TRACE−P, March−April 2001

DC−8 Flight tracks, narratives, and meteorological summaries

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Satellite imagery collected by David Westberg
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26 FEB 2001

DC−8: flight 04, Dryden−Kona, transit (20010226−20010226)

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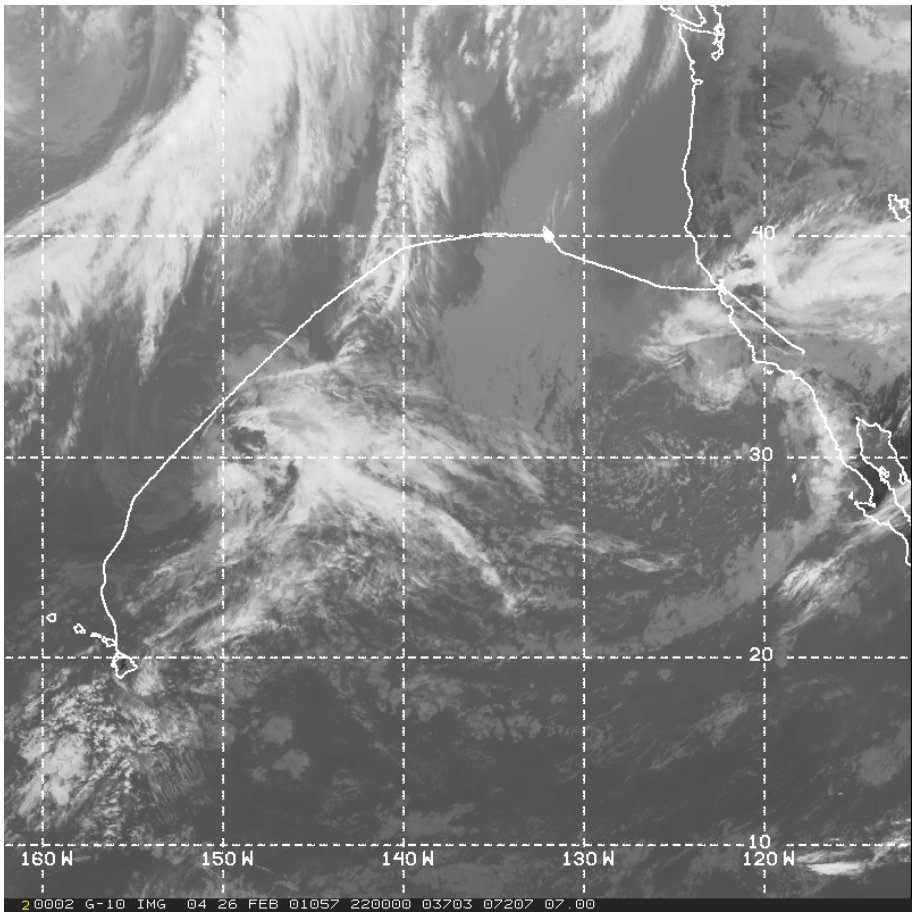

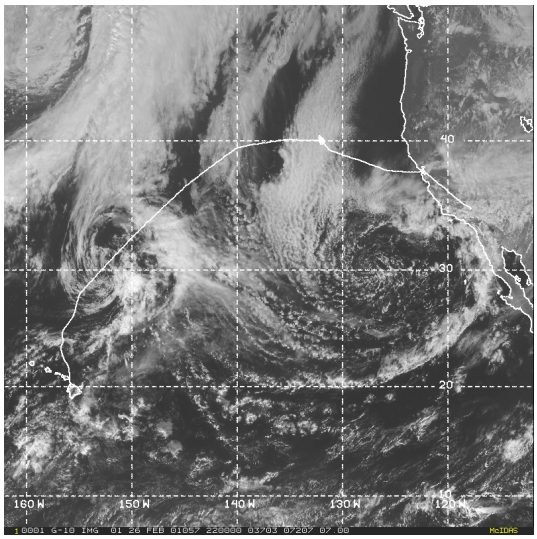

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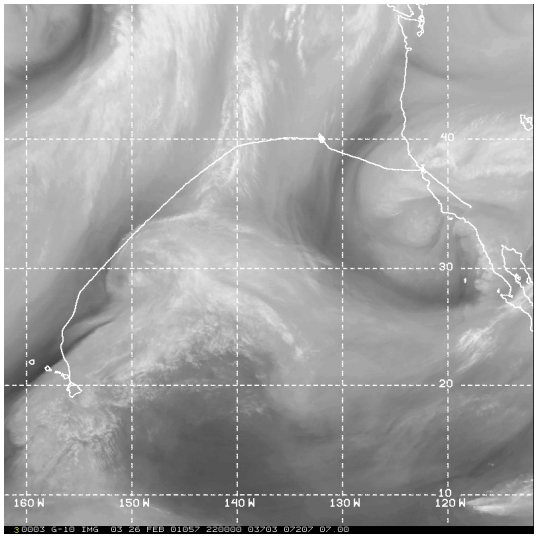

WV

DC−8 flight 04 Narrative

Title: Aged Asian pollution and MOPITT mid−latitudes validation
Objectives:
(1) to sample aged Asian fossil fuel and biomass burning pollution plumes, forecast to have been lifted frontally to the middle/upper troposphere and transported in less than 4 days across the Pacific at mid−latitudes;
(2) to conduct a MOPITT validation experiment for this air mass.
Execution: The MOPITT validation experiment was conducted at (40N, 132W, 2005 UTC) above a solid stratus deck with tops at 3.5Kft. The DC−8 arrived in position at cloud top at 1945 UTC and spiraled up to 35Kft, arriving there at 2007 UTC. It then spiraled back down along the same track to 0.5K to demonstrate the stationarity of the vertical profile. From there the DC−8 flew W and then SW to Hawaii, with four full vertical profiles along the way.
Results: Our objectives were met.
(1) We observed considerable Asian pollution influence from 40N to Hawaii; the location of the plumes was consistent with the model forecast although CO concentrations were higher than predicted, often exceeding 200 ppbv. By successive vertical profiling at different latitudes we observed a range of photochemical processing of Asian pollution, with ozone concentrations in excess of 100 ppbv at the low latitudes. There was evidence that this pollution represented a combination of fossil fuel and biomass burning (high PAN, high C2Cl4, high cyanides, high SO2, high non−volatile aerosol), with stronger contribution from the latter at low latitudes.
(2) the MOPITT validation experiment was a success. Skies were 100% clear above a solid stratus deck. The two spirals successfully demonstrated the stationarity of the air mass. The profile showed a large Asian pollution CO enhancement from 12 to 24Kft with values up to 270 ppbv. The top altitude reached by the aircraft (35Kft) corresponded to the tropopause, as indicated by in situ and lidar ozone, although CO there was still relatively high (120 ppbv).

Meteorological Summary

Relevant Flow Patterns
(1) Lower troposphere−A closed low pressure area near Dryden brought cloudy skies and considerable precipitation to that area. A high pressure area was centered over Hawaii, with a ridge extending northeast toward Canada.
(2) Middle troposphere−The closed low near California was better defined than near the surface. Split flow was evident over the eastern Pacific, with ridging to the north and troughing to the south. Closed low pressure was located just southwest of Hawaii. Subtropical highs were located southeast of Hawaii and west of Hawaii, with its ridge line extending all the way to Southeast Asia.
(3) Upper troposphere−The split flow pattern and closed flow near California continued. The only major anticyclone was midway between Hawaii and Southeast Asia. It dominated the flow over the western tropical Pacific. The jet stream was well north of the flight area−near 35oN.
Cloud Patterns
Low clouds were widespread over the flight area. Mid and upper level clouds were associated with the closed low near California. In addition, a major cloud band stretched northeast to southwest across the area. Its southern end was just south of Hawaii. This band moved slower than forecast, and was in the process of dissipating. A few slight showers were located near 33o30N, 149oW. The area of the MOPITT overpass was free of middle and high level clouds. There was a uniform deck of stratus/stratocumulus with tops of ~3500
ft.

27 FEB 2001

DC−8: flight 05, Kona−Guam, transit (20010227−20010228)

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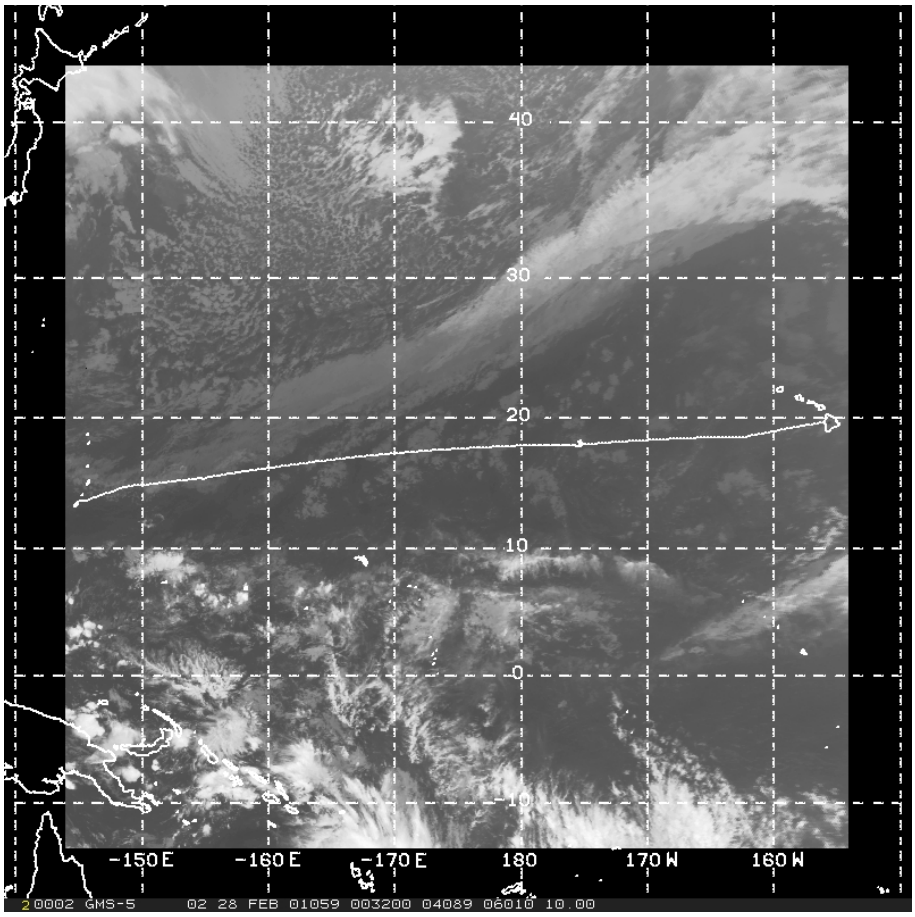

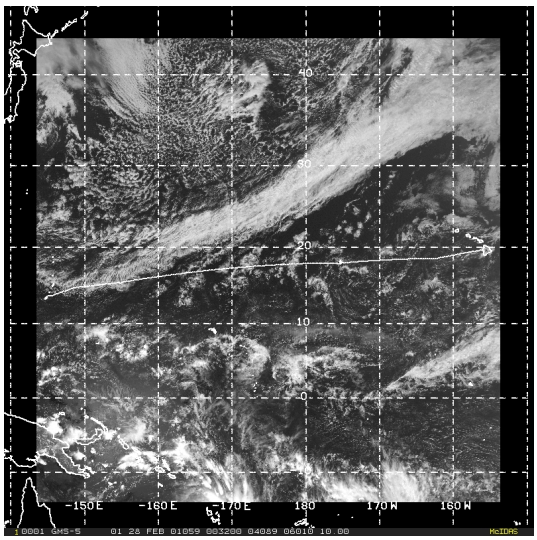

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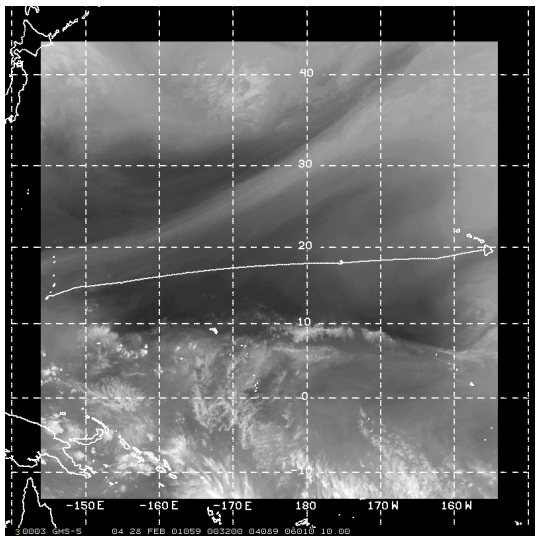

WV

DC−8 flight 05 Narrative

Title: Asian pollution subsidence and MOPITT tropical validation
Objectives:
(1) to sample aged Asian pollution subsiding in the tropics,
(2) to conduct a MOPITT tropical validation,
(3) to intercompare instruments on the DC−8 and P−3 aircraft.
Execution: The intercomparison, planned as a boundary layer run out of Kona with the two aircraft flying parallel tracks, had to be canceled because of lack of clearance. The DC−8 followed a straight flight track from Kona to Guam, with extensive vertical profiling. A MOPITT validation experiment was conducted at (18N, 175W, 2235 UTC) with a spiral from 31Kft to 0.5Kft above a broken cumulus deck (tops at 6Kft) in a strongly subsiding atmosphere.
Results: Our first two objectives were met.
(1) We observed and sampled repeatedly a layer of Asian pollution at 8−12Kft (CO up to 210 ppbv, ozone up to 80 ppbv) with background air above and below. This pollution was in a strongly subsiding layer on top of the trade wind inversion, and appeared to contain both fossil fuel and biomass burning influence. Through mapping with DIAL it was determined to extend from 170W to 162E. The layer was predicted in the chemical forecast where it was due to Asian outflow transported rapidly to the central Pacific, and then strongly subsiding and stagnating west of Hawaii, although the observed layer extended further west than forecast. Formaldehyde was elevated (up to 700 pptv), in contrast to the Asian plumes sampled on the Dryden−Kona flight, reflecting presumably the stronger photochemical activity.
(2) the MOPITT validation experiment was a success. Skies were 100% clear above 6Kft. Although the aircraft ceiling was 31Kft, DIAL observations showed very clean air above. The dominant feature of the profile was the strong layer of Asian pollution at 8−12Kft.

Meteorological Summary

Relevant Flow Patterns
Lower troposphere−Subtropical high pressure areas dominated the flight track. One center was near Hawaii, while a second was located over the western Pacific Basin.
Middle troposphere−Subtropical highs continued to dominate the area.
Upper troposphere−Continued high pressure over the area. The jet stream was centered near 35oN−well north of the flight track.

Relevant Cloud Features
The flight track mostly was devoid of middle and upper level clouds. However, scattered to broken cumulus and/or stratus covered much of the flight area. Water vapor imagery showed that the flight area was quite dry in the middle and upper troposphere. The dryness was associated with widespread subsidence associated with the subtropical highs described above. In situ soundings revealed classical subsidence−type temperature/dew point profiles. Chemical data indicated that the moisture and ozone/CO concentrations were consistently anti−correlated with each other.
The MOPITT evaluation area exhibited a scattered, thin layer of stratus with tops ~6,000 ft. There also was a broken cumulus deck with bases near 1500 ft, and tops reaching ~2500 ft. The clouds in the MOPITT area today were not as uniform as encountered yesterday.
Slight, brief rain rainshowers were encountered near Guam.

