Diurnal Cycle of Precipitation over 2-D Islands in Radiative Convective Equilibrium

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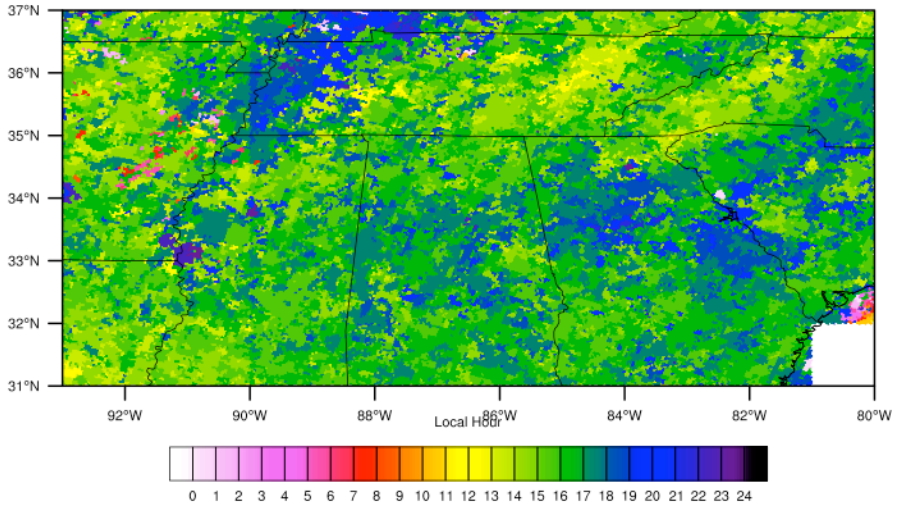
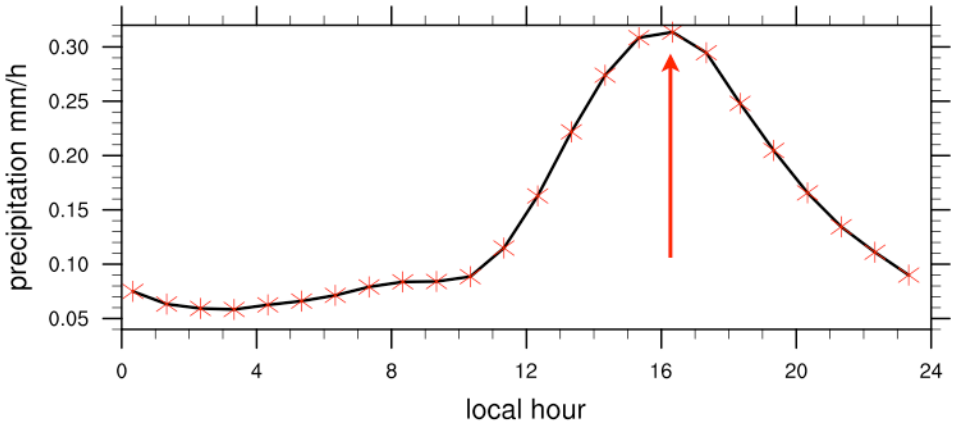
Diurnal cycle of deep convection over land

- Over land, precipitation tends to occur in late afternoon-early evening;
- South-Eastern US has precipitation maximum at around 4-5 pm;
- GCMs have great difficulty reproducing the observed diurnal cycle of precipitation over land.

Gridded Radar (Stage IV) 2002-2012 JJA, S.E. US (31-37N, 80-93W)

