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Date: 3/10/97 12:03pm
Subject: STERAO Daily Summaries

The summaries which follow are individual summaries which were written by myself, Steve Rutledge and Tom Matejka and Diana Bartels shortly after the aircraft portion of the project. I had hoped to combine the comments into one composited summary for each day, but won't have time before the workshop and these will give a good idea of the storms and activities on each day. Jeff Stith also has brief summaries of Citation flights. Perhaps if they are in a convenient form he could email them to me and I will forward, but I tried to incorporate his earlier notes in my summaries.

Be aware that I used local time, MDT, (GMT - 6hrs) in my summaries while others have used GMT (UTC). As pointed out by Tom and Diana in their summaries "Times are approximate. Assessments of the weather and data are preliminary."

Jim Dye
March 10, 1997

DAILY SUMMARIES FOR STERAO/DEEP CONVECTION

JUNE 17

A good squall line case with the P3

P3 (~1515 - ~2130 MDT) worked a strong line of convection at the very NE limit of the radar/interferometer range. The storm formed over WYO and moved ESE gradually developing new cells along outflow on the SW side of the main storm. In early stages of storm study the P3 did N-S crosssections beginning at 21000 ft and down to 500 ft AGL in passes through the outflow boundary. Afterwards 3 to 4 good Doppler legs were made in front of the convection on the SE side with focus on the southern most cells. These passes were mostly beyond the CHILL range. Interferometer disk saturated at ~1740 MDT, but data prior to that time should be good.

Instruments: P-3; CHILL; interferometer, flat plate at FTM (after 00Z or so). Field mill at FTM. Day began with strong convection near CYS. Outflow boundary tracked into NE Colorado with associated conv development. P-3 worked conv in east int lobe around 0100 UTC.

P3 Flight 1

2107 17 June 1996 - 0415 18 June 1996

Weather studied: A SW-NE intensifying squall line with some trailing stratiform precipitation, mid-level rear inflow. Line apparently propagated along axis to SW and perpendicular to axis to SE. Cells along line displayed different characteristics, possibly because of age gradient along line to NE.

Doppler Radar: 3 legs flown from 0110 - 0152 ahead of line. All legs good. No lower fuselage radar data until 0110.

Assessment: Very good prospects for airflow analysis supporting chemistry objectives. Interesting mesoscale squall line kinematics. Subsequent sampling behind line is probably in the location of earlier, dissipated thunderstorms.

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JUNE 20

Radar/interferometer study

Strong storm in E lobe of the network with tops above 50 Kft and very rapid growth. Roughly 1830 to 2000 MDT.

00 - 04 UTC. Explosive convective development. Sounding was highly unstable with strong CIN - which was overcome by outflow boundary collisions and/or storms rolling off foothills and tapping instability. Storm to 65 dBZ bisected FTM flat plate/field mill set up. Several hours of CHILL/interferometer data were obtained over the E. interferometer lobe which contained up to 5 storms at one time. Repeated volumes with 4-6 min. update were obtained.

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JUNE 21

20 UTC 21 June to 0200 UTC 22 June.
Good study of moderately-intense TRW's, mainly in E. interferometer lobe. Good SEC 1 and SEC 2 coverage with excellent temporal resolution. Strongest storm passed well in range of FTM flat plate. Some data obtained with mobile flat plate near 14/71 intersection, but some problems with gain setting/saturation. Overall a good data set for merging MP radar, NLDN and interferometer data.

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JUNE 22

A good narrow line case with the P3

The storm formed over the foothills to the W of Ft. Collins and moved E onto the plains. It was a very narrow line of convection but with lightning. P3 did chem. characterization then flew the anvil at 21 Kft to get on back side of the storm then later to the front side of the line. (~1400-2100 MDT)
The optical disk on the interferometer failed so no ITF data.

2000 UTC 22 June to 0300 UTC 23 June.

Main event was weak-to-moderate squall line that came off foothills and passed to east of CHILL a bit before dissipating. Not much s/f precip behind line, but large anvil extended to NE. Consistent with strong upper level flow. Moderate amount of lightning from interferometer.

