A Modular Retrieval System To Compare Microwave-Sounder Retrieval Approaches

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Tons of help by : J. Steward, B. Lambrigtsen, E.Fishbein

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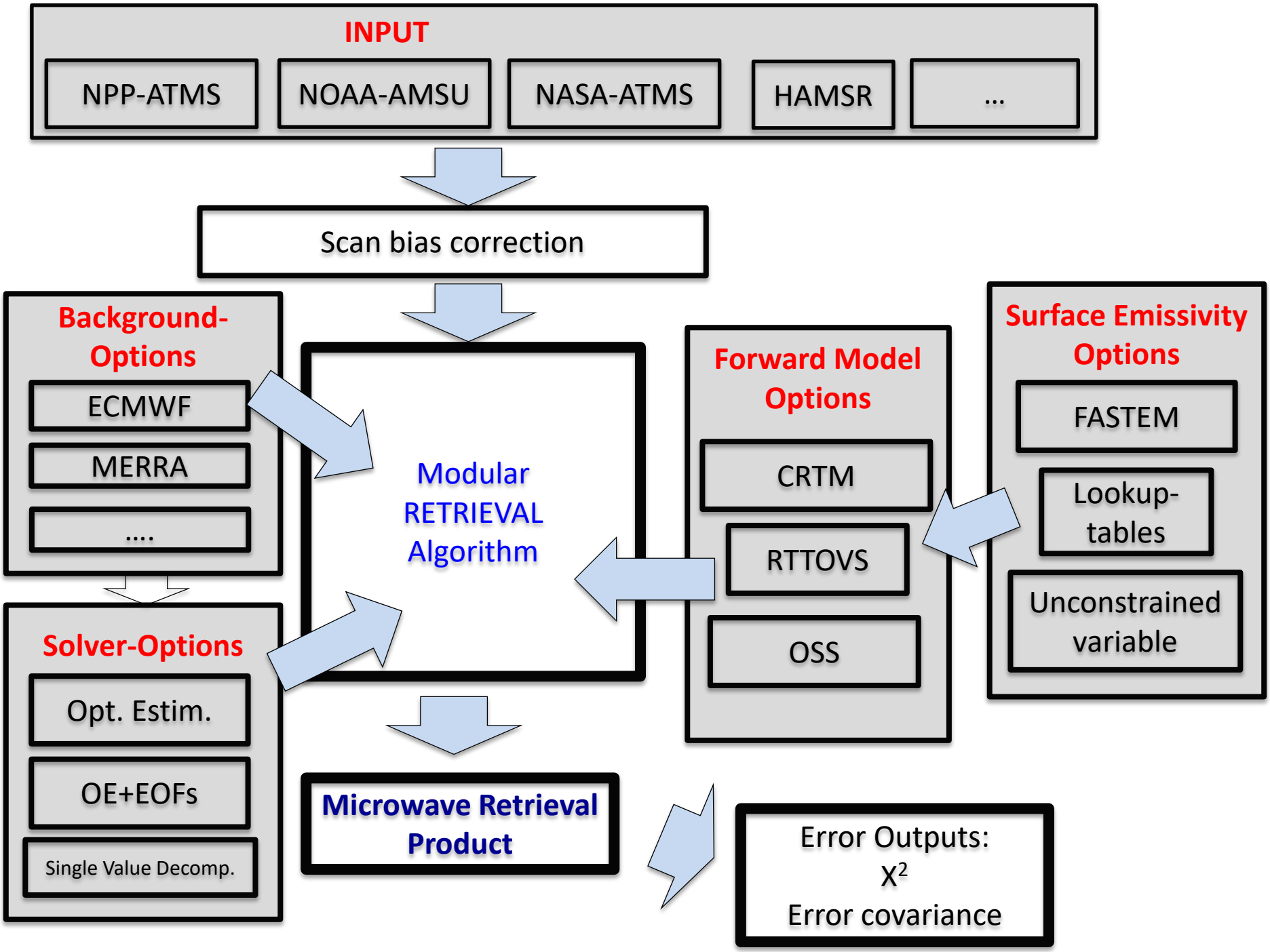
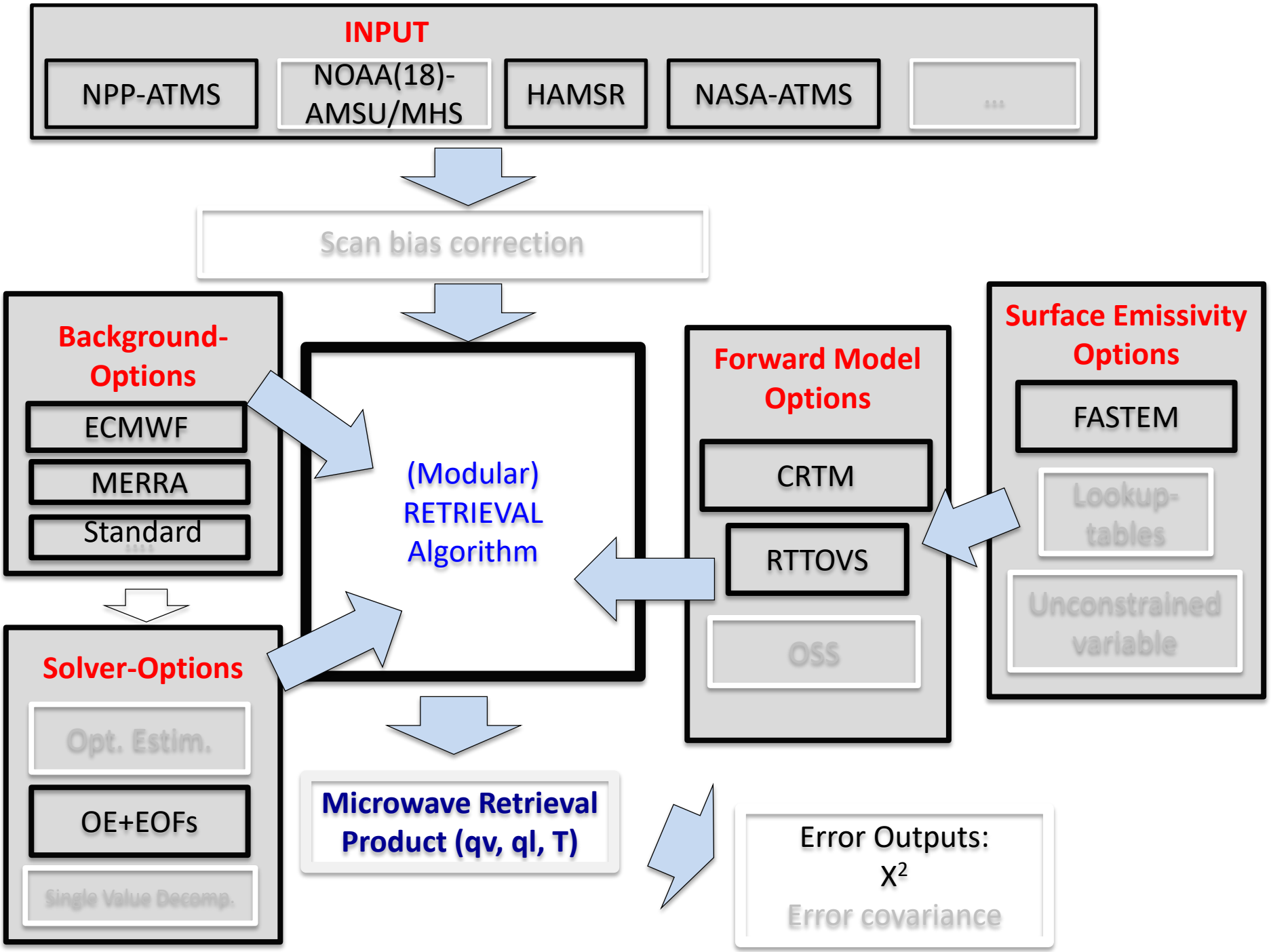

