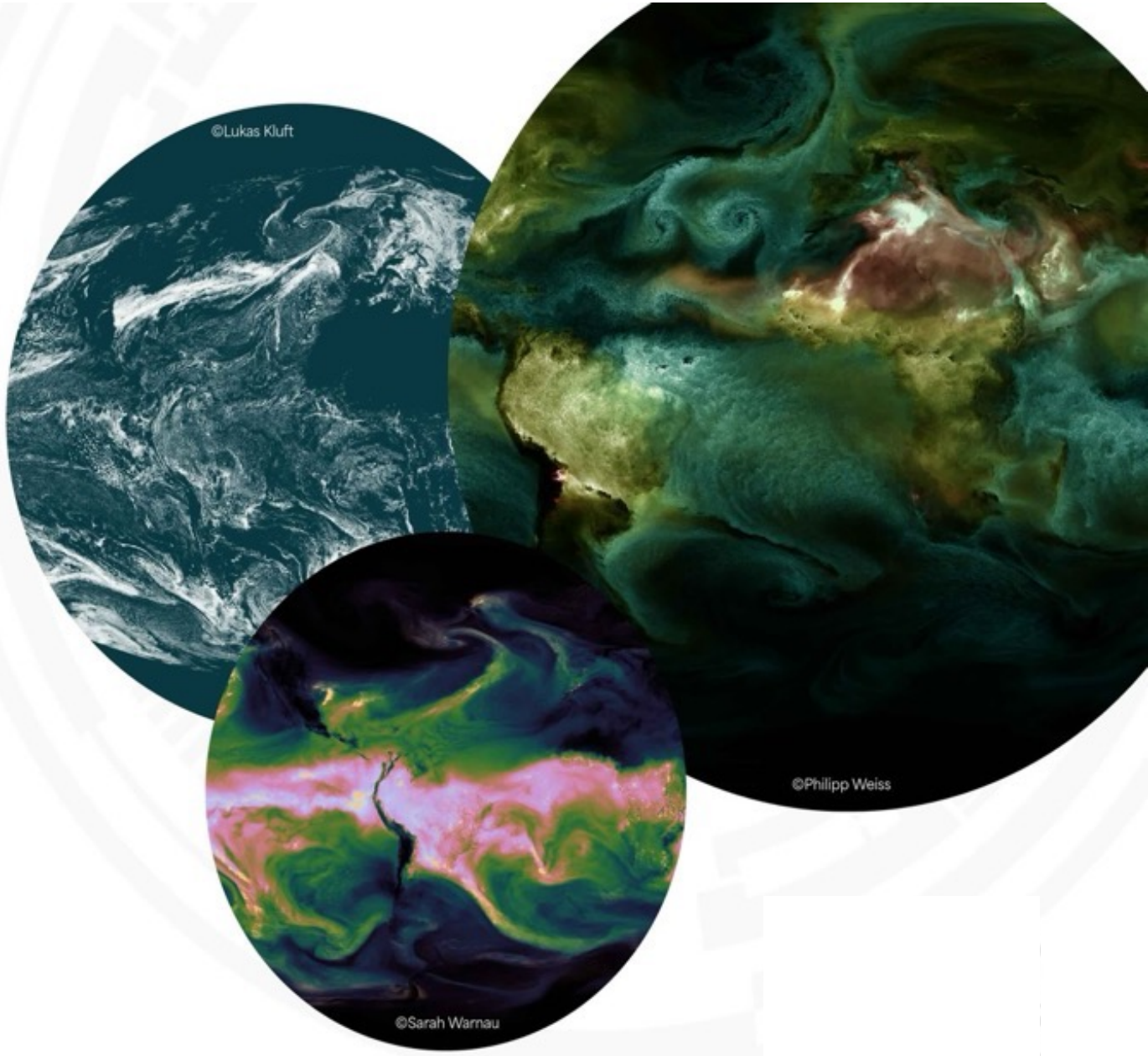
The Digital Earth Lighthouse Activity: WGNE Update



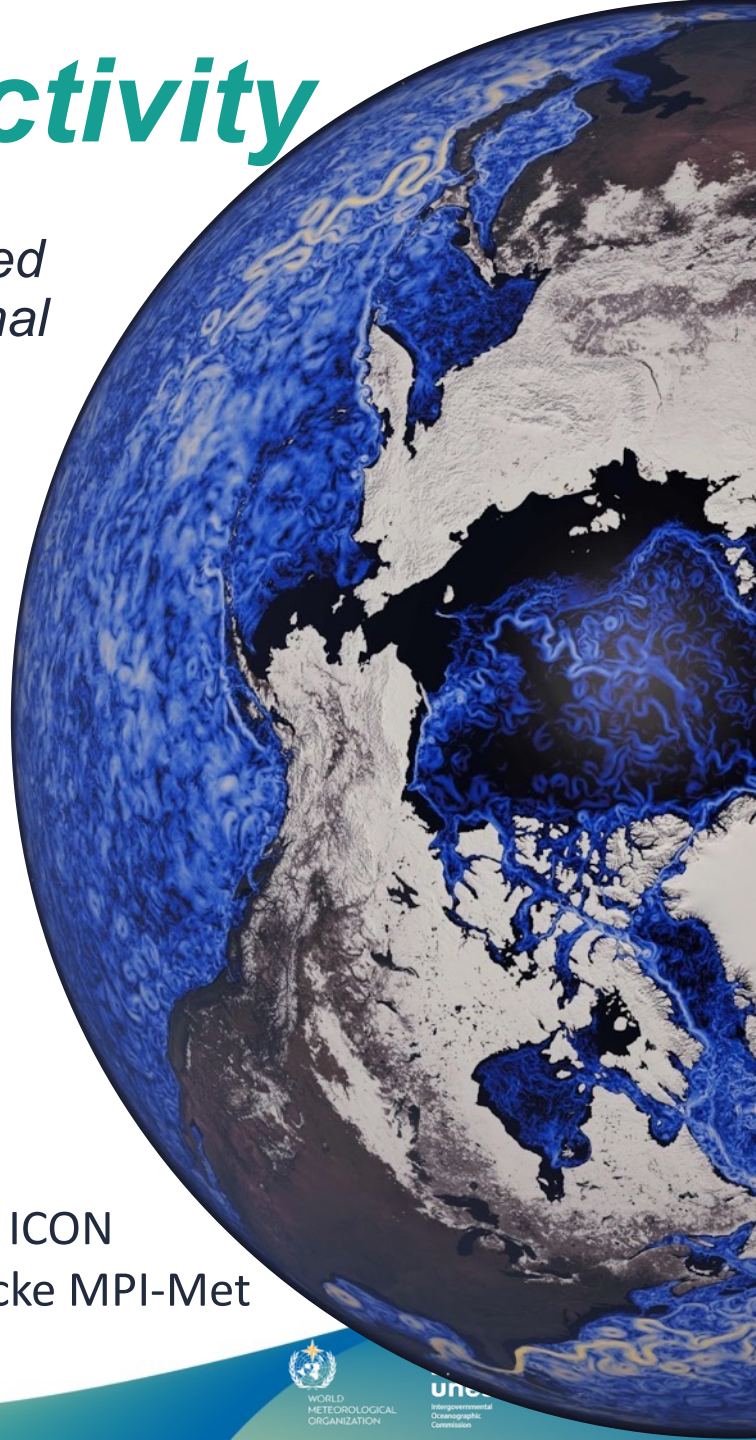
Andrew Gettelman, U. Colorado
Pier Luigi Vidale, NCAS/U. Reading

