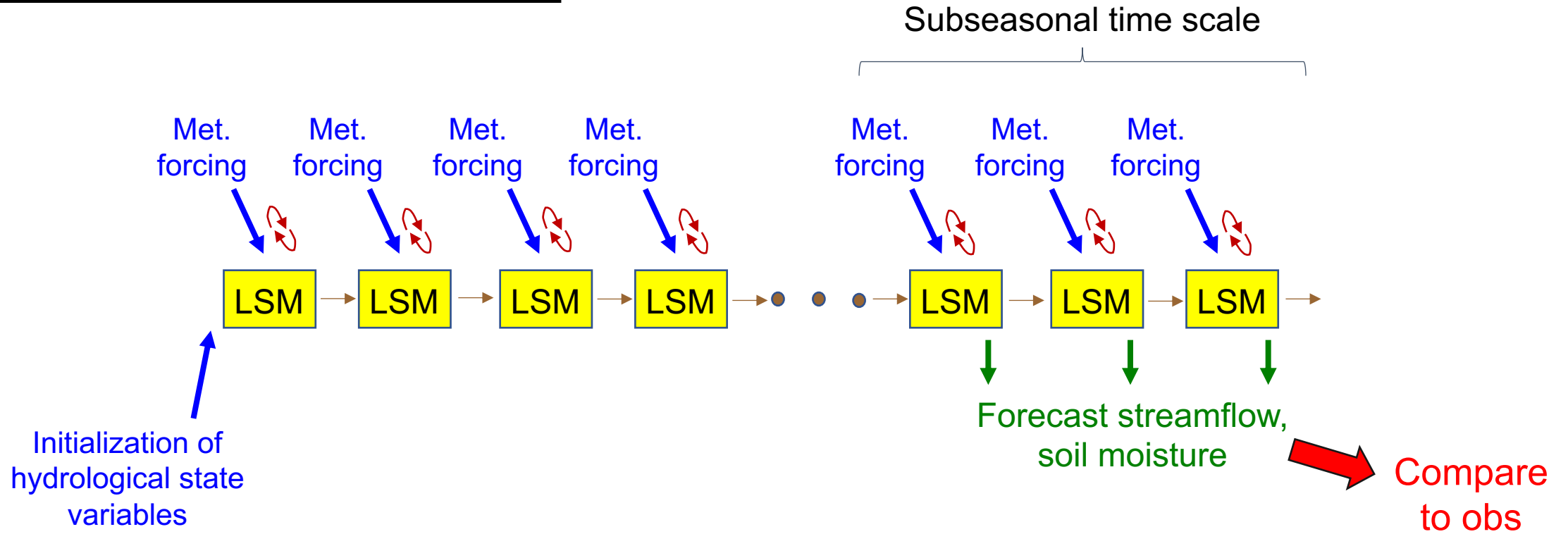


The Simulation and Subseasonal Forecasting of Hydrological Variables: Insights from a Simple Water Balance Model

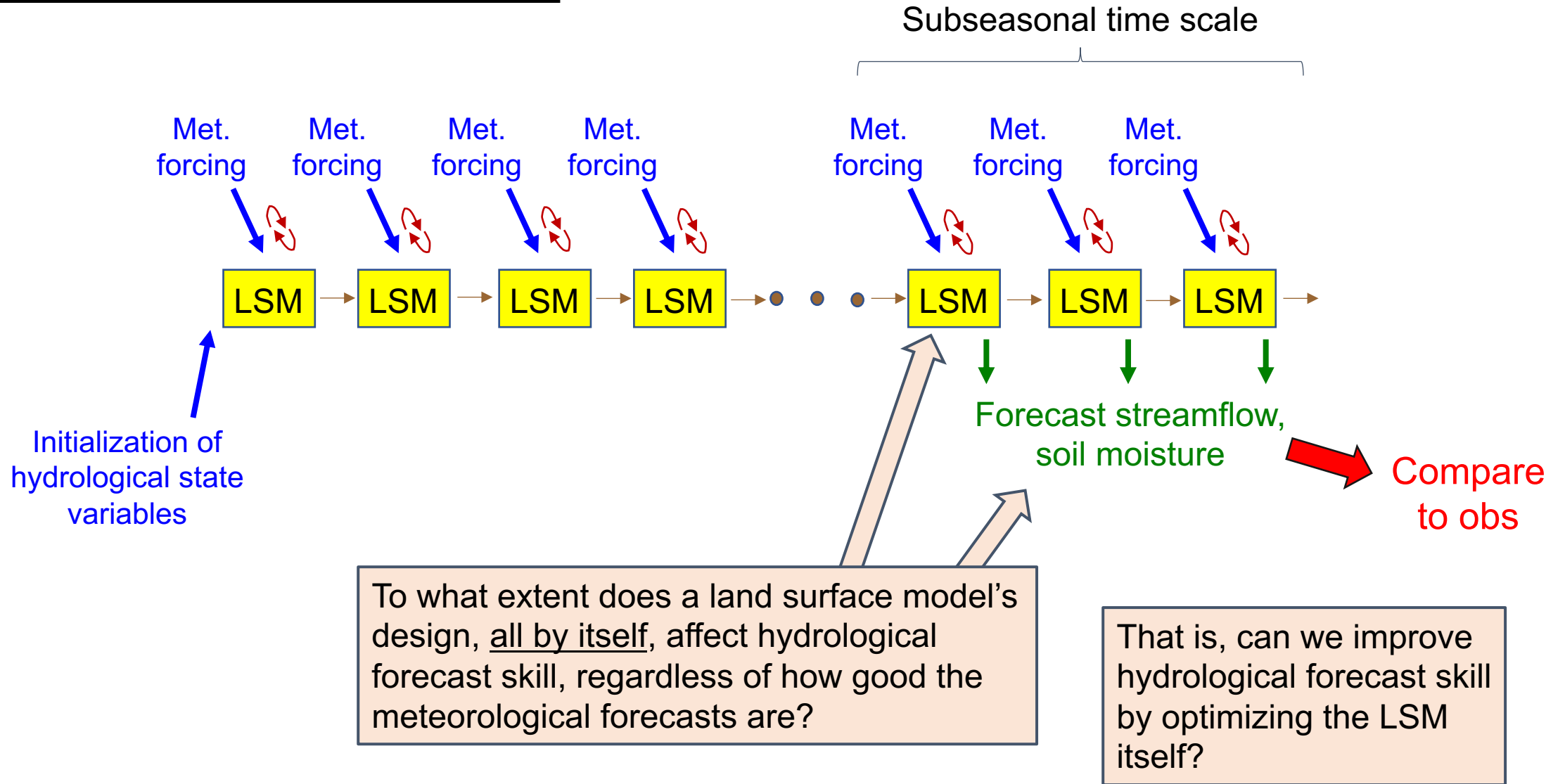
Randal Koster, Anthony DeAngelis¹ Qing Liu¹, Siegfried Schubert¹, and Andrea Molod
Global Modeling and Assimilation Office
NASA/GSFC, Greenbelt, MD

¹Also with Science Systems and Applications, Inc.

Subseasonal Forecast Modeling System



Subseasonal Forecast Modeling System





Approach: Examine problem with a “bare bones” representation of a land surface model.

Bare-bones representation: based on water balance equation

Soil profile water holding capacity

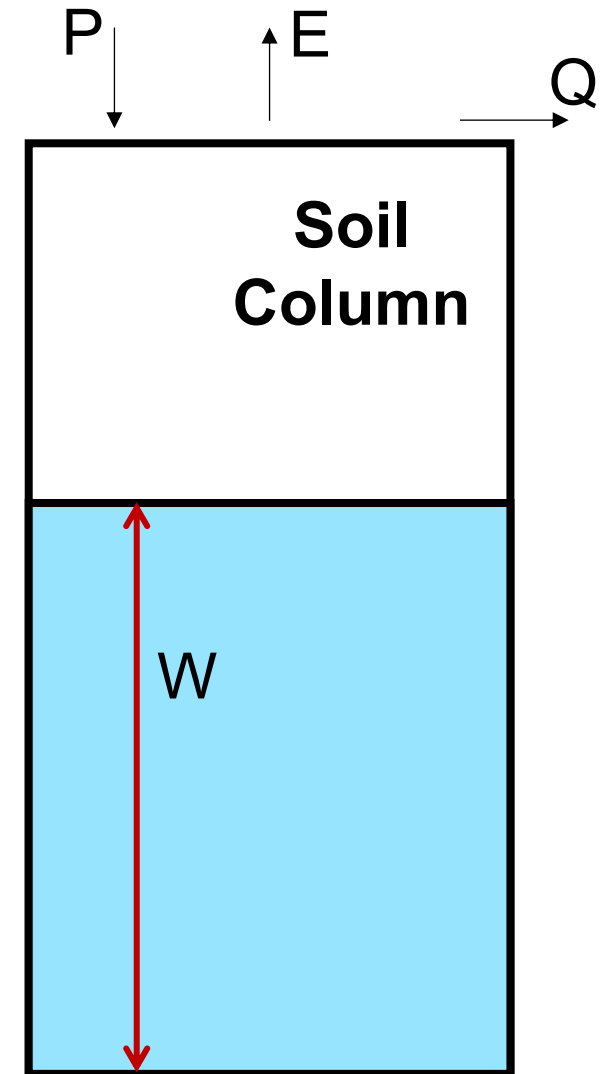
Precipitation

Evapotranspiration

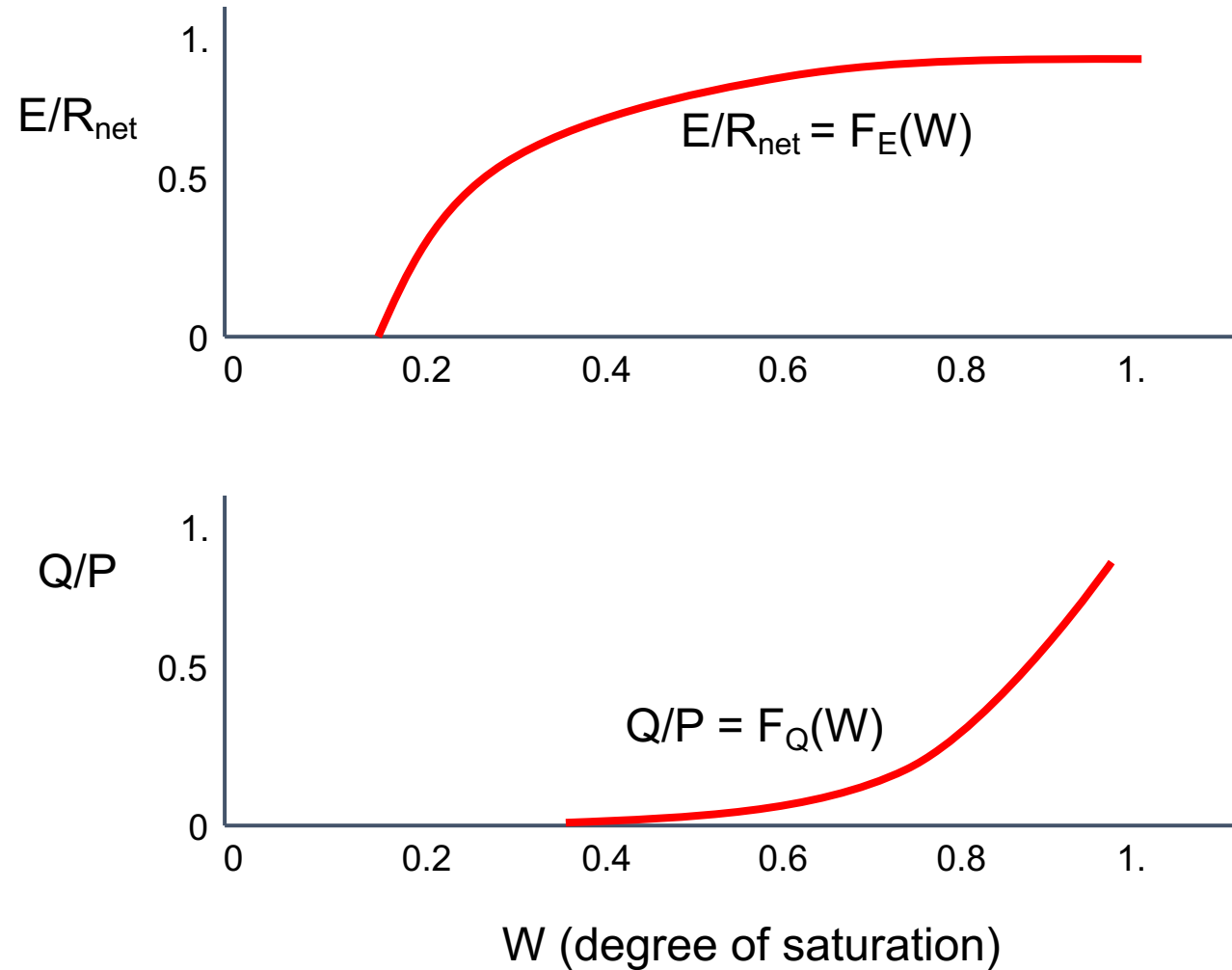
$$C W_{n+1} = C W_n + P_n - E_n - Q_n,$$