03 MAR 2001

DC−8: flight 06, Guam−Hong Kong, transit (20010303−20010304)

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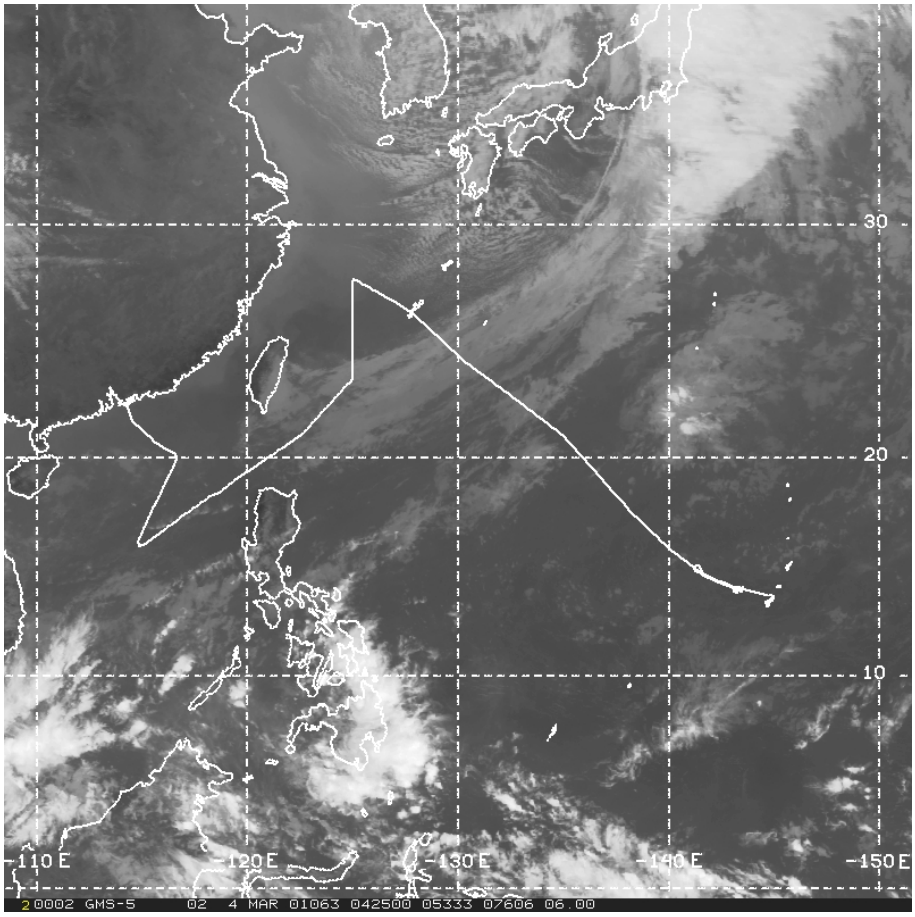

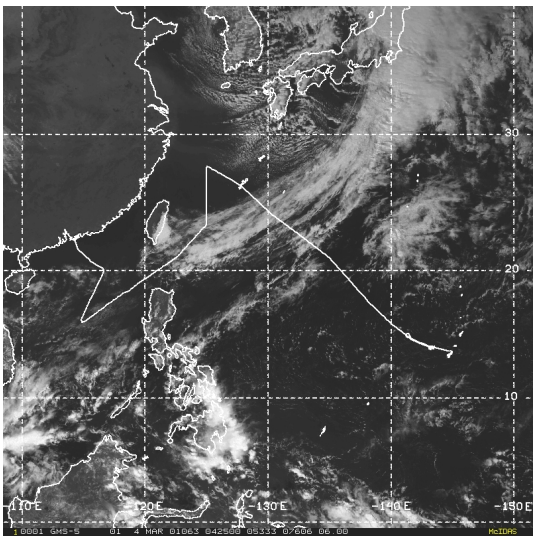

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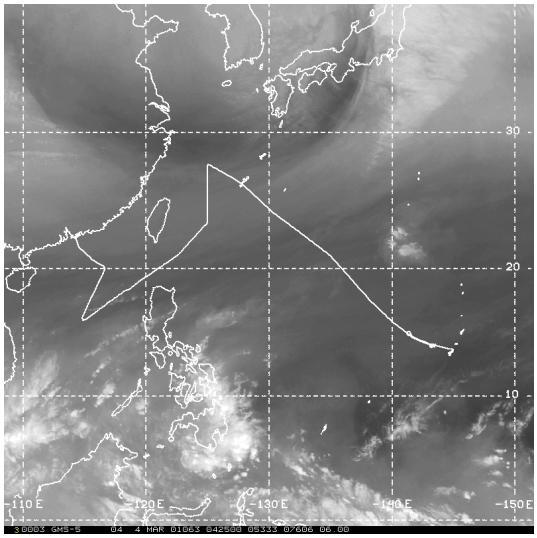

WV

DC−8 flight 06 Narrative

Title: Asian outflow: frontal, convective, and South China Sea
Objectives:
(1) to intercompare instruments on the two aircraft;
(2) to sample a variety of outflow patterns including post−frontal boundary layer outflow off the China coast, biomass burning outflow convected to the upper troposphere, and boundary layer outflow to the South China Sea.
Execution: The intercomparison experiment was conducted in the boundary layer out of Guam. The DC−8 and the P−3 flew parallel to each other (separated by 2000') for 20 minutes at 0.5Kft and then remained parallel as they climbed to 10Kft at a rate of 500'/min. The P−3 then flew WNW from Guam to the strait between the Philippines and Taiwan (20N, 121E) and conducted a southerly leg to (16N, 115E) to sample outflow over the South China Sea. The DC−8 flew NW to (27N, 126E) to cross a cold front moving across the western Pacific, and then S to overfly the P−3 and provide DIAL coverage.
Results: All objectives were met.
(1) The intercomparison was successfully conducted, in clear skies with broken shallow cumuli. The first half of the intercomparison was done in a homogeneous air mass but the second half showed significant gradients that will need to be investigated (aged ship plume?).
(2) Complex pollution outflow of biomass burning origin was observed in the upper troposphere along the DC−8 NW leg.
(3) The frontal crossing experiment was successful, showing a sharp contrast in the lower troposphere between clean air ahead of the front and highly polluted air behind the front off the coast of China. The polluted post−frontal boundary layer outflow was capped by a strong subsidence inversion at 7Kft and filaments of stratospheric air were observed at higher altitudes.
(4) Strong northerly outflow to the South China Sea was observed in a highly polluted layer extending up to 8Kft.

Meteorological Summary

Relevant Flow Patterns

At the surface, a low pressure area was centered just north of Korea. A cold front extended south of the low. Air ahead of the front was blowing from the south or southeast. Behind, the front, winds were strongly out of the northwest. Surface winds in the Hong Kong area were out of the northeast.

The low pressure over Korea persisted throughout the vertical column. Winds became more westerly with increasing altitude. The northeastly low level flow near Hong Kong also became westerly by 15,000 ft. The axis of the jet stream was located near 32oN. Our flight track intruded on the right rear quadrant of the jet streak. Peak winds encountered by the DC−8 were ~ 135 kt.

Relevant Cloud Features

The area of P−3 and DC−8 intercomparison was virtually free of all clouds. Only scattered cumulus and a few cirrus strands were observed. Cloud bases of the cumulus were ~2000 ft, with tops at ~4000 ft. A few isolated thin stratus were near 4,000 ft. The trade wind inversion in this area was located near 7,000 ft (moist air below and very dry air aloft).

The DC−8 intersected the surface position of the cold front near 22oN, 132oE. This area had a rather uniform and solid deck of stratocumulus. Fewer clouds were located behind the front. The descent area near the northern−most flight point was very hazy. Although difficult to estimate due to the absence of landmarks, visibility was ~ mile. The top of the haze layer was at ~8,000 ft. This probably corresponded to the top of the cold air mass. There were only isolated clouds in this area. Winds at 1000 ft were from 310o at ~30 kt. There was considerable turbulence in this flight segment. The descent area farther south also was very hazy. The top of the haze layer again was ~8,000 ft. There were broken cumulus in the area. Maximum cloud tops were ~3500 ft. Winds at 1,000 ft. were from the northeast. They shifted rapidly with height to westerly near 8,000 ft.

07 MAR 2001

DC−8: flight 07, Hong Kong local #1 (20010307−20010307)

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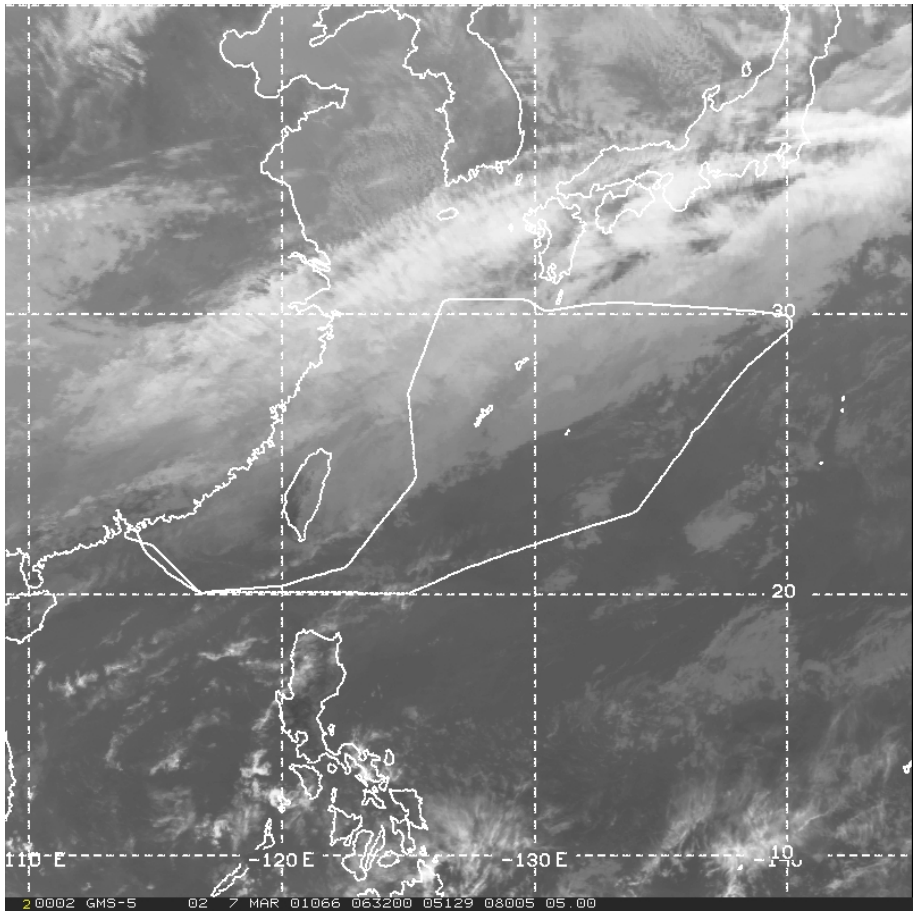

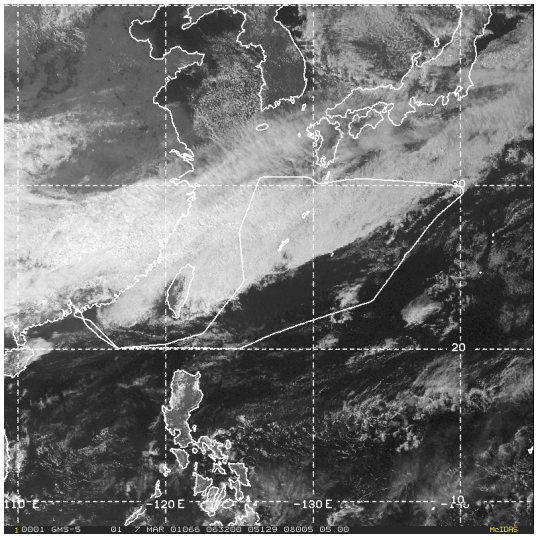

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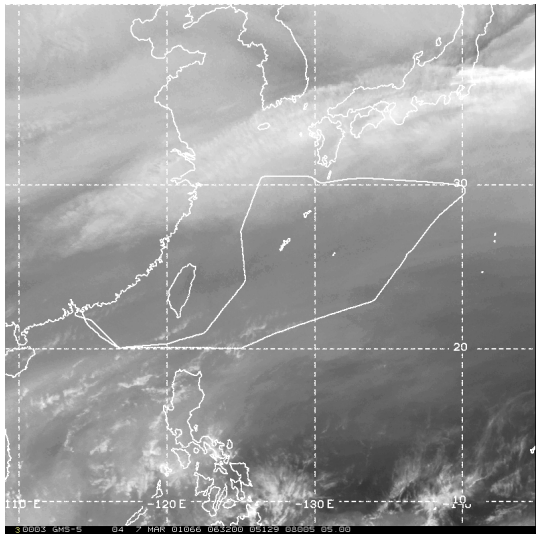

WV

DC−8 flight 07 Narrative

Title: China outflow and frontal crossing
Objectives:
(1) to sample fresh pollution advected to the western Pacific from China in the boundary layer behind a cold front,
(2) to cross the front and sample lifted pollution and clean air ahead of the front.
Execution: Both aircraft went around Taiwan and headed north. The P−3 remained close to the China coast, on a track extending up to 28N and returning along the same track. The DC−8 headed north to (31N, 125E) and from there east to (30N, 140E) to cross the front; it then returned to Hong Kong on a SW track, remaining ahead of the front.
Results: The objectives were met.
(1) High levels of fossil fuel and biomass burning pollution were sampled extensively behind the front, both in the boundary layer and in free tropospheric layers presumably lifted over China ahead of the front. Strong pollution outflow was observed from 17Kft to 28Kft at 30N, with CO levels in excess of 270 ppbv. Very dry subsiding layers were also observed. The DC−8 crossed the front and sampled clean air ahead of the front, with isolated pollution layers in the free troposphere again from frontal uplift. Air ahead of the front south of 24N was consistently clean. P−3B observations included upper tropospheric conditions (15Kft) representative of tropical air to begin the flight (CO−70s, O3−20s). Polluted conditions were first encountered around 10Kft at 22N (CO−300s, O3−90s). In the frontal region, cloud modulation of composition was recorded with changes in CO of 75% and doubling of NOy in and out of convective cells. CO values to the north behind the front were in the high 200−300 range. On the return to Hong Kong a well defined pollution layer only 1000 ft in thickness was encountered at 9Kft. Values in this layer for CO were double those encountered in the boundary layer and ozone values were almost quadrupled compared to BL values. On the last boundary layer leg, a ship plume was encountered that lasted 15 seconds with enhancements in NOy, particles, SO2, and CO2 as well as a significant titration of ozone.

Meteorological Summary

Relevant Flow Patterns

Surface−−A low pressure area was centered near 40N 140E. A cold front extended southwest to ~ 25N, 110E. A high pressure area was located near 25N, 150W. Flow ahead of the front was mostly from the southwest. Behind the front, there was brisk northerly flow. South of Hong Kong, there was onshore flow.

Middle troposphere−A low pressure area was centered between Korea and Japan. Subtropical highs stretched across the western Pacific, centered near 20N. There was westerly flow over the entire flight area.

Upper troposphere−The subtropical jet was just north of the Hong Kong area. It merged with the polar jet stream near Japan. A jet streak extended from the coast of Asia, across Japan, and into the western Pacific. The DC−8 flew through the entrance (western) portion of this jet streak, encountering winds as strong as 157 kt. There was westerly flow over the entire flight area.

