

# Prospects for converting climate models from macroscopes to microscopes

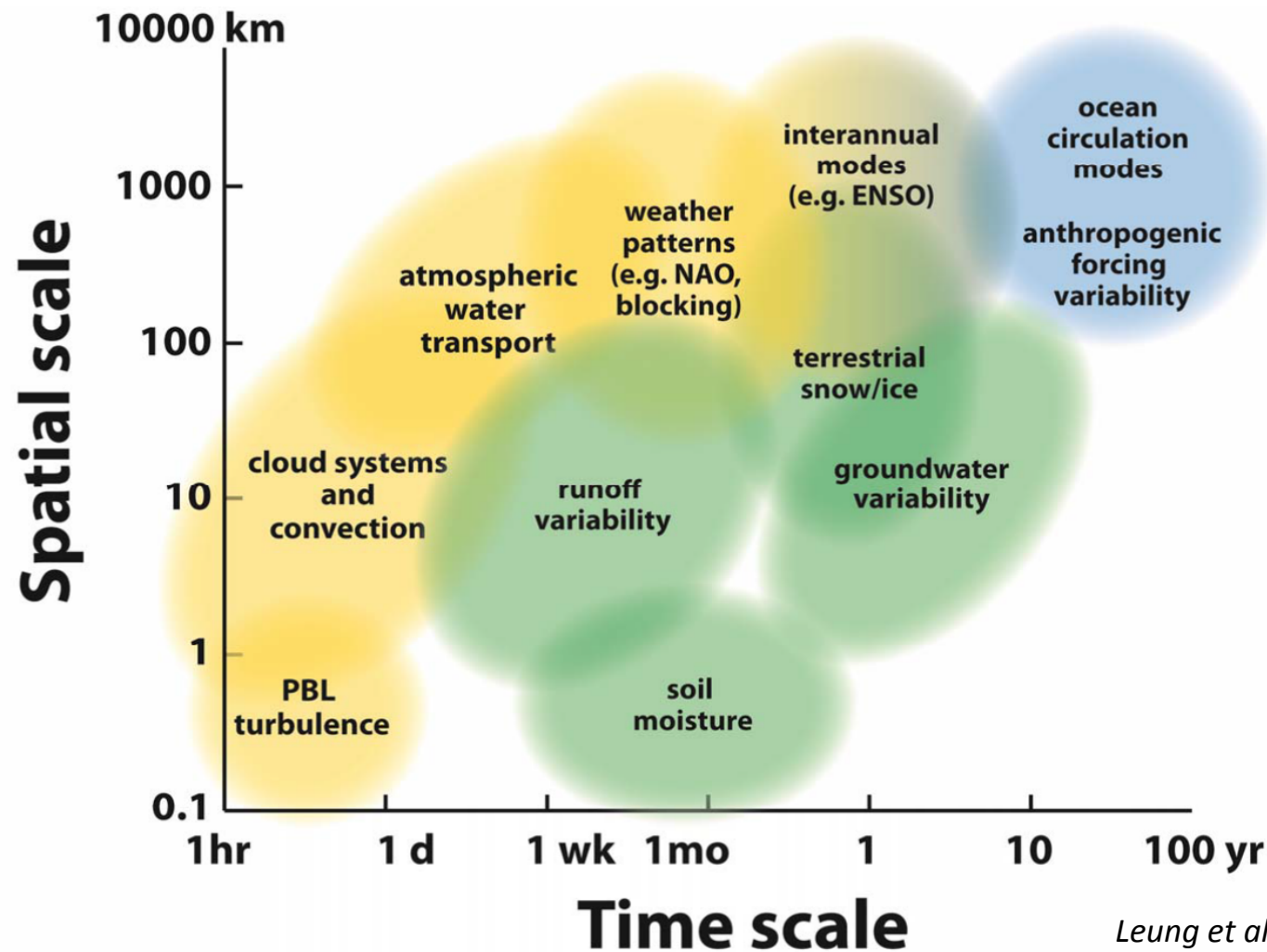


NASA

**William Collins**

*Berkeley Laboratory and University of California, Berkeley*

# Key space and time scales of the water cycle as case study



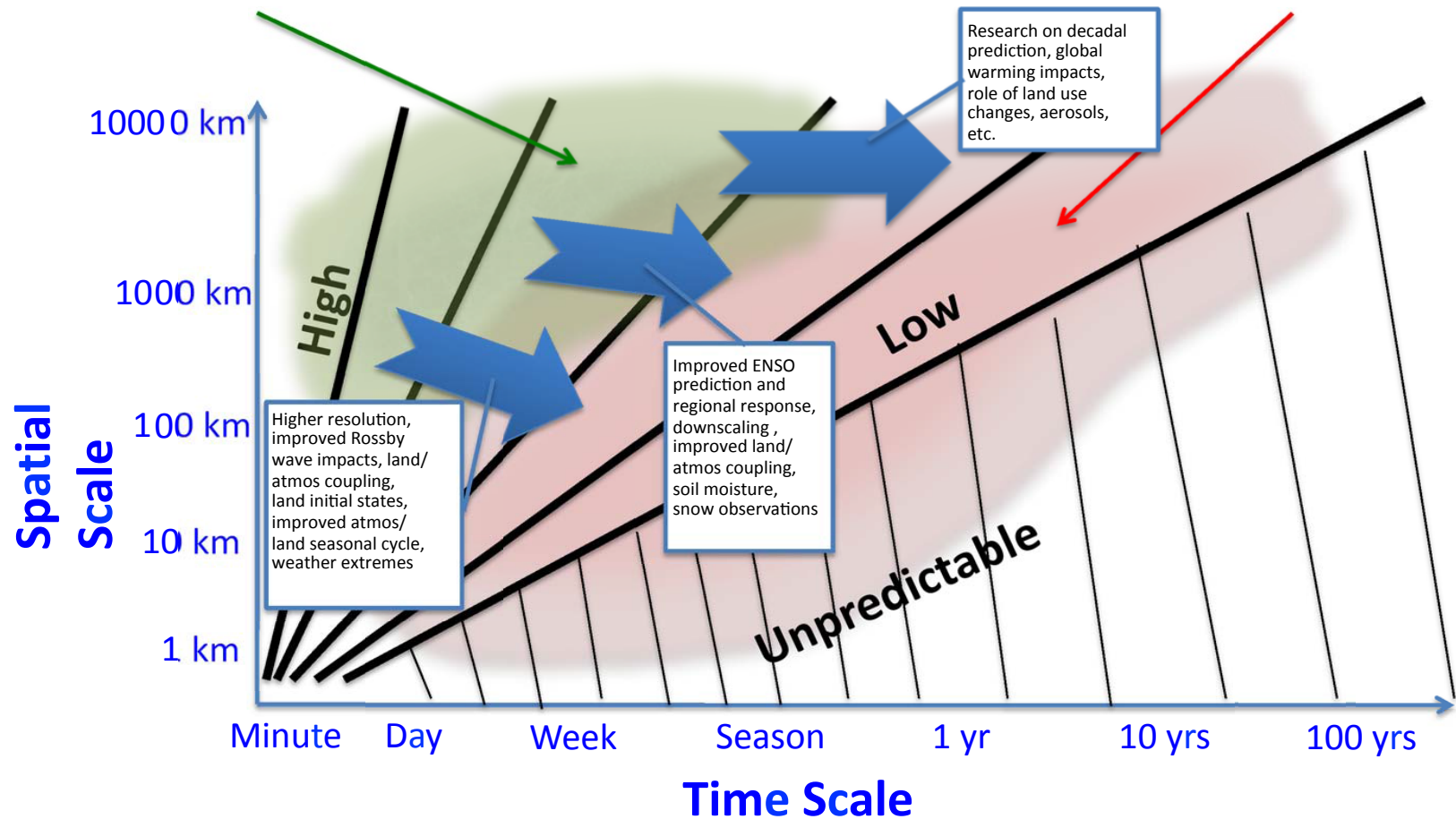
*Leung et al, 2012*



# Predictability of the water cycle

Current Skill

User Needs



Siegfried Schubert, [http://drought.wcrp-climate.org/workshop/ICPO\\_161\\_WCRP\\_Report.pdf](http://drought.wcrp-climate.org/workshop/ICPO_161_WCRP_Report.pdf)



