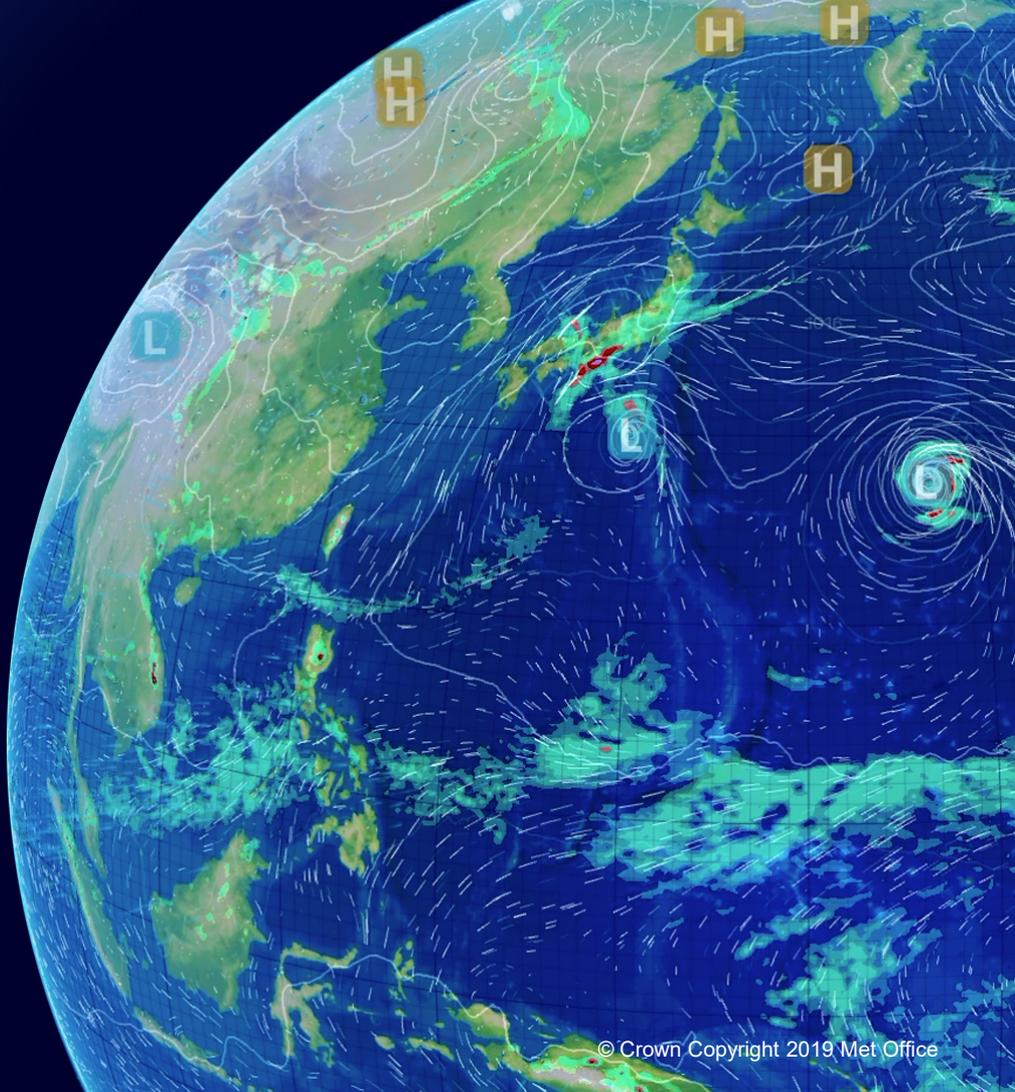


Towards all-sky MHS: Observation Preprocessing and Initial Results

Brett Candy & Stefano Migliorini

November 2019

Acknowledgements: Ed Pavelin, David Rundle



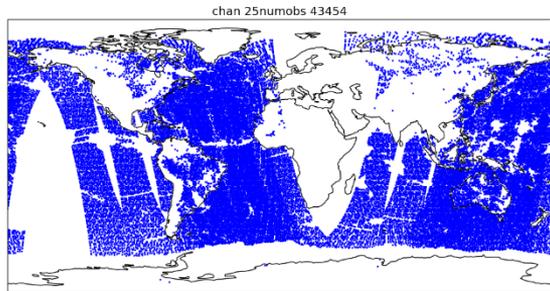
Talk Outline

- Current status of cloud affected AMSU-A processing
- Extension to MHS
- Extending forward modelling in cloud -RTTOVSCATT
- Review of scattering tests
- 1D-Var with RTTOVSCATT
- Observation error model
- Initial results of impact studies
- Future work

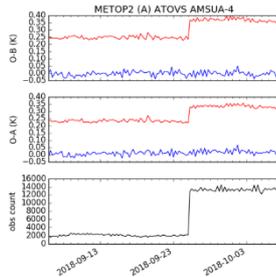
Motivation

- (MW) All sky improvements through increased use of observations. Cloud affected observations from AMSU-A already operational
- trials elsewhere show large impacts using humidity channels in all sky conditions (e.g. *Geer et al.*, 2014, “All sky humidity sounding contributes real medium range dynamical forecast skill and is catching up with the impact of temperature sounding”).
- This is mainly due to the interaction within the DA scheme including the non linear update. “Outer Loop cycling” Better fitting of cloudy radiances – leads to improved wind fields.
- Recent data denial at other centres (*Bormann et al.* 2019) highlight the very large impact of MW data in general on the wind field at all levels in the troposphere.

