# Soil Moisture Active Passive (SMAP)

## *Value Added Data Products*

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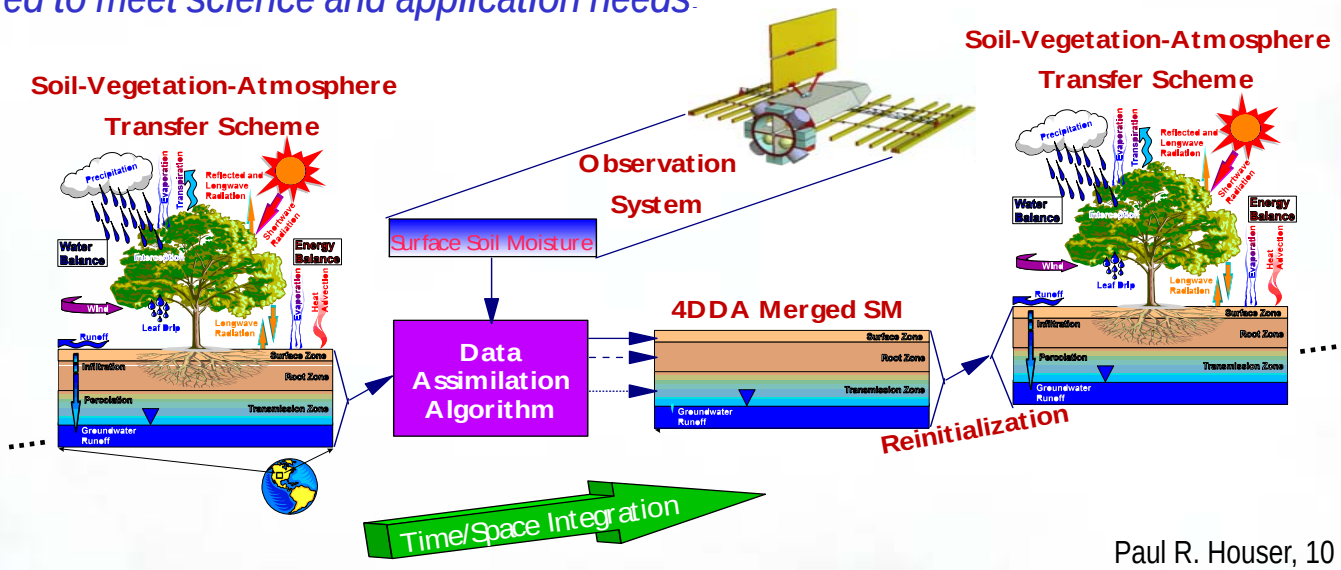
SMAP GOAL: *Map global soil moisture and freeze/thaw state to meet requirements for water, energy and carbon cycle sciences, weather and climate applications, and natural hazards decision support systems* (Decadal Survey).

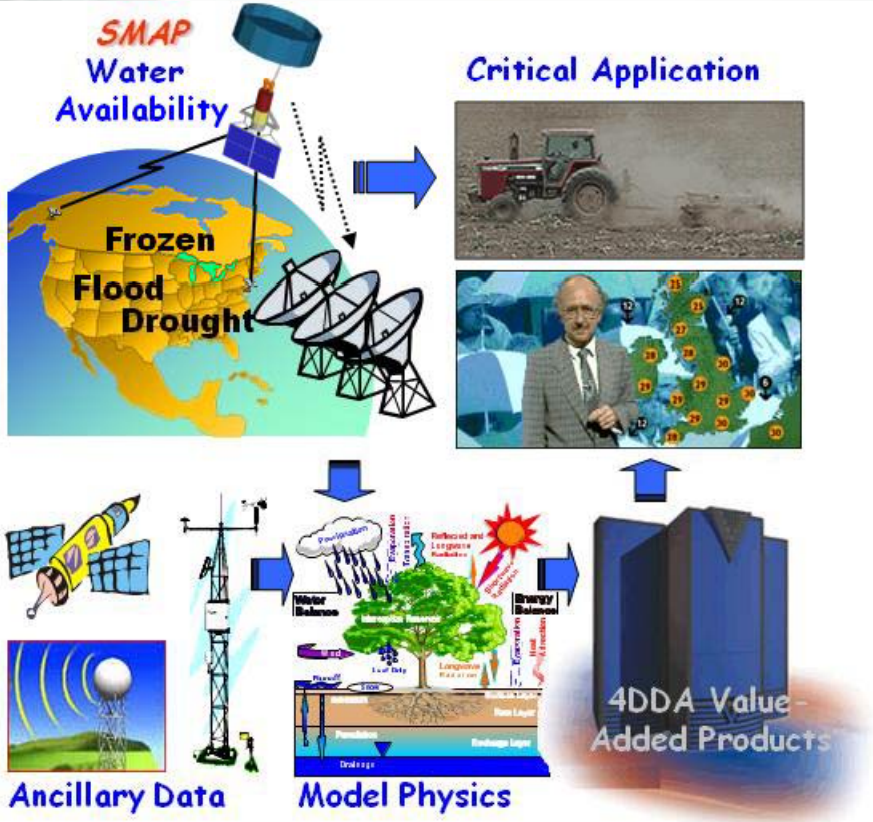
Key science questions: *How is the water cycle changing? Are northern forests taking up or releasing carbon? Etc…*

Key applications: *Enhance accuracy of weather forecasts. Monitor floods and droughts. Track and predict spread of water-borne diseases. Enhance agricultural productivity. Aid in military mobility.*

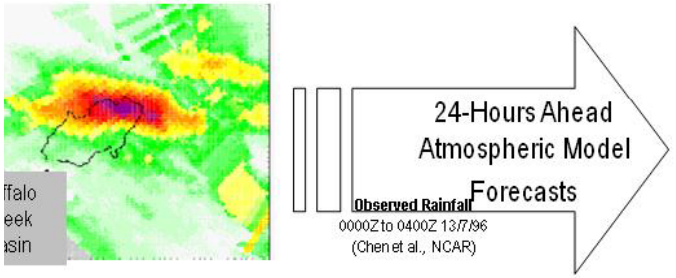
*SMAP Value Added Data Products: SMAP will measure surface microwave emission and backscatter every 3 days, so methods to merge the active/passive signal, extend the surface information to the root zone, downscale in time & space, and produce subsequent hydrologic and carbon fluxes (Runoff, Evaporation, etc.) are required to meet science and application needs.*