Total runoff

Soil moisture at start of day n (degree of saturation)

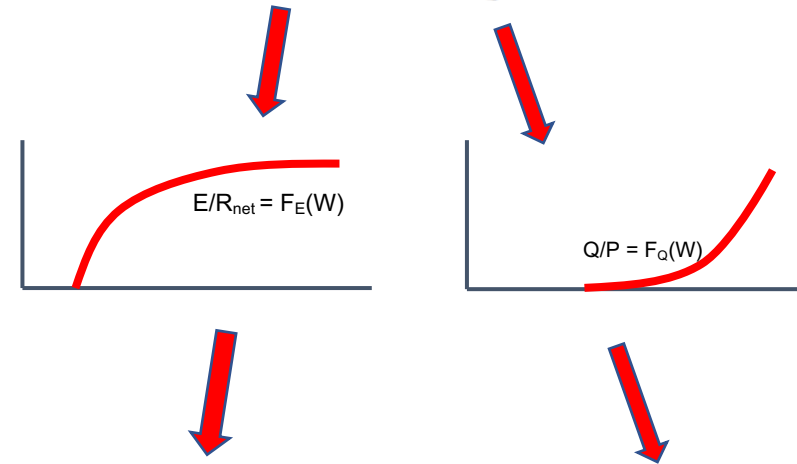


We can impose
simple relationships
between W and
both E and Q :



⇒ Replace

$$C W_{n+1} = C W_n + P_n - E_n - Q_n$$



with

$$C W_{n+1} = C W_n + P_n - F_E(W_n) R_{\text{net}-n} - F_Q(W_n) P_n$$

This, in a nutshell, is the bare-bones representation.

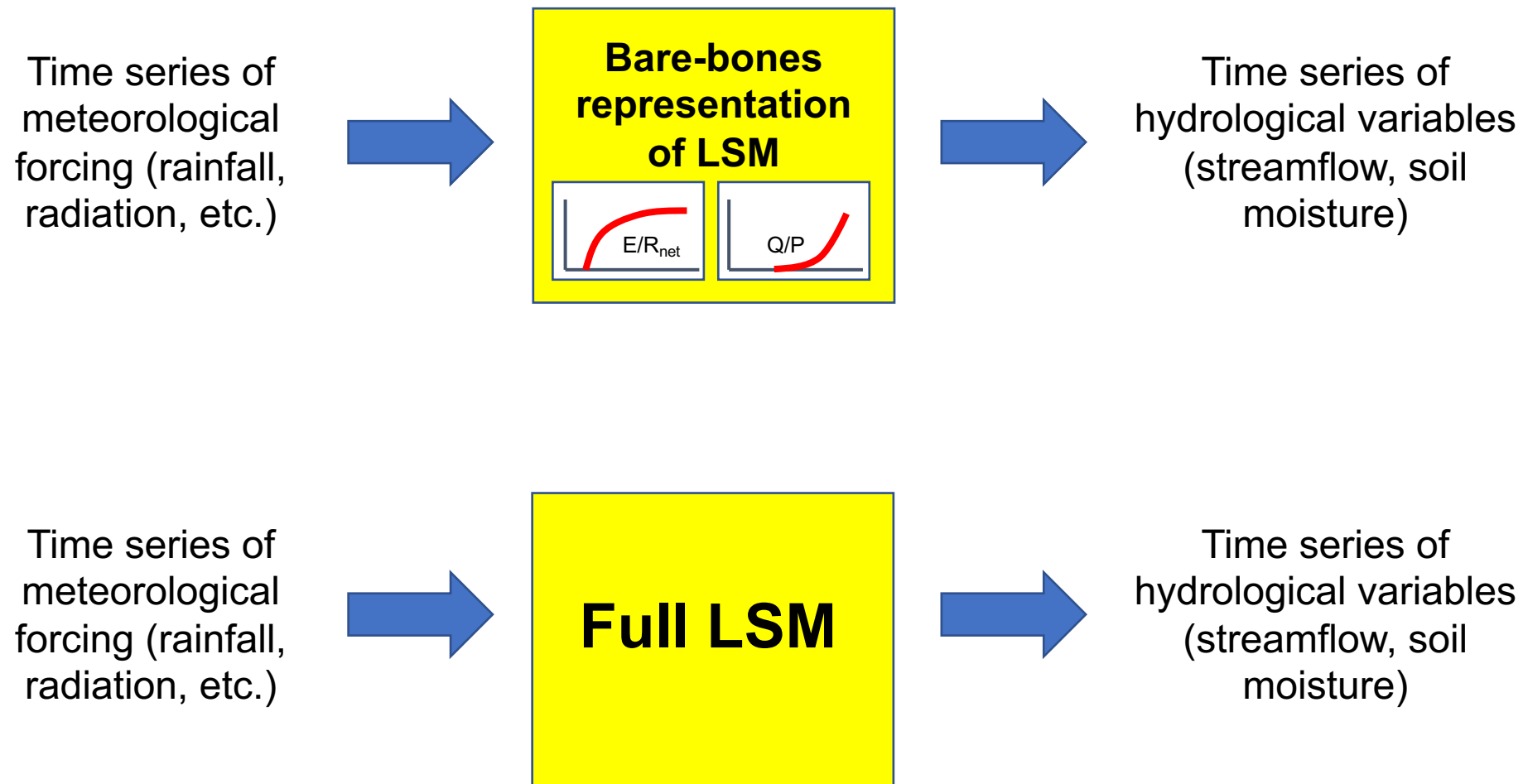
Time series of
meteorological
forcing (rainfall,
radiation, etc.)



**Bare-bones
representation
of LSM**

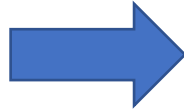


Time series of
hydrological variables
(streamflow, soil
moisture)



Can this...

Time series of
meteorological
forcing (rainfall,
radiation, etc.)



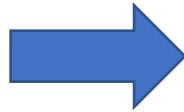
**Bare-bones
representation
of LSM**



Time series of
hydrological variables
(streamflow, soil
moisture)

...capture this?

Time series of
meteorological
forcing (rainfall,
radiation, etc.)



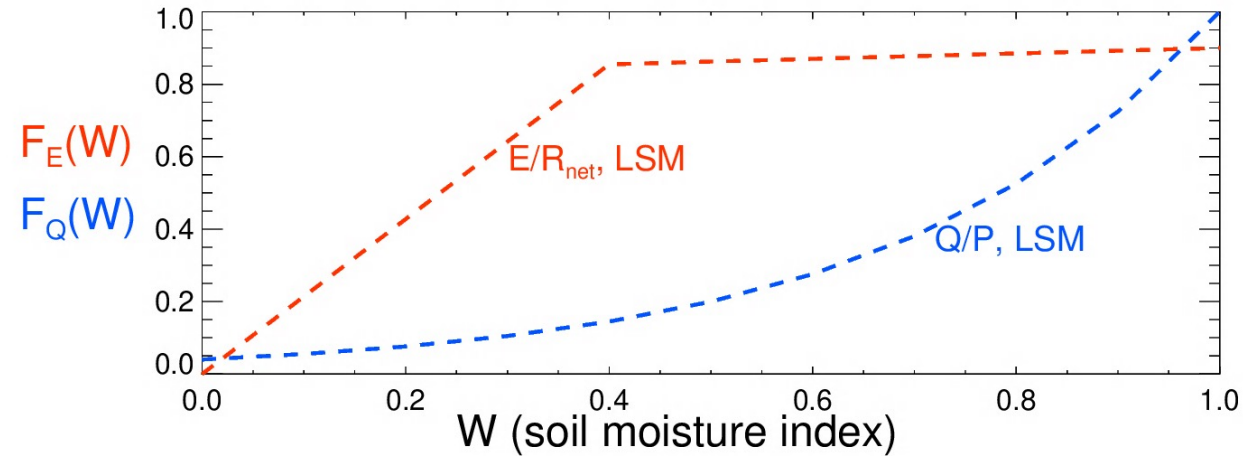
Full LSM



Time series of
hydrological variables
(streamflow, soil
moisture)

YES!

-- Calibrate curves to the behavior of a full LSM (the Catchment LSM, part of the MERRA-2 reanalysis) using data from 1980-1998.



-- Run the bare-bones model over 1999-2020

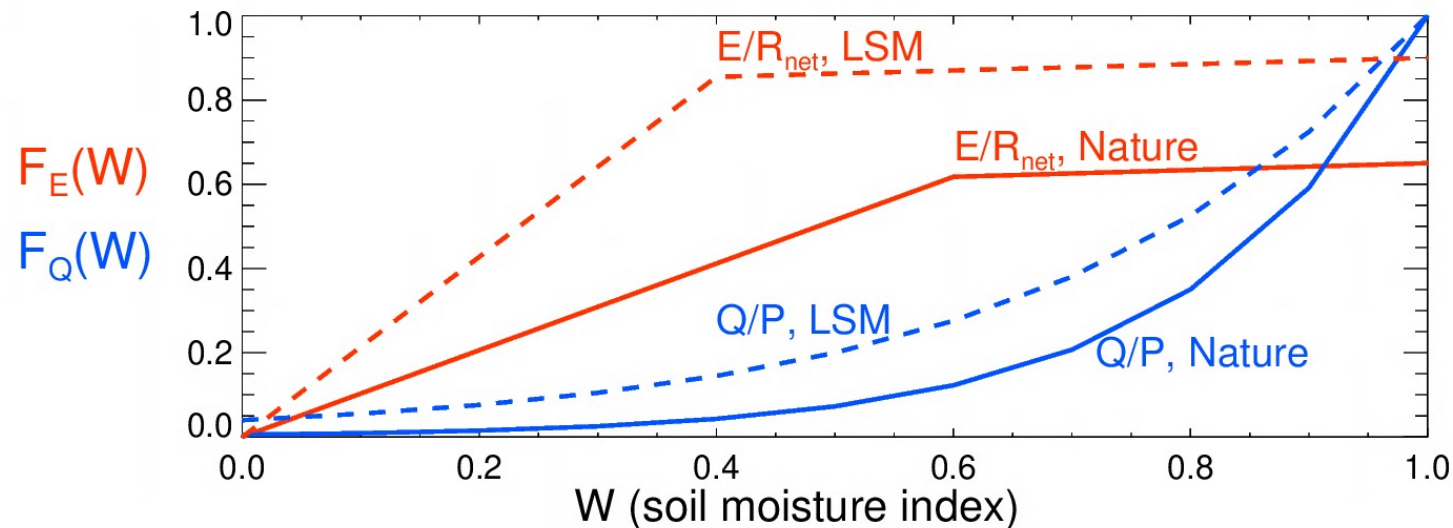
-- Compare the simulated hydrology to that of the full Catchment LSM, as produced in MERRA-2 during that latter period

⇒ Nice agreement!

(not shown here due to time constraints, but see [doi:10.1175/JHM-D-22-0050.1](https://doi.org/10.1175/JHM-D-22-0050.1))

But – are the calibrated curves optimal?

