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How do initial perturbation amplitudes and ensemble sizes influence ensemble forecast skill [U+FF1F]

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Singular vectors (SVs) have been widely adopted in the study of ensemble forecasting. However, the linearity of SVs limits the skill of ensemble forecast. The orthogonal conditional nonlinear optimal perturbations (CNOPs) are a group of mutually independent nonlinear optimal initial perturbations which is a natural generalization of the orthogonal SVs in nonlinear field. In the present study, the orthogonal CNOPs are used to yield the initial perturbations for ensemble forecast within the frame of the Lorenz-96 model and the impact of initial perturbation magnitudes and ensemble sizes on ensemble forecast skill are explored. It is found that the ensemble forecasts generated by the CNOPs, compared with those generated by the SVs, require a smaller magnitude of initial perturbations to achieve higher skill, and the highest skill of ensemble forecasts generated by the CNOPs is always higher than that generated by the SVs. Furthermore, the CNOPs provide much better spread-skill relationship and suggest that the ensemble spread of CNOPs-ensemble forecast can be used as a proxy for the forecast error statistics. In addition, results show that the skill of the ensemble forecast generated by either CNOPs or SVs tend to increase to be a maximum with the increscent amount of ensemble members and decreases subsequently, which sheds light on that an appropriate ensemble size is helpful for the ensemble forecast reaching the highest skill and the argument that the more the ensemble members, the higher the ensemble forecast skill does not hold. Further analysis demonstrates that the fast-growing initial perturbations are favorable for the increase of ensemble forecast skill while the slowly-growing or non-growing initial perturbations are less helpful for improving ensemble forecast skill. In sum, a conclusion is that the CNOPs with smaller amplitudes, together with an appropriate ensemble size, are most likely to make ensemble forecast of the highest skill.