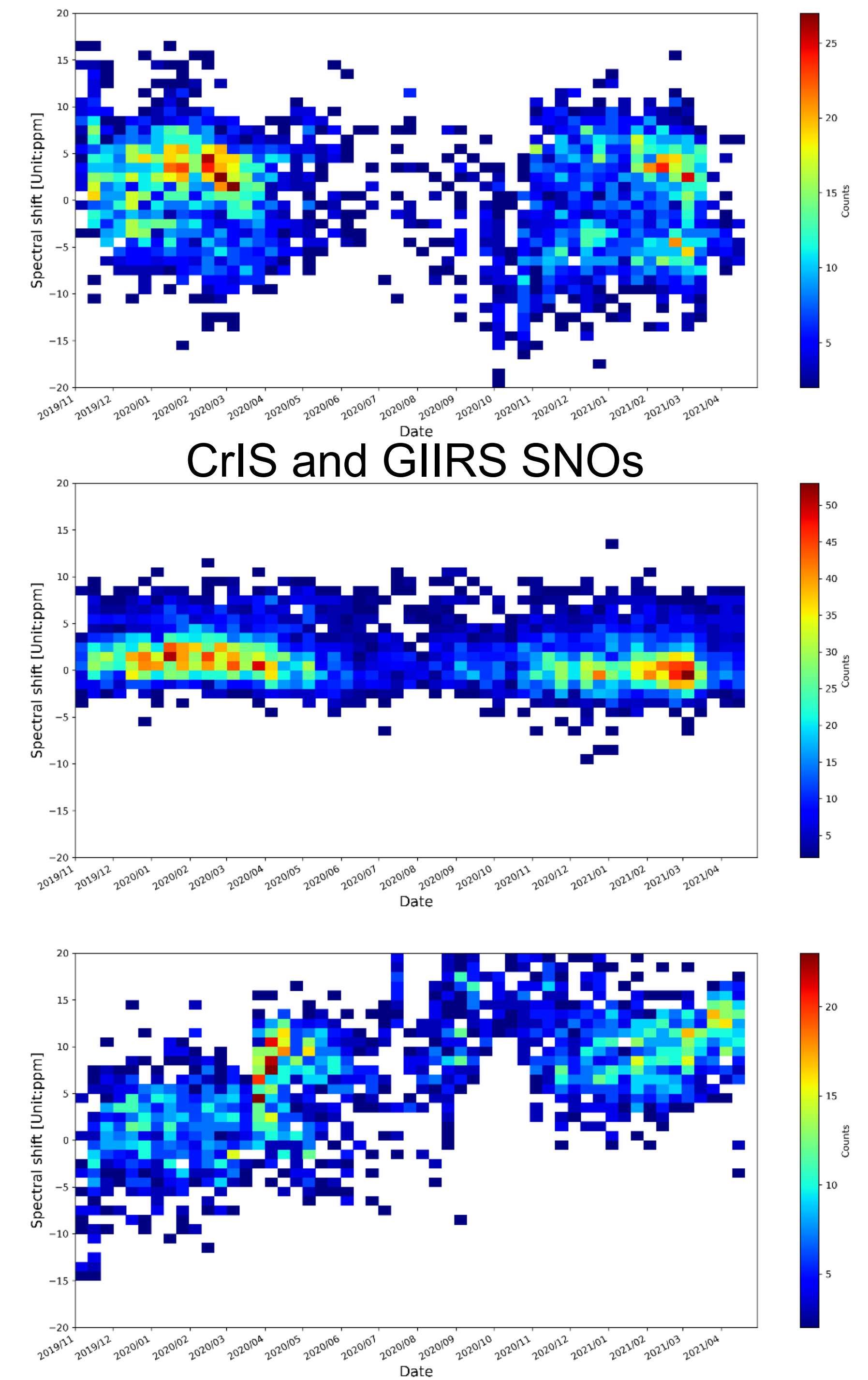




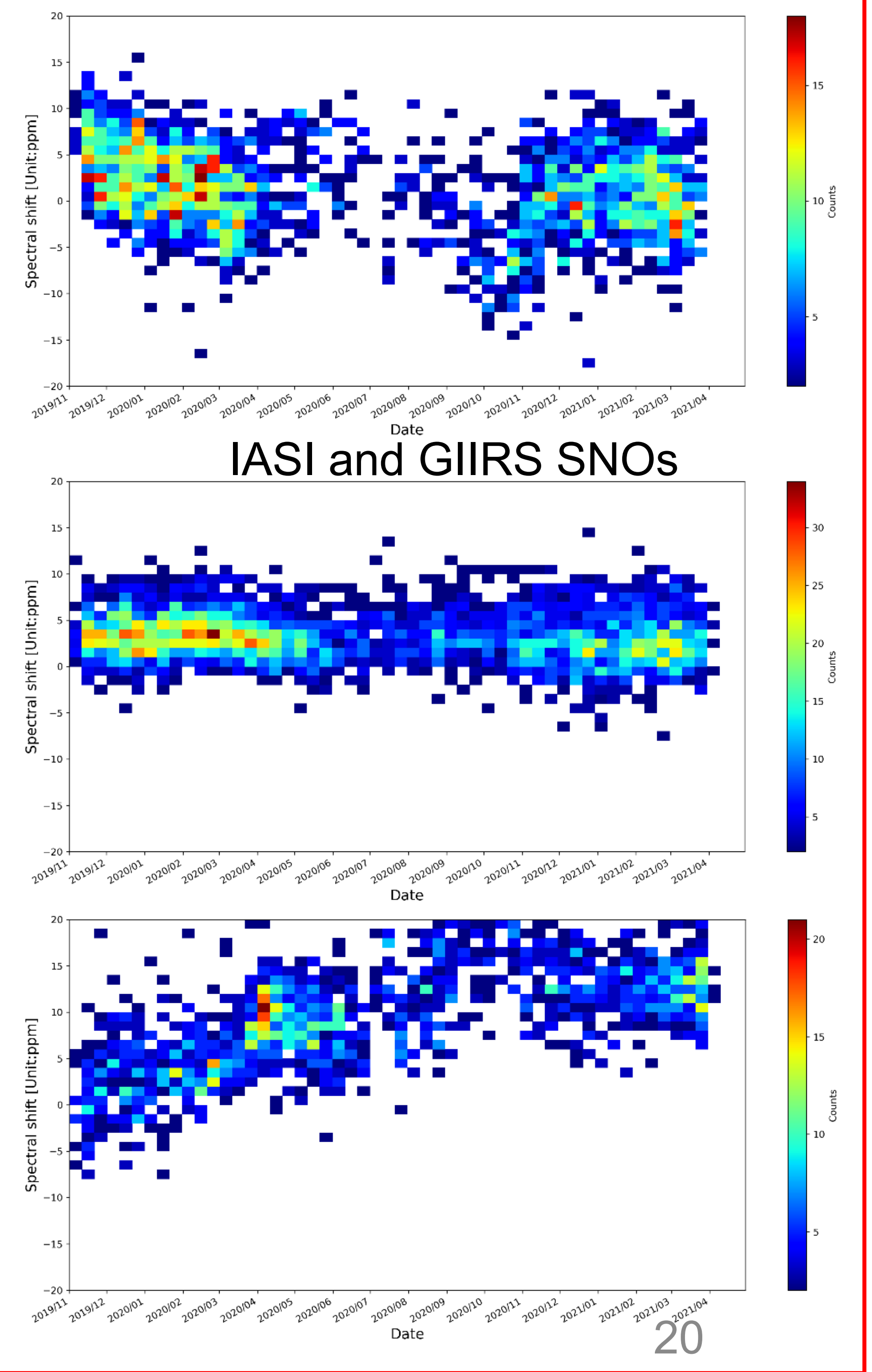


Long term spectral