16/03/2023
Session 1.05

SYNERGY
Infrared + Microwave
satellite observations

Statistical study of bayesian retrieval
in a simulated framework

PRESENTER
Ethel VILLENEUVE
PhD student

THESIS DIRECTOR
Nadia FOURRIE
Philippe CHAMBON

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01

PROBLEMATICS

Combining IR and MW all
sky data

WHAT IS NOW ASSIMILATED in ARPEGE

IR	- All observations in **clear-sky only**
MW	- Observations from MHS, MWHS2, GMI, AMSR2 in the ECMWF **all-sky** route - Observations from AMSUA, ATMS, SSMI/S in **clear-sky**

COMPLEMENTARITY of IR & MW observations

	sensitivity
IR	Top of clouds, TOA, Cloud fraction
MW	Cloud ice (sub-mm) Precipitations, Cloud sounding

PhD objective : Assimilation of IR data within clouds with a specific focus on synergy between IR and MW data.

PROBLEMATICS

Consistently assimilate IR observations in addition to MW observations?

DIFFICULTIES

Inconsistencies in RT modelling between IR and MW

NWP model uncertainties

METHODS

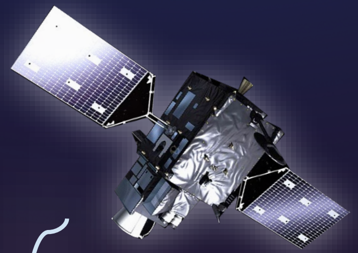
Evaluating the **relative importance** of RT inconsistencies compared to model uncertainties with the comparison of retrieved profiles in a simulated 1D framework

02

METHODS

Building 1D framework with simulated observations (controlled sources of errors in RTTOV-CLD and RTTOV-SCATT and in NWP parameterisations)

SPACE MISSIONS



MICROWAVE

EUMETSAT POLAR SYSTEM (EPS) SECOND GENERATION

MetOp-SG-B (early 2025)

Microwave Imager (MWI)

18.7 – 183.31 GHz

Ice Cloud Imager (ICI)

183.31 – 664 GHz

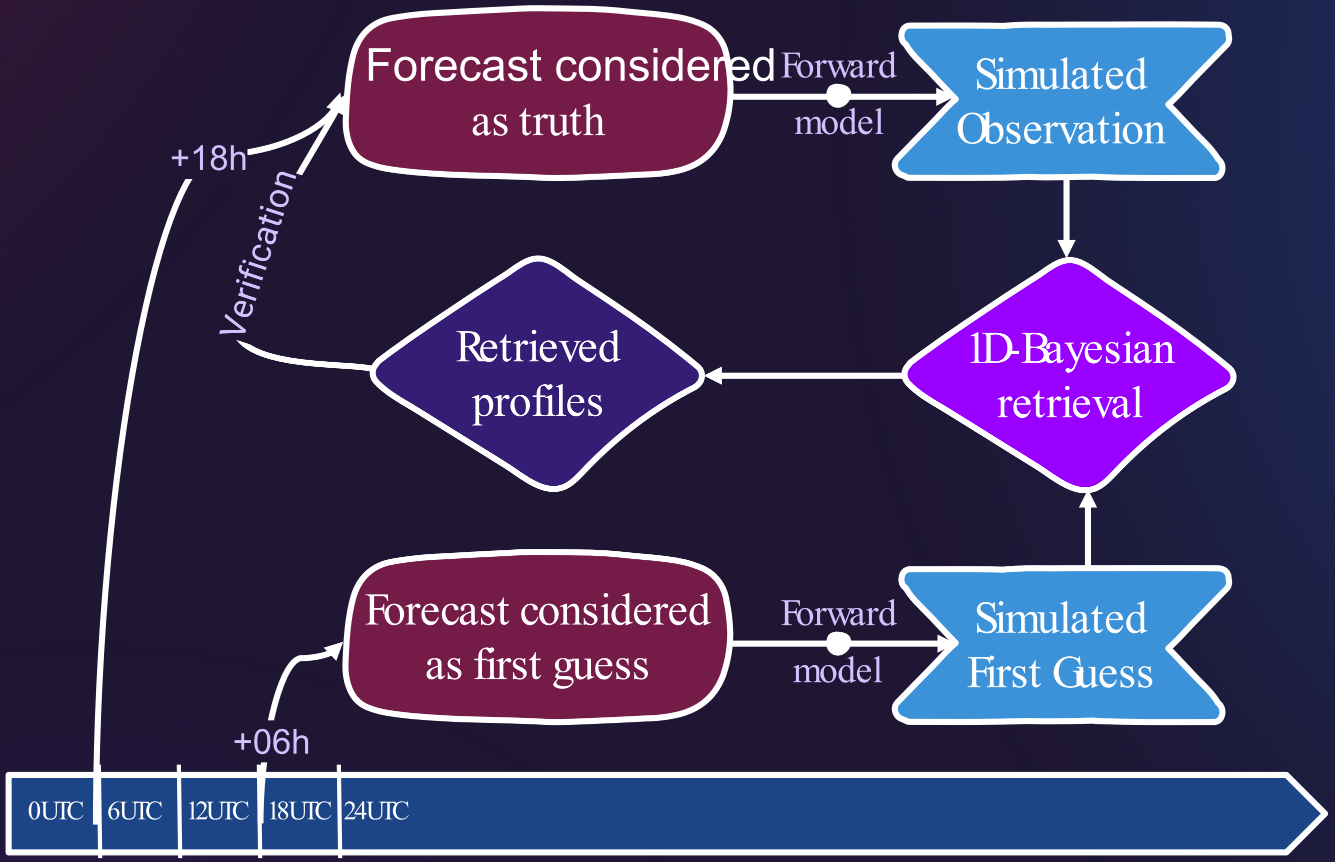
INFRARED

METEOSAT THIRD GENERATION

MTG-I (dec. 2022)

Flexible Combined Imager (FCI)

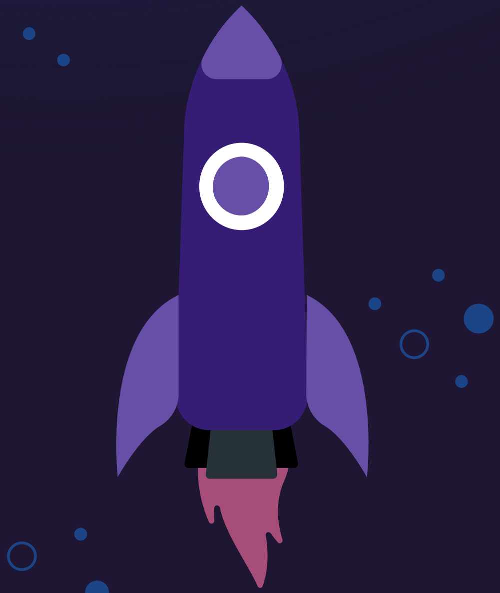
3.8 – 13.3 μm



Forecast considered as truth
Forward model
Simulated Observation
+18h
Verification
Retrieved profiles
1D-Bayesian retrieval
Forecast considered as first guess
Forward model
Simulated First Guess
+06h
0UTC
6UTC
12UTC
18UTC
24UTC

FRAMEWORK

noERR experiment



01	FG vs OBS	**SAME SETTINGS** between FG and OBS simulations
02	RTTOV v13	**FG and OBS** fully simulated with RTTOV
03	RTTOV OPTIONS	**HYDROMETEORS** simulated with the most realistic settings
04	GOAL	**ELIMINATE** the sources of inconsistencies