Digital Earth Lighthouse Activity

Cross-Cutting WCRP Activity supporting development of integrated interactive digital information systems providing global and regional information, including both natural and human systems

Areas of activity

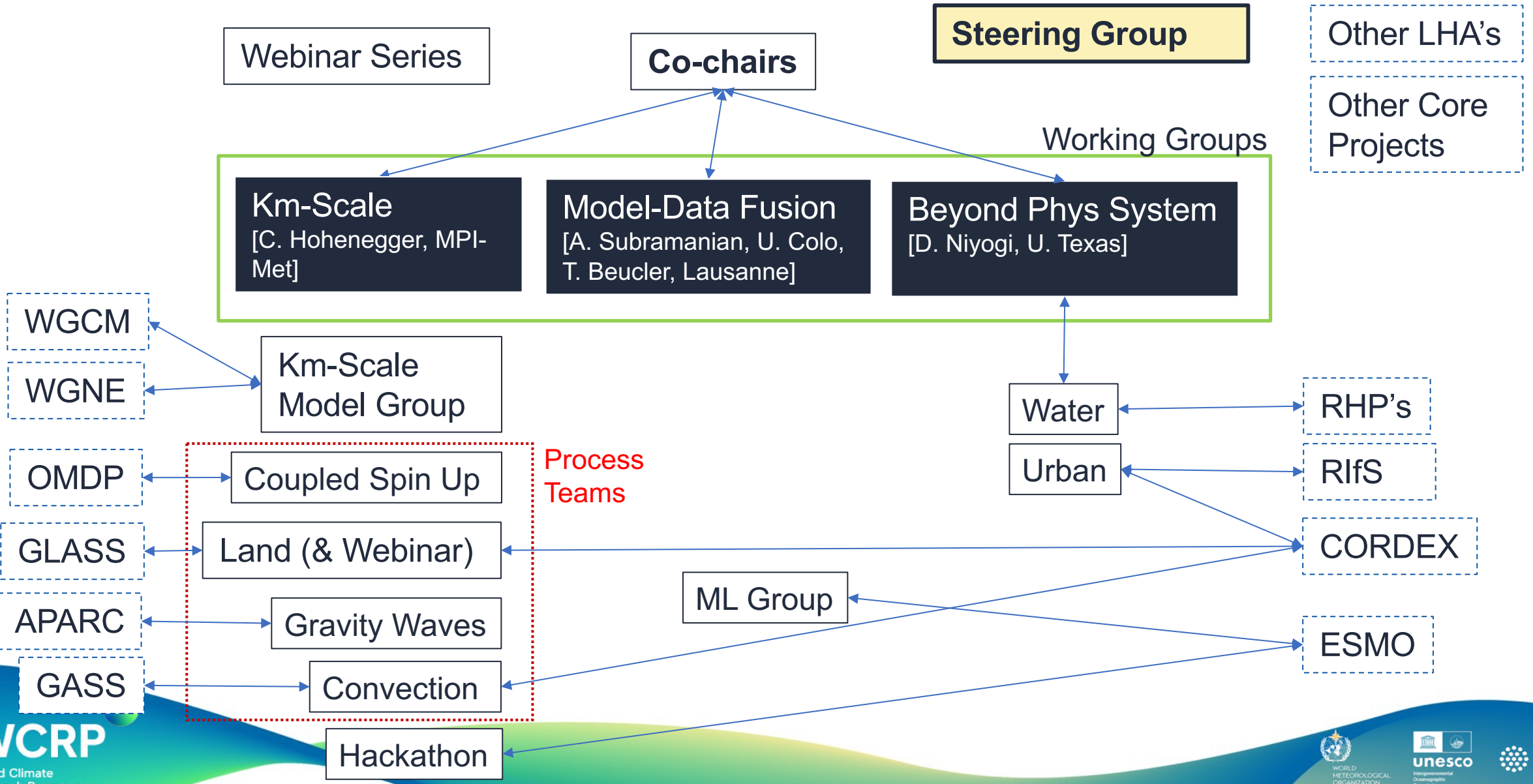
- **Fully coupled km-scale regional and global models**: Foster a global research network in km-scale modeling of the Earth system and individual components (**km-scale = Δx<10km)**
- **Data-Fusion for climate**: Establish an active community for *climate data assimilation* and *data driven modeling* (e.g. Machine Learning/AI methods), expanding on numerical weather prediction and re-analysis
- **Beyond the Physical Earth System**: Include human interactions on and impacts to human systems in ESMs



