

Recent and coming processing changes at the ROMSAF

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ROM SAF

Radio Occultation Meteorology Satellite Application Facility (ROM SAF)

- Decentralized facility under EUMETSAT
- Runs an operational radio occultation processing system
- High-level processing only (relying on EUMETSAT & UCAR/CDAAC low level processing)
- Provides bending angle, refractivity, temperature, pressure, and humidity profiles from the Metop satellites (and other missions to come)
- Provides climate products consisting of gridded monthly means
- Maintains the ROPP (Radio Occultation Processing Package) software
- Leading entity is the Danish Meteorological Institute (DMI)
- Cooperating entities:
 - ECMWF (European Centre for Medium-Range Weather Forecasts)
 - IEEC (Institut D'Estudis Espacials de Catalunya)
 - UK Met Office

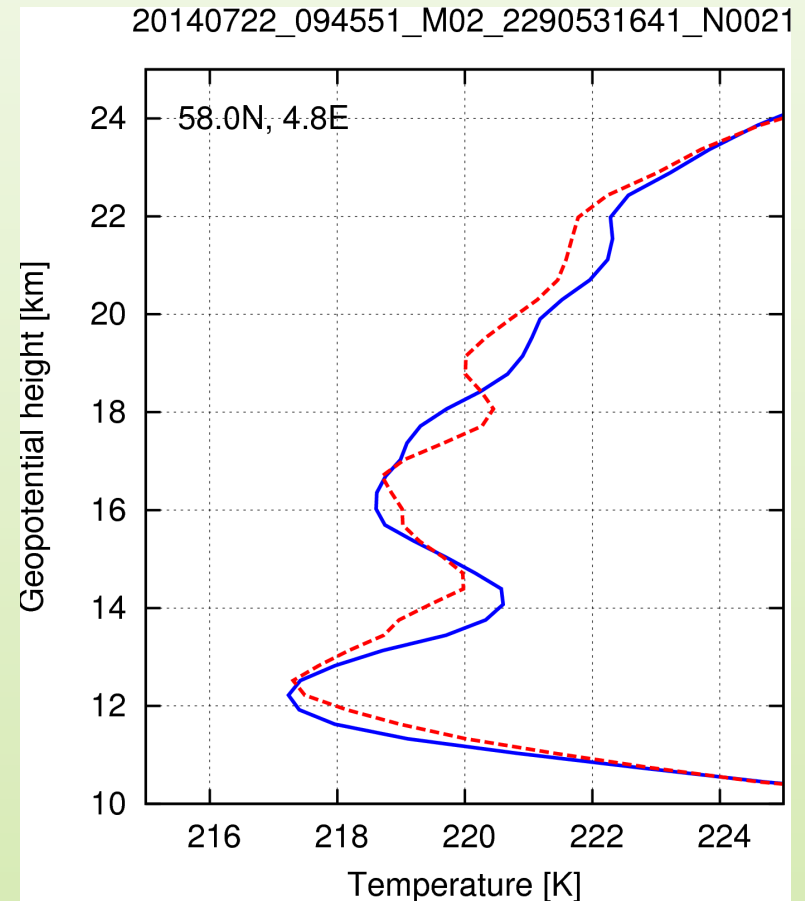
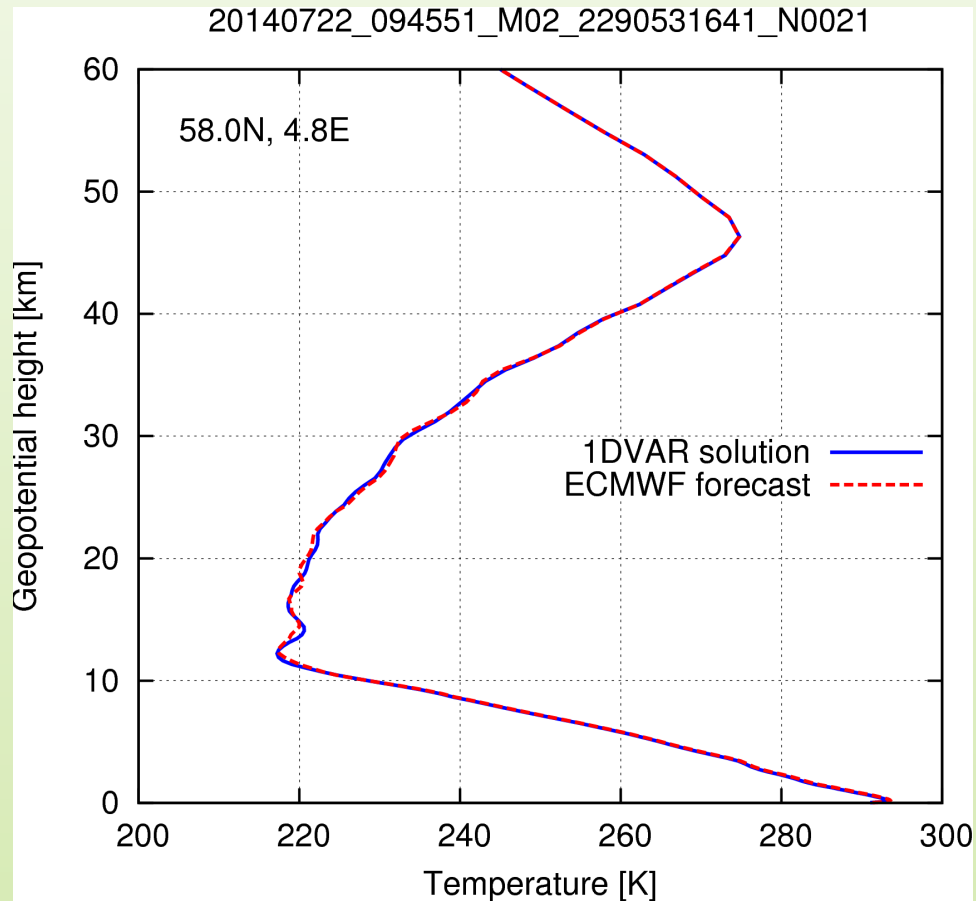
Outline

Activities at the ROM SAF GNSS Processing and Archiving Center (GPAC)

- Recent changes:
 - Provision of NRT 1DVAR products from Metop (started on July 22, 2014)
 - Provision of NRT dry temperature (started on July 22, 2014)
 - QC and flagging of refractivity (changed on July 22, 2014)
- Coming changes:
 - Vertical smoothing of NRT profiles (currently we smooth 'too much')
 - Improved 'search and fit' algorithm for statistical optimization
 - Use of a new climatology (BAROCLIM) for statistical optimization
 - Other changes coming from EUMETSAT (raw sampling and wave optics)
 - More satellites to be processed in off-line and for climate applications
- Schedule & Re-processing plan

