NASA Airborne Lidar (LASE) Measurements of Water Vapor and PECAN

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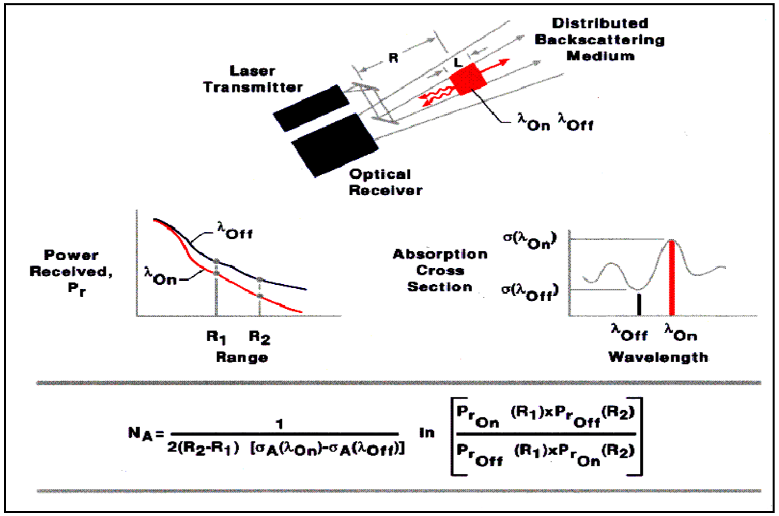
PECAN Planning Meeting

May 12-14, 2014

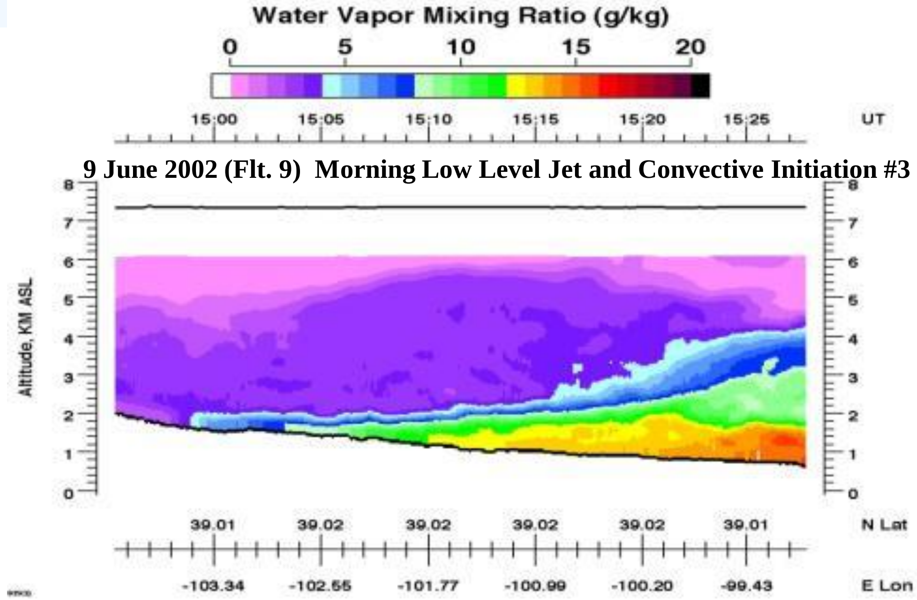
Lidar Atmospheric Sensing Experiment (LASE)



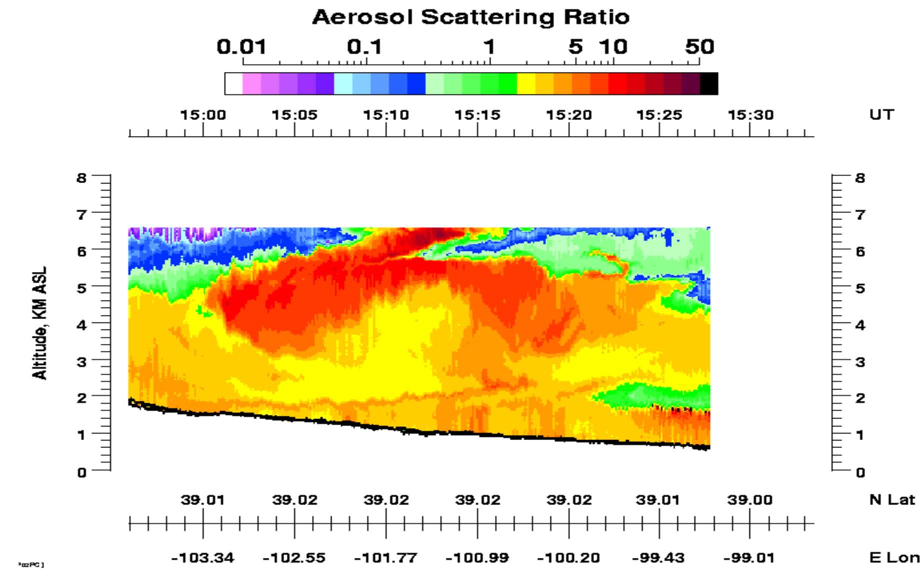
- Airborne Water Vapor DIAL
- Laser
  - 5 Hz doubled-pulsed Ti:sapphire
  - 100 mj at λ_{on} and λ_{off}
- Wavelengths
  - 815 nm (λ_{on}- λ_{off} = 40-70 pm)
  - Two separate line pairs
- NASA ER-2, P-3, DC-8 aircraft
- Simultaneous nadir, zenith operations
- Real-time data analysis and display

LASE Water Vapor, Aerosol, & Cloud Profiling on NASA DC-8

- Water vapor profiles
  - daytime and nighttime
  - surface to upper trop.
  - 0.01 to 25 g/kg
  - accuracy: 6% or 0.01 g/kg
  - resolution (variable)
    - vertical: 330 m
    - horizontal: 14 km (1 min)



- Aerosol/cloud profiles
  - daytime and nighttime
  - 0.03 to 25 km
  - resolution (variable)
    - vertical: 30 m
    - horizontal: 200 m