Relevant Cloud Patterns

Prior to reaching the cold front, clouds mostly were patchy, with areas of broken cumulus and cirrus. The top of the haze layer near Hong Kong was ~10,500 ft.

The first descent to the boundary layer was near 22N, 123E. There were a few scud at 1,800 ft, with the main cloud base at 2,400 ft, and most tops at 5,000 ft. A few stratus were near 6,500 ft.

The DC−8 intersected the surface position of the front near 24N,125E. Extensive clouds were behind the front.

The second descent to the boundary layer occurred near the northern point of the flight. This was an area of extensive deep, multi−layered clouds that extended to near 20,000 ft. The boundary layer run was shortened due to poor visibility and strong turbulence which persisted throughout the climb out.

The DC−8 crossed the surface frontal position a second time near 30N, 134W. Clouds rapidly diminished east of the front. The aircraft remained on the warm side of the front throughout the remainder of the flight. There was much less cloud cover in the warm air than the cold air. Only scattered clouds were encountered during the remainder of the flight−usually scattered, but sometimes broken. Very dry middle tropospheric air was encountered during middle portion of the southward leg. This was due to subsidence associated with the subtropical highs. There was some enhanced cirrus as the aircraft approached Hong Kong.

09 MAR 2001

DC−8: flight 08, Hong Kong−Okinawa (20010309−20010309)

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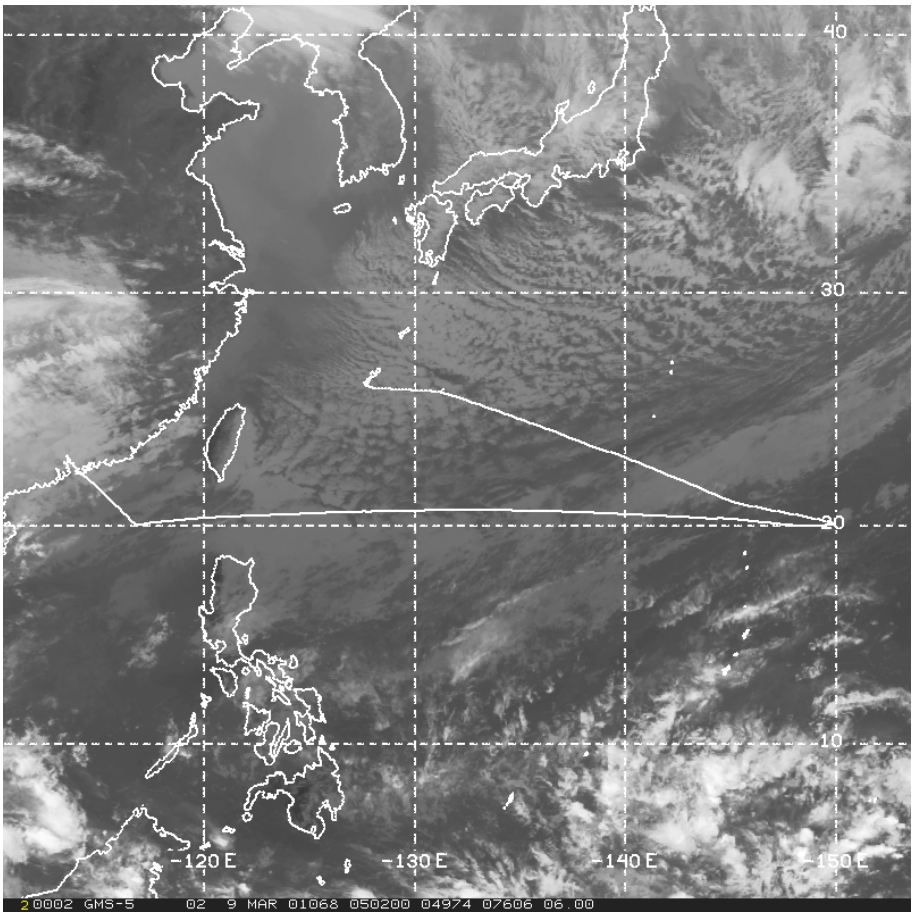

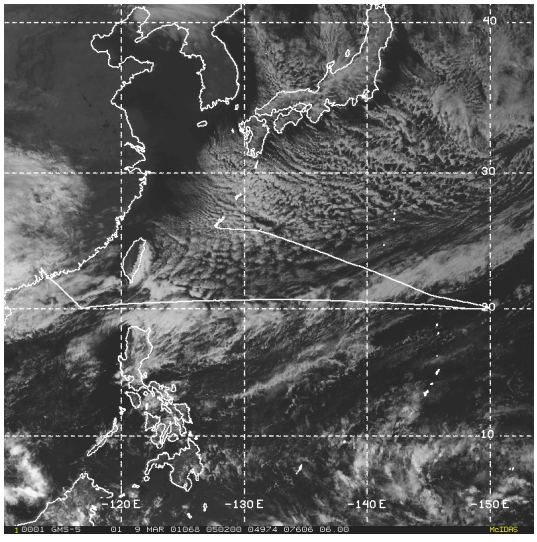

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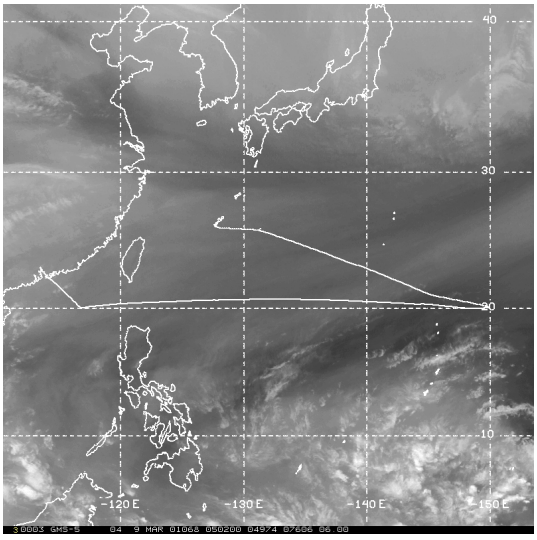

WV

DC−8 flight 08 Narrative

Title: chemical evolution of frontal outflow
Objective:
(1) to sample the aged frontal outflow band that had been previously sampled as fresh frontal outflow on the 0307 flight;
(2) to do laundry in Okinawa
Execution: The frontal outflow sampled on 0307 was forecast to have been transported along a SW−NE axis over the following two days, resulting in a band of aged pollution over the western Pacific The DC−8 flew east from Hong Kong to (20N, 150E) to sample aged free tropospheric outflow transported S ahead of this band and to reach the clean air ahead of the front at the easternmost waypoint; it then flew NW to Okinawa (26N, 128E) to cross and characterize this frontal band
Results: The flight was a success
(1) Biomass burning pollution plumes were sampled extensively on the eastbound leg west of 135E Further east, cleaner conditions were found, and the easternmost point was at the frontal transition On the NW leg to Okinawa, the polluted frontal band (with CO up to 300 ppb) was encountered at 140−142E, as expected; behind this band and into Okinawa the conditions were much cleaner, with strongly subsiding air in the free troposphere
(2) Free washing machines in Okinawa afforded astronomical savings over hotel prices for laundry in Hong Kong

Meteorological Summary

Relevant Flow Patterns

Surface−A low pressure area was centered near 30N, 155E. A cold front extended southwest to near 20N, 140E, becoming diffuse farther south of that position. High pressure was centered near Shanghai. Northerly to northwesterly flow covered most of the flight area. The major exception was northeasterly flow between ~ 20 − 25 N.

Middle troposphere−A subtropical high was located near 20N, 160E. A short wave trough was located just east of Japan. Westerly winds covered the flight area. Easterly flow was south of Hong Kong.

Upper Troposphere−Flow patterns were similar to those in the middle levels. The northern part of the flight pattern traversed the right entrance region of the jet streak.

Relevant Cloud Patterns

Middle level clouds blanketed the Hong Kong region, but dissipated during the eastward track. Scattered low level clouds covered most of the flight track. Most tops were less than 6000 ft.

The DC−8 strived to pass beyond the surface frontal zone at the eastward point of the flight. We entered the frontal zone of transition at 1000 ft, but apparently did not extend completely into the warm air. The character of the clouds changed and the winds decreased to ~ 6 kt. However, the wind directions did not shift in the appropriate way, i.e., they remained westerly.

10 MAR 2001

DC−8: flight 09, Okinawa−Hong Kong (20010310−20010310)

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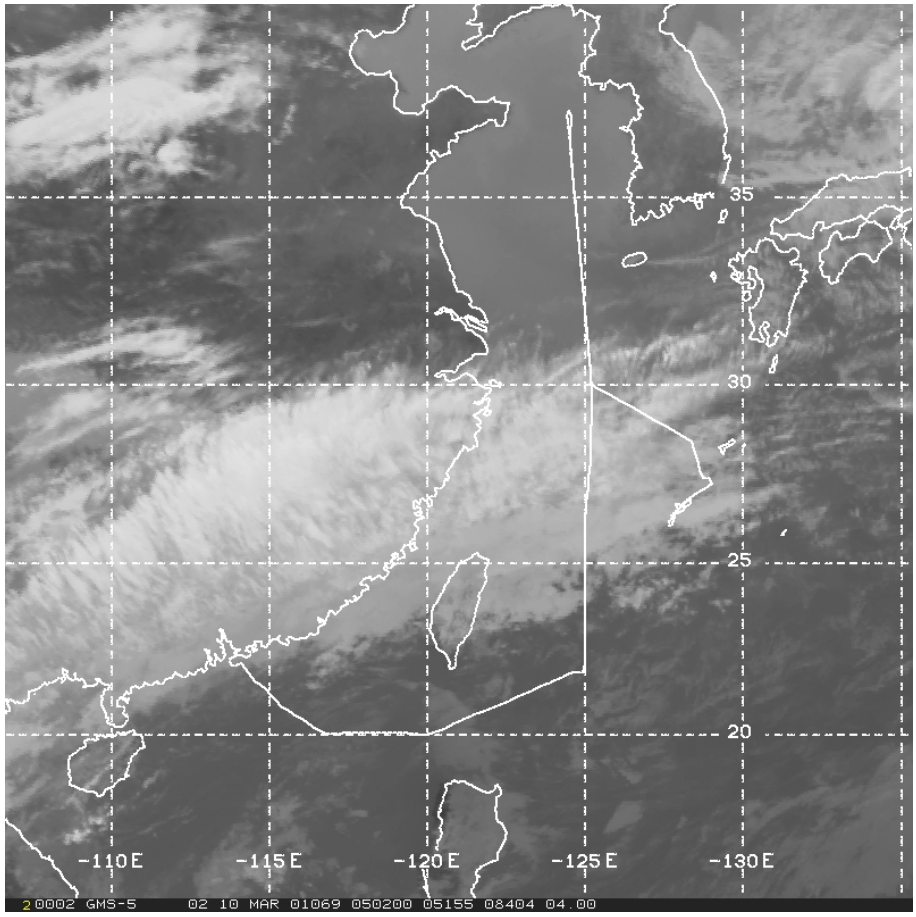

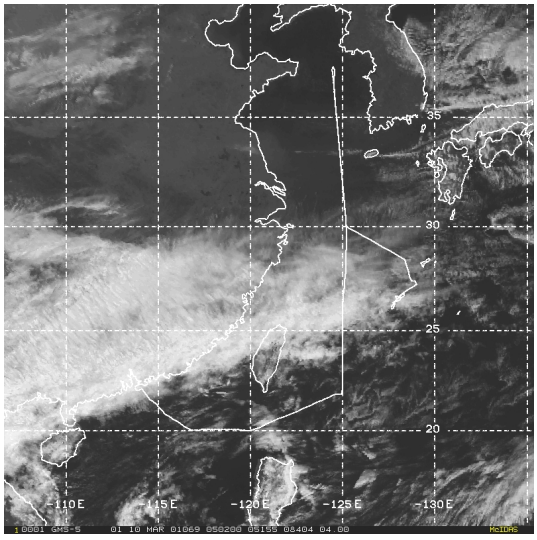

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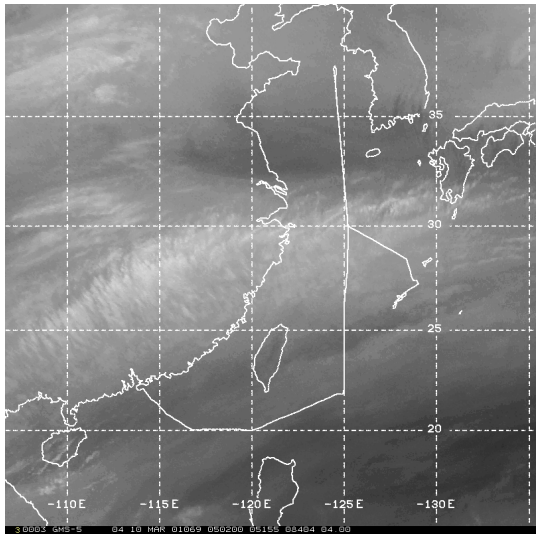

WV

DC−8 flight 09 Narrative

Title: China outflow to Yellow Sea
Objectives:
(1) to sample boundary layer outflow from China to the Yellow Sea around a surface High over the western Pacific;
(2) to sample frontal and convective outflow along the transect from the Yellow Sea to Hong Kong
Execution: The DC−8 headed NW and then N from Okinawa (26N, 128E) well into the Yellow Sea (38N, 125E) with extensive profiling in the boundary layer It then flew along a N−S transect back to Hong Kong (22N, 114E), mostly at high altitude but with a vertical profile and a long boundary leg getting into Hong Kong
Results: The flight was a success
(1) Extensive pollution was observed in the Yellow Sea, with considerable structure At 32−34N and below 5Kft CO concentrations approached 500 ppbv and CO2 was in excess of 380 ppmv Further N the air below 5Kft was cleaner, as expected from the shift in surface winds (now blowing from N Korea) but a highly polluted layer was sampled at 8 Kft
(2) The transect S into Hong Kong identified strong biomass burning pollution plumes from 20 to 30N and at 28−32 Kft altitude (CO in excess of 200 ppbv), and a pollution layer of considerable latitudinal extent was also observed at 10 Kft

Meteorological Summary

Relevant Flow Patterns

Surface−An anticyclone was centered between southern Japan and Okinawa, with clockwise flow around it. Thus, surface winds in the Yellow Sea mostly were from the south. The exception was northerly flow at the extreme northern point of the flight track. Farther south, easterly flow covered the southern half of the flight track. No fronts were in the area.

Middle troposphere−The low level anticyclone near Shanghai dissipated by the 10,000 ft level. However, a short wave trough was oriented along the western shore of the Yellow Sea. A major subtropical anticyclone was centered near 15N, 150E. Westerly flow covered the flight track in the middle troposphere.

Upper troposphere−Flow patterns were similar to those in the middle levels. The jet stream was located near 35N. The flight track entered the right rear (entrance) region of the jet streak that mostly extended southeast of Okinawa. Westerly flow covered the area. Trajectories indicated that some of this air had passed over parts of Southeast Asia.

Relevant Cloud Patterns

The Okinawa area had extensive clouds at low, middle and high altitudes. These clouds generally were located between 22 − 30N. Conditions were much improved over the Yellow Sea, with only scattered stratocumulus and isolated cirrus being observed.

