Cloud and Land Surface Interaction Experiment (CLASIC)

- Experiment Design

From the Literature

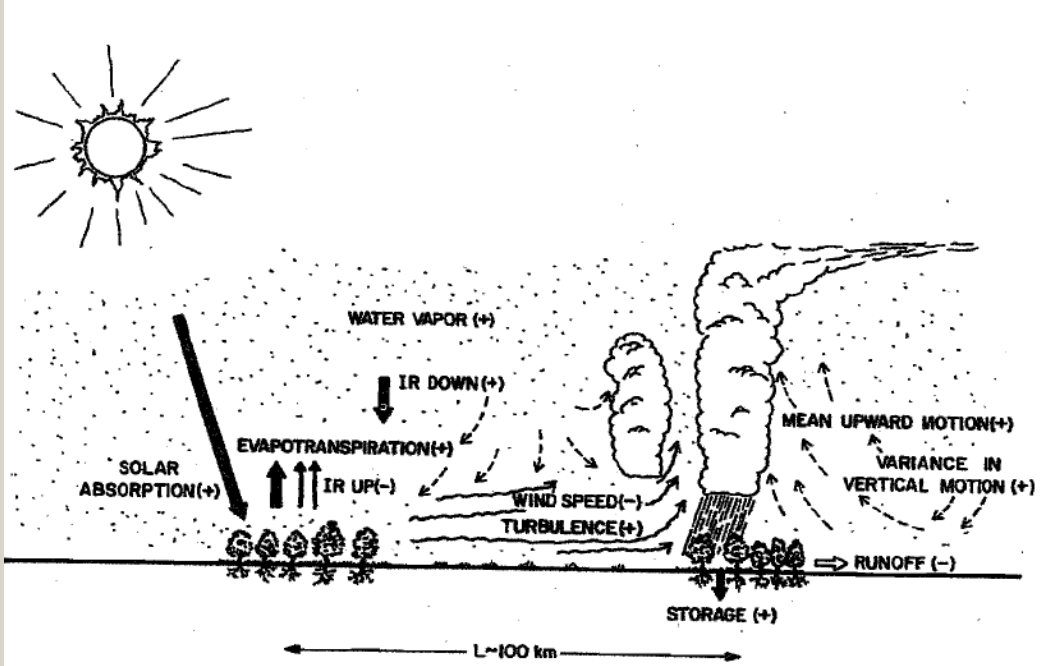


Figure 4: R. Anthes, JCAM, 1984: Hypothesized effect of establishing bands of vegetation in a semiarid region of previously bare soil. Increases or decreases of an effect or process following the introduction of vegetation are indicated by pluses and minuses, respectively.

- Our results indicate that both the cloud and and precipitation fields are strongly affected by the horizontal distribution of land-surface wetness, in particular in a drier atmosphere (Chen and Avissar, JAM,1994).
- A weak background wind of 2.5 ms^{-1} was strong enough to considerably reduce the impact of ground-surface heterogeneity (up to a scale of 40 km) on the dry CBL (Avissar and and Schmidt, JAS,1998)

Are there specific locations on the Earth's surface for which soil moisture anamolies have a substantial impact on precipitation?

Regions of Strong Coupling Between Soil Moisture and Precipitation

The GLACE Team: Randal D. Koster,[1*] Paul A. Dirmeyer,[2] Zhichang Guo,[2] Gordon Bonan,[3] Edmond Chan,[4] Peter Cox,[5] C. T. Gordon,[6] Shinjiro Kanae,[7] Eva Kowalczyk,[8] David Lawrence,[9] Ping Liu,[10] Cheng-Hsuan Lu,[11] Sergey Malyshev,[12] Bryant McAvaney,[13] Ken Mitchell,[11] David Mocko,[10] Taikan Oki,[14] Keith Oleson,[3] Andrew Pitman,[15] Y. C. Sud,[1] Christopher M. Taylor,[16] Diana Verseghy,[4] Ratko Vasic,[17] Yongkang Xue,[17] Tomohito Yamada[14]

SCIENCE VOL 305 20 AUGUST 2004

- Strong coupling in regions with large moisture gradients

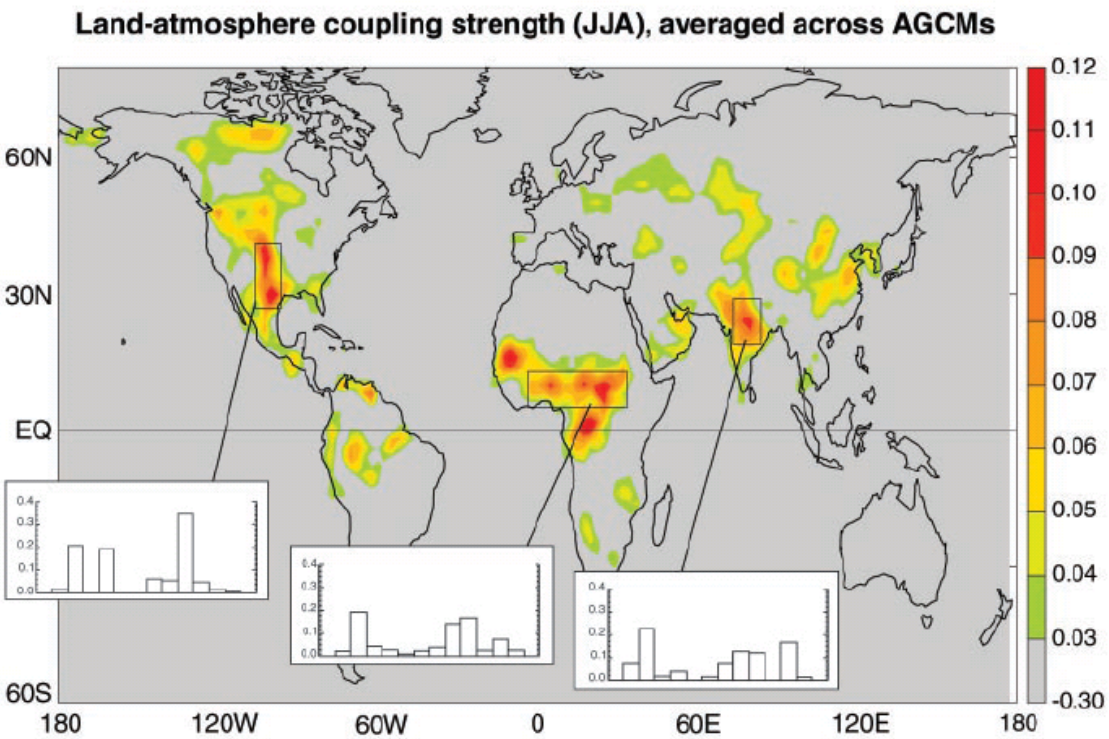


Fig. 1. The land-atmosphere coupling strength diagnostic for boreal summer (the Ω difference, dimensionless, describing the impact of soil moisture on precipitation), averaged across the 12 models participating in GLACE. (**Insets**) Areally averaged coupling strengths for the 12 individual models over the outlined, representative hotspot regions. No signal appears in southern South America or at the southern tip of Africa.

Experiment Foci

- Measurements of flux profiles, cloud structure and microphysics, aerosols, and cloud-scale dynamics in early stage cumulus convection as a function of soil moisture, land-use, and wind profile.
  - Aircraft
  - Three flux super-sites
    - ARM SGP Central Facility
    - Ft. Cobb-Little Washita
    - Okmulgee-EF-21 (Canopy and Carbon Flux)
- Radiation focus on the interplay between surface and cloud albedo
- Proper characterization of large scale dynamical forcing (advections)

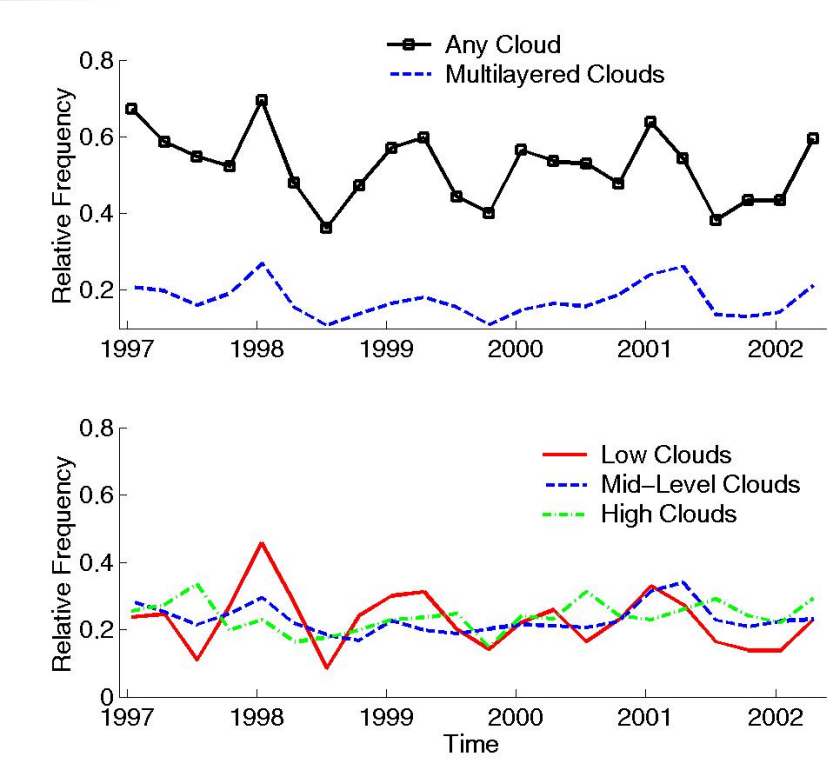
CLASIC Experiments

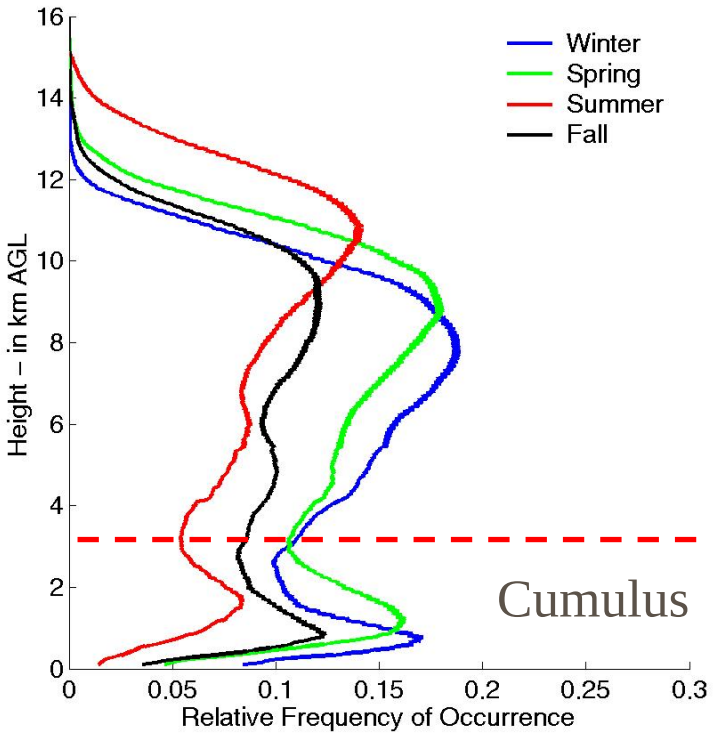
- Land surface forcing of convective activity
  - Partitioning of latent and sensible heat flux
  - Evolution of convective boundary layer
  - Timing and evolution of convection
    - Cloud Base Height
    - Updraft Velocity
    - Cloud Depth
    - CAPE
  - Aerosols and Cloud Microphysics?
- Role of cumulus convection and land cover in depleting low-level vapor advected from the Gulf of Mexico
- Convective forcing of the land surface
  - Rain-induced changes in soil moisture
    - Surface albedo
  - Photosynthesis
    - Latent Heat Flux
    - Surface albedo
    - Roughness length

Overview

- June 9-30, 2007 at SGP ACRF
- Dedicated Aircraft
  - CIRPAS Twin Otter (CLASIC)
  - NASA ER-2 (ARM UAV)
  - Duke HOP (NASA-pending; Avissar)
- Three Surface Sites—Flux measurements
- Other Platforms
  - CIRPAS-Mobile Rapid Scanning X-Band
  - SMART-Mobile C-Bands (NOAA-pending)

