Physics Suites, Testing and Diagnostic Tools for Assessing Interactions

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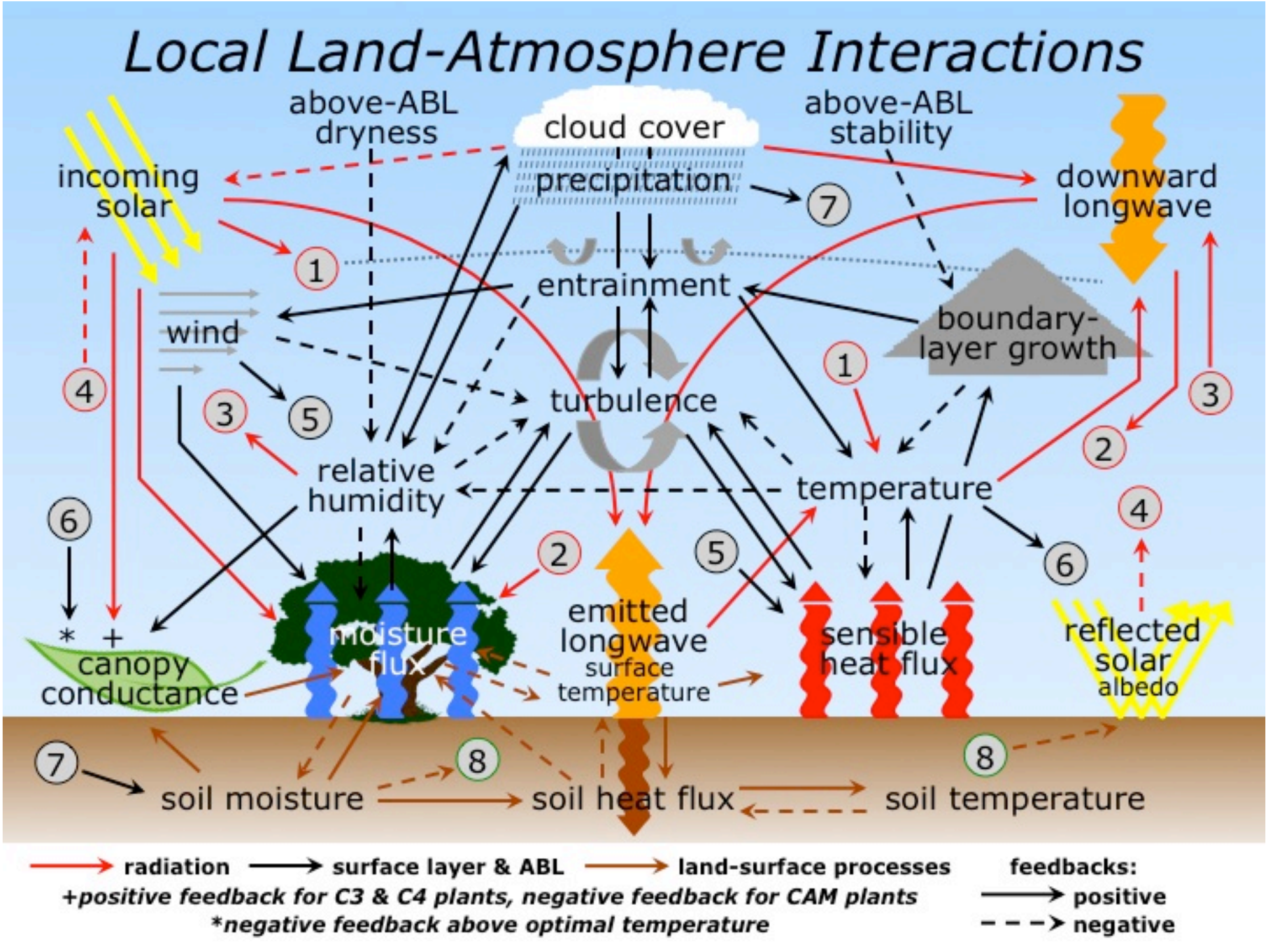
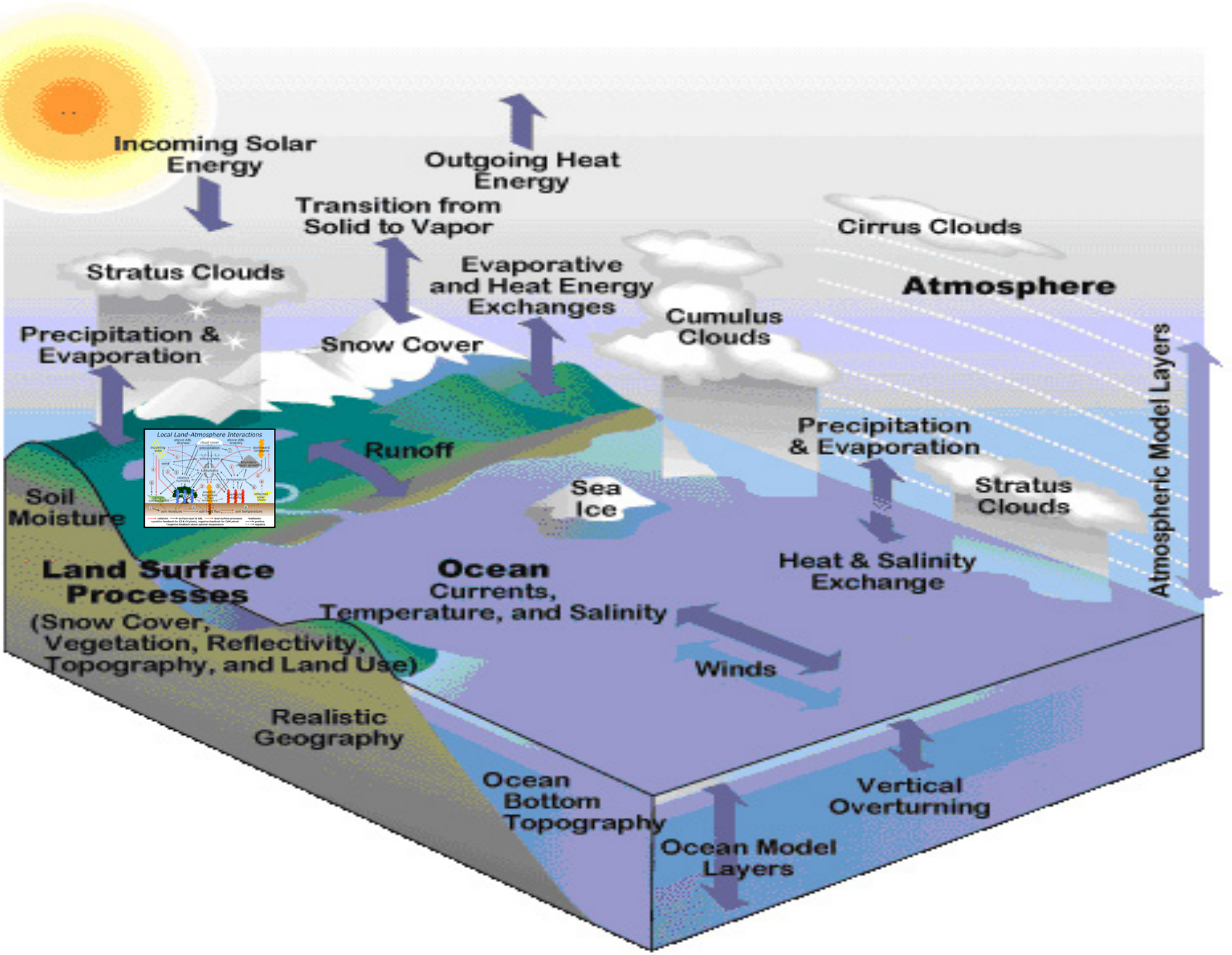
NGGPS Atmospheric Physics Workshop
NCWCP, College Park, Maryland
8-9 November 2016


Local Land-Atmosphere Interactions
above-ABL dryness
cloud cover
precipitation
above-ABL stability
incoming solar
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
feedbacks:
positive
negative
+positive feedback for C3 & C4 plants, negative feedback for CAM plants
*negative feedback above optimal temperature


Incoming Solar Energy
Outgoing Heat Energy
Transition from Solid to Vapor
Cirrus Clouds
Stratus Clouds
Evaporative and Heat Energy Exchanges
Atmosphere
Cumulus Clouds
Precipitation & Evaporation
Snow Cover
Atmospheric Model Layers
Local Land-Atmosphere Interactions
Runoff
Precipitation & Evaporation
Stratus Clouds
Soil Moisture
Sea Ice
Land Surface Processes
(Snow Cover, Vegetation, Reflectivity, Topography, and Land Use)
Ocean
Currents, Temperature, and Salinity
Heat & Salinity Exchange
Winds
Realistic Geography
Ocean Bottom Topography
Vertical Overturning
Ocean Model Layers

Complexity of Land-Atmosphere Interactions

GEWEX* Imperatives:
GEWEX Plans for 2013 and Beyond:
Diagnostics of stand-alone model components are more straight-forward, but there has been difficulty to establish metrics for coupled systems (e.g., land-atmosphere) to quantify strength of the interactions.
**GEWEX is a core pro-gram under WMO/WCRP.*