Recalibrate curves during the 1980-1998 period using observed streamflow as the calibration target $\Rightarrow$ get a different set of curves.



Hypothesize: if the land model's curves looked more like Nature's curves, it would perform better in a forecast model setting.

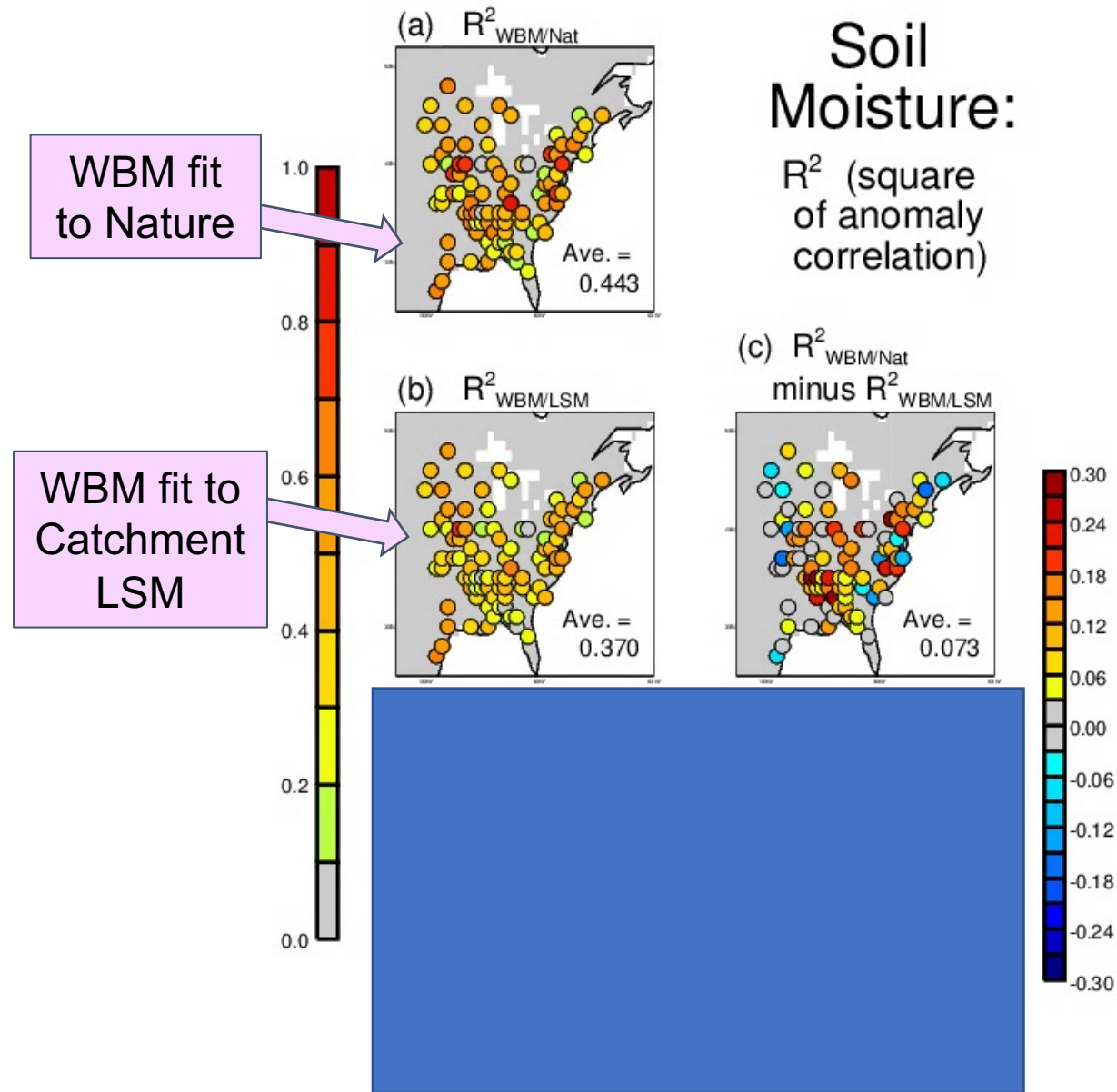
With these sets of curves in place, do a forecast analysis

Compare warm season (May – September) subseasonal forecasts of streamflow and soil moisture (at 11-20 day lead) to in-situ observations at a collection of measurement sites across the continental US:

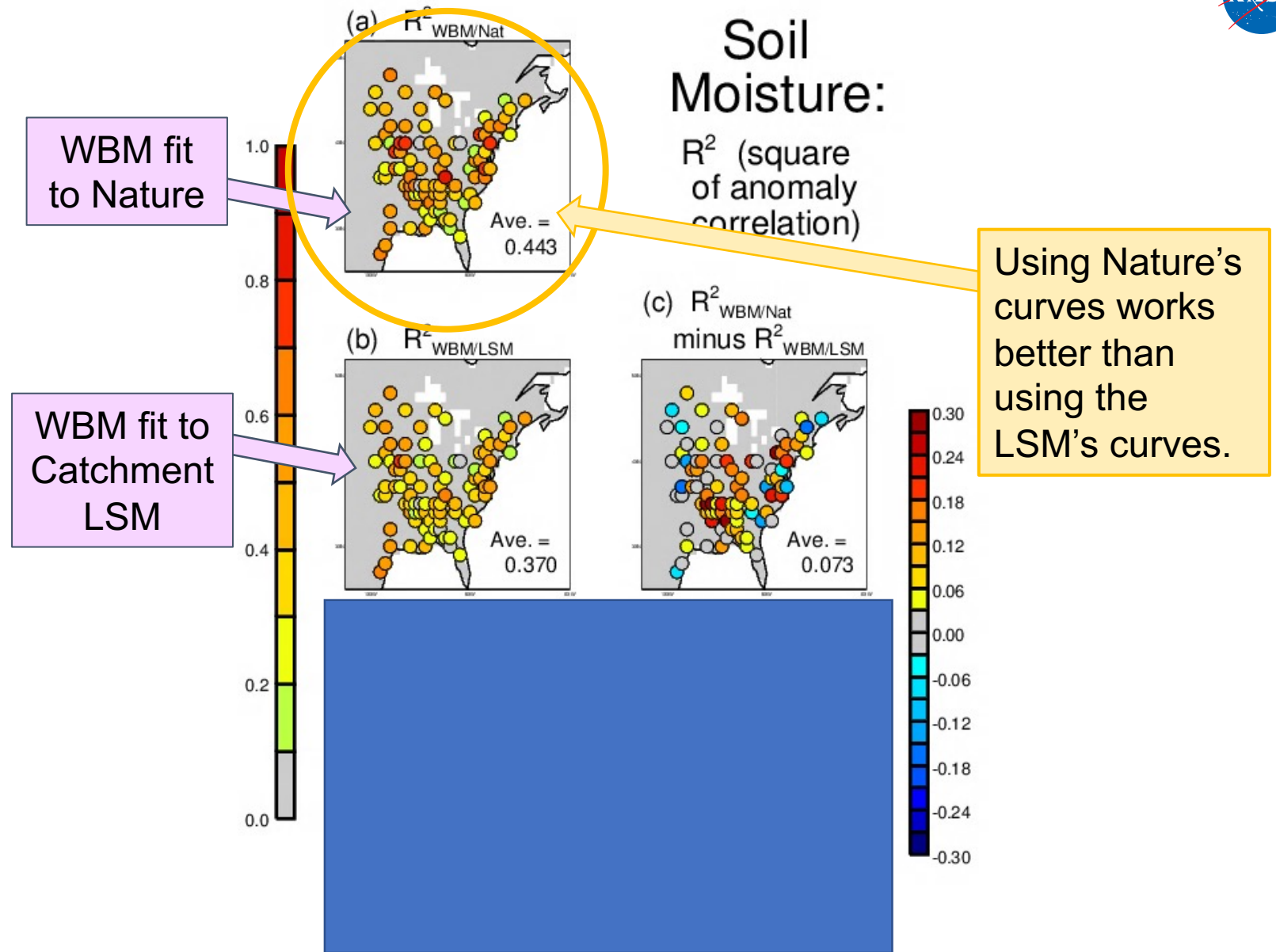
For full details on experimental design and more results, see:

[doi:10.1175/JHM-D-22-0050.1](https://doi.org/10.1175/JHM-D-22-0050.1)

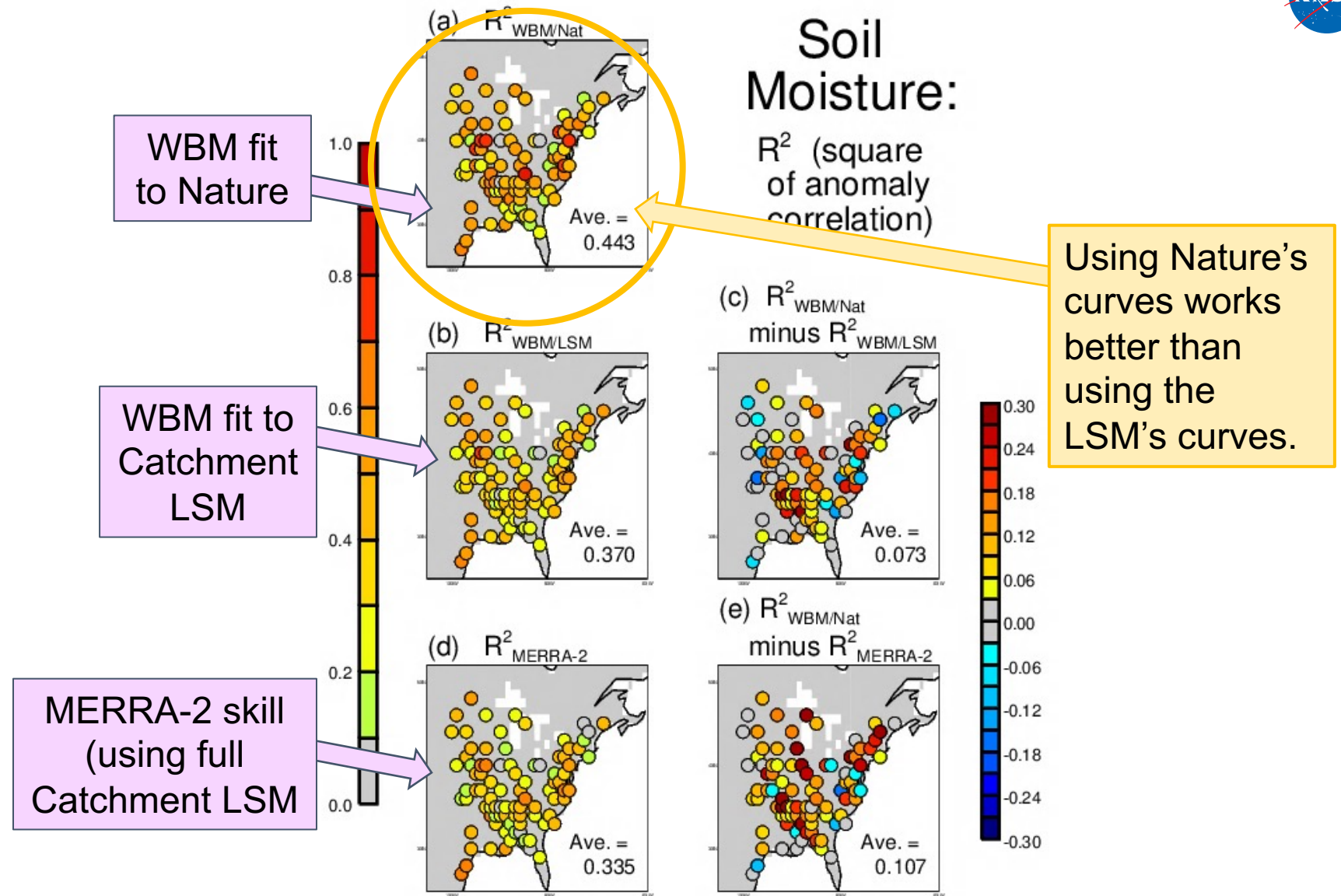
*Skill (R^2 vs obs.)
assuming “perfect”
meteorological
forecasts – basically,
the skill of a
hydrological simulation
with observed forcing.*



