NMRF/TR/04/2023

TECHNICAL REPORT

Pre-processing and Quality Control of Ocean Observations for its use in the NEMOVAR based Global Ocean Data Assimilation System at NCMRWF

Imranali M. Momin and S. Indira Rani

2023

National Centre for Medium Range Weather Forecasting
Ministry of Earth Sciences, Government of India
A-50, Sector-62, NOIDA, India 201 309

Pre-processing and Quality Control of Ocean Observations for its use in the NEMOVAR based Global Ocean Data Assimilation System at NCMRWF

Imranali M. Momin and S. Indira Rani

2023

National Centre for Medium Range Weather Forecasting
Ministry of Earth Sciences, Government of India
A-50, Sector 62, NOIDA-201309, INDIA

Ministry of Earth Sciences
National Centre for Medium Range Weather Forecasting
Document Control Data Sheet

1	Name of the Institute	National Centre for Medium Range Weather Forecasting
2	Document Number	*NMRF/TR/04/2023*
3	Month of publication	2023
4	Title of the document	Pre-processing and Quality Control of Ocean Observations for its use in the NEMOVAR based Global Ocean Data Assimilation System at NCMRWF
5	Type of Document	Technical Report
6	No of pages, Figuresand Tables	22 Pages, 8 Figures and 2 Tables
7	Number of References	16
8	Author (S)	Imranali M. Momin and S. Indira Rani
9	Originating Unit	NCMRWF
10	Abstract	NCMRWF receives a large number of global Ocean observations, both conventional and space based, from various sources and agencies. NCMRWF operationally runs the Nucleus European Modelling of the Ocean (NEMO) based Ocean Data Assimilation (ODA), popularly known as NEMOVAR. An Ocean Observation Pre-processing system (OOPpS) for the NCMRWF ODA system is developed. The objective of this report is tri-fold: (i) briefly describe the NCMRWF OOPpS, (ii) describe various quality control steps of the Ocean observations before its assimilation, and (iii) sensitivity experiments with the quality controlled observations in the ocean assimilation-forecast system. The observations processed in the OOPpS are the surface and Ocean soundings from conventional BUOY, SHIP, ARGO etc.; Sea Surface Height **(**SSH) anomaly from space based altimeters, Sea Surface Temperature (SST) from satellite based "Group for High Resolution Sea Surface Temperature (GHRSST)" dataset, and the sea ice concentrations. The quality control of the ocean observations is carried out using the UK Met office Observation Processing System (OPS). NCMRWF routinely receives quality controlled Ocean observations from the UK Met office. Sensitivity experiments were carried out to see the impact of quality controlled observations obtained from the UK Met Office and the observation pre-processed using OOPpS and quality controlled at NCMRWF in the NEMOVAR system.
11	Security classification	Non-Secure
12	Distribution	Unrestricted Distribution
13	Key Words	Quality Control, OPS, NEMO, ODA

Table of Contents

1. Introduction

Observations are key for understanding how the Earth system – the atmosphere, oceans, land and cryosphere – shapes our weather, climate and hydrology. NCMRWF routinely receives different meteorological and Ocean observations through various sources like Global Telecommunication System (GTS), EumetCast, NOAA, NRSC, IMD, etc., for its use in the numerical weather forecast systems. Pre-processing of these observations according to the requirement of the respective operational centres for further quality control and assimilation is a part of Global Data Processing System (GDPS). NCMRWF indigenously developed an Observation Pre-processing System (OPpS) for its Unified Model (UM) based NWP systems Prasad (2012); Prasad and Rani (2014); Prasad (2014); Buddhi et al. (2019). In line with the atmospheric OPpS, recently, NCMRWF developed an Observation Pre-processing System for the Ocean assimilation-forecast system. The Ocean Observation Pre-processing System (OOPpS) converts different types of Ocean observations into the required format (observation storage: obstore) for its quality control and assimilation.

Quality controlled Ocean observations are optimally combined with ocean model short lead-time forecast (background) using a mathematically rigorous process called data assimilation to define the state-of-the ocean (known as ocean "analysis") as accurately as possible for initializing the ocean models. Near real time availability of observations and their processing, including quality control, are essential to prepare better-quality ocean analysis. Both near real time and delayed time (late arrival) datasets are used in operational oceanography. The near-real-time data is important for operational ocean forecasting activities. The delayed informationis crucial for preparing the reanalysis and monitoring (and predicting) the seasonal and climate variability. The observational error and model uncertainty estimates are also critical to data assimilation systems. Le Traon et al. (2009) briefly describe the data assembly and processing centre requirements and their role and function for operational oceanography. They also show that the progress in terms of validation, inter-calibration, and merger of altimeter data from multiple satellites improved the accuracy and timeliness of products. Cumming et al. (2009) described the various data assimilation systems developed within the Global Ocean Data Assimilation Experiment (GODAE) in terms of quality control, cycling and time windows, model bias, initialization and performance. Balmaseda et al. (2009) showed the importance of ocean initialization for skilful seasonal forecasts, although errors in the coupled models can overshadow its impact. NCMRWF operationally runs the Nucleus European Modelling of the Ocean (NEMO) based Ocean Data Assimilation (ODA), popularly known as NEMOVAR (Madec, 2008). The quality controlled observations provided by the U. K. Met Office has been used in this system. This report describes the Ocean Observation Pre-processing System (OOPpS) developed at NCMRWF, quality control of ocean observations and sensitivity experiments with the quality controlled ocean observations from the NCMRWF and the UK Met Office.

An overview of the various ocean observations assimilated in the NCMRWF NEMOVAR system and their sub-types are described in section 2. The NCMRWF OOPpS system is described in section 3. The generation of NEMO background for its use in the Observation Processing System (OPS) is described in section 4. The OPS, which does the quality control of the observations, is described in section 5. Section 6 briefly described the spatial coverage of the various observations received at NCMRWF. Sensitivity experiments are carried out with assimilation of quality controlled observations from the NCMRWF and UK Met Office in the NEMOVAR. The result from above experiments are briefly described in the section 7. The summary of this developmental and research work is given in section 8.

2. Ocean observations: Surface and Space-borne

Compared to the conventional atmospheric observations, its ocean counterpart is very limited. Various conventional ocean observations are being received at NCMRWF through GTS e.g. BUOYs and SHIPs. These include both single and multi-level observations. Sea Surface Temperatures (SSTs) from the BUOYs and SHIPs are the main single level observations. The multi-level observations are, generally known as Ocean Soundings, include the BATHY, TESAC and Profiles from BUOY platforms. Both BATHY and TESAC reports are from the SHIPs. The BATHY report contains temperature observations at versus depth taken with instruments that provide the temperature with a resolution of 0.1 degrees Celsius or less, such as mechanical or expendable Bathythermographs, thermistor chains or others.The TESAC report is used for temperature values with a higher resolution and/or when salinity or current versus depth are reported. The BUOY profiles contain the observations from moored buoys, including the salinity and temperature measurements at different ocean depths.