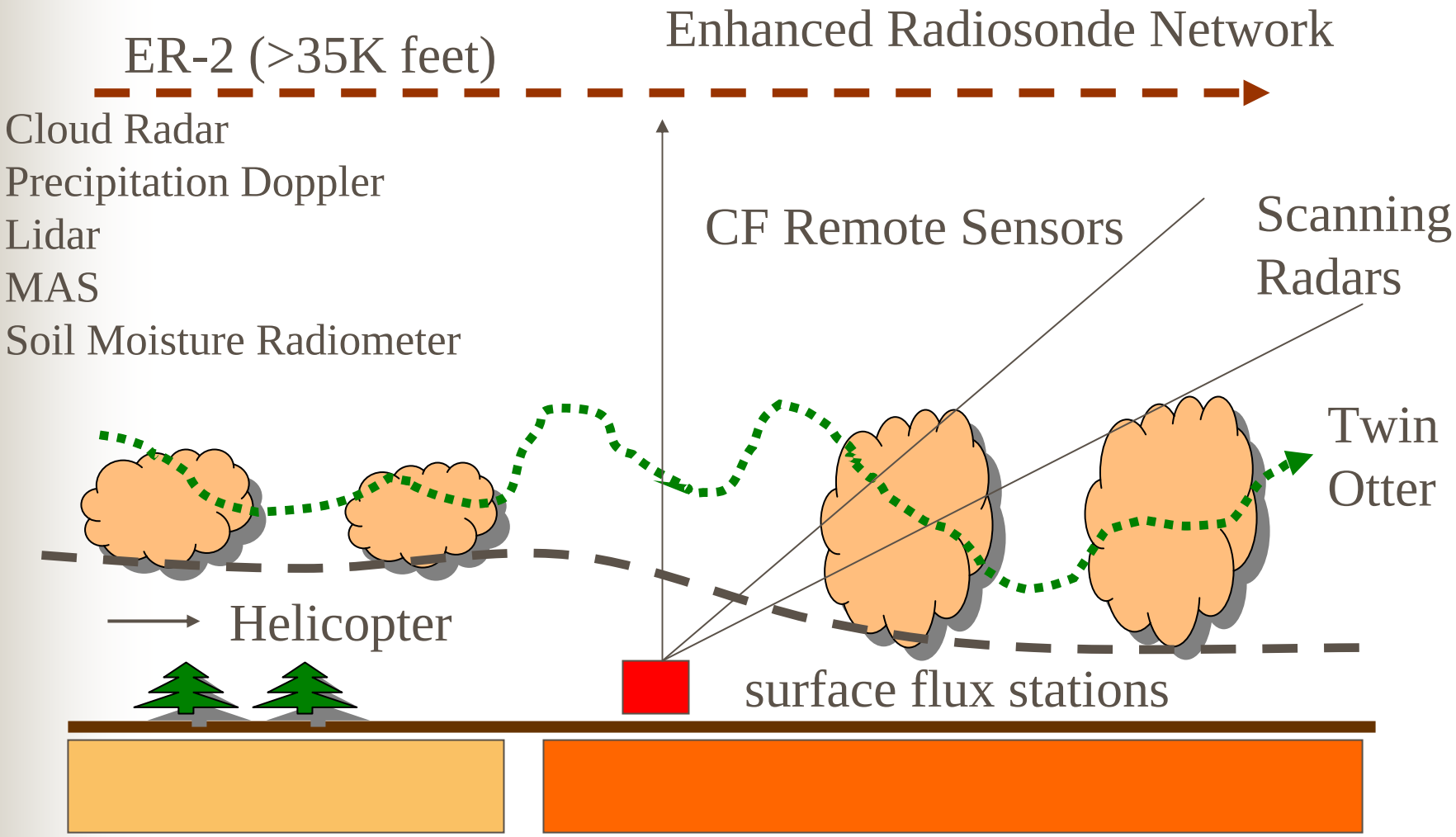
Cloud Climatology at SGP ACRF



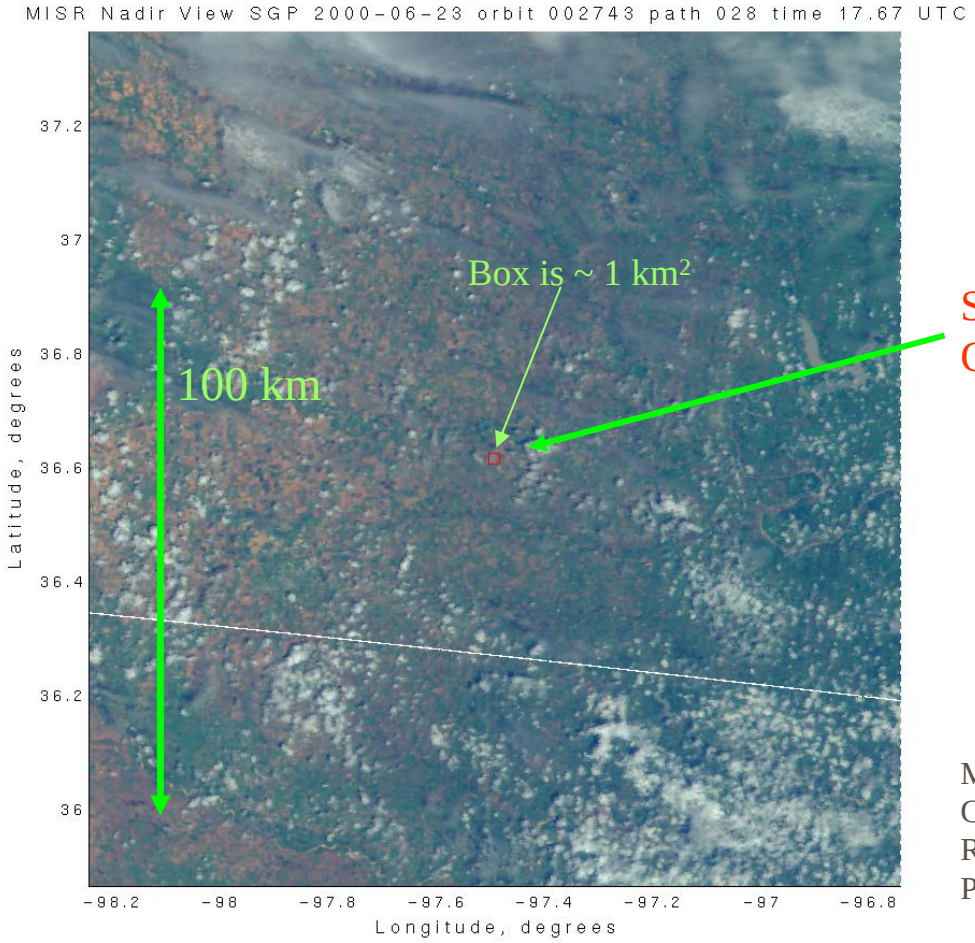


Courtesy of Roger Marchand / PNNL

Schematic


ER-2 (>35K feet)
Enhanced Radiosonde Network
Cloud Radar
Precipitation Doppler
Lidar
MAS
Soil Moisture Radiometer
CF Remote Sensors
Scanning
Radars
Twin
Otter
Helicopter
surface flux stations

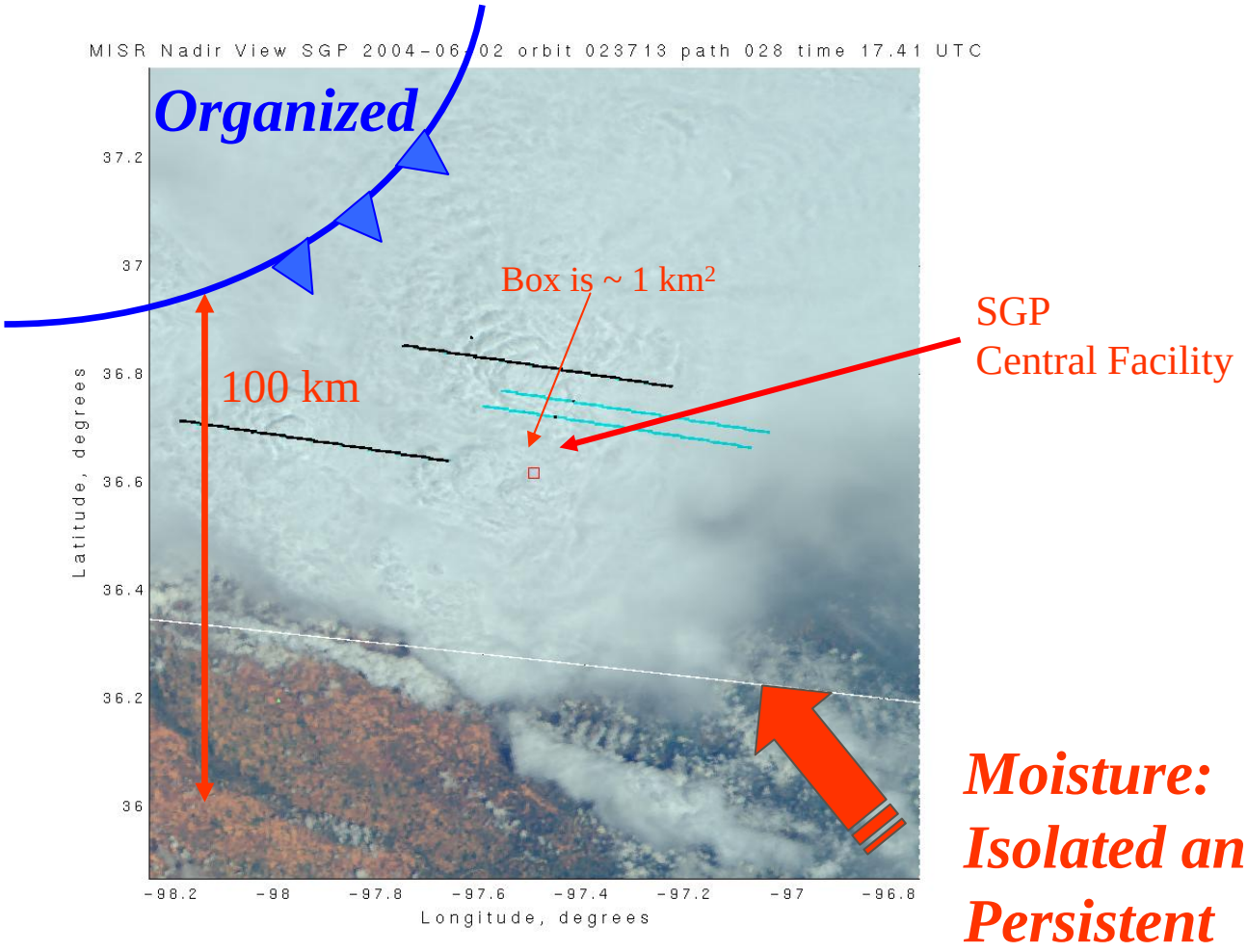
Cloud Morphology in June at the ARM SPG: The most likely cloud type is broken boundary layer cumulus often beneath thin to sub-visual cirrus. These boundary layer cumulus show little vertical development.



