Investigating the assimilation of IASI data in a limited area model

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Abstract

The assimilation of IASI data in the ALADIN-HARMONIE/Norway data assimilation system at the Norwegian Meteorological Institute is being carried out in the frame of the THORPEX-IPY Norway project. This project aims to improve the accuracy of high-impact weather forecasts in the Arctic region. The use of a limited number of channels was tested at the first stage using one IASI field of view (FOV) out of four available in each field of regard (FOR). Two techniques to handle the bias correction for satellite radiances (off-line estimation and variational correction) were studied for better assimilation of IASI data on top of ATOVS radiances. The first assimilation trial using CO2 stratospheric channels showed a rather slightly positive than neutral impact of the IASI data on temperature and geopotential. Beside the positive impact of the IASI data, observed mainly in lower troposphere, negative impact in the mid-troposphere was found, especially on humidity fields. Further studies are needed on tuning of the assimilation of the IASI data in order to achieve a better impact in the limited area model (LAM) HARMONIE/Norway system.

Introduction

Assimilation and impact assessment of the Infrared Atmospheric Sounding Interferometer (IASI) data at the Norwegian Meteorological Institute (Met.no) was defined in one of the working packages of the Norwegian international Polar Year project (THORPEX-IPY/Norway). The ALADIN-HARMONIE assimilation and forecasting system was chosen for this study. Since the operational numerical weather prediction model at Met.no is the HIRLAM, the ALADIN-HARMONIE system had to be implemented first. To learn more about the use of observations and about recent studies related to satellite observations in the HARMONIE/Norway, please refer to Storto and Randriamampianina (2008).

This paper describes the implementation of the IASI data in the ALADIN-HARMONIE/Norway assimilation system. After a brief description of main characteristics of the HARMONIE/Norway LAM model (next section), the results of the monitoring of the chosen IASI channels are discussed. The importance of the bias correction in the assimilation of satellite radiances is well known. In the IFS/ARPEGE/ALADIN codes, the correction of radiance biases can be done in two different ways: bias can be estimated in off-line regime (Harris and Kelly, 2001 - off-line bcor) or adaptively, using variational technique (Auligné et al., 2007 - VarBC). The power of both techniques is discussed in this paper to approve our decision on using the variational bias correction technique to correct the bias of the IASI data. Afterwards some preliminary conclusions and hints on future works are given.

Main characteristics of the ALADIN-HARMONIE/Norway

Two domains of the ALADIN-HARMONIE were created at Met.no: a smaller and a bigger one, with a horizontal resolution of 11 and 16 km, respectively. The geometries were chosen to match as close as possible those of the operational HIRLAM12 (12 km resolution) and HIRLAM8 (8 km resolution), correspondingly, in order to have similar domains for comparison purposes. The two created domains are shown in Figure 1. For both the domains, the vertical discretization consisted of 60 levels up to 0.2 hPa, using the former level definitions of the ECMWF/IFS global model.

Description of the implemented observations, the used measurements (channels in case of radiances) from each observation type and the thinning distance to assimilate the asynoptic data are given in Table 1. Note that assimilation of Seviri data is under development and one can refer to Storto and Randriamampianina (2008) for details about the first results of that study. An optimum interpolation scheme was used for surface analysis, and three-dimensional variational (3D-Var) assimilation technique was applied for the upper-air analysis. The background error statistics were computed using the so-called NMC method (Parrish and Derber 1992; Berre (2001)). The RTTOV code is used in ALADIN-HARMONIE system to simulate radiances from model parameters. The assimilation and forecast steps are run 4 times per day (00, 06, 12 and 18 UTC): at 00 and 12 UTC the forecast model produces forecasts up to 48 hours, while at 06 and 18 UTC it produces 6-hour forecasts, which are needed as background for the next assimilation cycle.