Tail Doppler data not too useful since system was fairly weak by the time P-3 got to it. Some good low-level passes behind and ahead of line for chemistry samples. P-3 also made penetration of NE anvil with RHI coverage by CHILL. Strong outflow ahead of line probably due to westward momentum being brought to the surface by convective scale descent.

P3 Flight 2

2010 22 June 1996 - 0246 23 June 1996

Weather studied: N-S weakening convective line moving E out of foothills after a cold frontal passage the previous evening. Line rapidly dissipated to comprise only one cell. Later in the flight, an unrelated weak thundershower.

Doppler Radar: 3 Doppler legs flown from 2205 - 2303, 2 behind the line, 1 ahead. Only leg 2 fairly good. Incidental Doppler data were collected in the weak thundershower.

Assessment: Fair prospects for airflow analysis at one time only in weakening line.

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JUNE 24

2100 UTC 24 June to 0500 25 June.

Very interesting day for sure. Day set out with very well-developed DEN cyclone and good amount of moisture. Td ~ 50F in most of the mesonet. Convection started as low precip convection, south of CHL. Had good reflectivities aloft but very little precip. Shafts were intercepted by

chase vans - they reported low concentration of huge drops. Not much lightning activity either, despite 50 dBZ in mixed phase region. Anvils on these storms were really large - is this associated with low precip, i.e. strong upper levels shearing off condensate to anvil? By 6-7 PM the cells to south produced heavy rain and hail up to marble size. More lightning at this time too. This activity formed a large complex in the E. interferometer lobe with an arc of new cells extending back to Boulder.

Lots of good stuff in W. interferometer lobe too. This will be an excellent interferometer CHILL data set. Some flat plate data too. Could do lightning studies in low precip vs. high precip storms. Would be interesting to look at total lightning in lobes vs. ice mass at various levels as function of time.

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JUNE 25

Radar/interferometer study

Early in day at ~1500 MDT weak storm SE of CHILL with very little lightning, maybe a good near null case (or was it out of interferometer detection region). Later at ~1930-2000 storm NW of Ft. Collins produced lots of lightning with good CHILL coverage.

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JUNE 26

2100 UTC 26 June to 0300 27 June

First flight of UND Citation. Fairly weak flow aloft with mainly southerly component. Td's BE 45 in NE plains. Convection began in Mountains west of Boulder/Longmont area. Cell of interest came off Mts south of FNL and moved off to NE. Tops to 40 k' MSL, with good anvil extending off to northeast. Good section coverage of this cell. Lots of lightning as evidenced by interferometer. Ran flat plate at CHL - seem to perform well. UND make good penetrations oriented NW - SE through upper levels of anvil. Core had peak intensity of ~ 55 dBZ.

UND reported some enhanced NOx values in cloud. They also made two penetrations of the overshooting top associated with the main convective core. Overall a great event, Citation crew really did well. CHL had numerous software hangs but no real long down periods.

UND reported winds up to 80 kts at FL 350 - 370. These seem high compared to available sounding data - need to check this out.

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JUNE 26

Good anvil "shakedown" flight for Citation

Nice, classic storm west of FTC with lots of lightning, Citation made anvil passes in upper part of the anvil and a penetration of an overshooting top. (~1715-2050 MDT) more details from Steve

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JUNE 27

1st P3/Citation flight, good study of small airmass storm

Nice study of small, isolated storm to the west of a much larger line of cells on east edge of the network. This storm produced some lightning, but not as electrically active as some. P3 (1400-~2000) had Doppler coverage at a very early stage of storm development.

Citation (1510-1830) initially looked at storms way to NE of the area, then anvils of

the larger, older system E, then sampled the anvil of the small storm with across and along axis passes.

P3 Flight 3

2003 27 June 1996 - 0017 28 June 1996

Weather studied: Three air mass thunderstorms that decayed immediately upon raining out.

Doppler Radar: 2 Doppler legs flown by first storm from 2047 - 2107.

All legs good. 0 Doppler legs flown by second storm. 3 Doppler legs flown by third storm from 2245 - 2318. All legs good.

Assessment: Fairly good prospects for airflow analyses supporting chemistry objectives, especially for third storm, where data collection possibly began before cessation of updraft.

