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TECHNICAL REPORT

Monitoring and quality control of surface meteorological observations at NCMRWF during June-July 2021

Srinivas Desamsetti, Priti Sharma, S. Indira Rani and M. Das Gupta

March 2023

National Centre for Medium Range Weather Forecasting
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10	Abstract	NCMRWF receives meteorological and oceanic observations via Global Telecommunication System (GTS) and from other data providers through FTP. This report describes spatio-temporal monitoring and quality control (QC) statistics of surface meteorological observation counts received at NCMRWF within the cut off time (± 3) of different assimilation cycles (00, 06, 12, 18 UTC) during June and July of 2021, under the framework of the NCMRWF Unified Model (NCUM) data assimilation (DA) and forecast system. This study has been carried out based on various QC procedures, and documented total received observations, observations available after QC checks, and percentage availability of observations for data assimilation in terms of different variables like temperature, surface pressure, relative humidity, and horizontal wind components. The observations are processed through the Observation Processing system (OPS) of NCUM. The OPS has many quality checks depending on the type of observation variable, region, etc. About 90000 global surface observation reports are being received at NCMRWF during each 6-hour assimilation cycle, and about 35% of these observations are being assimilated into the NCUM DA system.
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Abstract

National Centre for Medium Range Weather Forecasting (NCMRWF) receives meteorological and oceanic observations via Global Telecommunication System (GTS) and from other data providers through FTP. This report describes spatio-temporal monitoring and quality control (QC) statistics of surface meteorological observation counts received at NCMRWF within the cut off time (± 3) of different assimilation cycles (00, 06, 12, 18 UTC) during June and July of 2021, under the framework of the NCMRWF Unified Model (NCUM) data assimilation (DA) and forecast system. Various surface observation types of SYNOP, SHIP, and BUOY are presented here. This study has been carried out based on various QC procedures, and documented total received observations, observations available after QC checks, and percentage availability of observations for data assimilation in terms of different variables like temperature, surface pressure, relative humidity, and horizontal wind components. The observations are processed through the Observation Processing system (OPS) of NCUM. The OPS has many quality checks depending on the type of observation variable, region, etc. About 90000 global surface observation reports are being received at NCMRWF during each 6-hour assimilation cycle, and about 35% of these observations are being assimilated into the NCUM DA system. Out of the total surface observations, SYNOP counts ~40000 observations and about 27000 are usable in the NCUM DA system. Similarly, ~5000 SHIP (manual/automated) observations are received and ~3000 observations are usable after QC checks in each assimilation cycle. The global BUOY (drifters and moorings) observations count ~20000 to 25000 for each DA cycle while 15000 to 20000 of these observations are rejected due to the high temporal resolution of these reports. This study shows that majority of the BUOY reports over the southern hemisphere are rejected in the OPS. It is proposed to device proper bias correction methods and Observing Simulation Experiments (OSEs) to explore the possibility of including these BUOY observations in the DA system.

1. Introduction

National Centre for Medium Range Weather Forecasting (NCMRWF) receives global atmospheric and oceanic observations from various agencies, including GTS, NOAA, EUMETCast, IMD, ISRO, KMA, CMA, etc. The conventional meteorological observations are received from India Meteorological Department (IMD), New Delhi. IMD is a Regional Telecommunication Hub (RTH) of the Global Telecommunications System (GTS) network of the World Meteorological Organisation (WMO). NCMRWF has the National Knowledge Network (NKN) connectivity with normal FTP access as a fallback option, through which the GTS from RTH New Delhi would be received. Similarly, the satellite datasets have been received from global satellite operators such as ISRO, NOAA, EUMETSAT, CMA, KMA, etc. NCMRWF receives the Regional ATOVS Retransmission Service (RARS) data from Australia and Japan, Himawari-8 radiances from JMA and Indian Doppler Weather Radar (DWR) observations through GTS. More details of conventional data reception at NCMRWF can be found in Prasad (2020). All the global numerical weather prediction (NWP) centres like NCMRWF (https://www.ncmrwf.gov.in/t574-model/obs_monitor/NCMRWF_MMR.pdf), National Center for Environmental Predictions (NCEP, USA), European Centre for Medium-Range Weather Forecasts (ECMWF) (https://www.ecmwf.int/sites/default/files/medialibrary/2022-03/Global_Data_Monitoring_Report_202202.pdf), Japan Meteorological Agency (JMA), French National Meteorological Service (MeteoFrance) (http://www.meteo.fr/special/minisites/monitoring/BULLETINS/bul.html) generally prepare the monthly monitoring of the global observations reception at their respective centres (link for each Center reports are given in parenthesis). These monitoring help the NWP centers in identifying any abnormalities in any specific type of observation. NCMRWF has been monitoring various conventional and satellite observations routinely for the purpose of quality control and their subsequent assimilation into the NWP models (Das Gupta and Rani, 2010, Singh et al., 2018, Priti et al., 2019). Detailed monitoring and quality control of various satellite observations at NCMRWF are described in Bushair et al. (2019), Srinivas et al. (2020) and in Pattanayak and Prasad (2020). This report details the monthly monitoring and quality control of various surface observations (both land and ocean) being received at NCMRWF, under the framework of NCMRWF Unified Model (NCUM). The Observation Processing System (OPS), a component of the NCUM, processes different types of observations, and the technical details of OPS can be found in the OPS Technical Document Papers (OTDP). The details of the observation types are described in OTDP6. The surface observations received at NCMRWF includes various subtypes like SYNOP, BUOY, SHIP, METAR, etc. Various observations are packed into the NCUM parent data format, Obstores (OTDP17), as per NCUM observation types (OTDP6). NCMRWF has developed an in-house observation pre-processing system exclusively for NCUM (Prasad 2012, 2014; Prasad and Rani 2014; Jangid et al. 2019). The OPS does the quality control (QC) of various observations (OTDP21) and writes the quality controlled data which can be used in data assimilation (DA).

The implementation details of latest version of NCUM and its various components are described in Kumar et al. (2020). The OPS reads different types of observations in the "Obstore" format along with the model background filed (previous cycle model forecast).

The OPS assigns different “data use flags” referred as whether the observations should be used or not. Various QC checks included in the OPS are gross error check, internal consistency check, time consistency check, horizontal consistency check, hydrostatic check, background error check, extreme values, buddy checks, track checks, sonde consistency checks etc. After these QC procedures, OPS write separate statistics files along with the QC observations in the required format for DA. The output of the OPS would be the processed and quality controlled observations and the file is named as “VarObs”, similarly the model values interpolated at the observation location is written in a file named as “Var_Cx”. Both Varobs and Var_Cx files are inputs to the data assimilation system. To read these files, in the NCUM system, some utility programs are made available, such as, Print-obstore to read the obstore observation file, print-varobs to read the varobs, and print-varcx to read the VarCx file. For diagnostic purposes, all these utility programs are used, and necessary statistics are generated. The monitoring and quality control of the surface observation has been done using the OPS generated statistics. The statistics of total observations reported and rejected are part of the OPS statistics file. Along with the total observation count, the statistics file also contains the reported and rejected observations from individual subtypes, with the count of usable and rejected observations. The rejected observations are due to background checks, buddy checks, and final rejection.

Details of reported and rejected counts of surface observation subtypes during June, July 2021 are described in this report. Various types of surface observation types, and OPS quality control methods are discussed in section (2) monitoring of surface observations based on various QC checks are described in section (3) and the main findings from this study are summarized in section (4).

2. Data and Quality control

The NCUM DA system assimilates a large variety of observation types after required QC checks in the OPS. Various observation types assimilated in the NCUM DA system are tabulated in Table 1. The Surface observations are further classified into different subtypes like SYNOP, METAR, BUOY, and SHIP, as per the WMO classification. Surface variables are assimilated in the NCUM system if they satisfy the assimilation criteria based on OPS QC checks. The list of surface variables along with their measurement height is tabulated in Table 2. The majority of the MOBILE SYNOP or the Automatic Weather Station (AWS) observations are available over India and are not assimilated into the NCUM system. The METAR observations are also rejected in the NCUM system as they are surplus when considering the land SYNOP. The monitoring of AWS and METAR observations is not included in this report.

Table 1: NCUM observation types

Obstore Name	**Data types/ Satellite**
Surface	SYNOP, SHIP, BUOY, MOBILE SYNOP, METAR, TCBOGUS
Sonde	TEMP (RS/RW), PILOT Balloon, DROPSONDE, WINDPROFILER
Aircraft	AIREP, AMDAR
Scatwind	ASCAT, SEAWINDS
HLOSwind	ALADIN
Satwind	GOESBUFR, MSGWIND, JMAWIND
ATOVS	ATOVS radiances from MetOp1, MetOp3, NOAA15, NOAA18, NOAA19
SSMIS	F17, F18
AMSR	AMSR2
ATMS	JPSS, NOAA20
MWSFY3	FY34
MTSAPHIR	Megha-Tropiques
GroundGPS	GPSIWV
GPSRO	COSMIC-2, GRASS-A/B, TanDEM-X, Terra SAR-X, FY-3C
GMIlow	GPM
GMIhigh	GPM
IASI	MetOp1, MetOp3
CRIS	JPSS0, NOAA20
AIRS	EOS (Terra/Aqua)
IN3DIClr	INSAT-3D/ INSAT-3DR
IN3DS	INSAT-3D/ INSAT-3DR
SEVIRIClr	Meteosat SEVIRI
AHIClr	Himawari8
ABIClr	GOES-16

Table 2: Surface variables and the observation level

Variable	Observation level
Temperature (T)	2 m
Relative humidity (RH)	1.5 m
Winds (U, V)	10 m
Pressure (P)	Station height level

In the obstores, the observations are packed as observation groups (OTDP6) and are regulated by control files. The background data is obtained from the previous cycle of NCUM model forecasts valid for the current time. The prior statistics such as the observation error, probability of gross error, and data use flags for each observation are provided in a file called "Stationlist". These stationlists are updated regularly and based on these criteria the data for that station/ region/ channel is either accepted or rejected. The control files, stationlists and background fields are primarily used for quality control of the observations. For all the variables the probability gross error (PGE) check is performed. P(G) is the initial probability of gross error in observations, and PGE0 is the average observation gross error. This will be updated by consistency check and referred to as PGE1, along with the background check it is referred to as PGE2, and finally, PGE3 after the buddy check. The decision of rejection of the observation might be taken at any level of these 3 stages. After passing the quality check, the observation will be used for data assimilation. The QC system is based on the Bayesian probability theory. The Bayesian quality control system after performing all tests combines the results and makes an accept/reject decision for each observation type. Three types of OPS quality control checks have been performed which can be pointed out as: (1) Observation type specific checks, (2) Background checks, (3) Buddy checks.

2.1 Observation specific checks

The station list rejects criteria for various surface observation subtypes and parameters along with the specified error and PGE values are listed in Table 3. For the SYNOP subtype, the specified errors, (with PGE value limits) in pressure, wind, temperature, and relative humidity are 70 Pa (0.015), 1.4 m/s (0.02), 1.4 K (0.02), and 7% (0.1) respectively. The Reject = " F " indicates use of the data in the assimilation cycle. From the SYNOP subtype, all the above variables are assimilated in the NCUM DA after the required QC checks.

Table 3: Acceptable Error, PGE limits, and Reject report status for various Surface Observation subtypes used in the NCUM OPS.