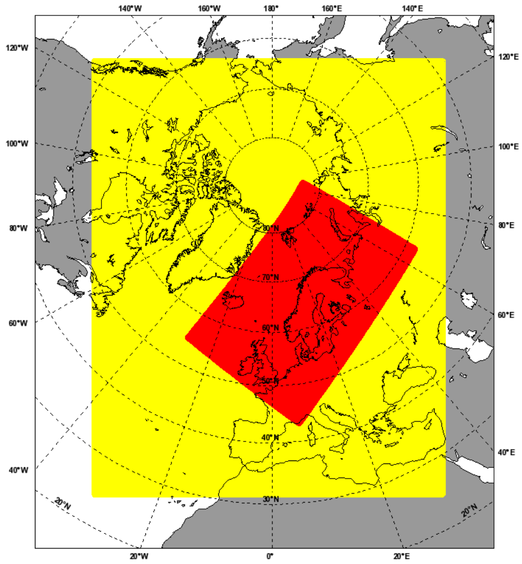

Fig 1: Geographical extension of the two HARMONIE limited area domains

Table 1: Use of observations in HARMONIE upper-air analysis: assimilated parameters and horizontal thinning for asynoptic data.

Domain	Parameters (channels) assimilated	Horizontal thinning
SYNOP LAND	Z	-
SYNOP SHIP	Z	-
AIREP/AMDAR	U, V, T	25 Km
AMV	U, V	25 Km
DRIBU/BUOY	Z	-
EUROPROFILER	U, V	-
RADIOSONDES	Z, U, V, T, Q	-
AMSU-A	5 to 13	80 Km
AMSU-B/MHS	3 to 5	80 Km
MSG/SEVIRI	5, 6, 7, 9, 10, 11	60 Km

Comparison of the bias correction schemes

Problems related to the use of Harris and Kelly's (2001) technique (off-line Bcor hearafter) to handle the bias problems in direct assimilation of satellite radiances in LAM data assimilation system were discussed by Randriamampianina (2005 and 2006). The most difficult question in using this technique is how often bias coefficients should be updated? The variational scheme (varBC hearafter) was implemented by Dee (2004) into the IFS system. The scheme was developed and put in operation by Auligné et al. (2007). Both schemes were available for the IFS/ARPEGE/ALADIN/HARMONIE assimilation system. The "power" of both the schemes was investigated through a monitoring system and an impact study. Monitoring results of the performance of the two bias correction schemes are shown in Fig. 2. The statistics of the observation departures (observation minus first-guess – O-B) and analysis increments (observation minus analysis – O-A) were computed for a one month and one week period for varBC and off-line Bcor, respectively. Use of the off-line Bcor resulted in less bias in radiance departures, but the analysis increments were biased especially in the stratosphere. Applying VarBC, biased radiance departures could be observed, however, less bias in the analysis increments was found.

We observed a large positive impact of VarBC compared to the off-line technique (Fig. 3). Nevertheless, negative impact of VarBC on temperature in lower troposphere was found. This problem seems to occur due to low-peaking AMSU-A channels (the problem can be seen through monitoring for the channels 5 and 6) which are not handled properly. Auligné (personal communication) promised a possible solution for this problem.

