Dynamical Forecasts of Tropical Terrestrial Carbon Fluxes with the NASA S2S Retrospective Forecast System

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Motivation

- Seasonal-to-subseasonal (S2S) forecast of meteorology is an active area of research.
- A study of forecasting ocean carbon shows success in predicting the phase of variability of the satellite chlorophyll in the Equatorial Pacific (Rousseaux and Gregg, 2017).
- On land, soil moisture plays a significant role in controlling air temperature on the S2S scale (Koster and Suarez, 2003; Koster et al. 2004), which also affects land productivity and carbon fluxes. Potential predictability of annual net ecosystem production was demonstrated in Lovenduski et al. (2019).
- Carbon forecasts can be useful for planning future observations.

Research Questions

1. How well can we forecast land carbon anomalies, such as Gross Primary Production (GPP) and Net Biosphere Exchange (NBE)?
2. Land initialization vs. predicted meteorology: which contributes more to land carbon forecast skill?

NBE = -GPP + Respirations + Fire

NASA GEOS S2S Retrospective Forecasts

- Current version of the system: *GMAO S2S_2.1
  - Experimental near-real-time climate forecasts
  - Provided to the North American Multi-Model Ensemble (NMME) prediction project
  - Showed good skill in predicting evolution of SST anomalies at the developing phase of the El Niño during the NH spring (Ham et al., 2014)
- For this study, we used 9-month NASA GMAO's retrospective forecasts (January to September), initialized in each December of 2007-2016 (4 members per forecast).
- Temperature, precipitation, radiation, humidity, and wind in the forecast were further bias-corrected with MERRA-2 climatology
- In this presentation, we aim to assess whether seasonal forecast meteorology can support skillful forecasts of carbon. For this reason, we treat the MERRA-2 driven carbon fluxes as "truth".

https://gmao.gsfc.nasa.gov/products/climateforecasts/geos5/index.php

Question 1

How well can we forecast land carbon anomalies (e.g., GPP and NBE)?

Experimental design (PART 1)

Meteorological forcings
MERRA-2
Retrospective forecast (bias-corrected)

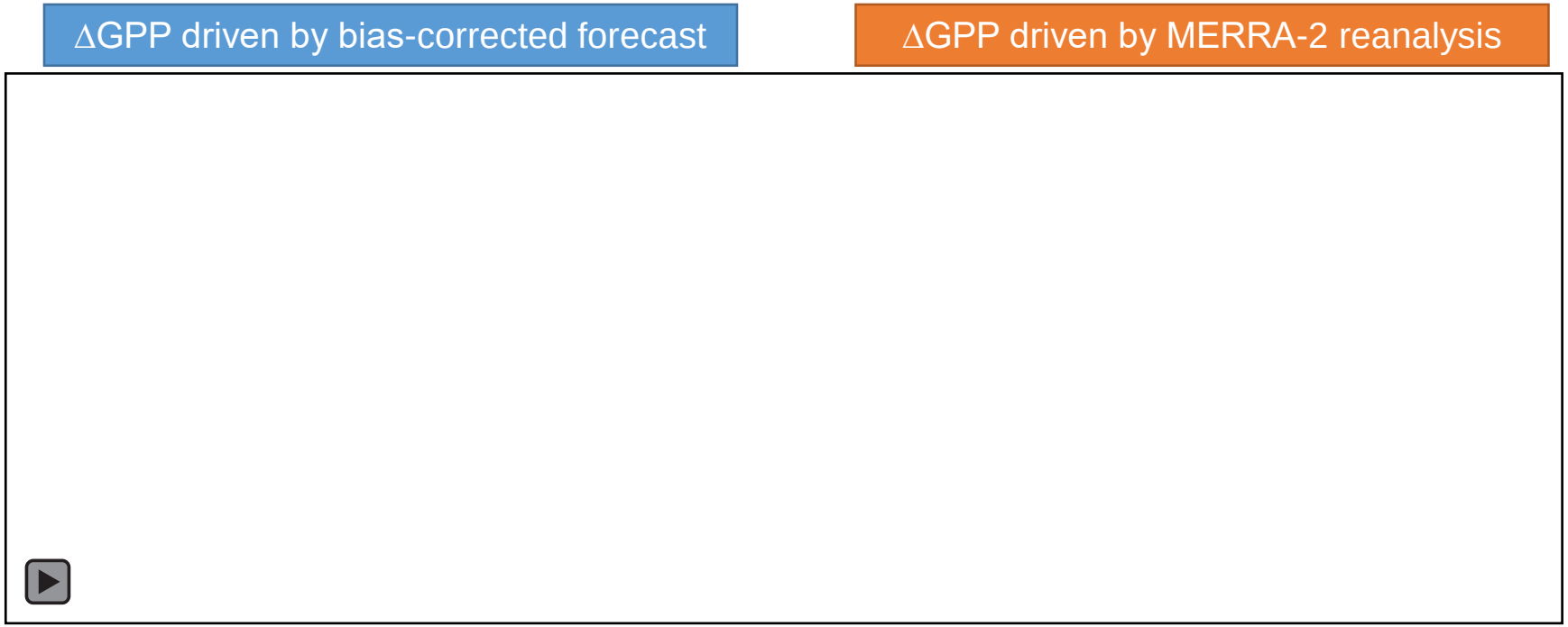
- Offline Catchment-CN model (Koster et al., 2014)
- Meteorological forcings: MERRA-2, or retrospective forecast
- 2007-2016 (10 years, including the most recent El Niño and La Niña years)

