Airborne Observing Systems

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NSF/AGS/LAOF-Supported Aircraft And Airborne Remote Sensing

NSF Deployment Pool Funded Aircraft:

NSF/NCAR EC-130Q Hercules C130
NSF/NCAR Gulfstream G-V
UWYO King Air
NPS/CIRPAS Twin Otter

Airborne Systems:

Wyoming Cloud Radar (WCR)
Wyoming Cloud Lidar (WCL)
GPS Dropsonde System (AVAPS)
ELDORA Airborne Doppler Radar (on NRL NP-3D Orion)

NSF C130: Heavy-lift research aircraft

- 10 + Hours Endurance
- Typical payload 15,000 lb
- Range 3100 nmi
- Altitude 26,000 ft

- 40 kVA (400Hz), 28 kVA (60 Hz), 400 A (28 VDC)
- Modified in house (1993-2011)
- 2000 upgrade of engines
- 2010 ~$8 M upgrades of avionics and propellers

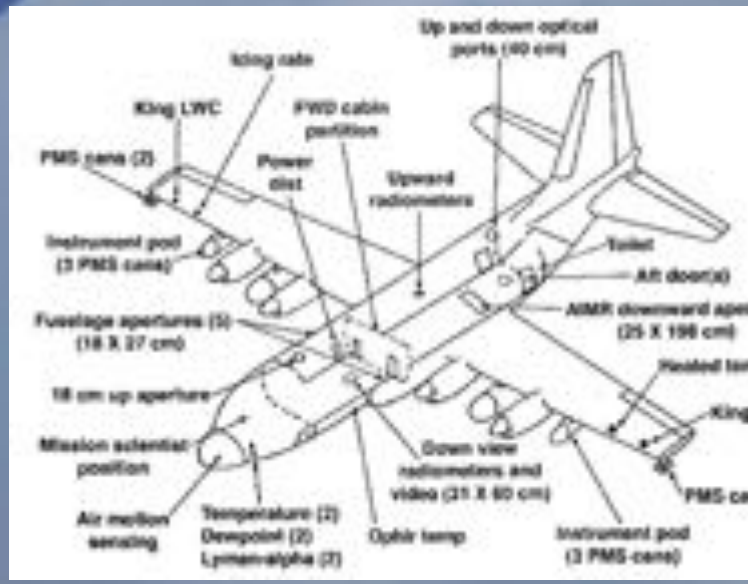

Photo courtesy of Tony Clarke, Univ. of Hawaii

Gulfstream V: Global Scale Platform

- High Altitude (up to 51,000 feet)
- 6000+ lb payload
- Up to 12 hours endurance (10 hours typical)

- Delivered new as major equipment purchase 2000-2004
- Modified as delivered, then by NCAR/EOL
- $14 M ($12.5 M external) of new community instrumentation: now ready to go!

- Fully FAA Certified
- Long-Range (over 6000 n miles--South Pole and back)
- Six under-wing hardpoints
- Up and Down (2) Co-Aligned 20 inch optical viewports
- Ample inlets and fuselage hard points

Wyoming King Air: remote sensing, cloud/aerosol, boundary layer

- Ceiling: 26,000 ft
- Wyoming Cloud Radar
- Wyoming Cloud Lidar (up + down)
- Pressurized
- Certified for flights into known icing conditions
- Payload Capacity: 1500 lbs.
- Available Payload Power:
  - 240 Amp of 28 VDC
- 4+ hours endurance, fully loaded
- Purchased new 1977; heavily modified
- Recent avionics and engine upgrades
- Single pilot operation: Scientist in the copilot seat

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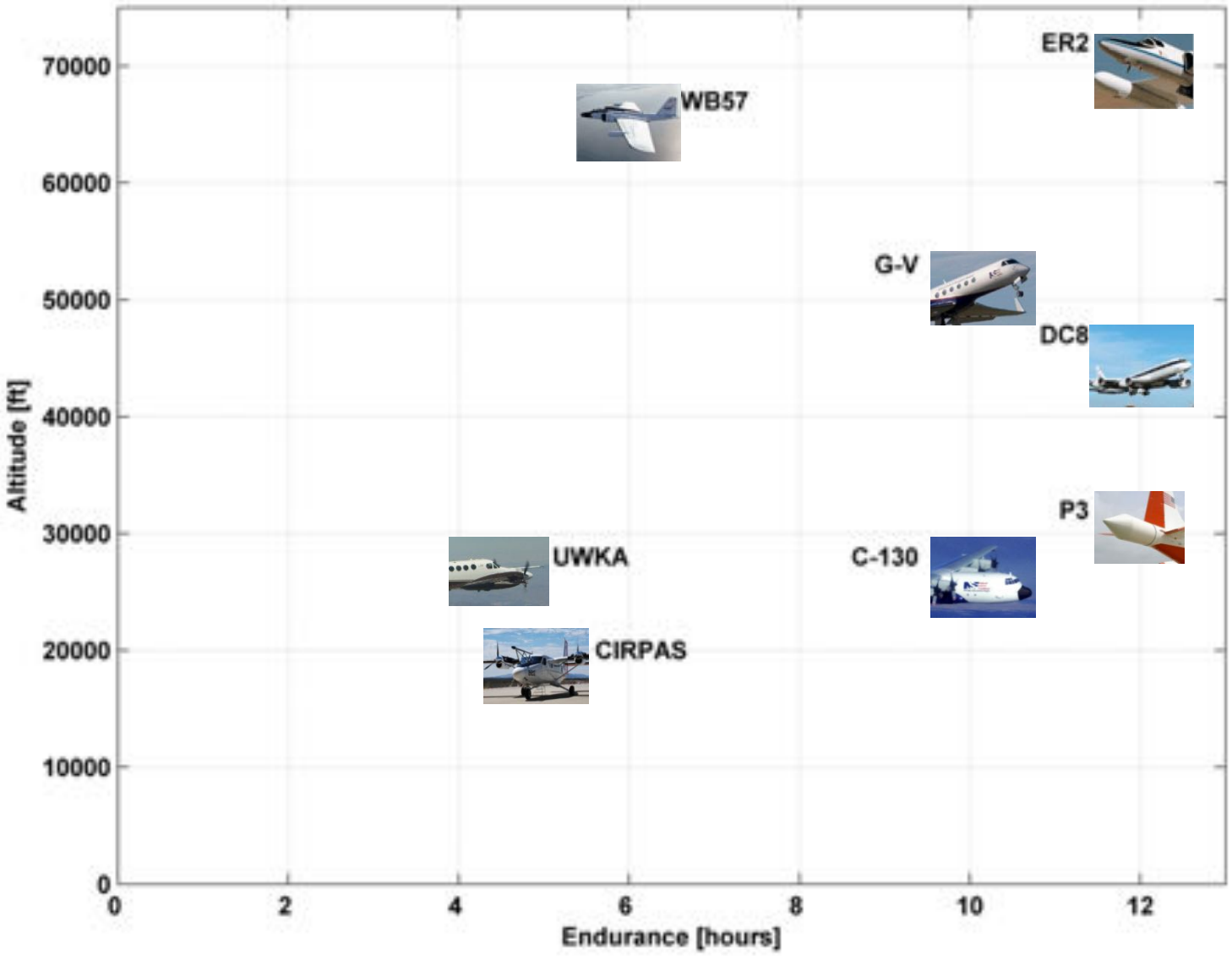
NPS/CIRPAS Twin Otter : air-sea interaction, boundary layer, cloud/aerosol studies

