Air Force Weather Agency

Fly - Fight - Win

Satellite Data Assimilation at the U.S. Air Force Weather Agency

JCSDA Science Workshop
May 2010

John Zapotocny
Chief Scientist

U.S. AIR FORCE

Overview

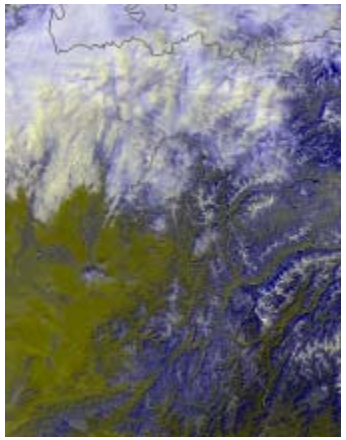
- Mission & Organization
- Products/Services
- Models Assimilating Satellite Data
  - Clouds (CDFS II)
  - Land Surface (LIS)
  - Regional NWP (WRF)
  - Dust/Aerosol (Future WRF-chem)
- Capability Shortfalls
- JCSDA projects

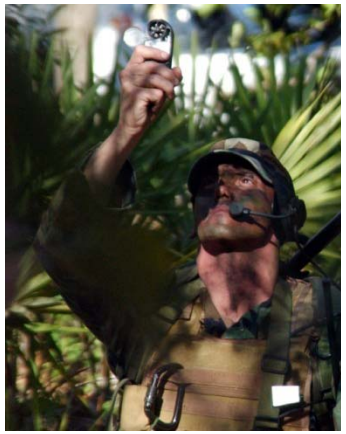
AFWA mission:

A Global Team for the Global Fight

Maximizing America's Power through the Exploitation of Timely, Accurate, and Relevant Weather Information;

Anytime, Everywhere





Mission Overview
Who We Support

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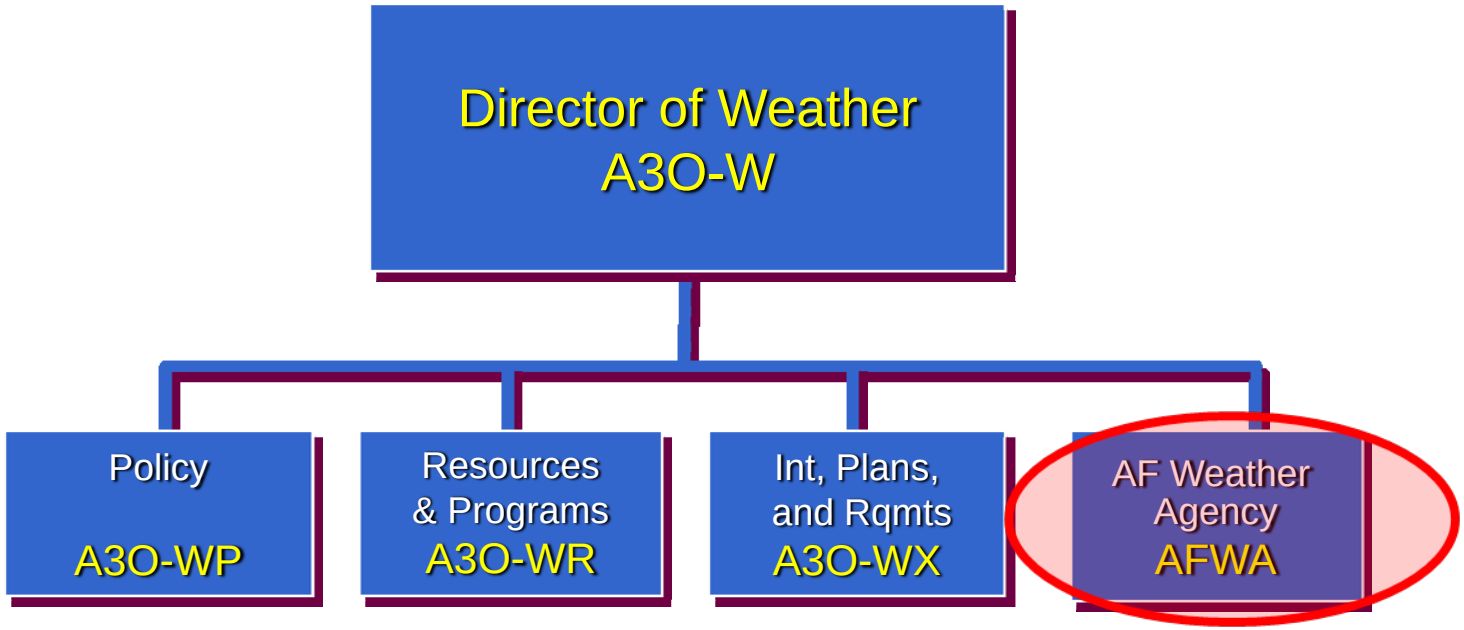
Air Force and Army Warfighters

National Decision Makers

Coalition Forces

Base and Post Weather Units

Air Force Weather Organization



AFWA Organization

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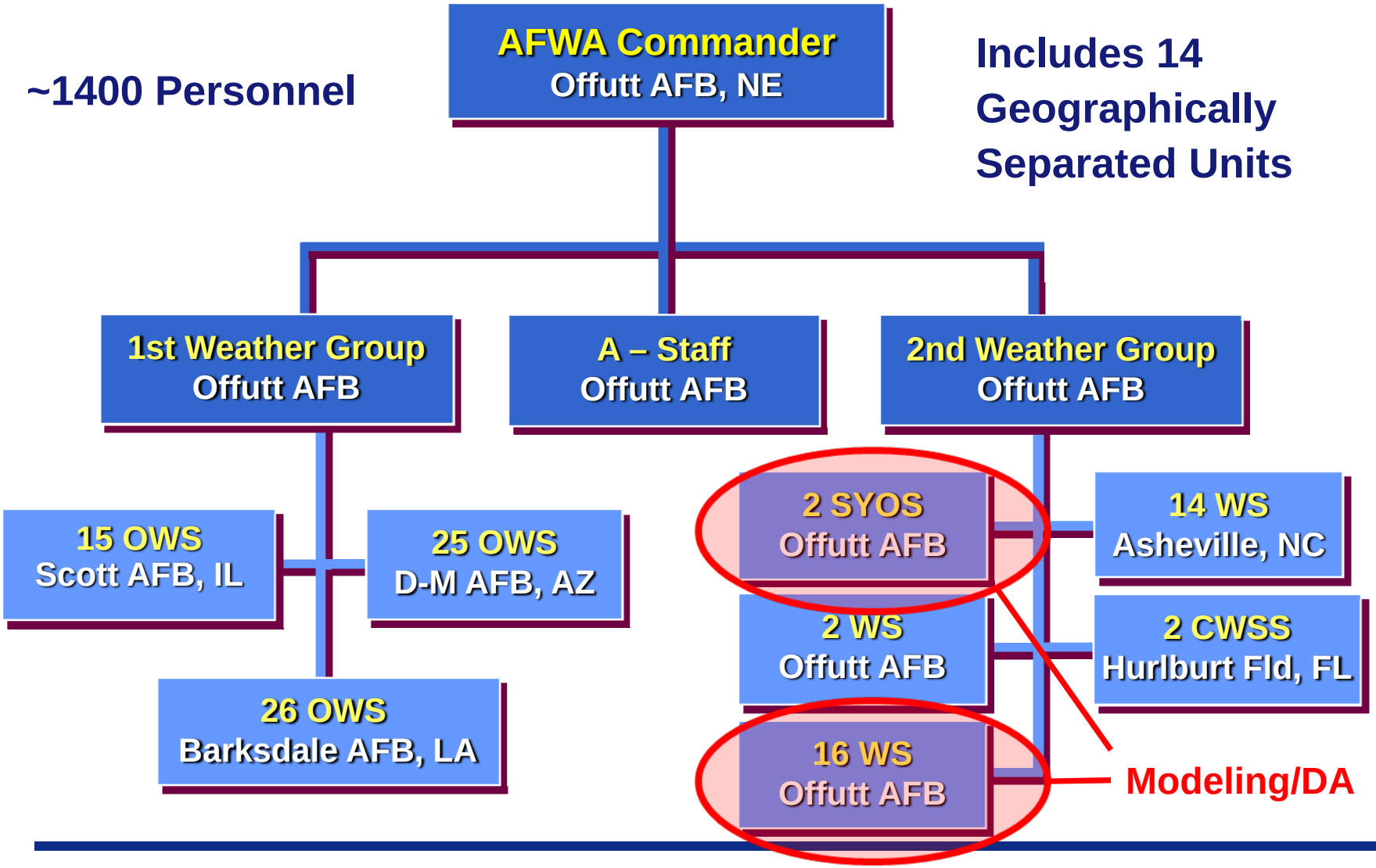
~1400 Personnel



