

# Hardware Performance, Software Tools and Data Formats

## Ground-Based Microwave Sounding Radiometers are prepared for Operational Networks and Data Assimilation

*Harald Czekala, Gerrit Maschwitz, Emiliano Orlandi, Thomas Rose  
RPG Radiometer Physics GmbH, Meckenheim, Germany*

**ISTP 2019 - Météo France - Toulouse**

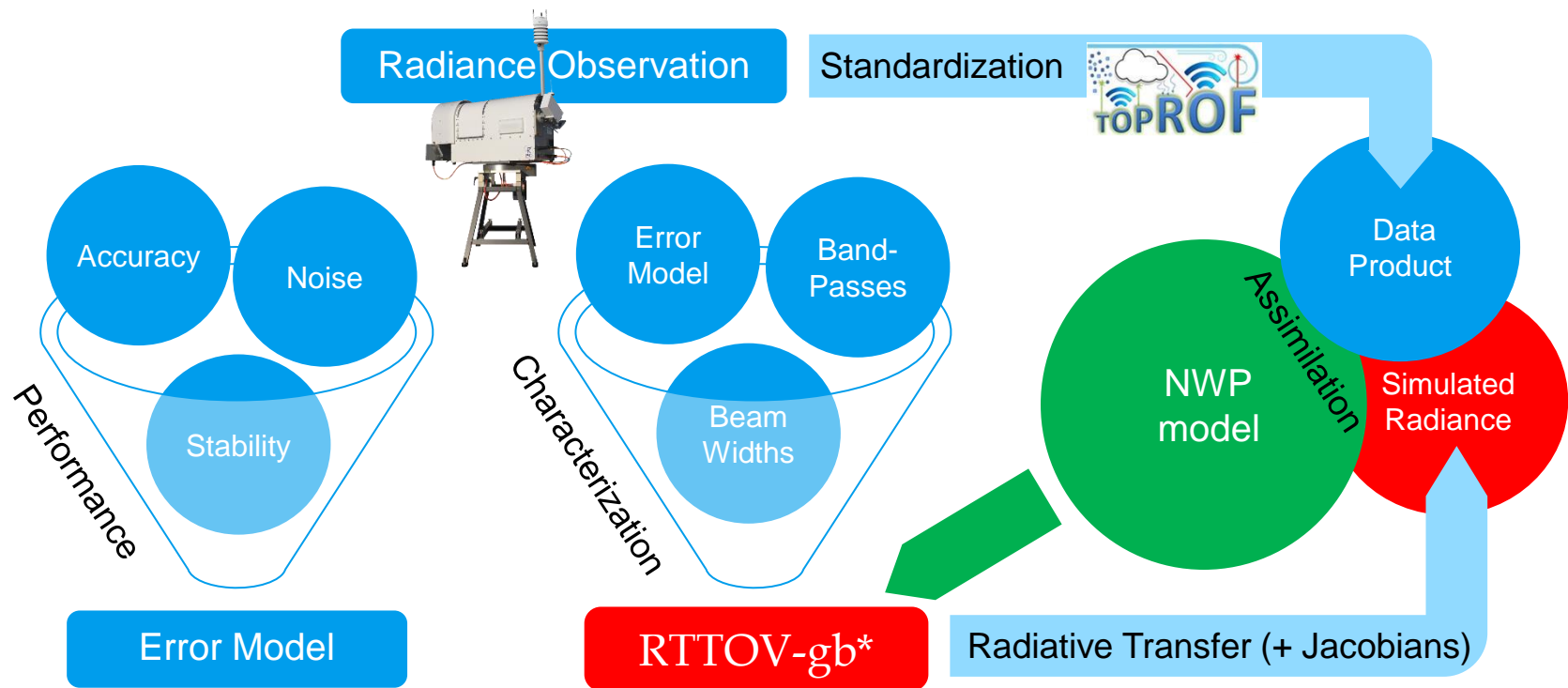
*May 23, 2019*

# Introduction

- Assimilation of global satellite observations revolutionized NWP
- Include the ground-based perspective to „close the observational gap in the boundary layer“
- A number of remote sensors are available for continuous atmospheric sounding
- **Microwaves radiometers ...**
  - ... measure vertical temperature and humidity profiles of the entire troposphere
  - ... provide valuable measurements in cloudy and even light rain conditions
  - ... offer a high-temporal resolution (minute-scale)
  - ... are successfully/continuously operated under all environmental conditions
- **Operational networks used for data assimilation require more:**