SOURCES OF INCONSISTENCIES

Radiative Transfer model

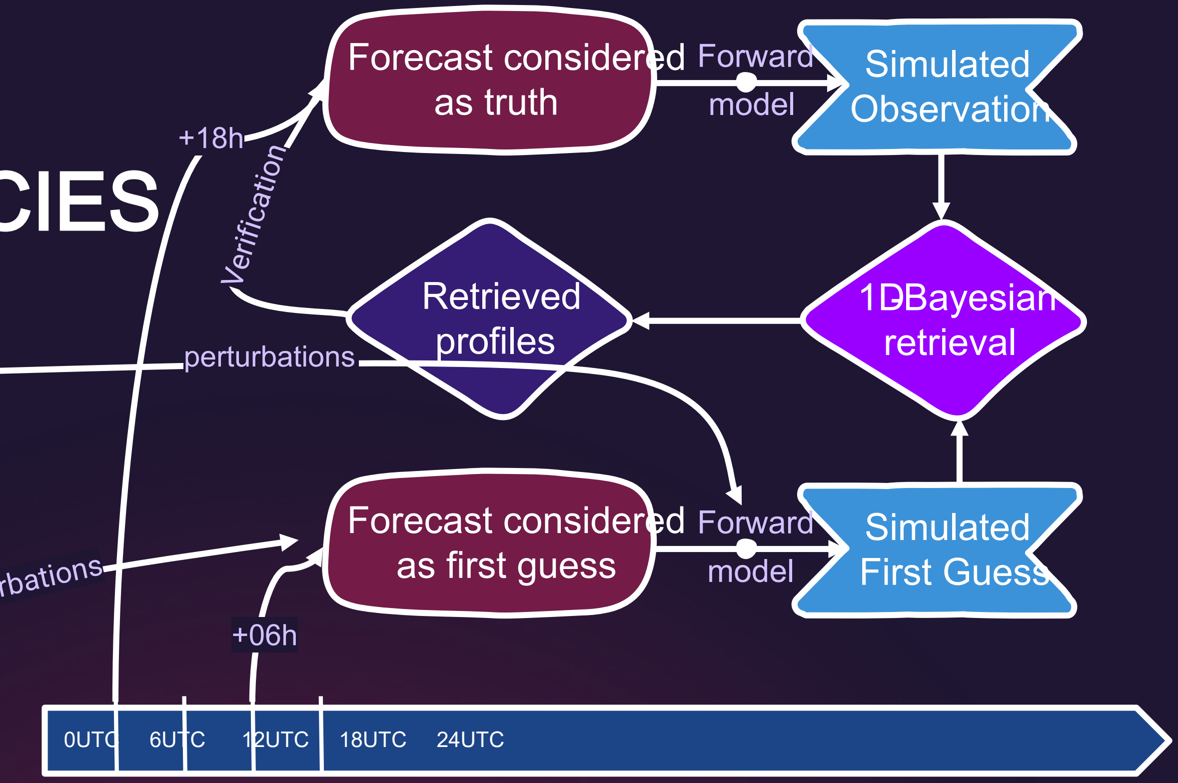
Particles shape & size distribution

mRT

NWP model

Uncertainties in microphysical scheme

mMOD



ADDING PERTURBATIONS:

mRT experiment

	Default	Perturbations in FG
MW	Geer et al. 2021 PSD & shapes 	Geer and Baordo 2014 PSD & shapes 
IR	Baran 2018	Baum 2011

mMOD experiment

Default	Perturbations in FG
Default value of operationa ARPEGE forecast model – microphysical and convection parameterisations	Replace the default value ir parameterisations by a random value in a range defined by ARPEGE ensemble prediction system

mALL experiment

mRTperturbations
(in RTTOV)

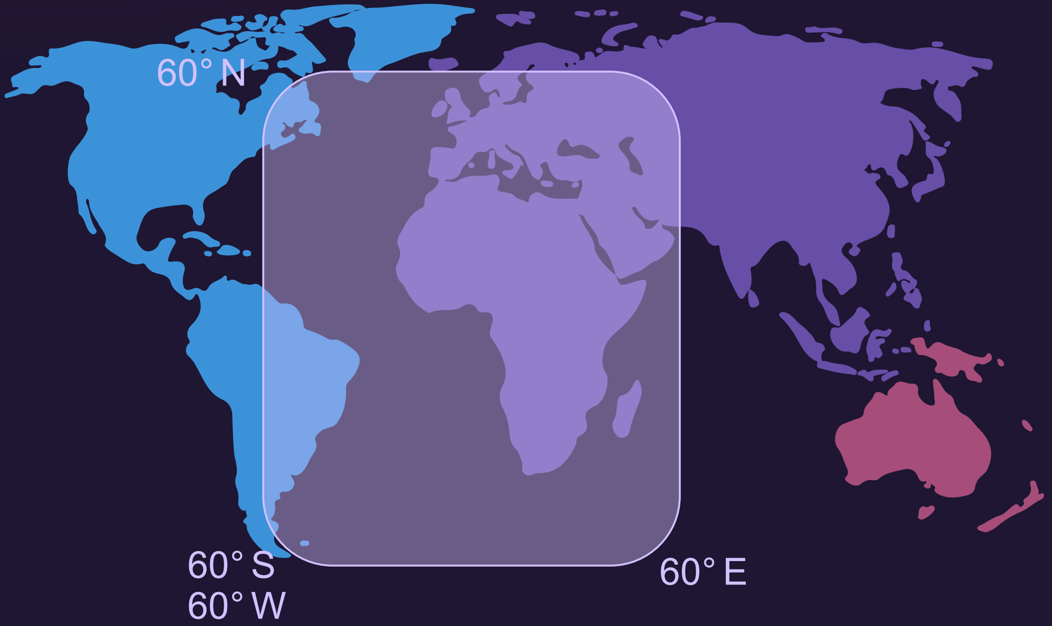
+

mMODperturbations
(in ARPEGE)

Which one predominates ?

Do the differences in the radiative transfer modelling have a significant impact on retrievals ?

STATISTICAL STUDY



June 2020						
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

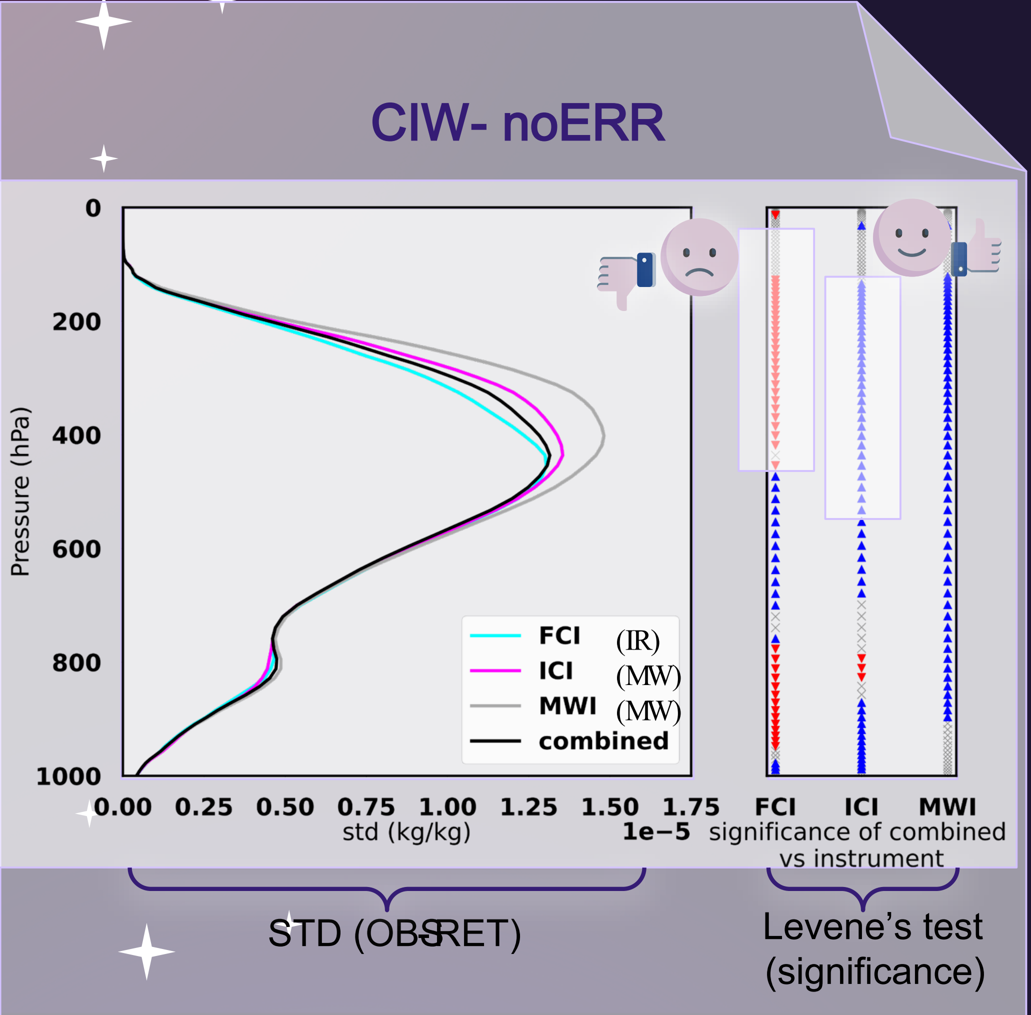
December 2020						
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