In addition to the above mentioned conventional observations, NCMRWF receives various satellite measured variables from different active and passive instruments. Altimeter observations, SSTs and Sea Ice concentration measured by various satellite instruments are a few of them. Satellite altimetry measures the time taken for the radar pulse to travel from the satellite to the sea surface and back to the satellite. Operational centres assimilate Sea Surface Height (SSH) anomaly from the altimeter in the Ocean and coupled assimilation systems.

Pre-processed ocean observations are classified into five different categories/types. They are

1. **Surface**: includes the SSTs from BUOY and SHIP observations
2. **Altimeter**: Sea Surface Height anomaly observations from satellite altimeters
3. **SatSST**: SSTs measured by satellite instruments
4. **OceanSound**: BATHY, TESAC, BUOY and ARGO profiles
5. **SeaICe**: Sea Ice concentration.

Many of the above observation types have various subtypes. Table 1 describes the different observation subtypes and their description.

Table 1: Various ocean observations with description and source of data

Sl.no.	Observation Type	Subtype Number	Description	Source
1	Surface	10200	SSTs from SHIP	GTS (ASCII and BUFR)
		10300	SSTs from BUOY	
2	Altimeter	23000	Altimeter SSH	My Ocean
		23001	Altimeter SSH (real time)	
		23002	Altimeter SSH with extra variables	
3	SatSST	24400	The Group for High Resolution Sea Surface Temperature (GHRSST)	GHRSST
4	OceanSound	60100	BATHY	GTS (ASCII and BUFR)
		60200	TESAC	
		60300	BUOY Profiles	
5	SeaICe	60500	Sea ice concentration	Eumetsat

3. Ocean Observation Pre-processing System (OOPps)

Before actual assimilation, the ocean observations have to be pre-processed and pack them in obstore format. Various parameters in the observational dataset have to be arranged in a specified fashion (element list), which is unique for each type of observation. The element list corresponding to the five types of ocean observations described in section 2 is available at https://code.metoffice.gov.uk/trac/ops/browser/main/branches/test/adammaycock/r5060_create-foam-obstores/rose-stem/etc/elements-eo. One time preparation of a header file corresponding to each observation type according to the element list is essential for "obstore" file generation. Each variable in the element list is indexed to a particular number and mapped to this unique number, and stored in the header file (more details in https://code.metoffice.gov.uk/trac/ops/browser/main/trunk/src/code/OpsMod_Index/OpsMod_Index.f90, https://code.metoffice.gov.uk/trac/ops/browser/main/trunk/src/code/OpsMod_Index/Ops_InitElementDescrip.inc).

Both Surface and profile observations are received through GTS in WMO ASCII and BUFR data formats. These observations are decoded using the NCEP decoder and write the observations in ASCII format according to the element list. The altimeter, satellite SSTs and Sea Ice observations are in NetCDF, and they are also written in ASCII according to the element list. All satellite data (MetOp-B, Jason-3, Sentinel 3A &3B, and SSMI/S) from different sources are converted into ASCII format using "ferret" software developed by the Thermal Modeling and Analysis Project (TMAP) atNational Oceanic and Atmospheric Administration/Pacific Marine Environmental Laboratory. The "ferret" scripts such as data_sst.jnl, data_sla.jnl, data_ice_nh.jnl and data_ice_sh.jnl convert SST, SLA and SIC data from NetCDF into ASCII format (Appendix-I). A collection of FORTRAN programmes and modules hasbeen developed to prepare the "obstore" files from these intermediate ASCII files. Figure 1 shows the flow chart of the different stages of "obstore" preparation.

The satellite instruments produced large amounts of measurements that can be ingested into the operational Ocean analysis system. These large volume data at different spatial and temporal scales require careful pre-processing and quality control before its use in the data assimilation system. Liu and Rabier (2002) have shown a connection between the observation density and the resolution of the model grid and shows that the analysis quality is decreased due to the large density of observational data. The GHRSST MetOp-B level 2 data is available in very high temporal and spatial resolution (every 3 minutes and ~1 km spatial scale). The data thinning (0.1^{o} resolution; ~10 km) is carried out before its use in the assimilation system.

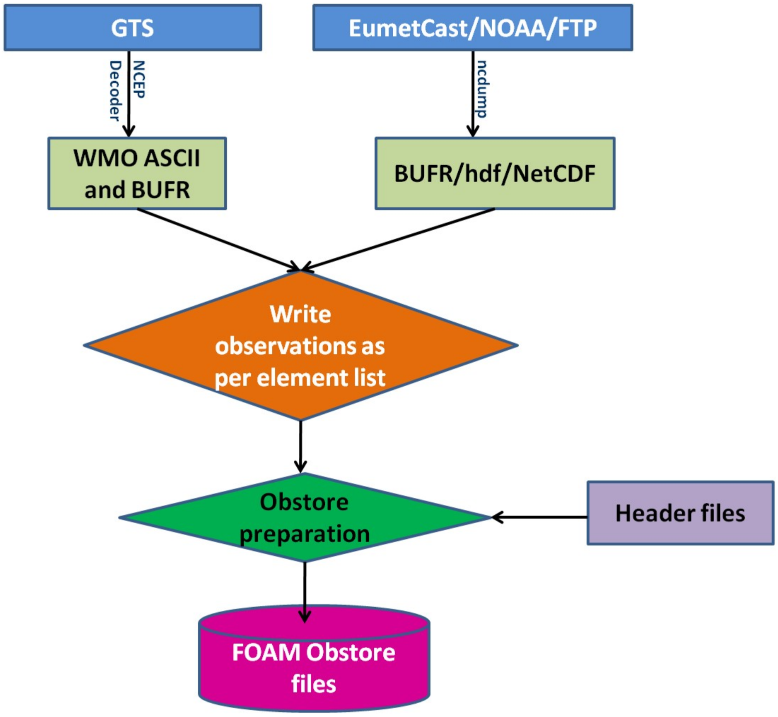

Figure 1: Flow chart depicting different stages of the preparation of various Ocean obstore files

4. Conversion of NEMO Background for its use in the assimilation system

In the Met Office Unified Model (UM), all the data files (dumps, ancillary, boundary, output files which are in Met Office field file(FF) format) have a well defined common structure which is described in the Unified Model Document Paper F3 (UMDP-F3). The UM files have a primary header record with pointers to a series of secondary header records and records pointing to the data areas. More detail of UMDP-F3 format is available in http://cms.ncas.ac.uk/documents/vn4.5/pf003.pdf. However, the NEMO based global ODA system produces three dimensional ocean states in NetCDF format, which is different from the UMDP-F3 format. The flow diagram depicting the conversion of NEMO NetCDF to the UM FF for its use in the OPS for the observation quality control is shown in Figure 2.