*Skill (R^2 vs obs.)
assuming “perfect”
meteorological
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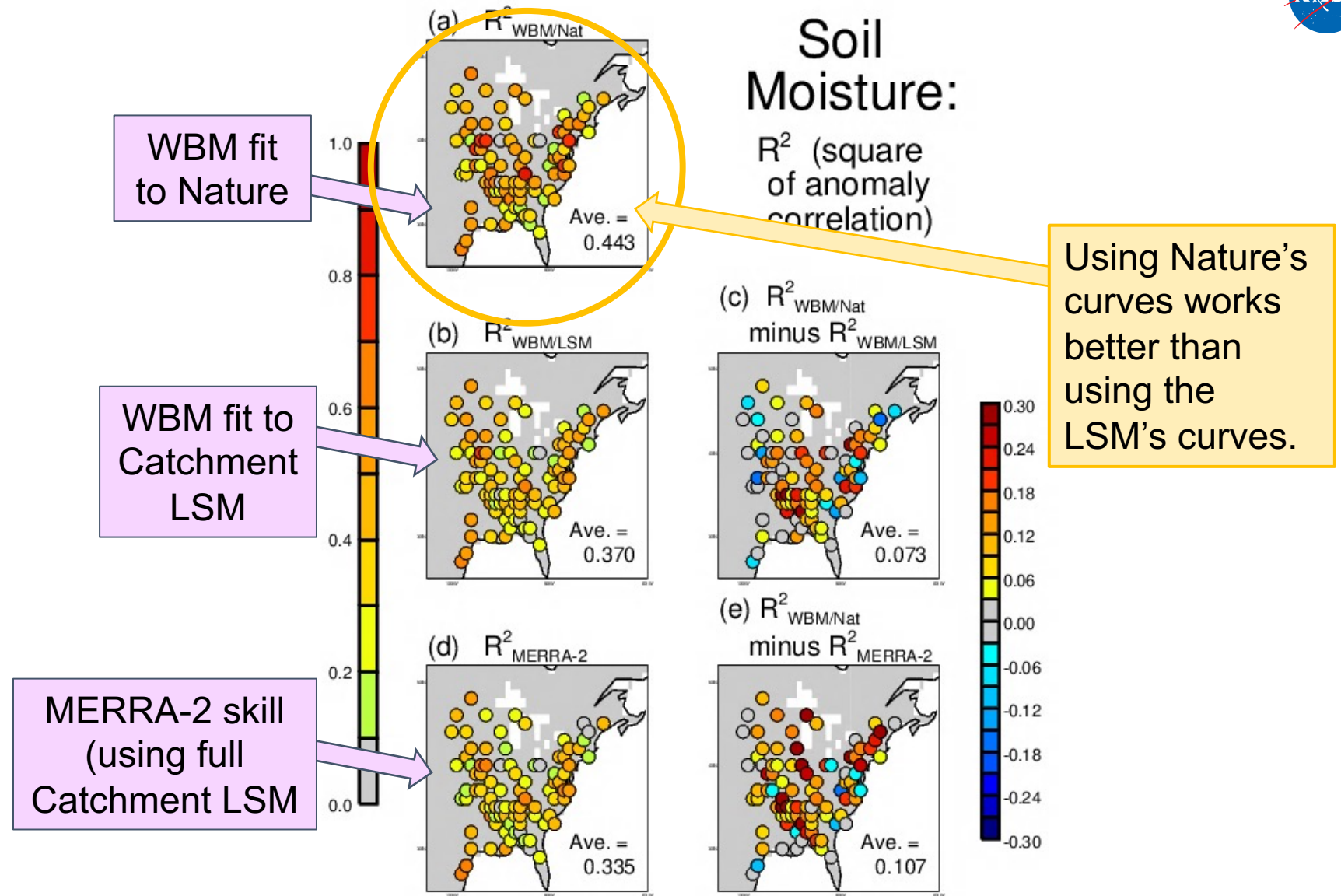


*Skill (R^2 vs obs.)
assuming “perfect”
meteorological
forecasts – basically,
the skill of a
hydrological simulation
with observed forcing*



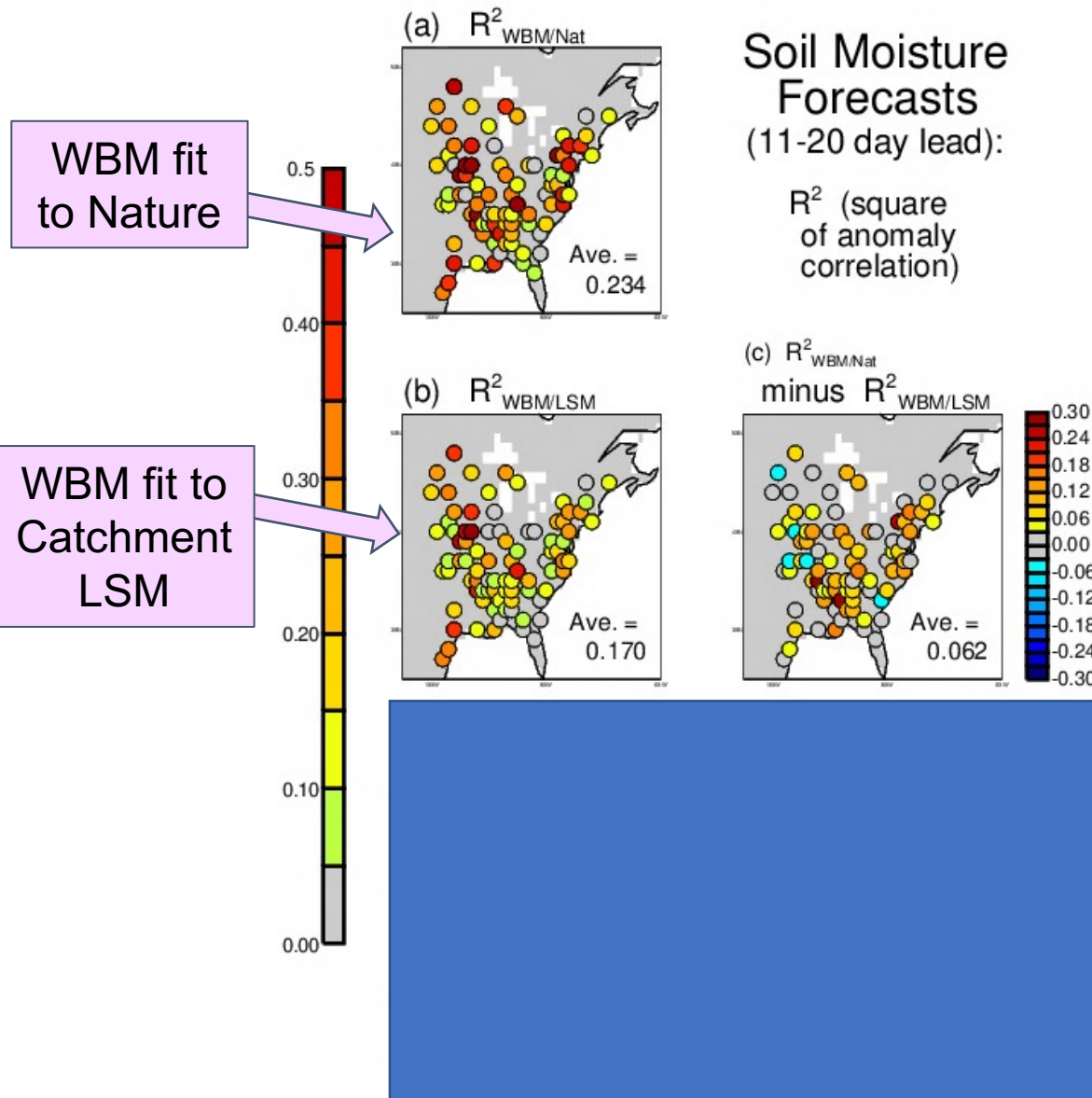
*Skill (R^2 vs obs.)
assuming “perfect”
meteorological
forecasts – basically,
the skill of a
hydrological simulation
with observed forcing*