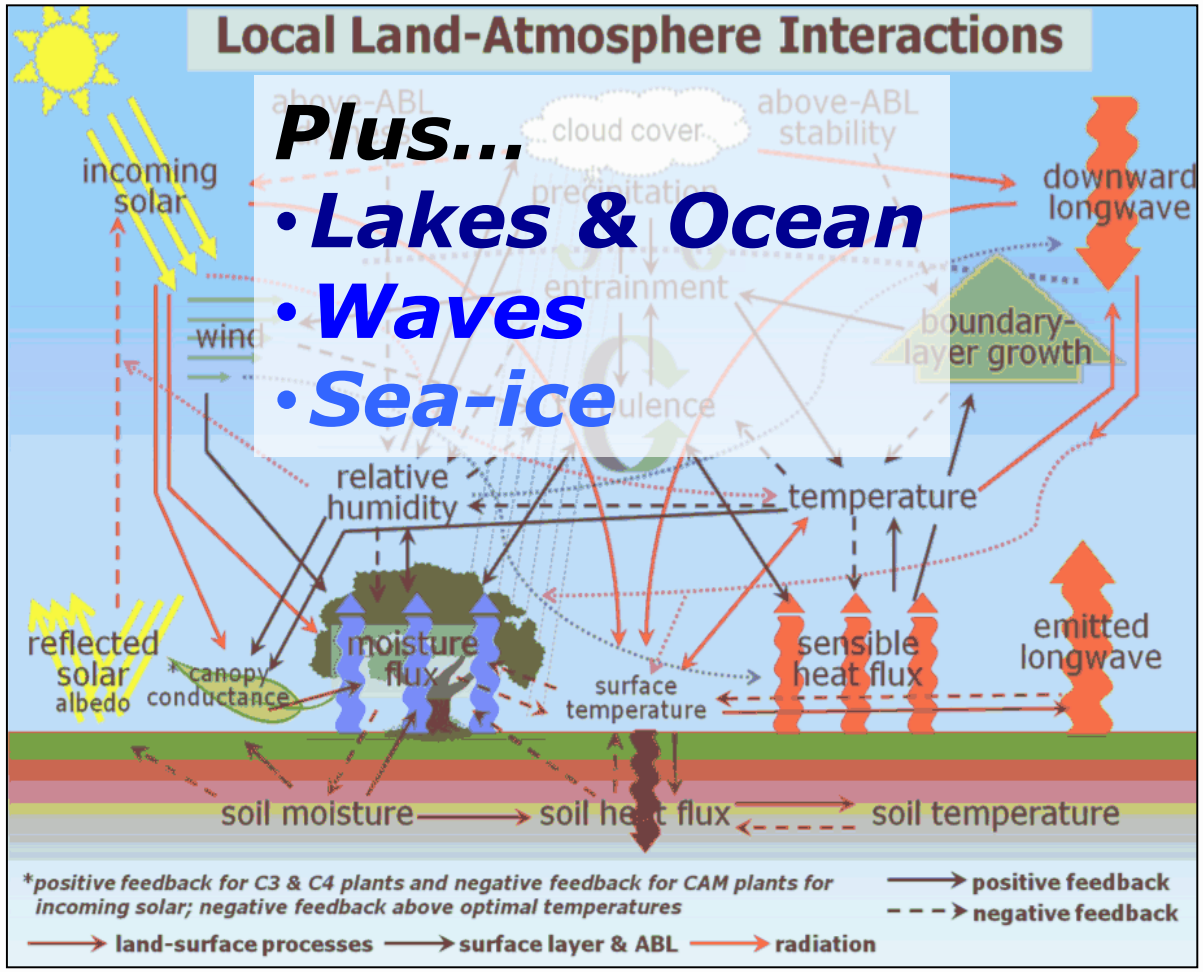
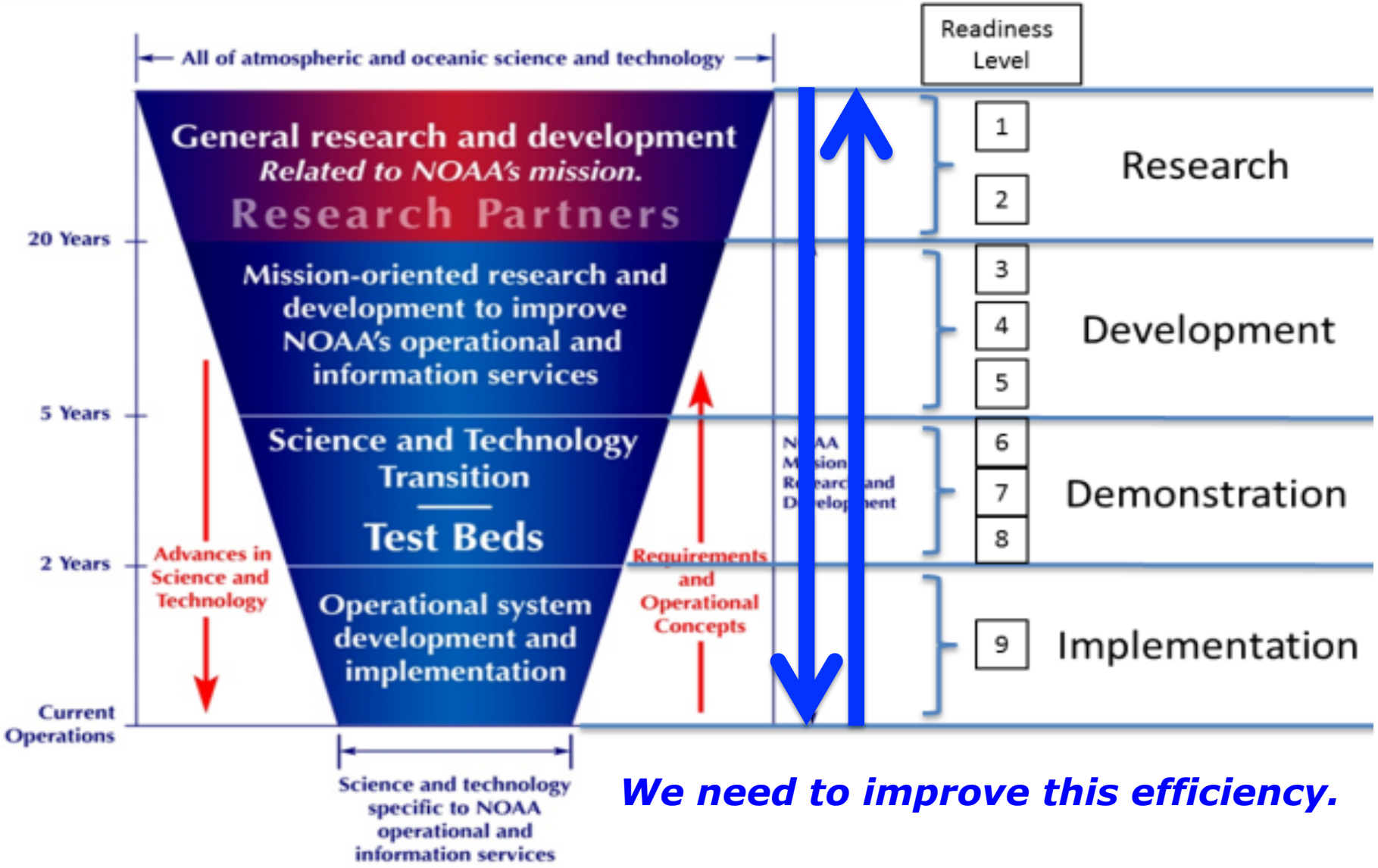


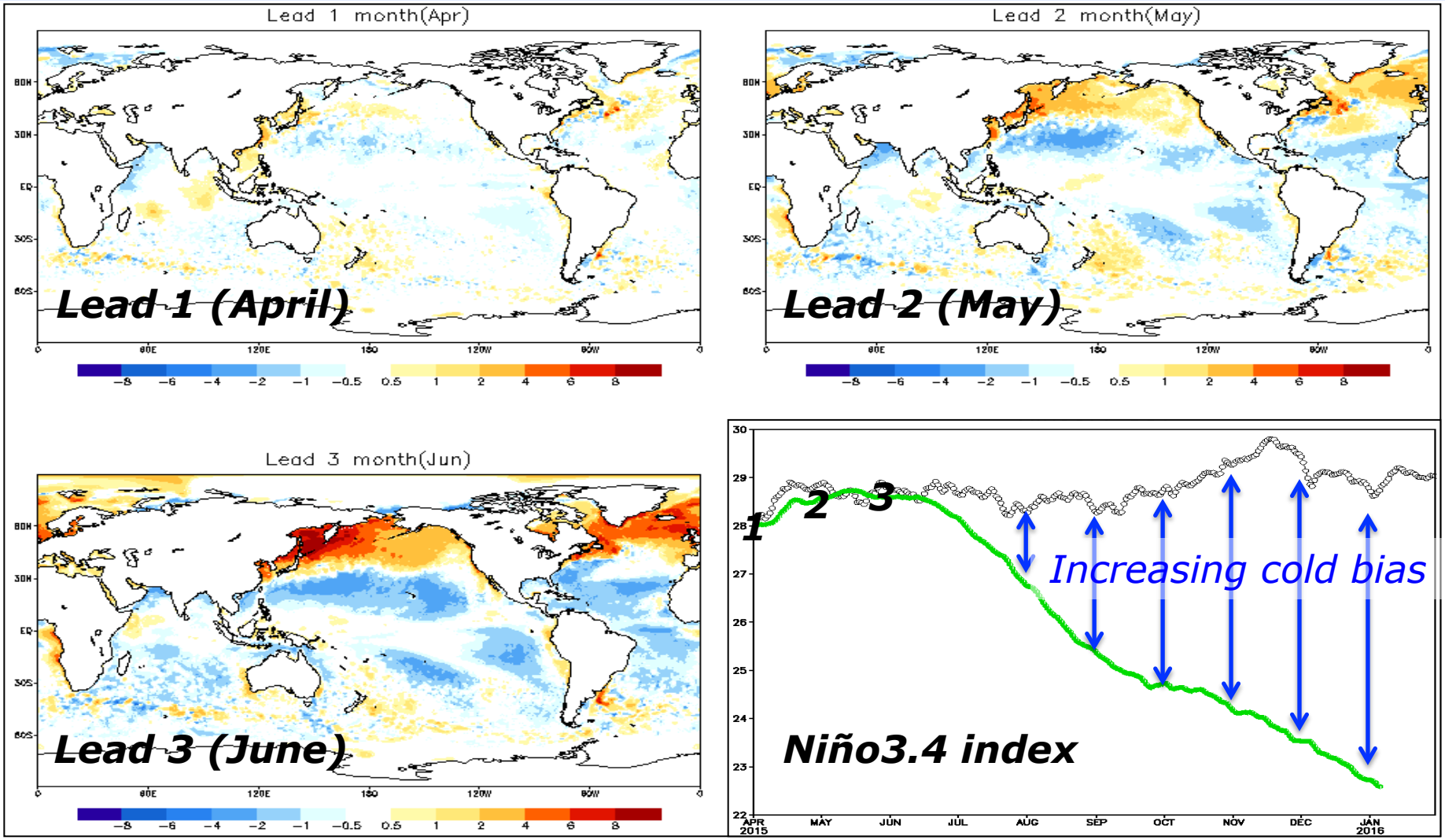
Fig. 3.1. Schematic of the complex interactions between the land surface, atmospheric boundary layer (ABL), and radiation via many variables (temperature, relative humidity, wind and associated turbulence, cloud cover, etc). Adapted from Ek and Holtslag (2004 J. Hydromet., 5, 86-99), courtesy Mike Ek & Kevin Trenberth.