  - Adequate hardware performance
  - Standardized data formats
  - Software tools for automated processing, quality checking and data distribution



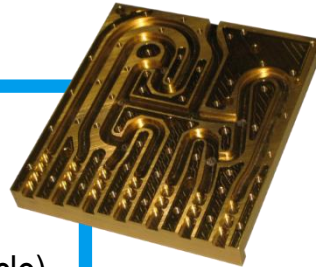
# Towards Radiance Assimilation of Ground-based Microwave Sounders



# Microwave Sounding Radiometer: RPG-HATPRO Design

## Direct Detection Filter-Bank Design

- 7 channel water vapour band (22 to 31 GHz)
- 7 channel oxygen band (51 to 58 GHz)
- all channels parallel @1 s res. (100% duty cycle)

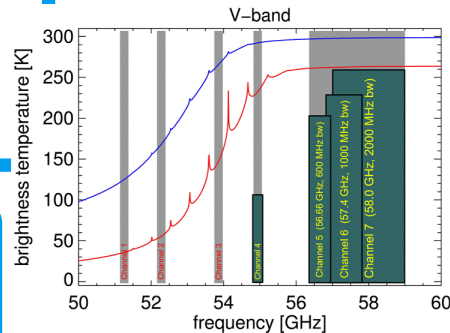


## Individual Band-Passes

200 MHz – 2000 MHz

→ optimized TB sensitivity

**Elevation Scanning** for enhanced information content



## Network Suitable

- TCP/IP interface
- internal monitoring
- housekeeping data
- sanity checks
- automatic alerts



# Microwave Sounding Radiometer: RPG-HATPRO Evolution



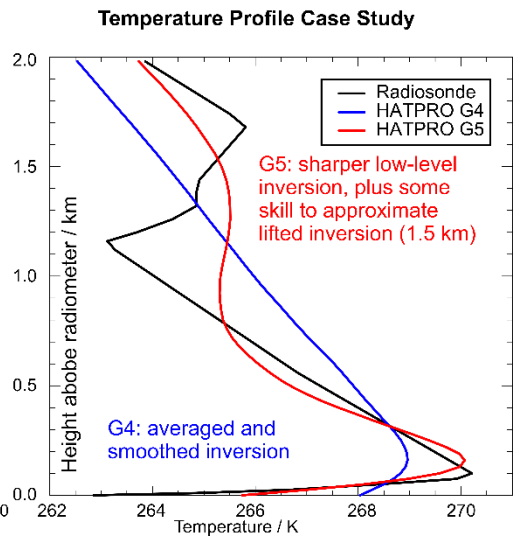
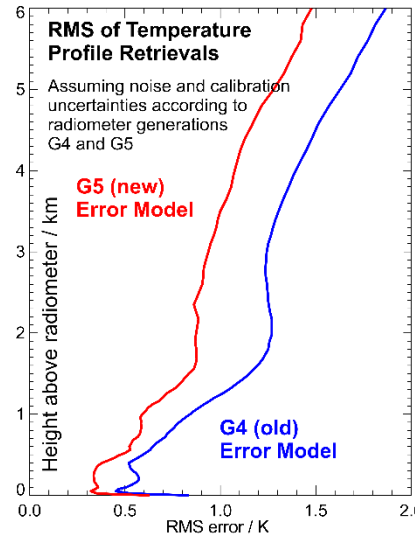
- First generation launched more than 15 years ago
- More than 200 deployments worldwide
- Evolution through instrument generations:

Improved ...

