Introducing Human Influences in Land-Surface models at NCEP

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and all of our collaborators

"Including Water Management in Large Scale Models"
Centre National de la Recherche Scientifique (CNRS)
Gif-sur-Yvette, France, 28-30 September 2016

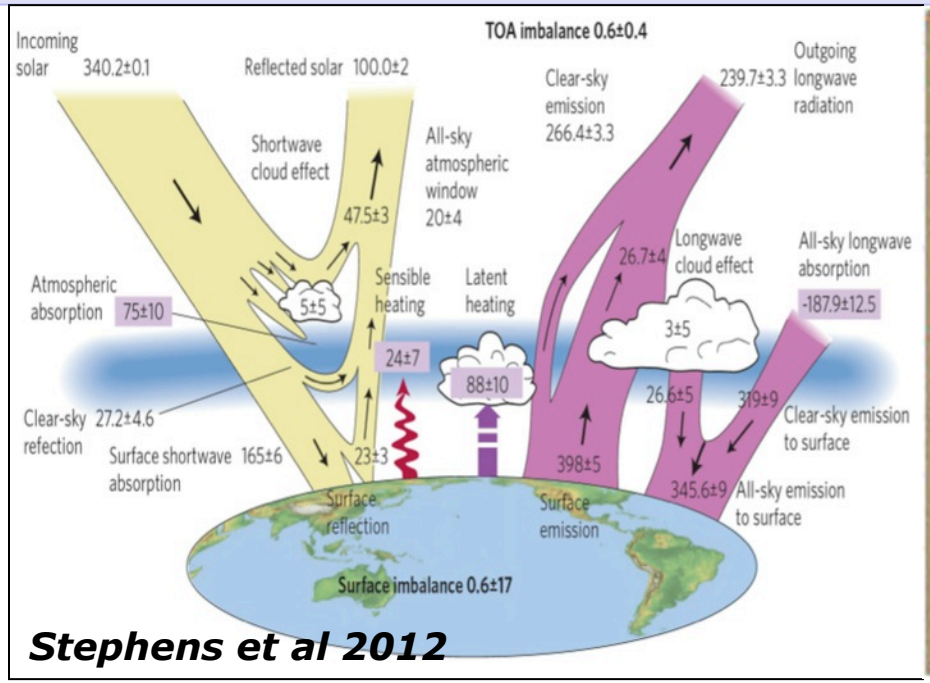
Role of Land Models

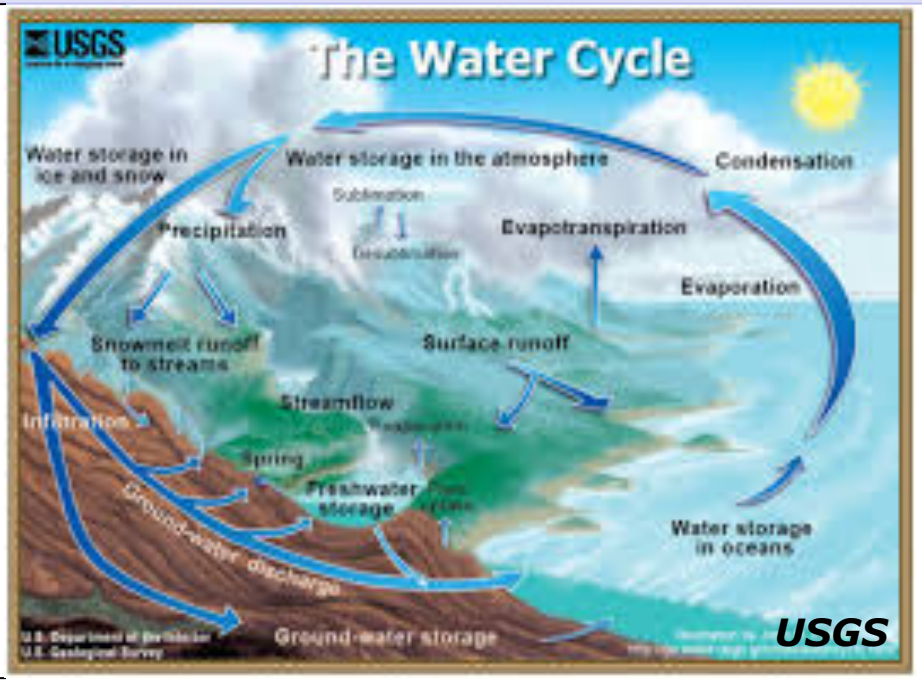
Traditionally, from the perspective of **Numerical Weather Prediction (NWP)** and (*coupled atmosphere-ocean-land-ice)* **Climate Modeling**, a land-surface model provides quantities as boundary conditions:

- Surface **energy budget** (sensible & latent turbulent heat fluxes, ground heat flux, emitted longwave and reflected shortwave radiation)
- Surface **water budget** (including groundwater)
- Surface **momentum exchange**

Human influences must be accounted for in these as part of urban regions, and for management of water, e.g. for agricultural uses & flood control.

