CWRF Prediction of the U.S. Terrestrial Hydrology

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Climate - Weather Research and Forecasting model

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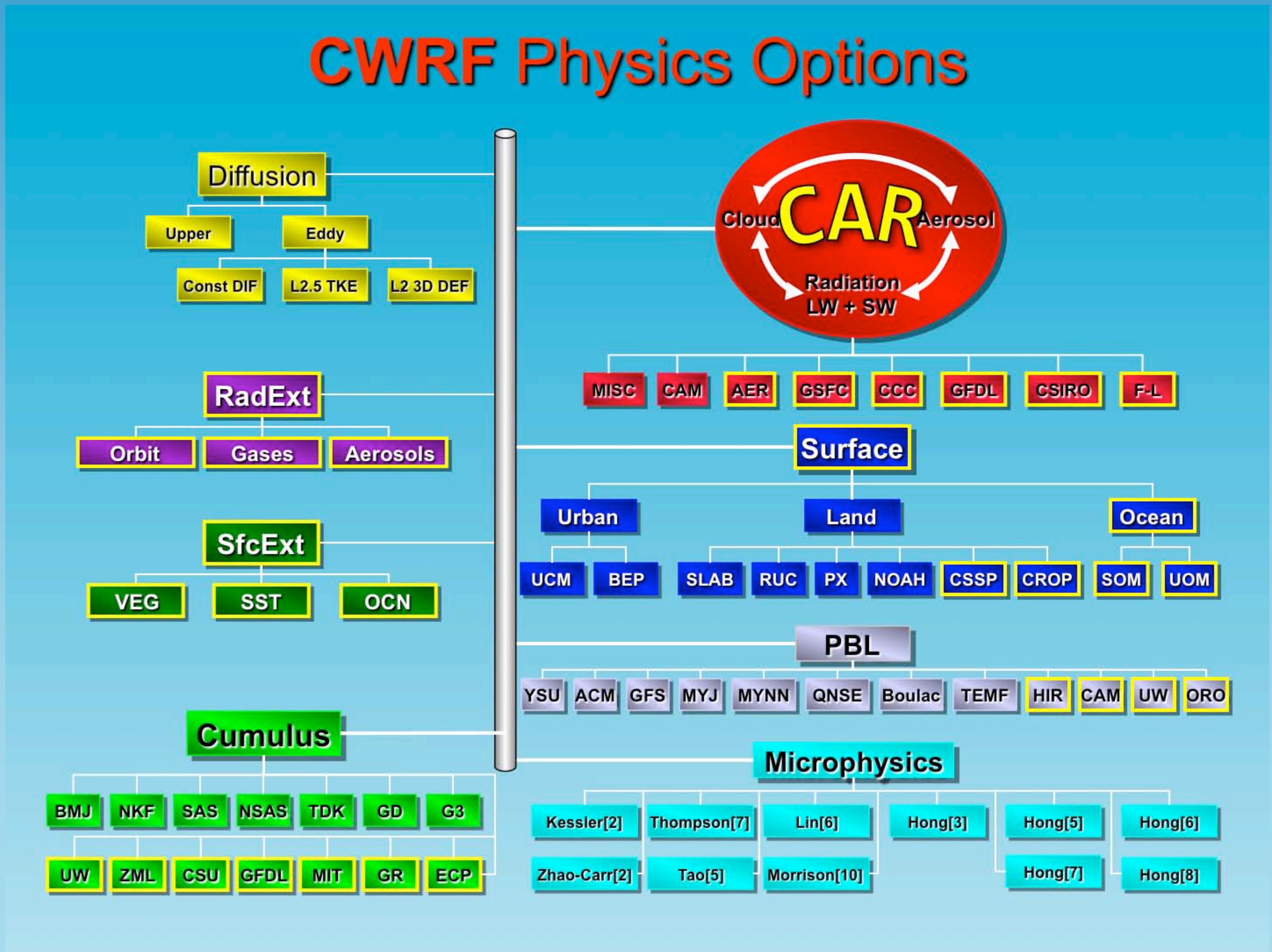
CWRF First Release at http://cwrf.umd.edu



CWRF improves predictions at regional-local scales

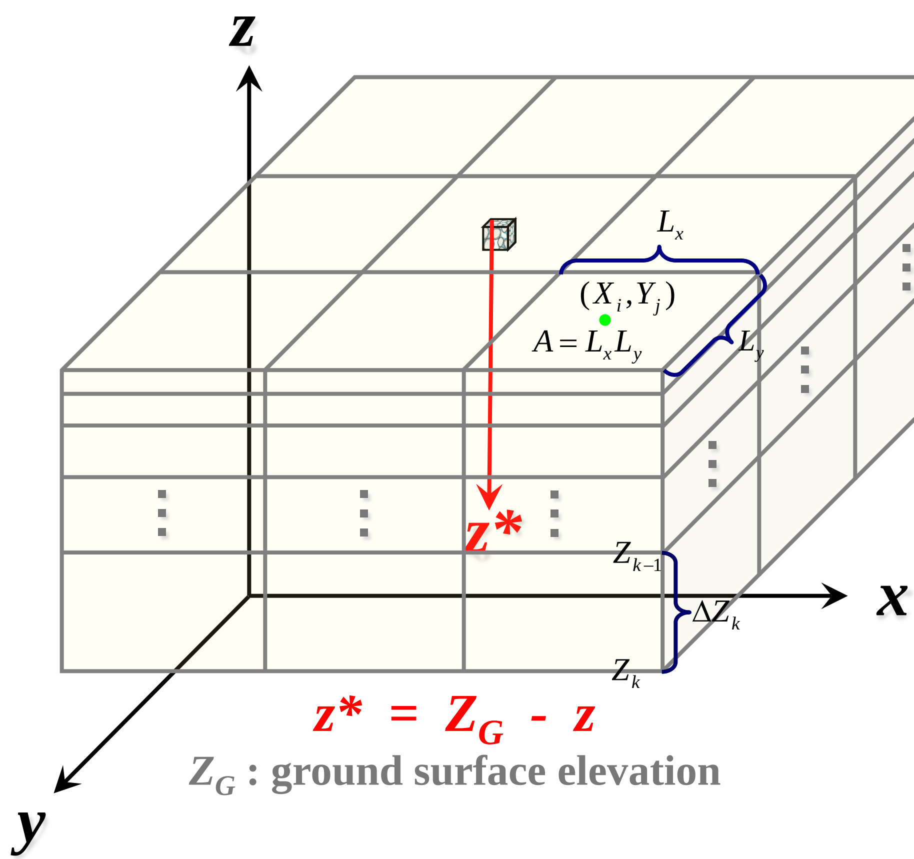
- CWRF includes advanced physics schemes crucial to climate
- CWRF couples essential components directly linking to impacts
- CWRF builds upon a super ensemble of alternative physics schemes for skill optimization and uncertainty quantification
- CWRF has greater capability & better skill than CMM5, WRF…
- CWRF downscaling improves CFS precipitation predictions

