NWP SAF

IRSPP Product Specification

Version 1.0

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IRSPP Version 1 Product Specification

This documentation was developed within the context of the EUMETSAT Satellite Application Facility on Numerical Weather Prediction (NWP SAF), under the Cooperation Agreement dated 7 December 2016, between EUMETSAT and the Met Office, UK, by one or more partners within the NWP SAF. The partners in the NWP SAF are the Met Office, ECMWF, DWD and Météo France.

Change record			
Version	Date	Author / changed by	Remarks
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1. INTRODUCTION

This document defines the specification for Version 1 of the Infrared Sounder Pre-Processor (IRSPP), in accordance with the requirements of the NWP SAF. The Product Specification describes the deliverable from the point of view of the user.

The purpose of the package is to provide tools to facilitate processing of data from the Infrared Sounder (IRS) on Meteosat Third Generation (MTG).

Version 1 of the package will be released before MTG-S1 launch, based on pre-launch test data. Version 2 will be validated with post-launch data.

1.1 Reference documents

[RD-1] NWP SAF Proposal for the Third Continuous Development and Operations Phase (CDOP-3) March 2017-February 2022

[RD-2] NWP SAF ECMWF IASI PCA-Based Compression Package Manual, version 1.0, 30.01.2008

[RD-3] NWPSAF-MO-SW-002, Development Procedures for Software Deliverables, version 3.11, 26.05.2016.

2. USER REQUIREMENT REVIEW

2.1 General considerations

User requirements for NWP SAF software deliverables are defined in consultation with the NWP SAF Steering Group, taking into account (i) the tasks agreed in the relevant proposal for the phase of the SAF being undertaken (e.g. CDOP-3), (ii) any new requirements that have been identified by the methods described below, and (iii) the resources available.

User requirements are typically gathered by several methods:

- Discussions at meetings and conferences, such as the International TOVS Study Conferences
- Feedback from users via the NWP SAF Helpdesk
- Feedback from users in connection with NWP collaboration projects
- Surveys

Additionally, requirements can arise due to external constraints, e.g.

- Satellite launches, launch delays or termination of satellite missions
- Support for new software compilers, or cessation of support for old compilers
- Changes in external packages on which the NWP SAF deliverable relies
- Availability of ancillary data

2.2 Input from RD-1 (CDOP-3 proposal)

RD-1 makes the following statements about IRSPP:

- The IRSPP will be developed to process hyperspectral sounding data from MTG. The data will be disseminated by EUMETSAT and the baseline is that Principal Components will be distributed.
- For IRSPP, the detailed requirements will be determined based on input from NWP users and advice from MIMAG *[MTG-IRS Mission Advisory Group]*. The requirements are likely to include spatial and spectral thinning or averaging; cloud detection; format conversion e.g. BUFR. There will also be a requirement to generate reconstructed radiances from principal component scores; this function can be used in isolation for non-NWP applications. There may be a need for corrections to the data due to the characteristics of the detector array.
- IRSPP will be a new development, targeting NWP applications. It will not overlap with the data calibration or correction processes that will be carried out as part of Level 1 processing at EUMETSAT.
- For IRSPP, use will be made of the Principal Component handling capabilities currently available in other NWP SAF packages, notably AAPP and the IASI PCA-based compression package. The software will be written to target the requirements of MTG-IRS. Coordination will be made with related activities of the EUMETSAT CAF and the NWC SAF in this area.
- IRSPP v1 will be released based on pre-launch simulated IRS data. IRSPP v2 is planned for release after launch. Development activities are subject to satellite launch dates and availability of pre-launch and post-launch data. We are currently assuming launch in 2021 for the first MTG-S satellite. The release of IRSPP v2 within CDOP-3 will be dependent on a launch no later than August 2021.

This document addresses the v1 release of the package, referred to above, and due in CDOP-3. Note that the MTG-S1 launch date is now scheduled for 2023 (later than envisaged in the CDOP-3 proposal), so IRSPP v2 is planned to be released in CDOP-4.

2.3 Input from ITSC-21 (Darmstadt, 2017) and the MIMAG

The proposed IRSPP was presented at ITSC-21[1] in a talk (1.06) and discussed in the "NWP" and "Advanced Sounder" working groups. The package was also presented to the MTG-IRS Mission Advisory Group (MIMAG) in October 2017. The following questions were posed to ITSC-21:

Which of the following would you like to see implemented in IRSPP?

