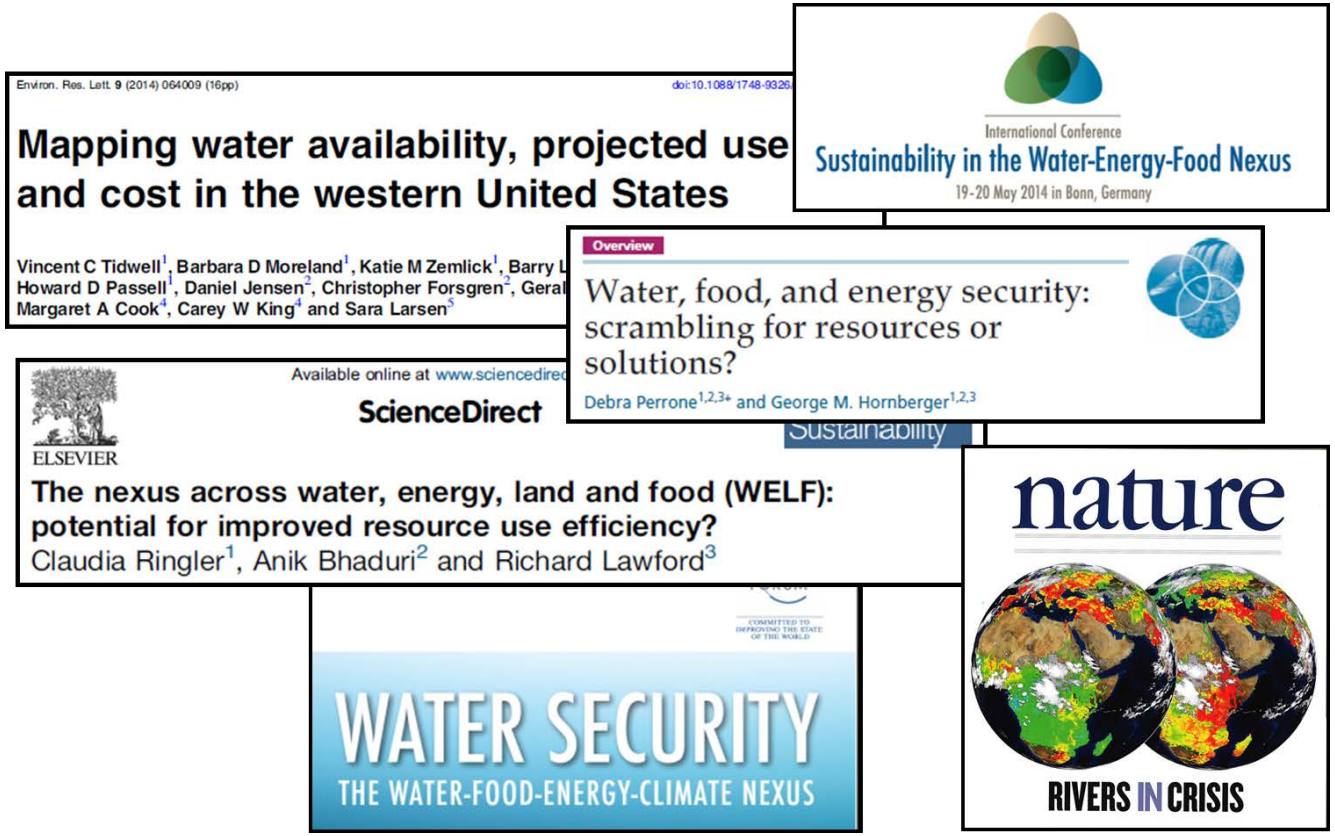
Envisioning a Terrestrial Systems Model

Tom Torgersen
Hydrologic Sciences
National Science Foundation

INFEWS Working Group

Food, Energy, and Water Systems

Growing populations, changes in land use, increasing geographic heterogeneity & seasonal variability … place increasing stresses on the critical resources of food, energy and water (FEW).

