Water Cycle and Land-Atmosphere Coupling in CFSv2

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- Water Cycle Drift in Reforecasts
- Land-Atmosphere Coupling
- Land Initial Conditions and Skill
Another View of the CFSR Suite

• “0-Lead” starts anywhere from 30 days prior to 7 days into forecast period.
• Four 9-month forecasts started every 5 days.
• 24-28 forecasts per month.
• Creates analysis challenges and opportunities.

Illustration of CFSv2 Reforecast Ensembles

Courtesy: J. Adams

1 May 2012 CFSv2 Evaluation Workshop – Riverdale, Maryland
Drift in Means, Variances

• Next slides show seasonal means of:
  – 0-Lead:
    • Mean global precipitation
    • Intra-ensemble standard deviation (24-28 members for each month)
    • Interannual standard deviation (of ensemble means – the “climate signal”)
  – Differences from 0-Lead at leads of 1, 4 and 8 months.

• Quantities averaged for DJF and JJA seasons.
Precip Lead 0

JJA

Intra-Ens_StdDev Lead 0

Interannual_StdDev Lead 0

ICs: MJJ

Lead 1

ICs: FMA

Lead 4

ICs: OND

Lead 8
Drift in Means, Variances

• Means show a drift to the CFSv2 model climate
  – Increase in oceanic ITCZ/tropical precipitation
  – Mainly decreases elsewhere (e.g., continents)

• Ensemble spread largely follows mean drift (ocean-driven??).

• Interannual variability decreases markedly with forecast lead.

• Need to consider: **Forecast climatology varies in 2 time dimensions** – seasonal cycle and forecast lead
Surface Water Cycle – A Multifarious Tale

- US Great Plains average:
- Surface layer soil moisture quickly drifts towards wet bias
  - Soil moisture initialized from offline Noah run (GLDAS).
  - This is the same stream used to reset CFS reanalysis every 24 hours, so reanalysis (black curve) is constrained by GLDAS.
Wet Bias Exists Throughout Upper Soil

• What is the driver of this drift in the CFS reforecasts?

• What are its implications?

• Note – the bars denote the interannual ±1σ for each forecast at each lead, and for reanalysis.
Culprit is Precipitation

- Positive biases in CFSR through much of the year.
  - Reanalysis precipitation actually a bit low in MJJ, yet CFSR is high.
  - Throughout the year, precipitation simulations trend positive with increasing lead time.

Observations from the COOP/SnoTEL based PRISM monthly product
Deep Soil Behaves Quite Differently

- Reanalysis (GLDAS) deep soil moisture is very flat.
- CFSR has a large annual cycle and an oscillation in the evolution of biases.
- Recall reanalysis states are constrained and there is no conservation enforced (characteristic of NWP’s DAS).
- The reforecasts are in a model that (largely) closes the water budget.
Runoff

• CFSR output does not discern between baseflow and surface runoff, but we see the signature of precipitation biases.

• How can the hydrologic community make use of such data?
Evapotranspiration

- CFSR ET is very high compared to the reanalysis.
- Recall CFSR SM is higher than in upper soil – source of extra ET.
- Implication – negative increments in SM in reanalysis – soil constantly dried, this limits moisture for ET.
- Forecasts free to run up.
Snow – the Final Frontier(?)

• The largest biases (percentage) appear to be in snowfall / snow cover.

• Biases also across North America and Eurasia.

• All of these evolving biases in water budget terms pose challenges to users in hydrologic, agricultural, and related fields.
Heavy snow bias and late snow melt manifests as cold bias in spring.

Evident in many other states and fluxes as well.
July Coupling Indices

- Positive correlation between evaporation and soil moisture indicates soil moisture is controlling surface fluxes.
  - Necessary condition for feedback
- Index is product of $r_{LHF,SM}$ and $\sigma_{LHF}$.
- Index grows with lead over US (spring ICs) and India (winter-early spring ICs)
  - Indicative of systematic precip errors.
How Does CFSv2 Compare?

- Index for CFSv2 with Noah is considerably weaker (+&-) than:
  - GSWP-2 (Land MME)
  - IFS run in climate mode
  - MERRA reanalysis (both L-A and the land-only “replay”).

Still July....
Left panels from Dirmeyer (2011):
GRL doi:10.1029/2011GL048268
Drift in Coupling

- Changes in coupling index shows the southern Great Plains gets stronger, but much of the rest of North America has weakening coupling.
- These changes come because soil moisture drifts in/out of “sweet spot” for flux sensitivity.
- Could this contribute to reduced skill (cf GLACE-2)?
Precipitation Skill by Lead

- Staggering of ICs in ensembles allows for a pentad-level assessment of skill.
- Averaged over CONUS, little skill in monthly means.

July Precip interannual correlation (skill)

Cheating going on
Temperature is Better

- Have yet to look at seasonal (3 month) skills – likely to be better than single month skills for both precipitation and temperature.
Precipitation Validation and Soil Moisture ICs

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Precipitation Validation and Soil Moisture ICs

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Precipitation Validation and Soil Moisture ICs

• CFSR monthly precipitation rapidly decorrelates from obs.
• CFSR precip similarly loses correlation with initial surface soil moisture anomalies.
• Observed precipitation has much stronger correlation with antecedent soil.
• Why? Positive L-A feedback, or persistent weather regimes?
And Extremes?

- Plots show the changes in correlation when only the forecasts with the driest/wettest 20% of soil moisture ICs are used (compared to previous slide).
- More skill and connection of forecasts to $SM_{IC}$.
- Observations also show even stronger correlations.
- Still an open question: what is the cause?

1 May 2012
Summary

• Huge drifts exist – CFSv2 climate is not naturally near the CFS Reanalysis climate. CFSv2 climatology varies in 2 time dimensions.

• Drifts and increments in state variables affect fluxes – this is very evident in local/regional water budgets.

• Land-atmosphere coupling metrics show patterns in good agreement with other global estimates, but generally weaker.

• Subsequent rainfall too weakly correlated with antecedent soil moisture
  – How much is weak coupling and how much is excessive high-frequency variability (or is variance simply following excessive mean rainfall)?