Recent changes: 1DVAR products

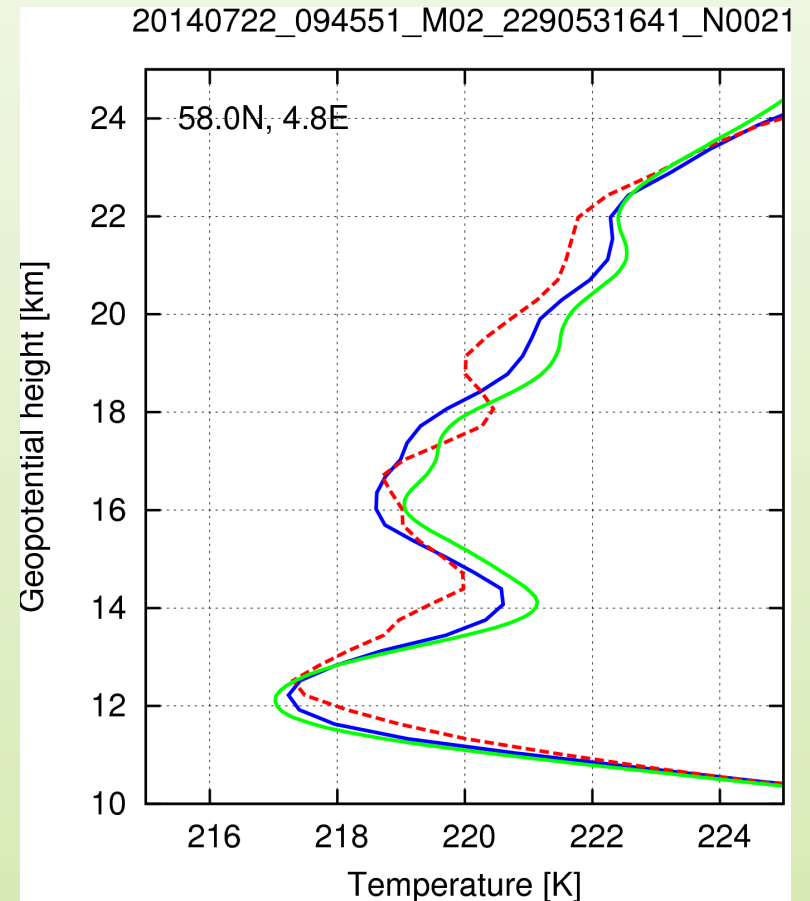
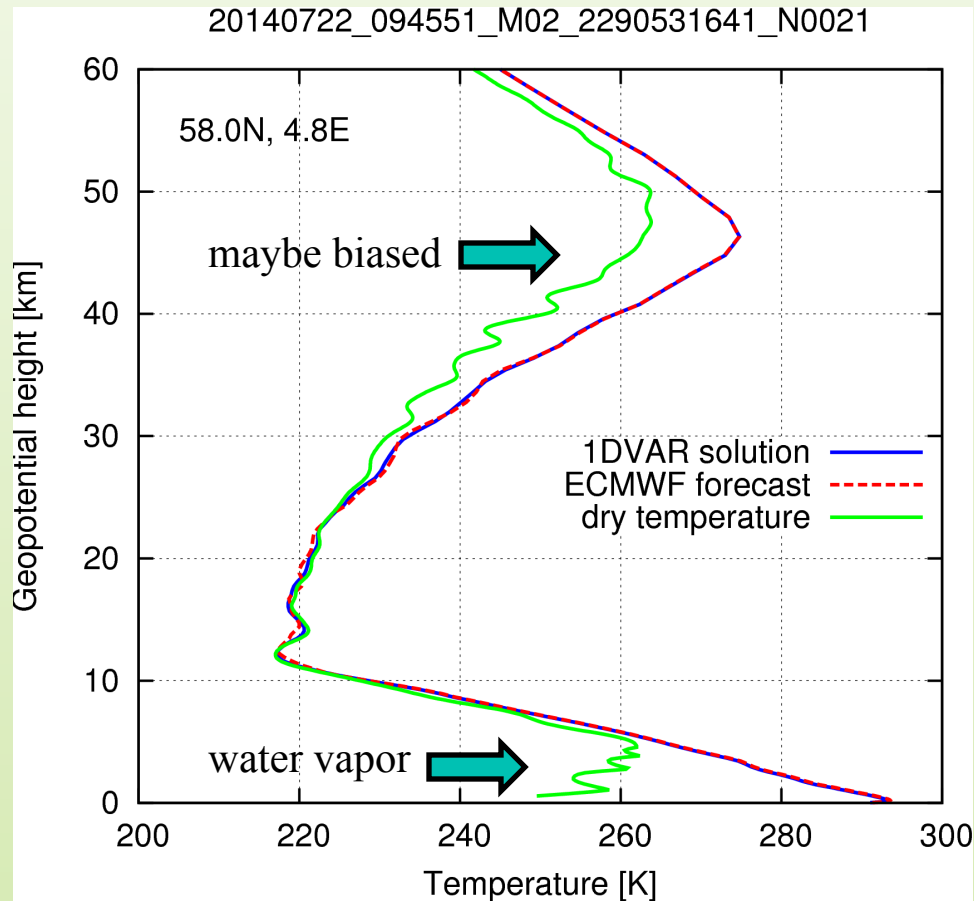
Provision of NRT 1DVAR products from Metop started on July 22, 2014



First 1DVAR solution for Metop-A (9:46 UTC July 22, 2014)

Recent changes: dry temperature

Provision of NRT dry temperature also started on July 22, 2014



First 1DVAR solution for Metop-A (9:46 UTC July 22, 2014)

Dry temperature is 'additional information' – not official product; not QC'ed

Recent changes: 1DVAR products

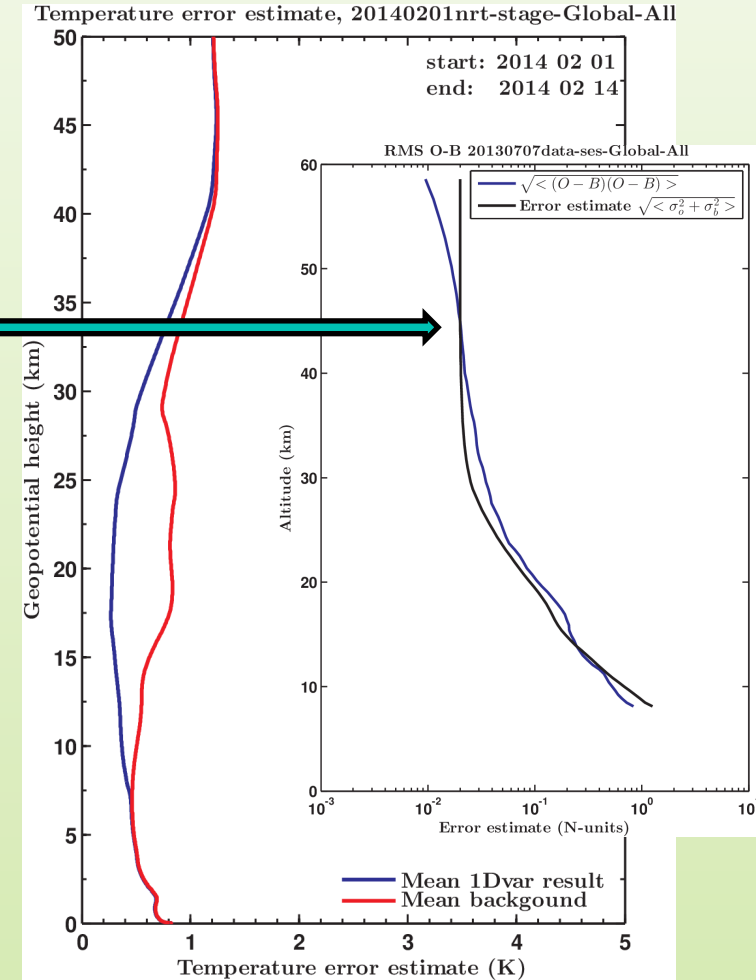
1DVAR solution based on minimization of cost function:

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x} - \mathbf{x}_b)^T \mathbf{B}^{-1}(\mathbf{x} - \mathbf{x}_b) + \frac{1}{2}(\mathbf{y}_o - \mathbf{H}(\mathbf{x}))^T \mathbf{O}^{-1}(\mathbf{y}_o - \mathbf{H}(\mathbf{x}))$$

$\mathbf{x} = (\mathbf{T}; \mathbf{q}; p_{\text{surf}})$ (using ECMWF forecasts as background)

$\mathbf{y}_o = \mathbf{N}$ (based on refractivity observation)

- Observation error: constant at high altitudes; enhanced at lower altitudes; depends on background tropopause height
- Observation error correlation: 1/e shaped – 3 km
- Background error covariance provided by ECMWF – fixed temperature uncertainty and fixed relative humidity uncertainty
- Solution on ECMWF 137 state vector levels
- Logarithmic representation of specific humidity (prevents $q < 0$)
- For current NRT: 8 km geopotential height cut-off due to closed loop and geometric optics processing – to be changed in 2015
- All 1DVAR products come with individual error estimates
- Also off-line 1DVAR processing of COSMIC data for generation of gridded (level 3) climate products (see presentation by Hans Gleisner tomorrow)



Recent changes: QC

QC of refractivity and flagging changed on July 22, 2014

Mainly two different QC checks. Refractivity profile is flagged as non-nominal if:

1. $(O-B)/B > \text{Threshold}$

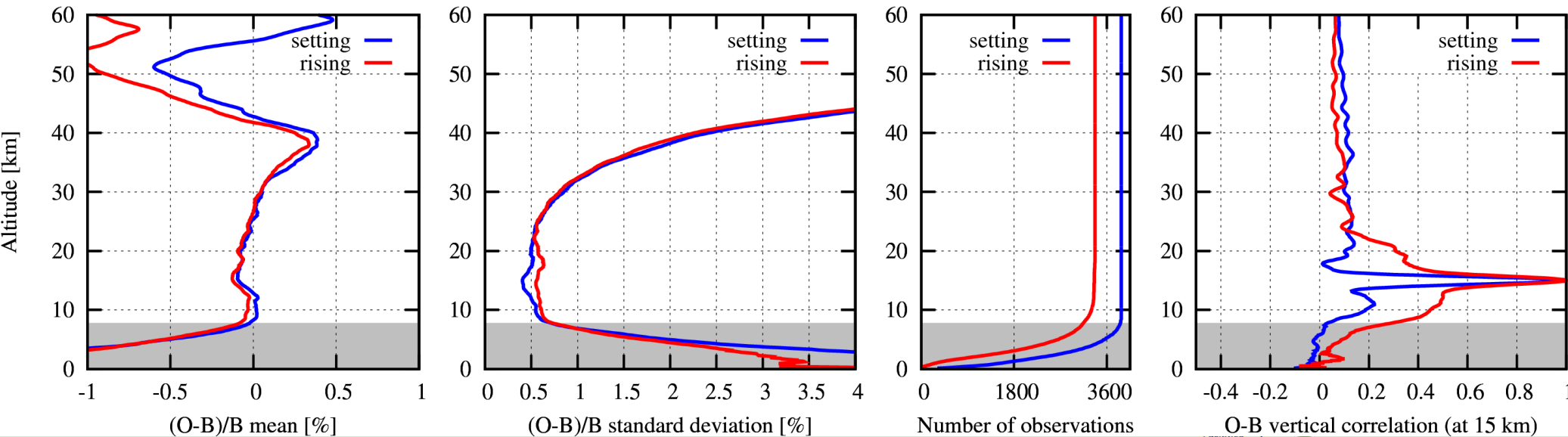
- Threshold = 10% between 30 and 40 km
- Threshold = 5% between 8 and 30 km
- No threshold below 8 km

We do not QC profiles below 8 km anymore. Instead we use the 'percent confidence' indicator to indicate that data are of poor quality below 8 km (indicator set to 0 for all profiles).

2. L1 – L2 bending angle for rising occultations diverge beyond given threshold

- Threshold = $|\Delta\alpha_{\text{strat}} - \Delta\alpha_{\text{trop}}| = 0.5 \text{ mrad}$

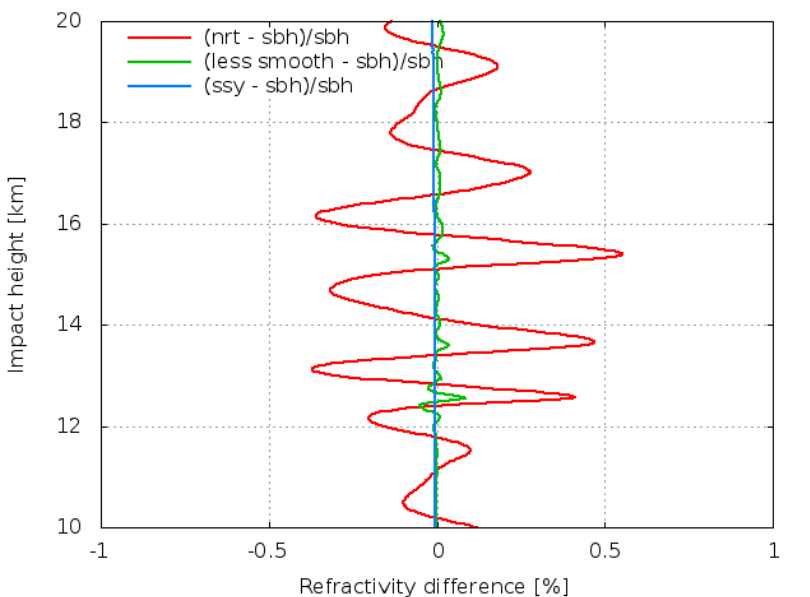
Refractivity, Global statistics against ECMWF, November 15-28, Metop-A NRT (GRM-01)



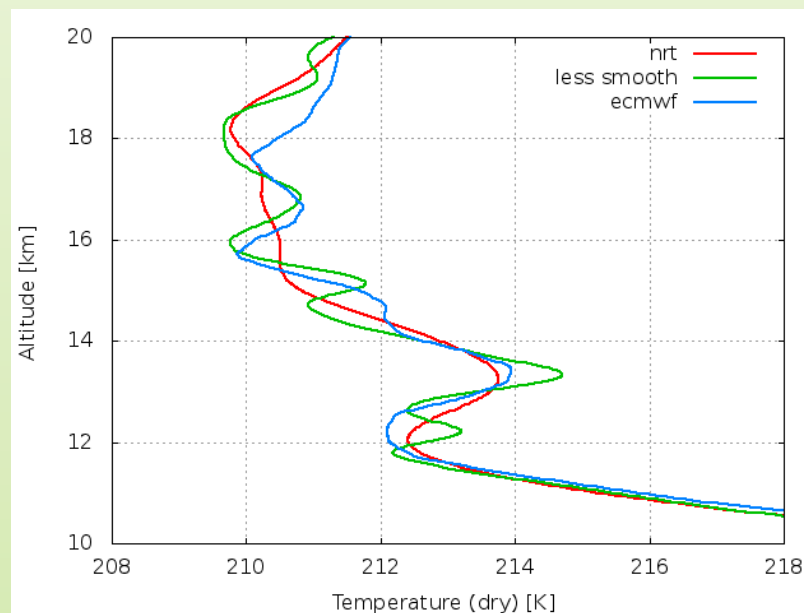
Coming changes: vertical smoothing

Discovered mistake in NRT code (thanks to Sean Healy)

- Related to stat. opt. (SO) part which follow method by Gorbunov (2002) – code not consistent with paper
- Effectively results in additional smoothing of refractivity (in most cases)
- Implications at high altitudes needs more study (examples on next slide)
- Change may fold into other changes to the SO currently under development (later slides)



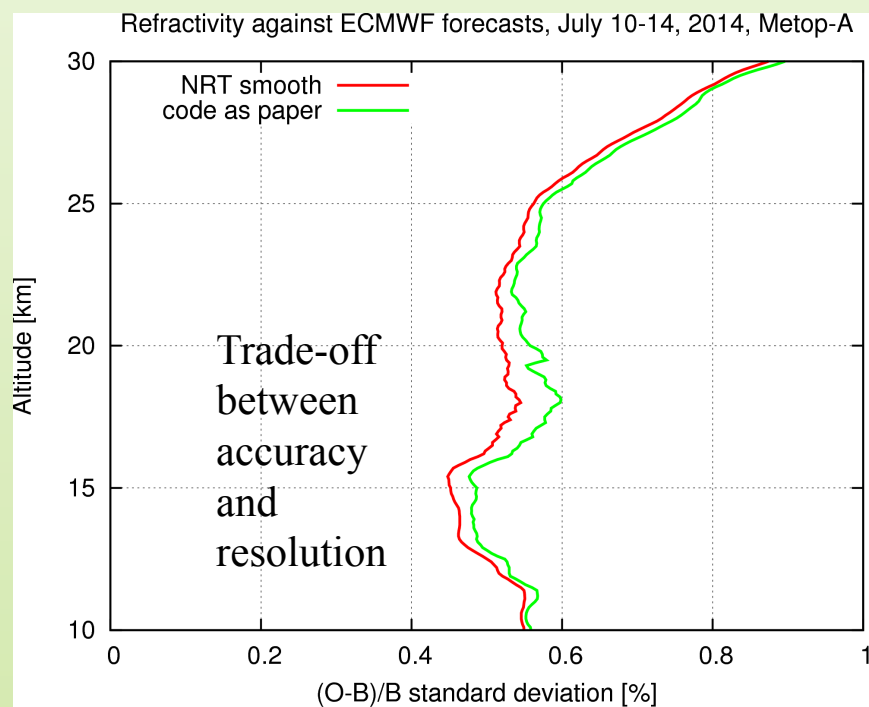
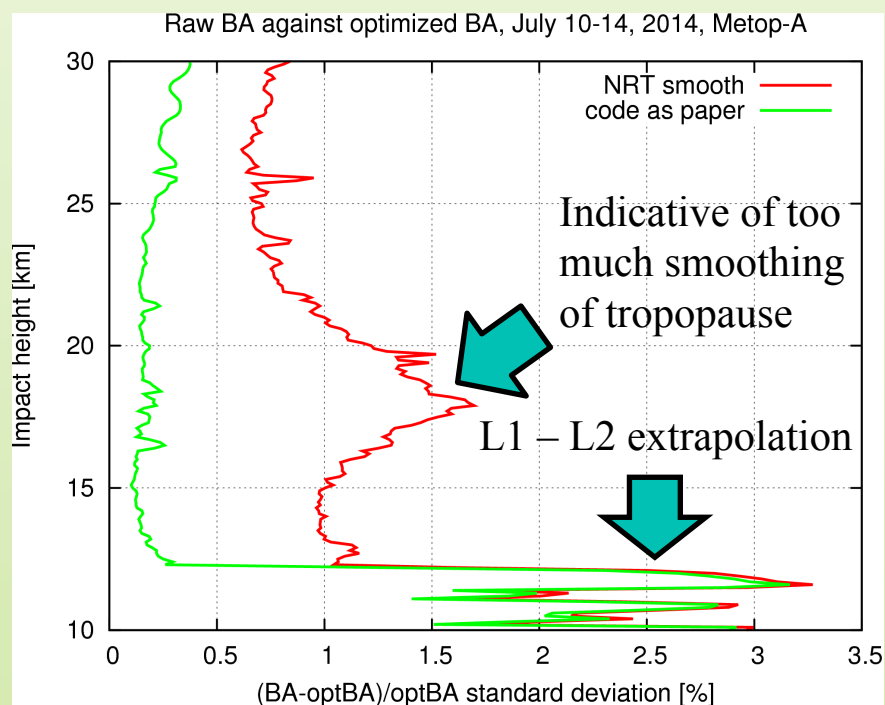
- BA already smoothed by EUMETSAT
- Different resolutions best seen from (dry) temperature retrievals