INPUT
NPP-ATMS
NOAA-AMSU
NASA-ATMS
HAMSR
...
Scan bias correction
Background-Options
ECMWF
MERRA
....
Solver-Options
Opt. Estim.
OE+EOFs
Single Value Decomp.
Modular RETRIEVAL Algorithm
Forward Model Options
CRTM
RTTOVS
OSS
Surface Emissivity Options
FASTEM
Lookup-tables
Unconstrained variable
Microwave Retrieval Product
Error Outputs:
X2
Error covariance


INPUT
NPP-ATMS
NOAA(18)-AMSU/MHS
HAMSR
NASA-ATMS
...
Scan bias correction
Background-Options
ECMWF
MERRA
Standard
....
(Modular) RETRIEVAL Algorithm
Forward Model Options
CRTM
RTTOVS
OSS
Surface Emissivity Options
FASTEM
Lookup-tables
Unconstrained variable
Solver-Options
Opt. Estim.
OE+EOFs
Single Value Decomp.
Microwave Retrieval Product (qv, ql, T)
Error Outputs:
X2
Error covariance

Type	Achieved	Further planned
Instruments	ATMS (h5), ATMS-SIPS (nc), AMSU-A/B, MHS (binary) HAMSR (nc)	
RTA	CRTM RTTOVS	ARTS, OSS, Rosenkranz code
Background	Standard (elevation adapted) ECMWF MERRA-2	Simplified climatology
Covariance Matrix	EOFs, based on ECMWF	Based on MERRA-2
Noise Matrix	Pseudo-inverse-Matrix to reduce influence from noisy channels (see later)	
Solver Approach	Adjoints Optimization via Limited Memory Bundle Method	Jacobians different Optimization routines
Error analysis	X^2	Final Error Covariance Matrix

RTA Comparison - General

Similarities between RTTOV and CRTM:

- Both provide forward, adjoints and Jacobian calculation
- Both have the option to use FASTEM (Version 4) or look-up tables
- Input conversion for both is straight forward
- Both adapt to variable input levels (91 for ECMWF, 72 for MERRA-2)
- Most instrument coefficients available

Differences:

- Slight speed difference: initialization of RTTOVS takes longer
- Scattering calculation:
    - CRTM: hybrid of matrix-operator-method and adding method
    - RTTOV: delta-Eddington approximation
- Unit conversion necessary (e.g., liquid water for CRTM: kg/m2, RTTOV: kg/kg)

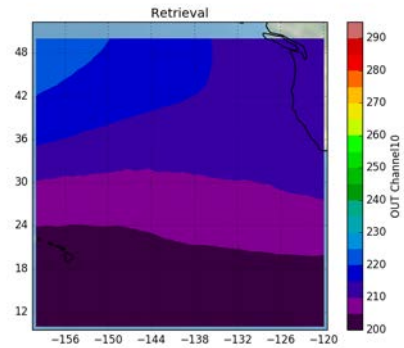
RTA – Impact on Simulation

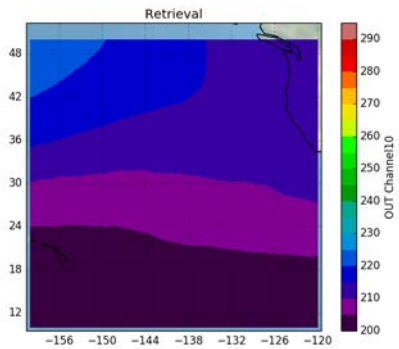
INPUT:

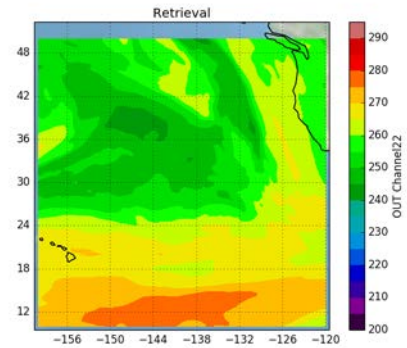
- Instrument data : ATMS – no corrections
- A-priori : ECMWF
- RTA: CRTM (lower), RTTOV(upper)
- Solver: OE (5 PC, 20 iterations)

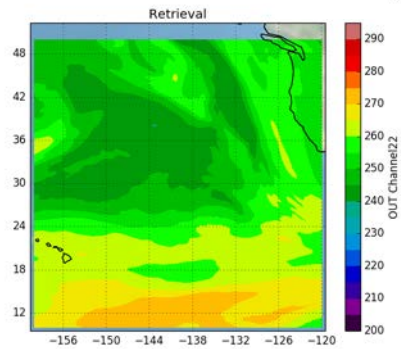
RESULT:

- Upper atmosphere: Minimal differences (example : Ch 10)
- Lower Troposphere: RTTO V seems to create warmer BT (example : Ch 22)









Background Comparison - General

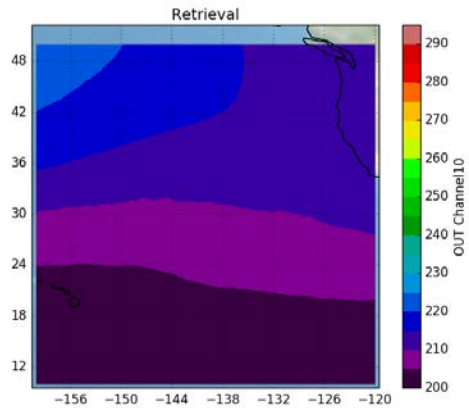
Similarities MERRA-2 and ECWMF:

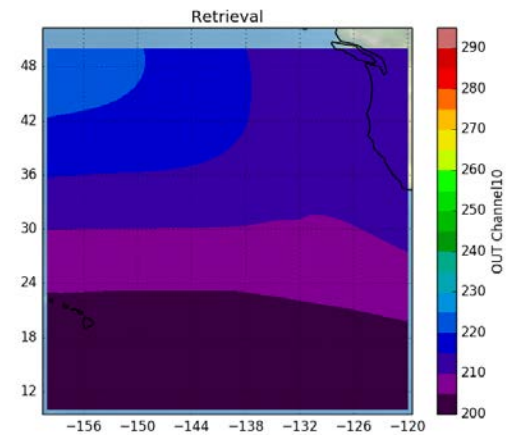
- Use re-analysis in both cases

Factor	ECMWF	MERRA-2	Standard
Resolution Lat/Lon	0.25	0.6/0.625	1
Levels	91	72	40 (adaptable)
Format	Grib	Netcdf	Internal or text-file
Reading time (Mac, SSD)	~4 sec per 3D-var	~2.5 sec per 3D-Var	1 sec to initialize entire field

