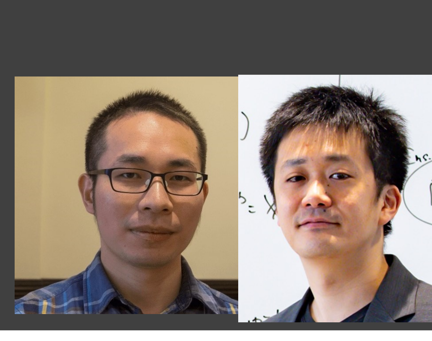
A hybrid data assimilation with reservoir computing to advance the control simulation experiment

Mao Ouyang[1], Shunji Kotsuki[1,2]

[1] CEReS, Chiba University, Japan; [2] IAAR, Chiba University, Japan

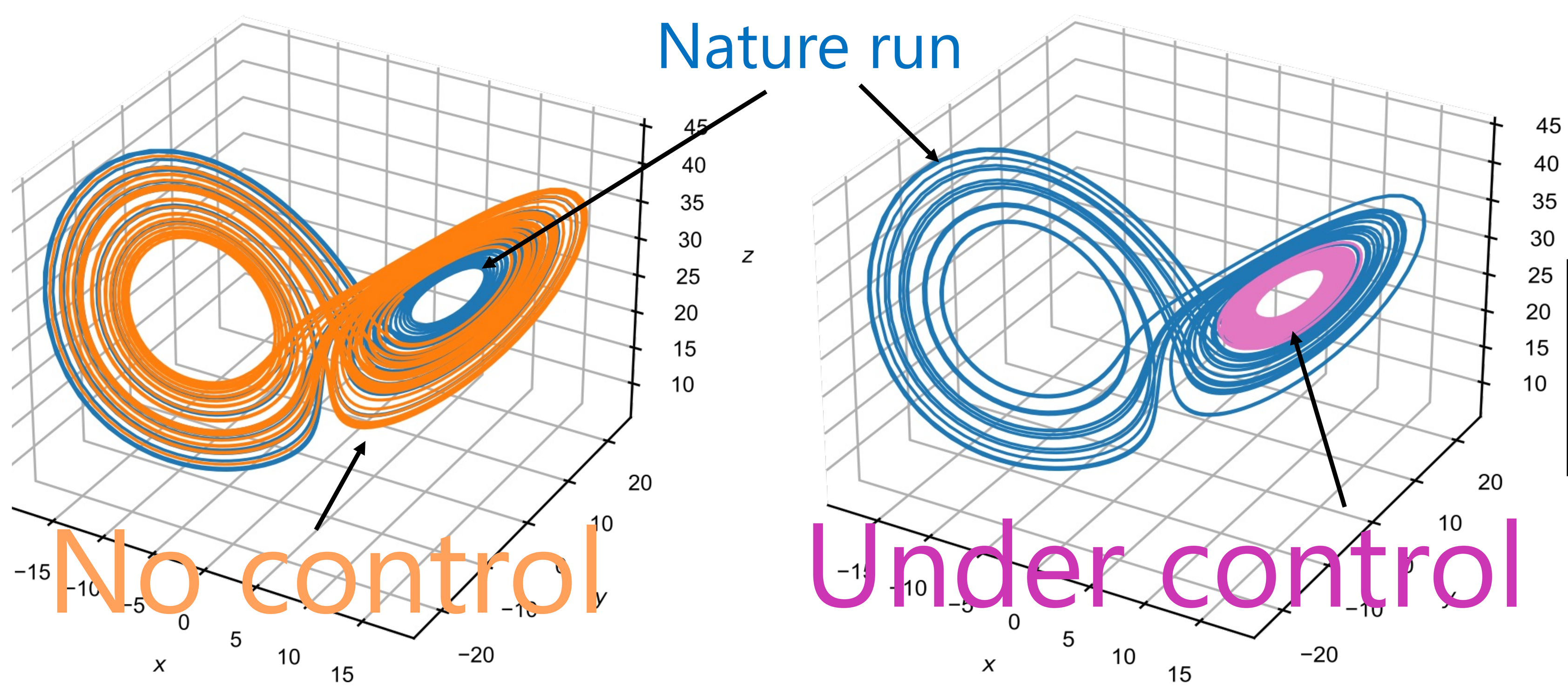
(ouyang.mao@chiba-u.jp)

Environmental Prediction Science Laboratory



Introduction

Control simulation experiment (CSE) (Miyoshi and Sun 2022)



Objective of CSE: control trajectory to stay in a wing of the butterfly attractor without shifting to the other.

