

Digital Earth

WCRP Lighthouse Activity

WCRP JSC-44 Update

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Judt, 4km MPAS



WCRP Structure

Joint Scientific Committee (JSC)

WCRP Secretariat

Lighthouse Activities

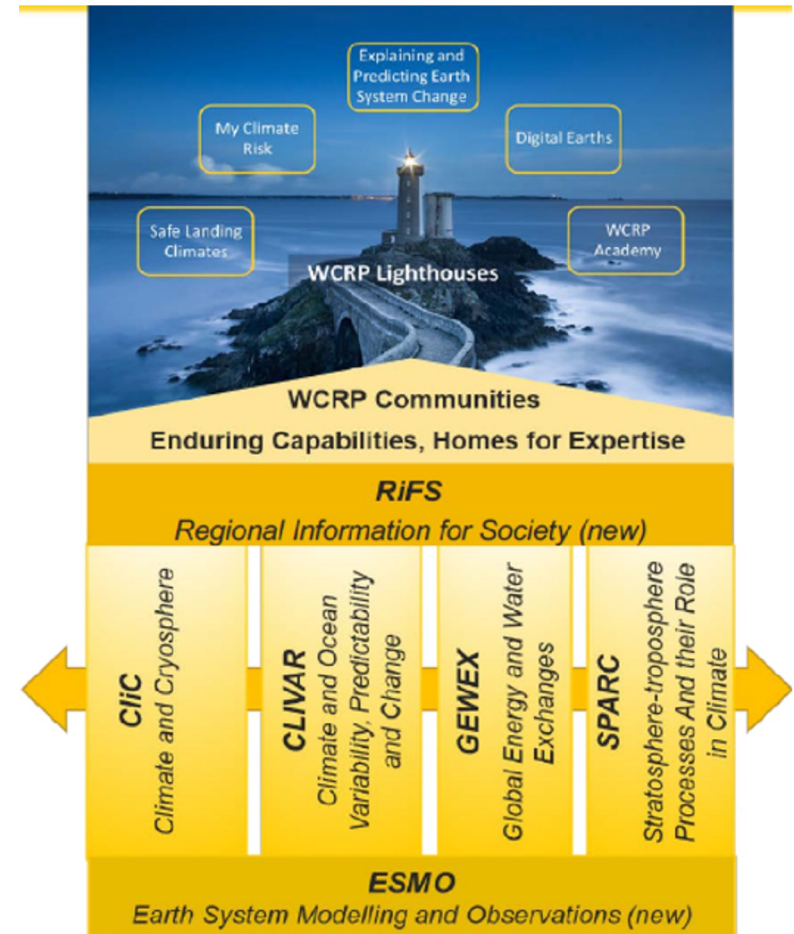
International Offices

Core Projects and Research Communities

- Climate and Cryosphere (CliC)
- Global Energy and Water Exchanges (GEWEX)
- Climate and Ocean Variability, Predictability and Change (CLIVAR)
- Stratosphere-troposphere Processes And their Role in Climate (SPARC)
- *Earth System Modelling and Observations (ESMO)*
- *Regional Information for Society (RiFS)*

Additional Activities and Forums

- Fixed-term projects
- Conferences and workshops
- Reference datasets, evaluations and benchmarking
- Diversity and capacity building: ECRs, regions
- Rapid updates, syntheses, assessments, gap analysis
- Communications and outreach

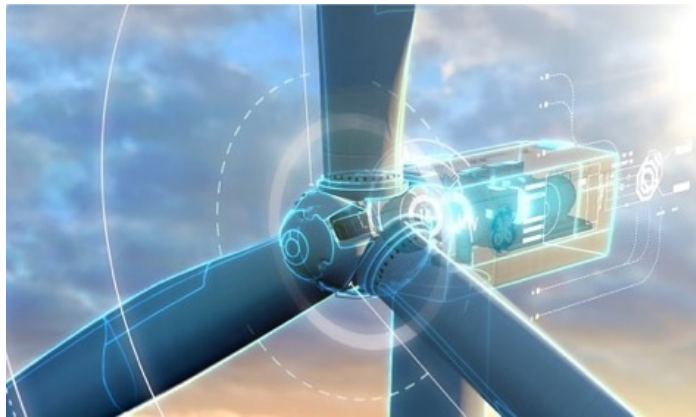


What is a Digital Twin?