- Payload Capacity: 1500 lbs.
- Available Payload Power:
  - 200 Ampere of 28 VDC (5600 Watts)
  - 4000 watts may be inverted to 120V AC at 60 Hz.
- 5 hours endurance, fully loaded.
- Practical Ceiling: 18,000 feet, 12,000 feet without oxygen.
- Non-pressurized
- Not certified for flights into known icing conditions
- NSF/NPS MOU 2010

NRL-P3: ELectra DOppler RAdar (ELDORA)

- Ceiling: 31,000 ft
- Endurance 12 hours
- Payload 4500 lb
- ELDORA developed jointly by NCAR and France's CRPE

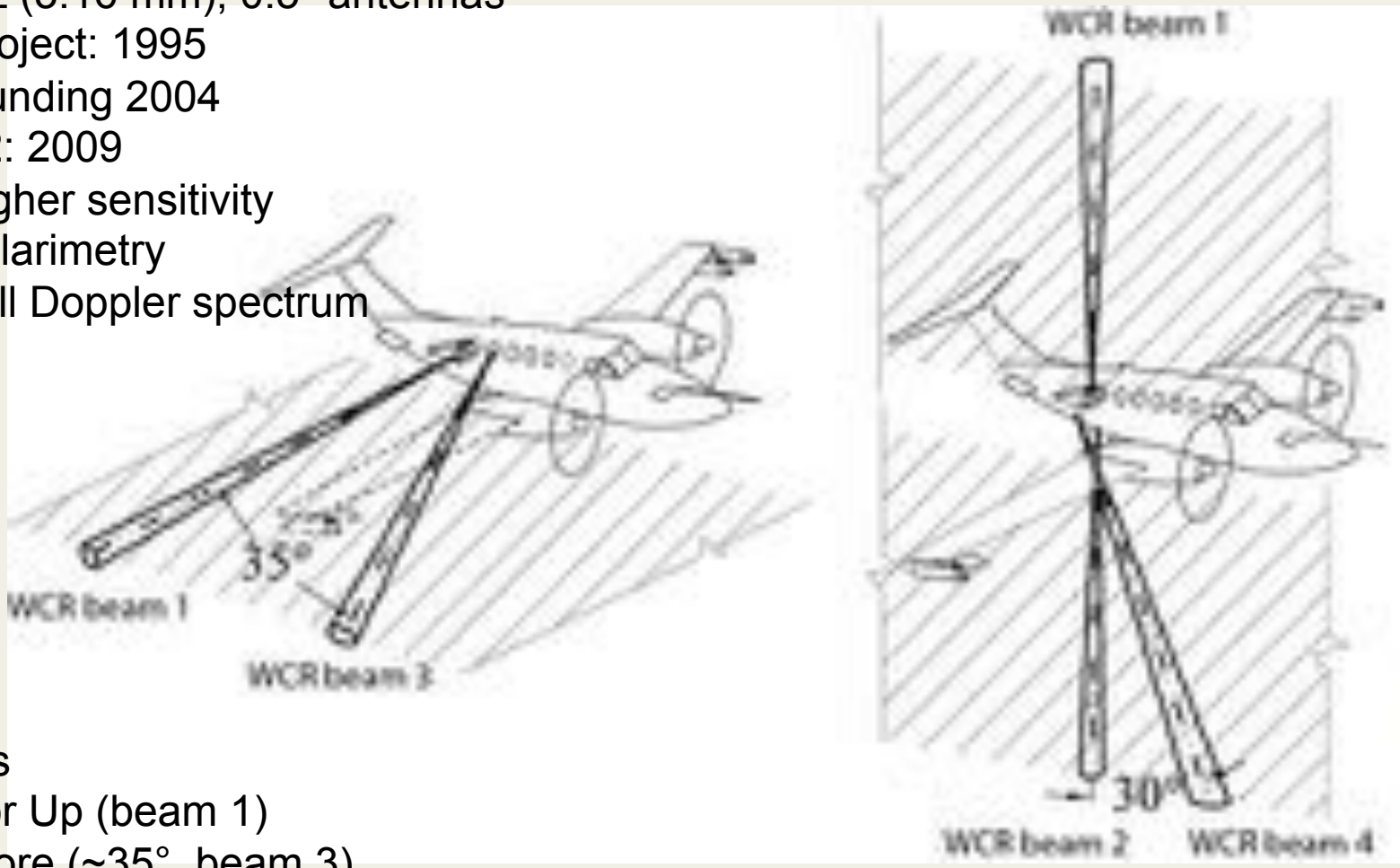
- NSF/NRL MOU (1 year left)
- Service life issue (wings)
- No NSF base funding