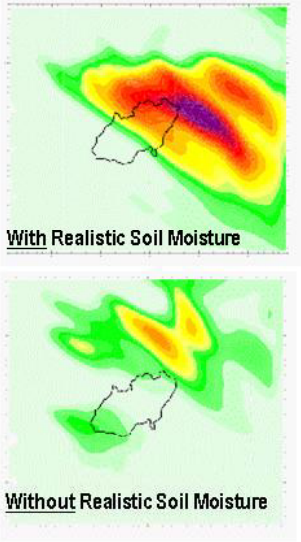


# SMAP: Applications

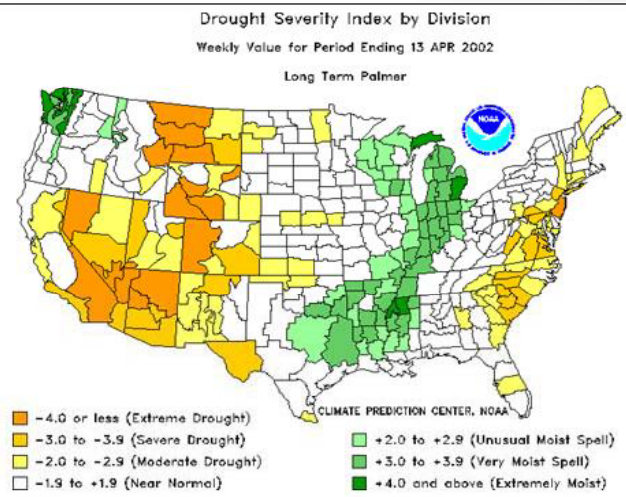



**SMAP Data Will Improve Numerical Weather Prediction (NWP) Over the Continents by Accurately Initializing Land Surface States**




| | JROC IORD II Requirements | | Current DMSP | Future NPOESS | SMAP |
|---|---|---|---|---|---|
| | Threshold | Objective | | | |
| Sensing Depth | 1 mm | 80 cm | 1mm (bare soil & known soil type) | 1mm (bare soil & known soil type) | 50 mm |
| Pixel Resolution | 1-4 km Clear 40-50 km Cloudy | 2 km All weather | 25 km (SSM/I 19 GHz) | 1-4 km Clear (VIIRS Vis/IR) 40-50 km Cloudy (CMIS 6 GHz) | 3-10 km (1.3 GHz) All Weather Day/Night |

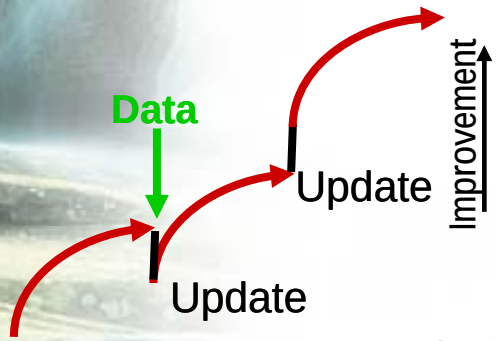



**Current NOAA and National Drought Mitigation Center (NDMC) Operational Drought Index is Formed by *Model* Soil Moisture Accounting**

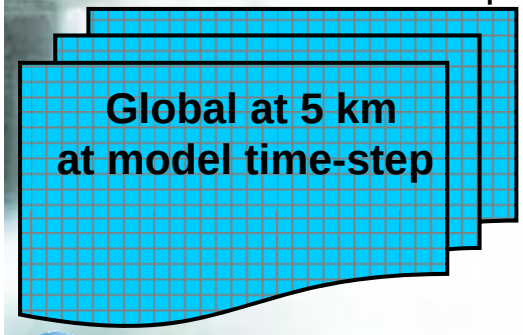
# SMAP: Value-Added Data Product Approach

**Value-added data products through integration of models and *multi-platform* measurements**

- Merge multi-source and multi-resolution data (GPM, MODIS, GPS, etc.).
- Account for missing data, and fill in spatial/temporal gaps.
- Use noisy high-res radar to downscale course radiometer.
- Optimally combine SMAP active and passive observations (radiance assimilation).
- Downscale hydrologic information to be more useful for applications (obs overlap).
- Extend SMAP information to soil profile and to other hydrologic states (through modeling).

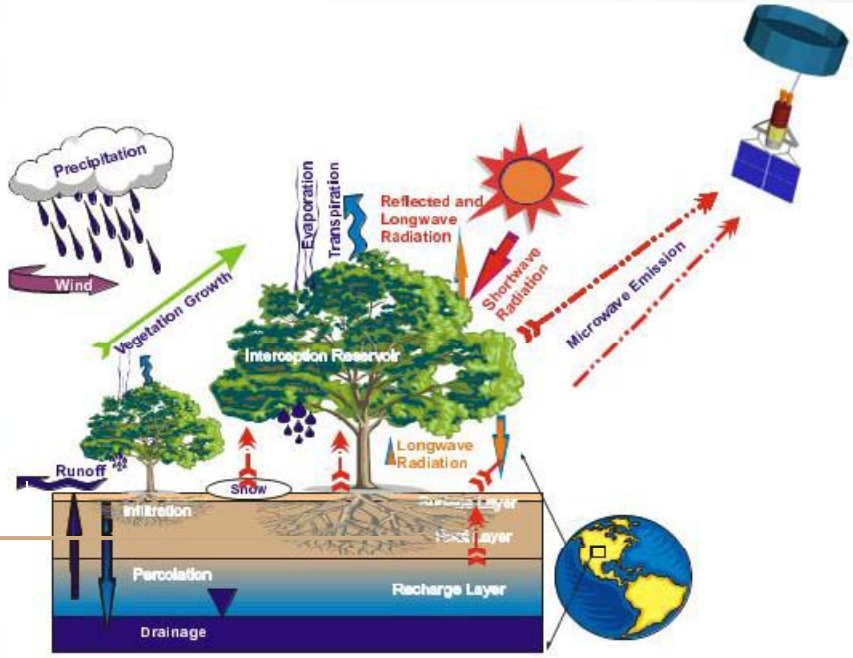



5 km Earth-Grid
Updated at 6:00, 12:00, 18:00 local




Surface soil moisture 0-5 cm
Root-zone soil moisture 5-100 cm
Surface temperature
Freeze/thaw state
Daytime evaporative-fraction
Gross Primary Production (GPP)