variation





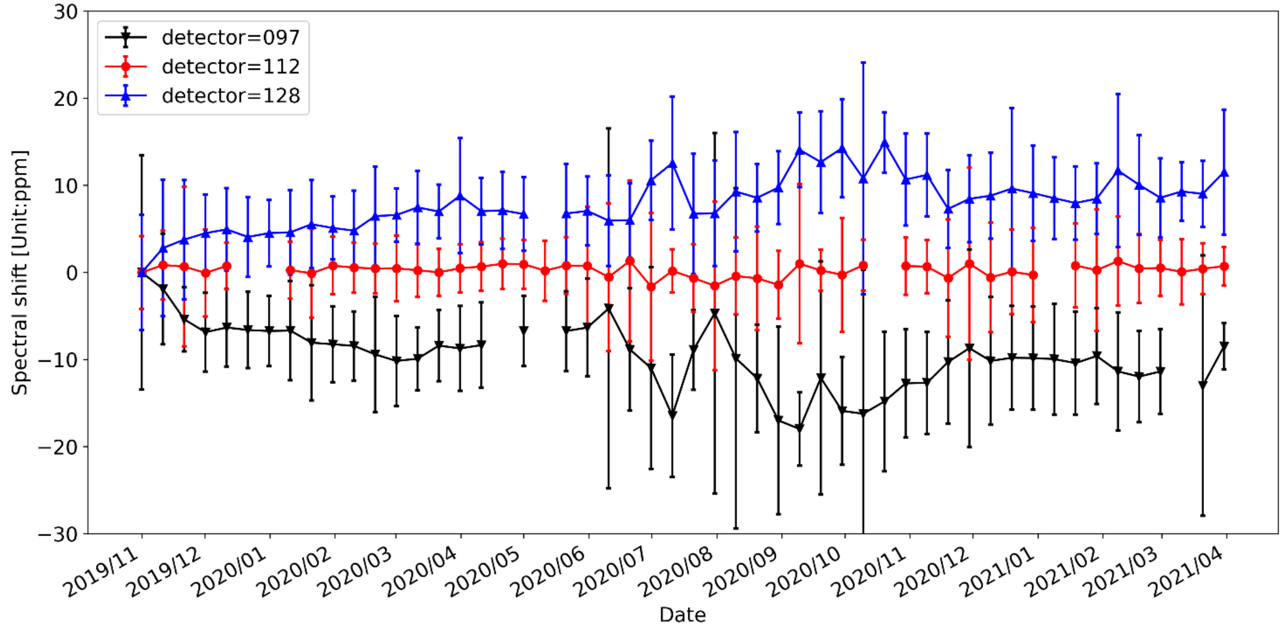
CrIS and GIIRS SNOs



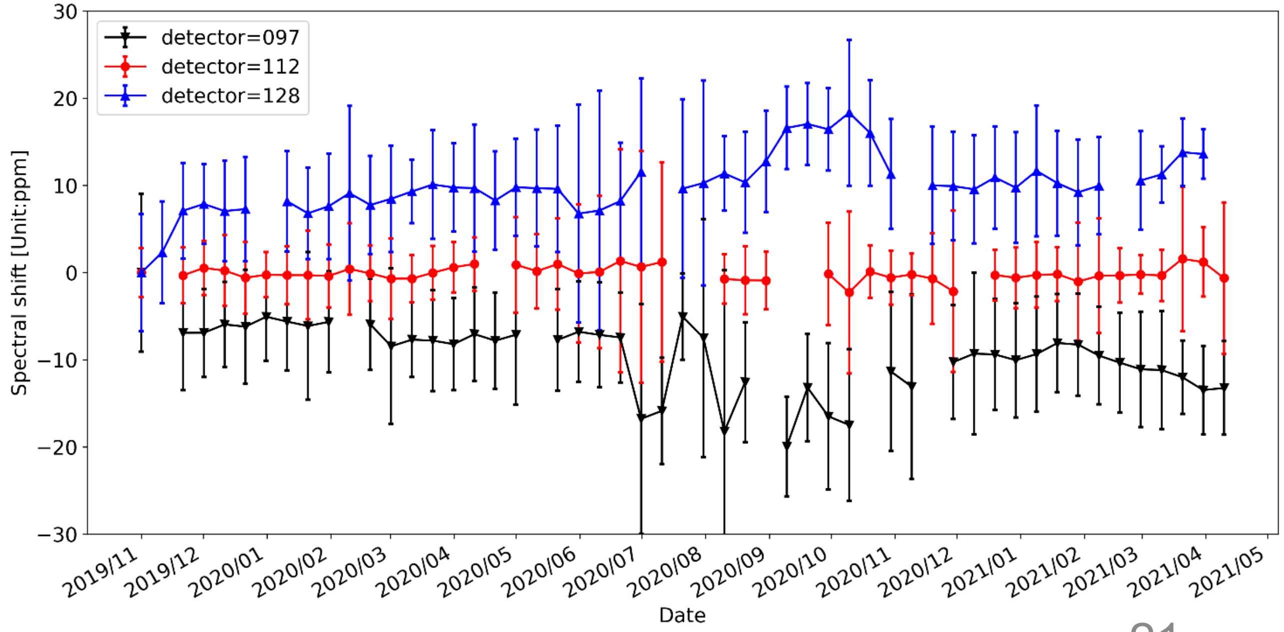
IASI and GIIRS SNOs

GIIRS spectral longer term variation(Relative changes to 20191107)