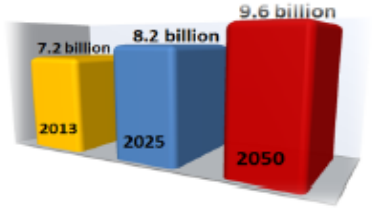


Multi-agency efforts…

FOOD-ENERGY-WATER SYSTEMS: THE 2050 PICTURE

WORLD'S POPULATION BOOMS

>9 BILLION by 2050



Larger, more urban and richer population

33% increase

Food production will need to increase ~60%

2010 2050

FOOD

Image credit: http://www.aquate.com

Water demand will increase ~30%

2010 2050

WATER

Energy production will need to increase ~50%

2010 2050

ENERGY

F, E, W, concerns are not going away … a complex coupled problem… personal security

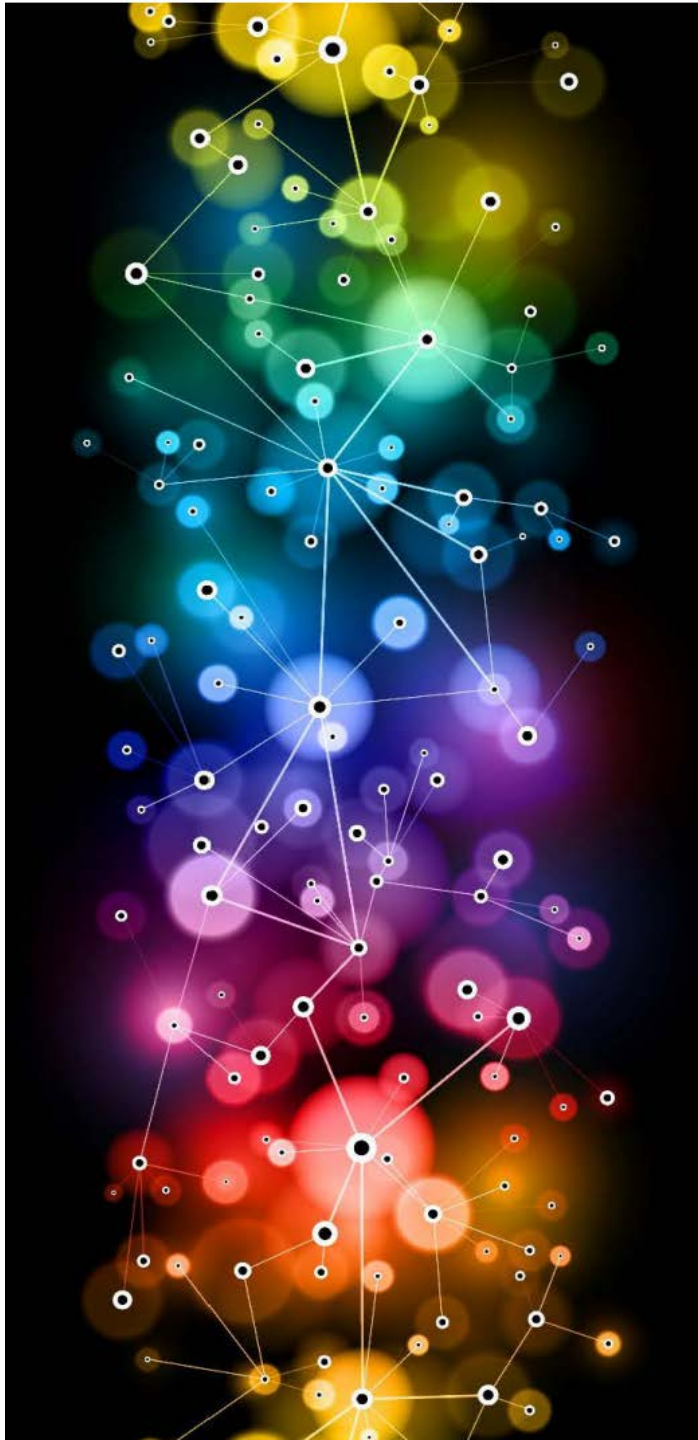
FEWS

...is a dynamic, coupled system of systems:

- 3% of US electricity is used to pump, treat, & transport water
  - This could account for 90% of energy on some farms
- 50% of water withdrawals in the US are for thermoelectric power plant cooling
- 30% of water withdrawals in US are for irrigating crops
- 10% of the US energy budget is associated with food production, processing, distribution, etc.

