Recoded Initialization Interface

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Abstract

In connection with the ongoing research work on Incremental Digital Filter Initialization (IDFI), major modification has been made within the HIRLAM forecast model to the subroutines and scripts involving initialization procedure, especially to the implementation of the Digital Filter Initialization (DFI). This note describes briefly the newly coded initialization interface, which is scheduled to be adopted in the coming update of the reference HIRLAM.

Compared to the original procedure, the new initialization interface has the following main features: 1)the main forecast subroutine `GEMINI` no longer contains initialization-related codes other than calls to the interface subroutines (`DFI` or `NMI`); 2)the control parameters for initialization have been separated from the main house keeping parameter block `NAMRUN` and placed in `NAMINI`; 3)the initialization and forecast are done with one execution of the forecast model and against a single set of input parameters; 4)there will be no intermediate output and input during the initialization stage as was done previously.

In addition, several previously experimented DFI schemes and filters by HIRLAM researchers have been put back to the codes, enabling experienced users to explore and fine-tune alternative DFI schemes. The setup for using IDFI (Lynch and Huang, 1994) has also been made.

The new initialization interface has been successfully tested with various initialization configuration. The validation tests against the parallel run using the original reference system (HIRLAM 5.0.2) showed satisfactory results.

1 Background

The quasi-continuous Delayed Mode Run (DMR) at ECMWF with the reference HIRLAM system has recently been found to suffer occasionally severe spin-up problems in forecasted moisture fields such as cloud cover, precipitation rate and liquid water cloud water. Preliminary investigation raised renewed concern on the performance of the initialization procedure used in the HIRLAM forecast system, as well as on the initial treatment of moisture fields in physical parameterization [see, e.g., the newsletter note by Yang and Sass (2000)]. Meanwhile, applications on short range forecast with frequent data assimilation cycles require also better initialized analysis with reduced moisture spin-up. These have motivated our recent effort to re-examine the HIRLAM initialization procedure. This note reports some of the suggested code changes as part of the ongoing work on the initialization issue.

The current HIRLAM forecast model has two optional initialization schemes: Digital Filter Initialization (DFI) and Implicit Normal Mode Initialization (INMI), with the former as the default scheme in the recent reference versions. With INMI, a limit number of vertical normal modes are derived from the input analysis and initialized. With DFI, time integrations are made for a limit length starting with the input analysis, and initialization is achieved by applying digital filter to the model trajectory. In fact, with the current default DFI scheme, the filter is applied twice to two separate integration trajectories: first with backward adiabatic integration, starting with analysis; second with the forward diabatic integration, starting with the preliminarily filtered analysis. On technical aspects, the initialization steps are implemented in following manner, as is shown schematically in Figure 1 for forecast using DFI scheme. (Similar structure applies for forecast using INMI scheme):