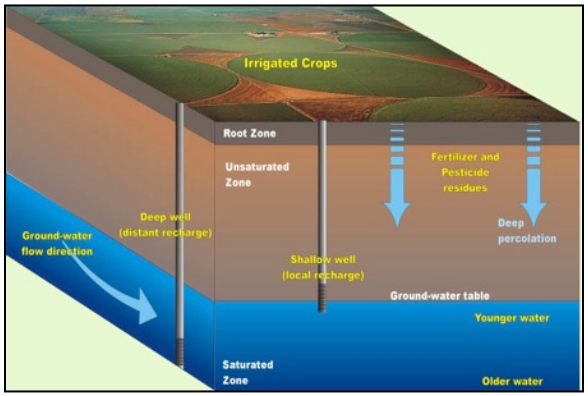
Atmospheric Energy and Water Budgets





- We must more properly represent & close the (surface) energy budget and water budget (hydrological cycle) to provide surface boundary conditions in weather and climate models as they expand their role in more fully-coupled Earth System models.
- It's a careful "bookkeeping" job for energy, water, and momentum, including the human influence on these quantities.

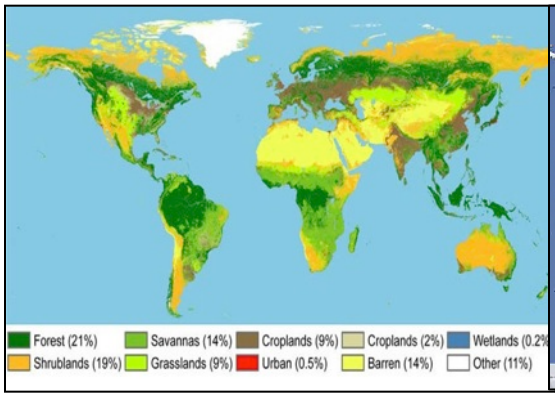
Human Influences/Water Management

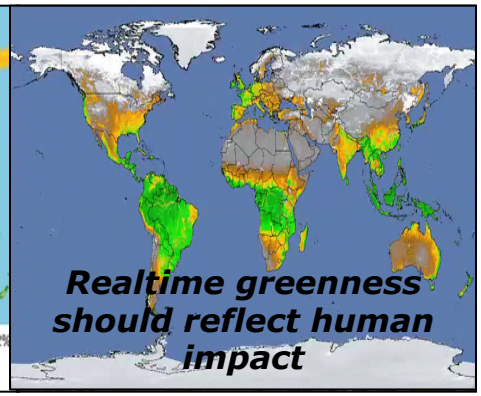


Groundwater Extraction

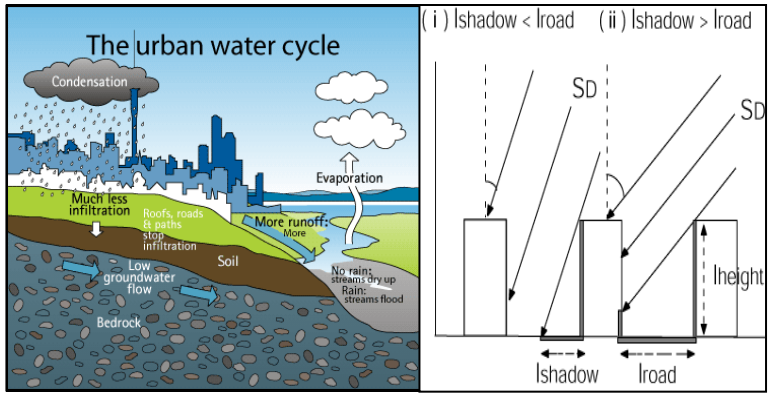
Irrigation

Reservoirs





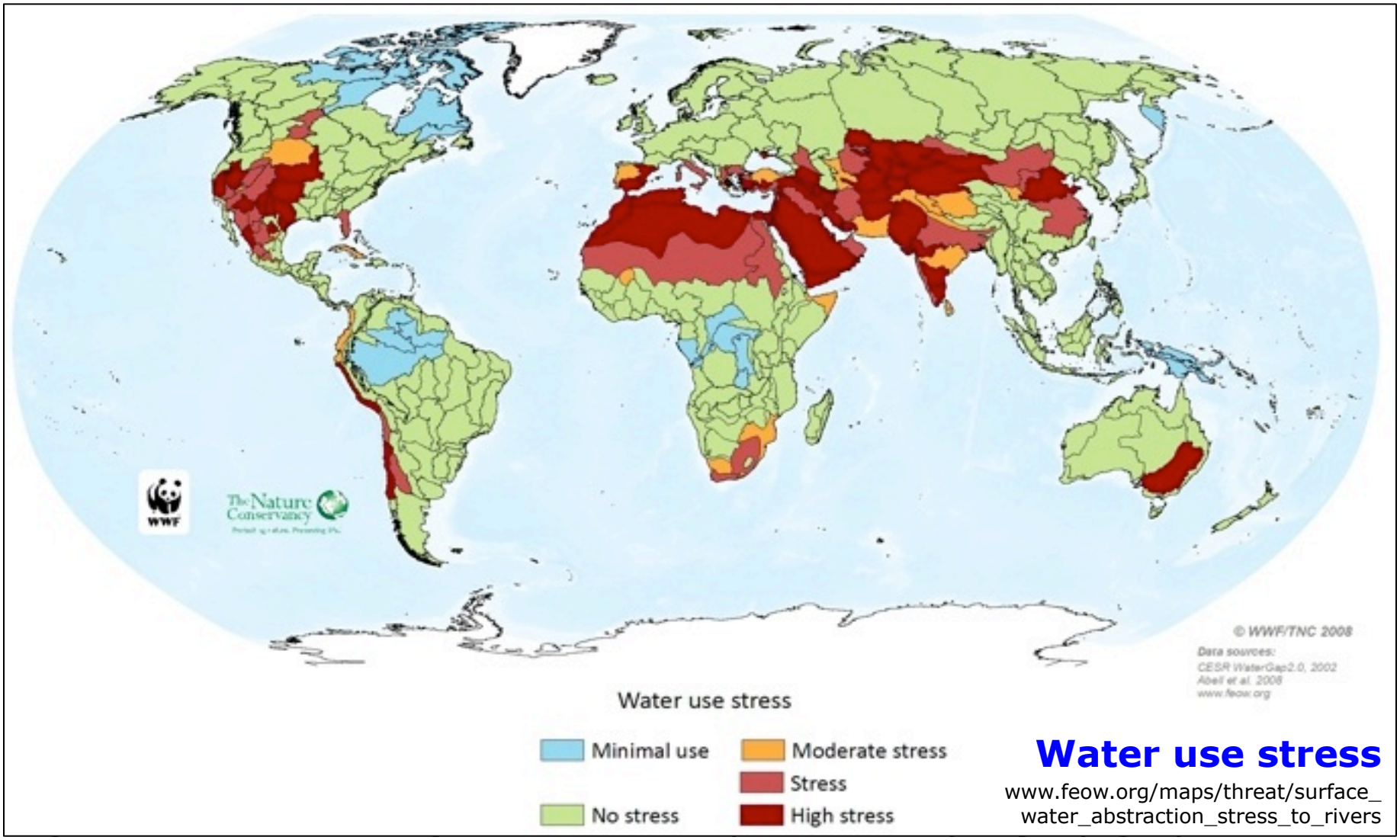
Land-cover change/deforestation



Urban areas/model

- Proper land initial conditions (e.g. via remote sensing), and improved land model physics parameterizations, including human influences.