**SMAP L4 products**




Modeled Land Surface Physics

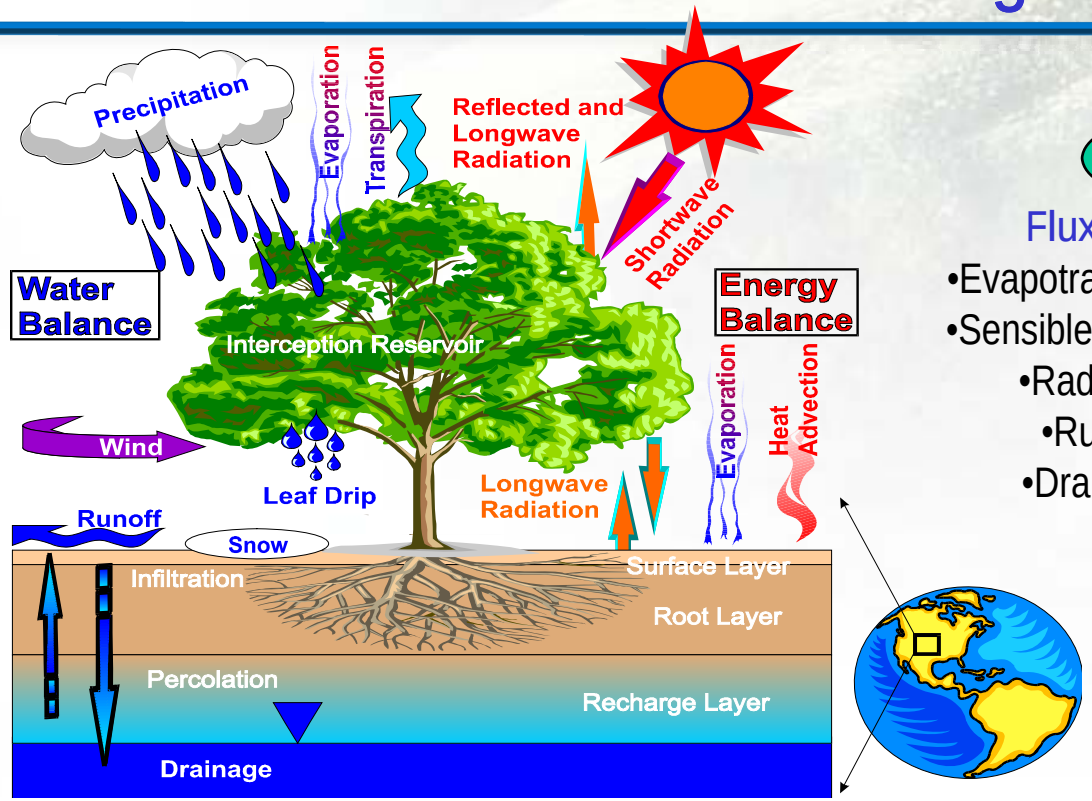
# Land Surface Observation and Modeling

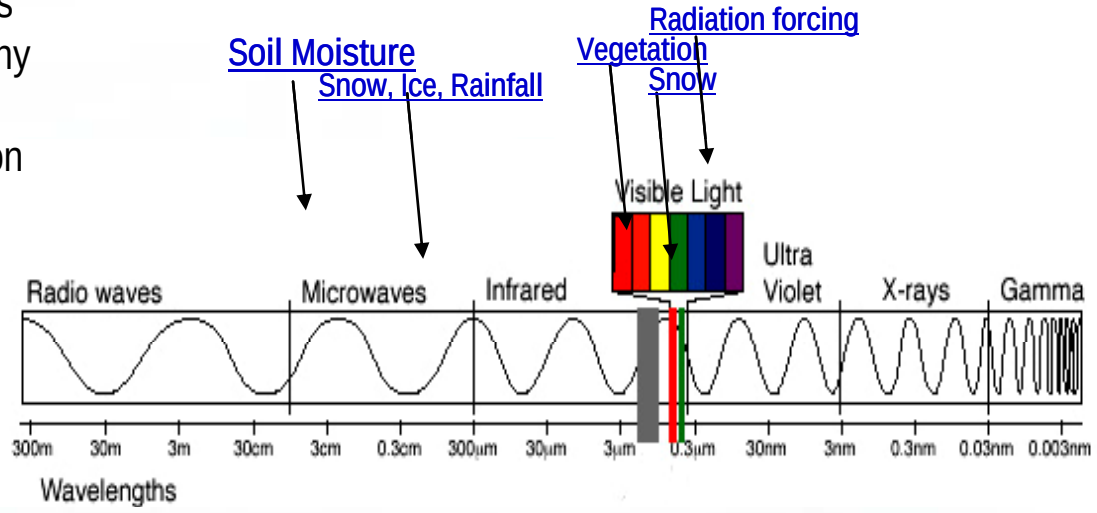
## Off-line LSM

### Forcing
- Precipitation
- Wind
- Humidity
- Radiation
- Air Temperature

## Calibration

### Parameters
- Soil Properties
- Vegetation Properties
- Elevation & Topography
- Subgrid Variation
- Catchment Delineation
- River Connectivity




## Validation

### Fluxes
- Evapotranspiration
- Sensible Heat Flux
- Radiation
- Runoff
- Drainage

## Assimilation

### States
- Soil Moisture
- Temperature
- Snow
- Carbon
- Freeze/Thaw
- Nitrogen
- Biomass

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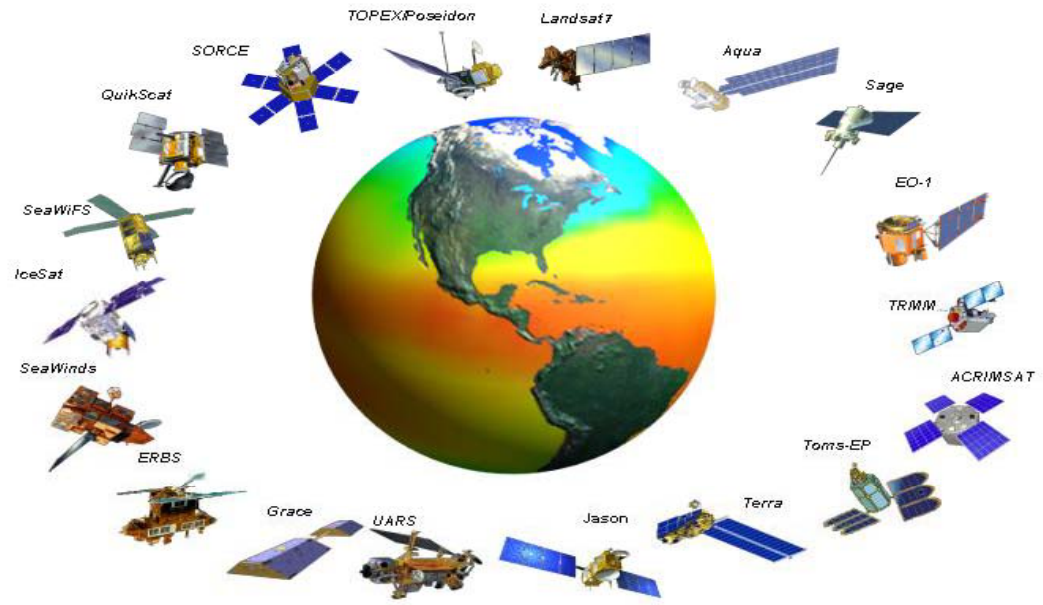
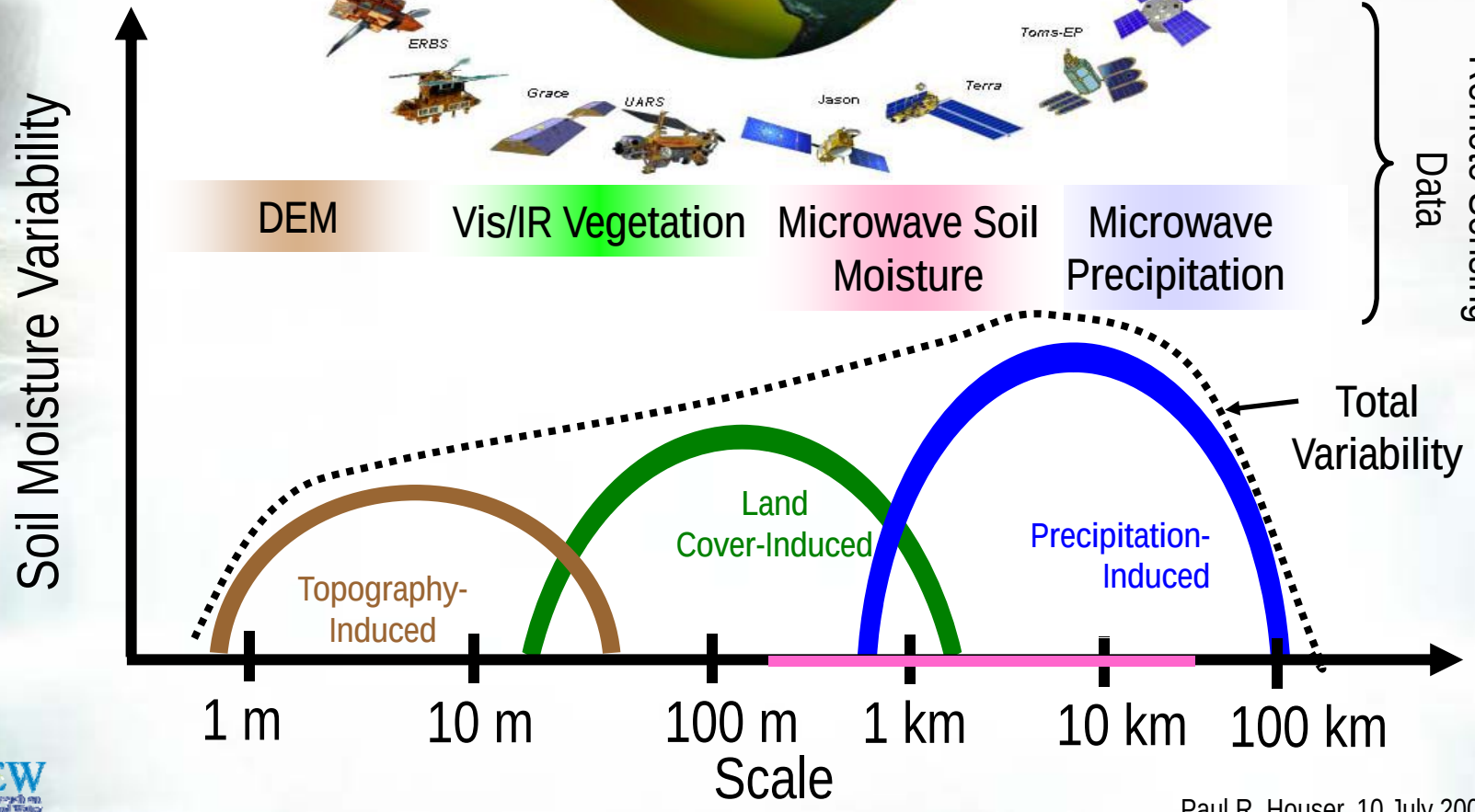
# SMAP: Multi-Scale Information