- noise performance
- radiometric stability
- calibration accuracy

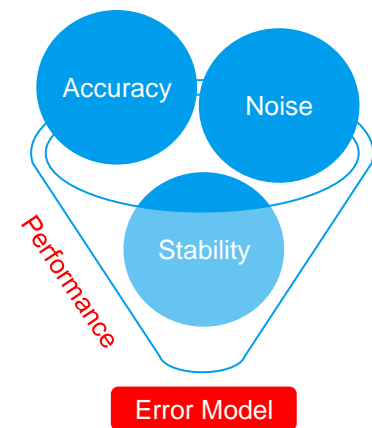
... drive retrieval quality:

- reduced RMS
- more degrees of freedom
- added features



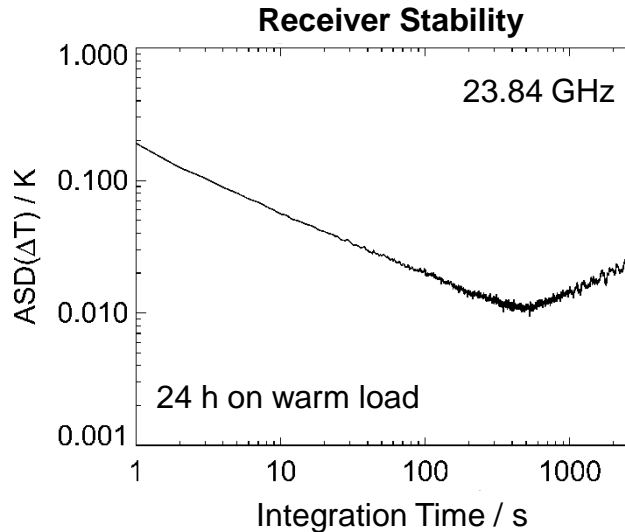
# Microwave Sounding Radiometer: RPG-HATPRO

## Error Model



### Receiver Noise

Int. time	1 s	10 s	100 s
<b>f / GHz</b>	<b>Standarddeviation / K</b>		
22.24	0.070	0.025	0.010
23.04	0.072	0.030	0.015
23.84	0.068	0.028	0.013
25.44	0.067	0.026	0.014
26.24	0.070	0.025	0.013
27.84	0.065	0.026	0.013
31.40	0.083	0.035	0.020
51.26	0.120	0.050	0.030
52.28	0.120	0.050	0.025
53.86	0.110	0.050	0.025
54.94	0.110	0.045	0.028
56.66	0.070	0.030	0.018
57.30	0.060	0.028	0.015
58.00	0.050	0.025	0.010

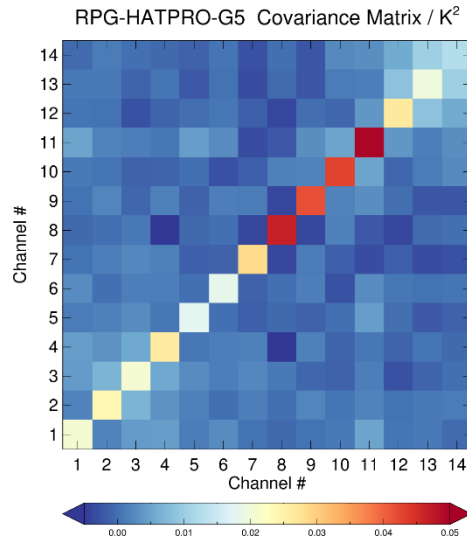
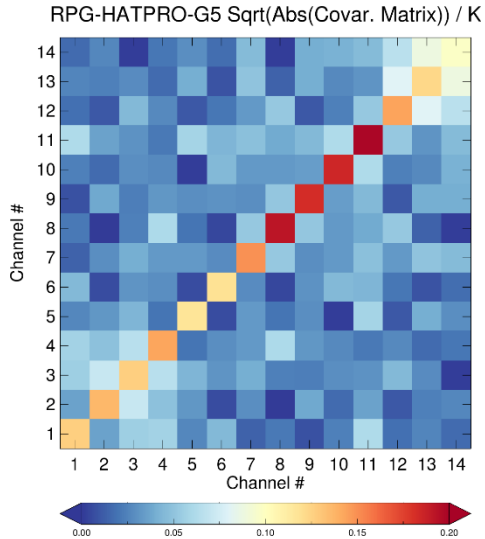
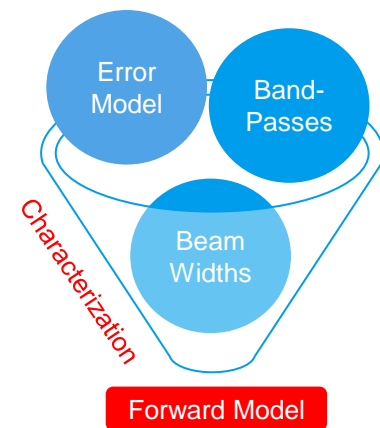