Research-to-Operations



We need to improve this efficiency.

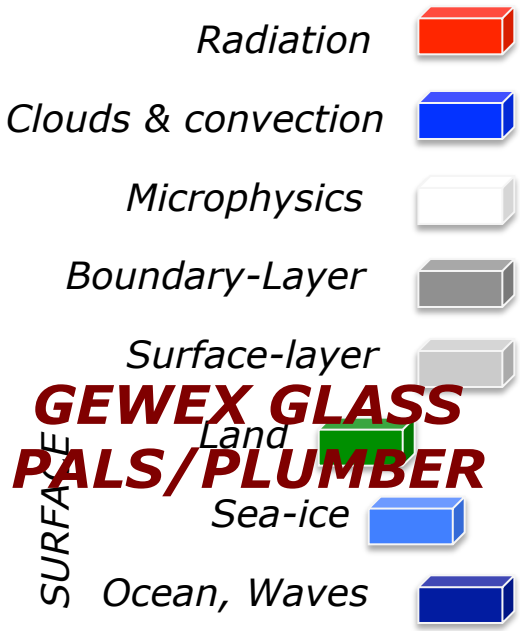
Example: Evolution of SST cold bias in UGCS



- *Bias: Monthly avg SST against obs; leads 1,2,3; Niño3.4 index.*
- *Clouds? Radiation? Other? How to address correcting this bias?*

Hierarchy of Model Physics Parameterization Development Individual Component "Simulators" to Fully-Coupled Global

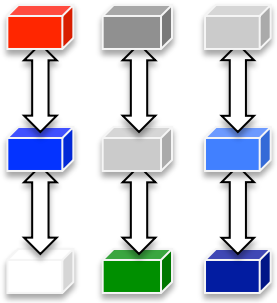
Simulators



GEWEX GLASS PALS/PLUMBER

- Simulators: test submodel parameterizations at process level, e.g. radiation-only, land-only, etc.
- 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 research-to-operations, community engagement, computational usage.

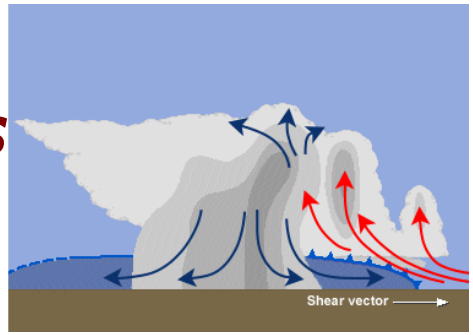
Interaction tests



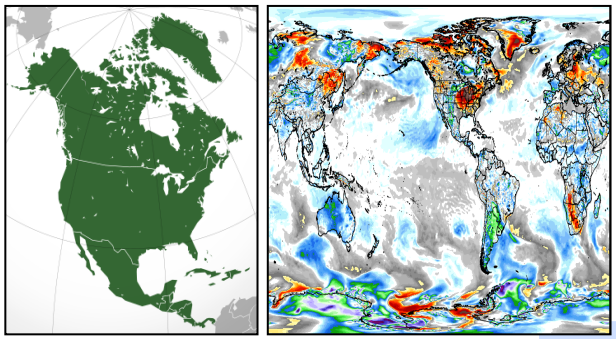
Column tests

GEWEX GLASS-GASS DICE

Limited-area

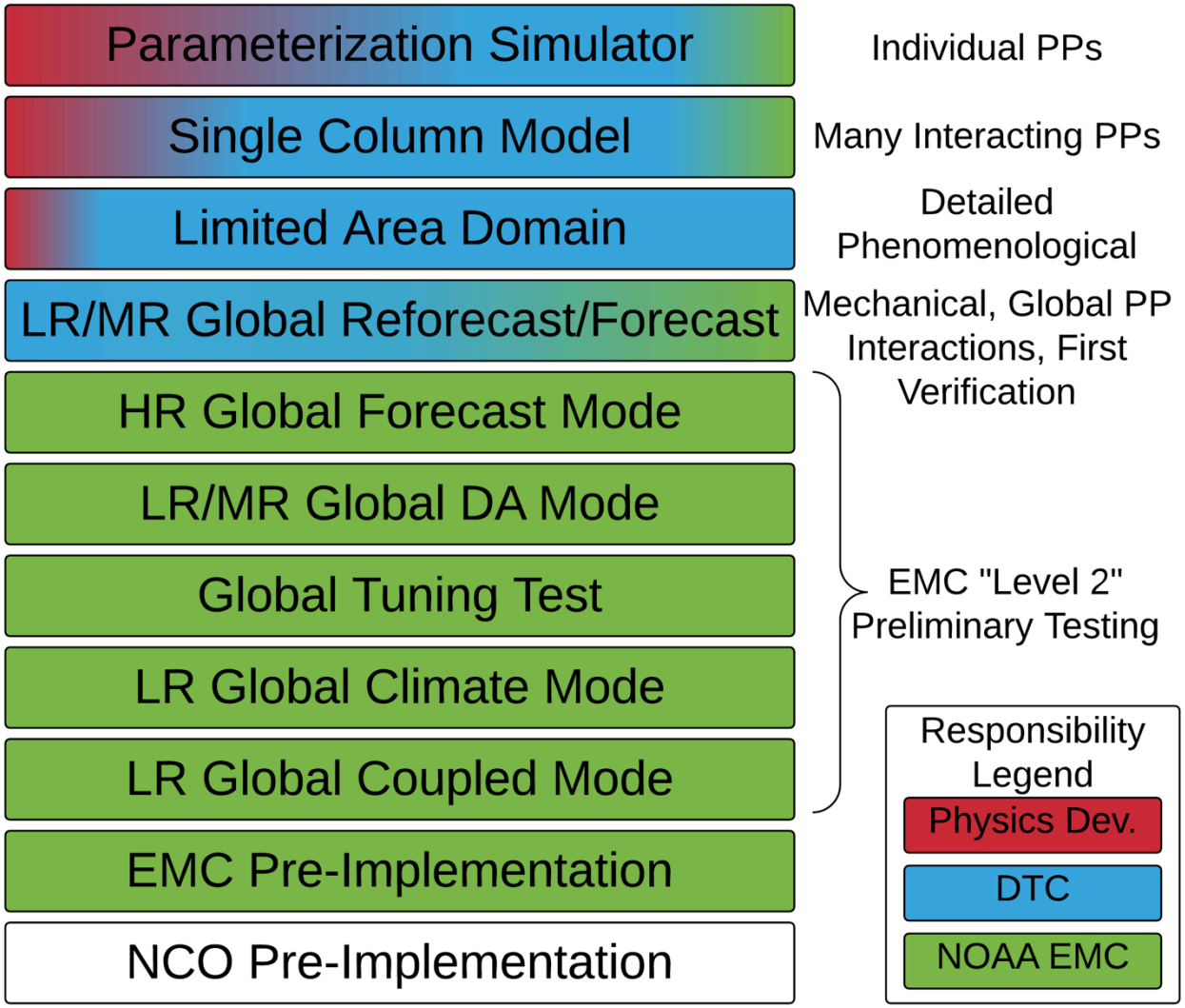


Regional & Global



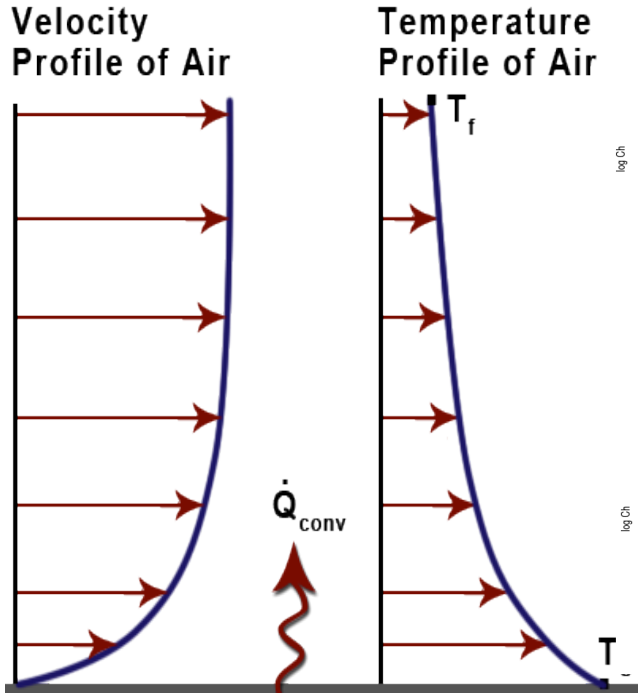
Leverage NGGPS, CPO, plus e.g. WMO WWRP & WCRP, other projects/programs

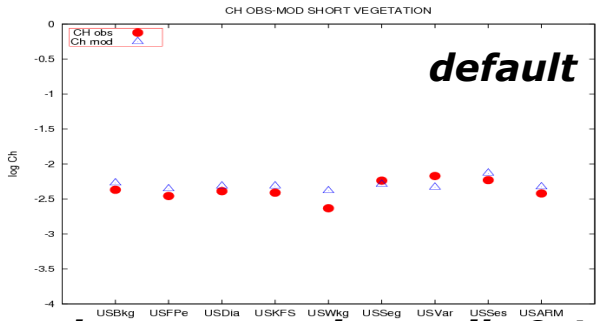
GMTB/EMC Testing Hierarchy



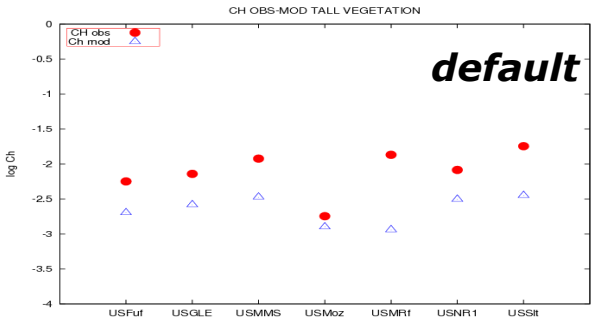
Surface-layer Physics: Simulator

- ***GOAL***: Improve surface turbulence exchange coefficients.
- Surface-layer simulation ("SLS") code simulates surface-layer and schemes from meso-NAM and medium-range GFS.
- Use observations to drive SLS (U,T,q and Tsfc) and compare with inferred Ch, Cd from independent "fluxnet" obs (H, LE, τ).
- Bias in surface heat exchange coefficient depends on canopy height. ***Action: adjust thermal roughness parameter.***