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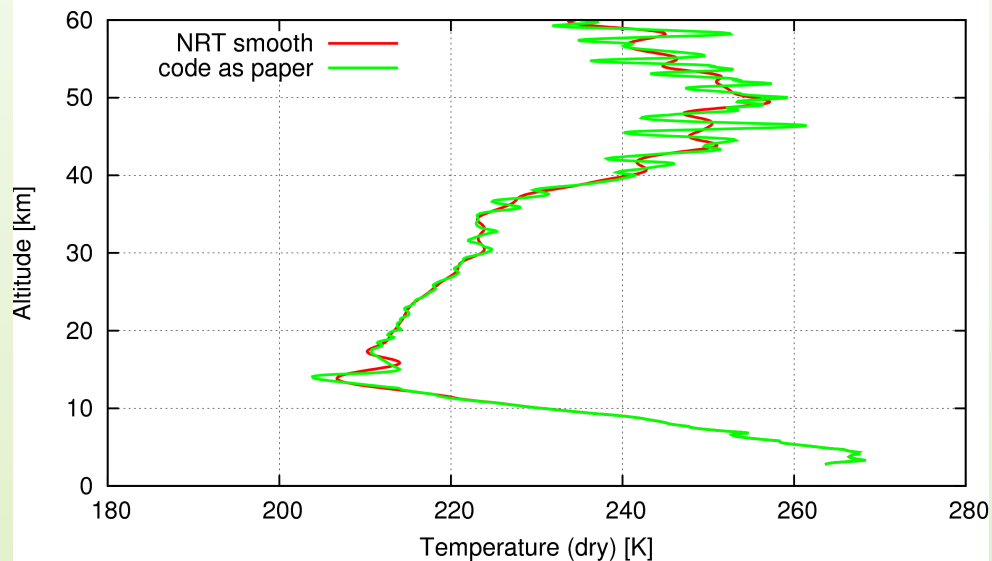
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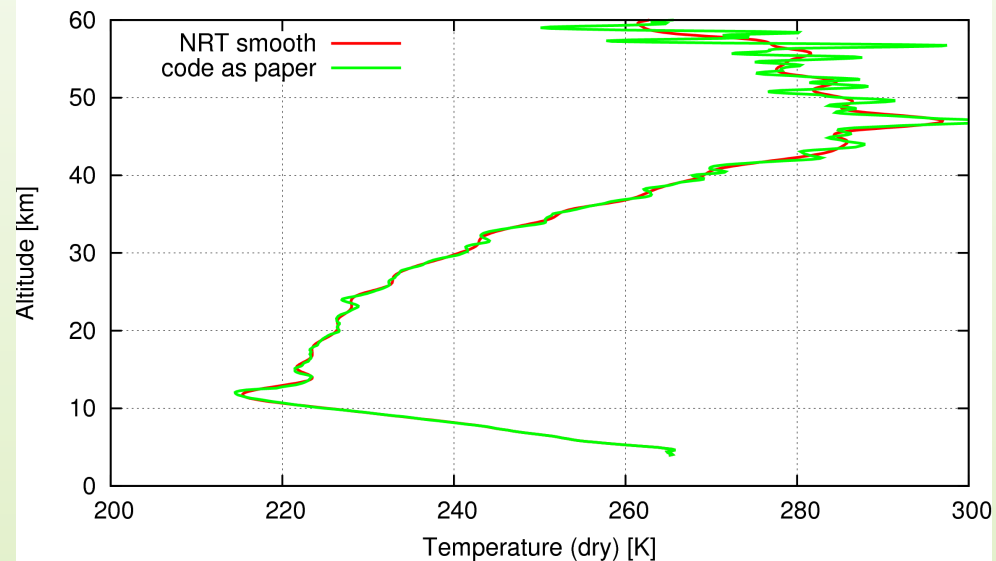


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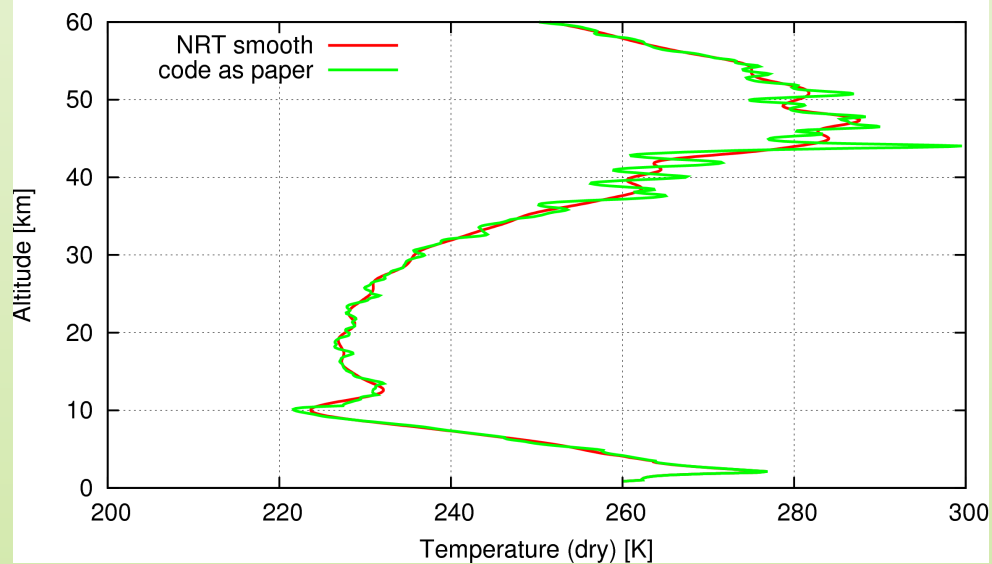
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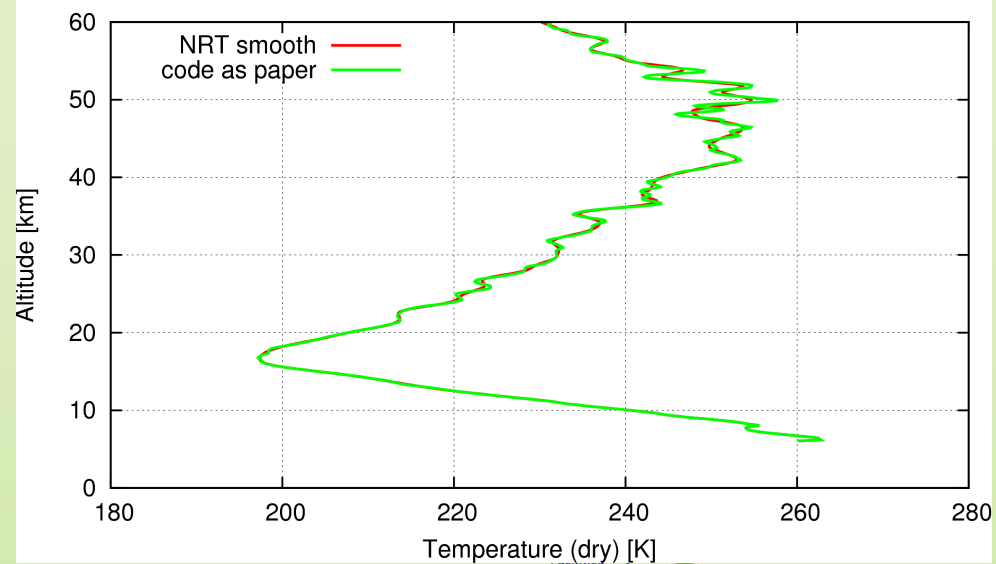
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Coming changes: statistical optimization (SO)