AMSUA all sky – Operational in autumn 2018



Over sea all conditions except precipitation
 Over land more extensive cloud screening



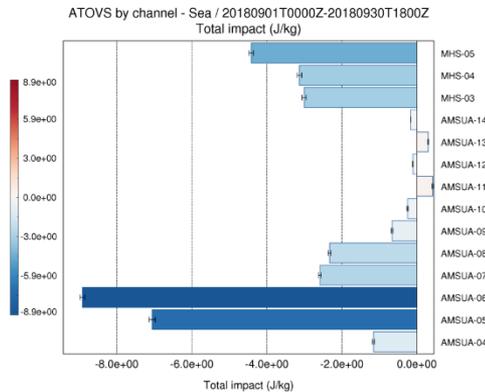
This change incorporated analysing cloud liquid water in 4D-Var

Refs:

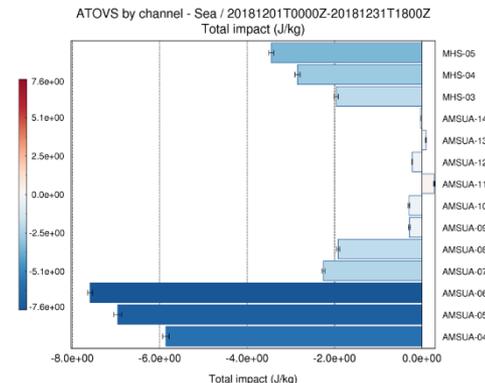
S Migliorini, A Lorenc & W Bell, 2018: A moisture incrementing operator for the assimilation of humidity- and cloud-sensitive observations, Q.J.R.M.S., doi:10.1002/qj.3216

S Migliorini & B Candy, 2019: All-sky satellite data assimilation of microwave temperature sounding channels at the Met Office, Q.J.R.M.S., doi: 10.1002/qj.3470

FSOI by AMSU channel



Before all sky update

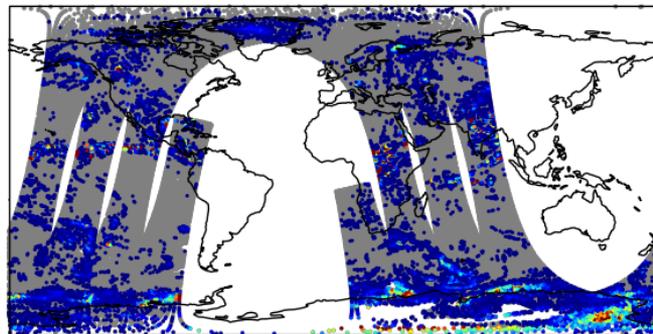


After

All sky MHS

- Extend MHS to scenes with significant cloud water and ice.
- Analysis of ice in 4D-Var and upgrade the radiative transfer model to include scattering due to cloud particles (RTTOVSCATT)
- Significant Rain will still be rejected. But other cloud tests removed.
- Typically around 45% of observations are rejected over sea. Majority of this is due to water cloud (detected via AAPP mwcloud test)
- Our focus here is on sea – for improvements to use of MHS over land see poster 12p07 – Stu Newman

MHS/AMSU-B Cloud cost

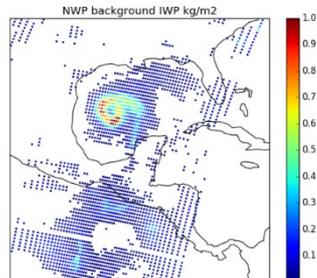
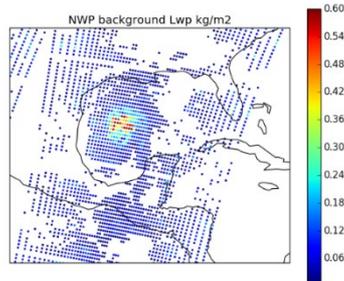


Grey: all obs
Colorscale: obs exceeding
cloud test threshold

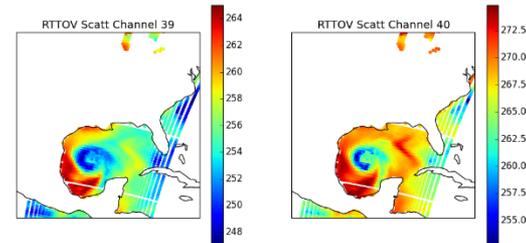
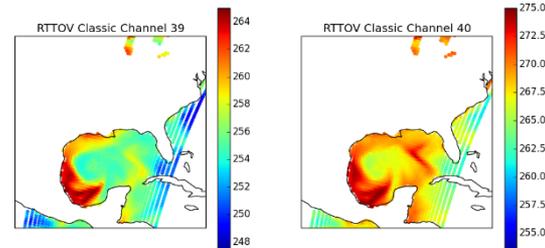
Introduction of RTTOVSCATT into Met Office assimilation scheme

