ncing the Understanding of the Earth System: enomena, Processes, Variability and Change

Overview (Atmosphere & Land focus)

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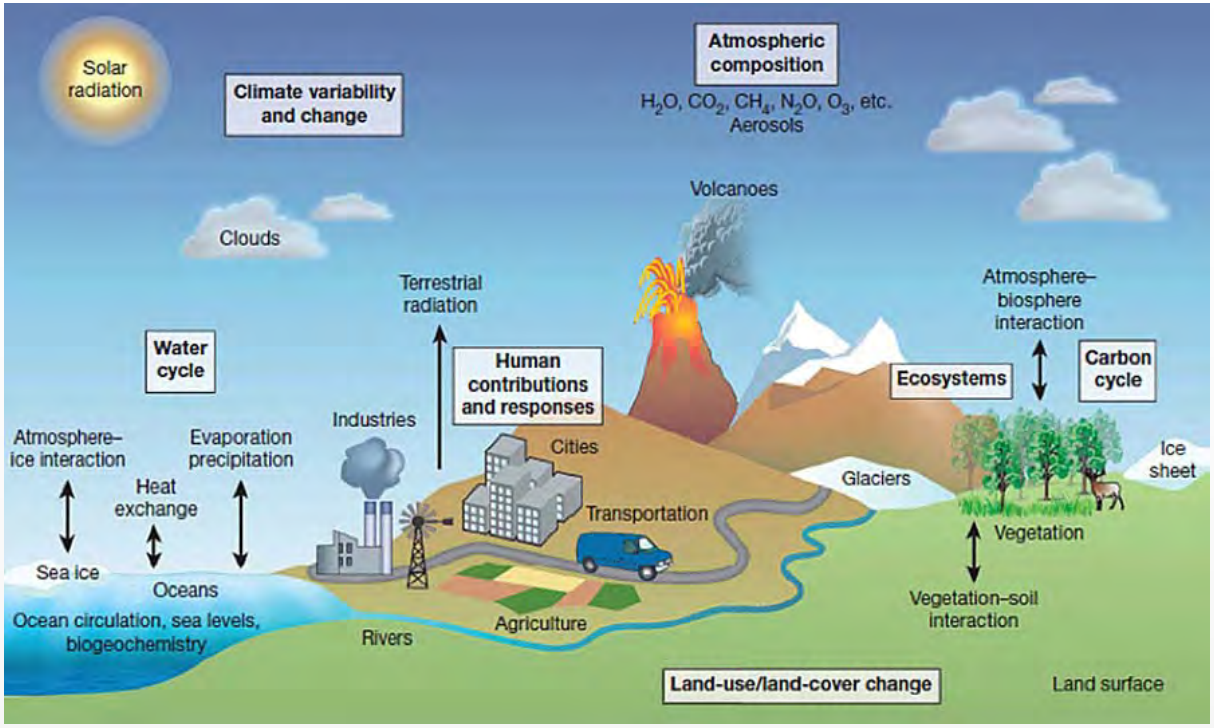
Understanding: the Linchpin of Model Development and Application

- GFDL is well-positioned to use **numerical modeling**, in conjunction with **observations**, to advance the fundamental understanding of **major Earth System phenomena and their underlying mechanisms**.
- The resulting knowledge base proves crucial for **informing model development**, and provides **scientific foundations for Earth System predictions and projections**, both of which are central to fulfilling NOAA/OAR's mission and goals.

"Research, Develop, Transition – **Conduct research to understand and predict the Earth system**; develop technology to improve NOAA science, service, and stewardship; and transition the results so they are useful to society"