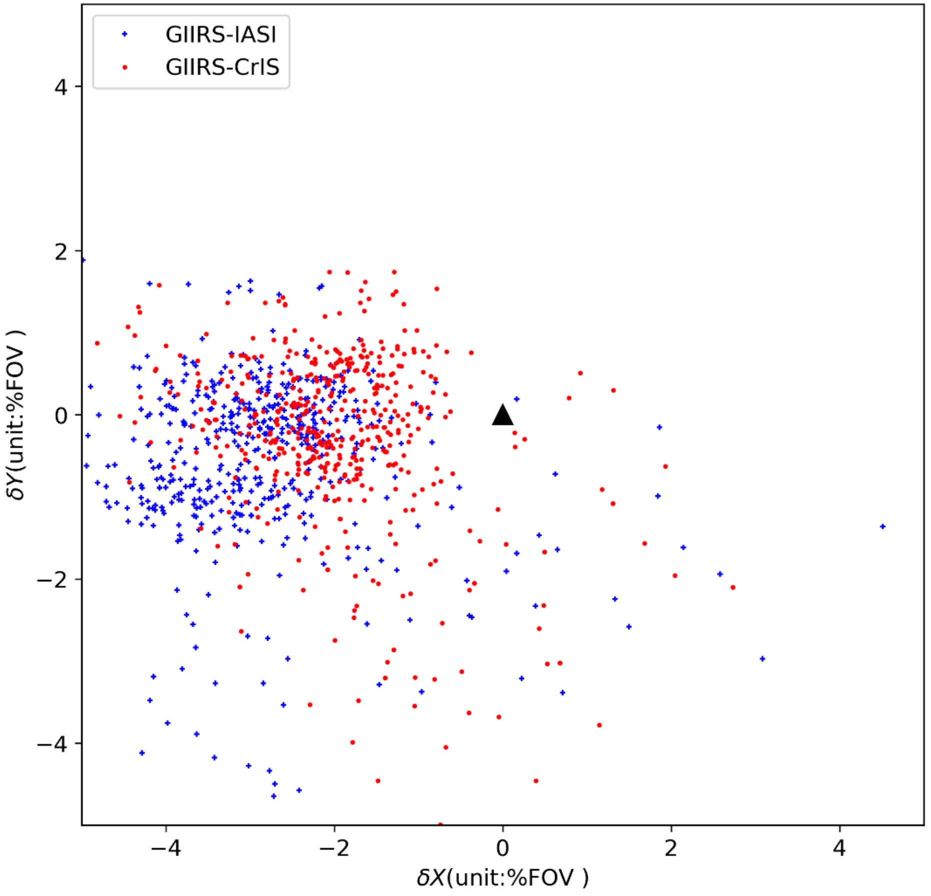
- Estimated using IASI_GIIRS SNOs

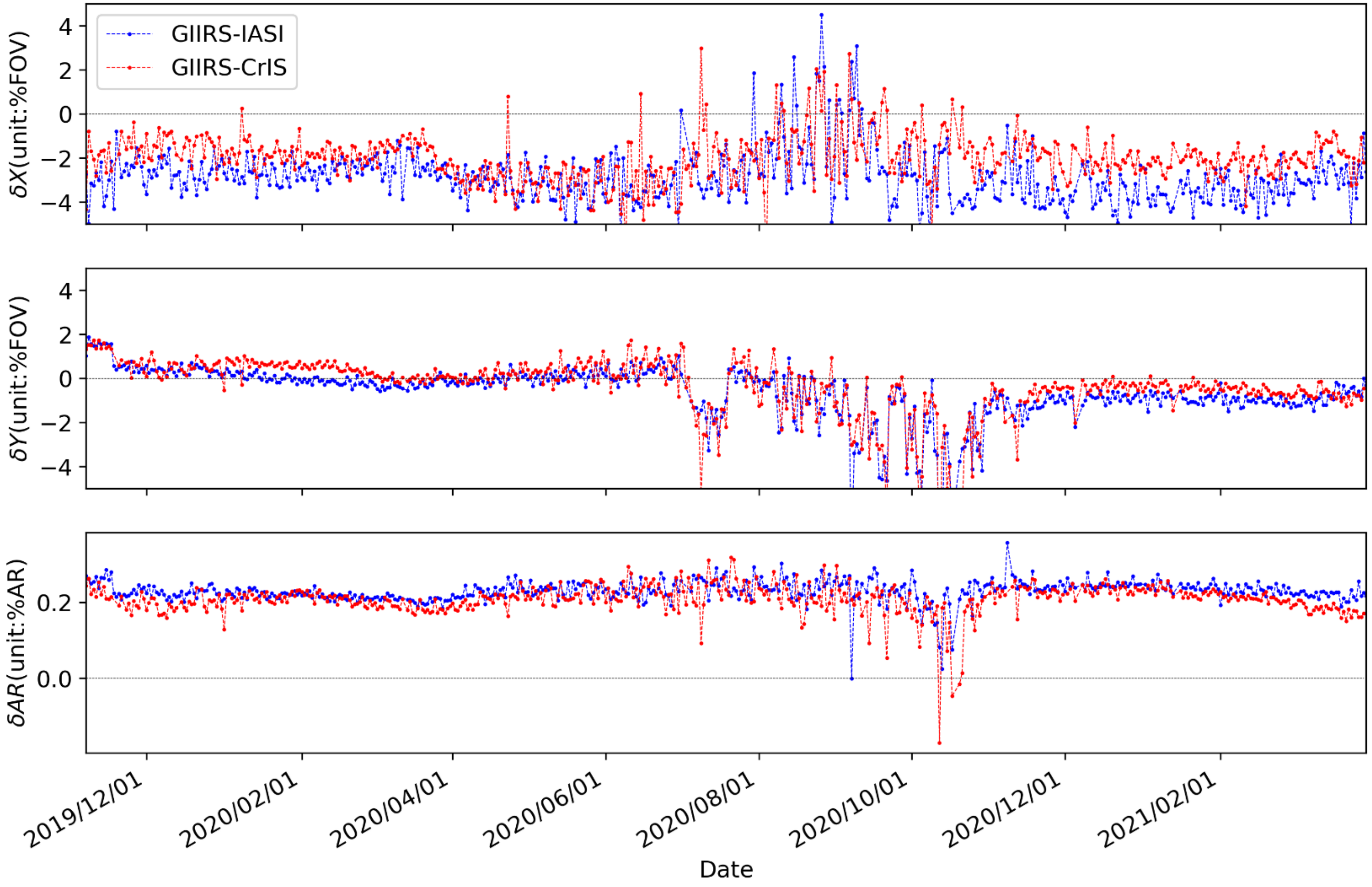


- Estimated using CrIS_GIIRS SNOs



Estimaiton of focal center and afocal ratio variation using GIIRS-IASI and GIIRS-CrIS SNOs