03

RESULTS

Can we build a synergy?

noERR experiment: STD study



STD of OBServation-RETrieval

Significance test between combined (IR+MW) inversion and single instrument inversion

Question :

Positive impact of IR in higher altitude and of MW in lower altitude?

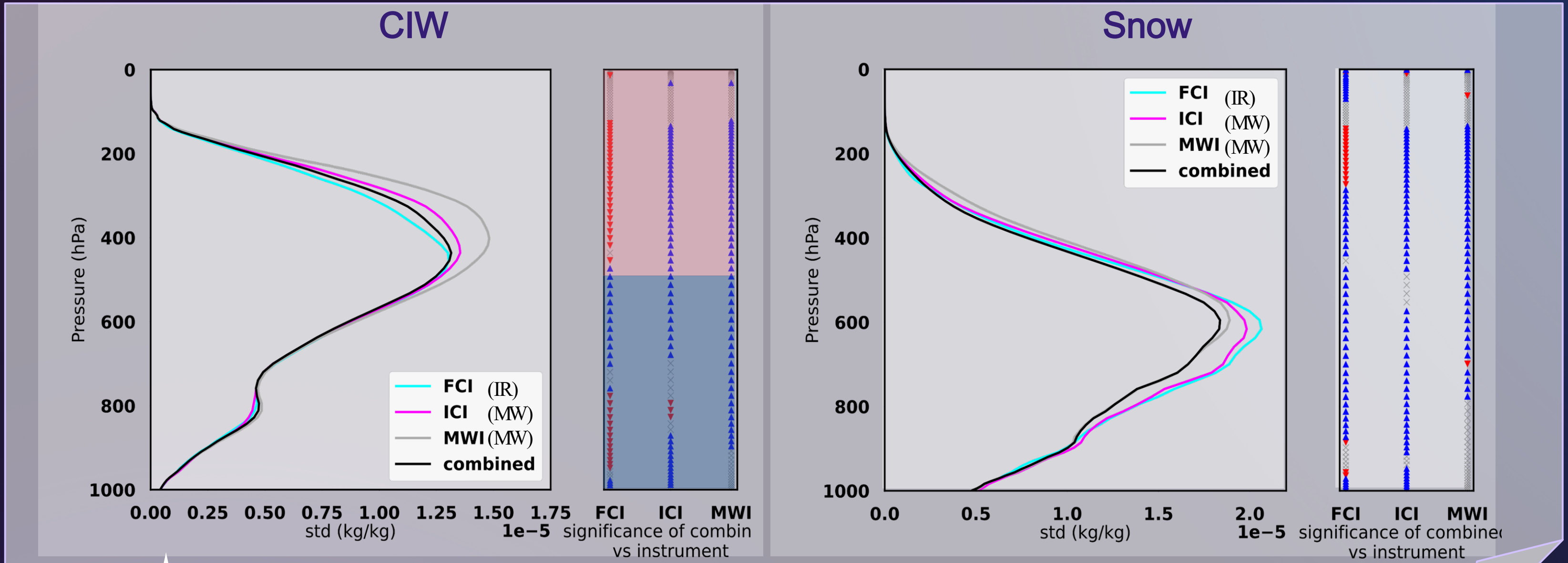
Precipitating hydrometeors improvement of IR and compromise for MW

Conclusion :

IR-MW synergy.

noERR experiment: STD study

Synergy? Yes



High altitude : improvement of MW
Low altitude : improvement of IR

Improvements of all instruments at all levels

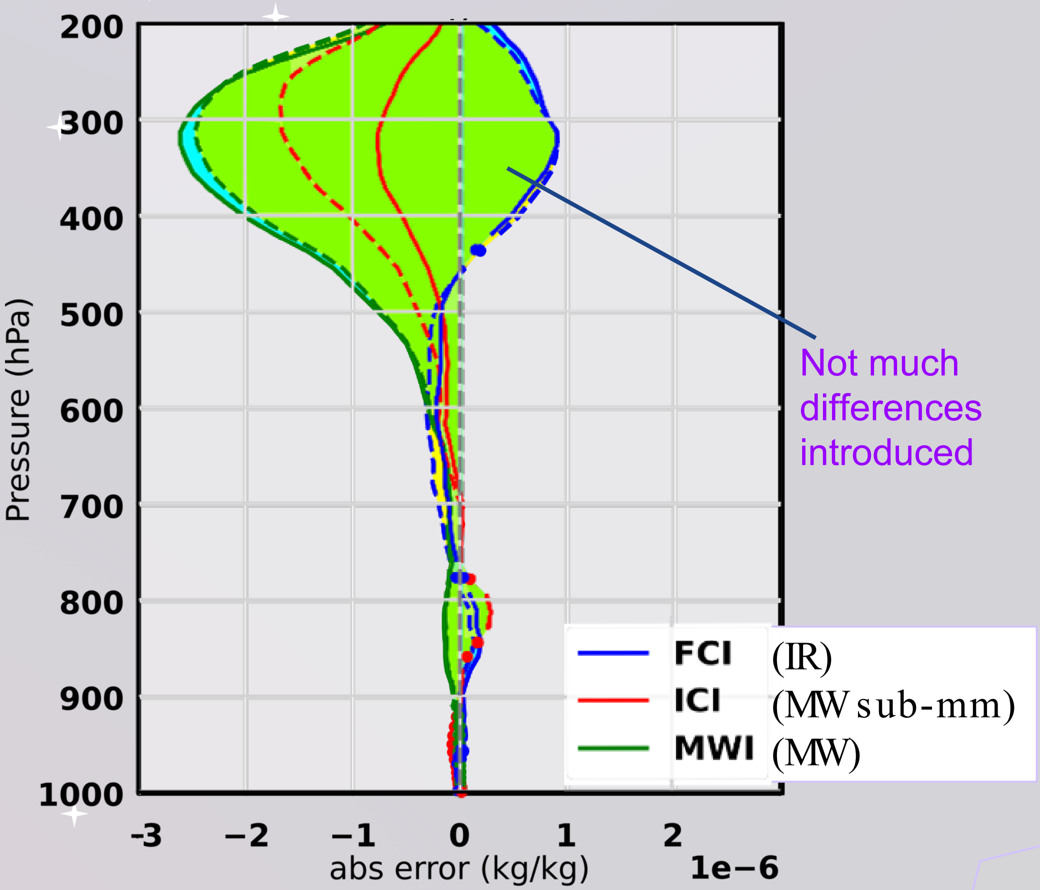
How do the perturbations affect the synergistic effect?