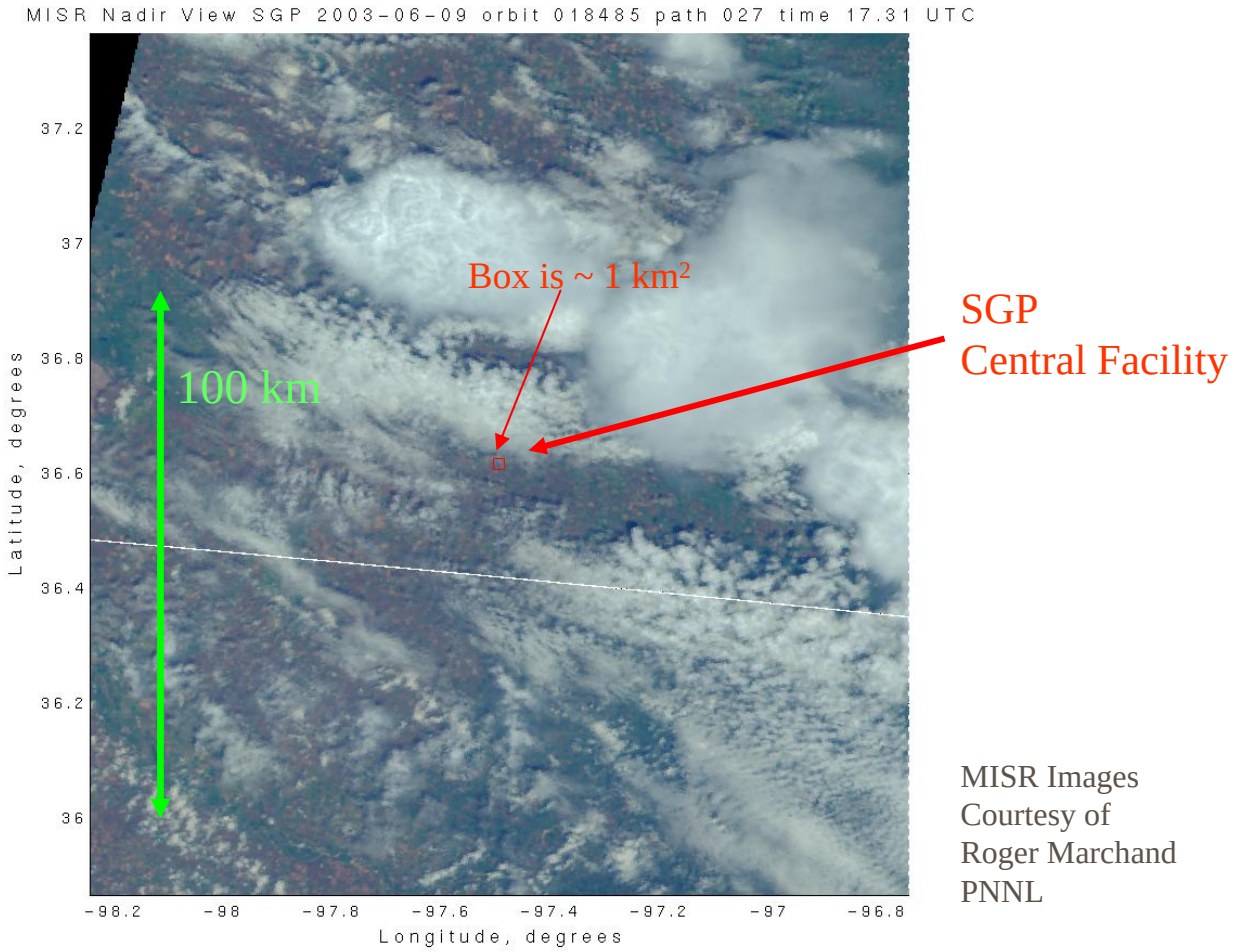
SGP
Central Facility

MISR Images
Courtesy of
Roger Marchand
PNNL

Cloud Morphology in June at the ARM SPG: Another common cloud type is deep convection, which most often occurs when moisture is advected from the Gulf or a cold front moves south.

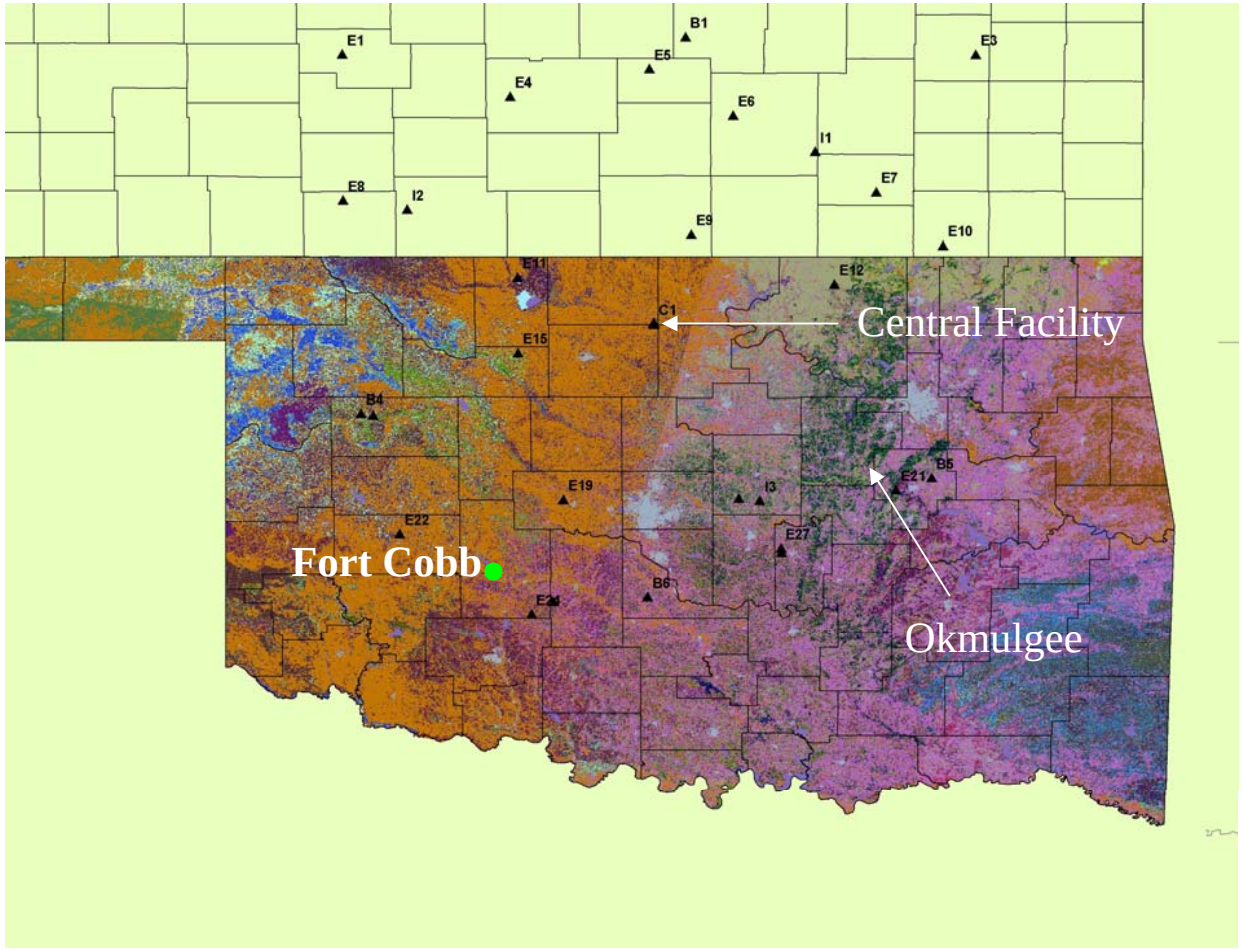


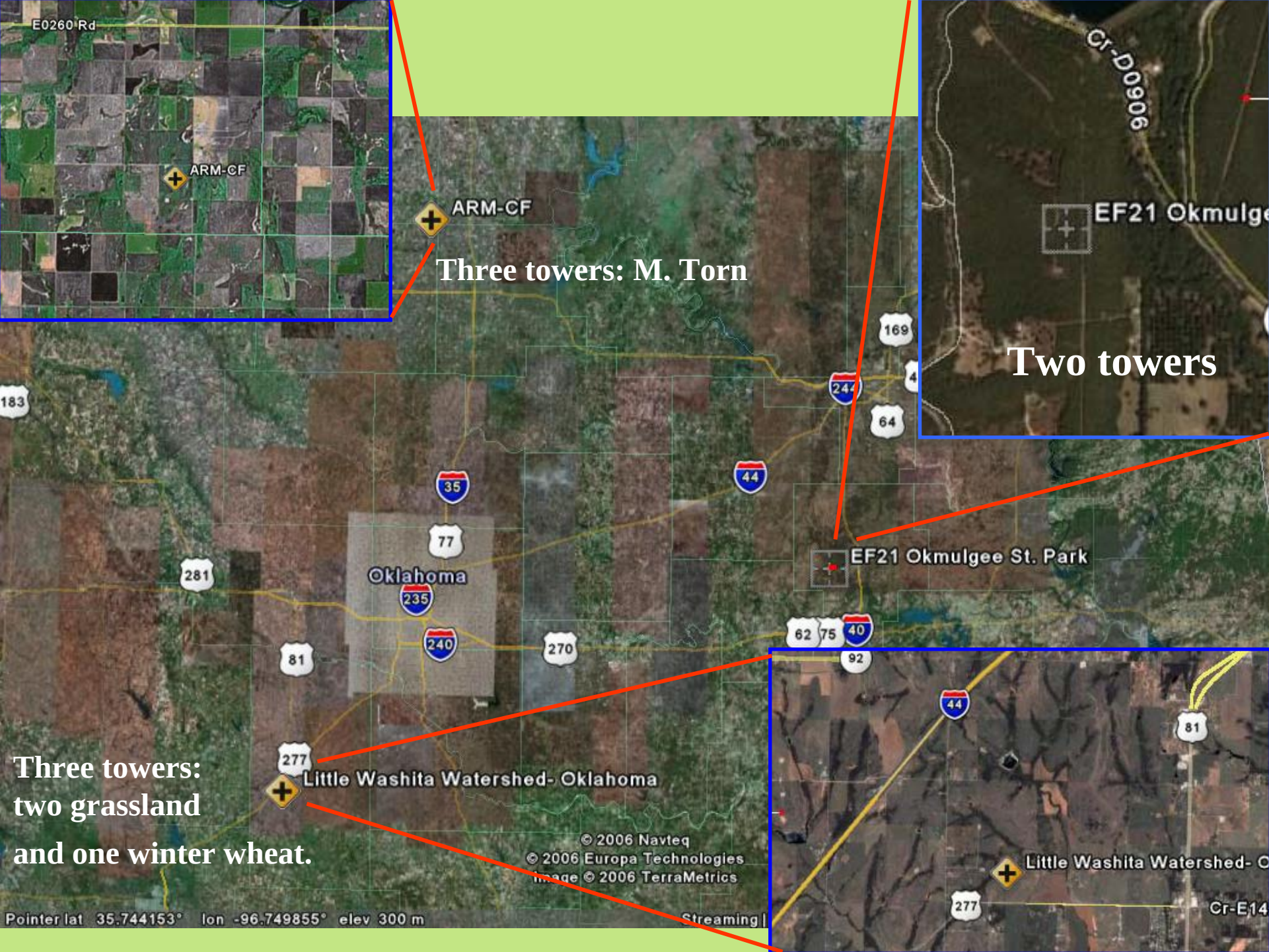
Cloud Morphology in June at the ARM SPG: A likely scenario on southwesterly winds from the Gulf is that cumulus appear in clusters prior to the onset of deep convection.



