Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2020-75-RC2, 2020

Geoscientific Model Development Discussions

Interactive comment on "Developing a common, flexible and efficient framework for weakly coupled ensemble data assimilation based on C-Coupler2.0" *by* Chao Sun et al.

Anonymous Referee #2

Received and published: 1 July 2020

This article describes the approach of extending the C-Coupler2.0 to provide data assimilation capabilities that can work with coupled models. It is motivated by attempts to use PDAF, however I am unsure that the criticisms of PDAF are sufficient motivation for developing the new system. The design of the new system is described, along with detailed discussion of how different components are implemented. An example of the working system is given where the data assimilation system from GSI/EnKF is ported to DAFCC1 and applied to the different components of the coupled model FIO-AOW in a weakly coupled DA context. Results are shown to indicate that the I/O bottlenecks associated with offline implementation are avoided by using MPI instead of file access.

General comments:

The motivation for developing your own system rather than using PDAF I found lacking. There were 2 main points I could find in section 2, namely "PDAF [... imposes] a precondition of process layout such that each ensemble member uses the same number of processes with successive IDs in the MPI_COMM_WORLD" and "[PDAF] only makes the processor cores of the first ensemble member available to the DA algorithm and forces the processor cores used by other ensemble members to idle when running the DA algorithm". The second statement I think is untrue, but Dr Lars Nerger has posted a short comment on PDAF so I trust he will ensure the correctness there. The first point I find to be obscure as I cannot think of a situation where you would not have ensemble members using sequential MPI process IDs. If you have a specific situation where this is the case, please elaborate on it so the reader can understand why this is important.

One overarching question which is not addressed is why would you design from the outset a "weakly coupled" data assimilation system? Why not design a strongly coupled system and then simplify it? I suppose the answer here is to still be able to piggyback on existing observation processing systems and to allow for different observation frequencies, but this should be clearly set out in the article.

I would like to see more clarity in relation to the comparisons that you make. There are a number of places where the comparison is against an system that uses I/O and reading/writing files from/to disk rather than MPI communications. In such a case phrases like "accelerating the DA system" should be qualified. There are other relations made where it is unclear what the comparison is with. For example in the abstract you state that the new methodology "enables the DA method to utilize more processor cores in parallel execution" but I cannot see the baseline for such a statement. Moreover would such a statement hold with a different baseline?

The article gives a reasonable overview and references for general data assimilation

concepts. However the article should point the reader to some of the latest examples of operational weakly coupled data assimilation. Good references for this include, with the first using PDAF:

Goodliff, M., Bruening, T., Schwichtenberg, F., Li, X., Lindenthal, A., Lorkowski, I., & Nerger, L. (2019). Temperature assimilation into a coastal ocean-biogeochemical model: assessment of weakly and strongly coupled data assimilation. Ocean Dynamics, 69(10), 1217–1237. https://doi.org/10.1007/s10236-019-01299-7

Skachko, S., Buehner, M., Laroche, S., Lapalme, E., Smith, G., Roy, F., ... Garand, L. (2019). Weakly coupled atmosphere-ocean data assimilation in the Canadian global prediction system (v1). Geoscientific Model Development, 12(12), 5097–5112. https://doi.org/10.5194/gmd-12-5097-2019

Browne, P. A., de Rosnay, P., Zuo, H., Bennett, A., & Dawson, A. (2019). Weakly Coupled Ocean-Atmosphere Data Assimilation in the ECMWF NWP System. Remote Sensing, 11(234), 1–24. https://doi.org/10.3390/rs11030234

Specific comments:

Lines 12,25. "better" than what?

Line 47: "how to conveniently (1) achieve an ensemble run of a coupled model" What is your measure of convenience here? This is a task which is regularly done at many centres around the world, do they all have inconvenient methods for running ensembles of coupled models?

Line 55: On the use of disk files, this is also a robust strategy when it comes to massively parallel computing, as this risk of random task failures increases with the size of the coupled models and the number of ensemble members. This should be noted as positive reason for using disk files, as well as the potential to use a larger ensemble than can be run at a single time on an HPC machine.

Line 57. PDAF is indeed *the* standard for ensemble based DA frameworks. Others

also exist. For example EMPIRE (https://pbrowne.bitbucket.io/empire) Browne, P. A., & Wilson, S. (2015). A simple method for integrating a complex model into an ensemble data assimilation system using MPI. Environmental Modelling \& Software, 68, 122–128. https://doi.org/10.1016/j.envsoft.2015.02.003

Line 93: "How to compile the code of DA methods with the model". This is not necessary. In particular if you run (using MPI) in MPMD mode then the model and the DA could be compiled independently.