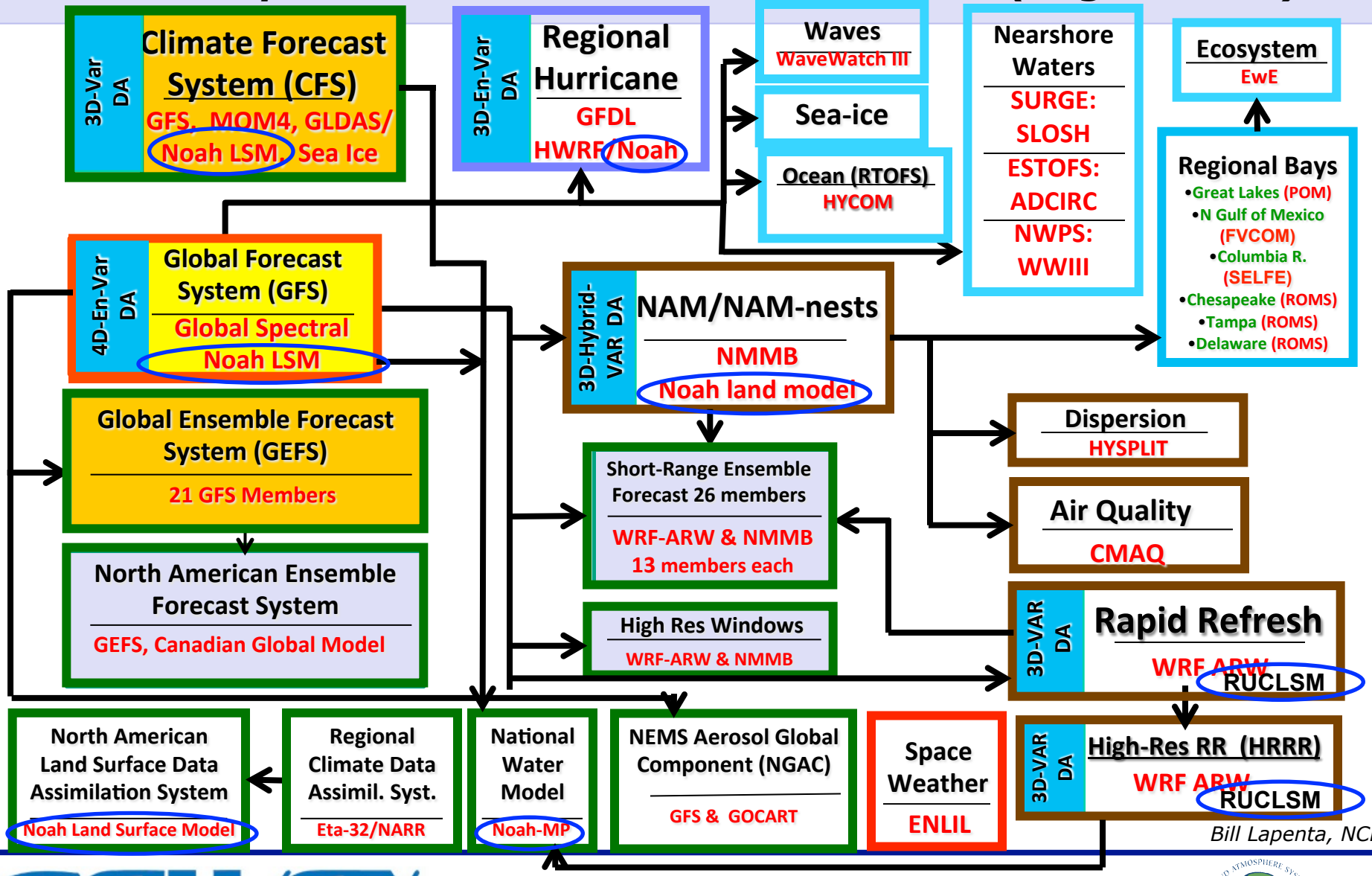
Human Influences/Water Management



Water use stress

www.feow.org/maps/threat/surface_water_abstraction_stress_to_rivers

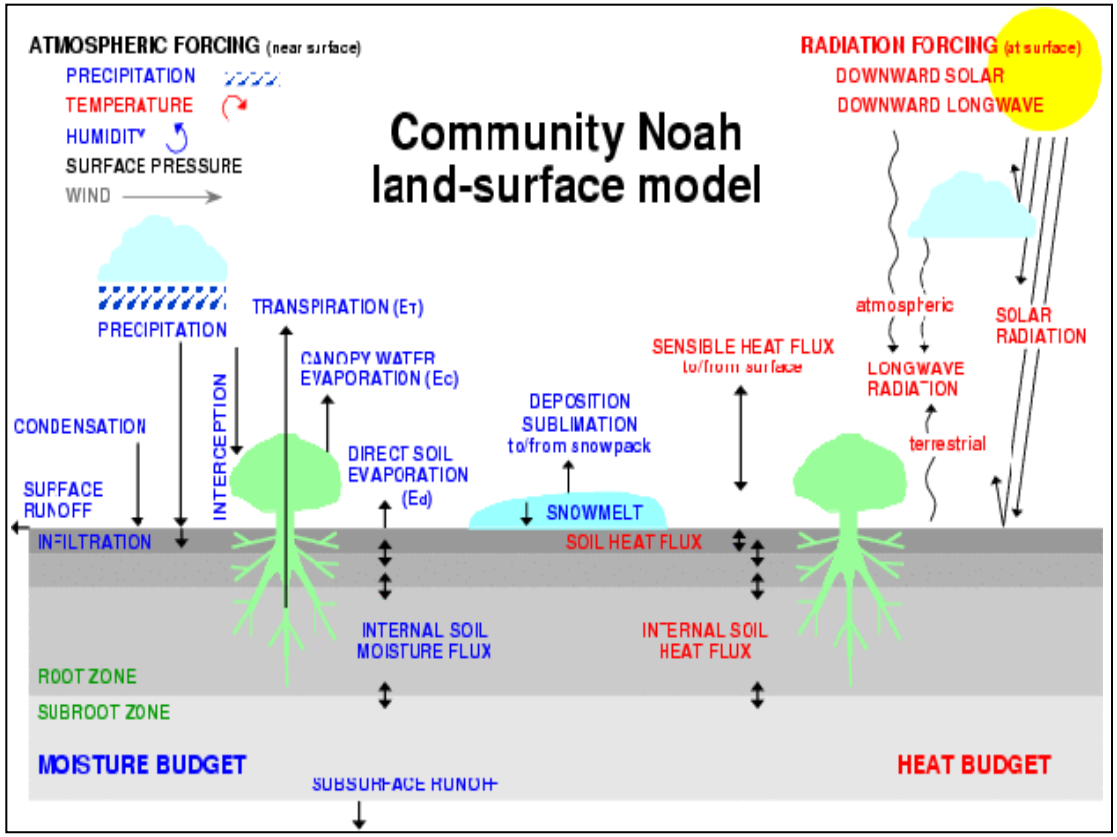
Land Applications for Weather and Seasonal Climate: NOAA's Operational Numerical Guidance Suite (August 2016)



Bill Lapenta, NCEP

Unified NCEP-NCAR Noah Land Model

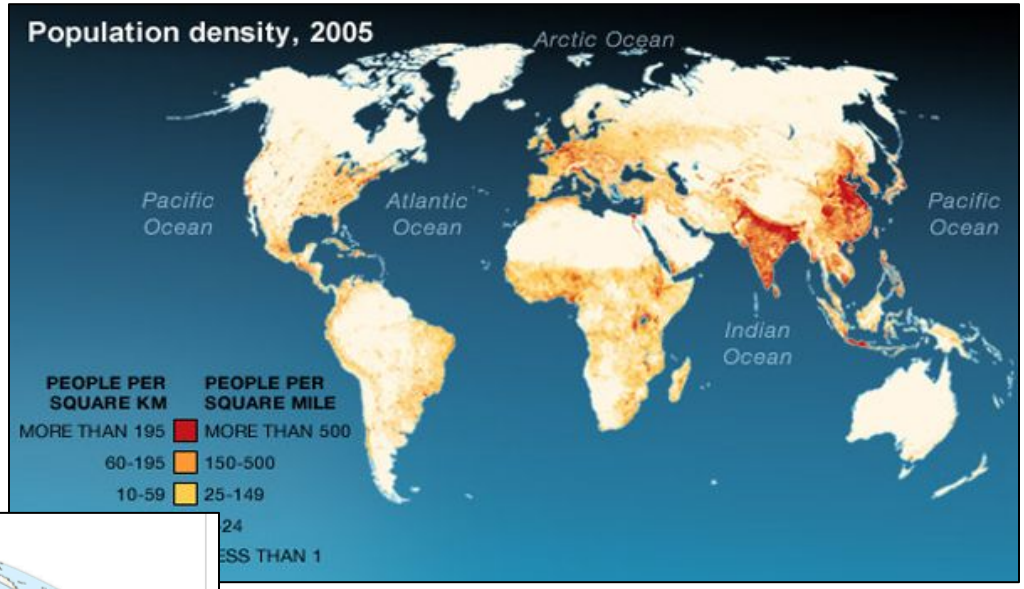
- Jarvis-Stewart "big-leaf" canopy conductance; canopy interception; direct soil evap; soil hydraulics/ thermodynamics, including veg. effect on thermal conductivity; patchy/ fractional snow cover effect on surface fluxes; snow-pack density/snow water equivalent; freeze/thaw soil physics.
- *Urban effects on heat, water, momentum.*
- *Irrigation land-use type.*
- ***No other explicit effects of water management.***
- *Noah-MP: includes groundwater.*

