Controlling hurricanes through optimal perturbations: Initial simulation experiments using a 4-d variational analysis system

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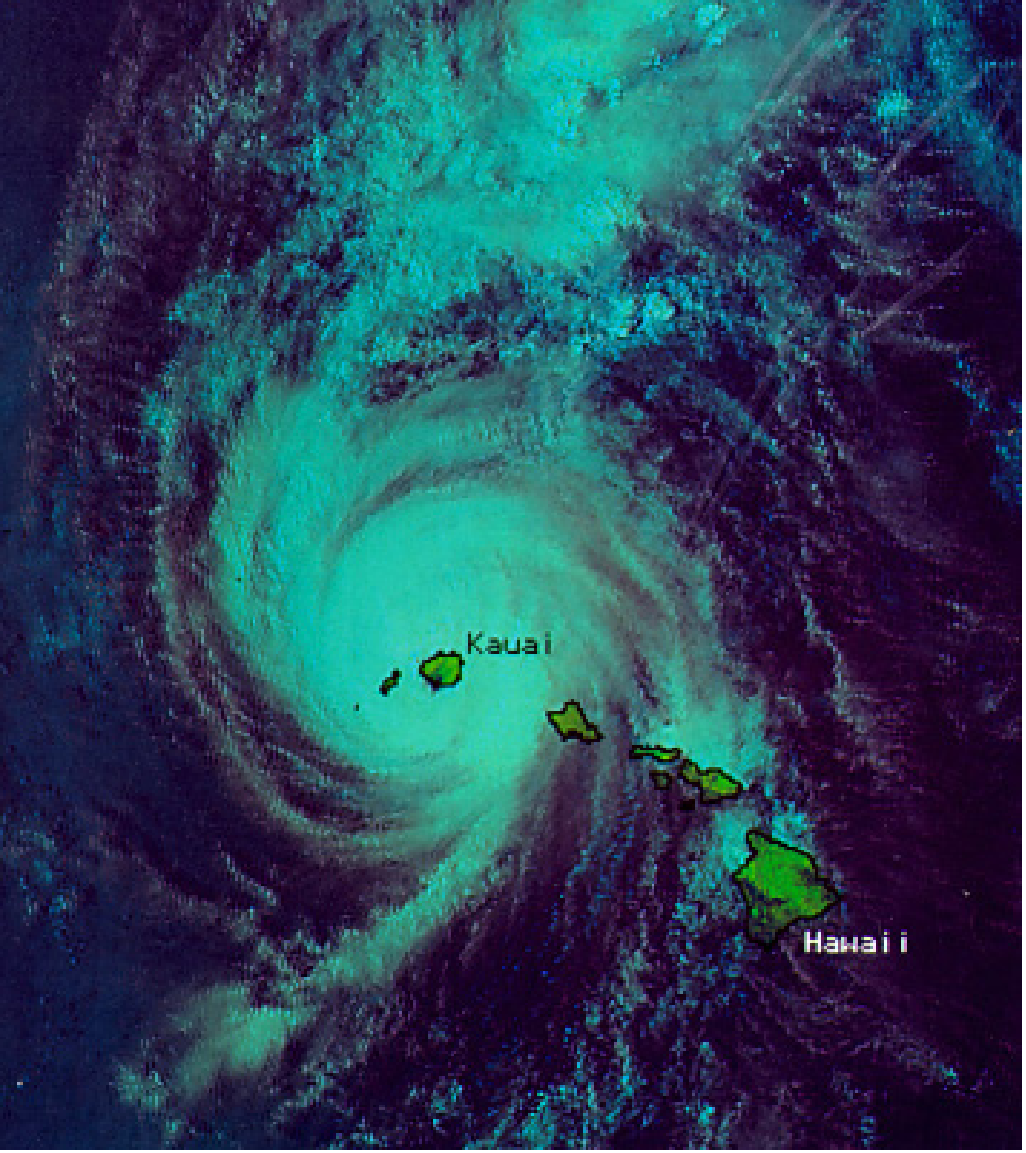
Image from the Historic NWS Collection of NOAA/DOC



H. Iniki 1992 (NWS image)

Thanks

- Supported by NIAC
  - NASA Institute for Advanced Concepts
- Tools & data
  - MM5/4d-VAR
  - NCAR/NCEP gridded data
- AER staff
  - John Henderson, Mark Leidner, George Modica