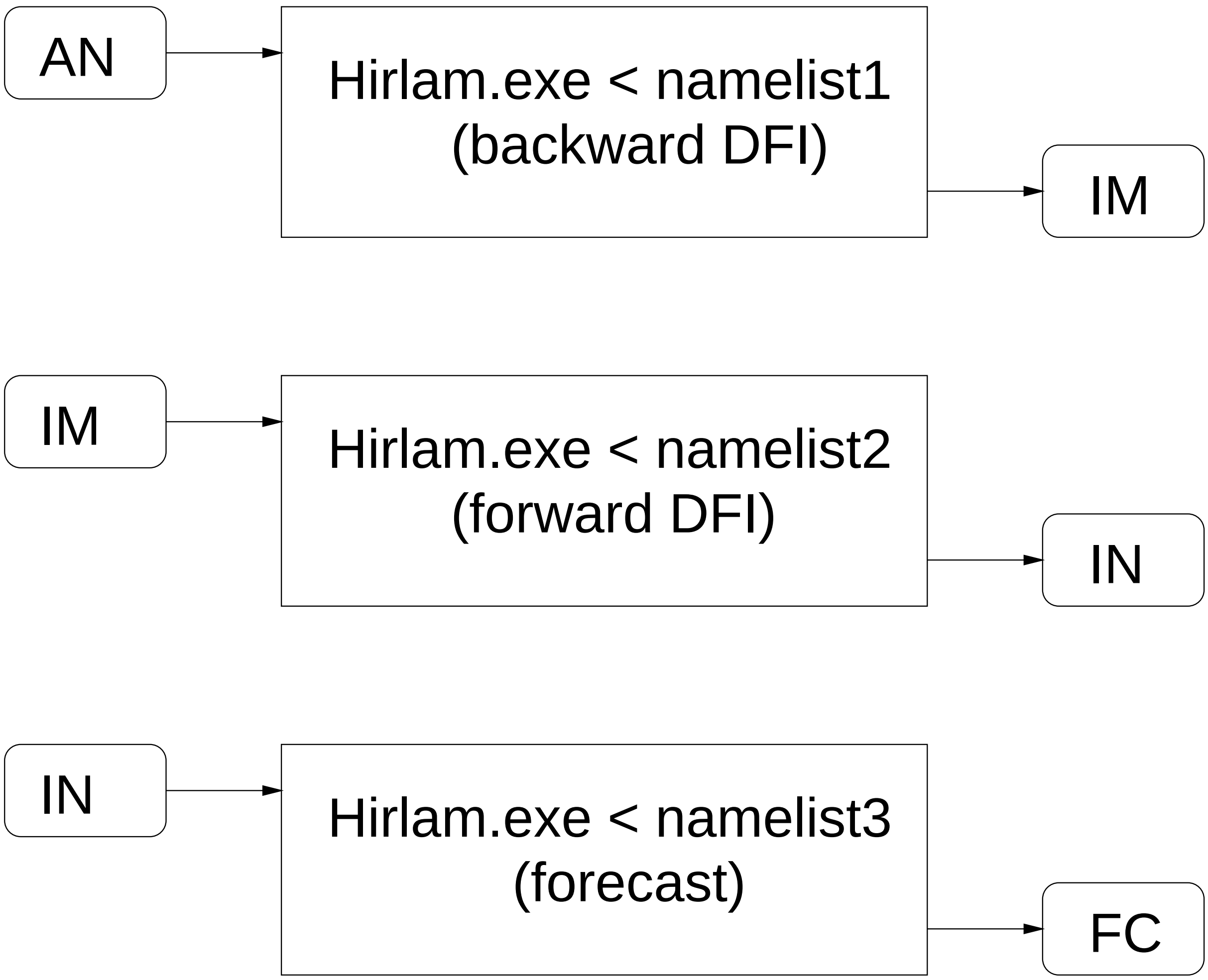

Figure 1: Schematic diagrams of the current HIRLAM reference setup.

First, the input analysis (AN) is read by the forecast model, and initialization is performed, with the result written to an output file (IM).

Then, in case of DFI using the default scheme, the preliminarily filtered field (IM) is read by the forecast model, and second segment of initialization procedure is conducted, with the result written out as initialized file (IN).

Finally, the initialized file (IN) is read by the the forecast model to perform forecast.

Note that in the above action chains during initialization and forecast, the forecast runs are performed repeatedly with different sets of control namelists and different input and output. The shortcoming with such a design of initialization procedure is obvious, to name just a few:

The initialization forecast interface involves unnecessary input/output and multiple sets of control namelists (`NAMRUN`) are needed, which could contribute to script errors by even experienced users;

For DFI, most required actions are coded to take place in the main forecast subroutine `GEMINI`. Many arrays for storage of filtered model trajectory have to be introduced, causing substantial increase in required memory space. The structure with DFI also makes it difficult to introduce other optional DFI schemes, such as the incremental DFI (IDFI). With IDFI, both the first guess (FG) and analysis (AN) will be used in the forecast step. DFI procedure is applied to both model trajectories started with FG and AN and the difference between the two filtered model states are then added to the FG as initialized analysis increment (Lynch and Huang, 1994).

We thus propose to recode the initialization interface aiming for a cleaner code and script structure, more flexibility in usage and better framework for further development of various optional initialization schemes. During the recoding, a number of previously tested DFI options have been re-introduced into the system and some new features, e.g., the incremental DFI option, have been implemented. The new interface has since been combined together with the recent experimental version of HIRLAM 5.0.2 featuring MINI-SMS script system, and validated against the previous default setup of the DFI through parallel data assimilation runs. The tests confirmed the desired effects of the code changes. This note briefs on the technical aspects of the code changes. More details on the re-implemented DFI schemes will be provided in a separate write-up.