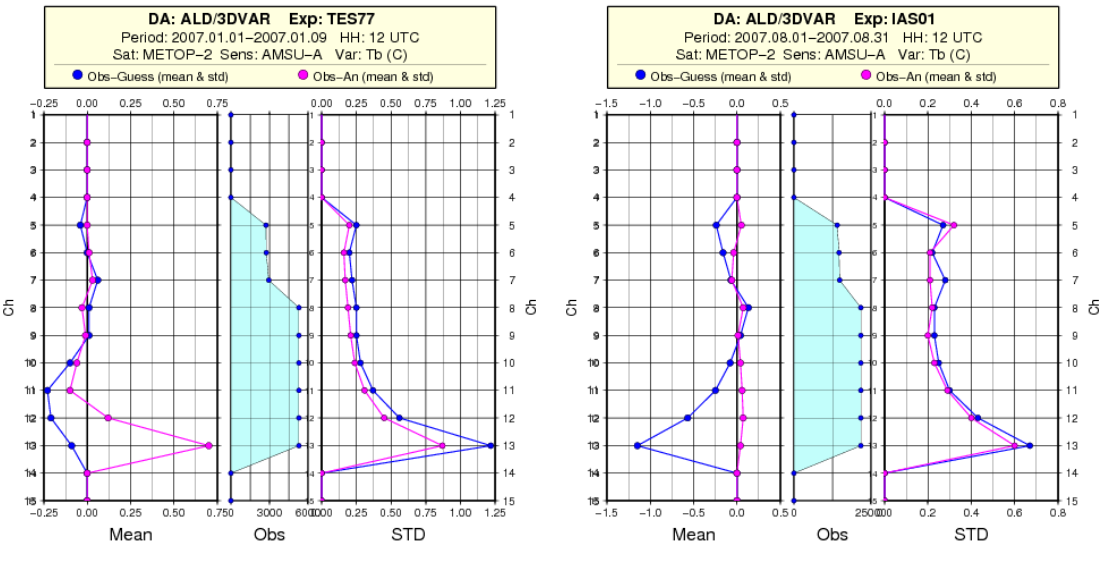

Fig. 2: Observation-minus-first-guess and observation-minus-analysis statistics for the off-line Bcor (left) and for the varBC (right).

Pre-processing and monitoring of the IASI data

One of the ECMWF's supercomputers – HPCE – was chosen for the implementation of the HARMONIE/Norway assimilation system. Observations were extracted from MARS archive. We extracted a set of 366 channels in this study. The list of channels was provided by Andrew Collard from the ECMWF. One field of view (FOV) out of four of each field of regard (FOR) was extracted guaranteeing one IASI FOV for each AMSU-A FOV. FOVs corresponding to 3 AMSU-A FOVs

(FOV with number less than 12 and bigger than 109) on both edges of the satellite track were rejected to avoid large bias. The variational technique was chosen for bias correction for satellite radiances (Auligné et al. 2007). The algorithm proposed by McNally and Watts (2003) was used for cloudy IASI pixels detection.

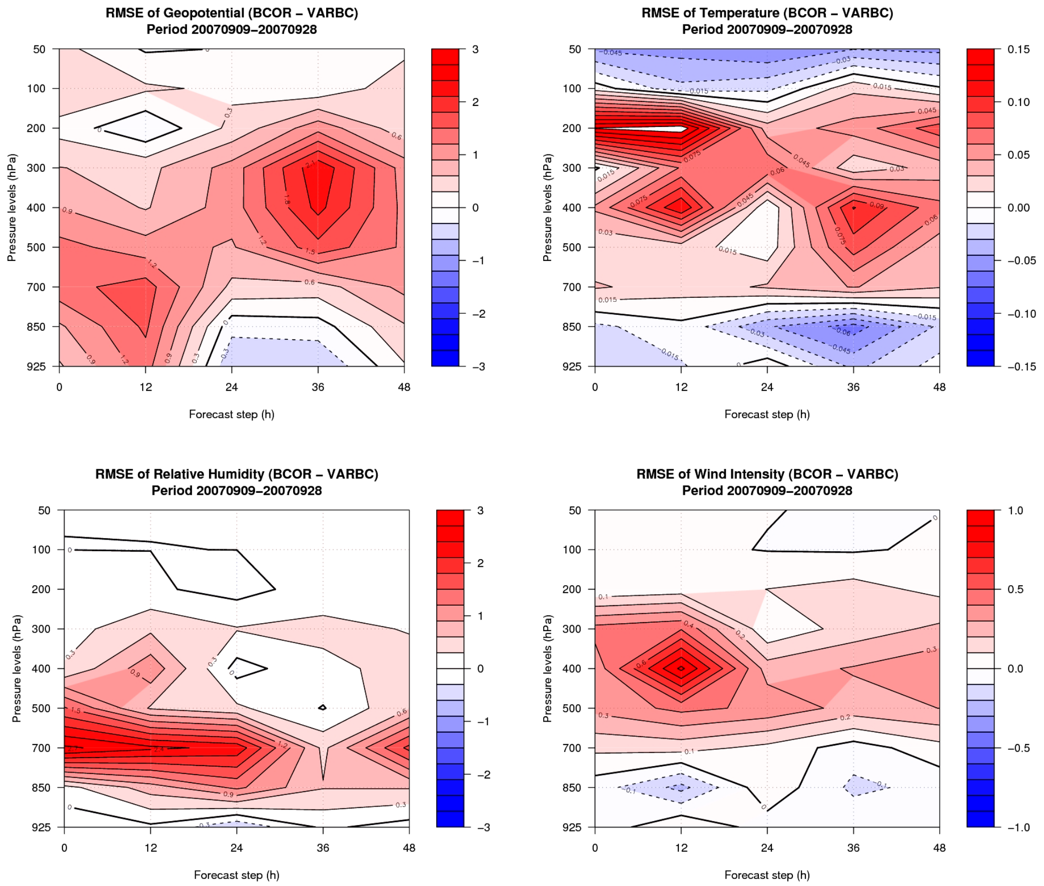

Fig. 3: RMSE differences between runs with off-line bcor and variational bias corrections.