13 MAR 2001

DC−8: flight 10, Hong Kong local #4 (20010313−20010313)

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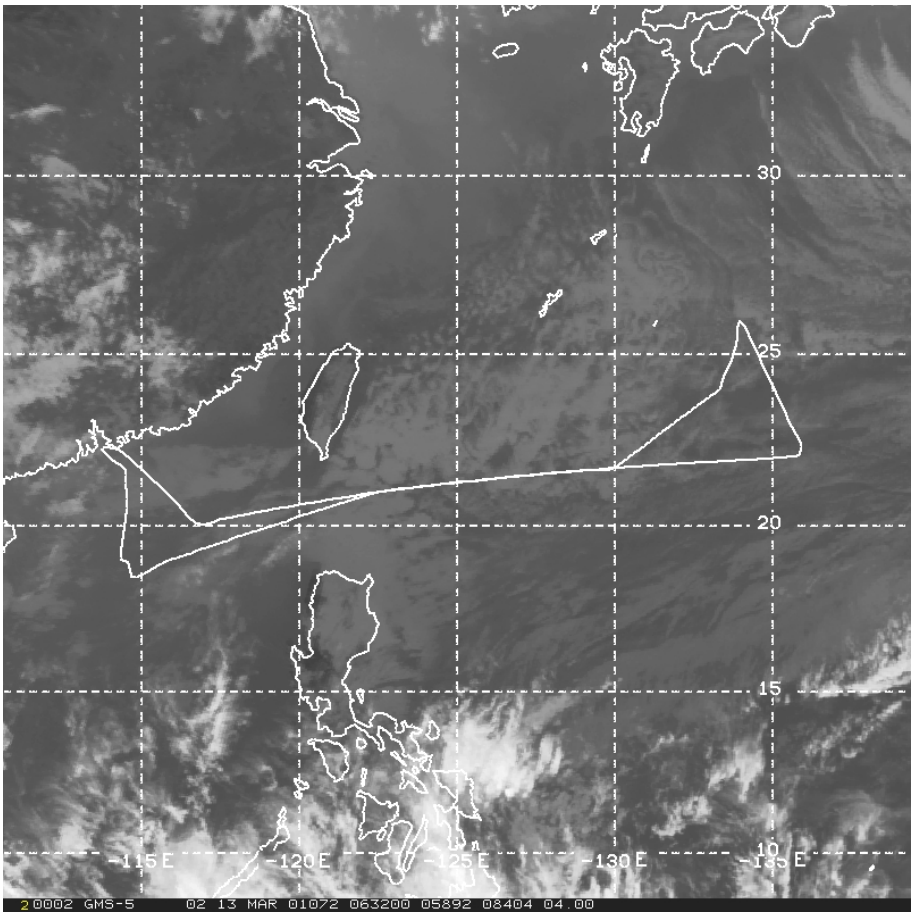

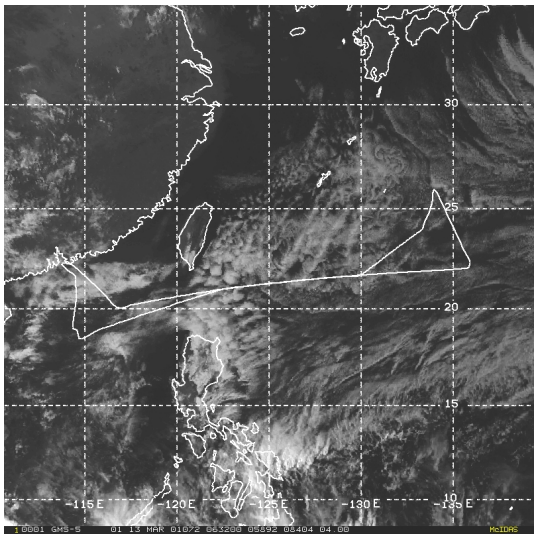

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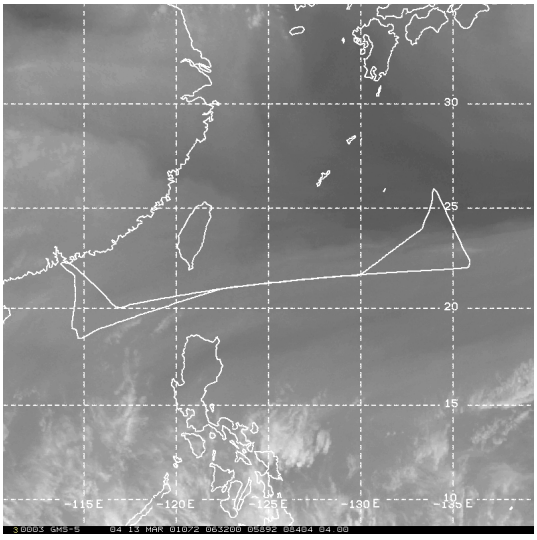


WV

DC−8 flight 10 Narrative

Title: Aged Asian outflow
Objectives:
(1) to sample aged Asian outflow slowly transported southeastward in the lower troposphere over the western Pacific around a weak high pressure system,
(2) to sample strongly subsiding air with stratospheric influence capping this Asian outflow,
(3) to sample upper tropospheric outflow from biomass burning in southeast Asia.
Execution: We flew an extended wall from HK east to (22N, 136E) with extensive low−altitude sampling on the eastern half of the wall . On the return we extended the wall south to (18N, 114E), with focus on high altitudes, in order to sample the biomass burning outflow.
Results: The flight was a success. Aged Asian pollution was consistently observed below 5Kft on the extended wall; this pollution was characterized by CO up to 190 ppbv, O3 up to 70 ppbv, high C2Cl4, high PAN, high sulfate (but low SO2), moderately high HCHO. Above 5 Kft the aircraft sampled strongly subsiding air with occasional evidence of stratospheric influence and some aged pollution layers at altitudes below 15 Kft (though not as strong as below 5 Kft). On the return the aircraft sampled combustion plumes in the upper troposphere (31−39 Kft) with high and correlated CO (up to 140 ppbv), CO2, O3, and aerosol (including a large non−volatile component); these plumes were probably of biomass burning origin although no confirmation of this was available from the flight data.

Meteorological Summary

Relevant Flow Features

Surface−A high pressure area was centered over South Korea. No fronts were located within the flight area. Most of the flight track experienced easterly or northeasterly low−level flow.

Middle troposphere−Westerly flow dominated the flight track by the 500 mb (~18,000 ft) level. A short wave trough was located just east of Japan, and a closed anticyclone was located near Southeast Asia.

Upper troposphere−A major subtropical anticyclone was located near 15N, 155W. A short wave trough was located near Japan. The polar jet stream was better defined than on most previous missions−it extended over northern Asia. The subtropical jet stream stretched across southern Asia. The two jets merged east of Japan. The DC−8 traversed the southern portion of the jet streak east of Japan. Westerly flow covered the entire flight area.

Relevant Cloud Patterns

Abundant low level clouds blanketed the flight track. They typically had bases near 3000 ft and tops near 5,000 ft. Middle and upper level clouds were virtually absent over the area.

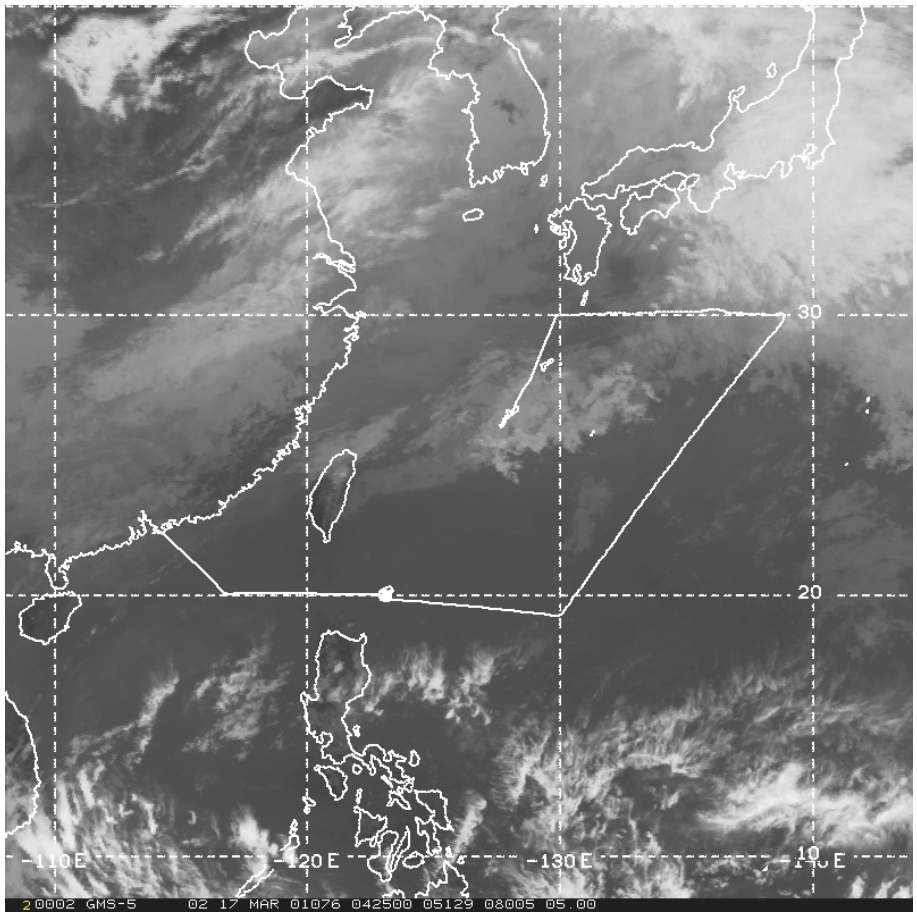
Southeast Asia had been experiencing scattered deep convection over the past several days, and this continued today. The Indonesia area also exhibited convection. Trajectories indicated that upper level outflow from these storms had been transported toward the DC−8 flight track.

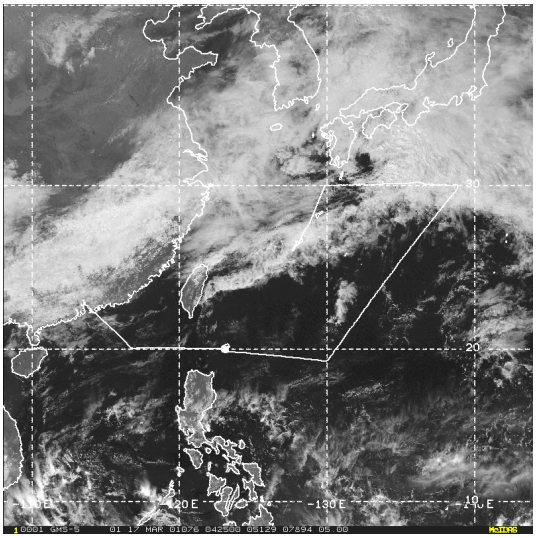
Water vapor imagery denoted an area of dry middle tropospheric air over the northeast portion of the flight area. This dry air probably was associated with subsidence due to the jet streak and the surface anticyclone in the area. In situ data showed that the dry air extended as low as 5400 ft. Other portions of the flight track were relatively humid in the middle levels.

17 MAR 2001

DC−8: flight 11, Hong Kong−Okinawa (20010317−20010317)

IR





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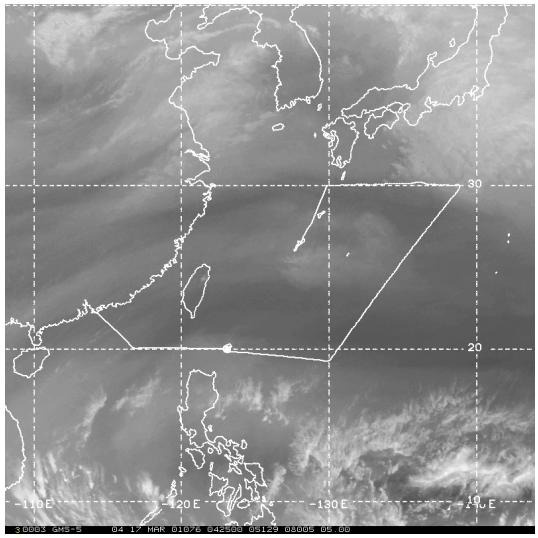


WV

DC−8 flight 11 Narrative

Title: MOPITT validation and China outflow
Objectives:
(1) to conduct a MOPITT validation experiment in a relatively uniform column (away from major Asian influence);
(2) to sample China outflow forecast in the lower free troposphere at 25−30N.
Execution: We flew from HK SE to (20N, 123E) for the MOPITT validation experiment, which consisted of two successive spirals above the same point bracketing in time the satellite overpass. We then went E and NE to (30N, 139E) to sample a forecast gradient of increasing China outflow going north, and then W and S into Okinawa (26N, 128E), to remain in that outflow. As usual, extensive in−progress vertical profiling was conducted.
Results: The objectives were met and the flight yielded some surprises. The MOPITT validation spot was in clear sky with only a few scattered low clouds; the spiral extended from 0.5 to 33Kft. CO was flat at 90 ppbv above 10Kft, and was enhanced below 10Kft with values of typically 130 ppbv (max. 150 ppbv). On vertical profiles for the rest of the flight we consistently encountered at 23−28Kft a "mystery layer" with high ozone (80−100 ppbv), flat CO, depressed CO2, and high PAN. At 30N this mystery layer had ozone up to 120 ppbv with flat but relatively high CO (160 ppbv), depressed CO2, high benzene, nitriles, PAN, low HNO3. relatively high NO. Our best guess was that this mystery layer represented African biomass burning outflow, but it could have been a soup of different tropical influences. Below 20Kft Asian pollution outflow was observed, with maximum in free troposphere and increasing with latitude. This Asian outflow contained high PAN, high C2Cl4, high N2O, only modest O3 enhancement (60 ppbv), and little HCHO enhancement. A possible source, on the basis of the chemical forecasts, is outflow from the high−elevation Szechuan Basin in central China. At our NE waypoint (30N, 139E) the CO concentration reached 330 ppbv and CO2 reached 386.4 ppmv, the highest observed in the mission so far. The strong Asian influence extended down to the surface, an unexpected result in view of the forecast onshore flow there. At 2.5 km the depolarization of the lidar return signal indicated the presence of high concentrations of non−spherical particles.