2 New Initialization Interface

The schematic diagram in Figure 2 shows the basic features of the new initialization-forecast interface. As the figure shows, with the new structure, there will be a single stream of namelist input, one execution of forecast programme, with the forecast step following directly after the initialization procedure, and no more extra file input/output during the initialization. As Figure 2 also indicates, in case of IDFI, a firstguess file FG is needed as input.

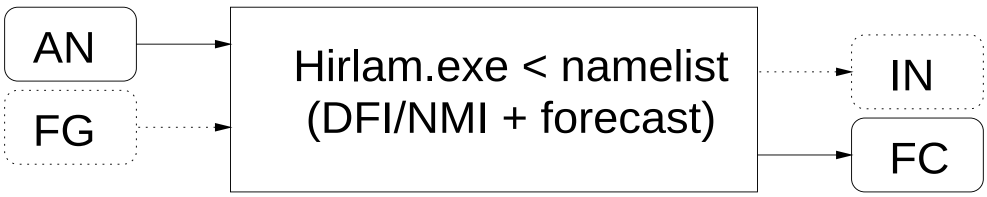

Figure 2: Schematic diagrams of the proposed setup.

In the new setup, all initialization (DFI or NMI) related codes are removed from the main forecast subroutine `GEMINI`. In `GEMINI`, after the input of analysis file, initialization procedure is activated by optional calls to the interface subroutines `DFI` or `NMI` according to specification of the logical namelists `LDFI` and `LNMI` in `NAMRUN` (`LNMI` is equivalent to `NLINMI` used in the previous code). In case of `LDFI` and `LNMI` both being .false., the initialization step will be skipped over and forecast starts directly from the initial input. The proposed initialization interface in `GEMINI` has the following structure:

```
SUBROUTINE GEMINI
....
IF(LNMI) CALL NMI
IF(LDFI) CALL DFI
....
END
```

Within the interface subroutine for INMI, `NMI`, the code structure looks like,

```
SUBROUTINE NMI
...
CALL RDNAMINI
```

```
CALL NORMOD
...
END
```

In NMI, the control parameters for the NMI procedure, specified in the namelist file, NAMINI, are read by subroutine RDNAMINI and communicated through a common block, COMINI. Afterwards the subroutine NORMOD is called to derive the initialized normal modes, which are passed over by NMI back to GEMINI.

Likewise, within the DFI interface subroutine DFI, the code structure looks like,

```
SUBROUTINE DFI
...
CALL RDNAMINI
CALL DFCOEF
DO N=1,NITDFI
   IF(IDFI) THEN
      CALL INCDFI
   ELSE
      CALL FULDFI
   ENDIF
ENDDO
...
END
```

In DFI, the subroutine RDNAMINI reads the control parameters for the DFI procedure from the namelist file, NAMINI. Some of the main control parameters are:

```
IDFI                ! .TRUE. FOR INCREMENTAL DFI
NDFI                ! 1. ADFI; 2. DDFI; 3. TDFI
NFILT               ! 1. LANCZOS; ...; 7. DOLPH
TSPAN               ! filter span
TAUS                ! inverse of filter cutoff frequency
```

Where the logical parameter IDFI determine the use of full (regular) DFI (FDFI) or incremental DFI (IDFI). The integer NDFI determines the use of DFI schemes with the index defined as:

1.- ADFI, adiabatic DFI (Lynch and Huang, 1992),

2.- DDFI, diabatic DFI (Huang and Lynch, 1993),

3.- TDFI, the default DFI scheme so far implemented in HIRLAM system (Lynch *et al.*, 1999). Since this scheme applies DFI filter twice and sequentially to the integration trajectory, we name the scheme Twice DFI (TDFI) here.

A schematic presentation of the above three DFI schemes is in Figure 3.

A value of 1 to 7 for NFILT specifies the choice of filters types. Among them, 1 is the Lanczos window(Lynch and Huang, 1992) and 7 is the Dolph filter (Lynch, 1997). Depending on the filter type specified by NFILT, the DFI filter coefficients are computed by subroutine DFCOEF, according to the input namelist read in by RDNAMINI.