### Calibration Accuracy



$$\Delta T_B = \pm 0.15 K$$

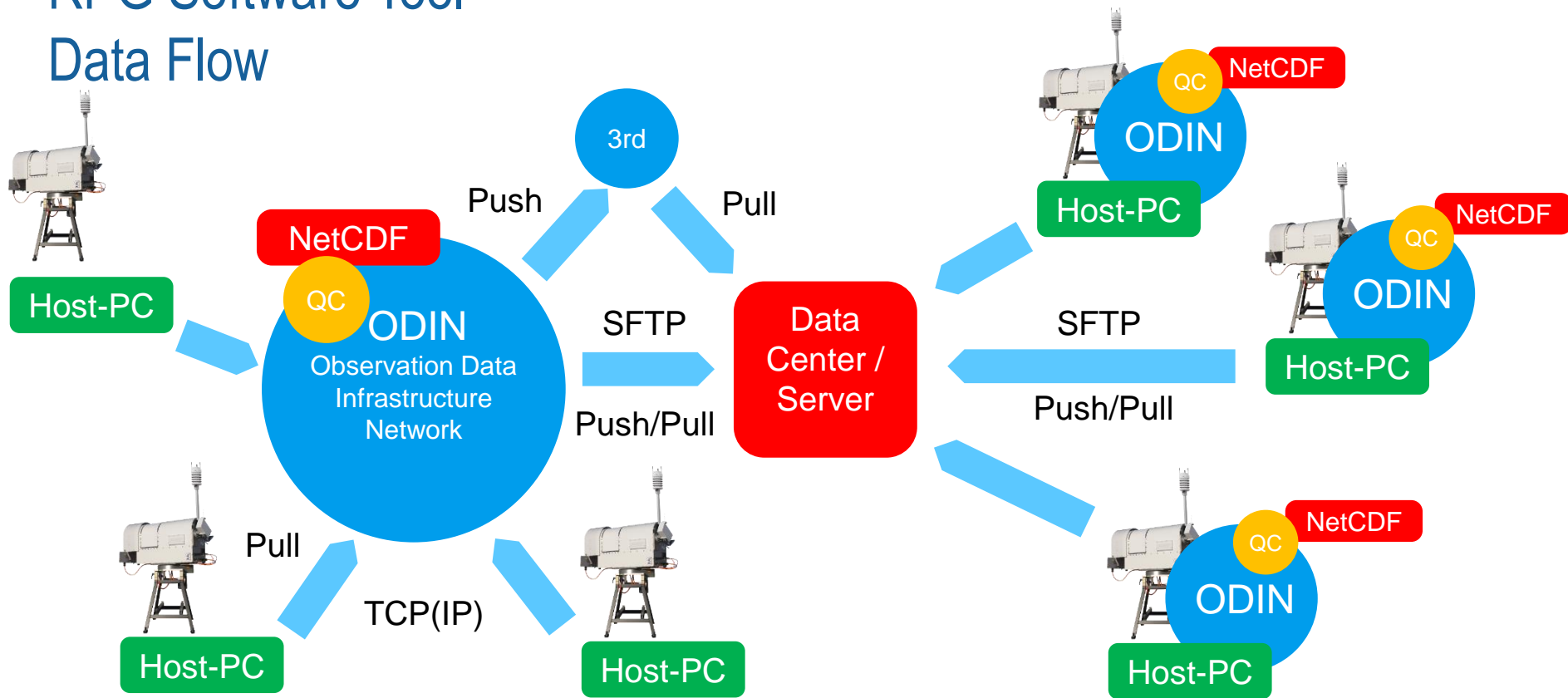
# Microwave Sounding Radiometer: RPG-HATPRO Covariance Matrix