- *Ingest of the MTG-IRS NetCDF4 input files (obviously this has to be done).*
- *Generation of Reconstructed Radiances (RR) for specified channels. A channel selection appropriate for RRs would need to be defined. Who will do this? Not more than ~150 in each band.*
- *Conversion to some other PC basis set – different from the one used by EUMETSAT.*
- *Output in BUFR for the RRs and/or PC scores? If so, somebody needs to propose a BUFR sequence because we don't want multiple sequences to evolve.*
- *Output in NetCDF4 (or some other format?) for the RRs.*
- *Spatial sub-sampling, e.g. thinning. How?*
- *Ability to change the apodisation (e.g. light to heavy). Can be done by manipulating the eigenvectors.*

[1] http://cimss.ssec.wisc.edu/itwg/itsc/itsc21/index.html

- *Options to use, or not to use any "extra PCs" that might be generated dynamically by EUMETSAT (see Tim Hultberg's talk 8.04).*
- *Ability to generate eigenvectors from full-spectrum datasets. This will in any case be done by EUMETSAT, but do users want to do it themselves also? Note: think carefully before requesting this because it will need many spectra (>100000). May need access to EUMETCast-terrestrial.*
- *Produce modular code that can be integrated into NWP Centre's own software.*
- *Anything else?*

Feedback received

From Meteo-France: "We agree with all the proposed functionalities and we recommend the ability of IRSPP to change light apodisation into a strong one."

Note that the term "light apodisation" is used here to describe an apodisation function that is unity over most of the optical path difference (OPD) range, falling smoothly to a low value as maximum OPD is approached. "Strong" apodisation affects the whole OPD range, for example the Gaussian function used for IASI.

The Advanced Sounder Working Group summary states that the above suggestions "were discussed in the working Group and endorsed". It was also noted that BUFR is still likely to be relevant in the 2023+ time frame.

The following two recommendations from the NWP working Group are also of relevance to IRSPP:

> Recommendation DA/NWP-10 to Data Providers: When using PC compression, noise normalisation should be performed using the full noise covariance matrix. (recurring recommendation)
>
> Recommendation DA/NWP-11 to EUMETSAT: Proceed with work on the use of Hybrid PC compression and investigate practical application of this method, including the incorporation of granule-based vectors in BUFR.

Recommendation DA/NWP-10 implies that lightly-apodised spectra, not heavily-apodised, should form the basis of the PC product.

The lack of more specific comments implies that NWP centres have not yet considered in detail their requirements for IRS processing. This is not surprising, since the launch (2023) is still several years away.

2.4 Relevant functionality in the IASI PCA-based compression package

The IASI PCA-based Compression Package was released in 2008. Despite its name, the package is generic, not specific to IASI. It contains the basic routines needed to

1. Generate eigenvectors from a set of spectra (which would be an off-line process).
2. Convert raw radiance spectra to reconstructed radiances, via the intermediate steps:

a. Raw radiance to PC scores
b. PC scores to reconstructed radiances.

The input files (spectra) are plain binary format, while the eigenvectors are ASCII.

The software makes use of LAPACK (Linear Algebra PACKage) and BLAS (Basic Linear Algebra Subprograms) libraries.

At one stage, consideration was given to incorporating the whole of the IASI PCA package into AAPP (see section 2.5). However, in a 2013 workshop at ECMWF[2] it was concluded there was no requirement at that time to undertake further work on the package. Therefore it remains as a separate NWP SAF deliverable.

For MTG-IRS, it is unclear whether users really require an eigenvector generation capability for operational use. But they may need it for research use. Therefore a pragmatic solution would be *to incorporate the eigenvector-generation capability of the IASI PCA package into IRSPP*.

2.5 Relevant functionality in AAPP

AAPP performs the following IASI-specific processing steps:

1. BUFR encoding and decoding for the level 1c spectra (i.e. converts between BUFR and AAPP internal binary format)
2. Converts level 1c spectra to PC scores, using a set of eigenvectors (in hdf5 format) supplied by EUMETSAT.
3. BUFR encoding and decoding for the PC product
4. Conversion of the PC product to reconstructed radiances
5. BUFR encoding for the level 1d reconstructed radiances

AAPP therefore provides the functionality of part 2 of the IASI PCA-based package, handling the data formats that are operationally used with IASI.

AAPP also has the capability to perform the above processing with CrIS data, but to date this has not been used, since NOAA do not distribute CrIS data in PC score format.