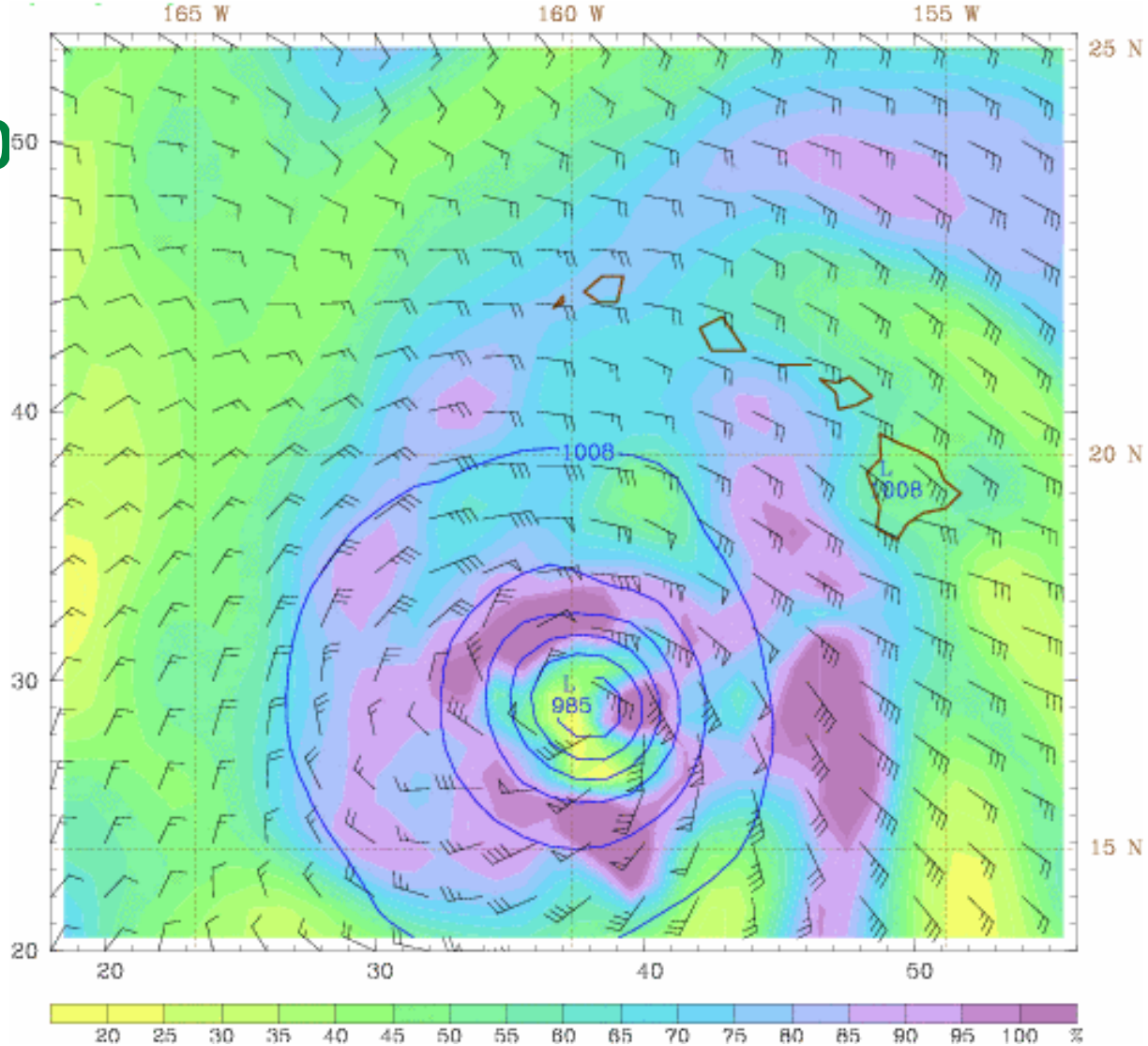
The line of reasoning

- The atmosphere is chaotic
- Implies extreme sensitivity to small changes or “perturbations” 
- A series of “just right” perturbations may control the weather
- The same reason why it is so difficult to predict the weather!


Seriously now.
How can we control this?

