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Routine checks of model consistency on terrestrial carbon sink components

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ARE WE GETTING MORE CONFIDENT ON TERESTRIAL CARBON SINK AS THE NUMBER OF MODELS GROWS? HERE WE PRESENT THE METHODOLOGY UNDERLYING THE OGED SERVICES ON TESTING MODEL CONSISTENCY.

What does model consistency mean?

The components of terrestrial carbon sink are estimated by means of models. Many different models are possible for any given component, and no criterion exists to pick one model over another [*1*]. Instead, the models form an ensemble, which is assumed to be a consistent estimator of the terrestrial carbon sink and its components -- that is, to be converging to the quantities being estimated as the number of models grows.

Checklist for evaluating a new model

Do model outputs fall within the bounds suggested by a normative collection of models? ☐

Will inclusion of the model into the normative collection shift the average estimates? ☐

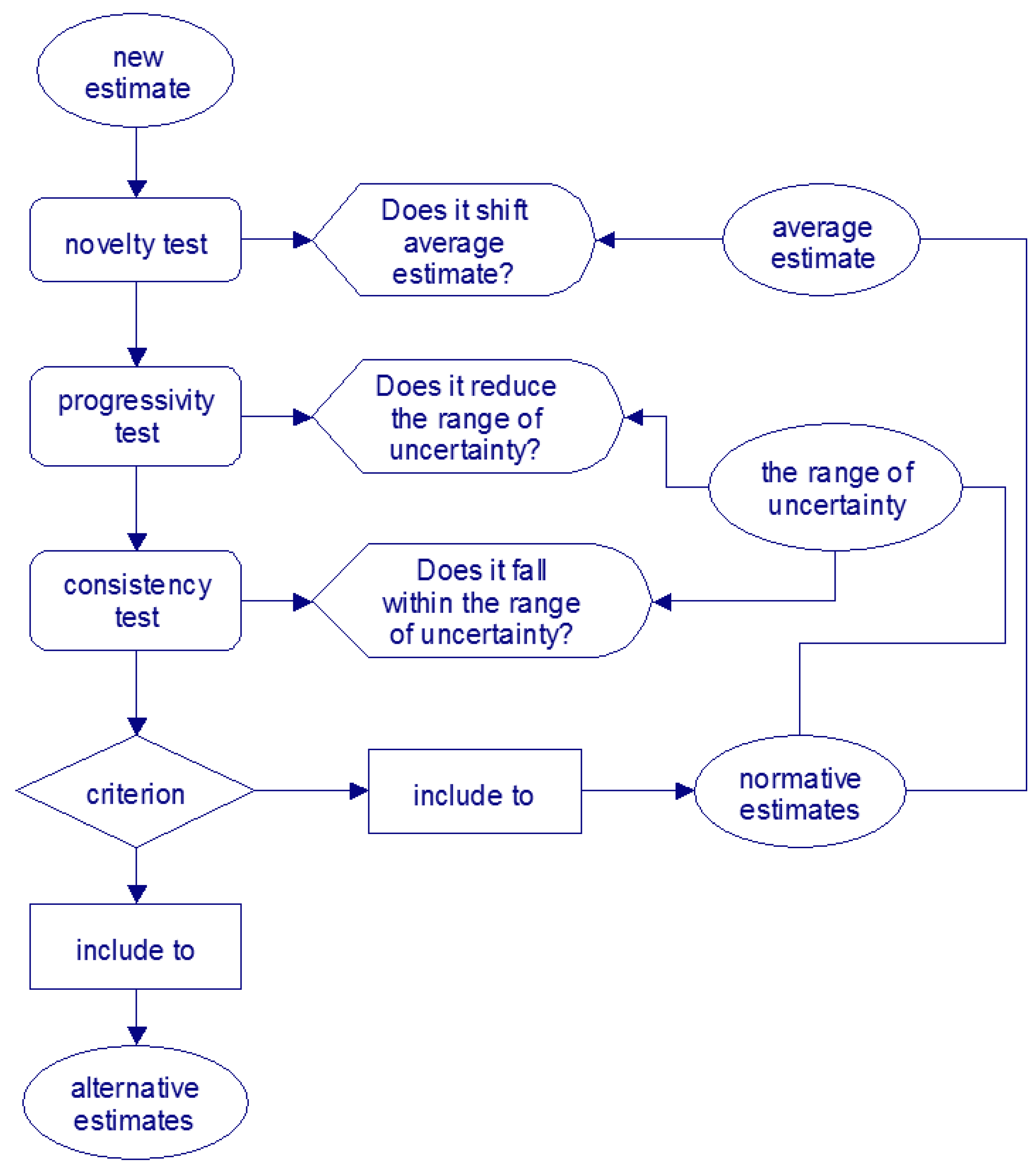
Will inclusion of the model into the normative collection reduce the uncertainties of average estimates? ☐