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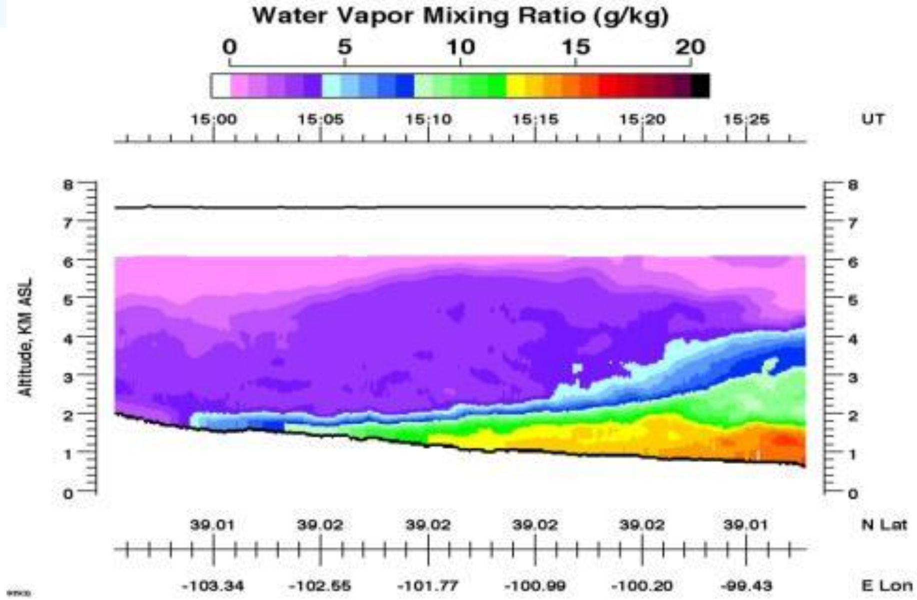
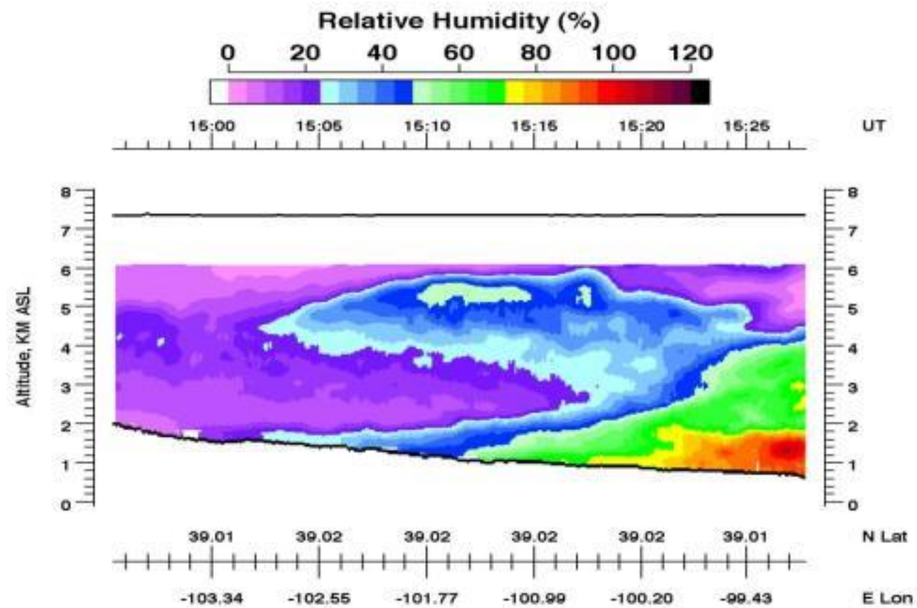


- Relative humidity profiles
  - derived using LASE water vapor and temperature from dropsonde, radiosondes, or interferometer