Scale Dependence

Model physics representation and predictive skill depend on spatial scale

Challenging

Volume Averaged Scheme



$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial x_l^*}\left[D_{x_l^*}(\theta)\frac{\partial\theta}{\partial x_l^*} + K_{x_l^*}(\theta)S_{x_l^*}\right]$$

where $x_l^* \in \{x, y, z^*\}$

$K_{x_l^*}(\theta)$: hydraulic conductivity

$D_{x_l^*}(\theta) = K_{x_l^*}(\theta)\frac{\partial\psi}{\partial\theta}$: diffusivity

$S_{x_l^*}$: terrain slope

$$\mathcal{F}(x_l^*, t) = \overline{\mathcal{F}}(\overline{x}_l^*, t) + \mathcal{F}'(x_l^*, t)$$

where $\overline{\mathcal{F}}(\overline{x}_l^*, t) = \frac{1}{V}\int_V \mathcal{F}(x_l^*, t)\, dV$

$$\frac{\partial\overline{\theta}}{\partial t} + \frac{\partial\theta'}{\partial t} =$$

$$\frac{\partial}{\partial x_l^*}\left[D_{x_l^*}(\overline{\theta} + \theta')\left(\frac{\partial\overline{\theta}}{\partial x_l^*} + \frac{\partial\theta'}{\partial x_l^*}\right) + K_{x_l^*}(\overline{\theta} + \theta')\left(\overline{S}_{x_l^*} + S'_{x_l^*}\right)\right]$$

$$\begin{aligned}\frac{\partial\overline{\theta}}{\partial t} = \; & \underbrace{\frac{\partial}{\partial z^*}\left[D_{z^*}(\overline{\theta})\frac{\partial\overline{\theta}}{\partial z^*}\right]}_{\text{mean term}} + \underbrace{\frac{1}{2}\frac{\partial^2}{\partial z^{*2}}\left[\dot{D}_{z^*}(\overline{\theta})\sigma_\theta^2\right]}_{\text{variability term}} \\ & - \underbrace{\frac{\partial}{\partial z^*}\left[K_{z^*}(\overline{\theta})\right]}_{\text{mean term}} - \underbrace{\frac{1}{2}\frac{\partial}{\partial z^*}\left[\ddot{K}_{z^*}(\overline{\theta})\sigma_\theta^2\right]}_{\text{variability term}} \\ & + \underbrace{\frac{\partial}{\partial x_l}\left[D_{x_l}(\overline{\theta})\frac{\partial\overline{\theta}}{\partial x_l}\right]}_{\text{mean term}} + \underbrace{\frac{1}{2}\frac{\partial^2}{\partial x_l^2}\left[\dot{D}_{x_l}(\overline{\theta})\sigma_\theta^2\right]}_{\text{variability term}} \\ & + \underbrace{\frac{\partial}{\partial x_l}\left[K_{x_l}(\overline{\theta})\overline{S}_{x_l}\right]}_{\text{mean term}} + \underbrace{\frac{\partial}{\partial x_l}\left[\dot{K}_{x_l}(\overline{\theta})\overline{\theta' S'_{x_l}}\right] + \frac{1}{2}\frac{\partial}{\partial x_l}\left[\ddot{K}_{x_l}(\overline{\theta})\overline{S}_{x_l}\sigma_\theta^2\right]}_{\text{variability term}}\end{aligned}$$

$$K_{x_l^*}(\overline{\theta} + \theta') \approx K_{x_l^*}(\overline{\theta}) + \frac{\partial K_{x_l^*}}{\partial\theta}\Big|_{\overline{\theta}}\,\theta' + \frac{1}{2}\frac{\partial^2 K_{x_l^*}}{\partial\theta^2}\Big|_{\overline{\theta}}\,\theta'^2$$

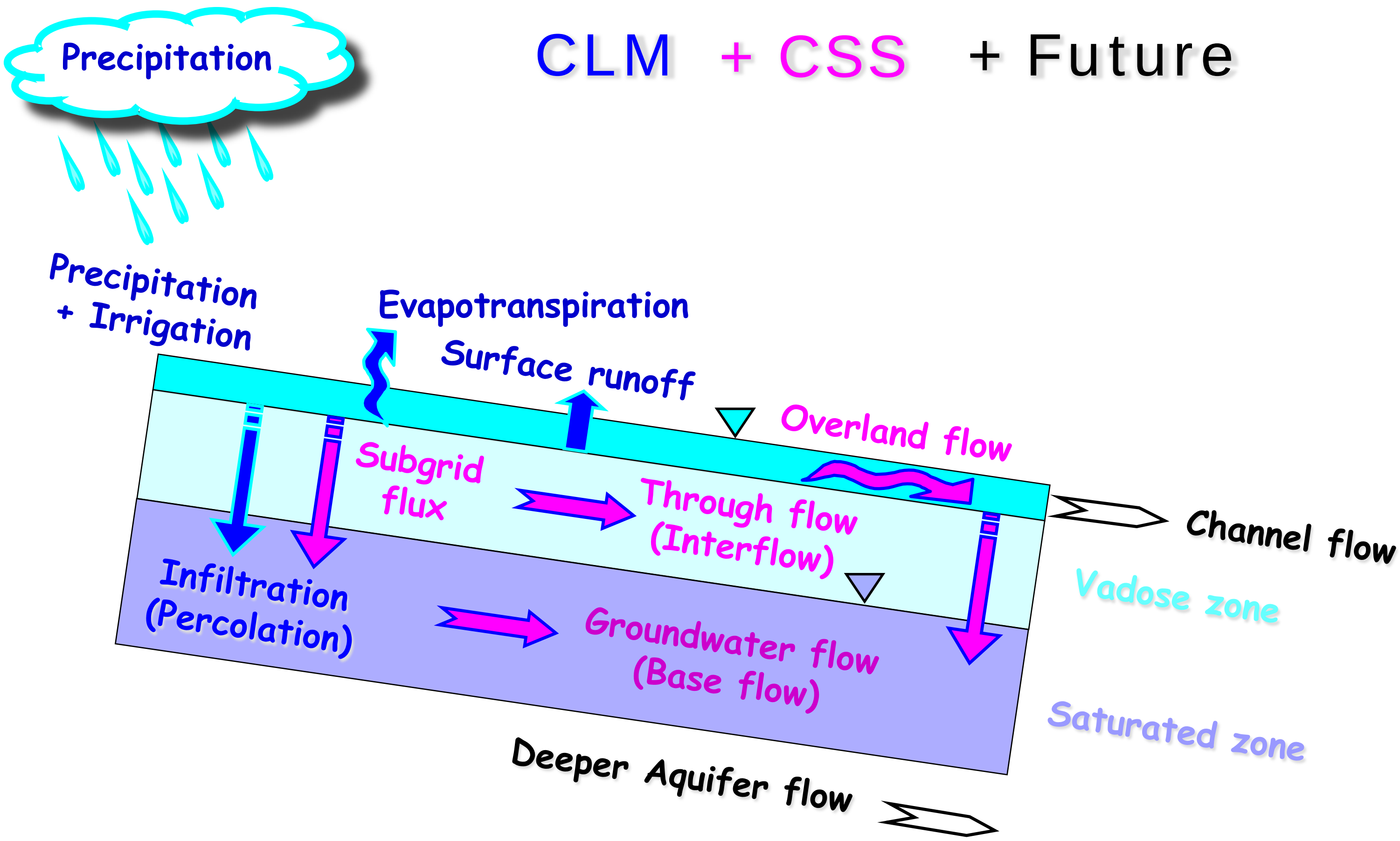
$$D_{x_l^*}(\overline{\theta} + \theta') \approx D_{x_l^*}(\overline{\theta}) + \frac{\partial D_{x_l^*}}{\partial\theta}\Big|_{\overline{\theta}}\,\theta' + \frac{1}{2}\frac{\partial^2 D_{x_l^*}}{\partial\theta^2}\Big|_{\overline{\theta}}\,\theta'^2$$