May one include the model into the normative collection? ☐

Should one include the model into the alternative collection? ☐

Algorithm of consensus-building

A biosphere model is a geographical extension of an ecosystem model, and so modeling ecosystems at global scale we are facing the same problem as at the local scale -- structural uncertainty. The structural uncertainty includes competing conceptual frameworks, lack of agreement on model structure, ambiguous definitions of system boundaries, inadequate description of significant processes [*2*]. The typical approach to this problem is assessing the maturity of the underlying science through retrospection of modeling efforts [*3*]. This displays either consensus building or paradigm shift. This approach can be formalized as shown at the flowchart and applied not only to retrospective studies but also for facilitating the process of forming normative data. Normative data are the set of standard estimates proceeding from which one may characterize the current state of knowledge in statistical terms — by the mean value of estimates and confidence interval of the mean value.



Flowchart for the process of building normative data

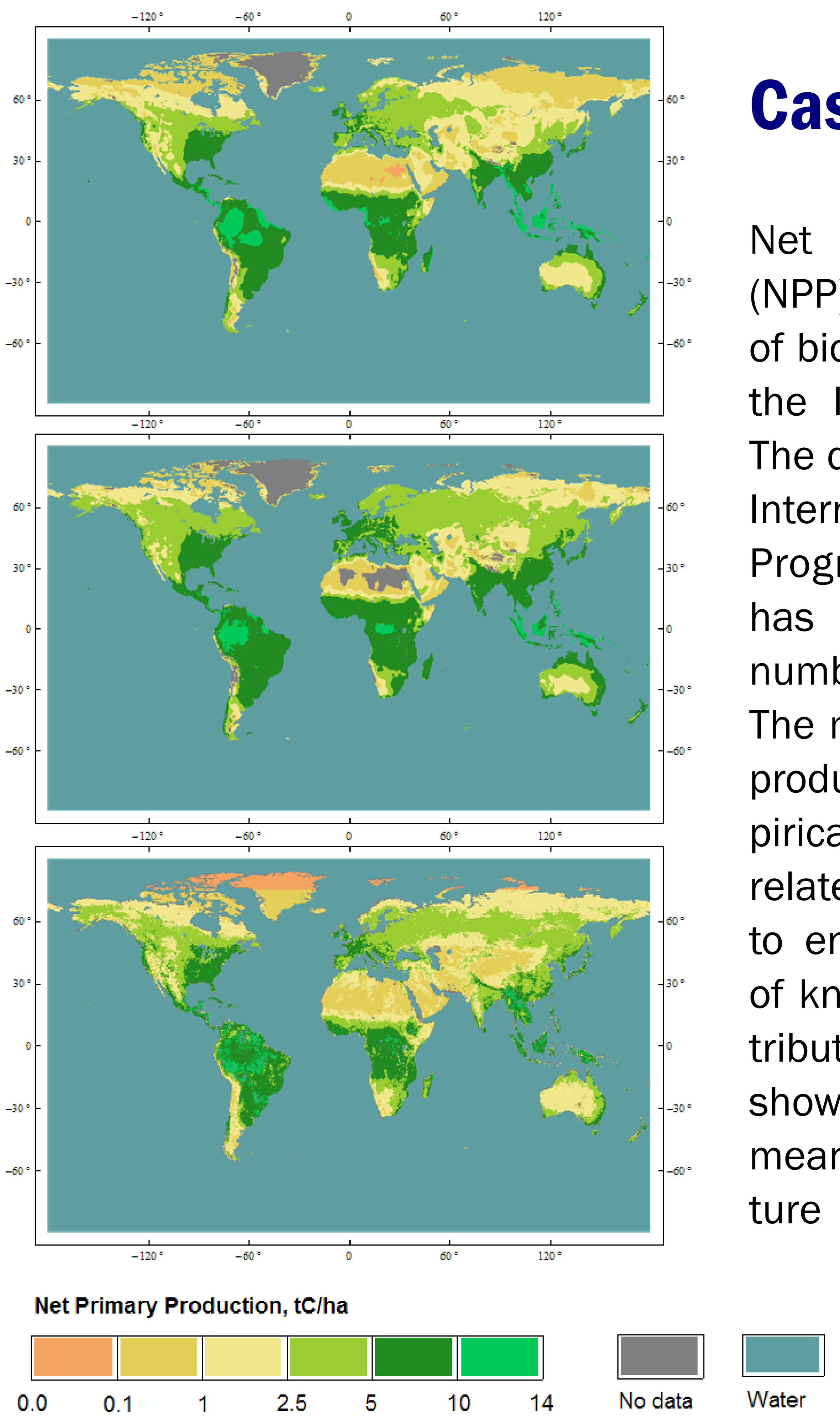
The tests

Consistency test is positive when estimate falls within the bounds defined by normative data, and negative otherwise. The estimate is said to be 100% consistent with the normative data if it coincides with the average estimate. The test shows how far is the estimate from the average in comparison to the lowest (or highest) normative estimate.

Progressivity test is positive if inclusion of the estimate into normative data narrows the confidence interval of the average estimate. It returns the relative decrease in the width of the confidence interval (in %).

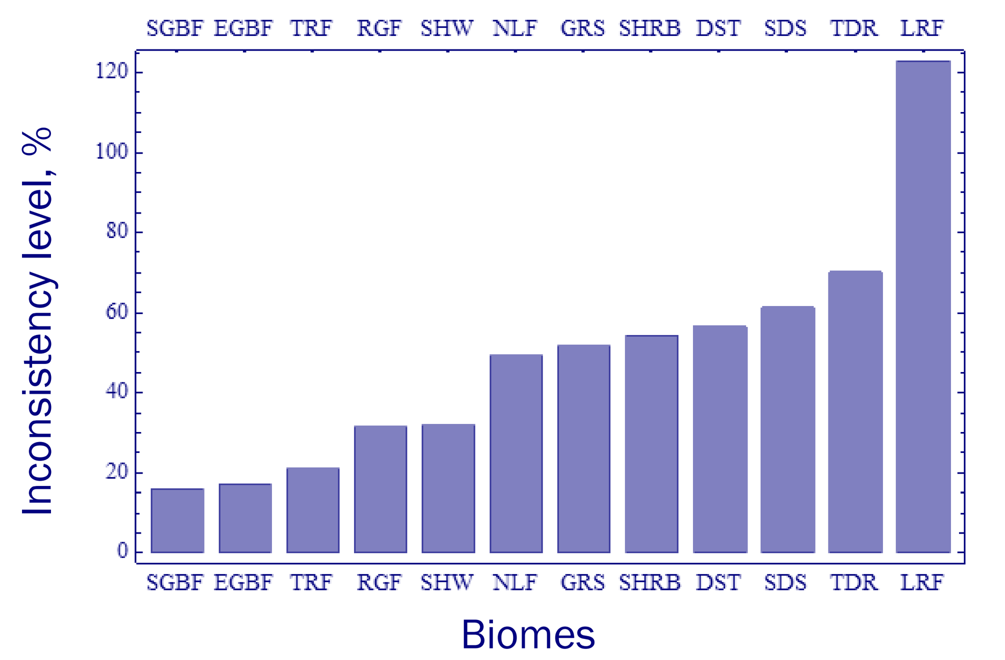
Novelty test is positive if inclusion of the estimate into normative data shifts the average estimate. It returns the relative value of the shift with respect to the width of the confidence interval (in %).

Criterion for inclusion to normative data is open to questioning. One may suppose that it is met if either consistency or progressivity test is positive.