Iniki (1992) Simulation

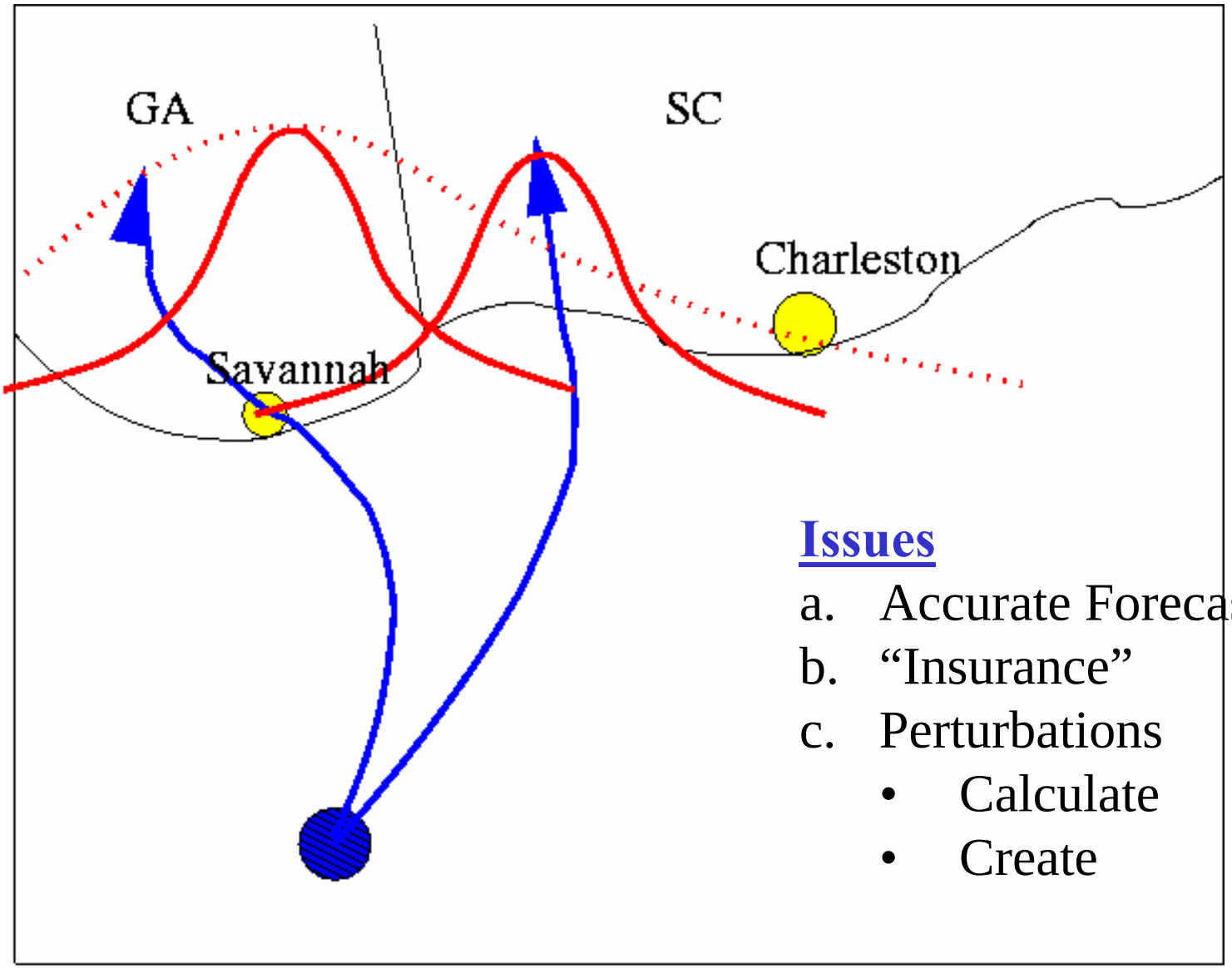
- **Landfall 0130 UTC 12 Sep**
- **750 mb RH**
- **950 mb V**
- **MSLP**



Future WxMod

- **Improved models, observations, and assimilation systems will advance to the point where forecasts are:**
  - **much improved, and**
  - **include an estimate of uncertainty**
- **Thus allowing advance knowledge that a change should be detectable in particular cases**