General approach at ROM SAF:

- Global search in bending angle climatology to find best fit to data between 40 and 60 km (α_{clim})
- Linear regression to adjust two parameters (c_1, c_2) to 'tweak' climatology to a better fit (β_{clim})
- Optimal linear combination with dynamic error estimation (Gorbunov, 2002)

Current approach:

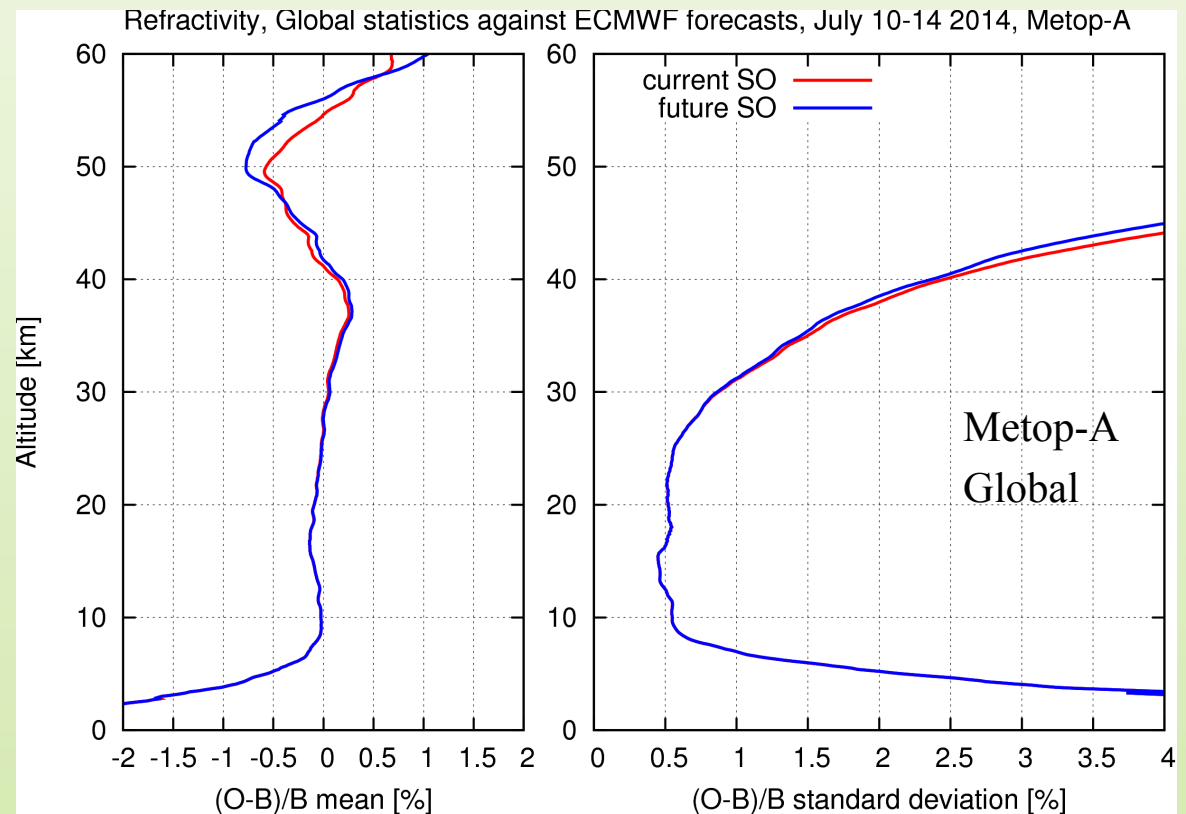
$$\beta_{\text{clim}} = c_1 \alpha_{\text{clim}}^{c_2}$$

- Tweak climatology simultaneously with global search
- Limitations in detecting and handling bad stratospheric data

Future approach:

$$\beta_{\text{clim}} = \begin{cases} c_1 \alpha_{\text{clim}} & \text{below 40km} \\ (c_1 \cos^2 \delta + c_2 \sin^2 \delta) \alpha_{\text{clim}} & \\ c_2 \alpha_{\text{clim}} & \text{above 60km} \end{cases}$$