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JUNE 28

P3/Citation flights in remnants of disorganized storm

Disorganized storm which moved off the foothills west of BLDR.

Reports of heavy rain and wind in Longmont, but no hail. It had lightning in the early phase over the foothills, but fell apart as it moved over the plains. P3 (1400-???) tried to set up for

Doppler scans but storm on it's last leg. Citation (1620-1830) came up but found little to work, so sampled a few turrets way outside of the area with some enhanced NO before returning to JFC.

P3 Flight 4

2009 28 June 1996 - 0221 29 June 1996

Weather studied: Squall line ahead of upper-level trough passage. Line oriented N-S, propagating to E very discretely. Most of the forward anvil was left behind the propagating line.

Doppler Radar: 4 Doppler legs flown from 2210 - 2326. All legs fair to good. Tracks not perfect because of need to avoid new convective elements ahead of line.

Assessment: Good prospects for airflow analysis supporting chemistry objectives. Rapid line propagation suggests that debris of earlier thunderstorms is to rear of line, which was sampled in subsequent segment of flight.

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JUNE 29

P3/Citation Intercomparison

Flew legs at 17.5, 13.5 and 7.5 Kft between 150/20 to 360/30 GLL in clear air from ~1400 to 1630.

2002 29 June 1996 - 0000 30 June 1996

Weather studied: None (intercomparison flight).

Doppler Radar: None.

Assessment: No appropriate storms.

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JULY 3

P3 flight to west slope and Jim Bridger power plant; radar/interferometer study???

I believe there was convection in the network later in the day which might be suitable for radar/interferometer study.

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JULY 5

Citation (1450-1800) studied a storm way to the east with cross anvil passes from 22 to 35 Kft and along anvil pass near top.

Citation, CHILL, interferometer, sounding. No P-3 today due to engine starter

repair. Fairly good case with UND working impressive anvil.
Tops to 45 k' MSL. UND reported 1 ppb NO @ 2230 UTC, a time when interferometer noted active lightning in main core. Good section coverage with CHL for entire event. UND reported several 100 - 1000 crystals/ liter during their anvil penetrations.

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JULY 6

P-3, CHILL, interferometer, sounding. No UND Citation today due to inverter problem. Their status for Sunday and early next week is at this time uncertain. Had FROPA early morning putting us into upslope.

Atmosphere was strongly capped as indicated by FTM soundings.

Development was mainly along CYS ridge and off Palmer Divide - evidently these areas of higher elevation were not affected so much by the cap. Lower elevations were.

P-3 departed Buckley at 1500 local and did their survey work. We then broke them off to do Doppler work on a cell near Grover that dissipated before they could set up on it.

However there was a massive anvil in extreme SE Nebraska that the P-3 did sample (generated by the numerous cells in this region). Flew legs at 21, 19, 17, and 15 k' MSL. P-3 fixed antenna into v.p. position for these anvil penetrations. They made passes in 20-25 dBZ reflectivity from our perspective.

P3 Flight 7 2103 6 July 1996 - 0015 7 July 1996

Weather studied: Weak, short-lived thundershowers.

Doppler Radar: None.

Assessment: No appropriate storms.

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JULY 8

P3 Flight 8

2137 7 July 1996 - 0107 8 July 1996

Weather studied: Small, weak, short-lived thundershowers.

Doppler Radar: Nearly none.

Assessment: No appropriate storms.

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JULY 9

Excellent P3/Citation study; 2 Citation flts -- Ft. Collins storm

Large storm which grew out of upslope with cells extending from southwest of FTC to north of the WYO border. Lots of lightning from this system with almost a lightning "front" moving east at one time. As the system moved over the plains it became less vigorous but did evolve to wide spread precipitating stratiform system with some lightning.

First Citation flight (1400-1600) investigated small storm (~065/50

GLL) with electrical activity which ended just before they started passes. Made a pass through tops of main cell then down anvil and finally a spiral descent from 35-25 Kft. P3 had engine start problems, but got off at ~1530 MDT and quickly went

to Doppler mode on the larger system. Later did legs at different altitudes in the stratiform region before landing at ~2100. On second Citation flight (1710-2020)

during climbout, ATC put them between the two main cells of the active system. They made passes across the anvil at first then flew downwind in anvil and made passes way downwind (100 mi) to look at anvil outflow, including a spiral up above the visible anvil, where they found high NOx. Flew back near anvil top on the way home.