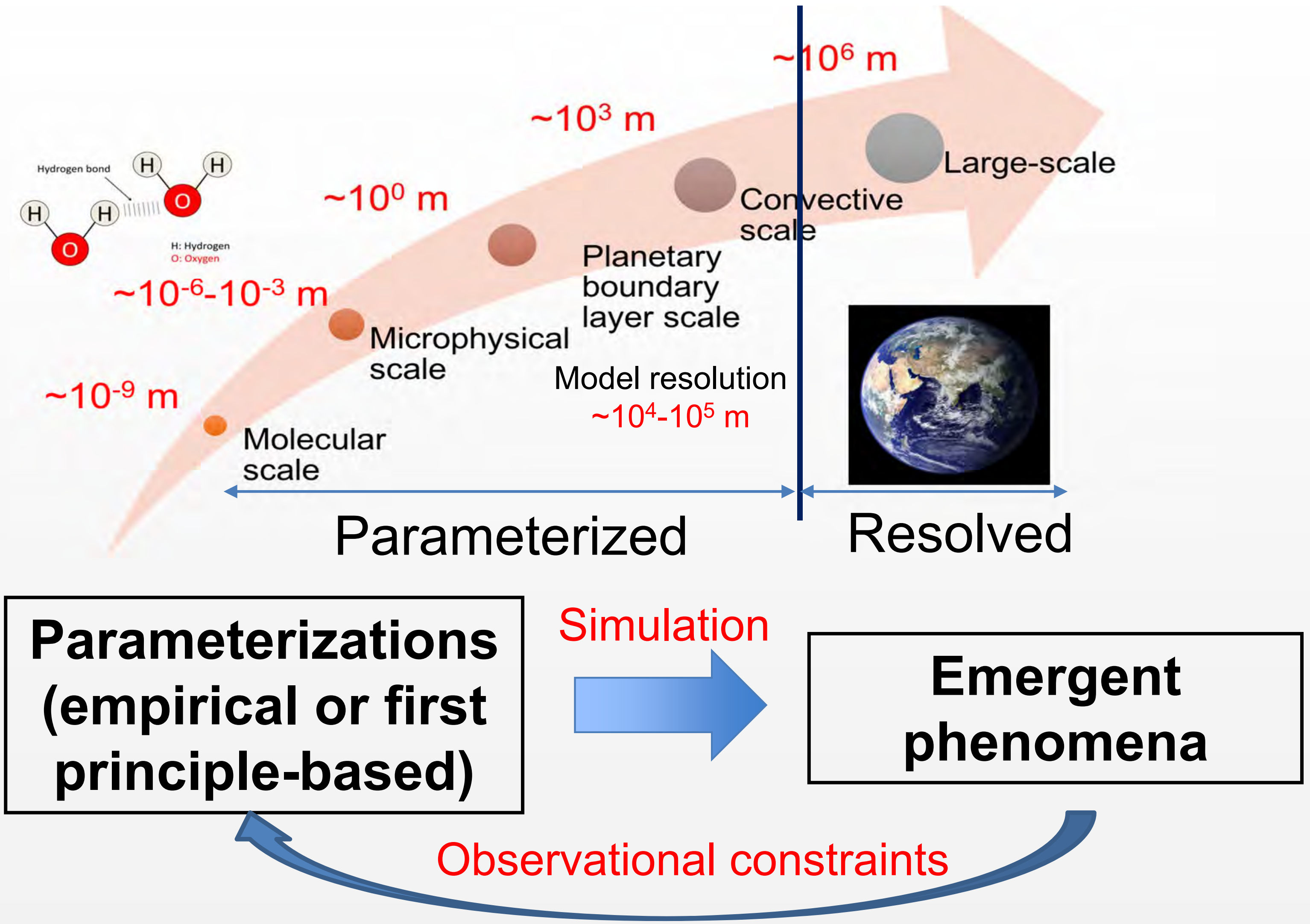
Interconnectivity of Earth System Components



- Traditional strength in understanding the physical climate.
- Recent forays into biogeochemical cycles and land-climate interactions.
- This session focuses on **atmosphere & land**, and the next one on **ocean & cryosphere**.