	Variable	Error	PGE	Reject
SYNOP	P	70.0 Pa	0.015	F
	UV	1.4 m/s	0.02	F
	T	1.4 K	0.02	F
	RH	7.0 %	0.04	F
SHIP (Manual)	P	130.0 Pa	0.06	F
	UV	2.0 m/s	0.06	F
	T	1.8 K	0.07	F
	RH	10.0 %	0.05	F
SHIP (Automated)	P	100.0 Pa	0.06	F
	UV	1.7 m/s	0.06	F
	T	1.8 K	0.07	F
	RH	10.0 %	0.05	F
BUOY (Moored)	P	80.0 Pa	0.03	F
	UV	1.7 m/s	0.04	F
	T	1.8 K	0.03	F
	RH	10.0 %	0.04	F
BUOY (Drifters)	P	90.0 Pa	0.05	F
	UV	2.5 m/s	0.08	T
	T	2.0 K	0.08	T
	RH	13.0 %	0.08	T

The conventional ocean surface observations are from SHIP and BUOY platforms. SHIP subtype is again classified into manual and automatic as per the data measurement and dissemination technique employed. The SHIP observations are similar to the SYNOP observations over the land, and the NCUM DA assimilates surface pressure, wind, temperature, and relative humidity observations after proper QC. However, the specified errors and PGE limits of various SHIP reported parameters are slightly different from those of SYNOP land stations. For the manual SHIP observations, the errors in surface pressure (130 Pa) and wind (2 m/s) are slightly relaxed than those reported from automated SHIP, 100 Pa and 1.7 m/s; while the PGE limit has been set to 0.06 for both surface pressure and wind reported from SHIP manual and automated. The errors in the manual and automated SHIP reported temperature and humidity are set to 1.8 K and 10 % with PGE limits 0.07 and 0.05.

BUOY reports are also from two different platforms, moorings and drifters. The errors and PGE limits in drifter BUOY reported variables are slightly relaxed than those of moored BUOYS. Surface pressure, wind, temperature and relative humidity errors (with PGE limits) are set to 80 Pa (0.03), 1.7 m/s (0.04), 1.8 K (0.03), and 10% (0.04) for moored BUOYS and all these variables are assimilated in the NCUM DA after QC checks. The errors (with PGE limits) are set to 90 Pa (0.05), 2.5 m/s (0.08), 2 K (0.08), and 13% (0.08) respectively for drifting BUOYS, and only the surface pressure information is assimilated in the NCUM DA, while other variables are set to Reject= " T " flag. It is mandatory for land SYNOP and manual SHIPs to report the station level pressure, while this flag is set "false" for automated SHIPS and BUOYS (both drifters and moorings).

2.2 Background check

The observed variables are checked against background field variables. Observations are either presumed to be 'good,' with normally distributed errors, or 'bad,' with gross errors. The subjective reasoning between different elements is performed, e.g. if the cross-check between pressure and wind indicates a doubt then the position might have been reported wrongly which affects the whole observation (the observation has a high probability of gross error). Similarly, all non-missing elements must undergo a background check to facilitate monitoring of data that isn't operationally used.

2.3 Buddy check

In the buddy check, the pairs of observations are considered at a time, and to facilitate the search for close pairs of observations, the observations are sorted by position. The buddy check compares observations of the same type (surface-surface). This check is implemented separately on surface pressure, temperature, wind, and relative humidity. Based on the assumption that both observations are accurate, the correlation of the background errors between the two positions is calculated for each pair of observations and used to calculate their joint probability. When values agree by only a small margin, there is a large value of the agreement for near observations, otherwise, they offer strong disagreement. In the case of distant observations, correlations are smaller and there is less agreement or disagreement and depend on the sign of difference from the background. After the buddy check, elements with PGE3 >= 0.5 are flagged as not to be assimilated.

3. Surface Meteorological Data Monitoring

Figure 1 shows the time series (four assimilation cycles per day) of total surface observations received and assimilated in the NCUM DA system during June-July 2021. The left Y-axis shows the observation count. The blue curve shows the total surface observations irrespective of specific variables (from various subtypes) received during June-July 2021. It can be seen that more than 90000 global surface observations were received during each assimilation cycle, and it is almost consistent in all assimilation cycles, except during one or two assimilation cycles (on 30 June 2021), due to some network issue at the Centre. The red curve in Figure 1 shows the time series of the total number of observations assimilated in the NCUM DA. More than 30000 surface observations are assimilated after QC checks. As mentioned earlier, some of the received observations are redundant, like METAR, and these are also included in the total number. The time series of assimilated observations are nearly consistent during various assimilation cycles during the reporting period. The right Y-axis of Figure 1 is the percentage of observations assimilated, and the violet dotted curve shows the time series of the percentage of surface observations assimilated. More than 35% of the received observations are assimilated in the DA system. It is interesting to notice from Figure 1 that, more than 35% of the received data has been assimilated during the reported network issue assimilation cycles too.

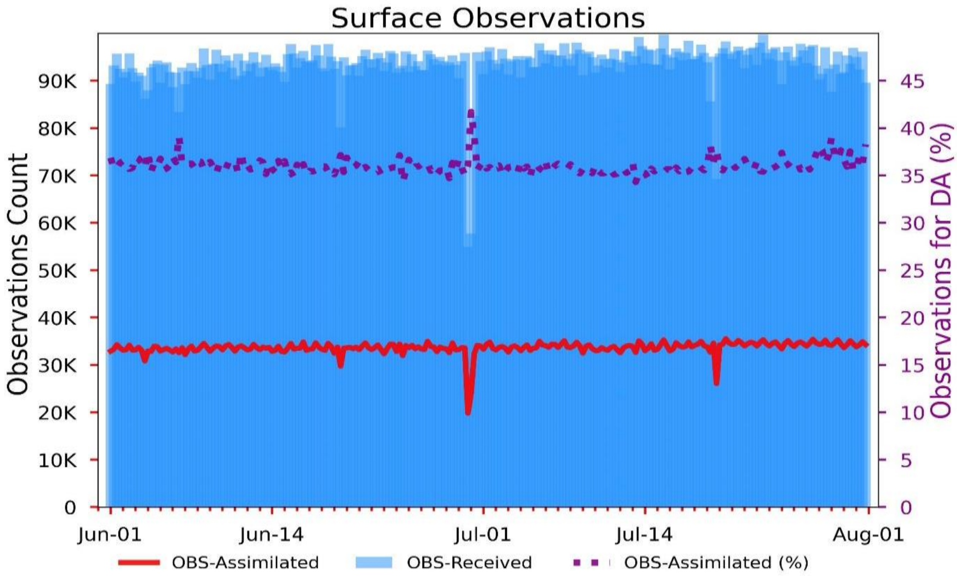

Figure 1: Time series of Total number of surface observations received (blue), number of observations available for DA (red), and the percentage of observations assimilated in the DA system (violet) in various assimilation cycles during June-July 2021.

To get a complete view of the observations received from various surface subtypes and their usage in the DA system in terms of the meteorological variables, we describe SYNOP, SHIP, and BUOY in detail in the following sections. Global coverage of the received surface and its sub-type observations valid on 20210615 and for 4 assimilation cycles is presented in Figure 2, and the coverage of observations assimilated in the DA system is depicted in Figure 3. The total count of received surface observations are 89726, 95587, 97682, 95695 respectively valid for 00, 06, 12 and 18 assimilation cycles (Figure 2), out of which the assimilated observations are 32748 (36.5%), 33546 (35%), 34510 (35.3%), 33333 (34.8%) in the respective cycles. The count of received SYNOP observations are 40540, 42785, 43229, 42451 respectively valid for 00, 06, 12 and 18 assimilation cycles (Figure 2), and the observations used in the assimilation system are 26805 (66%), 27534 (64%), 28283 (65%), 27488 (65%) for each respective cycle (Figure 3). Similarly, for the SHIP observation, counts are 6709, 6766, 6999, 6868 valid for 00, 06, 12 and 18 assimilation cycles (Figure 2), and the observations going into assimilation system are 2994 (45%), 2859 (42%), 2802 (40%), 2816 (41%) respectively for each cycle (Figure 3). Likewise, the BUOY observations counts are 18490, 20221, 20477, 20553 valid for 00, 06, 12 and 18 assimilation cycles (Figure 2), and the observations going into assimilation system are 2931 (15%), 3356 (17%), 3196 (16%), 3015 (15%) respectively for each cycle (Figure 3). The METAR observations received are 20480, 21607, 22369, 21582 (Figure 2) for each cycle respectively and the used observations for each cycle are 6, 0, 0, 0 (Figure 3). Most of these observations have the SYNOP stations, and in the OPS priority is set to SYNOP stations hence these are not assimilated in the NCUM. Similarly for SYNOP-MOBIL (AWS) observations received are 3507, 4208, 4608, 4241 (Figure 2) for each cycle and the assimilated observations are 8, 10, 9, 11 (Figure 3). Most of these observations are from India AWS stations, and these are not assimilated into the NCUM.

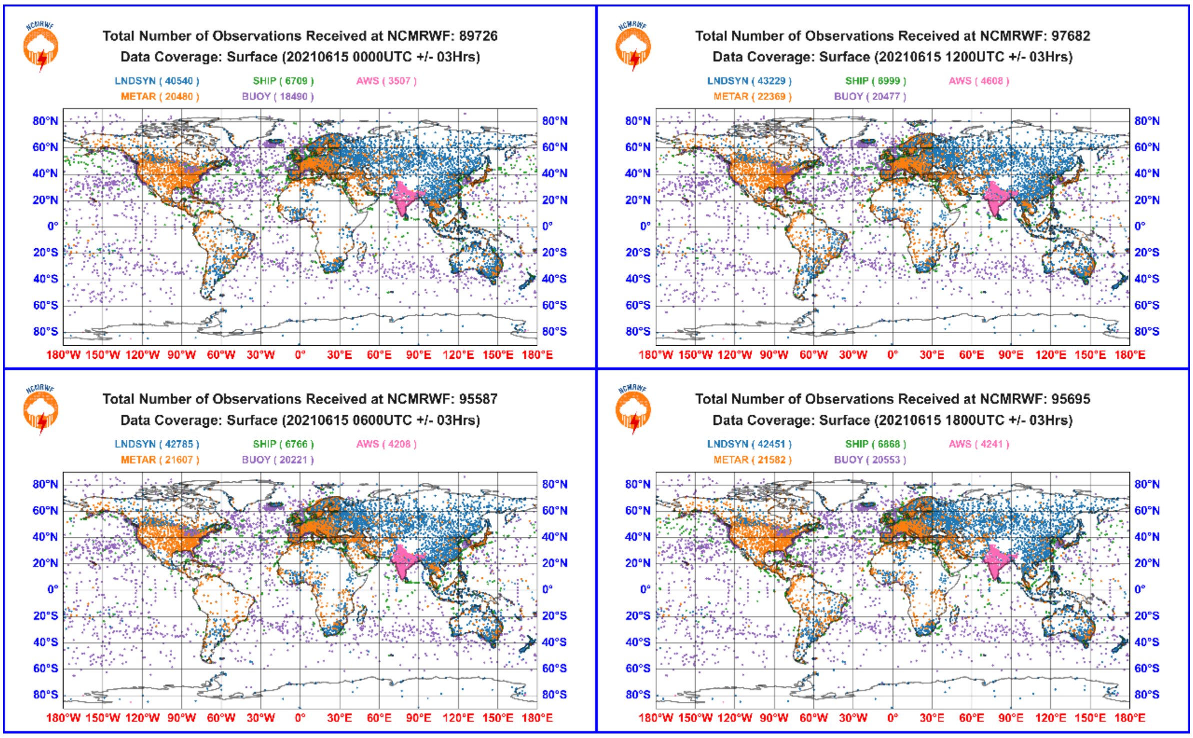

Figure 2: The spatial coverage of surface observations [LANDSYNOP (LNDSYN), SHIP, BUOY, METAR, MOBIL-SYNOP (AWS)] received at NCMRWF on a typical day (20210615) for four assimilation cycles.