To convert the NEMO background into the UM FF, the background fields such as temperature, salinity profiles, sea surface height, and sea ice concentration are first transformed from NetCDF to UM Post Processed (PP) format using an IDL programme (Appendix-II). These programs need basic information of STATH codes and FIELD codes for all background fields. Table 2 shows the list of background fields and their corresponding STASH and FIELD codes.

This information is part of a 64 word long header associated with each PP file. The PP file is then converted to UM FF (using pp2anc.exe executable) format, and used as the model background (first guess) field in the OPS for the observation quality control.

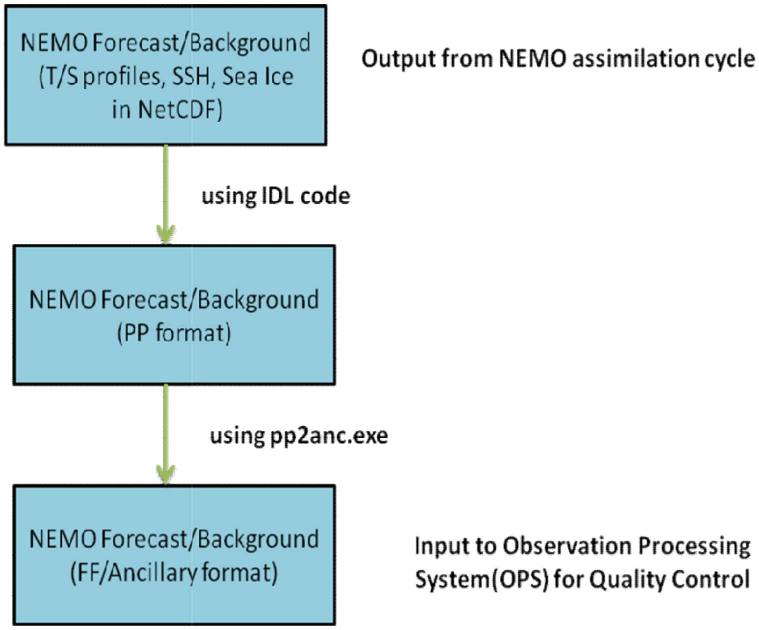

Figure 2: Processing of NEMO background(NetCDF to FF) for its use in OPS.

Table 2: List of NEMO background fields and associated stash code and field codes

Variables	Stash Code	Field Code
Votemper (Temperature Profile)	101	601
Vosaline (Salinity Profile)	102	602
Sea Surface Height	285	617
Sea Ice Concentration (SIC)	146	685

5. Quality Control of Ocean Observations: The Observation Processing System (OPS)

The quality control of observations is anessential step of the data assimilation system. The OPS does the quality control of observations. The OPS extracts the ocean observations from the database, processes them and write them inan appropriate format required by the data assimilation system. The OPS system uses “obstore” formatdata, model background field (UM FF), and related model error as the main inputs, in addition to some fixed files called stationlists which control the block wise listing of observations.

OPS reads the observations and model background fields and applies various quality checks such as internal consistency check, range check, profile check, multi-level check, track check, background check, buddy check, etc. More details of quality control methods for ocean temperature and salinity profiles with uncertainty estimates is well described in Good, Martin and Rayner (2013). We have used UM OPS (version 2019.02.0) for quality control of ocean observations, which has been implemented at NCMRWF in June 2020. Kumar et al. (2020) briefly described the current operational NCUM Global NWP System along with the OPS. The main OPS outputs are quality controlled and processed (thinning, stationlist rejection, etc.) observations in NetCDF format and observation statistics files.This NetCDF output of OPS is used as input to the NEMOVAR assimilation system.

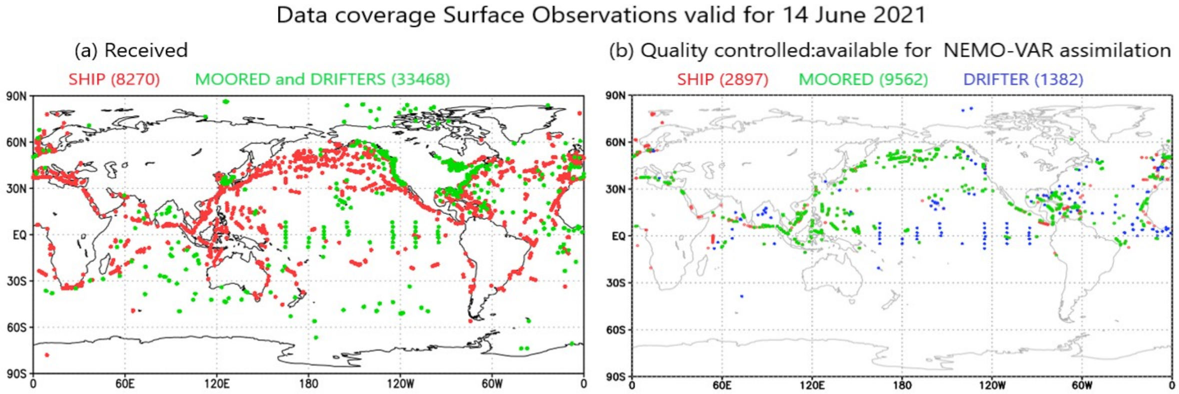

Figure 3: Ocean surface (single level) observation coverage plots. (a) the number of observations received and (b) the number of OPS quality controlled observations that are available for NEMOVAR assimilation for a typical day, 14 June 2021.

Figure 3 compares the surface observation coverage, the number of observations received (Figure 3a) and the number of observations available for NEMOVAR assimilation after quality control and thinning (Figure 3b). The OPS rejects many observations that are not meeting the quality criteria, as seen from Figure 3. It is also noticed that a large number of surface observations over the Southern Hemisphere are being received at NCMRWF, but most of them are rejected after quality control procedures. The SSTs from SHIP and BUOY (both moorings and drifters) platforms are packed as 10200 and 10300 subtypes in the “obstore”, while the OPS segregate the observations according to the SHIP/BUOY identity. Figure 3b shows separate moorings and drifter observations from BUOY platforms after OPS quality control.

Figure 4 is similar to Figure 3 but for the ocean profiles from various platforms. Identical to the surface observations, a large number of ocean profiles are being received at NCMRWF through GTS (Figure 4a), while OPS rejects large numbersafter quality control procedures (Figure 4b). Unlike the surface observations, profiles from the Southern Hemisphere pass quality control checks,as seen from Figure 4b.