	2007 init	2008 init	2009 init	2010 init	2011 init	2012 init	2013 init	2014 init	2015 init	2016 init
2007 met (4 members)	X									
2008 met (4 members)		X								
2009 met (4 members)			X							
2010 met (4 members)				X						
2011 met (4 members)					X					
2012 met (4 members)						X				
2013 met (4 members)							X			
2014 met (4 members)								X		
2015 met (4 members)									X	
2016 met (4 members)										X

Analysis metrics

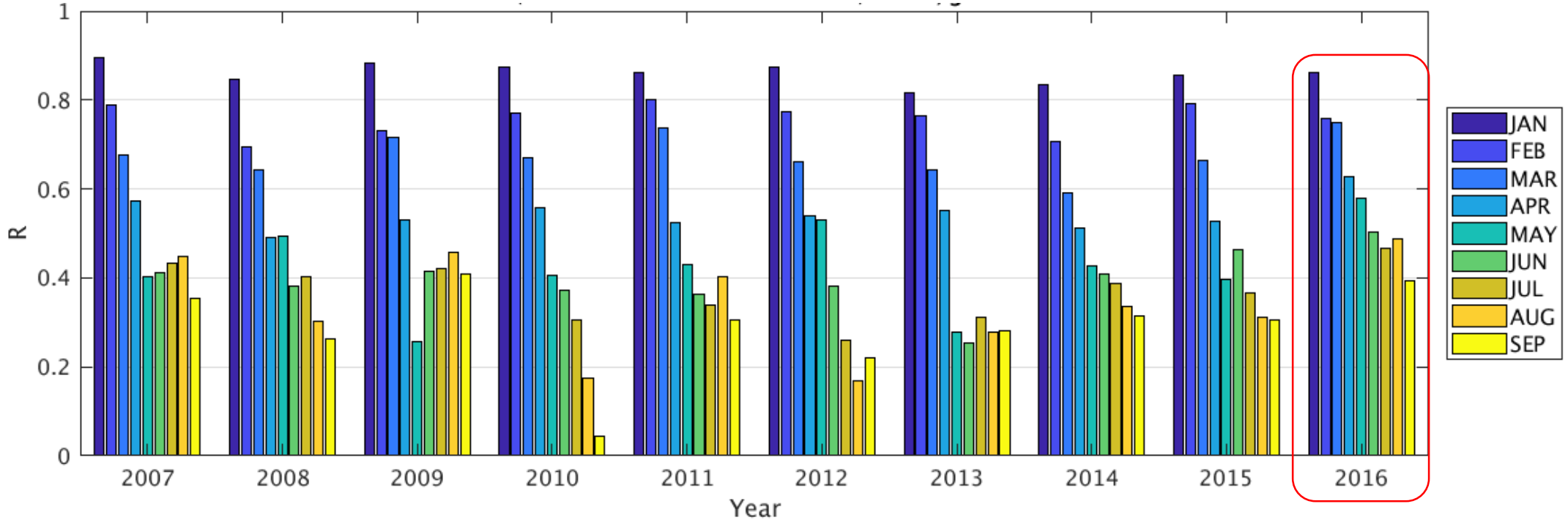
- [Step 1] Compute the anomalies, relative to the climatology (2007-2016 mean from 40 simulations)