Parameterized Nature of Global Weather/Climate models

Earth's multi-scale, turbulent climate system

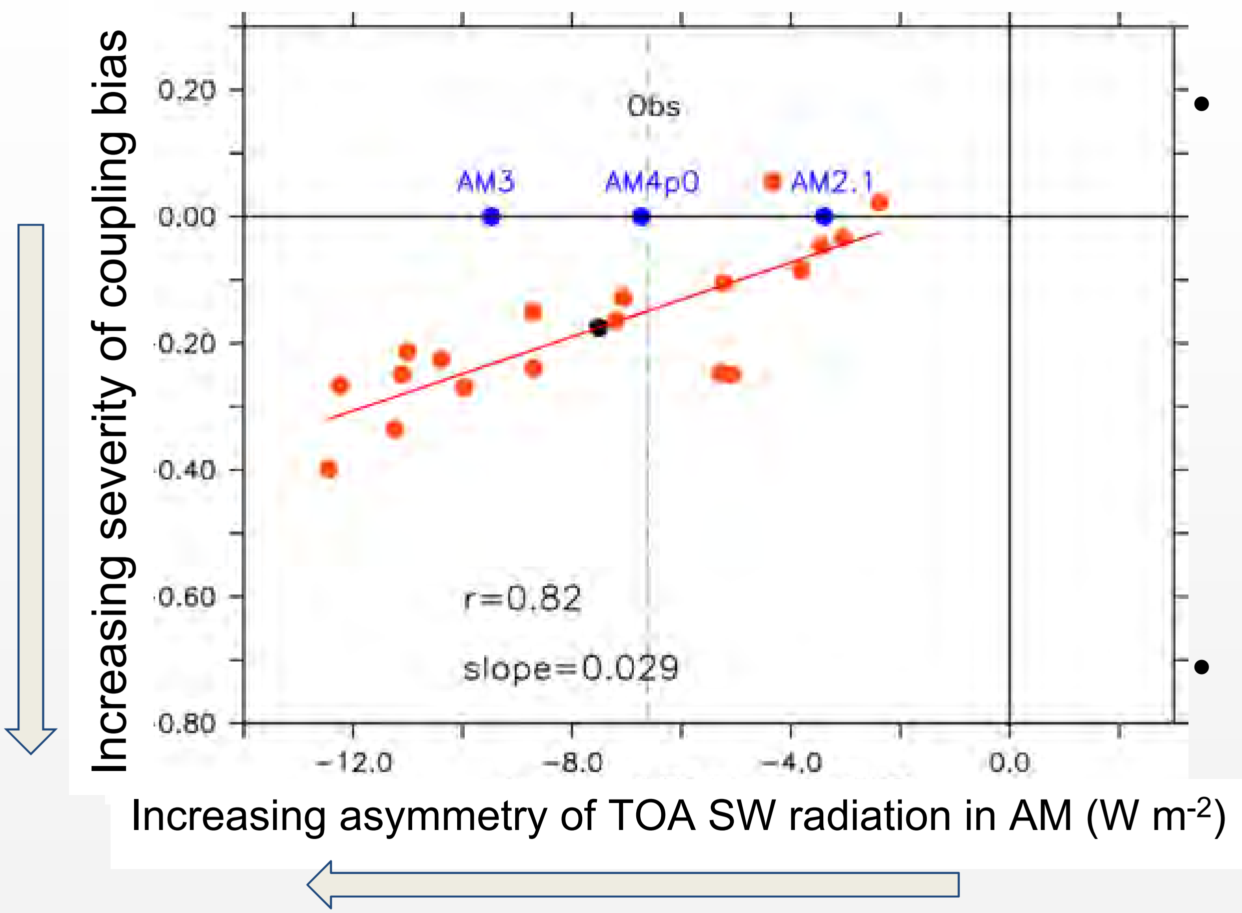


Key Pathways Toward Understanding of Lasting Value

- Process-level understanding and reduction of model biases
- Emergent constraints
- Construction of model hierarchies
- Theoretical development