$$J(x) = \frac{1}{2} (x - x_b)^T B^{-1} (x - x_b) + \frac{1}{2} (y - F(x))^T R^{-1} (y - F(x))$$

# RPG Software Tool

## Data Flow





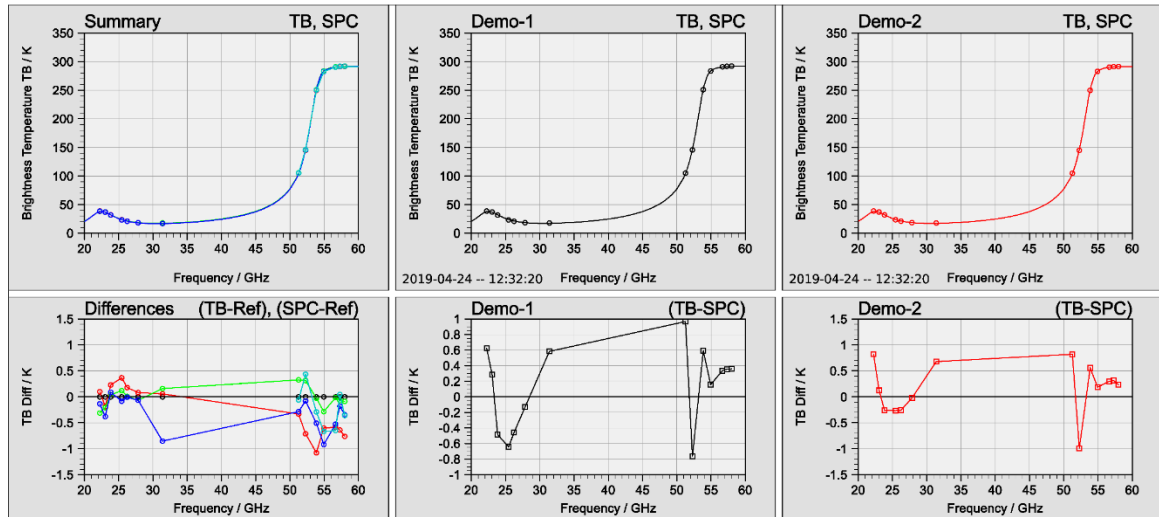
# RPG Software Tool

## Quality Checks

QC

ODIN

- Train spectral retrieval  $T_B^{instrument} = f(T_B^{measured})$
- $T_B^{instrument}$  considers instrument characteristics (error model / band-passes / beam widths)
- Analyse spectral deviations
- Apply automatic quality checks:
  - hardware mal-functions
  - heavy rain events
  - ...



# RPG Software Tool

## Data Formats

- Definition of a standard data format: **CF (1.6) compliant NetCDF** files
- Implementation by manufacturer
- **Naming convention adapted to the satellite community:**
  - L1B: per sensor, Microwave-TB, IRR-TB, ...
  - L1C: co-located on time-grid
  - L1D: derived L1 like cloud-removal from TB
  - L2B: retrieved products (T, Q, IWV, LWP, ...)
- **Meta-data section in the file header:**
  - L1: covariance matrix, absolute accuracy, band-pass filters, beam widths
  - L2: retrieval type, data source, RTM, ...