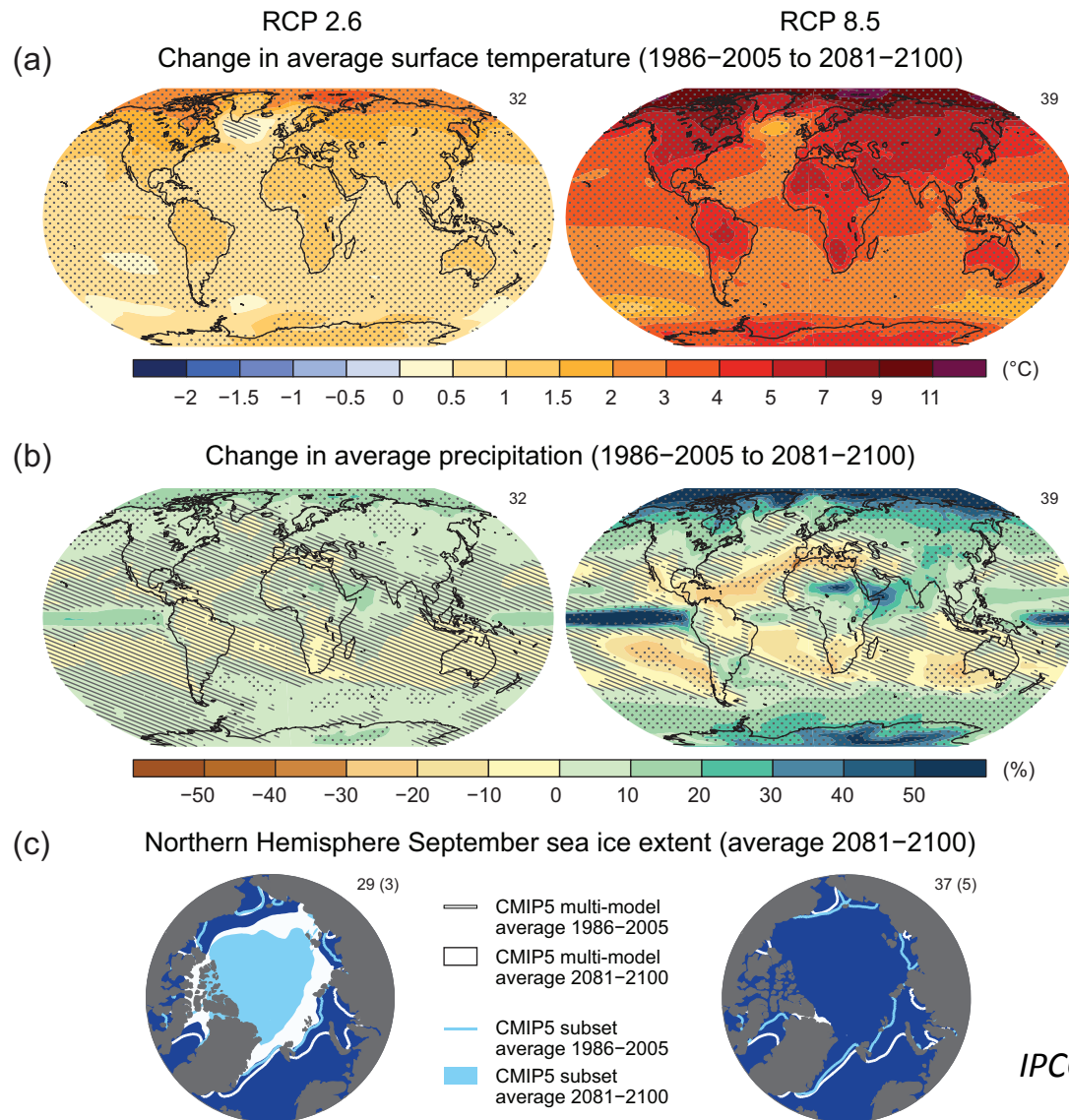
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# Greater resolution $\neq$ greater multi-model consensus

420 ppm

940 ppm



IPCC AR5



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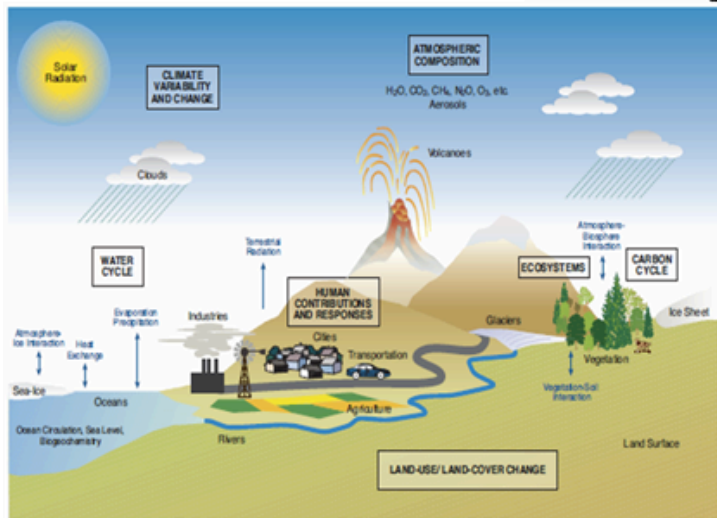
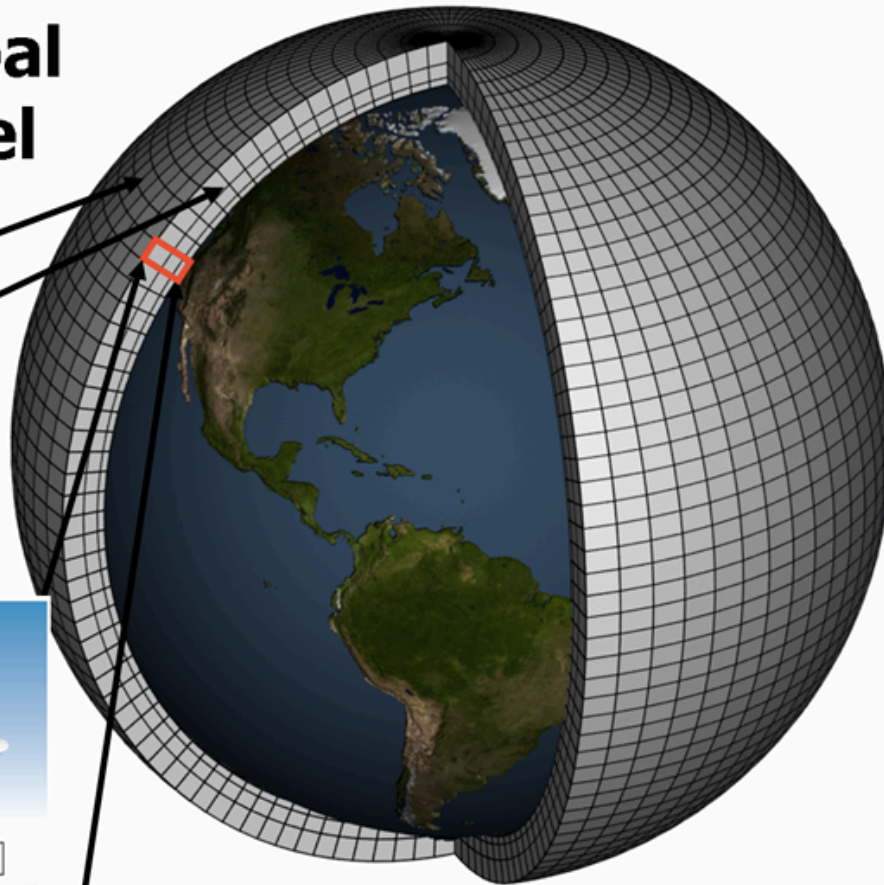