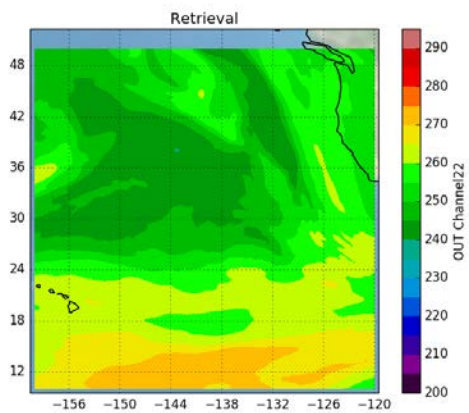
Background - Impact on Simulation

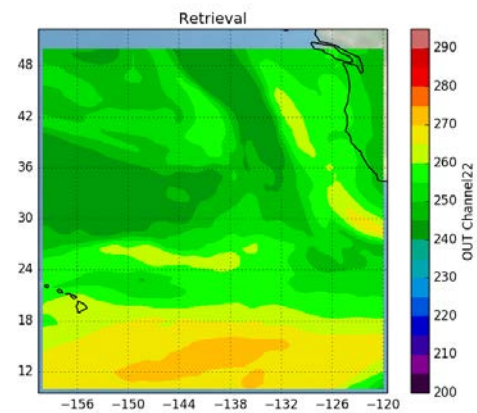
Instrument: ATMS
RTA : CRTM
Background: ECMWF, MERRA-2





- Small, but visible impact (channel 10)
- Lower Troposphere has slight structural differences, but similar BT (example : Ch 22)





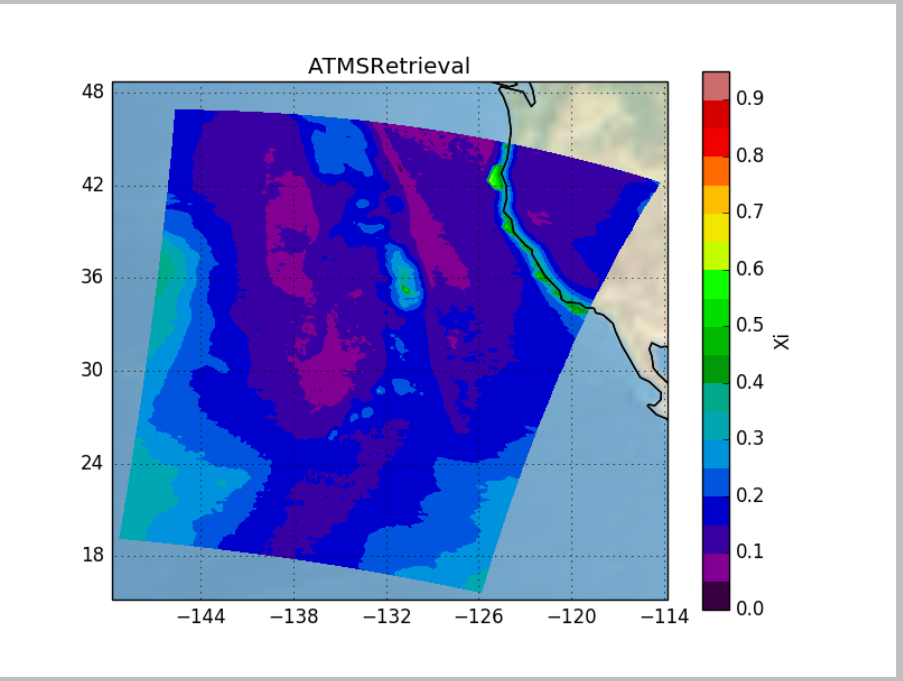
RTA/Background - Impact on Retrieval

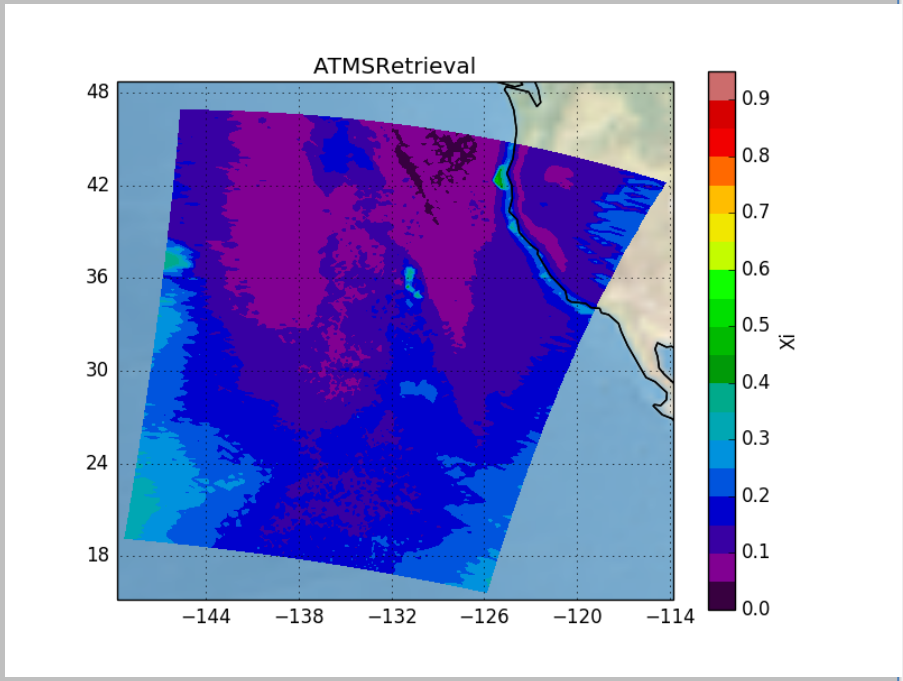
INPUT:

- Instrument data : ATMS – no corrections
- A-priori : Standard
- RTA: CRTM (left), RTTOV(right)
- Solver: OE (5 PC, 10 iterations)

RESULT for X^2:

- Both get worse for tropical areas
- Both are Noisy, but RTTOV more noisy
- RTTOV gets closer to solution