Includes 14 Geographically Separated Units

Fly - Fight - Win

AFWA's Worldwide Team

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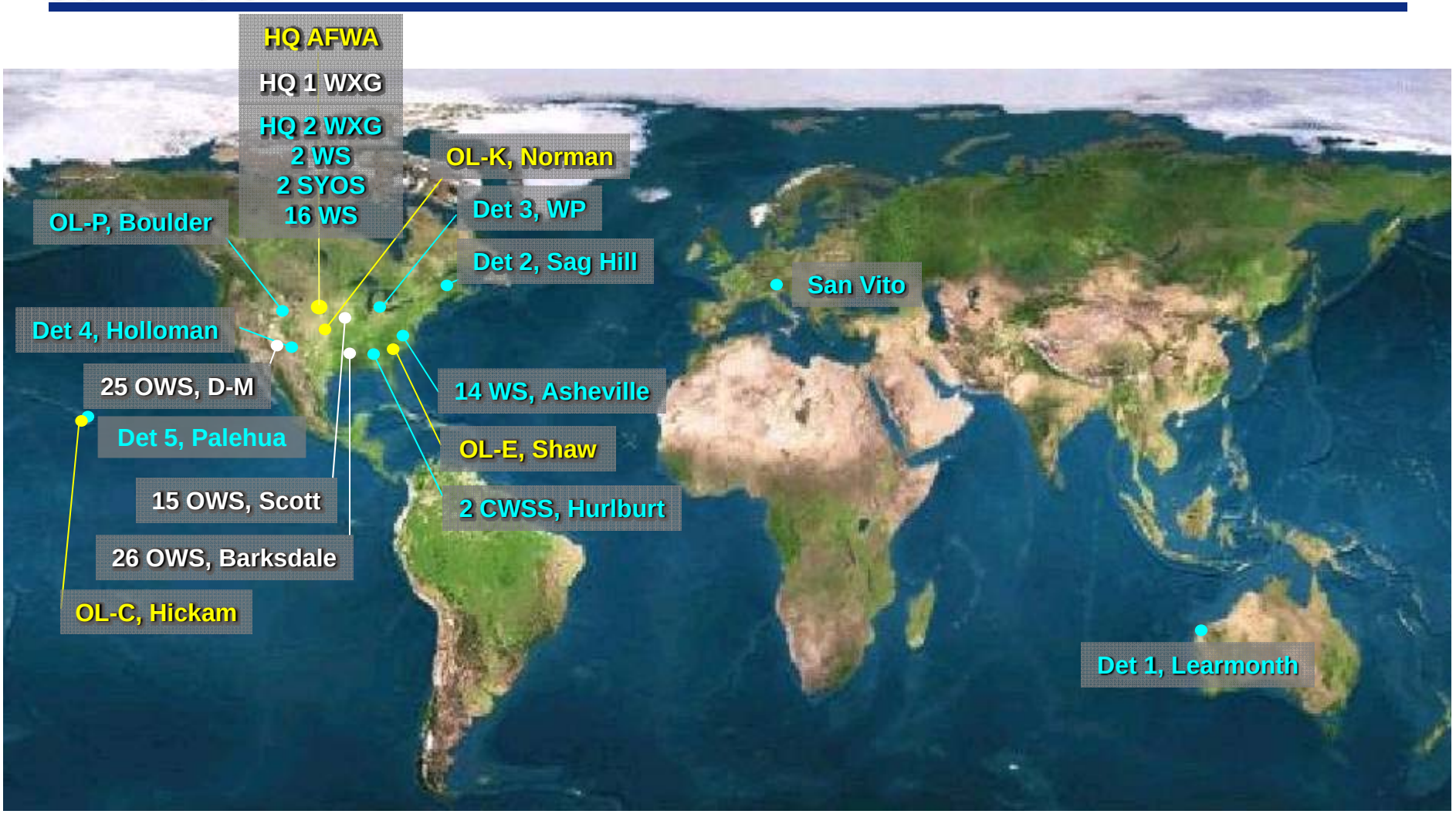

Products and Services

Terrestrial Weather

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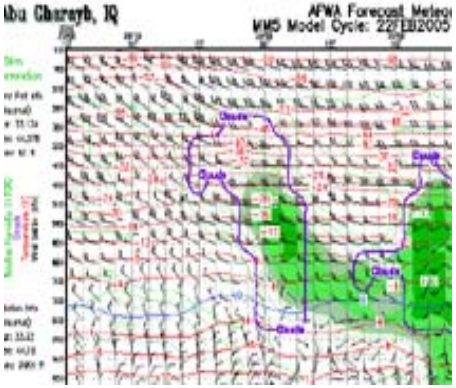
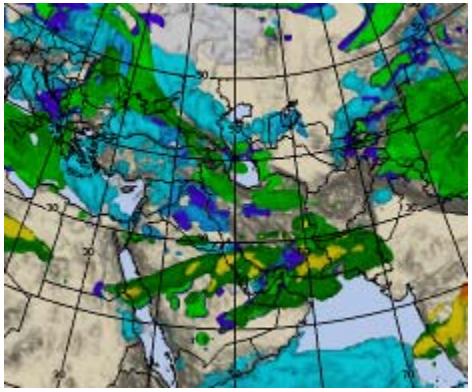
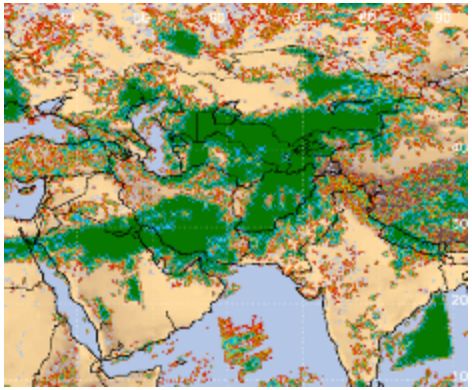
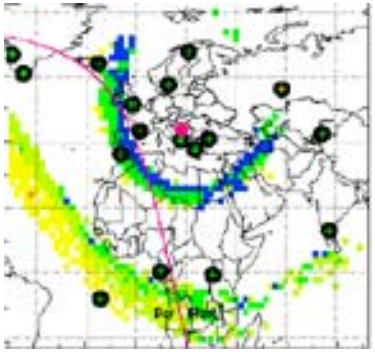


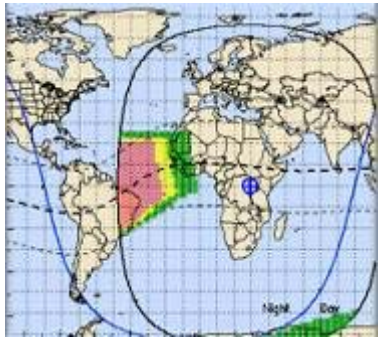


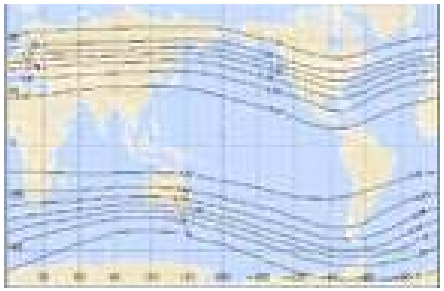


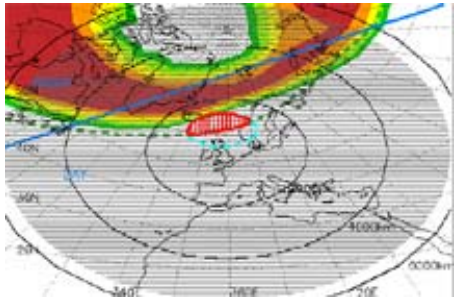
Products and Services

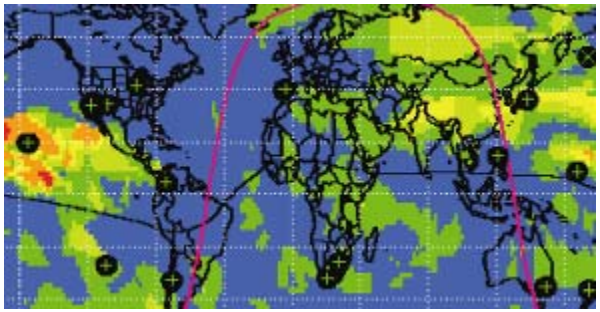
Space Weather

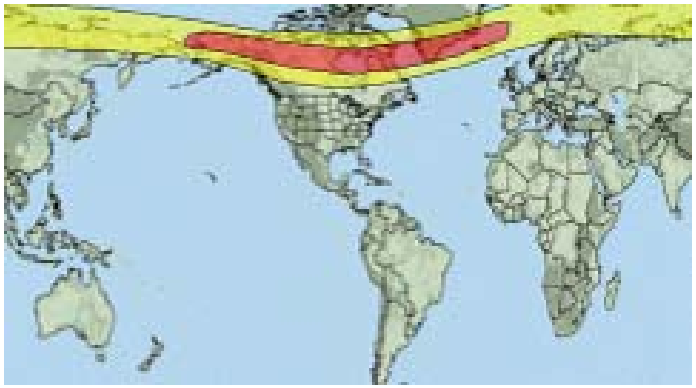






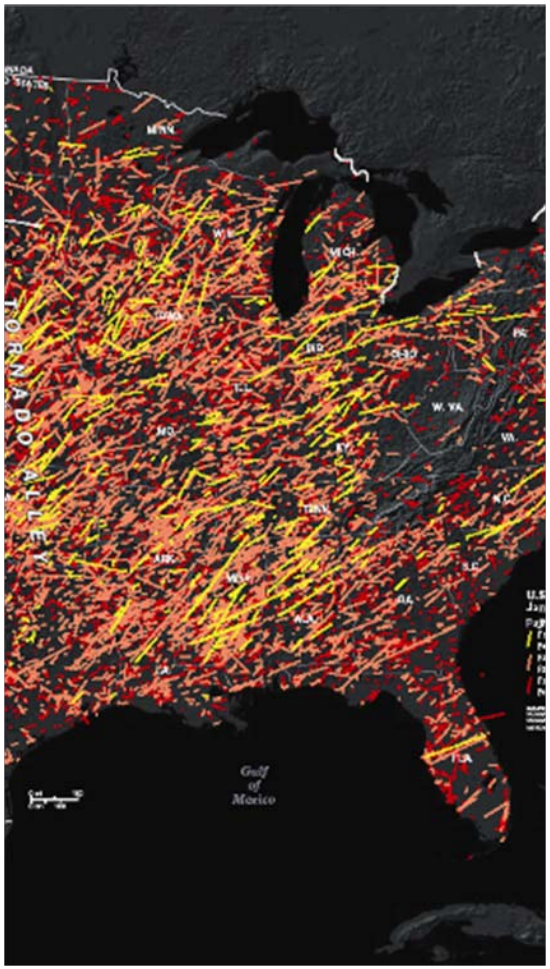


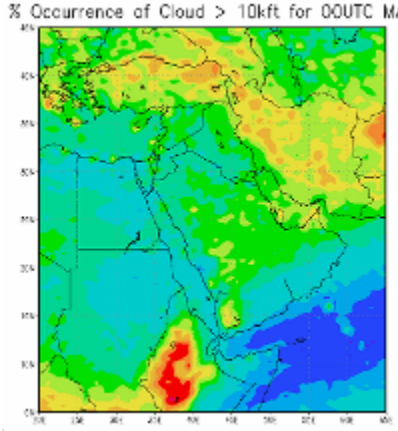


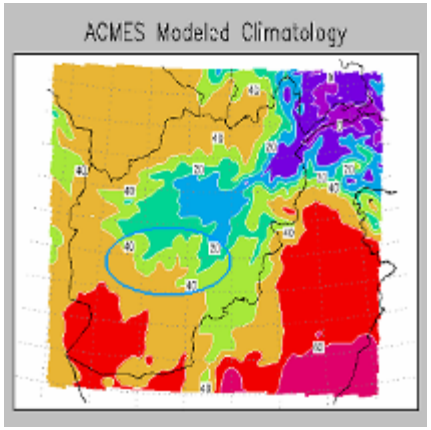


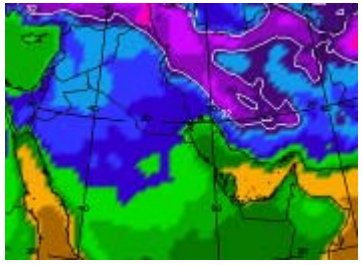
Products and Services

Climatology









Meteorological Models

Clouds and Surface Characterization

- **Clouds**
  - **Cloud Depiction and Forecast System (CDFS) II**
    - **World-wide Merged Cloud Analysis generated hourly**
    - **Global and regional cloud forecasts**
      - **Stochastic Cloud Forecast Model (SCFM) - Global**
      - **Diagnostic Cloud Forecast (DCF) - Regional**
- **Land Surface**
  - **Land Information System (LIS)**
    - **Soil moisture**
    - **Snow depth, age, liquid content**
    - **Soil temperature**