Example:
GPP anomaly
in 2016



- [Step 2] Compute **spatial correlation coefficients (R)** between the monthly anomalies (forecast driven vs. MERRA-2 driven)
- Temperature, Precipitation, Radiation (Incident Photosynthetically Active Radiation (iPAR))
- GPP, NBE, and fire carbon loss

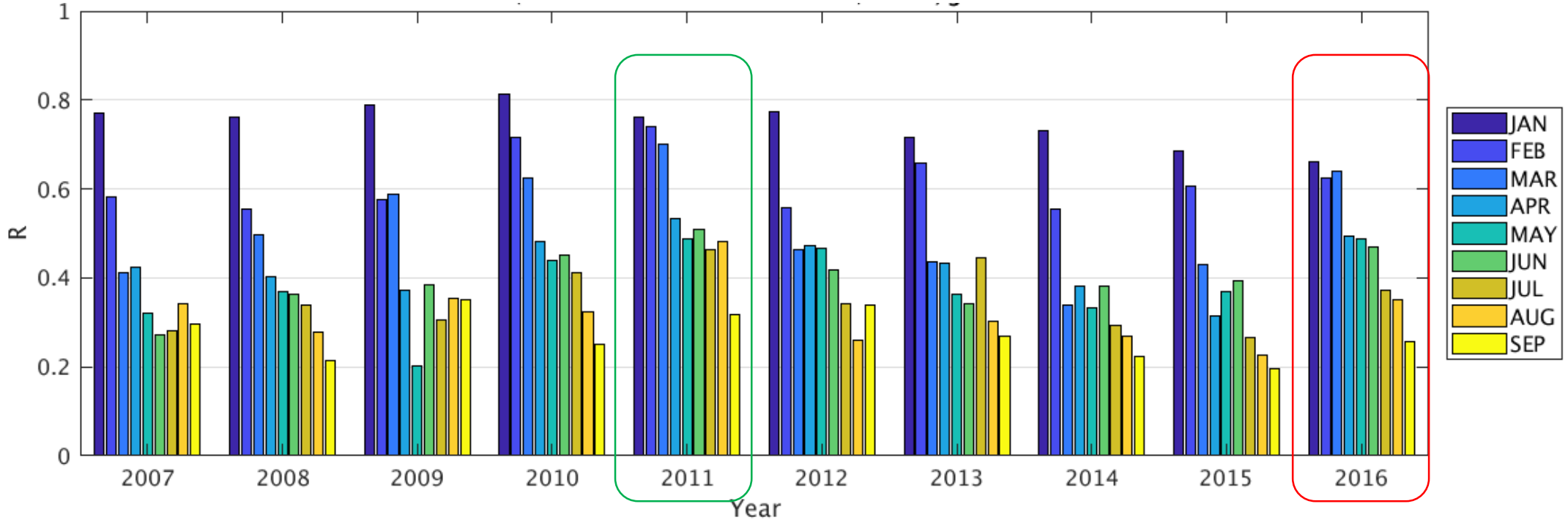
Spatial correlation coefficient (R): global GPP anomalies