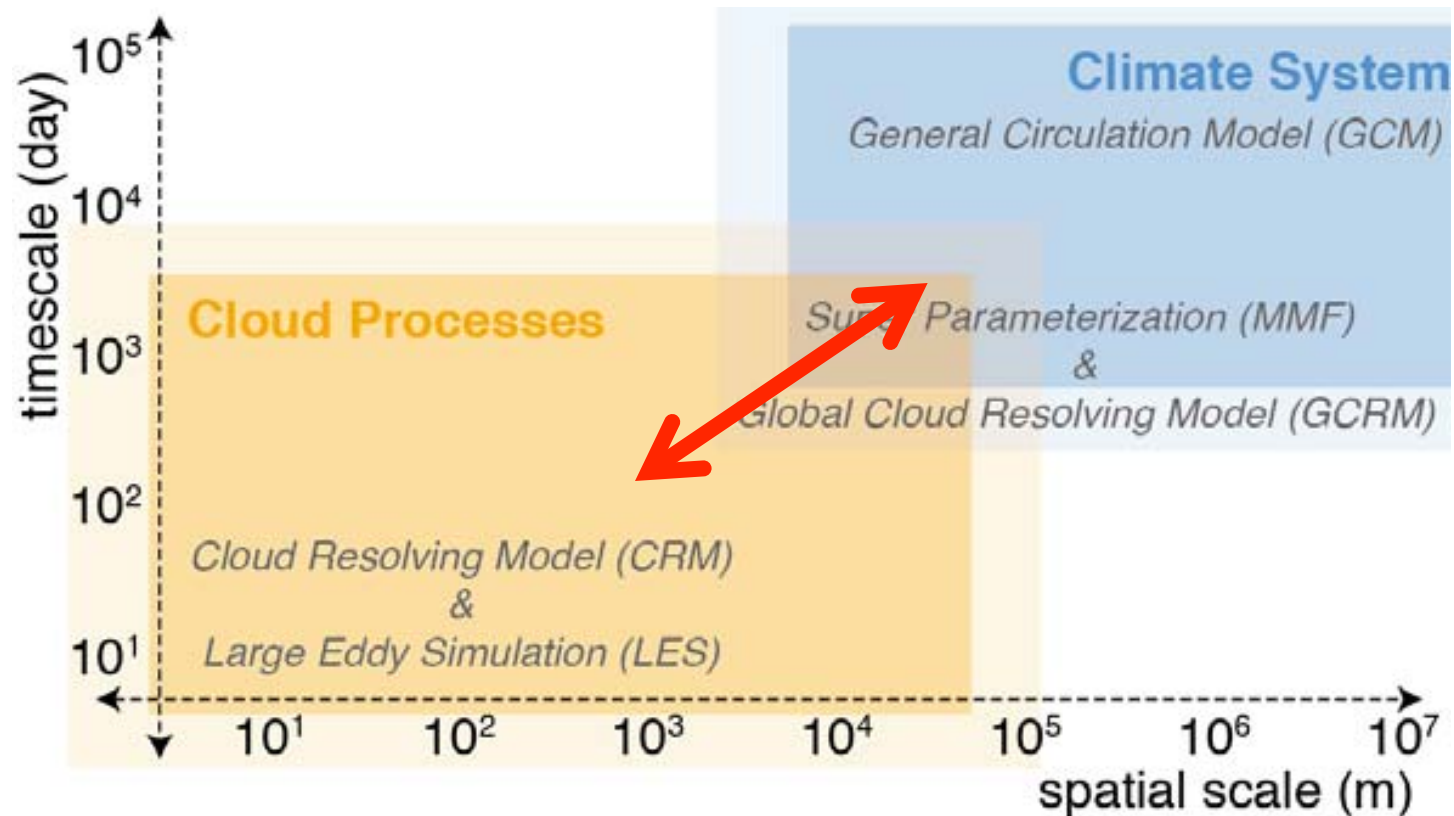
## Schematic for Global Atmospheric Model