Global Cloud Analysis System

CDFS II is Reliant on Satellite Data

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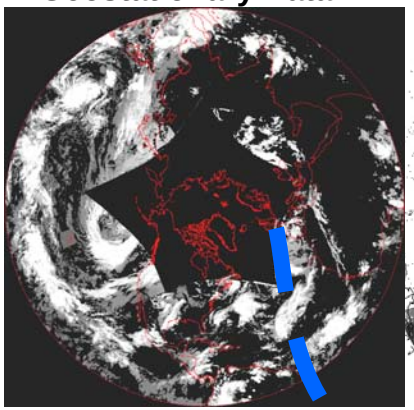
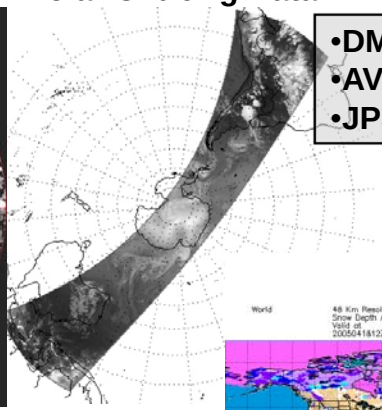
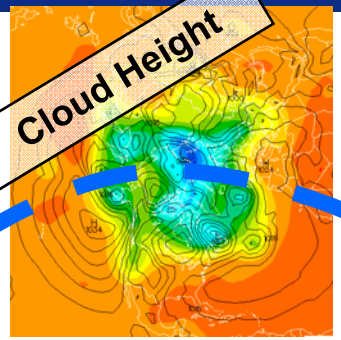
Geostationary Data



Polar Orbiting Data

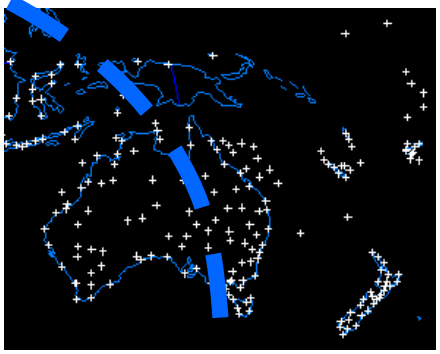


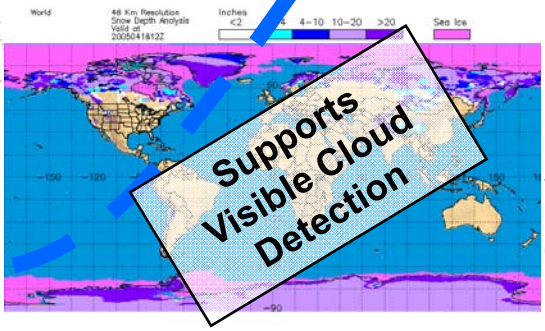
- DMSP
- AVHRR
- JPSS (Future)



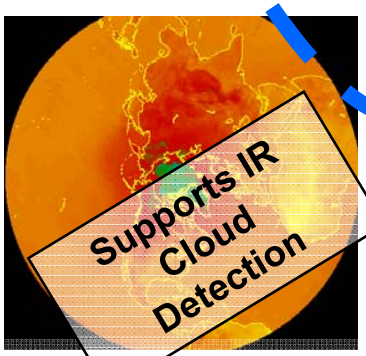
GFS
Upper Atmos. Temp
Near Surface Temp/RH/Wind

Surface Observations





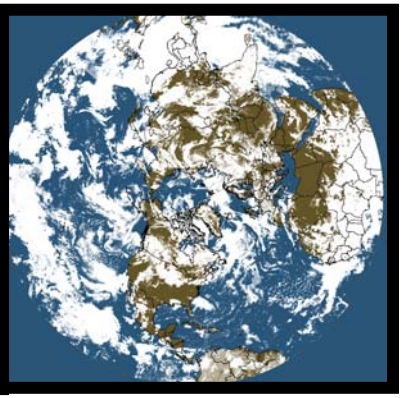
Snow Analysis
Resolution: 12 nm
Obs: Surface, SSM/I
Freq: Daily, 12Z



Surface Temp Analysis
Resolution: 12 nm
Obs: IR imagery, SSM/I Temp
Freq: 3 Hourly

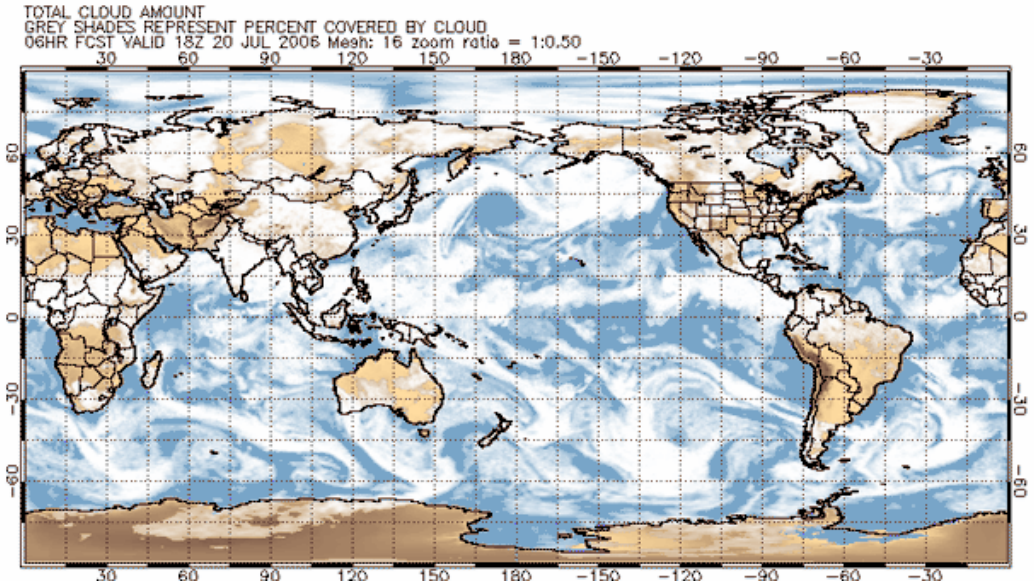
World-Wide Merged Cloud Analysis (WWMCA)
Hourly, global, real-time, cloud analysis @12.5nm

Total Cloud **and** ***Layer Cloud*** **data supports National Intelligence Community, cloud forecast models, and global soil temperature and moisture analysis.**



Cloud Forecast Models

Stochastic Cloud Forecast Model



SCFM

- *Global* cloud cover model developed by 2 WXG (Dr. Dave McDonald)
- Pairs GFS Temp, RH, VV, and Surface Press. with WWMCA cloud amounts
- 16th mesh Polar Stereographic projection
- 5 vertical layers
- 3-hr time step
- 84 hr forecast

SCFM products:

- Total fractional cloud coverage
- Layer coverage (5-layers)
  - 500 meter AGL, 850mb, 700mb, 500mb, 300mb layers

Cloud Forecast Models

Diagnostic Cloud Forecast

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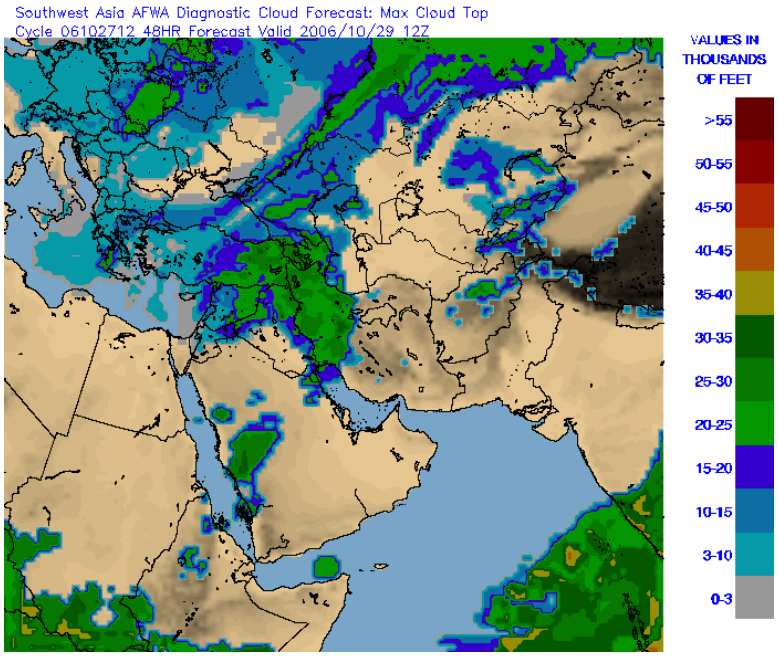


DCF

- Regional & global cloud cover model developed by AFRL
- Pairs WRF & GFS output with CDFS-II WWMCA analysis
- Statistically "chooses" which clouds best correlate with WRF or GFS predictors
- 45/15/5 km WRF grids & global ½ degree GFS grid
- 3-hr time step
- 30 to 84 hr forecast length (depends on grid)