nvc0 = 14.438

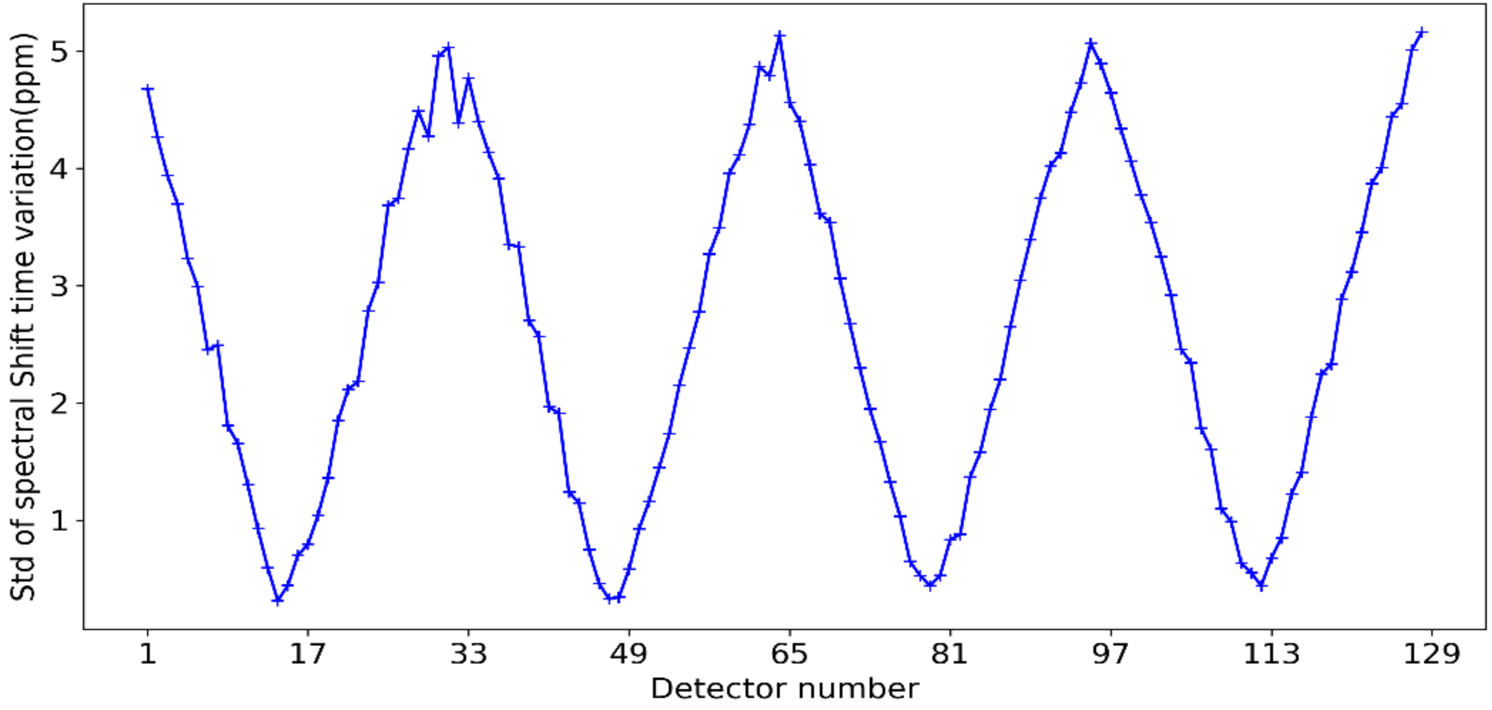
nhc0 = 2.134

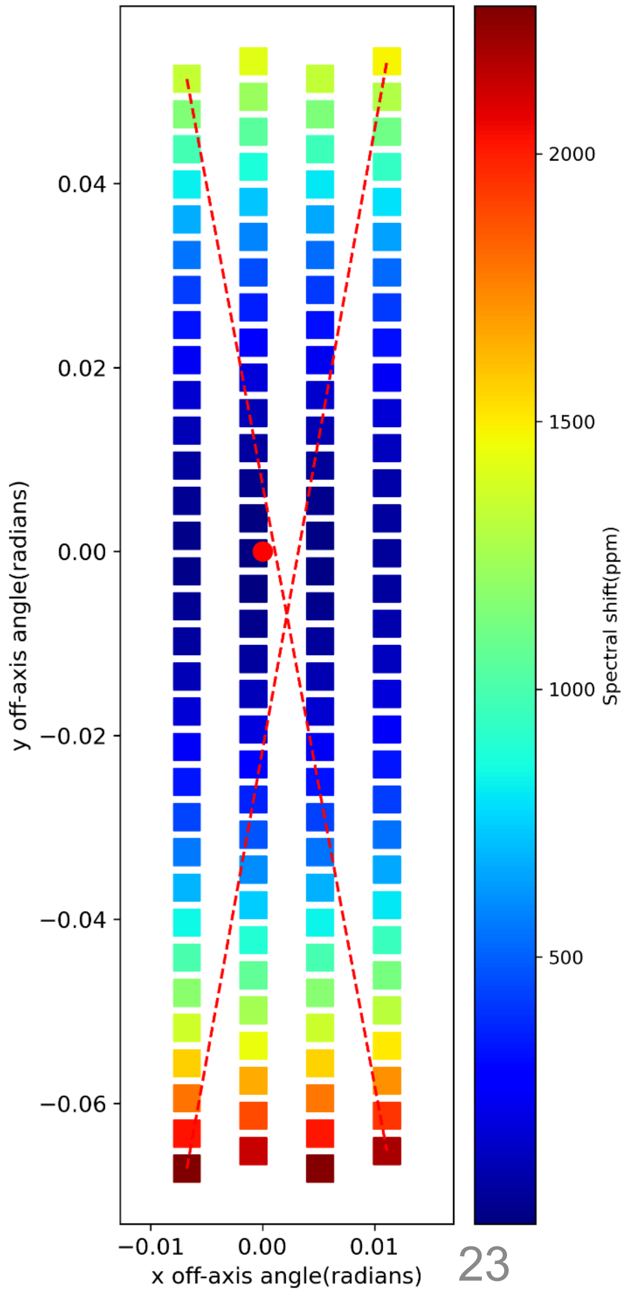
Suggestions for NWP user community on FY-4A GIIRS QC

Suggestion on the use of current FY-4A GIIRS L1 (V3):

- Best detectors: 14,47,48,79,112
- Detector selection: 3-25,36-57,67-89,102-123
- Time selection: 00Z-09Z