For most filters, the important parameters are the filter span, TSPAN, and the inverse of filter cutoff frequency, TAUS. See e.g. Lynch and Huang (1992) for a discussion on these parameters.

It may be useful to notice that the namelists for IDFI, NDFI and NFILT are mutually independent, giving a great flexibility for exploring optimal combinations. The default values, however, have been set to:

IDFI=.false. (FDFI),

NDFI=3 (TDFI),

NFILT=7 (the Dolph filter),

as in the HIRLAM reference version 5.0.2.

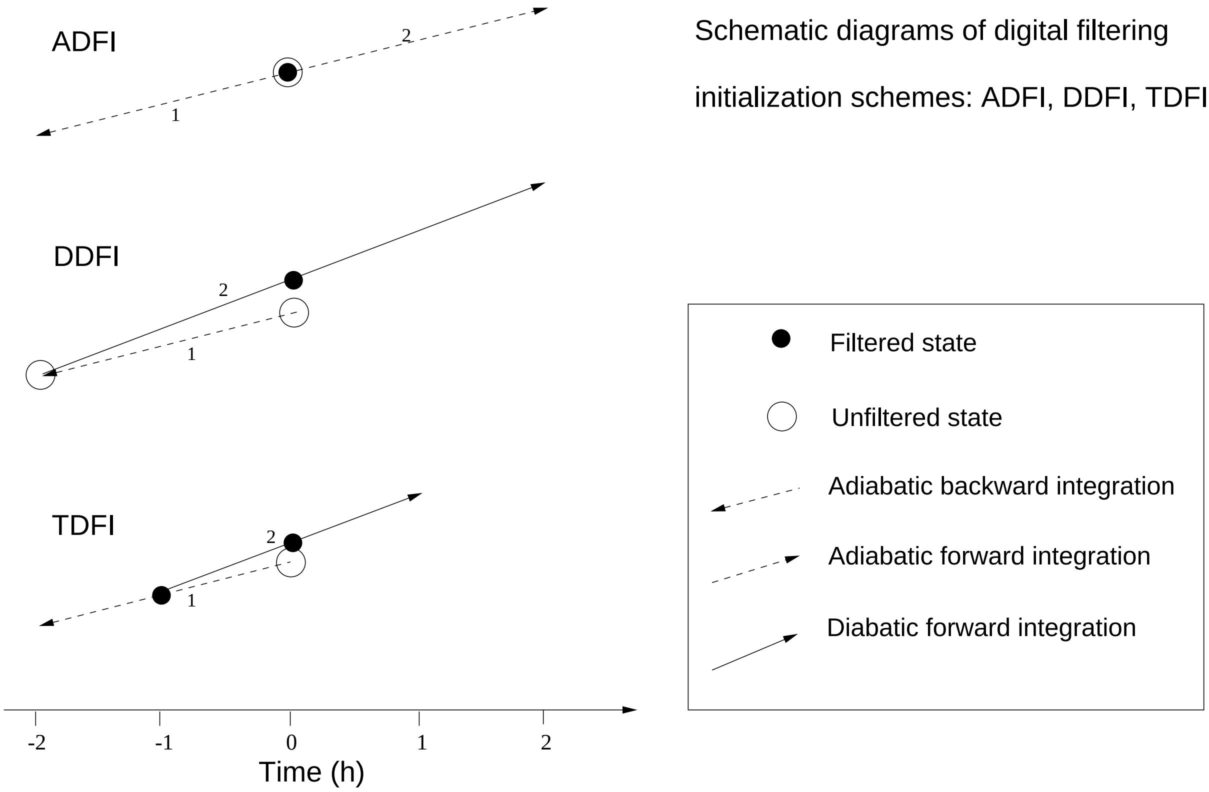

Figure 3: Schematic diagrams of the optional DFI schemes.

In addition, several new parameters have been introduced to the namelist set, as listed in the following.