1.2km ICON
D. Klocke MPI-Met

Digital Earth LHA Structure

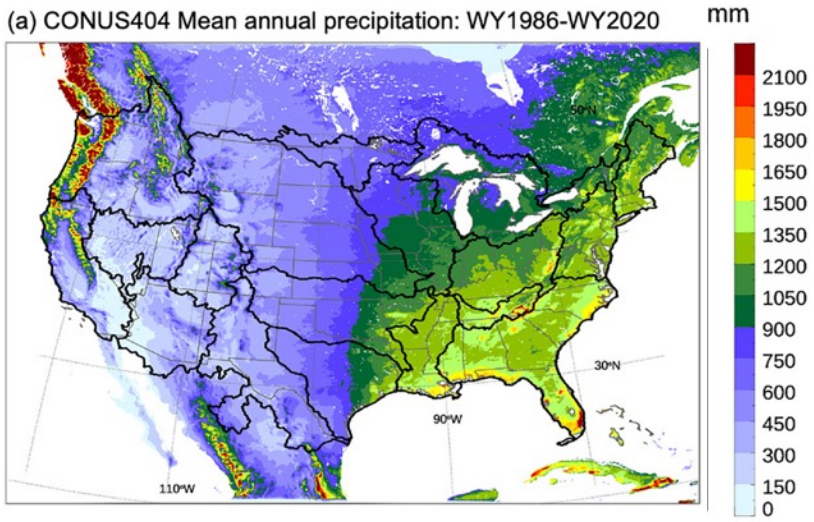
2025



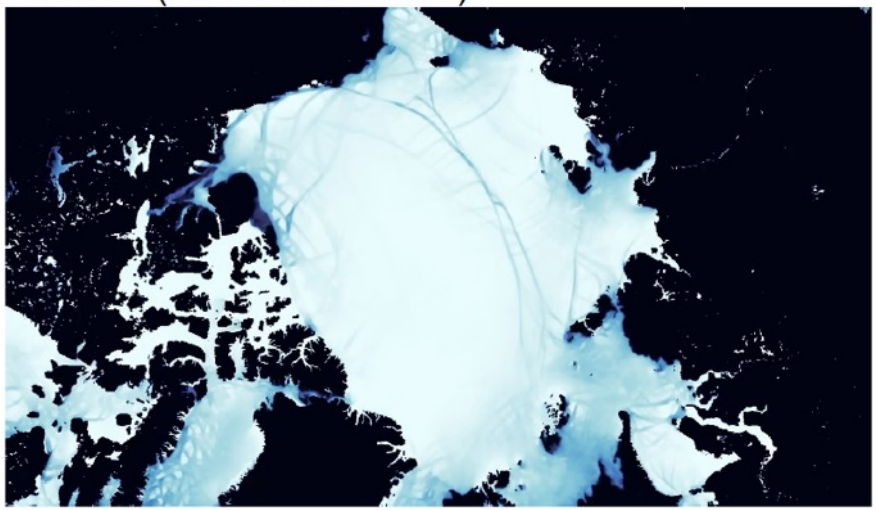
Regional & Global Km-Scale Models

- CORDEX Regional Climate Models @ km-scale (FPS)
- ~10 global km-scale atmosphere models
  - >1yr simulations with ~3km atmospheres (7 models)
- Several km-scale coupled models developed
  - Testing down to 1km global!
- Science use cases needing global models:
  - Small scale impacts on general circulation, Teleconnections
  - Coupling across ‘spheres’ (e.g. ocean – atmosphere)

Regional Climate Model (4km)
Rasmussen et al 2023, BAMS

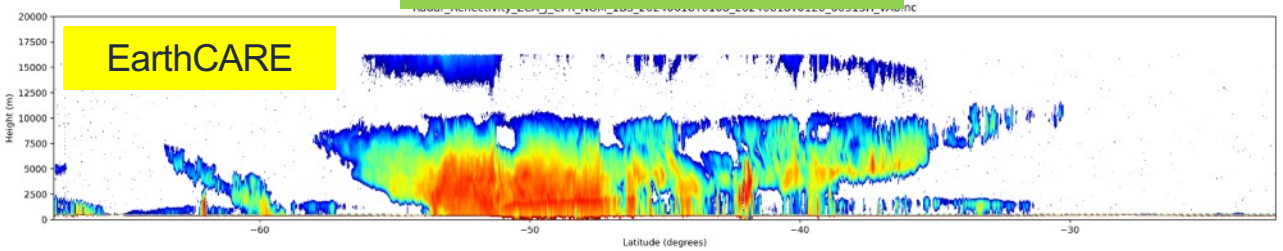


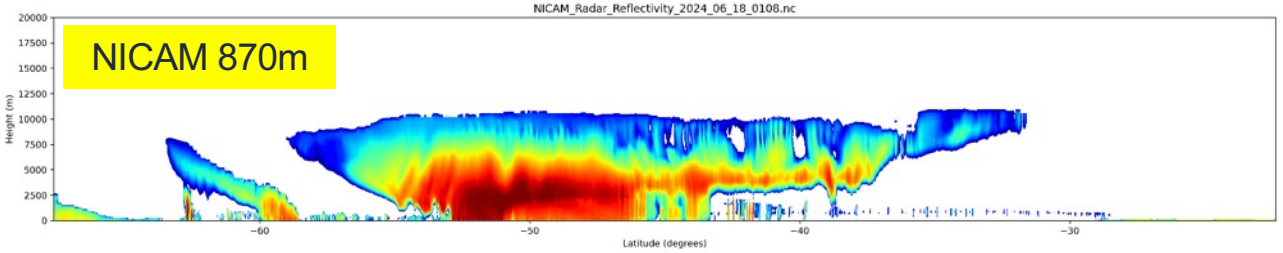
Simulated sea ice leads/cracks in the Arctic Ocean (FESOM at 4-5km)