where $x_l \in \{x, y\}$

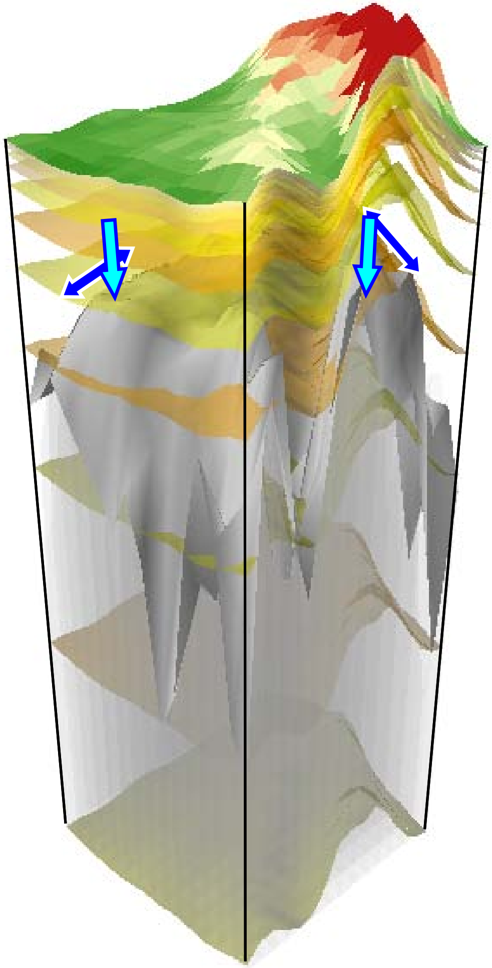
$$\dot{K}_{x_l^*}(\overline{\theta}) \equiv \frac{\partial K_{x_l^*}}{\partial\theta}\Big|_{\overline{\theta}}, \quad \ddot{K}_{x_l^*}(\overline{\theta}) \equiv \frac{\partial^2 K_{x_l^*}}{\partial\theta^2}\Big|_{\overline{\theta}}, \quad \dot{D}_{x_l^*}(\overline{\theta}) \equiv \frac{\partial D_{x_l^*}}{\partial\theta}\Big|_{\overline{\theta}}$$

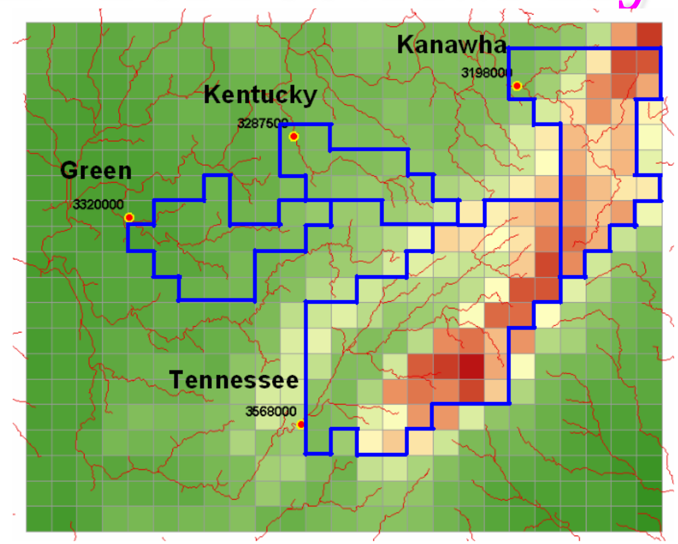
Conjunctive Surface-Subsurface Processes
Terrestrial Hydrology Modeling