- **Skillful forecast of spatial GPP anomaly up to ~3 months**

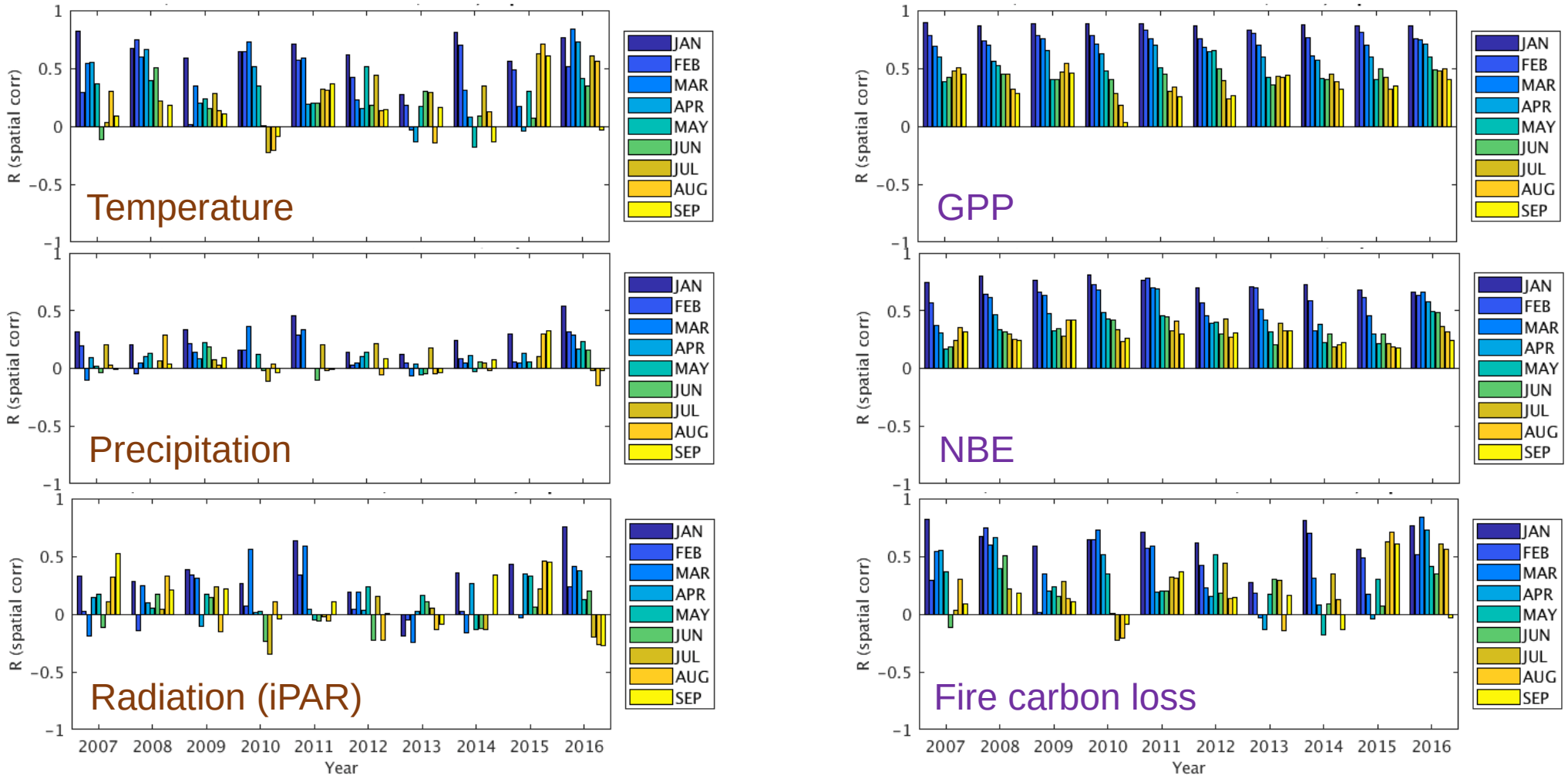
Spatial correlation coefficient (R): global NBE anomalies

net biosphere exchange



- **NBE forecasts less skillful than GPP, but still good at 1-2 month lead**
- **Highest skill under La Niña/El Niño conditions in 2011, 2016**