Challenges in improving CSE

1. CSE can be improved by a better data assimilation scheme for accurately representing the chaotic behaviours

This study proposes to implement hybrid scheme to improve data assimilation

2. CSE can be improved through finding the optimal manipulations (ensemble members) to control the trajectories

This study proposes to introduce reservoir computing for finding optimal ensembles

Method

Hybrid LETKF (Kotsuki et al. 2022)

$$\mathbf{Z}^b_{hyb} = \left[\frac{\sqrt{\alpha}\delta\mathbf{X}^b_{ens}}{\sqrt{m-1}}, \frac{\sqrt{1-\alpha}\delta\mathbf{X}^b_{aug}}{\sqrt{c-1}}\right]$$

$\delta\mathbf{X}^b_{ens}$: Dynamic ens. ptb.
$\delta\mathbf{X}^b_{aug}$: Climatological ens. ptb.
m: Dynamic ens. size
c: Climatological ens. size
α : Hybrid coefficient

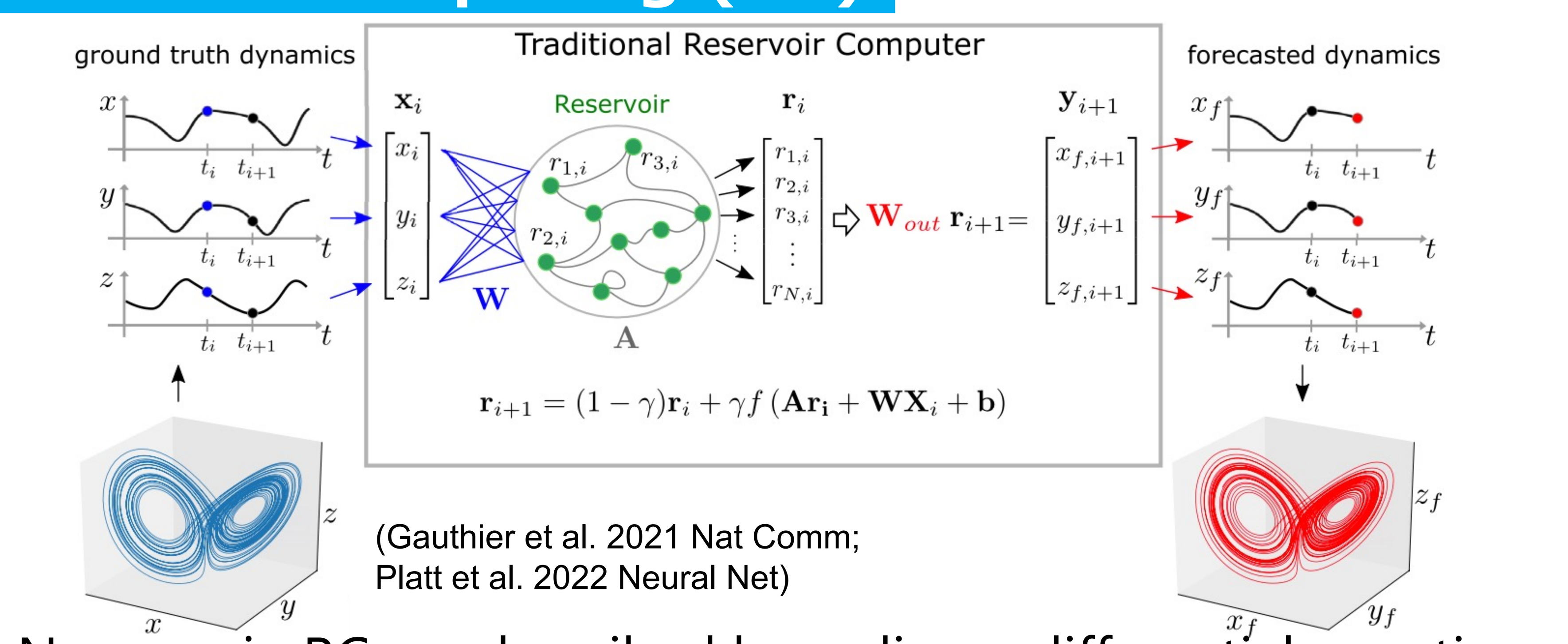
$$\mathbf{P}^b = \alpha\mathbf{P}^b_{ens} + (1-\alpha)\mathbf{P}^b_{aug}$$