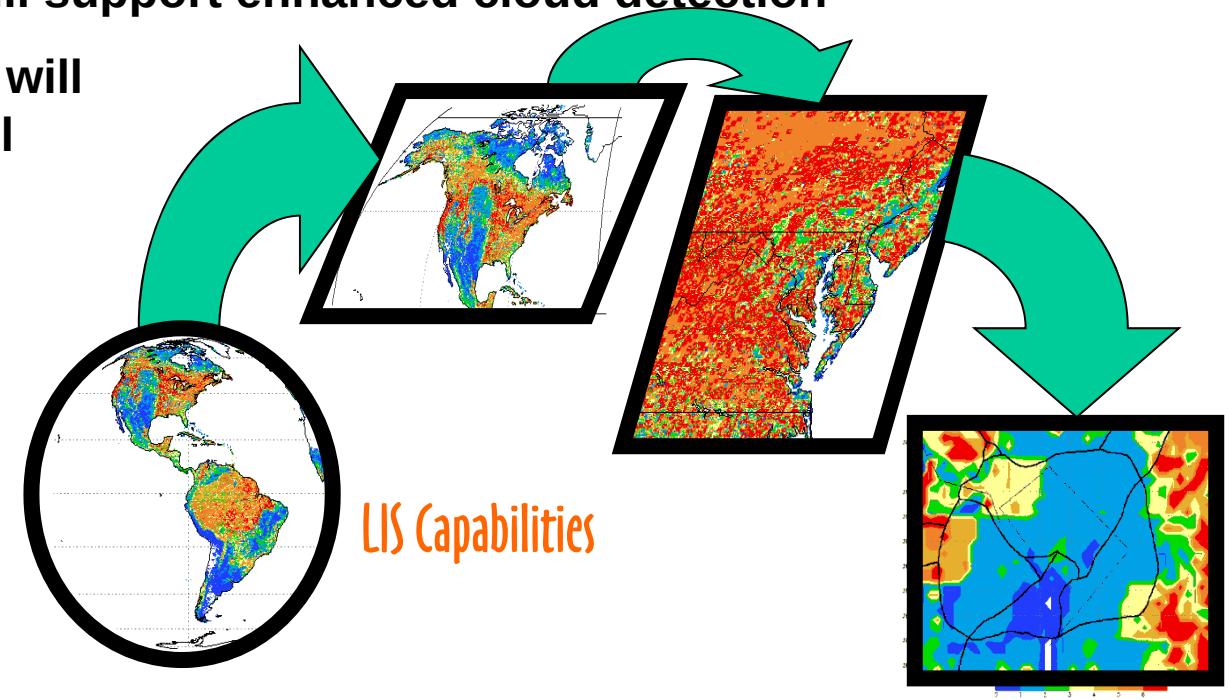
DCF products:

- Total fractional cloud coverage
- layer coverage (5-layers)
- layer top height & thickness
- layer type

Land Information System

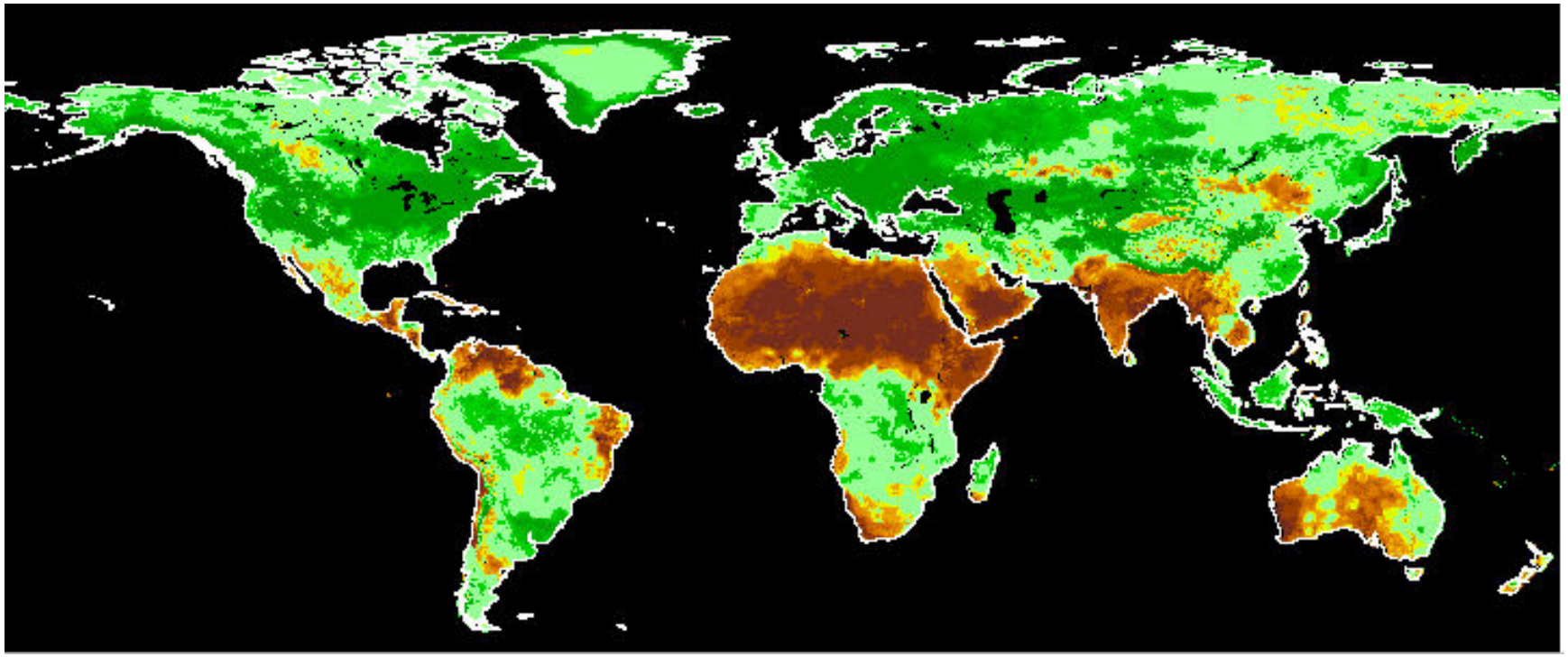
Background

- Initial Operating Capability achieved Feb 09
- New common infrastructure for surface characterization—joint effort between AFWA, NASA, NOAA and Army
- Global capability will support enhanced cloud detection
- Regional capability will support NWP model initialization and future ensemble modeling efforts
- New reliance on satellite obs to enhance surface characterization (e.g., microwave & IR skin temp data)



Land Information System

Background



- Global resolution 25km capable of 1km regionally
- Data produced at 3 hourly intervals
- 12 hour runs at 00 & 12Z plus 6 hour runs at 06 & 18Z at cycle +5.5 hours

Land Information System

Satellite Data is Primary Input

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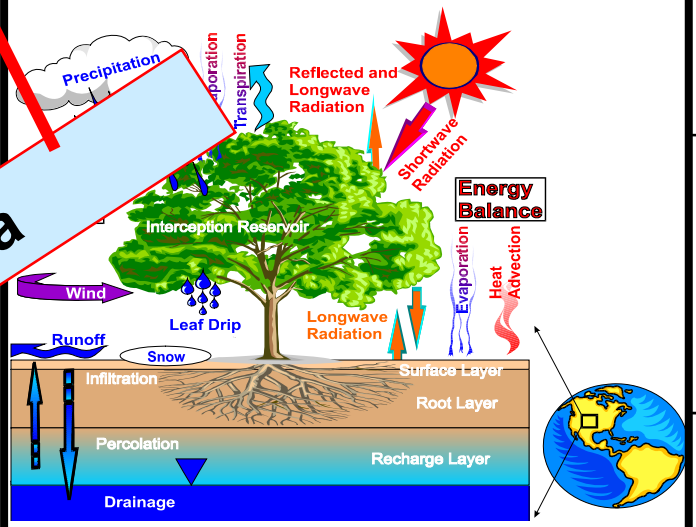
Inputs

- Topography, Soils
- Land Cover, Vegetation Properties
- [illegible]logy
- Snow Soil Moisture Temperature

Physics

- Land Surface Models
- Data Assimilation Modules



Satellite Data

Outputs

- Soil Moisture & Temperature
- Evaporation
- Runoff
- Snowpack Properties

Applications

- WRF Theater Forecasts
- Army/AF Tactical Decision Aid Software
- Crop Forecasts
- NCEP

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Regional Scale NWP

WRF

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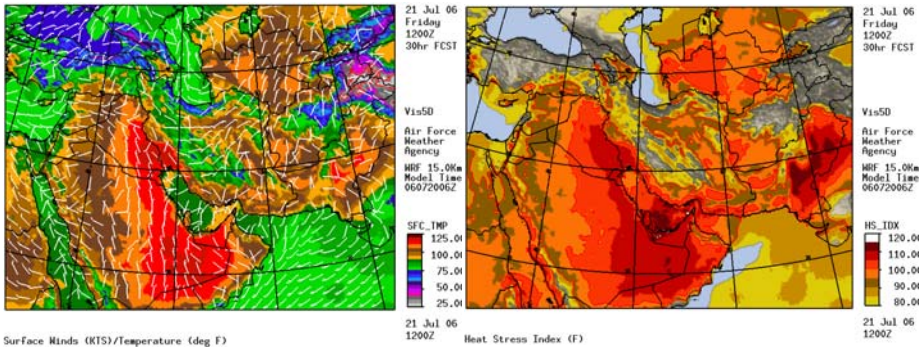
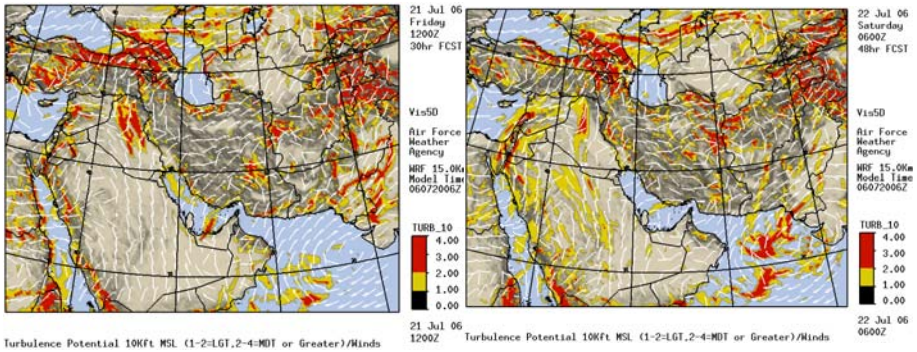
Surface temperature and heat stress forecasts, 20 Jul 2007, 06Z cycle