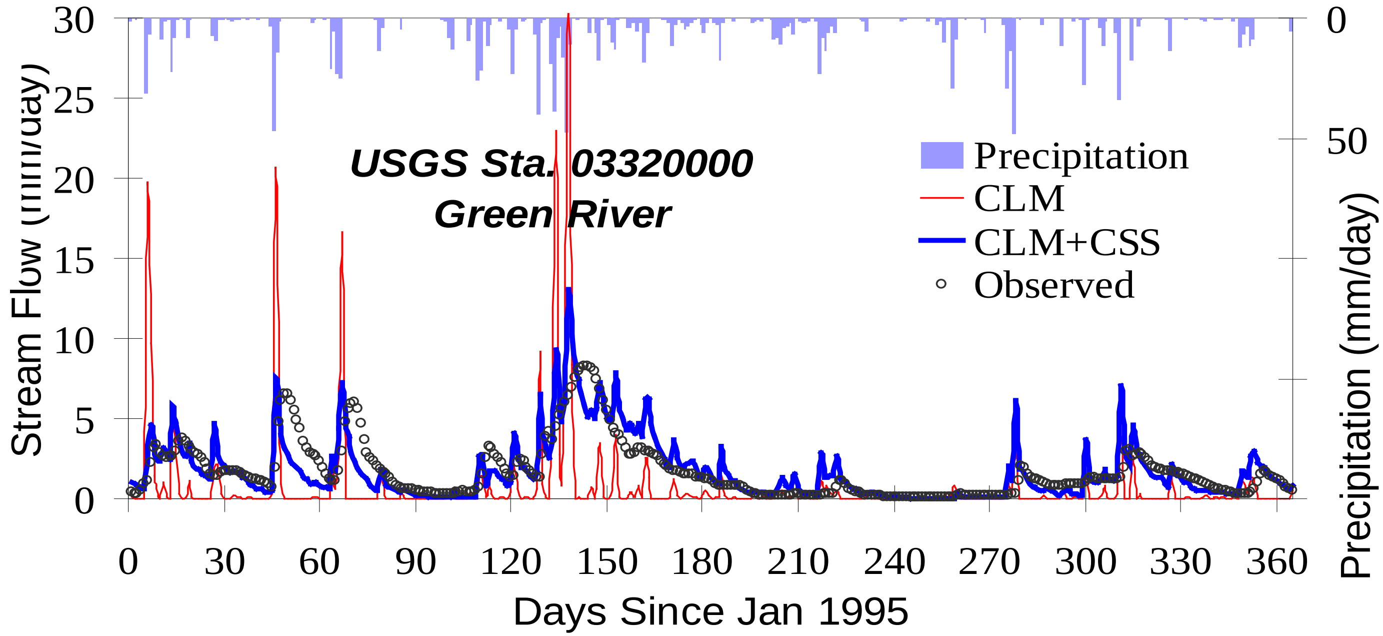
CLM + CSS + Future



CWRF Terrestrial Hydrology

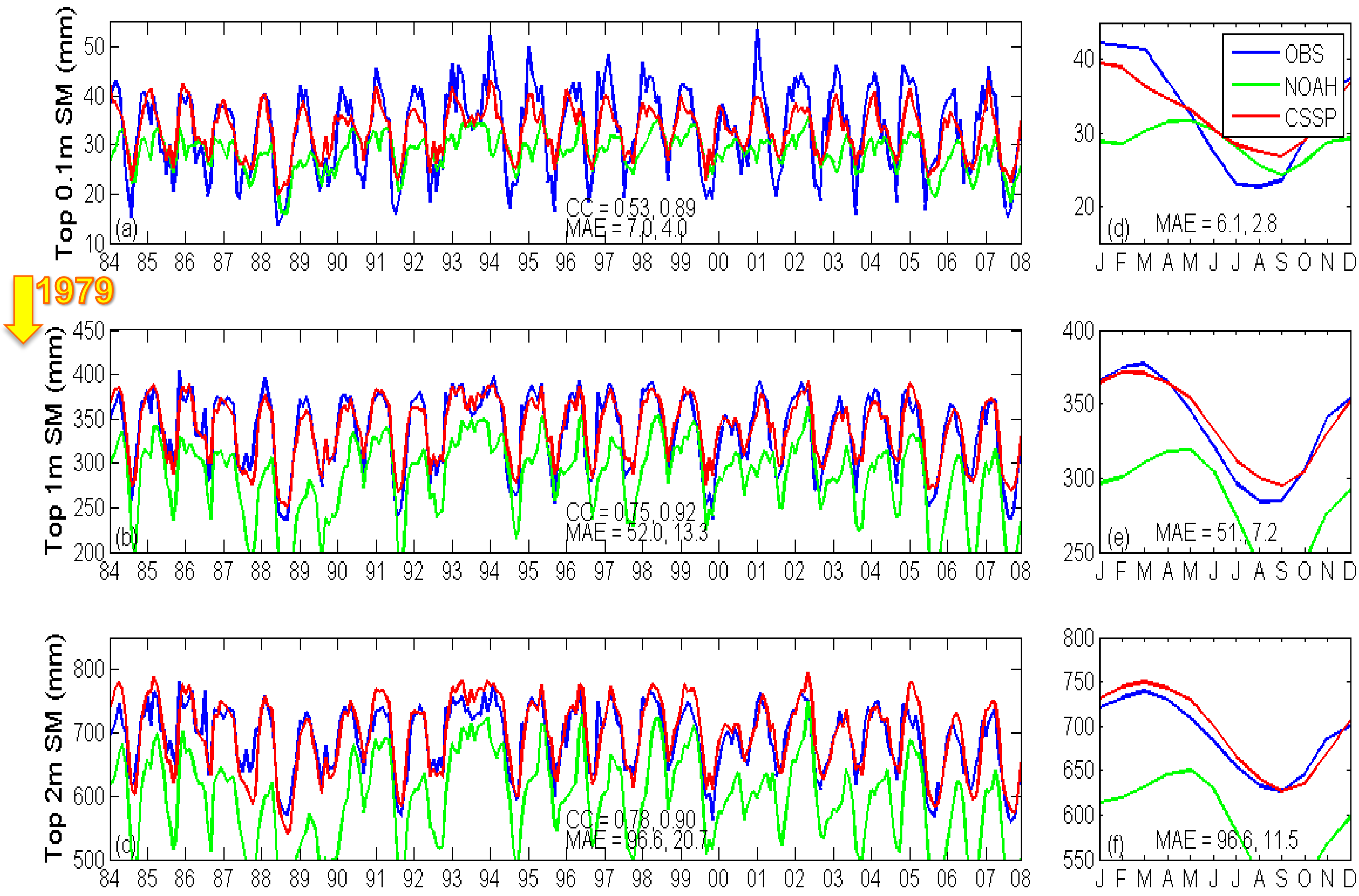




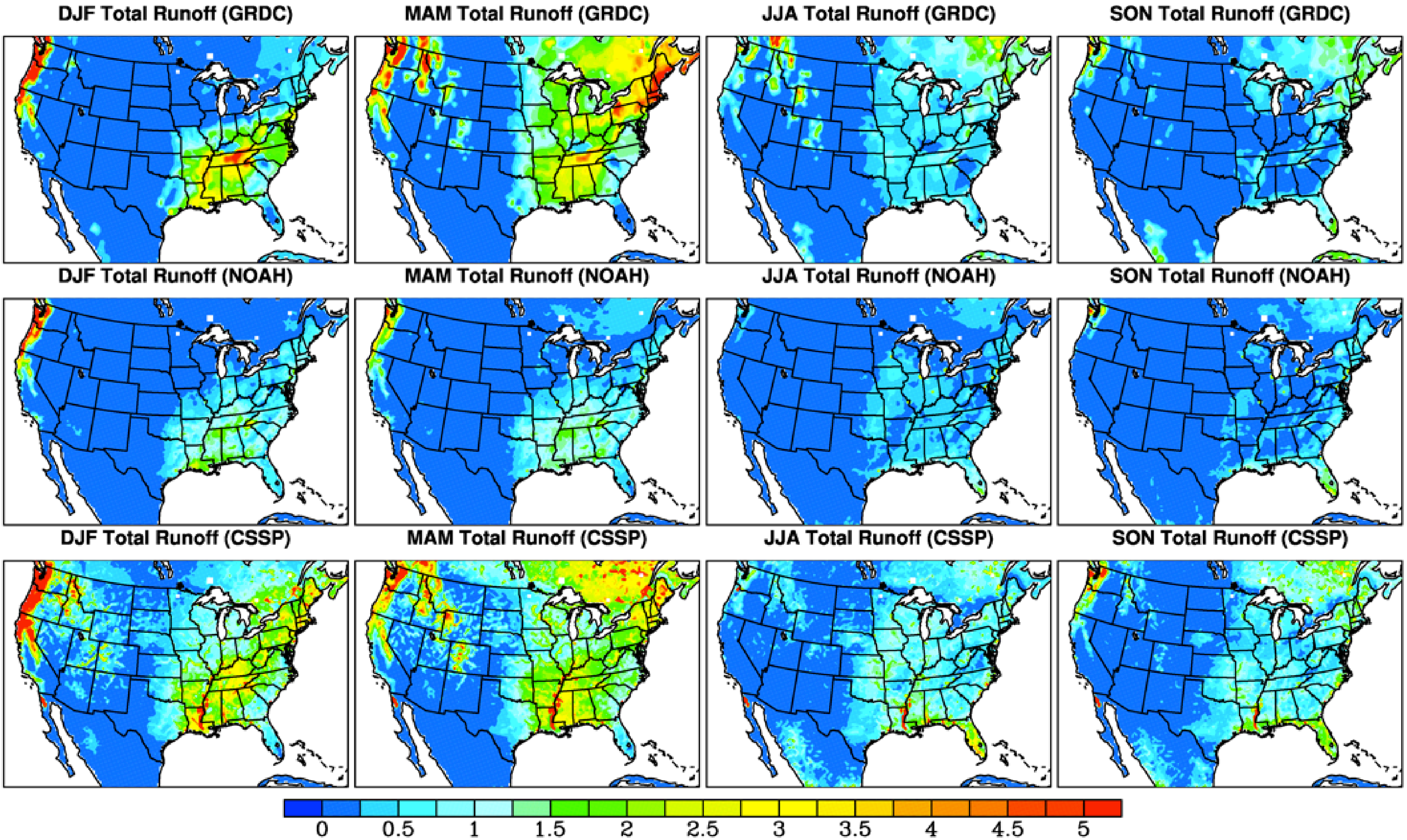