A virtual representation of an object or system that spans its lifecycle, is updated from real-time data, and uses simulation to help decision-making

- IBM

Wind turbine (Asset DT)



Building (System Twin)



'Digital Earth' = Digital Twin of the Earth

“An interactive information system for the past, present & future state of the earth”



The Digital Earth: Understanding our planet in the 21st Century

by Al Gore

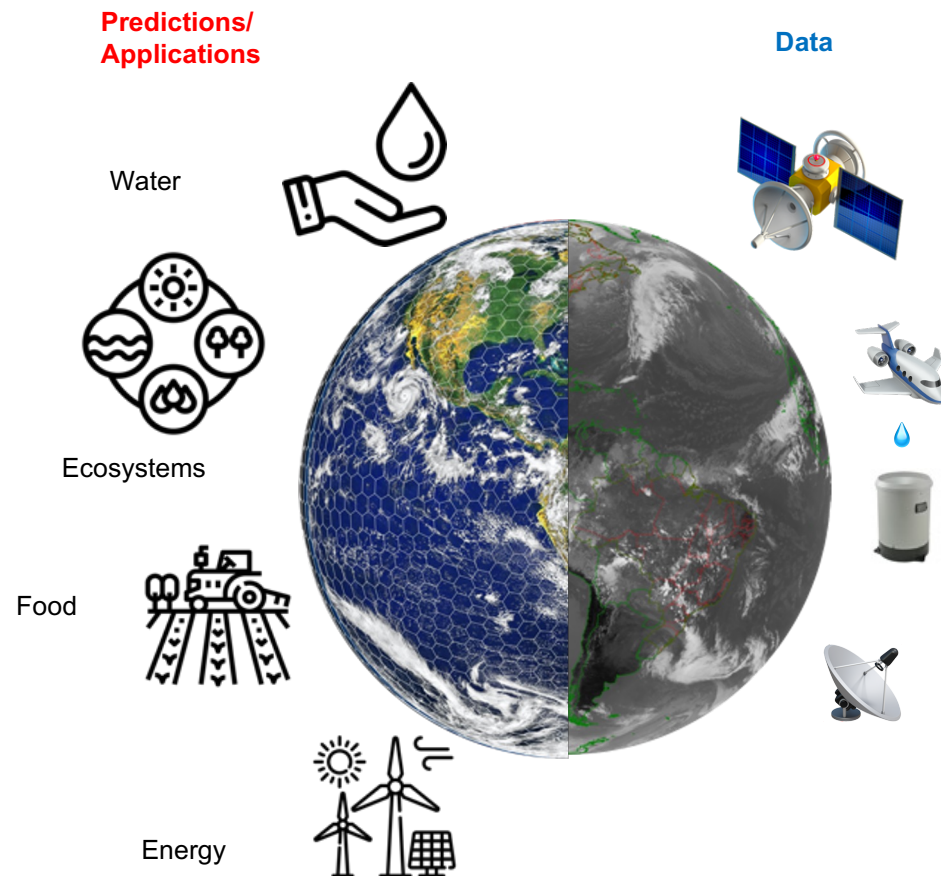
The tools we have most commonly used to interact with data, such as the "desktop metaphor" employed by the Macintosh and Windows operating systems, are not really suited to this new challenge. I believe we need a "Digital Earth". A multi-resolution, three-dimensional representation of the planet, into which we can embed vast quantities of geo-referenced data.

January 31, 1998

Why is a DT different than just a 'model'?