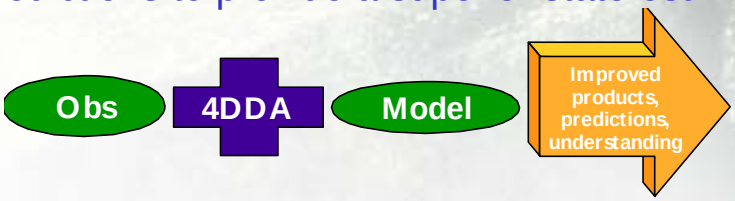


# SMAP: Soil Moisture Data Assimilation

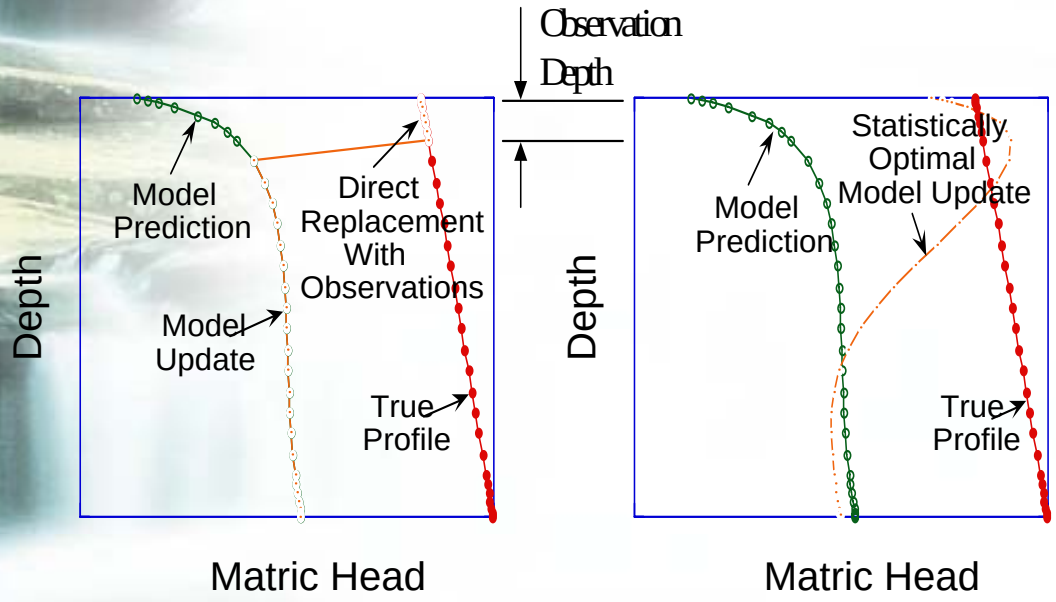
**Data Assimilation** merges observations & model predictions to provide a superior state estimate.

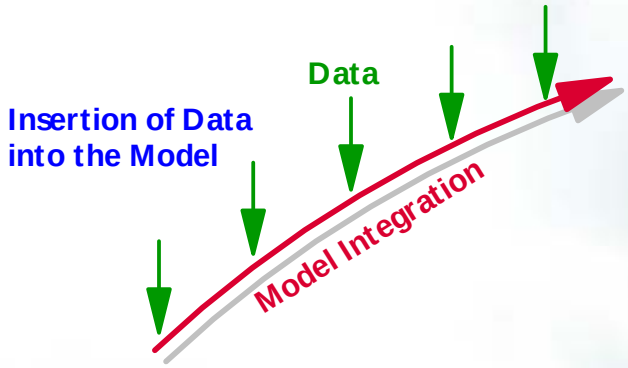
$$\partial x/\partial t = dynamics + physics + \Delta x$$




Remotely-sensed hydrologic **state** or storage observations (*temperature, snow, soil moisture*) are integrated with a land surface model prediction.

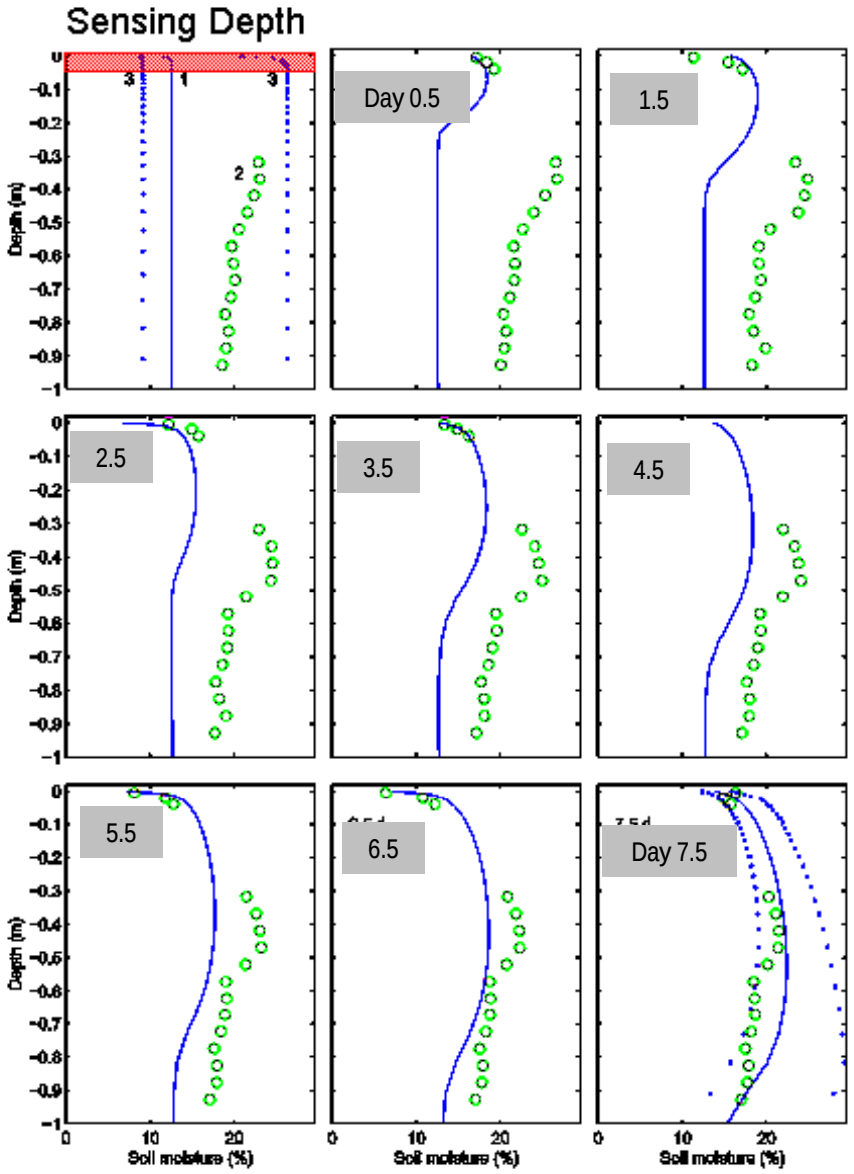
- Errors in land model prediction result from:
  - Initialization error.
  - Errors in atmospheric forcing data.
  - Errors in LSM physics (model not perfect).
  - Errors in representation (sub-grid processes).
  - Errors in parameters (soil and vegetation).