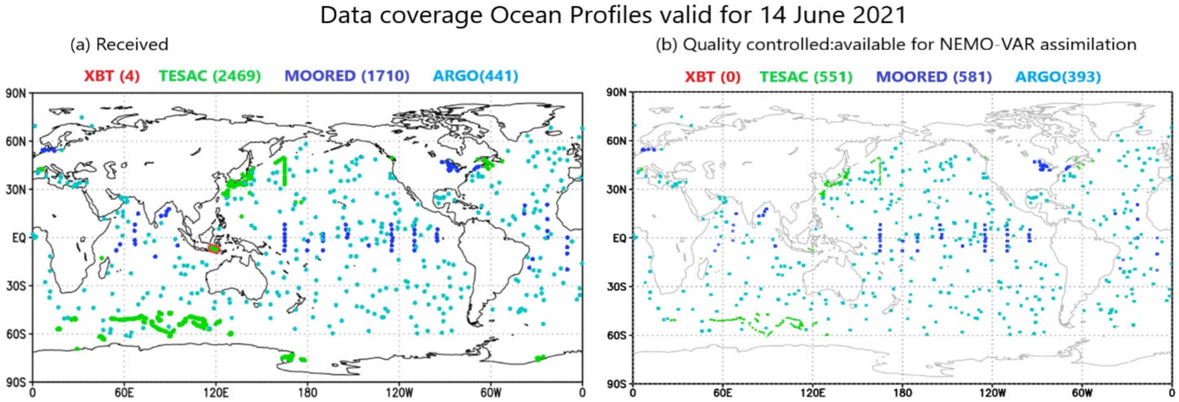

Figure 4: Similar to Figure 3, but for the Ocean profiles from various platforms.

The other datasets described in Table 1 (Altimeter, SatSST, and SeaICe) show almost similar spatial coverage after the quality control as seen in the data reception coverage, with some difference may be due to observation thinning or bad dataset. Those coverage plots are not included here but shown in the next section,explaining the sensitivity experiments.

6. Sensitivity Experiments

NCMRWF receives quality controlled Ocean observation from the U. K. Met Office, and the same has been routinely assimilated in the NEMOVAR. Sensitivity experiments with the quality controlled observations from the Met Office and NCMRWF were carried out for one month from 17 September to 17 October 2020 (one month). This section describes the differences in the coverage of various ocean observations from Met Office and NCMRWF and the details of sensitivity experiment results.

Figure 5 shows the locations of quality controlled ocean observations from NCMRWF and Met Office on a typical day (01 October 2020). The first column in Figure 5 shows the Surface, SatSST, Altimeter Sea Level Anomaly (SLA), and SeaICe observations from NCMRWF, whereas the second column shows the similar coverage from Met Office data. The quality controlled satellite observations are identical from both the centres (Figures 5c to 5h). Contrary to satellite observations, there is a significant difference in the coverage of quality controlled conventional observations (surface) from both the centres, as seen in Figures 5a and 5b.

NCMRWF is not receiving many conventional in-situ ocean surface observations over the Southern Hemisphere (Figures 3a and 5a). The underlying reasons for the difference in the number of surface observations have to be investigated further.

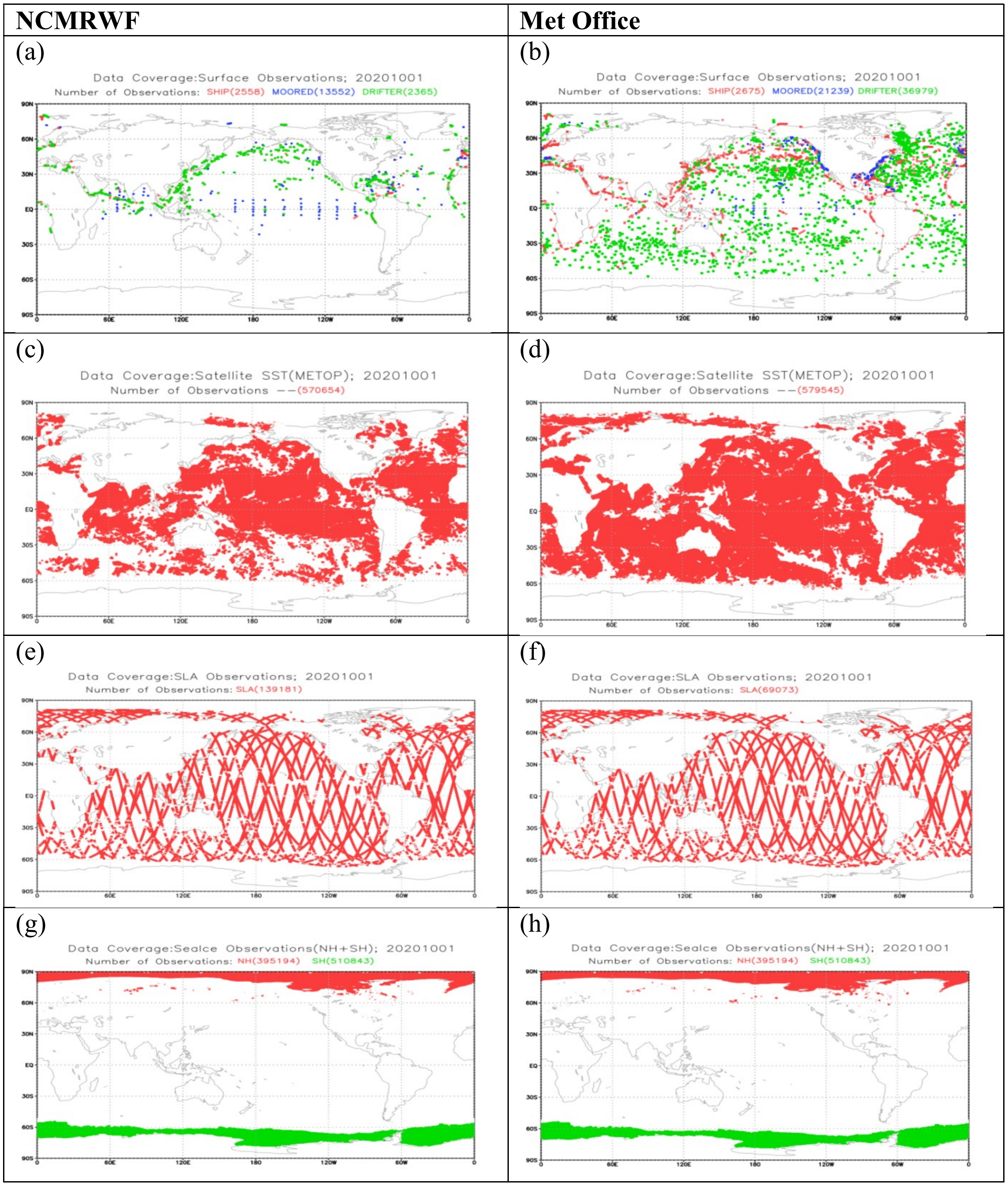

Figure 5: Locations of quality controlled observations from NCMRWF (first column) and Met Office (second column) on a typical day (01 October 2020). The coverage plots of Surface, SatSST, Altimeter, and SeaICe are presented here.