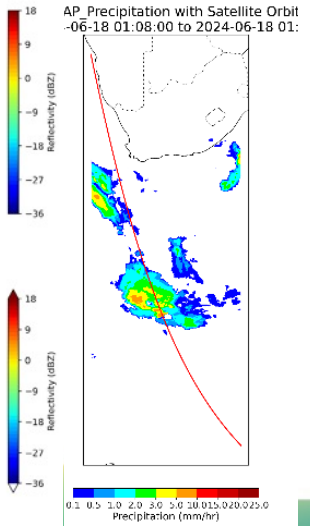


Racknow, ECMWF, Koldunov, AWI : NextGEMS Coupled Ocean/Ice (5km) & Atmos (9km)

Radar reflectivity







DE km-scale Modeling Science Initiatives

- Nurture the development of **process comparisons/teams**
  - Km-scale **Land-Atmosphere interactions**
  - **Convective organization** team re-forming
  - **Gravity waves** may be forming with APARC
- **Km-scale model working group** (regional and global): with WGNE
- **Seminar Series** on km-scale modelling
- Participating in **conferences/workshops**
  - Hosting/supporting meetings/sessions where necessary
- Global **'pan-hackathon' for km-scale modelling** this week
  - Multiple models, sharing tools and workflows, data sets
  - Increase ability of users to analyse km-scale models
  - Bring analysis capabilities and data to users worldwide

All these activities are for **global AND regional models**

WCRP Digital Earth Lighthouse Activity
Global km-Scale Hackathon

When: 12-17 May 2025
Where: 11 regional nodes worldwide

Join us and contribute to strengthening collaborations in weather and climate research, driving advances in storm-resolving models for better predictions!

Organisers: WCRP Digital Earths Lighthouse, in collaboration with other international partners and initiatives

Our partners:

WCRP World Climate Research Programme · ESMO Earth System Modelling and Observations · next GEMS · WARM WORLD · Destination Earth · EERIE European Eddy-Rich ESMs

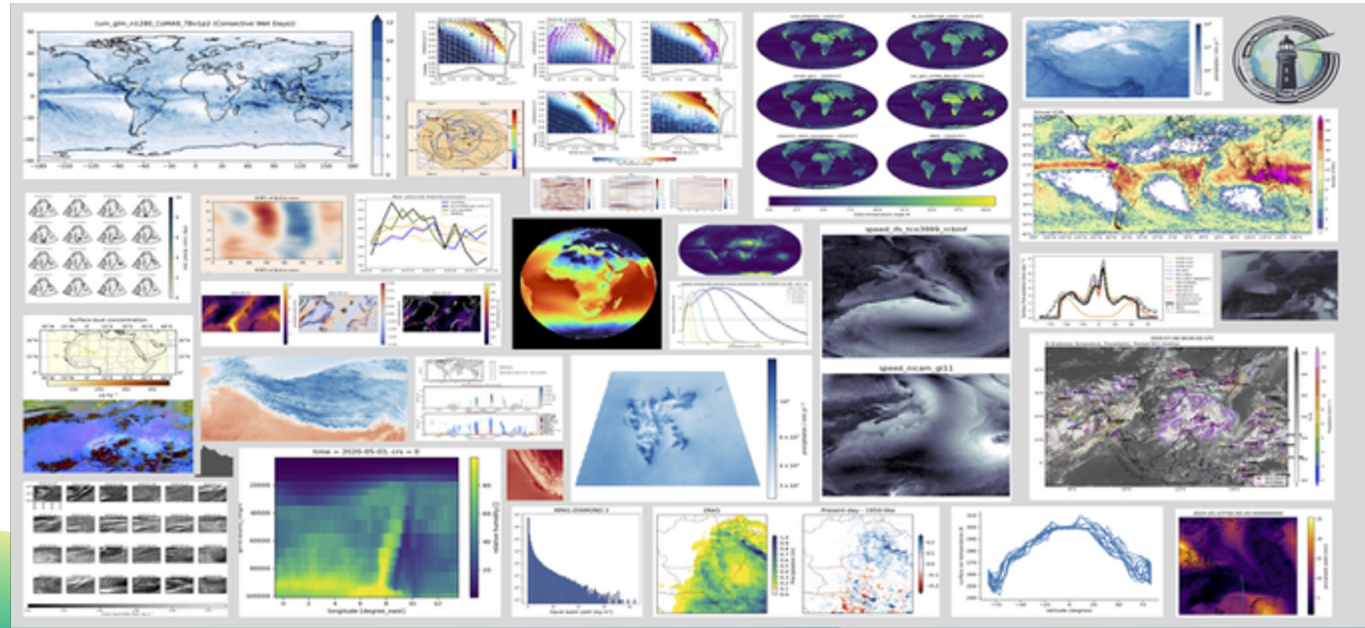
700 participants

10 cutting edge models

+ Observations and AI teams

Over 1000 plots in a week!