STD differences

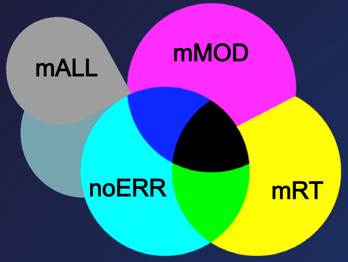
$$DIFF_{mEXP} = STD^{c}_{mEXP} - STD^{i}_{mEXP}$$

> 0 if combined inv. less good than sing.-inst. inv.
< 0 if combined inv. better than single-inst. inv.

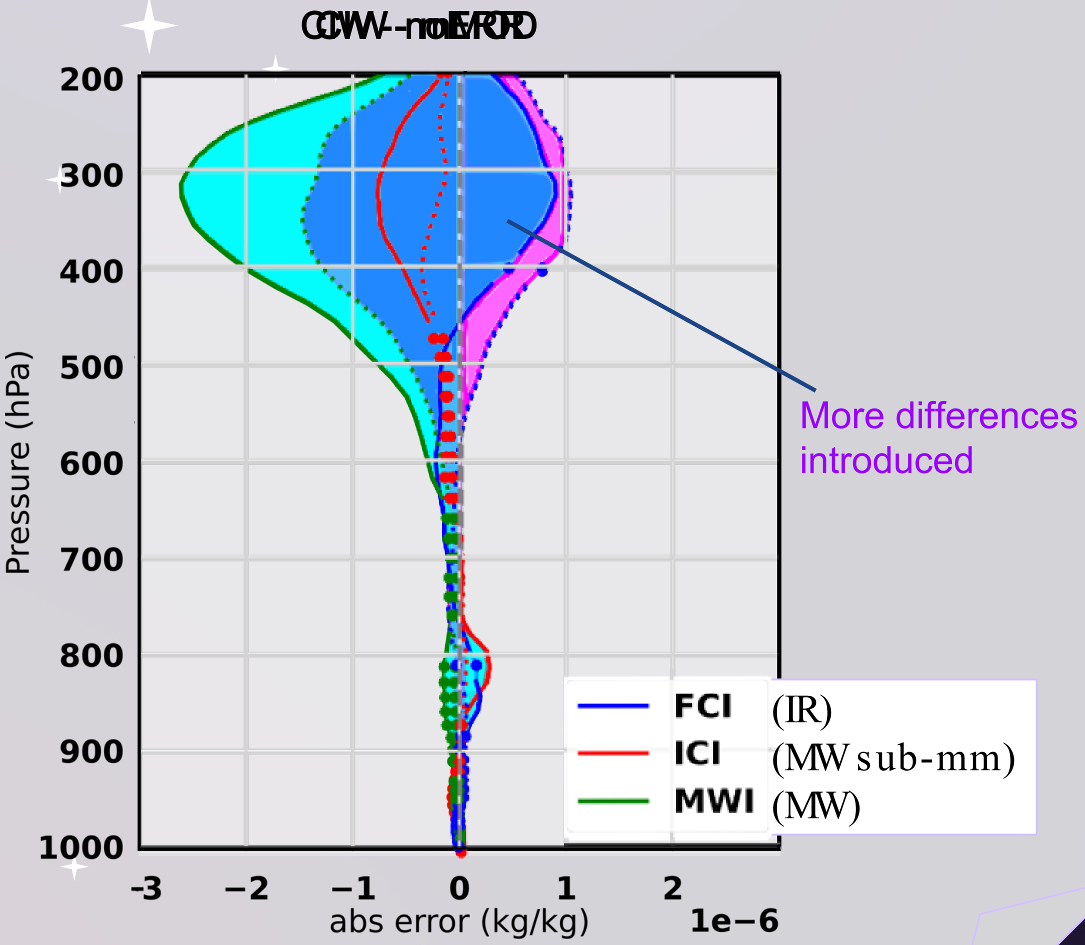
Perturbations impacts



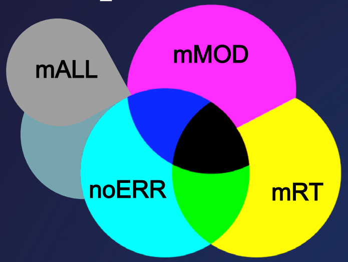
Not much differences introduced



Coloured areas superposition gives information on the amount of differences introduced by the perturbations



Perturbations impacts

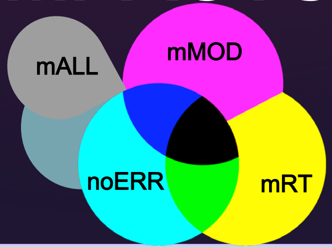


Coloured areas superposition gives information on the amount of differences introduced by the perturbations

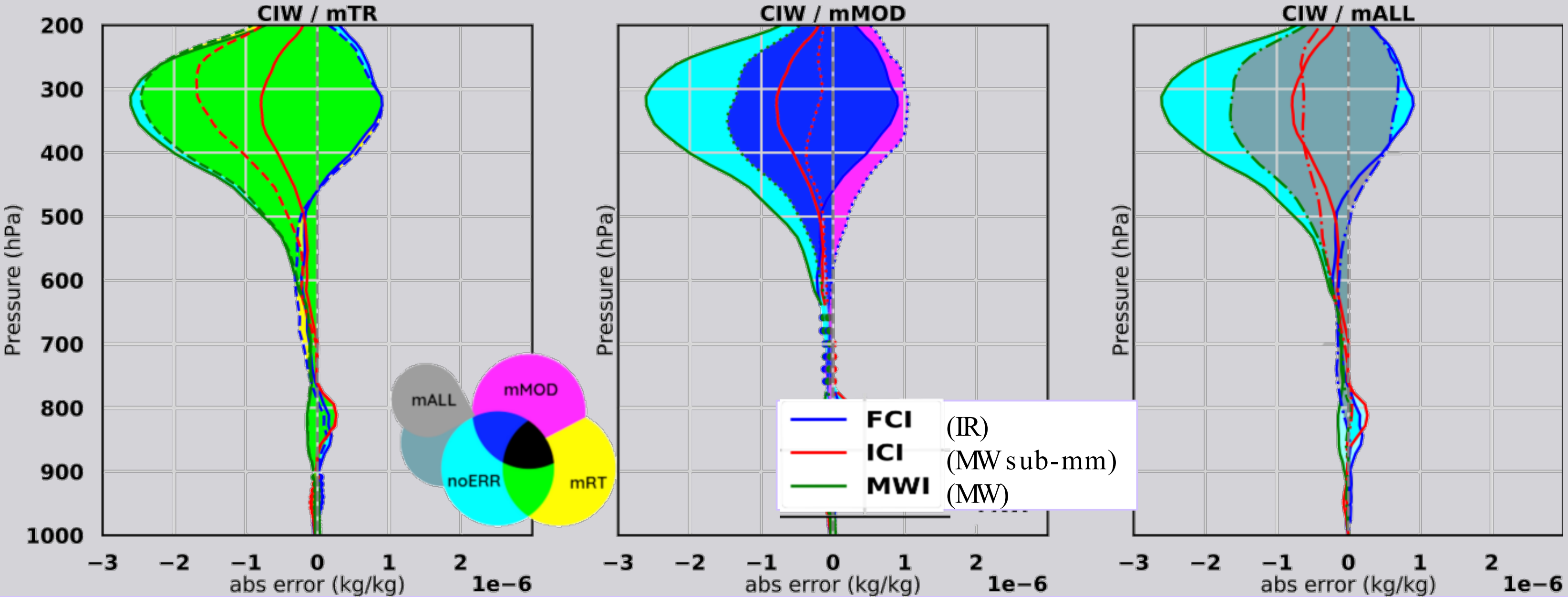
Conclusions

mMOD has more impact than mRT on CIW.