- profiles now include large scale ice fields from the NWP model. Optical property tables are latest available from NWPSAF and assume Mie spheres for cloud ice and water droplets
- Example is the simulated brightness temperatures for Tropical Cyclone Harvey [mature cyclone with distinct eye]

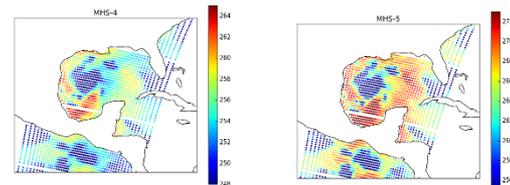
NWP
Model
cloud



RTTOV
Simulations

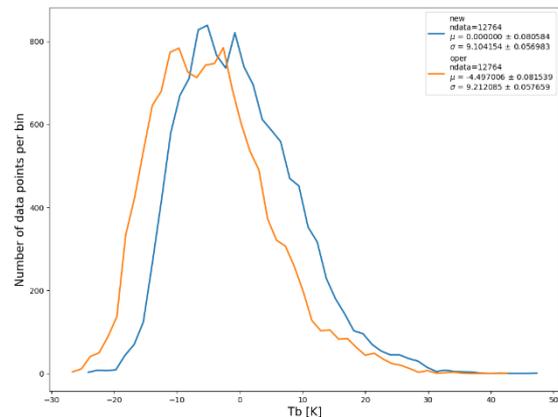
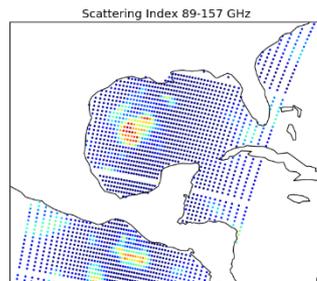
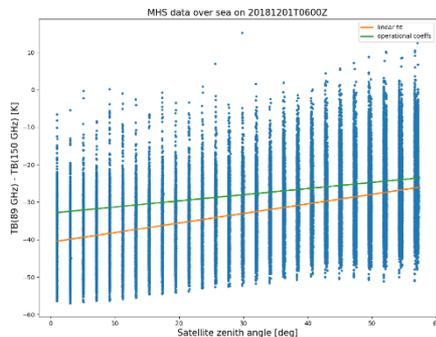


MHS
observations



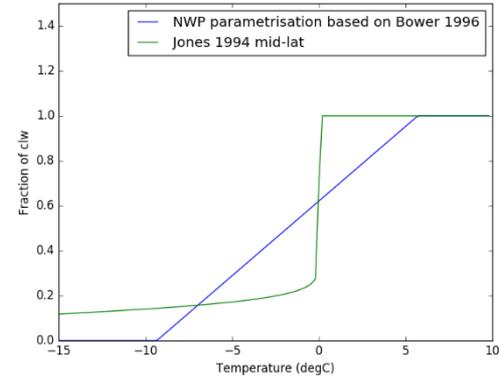
Screening of precipitating scenes

- Scattering index = $TB(89 \text{ GHz}) - TB(157 \text{ GHz}) - \text{offset (K)}$
- $\text{offset} = a + b \text{ SatZenithAng}$
- Observations rejected when $SI > \text{threshold}$
- Based on Bennartz et al., 2002
- Offset originally determined for AMSU-B channels. Recalculated here for MHS to take into account change in channel 2 frequency

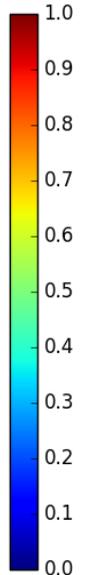
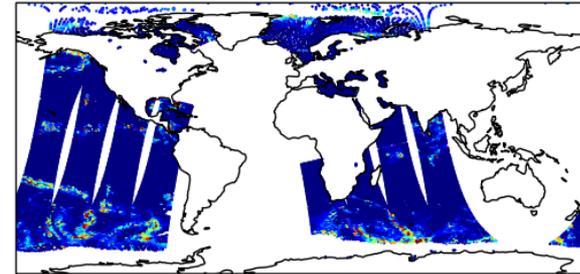


Inclusion of cloud ice in 1D-Var

- Extended the total moisture control variable beyond its original use to retrieve cloud liquid for quality control
- Ice cloud added to total moisture control variable, in a similar manner to cloud liquid. Excess amounts beyond saturation are partitioned between liquid and ice via mixed layer model dependent on temperature
- We are also developing a separate retrieval scheme for cloud to include cloud fraction using an ensemble based background error covariance matrix