R of the anomalies: Tropical region (15S-15N)



- **In tropics, carbon forecasts are more skillful than meteorological forecasts**
- **Carbon forecast skill is slightly better in the tropics than across globe**

Question 2

Land initialization vs. predicted meteorology: which contributes more to land carbon forecast skill?

Experimental design (PART 2)

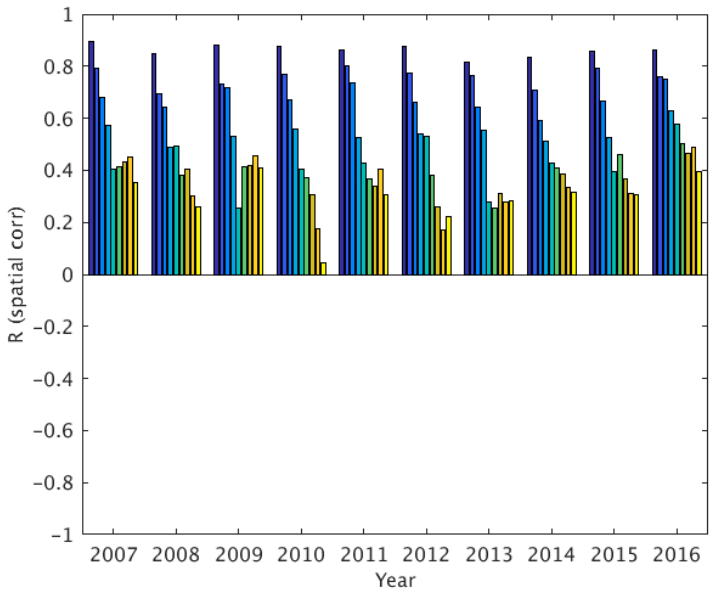
[Set 1] Apply 2016 Jan 1st Initial condition under different meteorology

[Set 2] Apply 2016 forecast meteorology for all ten years (2007-2016)

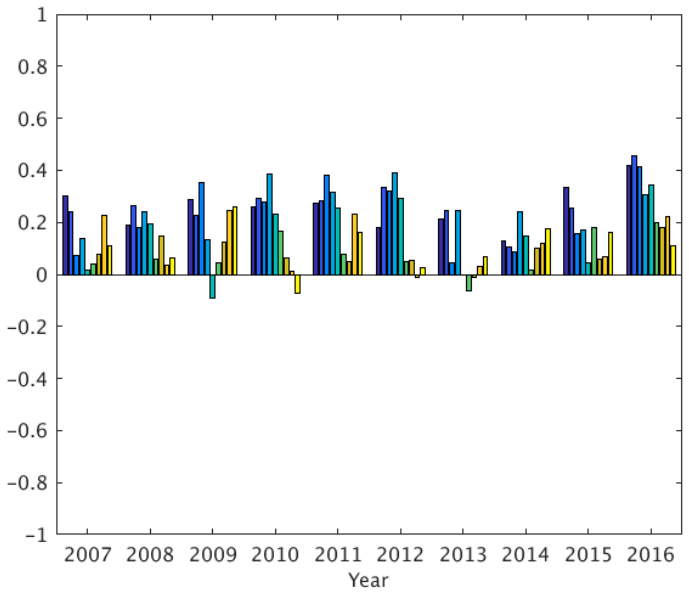
	2007 init	2008 init	2009 init	2010 init	2011 init	2012 init	2013 init	2014 init	2015 init	2016 init
2007 met (4 members)	**X**									X
2008 met (4 members)		**X**								X
2009 met (4 members)			**X**							X
2010 met (4 members)				**X**						X
2011 met (4 members)					**X**					X
2012 met (4 members)						**X**				X
2013 met (4 members)							**X**			X
2014 met (4 members)								**X**		X
2015 met (4 members)									**X**	X
2016 met (4 members)	X	X	X	X	X	X	X	X	X	**X**