Approximate 35% of the received surface observations are used in the assimilation system. More than half of the received SYNOP observations are used in each assimilation cycle (>60%), whereas the OPS rejects more observations over the Ocean. Less than half of the reported SHIP observations are used in the assimilation system (~ 40%). The least used surface observation type is from the BUOY platforms. Only 15-17% of the BUOY observations are used in the DA system. We also noticed that many BUOYs are reporting observations over the southern hemisphere oceanic region, but a large majority of the data are rejected. Figure 4 shows the BUOY locations which reported surface pressure during the four assimilation cycles on a typical day of 15 June 2021. Comparing Figures 3 and 4 clearly shows the rejection of southern hemisphere BUOY observations in the assimilation system. Further investigations showed that the heavy rejection of BUOY data over the southern hemisphere ocean is due to the high PGE error. Proper bias correction methods and Observing Simulation Experiments (OSEs) have to be designed to explore the possibility of including the BUOY observations over the southern hemisphere in the DA system.

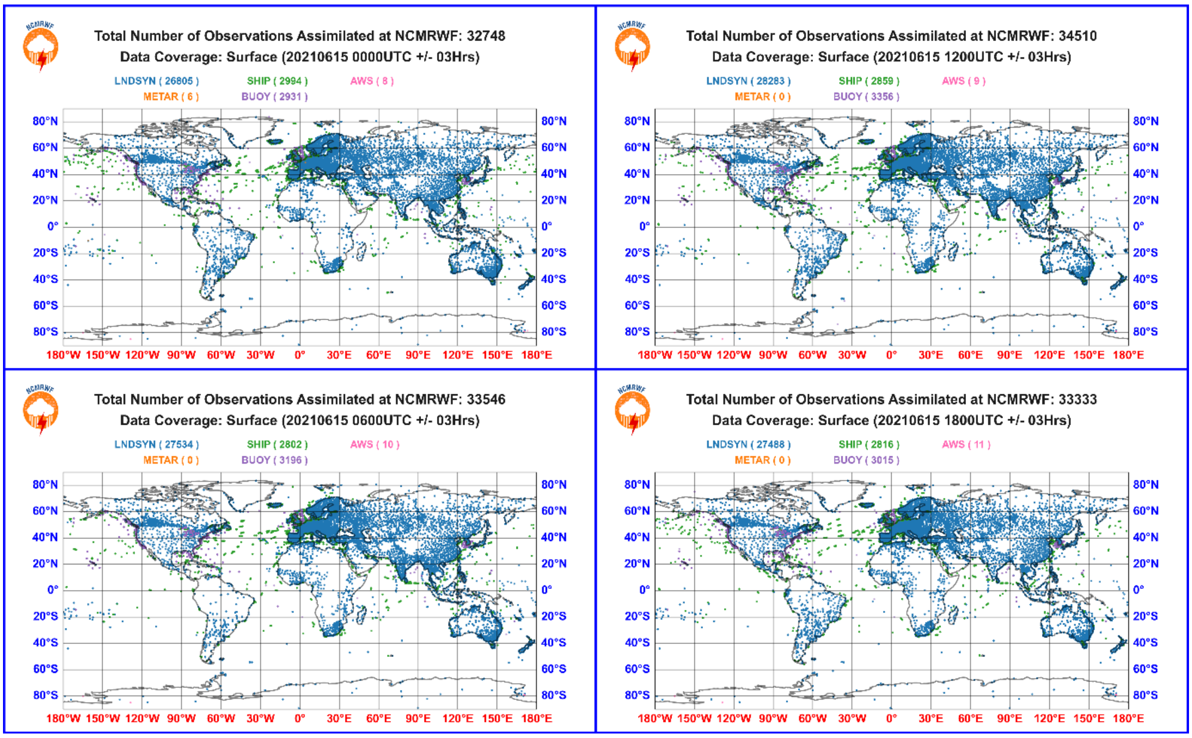

Figure 3: The spatial coverage of surface observations [LANDSYNOP (LNDSYN), SHIP, BUOY, METAR, MOBIL-SYNOP (AWS)] being used by DA system at NCMRWF on a typical day (20210615) for four assimilation cycles.

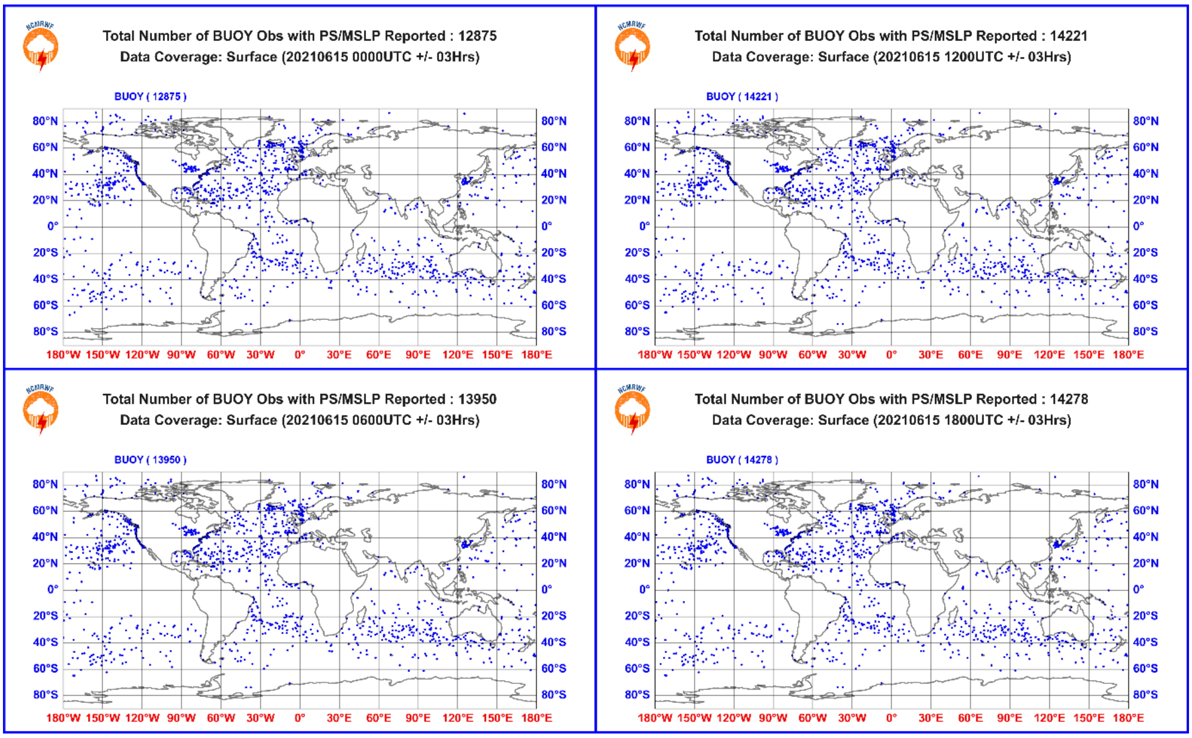

Figure 4: The spatial coverage of the locations of BUOY which reported surface pressure variable during the four assimilation cycles on a typical day (20210615).

3.1 SYNOP Observations:

Figure 5 shows the time series of land SYNOP observations valid for the 00Z assimilation cycles. The time series of total SYNOP observations (including all variables reported from a station) received, rejected after QC procedure, and usable in the 00Z assimilation cycles of June-July 2021 is shown in the top panel of Figure 5. The time series shows that the received, rejected and usable observation counts are respectively ~ 40000, ~13000, and ~27000, and they are consistent throughout the period of monitoring. The middle panel of Figure 5 shows detailed information in the usable observations in terms of different meteorological variables, surface pressure (P), temperature (T), relative humidity (%), zonal (U) and meridional (V) wind components. The maximum reported variable from the stations in the usable list is temperature, followed by relative humidity and wind, and then surface pressure. This indicates out of ~27000 usable stations, ~24000 stations report all the meteorological variables, while the remaining ~3000 stations fail in reporting some of the variables, mainly the surface pressure (middle panel).

The lower panel of Figure 5 is similar to the middle panel, but the percentage of surface parameters, in terms of their respective usable count, available for DA. From the respective usable count of variables, the assimilation system used ~98% of the surface pressure, ~88% of temperature and humidity, and ~63% of wind information. It is noted that almost all the usable surface pressure information is used in the assimilation system, which is very essential to adjust the model surface terrain pressure. The wind observation is found to be the least used amongst the other variables, which is due to the rejection of SYNOP wind information over the tropics. Similarly, for the other three assimilation cycles (06, 12, 18 Z) the time series follow a similar pattern as of the 00Z cycle. Figures 6, 7, and 8 are similar to Figure 5, but for the 06, 12, and 18 Z assimilation cycles. Some intermittent data issues in the data reception can be noticed during 06 and 12 cycles compared to 00 and 18 cycles. The percentage count of different meteorological variables available for assimilation is almost the same in all four assimilation cycles.

The SYNOP observations rejected are mainly included in four categories: (1) background check rejection, (2) buddy check rejection, (3) final rejection, and (4) no-assimilation. Figure 9 shows the various category of rejection in different SYNOP variables. The meteorological variables temperature, zonal wind, meridional wind, relative humidity, and surface pressure are denoted as tt, us, vs, rh and ps respectively in Figure 9. Depending on the rejection checks, alphabets b (background error), d (buddy), f (final rejection), and n (no-assimilation) are suffixed to the meteorological variables shown in the four different panels of Figure 9. The background check and buddy check reject more humidity observations compared to the other variables. The T,U,V,P rejection is <1%, and the rejection of RH is <4% in the background check. Similarly, for buddy check, and final rejection in the variables T, U, V, P show <1.5%, and <4% for RH. U and V show ~30% in the no-assimilation, which are due to the no-assimilation of winds from land SYNOP winds over the tropics due to large errors. Other variables do not show much rejection (nearly zero) in the "no-assimilation" category. All the variables show some outliers in the percentage rejection of usable counts in various checks.