Uncertainty can be propagated



Issues

a. Accurate Forecasts
b. "Insurance"
c. Perturbations
   - Calculate
   - Create

New active observations

- **Lidars - heating?**
  - **Future lidar sensors will observe winds, temperature, and atmospheric composition**
- **MEMS - CCN?**
  - **MicroElectro-Mechanical Systems**

Computer technology

- **Advances in NWP require advances in computer technology:**
  - **nano-technology**
  - **DNA computers**
  - **quantum computing**

Current NWP operational practice

- **NWP centers have developed forecast techniques that capitalize on the sensitivity of the atmosphere**

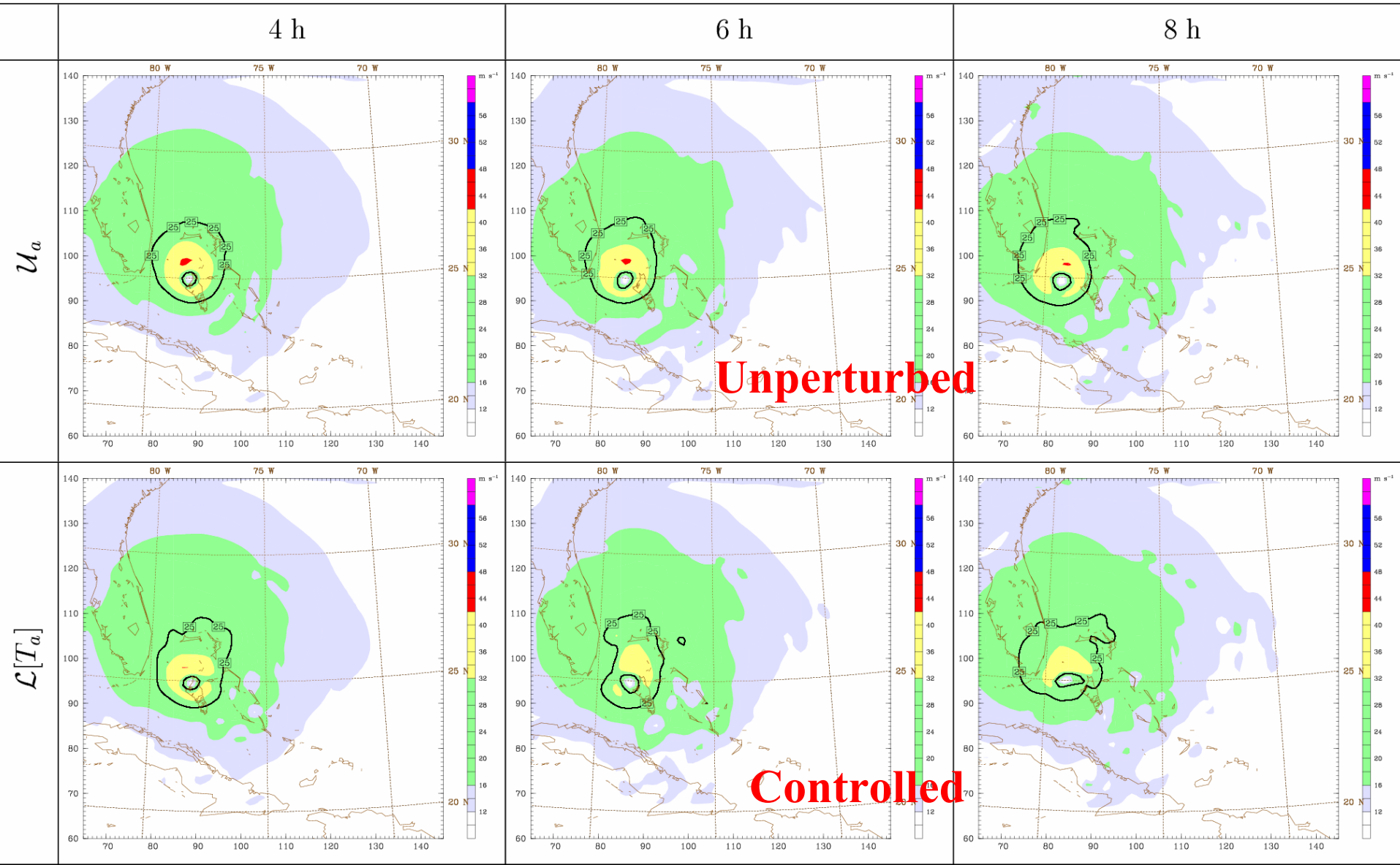
  1. **4D variational data assimilation**
  2. **Generation of ensembles**
  3. **Adaptive observations**