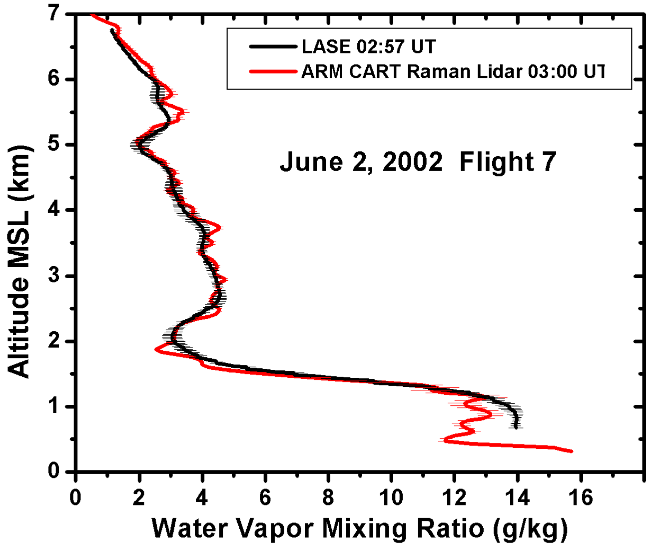
LASE Field Experiments

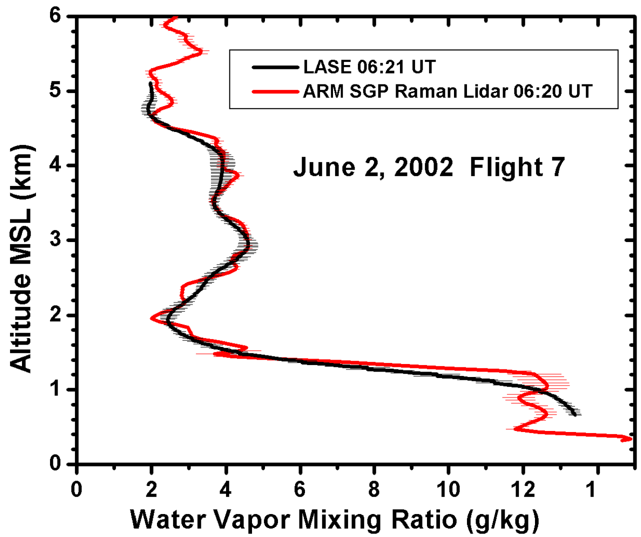
1995 Lidar Atmospheric Sensing Experiment (LASE) Validation (LASE-Validation) ***Sept 9 – Sept 26***
1996 Tropospheric Aerosol Radiative Forcing Observational Experiment **(TARFOX)** ***July 14 – July 26***
1997 Southern Great Plains 1997 Experiment (SGP97) ***July 11 – July 17***
1998 The Third Convective and Moisture Experiment (CAMEX3) ***Aug 21 – Sept 22***
1999 Pacific Exploratory Mission - Tropics B (PEM-TropicsB) ***Mar 6 – Apr 18***
1999-2000 SAGE III Ozone Loss and Validation Experiment (SOLVE) ***Nov 30 – Mar 15***
2000 ARM - FIRE Water Vapor Experiment (AFWEX) ***Nov 27 – Dec 11***
2001 The Fourth Convective and Moisture Experiment (CAMEX-4) ***Aug 15 – Sept 24***
2002 The International H2O Project (IHOP_2002) ***May 13 – Jun 25***
2006 NASA African Monsoon Multidisciplinary Analyses (NAMMA) ***Aug 15 – Sept 15***
2007 Tropical Composition, Clouds and Climate Coupling Experiment (TC4) ***July 13 – Aug 11***
2010 Genesis and Rapid Intensification Processes (GRIP) ***Aug 15 – Sept 30***

International H_2O Project (IHOP)

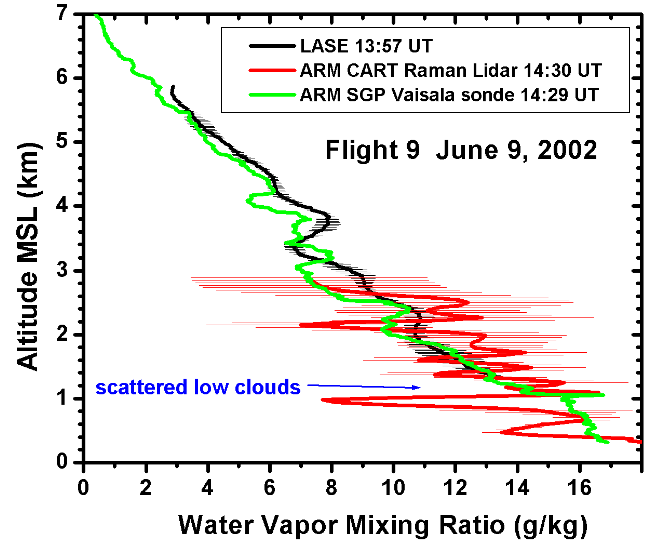
LASE Water Vapor Comparisons During IHOP