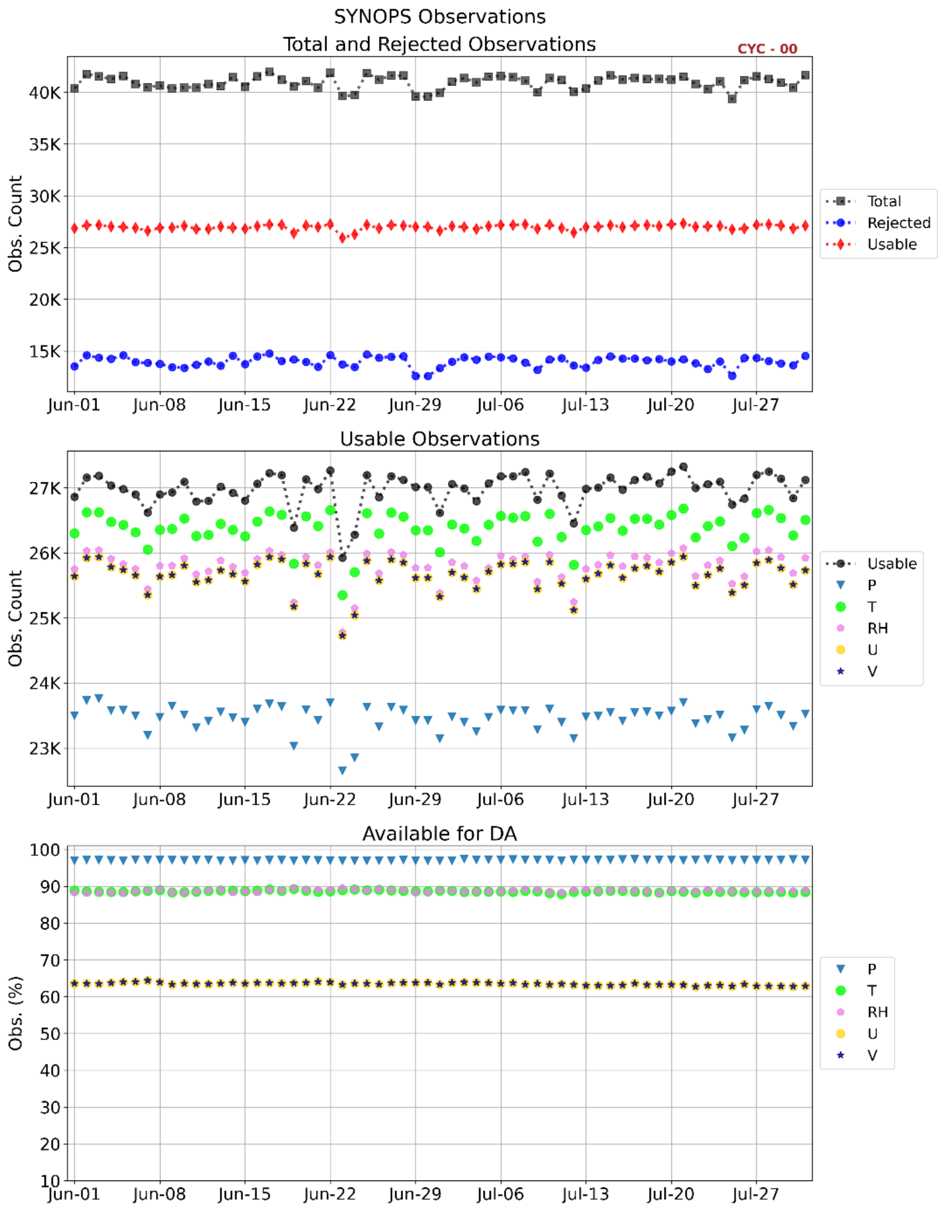

Figure 5: Time series of land SYNOP observation counts in the 00Z assimilation cycle (top) total received, rejected and usable, (middle) variable wise usable counts and (lower) percentage of variables available for DA during June-July 2021.

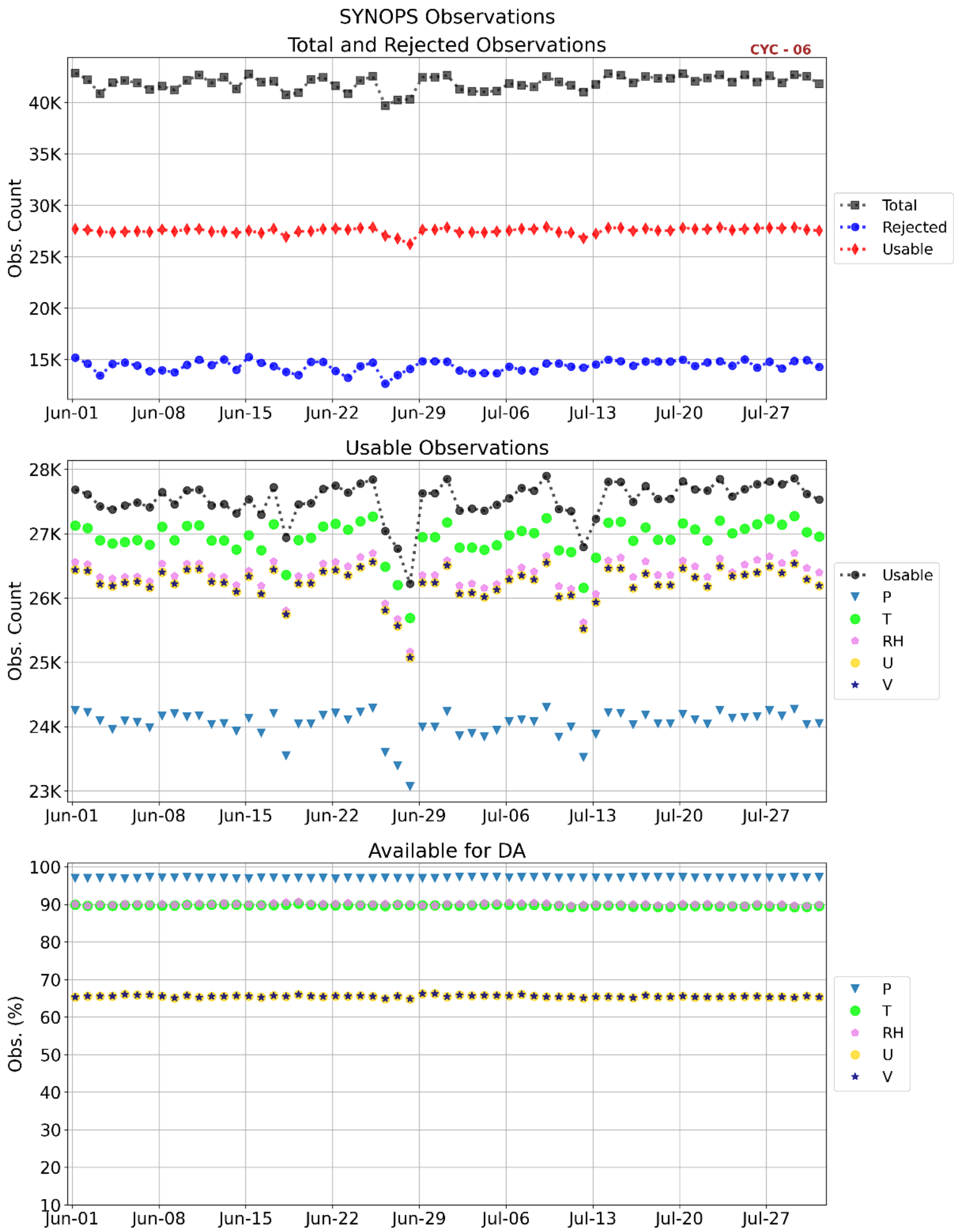

Figure 6: Similar to Figure 5, but for 06Z assimilation cycle.

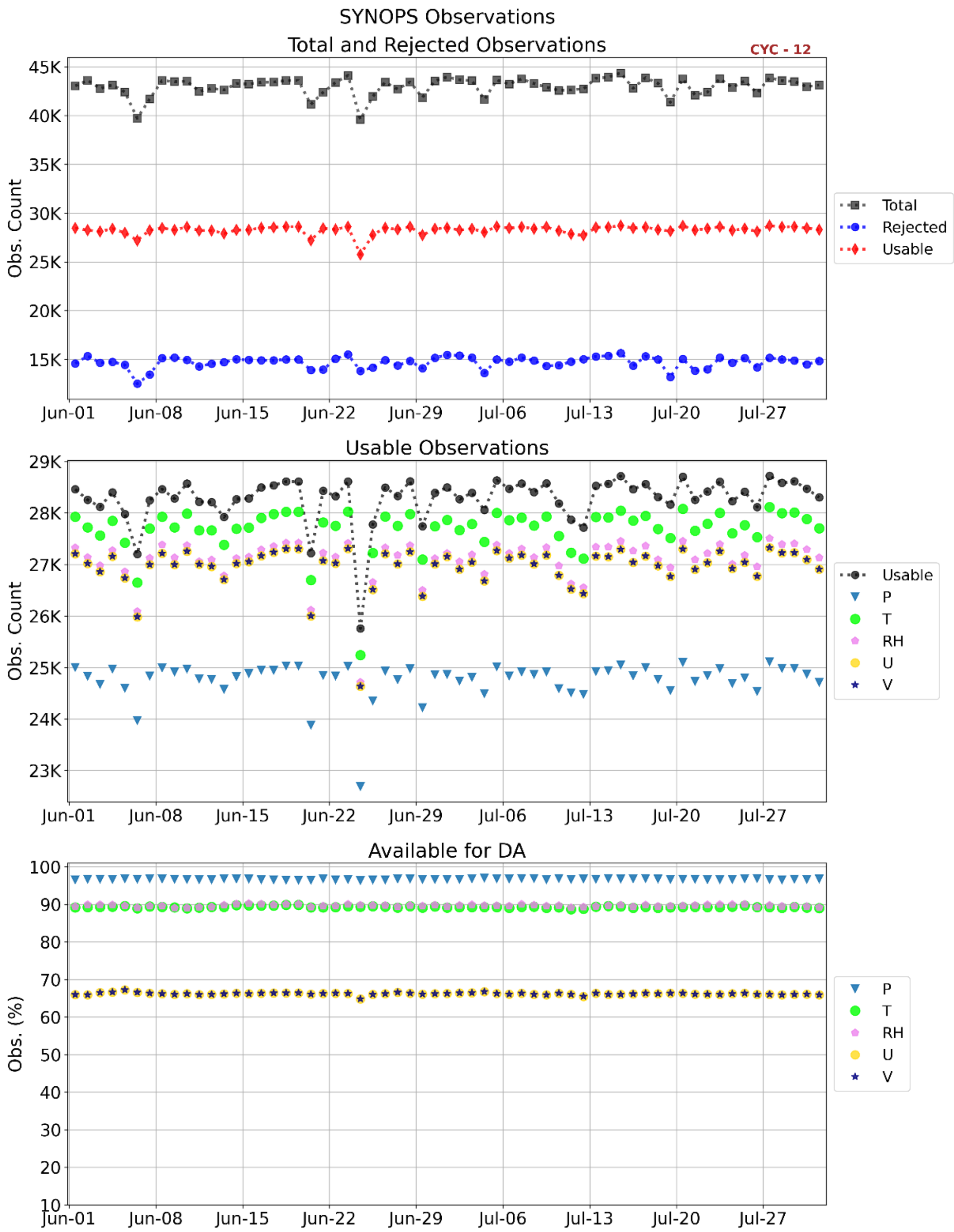

Figure 7: Similar to Figure 5, but for the 12Z assimilation cycle.