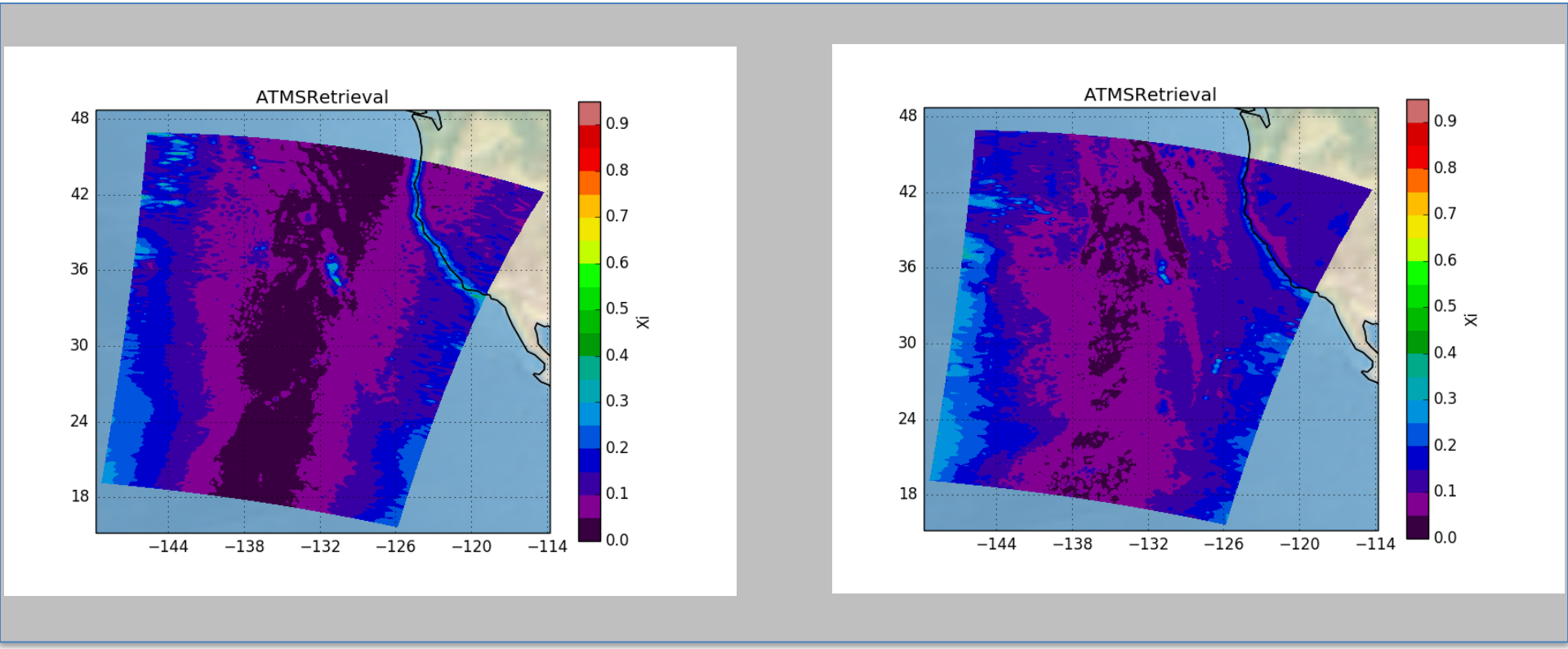
RTA/Background - Impact on Retrieval

INPUT:

- Instrument data : ATMS – no corrections
- A-priori : ECMWF
- RTA: CRTM (left), RTTOV(right)
- Solver: OE (5 PC, 10 iterations)

RESULT for X^2:

- Both have scan angle dependence
- Both are Noisy
- CRTM closer to 0 at nadir



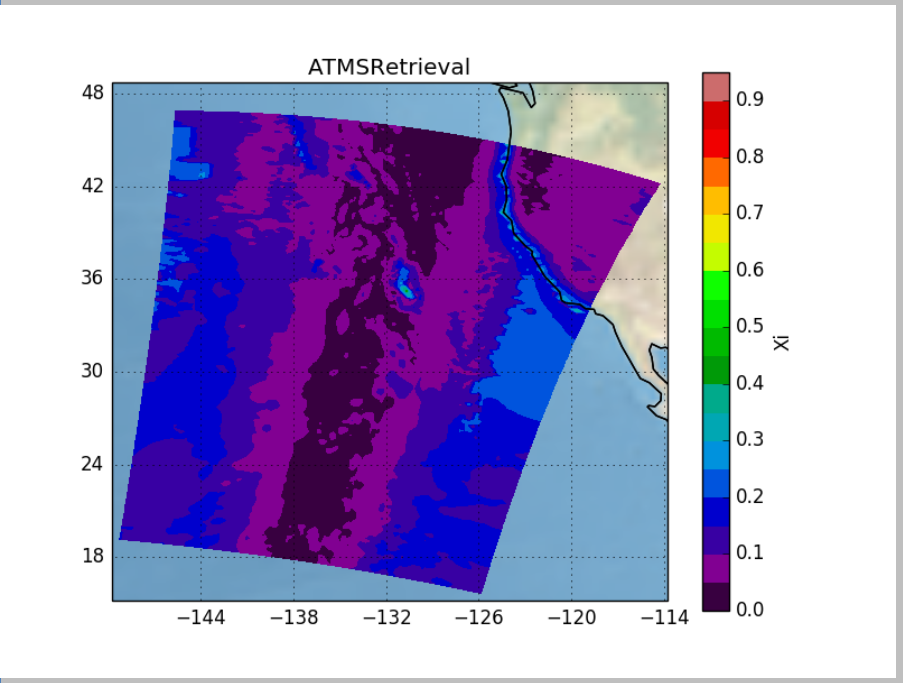
RTA/Background - Impact on Retrieval

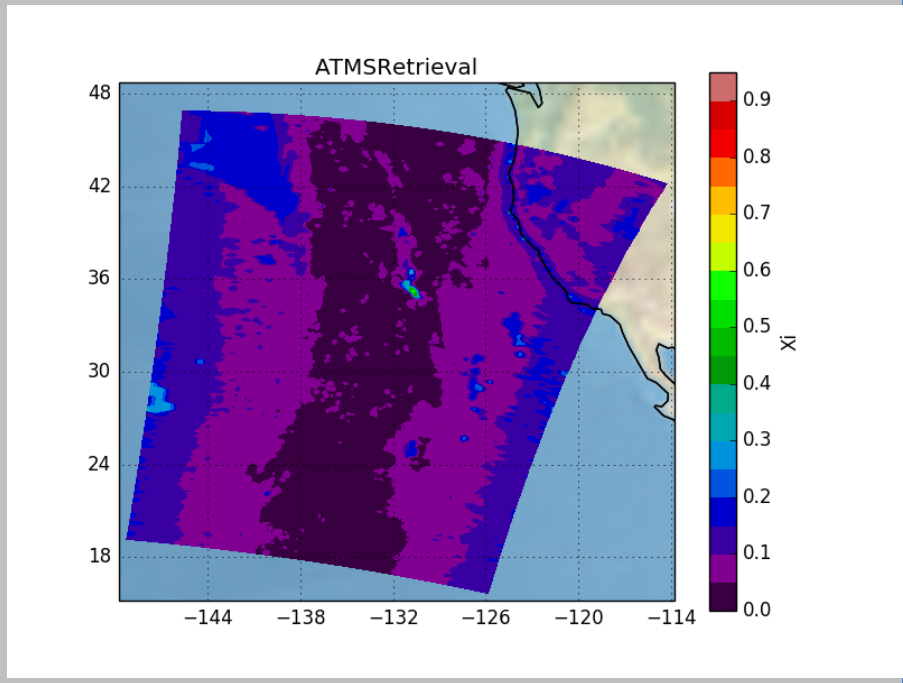
INPUT:

- Instrument data : ATMS – no corrections
- A-priori : MERRA-2
- RTA: CRTM (left), RTTOV(right)
- Solver: OE (5 PC, 10 iterations)

RESULT for X^2:

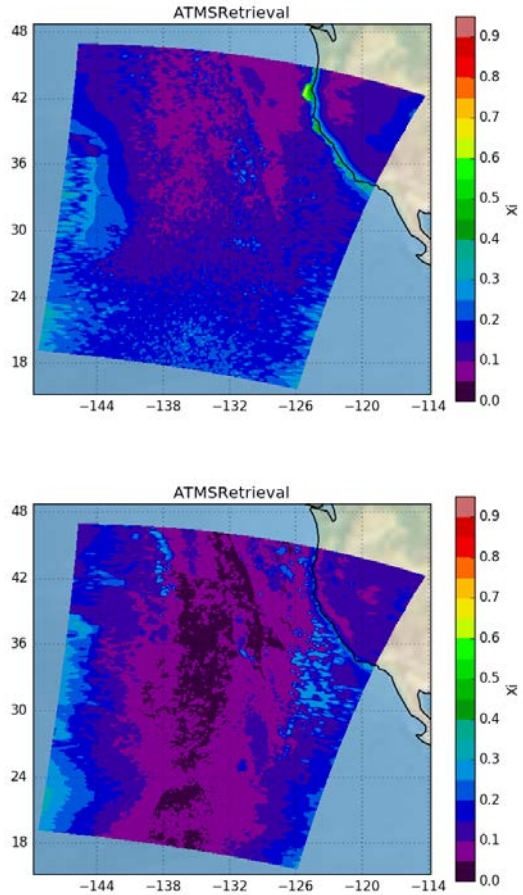
- Both have scan angle dependence
- Less Noisy (lower resolution ?)
- RTTOV gets closer off nadir