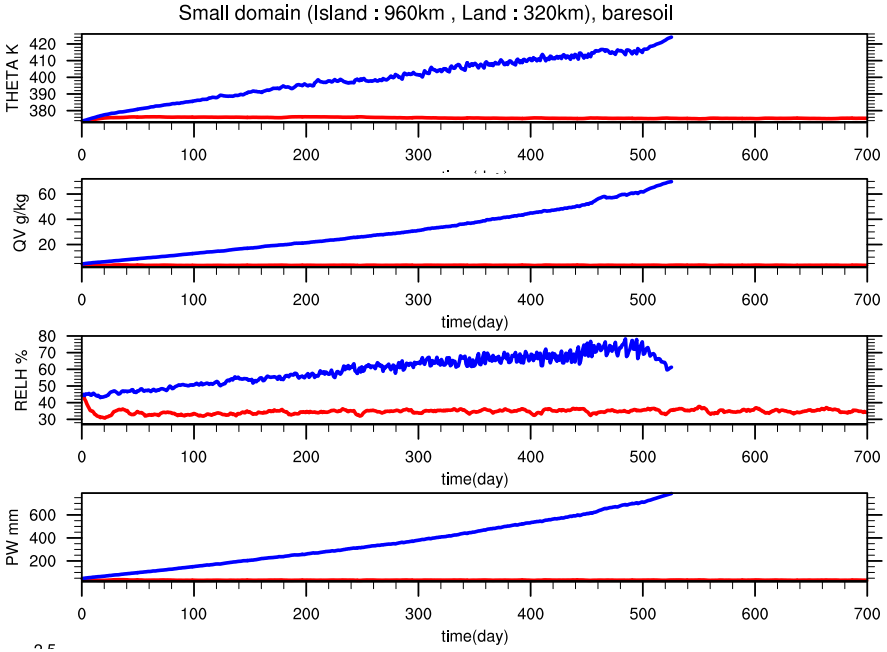


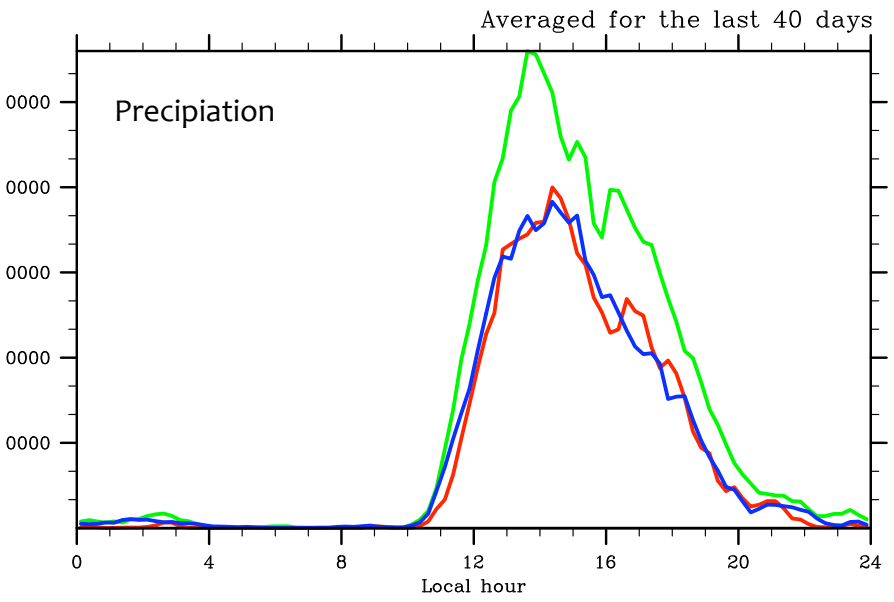


- **Is the late afternoon precipitation peak entirely explained by the *local* PBL/ surface interactions?**

Diurnal convection over land

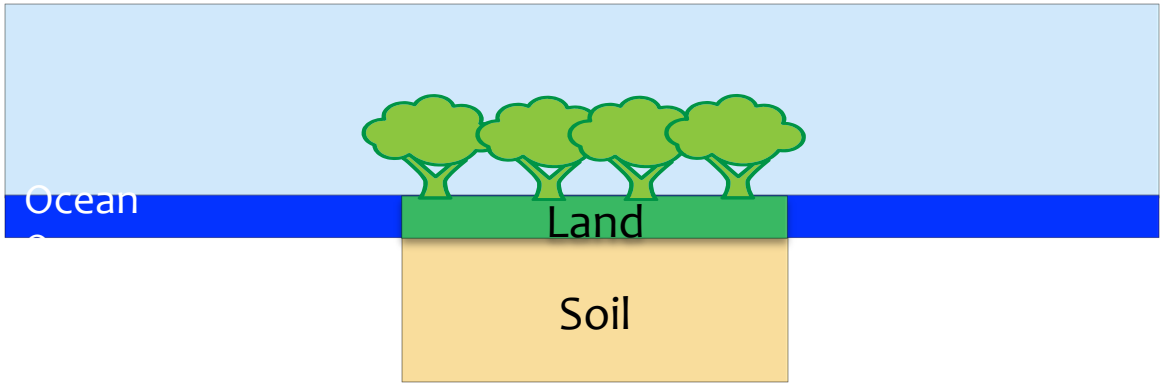
- 2D RCE simulation (~300 days) over land (forest, baresoil or grass) with land model
  - Grid: 4096x256, dx=100m, dt=2s
  - Shows too early precipitation peak (2-3pm)
  - *Doesn't reach equilibrium* – needs energy transport out
- Much shorter 3D LES (100m grid; 10 days) also shows 2ish pm maximum – too early
- **What is the role of surrounding oceans in cooling the land and modulating diurnal cycle over land?**