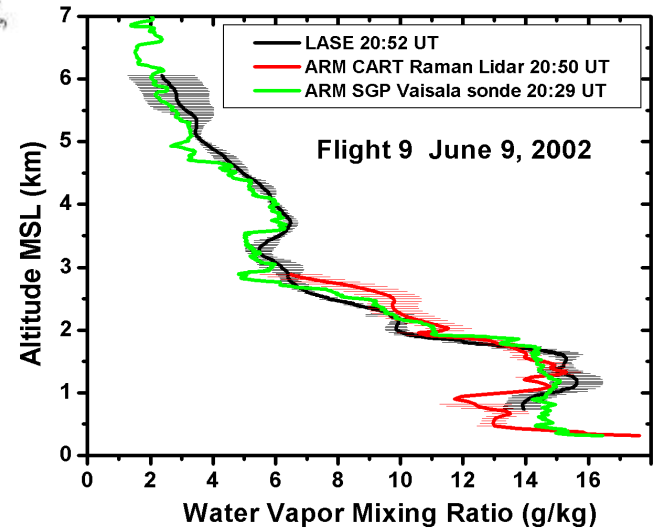
Nighttime



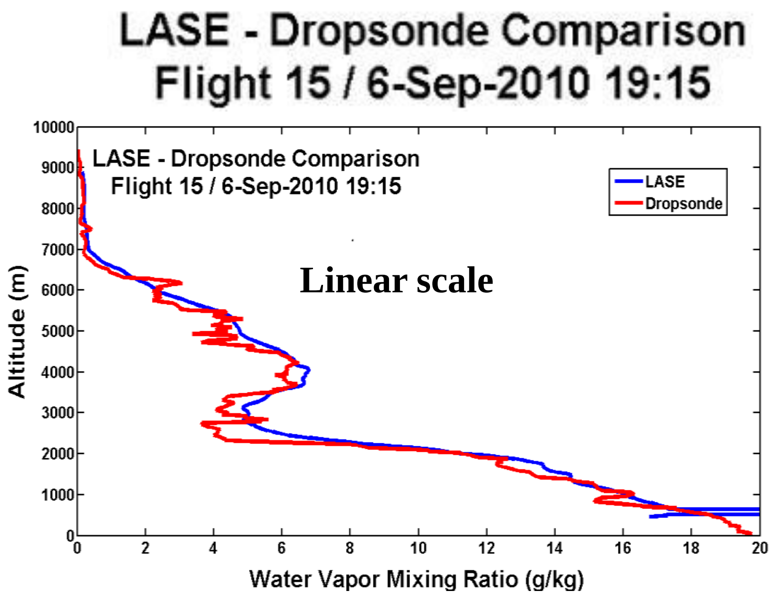


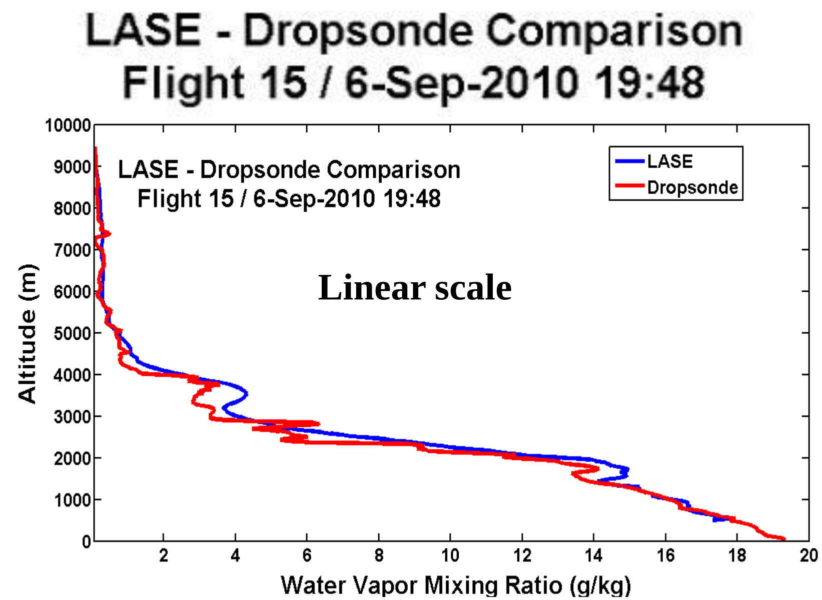
Daytime

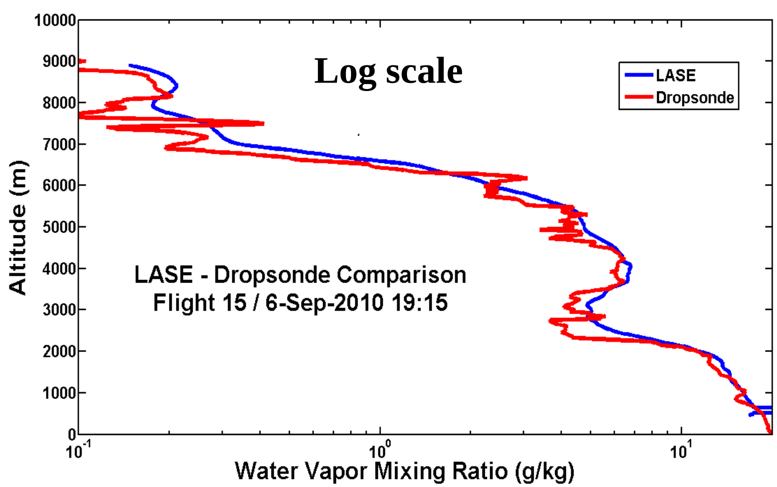


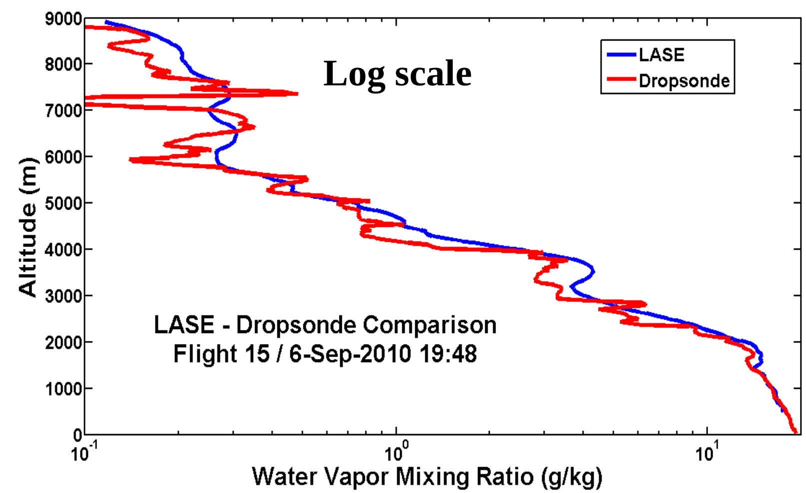


LASE Water Vapor Comparisons During NASA GRIP

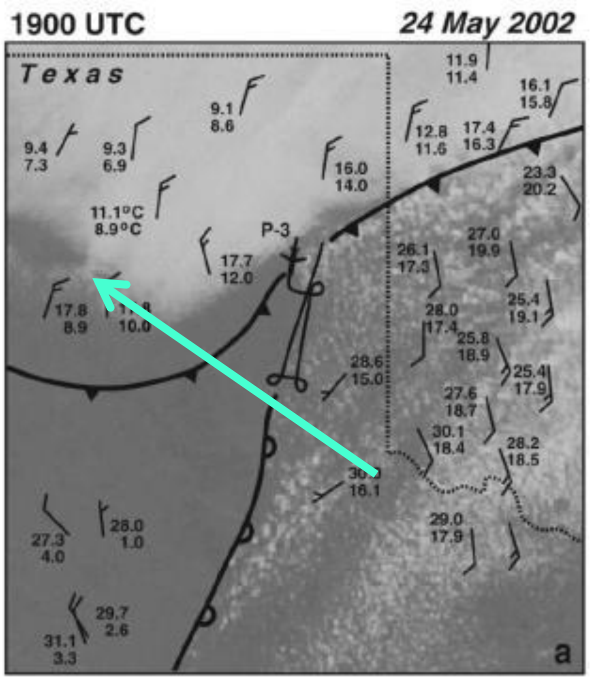


