NSF IIS-GEO workshop – Position Statement - Pierre Lermusiaux, MIT – 03/20/2015

1) 2-3 computing innovations in recent years that you believe have had the most impact in your field

- *Distributed and cloud computing*: allows efficient parallelization of computational fluid dynamics and ocean dynamics codes, and higher-order simulations for high-fidelity scientific exploration and applications
- *Nvidia graphic accelerator / GPU*: this has the potential to further accelerate computations and allow machine-intelligent analysis of complex data sets and large-scale inference
- *Improved object-oriented software for incubation of ideas and methods:* Matlab, Python, C++
- *Faster CPUs and cheaper data storage*
- *Social media software and hardware*: this definitely has a big indirect impact

2) Science challenges that you think would benefit from innovations in intelligent and information systems research.

Computational science and engineering challenges:

- *Bayesian inference of dynamical models*: Rigorous Bayesian inference of stochastic dynamical models for complex "big" systems such as the ocean (or any geoscience domain). Machine-intelligent computational systems that compare scientific hypotheses and stochastic dynamical models (differential equations) in a rigorous fashion, rank and combine models, suggest new equations or discover better models. This machine learning for geosciences occurs both forward and backward in time, and on multiple scales
- *Adaptive computational methods and systems:* dynamic computational systems that evolve based on the predicted dynamics and the measurements collected. This can include adapting the resolution and computational scheme but also updating the model itself throughout the computations.
- *Agent-based discovery*: Computing agents that decipher complex data or dig in complex model outputs, collaborate among each other, and then provide inputs or synthesis suggestions to scientists.
- *Adaptive and intelligent sensing robots:* optimal marine sensing using collaborative swarms of heterogeneous autonomous platforms (in the ocean: AUVs, gliders, ships, moorings and remote sensing platforms) that are smart, i.e. knowledgeable about the predicted environment and uncertainties, and about the predicted effects of their sensing.
- *Visualization*: Automated and interactive visualization of multivariate data sets (multi-dimensional multi-field visualization), discovery and automated extraction of complex features, visualization of uncertainties and probability density functions

Ocean science and engineering challenges:

- *Multiscale and nonlinear ocean interactions:* such nonlinear interactions at varied time and space scales are not yet well understood and are harder to discover by humans and to simulate computationally. Hence, intelligent systems could help, both for the discovery and for more efficient multiscale computations.
- *Coastal and regional ecosystems*: quantify, discover and model fundamental ecosystem functioning and their interactions with oceanic flows, transports and mixing, and with external atmospheric and anthropogenic forcing
- *Sea level change*: understand the factors driving of sea-level changes, global and regionally, and predict their impacts
- *Longer-term ocean and earth-system predictions:* characterize and predict the ocean and the earth system at seasonal, annual, decadal and climate time and space scales. Include regional impacts
- *Observational ocean science:* develop and obtain ocean sampling systems that adapt to the dynamics as it occurs in the real-ocean, providing optimal data for analyses by humans and other robots