Horizontal Grid (Latitude-Longitude)

Vertical Grid (Height or Pressure)

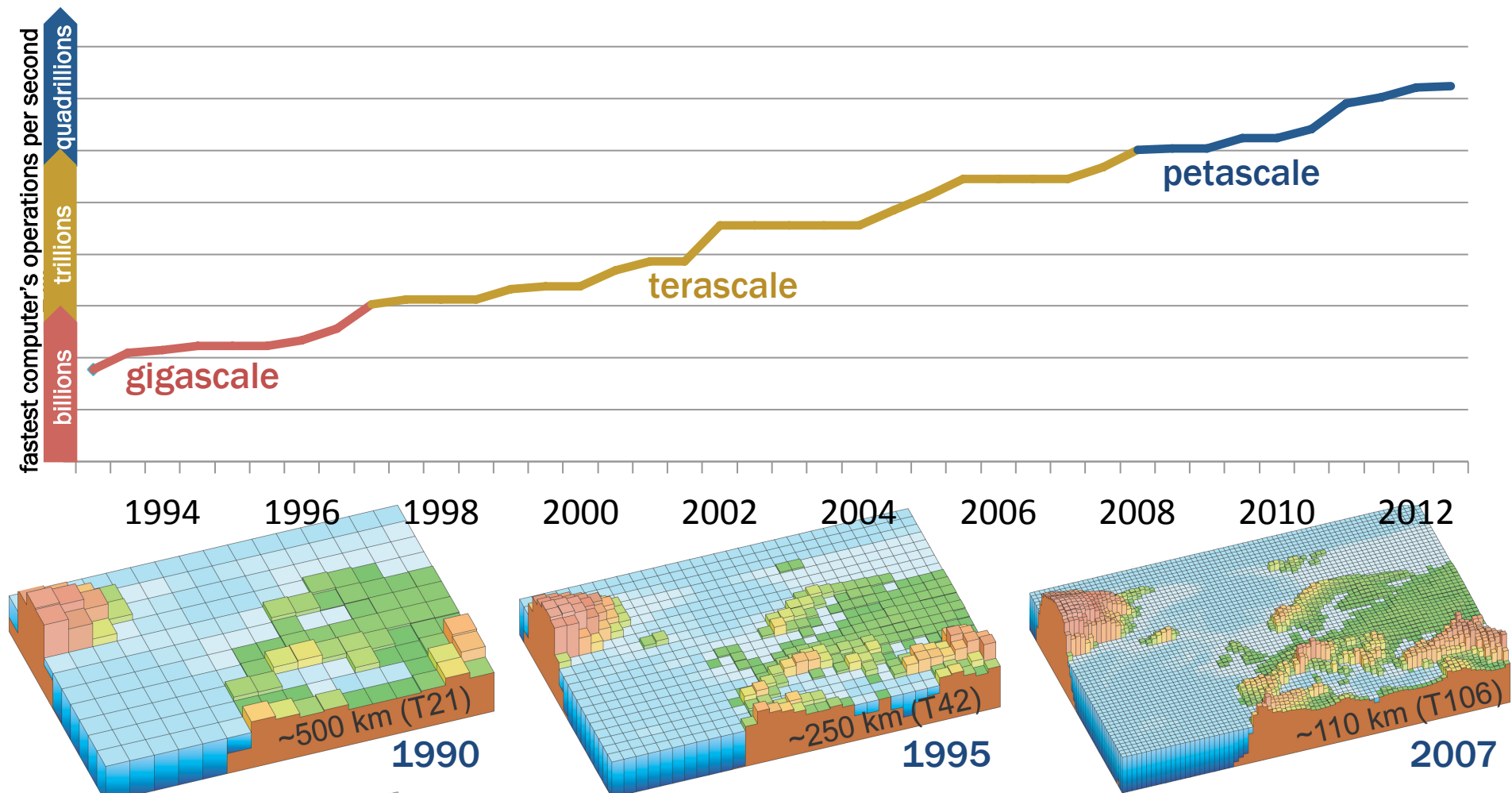


# New types of climate models can bridge to local scales



IPCC AR5 WG1