Sensitivity experiments are carried out to understand the impact of quality controlled ocean observations from NCMRWF and Met Office on NEMOVAR for one month, 17 September 2020 to 17 October 2020. The two sensitivity experiments, EXP_NCMR (uses observations processed at NCMRWF) and EXP_MetO (uses observations received from Met Office), are carried out to see the changes in assimilation due to the differences in the observation dataset. NEMOVAR assimilation system with NEMO based global ocean model and the Los Alamos Sea ice model (CICE) at ~¼ degree horizontal resolution with 75 layers in vertical is used in the experiments. More technical detail of NEMOVARODAsystem at NCMRWF is available in Momin et al., (2020). NEMOVAR analysis is used to initialize the global coupled atmosphere-ocean model for weather, extended range and seasonal forecasts (Gupta et al., 2019). In each assimilation cycle, the NEMO background fields are mapped into the observation space using the bilinear and cubic splines interpolation along the horizontal and vertical directions to create the First Guess at Appropriate Time (FGAT) and innovations (difference between first guess and observation). NEMOVARassimilation system uses the innovations to generate the increments in background fields (temperature, salinity, SSH, and currents) and produces the analysis using multivariate relations through a linearized balance operator (Weaver *et al*., 2005).

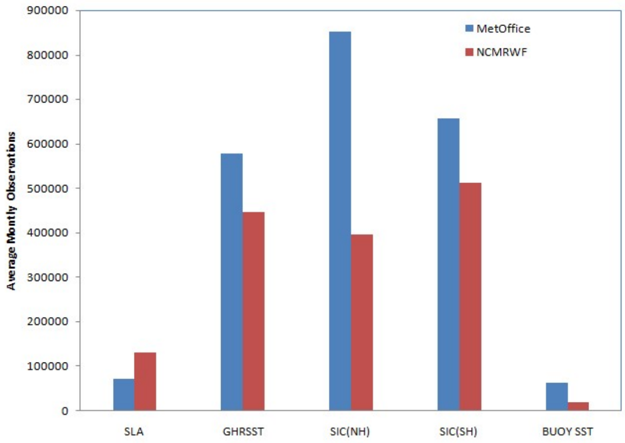

Figure 6: Monthly mean count of Ocean observations assimilated in the two sensitivity experiments: Met Office (Blue) and NCMRWF (Red).

Figure 6 shows the monthly mean count of various Ocean observations assimilated in the EXP_MetO and EXP_NCMR. It is noted from Figure 6 that except for the Sea Level Anomaly (SLA) observations, EXP_MetO assimilated more observations than the EXP_NCMR. Though the coverage plots (Figure 5) show both the centres have a nearly similar coverage of satellite observations, more satellite SST (GHRSST) and Sea ice information is there in the Met Office quality controlled dataset. As seen from the coverage plots of conventional ocean surface observations (Figures 3 and 5a), the number of observations assimilated in the EXP_NCMR is almost half that assimilated in EXP_MetO.

Figure 7 shows the monthly mean analysis increments in the SST and Sea Surface Salinity (SSS) from the two sensitivity experiments. The monthly mean analysis increments in the SST shows noticeable differences between the EXP_MetO (Figure 7a) and EXP_NCMR (Figure 7b). The differences in the analysis increments in the SST from both the experiments can be attributed to the assimilation of more conventional and satellite SST observations in the EXP_MetO than the EXP_NCMR. Less conventional SST observations assimilated in EXP_NCMR might be a reason for the higher values of analysis increments over the Southern Hemisphere (Figure 7b). The analysis increments in the SSS are similar from both the experiments, as shown in Figures 7c and 7d.

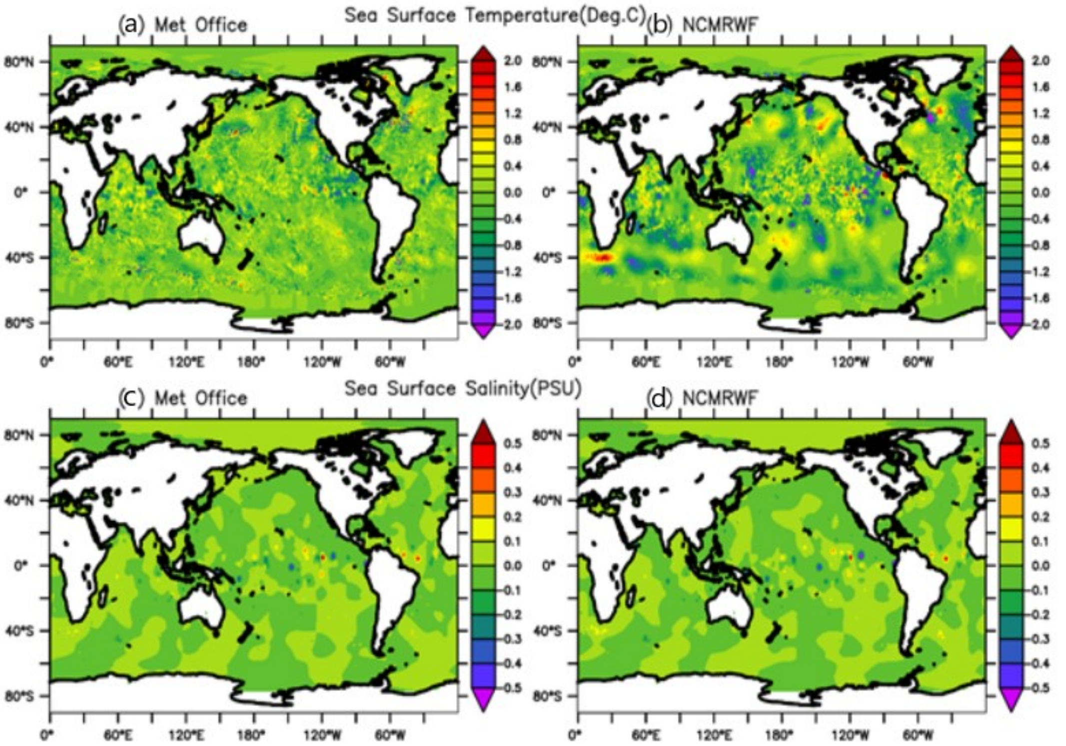

Figure 7: Comparison of monthly average analysis increments from EXP_MetO and EXP_NCMR. SST(Deg. C) increments in (a) Met Office, (b) NCMRWF and SSS(PSU) increments in (c) Met Office and (d) NCMRWF.

Figure 8 is similar to Figure 7, but for the monthly mean analysis increments in the temperature and SSS at a depth of 200 m. Compared to the monthly mean increments in the SST (Figures 7a and 7b), there is a consensus in the temperature increments at the depth of 200 m from the Met office, and NCMRWF runs as seen from Figures 8a and 8b. The SSS increments at 200 m depth from both the runs are similar (Figures 8c and 8d).