NDFSFT. Lynch et al (1999) found that by excluding the model state at time step 0 the filter results are improved. Although this has not been found to be generally true for some of the tested DFI configuration, we keep this feature and make it an option. The parameter NDFSFT specifies the starting time step for applying the filter, with default value as 1. Following the arguments by Lynch et al (1999), one could even ignore a few more time steps by increasing NDFSFT. However, NDFSFT must be set to zero when ADFI (NDFI=1) is used.

NLTANH_INI. This specifies the shape of the boundary relaxation function used in DFI integration.

Diffusion coefficients. The horizontal diffusion has been assumed as an irreversible process in many applications of DFI. On the other hand, if we only regard the procedure as a control for numerical noise, it is also easy to accept the same control in the backward numerical integrations. The previous DFI implementation (TDFI-ref) allows for an implicit horizontal diffusion scheme in both forward and backward integrations. In order to allow for similar flexibility, we have added all horizontal diffusion related parameters in NAMINI with suffices _BWD and _FWD, indicating parameters for backward and forward integrations, respectively. Their default values are set according to TDFI-ref.

LBDYSWAP. This logical parameter specifies whether to use filtered fields to replace the initial (analysis) input when used to derive interpolated lateral boundary at each time step. Although the practice could be questionable, the default LBDYSWAP is set to .true. as is implied in TDFI-ref.

DTINI. This namelist parameter specifies the time step used during the DFI integration.

Based on the experience with the current reference system, we set its default value the same as that used in the forecast. However, in view of the lack of physical processes and possibly also horizontal diffusion in adiabatic DFI integration, a shorter time step may sometimes be desirable to avoid numerical instabilities.

Finally, a new namelist variable `NITDFI` is added, giving the possibility of iterating DFI.

For the INMI scheme, `NMODES`, which specifies number of vertical modes to be initialized, and `ITNMI`, which specifies number of iterations in NMI, have been moved from `NAMRUN` to `NAMINI`. In addition, `NOPTION_NMI` is added in `NAMINI` to specify physics option at NMI. NMI also shares with DFI following control parameters:

`NBDPTS_INI`,

`NLTANH_INI`,

`DTINI`,

where the default DTINI for NMI is 60s. The relatively short time step is suggested for accuracy considerations.

3 Implementation and Code Validation

The above mentioned code modification has been done based on the recent HIRLAM reference release 5.0.2, which features MINI-SMS script system. In connection with the new interface, modifications to several scripts under 5.0.2 have been necessary, e.g., in the experiment description file, `Env_expdesc`, specification needs to be made for the options of `IDFI`, `NDFI` and `LNMI`, in addition to `LDFI` as required before; in the input data file for forecast model, `FCinput`, major changes have taken place to produce single stream of namelist sets. Here `NAMINI` is placed at the last position of the namelist sets to be read by the forecast model. `NAMDFI` which is previously required is now gone. In `Postpp`, changes have also been made accordingly to accommadate changes in the sequence of namelist read-in.

A number of data assimilation experiment has been configured to examine various initialization schemes using the modified system. The experimental model domain is 114x100x31 with 0.5 degree resolution and one of the main assimilation period is from Aug 18, 2000, 1800 UTC to Aug 29, 2000, 1200 UTC. All the runs are performed on ECMWF computers. These experiments are configured with different initialization schemes, e.g., with no initialization, use NMI, or use ADFI, DDFI, TDFI and IDFI, etc. So far all the experiment runs have been smooth and results of these experiments will be discussed in separate write-ups. Of relevance here is the result from the parallel experiments using the reference model 5.0.2 and using the new code. In both runs the default TDFI scheme has been used with the Dolph filter. This test is designed solely for code validation, and with all parameters set to be the same, the modified source code and scripts should be able to reproduce the results by the original reference version 5.0.2 with TDFI-ref default setup.

In Figure 4, the time series of the domain averaged mean absolute surface pressure tendency, liquid cloud water content and precipitation rate from the first 6hr forecasts in the first data assimilation cycle started on August 18, 2000, 1800 UTC, are plotted. These plots show practically identical results from the two experiment setup. In addition, the observation verification for the whole assimilation period also showed almost identical scores. The marginal differences from the parallel runs are believed to be caused by precision errors in the grib input and output which are necessary in TDFI-ref. We thus believe that the implementation of the new initialization interface has been successful from technical aspects.