Choi 2006; Choi et al. 2007; Choi and Liang 2010; Yuan and Liang 2010; Liang et al. 2010d

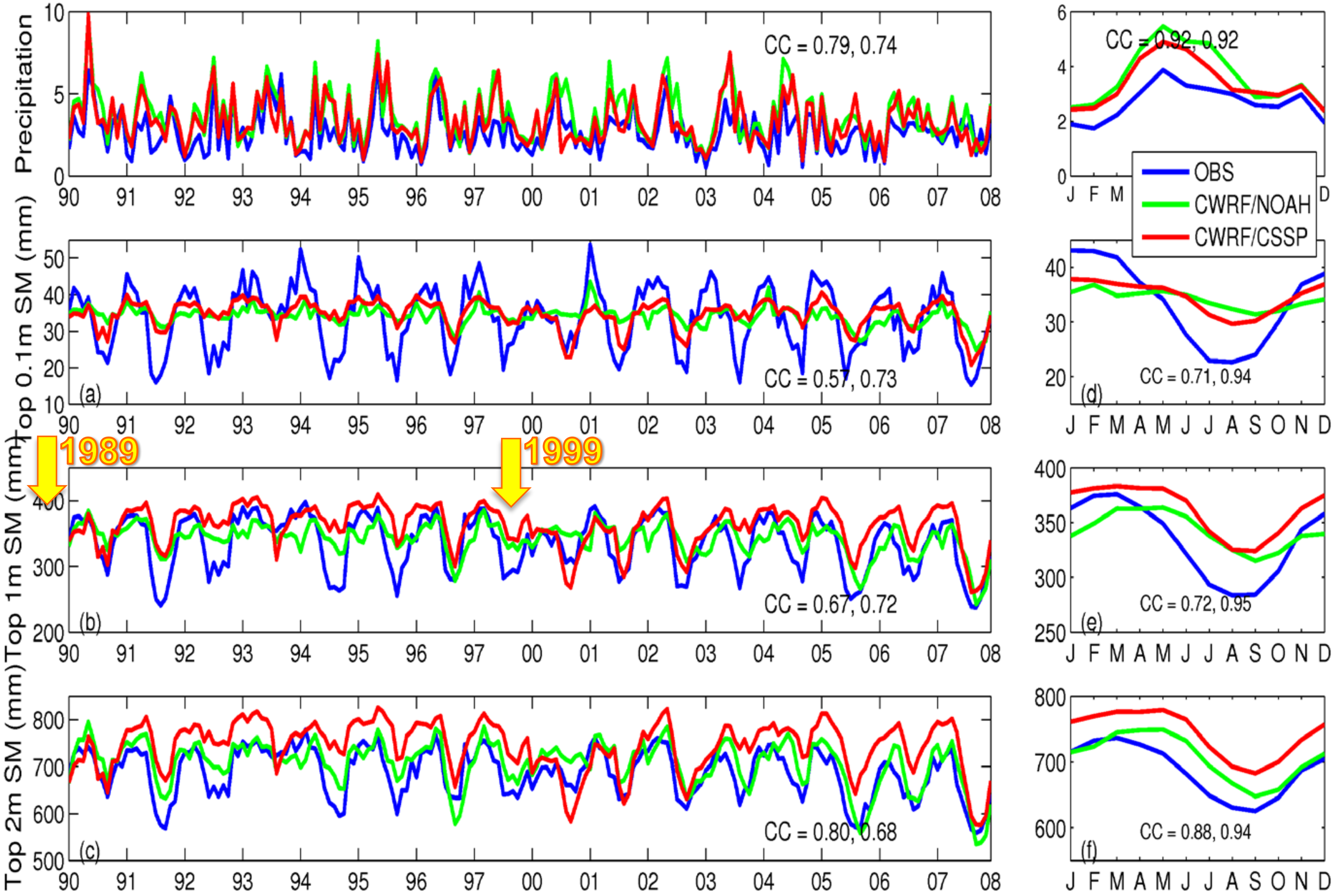
Illinois Soil Moisture by Offline CSSP vs NOAH