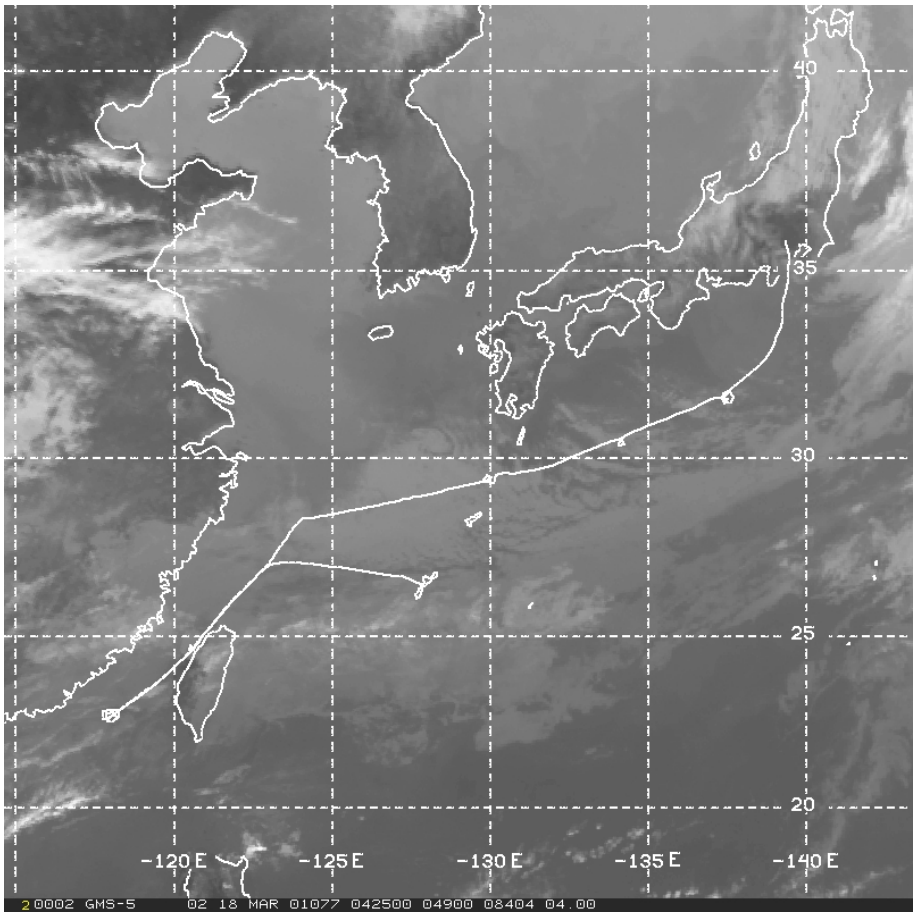
Meteorological Summary

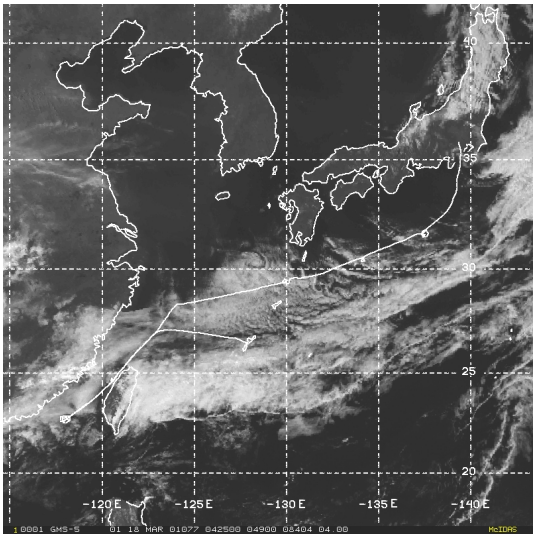
Relevant Flow Features
Surface−A developing wave cyclone was located near Shanghai. An anticyclone was centered just east of Tokyo. The wave cyclone intensified during the day and moved eastward. Its associated cold front also swept toward the east, passing Kadena between 0700 − 0800 Z−just before our landing. Surface winds over most of the area were from the south or east. However, winds behind the front were from the north.
Middle troposphere−The subtropical high was located over the northern Philippines. A short wave trough was just west of the Yellow Sea. Westerly winds dominated the flight area.
Upper troposphere−Westerly flow continued over the flight area. The polar and subtropical jet streams continued to be clearly separated over the area. The axis of the polar jet stream passed over northern Japan. The subtropical jet stream was located near 30N. Its area of maximum speeds (the jet streak) was over the Shanghai area. This location is somewhat farther west than on the previous several days.
Relevant Cloud Features
The MOPITT validation area near 20N, 123E was virtually cloud free. Only isolated small cumulus were present. Some cirrus were located south of the spiral points, but these clouds never were overhead.
The boundary layer run near 0411 Z had only scattered cumulus clouds with bases of 1800 ft and tops of 2400 ft.
Clouds increased greatly shortly after the third boundary layer run. During the ascent, a deep cloud layer with tops near 15,000 ft was encountered. Some of the clouds appeared convective shortly after our turn to the west near 0615 Z. A few isolated tall towers were noted near 0652 Z. These towers probably were associated with the surface position of the cold front.

18 MAR 2001

DC−8: flight 12, Okinawa−Yokota (20010318−20010318)

IR





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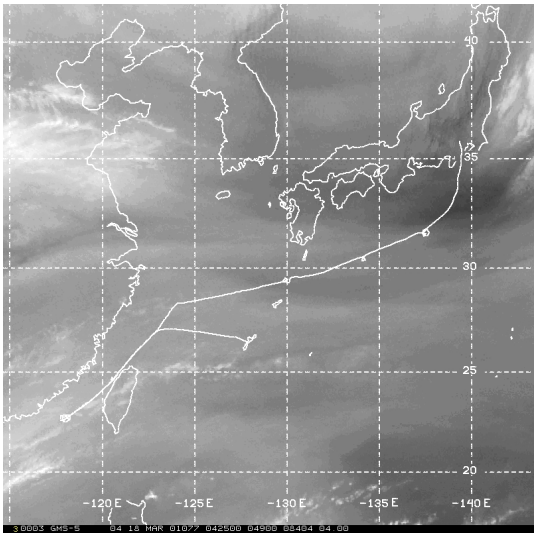


WV

DC−8 flight 12 Narrative

Title: Formosa strait and China outflow
Objectives:
(1) to sample boundary layer outflow from China to the Formosa strait;
(2) to sample different types of Asian outflow during transit from Taiwan to Yokota.
Execution: We flew from Okinawa (26N, 128E) SW to (23N, 118E), at the southern end of the Taiwan strait, setting up for a spiral at that SW point and a return wall. A solid stratus deck prevented us from extending the spiral below 4Kft where most of the outflow was forecast. We stopped the spiral at that altitude and returned NE to (25N, 121E − midway in the Formosa strait) where we found a break in the clouds and spiraled down to 1 Kft before continuing to head NE. We then continued on a roughly NE track to Yokota (36N, 139E) with extensive profiling and three spirals.
Results: The objectives were met and the flight brought some new perspectives on Asian outflow. The boundary layer leg in the Formosa strait showed for many gases the highest concentrations seen by the DC−8 so far in the mission (CO up to 520 ppbv, CO2 up to 394 ppmv, elevated CH4, N2O, 3.3 ppbv HCHO, 1 ppbv CH3CHO, high acetone, etc). The transit from Taiwan to Yokota showed (1) strong post−frontal boundary layer ouflow (CO ~ 250 ppbv), (2) a layer with CO in excess of 400 ppbv at 10Kft, and no biomass burning tracers, possibly due to westerly transport from the Szechuan Basin; (3) biomass burning enhancements at 18 Kft (characterized by high O3 and nitriles); (4) dust outflow at 8 Kft (seen by DIAL as layer of depolarizing aerosol, and characterized in a 15−min leg in situ). The dust layer contained high concentrations of large particles, very low peroxides, low HO2, but otherwise everything was flat. Descent to Yokota indicated layers of extremely high ozone (up to 165 ppbv) with flat or depressed CO and CO2; biomass burning? Stratosphere? These layers will probably be a recurring theme in our sorties from Yokota.

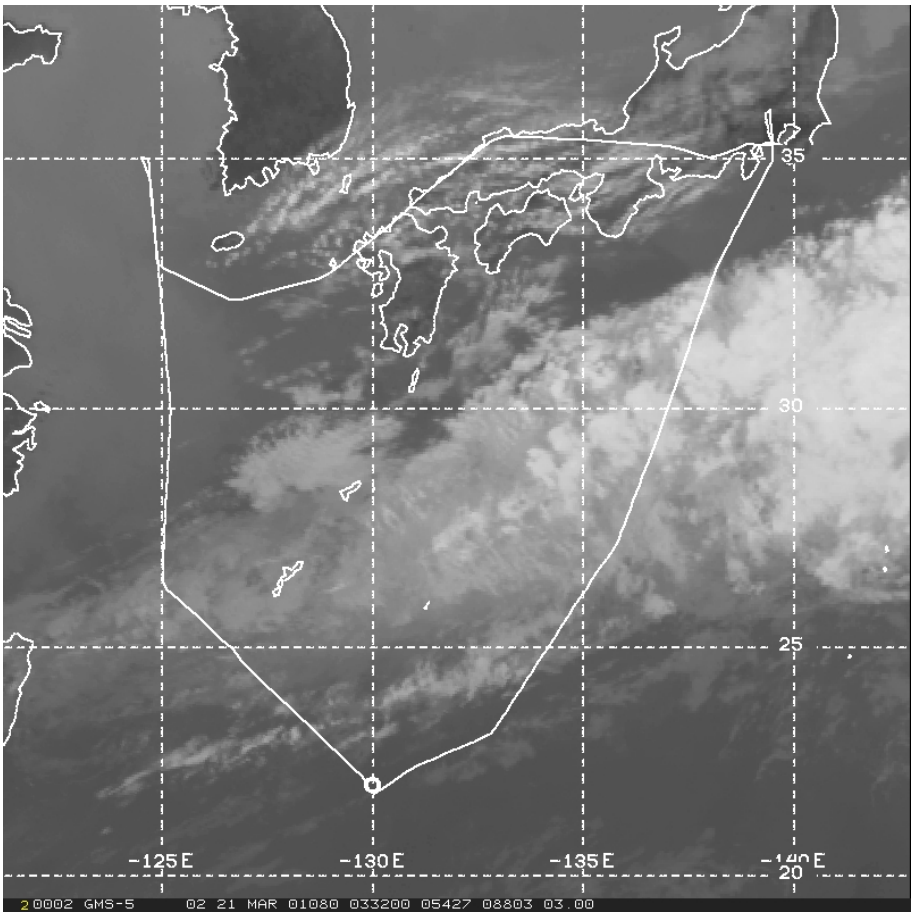
Meteorological Summary

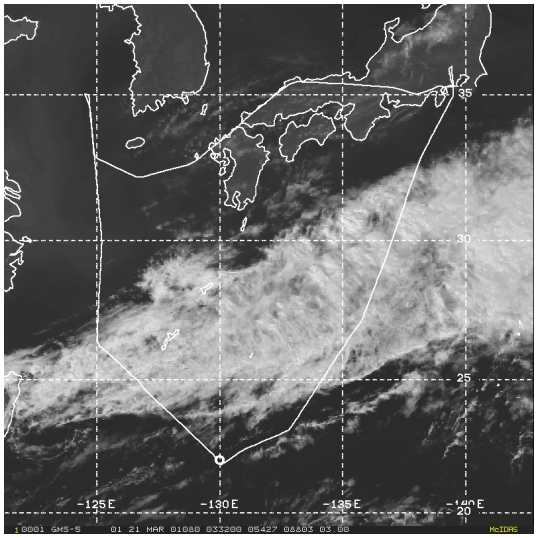
Relevant Flow Features
Surface−A developing wave cyclone was located just off the northeast coast of Japan. It was moving toward the northeast. A cold front extended southwestward, east of Kadena (it had passed the previous late afternoon), and through the Taiwan Strait. Only weak high pressure was behind the front.
Middle troposphere−Conditions were similar to those of the previous flight day. The subtropical high was located just northeast of the northern Philippines, and a short wave trough was between Korea and Japan. There was westerly flow over the entire flight area.
Upper troposphere−The polar jet stream was not as well defined as the day before. The subtropical jet stream was strong, but not as strong as the previous week. The center of the jet stream was over southern Japan. Westerly flow dominated the area.
Relevant Cloud Conditions
Upon leaving Kadena, deep convection was evident far south of the area. These storms marked the leading edge of the cold front that had passed Kadena the previous afternoon.
The Taiwan Strait contained extensive clouds due to the frontal zone. In some areas, there was a solid overcast, preventing a penetration of them. These clouds had tops of ~4,000 ft, and bases of ~1,000 ft. When flying at 1,000 ft in the Strait, we skirted the bases of these clouds. Cirrus clouds also were extensive in the Strait. Much of the cirrus appeared to be diffused contrails. Many commercial jets were observed to emit long contrails which spread out with time.
During our first excursion to 1,000 ft, the front was intersected at an altitude of ~3,000 ft. Above the front winds (e.g., 5,000 ft) were from the southwest, below the front they were from the northeast. As the DC−8 continued deeper into the cold air, streamlines suggest that the air was farther removed from the Asian Coast. This is supported by the smaller observed values of some chemical species.
The wind shift described above also was observed during our descent to 1000 ft that occurred near 0517 Z. Extensive stratocumulus blanketed this location, with bases and tops of 2200 and 3600 ft, respectively
The boundary layer run near 0700 Z was relatively cloud free.
A volcano was observed near 0750Z.

20 MAR 2001

DC−8: flight 13, Yokota local #1 (20010320−20010320)

IR





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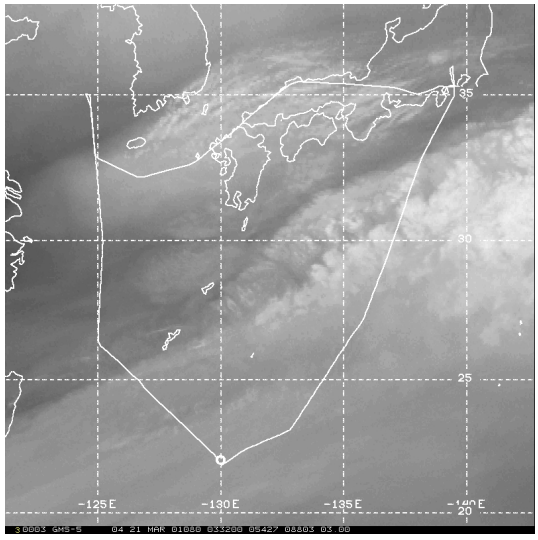


WV

DC−8 flight 13 Narrative

Take−off time 8:20 am local (2320 Z on 0320); flight duration 9.4 hours
Title: Frontal lifting and dust outflow
Objectives:
(1) to characterize the lifting of Asian outflow by a cold front,
(2) to sample convective outflow from SE Asia in the upper troposphere
(3) to sample dust and pollution outflow near the China coast,
(4) to sample the stratosphere subsiding on the north side of the jet stream,
(5) to conduct a MOPITT validation experiment in background tropical air.
Execution: We flew from Yokota (36N, 139E) SW to cross an active cold front (vertical profiling) and conducted a MOPITT validation spiral from 35 to 0.5 Kft at (22N, 130E). We then flew NW to (30N, 125E), re−crossing the front with vertical profiling, and conducted a N return leg into the Yellow Sea to (35N, 125E) to sample dust and pollution outflow. From there we climbed to cruise altitude and returned to Yokota.
Results: All objectives were met.
On the climb up from Yokota we sampled the "high−ozone layer" (90 ppbv O3, flat CO, depressed CO2, high HCHO, PAN, nitriles) which appears to originate from aged biomass burning (although exact origin is still a mystery). Fresher biomass burning outflow, most likely of SE Asian origin, was sampled at 31Kft on the SW leg from Yokota to (22N, 130E). Crossing of the front at (36N, 136E) was conducted under particularly active conditions below 10Kft, with considerable structure in the frontal cloud outflow reflecting fresh lifting of Asian pollution (high CH3OOH/H2O2 ratio, high C2Cl4, high nitriles, considerable fine structure in CO, CO2, CH4, N2O). Continuing SW, as we got in the boundary layer at 1Kft we returned on the cold side of the front (CO over 300 ppbv, acetone over 1 ppbv). This boundary layer outflow was capped at 5Kft, as seen in previous flights; above that altitude we were on the warm side of the front with clean air and little structure. Our MOPITT spiral (delayed 30 min because of ATC) was conducted in a relatively featureless atmosphere with only a modest boundary layer enhancement of CO. On our flight NW we re−crossed the front at 26N, sampling lifted Asian pollution at 12 Kft (CO up to 210 ppb, CO2 above 382 ppmv), and we then hit considerable Asian pollution behind the front heading north in the boundary layer, including in particular a well−defined crossing of the Shangai plume at 30N (CO up to 1240 ppbv, O3 up to 140 ppbv, HCHO 8 ppbv, Acetone 6 ppbv, HCN 2 ppbv, PAN 6 ppbv, high SO2, CH4 up 10−15%, etc). There was strong evidence of dust associated with this plume (yellow aerosol filters!). The pollution was capped at 5Kft by a dry subsiding air mass with low CO. Heading further north into the Yellow Sea we identified dust layers mixed with pollution using the DIAL depolarization signal and conducted boundary layer sampling in a mixture of pollution and dust. The dust−pollution mix was in contrast to the "clean" dust layer sampled on the Okinawa−Yokota transit. Climibing up on our return leg from the Yellow Sea we entered the stratosphere at 29Kft and stayed there for most of our return to Yokota.