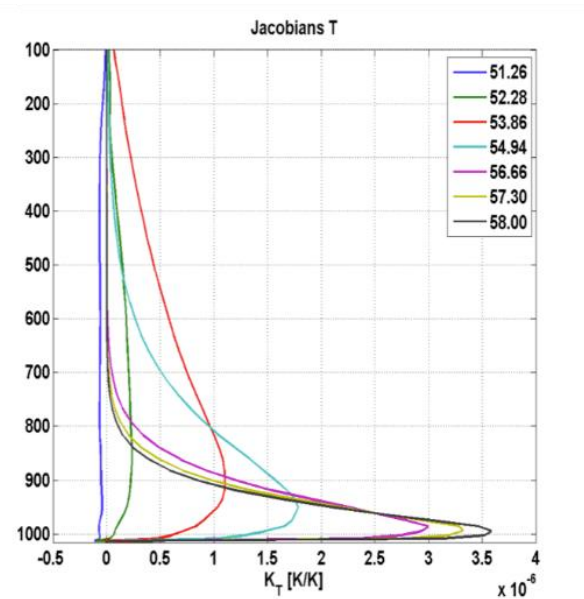
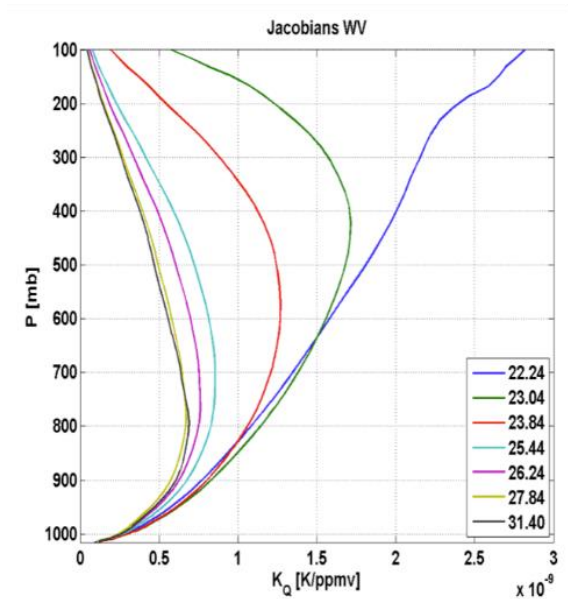
# Summary

- The latest Generation-5 of HATPRO radiometers have reached maturity in precision, stability, robustness.
- By joint efforts of the user community - like COST-TOPROF – microwave radiometers have been prepared for operational networks in terms of standardization, procedures and software tools.
- Ground-based microwave radiometers are ready for operational networks and data assimilation to close the observational gap in the boundary layer.

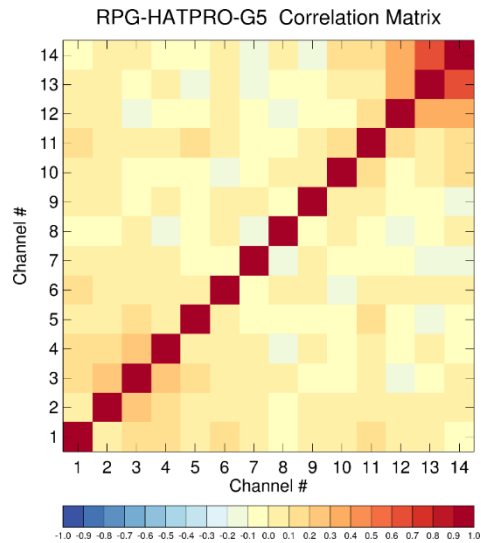
Thank you very much.



# Jacobians from RTTOV-gb



# RPG-HATPRO Correlation Matrix



# Data Flow