- Tweak climatology after global search
- Easy to detect bad stratospheric data



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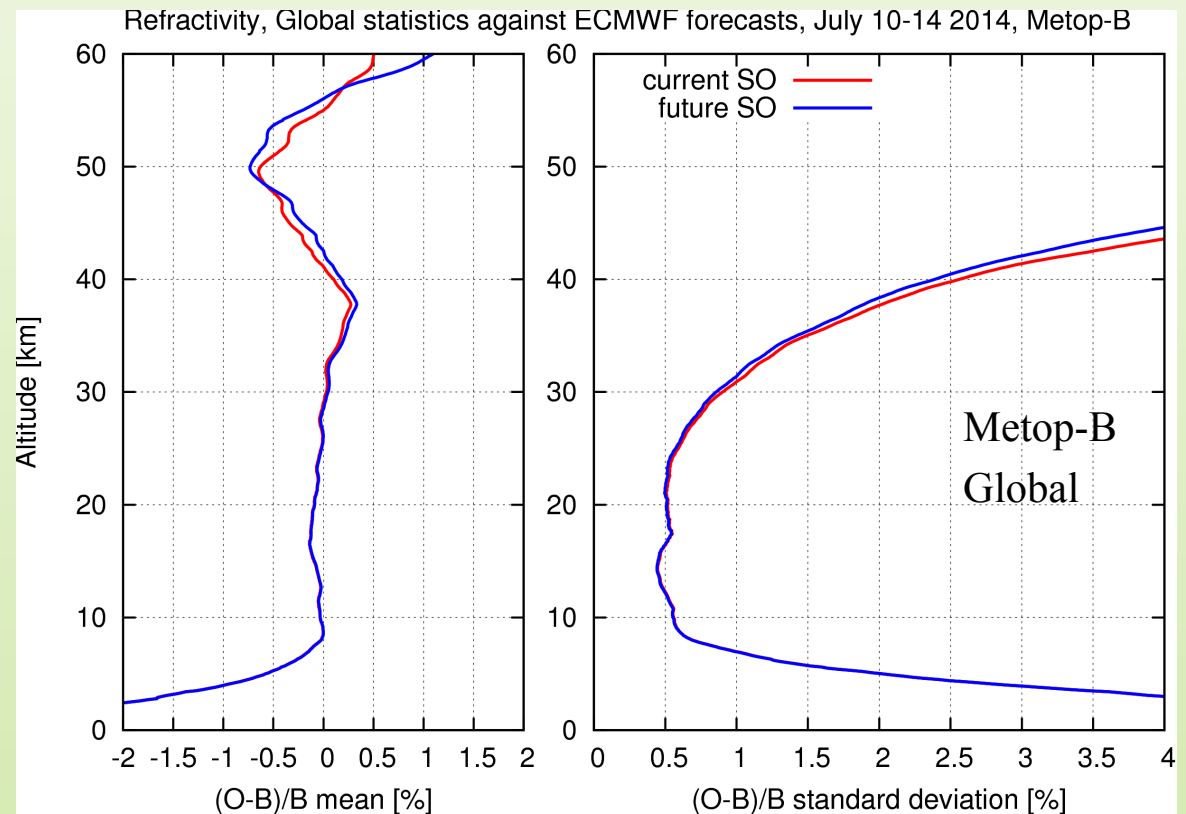
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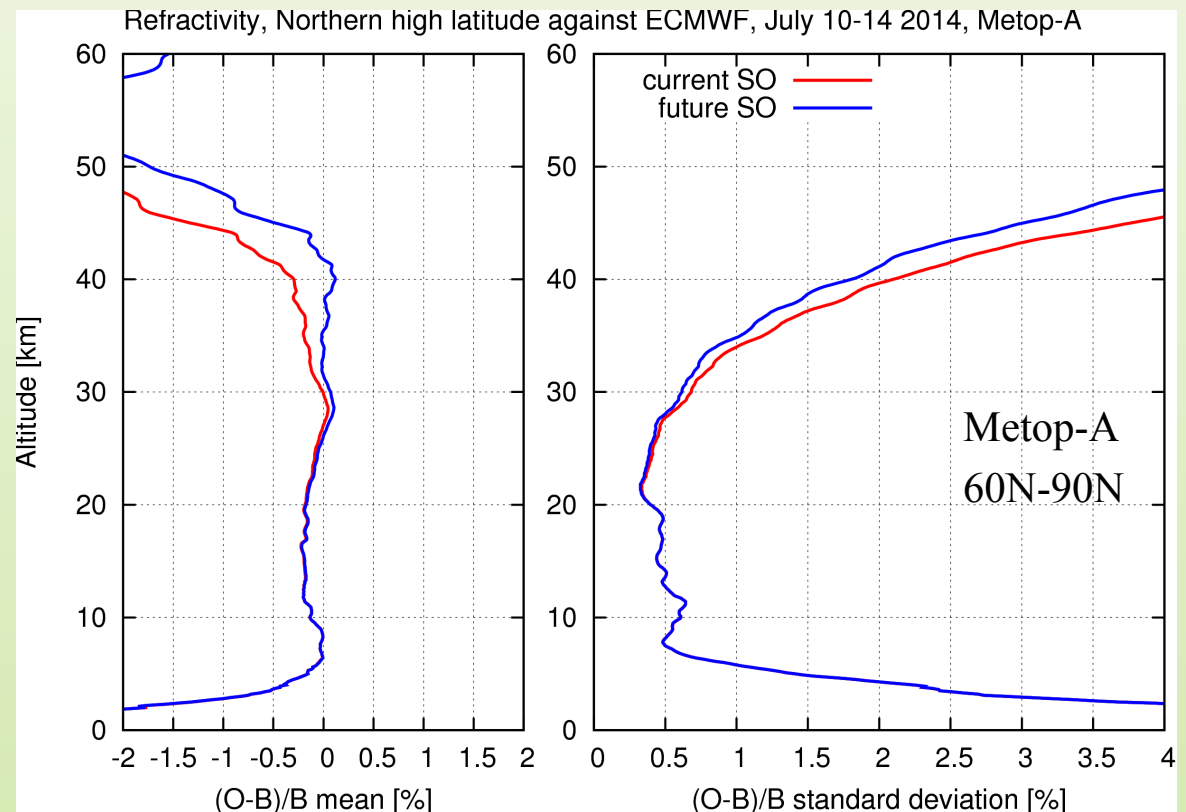
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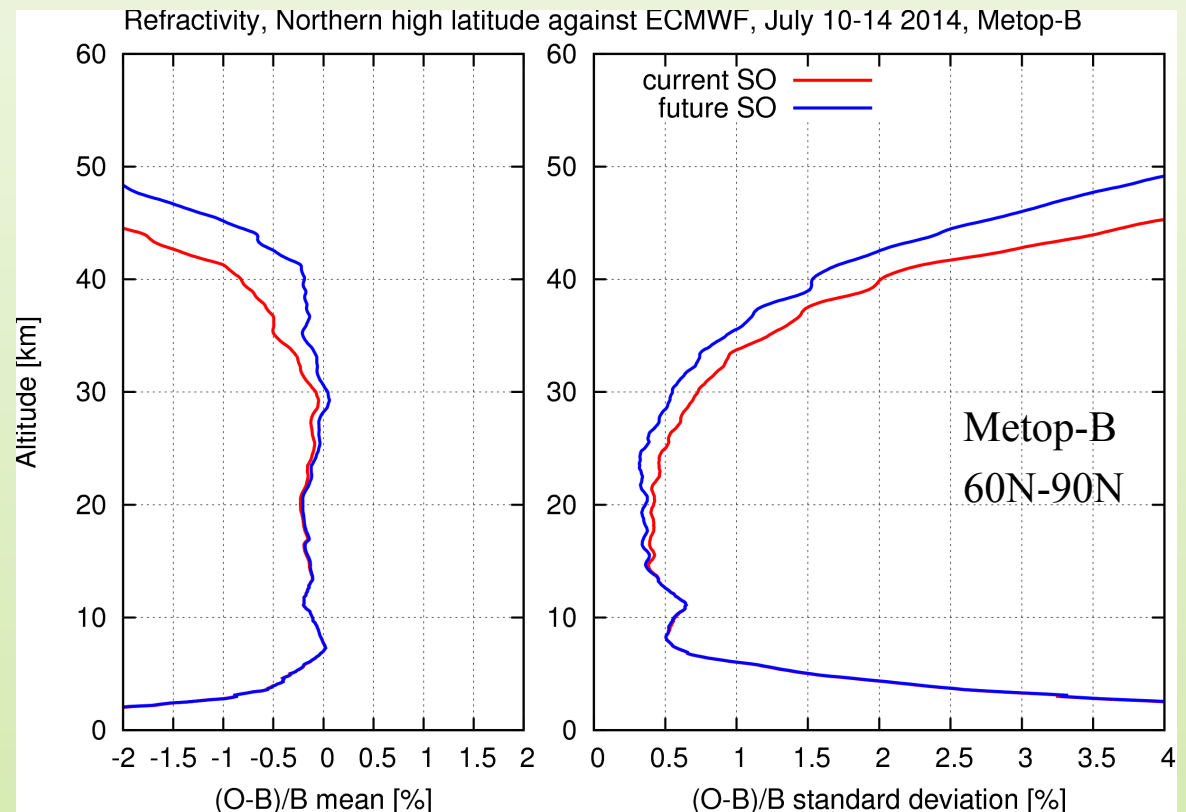