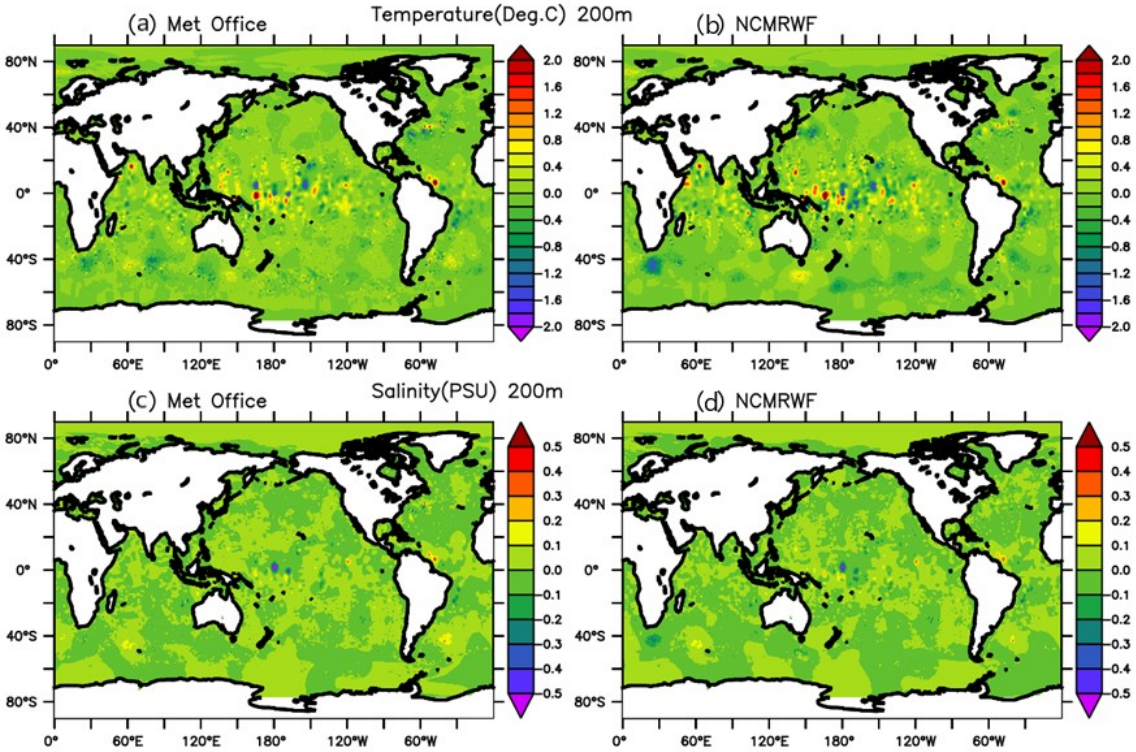

Figure 8: Similar to Figure 6, but for the temperature and salinity at 200 m depth.

The sensitivity experiments show that, in general, the SSS increments from both the experiments are approximately the same at the surface and 200 m depth. There is a visible change in the SST increments from both the runs, whereas the temperature increments are similar at 200 m depth in both experiments.

7. Summary and Conclusions

An indigenously developed Ocean Observation Pre-processing System (OOPpS) is introduced in this report. The OOPpS processes various observations received at NCMRWF,including those from conventional and satellite platforms. The pre-processed observations are quality controlled through the OPS, which compares the observations with the background fields and does various quality checks. Sensitivity experiments were carried out to assess the impact of these quality controlled observations prepared using the newly developed OOPpS system and OPS in the NEMOVAR system. Sensitivity experiments have been conducted with two sets of quality controlled observations, those from Met Office and NCMRWF, for one month. The study shows that the analysis increments in the sub-surface fields are identical in the two runs using Met Office and NCMRWF datasets. In contrast, the increments in the SST shows noticeable differences between the two runs. The differences in the SST increments can be attributed to the fewer observations received and packed into the NCMRWF dataset than the same from the Met office. Efforts are on at NCMRWF to acquire and process more ocean conventional observations.

Acknowledgements

The authors would like to thank Dr. D. Lea for his technical help related to the conversion of NetCDF to PP format. We also would like to thank Dr. Matt Martin for his valuable suggestion related to the quality control of satellite SST data. We are thankful to the NEMOVAR consortium for their support. The GHRSST project, MyOcean project and EUMETSAT website are also thankfully acknowledged for providing the near real time satellite SST, SLA, and Sea Ice data, respectively.The authors also express heartfelt gratitude to Dr. V. S. Prasad (Head, NCMRWF), Dr. A.K. Mitra (Ex Head, NCMRWF), Dr. Munmun Das Gupta, Dr. John P. George, Dr. Sumit Kumar and Dr. Priti Sharma for their help during various stages of the study.

References

Balmaseda, M.A., O.J. Alves, A. Arribas, T. Awaji, D.W. Behringer, N. Ferry, Y. Fujii, T. Lee, M. Rienecker, T. Rosati, and D. Stammer. 2009. Ocean initialization for seasonal forecasts. Oceanography 22(3):154–159, https://doi.org/10.5670/oceanog.2009.73.

Cummings, J., L. Bertino, P. Brasseur, I. Fukumori, M. Kamachi, M.J. Martin, K. Mogensen, P. Oke, C.E. Testut, J. Verron, and A. Weaver. 2009: Ocean data assimilation systems for GODAE. Oceanography 22(3):96–109, https://doi.org/10.5670/oceanog.2009.69.

Good S. A., M. J. Martin and N. A. Rayner, (2013): EN4: Quality controlled ocean temperature and salinity profiles and monthly objective analyses with uncertainty estimates, Journal of Geophysical Research Oceans, 118(12), 6704-6716.

Gupta A., A. K. Mitra and E. N. Rajagopal, 2019: Implementation of Unified Model based global Coupled Modelling Systemat NCMRWF, NMRF/TR/01/2019, 52pp.

Jangid, B. P., Bushair, M. T., Rani, S. I., George, G., Kumar, S., and George, J. P., 2019: Improved NCUM Observation Pre-processing System (NOPpS), NMRF/TR/05/2019 (https://www.ncmrwf.gov.in/Reports-eng/NOPps_TR_May2019.pdf)

Le Traon, P.-Y., G. Larnicol, S. Guinehut, S. Pouliquen, A. Bentamy, D. Roemmich, C. Donlon, H. Roquet, G. Jacobs, D. Griffin, F. Bonjean, N. Hoepffner, and L.-A. Breivik. 2009.

Data assembly and processing for operational oceanography: 10 years of achievements. Oceanography 22(3):56–69, https://doi.org/10.5670/oceanog.2009.66.

Liu Z-Q, Rabier F. 2002. The interaction between model resolution, observationresolution and observation density in data assimilation: A one-dimensional study. Q. J. R. Meteorol. Soc. 128: 1367–1386.