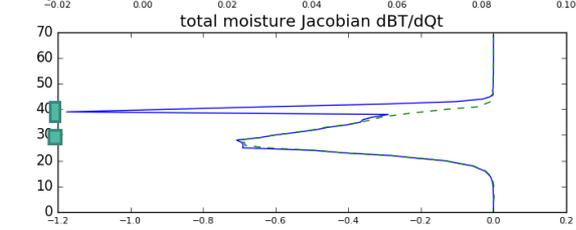
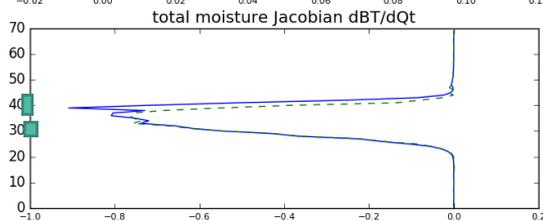
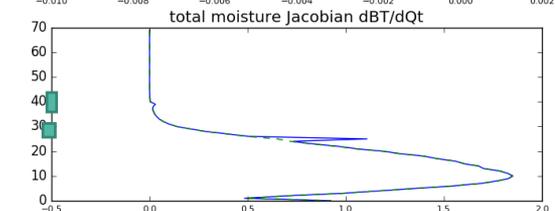
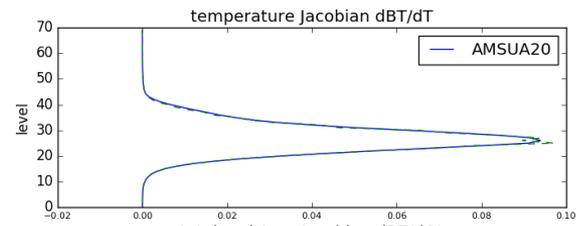
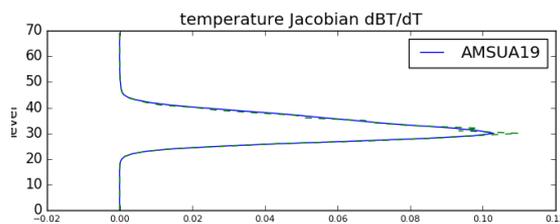
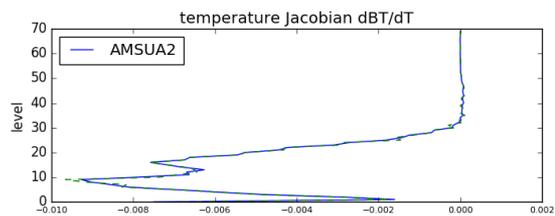


Retrieved IWP kg/m²



Effect of Jacobians in 1D-Var

one example- Tropical location with overcast cirrus just below tropopause at 200 hPa



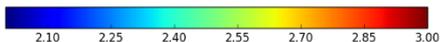
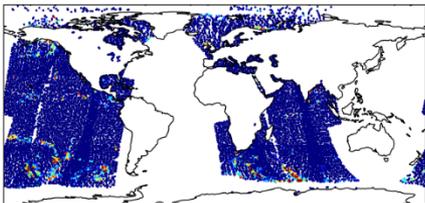
Blue is RTTOVSCATT , Dashed RTTOV. Largest change for lowest peaking MHS channel.

Observation error model in cloud

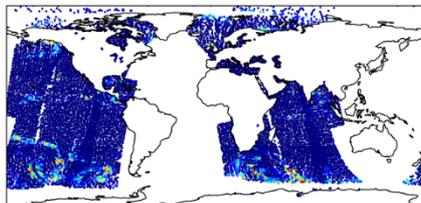
- Based on analysis of Obs/Model difference we decided to represent the obs errors as a 2D-surface $\sigma_i = \sigma_i^{clr} + a_i LWP + b_i IWP$

Where σ_i^{clr} represents the clear standard deviation and a_i, b_i are found by regression for each channel – further details see poster 5p01 Stefano Migliorini

MHS-3 obs error (K)



MHS-5 obs error (K)



Trial of the new scheme

- 1 season trial (3 months Dec 2018 – Feb 2019)
- Switched to RTTOVSCATT for AMSU/MHS
- MHS – three instruments MetOp-A,-B NOAA19
- *Over land* : retain cloud tests
- *Over sea*: Reject only if rain detected in field of view via AAPP test or MHS SI. For latter we use the new coefficients and threshold
- Baseline is current parallel suite configuration: New UM physics scheme & hybrid 4D-Var (hybrid from Ens. 4D-EnsVar). For trial turnaround we use reduced resolution 40km in NH rather than 12km.
- MHS channel usage over sea increases by: ~10% channel 4, ~45% channel 5