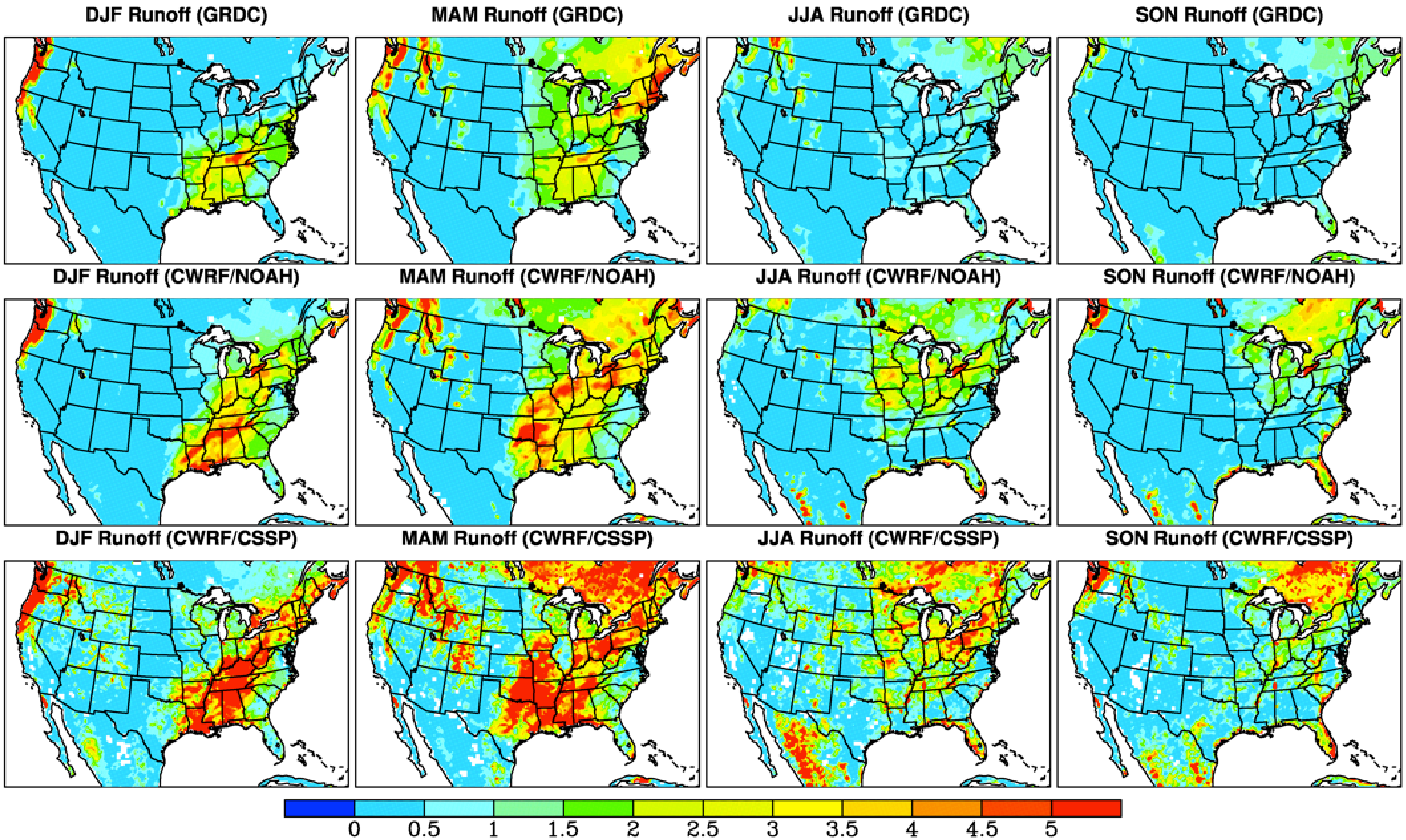
Seasonal Total Runoff by Offline CSSP vs NOAH