Experiment set up

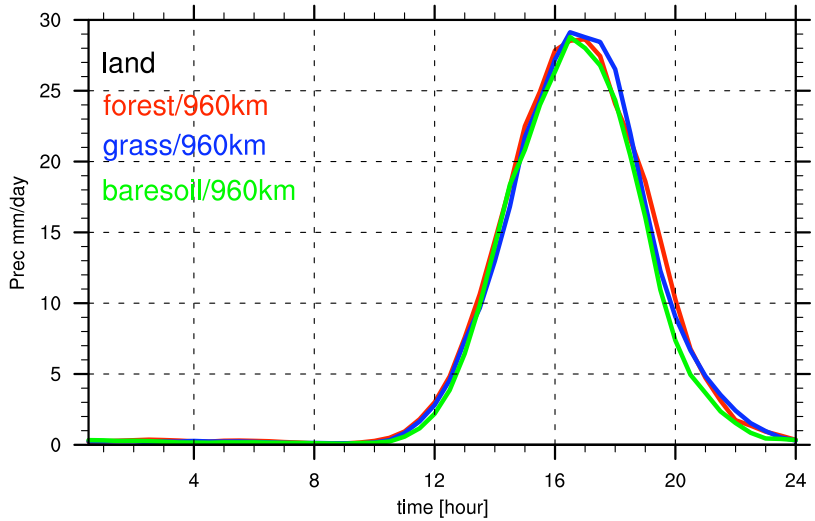
- Model: SAM with Simple Land Model (SAM-SLM)
- Radiative Convective Equilibrium (RCE)
- 2-D (x-z) domain
  - Land is 1/3 of the domain;
  - Δx=500m, Δt=10 s, 64 levels.
  - Run for 500-700 days to equilibrate soil moisture; water table at 2 m
  - Sea-surface temperature (SST) is fixed: 22, 25, and 28 ^{o}C
  - Land types : forest, grassland, bare soil
  - Land width : 960, 2880, and 5760 km
  - Mean background wind : 0 m/s

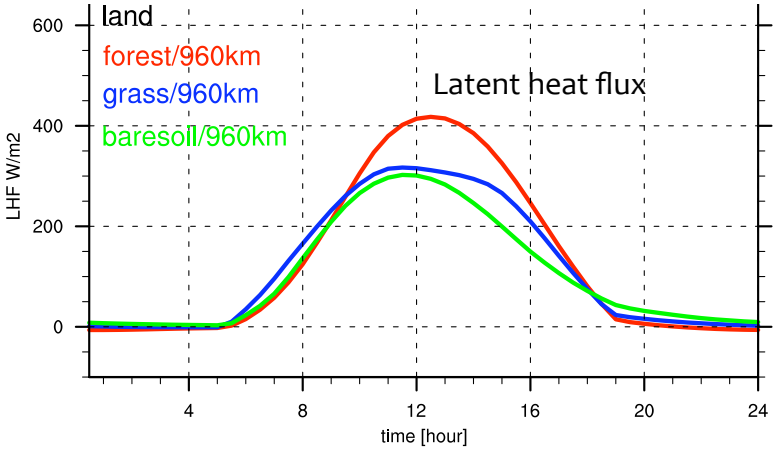


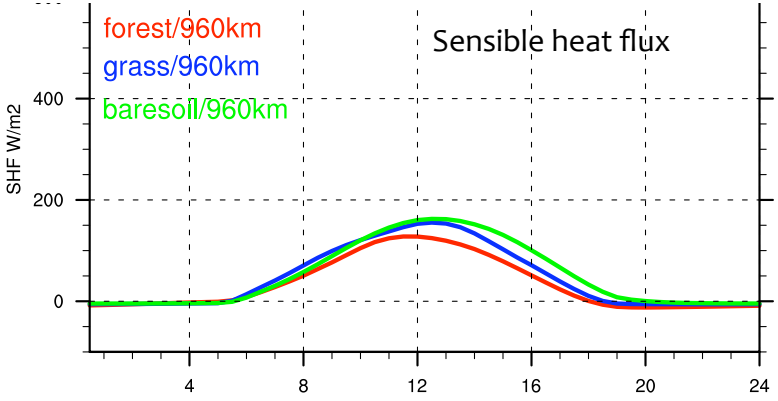
Land surface sensitivity : forest, grassland and baresoil