*Results for
streamflow
are similar!*



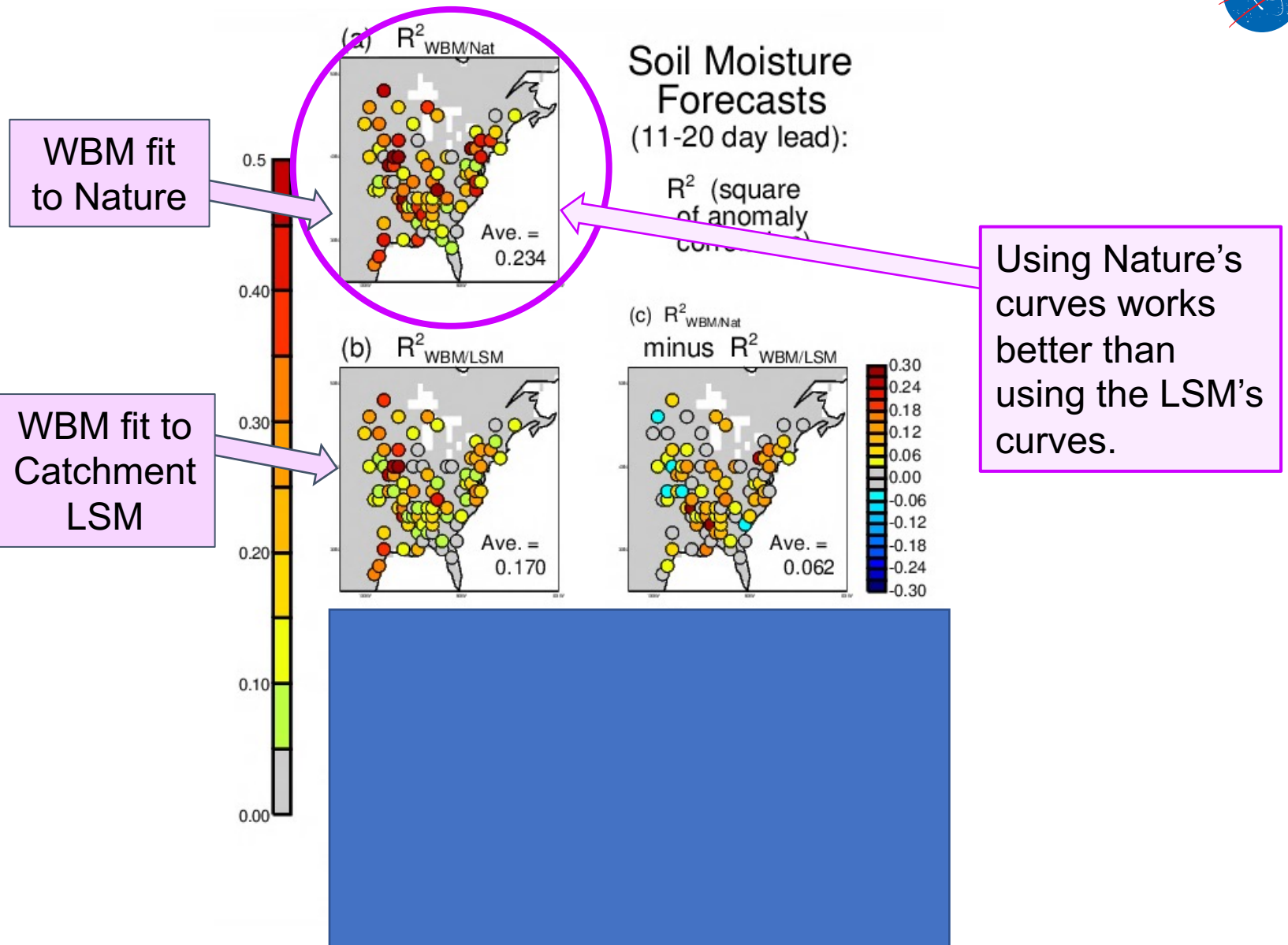
Actual forecasts at 11-20 day lead

*Skill (R^2 vs obs.)
assuming zero-skill
meteorological
forecasts*



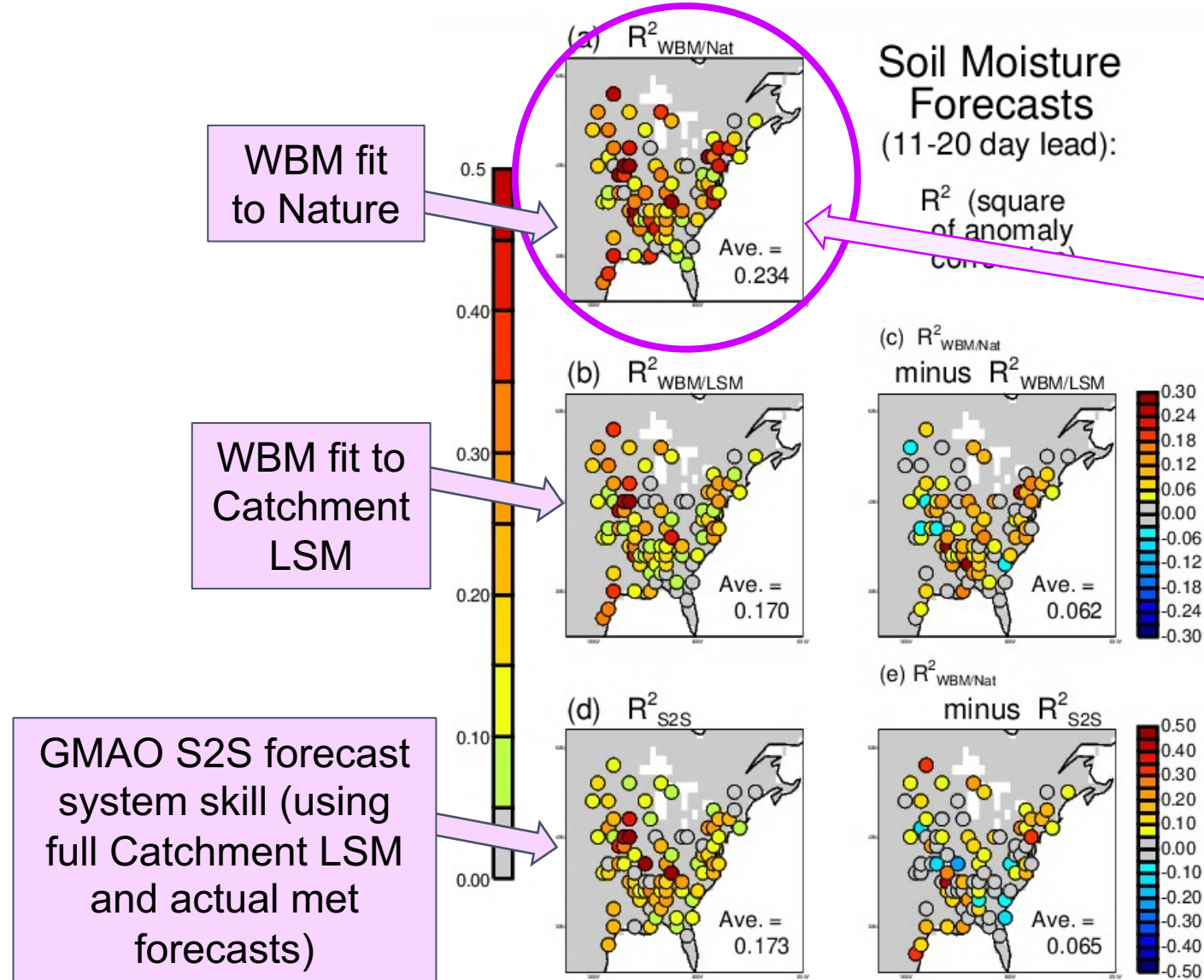
Actual forecasts at 11-20 day lead

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Actual forecasts at 11-20 day lead

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Actual forecasts at 11-20 day lead

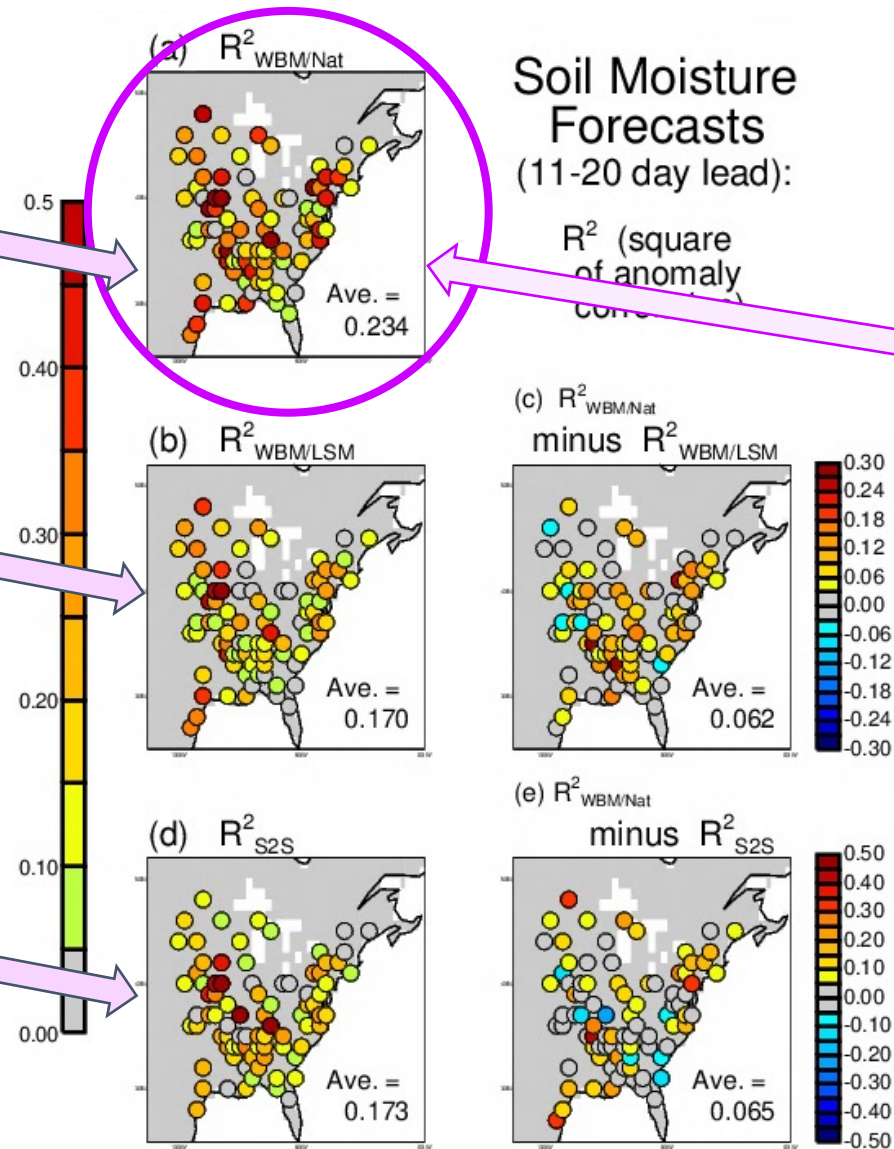
*Skill (R^2 vs obs.)
assuming zero-skill
meteorological
forecasts*

*Results for
streamflow
are similar!*

WBM fit
to Nature

WBM fit to
Catchment
LSM

GMAO S2S forecast
system skill (using
full Catchment LSM
and actual met
forecasts)



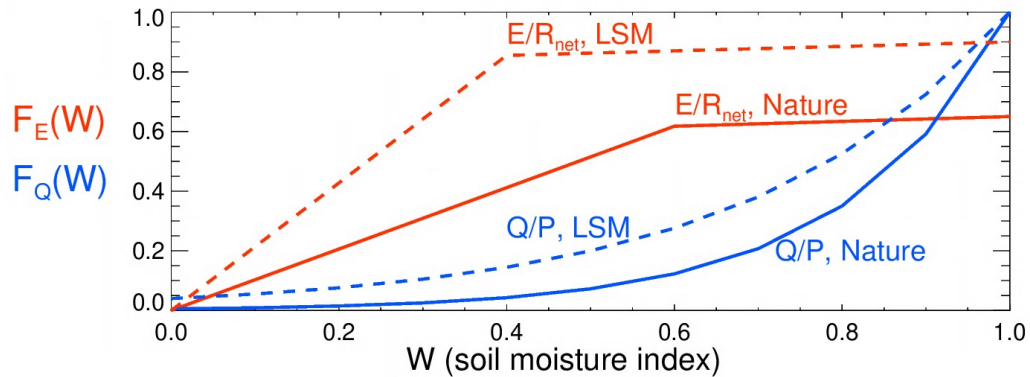
Soil Moisture
Forecasts
(11-20 day lead):

R^2 (square
of anomaly
coeff.)

Using Nature's
curves works
better than
using the LSM's
curves.

Implications of all this:

- As illustrated here and in past work, an LSM's implicit E/R_{net} vs. W and Q/P vs. W relationships control, to first order, its hydrological behavior.



Again, see:

[doi:10.1175/JHM-D-22-0050.1](https://doi.org/10.1175/JHM-D-22-0050.1)

- An LSM's relationships may be sub-optimal.
- Calibrating the LSM's parameterizations to bring the relationships more in line with "Nature's curves" should lead to improved performance in subseasonal hydrological forecasting.

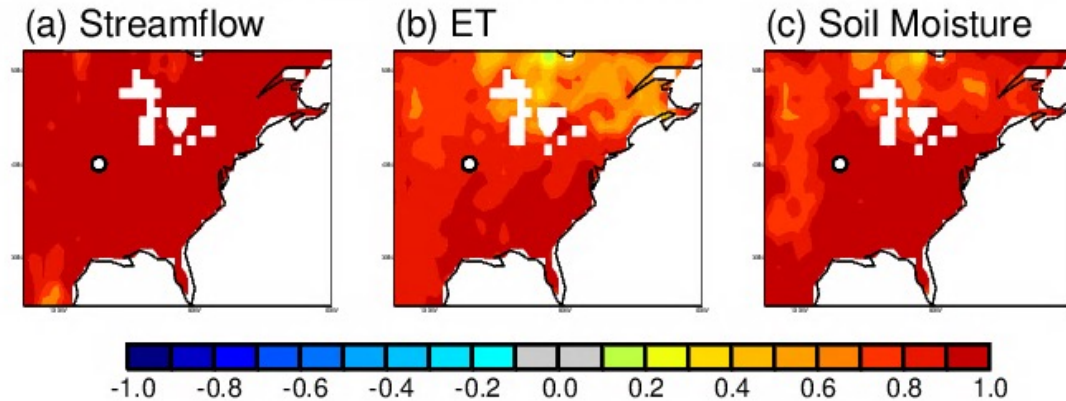


Extra Slides

High anomaly correlations between the bare-bones representation (the “WBM”) and the full Catchment LSM as used in MERRA-2