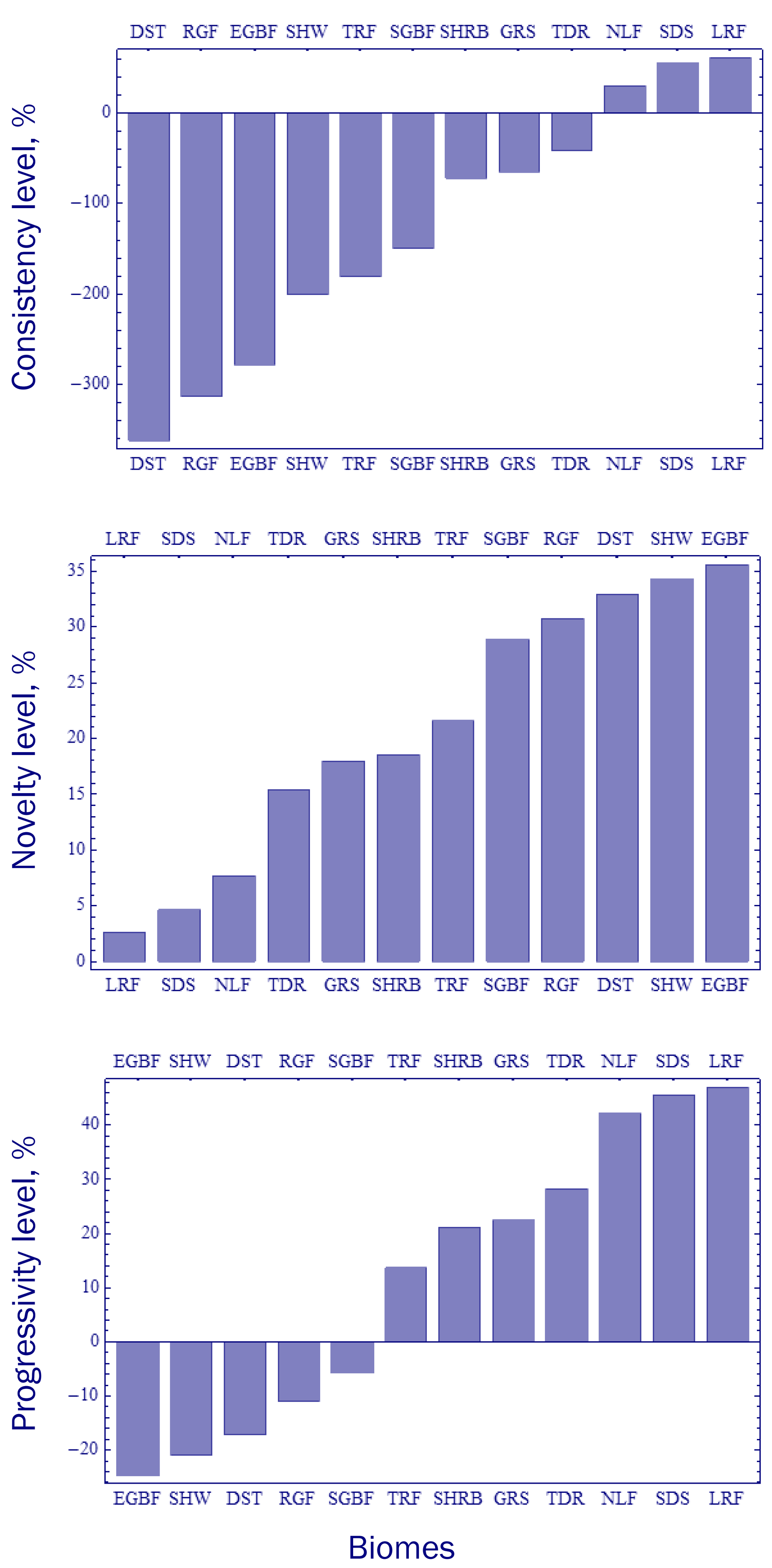
Case study: normative models of plant productivity

Net primary production (NPP) has been a focus of biosphere studies over the last three decades. The data collected during International Biological Program (1965-1974) has been turned into a number of NPP models. The maps on the left are produced with three empirical models [*4*] that relate gradations in NPP to environmental factors of known geographic distribution. The upper map shows NPP as related to mean annual temperature and precipitation (Miami model). The middle map shows NPP as related to actual evapotranspiration (Montreal model). And the lower map shows NPP as related to annually integrated NDVI (a vegetation index derived from Earth surface reflectance). Although the models were derived from the same NPP data (Osnabrück database) [5], inconsistency of their ensemble may be high in some cases (see the chart on the right).



Inconsistency of the model ensemble—The width of confidence intervals, in percentage of mean values. Legend: EGBF - evergreen broad-leaved forests, RGF - raingreen forests, TRF - tropical rainforests, SGBF - summer-green broad-leaved forests, SHW - subhumid woodlands, TDR - tundra, GRS - grasslands, NLF - needle-leaf forests, SDS - semi-desert scrubs, DST - deserts, SHRB - shrublands, LRF - larch forests.