PERTURBATIONS IMPACTS



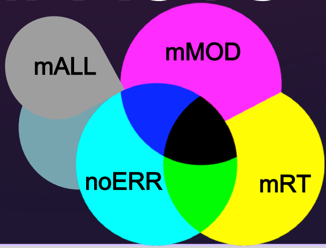
CIW



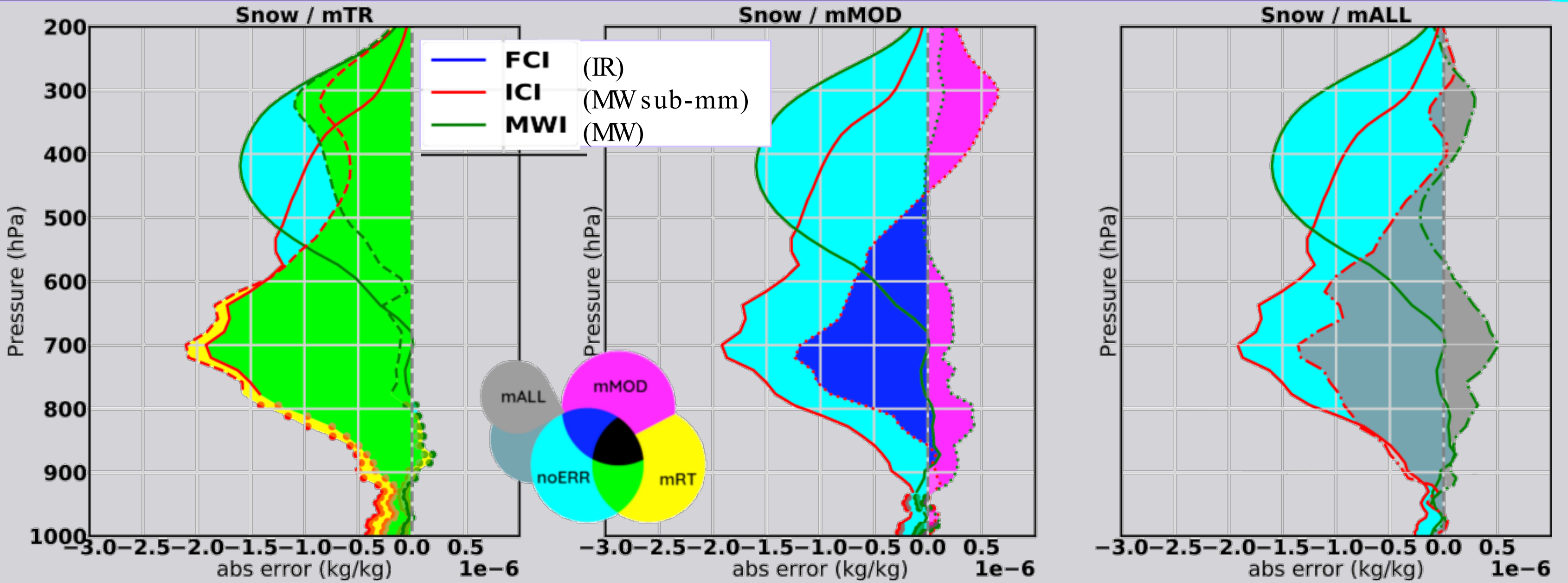
Conclusions

mMOD has more impact than mRT on Snow.

PERTURBATIONS IMPACTS



Snow



Conclusions

Article submitted to AMT

Synergistic approach of hydrometeor retrievals: considerations on radi
transfer and model uncertainties in a simulated framewo

E. VILLENEUVE, P. CHAMBON and N. FOURRIE

Combination IR+MW => gathering of benefits leading to a better retrieval

noERR synergy

1

Adding perturbations => combination of IR+MW still leads to a better retrieval

mEXP synergy

2

Inconsistencies in RT modelling do not prevent IR and MW synergy

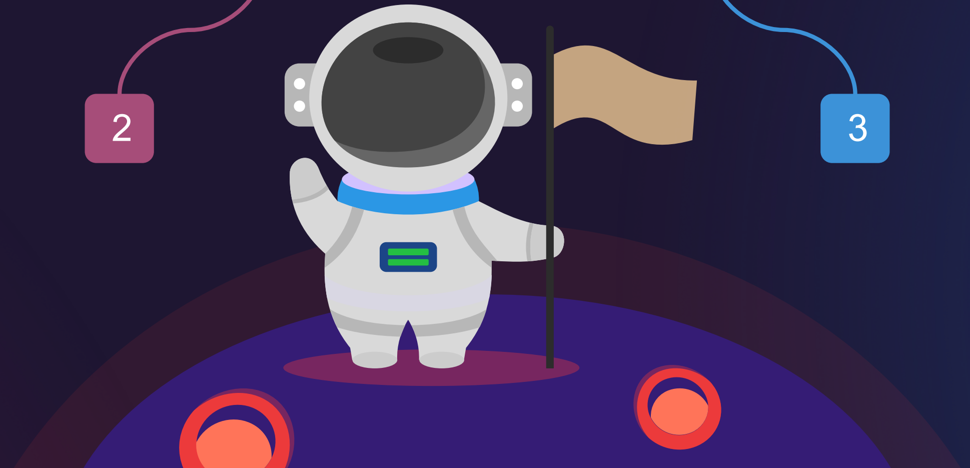
Consistency

3

Adding both perturbations leads to a more moderated response. One of the perturbations is predominant on the other.

mALL experiment

4



04

FUTURE WORKS

Implementing all-sky IR GOES-16/ABI raw radiances in 4D-Var assimilation system

Starting point: code branch that Alan Geer shared with us and used in his paper on IASI all-sky assimilation (2019)

Article submitted to AMT

Synergistic approach of hydrometeor retrievals: considerations on radi transfer and model uncertainties in a simulated framewo

E. VILLENEUVE, P. CHAMBON and N. FOURRIE

Any questions?

noERR synergy

1. Combination IR+MW => gathering of benefits leading to a better retrieval

mEXP synergy

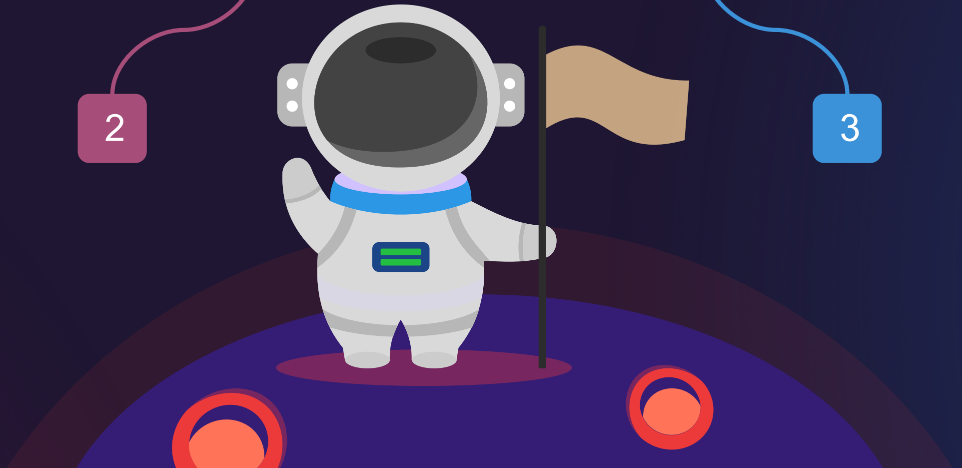
2. Adding perturbations => combination of IR+MW still leads to a better retrieval