FEW

- F.E.W. are the people-security issues that describe the interactions of humans and the planet. Adding “Health” makes it universal…
- F.E.W. …Human interaction with the planet is ubiquitous and significant
- Solutions: tech/social… ask the right Question
- Convey information, multi-level… multi-discipline; convergence and education



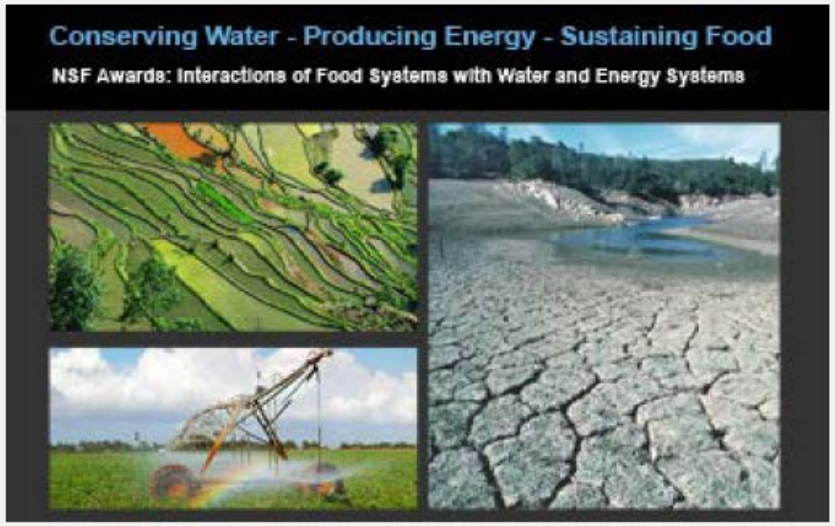
Innovations at the Nexus of Food, Energy and Water Systems

- **FY15-18… NSF $170M**
  - Integrated systems modeling;
  - Effective data integration/cyber elements;
  - Innovative tech/soc solutions;
  - Support education, workforce and community development

Press Release 15-090

New grants foster research on food, energy and water: a linked system

Amid population growth, drought and increased urbanization, understanding food, energy and water availability is increasingly important



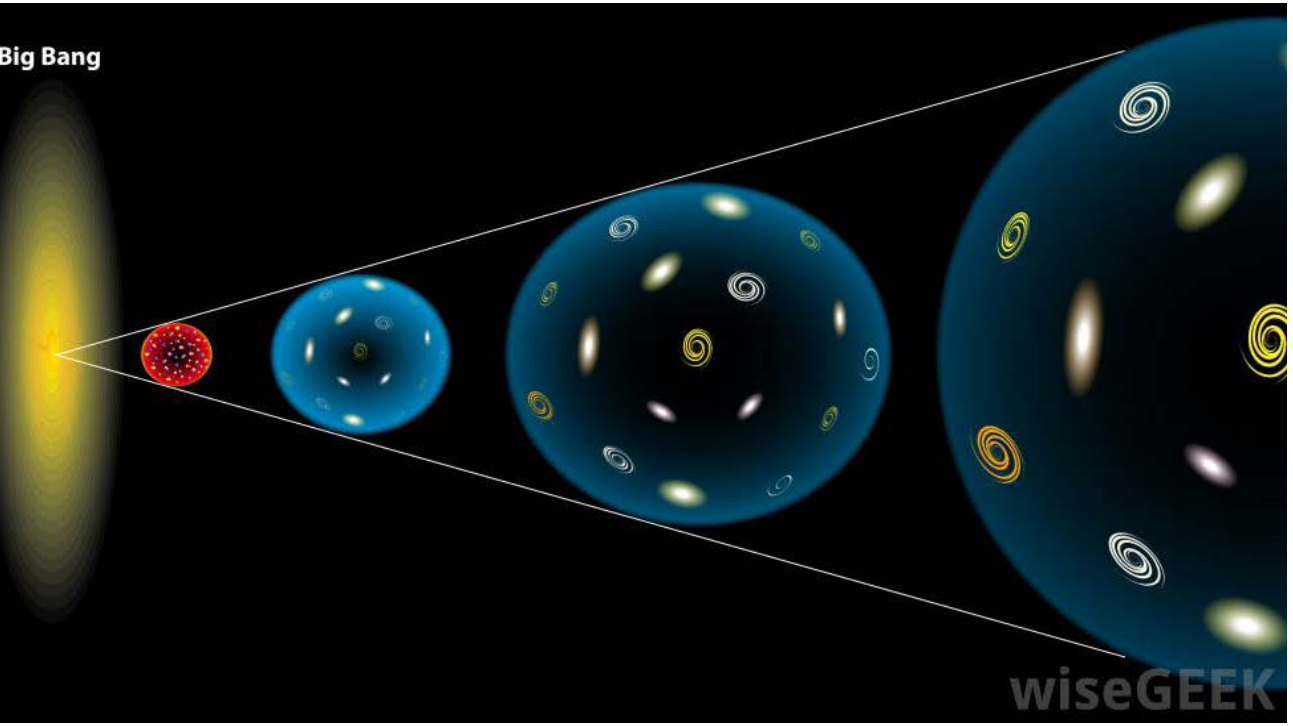
How food, water and energy systems interact: a photo gallery.
Credit and Larger Version