ER2
WB57
G-V
DC8
P3
C-130
UWKA
CIRPAS
70000
60000
50000
40000
30000
20000
10000
0
Altitude [ft]
0
2
4
6
8
10
12
Endurance [hours]

-->UAS

Wyoming Cloud Radar: deployable on UWKA and C-130

- 95 GHz (3.16 mm), 0.5^{o} antennas
- First project: 1995
- Base funding 2004
- WCR-2: 2009
  - Higher sensitivity
  - Polarimetry
  - Full Doppler spectrum



Antennas

- Side or Up (beam 1)
- Side-fore (~35°, beam 3)
- Down (near nadir, beam 2)
- Down-fore (~30°, beam 4)

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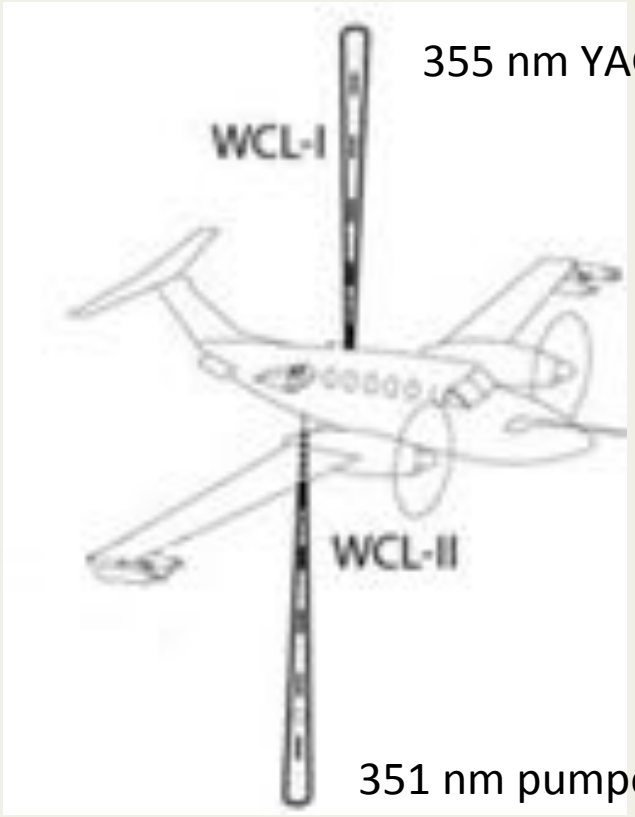
Table 2. WCR specifications.	
Transmit frequency | Wavelength	94.92 GHz | 3.16 mm
Pulse width | Pulse repetition frequency (PRF)	100–500 ns | 1–20 kHz
Antennas	Aperture | beamwidth
• Side or up (beam 1)	0.305 m | 0.7°
• Side fore (~35°, beam 3)	0.305 m | 0.7°
• Down (near nadir, beam 2)	0.457 m | 0.5°
• Down fore (~30°, beam 4)	0.381 m | 0.6°
Receiver channels	2
• Outputs	Digital (12 bits)
• Dynamic range	65 dB
• Noise figure	5 dB
Sampling rates	
• Along beam	Minimum 7.5 m
• Along flight	Minimum ~3m
Doppler radial velocity processor	
• Pulse pair	1st & 2nd moments
• Fast fourier transform (FFT) spectrum	16–512 spectral lines
Maximum unambiguous Doppler velocity	±15.8 m s^{-1} at 20 kHz PRF
Maximum measurement range	~ 10 km
First usable range gate	~ 100 m

Wyoming Cloud Lidar: deployable on UWKA and C-130



Compact polarization lidar (elastic)

- Polarization and Backscatter ratio
- 3.75 m vertical
- 5-2 m horizontal (SNR issue)
- Base funding 2010

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Wyoming Cloud Lidar: deployable on UWKA and C-130

Ultra-pulsed Nd:YAG laser from Big Sky Laser Technique, Inc	
Transmit wavelength	355 nm
Transmit pulse length	10 ns (3 m)
Range gate resolution	3.75 m
Pulse Rep. Frequency	10 Hz
Beam Width	~ 1 cm + 0.3 mrad
Pulse Averaging (typical)	1-4 (typical) 0.1-0.4 s along track
Detector(s)	2 orthogonal PMT (co- & cross-pol pwr)

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NCAR Dropsonde Technology

Complete end to end solution

Dropsondes

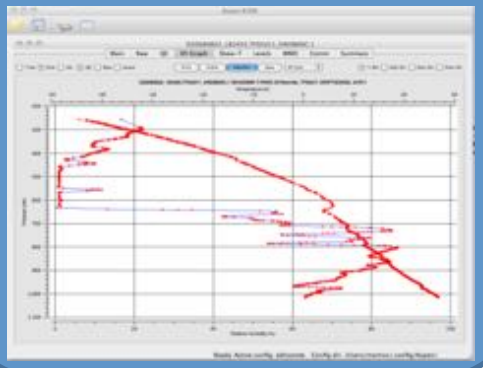
Aircraft Data Systems

Atmospheric Profiling

- **Research quality sensors**
- **Fast sample rate- high vertical resolution**
  - **Pressure**
  - **Temperature**
  - **Humidity**
  - **Winds**
- **Capability of rapid launch, up to 8 sondes in the air simultaneously.**
- **Launch Platforms**
  - **Manned Aircraft Systems**
  - **Global Hawk UAS**
  - **Long duration balloons (Driftsonde)**