Data goes in. Human scale **predictions** come out

- Key differences from an ESM
 - Data: Assimilation & Data Models
 - Coupling to human systems
 - Explicitly for decisionmaking
- Is this just Hype?
- Digital Earth may be Regional
- Hierarchy of models/configurations
- Configurable system



Example 1: Destination Earth (EU) Funded High resolution ESM & Weather models = Digital Earths

DESTINATION EARTH



UNLOCKING THE POTENTIAL OF DIGITAL MODELLING

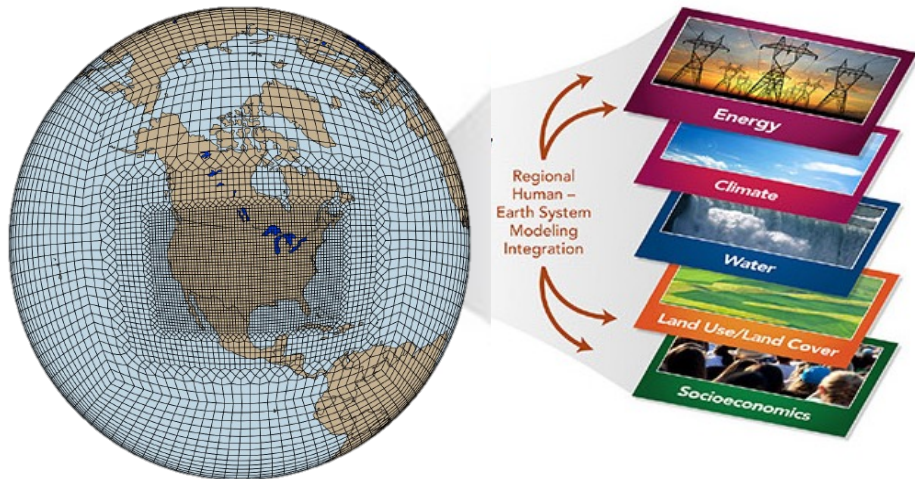
Utilising high-performance computing, machine learning and satellite data, the digital twins of **Destination Earth** will provide us with an accurate representation of the past, present and future changes of our world.



Example 2: US Department of Energy

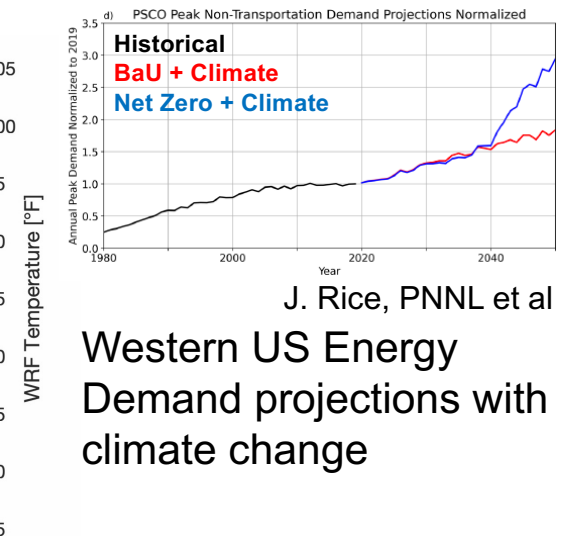
Diverse Weather/Climate + Multi-Sector Dyn Models = Digital Earth 'like'

E3SM + Multi-Sector Dynamics (MSD models)



'GoDEEP': WRF + TELL Energy Demand Model

June 09, 2019 00:00 UTC



J. Rice, PNNL et al

Western US Energy Demand projections with climate change

Digital Earth LHA Goal

Support the design and building of **integrated interactive digital information systems** that provide global and regional information on the past, present, and future of our planet, including both natural and human systems.

Areas of activity

- **Fully coupled km-scale regional and global models:** Need a global research network in km-scale modeling of the Earth system and individual components
- **Data assimilation for climate:** Establish an active community in data assimilation for climate, expanding on the existing numerical weather prediction and re-analysis efforts
- **Beyond the Physical Earth System:** Include human interactions on and impacts to human systems in ESMs