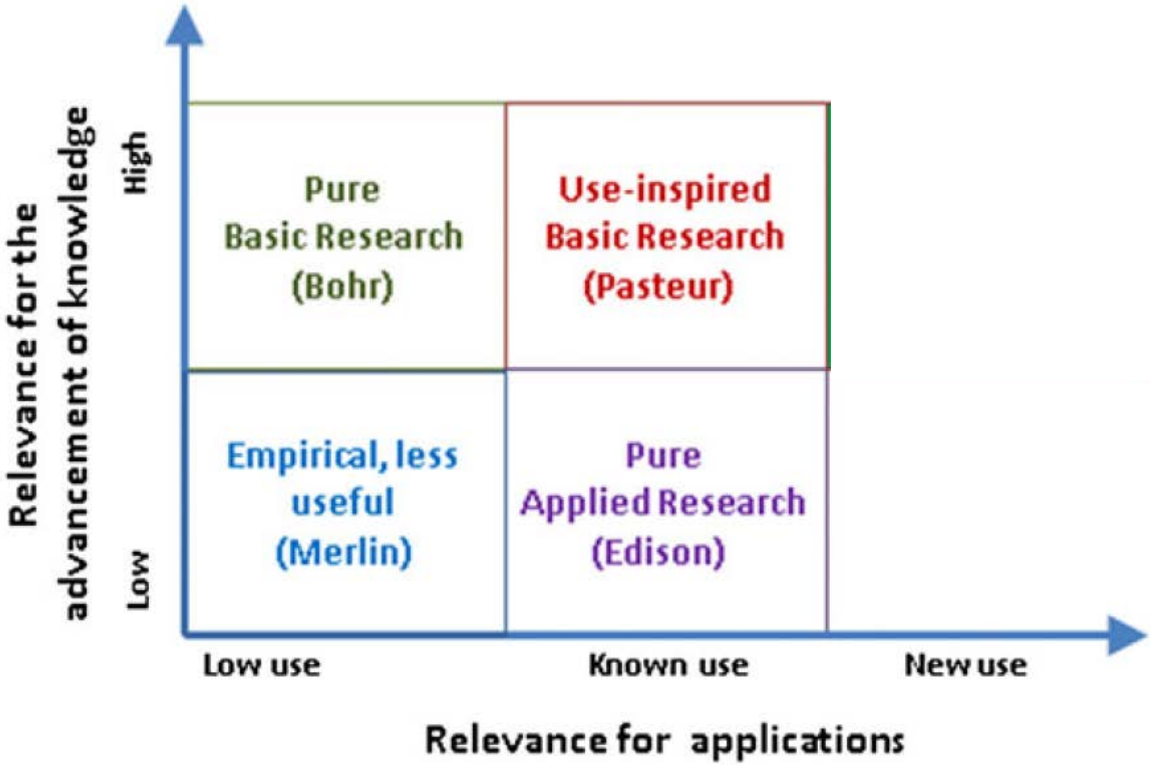
August 14, 2015

In a world where a growing number of people lack food, water and sources of energy, providing these resources has become a challenge.