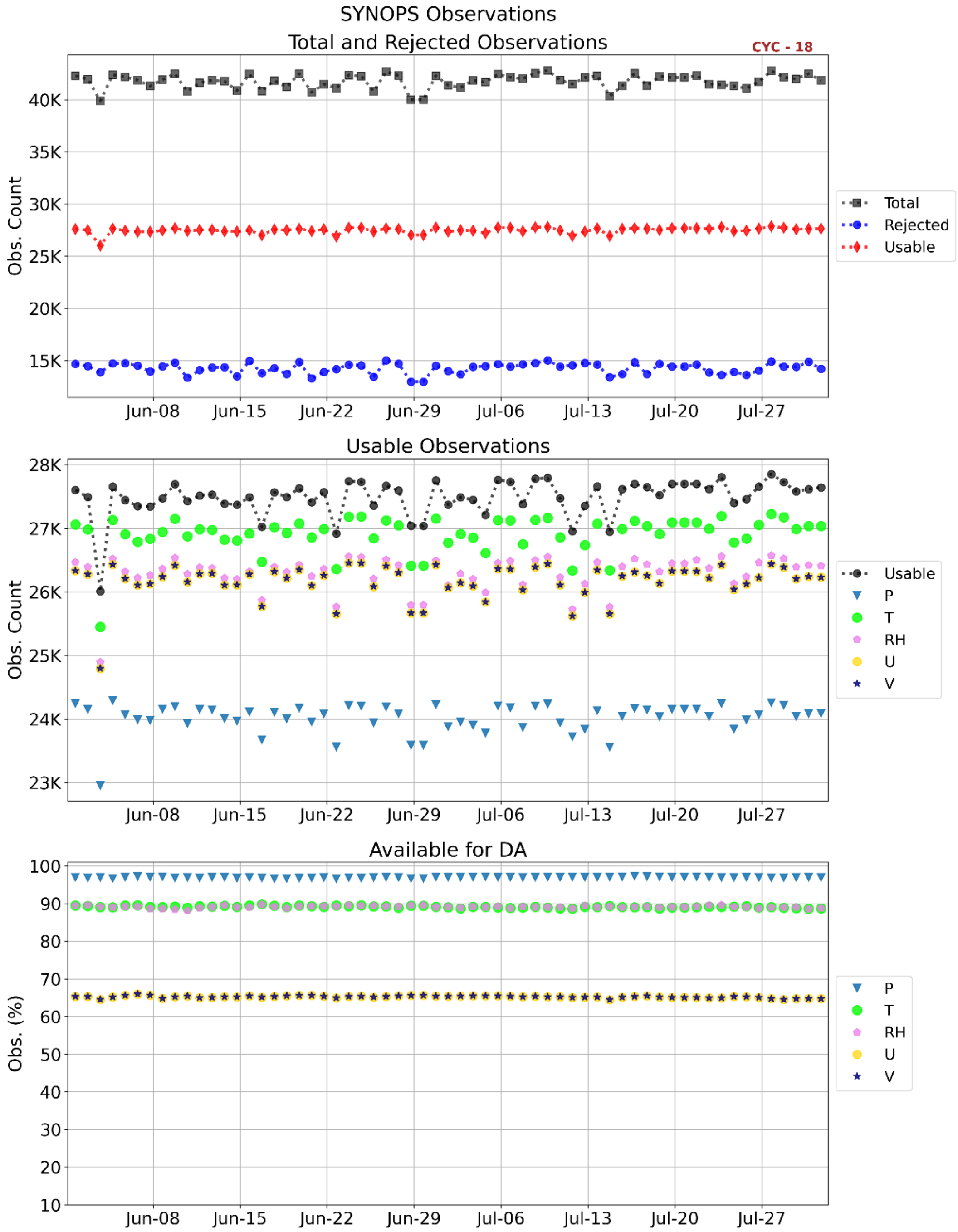

Figure 8: Similar to Figure 5, but for the 18Z assimilation cycle

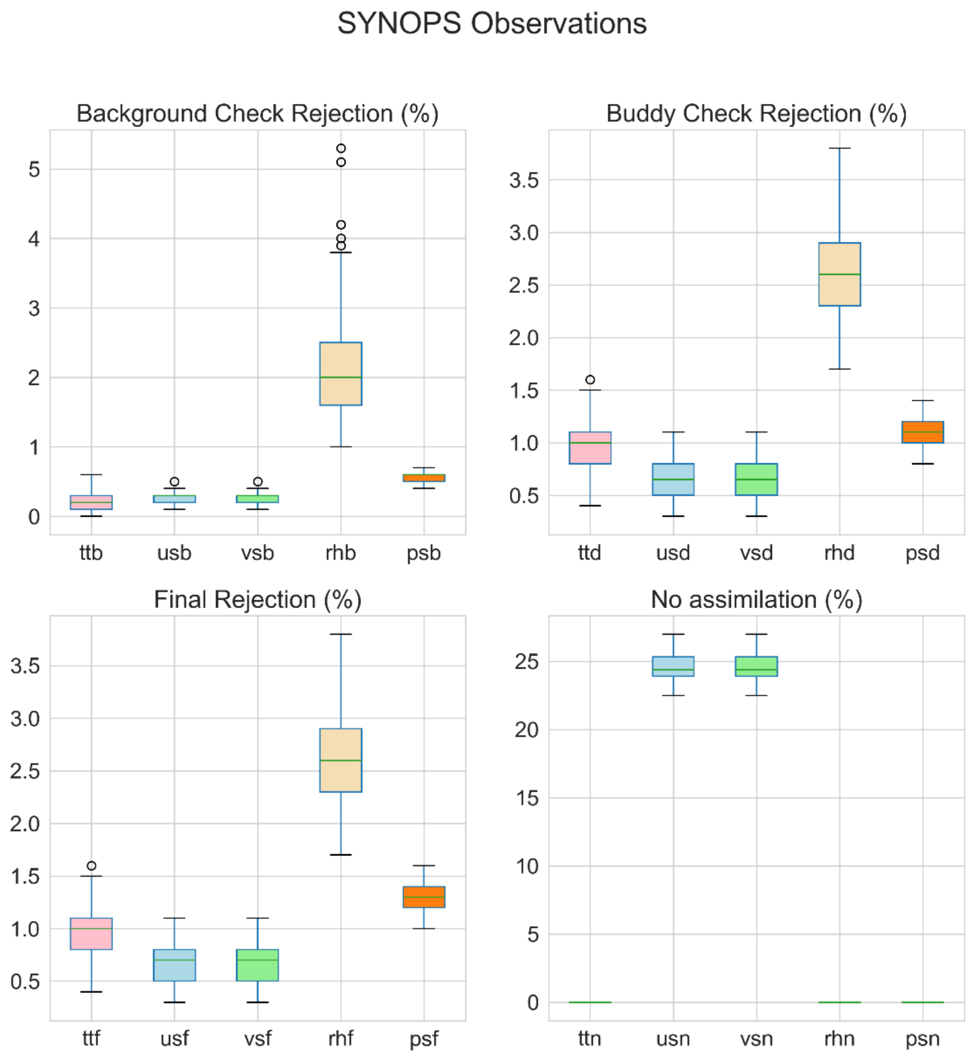

Figure 9: Percentage rejection of different SYNOP variables in different quality checks: background, buddy, final rejection, and no-assimilation during June-July 2021.

3.2 SHIP observations:

Figure 10 is similar to Figure 5, but for the time series of SHIP observations (manual and automated) valid for the 00Z assimilation cycles. The number of observations received from the SHIP platform is obviously less compared to the land SYNOP observations. ~5000 observations were received during 00Z assimilation cycles during June-July 2021 (Top panel of Figure 10), but with a large variability compared to the consistent observation count of SYNOP. ~2000 observations were rejected in various QC checks and ~3000 observations are available in the usable category. A slightly increasing trend in the received number of observations and hence in the rejected and usable count in July can also be seen from the top panel. The time series of total and variable wise counts is shown in the middle panel. Out of ~3000 usable observations, ~2800 include both T and P, ~2000 stations reported wind components and ~2500 stations reported humidity information. The percentage count of different variables available for DA in terms of their respective usable count is shown in the lower panel of Figure 10. More than 90% of the usable counts of surface pressure, temperature, and wind components are assimilated in the DA, however ~50-60% of the usable humidity observation is used in DA.

Compared to the land SYNOP observations, more percentage of usable wind observations are assimilated from SHIP, whereas the percentage rejection of humidity observation is more. The percentage assimilation of surface pressure and temperature information is nearly the same from both land SYNOP and SHIP. Figures 11, 12, and 13 are similar to Figure 10, but for the time series of SHIP observations during 06, 12 and 18 Z assimilation cycles. A similar number of observation counts are noted for the other three cycles, except for the percentage count of relative humidity observation available for DA. The percentage count of available RH observation is found to be ~40% during 06Z assimilation cycle (lower panel of Figure 11), while it is further reduced to 30-20% in the 12 and 18 Z assimilation cycles (lower panels of Figures 12 and 13).

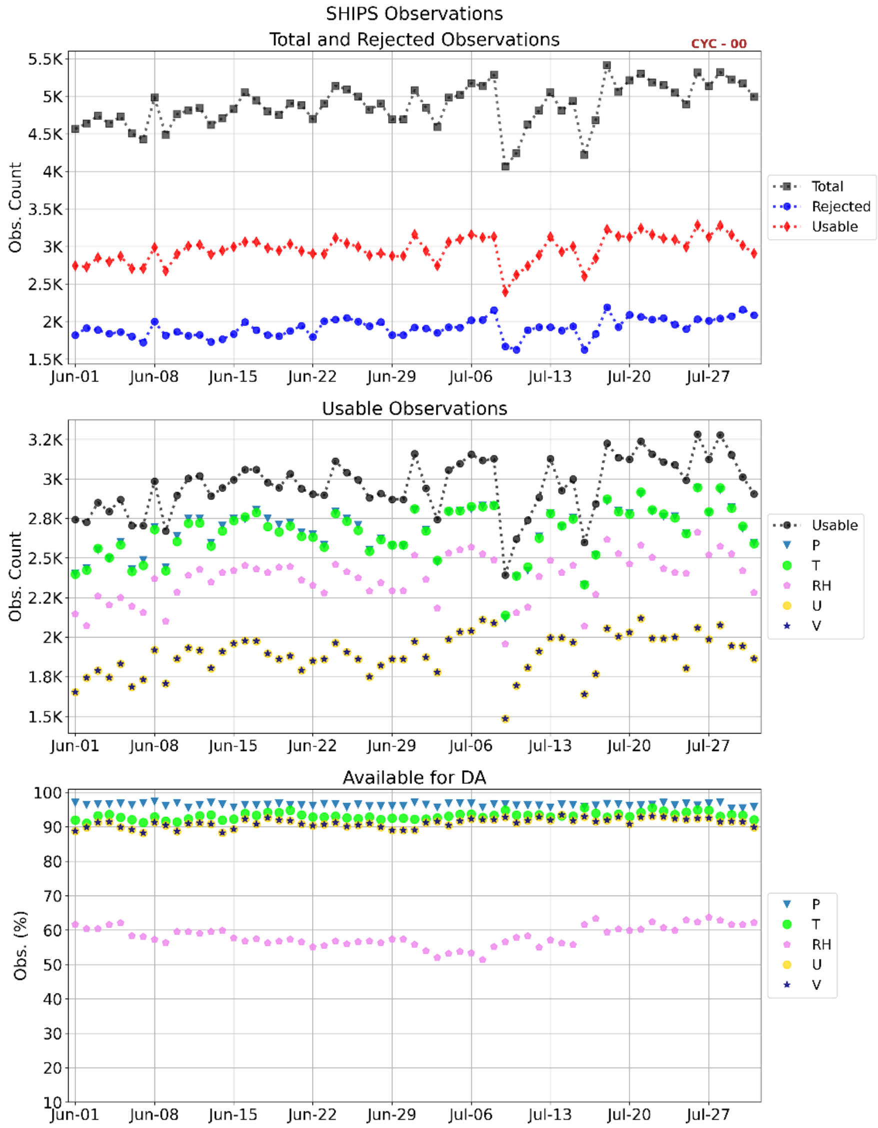

Figure 10: Time series of SHIP observation counts in the 00Z assimilation cycle (top) total received, rejected and usable, (middle) variable wise usable counts and (lower) percentage of variables available for DA during June-July 2021.