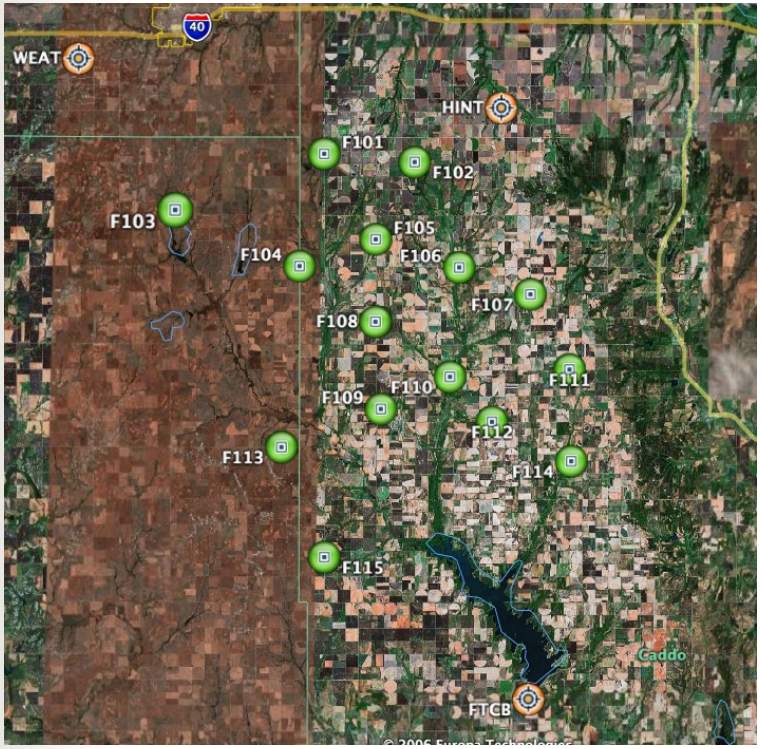
MISR Images
Courtesy of
Roger Marchand
PNNL

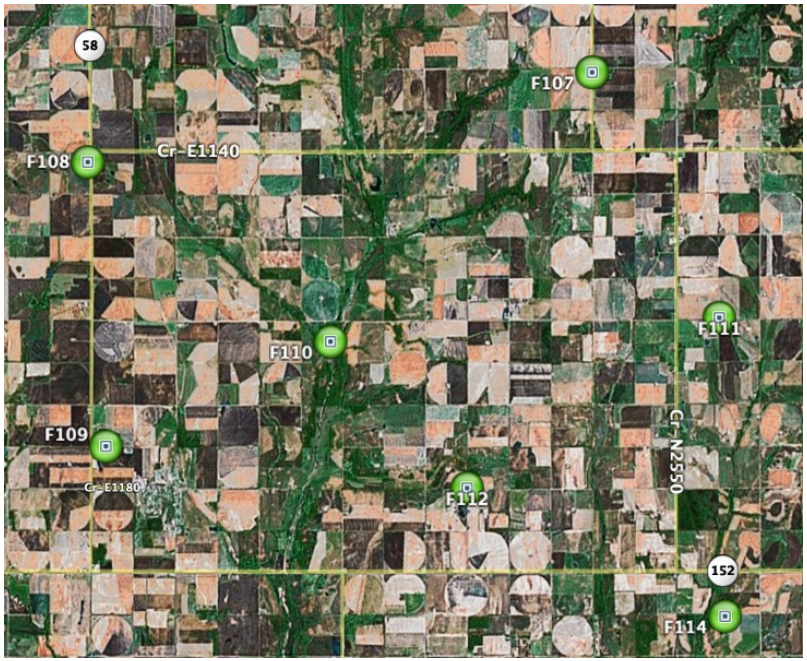
Land Coverage




E0260 Rd
ARM-CF
ARM-CF
Three towers: M. Torn
Cr-D0906
EF21 Okmulge
Two towers
169
244
64
183
35
44
77
Oklahoma
235
281
EF21 Okmulgee St. Park
240
270
62
75
40
81
92
44
81
277
Little Washita Watershed- Oklahoma
Three towers:
two grassland
and one winter wheat.
© 2006 Navteq
© 2006 Europa Technologies
Image © 2006 TerraMetrics
Pointer lat 35.744153° lon -96.749855° elev 300 m
Streaming
Little Washita Watershed- O
277
Cr-E14

Little Washita—Fort Cobb





Micronet sites (green)
Mesonet sites (yellow)

Norman, Oklahoma

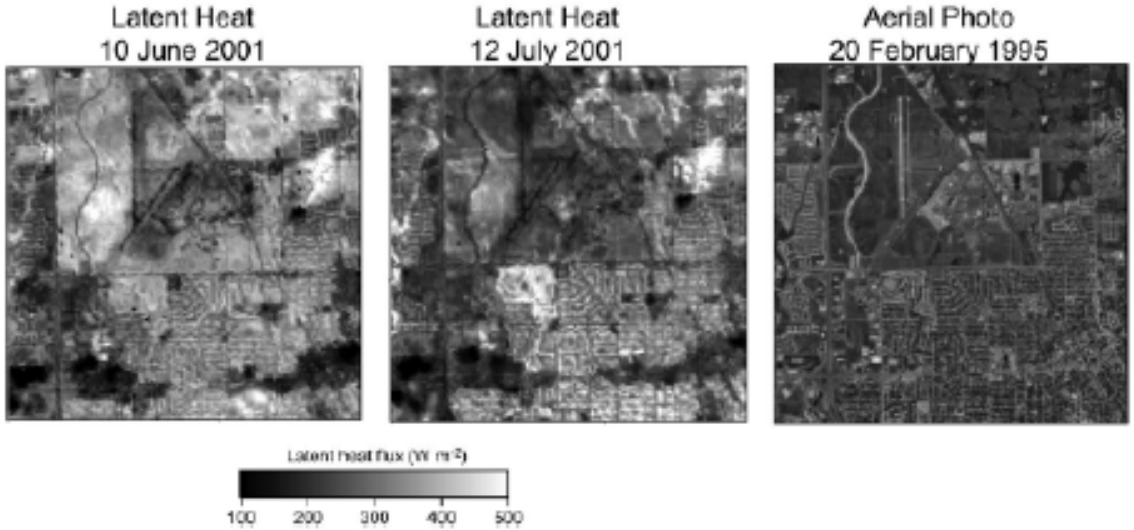


FIG. 9. Disaggregated fields of latent heating at 30-m resolution over scenes containing the NORM OASIS site on 10 Jun and 12 Jul 2001 (thermal inputs sharpened using the CS technique). An aerial photograph of the scene at 16-m resolution taken on 20 Feb 1995 is included for comparison.

From:

Anderson, M.C., Norman, J.N., Mecikalski, J.R., Torn, R.D., Kustas, W.P., and Basara, J.B., A Multi-scale Remote Sensing Model for Disaggregating Regional Fluxes to Micrometeorological Scales. Journal of Hydrometeorology 5:343-363. 2004

1. Tower observations of surface fluxes including sensible, latent, and CO2 fluxes at four locations with replication (if possible) to obtain a near-continuous monitoring of fluxes for key landuse types prior to and during the IOP, and possibly over an extended period beyond the IOP. Replicate towers will help quantify flux variance within each landuse as well as provide useful statistics for examining differences in fluxes across landuse.
2. Satellite-based flux products throughout the region
3. Digital cameras programmed to observe both site (ground and surface conditions) as well as sky conditions to detect the type and onset of cloud formation.
4. *Intensive soil moisture for specific regions within the domain using in-situ networks and new aircraft sensors. Intensive soil temperature and measures of ground heat flux using newly designed soil heat flux probes.*
5. Assistance in the application of soil moisture retrieval algorithms and processing of PSR data sets
6. Regional soil moisture from satellites
7. Cooperation with CLASIC in the development of geographic resources including land cover, crop residue, hyper spectral reflectance, NDVI and LAI products for each land use.

Milestones

- Draft of Science Plan (1-Month)
- Implementation Plan (February)
- Workshop-February
- Training Exercise (April)
- THANKS: Jimmy Voyles, Sylvia Edgerton, Pete Lamb, Beat Schmid, Greg McFarquhar, Larry Berg, Dave Turner, Tom Jackson, Bill Kustas, Roni Avissar, Qilong Min, others

NASA-ER2

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: EC99-45225-2 Date: October 1999 Photo by: Jim Ross

Lockheed ER-2 #809 high altitude research aircraft in flight

Cloud Lidar System (CLS)

- Laser: Nd:YAG I,II
- Wavelength: 1064/523 nm
- Energy: 90, 30 mJ
- PRF: 10 Hz
- Beamwidth: 1.4 mrad
- Diameter: 0.15 m
- Polarization: vertical and horizontal
- Sample Rate: 20 m intervals at 200 ms^{-1} airspeed
- Range Resolution: 7.5 m
- Number of Channels: 4
- Samples per channel: 3310
- Record capacity: 8 hours

MODIS Airborne Simulator (MAS)

Resolution:	16 bits
Ground Resolution:	50 meters (163 feet) from 19.8 km (65,000 ft.)
Swath Width:	22.9 mi/19.9 nmi (36 km)
Total Field of View:	85.92 deg.
Instant. Field of View:	2.5 mrad
Pixels/Scan Line:	716
Scan Rate:	6.25 scans/second
Ground Speed:	400 kts (206 m/second)
Roll Correction:	Plus or minus 3.5 degrees (approx.)

Spectral Channel	Band center	Band width	Spectral Range		Spectral Channel	Band center	Band width	Spectral Range
	(micrometers)					(micrometers)		
1	0.4649	0.0397	0.4451-0.4848		26	3.1192	0.1616	3.0384-3.2000
2	0.5494	0.0417	0.5285-0.5703		27	3.2809	0.1486	3.2066-3.3552
3	0.6550	0.0511	0.6294-0.6805		28	3.4330	0.1617	3.3521-3.5138
4	0.7024	0.0415	0.6816-0.7231		29	3.5940	0.1539	3.5170-3.6709
5	0.7431	0.0420	0.7221-0.7641		30	3.7449	0.1449	3.6724-3.8174
6	0.8248	0.0427	0.8034-0.8461		31	3.9069	0.1602	3.8267-3.9870
7	0.8667	0.0414	0.8460-0.8874		32	4.0707	0.1554	4.1365-4.2034
8	0.9072	0.0409	0.8867-0.9276		33	4.1699	0.0669	4.1365-4.2034
9	0.9476	0.0397	0.9277-0.9674		34	4.4029	0.1255	4.3401-4.4656
10	1.6422	0.0519	1.6163-1.6682		35	4.5404	0.1512	4.4648-4.6160
11	1.6975	0.0505	1.6722-1.7228		36	4.6979	0.1591	4.6184-4.7775
12	1.7499	0.0506	1.7245-1.7752		37	4.8536	0.1516	4.7778-4.9294
13	1.8014	0.0491	1.7768-1.8259		38	5.0033	0.1468	4.9298-5.0767
14	1.8548	0.0489	1.8303-1.8792		39	5.1588	0.1400	5.0888-5.2288
15	1.9044	0.0487	1.8801-1.9288		40	5.3075	0.1327	5.2412-5.3738
16	1.9553	0.0483	1.9312-1.9794		41	5.3977	0.0775	5.3590-5.4365
17	2.0048	0.0487	1.9804-2.0291		42	8.5366	0.3950	8.3391-8.7341
18	2.0551	0.0484	2.0309-2.0793		43	9.7224	0.5365	9.4541-9.9906
19	2.1037	0.0486	2.0794-2.1280		44	10.5071	0.4579	10.278-10.736
20	2.1532	0.0483	2.1291-2.1774		45	11.0119	0.4710	10.776-11.247
21	2.2019	0.0481	2.1779-2.2259		46	11.9863	0.4196	11.777-12.196
22	2.2522	0.0486	2.2278-2.2765		47	12.9013	0.3763	12.713-13.089
23	2.3021	0.0487	2.2777-2.3265		48	13.2702	0.4584	13.041-13.500
24	2.3512	0.0476	2.3274-2.3750		49	13.8075	0.5347	13.540-14.075
25	2.4005	0.0483	2.3764-2.4246		50	14.2395	0.3775	14.051-14.428

Low Altitude
-Twin Otter

High Altitude
-MAS
-Cloud Radar
-lidar
-scanning soil moisture radiometer

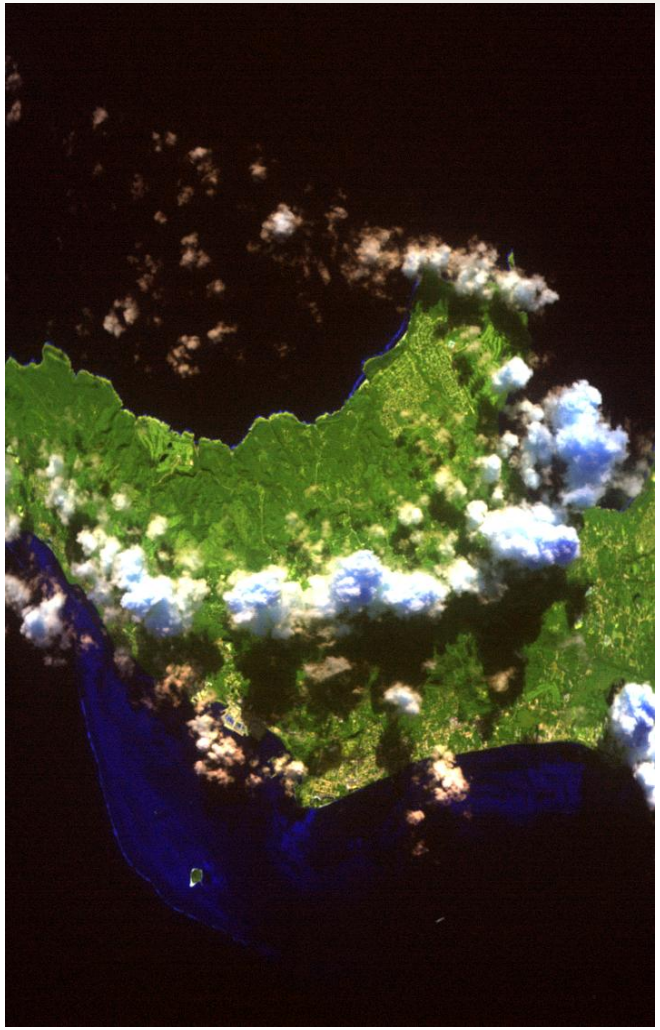


Figure 2A: Example of true color composite MASTER image obtained over trade cumuli like clouds over N. Marinas by NASA DC8 flying about 28000 ft above surface. Horizontal resolution is approximately 22 m.