Madec G, 2003: Nemo ocean engine. In Note du Ple de modlisation, number 27.

Martin M. J., M. Balmaseda, L. Bertino, P. Brasseur, G. Brassington, J.Cummings, Y. Fujii, D.J. Lea, J.-M. Lellouche, K. Mogensen, P.R. Oke, G.C.Smith, C.-E. Testut, G.A. Waagbø, J. Waters & A.T. Weaver, 2015: Status and future of data assimilation inoperational oceanography, Journal of Operational Oceanography, 8:1, s28-s48, DOI:10.1080/1755876X.2015.1022055.

Momin I. M., Ashis K. Mitra, and E. N. Rajagopal, 2020: Implementation of NEMO based Global 3D-Var Ocean Data Assimilation system at NCMRWF: Technical Aspects, NMRF/TR/02/2020, 26pp.

Prasad, V.S., 2012: Conversion of NCEP Decoded data to UKMET office Obstore format,NCMR/OB/1/2012, 34 pp.

Prasad, V. S., 2014:Satellite Data Processing for NCMRWF Unified Model (NCUM), NMRF/RR/2/2014.

Prasad, V. S., and Rani, S. I., 2014:Data Pre-Processing for NCMRWF Unified Model (NCUM): Version 2, NMRF/RR/1/2014

Kumar, S., M. T. Bushair, Buddhi Prakash J., Abhishek Lodh, Priti Sharma, GibiesGeorge, Indira Rani, John P. George, A. Jayakumar, Saji Mohandas, Sushant Kumar, Kuldeep Sharma, S. Karunasagar, and E. N. Rajagopal, 2020: NCUM Global NWP System: Version 6 (NCUM-G:V6), NMRF/TR/06/2020, 32pp.

Waters J., D. J. Lea, M. J. Martin, I. Mirouze, A. T. Weaver, and J. While, 2014: Implementing a variational data assimilation system in an operational 1/4 degree global ocean model, *Q. J. Roy. Meteor. Soc.,* doi:10.1002/qj.2388.

Weaver, A.T.; Deltel, C.; Machu, E.; Ricci, S., and Dagget, N., 2005. A multivariate balance operator for variational ocean data assimilation. Quarterly Journal of the Royal Meteorology Society, 131(3), 3605-3625.

Appendix-I

```
##############################  NetCDF to ASCII conversion ##########################
```

SST Script:ferret –script data_sst.jnl 20201106000103-OSISAF-L2P_GHRSST-SSTsubskin-AVHRR_SST_METOP_B-sstmgr_metop01_20201106_000103-v02.0-fv01.0.nc

```
use $1
set mem/size=10000
let sst=sea_surface_temperature
let wind=wind_speed
let ssestd=SSES_STANDARD_DEVIATION
let ssebias=SSES_BIAS
list/x=0:360/y=-83:89/clobber/noheader/file=data.txt/format=(2(f7.2,2x),5(f9.3,2x))
x[g=sst],y[g=sst],sst,wind,ssestd,ssebias,quality_level
##################################################################################
##############################  NetCDF to ASCII conversion ##########################
```

SLA Script:ferret –script data_sla.jnl j3_L3_YYYYMMDD.nc (Jason-3); ferret –script data_sla.jnl s3a_L3_ YYYYMMDD.nc (Sentinel 3A); ferret –script data_sla.jnls3b_L3_ YYYYMMDD.nc (Sentinel 3B)

```
use "$1"
let year=$2
let mon=$3
let day=$4
list/clobber/file="sla.txt"/noheader/format=(2(f7.2,2x),3(f5.0,2x))
latitude[d=1],longitude[d=1],year,mon,day
let satid=latitude*0+$5
list/clobber/file="sla1.txt"/noheader/format=(1(f7.1,2x),1(f9.3)) satid,sla_filtered[d=1]
list/clobber/file="sla2.txt"/noheadersla_filtered[d=1]
##################################################################################
##############################  NetCDF to ASCII conversion ##########################
```

SIC Script:ferret –script data_ice.jnl ice_conc_nh_polstere-100_multi_YYYYMMDD1200.nc (NH Sea Ice);**ferret** –script data_ice.jnl ice_conc_sh_polstere-100_multi_YYYYMMDD1200.nc (SH Sea Ice).

```
use $1
set mem/size=10000
let year=$2
let mon=$3
let day=$4
let hr=$5
let mn=$6
let stlt=5
let ice_conc1=ice_conc/100  !   convert sea ice concentration 0 to 1
set var/bad=-999. ice_conc
list/clobber/noheader/file=lat.txt/format=(f7.2,2x) lat
list/clobber/noheader/file=lon.txt/format=(f7.2,2x) lon
list/clobber/noheader/file=data.txt/format=(3(f5.0,2x),2(f5.2,2x),f9.2))year,mon,day,hr,mn,ice_co
nc1
sp paste lat.txt lon.txt > data1.txt
##################################################################################
```