Consistency

3. Inconsistencies in RT modelling do not prevent IR and MW synergy

mALL experiment

4. Adding both perturbations leads to a more moderated response. One of the perturbations is predominant on the other.

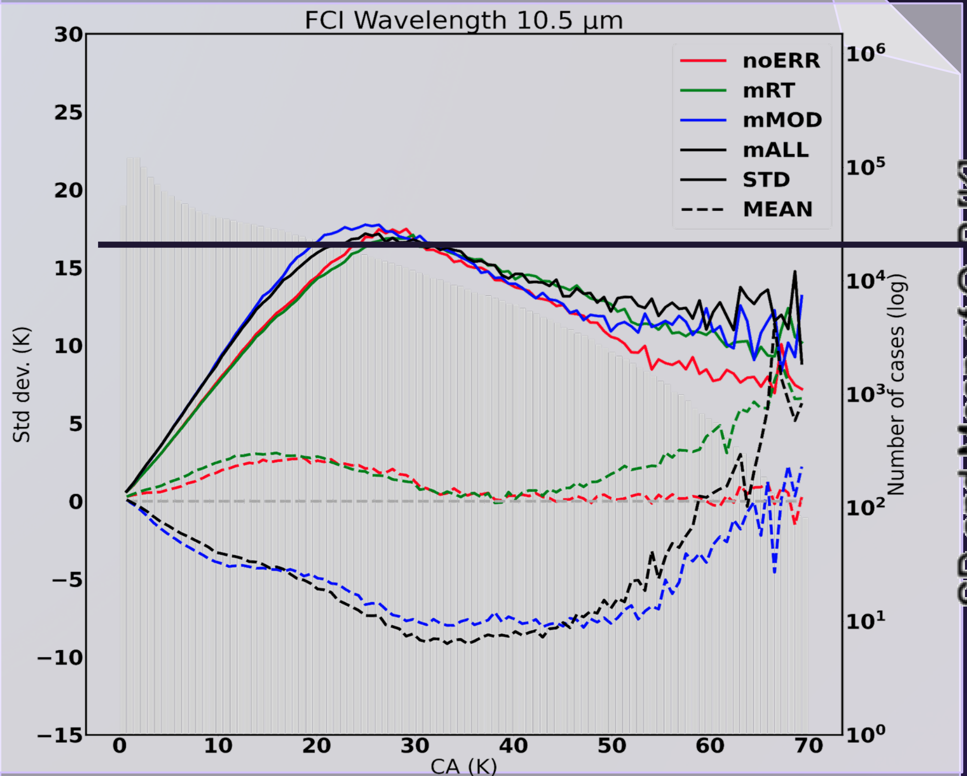


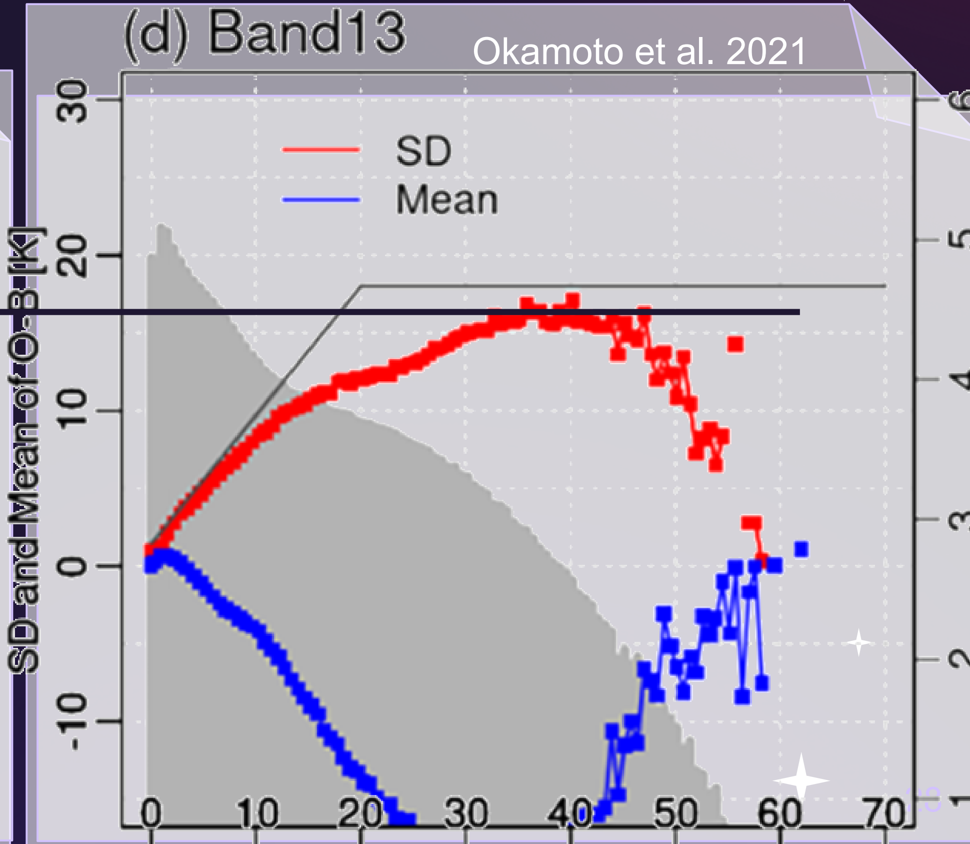

APPENDIX

A1

VALIDATION

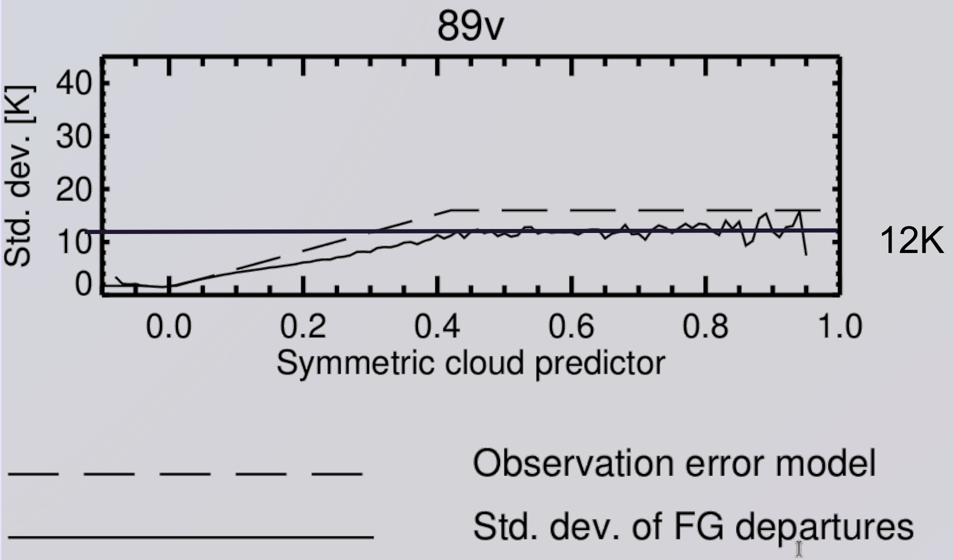
Cloud predictor (IR)