To find new answers, the National Science Foundation (NSF) has funded 17 grants, totaling $1.2 million, to support workshops on the interactions of food, energy and water, or FEW. Additionally,

What do we need to know… now?
Use-inspired… Pasteur's quadrant





The current state of the problem …

- Understanding how natural, engineered and human processes interact as a complex coupled systems across the natural, built and altered environment… challenge and opportunity
  - Need to “test” policy scenarios …impacts
- These coupled systems interactions require not only multi-disciplines and multi-agencies, etc… but also raise additional issues
  - Communication is an issue to pose the question
  - Translation to public is an issue…
  - Input/output of data/knowledge/information
- Can’t measure everything, everywhere and all the time….
- ***We recognize a multi-disciplinary opportunity, a scientific challenge and a responsibility to more fully develop our understanding of the terrestrial system (99.9%).***

Where does this lead NSF "discovery science"? …the terrestrial system science

- We live in terrestrial/tech/human environment
  - couples and feedbacks….
- Investigating the impact of LULC change, population change, population migration, crop/forest changes, urbanization, climate
- …<u>need specificity of the environment … we need fine resolution ($\Delta x \Delta t$) to enable feedback loops;</u>
- CZOs, LTARs, etc. discover new couplings among components of the environment leading to further nonlinear responses and multiple threshold/tipping-pts overall complexity
- We need "observational and computational horsepower"
- <u>New soc/tech for "fixes"; we need to communicate knowledge and knowledge for decision-making</u>

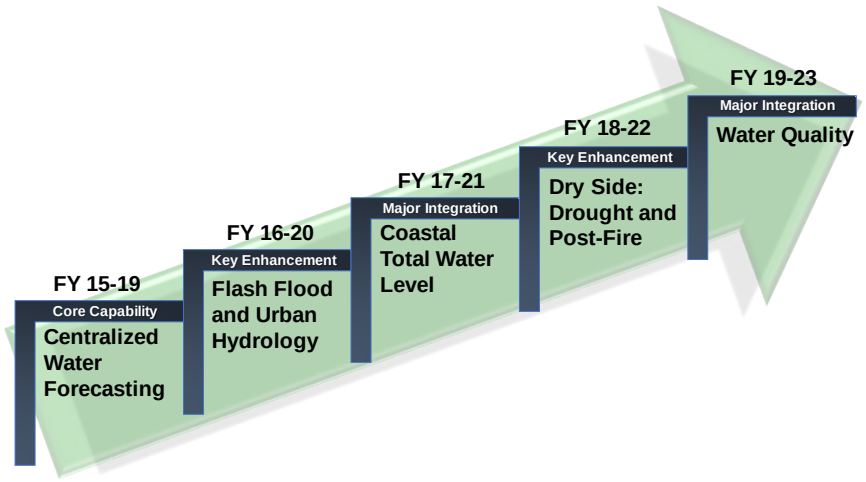
What are the immediate and long range research goals of a focused effort in terrestrial modelling?

- … enhance understanding of human/terrestrial sphere through CONUS modelling … the broader impact is significant … Why CONUS?
  - Ogallala
  - San Diego
- … CONUS-scale terrestrial modelling … scalability and transferability
- … research needs across issues of $\Delta x \Delta t$ heterogeneity and interpolation
- … the coupling of multi-disciplinary layers and how are they to be accommodated within modern computational capabilities
- … modelling requires straddling disciplines and minimizing "stovepiping" across disciplines and agencies?