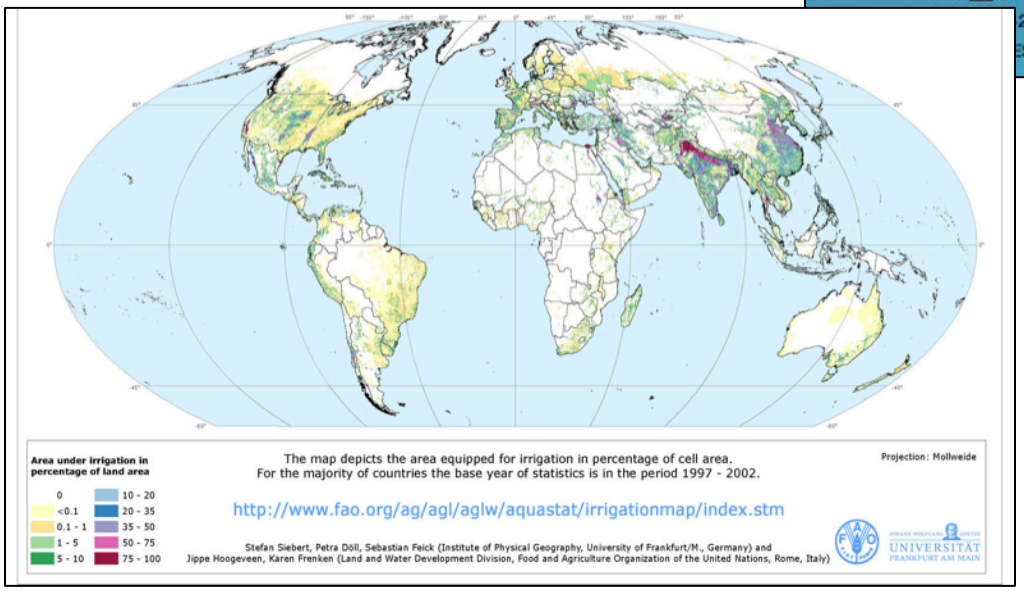


- **Noah for NWP & seasonal prediction**, coupled with NCEP short-range NAM, medium-range GFS, seasonal CFS, and HWRF, uncoupled NLDAS & GLDAS, etc.

Terrestrial Water in Noah LSM: Current Capabilities
Irrigated gridboxes or subgrid tiles, Urban regions

- *Urban land-use (one vegetation type) & small vegetation fraction, "adjusted" hydraulic/thermal properties to approximate an urban heat island.* ***But no explicit accounting in water budget.***



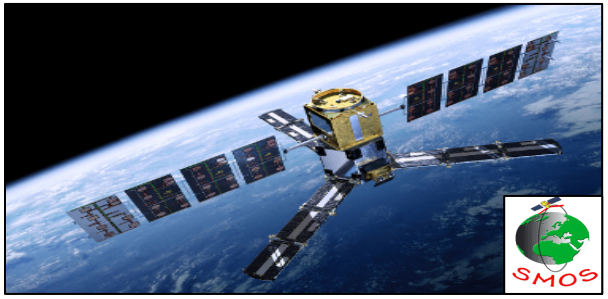


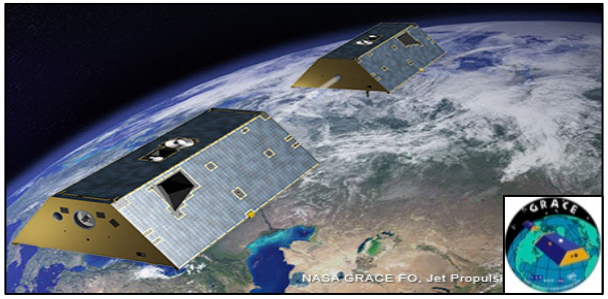
- *Irrigation land-use type as an option in Noah LSM; soil moisture held at field capacity.* ***But no explicit accounting in water budget.***

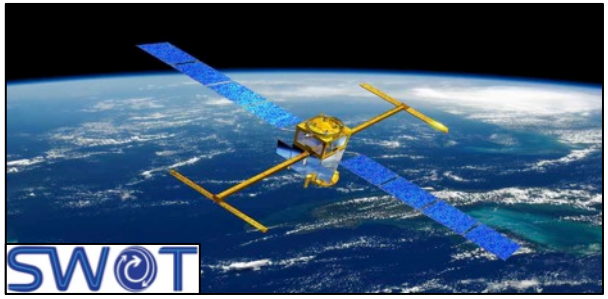
Terrestrial Water in Noah LSM: Current Capabilities
National Water Model: Noah-MP+WRF-Hydro; no management