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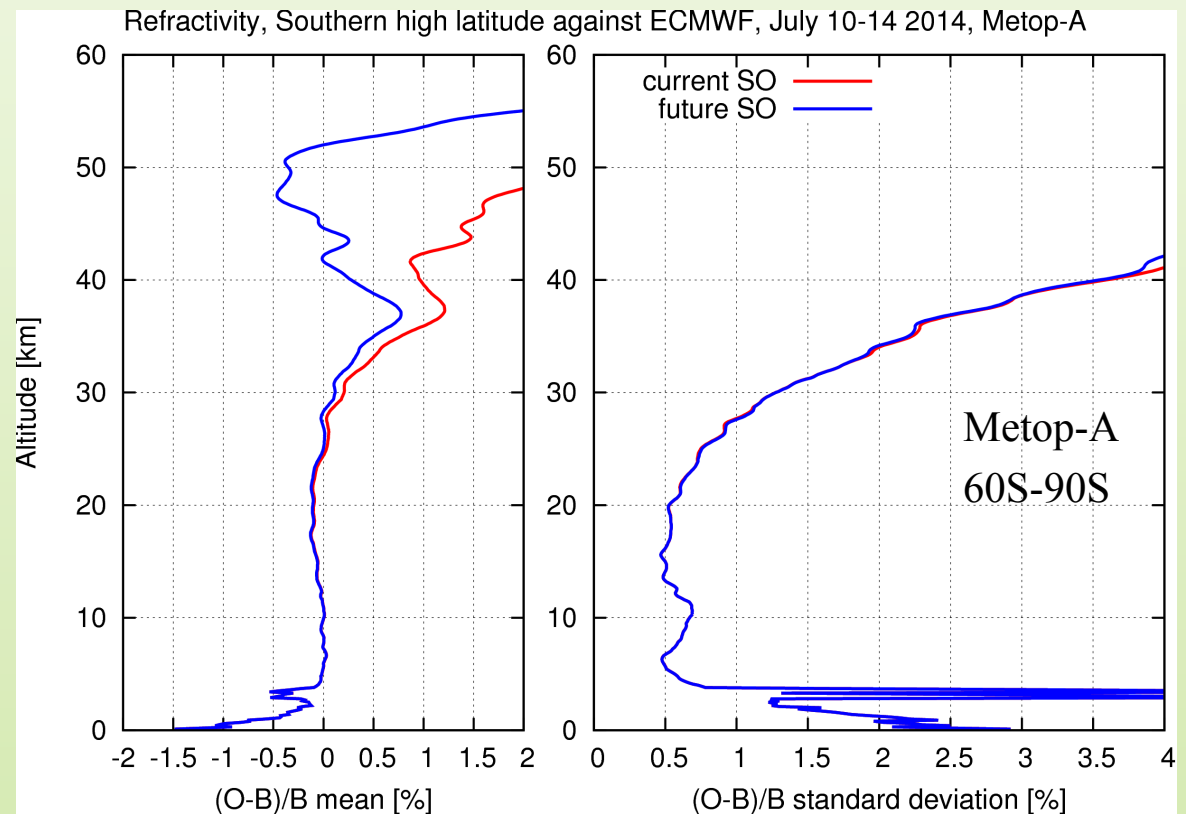
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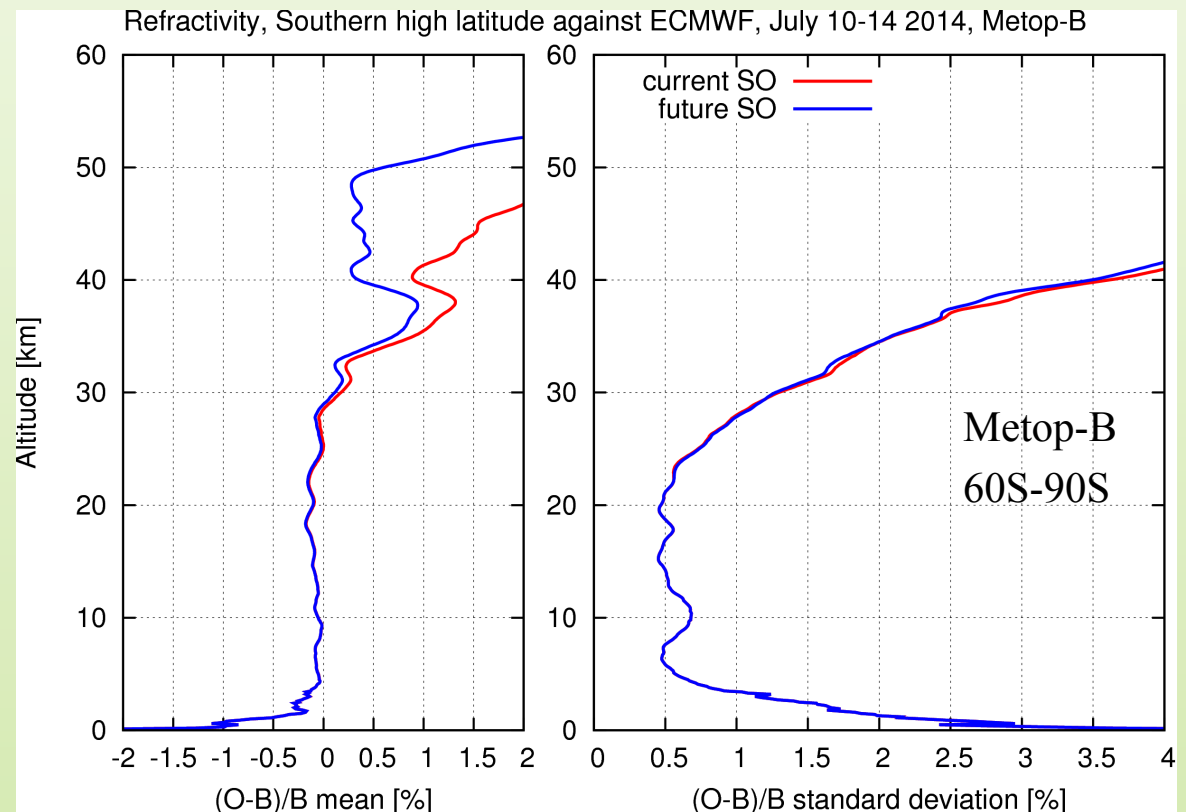
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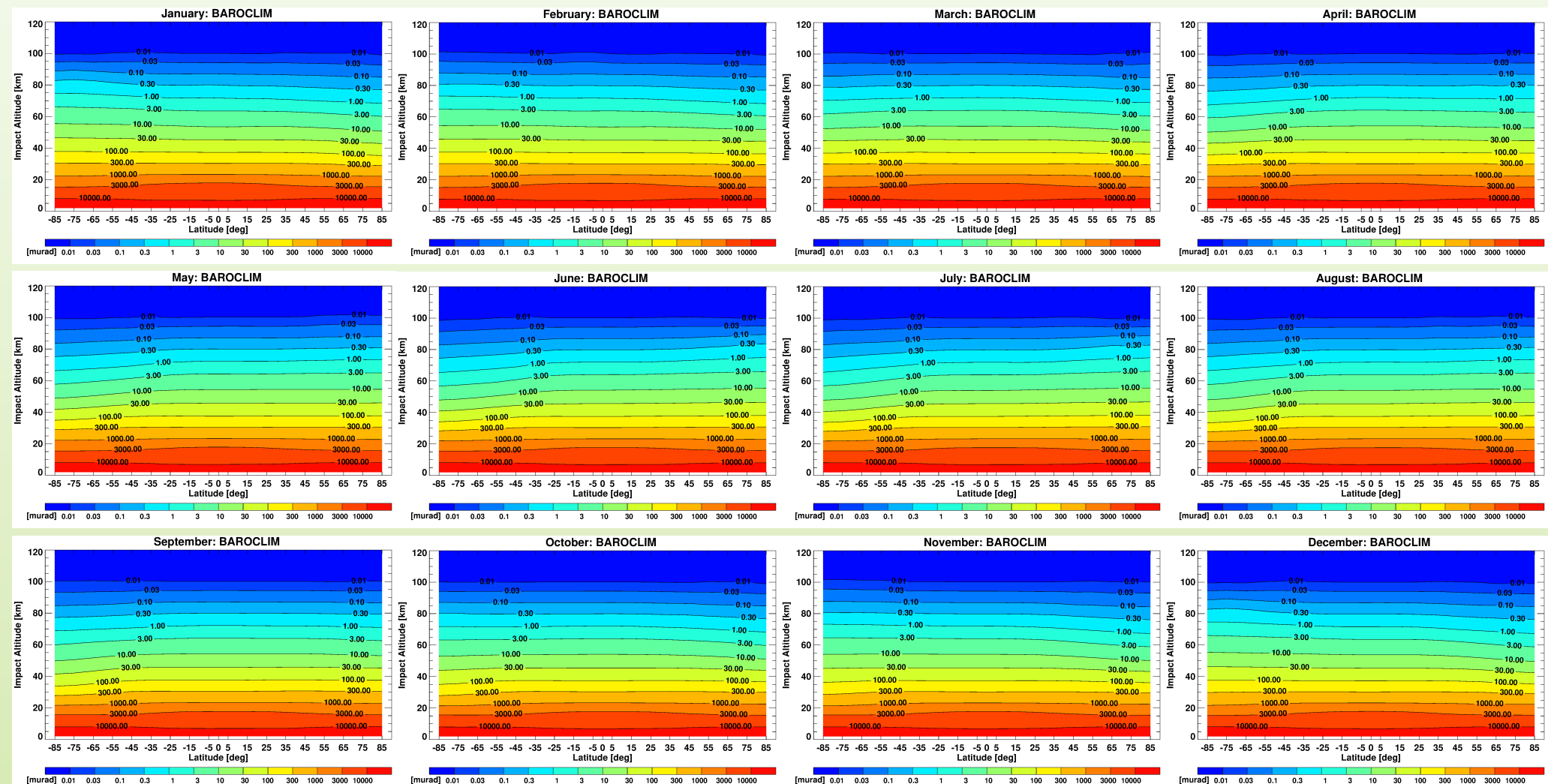
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Coming changes: BAROCLIM