ASPEN Software

Data Quality and Temp Drop message



Automatic launcher

Global Hawk HS3 Dropsonde Mission
North Pacific Cross Sections

Cold tr
tropop

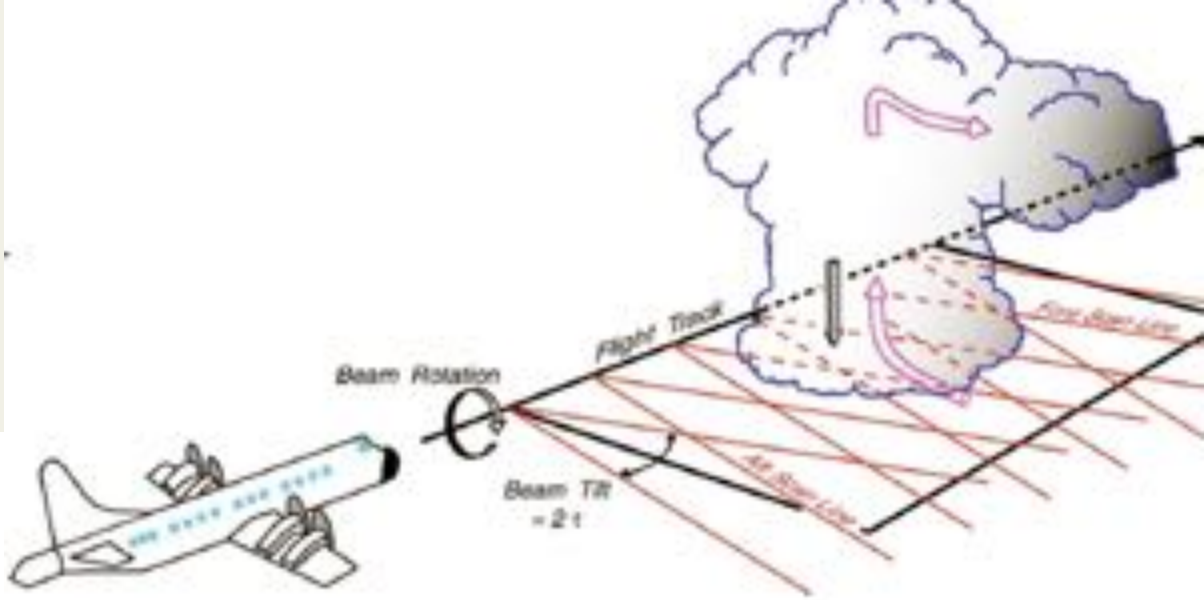
Extratr
storm

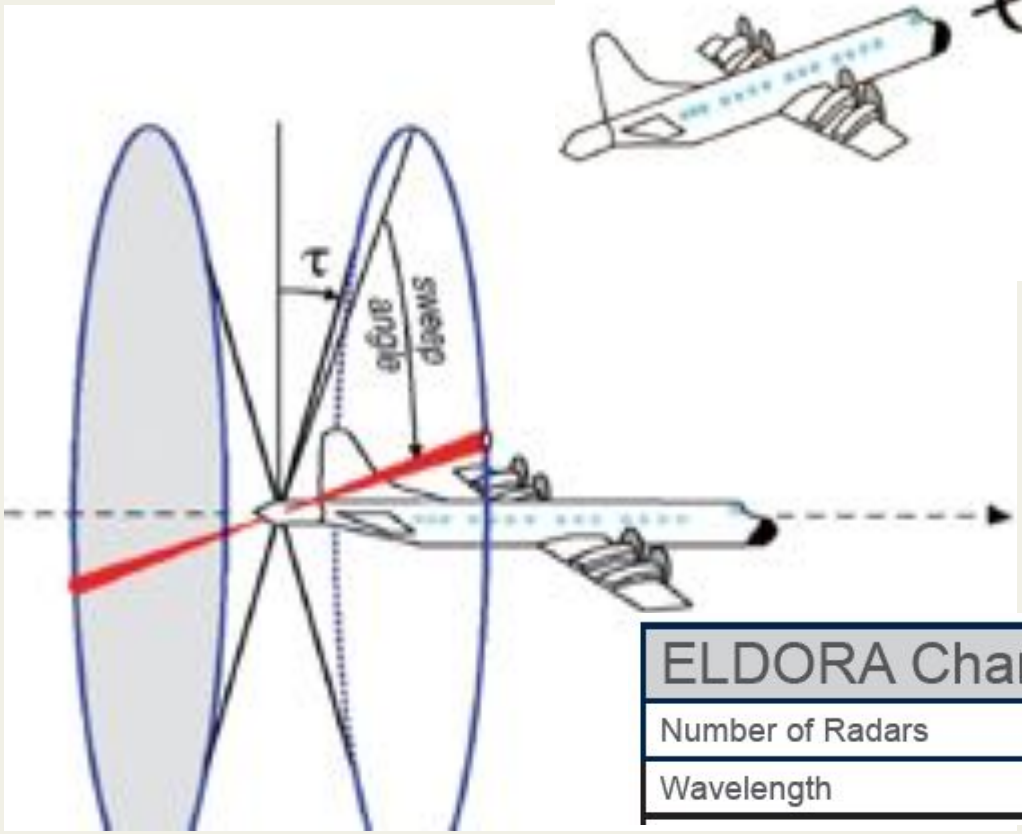
Dry
subtro

oper

SRL

ELDORA on P3





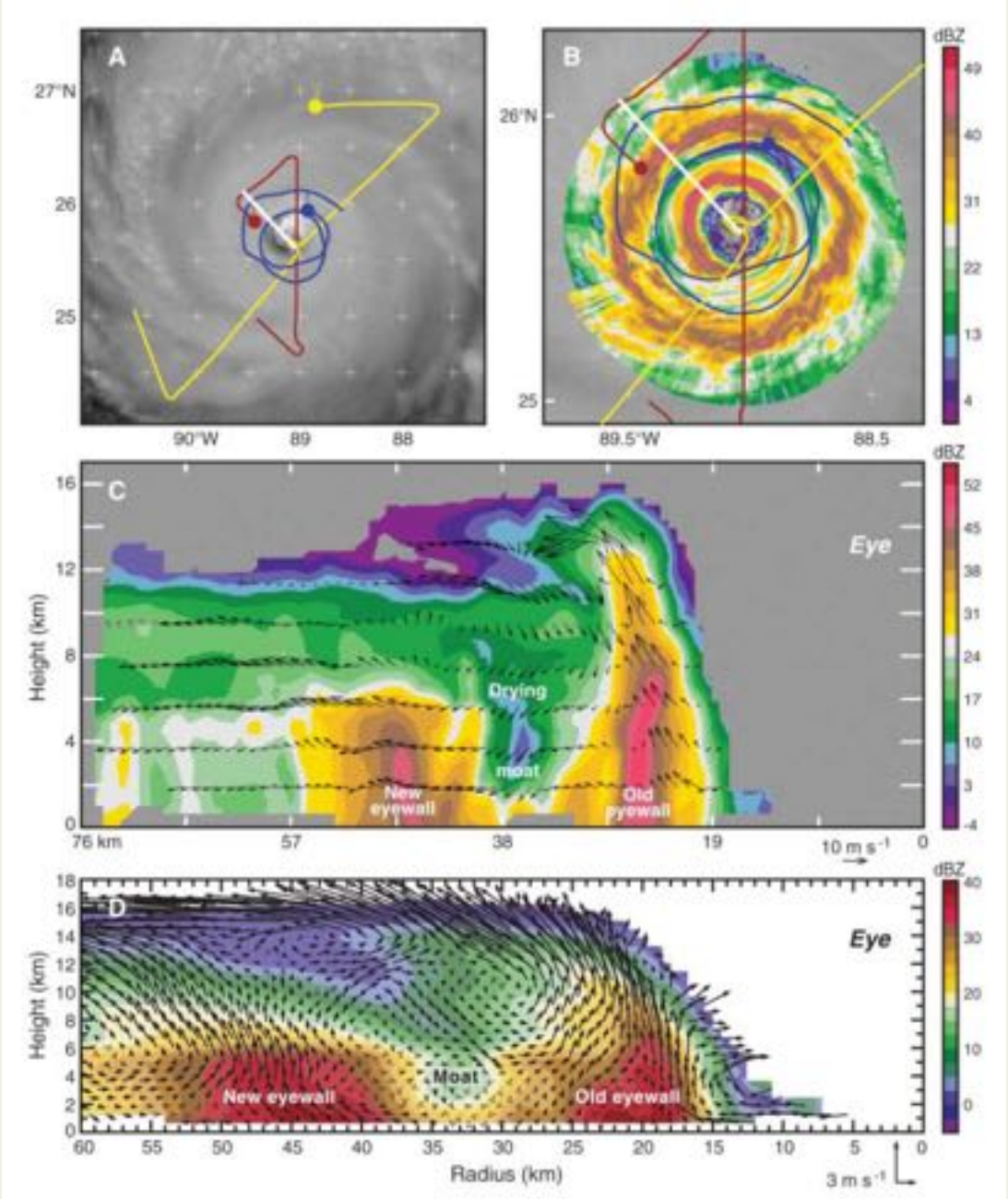
ELDORA Characteristics	
Number of Radars	2 (fore and aft)