In accordance with the results, reported by Collard (2007) and Hilton (2007), we started our study with temperature (CO_2) channels. At first stage, channels "obeying" the VarBC scheme (having good convergence at the end of the setup for VarBC) were chosen. So, neither the column nor the humidity channels were selected. IASI data were monitored by a set of hundred channels. Figure 4 shows monitoring of the first assimilated set of 93 channels.

Contribution of the IASI data in the analyses

The degrees of freedom for signals (DFS) of all observations used in the analysis system were computed in the runs with and without IASI data. Fig. 5 shows the impact of the IASI data on the analysis. Evaluating the relative values of the DFS, we found that the use of the IASI data increased the contribution of most of the parameters from different observation types, especially those directly related to surface fields (e.g. geopotential or radiances). Positive impact of the IASI data was clearer in the lower part of the troposphere (see below). This could probably be interpreted as follows: the use of the IASI data produces consistent and better background fields (guesses, which are 6-hour forecasts) to assimilate the above mentioned observations.

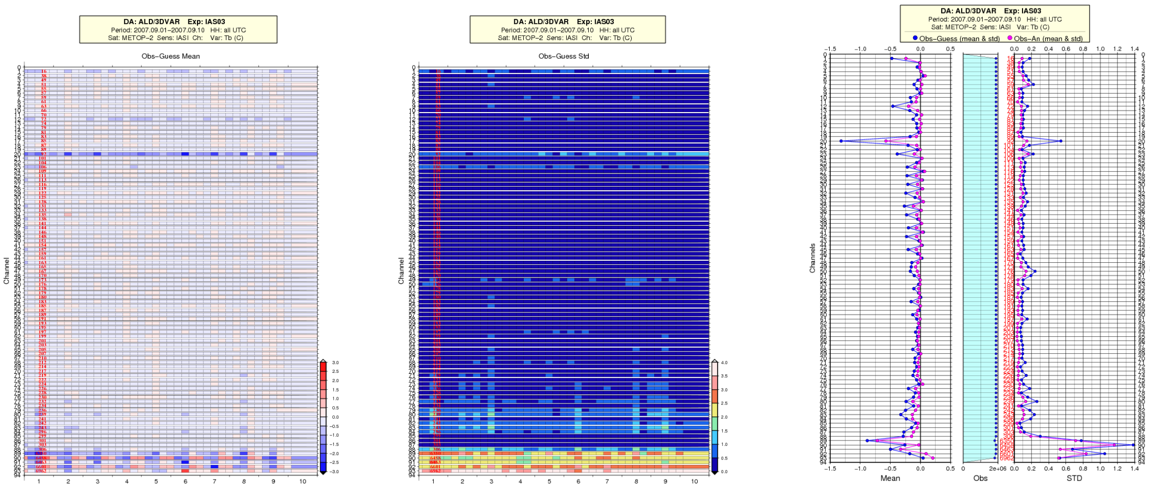

Fig. 4: Monitoring of the assimilation of the first chosen 93 channels. One can see the time series of bias (left) and the RMSE (middle) of the observation departures. Right graphs show the averaged values of bias (left) and standard deviation (right) for the chosen 93 channels.

Impact of the IASI data

The impact of IASI data on analysis and forecasts was evaluated comparing the runs with and without the assimilation of the IASI data. The bias and root-mean-square error (RMSE) were computed from the differences between the analysis/forecasts and observations (surface and radiosondes) as well as analysis/forecasts and ECMWF analyses.