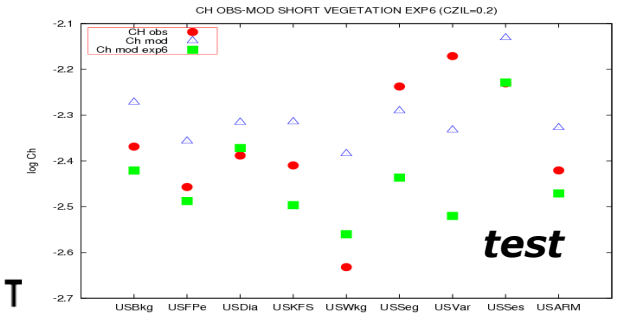




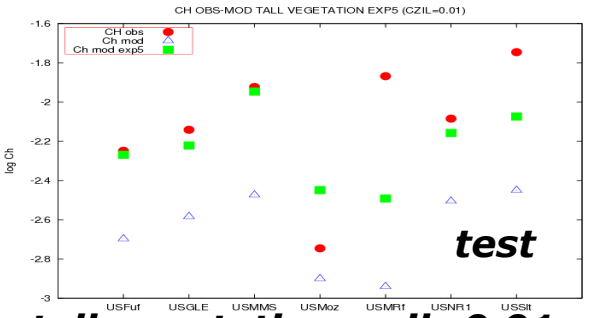
short vegetation, czil=0.1



tall vegetation, czil=0.1



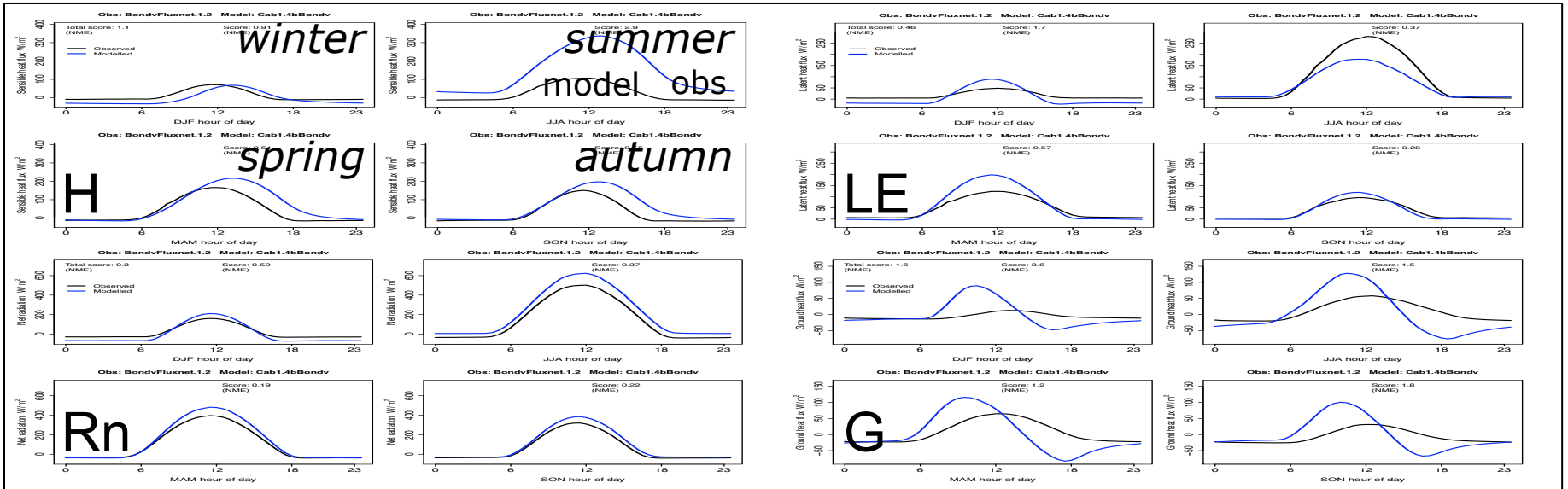
short vegetation, czil=0.2



tall vegetation, czil=0.01

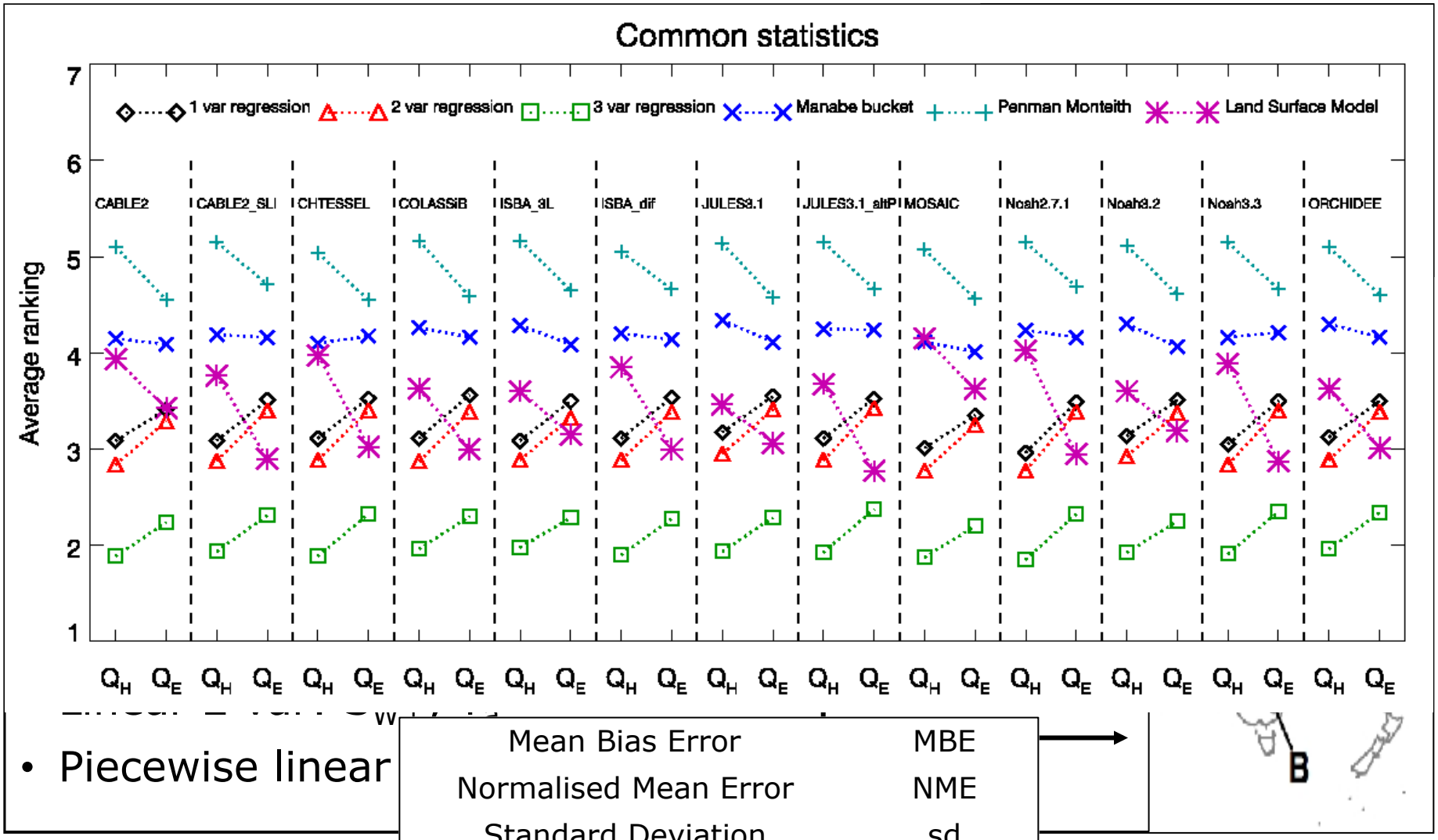
Land Model: Benchmarking

- Benchmarking: Decide how good model needs to be, then run model and ask: *Does model reach the level required?*
- ***P**rotocol for the **A**nalysis of **L**and **S**urface models (**PALS**)*: www.pals.unsw.edu.au. *Global Energy and Water Exchanges (GEWEX) / Global Land/Atmosphere System Study (GLASS).*
- Compare models with empirical/statistical approaches, previous model versions, other land models. Different plots/tables of model validation and benchmarking metrics.
- ***Identify** systematic **biases** for model development/validation.*



PALS example: CABLE (BOM/Aust.) land model, Bondville, IL, USA (cropland), 1997-2006, avg diurnal cycles.