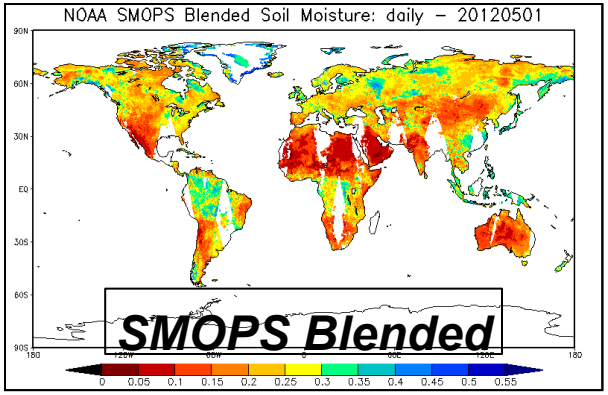
Video Unavailable

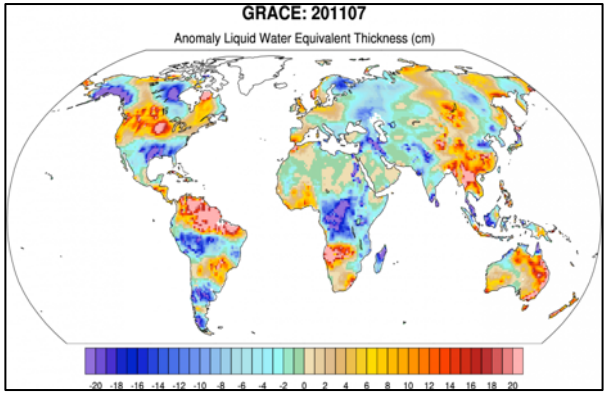
Terrestrial Water in Noah LSM: Future Capabilities
Remote Sensing: Soil moisture, Groundwater, Surface Water

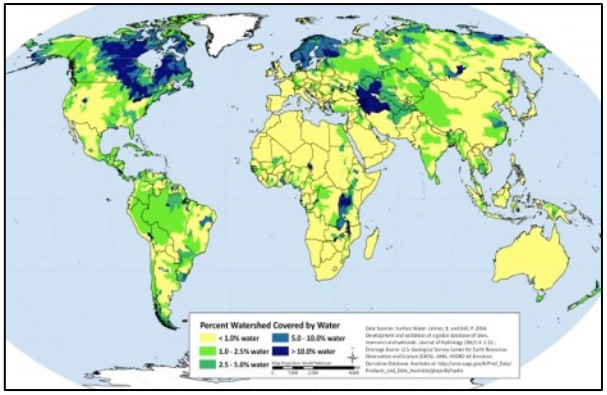












NESDIS Soil Moisture Operational Product System (SMOPS): Blended Microwave.

Gravity Recovery and Climate Experiment (GRACE): Terrestrial Groundwater.

Surface Water Ocean Topography (SWOT): Terrestrial Surface Water.

- Proper initial conditions (e.g. via remote sensing) with land data assimilation, and improved land model physics parameterizations, to include human influences. Compare with in situ measurements/studies.

Summary

In a fully-coupled ***Earth System***, land models must include human impact on heat, moisture/water, and momentum budgets (e.g. water management, urban regions), where land models provide boundary conditions for ***Weather & Climate*** models with connections to:

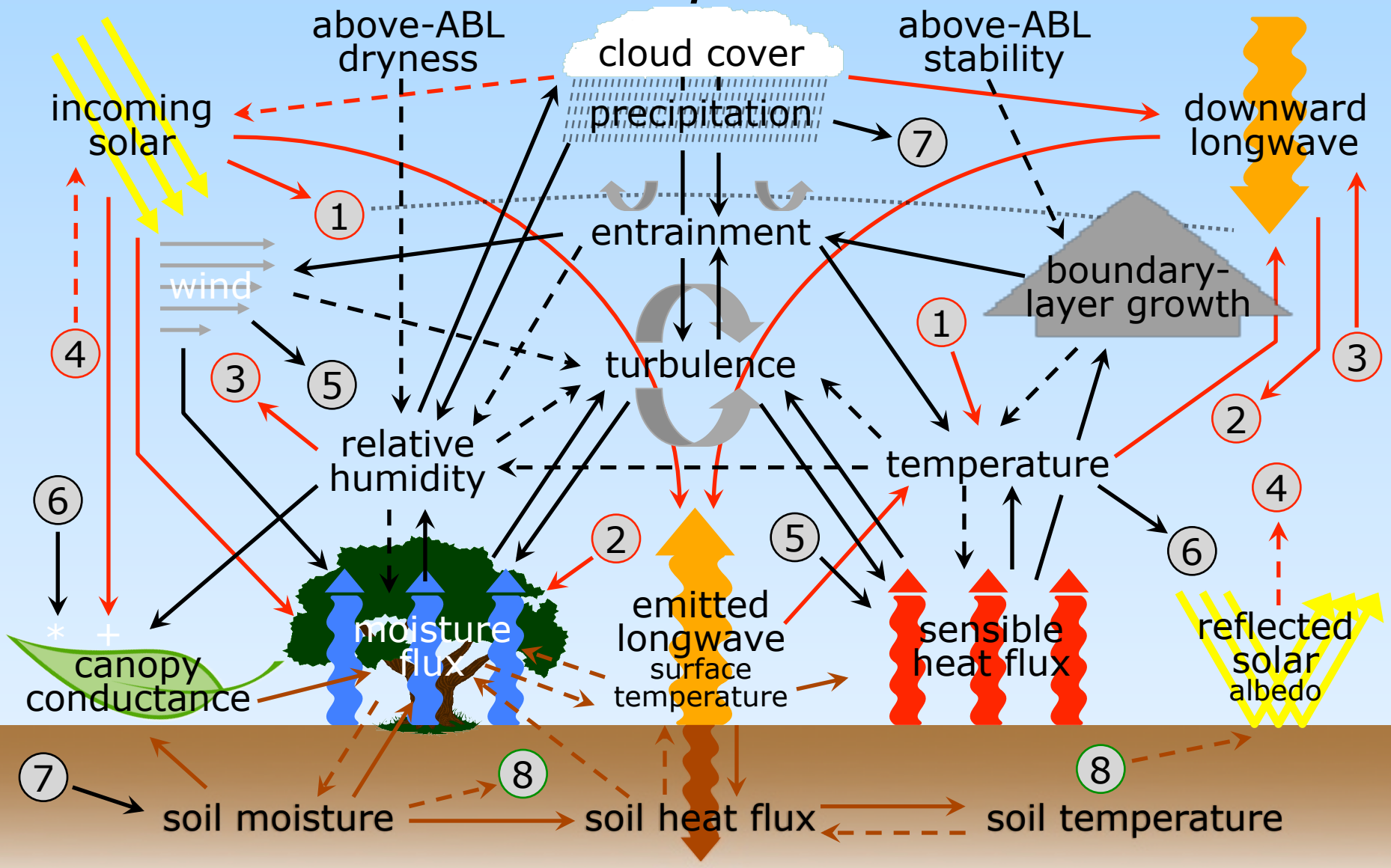
- ***Hydrology***: soil moisture & ground water/water tables, irrigation and groundwater extraction, water quality, streamflow and river discharge to oceans, drought/flood, lakes/reservoirs.
- ***Biogeochemical cycles***: application to ecosystems, both terrestrial & marine, dynamic vegetation and biomass, carbon budgets, etc, including ***Air Quality***: interaction with boundary-layer, biogenic emissions, VOC, dust/aerosols, etc.

Rely on remote sensing & land data assimilation systems.

More constraints/less degrees of freedom, i.e. must simultaneously close energy & water budgets, BGC cycles, etc.

We need to get the right answers for the right reasons!

Local Land-Atmosphere Interactions



radiation **surface layer & ABL** **land-surface processes**

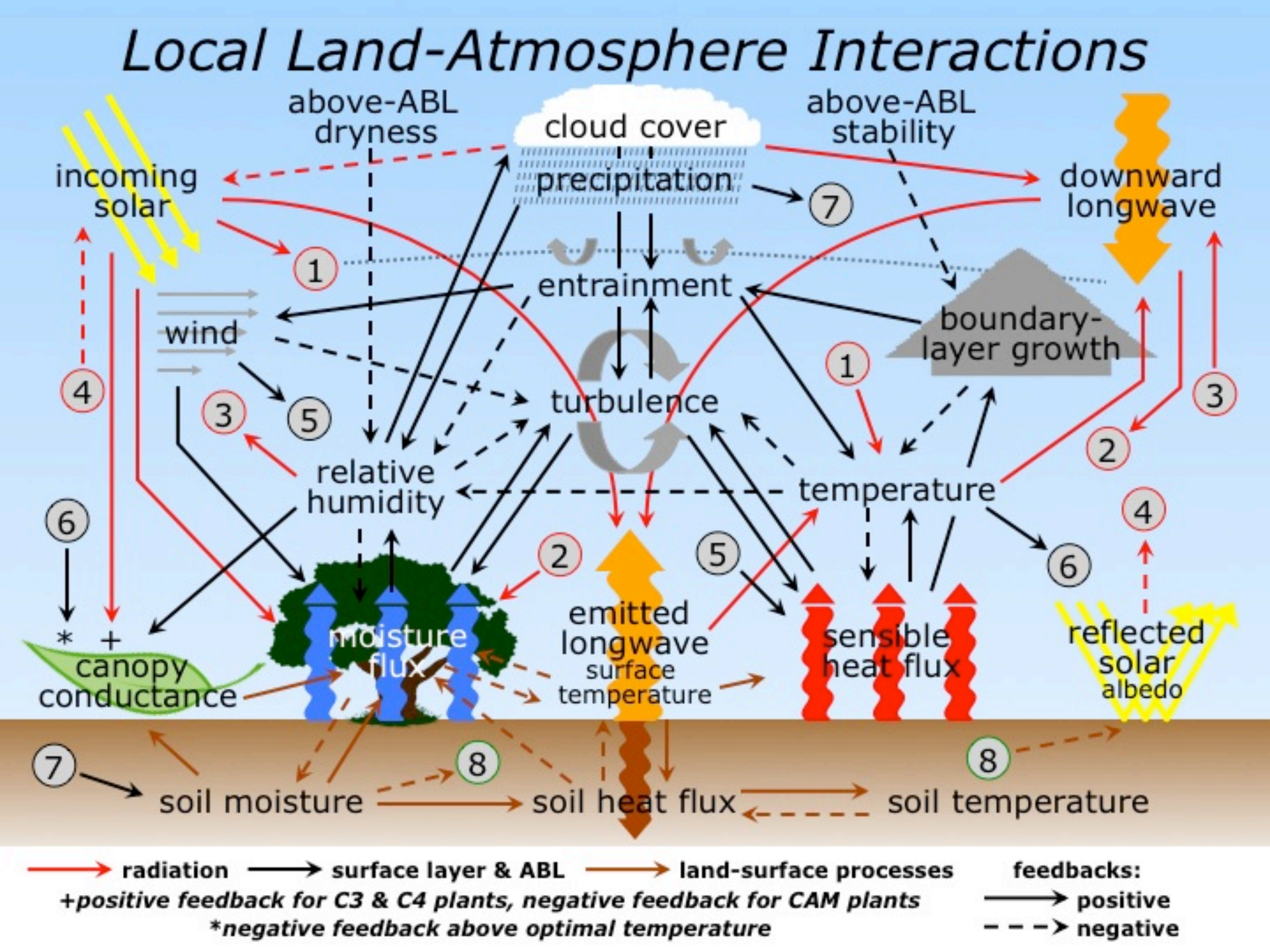
+positive feedback for C3 & C4 plants, negative feedback for CAM plants