References

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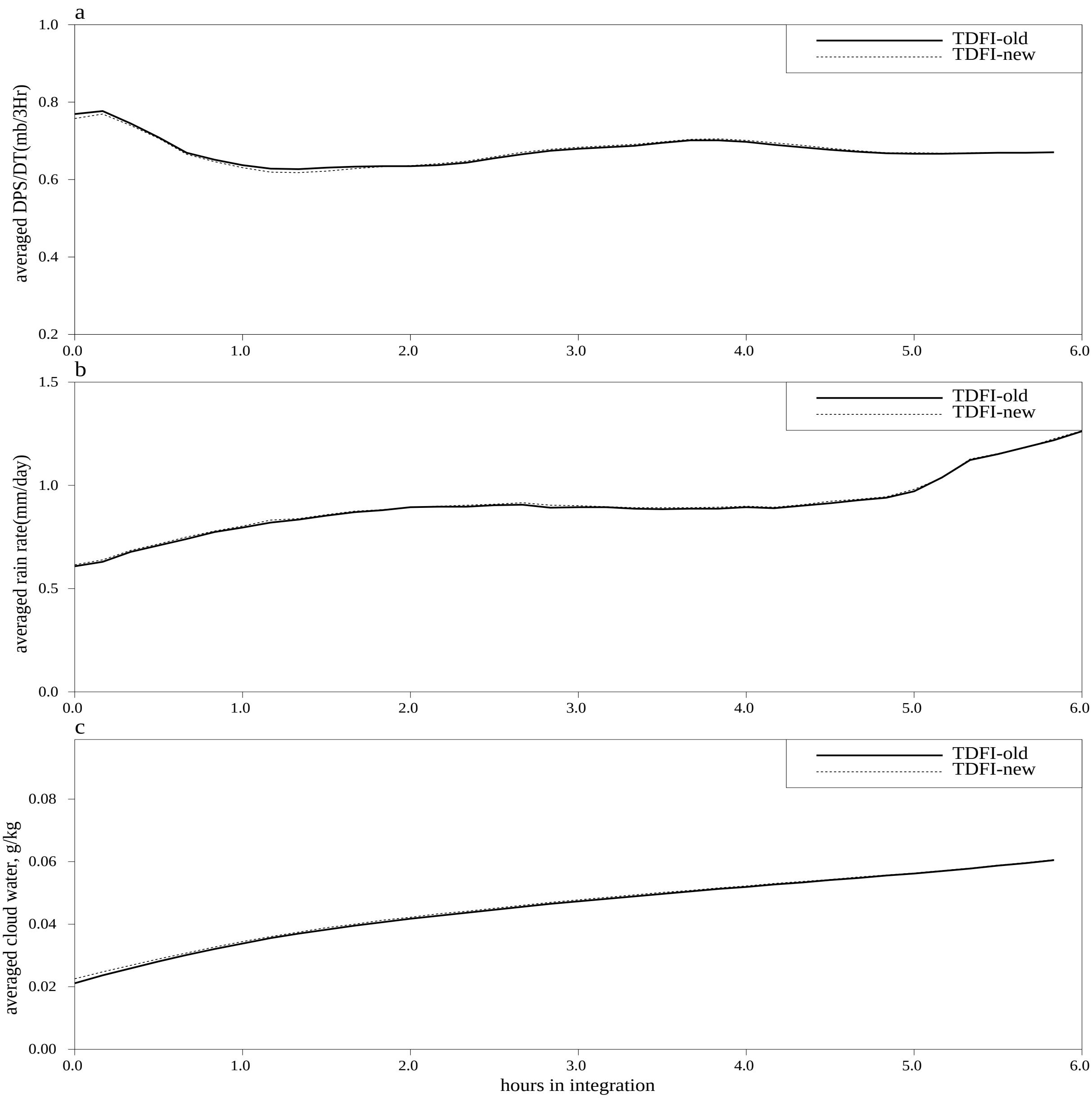

Figure 4: The time series of the domain averaged (a) Noise parameter N in hPa/3h, (b) mean rain rate in mm/day, (c) mean cloud water in g/kg, from the first data assimilation cycle stated at 1800UTC 18 Aug 2000. The full line is for TDFI-old and the dashed line for TDFI-new.

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