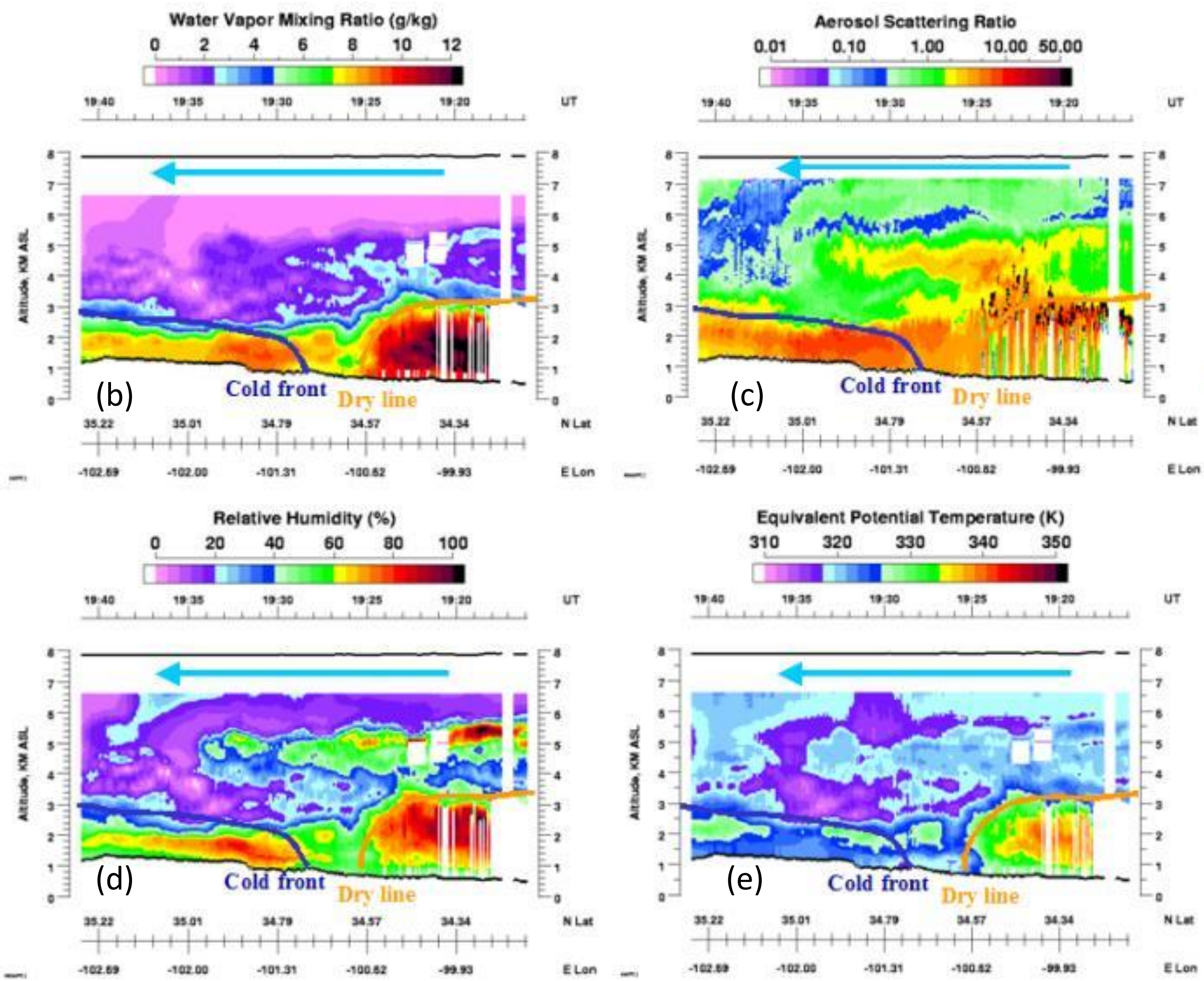






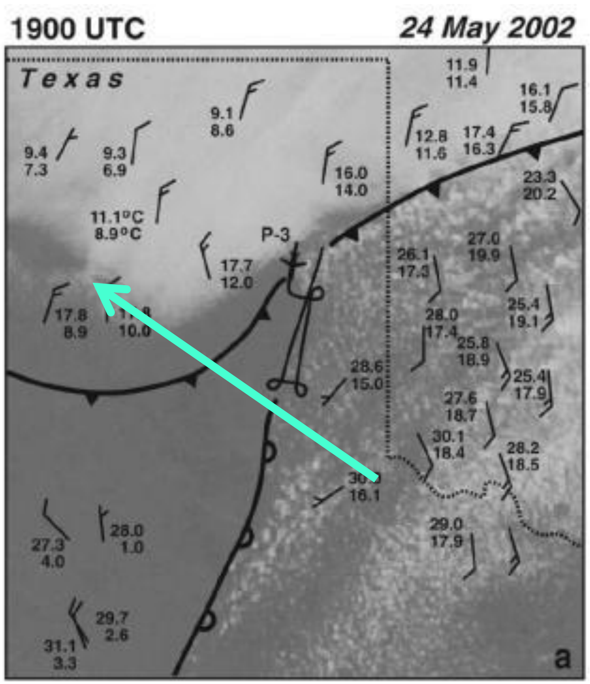
Triple Point Case of May 24, 2002





Triple Point Case of May 24, 2002

Use IHOP airborne profile data to evaluate potential for deep convection

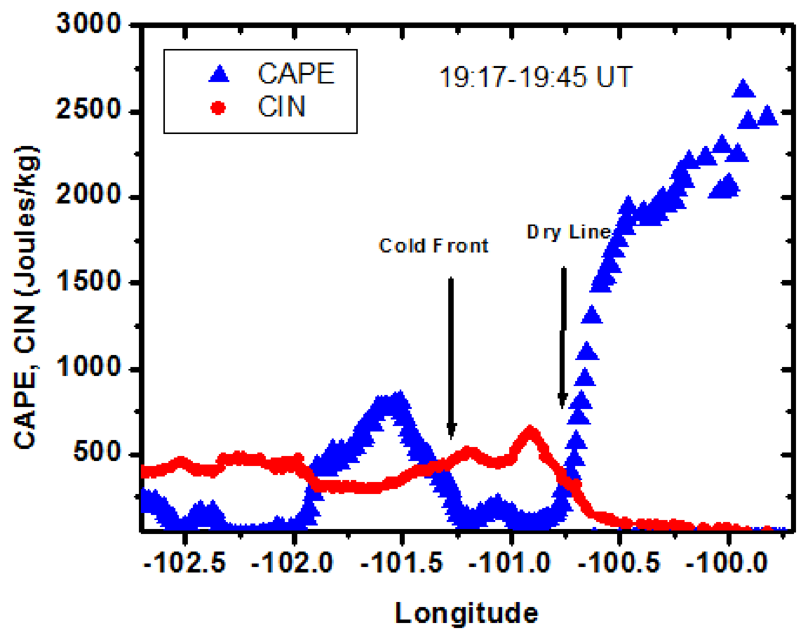


(Wakimoto et al., MWR, 2006)