Standard 4D-Var cost function

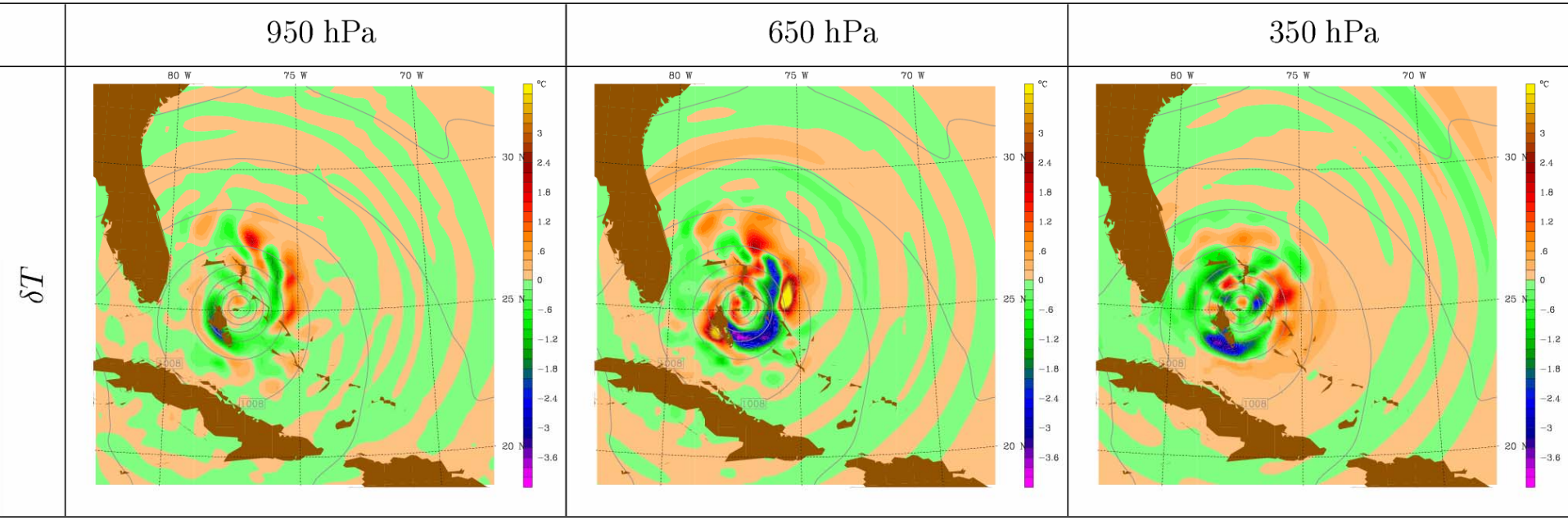
$$J = \sum_{xijkt} [(P_{xijk}(t) - G_{xijk}(t))/S_{xk}]^2$$

- J is the cost function
- P is the perturbed forecast
- G is the goal
  - G is the target at t=T and the initial unperturbed state at t=0
- S is a set of scales
  - S depends only on variable and level
- x is temperature or a wind component
- i, j, and k range over all the grid points