Meteorological Summary

Relevant Flow Patterns

Surface−A low pressure area was centered over extreme northern Japan. A cold front extended from it−first toward the southeast along 150E, and then southwest toward Taiwan. The surface high pressure behind the front was relatively small. A developing low pressure area was located over northeastern Asia.

Middle Troposphere−A closed low was located just north of Japan. It was the middle level reflection of the surface cyclone described above. The subtropical high was located near 19N, 140E. Westerly flow dominated the flight track.

Upper troposphere−The subtropical jet stream was oriented just south of Japan. Strongest speeds (the jet streak) stretched from east to west from south of Tokyo to near Okinawa. Westerly winds covered the entire flight track.

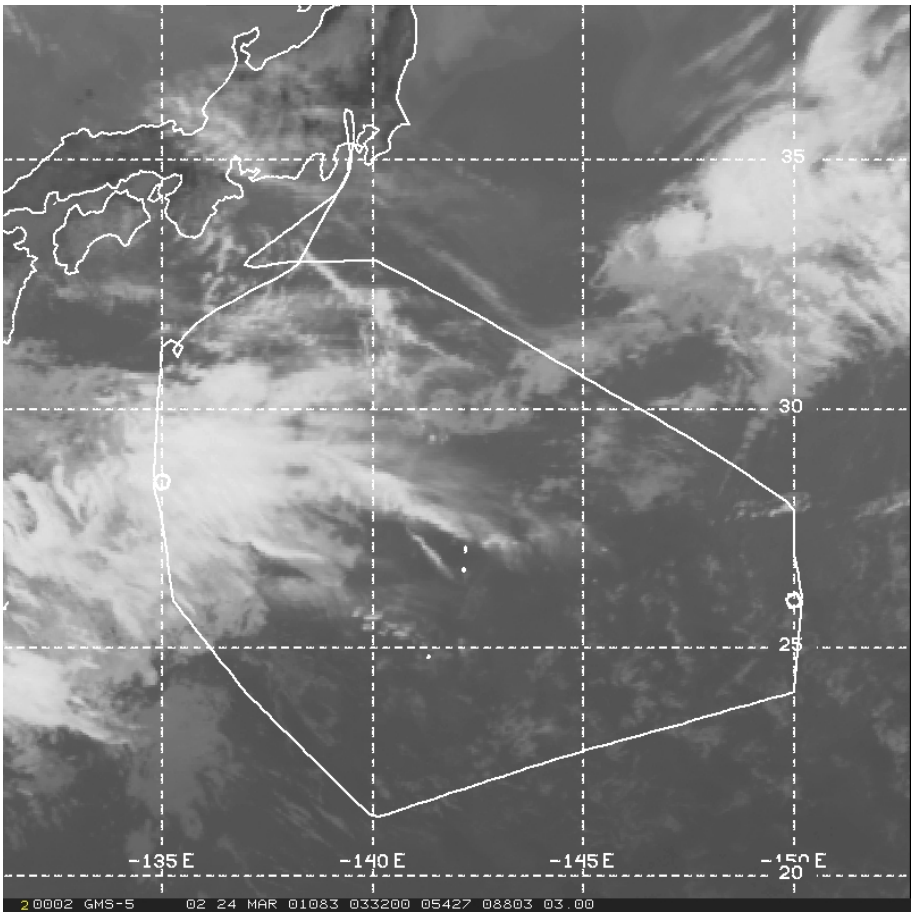
Relevant Cloud Patterns

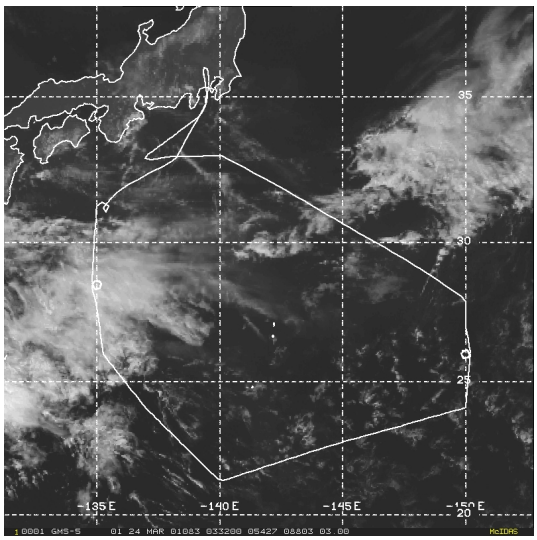
The overall pattern was a band of middle and upper clouds stretching from south of Tokyo to near Hong Kong. The cloud band was widest just south of Tokyo and quite narrow on its southwestern edge. Low level clouds covered much of the flight track. Details area given below. First boundary layer run−The DC−8 penetrated the frontal zone from above at an altitude of ~5,000 ft. Winds below were from the northwest, and from the west above. Rain was encountered in the area. Considerable turbulence was encountered due to the convective nature of the clouds. We apparently did not pass into the warm air while at 2,000 ft, but were close to the leading edge of the front. MOPITT area−Only scattered cumulus were in the area. Bases were near 1500 ft, and tops near 5,000 ft. Some cirrus were south of the cloud track. Due to ATC problems, the DC−8 had to circle the area before descending. Contrails were created during this time. The DC−8 crossed the surface position of the front a second time as it headed northward along the western portion of the flight track

23 MAR 2001

DC−8: flight 14, Yokota local #2 (20010323−20010323)

IR





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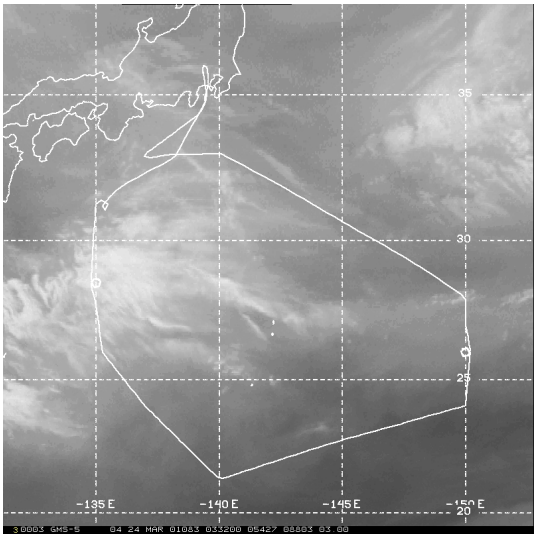


WV

DC−8 flight 14 Narrative

Take−off time 8:20 am local (2320Z on 0321); flight duration 9.0 hours
Title: Convective outflow
Objectives:
(1) to sample high−altitude outflow from intense convective activity developing over SE Asia, China, and the western Pacific;
(2) to conduct a high−altitude intercomparison with the P−3,
(3) to conduct a MOPITT validation experiment.
Execution: The intercomparison between the two aircraft consisted of a level leg at 17Kft with the two planes flying in parallel (2000' apart) for 30 minutes. This leg was conducted upon take−off from Yokota along a (33N, 137−140E) track. We then flew SE to (24N, 150E) for a MOPITT underpass spiral from 35 to 0.5Kft and to sample expected convective outflow. From there we flew SW to (21N, 140E) and then NW to (26N, 135E) where we headed N, downstream of a thunderstorm developing to our W. We conducted a spiral up at (29N, 135E) to sample outflow from the storm but were restricted to 27Kft by ATC. We were able to climb to 33Kft at (31N, 135E) and from there headed to Yokota with a slow in−progress descent.
Results: The objectives were met and the flight yielded several surprises. The intercomparison was a success: both aircraft managed to operate at the same speed, air was dry, and skies were clear. There was quite a bit of structure in ozone, anticorrelated with H2O (stratospheric influence?), and a transition in air mass was seen over the course of the intercomparison leg. On the leg SE toward the MOPITT underpass we sampled structures indicative of stratospheric filaments, aged Asian outflow in the lower free troposphere, and deep convective outflow. At 35Kft at the MOPITT underpass point we found the strongest pollution influence sampled so far in the mission in the upper troposphere (CO 200 ppbv with O3 80 ppbv, HCHO 200 pptv). This pollution reflected a combination of industrial and biomass burning influences (high C2Cl4, high CH3CN) and appeared from satellite imagery to originate from deep convection over eastern China. The MOPITT underpass spiral was conducted under clear skies with high−CO layers at 35Kft, 7 Kft, and 12 Kft. In the boundary layer at (24N, 150E) there was a surprising level of pollution influence (O3 50 ppbv, CO 140 ppbv). Climb to 29 Kft at 21N indicated again high levels of pollution associated with convective outflow, presumably over eastern China. Further vertical profiling on the way back to Yokota indicated surprisingly high levels of pollution at all levels, with CO frequently above 200 ppbv.

Meteorological Summary

Relevant Flow Features

Surface−Several weak low pressure areas were relevant to the flight. The strongest was over extreme northern Japan, while weaker lows were centered over the northwestern Yellow Sea and over southeastern China (northwest of Taiwan). A weak anticyclone was over central Japan. Surface flow over much of the flight track was from the east or northeast.

Middle troposphere−A closed cyclone was just north of Japan. Westerly flow covered all of the flight track.

Upper troposphere−The polar jet stream continued to be poorly defined at 300 mb. However, the subtropical jet stream was well defined at 200 hPa, with its axis over the flight track along ~30N. However, unlike most previous flights, strongest winds were not near Japan. Instead, one jet streak was over eastern China, while a second stretched over Saudi Arabia and northwestern India. Maximum jet stream speeds appear to have weakened since the start of TRACE−P. Westerly winds were over the entire flight area.

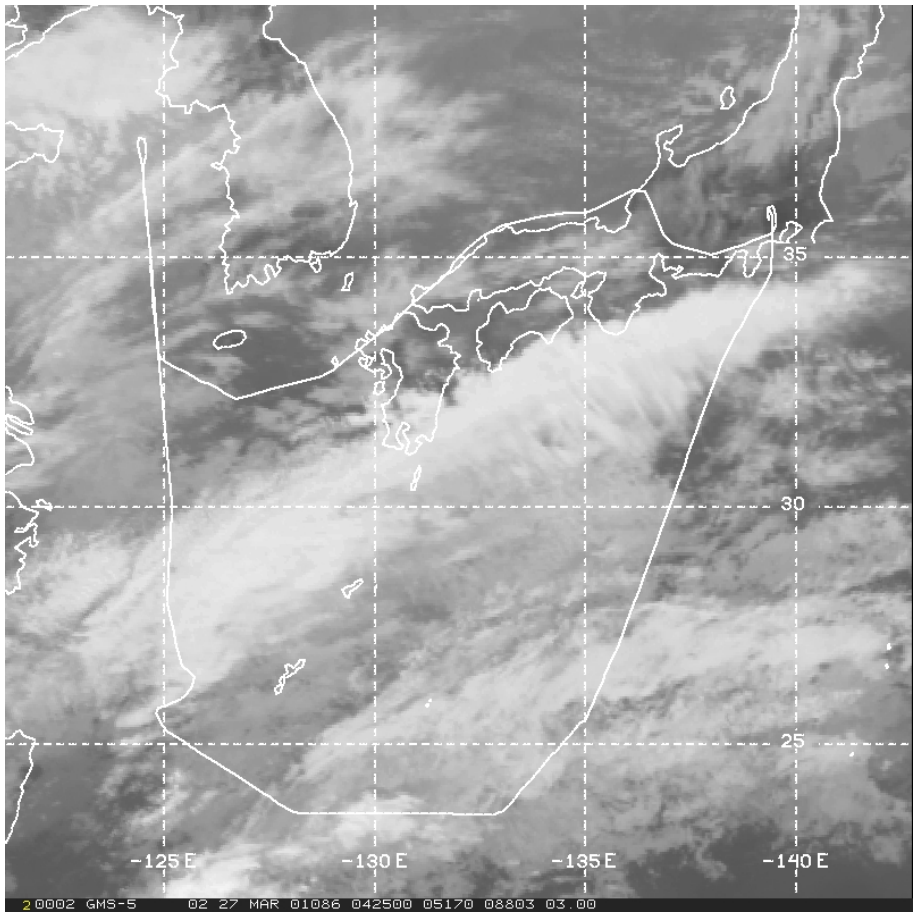
Relevant Cloud Features

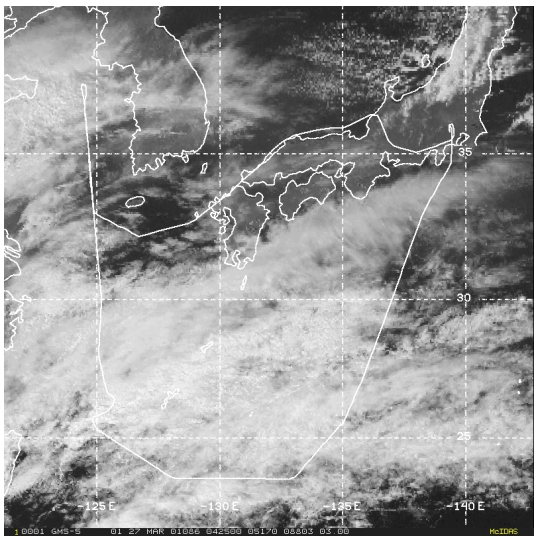
An area of deep convection formed over eastern China the previous day. It was the biggest area of Asian convection seen thus far. The area moved eastward into the western Pacific during the night. By 2030Z on the flight day, the storm complex was near 28N, 128E. Water vapor imagery revealed a plume of vapor extending eastward from the storms, remaining evident as far as 148E. The storm area moved southeastward during the flight. At 0700Z the storms extended along 134E from 23−26N. A second area of deep convection formed during the day near these same latitudes but between 140−147E. For the first time during TRACE−P, the Stormscope detected a number of lightning flashes. Clouds conditions near the DC−8 − P−3 rendezvous were ideal. Only small scattered cumulus and thin scattered cirrus were observed. Ideal cloud conditions also covered the MOPITT underpass area. Isolated small cumulus had bases near 2800 ft and tops near 4800 ft. A few thin cirrus strands were along the northern portion of the spiral area. However, they did not appear to be directly overhead at any time. The second boundary layer run (near 0440Z) had scattered cumulus with bases near 2,200 ft and most tops near 3,000 ft (although a few tops reached 5,000 ft). On the other hand, the third boundary layer run (near 0546Z) was characterized by an overcast layer of multiple layered clouds. Rain occurred during part of this run. During the ascent, the main cloud layers had tops of ~19,000 ft. However, broken cirrus was at even higher altitudes.