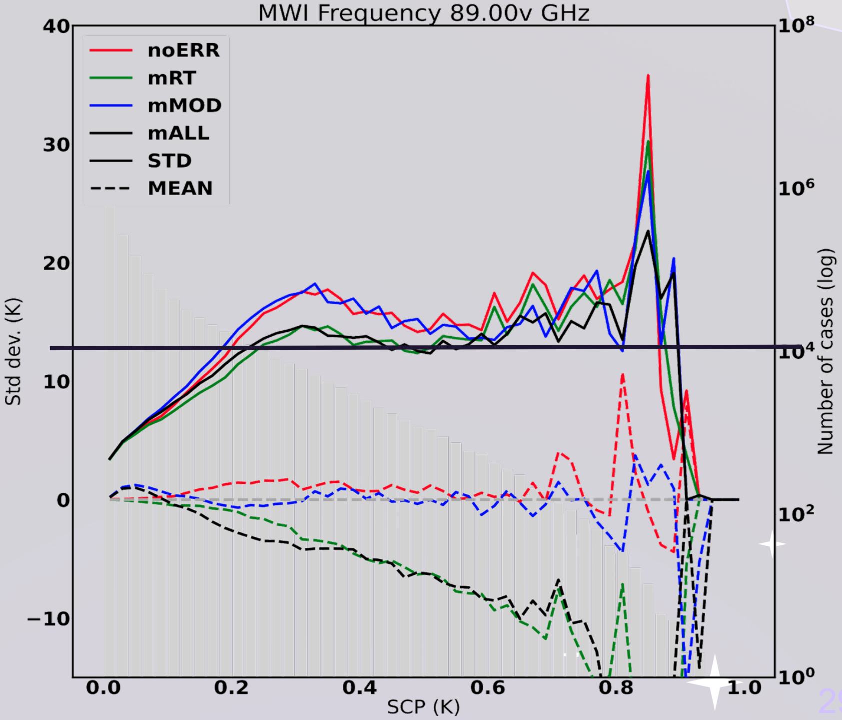




Cloud predictor (MW)

Lean et al. 2017





Desroziersdiagnostic (Desrozierset al. 2005)

To determine observation errors

$$Dx = \sqrt{(BT_{OBS} - BT_{FG}) \times (BT_{OBS} - BT_{RET})}$$

Several iterations

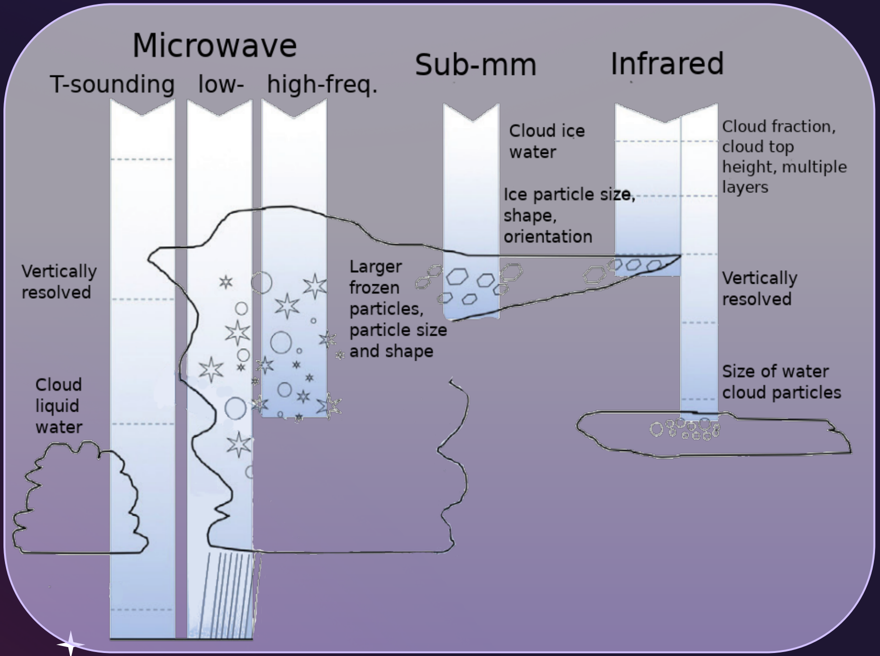
1. Simulate BTs withNEdTas observation error
2. Compute D1 for each channel
3. Simulate BTs with D1 as observation error
4. Compute D2 for each channel
5. …
6. Stop whenDn and Dn-1 do not differ anymore

UseDn as observation error in the experiments

A2

PERTURBATIONS

STARTING POINT



Microphysical closure - Recent progress in all-sky radiance assimilation, Geer A. et al. 2019 (modified)

COMPLEMENTARITY of IR and MW

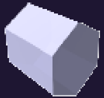
MW : Precipitations, cloud sounding ;
MW sub-mm : cloud ice

IR : Top of clouds, TOA, cloud fraction

ADDING PERTURBATIONS: mRT experiment

Shapes in FG

PSD in FG

MW	noERR Geer et al. 2021		mRT Geer and Baordo 2014	
CIW	Large Column Aggregate (ARTS)		Mie Sphere	
Graupel	Column (ARTS		Sector Snowflake (ARTS)	
Snow	Large plate aggregate (ARTS)		Sector Snowflake (ARTS)	

MW	noERR	mRT
Ice water parameters	$\mu = 0$ $\Lambda = 1.10^4$ $\gamma = 1$	$\mu = 2$ $\Lambda = 2.05\ 10^5$ $\gamma = 1$
PSD modified gamma distribution	$\Gamma(x) \propto x^{\mu} . \exp(-\Lambda x^{\gamma})$	

Parameterisation in FG

ADDING PERTURBATIONS: mRT experiment

IR	noERR	mRT
Ice water parameterisation	Baran 2018	Baum + Wyser (2011, 1998)

ADDING PERTURBATIONS: mMOD experiment

	Parameters	
noERR	Default value (operational model ARPEGE)	
	Random value in a range defined within the ARPEGE-EPS (ensemble prediction system) (Descamps et al. 2014)	
mMOD	**Microphysical scheme:** sedimentation velocity (cloud ice, cloud water, snow, rain), auto-conversion (cloud ice into snow, cloud water into rain, minimum ice content, maximum ice content, critical water content), coefficients (accretion, stratification and ice aggregate, aggregation, calculation of water/ice partitioning, calculation of relative humidity, calculation of cloud liquid water into rain conversions, maximum evaporation rate)	**Convection scheme:** downdraft mass flux, entrainment rate, detrainment rate

A3

GRAUPELS

Conclusion :

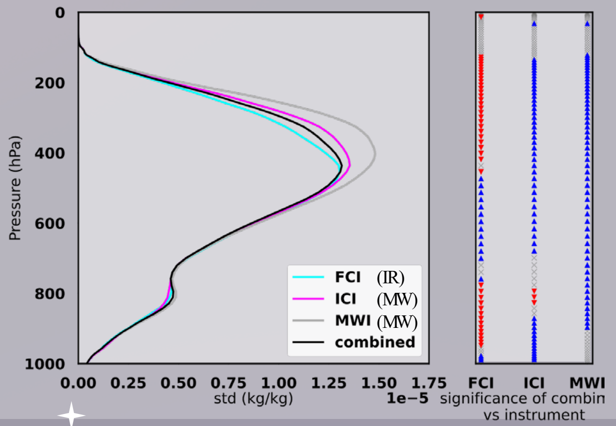
Positive impact of IR in higher altitude and of MW in lower altitude.

Precipitating hydrometeors: improvement of IR and compromise for MW

Synergy?