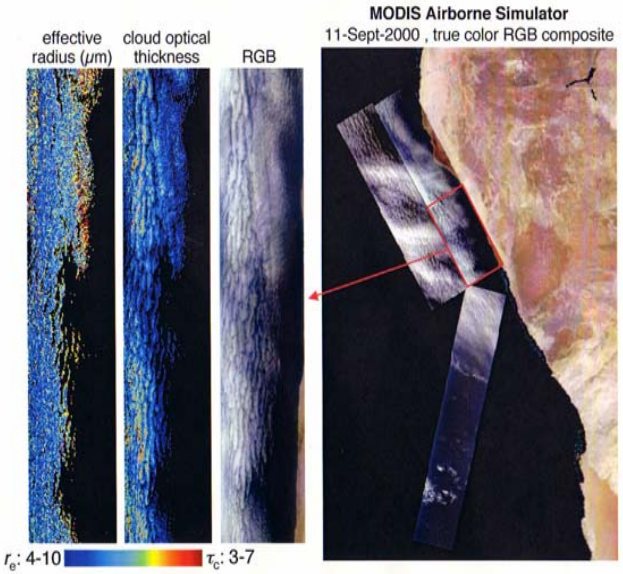


Figure 4A: Example of retrieval of r_e and τ_{ext} from MAS during SAFARI project

NASA Airborne Cloud Radar

The 94-GHz (W band) Cloud Radar System (CRS) has been developed and flown on a NASA ER-2 high-altitude (20 km) aircraft. The CRS is a fully coherent, polarimetric Doppler radar that is capable of detecting clouds and precipitation from the surface up to the aircraft altitude in the lower stratosphere. The radar is especially well suited for cirrus cloud studies because of its high sensitivity and fine spatial resolution.

CIRPAS Twin Otter:

65 Flight hours (includes transit and testflight)
5 Days in Marina, CA (integration+testflight)
23 Days in field (incl. transit)
Based in Ponca City, OK
CIRPAS staff: 2 Pilots, 1 Mechanic, 2 Scientists
Platform Scientist: Beat Schmid (BAER Inst.)

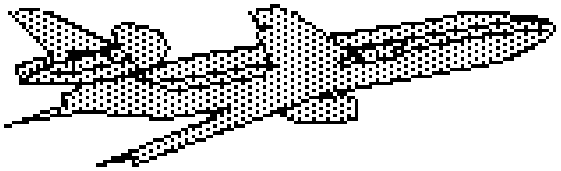
Available Measurement	Instrument	PI or Group
Total aerosol number concentration	Condensation Nucleus Counter (CNC)	CIRPAS
Aerosol size distribution: d=0.5 µm - 5µm	TSI Aerodynamic Particle Sizer	CIRPAS
Aerosol/cloud size distribution d=0.1 - 2.5 µm d=0.8 - 80 µm	Passive Cavity Aerosol Spectrometer Probe (PCASP) Cloud Aerosol and Precipitation Spectrometer (CAPS)	CIRPAS
Aerosol/cloud size distribution d=2.5 – 50 µm	Forward Scattering Spectrometer Probe (FSSP)	CIRPAS
Cloud liquid water content	Gerber PVM Johnson probe on CAPS	CIRPAS
Meteorological state parameters: Dry-bulb temperature Dew point temperature Pot. T, Equiv. Pot T Pressure Horizontal wind vector Updraft velocities Surface Temp	Various instruments (with redundancy) Gust probe Heiman KT18.95	CIRPAS

Available Measurement	Instrument	PI or Group
Aircraft state parameters: Position Airspeed Pressure altitude Attitude (pitch, roll, yaw)	Various instruments (with redundancy)	CIRPAS
Aerosol scattering	TSI Nephelometer (450, 550, 700 nm)	CIRPAS+Ogren (NOAA)
Aerosol absorption	Soot Photometer (PSAP, 467, 530, 660 nm)	CIRPAS+Ogren (NOAA)
Cloud condensation nuclei supersaturation spectrum	CCN instrument	Collins (Texas A&M)
Aerosol size distribution and hygroscopicity	Tandem Differential Mobility Analyzer (TDMA)	Collins (Texas A&M)
Cloud size distribution	Phased Doppler Cloud Probe	Chuang (UC Santa Cruz)
Cloud Extinction (uncertain)	Extinctiometer	Lawson

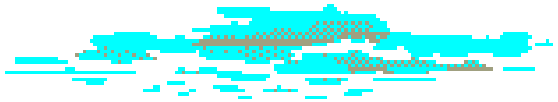
Land Surface Characterization

- Tower observations of surface fluxes at four locations with replication (up to 8 flux stations) to obtain a near-continuous monitoring of fluxes from Late Spring to early Fall
- Satellite-based flux products throughout the region
- Regional soil moisture from satellites (new disaggregation approaches)
- Intensive soil moisture for the LW and Fort Cobb areas using *in situ* networks and new aircraft sensors
- Soil moisture retrieval algorithms and processing of PSR data sets
- Land cover, Crop residue, Normalized Difference Vegetation Index (NDVI) and Leaf Area Index (LAI) products