3. CONSOLIDATED REQUIREMENTS FOR IRSPP

3.1 High level requirements

Taking account of the above requirements review, it is proposed that IRSPP version 1 should have the following high-level capabilities:

1. Ingest of native-format (NetCDF4) PC-score data from MTG-IRS
2. Code to convert PC scores to reconstructed radiances for specific channels, using externally-supplied eigenvectors. These eigenvectors may be a fixed set or there may also be some dwell-dependent eigenvectors.
3. Code to convert PC scores to an alternative basis function, using an externally-supplied transformation matrix

[2] https://www.ecmwf.int/en/elibrary/13887-ecmwf-workshop-efficient-representation-hyper-spectral-infrared-satellite

4. Conversion of PC scores to BUFR
5. Conversion of reconstructed radiances to BUFR
6. Conversion of reconstructed radiances to NetCDF4
7. Spatial sub-sampling, to a user-defined grid (nearest neighbour approach)
8. Ability to change the apodisation of the eigenvectors (for example, convert EUMETSAT's "light" apodisation to a Gaussian)
9. Facility to download ancillary information (e.g. eigenvectors) from EUMETSAT, where required
10. Tool for generating eigenvectors from a base set of spectra, via a covariance matrix, incorporating the relevant functionality of the IASI PCA-based Compression Package.

The algorithms to be used will be specified more fully in the Top Level Design.

Code should be modular where possible, to allow for possible integration of parts of the package in the user's own application.

At this stage, specific cloud detection modules have not been included in IRSPP, as it is expected that EUMETSAT will provide a basic cloud mask as part of the level 1 product[3]. If a requirement emerges for additional cloud processing steps that could reasonably be incorporated in IRSPP, then consideration will be given to adding that functionality.

3.2 Software provision

The package will normally be distributed via the NWP SAF web site as source code, with separate data files as required.

3.3 Language

Fortran 90 is the language of choice for the main modules, following the standards described in [RD-4].

Additionally, C, Python, Perl, bash or ksh may be used where appropriate.

A suitable configure/build system should be included in the package.

3.4 Operating system and hardware

The software is required to run on a 64-bit Linux PC, running a current operating system such as CentOS7 or RHEL7.

3.5 Performance

The goal is to achieve a system that can process MTG-IRS data in near real time, i.e. process a 15-minute LAC in a few minutes.

[3] MTG-IRS Level 1 Algorithm Theoretical Basis Document, EUM/RSP/TEN/16/878765, v1E Draft, 7 June 2017

Run-time examples should be included in the user documentation.

3.6 Interface requirements

Where external libraries are required, IRSPP may rely only on free software libraries. These libraries will either be packaged together with the relevant sections of IRSPP or the user will be given instructions on how to download them from a third party. Use of ecCodes (from ECMWF) is foreseen.

3.7 Test cases

Suitable test cases shall be prepared and made available to users.

4. DOCUMENTATION

Scientific and technical documentation shall be written and supplied to users via the NWP SAF web pages. The documents should address:

- Product specification
- Top level design
- Test plan
- Science description
- Installation guide
- Operation guide

Two or more of the above may be combined into a single document, if it makes things easier for the user.

5. REQUIREMENTS SUMMARY

The Test Plan should address the verification of the following requirements:

Identifier	Requirement	How to verify
IRSPP1	Documentation is clear, understandable and complete	Beta testing
IRSPP2	Code conforms to the requirements of [RD-4]: commented, understandable and modular	Inspection
IRSPP3	Any necessary external libraries are freely available	Inspection (e.g. examine the corresponding web sites for the external libraries)
IRSPP4	Code builds with no errors on a 64-bit Linux PC, running a current operating system such as CentOS7 or RHEL7. More than one Fortran compiler shall be tested.	Test

IRSPP5	Ingest simulated MTG-IRS PC-product files in NetCDF4 format	Test
IRSPP6	Convert from PC scores to reconstructed radiance, using EUMETSAT-supplied eigenvectors	Test
IRSPP7	Convert from PC scores to an alternative basis set, using a user-defined transformation matrix	Test
IRSPP8	Creation of BUFR output files for the PC product	Test
IRSPP9	Creation of BUFR output files for reconstructed radiances	Test
IRSPP10	Creation of NetCDF output files for reconstructed radiances	Test
IRSPP11	Spatial thinning onto a user-defined grid (nearest neighbour)	Test
IRSPP12	Ability to change the apodisation of the eigenvectors	Test
IRSPP13	Facility to download ancillary information (e.g. eigenvectors) from EUMETSAT, where required	Test
IRSPP14	Tool to generate eigenvectors from a base set of spectra, via a covariance matrix	Test
IRSPP15	Run times are documented in the test log and are compatible with NRT use of the software	Test and inspection
IRSPP16	Test cases for the users exist, have clear instructions and run correctly	Beta testing