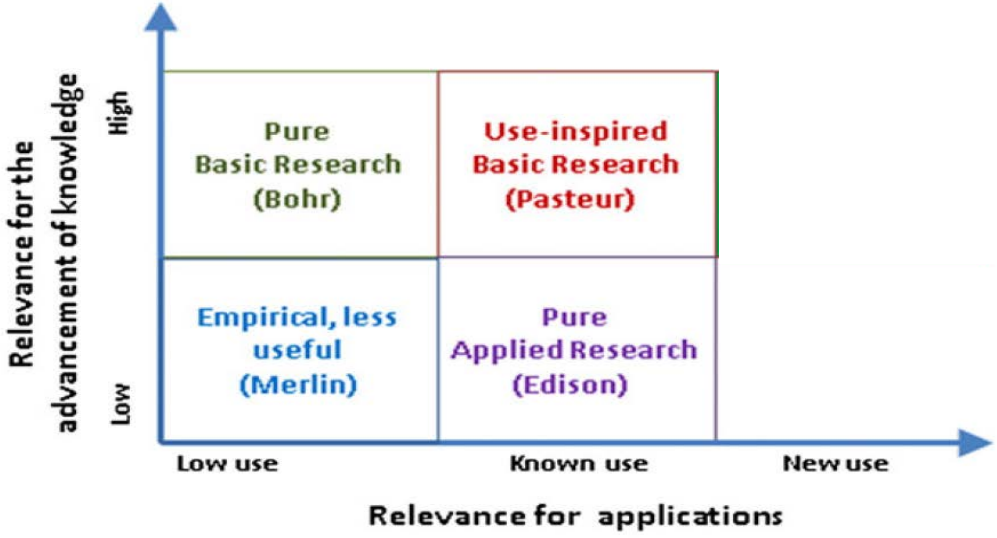
The Outlook… context

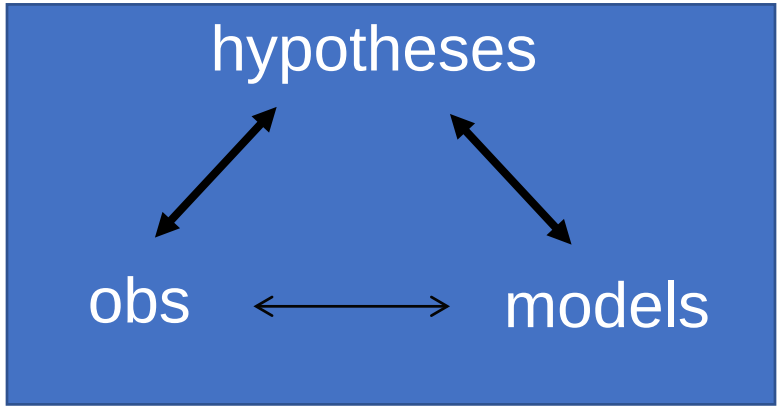
- CENRS Cmtee recognized the need for a framework for a natl hydrologic model …. Multiagency context to better understand, implement and utilize
  - Water-use data for water availability
  - Utilization of nontraditional waters
  - Groundwater sustainability
  - Open Web-available data streams from multiple sources
- NOAA/OWP is creating NWM (NWC, Tuscaloosa): R2O/O2R
- DOE has “Community Model of…Integrated Water Cycle” All of which should be linked within framework to be best used/compared