Noise reduction with reduced PCs, when creating Covariance/R-Matrix

22/22



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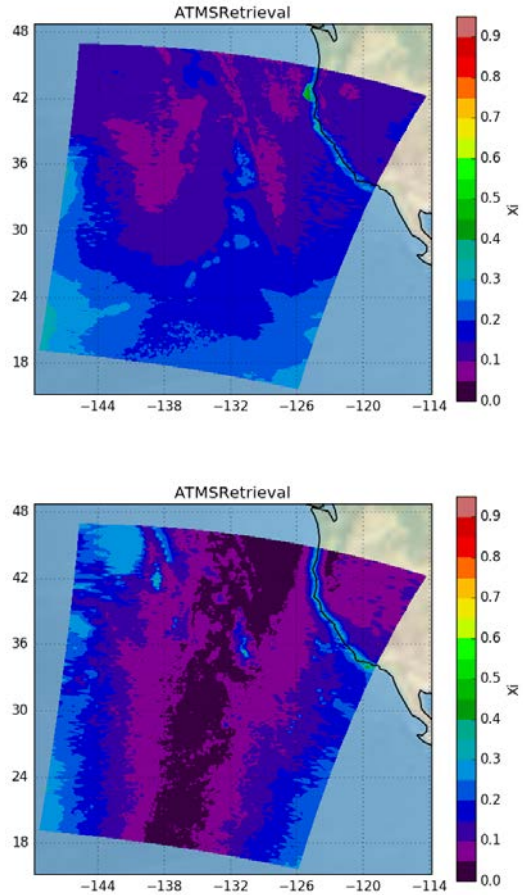

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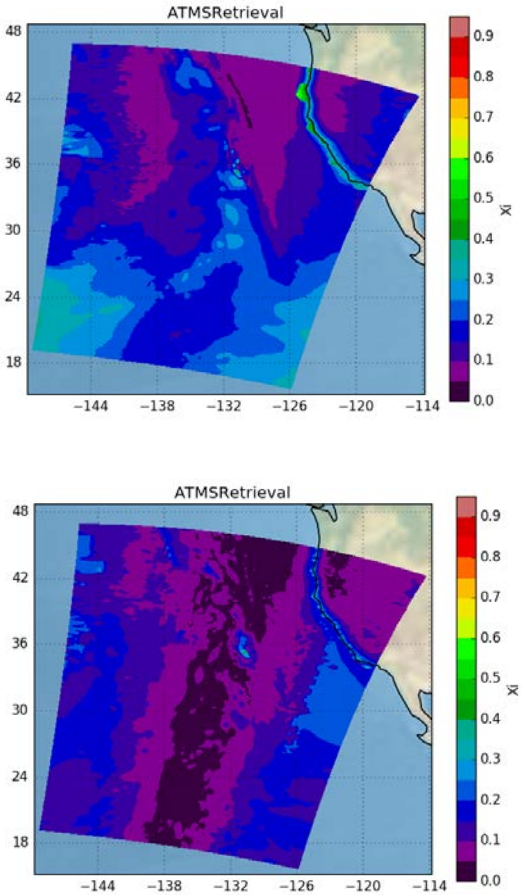


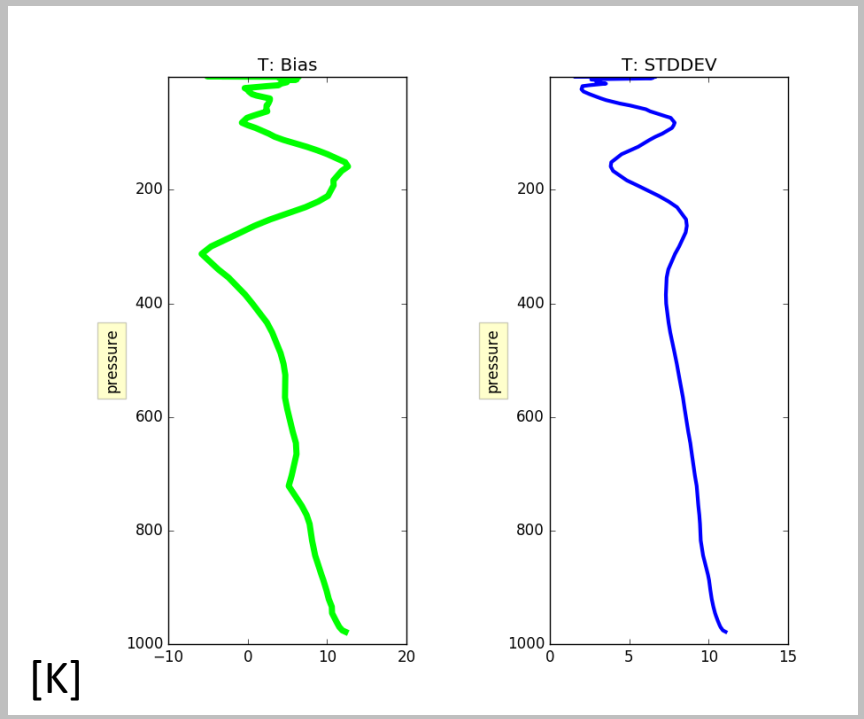
Temperature retrieved against ECMWF

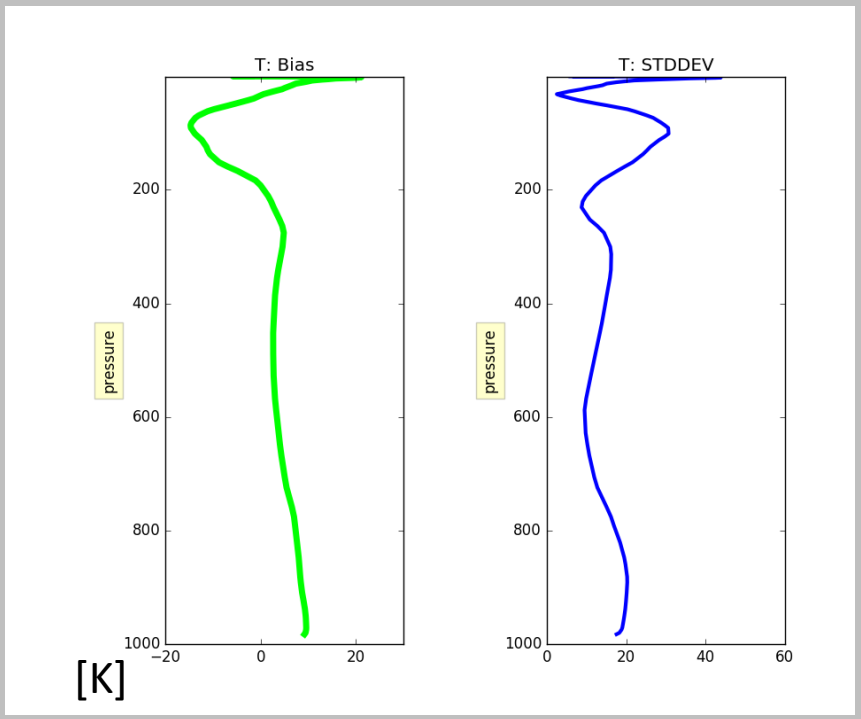
INPUT:

- Instrument data : ATMS – no corrections
- Background: FIXED
- RTA: CRTM (left), RTTOV(right)
- Solver: OE (5 PC)

RESULT:

- With CRTM : high bias, low STDDEV
- With RTTOV: high bias, high STDDEV





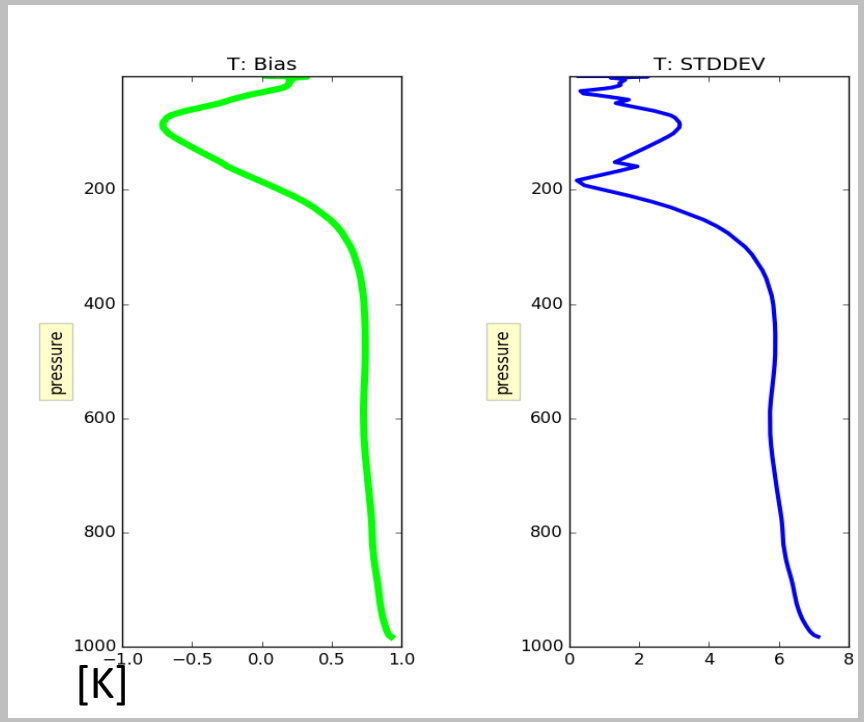
Temperature retrieved against ECMWF

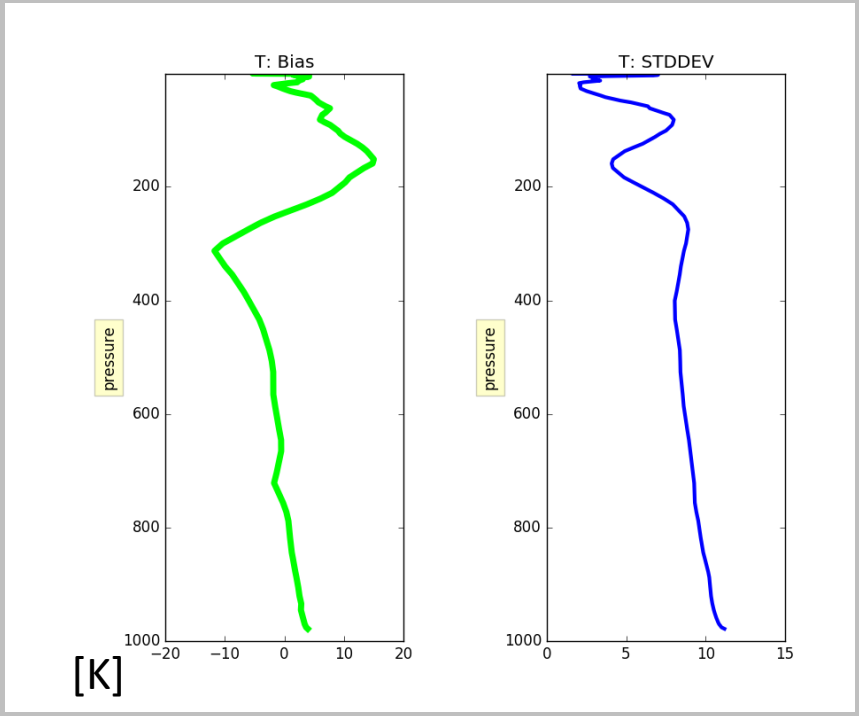
INPUT:

- Instrument data : ATMS – no corrections
- Background: ECMWF
- RTA: CRTM (left), RTTOV(right)
- Solver: OE (5 PC, 10 iterations)

RESULT:

- With CRTM : smaller bias, relative low STDDEV
- With RTTOV : wrmer than ECMWF in troposphere, colder above