4km MPAS-A
Falco Judt, NCAR

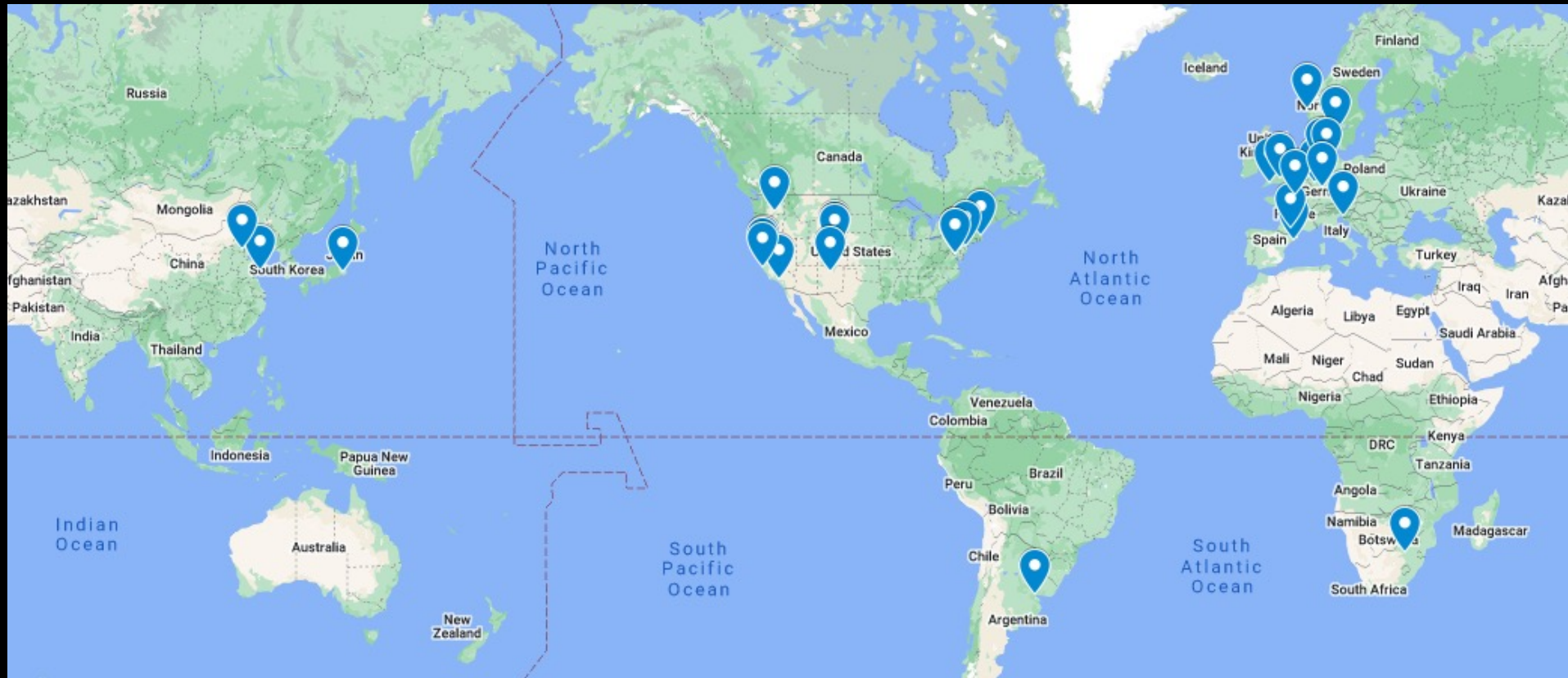


Progress

- DA: Workshop (May 2022) Discussion of DA for climate, going beyond traditional DA (Lead: Aneesh Subramanian, Univ. Colorado)
- **Km Scale Modeling Workshop** (October 2022): 65 in person, 30 online, Organized by NCAR
 - Workshop Report: <https://www.wcrp-climate.org/de-documents> (top link)
- Beyond the physical system: building bridges. Likely starting with engaging Regional Hydroclimate Projects (RHP)
- Discussions with CORDEX/EUROCORDEX & GEWEX- GASS & GLASS on collaborations
- Governance: 2 Co-chairs plus a loose Steering group from 2017 DE LHA Science Plan giving advice
 - More formal structure this year

Following thoughts are summaries from the Km-Scale modeling workshop

Map of km Scale Model Efforts: Regional & Global



21 different efforts identified. 12 global, 9 regional.
About $\frac{2}{3}$ of these groups attended meetings in person or virtually.