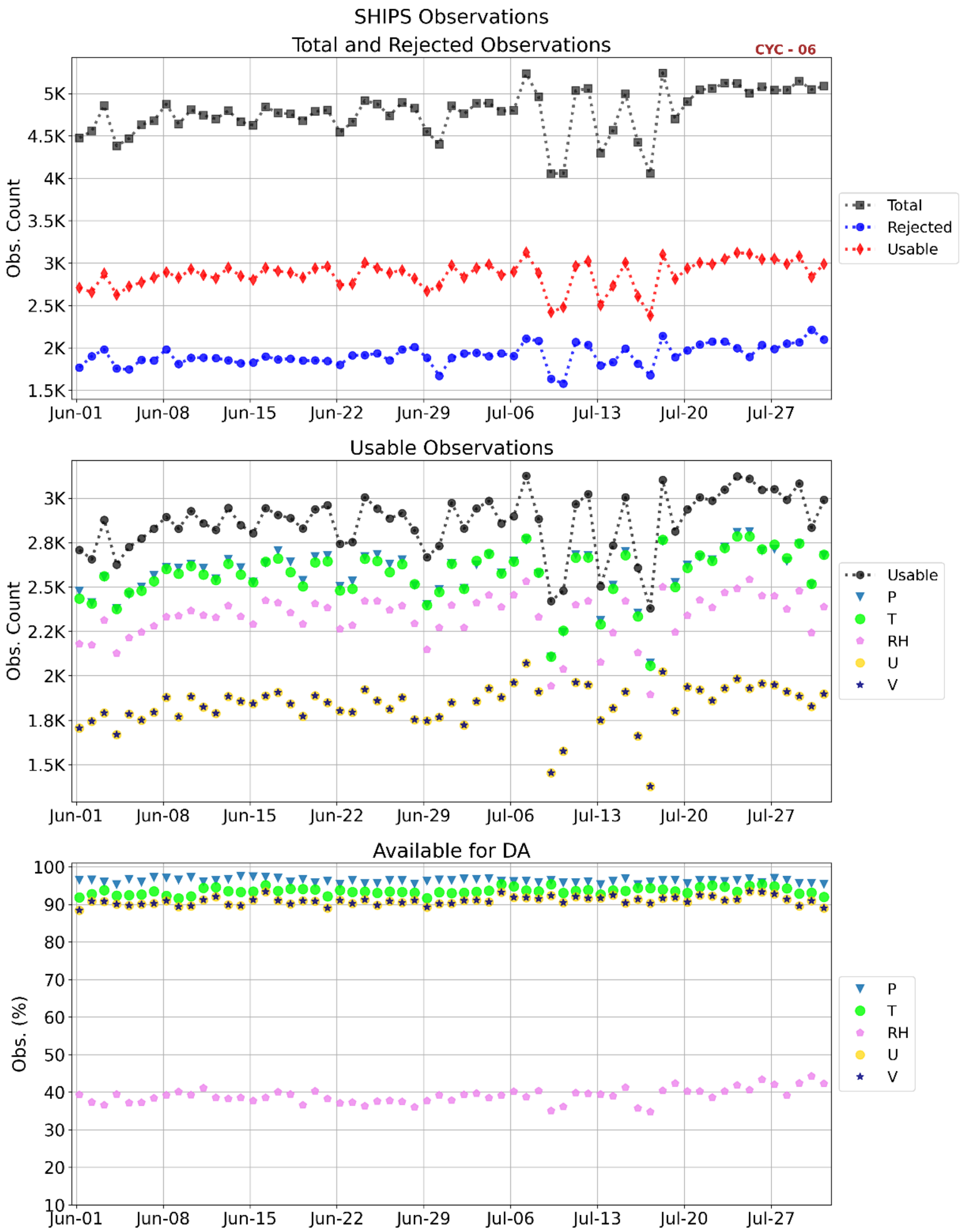

Figure 11: Similar to Figure 10, but for the time series 06 Z assimilation cycles.

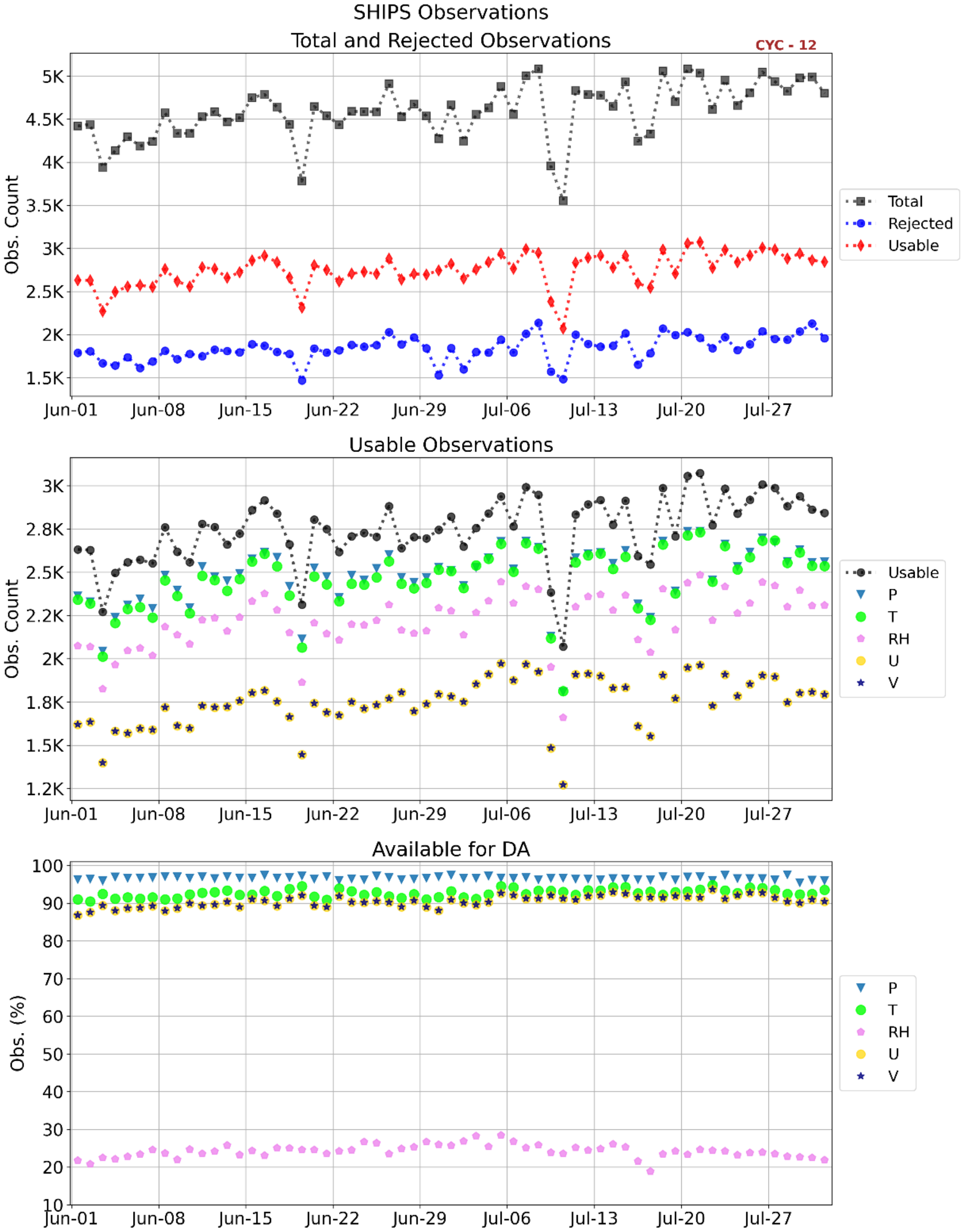

Figure 12: Similar to Figure 10, but for the time series of 12Z assimilation cycles.

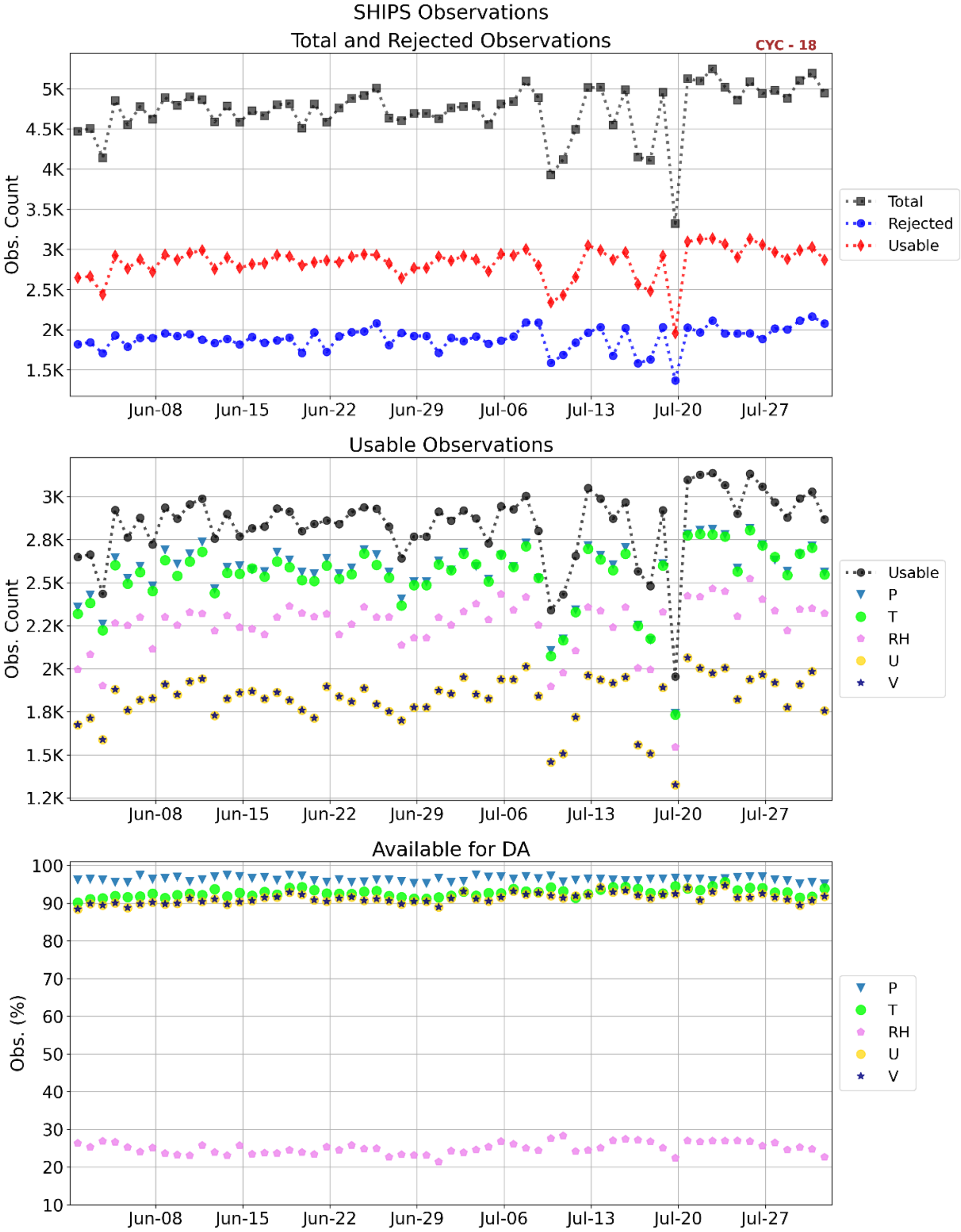

Figure 13: Similar to Figure 10, but for the time series of 18Z assimilation cycle.