Prototyped new methods for delivery of climate innovation



58 Princeton

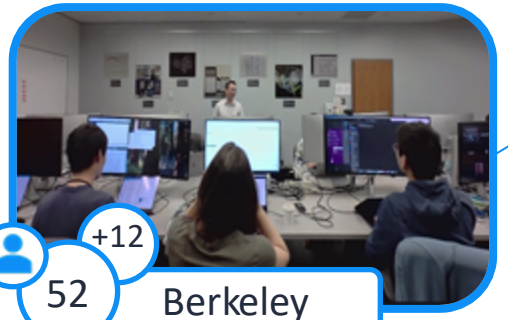
70 Oxford

115 Beijing

+6
116 Hamburg

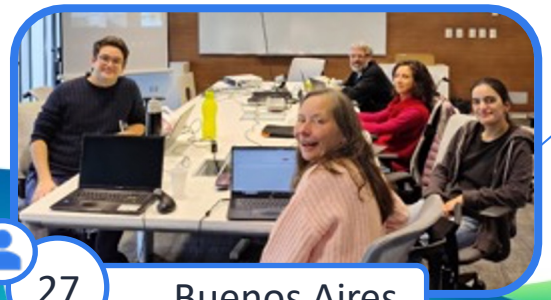
47 Boulder

53 Tokyo



+12
52 Berkeley

km-Scale Hackathon 2025



27 Buenos Aires

69 São Paulo

68 Canberra

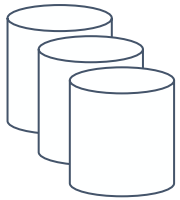
World Climate Research Programme

World Meteorological Organization

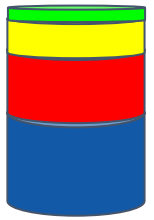
Intergovernmental Oceanographic Commission

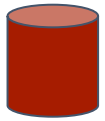
Hackathon Technical Stack

Local Storage

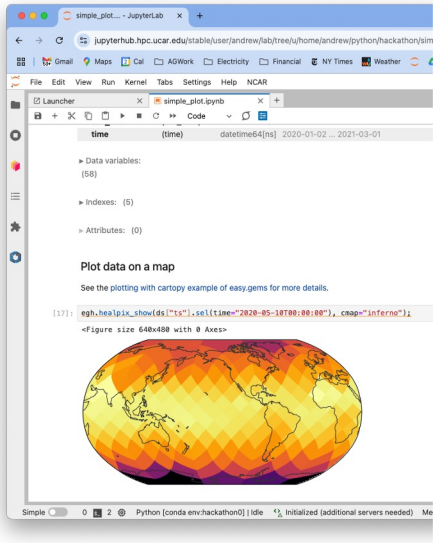


Object Storage (S3)