Wavelength	3.2 cm

Hurricane Rainband and Intensity Change Experiment (RAINEX, 2005)

Blue track: NRL P3
Red/Yellow tracks: NOAA P3

"Eyewall replacement process": Crucial input to high-resolution numerical models can lead to improvements in forecasting hurricane intensity.

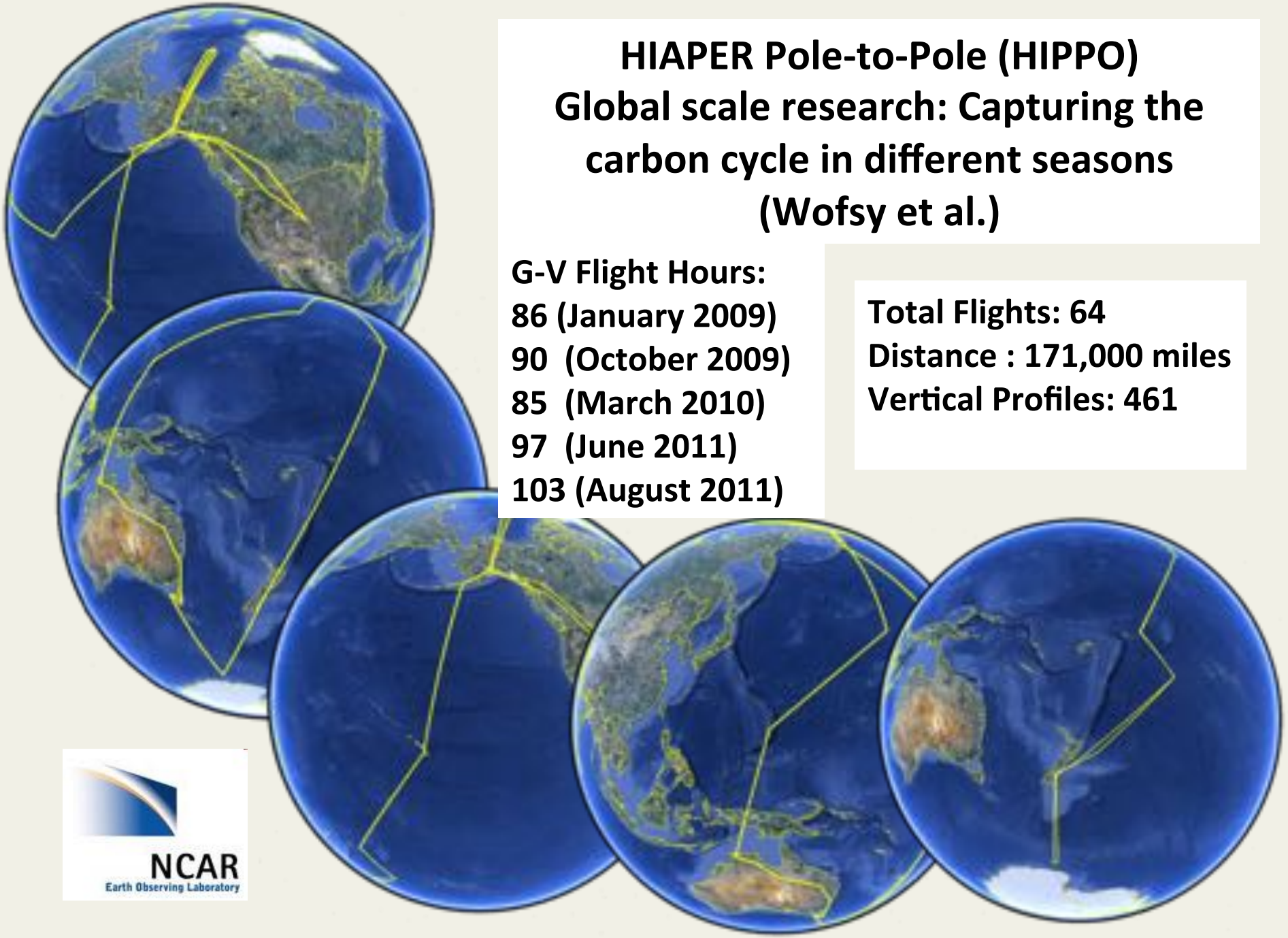
Houze, *et al., Science* **315**, 1235 (2007);