Appendix-II

IDL Code: Conversion of NEMO background (NetCDF) to PP format (Modified Code of Dr. D. Lea, Met Office, UK.)

```
; Create antsfile acceptable to the OPS; &the multiple commands are used on a single line

interp=1       ; interpolate to 1 degree
path='/home/imran/obsproces/Netcdf2PP/tsprof_data'
file=path+'/go.dump.030107.pp'
fldgo=ppa(file,SS(fc=683),0)
file1=path+'/mersea.grid_T.nc'&file11=path+'/cice.nc'

print,'opening',file1
ncid1 = ncdf_open(file1, /nowrite)&ncid2=ncid1
varid = ncdf_varid(ncid1,'nav_lon')&ncdf_varget, ncid1, varid, lon
varid = ncdf_varid(ncid1,'nav_lat')&ncdf_varget, ncid1, varid, lat
varid = ncdf_varid(ncid1,'deptht')&ncdf_varget, ncid1, varid, depth

varid = ncdf_varid(ncid1,'votemper')&ncdf_varget, ncid1, varid, votemper
varid = ncdf_varid(ncid1,'vosaline')&ncdf_varget, ncid1, varid, vosaline
varid = ncdf_varid(ncid1,'sossheig')&ncdf_varget, ncid1, varid, sossheig
varid = ncdf_varid(ncid1,'sokaraml')&ncdf_varget, ncid1, varid, sokaraml
ncdf_close, ncid1

print,'opening',file11
ncid2 = ncdf_open(file11, /nowrite)&print,'reading fields'
varid = ncdf_varid(ncid2,'aice')
ncdf_varget, ncid2, varid, aice
ncdf_close, ncid2
vosaline=(vosaline-35)/1000&print,'fields read'

bmdi=fldgo.bmdi&print, bmdi

FillValue=0.0000&wh=where(votempereqFillValue)&votemper(wh)=bmdi
wh=where(vosalineeqFillValue)&vosaline(wh)=bmdi
wh=where(sossheigeqFillValue)&sossheig(wh)=bmdi
wh=where(sokaramleqFillValue)&sokaraml(wh)=bmdi
FillValue=1.e+30&wh=where(aicegeFillValue)&aice(wh)=bmdi

print,'creating new pp fields'& print,’votemper’ & print,’vosaline’ & print,'sossheig'
; create a pp field with the appropriate fields in; will need to interpolate then

zx=lon(0,0)&zy=lat(0,0)&dx=lon(1,0)-lon(0,0)-.001&dy=0.16355

tmp_fld=makeppfield(votemper, zy=zy, dy=dy, zx=zx, dx=dx, mdi=bmdi)
if (interpeq 1) then votemper_fld=pp_regrid(tmp_fld, fldgo)
if (interpeq 0) then votemper_fld=tmp_fld

tmp_fld=makeppfield(vosaline, zy=zy, dy=dy, zx=zx, dx=dx, mdi=bmdi)
if (interpeq 1) then vosaline_fld=pp_regrid(tmp_fld, fldgo)
if (interpeq 0) then vosaline_fld=tmp_fld

tmp_fld=makeppfield(sossheig, zy=zy, dy=dy, zx=zx, dx=dx, mdi=bmdi)
if (interpeq 1) then sossheig_fld=pp_regrid(tmp_fld, fldgo)
```

```
if (interpeq 0) then sossheig_fld=tmp_fld

print,'sokaraml'
tmp_fld=makeppfield(sokaraml, zy=zy, dy=dy, zx=zx, dx=dx, mdi=bmdi)
if (interpeq 1) then sokaraml_fld=pp_regrid(tmp_fld, fldgo)
if (interpeq 0) then sokaraml_fld=tmp_fld

print,'aice'
tmp_fld=makeppfield(aice, zy=zy, dy=dy, zx=zx, dx=dx, mdi=bmdi)
if (interpeq 1) then aice_fld=pp_regrid(tmp_fld, fldgo)
if (interpeq 0) then aice_fld=tmp_fld

votemper_fld(*).lbuser(3)=101&vosaline_fld(*).lbuser(3)=102&sossheig_fld(*).lbuser(3)=285&sokaraml_fld(*).lbuser(3)=30324&aice_fld(*).lbuser(3)=146

votemper_fld(*).lbuser(6)=1&vosaline_fld(*).lbuser(6)=1&sossheig_fld(*).lbuser(6)=1&sokaraml_fld(*).lbuser(6)=1 &aice_fld(*).lbuser(6)=1

votemper_fld.lbfc=601&vosaline_fld.lbfc=602&sossheig_fld.lbfc=617&sokaraml_fld.lbfc=653&aice_fld.lbfc=683

votemper_fld.lbyr=FCSTYR&vosaline_fld.lbyr=FCSTYR&sossheig_fld.lbyr=FCSTYR&sokaraml_fld.lbyr=FCSTYR&aice_fld.lbyr=FCSTYR

votemper_fld.lbmon=FCSTMON&vosaline_fld.lbmon=FCSTMON&sossheig_fld.lbmon=FCSTMON&sokaraml_fld.lbmon=FCSTMON&aice_fld.lbmon=FCSTMON

votemper_fld.lbdat=FCSTDAT&vosaline_fld.lbdat=FCSTDAT&sossheig_fld.lbdat=FCSTDAT&sokaraml_fld.lbdat=FCSTDAT&aice_fld.lbdat=FCSTDAT

votemper_fld.lbday=FCSTJULD&vosaline_fld.lbday=FCSTJULD&sossheig_fld.lbday=FCSTJULD&sokaraml_fld.lbday=FCSTJULD&aice_fld.lbday=FCSTJULD

votemper_fld.lbyrd=ANLSYR&vosaline_fld.lbyrd=ANLSYR&sossheig_fld.lbyrd=ANLSYR&sokaraml_fld.lbyrd=ANLSYR&aice_fld.lbyrd=ANLSYR

votemper_fld.lbmond=ANLSMON&vosaline_fld.lbmond=ANLSMON&sossheig_fld.lbmond=ANLSMON&sokaraml_fld.lbmond=ANLSMON&aice_fld.lbmond=ANLSMON

votemper_fld.lbdatd=ANLSDAT&vosaline_fld.lbdatd=ANLSDAT&sossheig_fld.lbdatd=ANLSDAT&sokaraml_fld.lbdatd=ANLSDAT&aice_fld.lbdatd=ANLSDAT

votemper_fld.lbdayd=ANLSJULD&vosaline_fld.lbdayd=ANLSJULD&sossheig_fld.lbdayd=ANLSJULD&sokaraml_fld.lbdayd=ANLSJULD&aice_fld.lbdayd=ANLSJULD

votemper_fld.lbft=FCSTTIME&vosaline_fld.lbft=FCSTTIME&sossheig_fld.lbft=FCSTTIME&sokaraml_fld.lbft=FCSTTIME&aice_fld.lbft=FCSTTIME

votemper_fld.lbtim=11&vosaline_fld.lbtim=11&sossheig_fld.lbtim=11&sokaraml_fld.lbtim=11&aice_fld.lbtim=11

votemper_fld.lbhem=3&vosaline_fld.lbhem=3&sossheig_fld.lbhem=3&sokaraml_fld.lbhem=3&aice_fld.lbhem=3

votemper_fld.lbvc=2&vosaline_fld.lbvc=2&sossheig_fld.lbvc=2&sokaraml_fld.lbvc=2&aice_fld.lbvc=2
```

```
votemper_fld.lbnrec=63488&vosaline_fld.lbnrec=63488&sossheig_fld.lbnrec=63488&sokaraml_fld.lbnre
c=63488&aice_fld.lbnrec=63488

votemper_fld.lbproj=900&vosaline_fld.lbproj=900  &sossheig_fld.lbproj=900  &sokaraml_fld.lbproj=900
&aice_fld.lbproj=900

votemper_fld.lbtyp=250 &vosaline_fld.lbtyp=232    &sossheig_fld.lbtyp=310    &sokaraml_fld.lbtyp=238
&aice_fld.lbtyp=244

ldepth=indgen(75)&votemper_fld.lblev=ldepth&vosaline_fld.lblev=ldepth&votemper_fld.blev=depth
&vosaline_fld.blev=depth

votemper_fld.lbsrce=1111&vosaline_fld.lbsrce=1111&sossheig_fld.lbsrce=1111&sokaraml_fld.lbsrce=11
11 &aice_fld.lbsrce=1111

filew=path+'/ops.bg.prv.pp'&print, 'file writing'&ppw, votemper_fld, filew
ppw, vosaline_fld, filew, /append
ppw, sossheig_fld, filew, /append
ppw, sokaraml_fld, filew, /append
ppw, aice_fld, filew, /append
exit
end
```