Figure 14 is similar to Figure 9, but shows the various category of rejection in different SHIP variables. The percentage of rejection during background and buddy checks is larger than the final rejection and no-assimilation categories as shown in Figure 14. The percentage rejection of surface pressure observations is more in SHIP than from the SYNOP in the background, buddy, and final rejection. The no-assimilation category also shows ~3-7% in temperature, ~3-10 % in wind, and 1-5% in humidity, where the same is nearly 0% for surface pressure. Similar to land SYNOP meteorological variables, outliers are present in the percentage rejection of SHIP reported usable variables also.

Figure 14: Percentage rejection of different SHIP variables in different quality checks: background, buddy, final rejection, and no-assimilation during June-July 2021.

3.3 BUOY observations:

Figure 15 is similar to Figures 5 and 10, but for the time series of BUOY observations (drifters and moorings) valid for the 00Z assimilation cycles. Approximately 20000 – 25000 BUOY observations are reported during the 00Z assimilation cycles of June-July 2021. A slight increase in the observation count is seen since July 2021. In contrast to the SYNOP and SHIP observations, more BUOY reports are rejected. ~ 15000-20000 observations are rejected, while around 3500 observations/cycle were usable as seen in the top panel of Figure 15. The more rejection of the BUOY reports can be due to their frequent reporting, some BUOYs are reporting half-hourly, while others report either hourly or 3 hourlies. The OPS thins these observations hourly. Out of these ~ 3500 usable BUOYs, ~ 2000-2500 reports surface pressure, temperature, and wind observations as shown in the middle panel of Figure

15. The usable count of humidity information is ~ 1000-1500. Unlike land SYNOP and SHIP observations, the percentage of the usable count from the BUOY platforms lies between 80-95% for all variables as seen in the lower panel of Figure 15. The percentage assimilation of humidity information is slightly higher than that of other variables. A slight reduction in the percentage assimilation of all variables is noticed in July 2021, even though there is an increase in the number of observations received and hence the usable count. Figures 16, 17, and 18 are similar to Figure 15, but for the time series of BUOY observations for the 06, 12, and 18 Z assimilation cycles. Almost similar characteristics as those seen during the 00Z assimilation cycle can be seen in other cycles also.

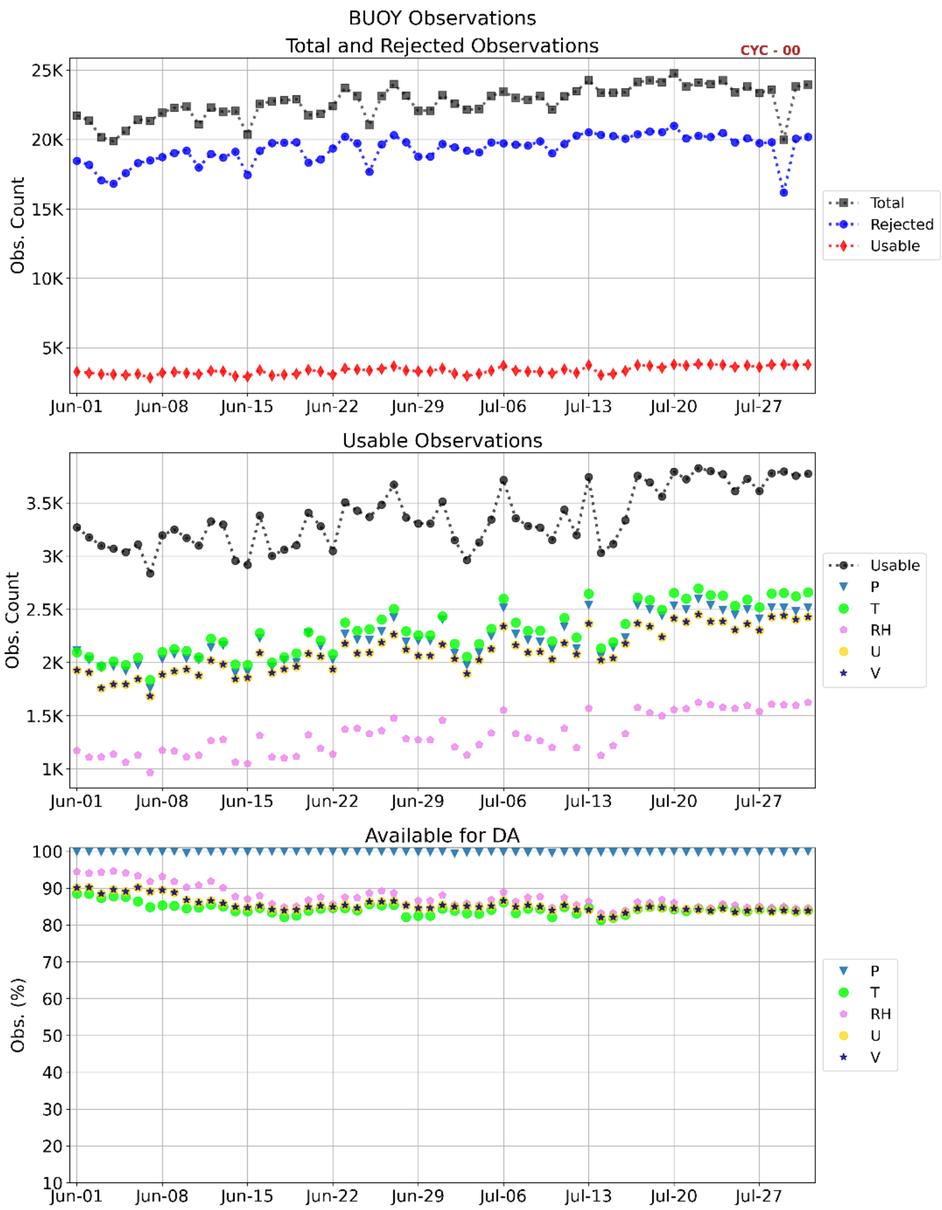

Figure 15: Time series of BUOY observation counts in the 00Z assimilation cycle (top) total received, rejected and usable, (middle) variable wise usable counts and (lower) percentage of variables available for DA during June-July 2021.

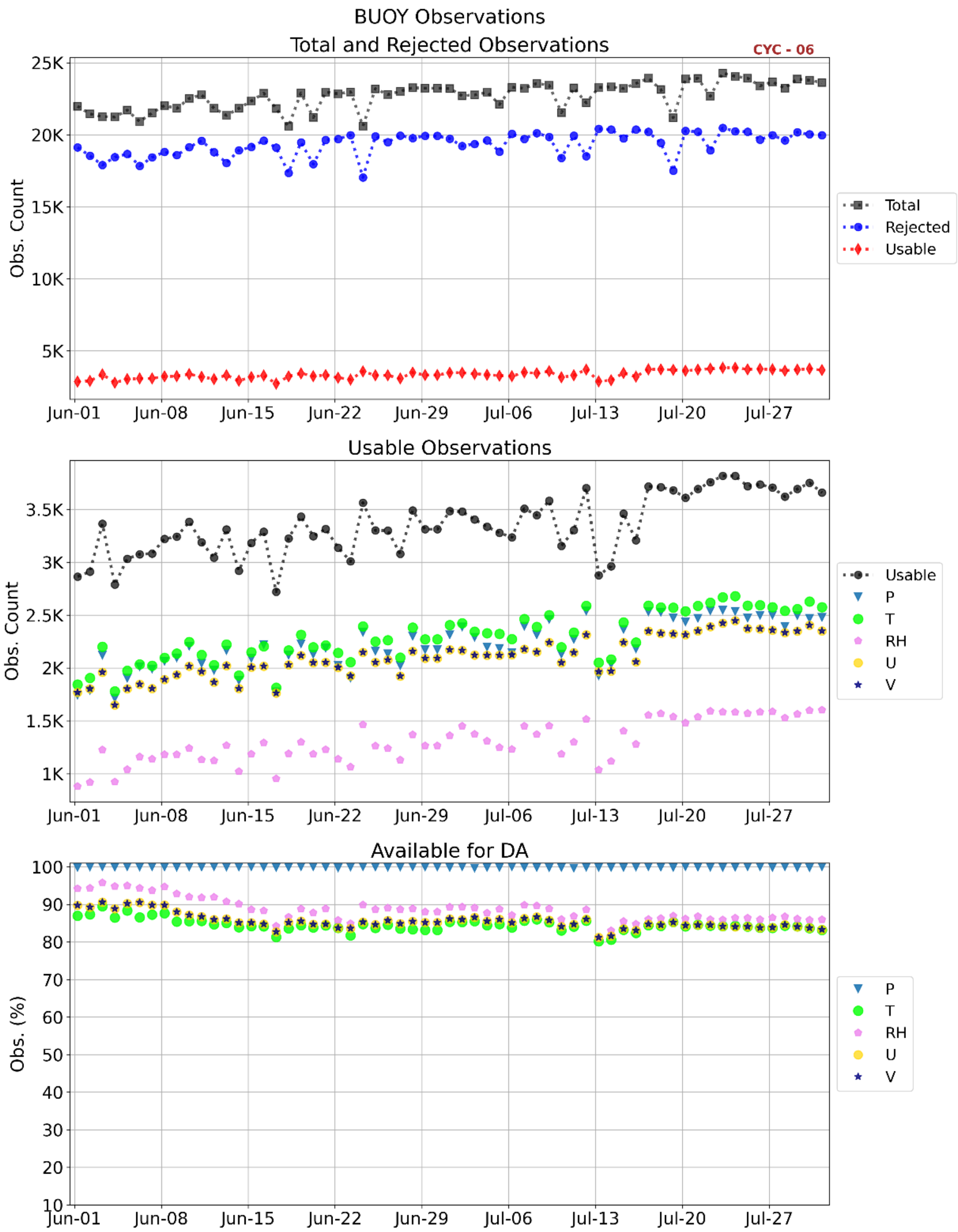

Figure 16: Similar to Figure 15, but the time series for 06Z assimilation cycles.