****negative feedback above optimal temperature***

feedbacks:

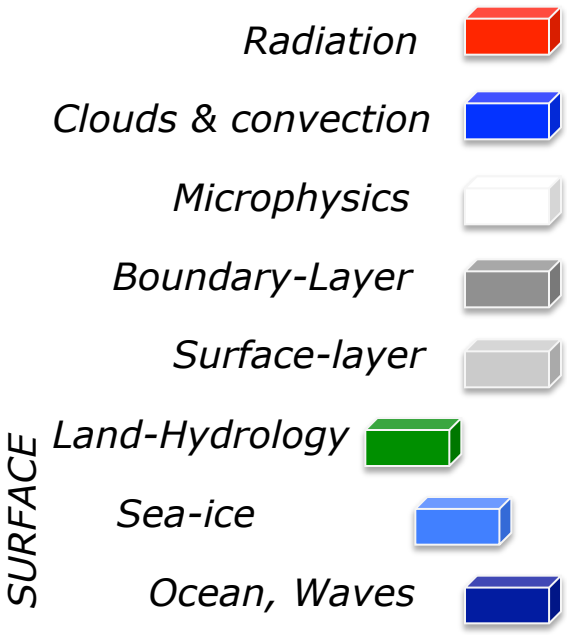
positive

negative


Local Land-Atmosphere Interactions
above-ABL dryness
cloud cover
above-ABL stability
incoming solar
precipitation
downward longwave
entrainment
wind
boundary-layer growth
turbulence
relative humidity
temperature
moisture flux
emitted longwave
surface temperature
sensible heat flux
reflected solar
albedo
canopy conductance
soil moisture
soil heat flux
soil temperature
radiation
surface layer & ABL
land-surface processes
+positive feedback for C3 & C4 plants, negative feedback for CAM plants
*negative feedback above optimal temperature
feedbacks:
positive
negative

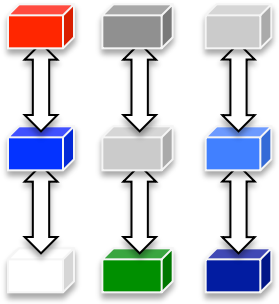
Hierarchy of Model Parameterization Development Simple-to-More Complex

Simulators

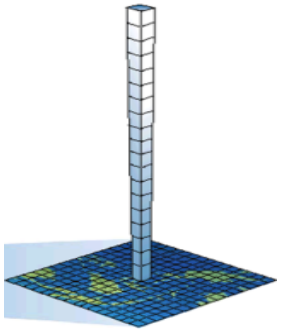


- Simulators: test submodel parameterizations at **process level**, e.g. radiation-only, land-only, ...
- Testbed data sets to develop, drive & validate submodels: observations, models, idealized, *with "benchmarks" before adopting changes*.
- Submodel interactions, *with benchmarks*.
- Full columns, *with benchmarks*.
- Limited-area/3-D (convection) *with benchmarks*.
- Regional & global NWP & seasonal climate, *with benchmarks.*
- **More efficient** model development, community engagement, R2O/O2R & computer usage.

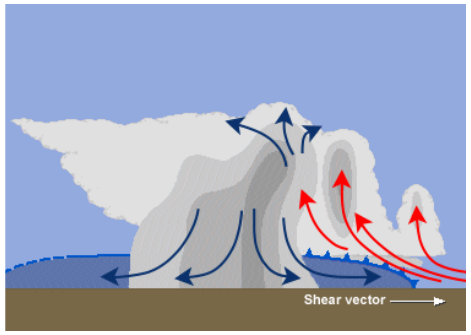
Interaction tests



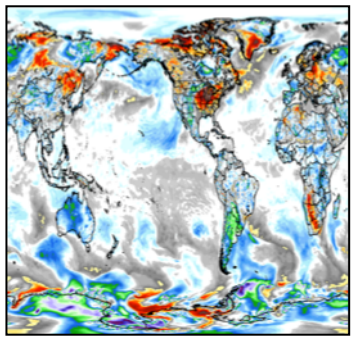
Column tests



Limited-area



Regional & Global



e.g. WCRP/GEWEX activities!

GEWEX Global Land/Atmosphere System Study (GLASS)