Spatial correlation (R) of global GPP anomaly relative to 10-year climatology

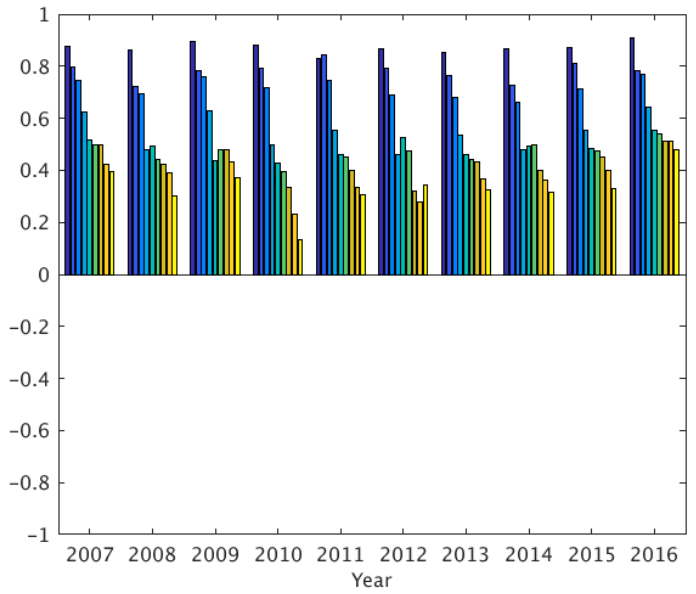
Both contributions



Contribution of met variability



Contribution of initial condition

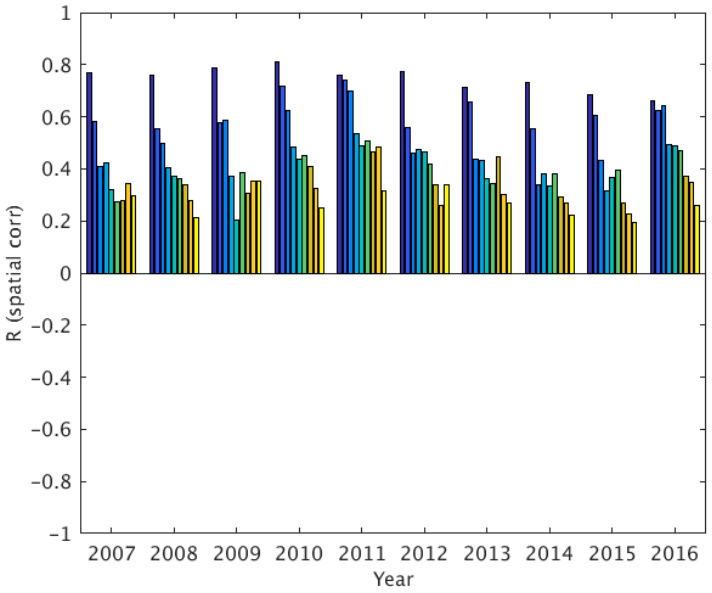


- **Contribution of land initial condition is larger to the GPP anomaly forecast skill than the predicted meteorology**