HIAPER Pole-to-Pole (HIPPO)
Global scale research: Capturing the carbon cycle in different seasons (Wofsy et al.)

G-V Flight Hours:
86 (January 2009)
90 (October 2009)
85 (March 2010)
97 (June 2011)
103 (August 2011)

Total Flights: 64
Distance : 171,000 miles
Vertical Profiles: 461



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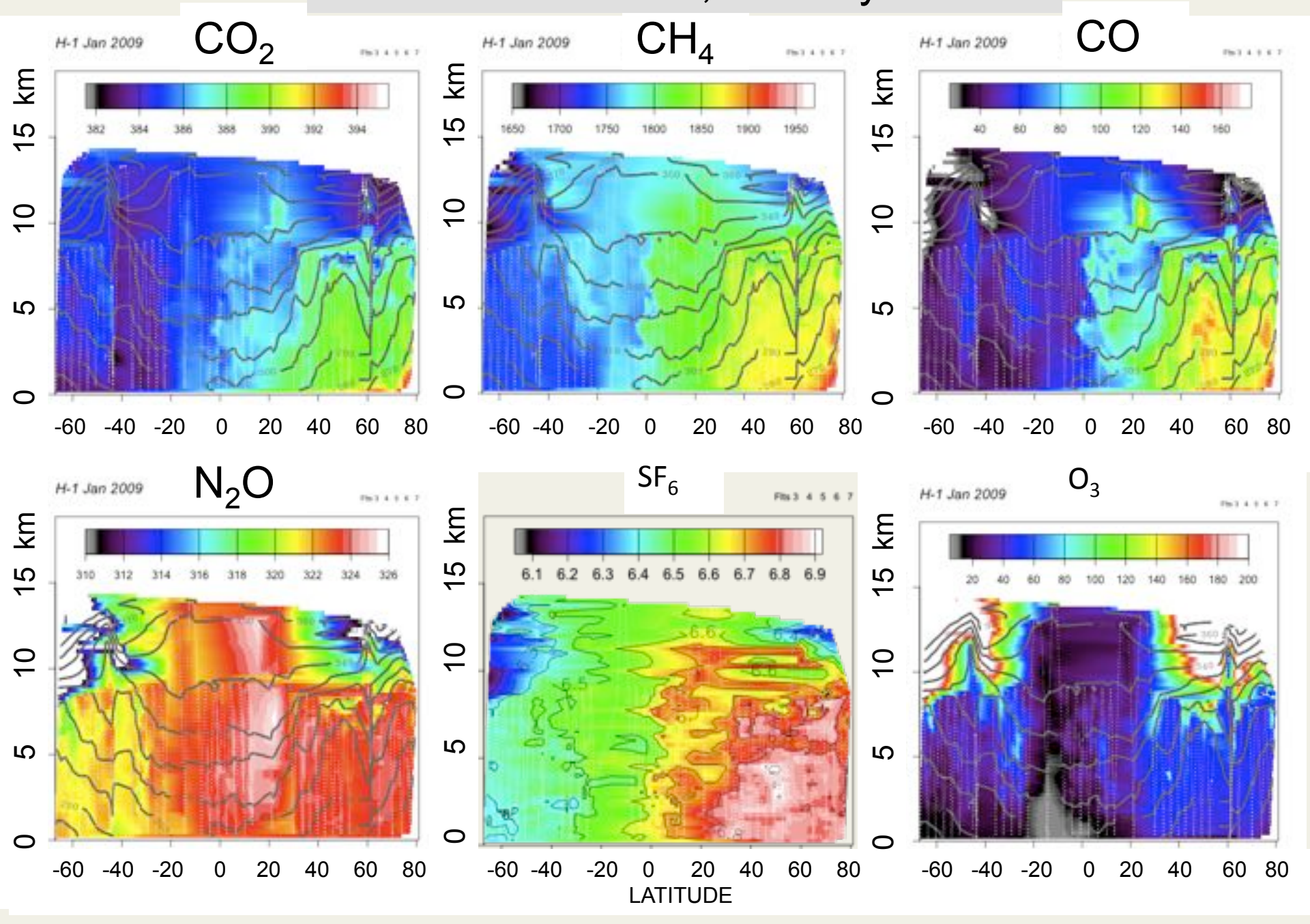
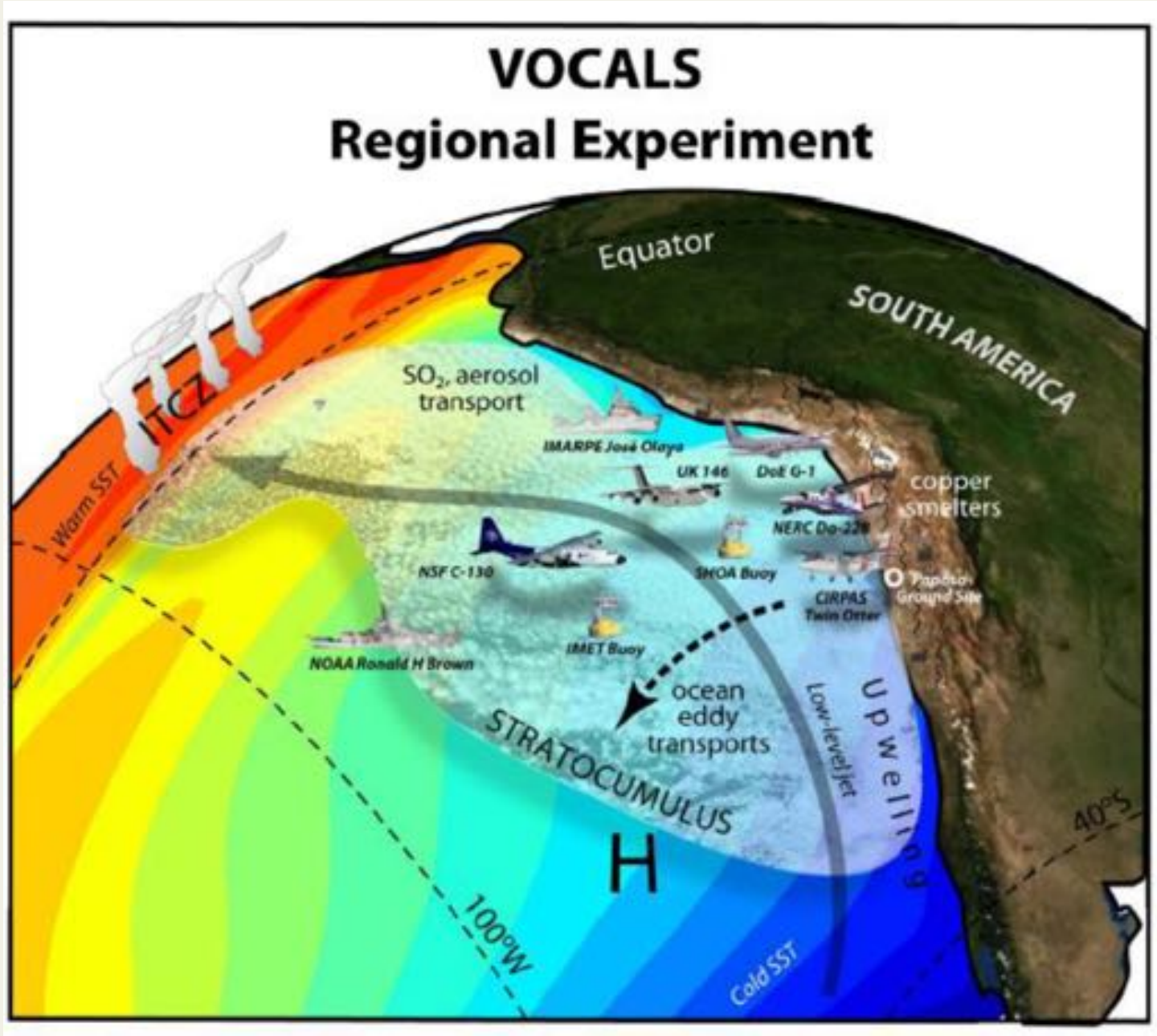
HIPPO sections, January 2009




VOCALS
Regional Experiment
Equator
SOUTH AMERICA
ITCZ
Warm SST
SO_2, aerosol transport
IMARPE José Olaya
UK 146
DoE G-1
copper smelters
NERC Do-228
NSF C-130
SMOA Buoy
Paposo Ground Site
CIRPAS Twin Otter
IMET Buoy
NOAA Ronald H Brown
ocean eddy transports
STRATOCUMULUS
Low-level jet
Upwelling
H
100°W
40°S
Cold SST

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Oregon State
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Logistic Support:
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NOAA/GFDL
NOAA PMEL
NRL
Pacific Northwest
Scripps
Woods Hole

VOCALS Goals

Elimination of CGCM systematic errors in the SEP, and improved model simulations of the coupled system in the region and global impacts of its variability.

Improved understanding and regional/global model representation of aerosol indirect effects over the SEP.

www.eol.ucar.edu/projects/vocals

Oper. Centers

BMC Australia
CPTEC Brazil
ECMWF Int.
JMA Japan
MetOffice Uk
NCEP US

Climate need: Understand the lifetime and albedo of marine stratus

- DYCOMS (1985 Electra)
- DYCOMS II (2001)
  - *"One last technological development that motivated a new observational attack…was the availability of the NSF/ NCAR C130"* From Stevens et al. BAMS 2003
- VOCALS (2008)
  - Largest marine stratus study to-date

The C-130 was a key platform for VOCALS due to:

- Long endurance:
  - Needed to capture diurnal variability
- Long range:
  - Needed to capture polluted coastal and clean remote parts of the cloud deck
- Large payload:
  - Turbulent fluxes
  - Trace gases
  - Aerosol particles
  - Cloud and precipitation particles
  - Cloud radar and lidar