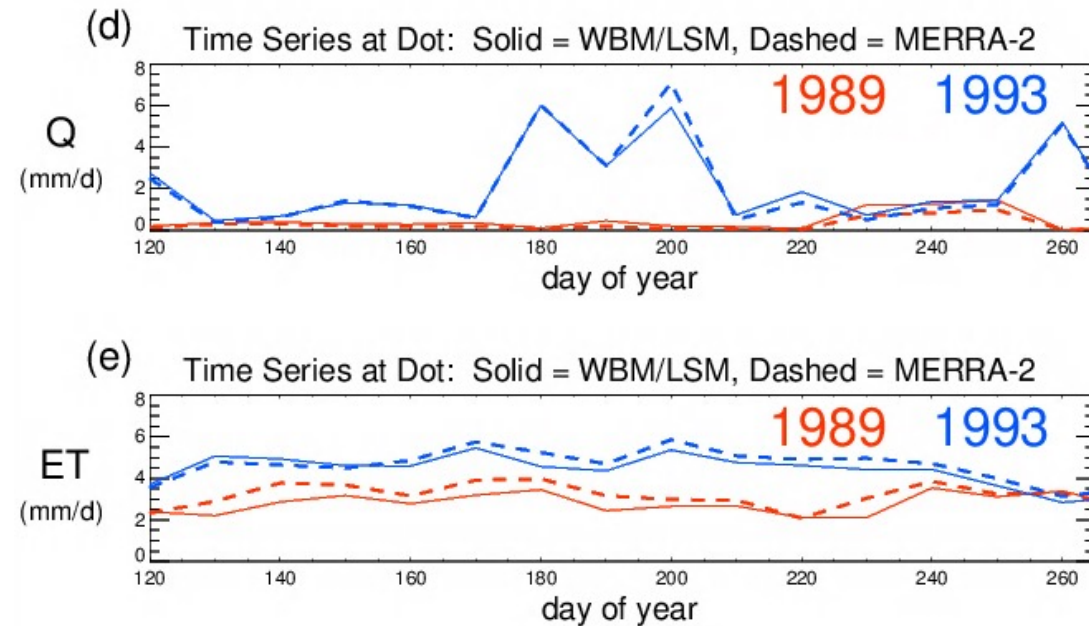
Anomaly Correlation: WBM/LSM vs. MERRA-2

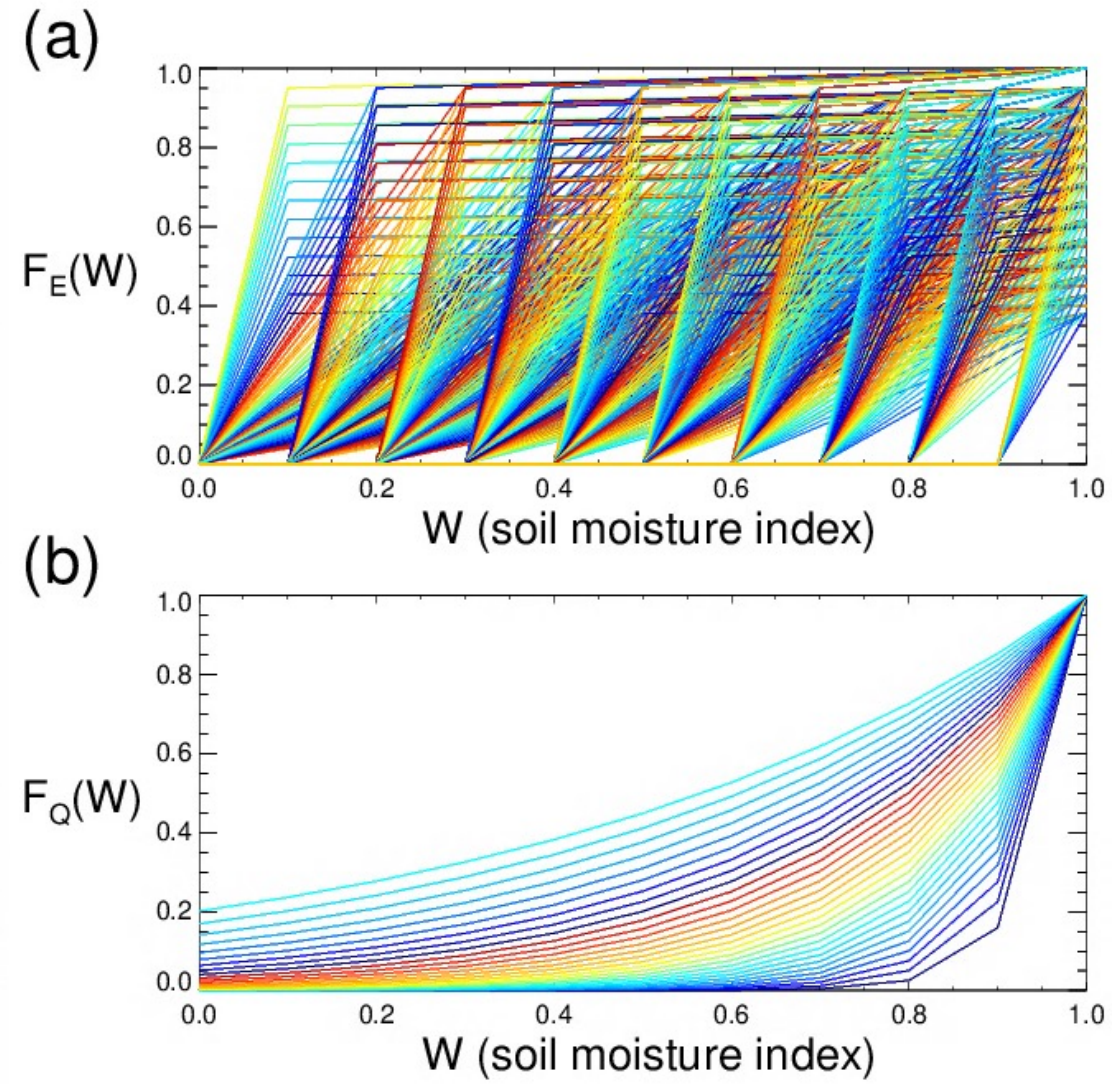


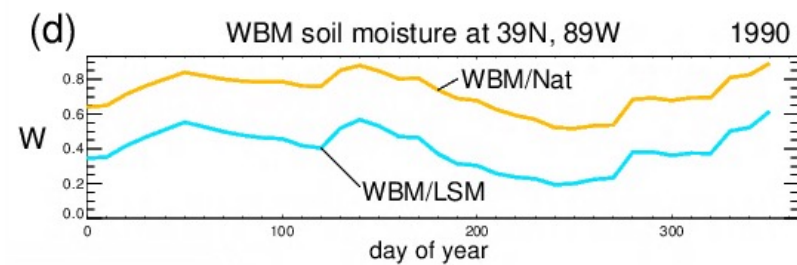
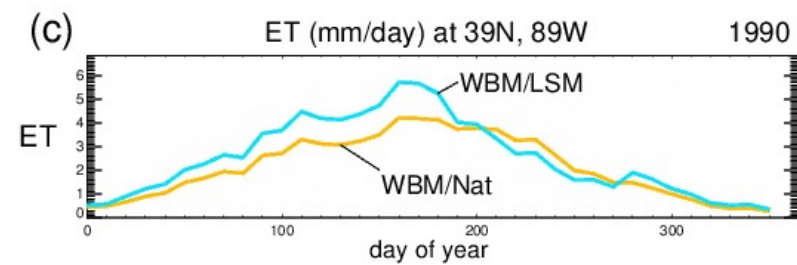
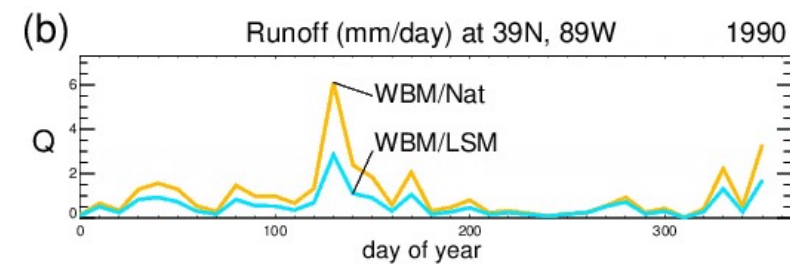
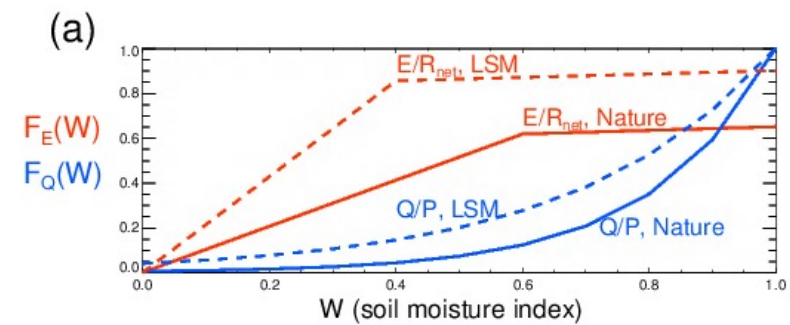
Sample time series comparisons



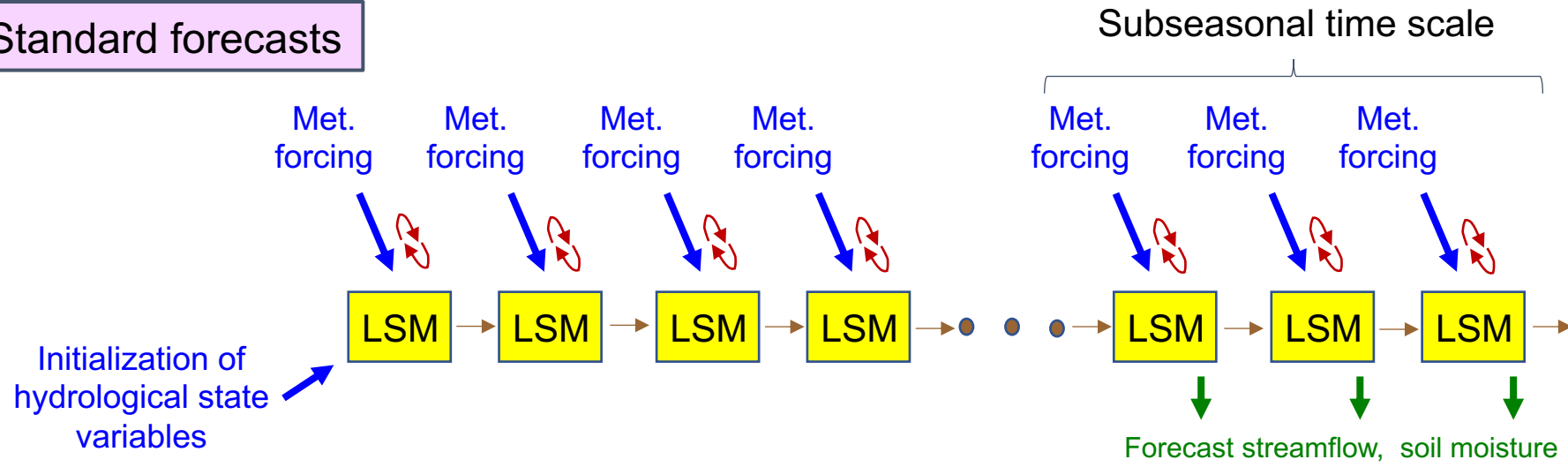
The bare-bones representation does capture the hydrological behavior of the full LSM!