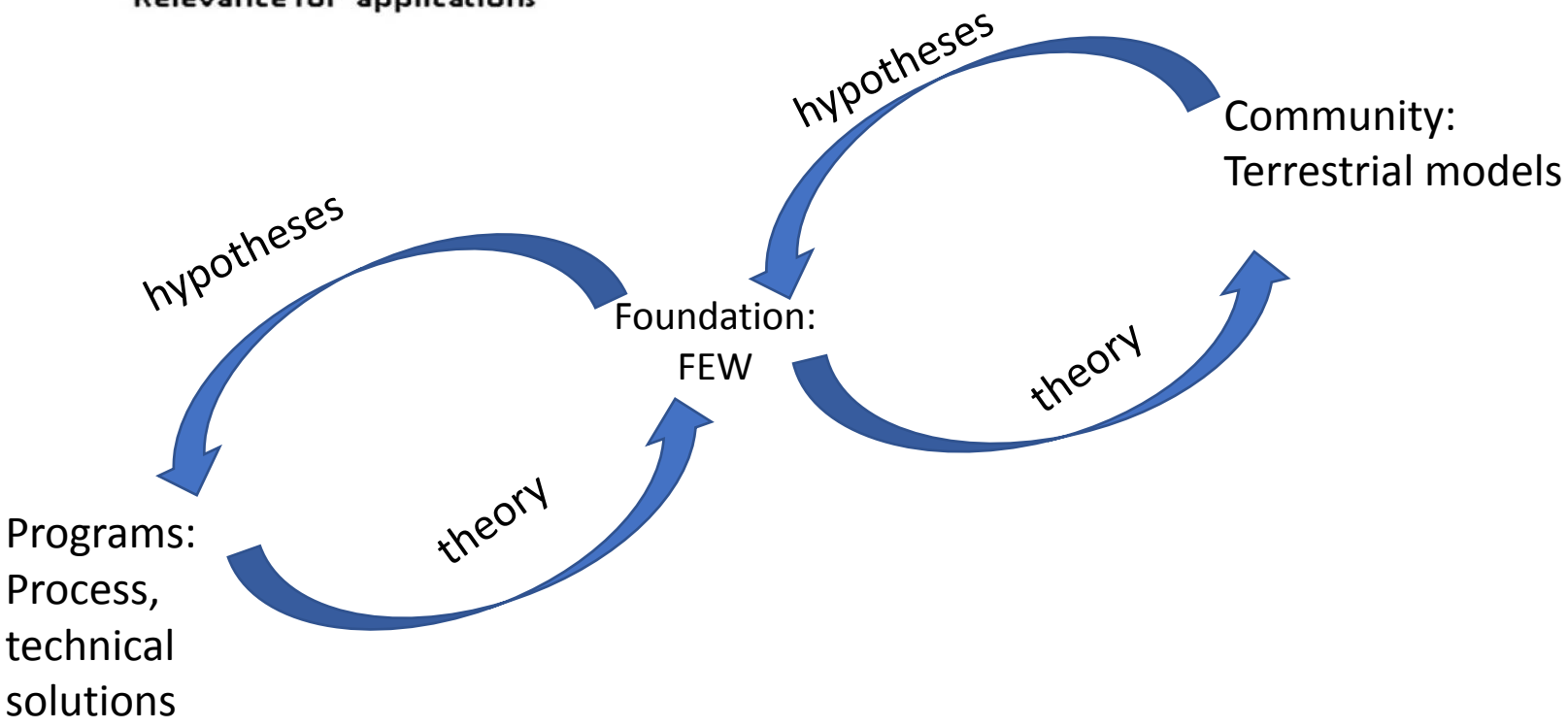
NWM at NWC



- NOAA is building NWM… R2O/O2R
- Research copy … of this NWM
  - Need to build-out complexity layers, process understanding … based on e.g. INFEWS, agency needs … in the RESEARCH COPY
  - Assimilate OBS and other data streams, appropriately scaled/calibrated
  - Need to build out “std” input for models
  - Need to build cyber-interface “std” output that is available to industry, citizens, agencies, local governance, etc.
  - a research program in modelling the terrestrial environment…


Relevance for the advancement of knowledge
High
Low
Pure Basic Research (Bohr)
Use-inspired Basic Research (Pasteur)
Empirical, less useful (Merlin)
Pure Applied Research (Edison)
Low use
Known use
New use
Relevance for applications


hypotheses
obs
models


hypotheses
Community:
Terrestrial models
theory
hypotheses
Foundation:
FEW
theory
Programs:
Process,
technical
solutions

Terrestrial Modelling goals

- Systems models that include/identify important coupled processes
- Research challenges with research impacts; not be a task list
- Compare/contrast multiple CONUS-scale models at multiple scales
- Compare/contrast multiple plot-scale models at multiple locales
- Discover/Assess system resilience; impact of adaptation and mitigation
- Search for/define tipping points and failure
  - How to search for risk of failure in complex coupled systems?
  - Risk Minimization across multiple foci not optimization of one goal
- Scalability in space and time; continental/national assessment scaled to county level assessment and action; CONUS to GLOBAL
- Cyber interfaces for data/in and data/out for public and business

- **<u>Terrestrial Modelling Research Program …</u>**
- Synergistic with agency missions
  - Model feeds problems to process research programs
  - Processes add detail to model
- Would require real-time data assimilation from multi-scale sources(obs, satellites, sensors, etc. (calibrated/validated)
- NWM could be used to design the framework (with agencies)
  - allows multi-model development and ensemble predictions
- serves natl “good” and multiple agency missions ... Each agency (partner?) contributes as per mission but all benefit

END