10,0000 FT MSL Turbulence forecasts, 20 Jul 2007, 06Z cycle



Weather Research and Forecast (WRF) model

- Development agent is NCAR
  - Implemented for classified support Jul 06
  - Unclassified transition to WRF completed Dec 09
- WRF DA system
  - Currently 3DVAR (WRFVAR)
  - Transition to GSI is being worked - ops cutover planned Fall 2011

Regional Scale NWP

Current Operational WRF Windows

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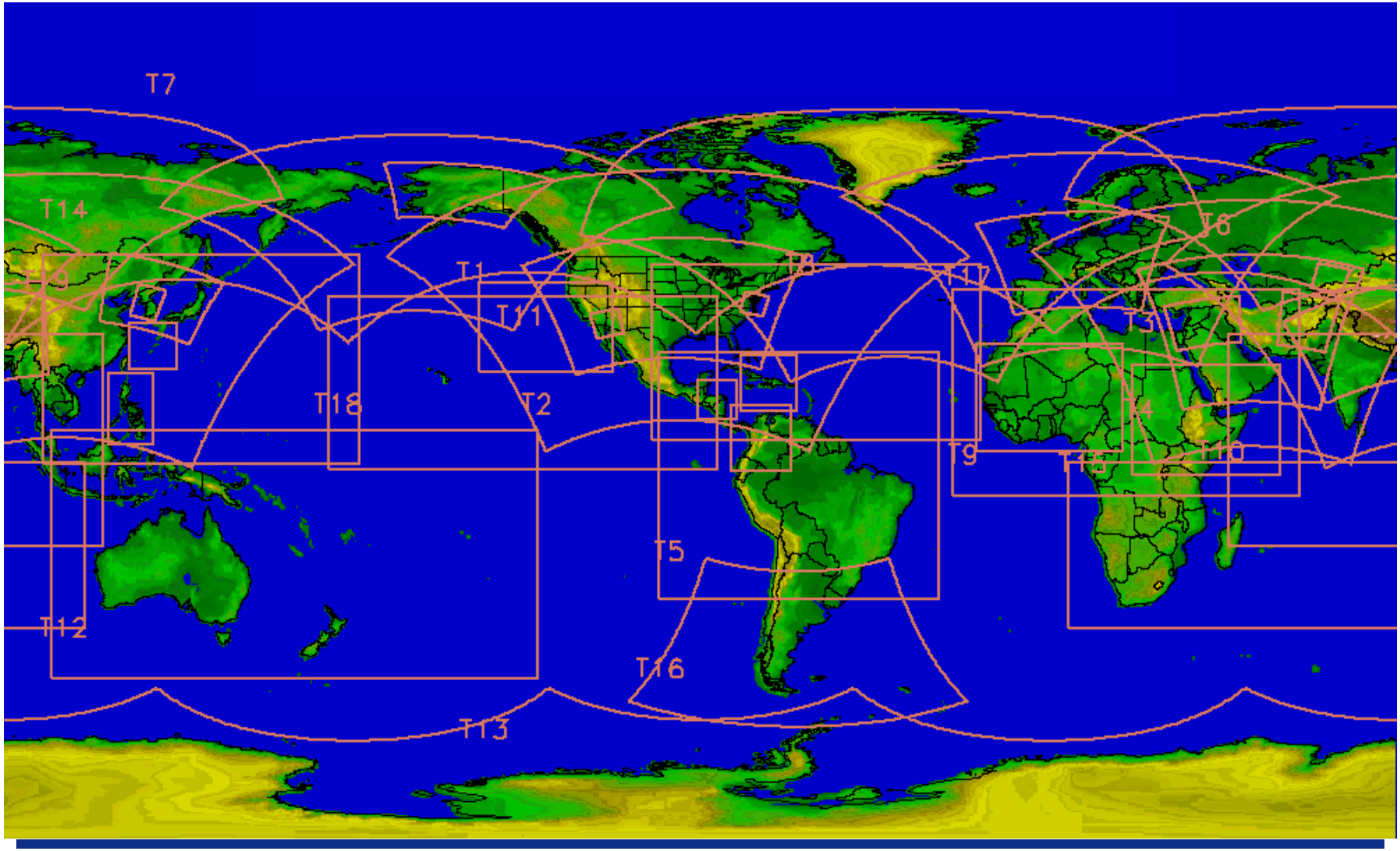

Aerosol/Constituent Modeling
WRF-chem

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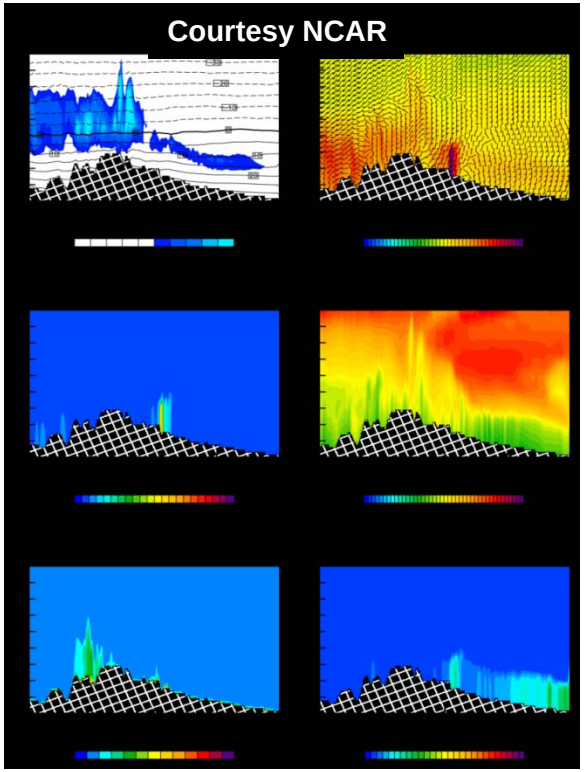
- WRF-chem is a version of WRF that simultaneously simulates the emission, turbulent mixing, transport, transformation, and fate of trace gases and aerosols. The WRF Atmospheric Chemistry Working Group is guiding the development of WRF-chem.

- New/Improved space borne sensors and assimilation techniques are needed to specify initial conditions



Capability Shortfalls

- DoD requirements demand improved cloud, aerosol, and surface trafficability forecasts
  - JCSDA Projects underway to:
    - Enhance cloud height and type specification
    - Improve accuracy of cloud forecasts
    - Couple land/air model assimilation and forecasts
    - Improve accuracy/resolution of cloud, land, dust, and regional NWP models
- Long-Term Goal is coupled/unified data assimilation and forecast system
  - AFWA Coupled Analysis & Prediction System