Reference focal center
nvc0 = 14.438
nhc0 = 2.134



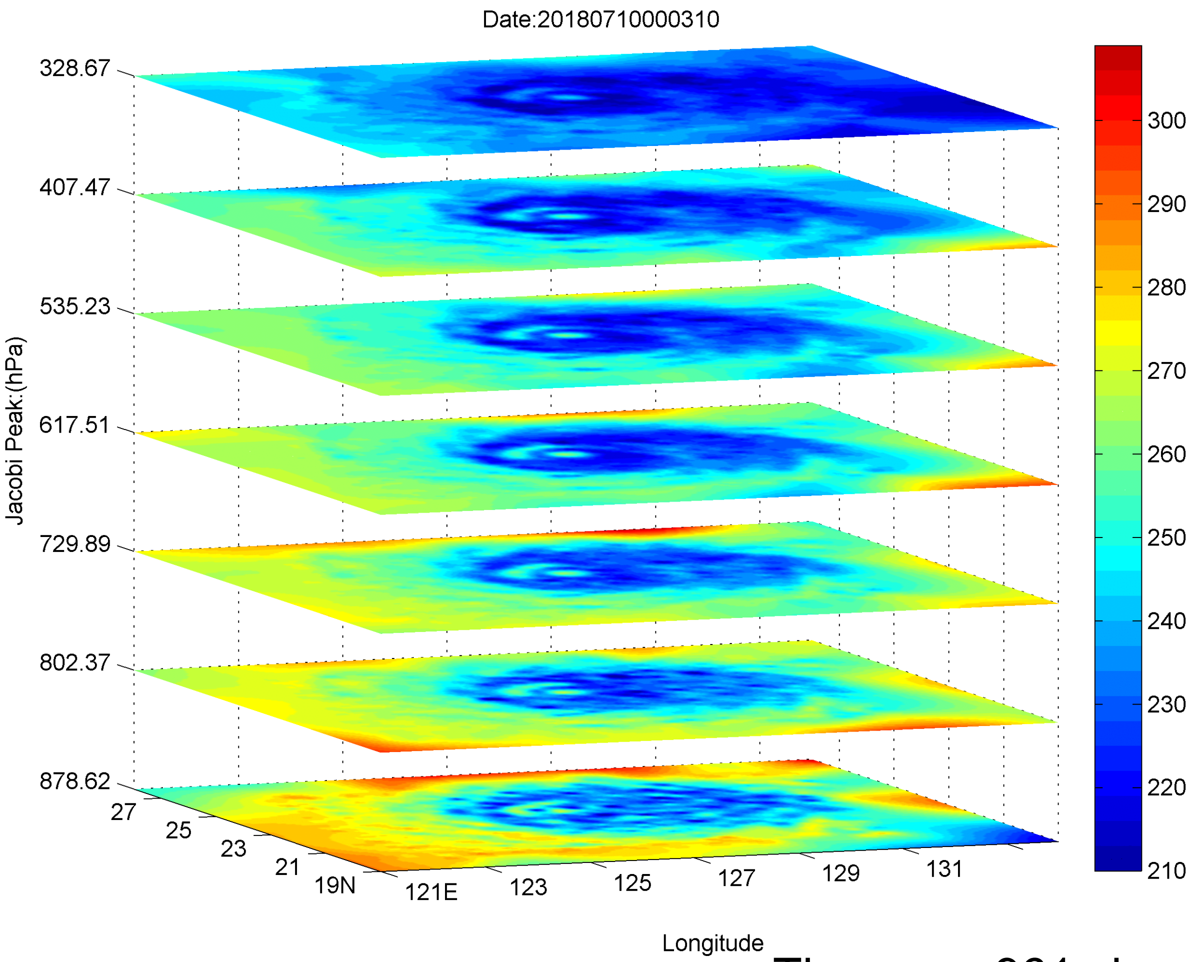


Winds FY-4A GIIRS humidity sounding(15min)

- Retrieve wind information using 4D-Var
- Retrieve winds using traditional AMV methods