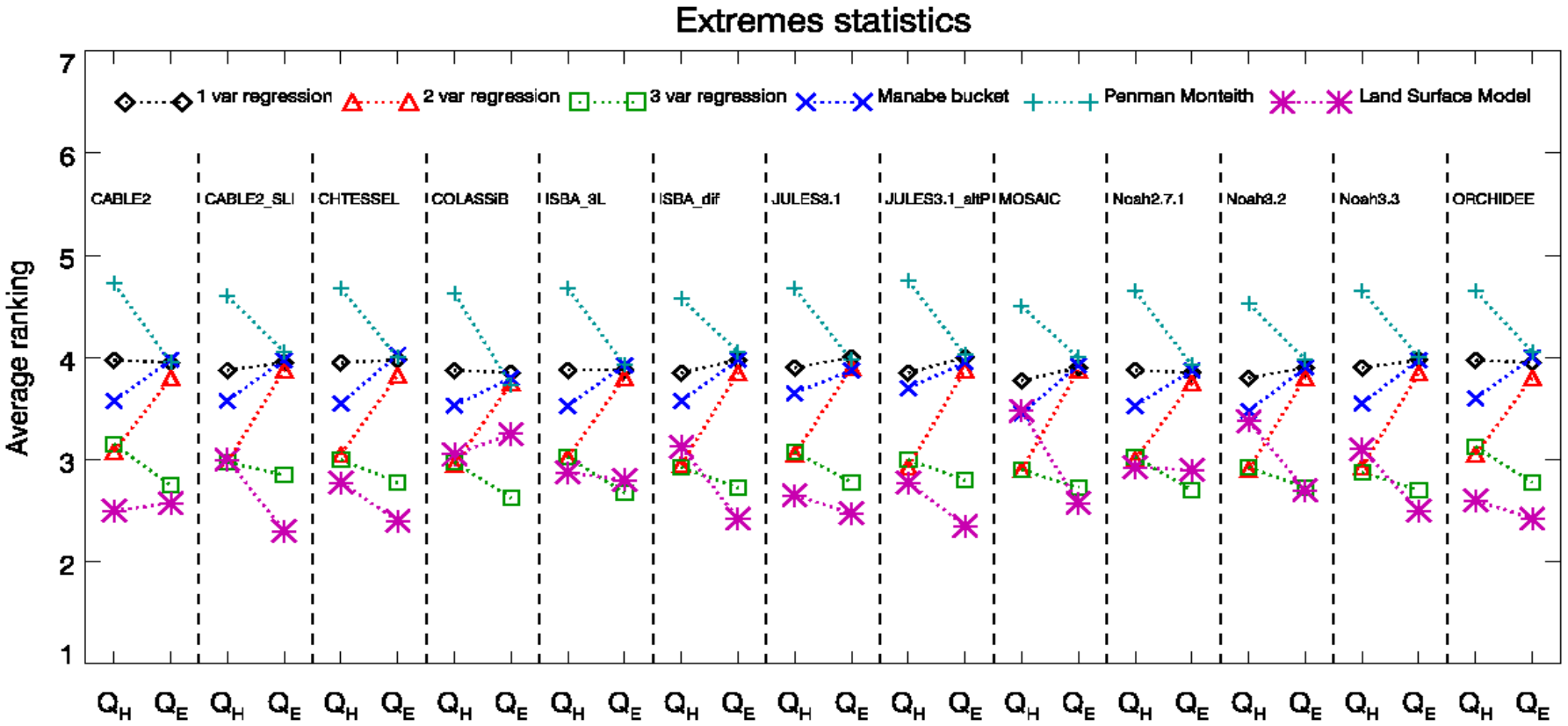
Benchmarking Against Common Statistics

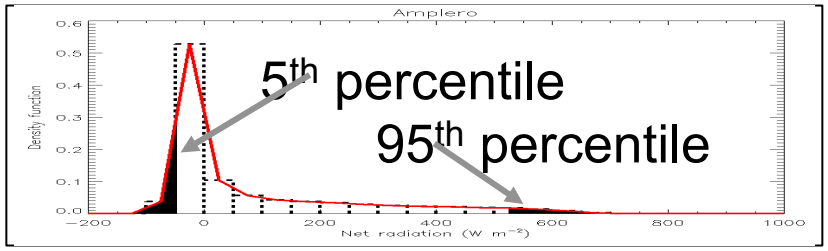


- Piecewise linear

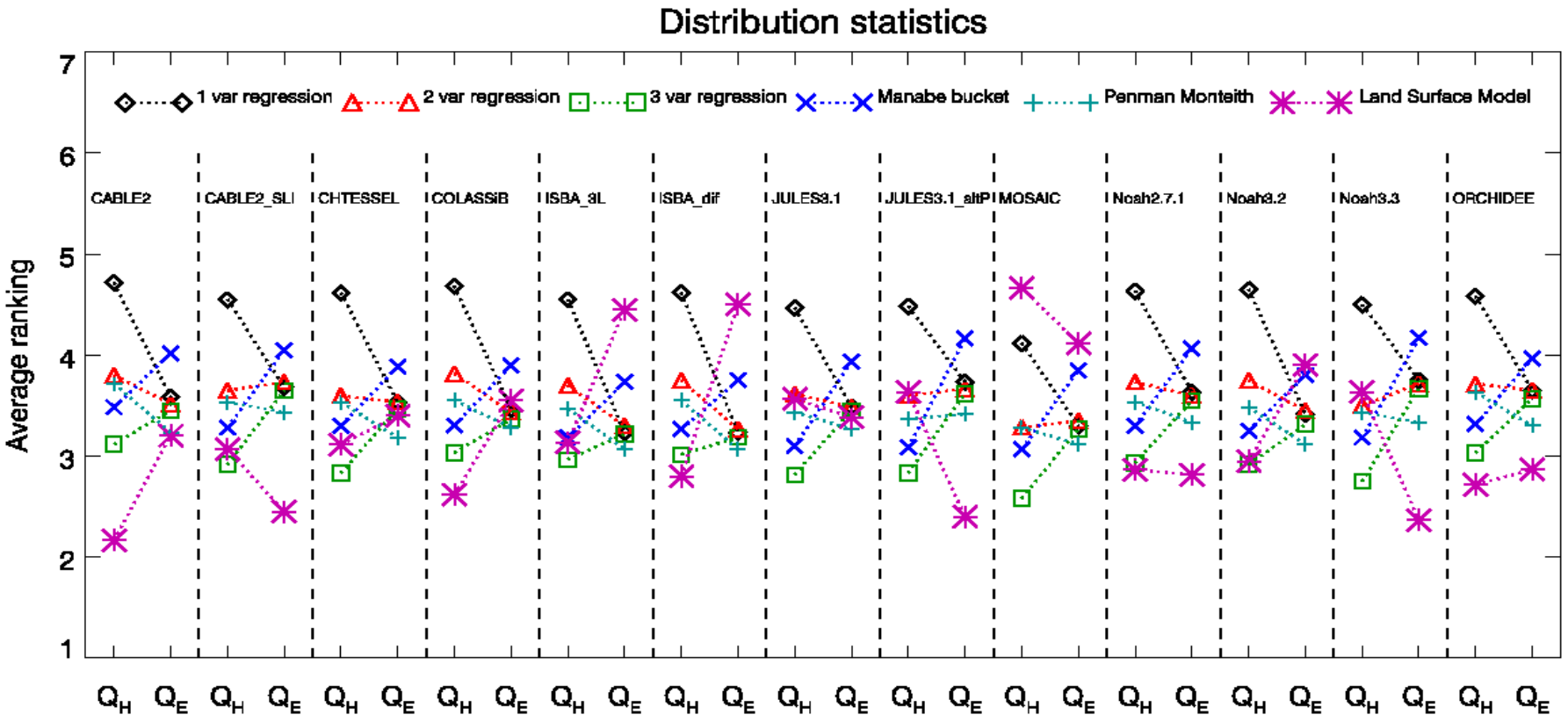
Mean Bias Error	MBE
Normalised Mean Error	NME
Standard Deviation	sd
Correlation coefficient	r

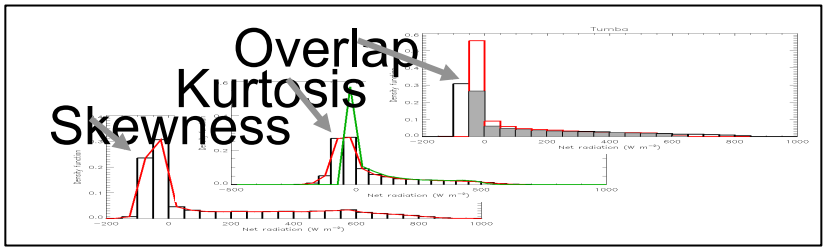
Benchmarking Against Common Extremes





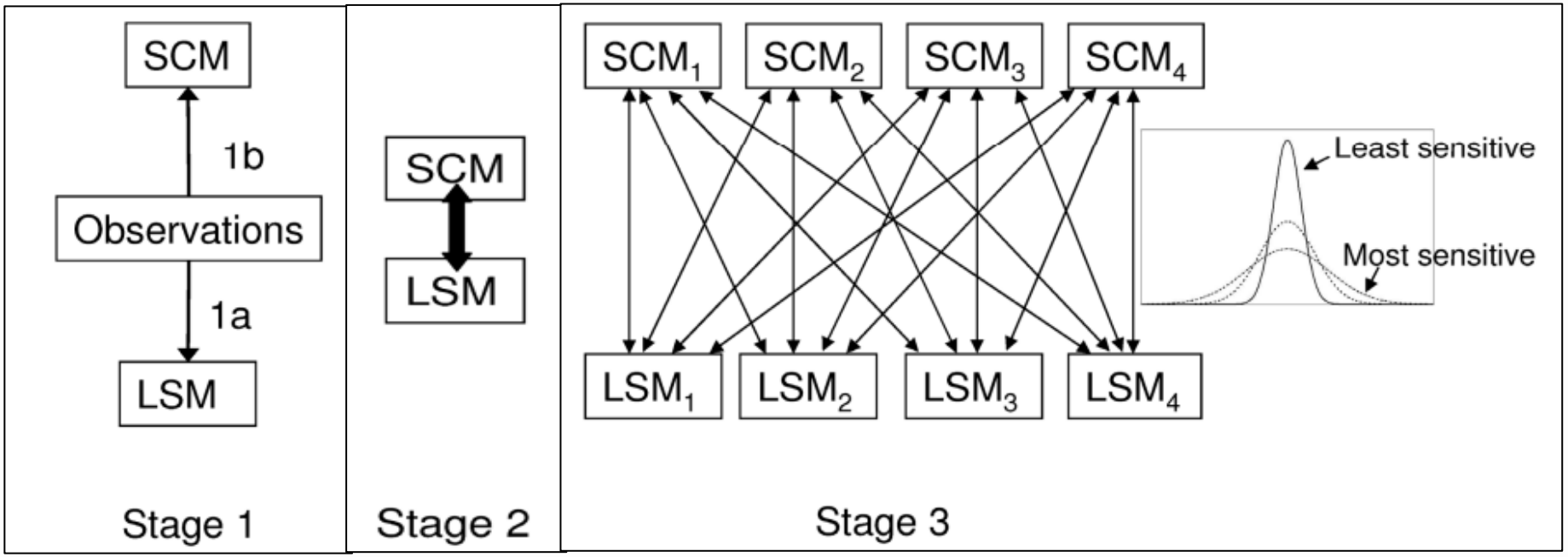
Benchmarking Against Distribution Statistics





Diurnal land/atmosphere coupling experiment (DICE)

- Joint activity between GEWEX Global Land/Atmosphere System Study (GLASS) and Global Atmosphere System Studies (GASS).
- Examine interactions between surface and atmospheric boundary layer.
- Use Land-Surface Models (LSMs) and Single Column Models (SCMs).
- Follow-on to GABLS-2 (GEWEX Atmospheric Boundary Layer Study, phase 2), where land-atmosphere coupling was identified as important.