Capability Shortfalls

High Fidelity Cloud & Aerosol Characterization are Driving Requirements

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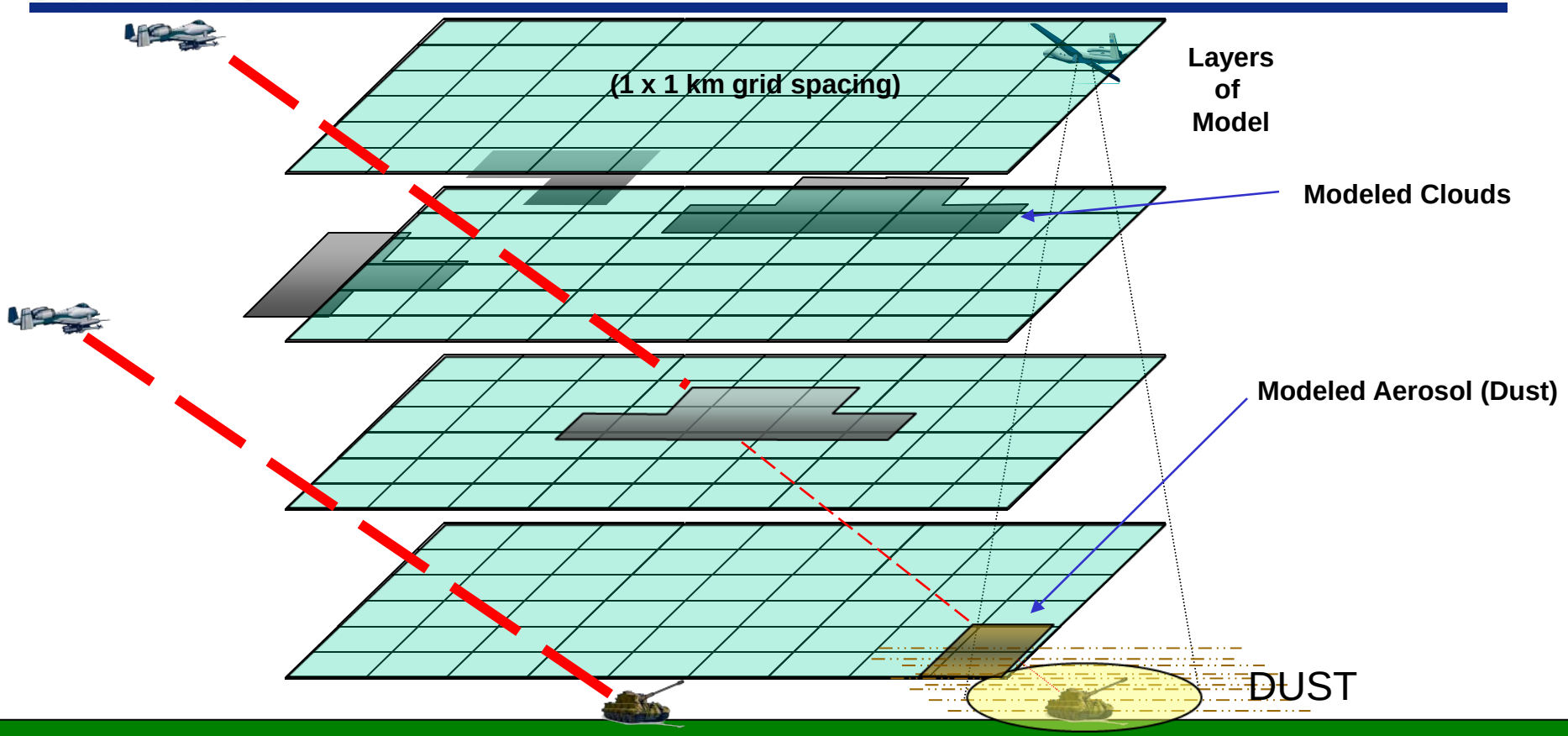
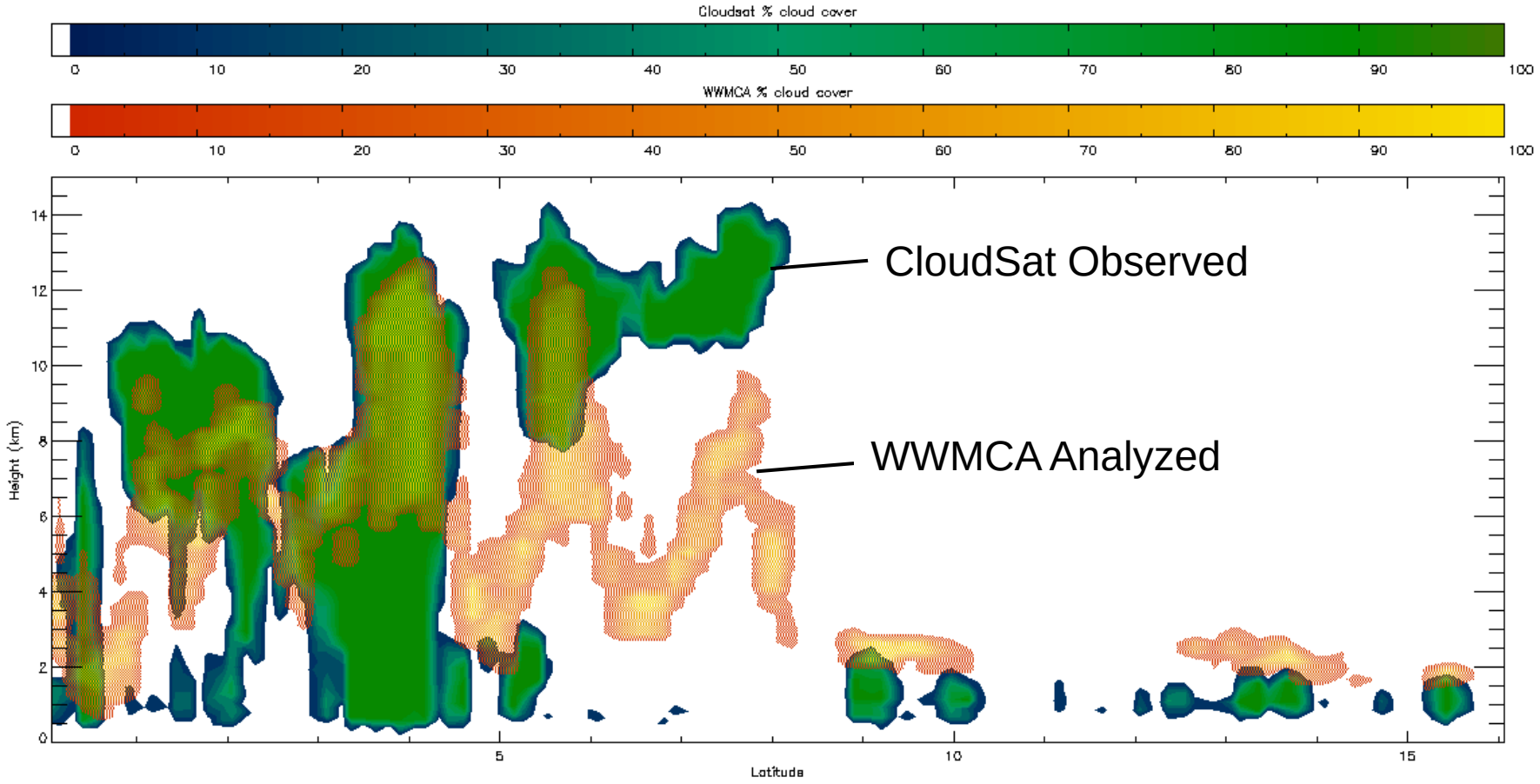


- Spatial resolution: Horizontal: 1 x 1 km, Vertical: # of layers in model (SFC to 10mb)
- Temporal resolution: 1hr steps for 0-12hrs, 3hr steps for 12-24hrs, 12hr steps for 24-72hrs
- Quantify aerosol/cloud “amount” on 1km grid for each layer of model
    - Predict slant path (visible/IR) detection by integrating layered cloud/aerosol forecasts
        - For visual acquisition, output defaults to CFLOS-like product that accounts for aerosols as well as clouds.
        - For IR acquisition, output defaults to TDA product since we must account for sensor type, target temp, background temp, etc. in addition to slant path clouds, aerosols.

Capability Shortfalls

WWMCA vs. CloudSAT

Cloud Coverage



Capability Shortfalls

Dust Forecasting

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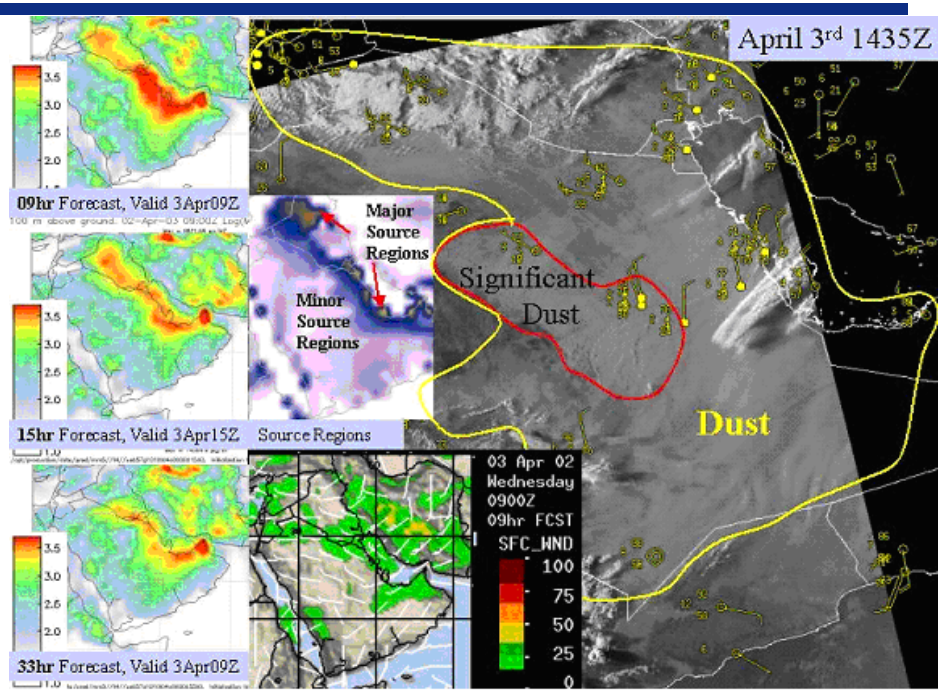
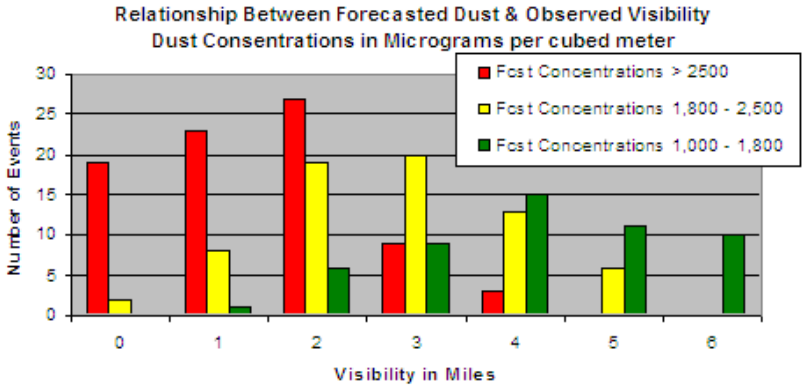
- Dust Transport Application (DTA) verification study established relationship between concentration & visibility
- Subjective verification technique
  - Area divided into grid
  - Hit/no hit evaluated
- Verification ongoing – visibility restriction due to dust added to model metrics
- Probability of detecting (POD) a dust storm beyond 24 hours is 50-80%



Selected Region	T+24 hrs	T+36 hrs	T+60 hrs
Iraq	70%	66%	60%
NE Afghanistan/Pakistan	80%	65%	50%
SW Afghanistan	65%	65%	65%



JCSDA Projects

Cloud Optical Properties (COP)