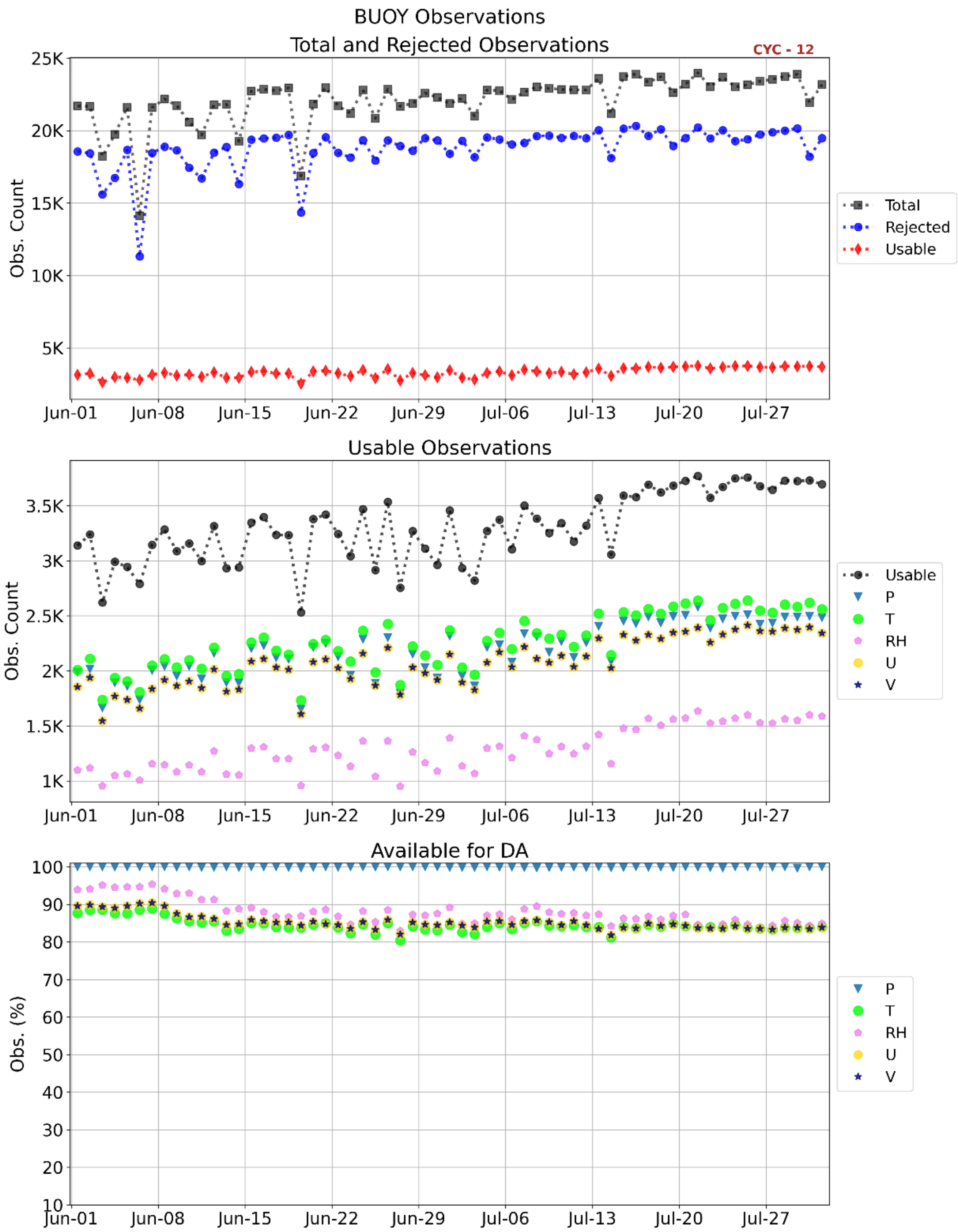

Figure 17: Similar to Figure 15, but the time series for the 12Z assimilation cycles.

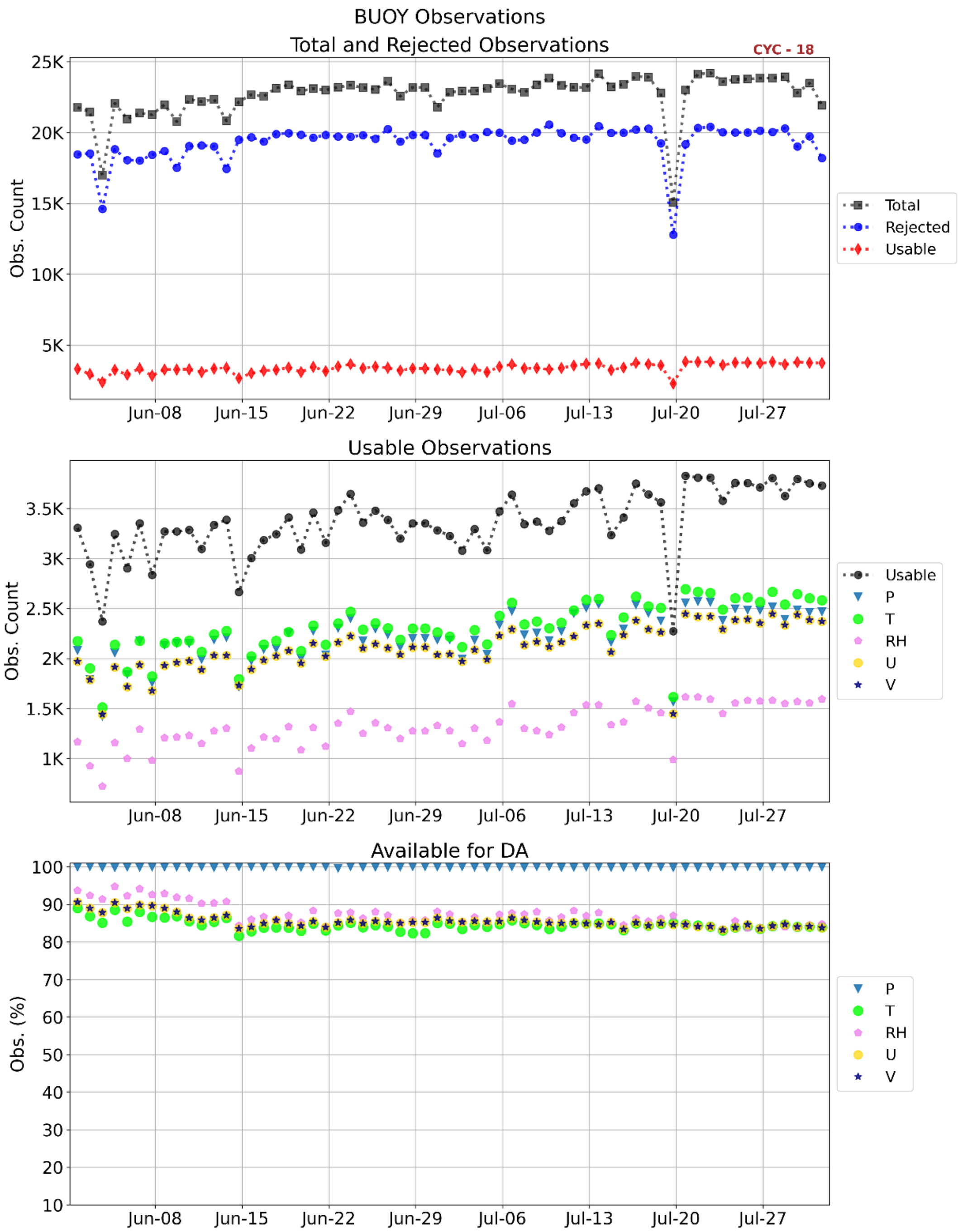

Figure 18: Similar to Figure 15, but the time series for 18Z assimilation cycles.

Figure 19 is similar to Figures 9 and 14, but for the various category of rejection in different BUOY reported variables. The percentage rejection of different variables in the background, buddy, and final checks are nearly the same as seen from Figure 19. It is ~ 0-0.2% for temperature and surface pressure, while 0-0.7% percentage for wind components, and nearly 0% for relative humidity. The no-assimilation percentage is slightly higher for BUOY meteorological parameters except for surface pressure as seen from Figure 19. ~ 11-18% of usable temperature and wind components, 3-18% of relative humidity, and nearly 0% percentage of surface pressure contribute to the no-assimilation category. Similar to land

SYNOP and SHIP reported meteorological variables; outliers are present in the percentage rejection of BUOY reported usable variables also.

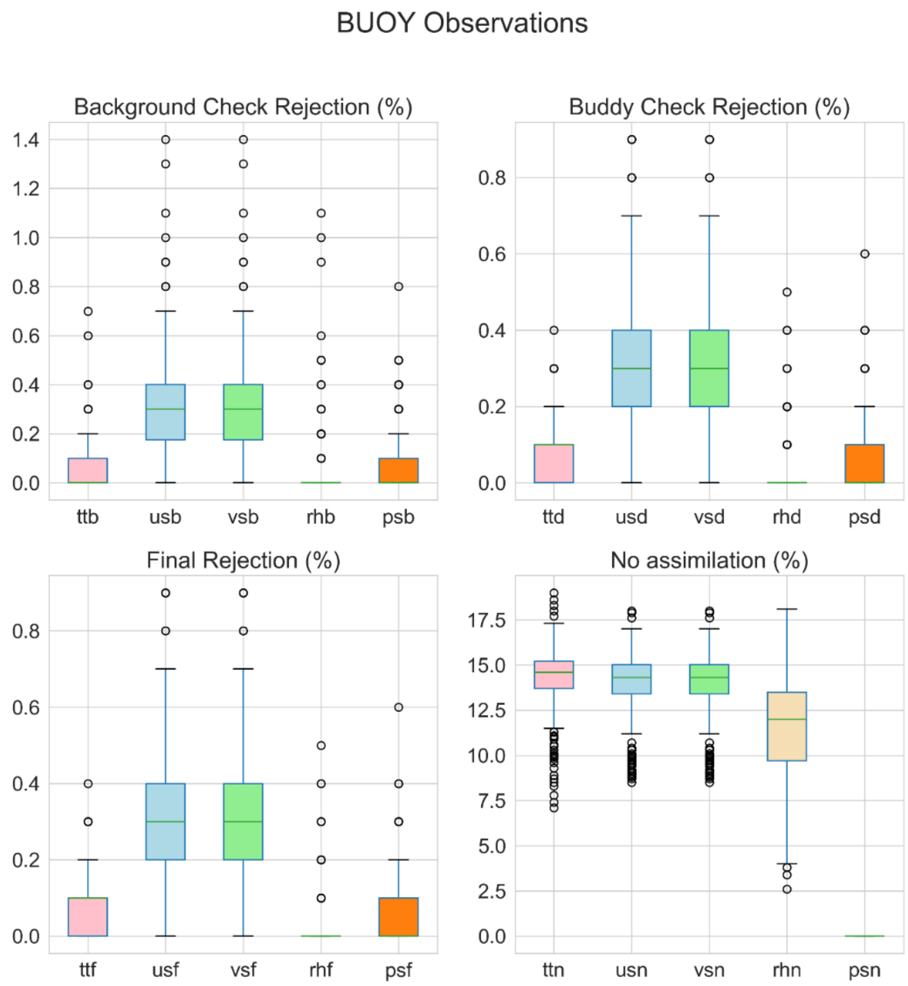

Figure 19: Percentage rejection of different BUOY variables in different quality checks: background, buddy, final rejection, and no-assimilation during June-July 2021.

4. Summary:

Surface meteorological observations received at NCMRWF during June-July 2021 have been monitored and reported in this report. Approximately 90000 global surface reports from various surface observation subtypes are received at NCMRWF during every 6 hourly assimilation cycles, and approximately 35% of these received observations are being assimilated in the NCUM DA system. These assimilated surface observation reports are mainly from SYNOP, SHIP, and BUOY. The pre-defined observation errors of different meteorological variables from the above surface observation subtypes are discussed in detail and tabulated in Table 3.

The count of reported land SYNOP observations is ~ 40000 per assimilation cycle, and around 27000 of these observations are usable in the DA system. Majority of the usable surface pressure information (98%) with 88% of temperature and humidity information and 63% of wind information has been used in every assimilation cycle. The less usage of land

SYNOP wind information is due to the rejection of wind over tropics due to the high reported error. The total count of SHIP (manual and automated) observations received at each assimilation cycle is ~5000, and ~3000 observations fall in the usable category after the quality control checks. More than 90% of the usable counts of surface pressure, temperature, and wind components from SHIPS are assimilated in each DA, while used only ~50-60% of the usable humidity observations. ~20000-25000 global BUOY (drifters and moorings) observations are received during each assimilation cycle, while ~ 15000 – 20000 of these reports are rejected. This huge rejection is mainly due to the high temporal resolution of the reports, and the observation processing system of NCUM thins these BUOY observations to hourly. Unlike land SYNOP and SHIP observations, the percentage of the usable count from the BUOY platforms lies between 80-95% for all variables.

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