May 24 2002 19:15 – 19:40 UT

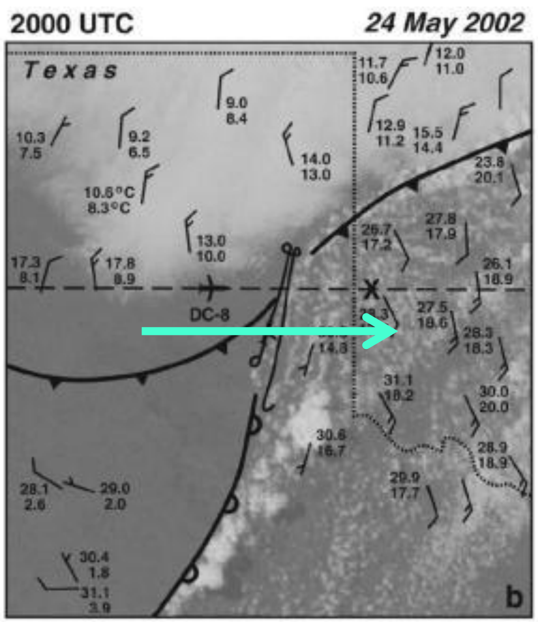
- **High values of CAPE (2000-2500 J/kg) indicate moderate to high instability ahead of dry line; low values of CAPE behind dry line and cold front**
- **Low values of CIN (<100 J/kg) indicate weak cap ahead of dry line**

➢ **Deep convection occurred ahead of dry line and cold front in southwest Oklahoma**

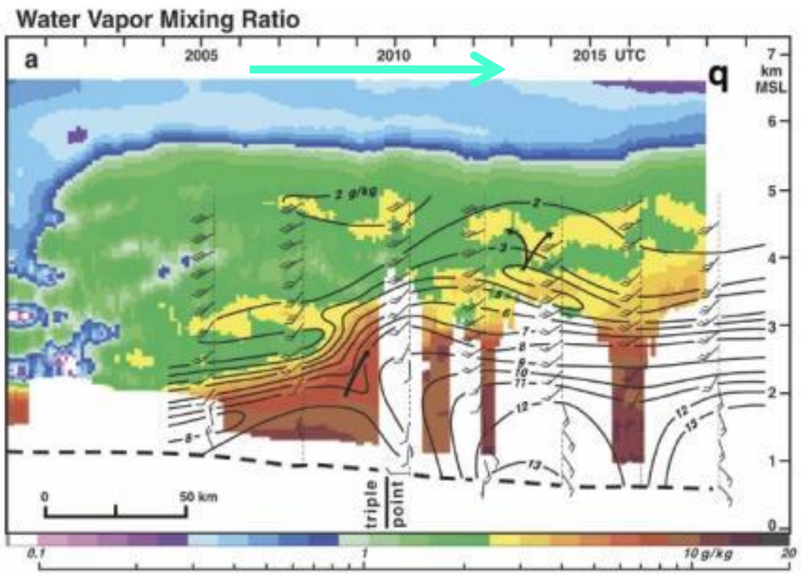


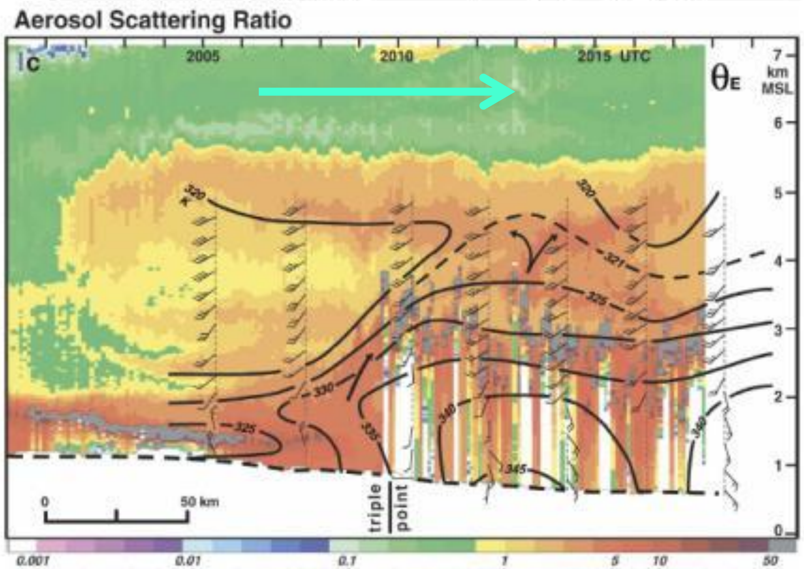
Triple Point Case of May 24, 2002

- Increase in depth of moist layer across triple point
- Cold dense air behind cold front is undercutting the moist air east of dryline
- Aerosol data reveal rising plume above and east of the triple point
- Largest potential instability is collocated with eastern plume



(Wakimoto et al., MWR, 2006)