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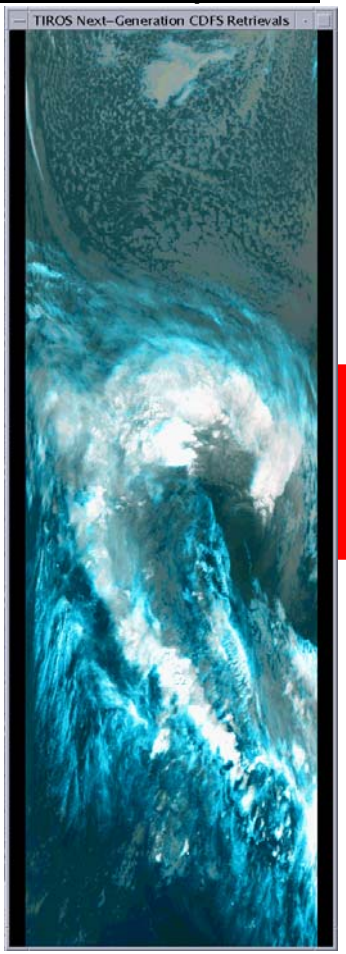
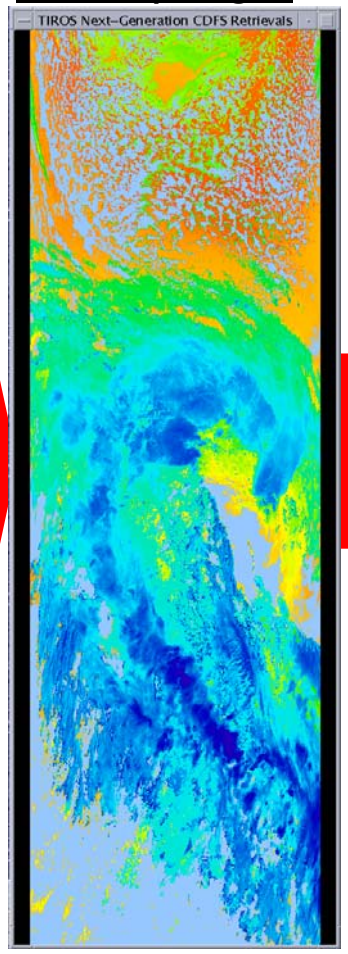
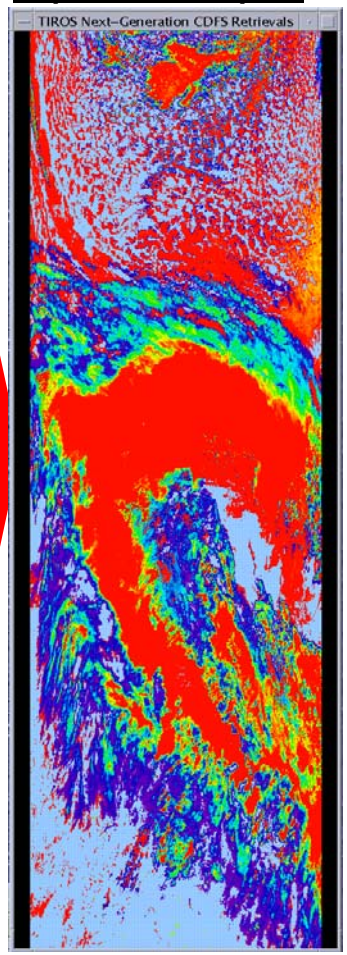
TIR Composite



Cld Top Hght



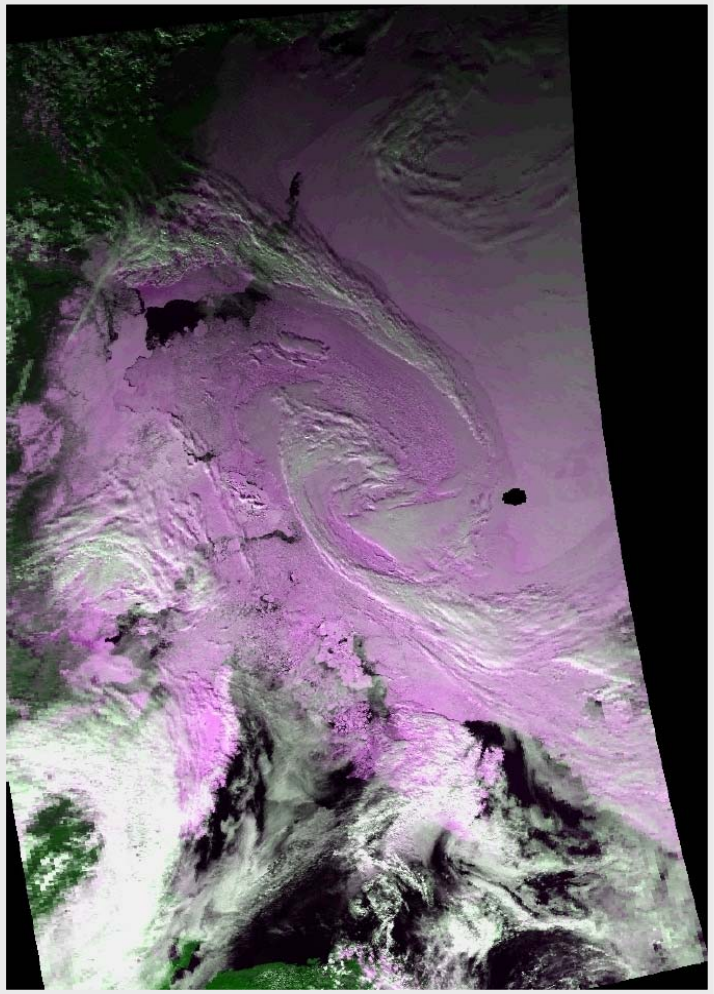
Optical Depth



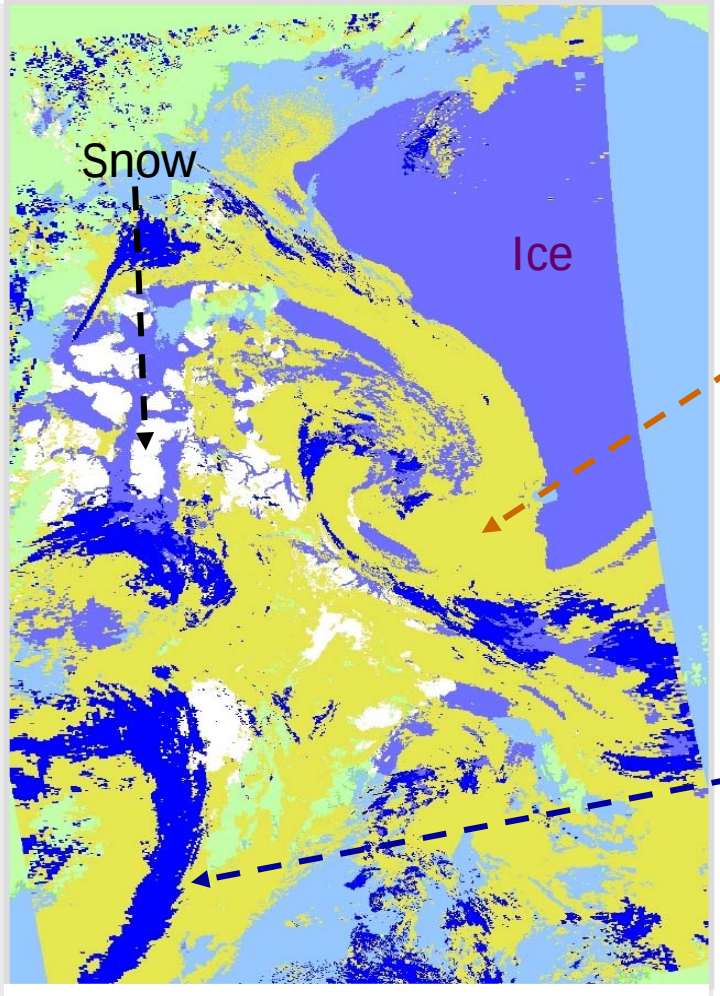
- **Cloud Optical Properties (COP): Dec 2010**
  - **Adds:**
    - **Cloud optical thickness**
    - **Liquid water path**
    - **Ice water path**
    - **Effective particle size**
- **Better estimates of:**
  - **Top/base altitudes**
  - **Transmissivity at specified wavelength**
  - **Optical depth**
  - **Effective particle size**
  - **Ice/liquid water path**

JCSDA Projects

COP Essential to Weapon Targeting



Visible - near-IR composite



Cloud Phase, Snow, Ice Mask

JCSDA Projects

Hyperspectral Cloud Retrievals

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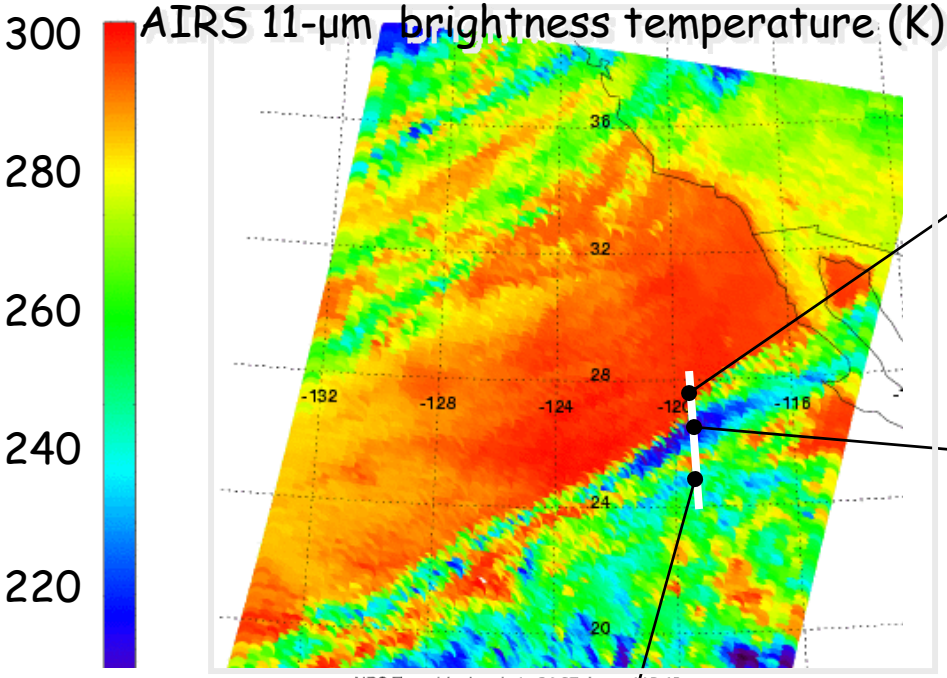
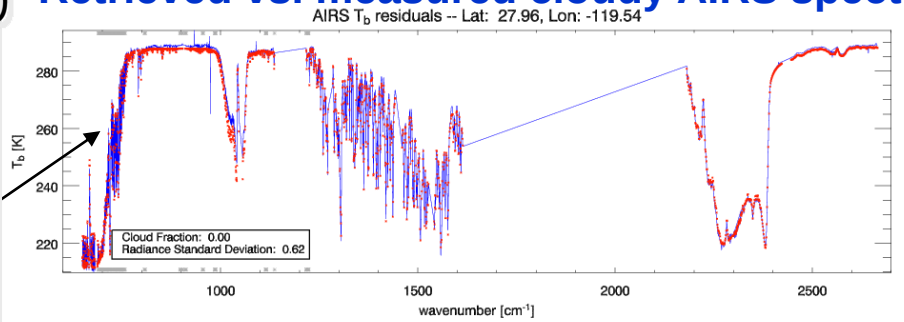
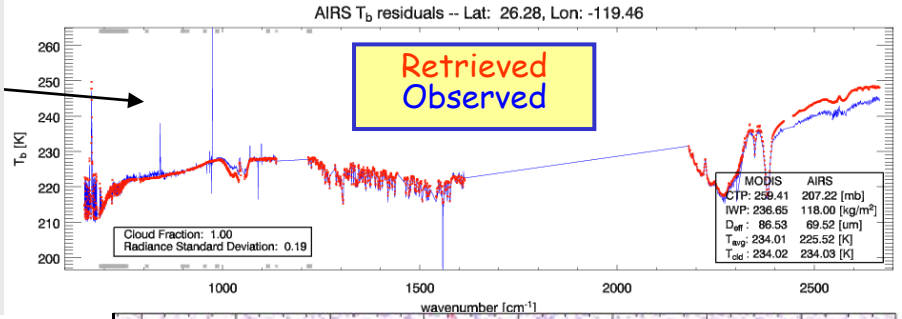
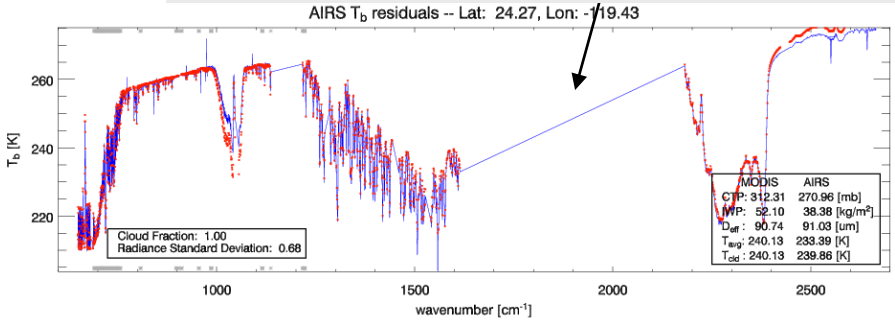
AIRS 11-μm brightness temperature (K)