Model Output / Observations



jupyterhub

xarray

python

Data

Storage

Communication

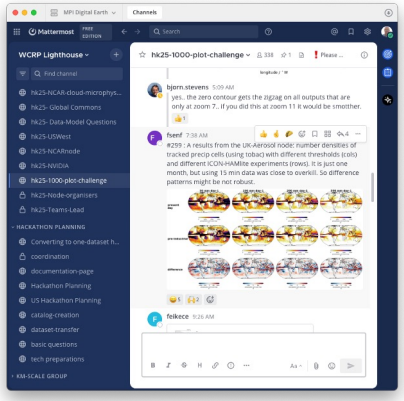
User

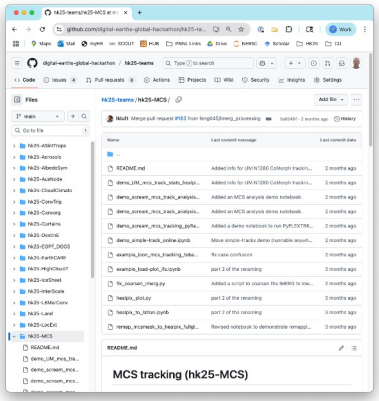
Organization

Zarr

Format

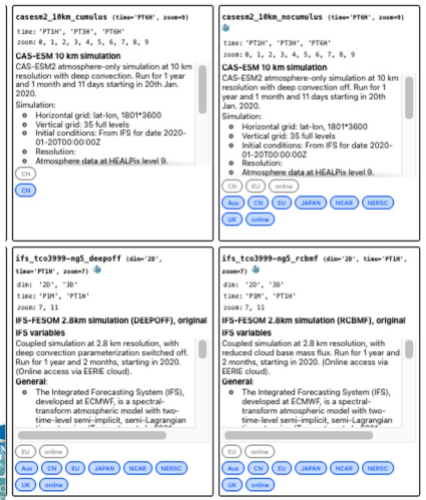
HEALPix Grids





INTAKE

Catalogs

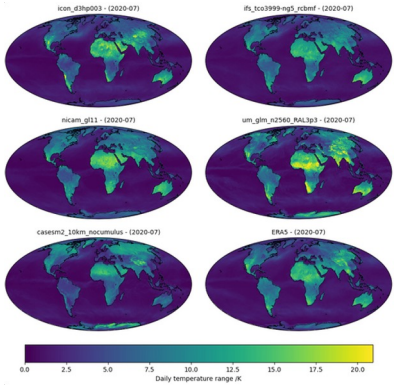


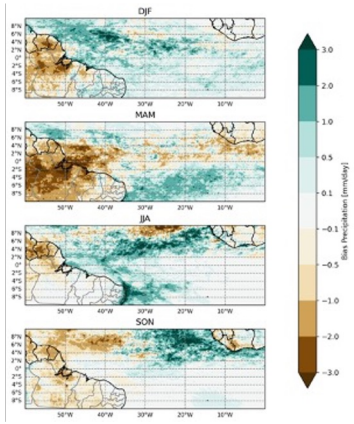
WCRP World Climate Research Programme

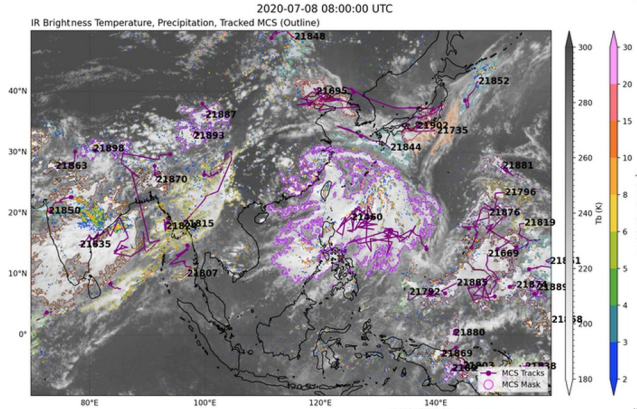
Mattermost

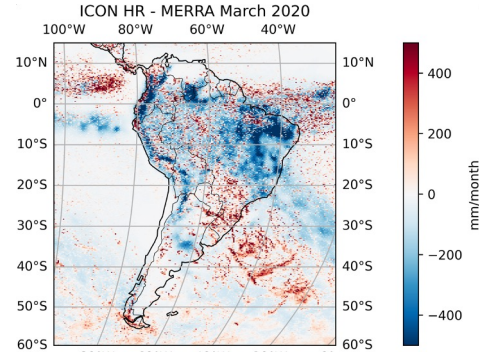
GitHub

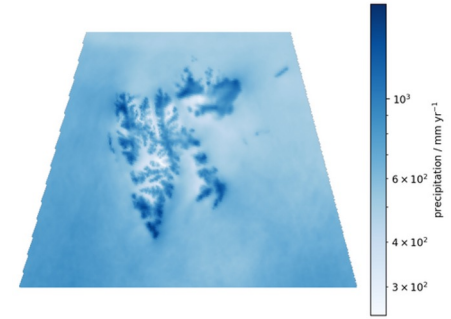
zoom

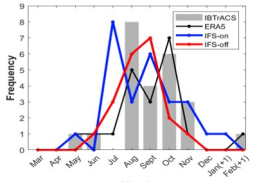

icon_d3hp003 - (2020-07)
ifs_tco3999-ng5_rcbmf - (2020-07)
nicam_gl11 - (2020-07)
um_glm_n2560_RAL3p3 - (2020-07)
casesm2_10km_nocumulus - (2020-07)
ERA5 - (2020-07)
Daily temperature range /K

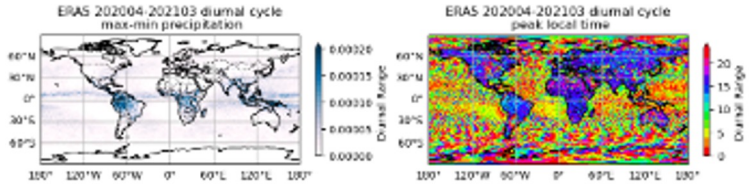

DJF
MAM
JJA
SON
Bias Precipitation (mm/day)

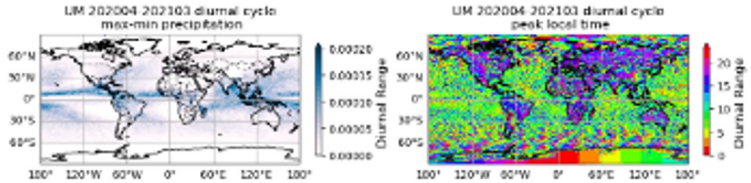

2020-07-08 08:00:00 UTC
IR Brightness Temperature, Precipitation, Tracked MCS (Outline)
MCS Tracks
MCS Mask
Tb (K)

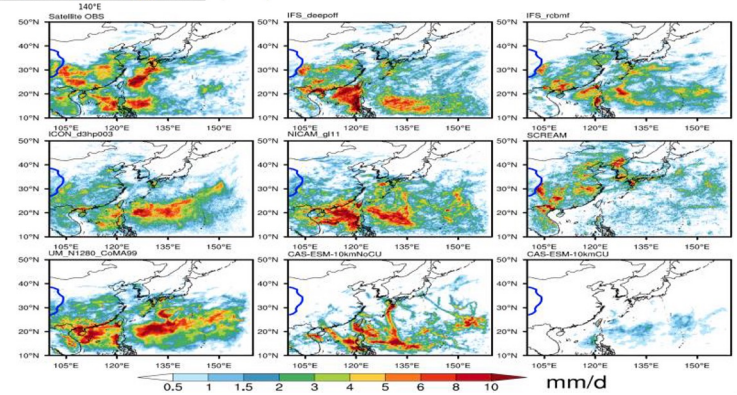

ICON HR - MERRA March 2020
mm/month

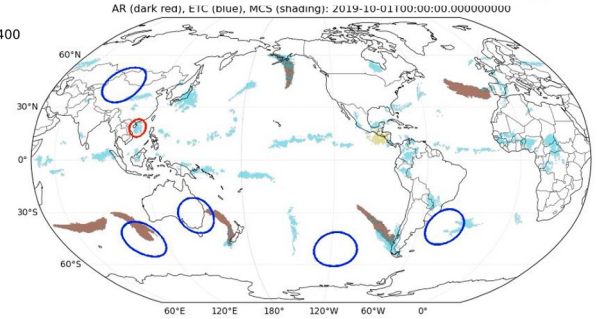

precipitation / mm yr⁻¹

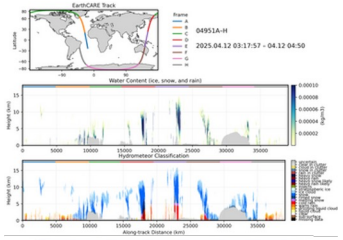

IBTrACS
ERA5
IFS-on
IFS-off
Frequency
Month

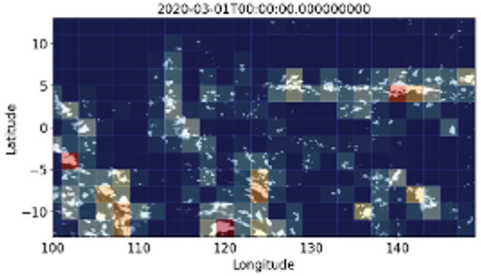

ERA5 202004-202103 diurnal cycle
max-min precipitation
peak local time
Diurnal Range

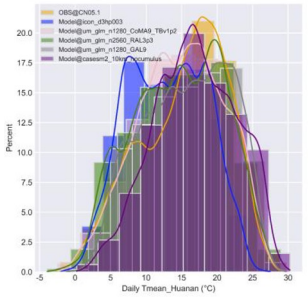

UM 202004-202103 diurnal cycle
max-min precipitation
peak local time
Diurnal Range