# Computing has enabled regional to continental projection



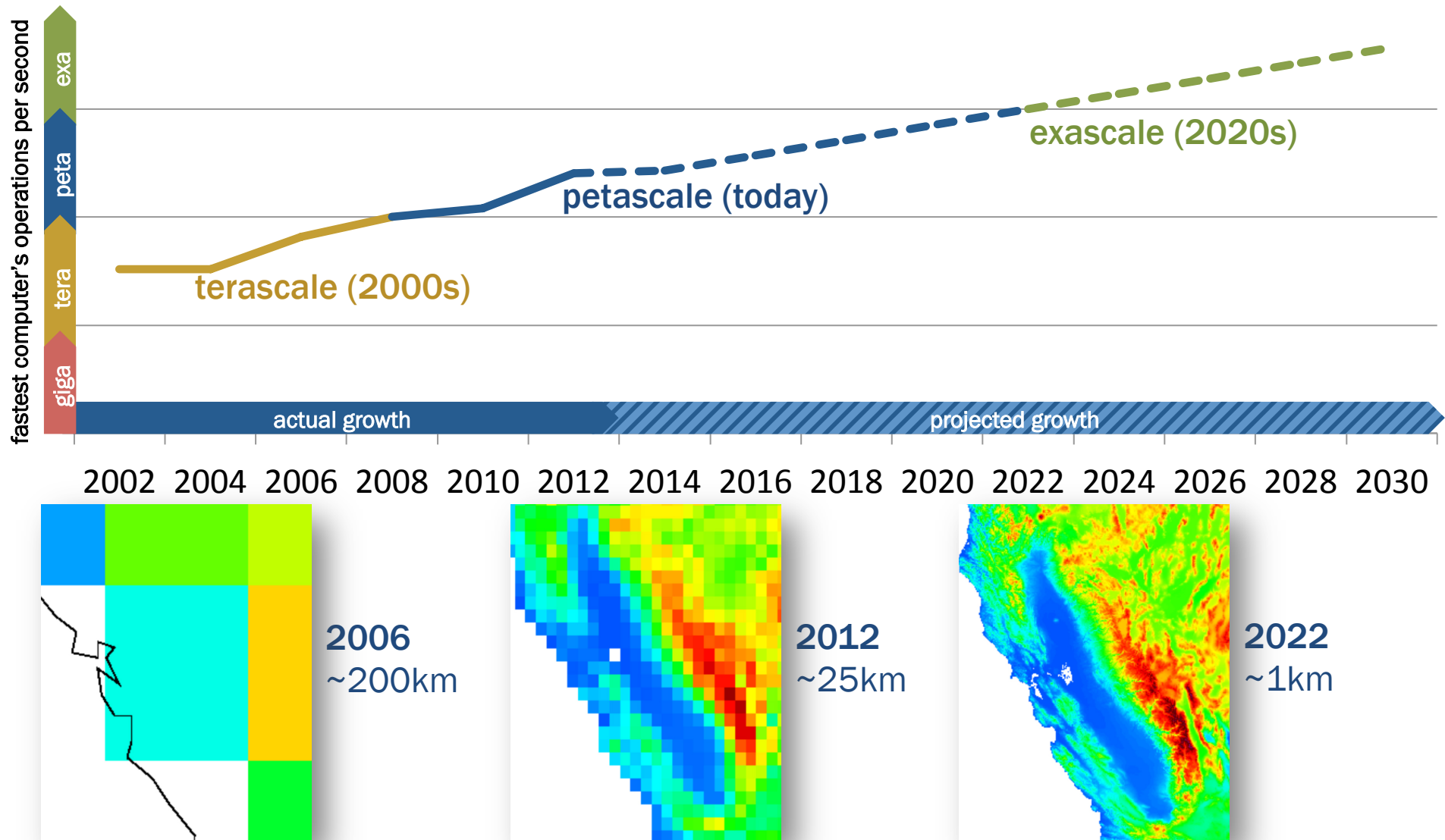
## Historical impacts of computing power



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# Exascale will enable localized projection