- Retrieve winds using AI techniques

$$\frac{\partial \delta q}{\partial t} + \vec{\mathbf{V}}^{b} \cdot \nabla \delta q + \delta \vec{\mathbf{V}} \cdot \nabla q^{b} = 0$$

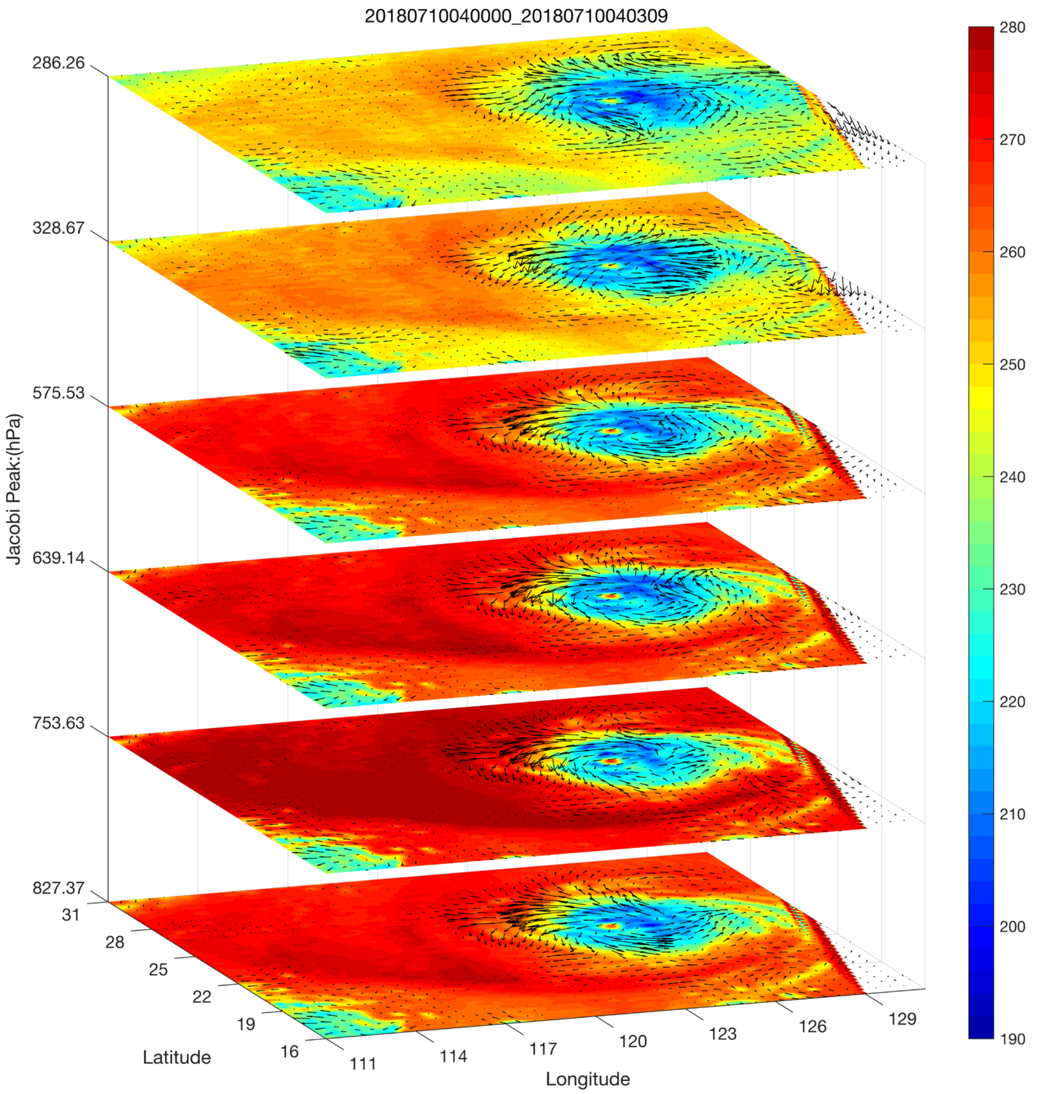
water vapor “tracer effects”