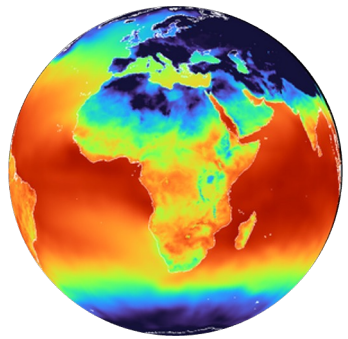

Satellite OBS
IFS_deepoff
IFS_rcbmf
ICON_d3hp003
NICAM_gl11
SCREAM
UM_N1280_CoMA99
CAS-ESM-10kmNoCU
CAS-ESM-10kmCU
mm/d

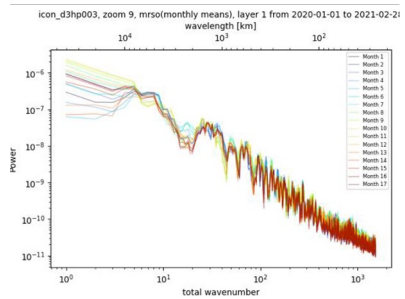

AR (dark red), ETC (blue), MCS (shading): 2019-10-01T00:00:00.000000000

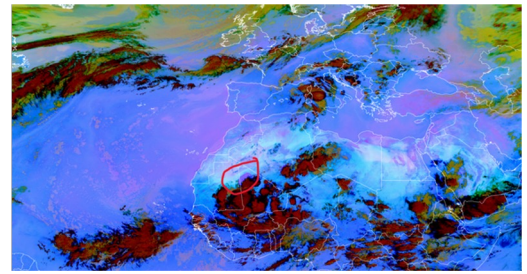

EarthCARE Track
04951A-H
2025.04.12 03:17:57 - 04.12 04:50
Water Content (ice, snow, and rain)
Hydrometeor Classification

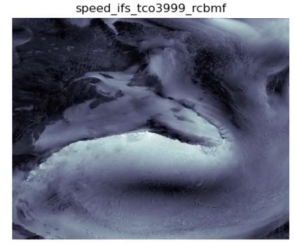

2020-03-01T00:00:00.000000000
Latitude
Longitude
Convective area fraction (%)

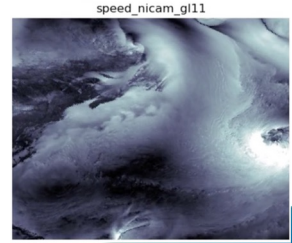

OBS@CN05.1
Model@icon_d3hp003
Model@um_glm_n1280_CoMA9_TBv1p2
Model@um_glm_n2560_RAL3p3
Model@um_glm_n1280_GAL9
Model@casesm2_10km_nocumulus
Percent
Daily Tmean_Huanan (°C)

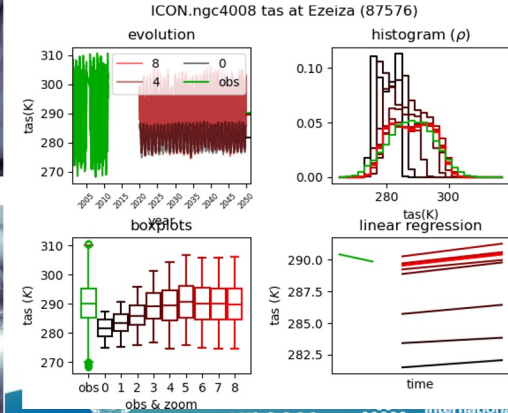


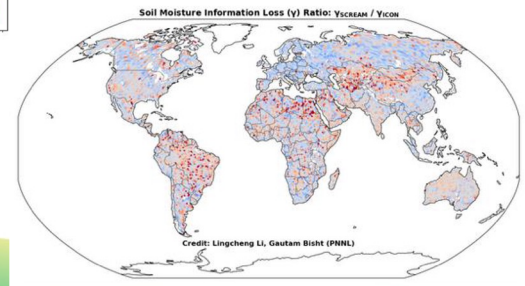

icon_d3hp003, zoom 9, mrso(monthly means), layer 1 from 2020-01-01 to 2021-02-2
wavelength [km]
Power
total wavenumber

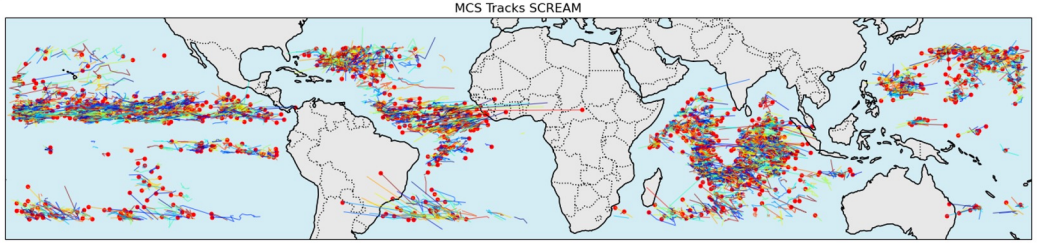



speed_ifs_tco3999_rcbmf


speed_nicam_gl11


ICON.ngc4008 tas at Ezeiza (87576)
evolution
histogram (ρ)
boxplots
linear regression
tas(K)
obs & zoom
time


Soil Moisture Information Loss (γ) Ratio: γSCREAM / γICON
Credit: Lingcheng Li, Gautam Bisht (PNNL)


MCS Tracks SCREAM

Km-Scale Model Working Group

Model/Center	Name	Location
ICON	Cathy Hohenegger	Germany (Chair)
MetOffice	Huw Lewis	UK
NCAR/Earthworks	Bill Skamarock	USA
DOE-E3SM	Hassan Beydoun	USA
NASA-GEOS	Bill Putman	USA
NOAA-GFDL	Lucas Harris	USA
NICAM	Daisuke Takasuka	Japan
COSMO (Regional)	Nikolina Ban	Austria
MCV	Xingliang Li	China
ECMWF-IFS	Benoit Vanniere	UK

Km-Scale Model Working Group

Joint with WGNE: needs some discussion

- Group has not met in 6 months or so.
- Was meeting regularly every ~ 4-6months
- Typically: updates on latest developments/ or discussion of a particular issue
- One key topic: organized convection at km-Scale
- Seems like interest from model development groups, but might need some more organization or structure
  - Could find a new chair and co-chair
  - Is the membership right
- One option: use results from km-scale hackathon to prompt a series of discussions on particular topics

Physical to Virtual Data Fusion for Climate

Chairs: A. Subramanian (Univ. Colorado), T. Beucler (Laussane univ.)