Science Issues for 'Digital Earths'

- Many km-scale model applications best done with regional models
- Km scale models (global and regional) should learn from established mesoscale model developers. Build teams including them.
- Investigate how better representing processes in at km scales feeds back onto the larger scale circulation and how it improves the simulation of climate & weather phenomena.
- Key science issues for the atmosphere: Org and intensity of deep convection (1-4km), shallow convection (4km-100m), extratropical storms. Collaborate with GEWEX GASS & GLASS.
- Engage km-scale ocean and sea ice communities with CLIVAR Ocean Model Development Panel and CLiC for process understanding.
- km-scale models could have a big impact improving hydrology simulations: coupling to water at the surface. Engage with existing land modeling efforts (GEWEX GLASS and GHP), and Regional Hydroclimate Projects (RHPs) to improve hydrology in km-scale land models.

Technical Issues for 'Digital Earths'

- Encourage collaboration and sharing of techniques for
 - new architectures (like GPUs)
 - coupling infrastructure
 - ported code (shared model physics)
- Best to analyze km-scale model output at the location of the data.
 - Discuss federating access to web-based development environments (facilitates cross model investigations & users from under-represented groups).
- Continue and sustain support for development of open-source data analysis tools. Digital Earth can also help by making a catalog of available tools.
- Ensure that data set access and open-source analysis tools are freely available and can be used in the easiest way possible.
- Invest in the human workforce for model infrastructure.

Current Activities

- **Process intercomparisons** between k-scale models (global & regional)
Entraining CORDEX interests. Topics:
 - **Convective organization** and tropical waves (with GASS)[F. Judt, NCAR & M. Singh, Monash U.]
 - **Land modeling at ultra-high resolution** (and land-atmosphere coupling) with GLASS [M.-H. Lo, NTU, Taiwan]
- High resolution processes **seminar series** [H. Lewis, MetOffice R. Rios, NCAR]
- Catalog of **high-resolution input data sets** (regional and global) being developed [P. Duben, ECMWF]
- Joint group for **initialization & spin up of (k-scale) coupled models**, with OMDP and DAOS WWRP working group [B. Fox-Kemper, Brown Univ]
- Catalog of **workflows and analysis tools** [J. Clyne, O. Eroglu, NCAR]
- **Urban Digital Twins** collaborations [D. Niyogi, U. Texas]

Current Activities

Goal is discussions that lead to products:

- Catalogs/Links to Resources
- White Papers/Reviews
- Meetings or Sessions at Meetings

Example from the Land-Atmosphere Interactions Group

The screenshot shows a web browser window with the URL `hydro.as.ntu.edu.tw/high-resolution/#explore`. The page title is "Land Model And Land-Atmosphere Coupling At High Resolution". Below the title is a blue wireframe landscape graphic and an "Explore" button. On the right side, there are social media icons for Facebook, Twitter, and LinkedIn. The main content area is titled "WCRP Digital Earth Lighthouse" and features a red heading: "Land model and land-atmosphere coupling at high resolution discussions". Below this heading is a list of activities:

- ✓ Sharing information on what people are doing.
- ✓ Process intercomparisons between km scale models.
- ✓ Joint analysis.
- ✓ Move towards (propose some options).
 - A web page for collecting information, sharing information and coordinate activities.
 - Monthly webinar.
 - Perspective or review paper that reflects the insights and ideas discussed during the conversations with the community.

At the bottom of the page is the WCRP logo (World Climate Research Programme) and logos for the World Meteorological Organization, United Nations Educational, Scientific and Cultural Organization, and International Science Council.

Next Steps

- Continue discussions with 'human side' (ISIMIP) and assimilation
- Planning for joint meetings in 2024
 - Coordinate a single one-week meeting for km-scale modeling
 - Specific days of that meeting for individual communities
 - Organize a hackathon/tutorial targeting PhD Students and PostDocs

DE LHA Governance

- Transition in co-chairs
 - P. Bauer (ECMWF) → A. Gettelman (PNNL)
 - C. Jakob (Monash) → P.-L. Vidale (Reading)
- Focused on initial workshops, getting discussions set up and established
- Now focusing back on a sustainable structure

Digital Earth LHA Structure

