

**Manuscript:** Estimating lateral nitrogen transfer through the global river network using a land surface model

### Major remarks

The authors developed a new scheme for the lateral transfer of nitrogen over the land surface and via the river network at 0.5° resolution. They implemented their scheme into the land surface model ORCHIDEE and named it ORCHIDEE-NLAT. The scheme considers three nitrogen compounds: PON, DON, and DIN. The manuscript presents an important contribution to Earth System Modelling. It utilizes the ORCHIDEE capabilities by providing daily nitrogen loads, and not only annual loads as in existing previous studies. It also comprises a good discussion on uncertainties (Sect. 3.4)

What I do not understand is why they did not run the full ORCHIDEE model themselves. Instead, ORCHIDEE-NLAT offline scheme was fed by output from ORCHIDEE-CNP and ORCHIDEE-Clateral. Hence, its results heavily rely on input data from other ORCHIDEE versions. If the present offline scheme is an independent model, why it is also called ORCHIDEE? Are there any processes duplicated in ORCHIDEE-NLAT, which had already been simulated by these other ORCHIDEE version? It should be clarified whether specific characteristics of the model output are due to the process representation in ORCHIDEE-NLAT or whether they originate from the used input from the other ORCHIDEE versions.

Lateral nitrogen flows are simulated for the period 1901-2014. Unfortunately, no information on the atmospheric forcing for the land surface model is provided (i.e. for the input provided by ORCHIDEE\_CNP).

I do not find the evaluation of the model results in Sect. 3.1 to be very convincing. In this respect, Figure 4 shows a rather trivial logarithmic plot where large (low) simulated discharge/N values correspond to large (low) observed values. It shows that the model values are generally of the right order of magnitude but hide the true magnitude of the biases. It may be better to show NSE or RRMSE in such a figure. In this respect, Figure 5 shows large biases with RRSME greater than 30% and medium to low NSE for the three rivers considered. While I do not expect a high performance for nitrogen loads, I am rather surprised by the low performance of the simulated river discharge. If this performance is already low, it will most likely prevent a good performance of the simulated nitrogen loads. In addition, it is implied that Fig. S4 shows a good agreement with the assessment of Marzadri et al. (2021), which I strongly disagree (see comment below). Also, the reasoning for existing model biases is insufficient (see comments below). In my opinion, the evaluation section requires a strong improvement before it is suitable for publication.

Another point of concern is that the paper uses rather short reference periods for comparison (1900-1910, 1991-2000 and 2001-2014). This is too short for climatological studies and the identification of trends, especially given the large interannual and decadal variability in hydrological variables, i.e. precipitation and river runoff, which largely influence the lateral nitrogen flows into the ocean.

As the manuscript includes a lot of typos and some overly long sentences, I recommend a thorough English proof reading.

In summary, the paper describes a relevant model development and provides valuable results, but currently suffers from several flaws, especially in the evaluation section and in the robust identification of trends. Hence, it may be accepted for publication after major revisions are conducted.

### **Minor remarks**

In the following suggestions for editorial corrections are marked in *Italic*.

#### Line 26

I found the naming of the new scheme (ORCHIDE-NLAT) inconsistent with the previously established lateral transfer scheme for carbon (ORCHIDEE-Clateral). In addition, NLAT is a typical abbreviation for No. of latitudes. I suggest a consistent renaming of the new scheme to ORCHIDEE-Nlateral.

#### Line 182

... of *the model* driving ...

#### Line 201, 214 and 218

In Sect. 2.1.2, you are referring to Table 1 several times. I could hardly find the table until I realized that it is located in Sect. 2.3.1 nine pages later.

#### Line 213

... and *the data* were downscaled ...

#### Line 219 – Sect. 2.1.3

Sect. 2.1.3 comprises several sets of very similar equations, e.g. eqs.1-3, 4-8, 12-16, 17-19, 20-24, 25-27. This makes this section lengthy and repetitive. Please shorten!

#### Line 354

... flow rates *are* equal to ...

#### Line 402 and 407

The RPE is commonly defined as mean bias or mean bias error (MBE). Please use one of the two common terms.

#### Line 403

Please provide the definition of the coefficient of determination that you have used.

#### Line 426-428

Grammar of sentence seems wrong. Please improve.

#### Line 439

Evaluation of the *simulated water discharge using* ...

#### Line 447

The unit  $\text{m}^3/\text{yr}$  is strange. Please use of the common units for river discharge:  $\text{m}^3/\text{s}$  or  $\text{km}^3/\text{yr}$ .

#### Line 447-448

It is written:

“...indicating that large errors only occur at some sites draining relatively small basins”

This is not necessarily the case. Such an error may also occur in large basins in dry areas. Please clarify!

Line 449-454

No, there are more factors. A very important factor is actually that biases in the land surface water balance of ORCHIDEE will introduce biases in runoff and, hence, in the discharge. And as you are using runoff inputs from an ORCHIDEE simulation, this factor is very likely the largest factor contributing to biases in streamflow/discharge.

Line 464-465

See comment to line 447-448.

Line 482-484

It is written:

“Nevertheless, the agreement between both assessments (Fig. S4) lends further confidence in the capacity of our model to realistically simulate the N cycle along the global river network.”

I strongly disagree with this statement as Fig.S4 indicates considerable differences between both assessments.

Line 513-515

It is written:

“The reality of this transient peak is however questionable as it results mostly from meteorological forcing, which is uncertain for the beginning of the 20th century.”

Unfortunately, no information on the atmospheric forcing is provided (see major remarks).

Line 531

... the grid boxes with ...

Line 541-545

Sentence is too long and difficult to read. Please rephrase.

Line 596

...simulations, *and* downscale ...

Line 595-596

It is written:

“ocean biogeochemical modelling community typically uses annual mean TN fluxes derived from Global News to force their simulations”

Please provide solid reference(s) for this statement, i.e. that is more than a utilization in a single study.

Line 602

... into *rivers*, denitrification ...

Line 624-628

Sentence is too long and difficult to read. Please rephrase.

Line 726

... model *used* in ...

Line 825

... *reproduces* ...

Line 827

... global *simulation* of ...

References

The reference section has to be carefully checked as many references include the full names of the authors instead of initials for the given names.