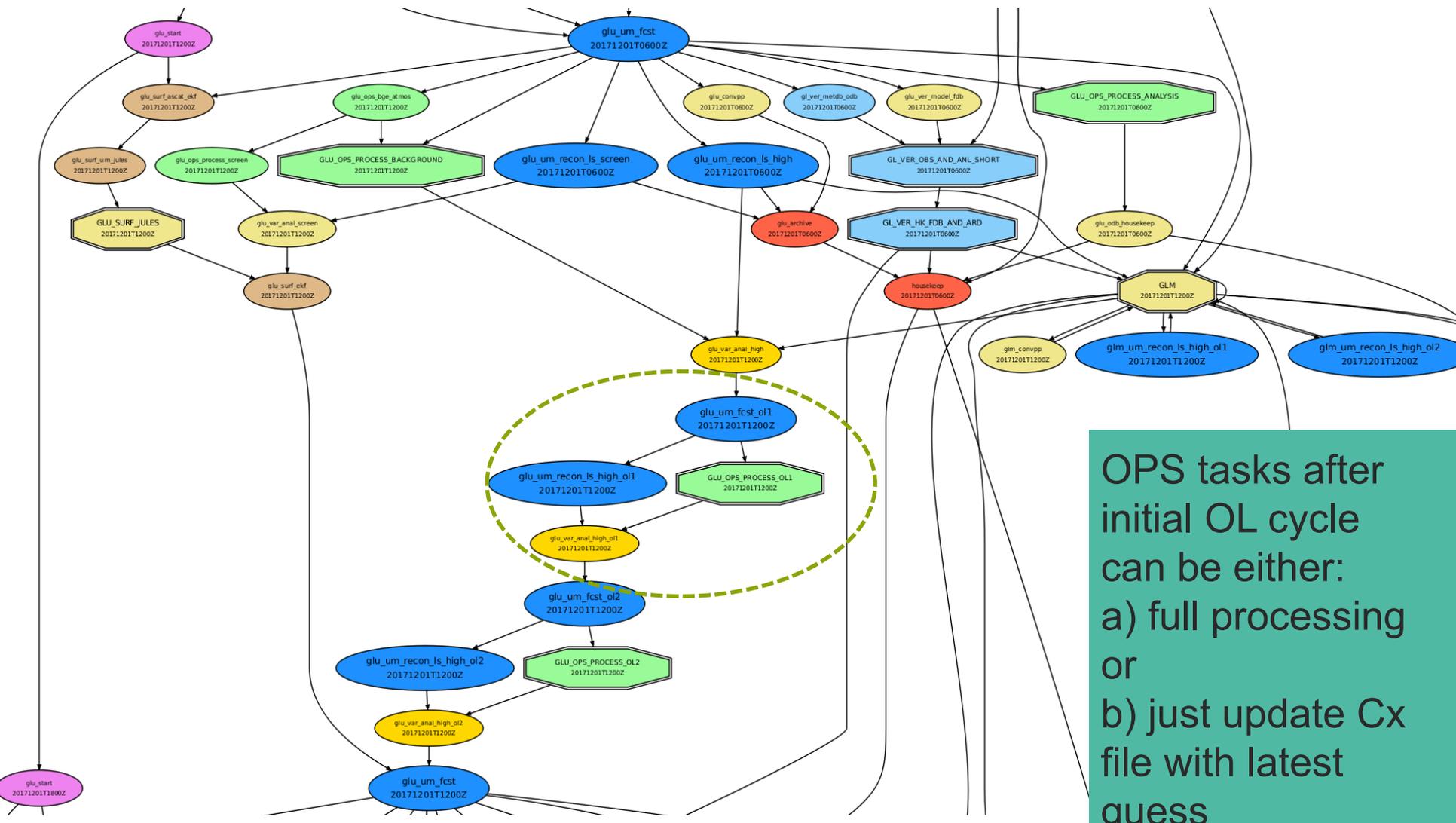
Future Developments

- Examine effect of using bias correction in clear scenes only (Ruth Taylor's talk on Tuesday)
- Extend all sky methodology to humidity channels on ATMS
- Treatment of cloud and ice water from convection scheme
- Inclusion of scenes with significant rain water in field of view
 - Inclusion of rain into error model and extend 1D-Var to include rain
- Test current methodology in successive outer loops as part of the data assimilation to see if this yields more benefit to the wind fields (nonlinear effect between humidity and wind)