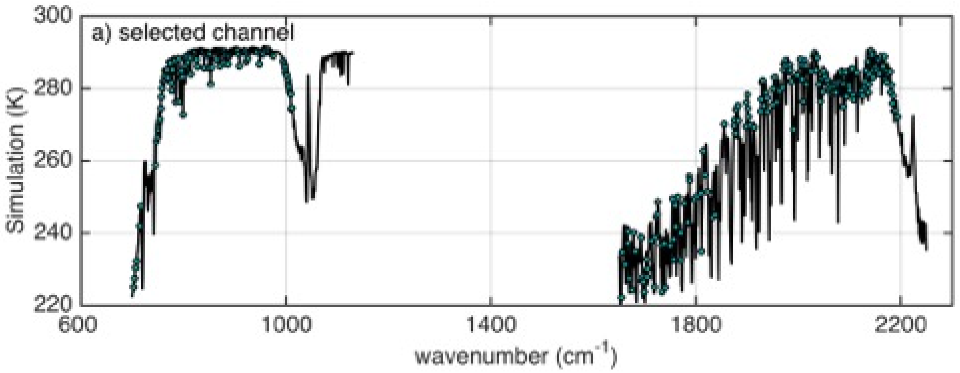


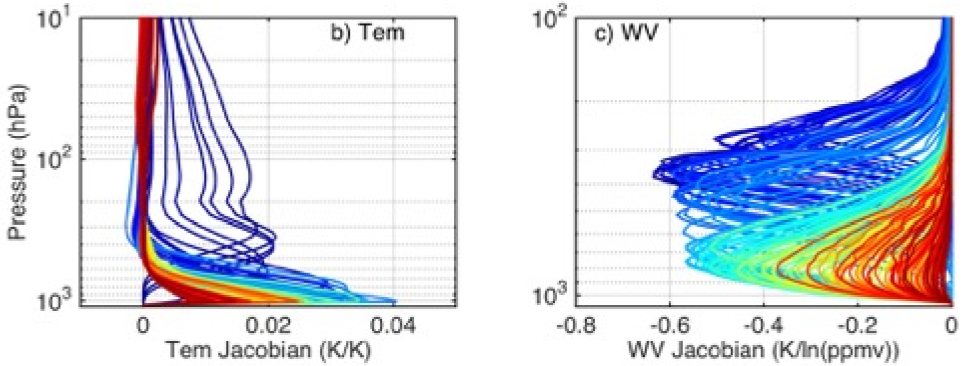
3D winds information through 4D-Var or retrieval

There are 961 channels in water vapor band

Assimilation of GIIRS 4D Winds







Han W., Yin R.,Di D.,Ma Z., Li J. and Knuteson R.,2021:Assimilation of four-dimensional winds from high temporal geostationary hyperspectral infrared sounder radiances, EUMETSAT 2021 conference (submitted).

Li J., Ma Z., Han W., Di D., Li Z., Yin R., Menzel P., and Schmit T., 2021: Four-dimensional wind field from geostationary hyperspectral infrared sounder radiances with high temporal resolution – Typhoon Maria case , EUMETSAT 2021 conference (submitted).

Summary

- Close collaboration between data assimilation and calibration
  - Satellite data monitoring
  - Understand well , use well (uncertainty information is also important)
- **NEW methods**
  - **ISSEC**, A fast and accurate spectral bias estimation algorithm
  - **OOPS**, On orbit parameter estimation using data assimilation methodology
- **NEW findings**
  - Diurnal and seasonal variation
  - Possible root cause: sensor parameter estimation based on NWP
  - The spectral accuracy and stability could be improved
- Assimilation of GeoHIS
  - Targeted Observing
  - Radiances + “4D Winds”

References

- Han W., R. Knuteson, J. Li, D. Dee and A. Thomas. 2021, Assimilation of Geostationary Hyperspectral InfraRed Sounders (GeoHIS): Opportunities and Challenges, *JCSDA Quarterly Newsletter*, Spring 2021 no.69, 1-11, https://doi.org/10.25923/KZKY-4383
- Han W.,et al:Assessment and Integration of the Geostationary Hyperspectral Infrared Sounder(GIIRS) in JEDI,2021 AMS.
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