LSM and SCM stand-alone performance against obs.

What is impact of coupling?

How sensitive are different LSMs and SCMs to variations in forcing?

DICE-1: CASES-99

Project started April 2013 *to study the interactions between the land-surface & atmospheric boundary layer*.

- Leads: Adrian Lock, Martin Best (UKMO).
- 12 models participating.

Workshops:

- 1st: 14-16 Oct 2013, UK Met Office.
- 2nd: 14-18 Jul 2014, GEWEX conf./Neth.
- 3rd: 20-22 May 2015, Météo-France.

Manuscript in preparation (for JHM).

- 9-year spin-up for LSMs.
- SCM: no relaxation of time-varying geostrophic wind (uniform with height); subsidence of T,q; horizontal advection of T,q,wind; radiation switched on in all simulations.
- 12 pages and 80 figures of results for stages 1, 2, 3!

CASES-99 Experiment (Southern Great Plains, USA)

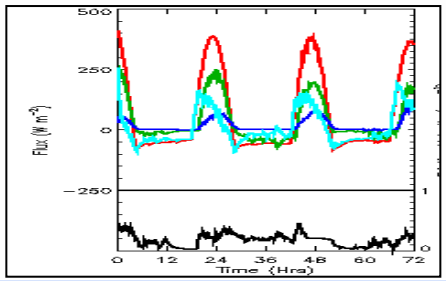
GLASS

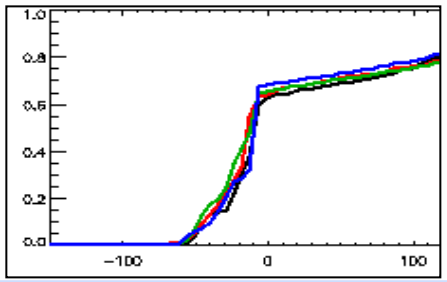
GASS GEWEX WCRP Global Atmospheric System Studies

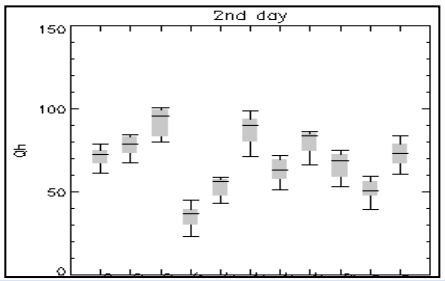
http://appconv.metoffice.com/dice/dice.html

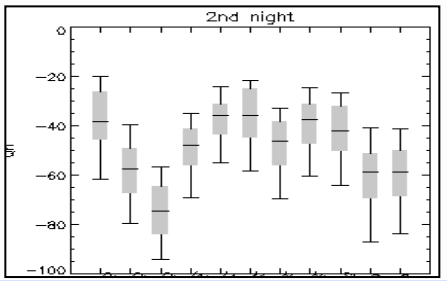
DICE-1: CASES-99

- SCM: no relaxation of time-varying geostrophic wind (uniform with height); subsidence of T, q; horizontal advection of T, q ,wind; radiation switched on in all simulations.
- Stage 1a (LSM-only): LHF generally far too large (LSMs didn't account for dead grass, adversely affecting bowen ratio); SHF and stress too large at night; 55m forcing too high for LSMs (vs 10m) especially for stable nighttime conditions.
- Stage 1b (SCM-only): Difficulty with wind profiles, particularly 1st night (intermittent turbulence); large differences in daytime parameterized entrainment; potential inaccuracy of (prescribed) large-scale forcing; SCM generally can be forced by observed fluxes and stresses.
- Stage 2 (LSM+SCM): excessive drag from LSMs generate deeper/less stratified SBLs; soil-surface coupling sensitivity at night; daytime PBL differences dominated by LSM surface fluxes, with RH dominated by SHF; more spread in PBL moisture; daytime PBL temperature…



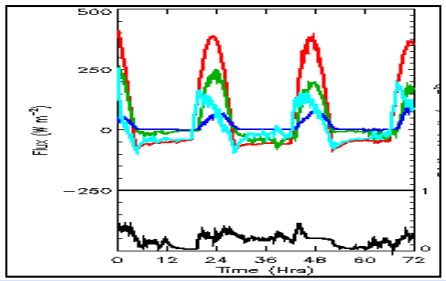


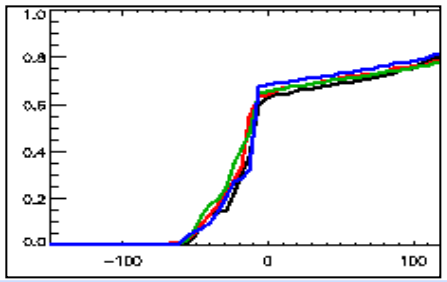


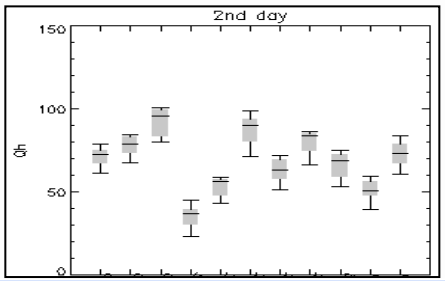


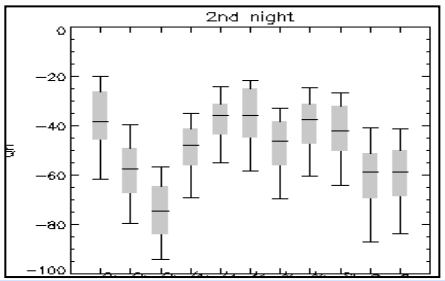
DICE-1: CASES-99 (page 2)

- …evolution depends on surface fluxes; PBL moisture more complicated.
- Stage 3a (LSM ensemble spread due to PBL variability forcing): largest variation in SHF during day & at night for more continuous turbulence.
- Stage 3b (PBL ensemble spread due to LSM variability forcing): day-time PBL: T, q dominated by sfc fluxes with variability between different SCMs similar, but sensitivity of inversion height very different.
- ***Summary***: *surface **momentum** flux and momentum profiles should be examined further by DICE community; large errors in **evaporation** (surface energy partition) may dominate signal and impact of coupling; further examine **nocturnal fluxes**, and **boundary layer & soil-surface coupling** sensitivities; differences in different models' (LSM +SCM) sensitivity to changes in forcing likely important in GCMs, and needs to be better understood.*
- ***Repeat for many other sites (DICEs), e.g. GABLS project for Antarctica: GABLS4 or "DICE-over-ICE" (next page), others.***









"DICE-over-ice" (GABLS4)

Project started in 2015 *to study the interactions between the ice/snow-surface & atmospheric boundary layer under conditions of strong stability*.

- Follow-on to earlier GABLS studies with focus on very stable conditions, and a surface with low conductivity and high cooling potential over snow/glacial ice.
- Follows DICE experimental design.
- Leads: E. Bazile, F. Couvreux, P. Le Moigne (Météo-France).
- Several models/centers participating.

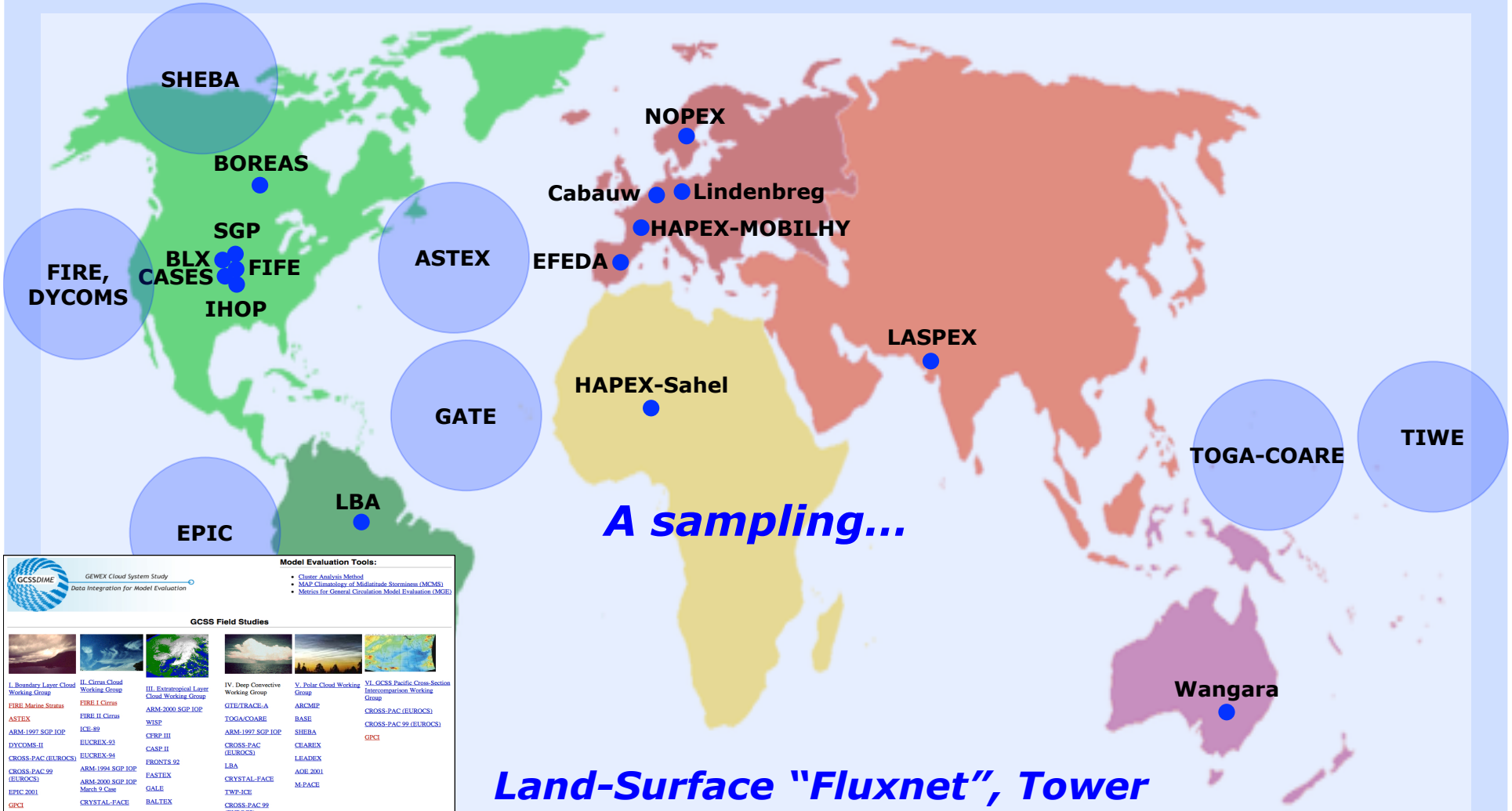
Dome C - Antarctica

Workshop:

- **Initial results presented at GABLS4-DICE Workshop, 20-22 May 2015, Météo-France.**
- ***Findings so far****: further examine:* ***momentum*** *flux & profiles,* ***nocturnal fluxes***, ***intermittent*** *turbulence,* ***ice/snow-surface coupling*** *sensitivities.*

http://www.cnrm.meteo.fr/aladin/meshtml/GABLS4/GABLS4.html

Field Programs for Model Physics Development
Focus: Land/Ocean/Ice Surface-Atmosphere



A sampling…

Land-Surface "Fluxnet", Tower data sets, Ship measurements, Radiosondes, Aircraft obs.