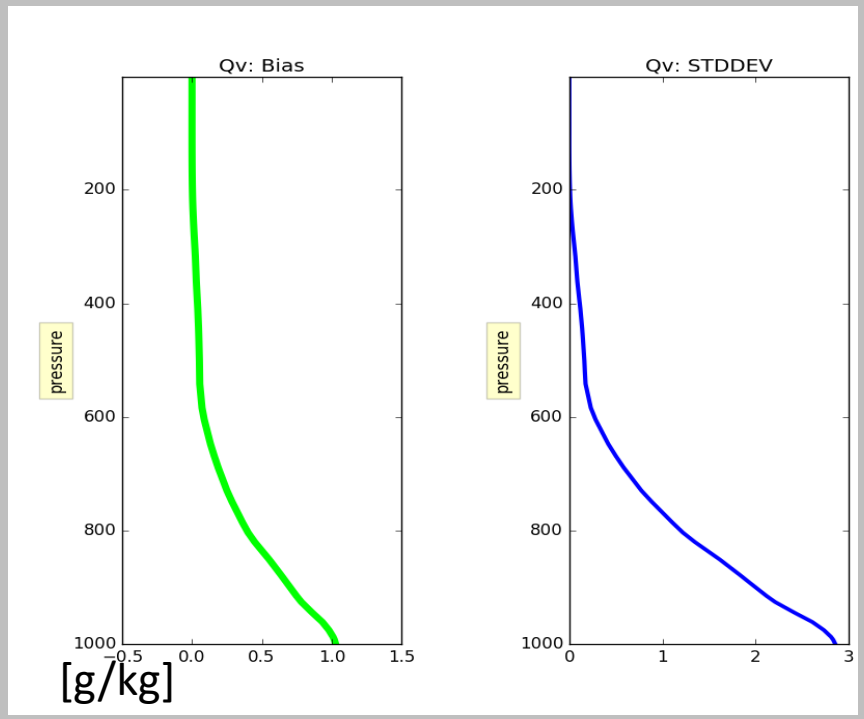
Water vapor retrieved against ECMWF

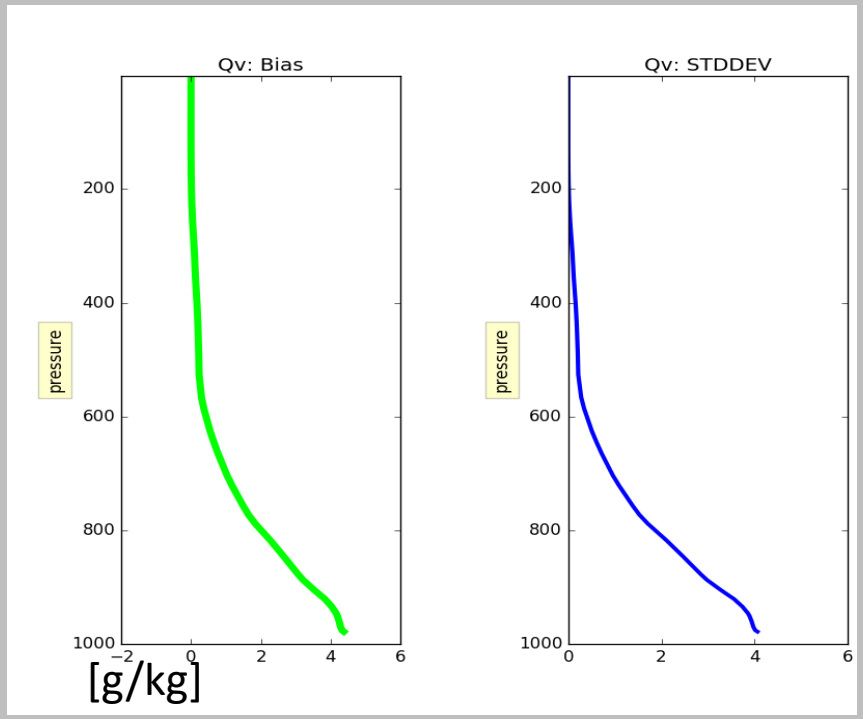
INPUT:

- Instrument data : ATMS – no corrections
- Background: FIXED
- RTA: CRTM (left), RTTOV(right)
- Solver: OE (5 PC)

RESULT:

- With CRTM: slight increase
- With RTTOV: strong increase in boundary layer Qv
- Comparable STDDEV





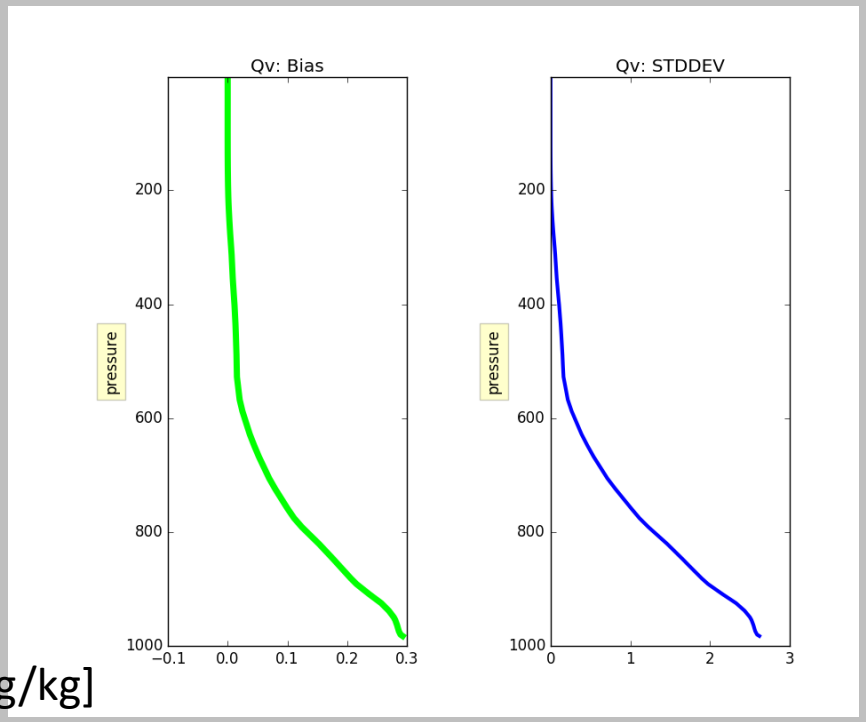
Water vapor retrieved against ECMWF

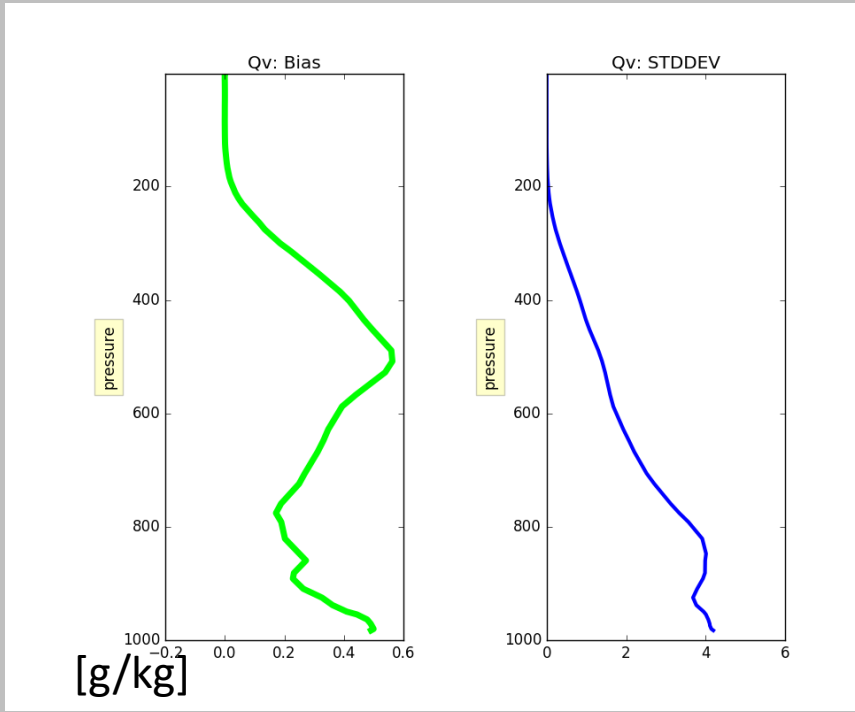
INPUT:

- Instrument data : ATMS – no corrections
- Background: ECMWF
- RTA: CRTM (left), RTTOV(right)
- Solver: OE (5 PC, 10 iteration)

RESULT:

- With CRTM : smooth increase, low STD
- With RTTOV: slightly higher
- Both stay close to ECMWF