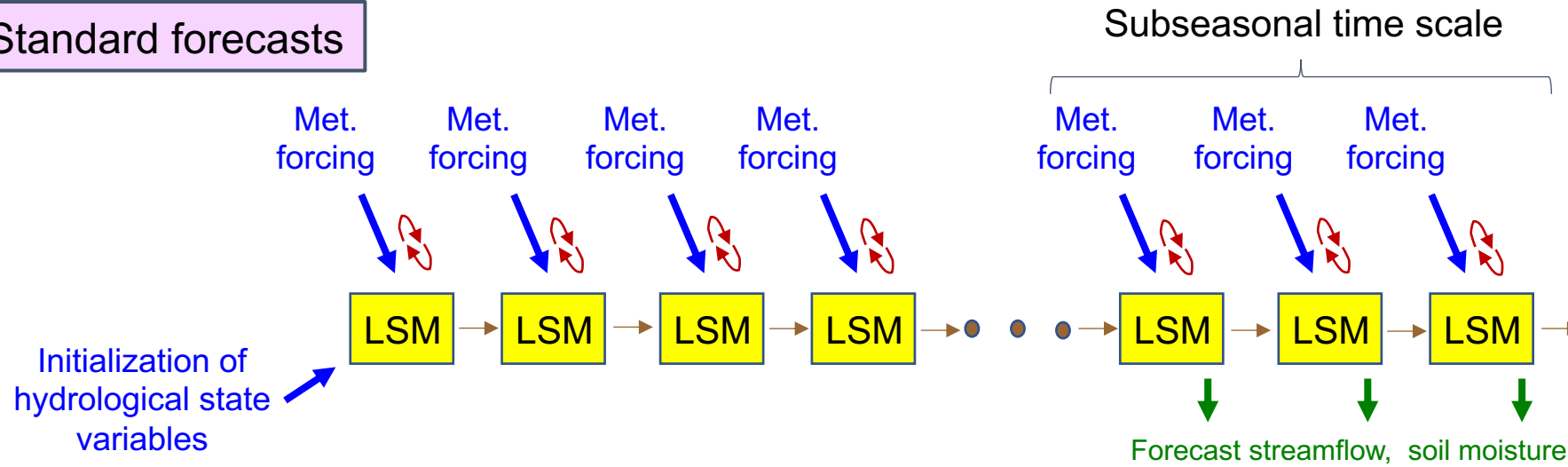




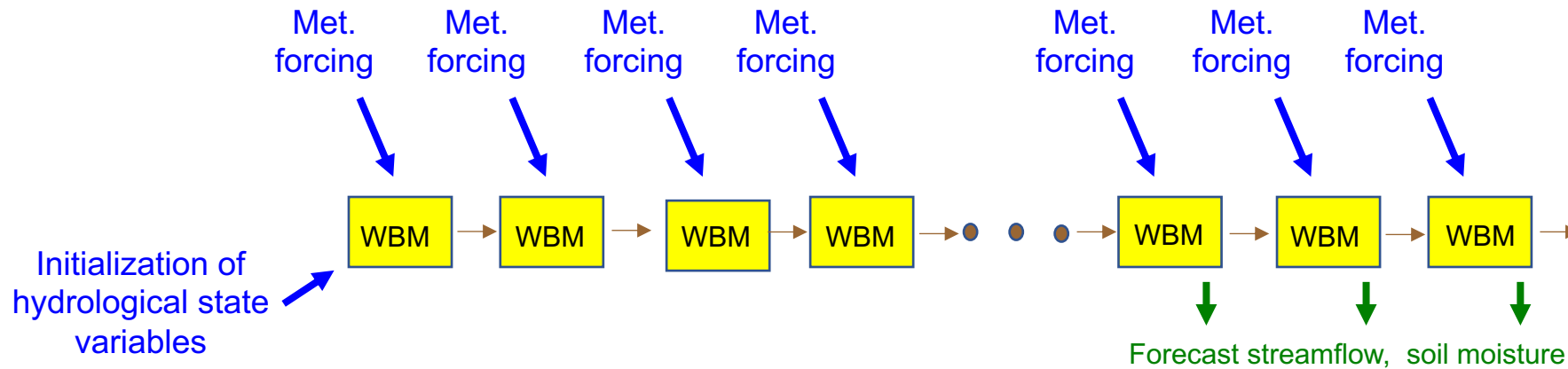
Standard forecasts



Standard forecasts

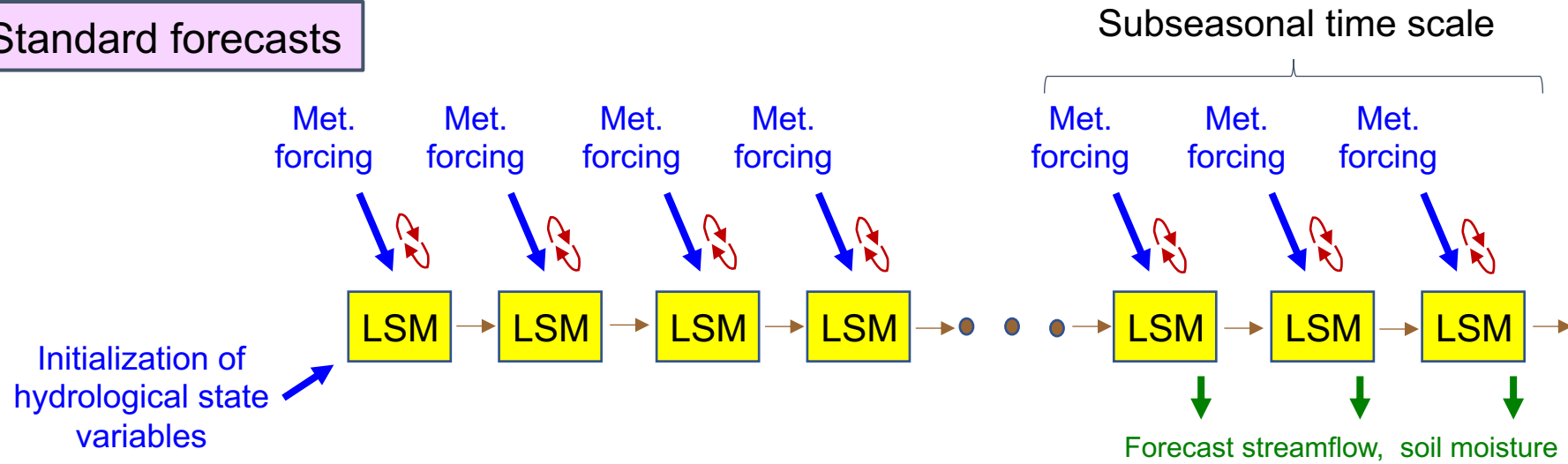


Offline forecasts using bare-bones (WBM) representation

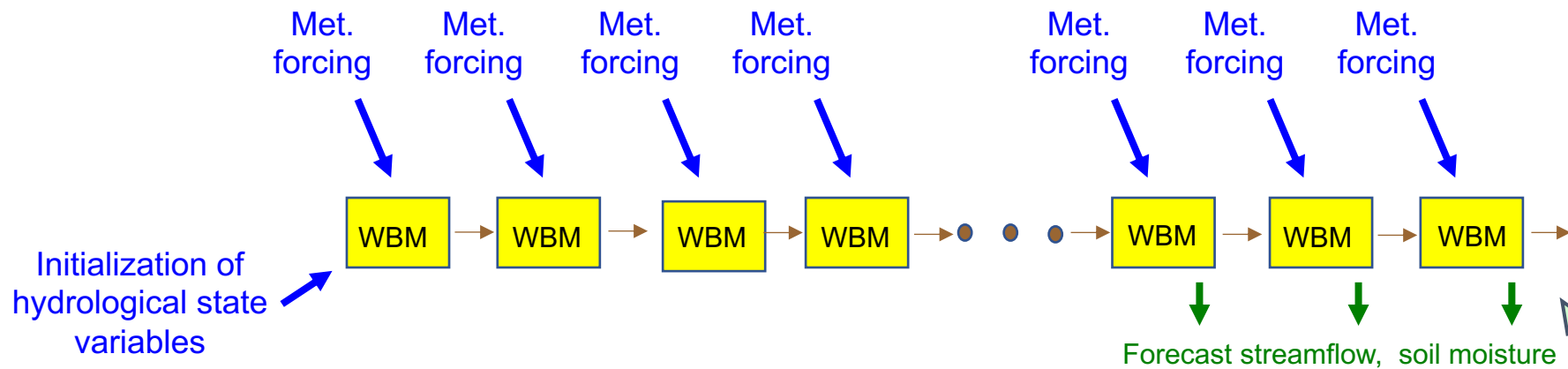


Let WBM represent
Catchment LSM

Standard forecasts



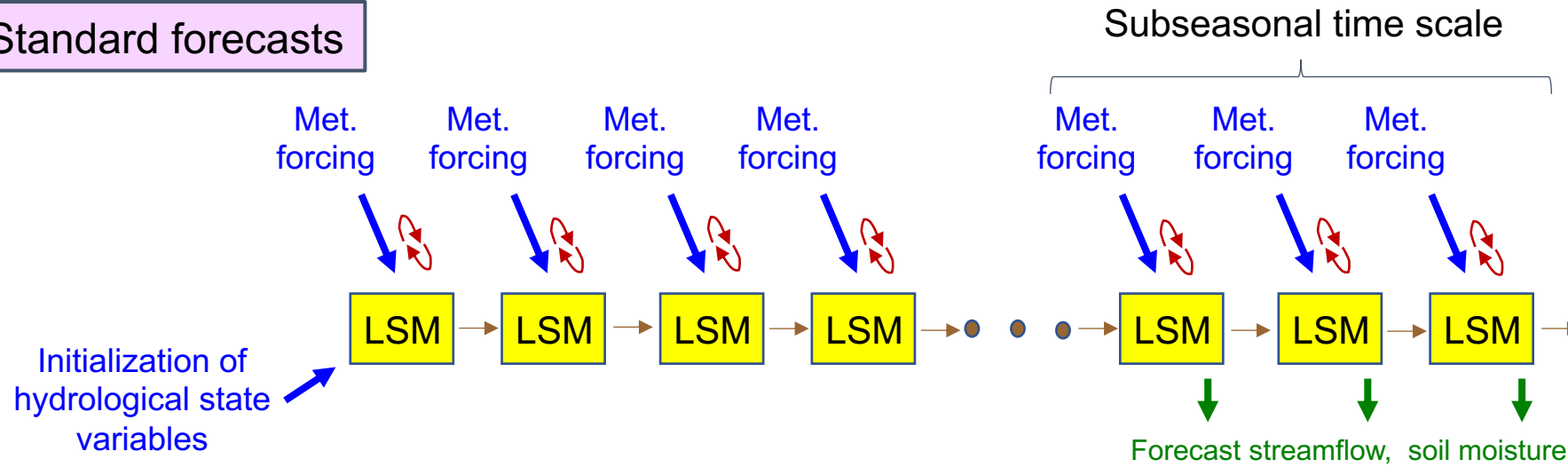
Offline forecasts using bare-bones (WBM) representation



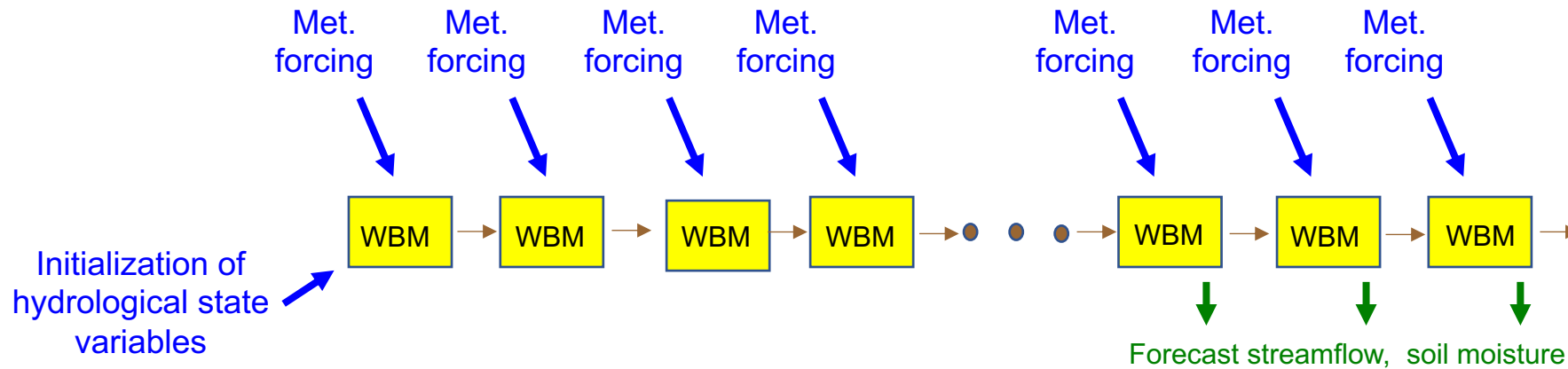
If met forecast is the same, hydrological forecast skill should be similar

