Initialized Decadal Predictions by LASG/IAP Climate System Model

FGOALS-s2: Evaluations of Strengths and Weaknesses

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Outline

- Model and initialization scheme
- Evaluation of hindcast runs
- Challenge for the prediction of global monsoons
- Summary
Radiative effects of volcanic eruptions were considered by changing stratospheric AOD.

Bao et al. 2013 AAS
Design of initialization scheme

- **Incremental analysis update (IAU) scheme** (*Bloom et al. 1996 MWR*).

- Observational oceanic temperature and salinity over upper 1000m derived from *the MetOffice gridded objective analysis data EN3_v2a* (*Ingleby and Huddleston, 2007, J. Mar. Sys.*).

- **Anomaly Assimilation approach**, no posterior bias correction.
In one assimilation cycle ($t \sim t + \tau$), the model was integrated freely firstly, which produced the first guess for the assimilation.

- The analysis increment were calculated.
- The model was restated from $t$ again and integrated to $t + \tau$, with analysis increments being introduced as a constant in every model step.

- Designed for data assimilation system of meteorology (Bloom et al. 1996), then applied to the ocean assimilation (Huang et al. 2002), and coupled model initialization (Tatebe et al. 2012).
• The **10-year-long hindcasts/forecasts** were **started every five years** over the period of 1960-2005.

• Initial conditions were obtained from the ASSIM runs.

• In the hindcast and forecast stages (before and after 2005), the model was driven by the time-varying radiative forcing consistent with the historical and representative concentration pathways 4.5 (RCP4.5) simulations, respectively.

• To estimate the uncertainties of the prediction, **we performed 3-member ASSIM runs with different initial conditions**, which further offered initial conditions for three sets of hindcasts/forecasts runs.
Root Mean Square Skill Score ($\text{RMSSS}$):

$$\text{RMSSS} = 1 - \frac{\text{RMSE(hindcast)}}{\text{RMSE(climatology)}}$$

Where RMSE is the root mean square error of the hindcast and no skill baseline.

**Ratio of RMSE** = $\frac{\text{RMSE(INIT)}}{\text{RMSE(NoINIT)}}$

Doblas-Reyes et al. 2013, *Nature Communication*
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1. Root Mean Square Skill Score of surface air temperature
2. RMSSS of land precipitation
3. Global mean surface air temperature time series
4. Atlantic multi-decadal variability (AMV)
5. Atlantic Meridional Overturning Circulation (AMOC)
6. IPO/PDO/Mega-ENSO
Hindcast of surface air temperature (FGOALS-s2)

Significant high predictive skills in the Indian Ocean, tropical western Pacific and Atlantic
Hindcast of surface air temperature (CMIP5 MME) - also high skills in the Indian Ocean, tropical western Pacific and Atlantic.

IPCC AR5 chp11
Hindcast of land precipitation (FGAOLS-s2)

Low skills over most part of the world
Hindcast of land precipitation (CMIP5 MME)

Better than FGOALS, but still low

IPCC AR5 chp11
Hindcast of global mean surface air temperature (GMST)

**Cor**

- a) Correlation over time for different initialization scenarios:
  - NoINIT
  - INIT
  - OBS

- Forecast time (yr):
  - 1-4
  - 2-5
  - 3-6
  - 4-7
  - 5-8
  - 6-9

**RMSE**

- Root Mean Square Error (RMSE) over time for different initialization scenarios:
  - NoINIT
  - INIT
  - OBS

- Forecast time (yr):
  - 1-4
  - 2-5
  - 3-6
  - 4-7
  - 5-8
  - 6-9

**FGOALS-s2**

**IPCC AR5 chp11**
Hindcast of global mean surface air temperature (GMST)

IPCC AR5 chp11

FGOALS-s2

CMIP5 Init  CMIP5 NoInit

OBS

NoINIT

INIT

c) 6-9yr
Hindcast of AMV Time Series

c) 6-9yr

FGOALS-s2

IPCC AR5 chp11
Variations of AMOC predicted by FGOLAS-s2

Interdecadal variation of AMOC is well predicted.

“Observed” AMOC derived from the assimilation (Yang et al. 2012 JC)
Where does the AMV skill come from?

Skills of the AMV prediction come from the prediction of AMOC.
The spatial pattern of the IPO/Mega-ENSO simulated by the FGOALS-s2 resembles that in the observation.
NO Skills in the prediction!
Another Exp with FGOALS-gl

- LICOM2.0 (1°*1°)
- GAMIL (5°*4 °)
- CLM3
- CSIM5

CPL6

Radiative effects of volcanic eruptions were considered by changing solar cycle variations

- FGOALS-gl: low-resolution version of FGOALS.
- Share the same initialization scheme with FGOALS-s2

Zhou et al. 2008 AAS
Correlations of the 10-year-mean SST predicted by FGOALS-gl

High skills in the equatorial Pacific, but low skills in the Atlantic.

Skills of decadal prediction are highly model dependent!
Hiatus in FGOALS-gl hindcast

-Wu and Zhou, 2012
Climate mean states of AMOC

(a) NoINIT

ocean depth

-20 -18 -16 -12 -8 -4 4 8 12 16 18 20

FGOALS-s2

(a) Climatology

Sv (10^6 m^3 s^-1)

0 1000 2000 3000 4000 5000

Depth (m)

30S 0 30N 60N

FGOALS-gl
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Global monsoon Domain

Lin, Zhou, Qian, 2014, J. Climate
Global monsoon index

E. Asian Summer Monsoon and Global Monsoon

Hiatus in E.Pac Pacemaker run

(a) Observed and Simulated GMST Anomalies (°C)

- HadCRUT
- HIST (0.91, 0.62)
- HIST-EP (0.94, 0.80)

Zhou, Song, Liu et al. 2015, to be submitted
COR=0.65, after removing interannual signals, 0.49
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Summary

- **Strengths of FGOALS-s2**: Significant predictive skills in the Indian Ocean, tropical western Pacific and Atlantic, *similar to the results of the CMIP5 multi-model ensemble*.

- The predictive skills of AMV are resulted from the northward heat transport anomalies associated with the preceding fluctuations of the AMOC.

- **Weakness of FGOALS-s2**: No skill is seen for PDO, posing a challenge for global monsoon prediction.

- **Discussion**: The skills seem to be model-dependent, even the models share an identical initialization scheme. *The treatment of volcanic effects may be one reason?*