Case Study: benchmarking a model of plant productivity

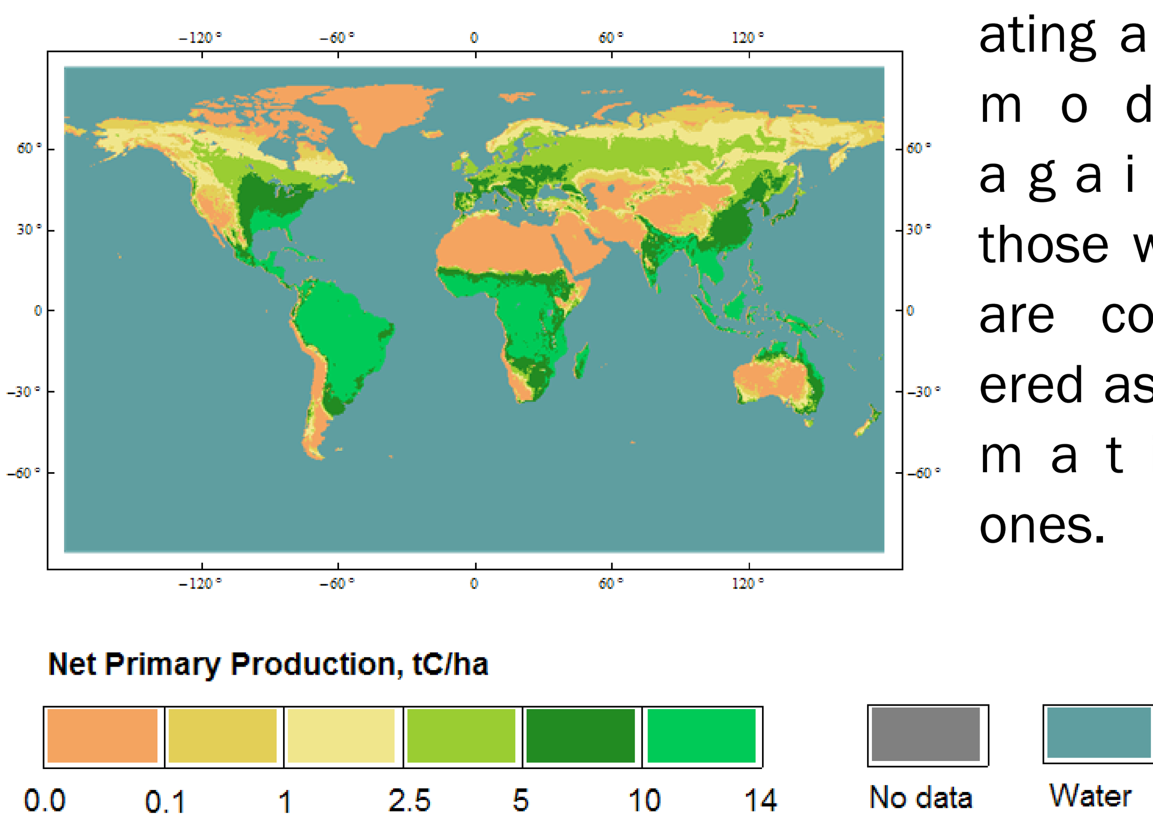


The results of consistency, novelty and progressivity tests. Legend: EGBF - evergreen broad-leaved forests, RGF - raingreen forests, TRF - tropical rainforests, SGBF - summer-green broad-leaved forests, SHW - subhumid woodlands, TDR - tundra, GRS - grasslands, NLF - needle-leaf forests, SDS - semi-desert scrubs, DST - deserts, SHRB - shrublands, LRF - larch forests.

At the same, this ensemble suggests, in many cases, quite narrow bounds for NPP estimates .

The estimates produced by a process-based model, calibrated with the same NPP data [6] and applied to the same input data (see the map on the right), do not fall within these bounds (see upper chart on the left). Nevertheless, the model does not shift average estimates beyond their confidence intervals (middle chart). Moreover, it reduces confidence intervals (lower chart) somewhere.

The novelty test implies the model can be included into the normative collection: this will not cause a paradigm shift. In contrast, consistency test suggests that model can be included into the alternative collection.



This case study shows the obvious need in a criterion for evaluating a new model against those which are considered as normative ones.

End notes

Routine checks of model consistency may lead eventually to cutting-edge conclusions

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6. Alexandrov, G.A., T. Oikawa and Y. Yamagata (2002), The scheme for globalization of a process-based model explaining gradations in terrestrial NPP and its application, *Ecological Modelling, 148*, 293-306.

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