Dynamic background error covariance

Augmented background error covariance

Provided by RC

Reservoir computing (RC)

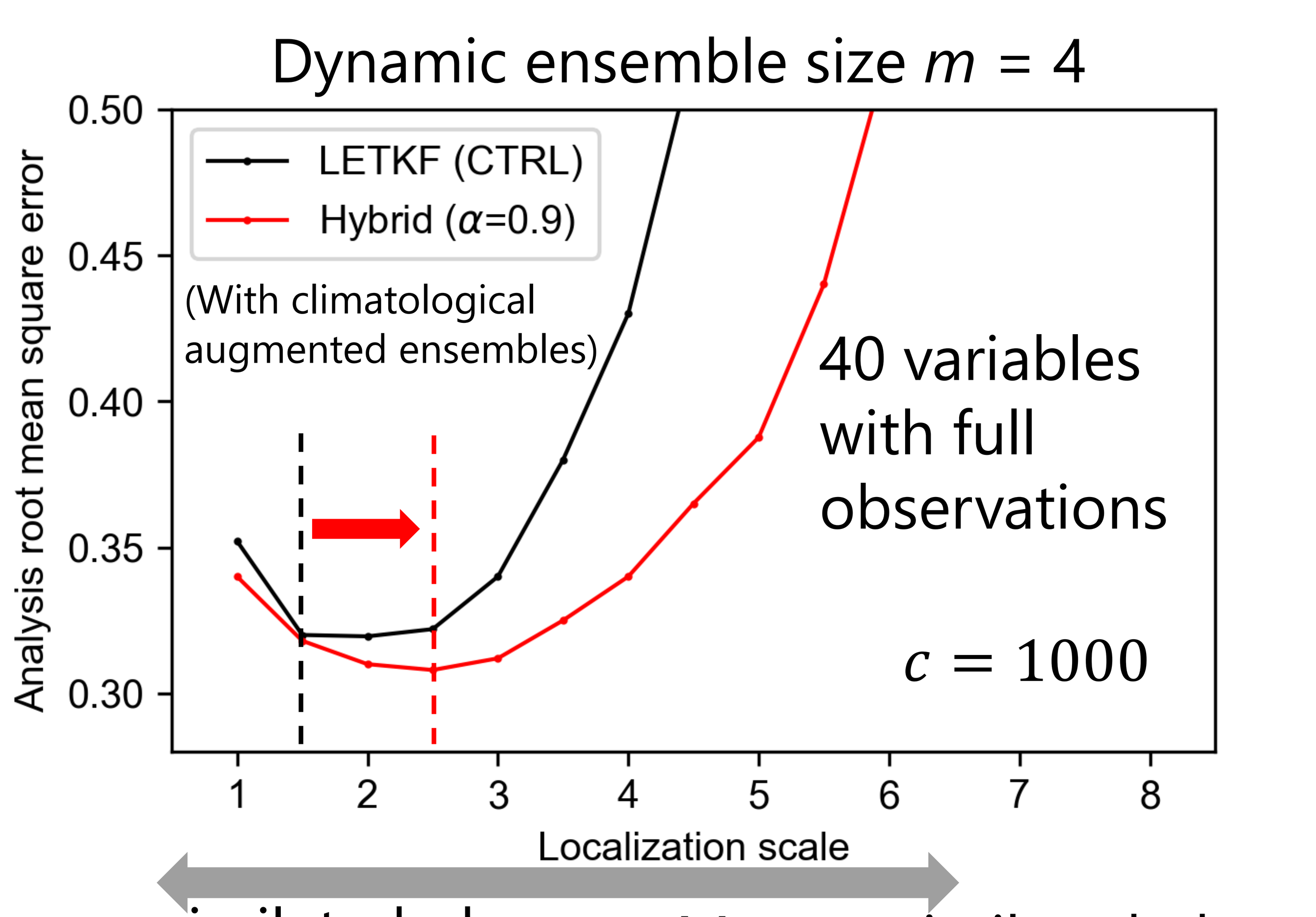


(Gauthier et al. 2021 Nat Comm; Platt et al. 2022 Neural Net)

Neurons in RC are described by ordinary differential equations, inherently have memory, which can predict dynamic systems