# *Retrieving soil moisture profile using data assimilation*

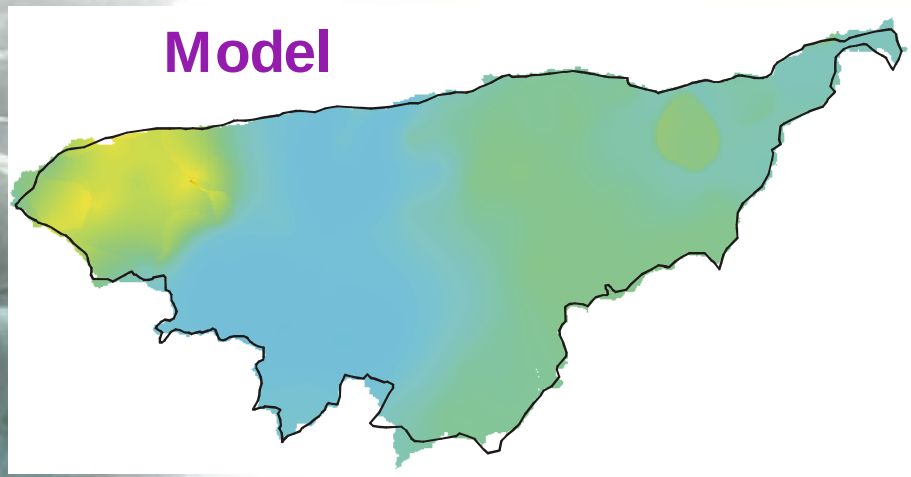
Sequential assimilation of surface measurements allows profile estimation through model-propagation of the joint probability density between the surface state and subsurface profile.

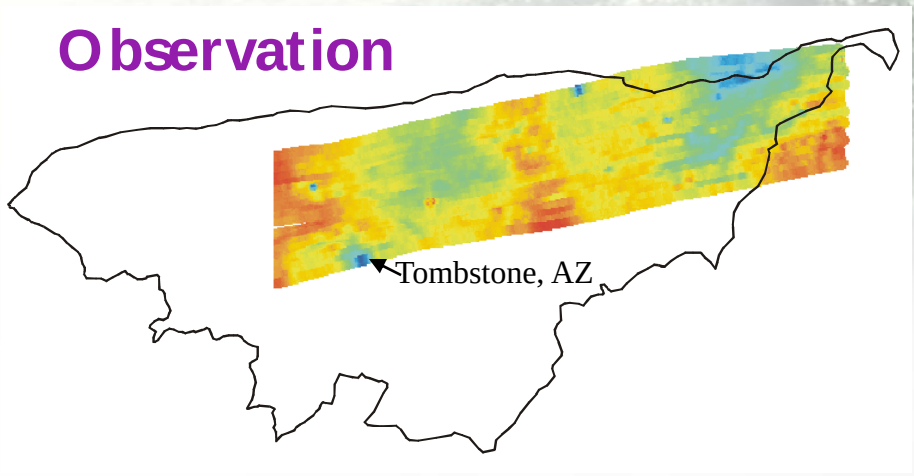


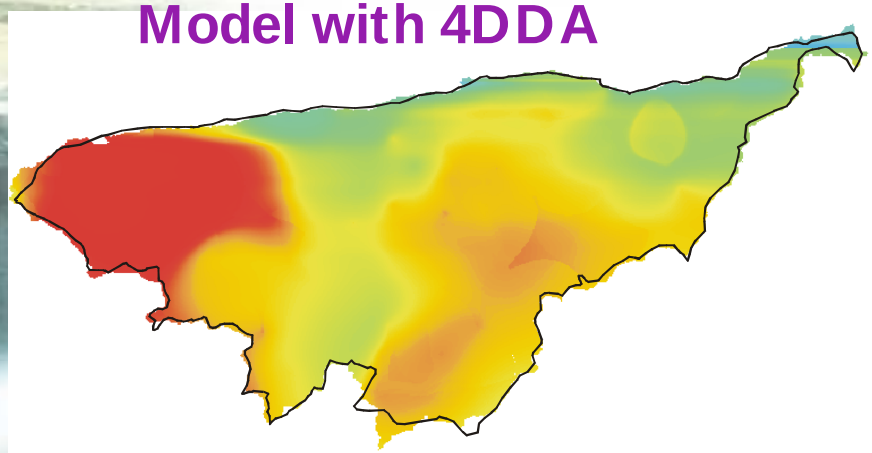

Example:

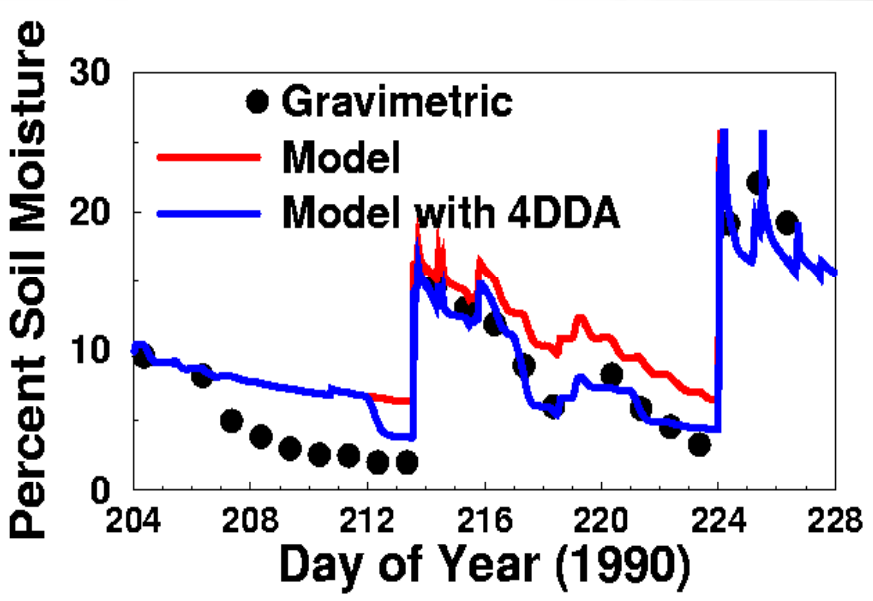
- Data assimilation (—)
- Truck-boom L-Band measurements
- in-situ ground-truth (o)