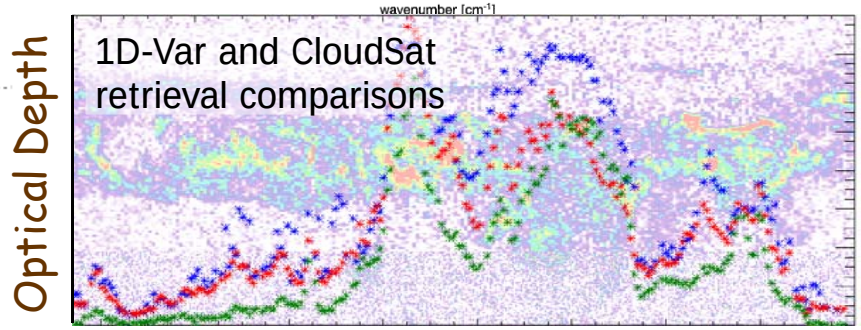


Retrieved vs. measured cloudy AIRS spectra









Retrieval with CRTM achieves close match with measurements

JCSDA Projects

LIS-WRF Coupling

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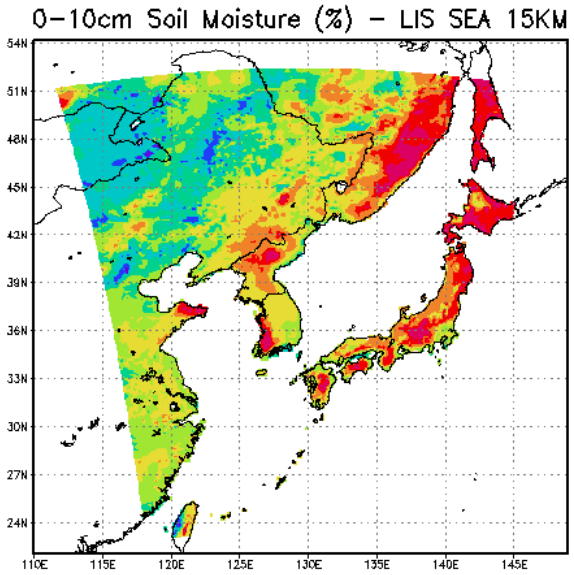
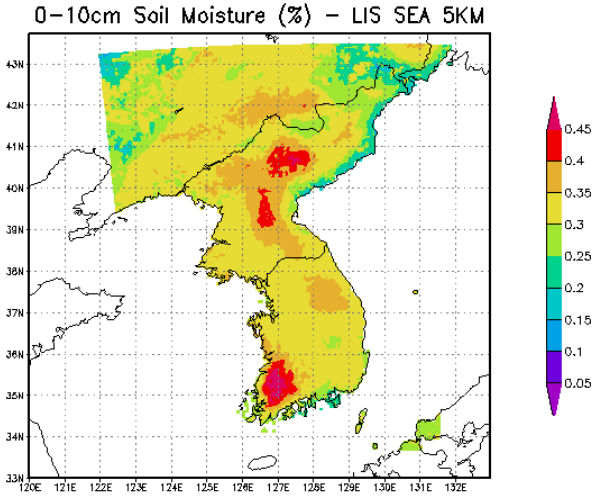
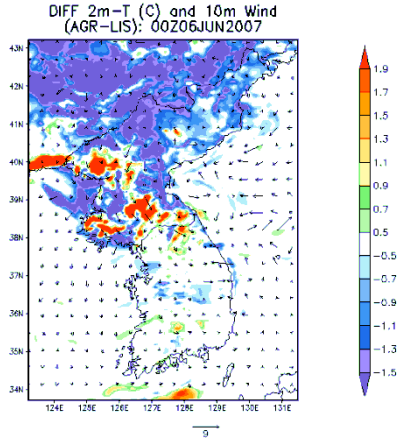


- Demonstrate and evaluate using LIS to initialize WRF SE Asia domain
- 4 seasonal test case periods
- Coupling via ESMF



STUDY RESULTS:

- LIS initialized runs were able to reduce WRF warm bias
- LIS affected 0-48 hour fcst variables of surface weather, boundary layer, cloud, and precipitation
- LIS soil and snow fields capture fine scale surface features, reflecting important role in high resolution NWP



Future Conceptual Design

Unified Analysis and Prediction System (Circa 2020)

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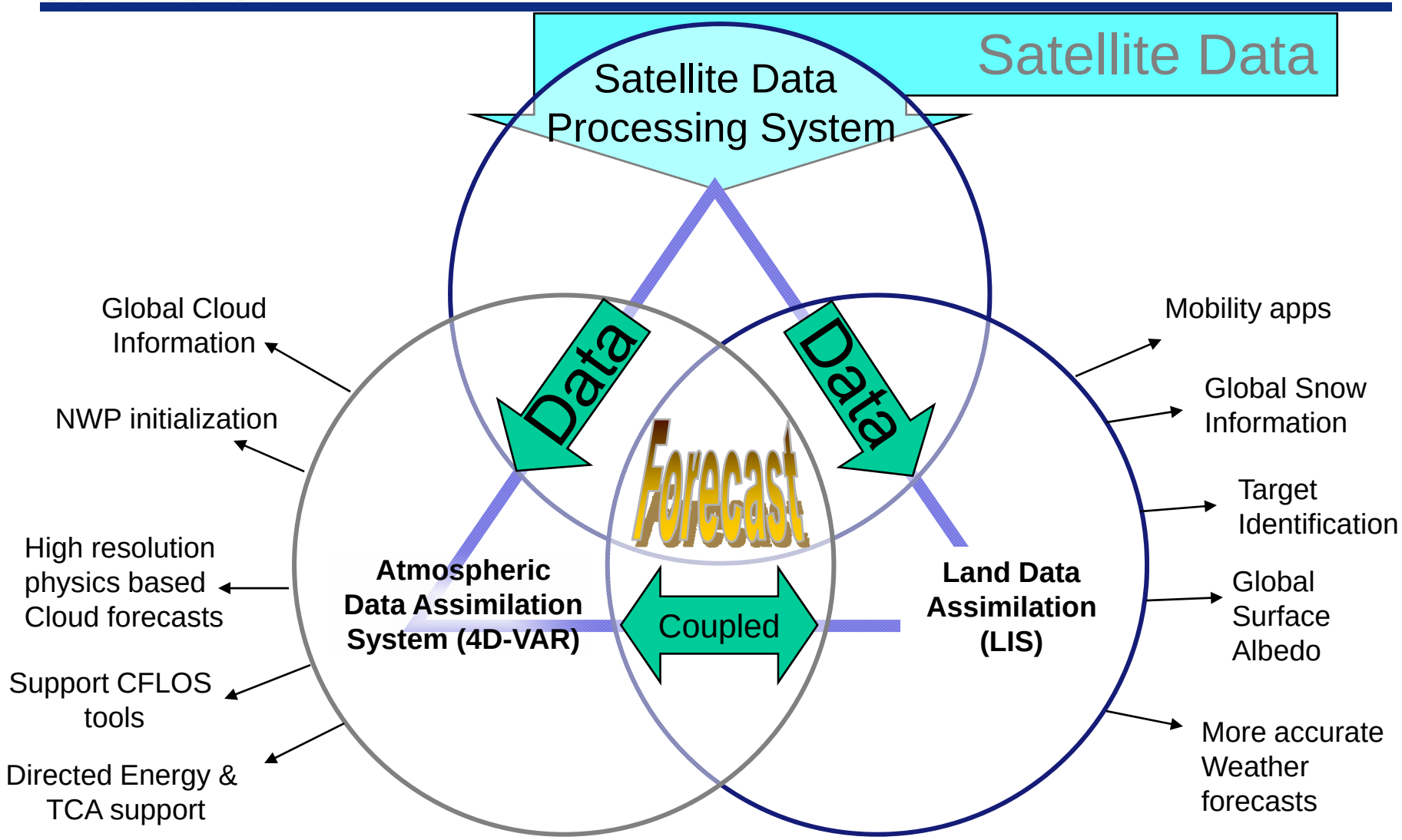

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Questions?

AIR FORCE WEATHER AGENCY