26 MAR 2001

DC−8: flight 15, Yokota local #3 (20010326−20010326)

IR





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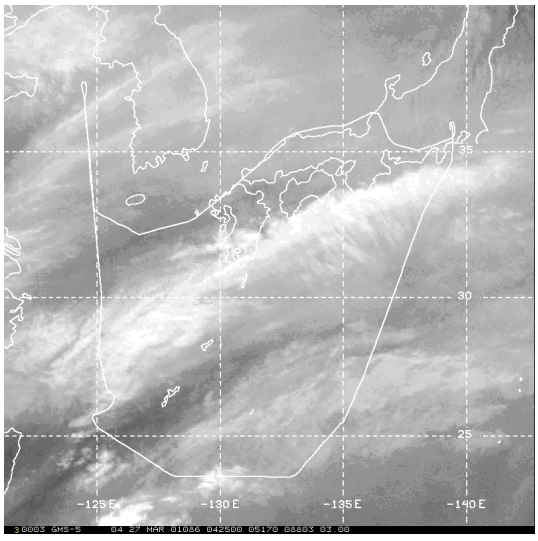


WV

DC−8 flight 15 Narrative

Take−off time 8:36 am local (2336Z on 0326); flight duration 9.4 hours
Title: Convective outflow and stratospheric influence
Objectives:
(1) to sample high− and mid−level outflow from intense convective activity and convergence developing over SE Asia and China;
(2) to sample a tropopause depression wrapped around the jet stream;
(3) to sample dust outflow from northern China.
Execution: The DC−8 conducted two extended walls along the Asian coast, one at 133−139E and one at 125E. After take−off from Yokota (36N, 139E), we flew SW to (23N, 133E) for our first wall to sample outflow from deep convection and convergence over Asia, and from there headed W to (25N, 125E) where we set up the second wall headed north into the Yellow Sea (37N, 125E). The purposes of this second wall were to sample convective outflow at all levels south of 30N, a depression of the tropopause around the jet stream at 30−32N, and dust outflow further north. We then backtracked to (33N, 125E), returning to Yokota around Korea and through the Sea of Japan.
Results: The objectives were in general met and the flight yielded some surprises. The first wall SW out of Yokota showed considerable Asian outflow at all levels as well as stratospheric filaments at the higher levels. Above 10Kft the outflow appeared to be of convective and mainly biomass burning origin (up to 200 ppb CO, high CH3CN, low C2Cl4, low SO2). Below 10Kft the outflow was mostly industrial (up to 300 ppb CO, high C2Cl4) and appeared to reflect post−frontal boundary layer outflow as well as weak convergent lifting over eastern Asia. Ozone showed complicated correlations with CO and CO2 in these profiles. During the W leg at our southernmost point we saw boundary layer outflow up to 5 Kft capped by clean tropical air; climbing up for a leg at 33Kft at (24N, 132E) we sampled outflow from a nearby marine thunderstorm (NO up to 600 pptv, high CH3OOH/H2O2, low ozone, high methylnitrate, low aldehydes, etc) superimposed first on clean tropical air but then later on biomass burning outflow. On our wall heading north at 125E we saw considerable outflow at all levels south of 30N and then ran a constant−altitude leg at 33Kft where we observed the sharp stratospheric intrusion at 30−32N forecast from the models. Profiling down to the boundary layer over the Yellow Sea yielded considerable outflow structure, again as forecast, with pollution layers in the free troposphere (convergent lifting over eastern China). This pollution outflow in the free troposphere over the Yellow Sea was in contrast to previous flights in the region where the pollution was confined to the boundary layer and was strongly capped by clean subsiding air. Flying back to Yokota we observed additional pollution layers as well as a dust layer at 10−15Kft over Japan. Boundary layer air over Yokota was highly polluted, with over 400 ppm CO2.

Meteorological Summary

Relevant Flow Patterns

Surface−Twin low pressure areas were centered over extreme southeastern Russia and over extreme northeastern Japan. A surface cold front extended southeast to near 30N 160E and then west to near Taiwan. The Siberian anticyclone was well defined, with a weaker high over South Korea. A weak low was developing just south of Taiwan. Surface winds were from the northeast or east over most of the flight area. *Middle troposphere*−Closed low pressure was just northwest of Japan. The subtropical high was just east of the Philippines. Westerly flow covered the flight track. On a broader scale, a sharp ridge was over central Asia, while more zonal flow was south of about 35N. The effects of this split flow were evident in the backward trajectories. *Upper troposphere*−The jet stream had strengthened considerably just south of Japan. A zone of winds exceeding 160 kt extended eastward from near Shanghai to ~155E. The split flow described above continued.

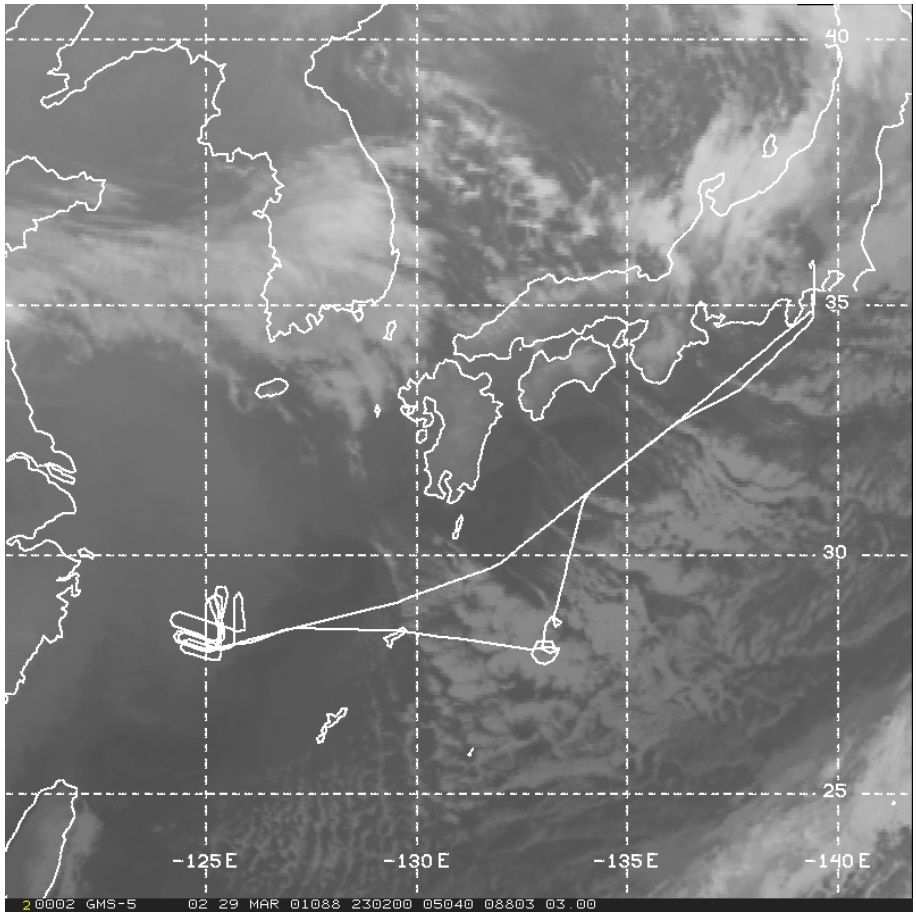
Relevant Cloud Patterns

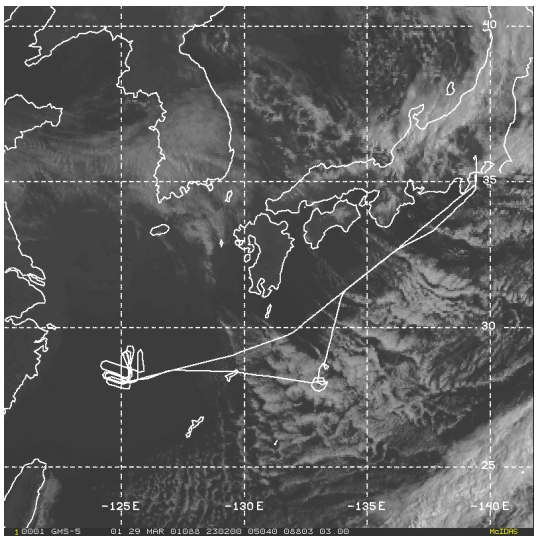
On the broad scale, an extensive cloud band was associated with the wave cyclone and frontal system described above. Details along the flight track are described below. As we headed south from Yokota, clouds rapidly increased at all altitudes. The first boundary layer run (near 0130Z) had overcast clouds at multiple layers. Occasional light rain occurred, and the ceiling was ragged, with some scud at flight level. As we ascended, we appeared to pass through the frontal boundary at ~6,000 ft, where a sharp chemical transition was observed. The second boundary layer run (near 0315 Z) also was overcast, with fog. The southerly winds at this point suggested that we were near the surface position of the old front. Clouds were at multiple levels. At the beginning of the segment, light rain occurred. However, as the segment continued, the rain became very heavy (near 0424Z). Considerable sharp turbulence was encountered. As we ascended, cloud tops were ~ 33,000 ft. Stratospheric air was encountered at 33,000 ft beginning near 0440 Z. The Yellow Sea had broken to overcast clouds at multiple levels. Winds at 2,000 ft (3rd boundary layer run) were from the east−contrasting with the westerly winds encountered there on previous flights. The fourth boundary layer run (near 0613ZZ) had overcast stratocumulus with bases near 5,000 ft. Finally, the fifth boundary layer run in the Sea of Japan (near 0733Z) had an overcast deck of altostratus near 18,000 ft.

29 MAR 2001

DC−8: flight 16, Yokota local #4, sunrise (20010329−20010329)

IR





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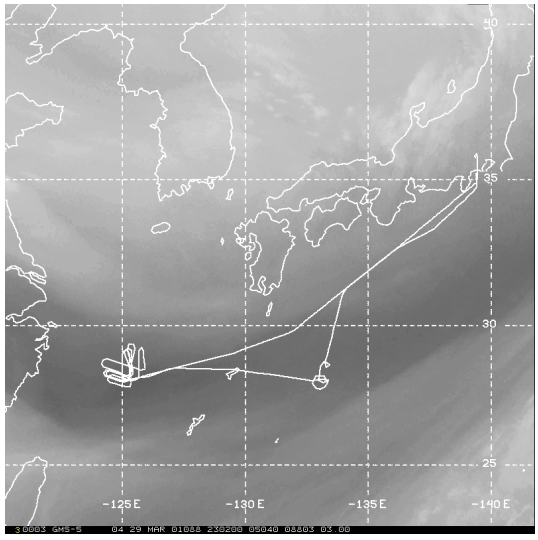

WV

DC−8 flight 16 Narrative

Take−off time 3:16 am local (1816Z on 0329); flight duration 9.4 hours
Title: Sunrise photochemistry of Asian outflow
Objectives: (1) to examine the photochemical evolution of Asian outflow at sunrise; (2) to determine the role of the ocean as a source/sink of oxygenated hydrocarbons; (3) to conduct a MOPITT underpass.
Execution: This flight was intended as a suitcase flight to Okinawa, but a generator failure early in the flight required that we return to Yokota at the end of the flight. We transited to (28N, 125E), a center of high pressure off the China coast, arriving at 1Kft at 2100Z (30 minutes before sunrise). There we set up a repeated wall at 1 Kft and 9 Kft (above the inversion) with 20 minutes at each altitude and 1Kft/min altitude changes between the two. We repeated that pattern until 0050Z and then climbed to 37Kft at (28.5N, 133E) for a MOPITT underpass spiral down to 0.5 Kft. We then climbed back to cruise altitude and returned to Yokota.
Results: Cancellation of the Okinawa suitcase precluded the Taiwan strait flight planned for 0331. Nevertheless the objectives of the present flight were met. The sunrise experiment was conducted under clear skies and weak and variable winds at 1 Kft, and steady W winds (30kts) at 9 Kft. There was strong subsidence capping the Asian outflow below 7 Kft. All instruments functioned. Vertical profiling from 1 to 9Kft (conducted 8 times over the course of the experiment) sliced through a persistent China outflow plume at 4−6Kft (CO 350− 380 ppbv). The base of the inversion remained at 7Kft throughout. There were a lot of ships in the area, and a number of ship plumes were sampled on the 1 Kft leg (or so it seems − we had spikes of NO but little aerosol enhancement). Oxygenated hydrocarbons appeared to show little temporal variation over the course of the experiment, either in the marine boundary layer or in the pollution plume above, although they showed pronounced vertical gradients. Climbing up towards the location of the MOPITT overpass we sampled unexpected "mystery ozone layers" at 24−37Kft with complicated chemical signatures. The MOPITT underpass was conducted in a clear area and showed low featureless CO concentrations down to 5Kft with high concentrations (up to 200 ppbv) at lower altitude.

Meteorological Summary

Relevant Flow Features

Surface−A rapidly deepening wave cyclone was located near 38N, 148E. A cold front extended south and west from the low center, but it was far outside the flight area. Surface high pressure was centered near 28N, 125E, i.e., near the location of the 4 hour sunrise flight pattern. A weak low was developing over the Yellow Sea.

Middle troposphere−A major closed low was centered over the northern Sea of Japan. Westerly flow dominated the area. A major ridge was located over central Asia, while flow to the south of ~35N was more zonal in nature. Backward trajectories showed that air on the northern portion of the flight track may have originated over Europe.

Upper troposphere−The jet stream was quite strong just south of Japan. A rather broad region contained winds in excess of 160 kt. The jet was strongest east of the Asian Coast. The split flow described above continued in the upper levels.

Relevant Cloud Patterns and Other Goodies

A broad shield of multi−layered clouds was associated with the major wave cyclone described above. However, most of these clouds were outside of the flight region.

The area of the 4 hour sunrise pattern was totally clear at all levels. Winds at 1000 ft generally were from the south, but had a more easterly component on the eastward portion of the track. Speeds were less than 10 kt, with almost calm winds on the eastward side. Thus, the center of the high was very near the eastern edge of the flight track at 1000 ft. Winds along the 9,000 ft runs were almost due westerly at speeds of ~ 30 kt. A surface based haze layer had a top near 6000 ft., and this corresponded to the level of a pronounced wind shift, i.e., from westerly above to southerly below.

The area of the MOPITT underpass had only scattered small cumulus clouds with bases near 4,000 ft and tops near 5,000 ft. There were no middle or high clouds in the area.