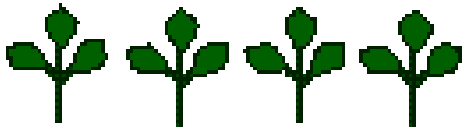
Courtesy:
Tom Jackson
ARS-USDA



$$\varepsilon_{obs} = TB / T_s$$



$$\varepsilon_{sur} = 1 + (\varepsilon_{obs} - 1)\exp(2bW_v)$$

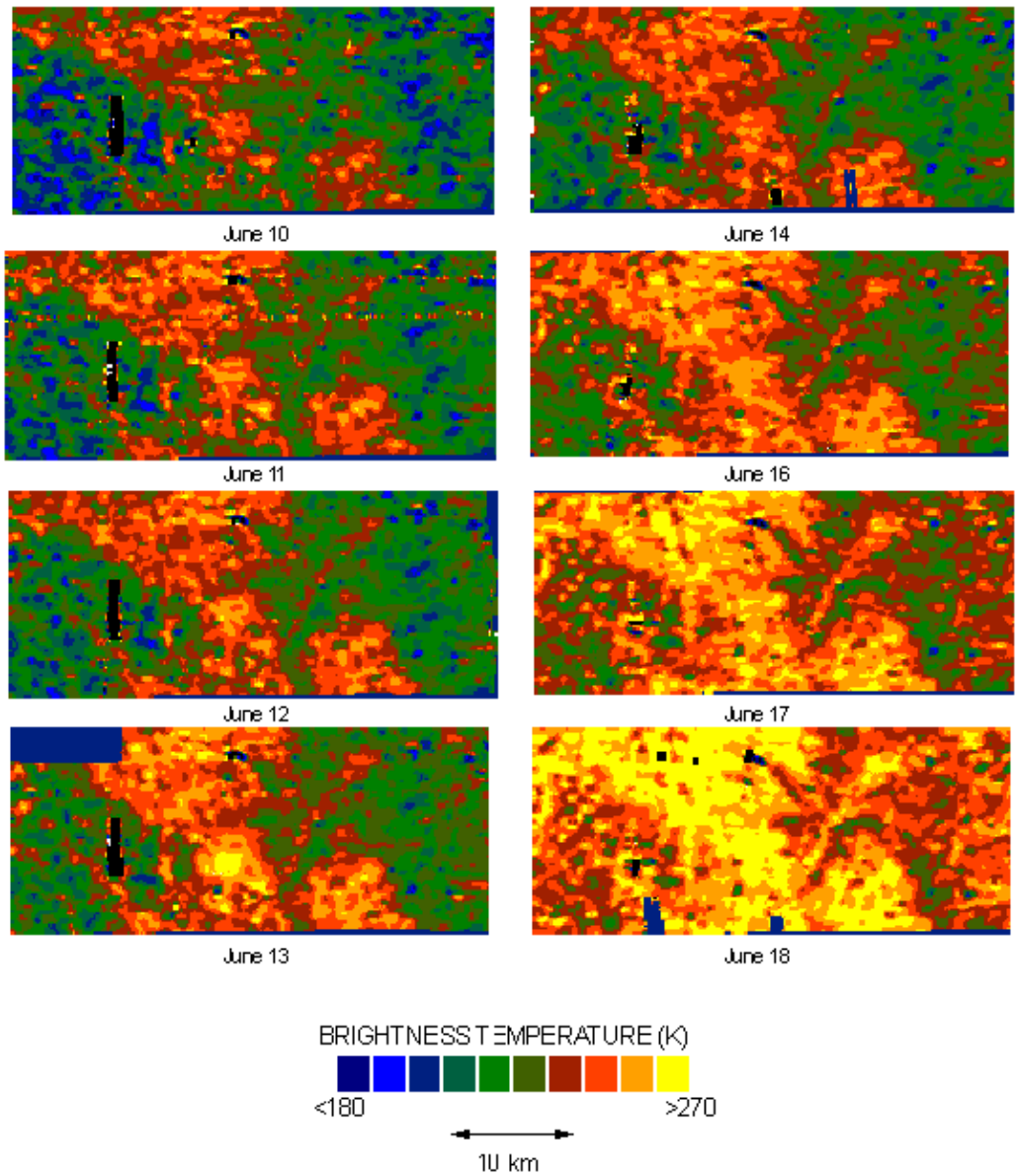


$$\varepsilon_{soil} = 1 + (\varepsilon_{sur} - 1)\exp(h)$$

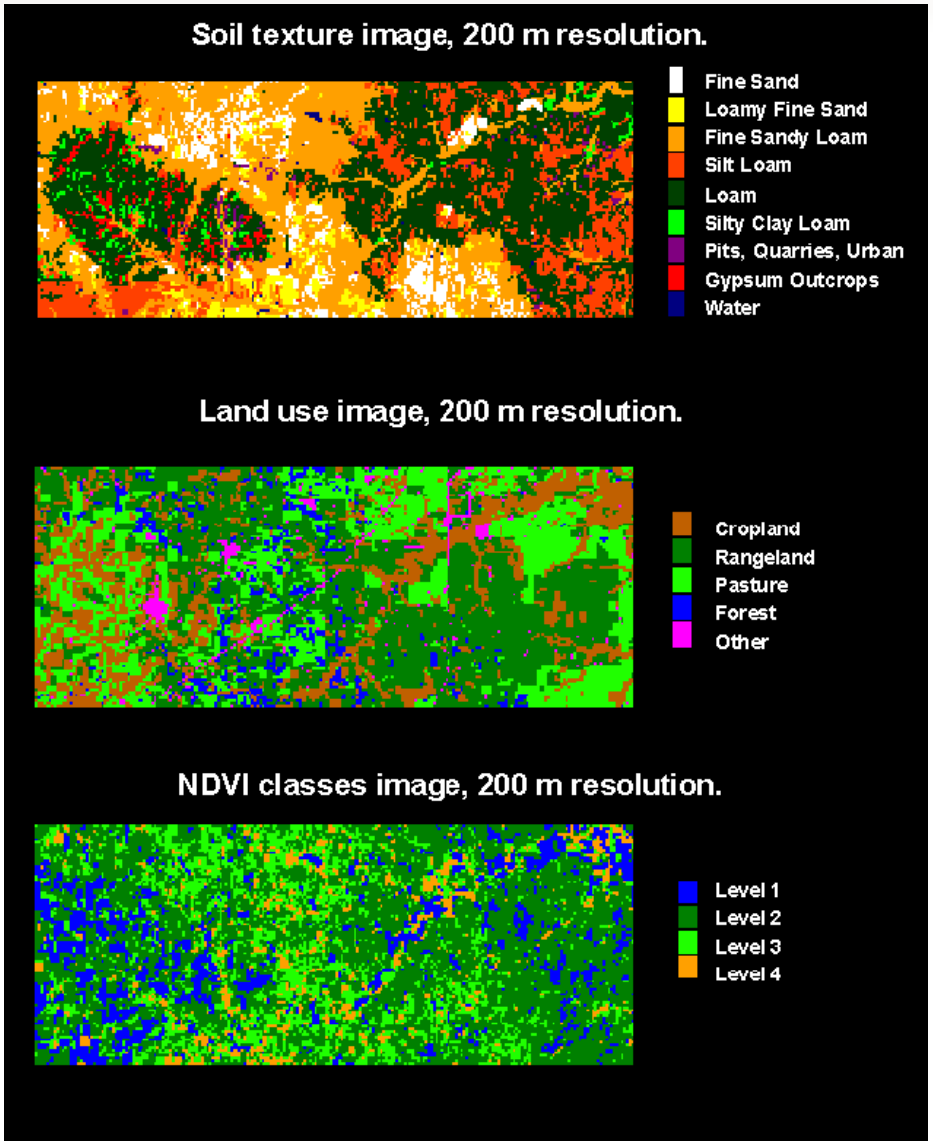
$$k = ((1 - \varepsilon_{soil})^{0.5} - 1)/((1 - \varepsilon_{soil})^{0.5} + 1))^2$$

Soil Moisture = f(k, soil texture)

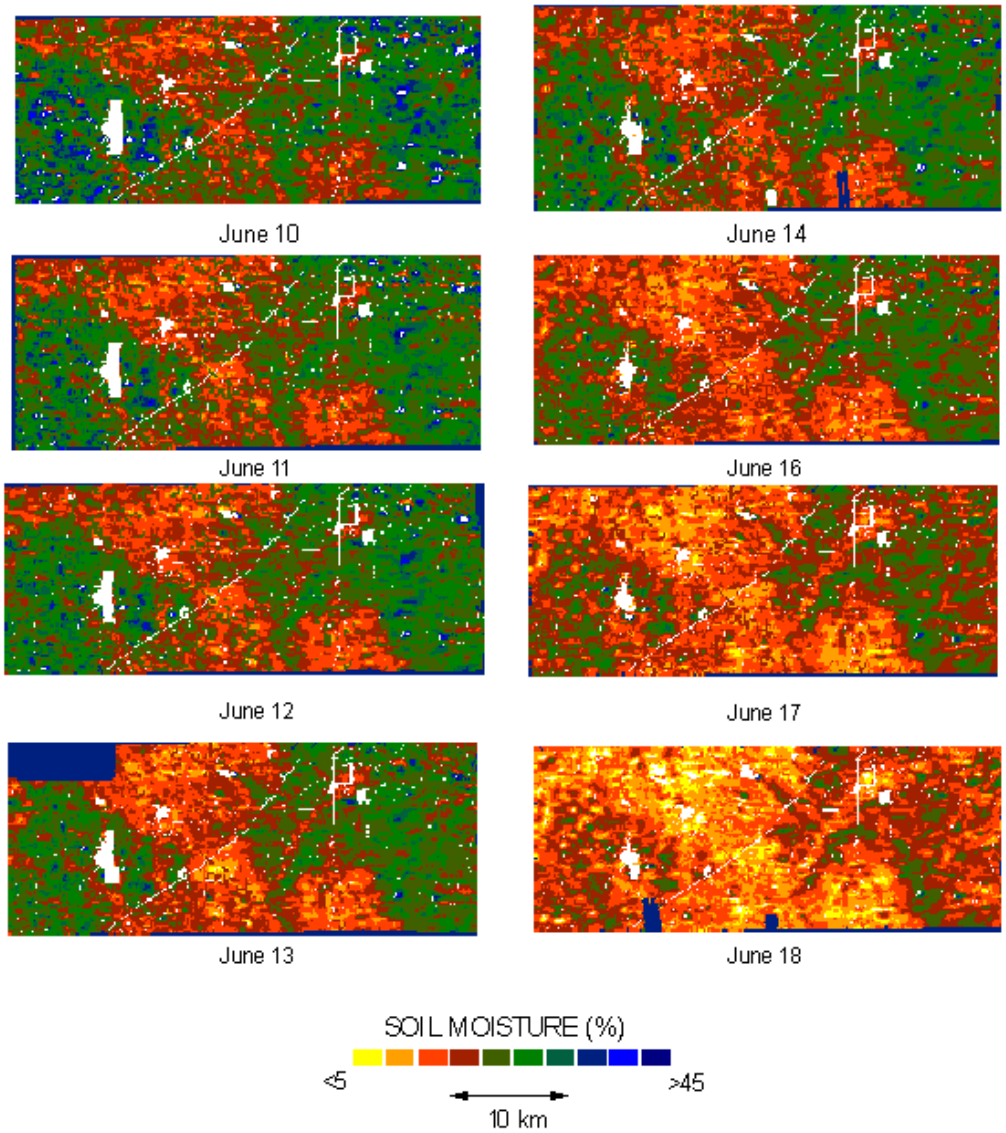
Step 1:
Collect data using
Passive Radiometer
L-Band (this case)
(T. Jackson)

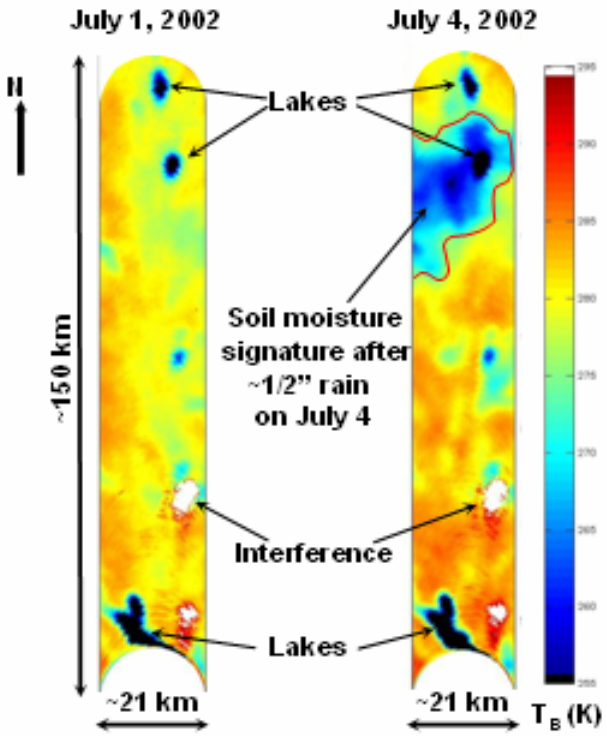


Step 2: Input soil texture, land use, and vegetation



Step 3:
Soil Moisture





Soil moisture signature observed ~150 km NNW of Des Moines, Iowa on July 4, 2001 using the NOAA PSR/CX imaging radiometer. The arrows show the location of rainfall (outlined in red), lakes, and some sources of radio frequency interference.