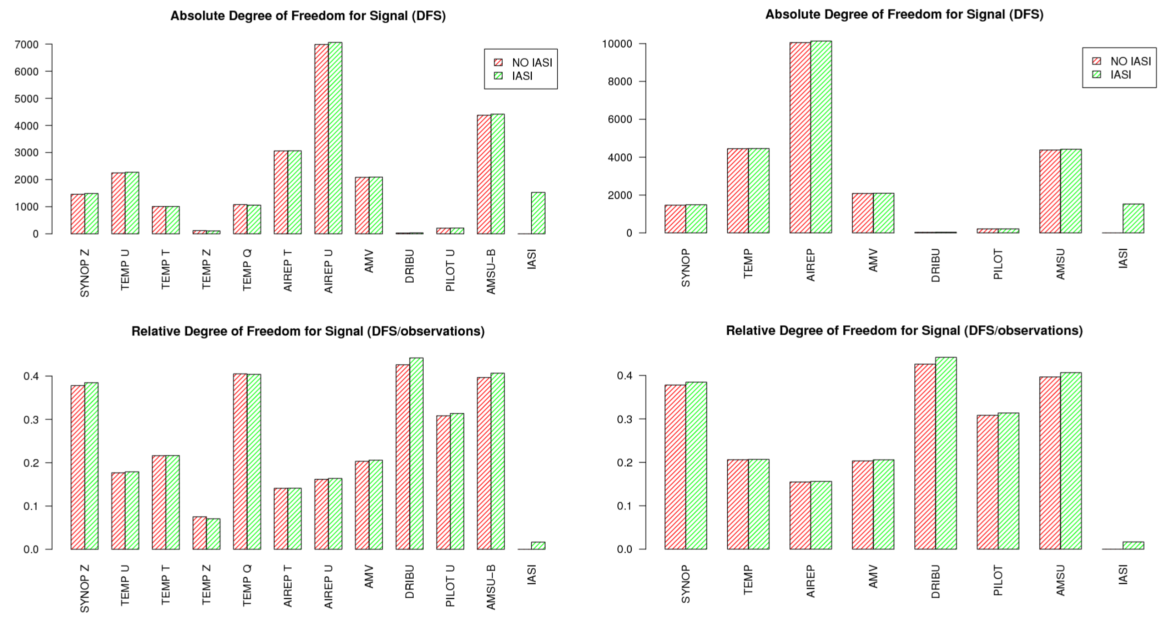

Fig. 5: Degrees of freedom for signals of observations computed using analyses with and without the assimilation of the IASI data.

Comparison against observations

Comparison against observations showed cooling and moistening effect of the IASI data in the upper troposphere, while heating and drying effects were observed in the lower part (Fig. 6). The impact of the IASI data in the lower troposphere was rather slightly positive than neutral (true for wind, geopotential, temperature and humidity). The cooling and moistening effect in the upper troposphere seems not to be the proper "tendency" for obtaining better analyses and forecasts in our system. The negative impact of IASI data in the mid- and upper troposphere still calls for further efforts on the tuning of IASI data in the assimilation system. Analysing the bias on wind fields (not shown), assimilation of the IASI data intensified the wind speed in lower troposphere for the day-one, and mostly in the upper troposphere for the day-two forecasts. This impact resolved mainly a positive impact (not shown).

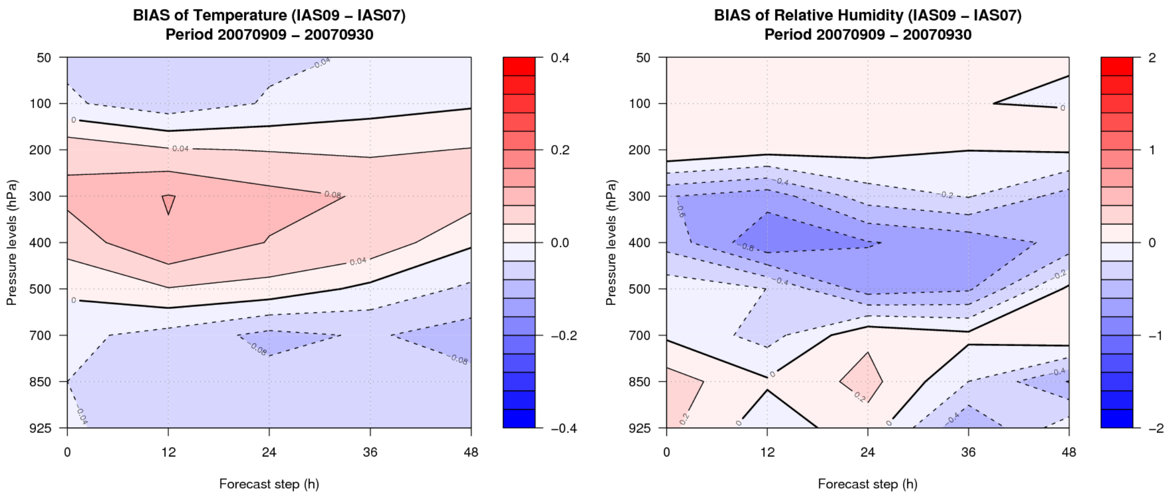

Fig. 7: BIAS difference between runs with (IAS07) and without (IAS09) IASI data for temperature (left) and humidity (right).