Illinois Soil Moisture by CWRF CSSP vs NOAH



Seasonal Total Runoff by CWRF CSSP vs NOAH

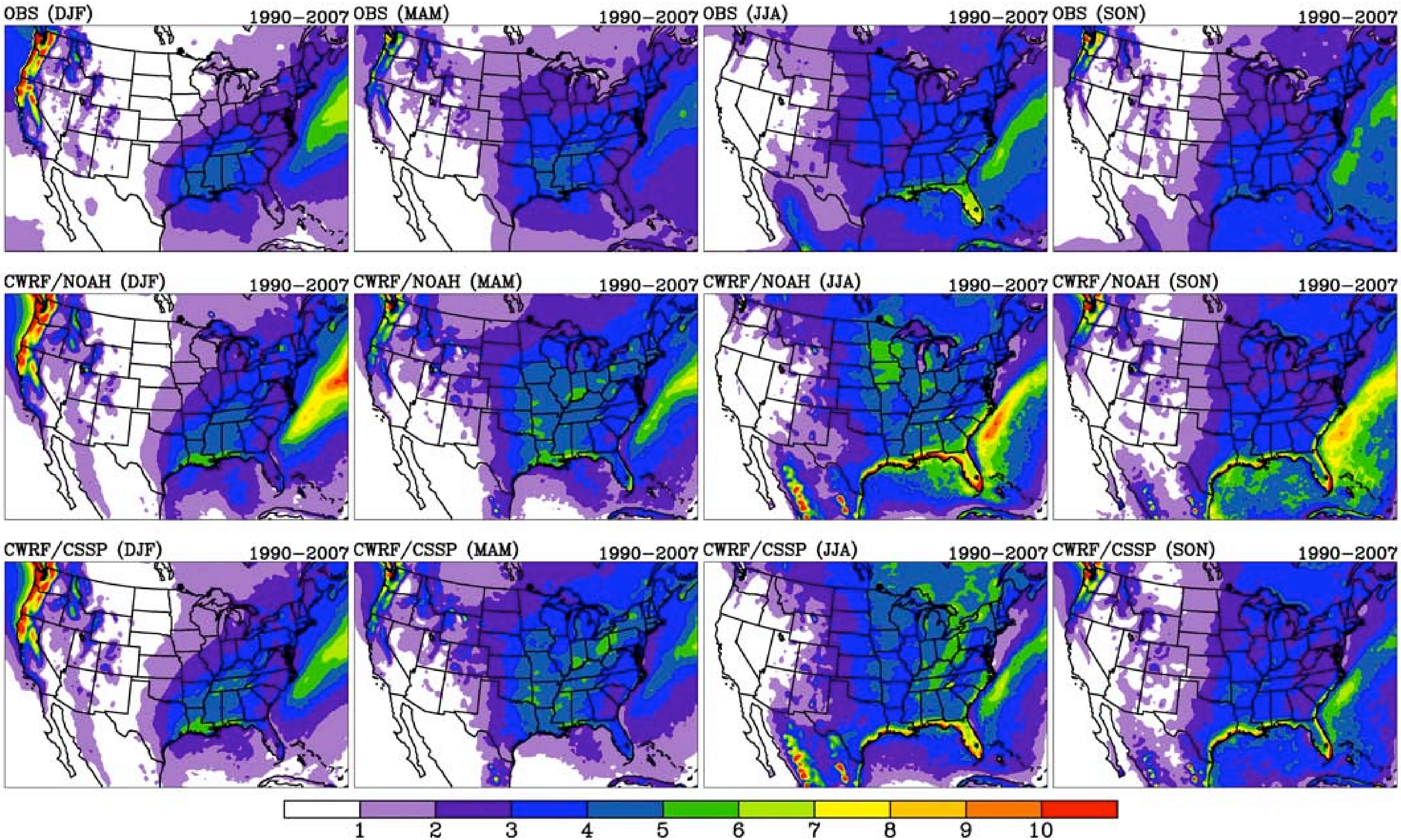


Critical Feedback

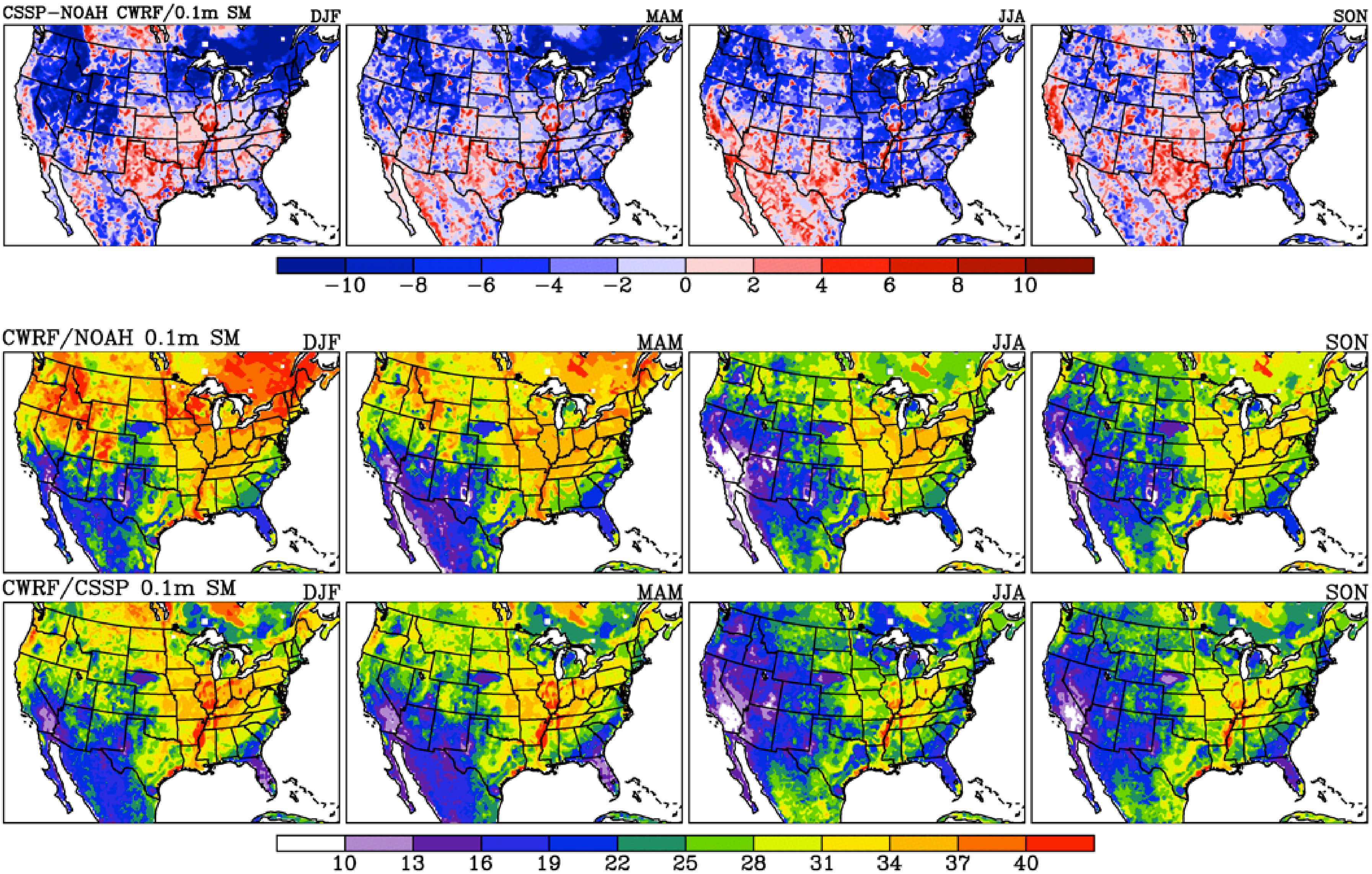
Model physics parameterizations tuned offline may perform poorly online due to the critical feedback processes