Conclusions

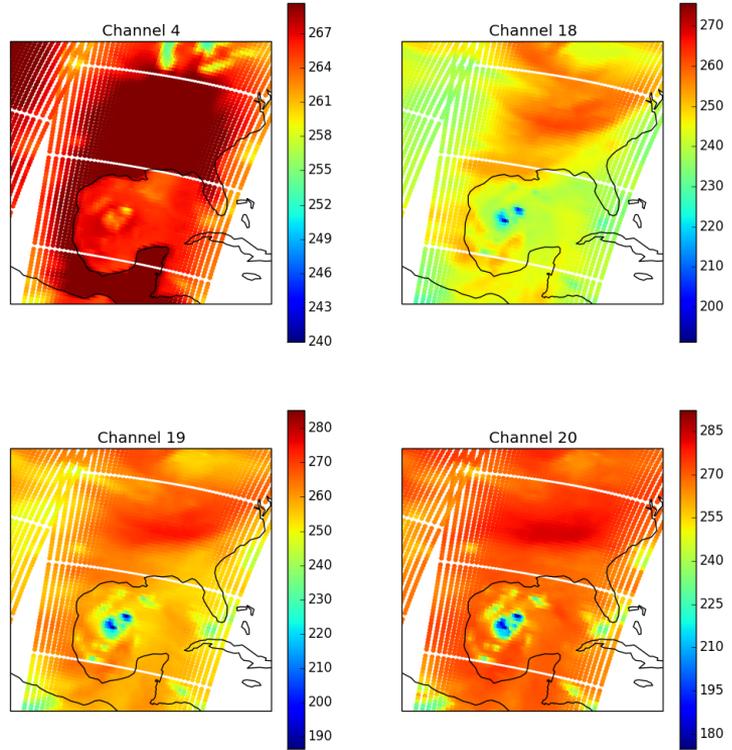
- We have begun using MHS channels in regions of significant cloud effects from water and ice cloud. This has involved incorporating RTTOVSCATT into our OPS pre-processing and 4D-Var
- To account for the effects of cloud we have
 - a) Reviewed our current quality control for significant scattering
 - b) Included retrieval of ice in 1D-Var
 - c) Developed an observation error model that includes effects from liquid and ice cloud
- Forecast impacts suggest benefits in the wind field forecast errors of the extratropics e.g. 0.8% improved at T+48 and we intend to run a second season, including outer loop cycling in the assimilation

Backup



OPS tasks after initial OL cycle can be either:

- full processing
- just update Cx file with latest guess

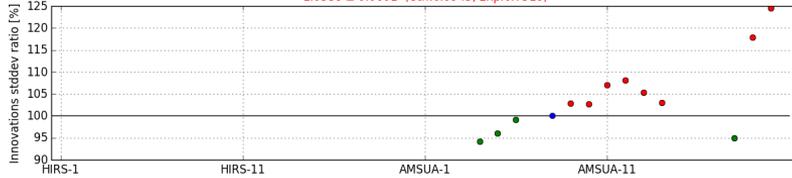


Obs fit when assimilating all-sky MHS

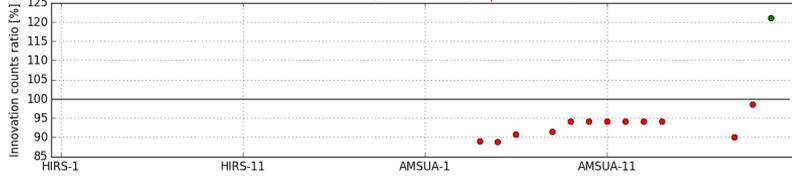
MetOp1 (B) ATOVS: [with Ctrl: u-bk931-GM and Exp: u-bm074-GM]

$$\frac{|O - B|_{Exp}}{|O - B|_{Ctrl}}$$

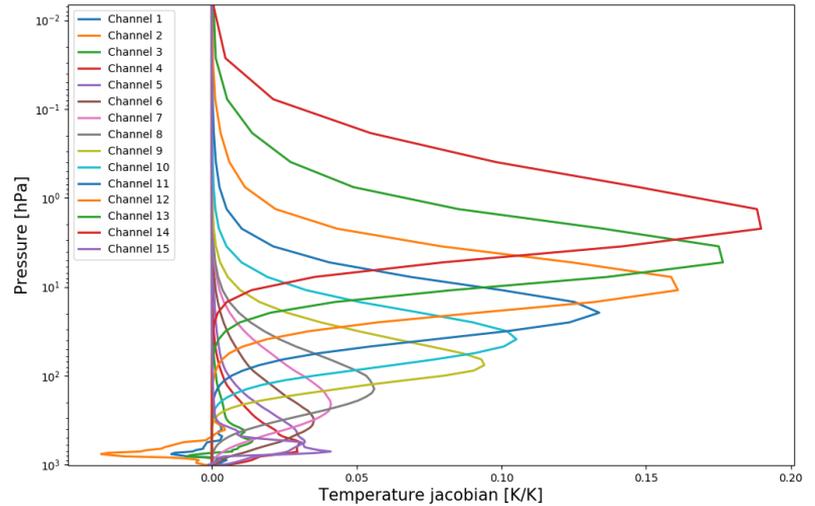
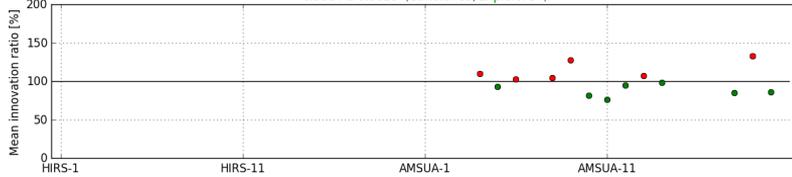
1.0538 ± 0.0001 (Ctrl:0.6943, Exp:0.7316)