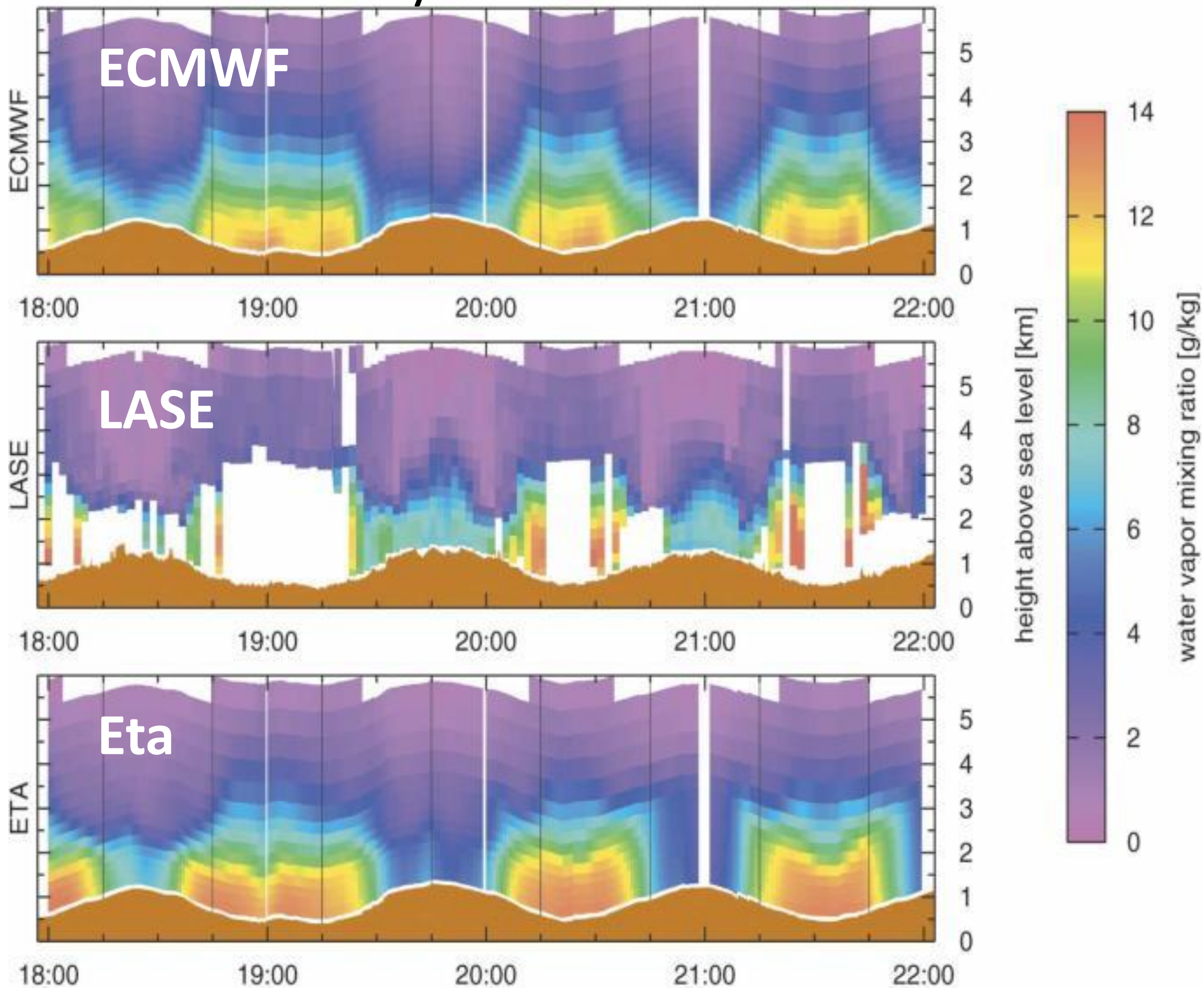




Comparison of LASE and model water vapor distributions

May 24 2002

- Dry line location is similar
- ECMWF was ~ 2g/kg drier than LASE in PBL, especially west of dryline
- West of dryline, ECMWF PBL depth was too low by about 500 m
- Eta was wetter than LASE in moist section and drier than LASE and ECMWF in dry sector

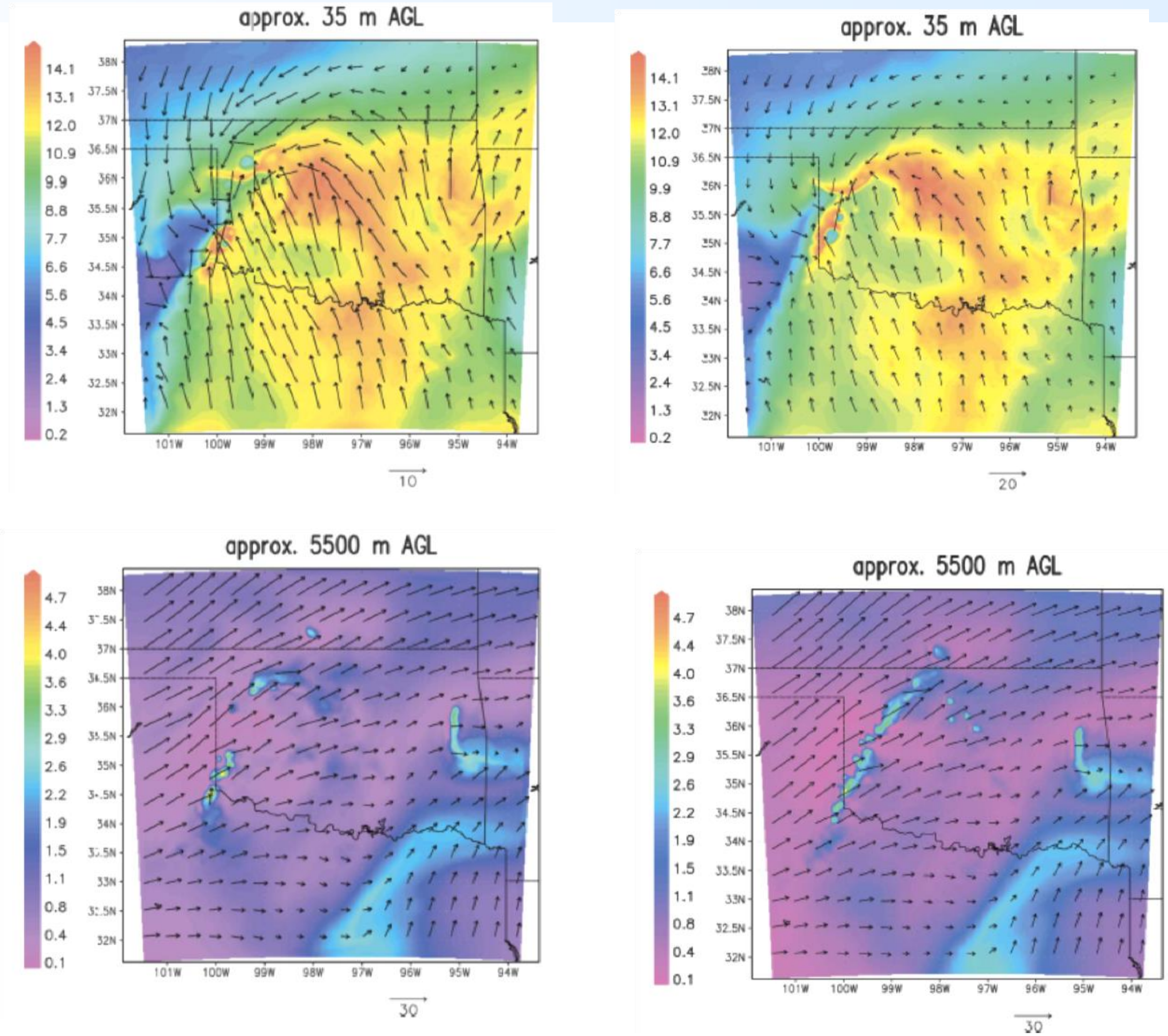


(Wulfmeyer et al., MWR, 2006)