Process-level Understanding and Reduction of Model Biases

Double ITCZ linked to TOA radiative balance

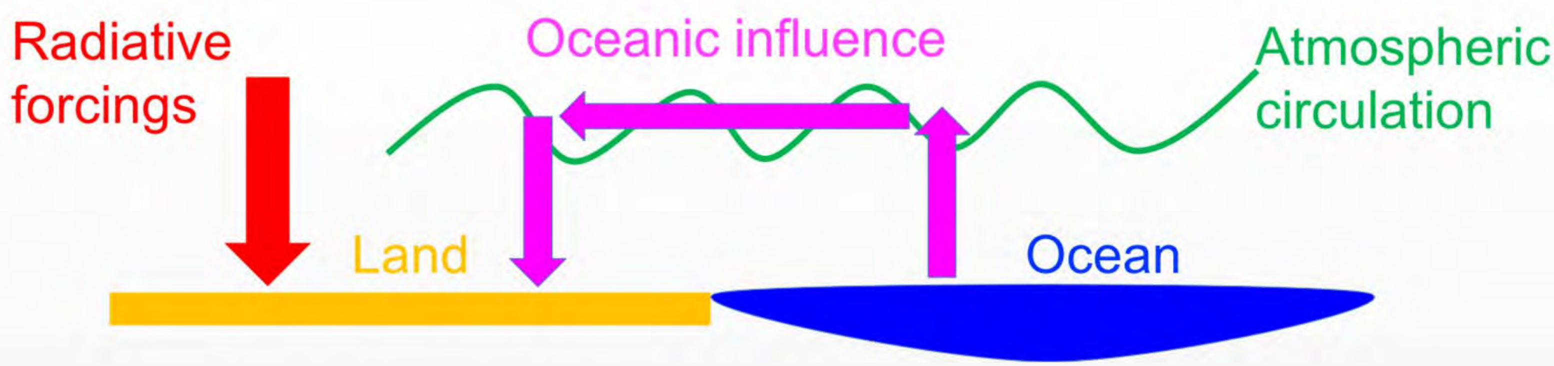


- One can predict the severity of double ITCZ in coupled models (CM) from the atmospheric model (AM) simulation of TOA radiative balance.
- AM4 performs better than AM2 and AM3 in this regard.

Xiang et al., GRL, 2017; Zhao et al., JAMES, 2019

Emergent Constraints

Constraining aerosol forcing and climate sensitivity with historical temperature records

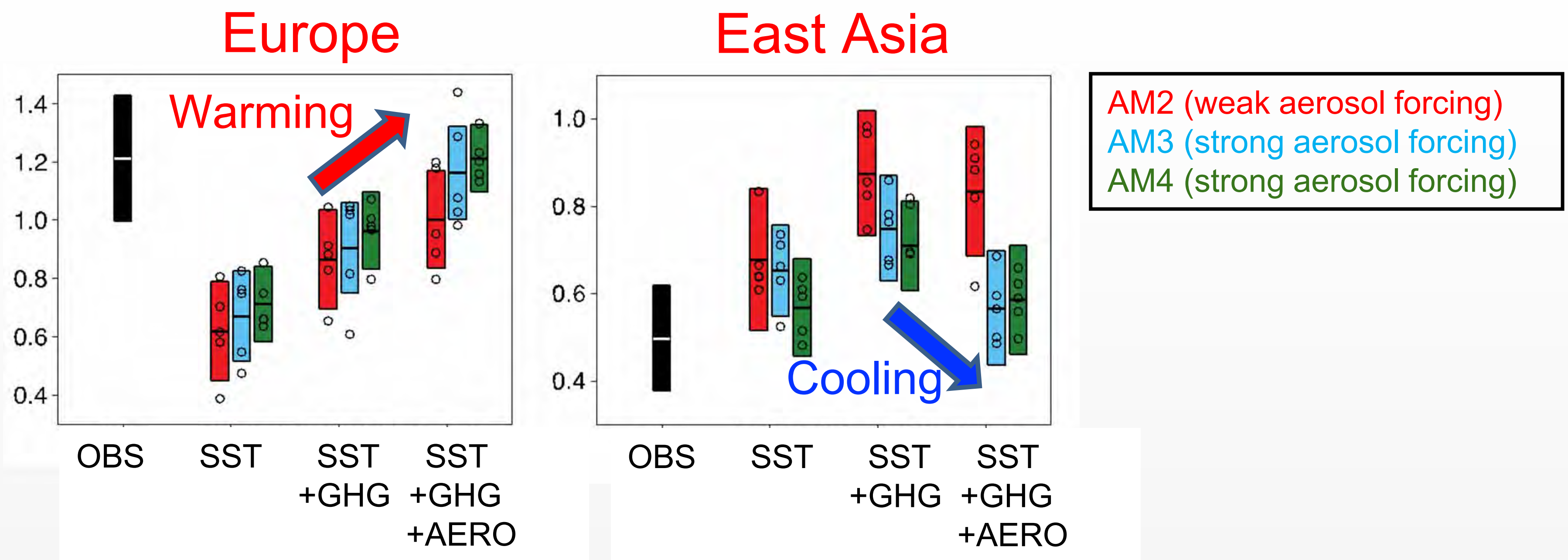


- Land temperature is driven locally by radiative forcings (fast response), and remotely by sea surface temperatures (SST) (slow response).
- The fast response contains information on radiative forcings.
- Three AMIP-type simulations:
  - ❖ #1 historical SST warming only, no radiative forcing
  - ❖ #2 historical SST warming + GHG
  - ❖ #3 historical SST warming + GHG + aerosols

Shen, Ming and Held, in preparation

Emergent Constraints (2)

June-Nov. regional land temperature change (2001-2015 minus 1961-1980)



- Aerosol forcing is essential for getting the right regional temperature trends.
- Consistent with the past aerosol emission trends.
- Potential for using observed land temperature to constrain historical aerosol forcing and climate sensitivity.
- Complementary to coupled models-based detection and attribution (circumventing model uncertainties in climate sensitivity and natural variability).