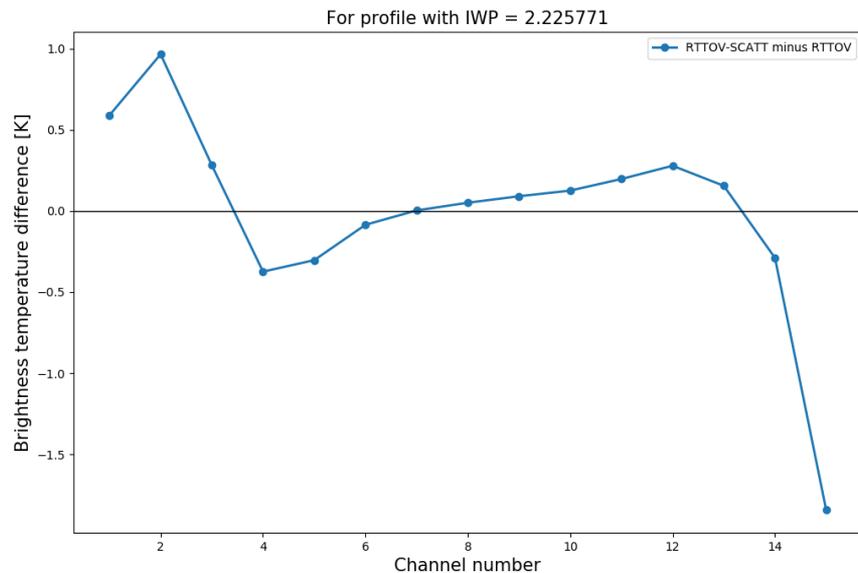
0.94265396212 (Ctrl:71780286.0, Exp:67663971.0)



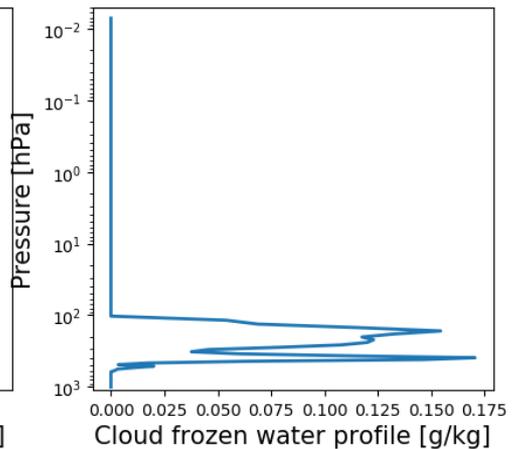
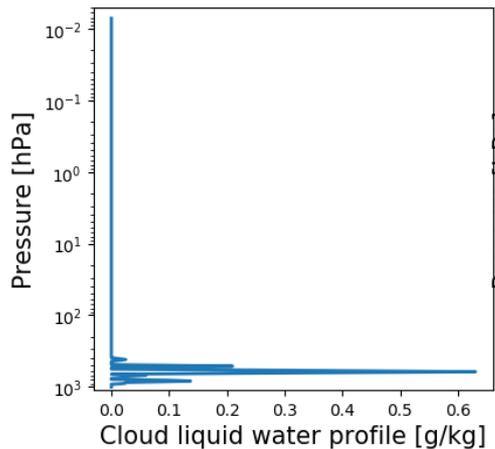
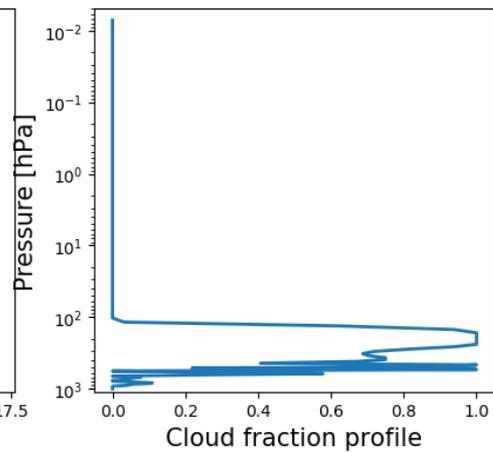
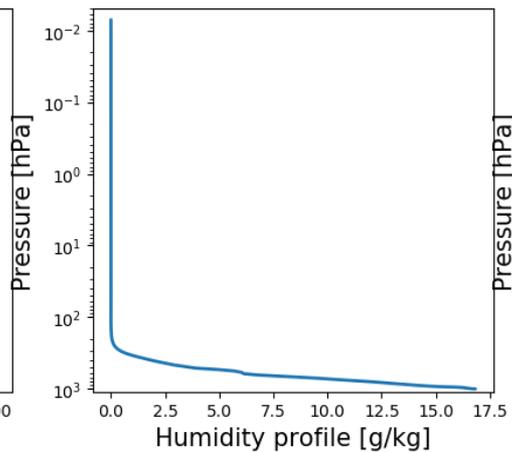
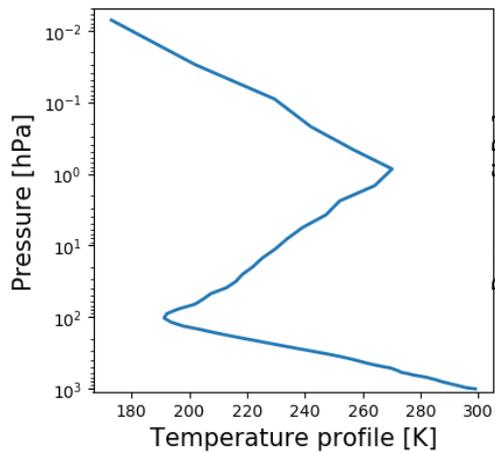
0.9884 ± 0.0016 (Ctrl:0.0766, Exp:0.0757)