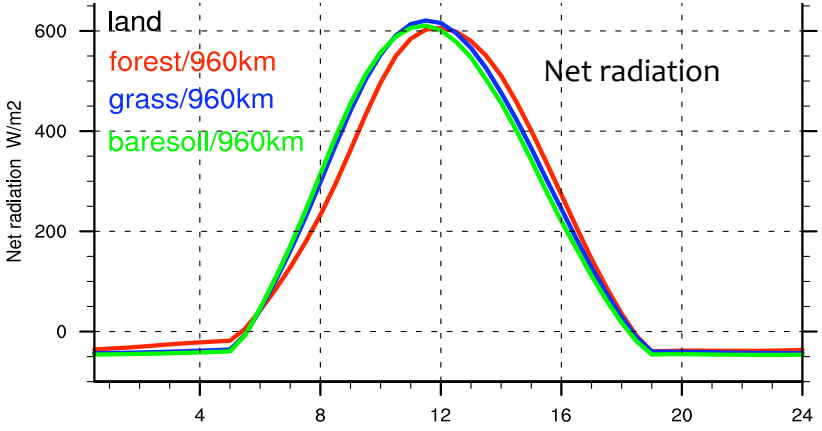
Case : 960km domain, SST=25degC

- Precipitation maximum around 4-5 pm!
- More evaporation over forest





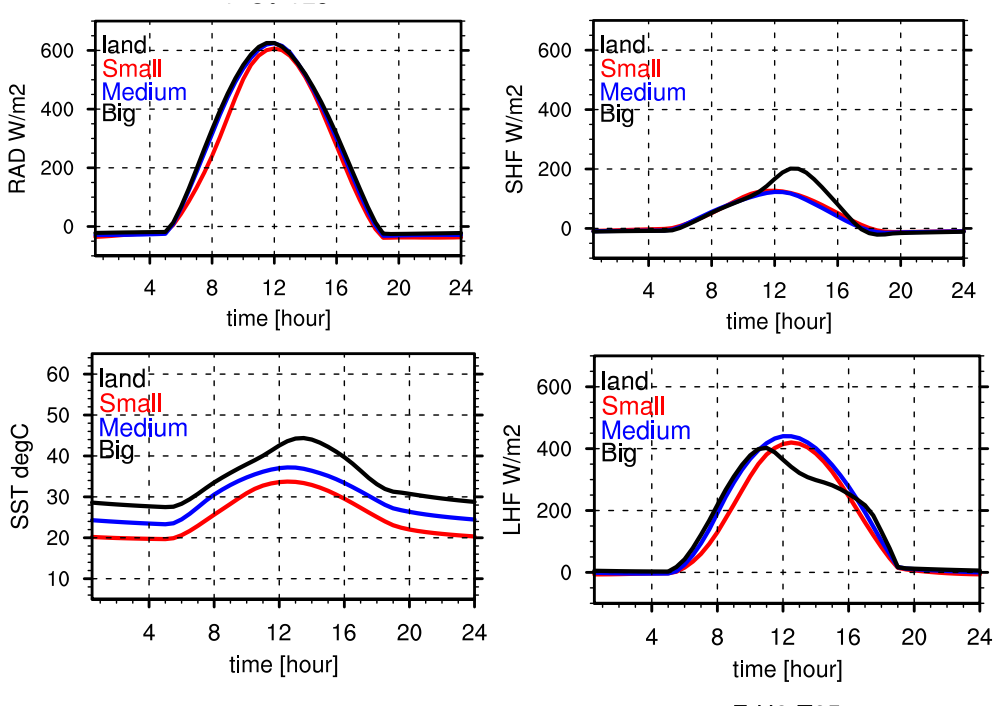




Domain size sensitivity : 960, 2880 and 5760km island

Case : Forest, SST=25degC

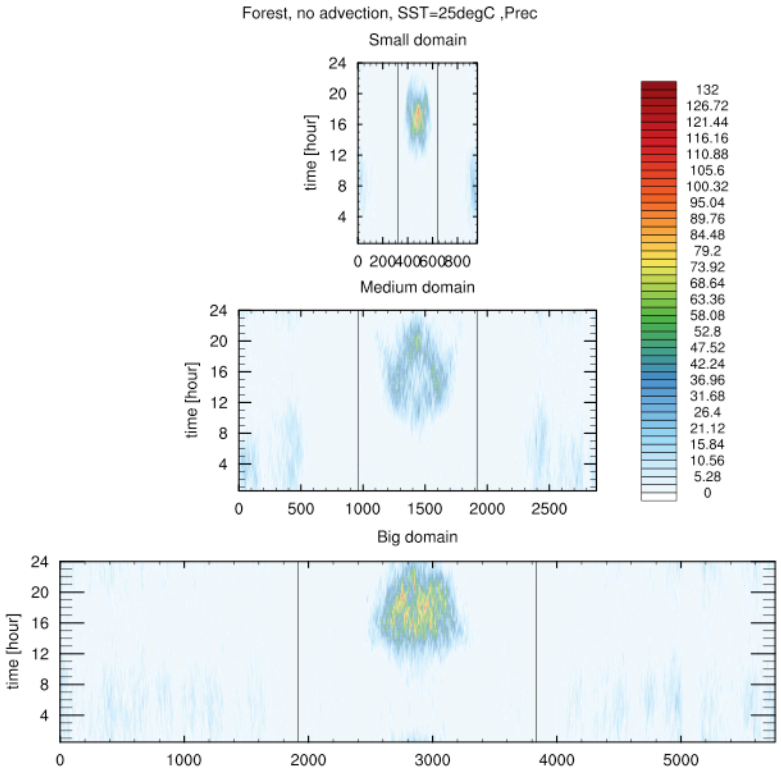
- Composite diurnal cycle of the energy budget and land surface temperature
  - Land-surface temperatures get higher (by about 10K) for bigger land
  - Similar net radiation
    - Small domain has less radiation in the morning due to the denser fog from the cooler morning temperatures
  - Transpiration is limited above a temperature threshold
    - Sudden decrease of the evaporation & increase of the sensible heat flux in the afternoon in a big domain