P3 Flight 9

2130 9 July 1996 - 0306 10 July 1996

Weather studied: Multiple-cell line moving off mountains embedded in much widespread cloudiness. NE-SW orientation. The environment contained deep moisture.

Doppler Radar: 7 Doppler legs flown from 2233 - 2353. All legs good except leg 1.

Terrain restrictions prevented the southwestern portion of the line from being observed early in the period. The lower fuselage radar was inoperative for the entire flight.

Assessment: Very good prospects for airflow analysis supporting chemistry objectives. Sampling behind the line in the subsequent segment of the flight was probably in the debris of dissipated thunderstorms.

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JULY 10

Excellent P3/Citation study -- Kimball storm

An isolated storm formed just NW of Kimball, Nebr. around 1600 which at first moved ESE then evolved into a small line of intense cells, sometimes isolated with growth on the SW side of existing line and gradually moved in direction of CHILL. During the last 1 - 1 1/2 hrs it evolved into a classic LP supercell (1930-2100). In the earlier stages there was moderate but not intense lightning but more during the supercell stage.

Both P3 (~1530-2030) and Citation (1615-1930) went to the storm in an early stage of its development. P3 obtained many (6 or 7) good Doppler legs on the SW side of the line and made low level passes on SW side then made vert. ascent to 21Kft and flew between two cells of the line to do a descent to ~500 AGL on the N side of line.

Citation initially made passes through the upshear anvil, then flew downwind and made passes across the anvil from top to bottom, then spiralled up in the anvil above tops and came back near top of the anvil passing through top of older decaying cell and near the very active NW cell, which evolved into the supercell. Found high O3 values suggestive of stratospheric air just above the anvil especially on S side.

P3 Flight 10

2136 10 July 1996 - 0225 11 July 1996

Weather studied: Very intense thunderstorm ahead of upper level trough and in strong vertical shear. Two convective cores elongated into a line oriented NW-SE and later became two cores. The core on the S edge of the line developed supercell characteristics toward the end of the data collection.

Doppler Radar: 10 Doppler legs flown from 2248 - 0105. All legs good. The lower fuselage radar was inoperative from the start of the flight through Doppler leg 3.

Assessment: Excellent prospects for airflow analysis supporting chemistry objectives. Interesting evolution of storm organization. The apparent propagation in different directions along axis (to N and S) and perpendicular to axis (to SW) was probably associated with the interesting evolution of shape.

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JULY 12

Excellent P3/Citation study; Cheyenne storm

Around 1615 a storm moved from NW and grew over CHY. Initially was disorganized with a cluster of cells moving SE, but by 1745 showed solid growth with >65 dBZ and started moving towards 170 deg. until it eventually moved just to the E of CHILL at ~1930. Lots of lightning especially in the organized stage. Started weakening by 2000 and by 2050 only a very few flashes.

P3 (~1430-2130) did a good chem. charact. of the area before the storm then several good Doppler passes on SW and then N side of the storm; made passes through the anvil; made broad circumnavigation of the storm in decaying stage and flew through low level storm remnants.

Citation (1625-1925) made anvil passes in close to the active convection, then a spiral up through the anvil well downwind of main activity and then additional cross passes in closer about 90 mi downwind. Citation had power problems during the flight and resorted to one inverter so last part of flight was with NO, NO2, O3 and 2DC, so no CO after ~1750.

Lightning van in excellent position NNW of CHILL for slow antenna, interferometer, NLDN comparison.

P3 Flight 11

2035 12 July 1996 - 0314 13 July 1996

Weather studied: Intense, long-lived thunderstorm in convective field that formed over and moved off mountains.

Doppler Radar: 12 Doppler legs flown from 2305 - 0132. All legs good. Radar occasionally malfunctioned and was down between 2237-2305 and 2310-2327.

Assessment: Very good prospects for airflow analysis supporting chemistry objectives. Interesting simultaneous storm propagations in different directions along axis (to NW) and perpendicular to axis (to S) associated with evolution of shape.