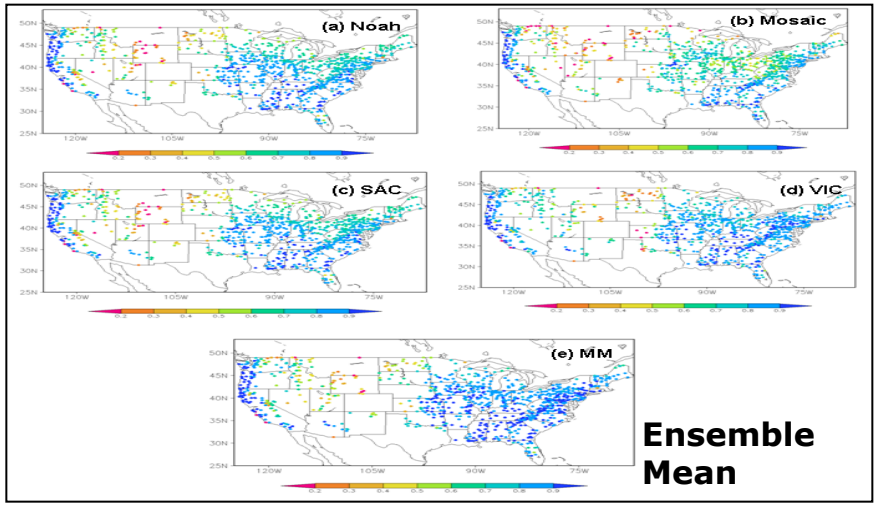
Uncoupled Land Model (2-D): North American Land Data Assimilation System

Comprehensive evaluation against *in situ* observations and/or remotely sensed data sets.

Energy flux validation from tower: net radiation, sensible, latent & ground heat fluxes.

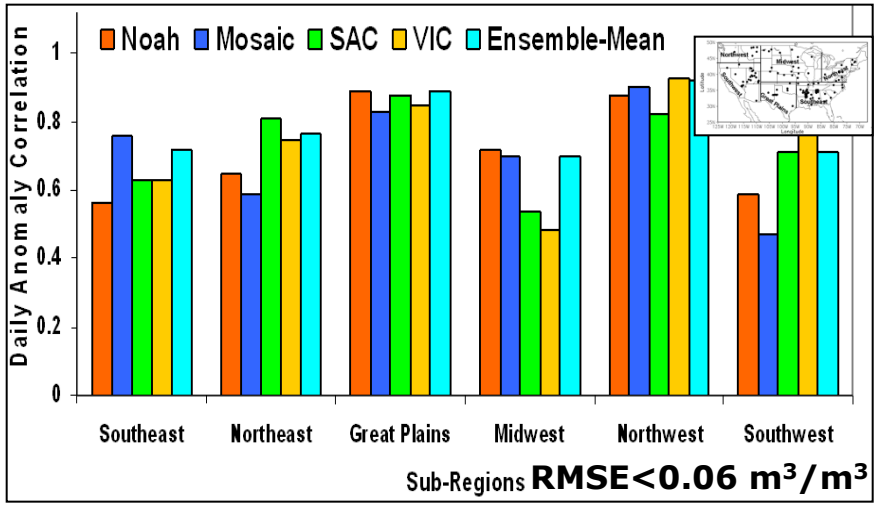
Water budget: snow, evaporation, total runoff/streamflow.

State variables: soil moist., soil/skin temp., snow depth/cover.



Xia et al., JGR-atmosphere (2012)

Monthly streamflow anomaly correlation (1979-2007 USGS measured streamflow)



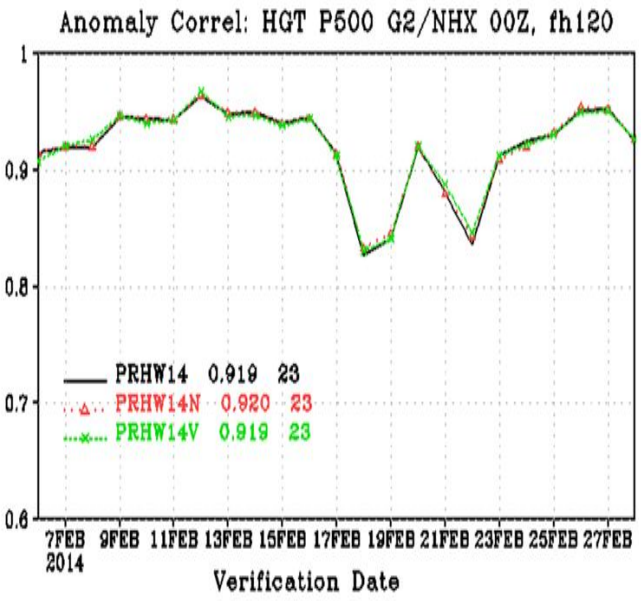
Xia et al., J. Hydrol. (2014)

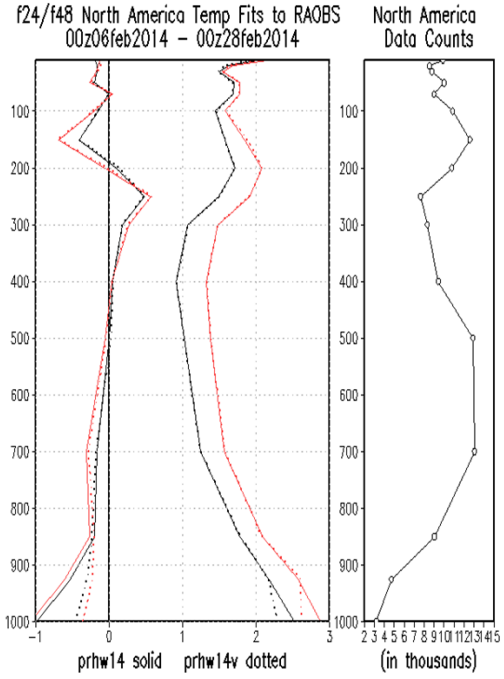
Daily top 1m soil moisture anomaly corr. (2002-2009 US SCAN Network)

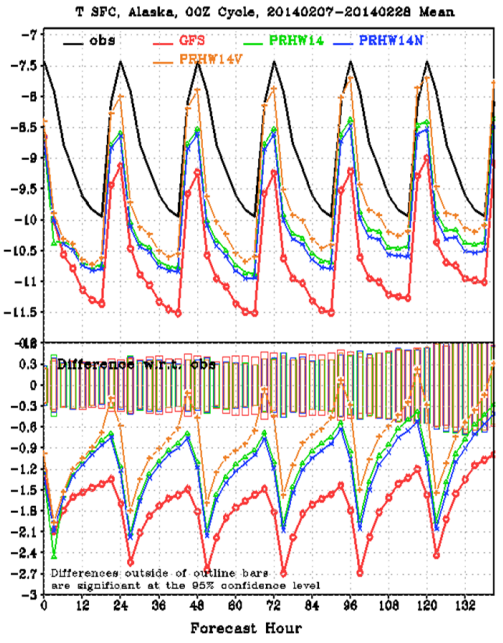
Youlong Xia (NCEP/EMC)

NCEP Global Forecast System (GFS)

- Forecast only
- Cycled (analysis cycle with data assimilation)
- Full parallel (multiple seasons)
- Metrics: *precip, 500mb AC, upper air, surface temp/wind, etc.*
- Examples:







Results from the new LSC dataset tests on the GFS

Helin Wei et al, NCEP/EMC

Model Physics Development Summary

- Data needs: Extensively "mine" routine & field program surface (land, ocean, ice) and boundary-layer data sets for different ecosystems/regions, diurnal cycles and seasons, including: land/soil states, surface fluxes, low-level meteorology, atmospheric measurements from towers, radiosondes, aircraft, other.
- Leverage support from research community, and from other projects & programs, nationally (e.g. NGGPS, CPO) & internationally (e.g. WMO) to *improve process-level understanding*.
- Make system efficient to use & comprehensive in terms of a hierarchy of component testing & their interactions, readily transferable to operations; including system "coupling" metrics.
- Weather and climate models are increasingly becoming more fully-coupled Earth-System Models (atmosphere-ocean-land-sea ice-waves-areosols) with **connections** between ***Weather & Climate*** and ***Hydrology***, ***Ecosystems*** **and** ***Biogeochemical*** cycles (e.g. carbon), and ***Chemistry/Air Quality.***

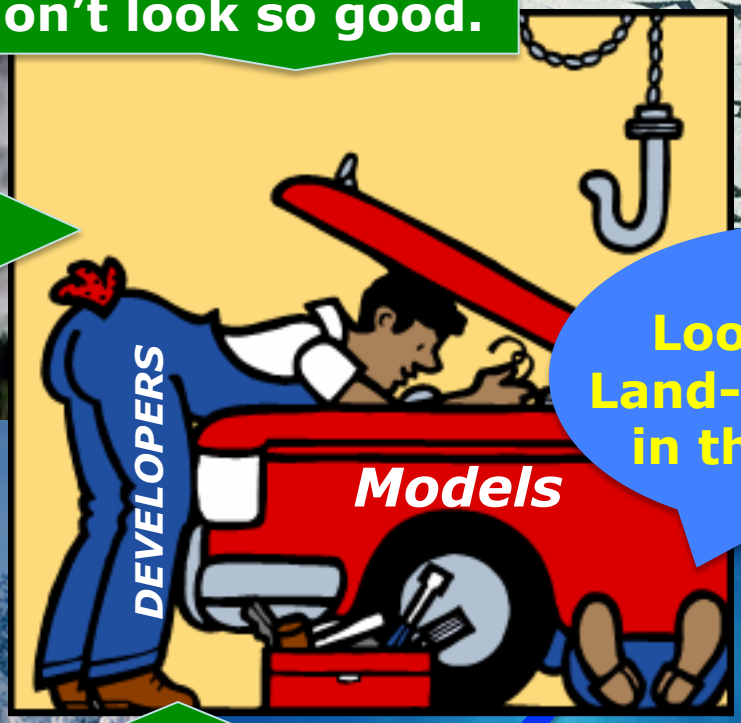
We need to get the right answers for the right reasons!