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Multi-sensor retrievals:

Optimally combine

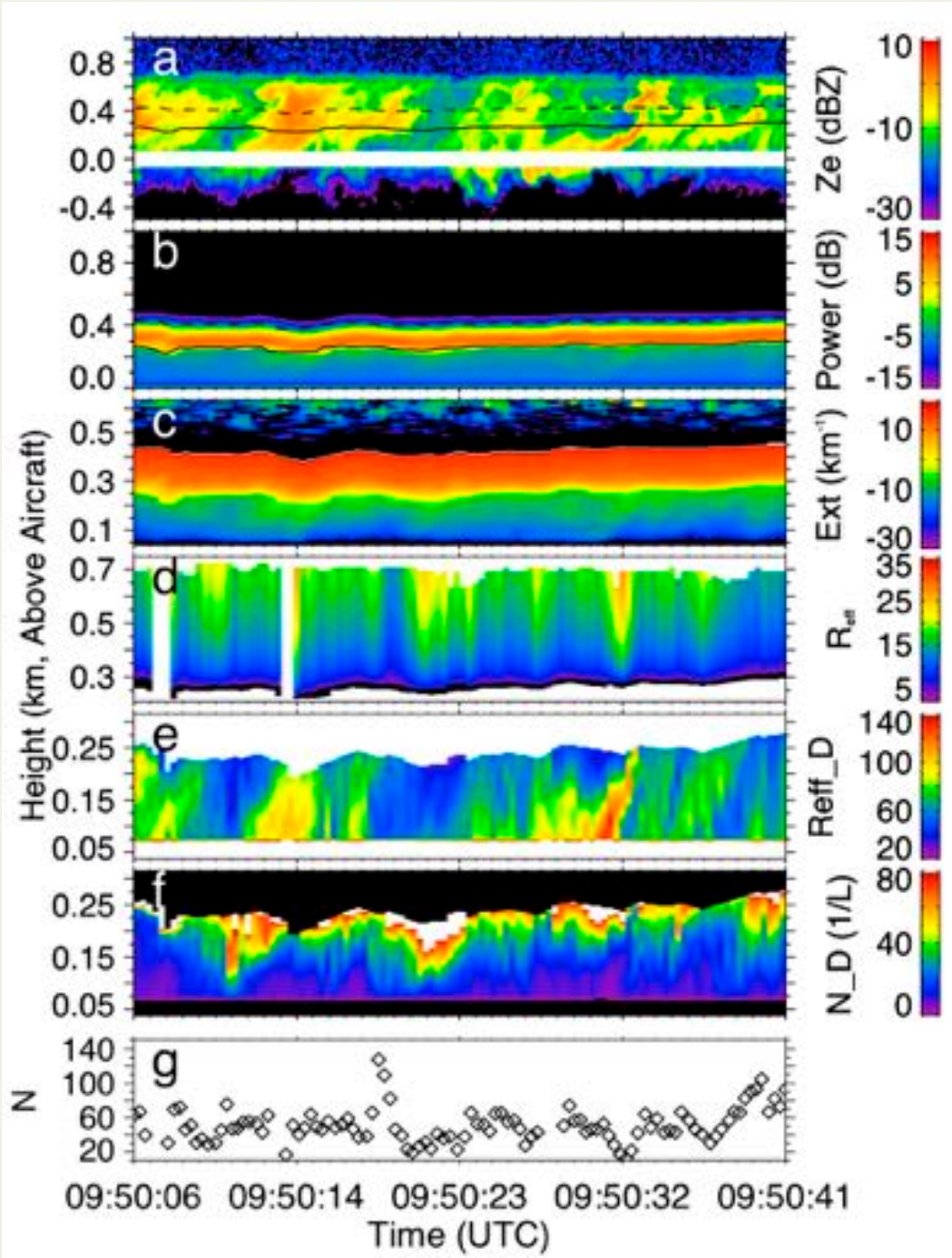
- **In situ data: small sample volume, size resolved**
- **Remote sensing data: integrated properties**

TABLE 3. A list of measurements needed to retrieve ice-, water-, and mixed-phase cloud microphysical properties.

Measurements	Ice clouds	Water clouds	Mixed-phase clouds
	IWC and D_{ge}	LWC , r_{eff} , and drizzle property	IWC and D_{ge} for ice phase LWC and r_{eff} for water phase
WCL	Extinction	Extinction	Extinction depolarization ratio
WCR	Z_e	Z_e	Z_e or spectrum
GVR (*)		LWP	LWP
References	Donovan and van Lammeren (2001), Wang and Sassen (2002), Heymsfield et al. (2008), Deng et al. (2010)	Frisch et al. (1995), Sassen et al. (1999), O'Connor et al. (2005), Wang (2007)	Wang et al. (2004) and Shupe et al. (2008)

(*) G-band (183 GHz) radiometer: 4 channel, PLW and LWP (Pazmany, 2007)

WCR and WCL observations of drizzling stratocumulus clouds during VOCALS:
(a) WCR Z_e,
(b) WCL attenuated backscatter power
(c) retrieved visible extinction coefficient
(d) cloud effective radius (μm) above cloud base,
(e) drizzle effective radius (μm) below cloud base,
(f) drizzle number concentration below cloud base, and
(g) layer mean cloud droplet number concentration.
In (a) and (b), the solid lines indicate WCL identified cloud base and the dashed lines represent the top of useable WCL data.



Wang et al, BAMS, 2012.

Challenges:

- **Installation and certification of instrumentation**
  - **Commonality of instruments among platforms**
- **Risk Management for unusual research flight operations**
  - **Volcanic ash**
  - **High electric fields**
  - **Lightning (King Air)**
  - **Dropping sondes**
- **International Operational challenges (e.g. diplomatic clearances)**
- **Access to airspace (ATC clearances and related)**

Questions?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