- Data Assimilation for Climate
  - Co-hosted several workshops (Boulder 2022, Boston 2024)
  - Connecting with coupled DA efforts lead by WWRP DAOS
  - Climate DA: participating in investigations of ML based DA, currently it does NOT outperform traditional methods
- Machine Learning and Data Driven Modeling
  - Coordinating efforts for Climate (with ESMO): joint group
  - Connecting to WWRP PDEF who are starting a new ML effort for NWP
  - ML Exploration in all aspects of ‘digital earth’
    - Urban Digital Twin group at UT-Austin has produced a ML Hindcast Dataset, we are helping to advertise it for community use.
  - Bi-monthly webinars and WG meetings will start soon
  - Several DE members attended GRC- AI/ML meeting in summer 2025
  - Planning a meeting on AI/ML Climate modeling for September 2026 (Boulder, CO)

Human Systems: Beyond the Physical

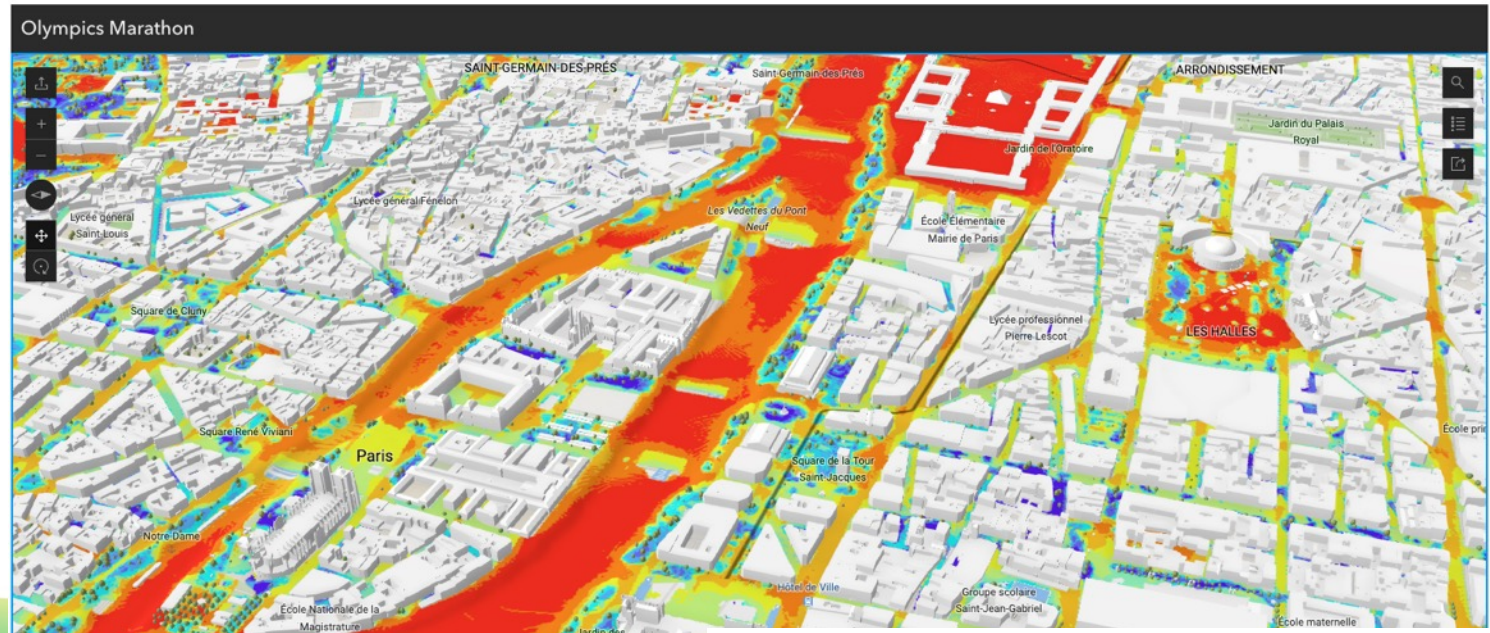
Chair: D. Niyogi (U. Texas)

- Core competencies of Earth System Models: Water, Energy, Land
  - Emerging efforts with: Hydrology, Energy Systems, Crops
  - Example: GEWEX Regional Hydroclimate Project (RHP) for the US (H2US)

- Humans dominate in Urban environments
  - Urban Digital Twin effort started: data sets, academic/city twins

  (Dev Niyogi, U. Texas)
  - Connecting with CORDEX Urban FPS
  - Also WWRP Urban warning systems project

2024 Paris Olympics Weather Forecast by Street….



https://texuslab.org/ParisOlympics

WCRP
World Climate Research Programme

Interactions with WGNE

How can Digital Earth Help?

- Machine Learning and AI
  - DE is focusing on climate (not weather generators, but climate and coupled models)
  - DA and initialization for climate simulation
- Km-Scale Model Development
  - Is the km-scale Working Group useful?
  - Goal is to nurture development and discussion of development issues
  - Focus has not been on forecasting, but km-scale model development
  - How to structure this between DE, WGNE, WGCM (and where will it eventually land)
    - This may be something to discuss as part of WGCM relaunch

Thoughts? Discussion? Next Steps?