Challenging

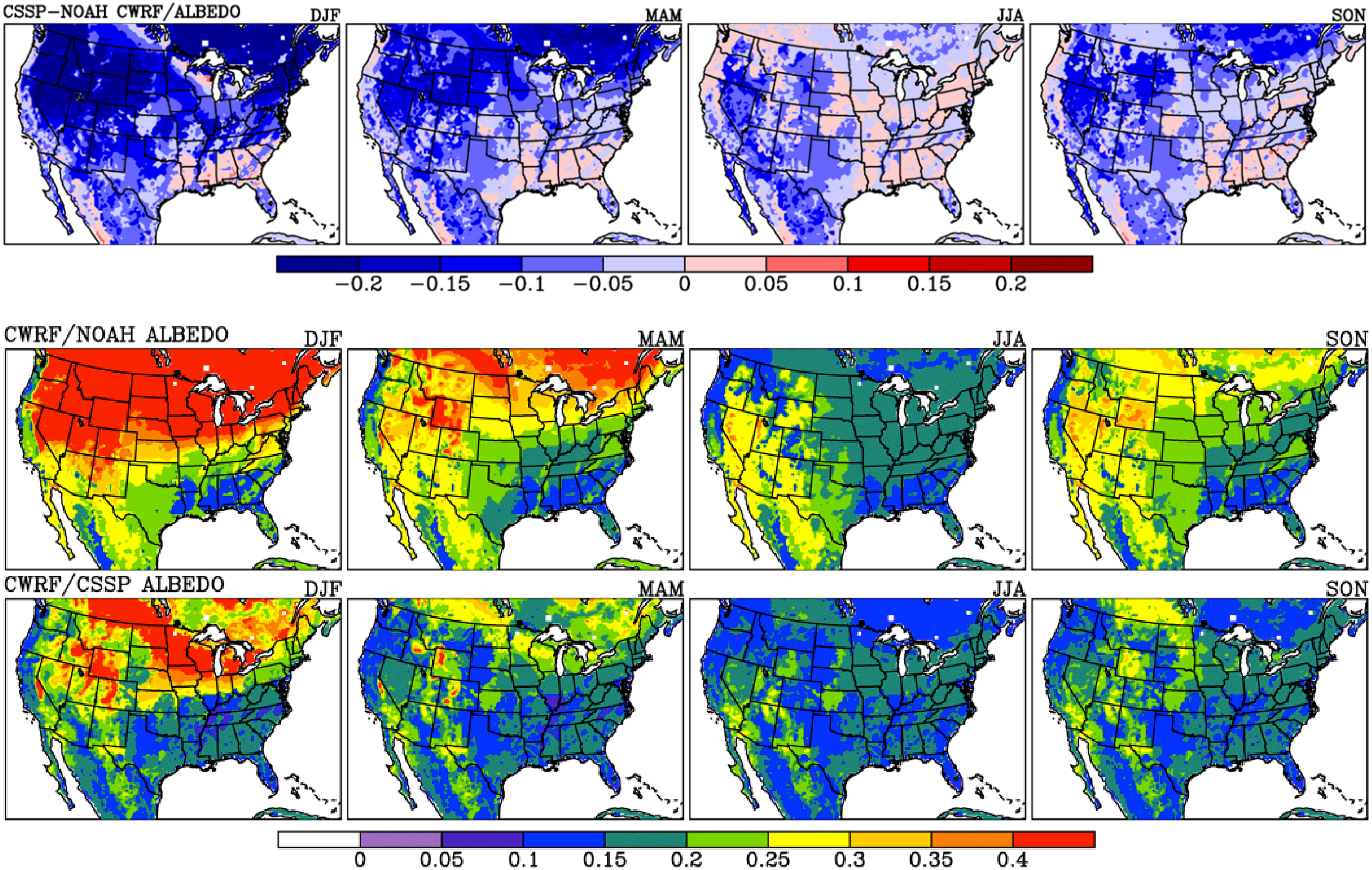
Seasonal Mean Precipitation by CWRF CSSP vs NOAH



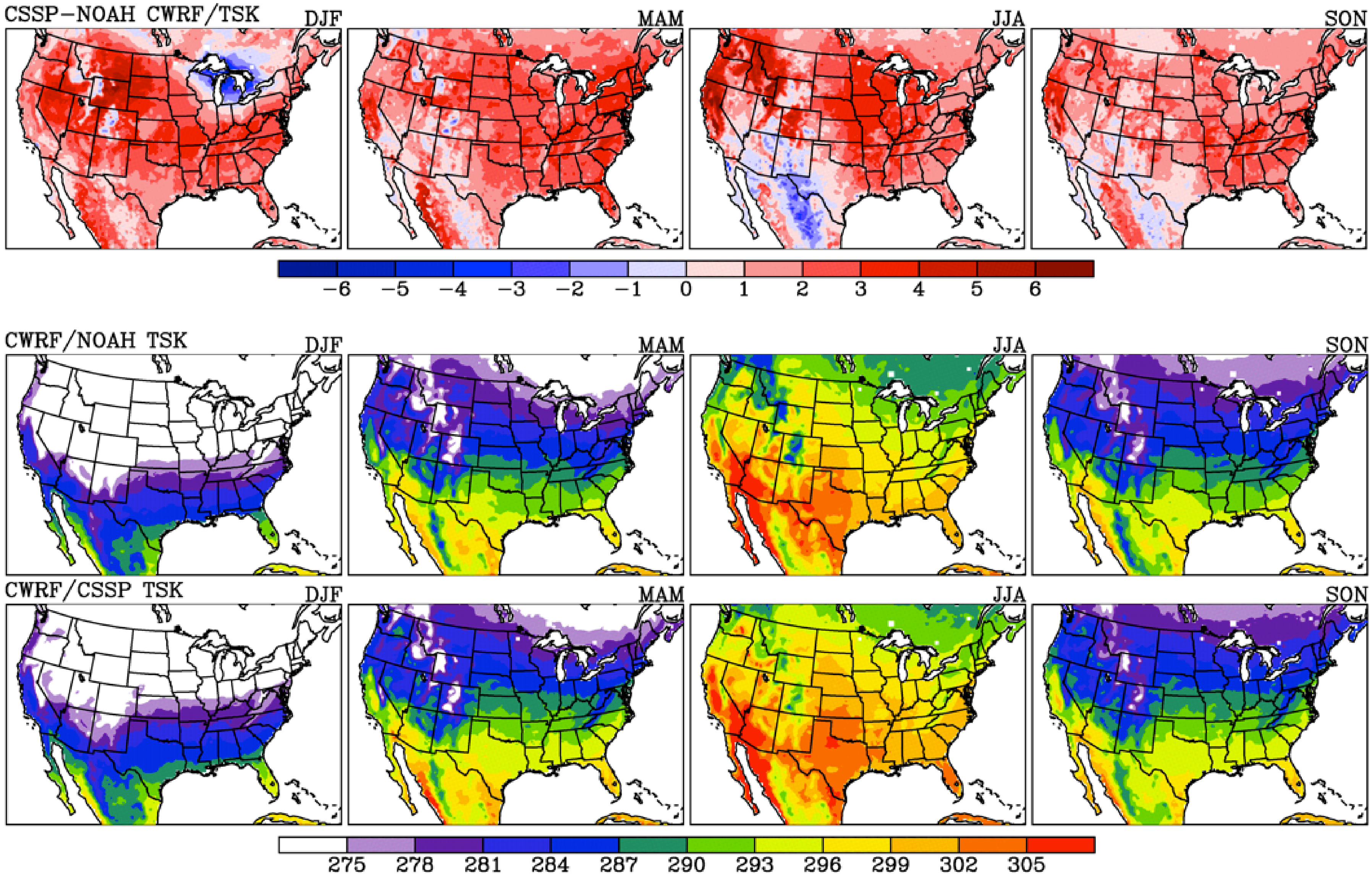
Seasonal Mean SM by CWRF CSSP vs NOAH



Seasonal Mean Albedo by CWRF CSSP vs NOAH



Seasonal Mean TSK by CWRF CSSP vs NOAH



It is challenging to uncover feedback processes

- Does precipitation overestimation cause wetter soil moisture?
- Does feedback cause an enhanced terrestrial hydrology cycle?
- How can the two causal factors be separated?
- How can physics schemes be objectively tuned?
- Should we seek the overall system optimization?