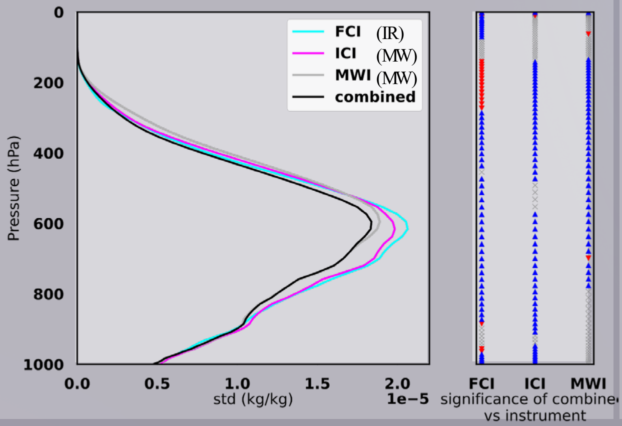
noERR experiment: STD study

CIW



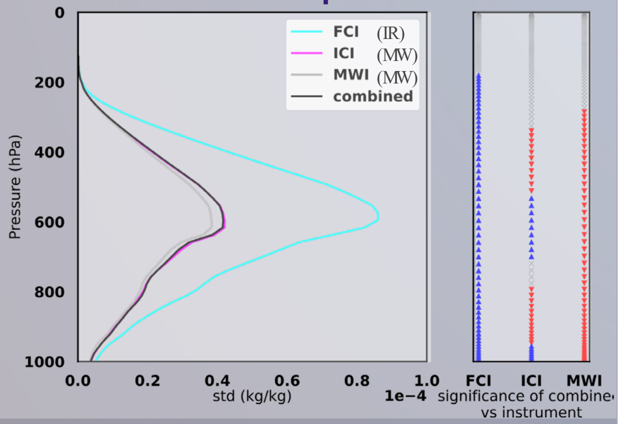
High altitude : improvement of MW
Low altitude : improvement of IR

Snow



Improvements of all instruments at all levels

Graupel



FCI : great errors (x2)

Combined inversion sticks to MW

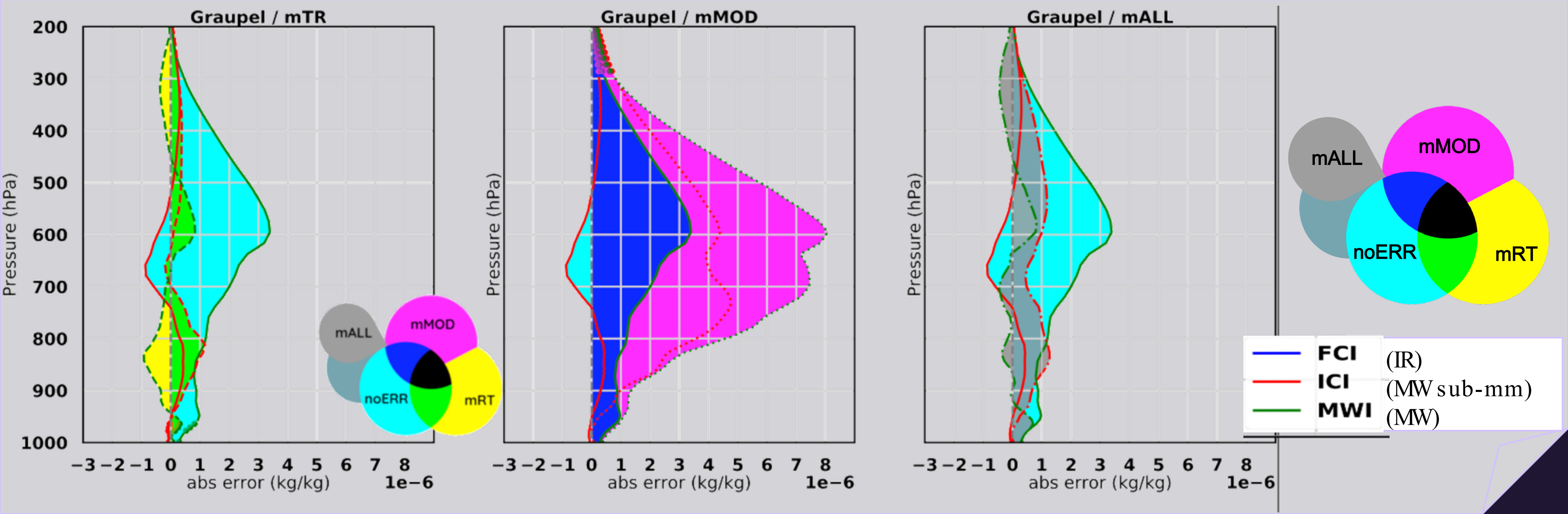
Conclusions

PERTURBATIONS IMPACTS

mRT has more impact than mMOD on Graupel.

=> reduce negative effects of mMOD

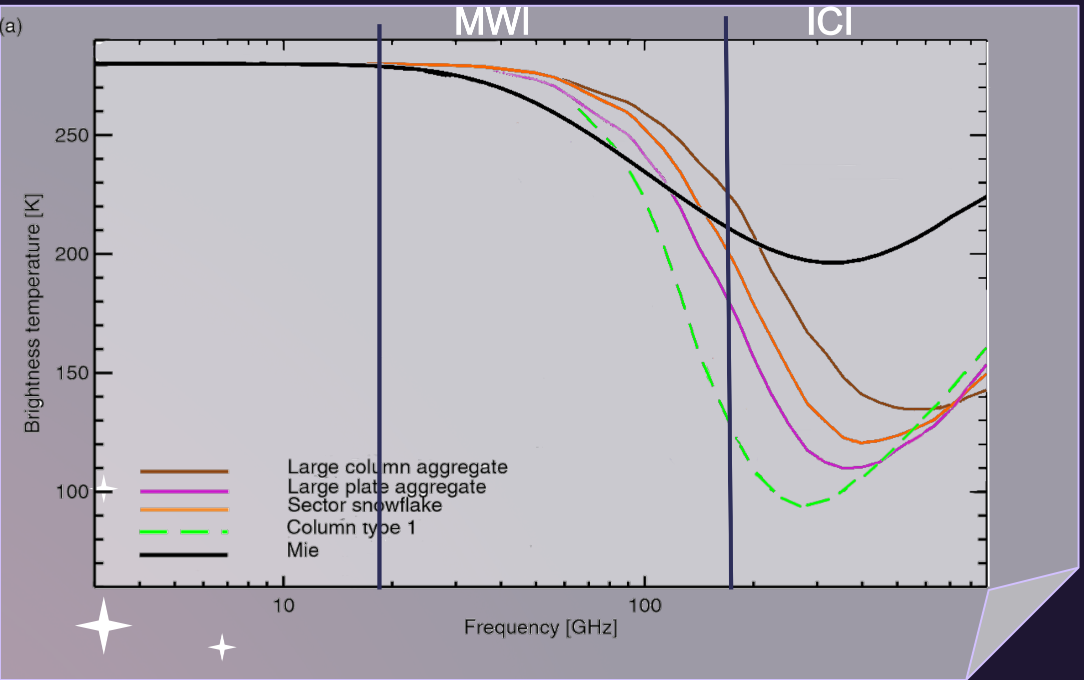
Graupel



Geer et al. 2021 *Bulk hydrometeor optical properties for microwave and sub-millimetre radiative transfer in RTTOV-SCATT v13.0* figure 9.a (modified)

Perturbations impacts

Impact of hydrometeors shape modifications



	noERR	mRT
CIW	Large column aggregate (ARTS)	Sphère de Mie
Graupel	Column (ARTS)	Sector snowflake (ARTS)
Snow	Large plate aggregate (ARTS)	Sector snowflake (ARTS)