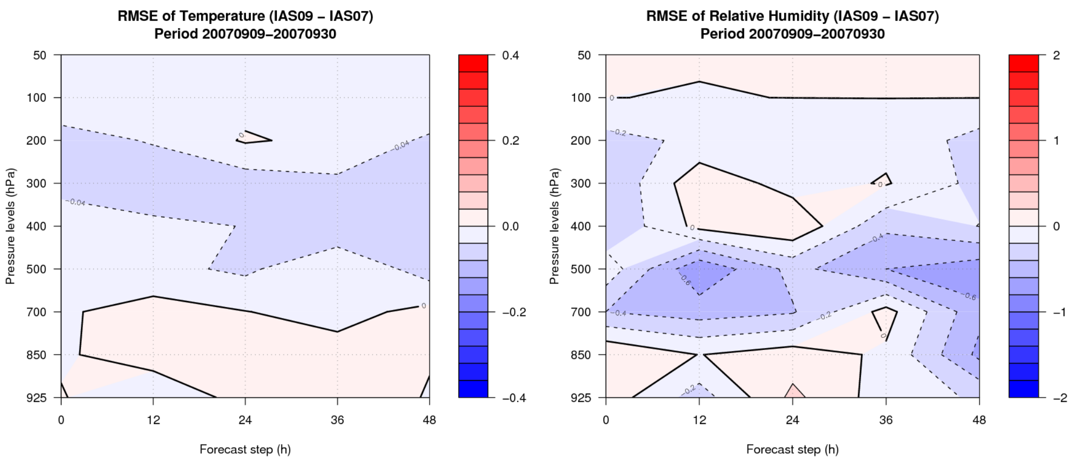

Fig. 8: RMSE difference between runs with (IAS07) and without (IAS09) IASI data for temperature (left) and humidity (right).

Comparison against ECMWF analyses

Comparison against analyses showed similar results to that against observations. Here we observed clearer impact of IASI data on temperature (Fig. 9).

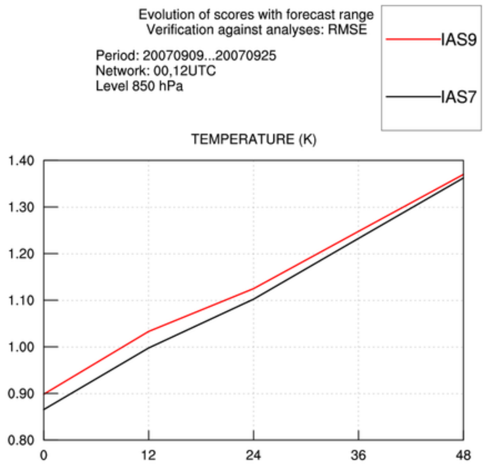

Fig. 8: RMSE for run with (IAS7) and without (IAS9) IASI data for temperature at 850 hPa.

Conclusions and future work

Variational bias correction technique was found to be very efficient in handling the radiance bias correction in LAM assimilation. Applying this technique the problem of updating the bias coefficients could be eliminated. Compared to the off-line bcor, the variational technique had much better verification scores on the analysis and forecasts.

Use of stratospheric channels not only over sea but also over land and tuning of the cloud detection scheme improved the outcomes of the assimilation of IASI data, even thought the overall impact of the IASI data remained rather slightly positive than neutral for temperature, geopotential, wind and humidity, especially in the lower troposphere. According to temperature and humidity biases IASI is cooling the upper tropospheric layers producing moistening effect, and heating the lower troposphere producing a drying effect. DFS computation showed that despite a large number of active IASI channels, their relative "contribution" was small, but assimilation of the IASI data produced better first-guesses, inducing more effective use of most of the parameters from different observation types used in the system.

We concluded that a revision of active channels list is required before starting further work with humidity and surface channels.

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