Construction of Model Hierarchies

Comprehensive GCM

Idealized moist GCM w/ full radiation
Clark, Ming and Held (2018) J. Clim.

Idealized moist GCM
(Gray-atmosphere)

Dry GCM w/ passive water vapor & clouds
Ming and Held (2018) J. Clim.

Dry GCM (Held-Suarez)

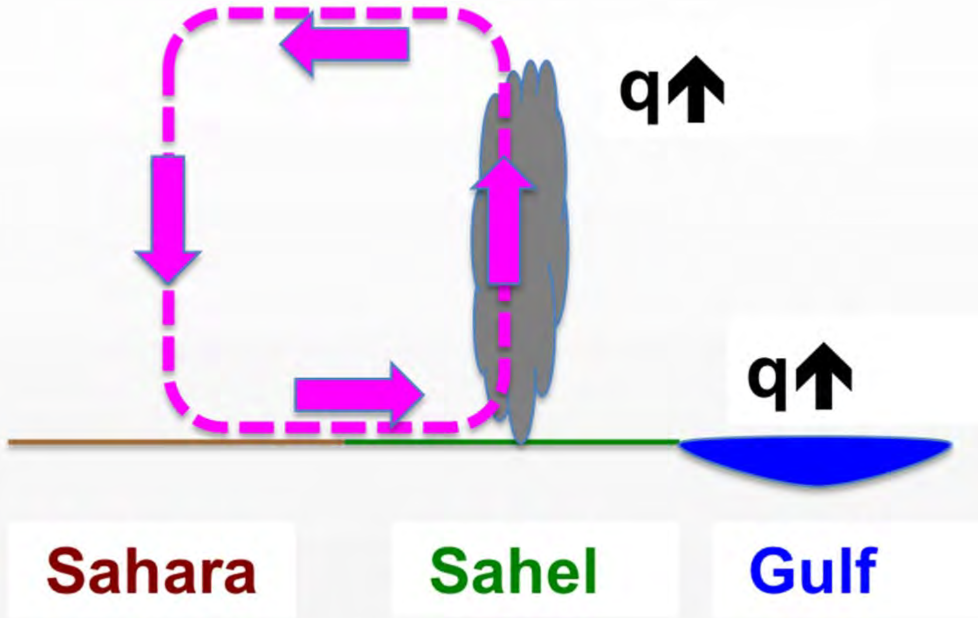
Two-layer QG model

Held, BAMS, 2005

Theoretical Development

Moist static energy (MSE) budget-based theory for understanding regional precipitation change

$$\delta(\bar{\omega}) \approx -\frac{\bar{V} \bullet \delta(\nabla h)}{\bar{h}_p}$$



- For warming, the MSE balance is between the increased horizontal advection of MSE and the decreased vertical advection (a drying factor).

Hill et al., J. Clim., 2017, 2018

Future Directions

- GFDL is well suited for **long lead-time work** with the potential for significant scientific breakthroughs.
- The need to carefully balance competing needs (**risk vs. return, process-level understanding vs. simulation of emergent phenomena, simplicity vs. comprehensiveness**, etc.).
- The suite of GFDL models (AM4, CM4, SHiELD, and SPEAR, as well as FV3-based global cloud system resolving models) presents an opportunity to tackle some long-standing issues related to **aerosol-cloud-convection-radiation-circulation-climate connections**
- GFDL will continue to deepen understanding of **interactions within and between Earth System components**.
- CM4 and ESM4 will produce simulations of **internal climate variability** and **climate responses to external forcings**.
- Confronting models with **observations** will remain a crucial activity.

Introduction of Individual Talks

- Radiative impacts of aerosols and greenhouse gases – David Paynter
- Chemistry climate interactions – Fabien Paulot
- Land-biosphere feedbacks on air quality – Meiyun Lin
- Land-coastal ocean interactions: insights from the GFDL land models -Minjin Lee
- Stratospheric processes and impacts – Pu Lin