…but we have less degrees of freedom & more constraints.

Earth System Modeling

Uh oh! These surface fluxes don't look so good.

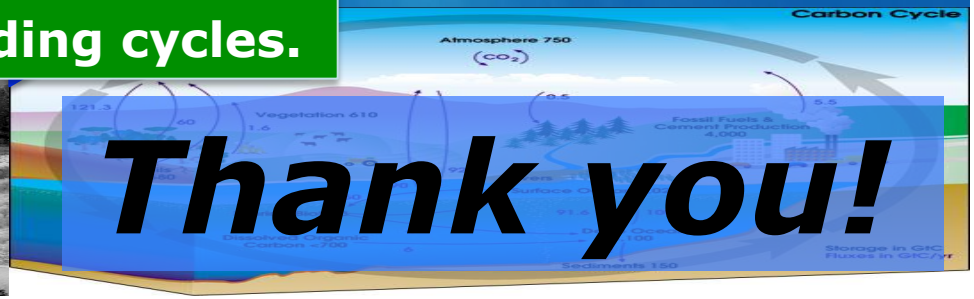
...and you're going to need an Atmosphere interaction alignment with Ocean and the other earth system compnents.



Ugh! Look at the Land-Hydrology in this thing!

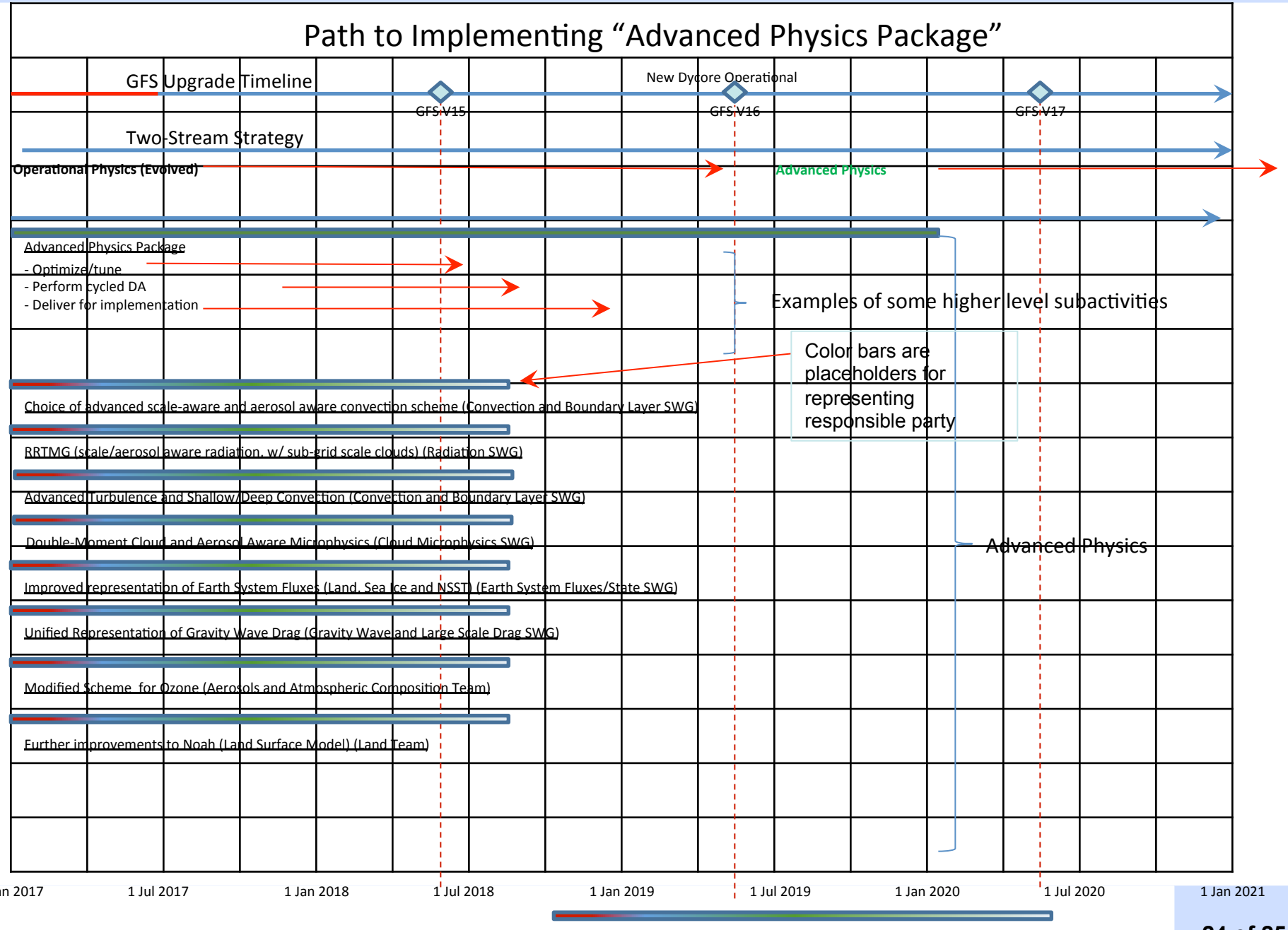
MODEL USERS: But how much will this cost to fix?!

Well... at least several more funding cycles.



Thank you!

NGGPS Physics Team Plan

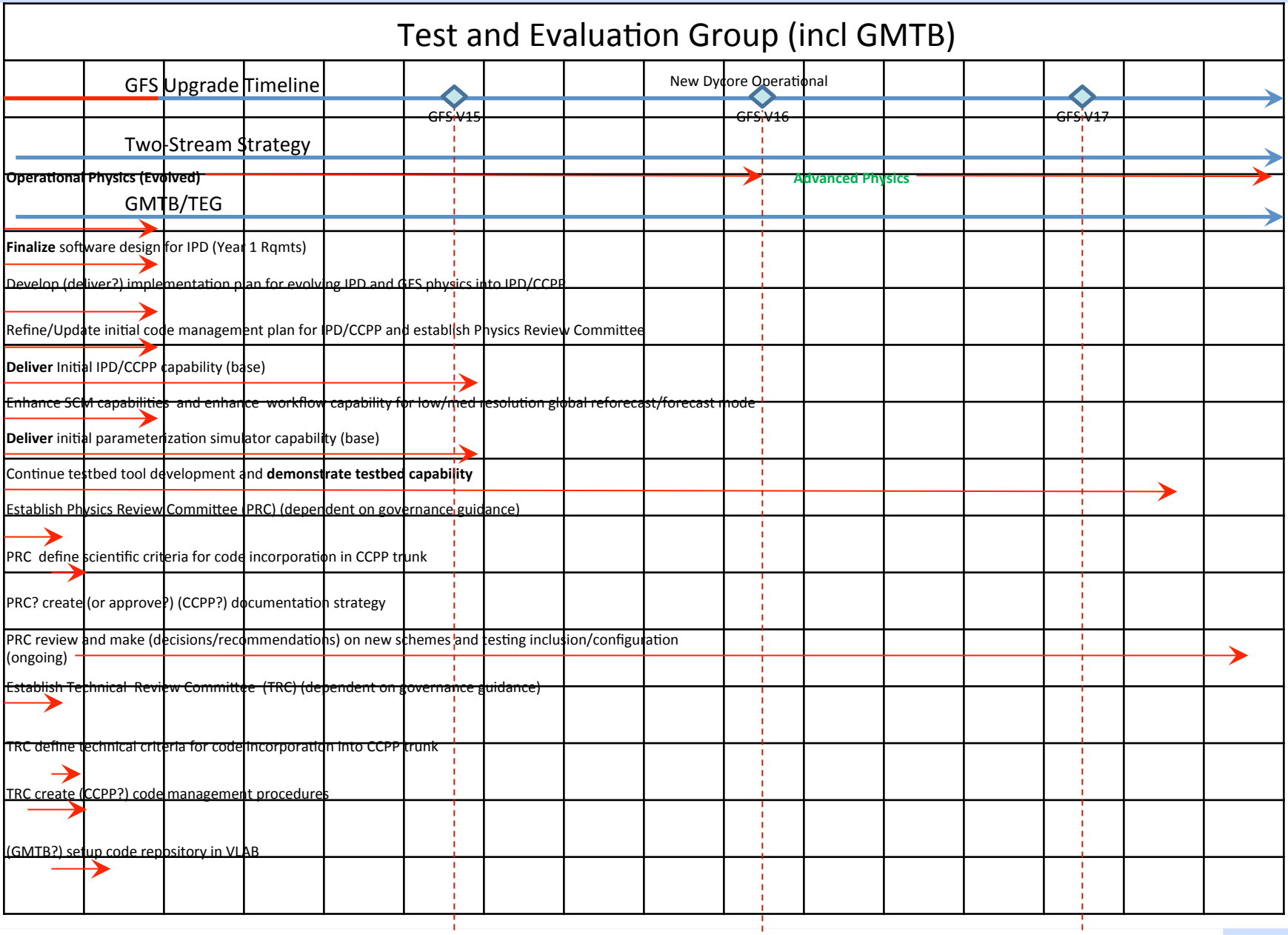


Legend: Red text = unfunded; (add colors to indicate funding source?)

Red = Phys Dev; Blue = DTC; Green = EMC

Note: Should this be renamed just "GMTB" vice TEG (and GMTB)

NGGPS Physics Team Plan



Legend: Red text = unfunded; (add colors to indicate funding source?)