# *Retrieving soil moisture maps using remote sensing*




Houser et al., 1998

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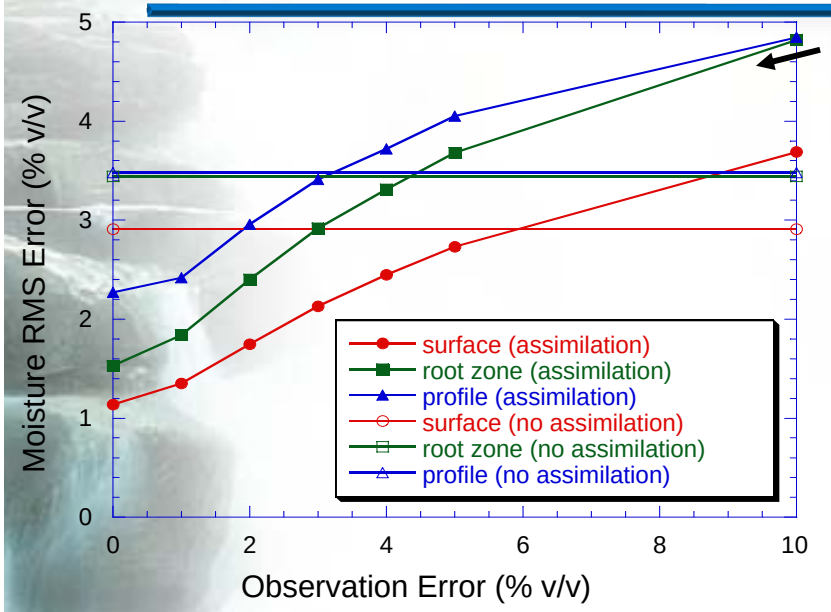
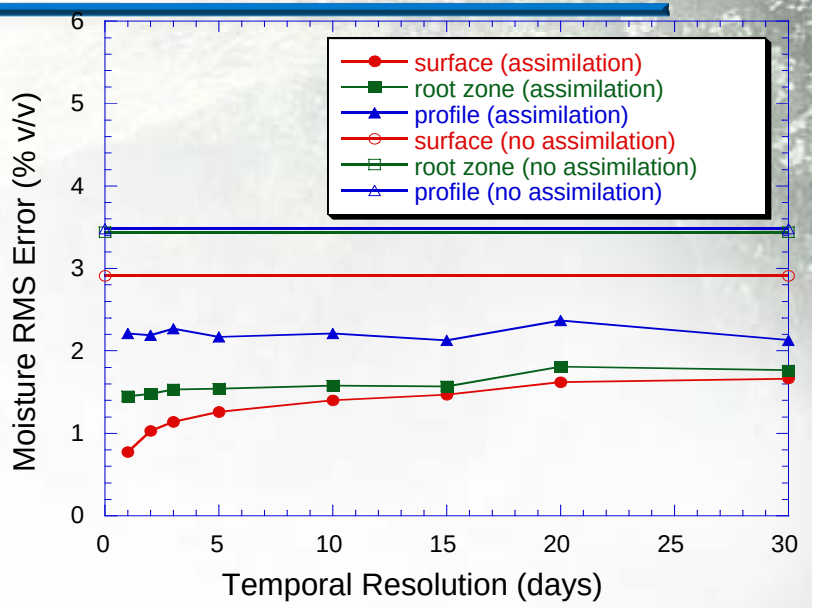
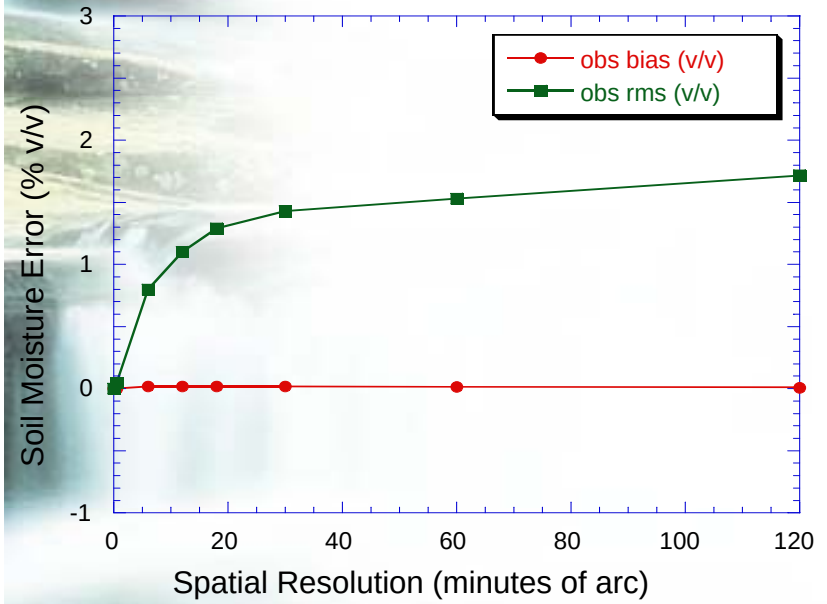
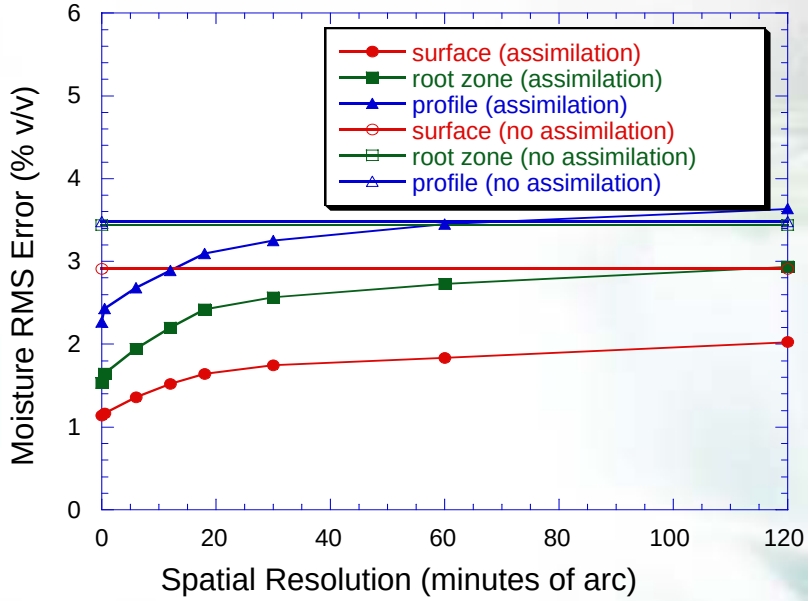
# Soil Moisture Observation Error and Resolution Sensitivity:




NOTE: Assimilation of near-surface soil moisture can degrade profile soil moisture if errors are not known perfectly