Super Sites

-CO_2 flux

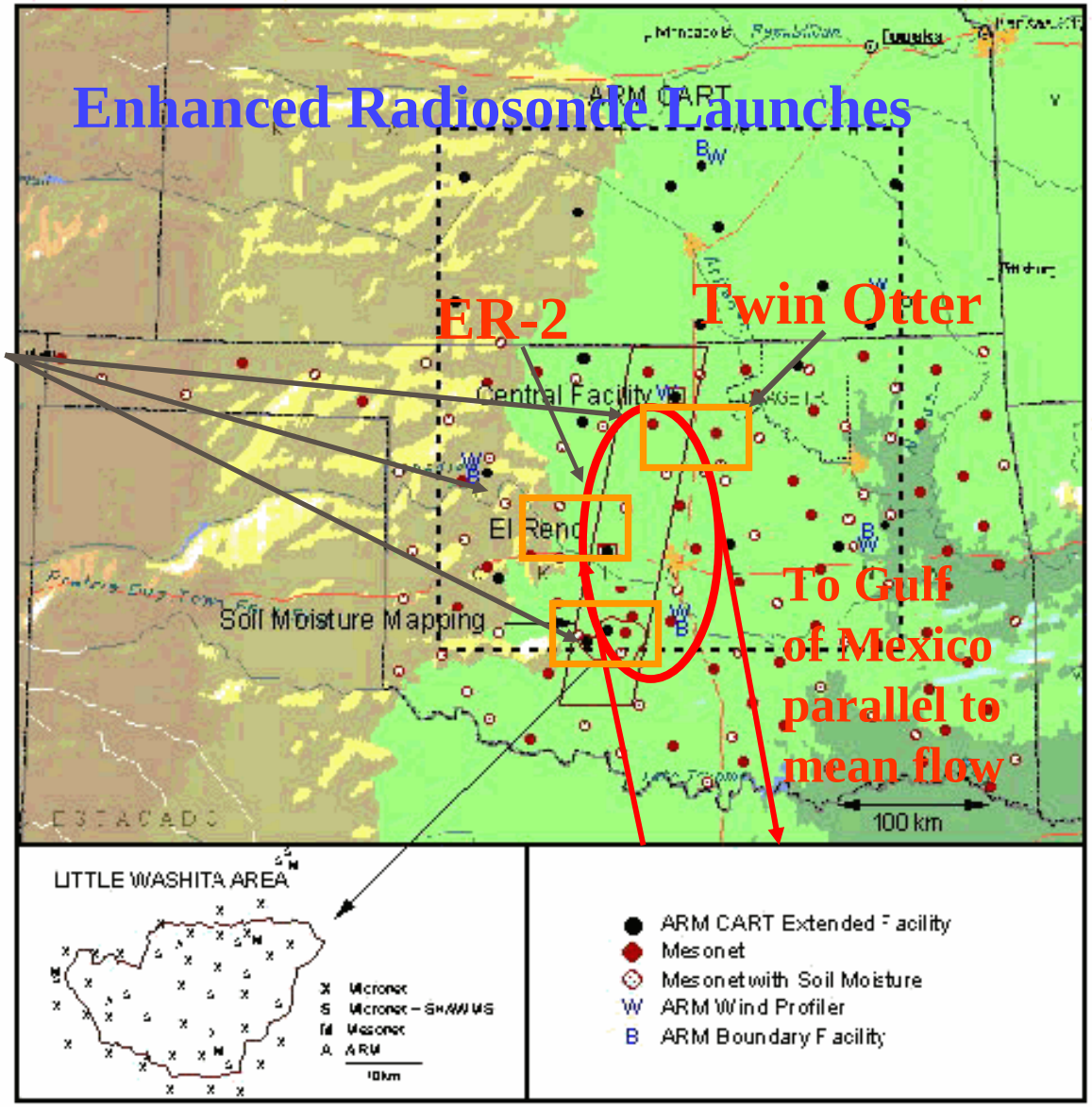
-heat flux

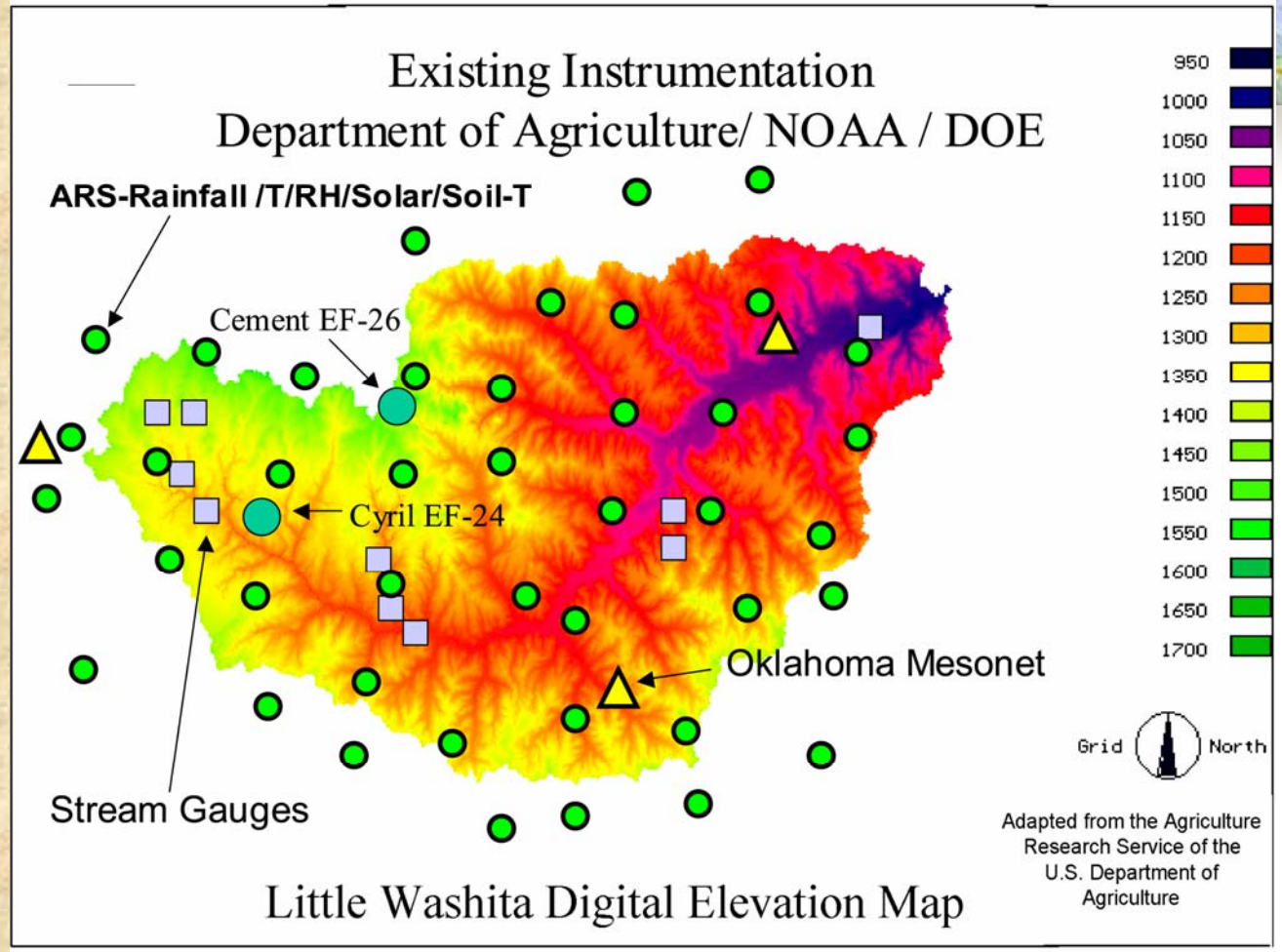
-soil moisture

--radiation

>spectral albedo

-hydrology




Existing Instrumentation
Department of Agriculture/ NOAA / DOE
ARS-Rainfall /T/RH/Solar/Soil-T
Cement EF-26
Cyril EF-24
Oklahoma Mesonet
Stream Gauges
950
1000
1050
1100
1150
1200
1250
1300
1350
1400
1450
1500
1550
1600
1650
1700
Grid
North
Adapted from the Agriculture Research Service of the U.S. Department of Agriculture
Little Washita Digital Elevation Map

Washita River near Anadarko
Upstream

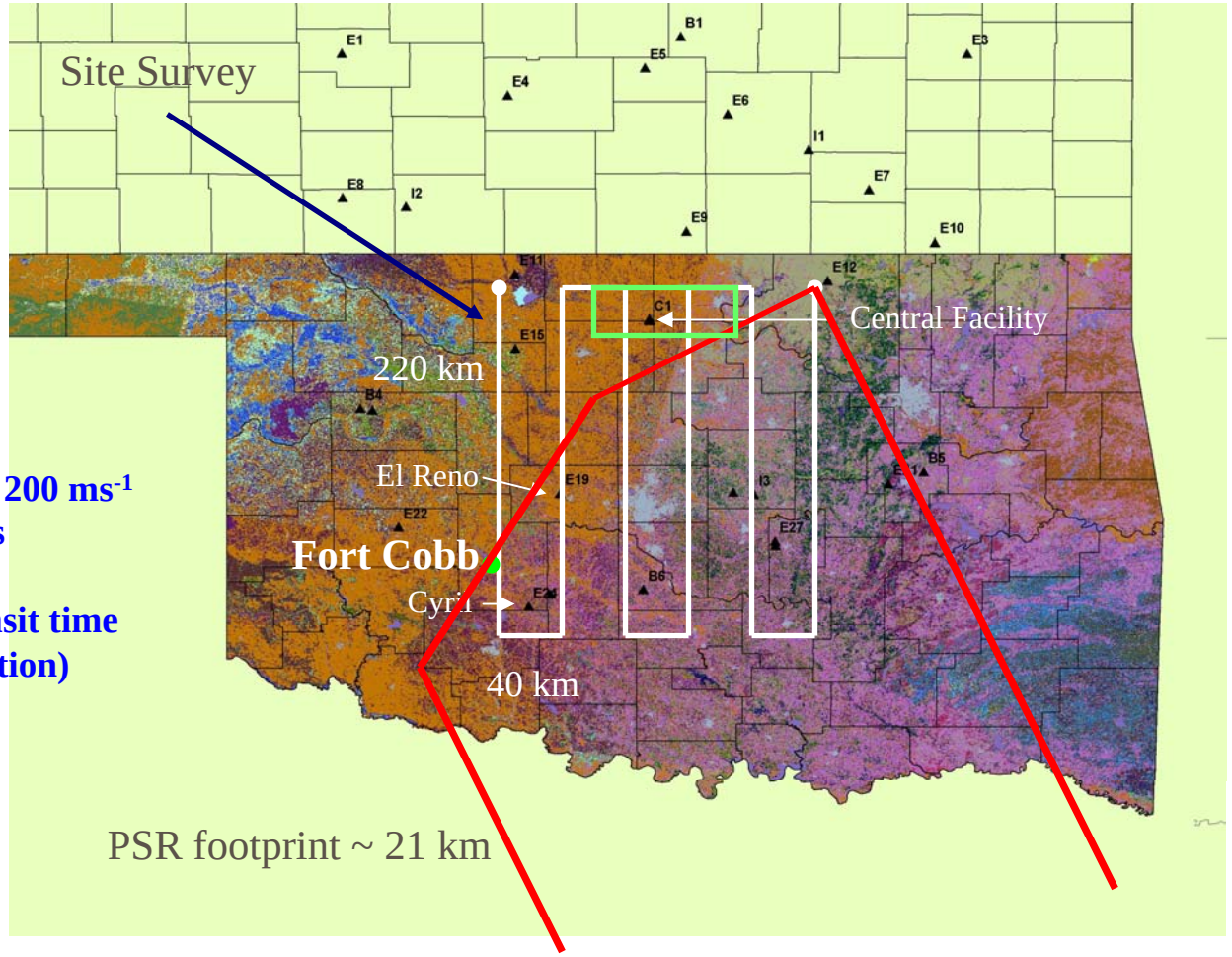
Downstream

ER-2 Flight Track—Draft #3

Gulf Trajectory

Cloud Development

Circuit
~1520 km
Airspeed = 200 ms^{-1}
2.8 Circuits
in 6 hours
1 hour transit time
(each direction)



Proposed Instrumentation Budget

Platform	PI	Budget (K)	Scientific Objective
Twin Otter	Schmid	431	In situ sampling of cloud and aerosol microphysics
Two Flux Stations at Fort Cobb?	Tilden Meyers, John Prueger and Bill Kustas	90	Spatial measurements of updraft structure across soil moisture and land use gradients, ARM CF, and in vicinity of OKC
Satellite-based Fluxes, Regional Soil Moisture, Land Cover, NDVI, LAI	Tom Jackson	70	Vertical profiles of updraft velocity in the vicinity of cumulus clouds at the ARM CF
ER-2	Heymsfield	UAV	Profiles of cloud location, radar reflectivity, and lidar backscatter. Visible scanning spectrometer (MAS) and scanning MWR (soil moisture and/or vapor profiles)
Enhanced Soundings in SGP domain	Cloud Parameterization and Modeling Group	80	Enhanced soundings are necessary to insure proper dynamical forcing is computed for the SGP domain.
EXPERIMENT TOTAL		671.0	Allotment 668K—(3K)

Additional Instrumentation

Platform	PI	Budget	Scientific Objectives
Mobile SMART C-Band Radar	Mike Biggerstaff	80.5K (NOAA?)	Characterization of convective activity across soil moisture gradients, at the ARM CF, and at the other surface sites (El Reno and Ft. Cobb)
Doppler Lidar	Mike Hardesty	165K (NOAA?)	Vertical profiles of updraft velocity in the vicinity of cumulus clouds at the ARM CF

Detailed Measurements of Shallow Convection at CF

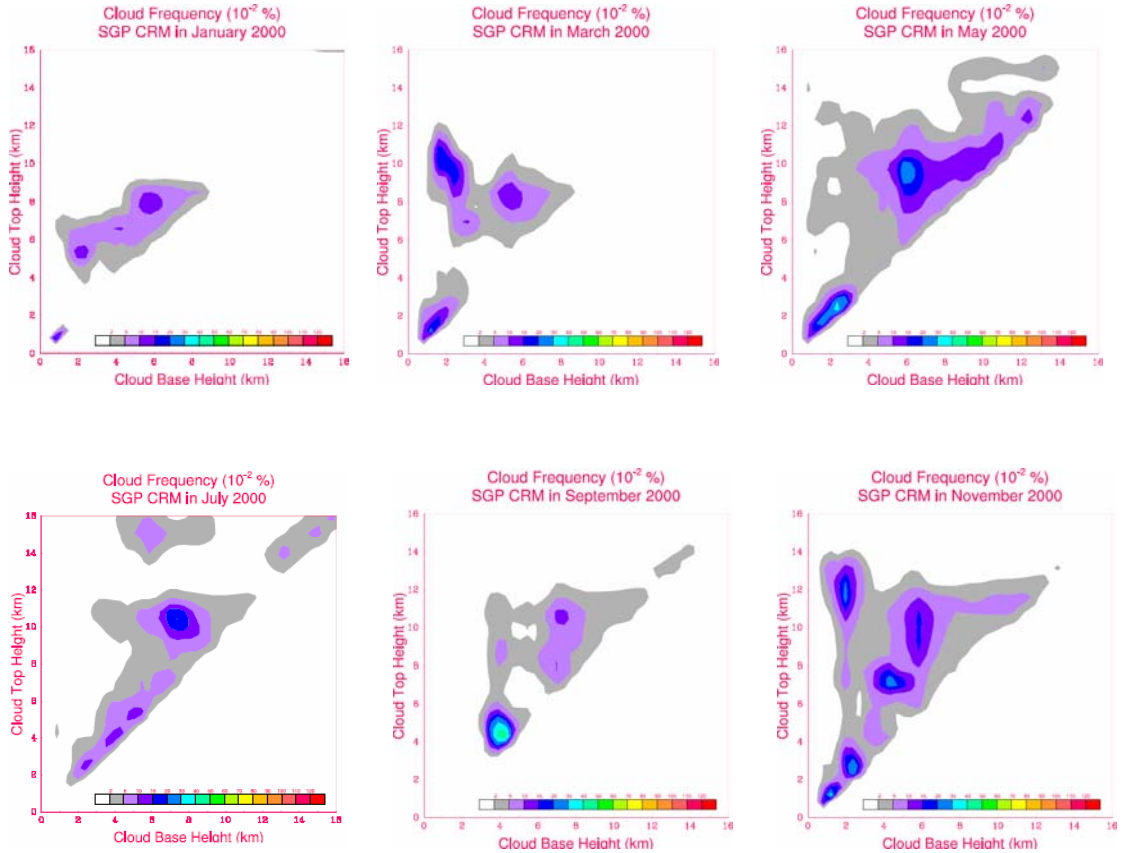
- Multiple Frequency Doppler Cloud Radars, Raman lidar, conventional lidar, microwave radiometers, AERI, solar spectrometer
  - Updraft velocity and cloud microphysical structure
- Aircraft Overflights
- Enhanced measurements of surface fluxes, albedo, soil moisture