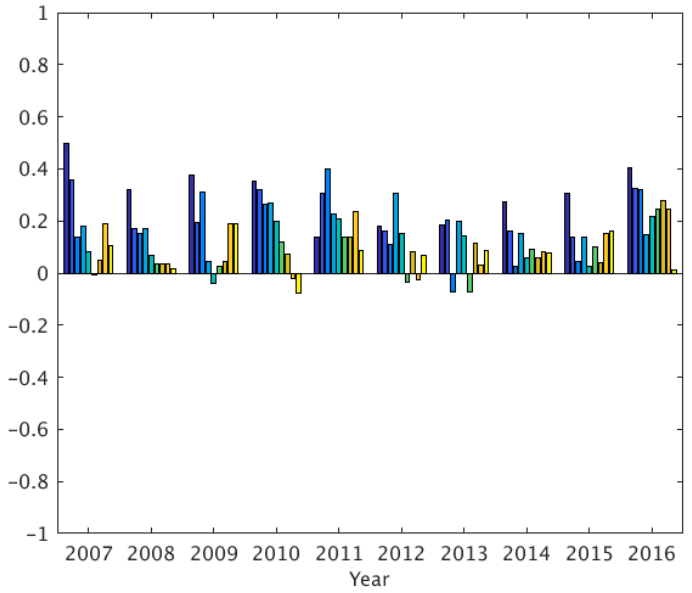
Note: each baseline climatology from 40 simulations can differ

Spatial correlation (R) of global NBE anomaly relative to 10-year climatology

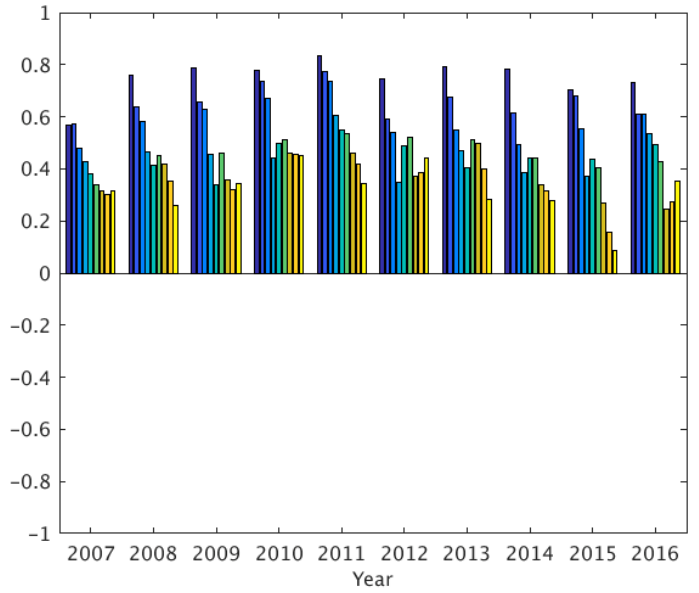
Both contributions

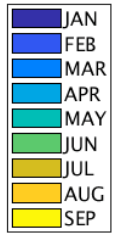


Contribution of met variability



Contribution of initial condition





- **Similar story for NBE: land initialization contributes more to the NBE anomaly forecast skill than does the meteorological variability**

NBE = -GPP + Respirations + Fire

Note: each baseline climatology from 40 simulations can differ

Summary

[Part 1] Evaluation of Carbon Forecast Skill

- Good skill in the carbon forecast (2~3 months in advance)
- Higher skill under La Niña/El Niño conditions (2011 and 2016)
- Tropical carbon forecast skill is generally higher than the global-scale forecast skill using the forecast initiated in December. The forecast skill with initialization in the NH spring/summer may differ (in progress)

[Part 2] Land Initialization vs. Predicted Meteorology in forecast

- Globally, the great majority of the carbon forecast skill comes from the land initial condition.
- The predicted meteorology may have a larger influence on carbon forecast during La Niña/El Niño years.
- Implications
  - Importance of satellite data in initializing seasonal forecasts of carbon fluxes
  - Possibility of simplifying the experimental design: you may not need large ensembles given the overwhelming importance of the initialization