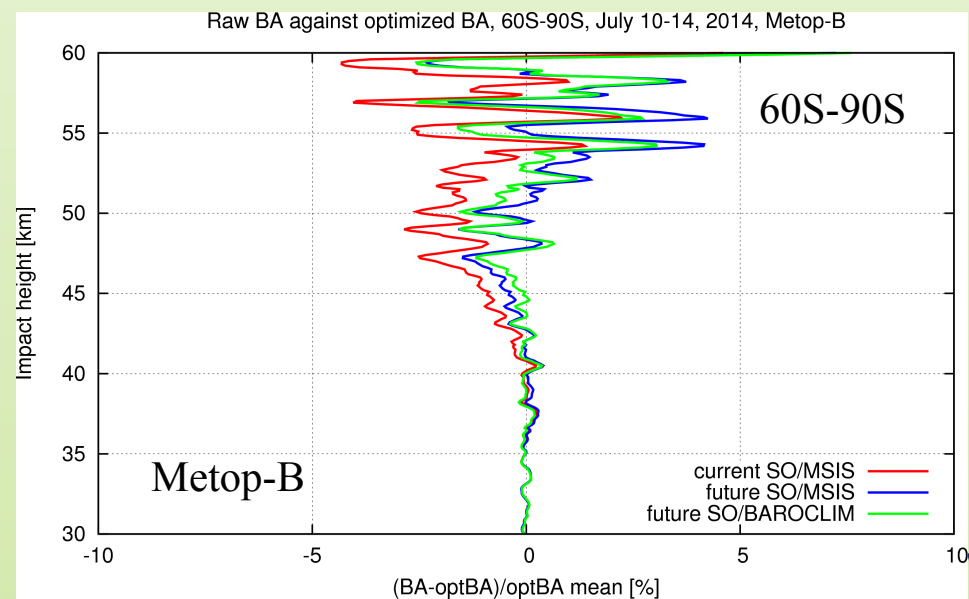
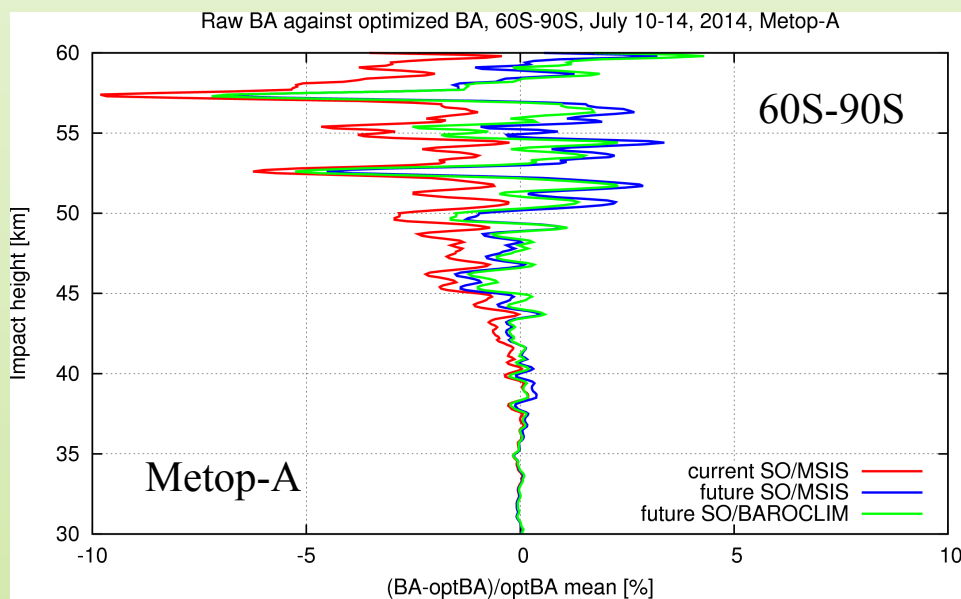
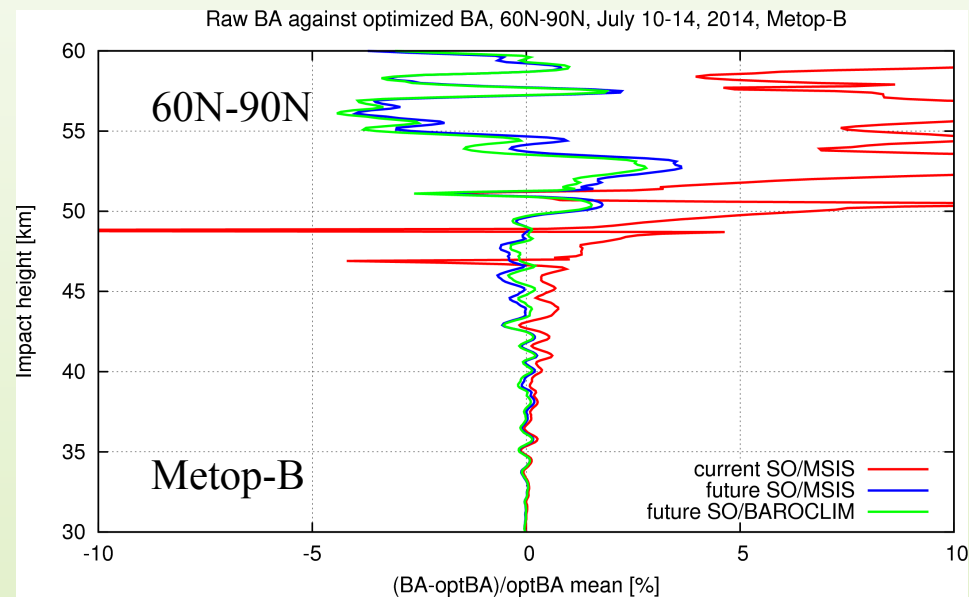
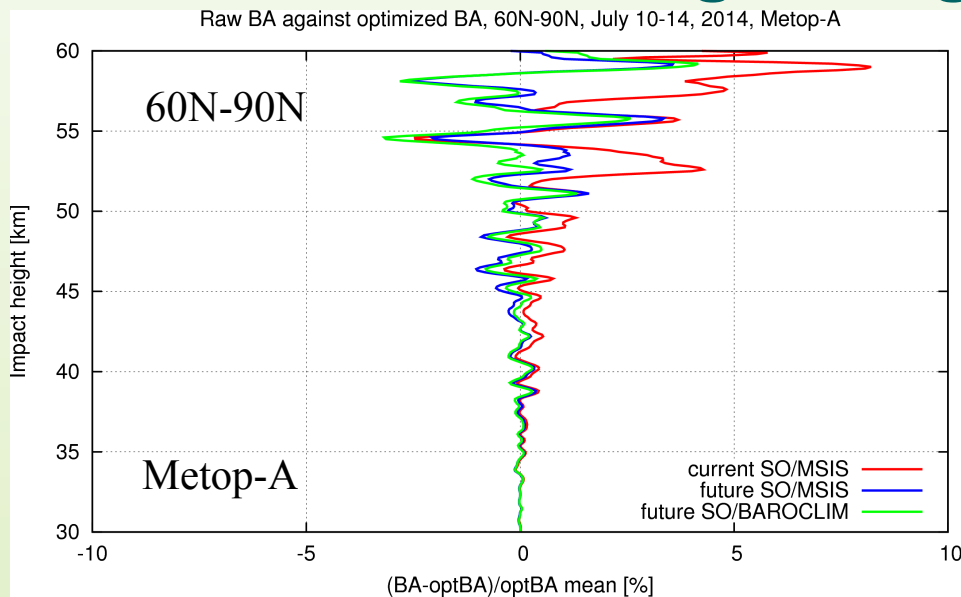


Spectral model of bending angles based on COSMIC data (Scherllin-Pirscher et al., 2013)

The EUMETSAT
Network of
Satellite
Application
Facilities



Coming changes: BAROCLIM



Coming changes & re-processing plan

Anticipated NRT changes from EUMESAT:

- New NetCDF4 format (internal; users wont notice)
- Wave optics processing
- Raw sampling processing

Coordinated re-processing effort:

- EUMETSAT will provide re-processed level 1a data for various missions (also provides level 1b)
- ROM SAF will process to level 1b (bending angle), level 2a (refractivity; dry temperature), level 2b (1DVAR products), and level 3 (gridded climate products)

Boxes indicate only approximate scheduling

	Q4 2014	Q1 2015	Q2 2015	Q3 2015	Q4 2015
NRT:		raw sampling; wave optics; smoothing fix;		new SO & BAROCLIM; new NRT code;	
Off-line:	smoothing fix; new SO & BAROCLIM;	Currently only COSMIC level 3 (gridded) data;	Metop-A & B operational in off- line;	NRT code based on off-line code; use ROPP;	
Re-processing with off-line code:		Metop-A;		COSMIC; CHAMP; GRACE; Metop-B;	