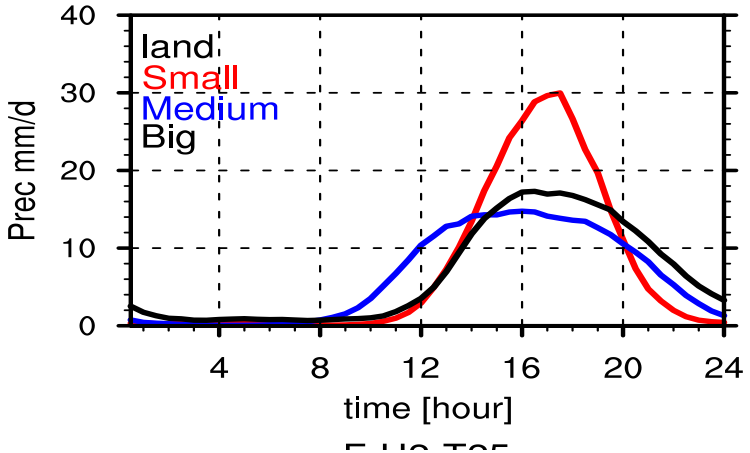


Domain size sensitivity : 960, 2880 and 5760km island

Case : Forest, SST=25degC

- Little sensitivity of the time of precipitation maximum to the domain size



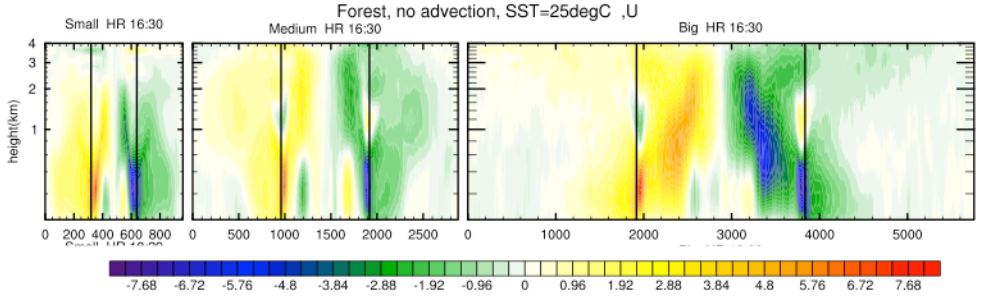


Domain size sensitivity : 960, 2880 and 5760km widths

Case : Forest, no advection and SST=25degC

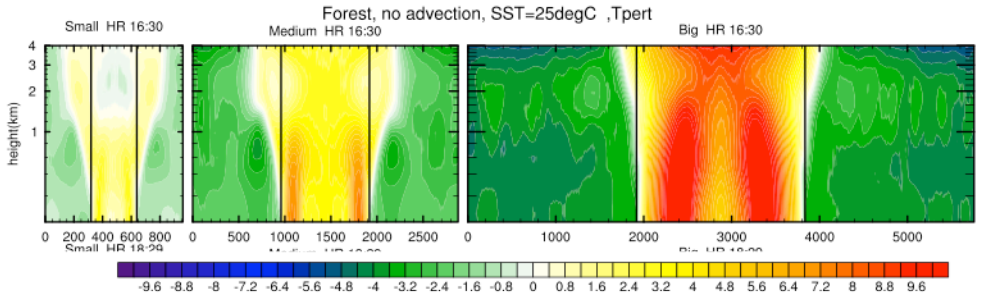
- Snapshot of the domain at 4:30PM
  - Strong sea breeze circulation near the coastlines
  - Similar patterns in the temperature anomaly
  - As the temperature over the big domain becomes high, the VPD becomes large over the most of land domain => Smaller relative area with precipitatation.