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JULY 13

Storm in W lobe with P3/Citation

check Steve's notes apparently storm passed through the W lobe of network which the

P3 and Citation (1515-1800) worked. Then later an electrically active storm moved through the E lobe of the network???

Notes from Jeff say "Good case, but hard to sample all regions of anvil due to large size."

2000 13 July to 0200 14 July.

Synoptic situation: Stalled frontal boundary oriented E-W near Denver. Good moisture, high CAPE (2-3 k J/kg). Also there was a short wave due in near 00Z on 14 July - but I think this came through more like 19-21 Z on 13 July. Early development of strong convection in NW and NE quadrants from CHILL. Numerous cores in excess of 55 dBZ, some producing up to 1.5 inch hail. Both P-3 and UND conducted successful missions this day. Storm of interest formed NW of CHILL, passed over

CHILL, and continued off to the SE of CHILL. P-3 did about 10 Doppler legs on this storm, which had peak dBZ's to ~ 60. They flew a step down descent pattern in the debris of this cell towards the end of their mission. The Citation initially worked to the east of the P-3 in a large anvil complex. Once it was clear that the P-3 would work the storm to the west, the UND was directed to that target. They did repeated anvil passes and also a spiral descent in this anvil. They reported 2 ppb of NOx at 2332 UTC at flight level 290. Downside of mission was loss of power @ Grover thus taking out interferometer lightning coverage between 2210 and 0110 (14 July). Overall good case.

P3 Flight 12

2114 13 July 1996 - 0221 14 July 1996

Weather studied: Thunderstorm in crowded convection field ahead of upper-level trough. Several cores in WNW-ESE orientation. Storm intense at first, then decaying.

Doppler Radar: 10 Doppler legs flown from 2150 - 2345, 4 ahead of (S of) storm, 6 behind. Radars down briefly between legs 8 and 9. All legs good, leg 9 somewhat more distant than optimum.

Assessment: Excellent prospects for airflow analysis supporting chemistry objectives. Debris of the storm was penetrated immediately after the Doppler legs.

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JULY 15

Strong storm Citation tried to work

check Steve's notes

Citation (1615-1850) had trouble getting clearance from ATC so couldn't work very well. Did spiral through lower portion of upshear anvil. Got in to some feeder cells.

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JULY 17

17 July 200 UTC - 18 July 0200 UTC. Quite a lot of convection this period but very little lightning. Sounding indicated a stable layer between 450 - 400 mb which acted

as a lid for the convection. Tops were at about this level most of the day. Apparently convection was not deep (vertically developed) enough to electrify. Could be a good null case study. A fairly good storm did develop about 0230. Speculate that this stable layer may have been removed by radiational cooling allowing convection to become more vigorous. But even this storm appeared to have been rather squatty. But pretty good lightning flash rates. ELCHEM reported need for 9 km tops before lightning would occur.

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JULY 23

23 July 2100 - 24 July 0100 UTC.
Good storms were monitored in E. interferometer lobe. High temporal resolution on sections maintained throughout afternoon and evening. Interferometer appeared to work well during the operation. Good case of multiparameter/lightning coverage of intense storms.

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JULY 24

2100 UTC 24 July to 0100 UTC 25 July.
Good case with CHL and interferometer. Flat plate had a problem so no data from lightning van. Bad cable appears to have been the culprit. Storm was isolated and quite strong between 2300 and 00 UTC (25 July). Excellent temporal resolution with volume scans. Overall a good case of MP/interferometer data.

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JULY 25

2000 UTC 25 July to 0030 UTC 26 July.
Atmosphere remained capped over plains in NE Colorado. Convection developed over mountains west of Ft. Collins. Took south easterly course and crossed I-25 west of Plateville. Storm was quite strong prior to exiting Front Range. Rapid dissipation occurred once storm got into plains. Lightning van got hour of good data on this event west of Windsor. Good sector coverage with CHILL. Interferometer was mostly up for this event but storm remained outside of W. lobe.

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Interferometer and radar coverage extended into early Sept. If interested in the data talk to Steve, Jim and/or Pierre.

CC: Dan Albritton <dla@al.noaa.gov>