# Technology is disruptive – and that can be empowering

iPad 2



Cray 2

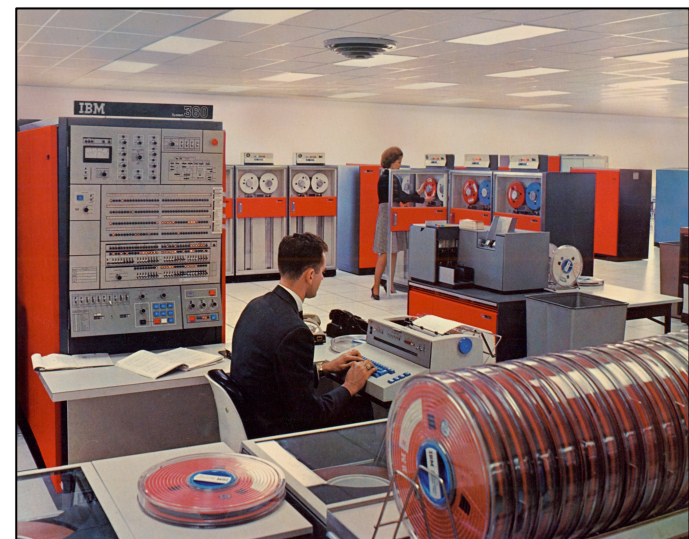


|v|

iPhone 6



IBM 360

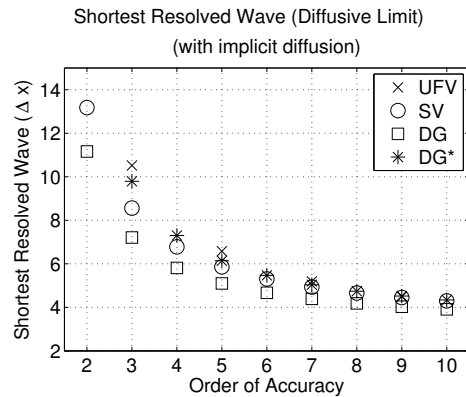


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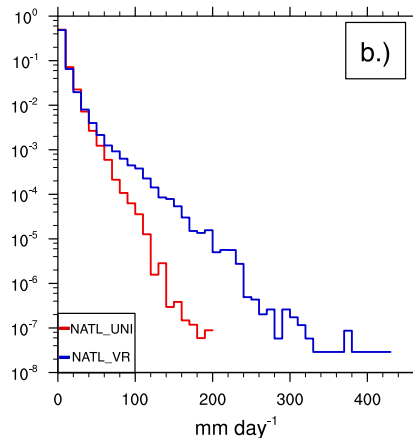
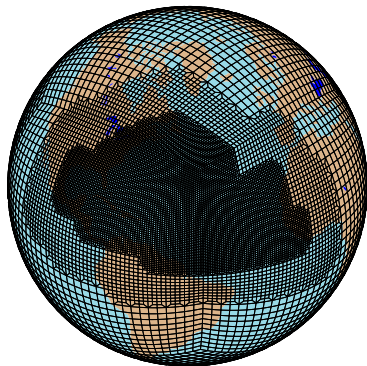


# Variable resolution can accelerate progress



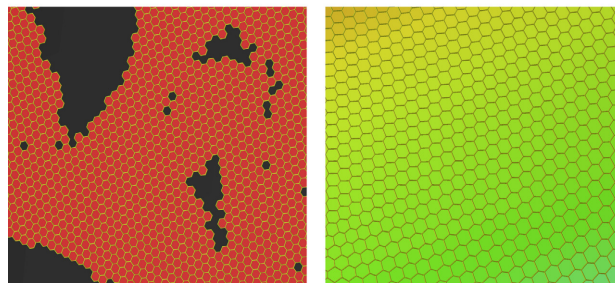
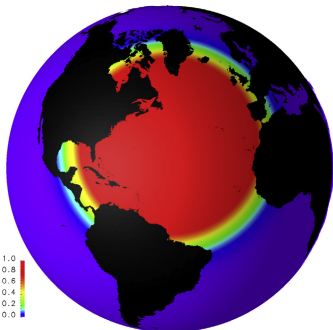
**Resolving features at the onset of non-hydrostatic, 3D motion in the atmosphere will require resolutions of  $O(1 \text{ km})$ .**