Zonal wind

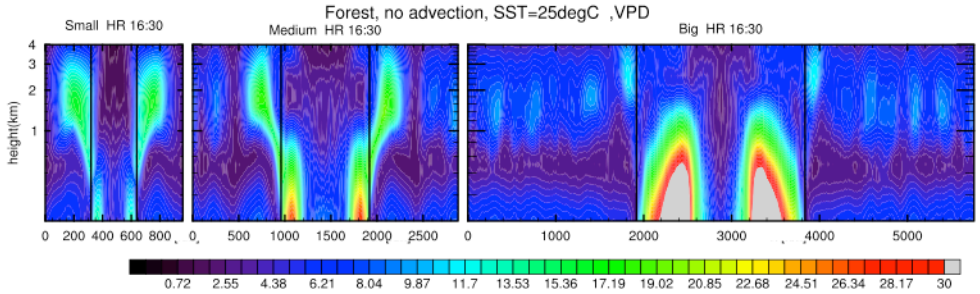


Temperature anomaly

T-horizontal mean of T



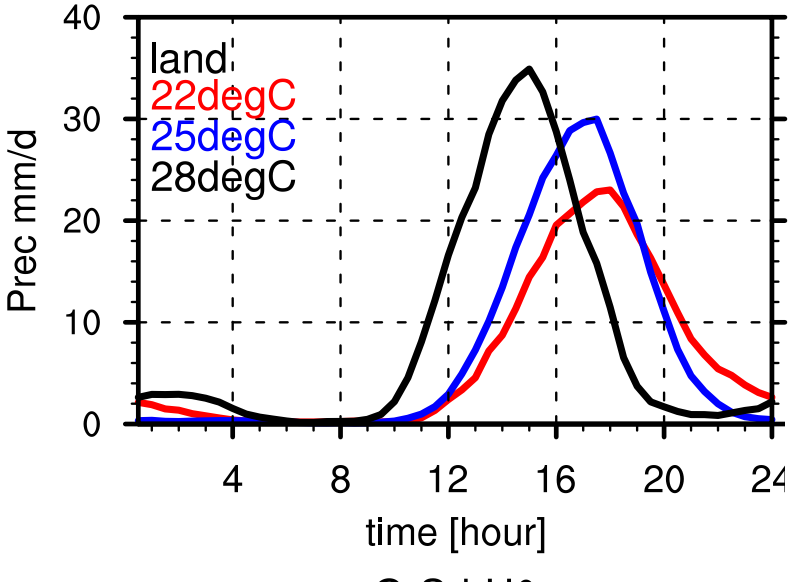
Vapor pressure deficit

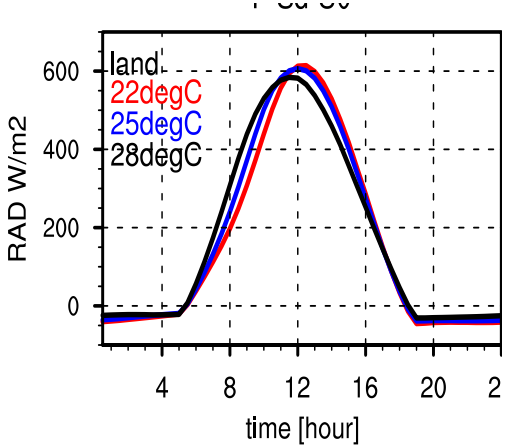


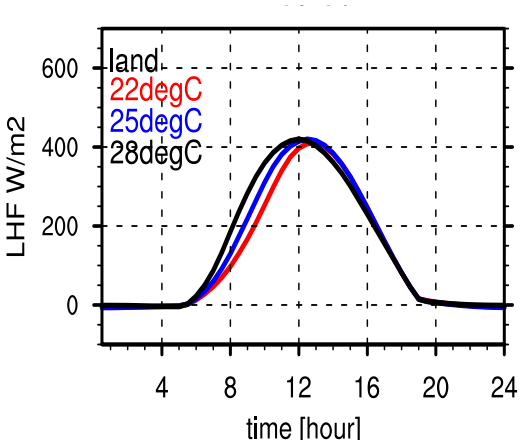
SST Sensitivity : 22, 25, and 28 degC

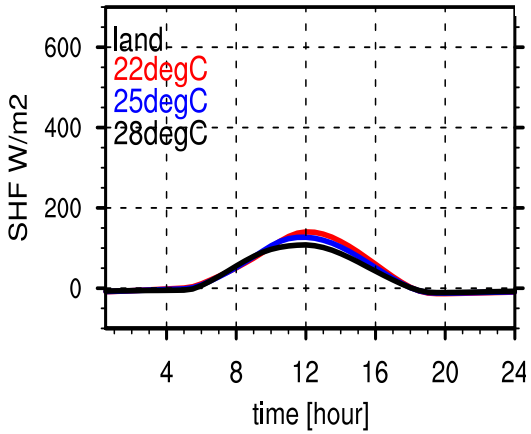
Case : 960km domain, forest

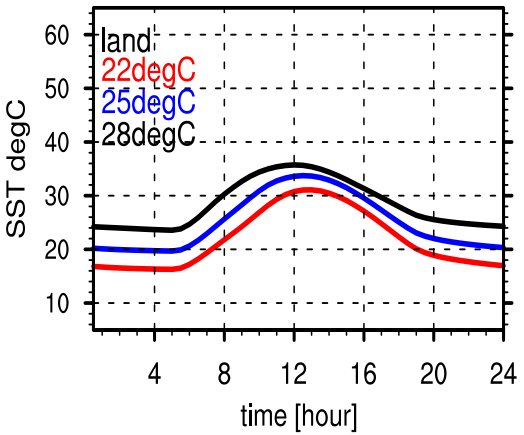
- Earlier precipitation maximum for warmer SST
- Land surface is warmer for warmer SST











Summary/Conclusions

- Over land, observed precipitation tends to pick at late afternoon-early evening (at 4-5 pm in the SE US);
- Idealized CRM simulations of land-only RCE produce earlier precipitation maximum, closer to the local noon;
- Hypothesis: the local diurnal cycle of precipitation over land is strongly modulated by the surrounding oceans;
- Tool: idealized 2D RCE over islands of different size, vegetation cover surrounded by ocean with different fixed SSTs.
- Preliminary results:
  - Incorporation of the ocean seems to reproduce the observed precipitation pick at 4-5 pm;
  - Vegetation type and island size don't have much effect on precipitation timing;'
  - Bigger islands tend to have warmer surface temperatures; continental scale islands have extensive drought zones.
  - The timing of precipitation maximum is strongly affected by the SST of the surrounding ocean, that is warmer SST leads to earlier pick.
- Implications for future world with much warmer SSTs?

Conclusions