Surface wind field evolution



Temperature perturbations



Hurricane Andrew at 00 UTC 24 Aug 1992: controlled minus unperturbed

4d-Var over 6 h; 20 km grid; temperature increments only; simple physics

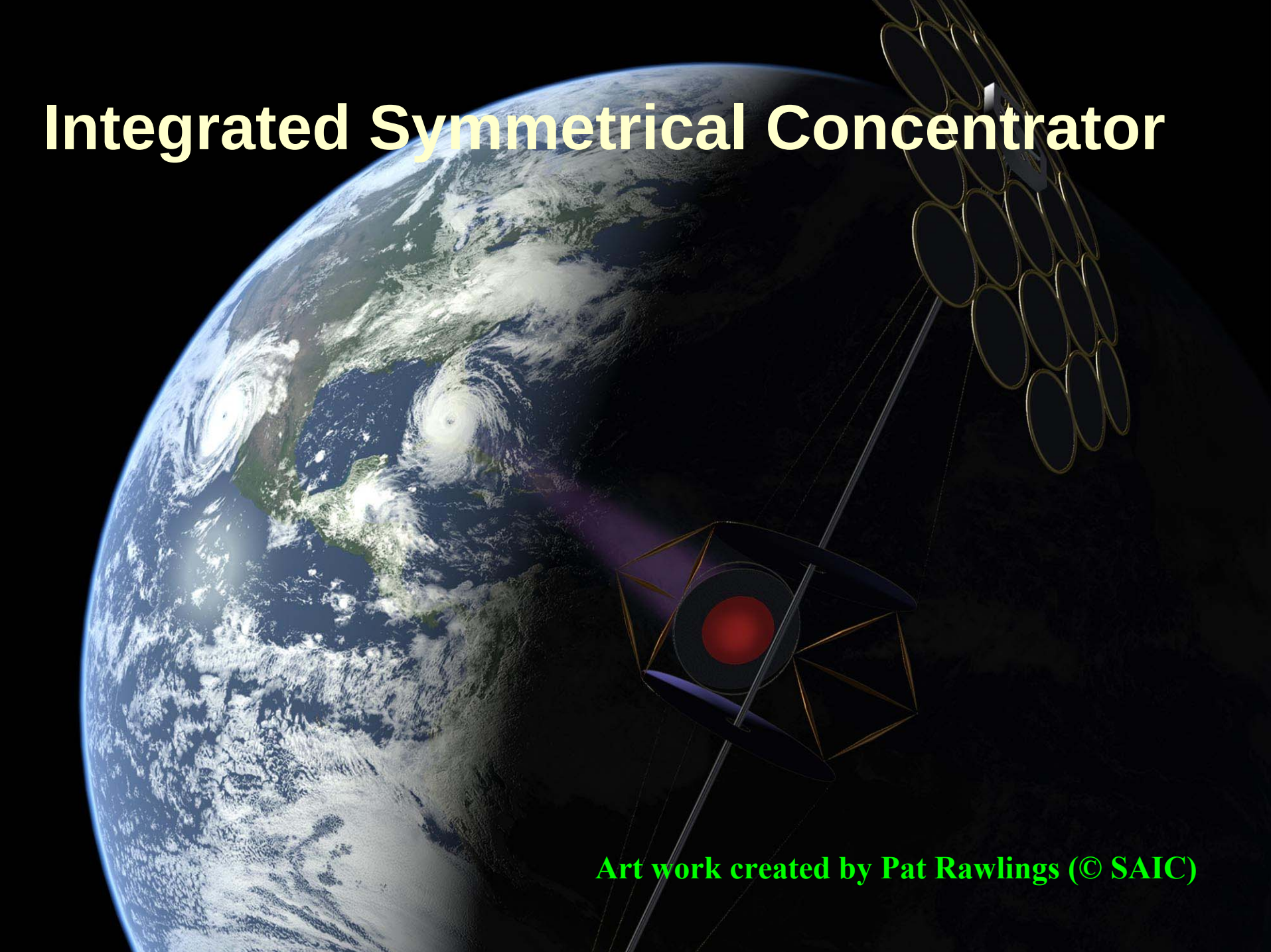
Results

- Perturbations calculated by 4d-Var
- Control path, intensity of simulated hurricane
- Power requirements are huge