*Ullrich, QJR Met Soc, 2012*



**Regional static mesh refinement is being developed to increase resolution only where such features must be resolved.**

*Zarzycki et al, J. Climate, 2015*

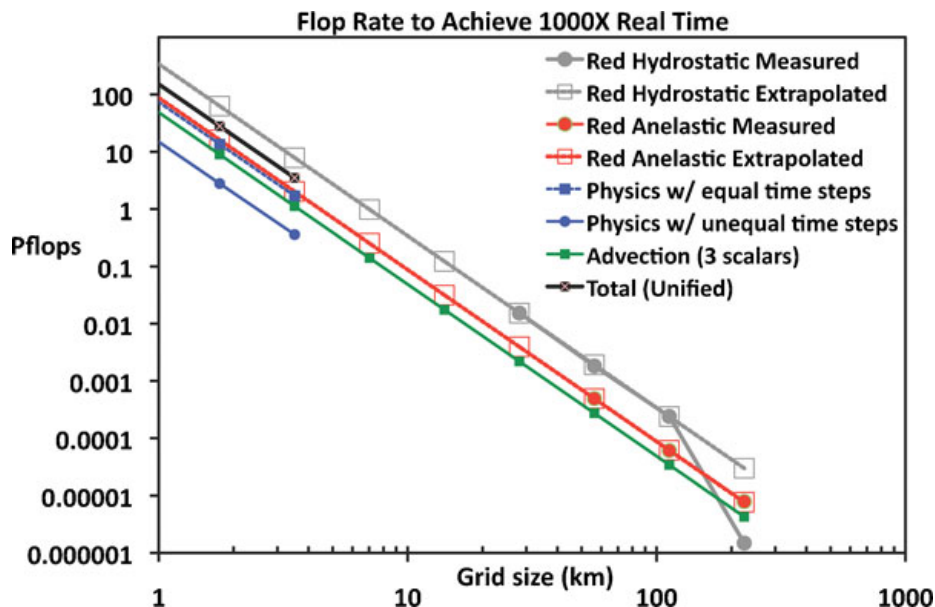


**Similar research is underway in ocean modeling to provide regional, high-resolution, “eddy-allowing,” codes**

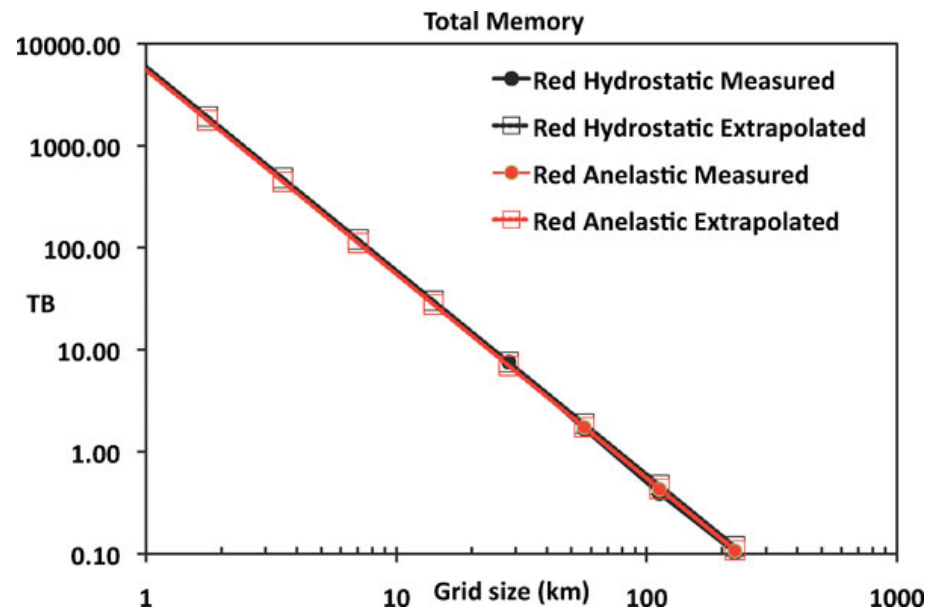
*Ringler et al, Ocean Modeling, 2013*

# Localized models are demanding

## Computational throughput



## Memory usage



Models of this class will break the atmosphere into 100 billion cells.

... Imagine averaging 100 billion numbers just to get the mean temperature.

# Critical role of numerical software package

Factor	Trend	App Requirement
Concurrency	$10^8$ PEs	1000x improvement
Reliability	Much shorter MTBF	Adaptive error management
Power Consumption	Must be $\leq 25$ MW	100x improvement

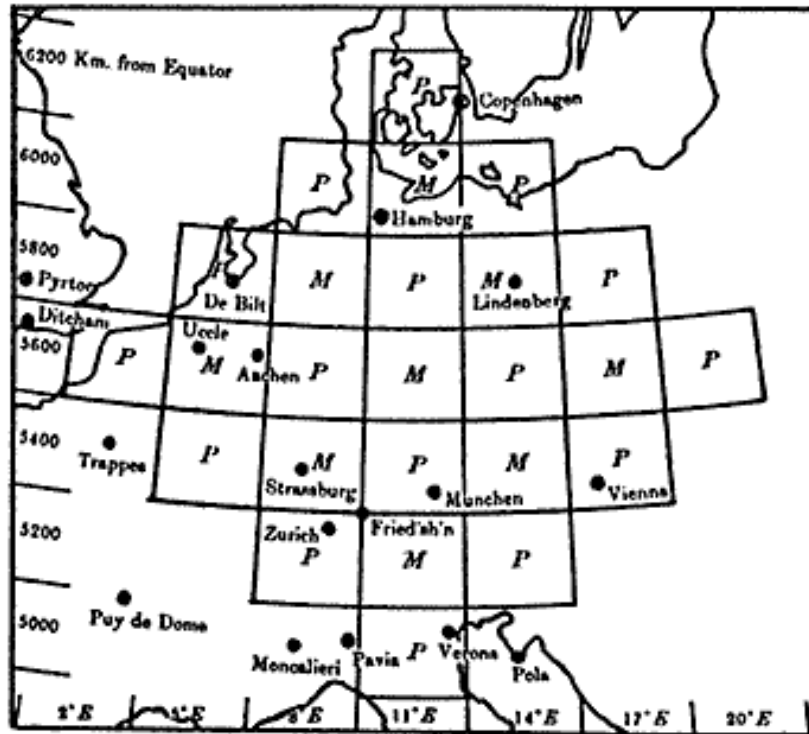
Challenges faced by applications will require major advances in technology.

Dongarra et al , 2011



# Analogy to Richardson's human computer for weather

Richardson's WWI Europe Predictions



His Conceptual (Human) Weather Computer



Imagine coordinating the work of  $O(100 \text{ million people})$  working on a single problem...

... That's the number of tasks to be coordinated for exascale climate projection.



- On July 29, 2015, President Obama signed an Executive Order establishing the ***National Strategic Computing Initiative.***
- The NCSI has 5 strategic themes:
  1. ***Create systems that can apply exaflops of computing power to exabytes of data***
  2. ***Keep the United States at the forefront of HPC capabilities.***
  3. ***Improve HPC application developer productivity***
  4. ***Make HPC readily available***
  5. ***Establish hardware technology for future HPC systems.***



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A high-resolution photograph of Earth from space, showing the curvature of the planet and a bright sun in the upper center. The word "Questions?" is written in white text across the upper portion of the image.

Questions?