BT difference RTTOV-SCATT - RTTOV

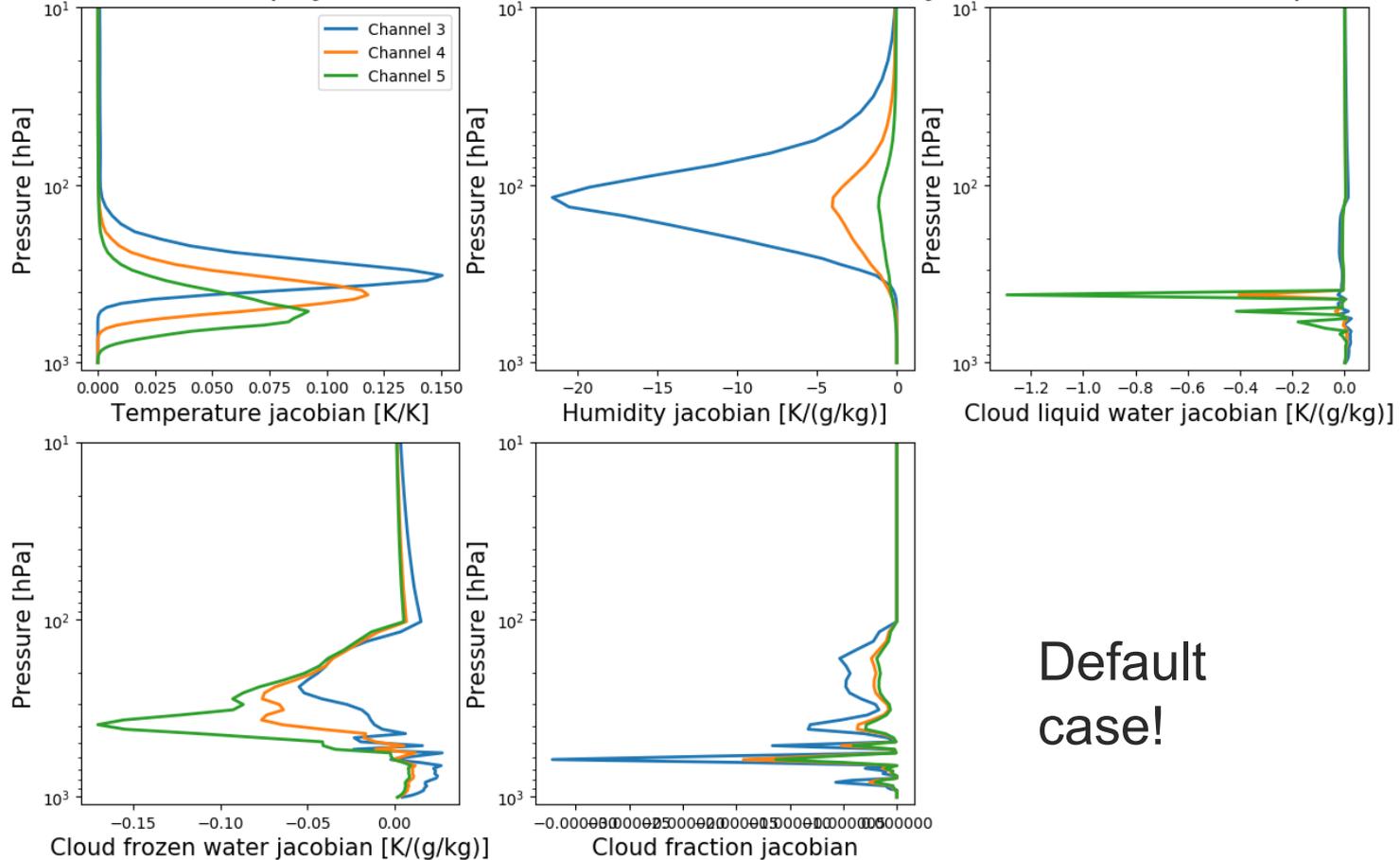


- No radiative effect of ice in RTTOV
- Also differences in modelling cloud liquid water extinction





RTTOV-SCATT (HydroCfracTLAD = True; ZeroHydroTLAD = False)



Default case!



RTTOV-SCATT (HydroCfracTLAD = True; ZeroHydroTLAD = True)