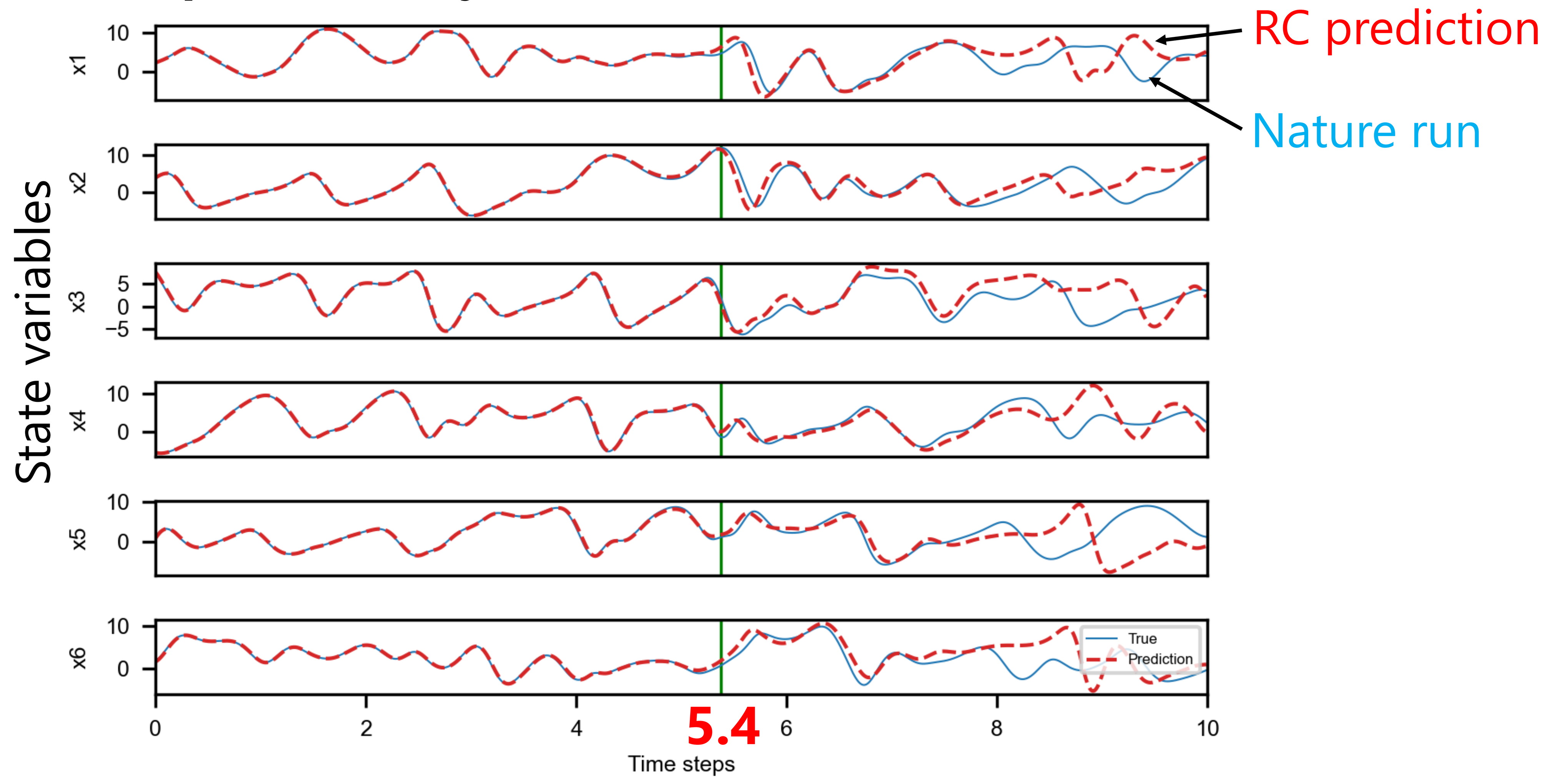
Preliminary results

Effects of Hybrid LETKF by Lorenz-96 model



Hybrid LETKF is efficient when the localization scale is large, e.g., hybrid enables to assimilate more obs.

The predictability of RC on 6-variable Lorenz-96 model



The RC could well predict the chaotic behaviours of Lorenz-96 model to around 5.4 time steps, which is longer than the DA step, e.g., 0.05.

Summary and plan

- **Hybrid LETKF provides an effective approach to improve the data assimilation** through the augmented ensemble members
- The **chaotic behaviours of Lorenz-96 model could be well predicted by the trained RC**, which showed around 5.4 valid prediction time steps
- Next step will be implementing the RC to provide additional ensembles for (a) **improving the data assimilation by hybrid LETKF**; and (b) **finding the optimal ensembles in the CSE**