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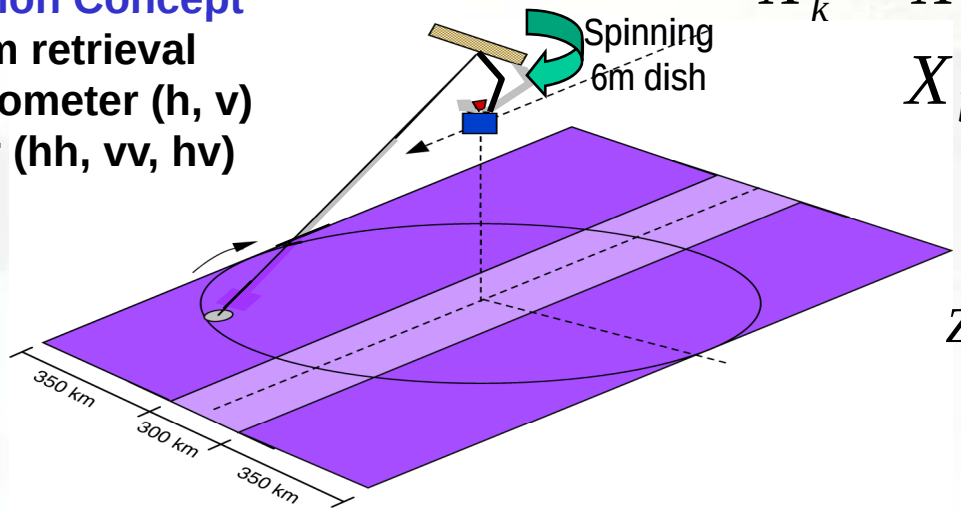
# An *OSSE* for the *HYDROS* *soil moisture* mission

**L-band Mission Concept**

**GOAL: 9km retrieval**

**~36km radiometer (h, v)**

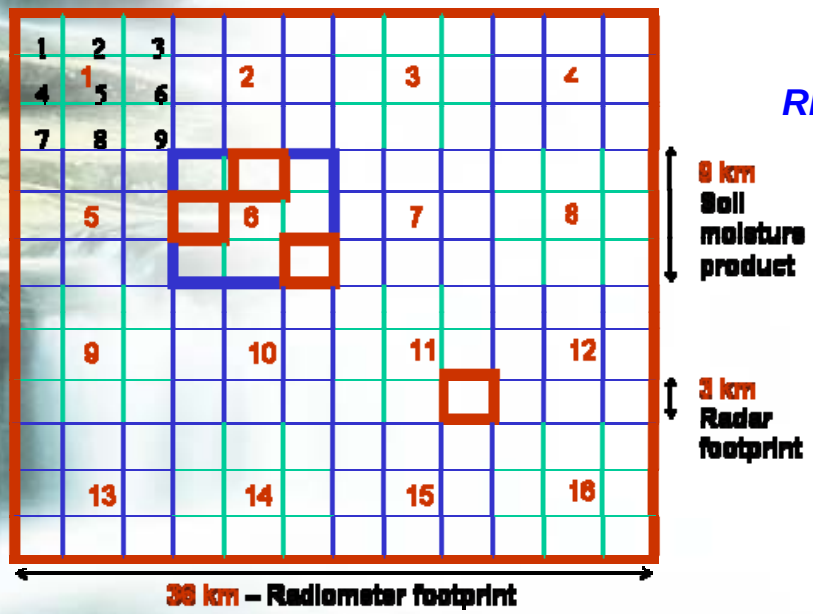
**~3km radar (hh, vv, hv)**




$$X_k = X_{b,k} + K_k[Z_k - h(X_{b,k},0)]$$

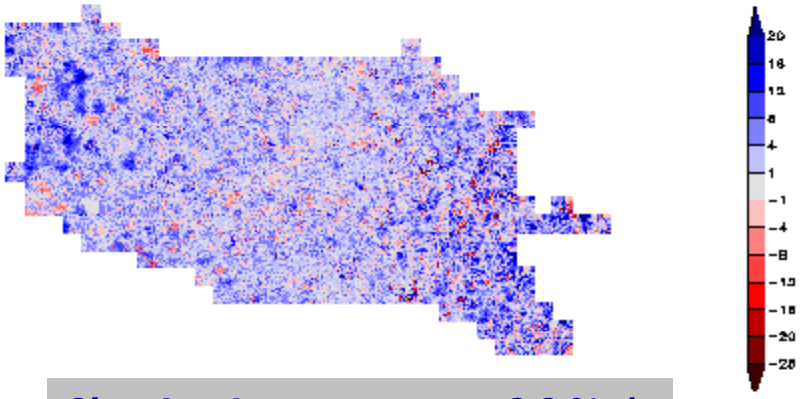
$$X_{b,k} = LSM$$

$$Z_k = \begin{pmatrix} T_{b_{v,f}} \\ T_{b_{h,f}} \\ \sigma_{vv,f} \\ \sigma_{hh,f} \\ \sigma_{vh,f} \end{pmatrix} \qquad H = \begin{pmatrix} \partial T_{b_{v,f}} / \partial x_f \\ \partial T_{b_{h,f}} / \partial x_f \\ \partial \sigma_{vv,f} / \partial x_f \\ \partial \sigma_{hh,f} / \partial x_f \\ \partial \sigma_{vh,f} / \partial x_f \end{pmatrix}$$