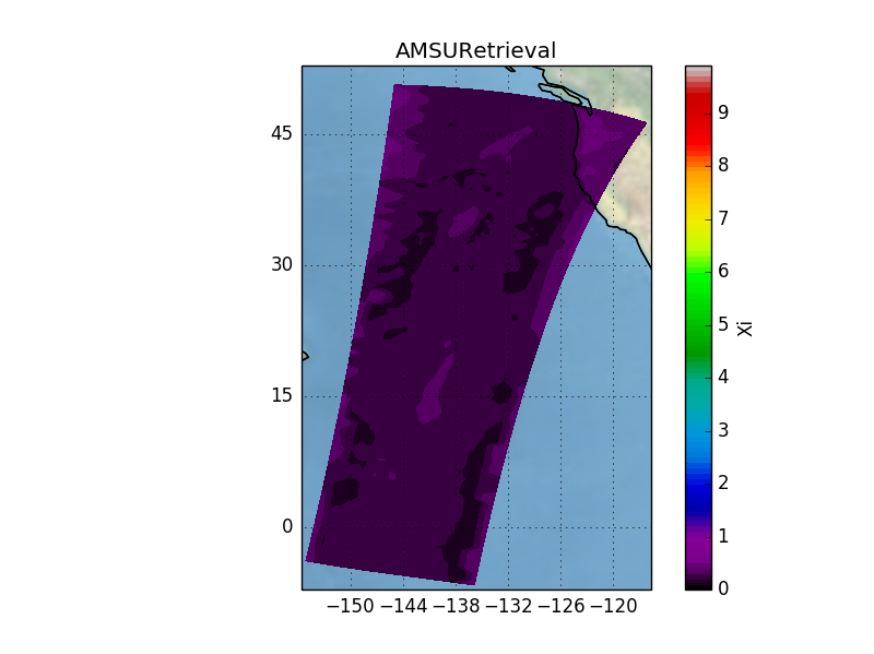
AMSU-A retrieval

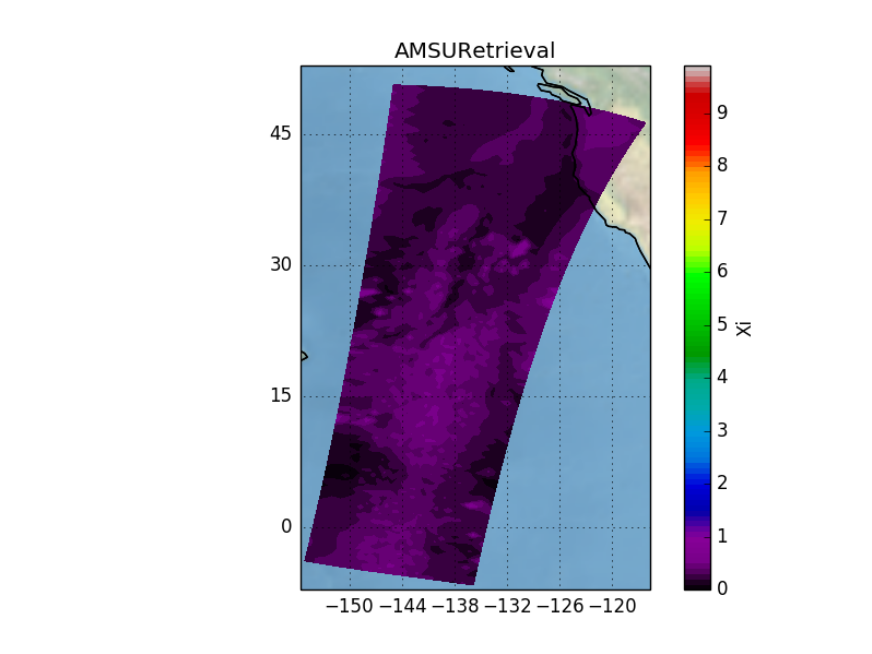
INPUT:

- Instrument data : AMSU-A/B – no corr.
- A-priori : FIX
- Solver: OE (5 PC)

RESULT:

- CRTM looks better than RTTOV





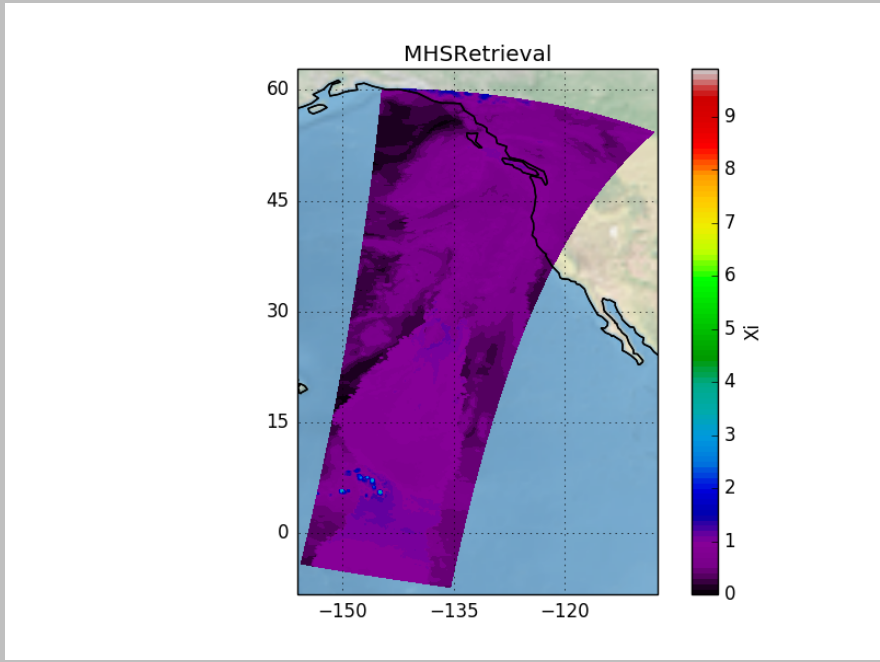
MHS retrieval

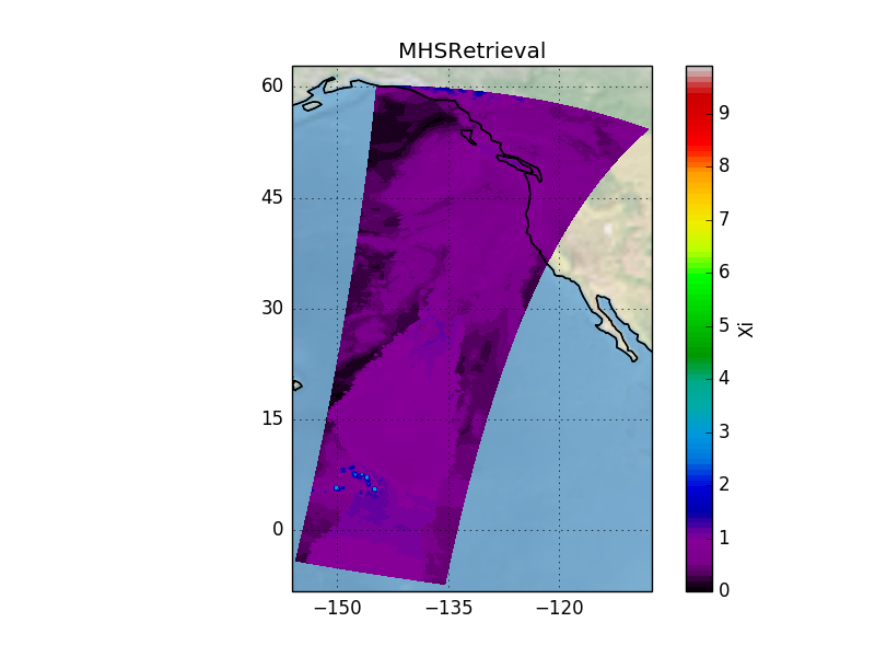
INPUT:

- Instrument data : AMSU-A/B – no corr.
- A-priori : FIX
- Solver: OE (5 PC)

RESULT:

- RTTOV and CRTM look similar





Conclusion

Creating a modular retrieval system to compare different approaches:

- **Can ingest a variety of instruments (ATMS, AMSU, HAMSR, ...)**
- **Allows RTA comparison (CRTM vs RTTOVS)**
- **Allows Background comparison (MERRA-2, ECMWF, standard)**
- **Allows change of PCA-components**
- **Extendable (RTA: OSS, ARTS, Solver-Approach, ...)**
- **Still bugs to solve**

Current Observations:

- RTTOV seems to create warmer BTs in near-surface channels
- Range of BTs from MERRA-2 and ECMWF are similar
- Structural differences
- These small differences result have strong impact of several degrees in retrieved profiles of Temperature and water vapor
- Standard and ECMWF can have variations of up to 10 K and water vapor of up to 5 g/kg

Still a construction zone ....