Line 108: "Although PDAF enables a DA algorithm to run in parallel, it only makes the processor cores of the first ensemble member available to the DA algorithm and forces the processor cores used by other ensemble members to idle when running the DA algorithm." This is not my understanding of PDAF. I see that Dr Lars Nerger has already submitted comments in relation to PDAF, so I am assured that he will have given you the latest and correct information in relation to this.

You need to discuss other parallel strategies such as that used by P.A. Browne, S. Wilson, 2015.

Line 115: what are such preconditions? Can you give examples where these exist, and if they do, why they are a problem?

Line 122: You should make clear this is because the MPI processes from all ensemble members are available. Or are there even more available?

Line 131: Are you suggesting a coupled model which uses a different coupler, such as OASIS, would then be put into C-Coupler2.0 for the DA component?

Figure 1: This has no explanation. I fail to see the usefulness of this figure.

Line 143: What is the alternative to DLL?

Line 146: "The ensemble component manager is responsible for generating and managing the communicator of ensemble members of a component model." Does this

mean you have a separate ensemble component manager for every component of your coupled model, such as atmosphere, ice, land, composition, etc? If so please state this to help the reader.

Line 155/Figure 3: Is a restriction that the components in each ensemble members run on the same number of MPI processes? Surely there is a restriction enforced by the DA algorithms that the component model is on the same grid for every ensemble member, or has some very exotic DA methodology been implemented? In the case they have, how do you then establish which DA algorithms are applicable given the difference in the ensemble members?

Line 159/160: "execution of a DA algorithm in a component model does not force the processes of other component models to be idled". This must relate to the timestepping procedure of the coupled model. In fact here are you for the first time enforcing that all components of the model must have separate MPI processes? This is not the case in, for example, the ECMWF earth system model (Mogensen, K., Keeley, S. and Towers, P., 2012. Coupling of the NEMO and IFS models in a single executable. Reading, United Kingdom: ECMWF.)

Line 165). Point 4. Please give an examples of such a DA algorithm procedures. Do you mean, for example, that DA algorithm 1 procedure 1 would be calculation of model equivalents ($H(x)$) and DA algorithm 1 procedure 2 would be something like an SVD of the ensemble perturbation matrix?

Line 169: "Scripts are allowed to conduct necessary process control". This comes out of the blue, and it is not clear how this fits within the methodology of having everything using MPI communication. Can you give examples in section 4.4.

Line 188: The "weakly coupled" component of your methodology then relies on using the C-Coupler2.0 to control the coupling of the model then?

Figure 5: Why is there no red within the DA_CCPL_RUN subroutine to indicate data

exchange between the model and the DA?

Section 4.4, 2). Terms such as periodic timer, period_unit, period_count and lag are introduced with no context. These should be defined as well as an explanation of why they are needed for data assimilation.

Section 4.4) I fail to see why any of this is relevant to data assimilation. What is an example of statistical processing in a DA context?

Line 330) "A sample weakly" - do you mean "An example weakly coupled ensemble DA system"? I don't know what "sample" refers to here. This is used many times throughout the manuscript - please clarify.

Section 6.1) The details of the EnSRF (i.e. localization radius and inflation factors) are not useful without a description of the model

Line 410) "We evaluate the effectiveness of DAFCC1 in developing a weakly coupled ensemble DA system". I don't see the justification for this statement. I can see you have implemented the system and shown how it performs computationally with various parameters, as well as a very simplistic verification that the data assimilation is implemented correctly. You should state a measure for effectiveness - was it simply to have a functioning system? Compare this with Browne and Wilson, 2015, where they "propose a simple implementation strategy which does not focus on maximum efficiency of the code. Instead the focus is on the speed of implementation."

Line 424) Why were 3200 cores used when each node has 24 processors? mod(3200,24) != 0.

Line 436) "variables used for DA" -> "are the prognostic, or analysed, variables in the data assimilation".

Section 6.2 could be a simple statement saying that WRF-GSI/EnKF with DAFCC1 is bit-identical to the original offline WRF-GSI/EnKF.

Line 460/Figure 11c) Why does the offline timing of GSI vary with different numbers of ensemble members? On line 458 you state that you run all ensemble members of the offline system concurrently, so I would expect a constant value of time for the model run as you change the number of ensemble members. This clarification will be essential in understanding the rest of the figures here, as otherwise it seems like the comparison may be unfair. Could it be i/o related? With every member trying to write output files at the same time your system slows? If this is the case it should be explicitly accounted for in the final paragraph of this section. Furthermore, you should detail what file system architecture is used at BSCC in section 6.1. Is it something like lustre?

Section 6.4) This is not a measure of the effectiveness in developing a weakly coupled ensemble DA system. Figure 15 shows results for northern hemisphere (25N-90N) and tropics (25S-25N) but I understood this was a limited area system, running from 0N-50N. You should update the figure to reflect this. All this figure appears to show is that the DA system is producing increments which have the correct sign.

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