Hurricane WxMod

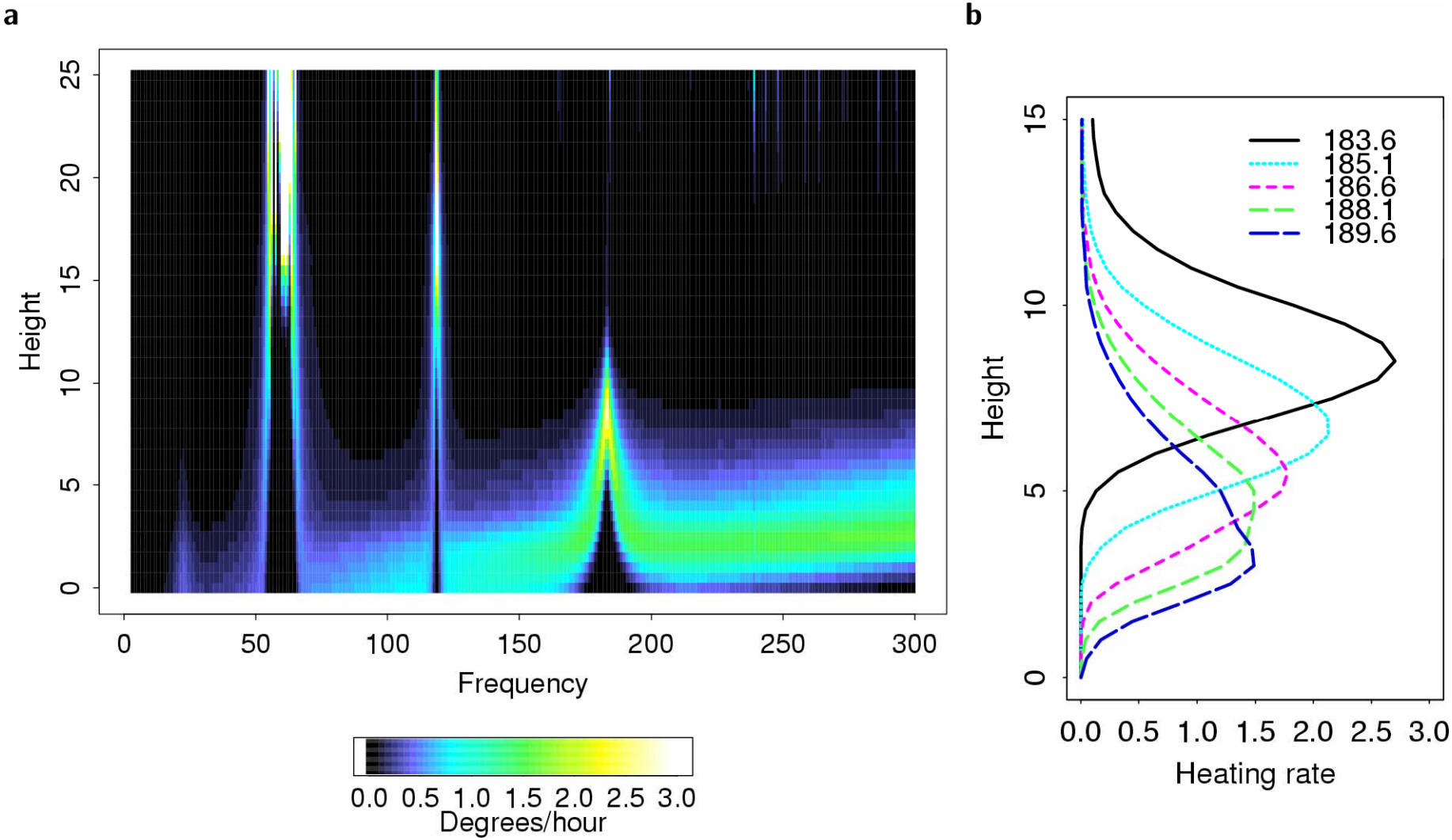
- Energetics
  - Biodegradable oil
  - Pump cold water up to the surface
- Dynamic perturbations
  - Stormfury: cloud seeding
  - Space based heating

Integrated Symmetrical Concentrator



Art work created by Pat Rawlings (© SAIC)

Microwave heating rates



Power requirements

- **Heating rates calculated for 1500 W/m^2**
- **Equal to 6 GW/(2 km)^2**
- **Current experiments require similar heating rates over an area 100s times larger**
- **Longer lead times, higher resolution will reduce these requirements significantly**

Hurricane environment

- **Instead of altering the hurricane, change the environmental winds**
  - **Predictable over several days**
  - **Depth averaged flow controls tracks**
  - **Shear of environment can weaken intensity**

eXigent forecasting

- Calculation of worst cases for particular interests.
- Consistent with J_b, what is the
  - Maximum wind damage in Miami
  - Minimum temperature in citrus groves
  - Maximum snow fall over Boston
- Relative likelihoods estimated

The future

- Weather modification and weather control raise a number of legal and ethical questions
  - If we might, dare we hesitate?
  - If we can, do we want to?
- A global weather controller will build upon future advances in several disciplines
  - Numerical weather prediction, observing systems, computer technology, space engineering, and system engineering
- Technology to implement this may exist in 30 – 50 years

end… More info @

- **www.niac.usra.edu**
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