Collaboration with ASP in Oklahoma City

- Move resources to assist ASP
  - Surface aerosol measurements

Cloud-Resolving Model (CRM): Cloud formation

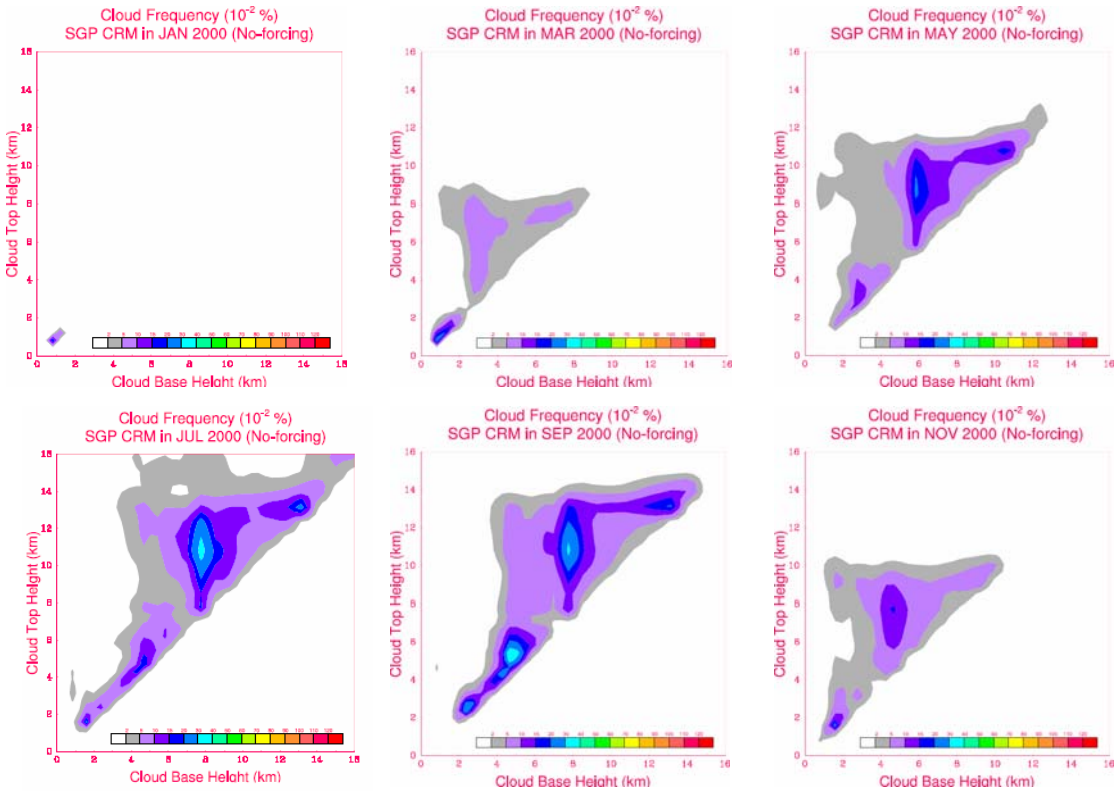
Cloud statistics: with large scale forcing (control run)



Xie and Min

Cloud-Resolving Model (CRM): Cloud formation

Cloud statistics: without large scale forcing (only surface fluxes)



Evaluation and development of ECMWF convective physics

Roel Neggers, Martin Koehler, Anton Beljaars,
Peter Bechtold, Sylvain Cheinet

European Centre for Medium-range Weather Forecasts
Europäisches Zentrum für Mittelfristige Wetterforhersage
Centre européen pour les prévisions météorologiques à moyen terme

I. Evaluation of the IFS 24h forecast against ARM SGP observations

Sylvain Cheinet et al. (2005, ECMWF technical memorandum)

Central Facility (C1, located 36.5N, 97.5W)

July 2003

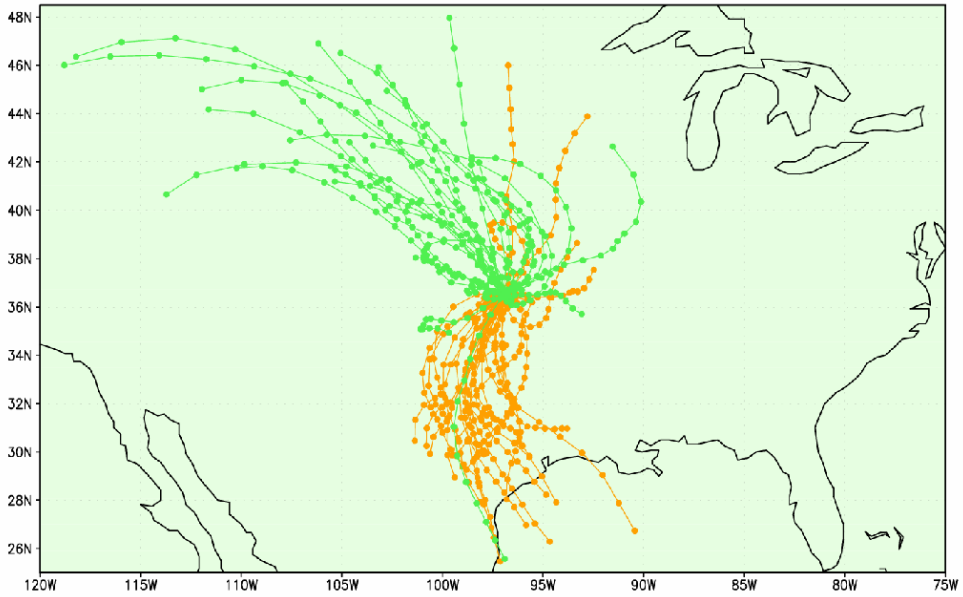
Radiosondes, Radar

Actively Remote Sensed Cloud Location (ARSCL) algorithm (Clothiaux et al., 2000)

ECMWF IFS Cycle 28R1, 24-hour forecasts

Mean tropospheric flow:
mid-latitude westerlies
passing over the Rockies

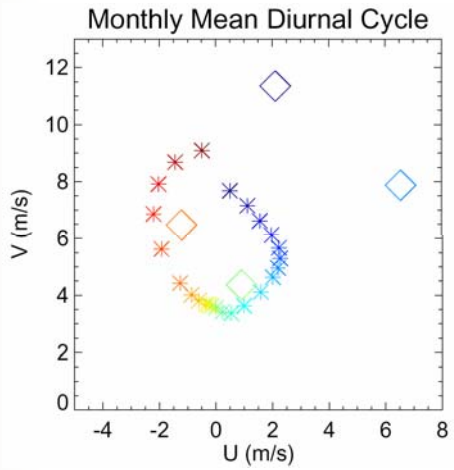
Boundary layer flow:
from Gulf of Mexico through
the Low Level Jet



IFS backward trajectories starting at the SGP site, as derived from IFS. Low level trajectories are orange, upper level trajectories are green. Each trajectory represents one single day in July 2003.

Boundary layer biases in IFS

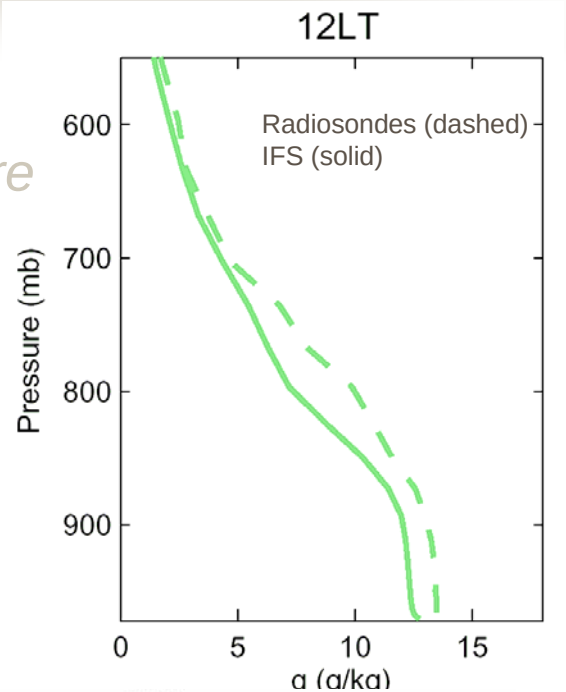
Winds



Observations (diamonds)
IFS (asterisks)

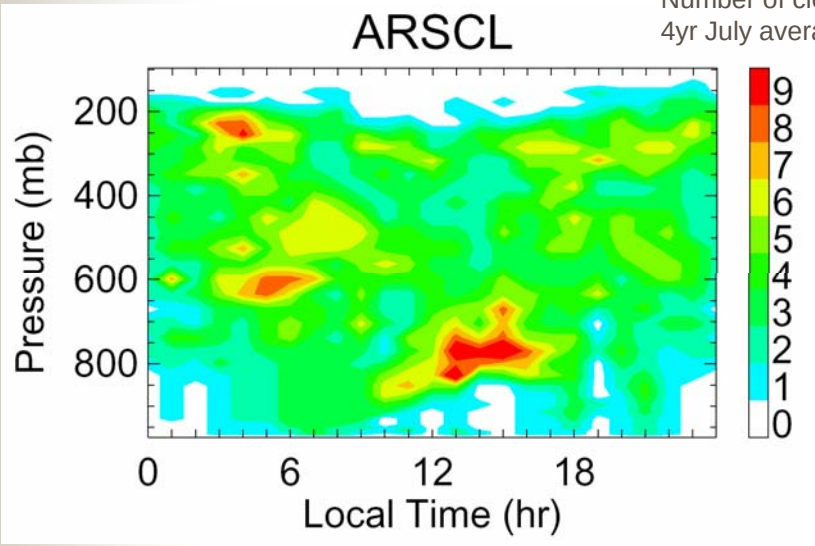
Black 00LT
Blue 06LT
Green 12LT
Red 18LT

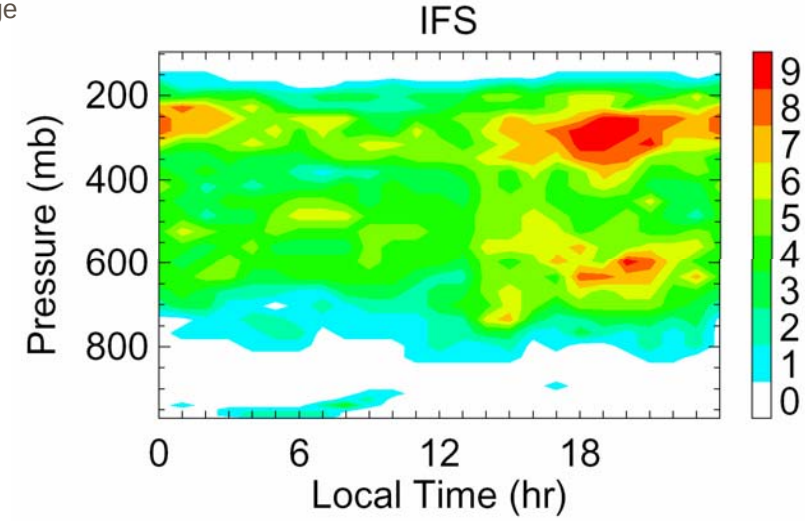
Humidity structure



Cloud climatology

Number of cloudy hours per day,
4yr July average





Conclusions

Continental cloud representation in IFS suffers from serious biases in deep and shallow cumulus occurrence over the Northern American continent. These problems have their origin in the dry convective and moist convective parameterization schemes.

These conclusions are reached only after considering the impact of remote processes on the flow reaching the SGP site. Point-measurements in a geophysical flow can never be properly understood without knowledge of the history of the advected air.

Accordingly, the availability of ARM type measurements at other well-chosen locations upstream or downstream of the SGP site is essential for advanced evaluation and development of parameterizations in GCM's.