Let WBM represent Catchment LSM

Standard forecasts

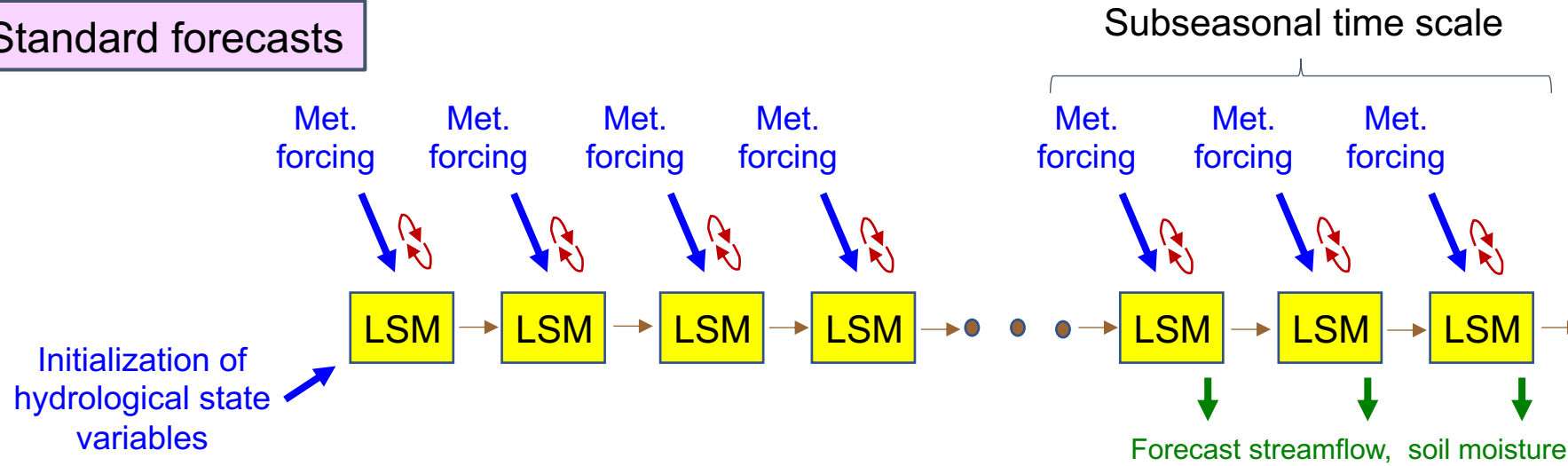


Offline forecasts using bare-bones (WBM) representation

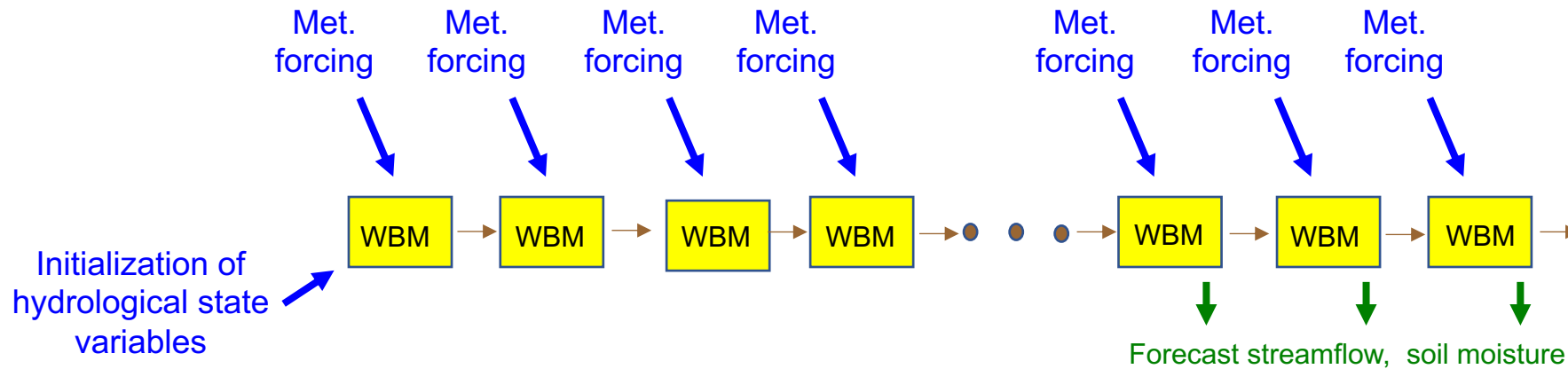


Let WBM represent
what happens in
Nature

Standard forecasts



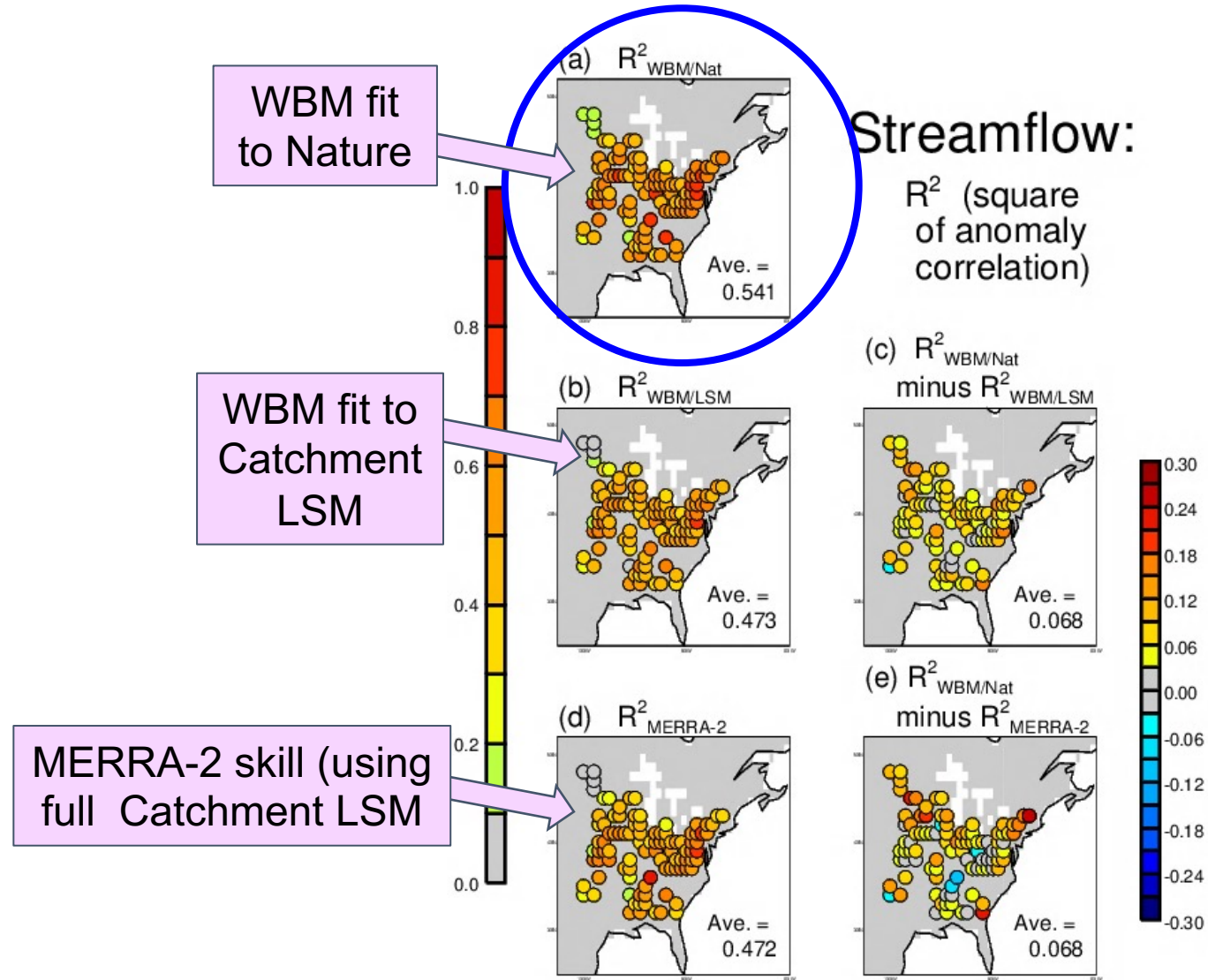
Offline forecasts using bare-bones (WBM) representation



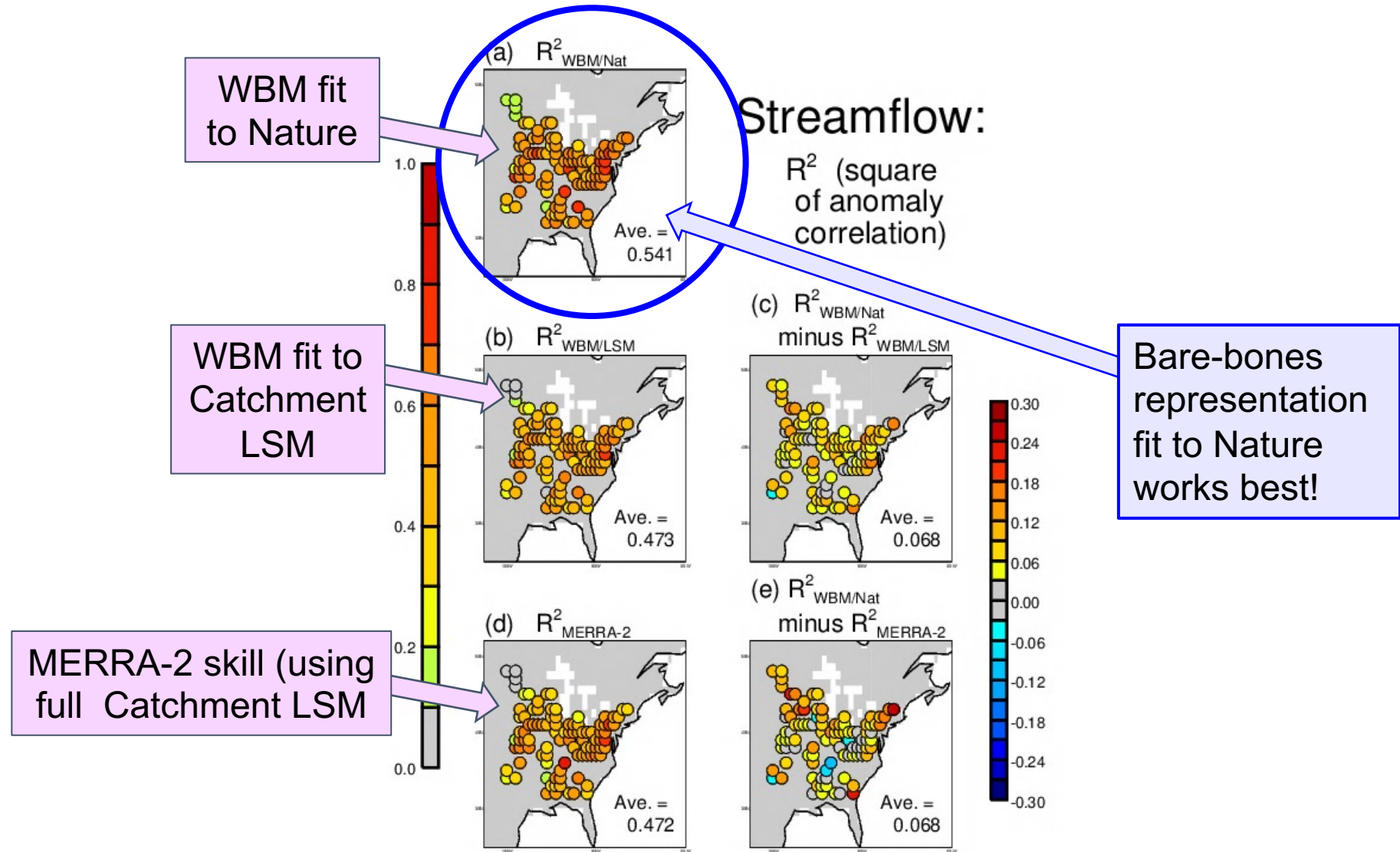
*Again, hypothesize:
If met forecast is
the same, the
hydrological
forecast skill here
should be higher*

*Let WBM represent
what happens in
Nature*

*Skill (R^2 vs obs.)
assuming “perfect”
meteorological
forecasts –
basically, the skill
of a hydrological
simulation with
observed forcing*



*Skill (R^2 vs obs.)
assuming “perfect”
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basically, the skill
of a hydrological
simulation with
observed forcing*



*Skill (R^2 vs obs.)
assuming zero-skill
meteorological
forecasts*