Assimilation of LASE water vapor data

Assimilation of LASE data resulted in:

- **erosion of moisture gradient along dry line south of triple point**
- **enhanced southwesterly moisture transport southwest of triple point**
- **moisture convergence and convective initiation enhanced 150 km south of triple point along dryline**
- **convective initiation reduced in region of triple point**
- **better agreement with radar images and forecasts of precipitation**



Assimilated LASE data

No assimilation

(Wulfmeyer et al., MWR, 2006)

LASE Science Goals

- Investigate:
  - Distribution of water vapor, clouds, and aerosols relative to elevated layers of Convective Available Potential Energy (CAPE)
  - How the water vapor distribution impacts the development and maintenance of nocturnal convection
- Mapping the characteristics of water vapor inflow to convective systems
- Acquisition of water vapor profiles for assessing the ability of measurements from the spaceborne Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) to represent the moisture and stability fields associated with these nocturnal elevated convective systems

DC-8 Flights before PECAN (Polar Winds—April- May 2015)

PolarWinds 2015 Instruments

DAWN - flown on DC-8 (Nadir 7)

TwiLight- New instrument to DC-8 but installation has been initially look at to install on Nadir 2

Dropsonde System - flown numerous times on DC-8

ARMAS (piggyback)- flown numerous times on DC-8

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1	2	3	4
5	6	7	8	9	10	11
12	13	14 Tech Brief	15 DC-8 Instrument Integration	16 ORR	17	18
19	20 DC-8 Instrument Integration	21	22	23	24	25
26	27 Instrument Elect. Load Distribution Check; Laser Calibrations	28 Weight + Balance; Cabin Press Ck	29 Shakedown flt (No Science Team); Inst. Chk Flight #1	30 Schedule Margin	1 Science Gear/DC-8 Pack	2
3	4 Deploy from Palmdale to Kangerlussuaq, Greenland; DC8 deployment	5	6	7	8	9
10 DC8 deployment	11 Notional Hard Down Day	12	13	14	15	16
17 DC8 deployment	18 Deploy from Kangerlussuaq, Greenland to Palmdale	19 Notional Hard Down Day	20 Instruments Download	21	22	23
24/31	25 Memorial Day Holiday	26	27	28	29	30

DC-8 PECAN/SARP Schedule
May/June/July 2015

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
24 May Memorial Weekend	25 Day Holiday	26 PECAN/SARP Tech Brief	27	28 PECAN ORR	29	30
		PECAN & SARP Instruments DC-8 Upload				
31	1 June	2	3	4	5	6
	PECAN & SARP Instruments DC-8 Upload					
7	8	9	10	11 Instrument Elect. Load Distribution Check	12	13
	PECAN & SARP Instruments DC-8 Upload			Laser Calibrations		
14	1 Cabin Press Ck; Weight + Balance; SARP Students Arrive on Site @ Palmdale/DAOF Tour	1 Shakedown flt (No Science Team); PECAN Inst. Chk Flight #1	17	18 Student Flight Safety Brief; PECAN Inst. Chk Flight #1	19	20
21	SARP2015 FLIGHT #1 EXP CHK FLT 9AM T/O 11AM LAND; SARP2015 FLIGHT #2 SCIENCE FLT 1PM T/O	SARP2015 FLIGHT #3 SCIENCE FLT 830AM T/O 1130AM LAND; SARP2015 FLIGHT #4 SCIENCE FLT 130PM T/O	SARP2015 FLIGHT #5 SCIENCE FLT 830AM T/O 1130AM LAND; SARP2015 FLIGHT #6 SCIENCE FLT 130PM T/O	25	26 Science Gear/DC-8 Pack	27
				SARP Instruments DOWNLOAD		
28	29 Deploy from Palmdale to Kansas or Oklahoma	30	1 July	2	3 July 4th Holiday Weekend	4 July 4th Holiday Weekend
	DC8 deployment					
5	6	7	8	9	10	11
DC8 deployment						
12 Notional Hard Down Day	13	14	15	16	17	18 Deploy from Kansas or Oklahoma to Palmdale
DC8 deployment						
19 Notional Hard Down Day	20	21	22	23	24	25
	PECAN Instruments Download					
26	27	28	29	30	31	11

Summary

- LASE water vapor measurements from 13 field experiments are in excellent agreement with in situ and remote sensing instruments
- LASE will provide self-calibrated water vapor measurements along with aerosol and cloud distributions over the entire PECAN domain
- LASE can be used as calibration source of other humidity sensors and can serve as a transfer standard for PECAN
- NASA DC-8 is available during PECAN field experiment and can fly with NAST-I to capture full 3-D moisture, RH and temperature fields
- There is an interest in using LASE data in satellite Cal/Val studies
- Current DC-8 flight schedule shows that PECAN science flights will be during June 29 to July 18, 2015.

Extra Slides

Potential for Deep Convection

Deep convection requires:

- moist layer in low to mid troposphere
  - high water vapor mixing ratio, relative humidity
- steep lapse rate to allow for large buoyant energy
  - high Convective Available Potential Energy (CAPE)
  - Equiv. Pot Temp – θ_e decreases with height – convectively unstable
- sufficient lifting to allow parcel to reach Level of Free Convection (LFC)
  - small Convective Inhibition (CIN)
  - lifting mechanism

International H_2O Project (IHOP)

Use IHOP airborne profile data to evaluate potential for deep convection

- Triple Point Case of May 24
- Water Vapor Profiles – LASE
- Temperature Profiles – Scanning HIS and dropsondes