***RKF Retrieval Error Improvement over Direct Radar Inversion***

***Improvement = |truth-Inversion|-|truth-EKF|***



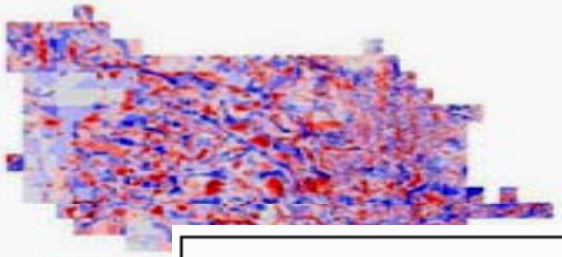

***3km Ave Improvement = 2.8 %v/v***

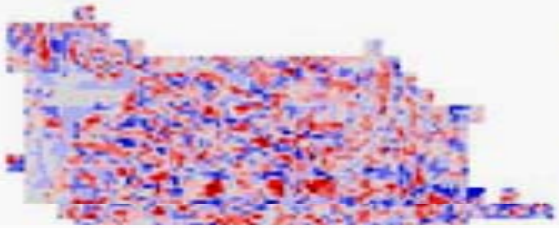
432 Radar Observations

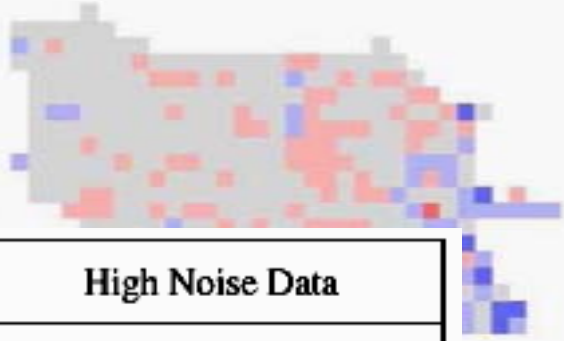
2 radiometer observations

Zhan et al., 2006

# An *OSSE* for the *HYDROS* *soil moisture* mission

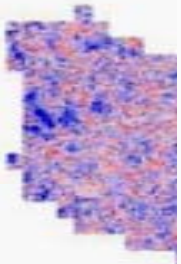




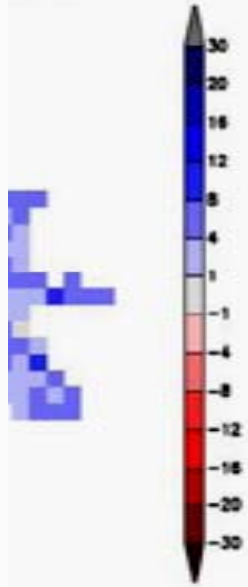


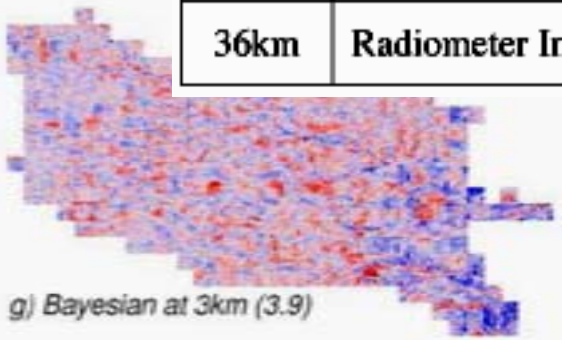
a) $T_B$ Inv at 3

| Method | | Low Noise Data | | | High Noise Data | | |
|---|---|---|---|---|---|---|---|
| | | Compared with truth at | | | Compared with truth at | | |
| | | 36km | 9km | 3km | 36km | 9km | 3km |
| 3km | Bayesian Merging | 1.5 | 2.1 | 2.8 | 1.6 | 2.7 | 3.8 |
| | Radar Inversion | 1.9 | 2.6 | 3.6 | 3.2 | 4.1 | 6.0 |
| 9km | Bayesian Merging | 1.4 | 2.7 | 5.0 | 1.5 | 4.4 | 6.1 |
| | Radar Inversion | 2.7 | 3.7 | 5.7 | 2.6 | 5.0 | 6.6 |
| 36km | Radiometer Inversion | 1.5 | 4.4 | 6.2 | 1.6 | 4.5 | 6.3 |

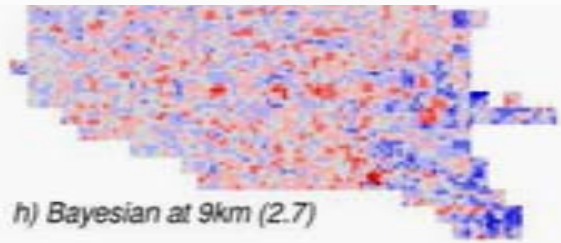


d) σ Inv at 3k

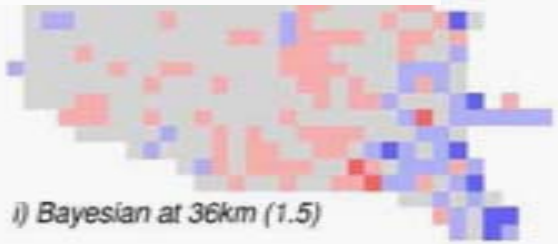


g) Bayesian at 3km (3.9)



h) Bayesian at 9km (2.7)



i) Bayesian at 36km (1.5)

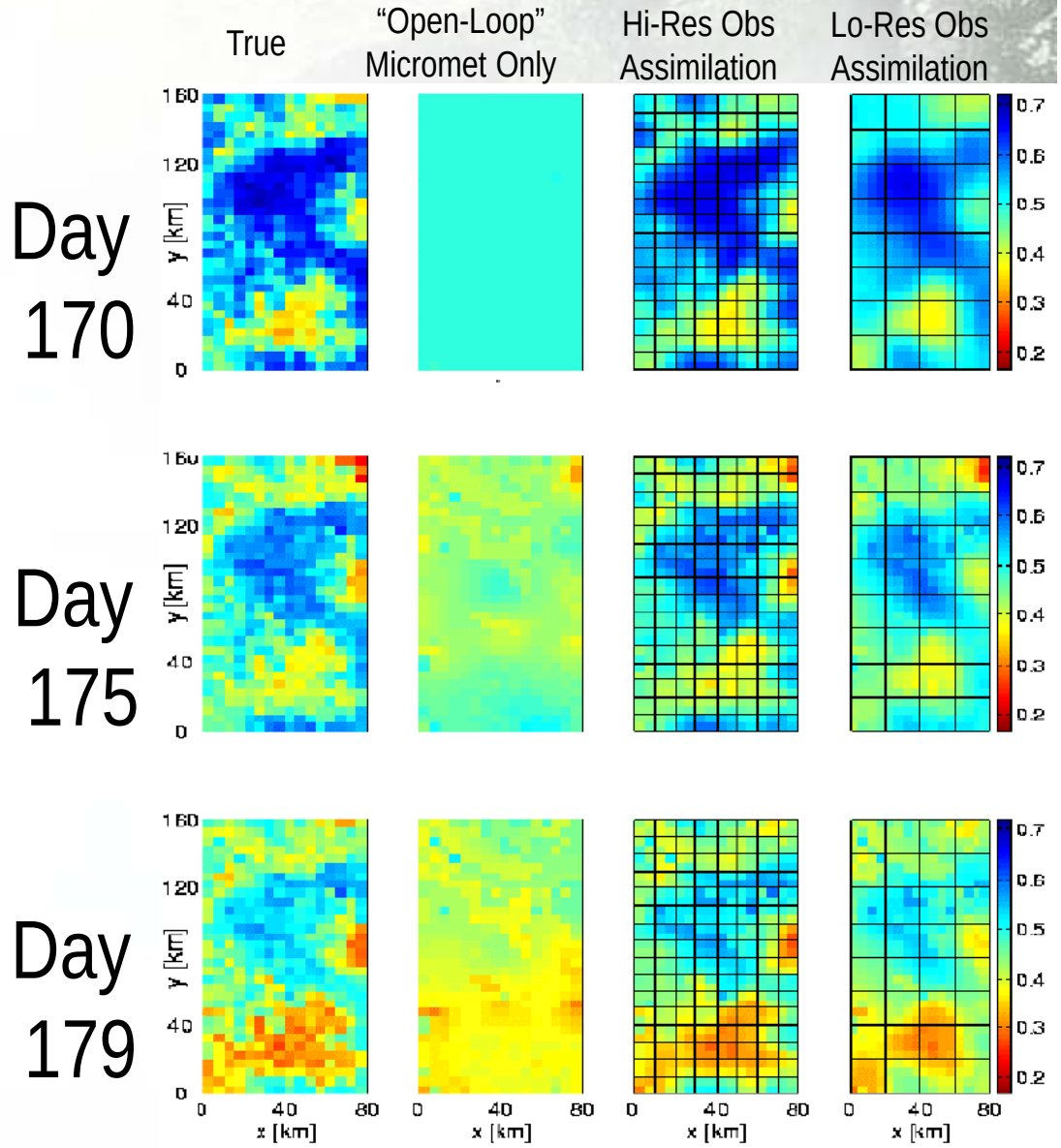
# An *OSSE* for the *HYDROS* *soil moisture* mission

***Product:***

L4_ 5km_4DDA

***Objective:***

Merge multi-source and multi-resolution data and models into the most comprehensive ever view of the global land surface conditions.




Surface soil moisture estimate over SGP region in Southern Great Plains: OSSE Radar and Radiometer Observations

# SMAP Value Added Data Products

*SMAP Value Added Data Products:*

- *merge the active/passive signal*
- *extend the surface information to the root zone*
- *downscale in time & space*
- *produce subsequent hydrologic and carbon fluxes (Runoff, Evaporation, NPP, etc.)*

*Readiness:*

- *Relevance to science and applications are clear.*
- *Modeling and assimilation tools are mature and have been demonstrated.*
- *Hydros OSSE studies demonstrate SMAP specific value-added products.*

*Issues:*

- *Need to integrate freeze/thaw information in L4 model analysis*
- *Need additional field studies to optimize/calibrate algorithms for various landscapes.*
- *Need to work with end-users to optimize integrated system solutions.*

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