31 MAR 2001

DC−8: flight 17, Yokota local #5 (20010331−20010331)

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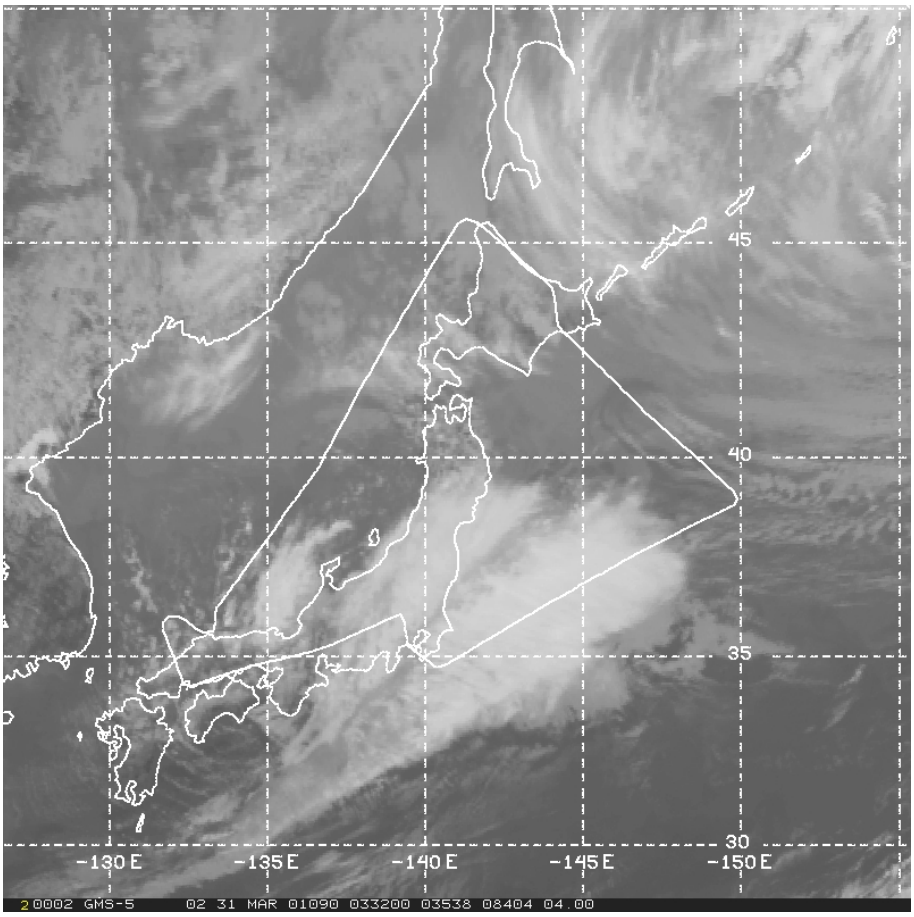

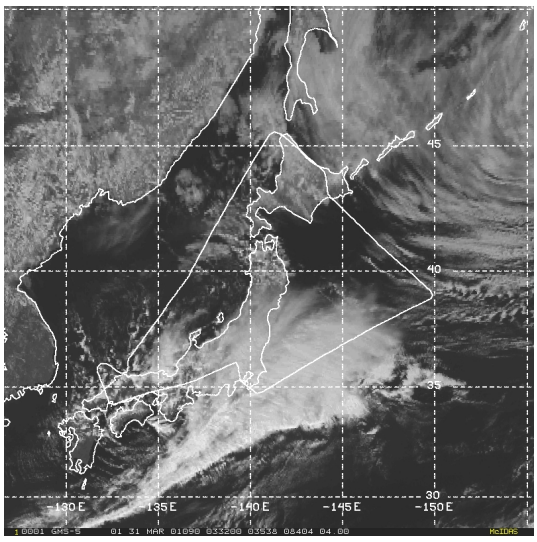

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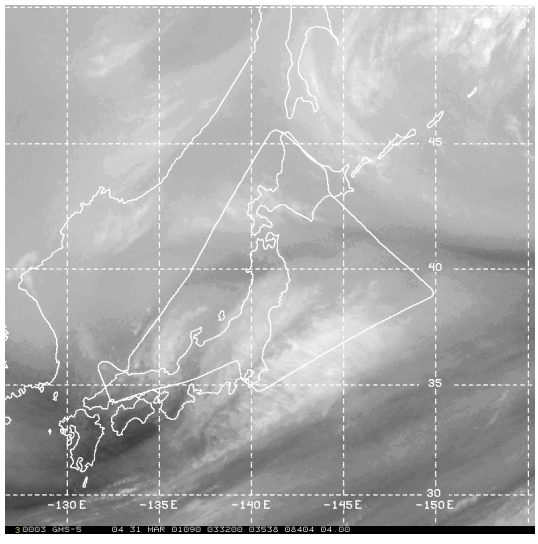

WV

DC−8 flight 17 Narrative

Take−off time 9:12 am local (0012Z); flight duration 7.5 hours
Title: Warm conveyor belt and cyclonic recirculation
Objectives:
(1) to examine the "wrap−around" recirculation around a kamikaze cyclonic bomb NE of Japan;
(2) to sample the warm conveyor belt ahead of a newer front pushed east from Japan (and responsible for snow over Yokota that morning);
(3) to provide DIAL support to the ACE−Asia Twin Otter radiation experiment over the Sea of Japan north of Iwakuni.
Execution: The flight track was a "box" around Honshu and Hokkaido. We headed W to (35N, 131E) to overfly the Twin Otter on their wall between (35.5N, 131.8E) and (35.7N, 131.7E) at 0135−0138Z. We then headed NE to the northern tip of Hokkaido at (45N, 141E) followed by a SE leg to (39N, 150E) to sample the wrap−around circulation around the kamikaze cyclonic bomb that had been sitting to the NE of Hokkaido for the past few days. From there we flew SW to Yokota (36N, 139E), sampling the rising air along the warm conveyor belt pushed east of Japan.
Results: We met our objectives and sampled complicated chemical signatures associated with the warm conveyor belt and the cyclonic recirculation. Climbing out of Yokota we saw considerable fine structure below 10Kft associated with lifting of Japanese pollution by the front sitting over the area at the time, and coarser pollution structure above interwoven with stratospheric filaments (recirculation around the kamikaze?). The 31Kft leg to Iwakuni was in and out of the stratosphere. The Twin Otter overfly was conducted in a clear patch in a broken cloud field with good functioning of the DIAL. Heading NE over the Sea of Japan, we observed a depressed tropopause at 18Kft (jet stream), complicated pollution influences just below (the recirculation?) and direct Korean outflow below 10Kft with everything elevated (200−250 ppbv CO). As we approached the northern tip of Hokkaido the tropopause rose, and we sampled extensive aged (?) pollution at all altitudes (CO 150−200 ppbv, high PAN, C2Cl4, nitriles, moderately high SO2, HCHO,). Heading back SE and then SW we observed a range of Asian outflow layers at all levels with different chemical signatures. The recirculating pollution in the north showed moderately high CO (150−200 ppb), high C2Cl4, PAN, nitriles, low HCHO, and was interleaved with stratospheric filaments. The warm conveyor belt further south showed higher CO (up to 300 ppb). NO was very low in the "recirculating pollution" (< 10 pptv) but had a lot of structure with values in excess of 100 pptv in the warm conveyor belt associated with recent convection (high CH3OOH/H2O2 ratios). The NO structure was probably associated at least in part with lightning.

Meteorological Summary

Flow Features:

Surface−−A major low pressure area was centered near 47N 158E. With a central pressure of ~974 mb, this system previously had reached "bomb" status. A developing low pressure area was moving up the eastern coast of Japan. Although its central pressure was only ~1004 mb, it produced widespread light snow and rain over eastern Japan during the entire day. The cold front extending south of the low reinforced the cold air already in place over Japan. A high pressure area was located near Shanghai.

Middle troposphere−The major closed cyclonic circulation was nearly vertically stacked with its surface counterpart described above (47N 158E). A short wave trof extending southwest of this system was associated with the developing surface system.

Upper troposphere−The closed cyclone continued, with an additional cyclonic center located just west of northern Japan. This system was merely a trof at lower levels. It produced light southerly winds along the northern part of the flight track (an unexpected occurrence). The axis of the jet stream stretched from just south of Japan toward the east−northeast. The jet was quite intense, with strongest winds (~ 170 kt) located near 38N, 160E. Speeds near 100 kt were even as low as 500 mb.

Cloud Features and Other Goodies:

The major cloud feature was a classic "comma" shaped pattern associated with the developing low skirting the east coast of Japan. Clouds at all levels were occurring in this area. The Stormscope indicated a few lightning flashes east of Japan in the area of the developing low. However, these flashes were few in number.

The area of the Twin Otter overpass was mostly cloudy with middle and upper level clouds. However, some breaks were present, and the two aircraft took maximum advantage of this fortuitous event. Stratospheric air was encountered during the southwestern part of the flight track. This region was in the left entrance region of the jet streak described above.

03 APR 2001

DC−8: flight 18, Yokota−Kona, transit (20010403−20010403)

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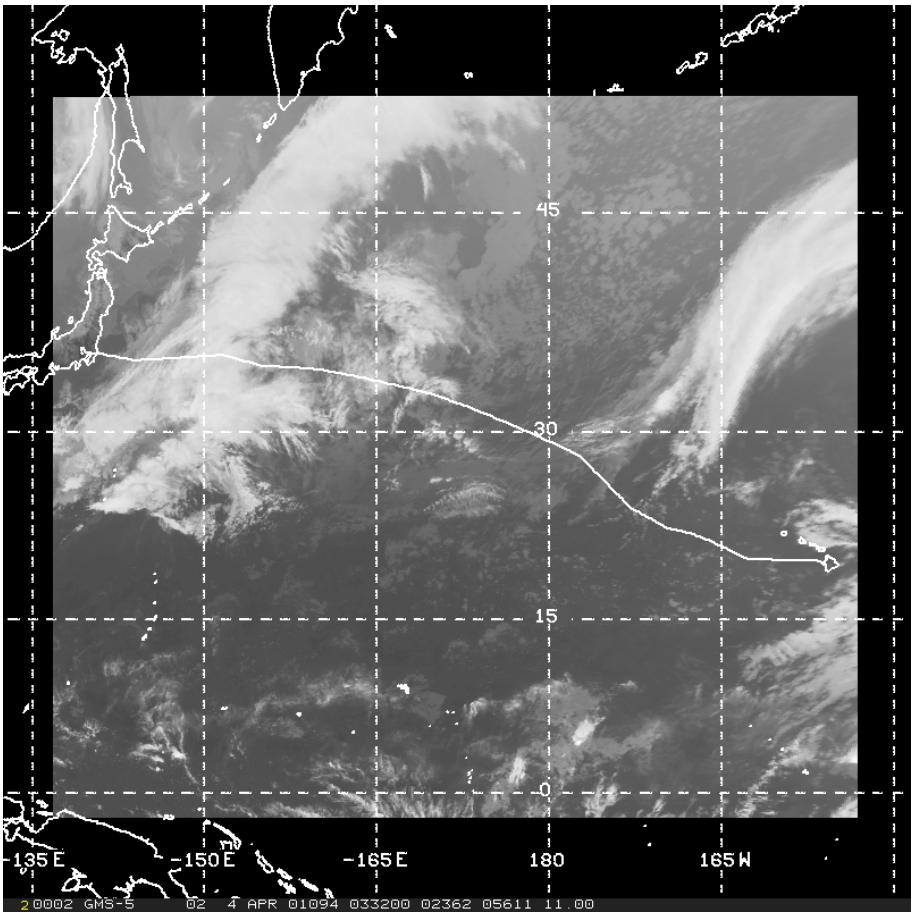

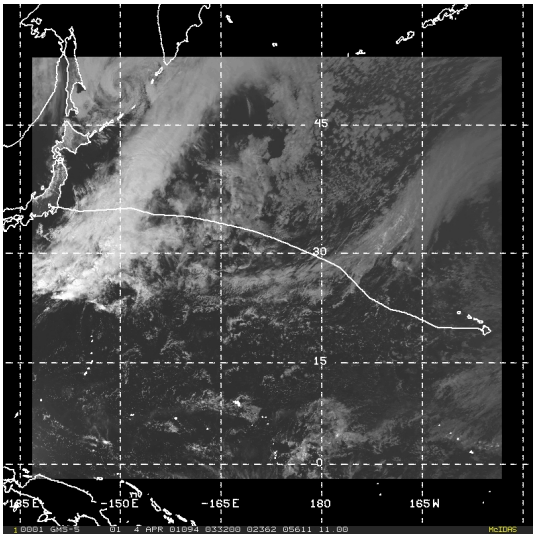

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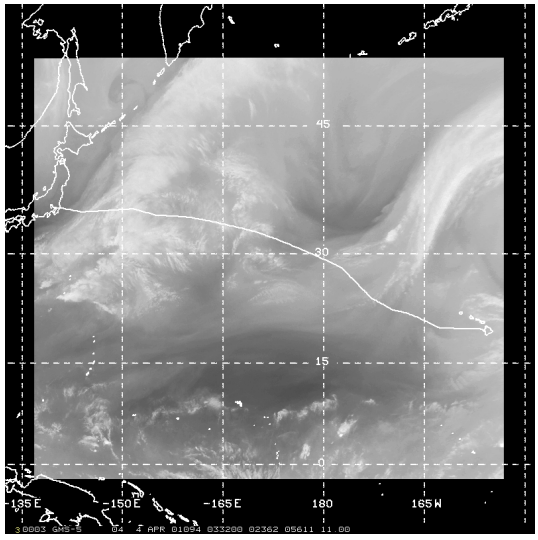

WV

DC−8 flight 18 Narrative

Take−off time 8:39 am local (2239Z); flight duration 9.1 hours
Title: High−altitude Asian outflow and sunset MBL chemistry
Objectives:
(1) To sample the warm conveyor belt associated with a frontal passage over Japan;
(2) to sample high−altitude biomass burning outflow and subsiding Asian pollution over the central Pacific;
(3) to characterize MBL chemistry across sunset;
(4) to conduct a MOPITT validation experiment.
Execution: We flew a straight track from Yokota to Kona with a dog leg to the south towards the end for the sunset MBL experiment. A series of vertical profiles from cruise altitude (33−37Kft) down to 0.5 Kft were conducted, in coordination with the P−3 (flying the same track) to obtain a curtain of atmospheric composition. The sunset MBL chemistry experiment was done in background tropical air from (24N, 173W) to (22N, 166W), and consisted of a sequence of two 1Kft legs on both sides of sunset with a 20−min 10Kft leg in between.
Results: The MOPITT validation experiment had to be scrapped because of clouds. The other objectives were met. Coordination with the P−3 worked well and we achieved a high degree of complementarity in sampling along the flight track. Climbing out of Yokota we encountered a stratospheric intrusion between 18 and 28Kft (behind the front located east of Japan). Heading south we sampled two principal Asian outflow features: a high−altitude outflow above 20Kft with increasing biomass burning signature as we got further south, and a low−altitude outflow below 8Kft of dominantly industrial origin and which appeared to be due to recirculation of pollution around the western Pacific High. Crossing the dateline on a 1−hour leg at 31Kft we observed a transition into a highly polluted layer beginning at 177W (CO up to 240 ppbv, ozone 110 ppbv, HCHO 160 pptv, non−volatile aerosol, high CH3CN, high C2Cl4); this layer could be attributed from the forecasts to biomass burning in SE Asia although the high C2Cl4 is not consistent with this explanation. The first 1 Kft leg of the sunset MBL chemistry experiment indicated extremely high concentrations of carbonyls and methylhydroperoxide, dropping with altitude. Concentrations of HNO3 were puzzlingly high (150 pptv). The second 1Kft leg had higher wind speeds (14 vs. 3 knots). Going back up to cruise altitude before reaching Kona revealed several high−ozone layers, some correlated with CO while others of stratospheric origin.

Meteorological Summary

Relevant Flow Features:

Surface−Two frontal systems affected the weather along the flight track. A developing wave cyclone was centered near 50N, 150E, with a cold front extending southward. This front had passed through Yokota during the previous afternoon, bringing abruptly cooler temperatures and light rain. The second system was a deeply occluded low just west of Alaska. Although its trailing cold front influenced the eastern third of the flight track, this southern portion of the front was very weak. Major surface anticyc−lones were located near 40N, 170E and 40N, 145W. *Middle Troposphere*−Troughs were located just east of Japan and along 175W, in association with the surface lows described above. A well developed subtropical high was centered near 20N, 160E, while a weaker high was located north of Hawaii, near 35N, 155W. A weak middle level low was developing southwest of Hawaii. Middle level winds were predominately westerly over the flight track. The only exception was northwest of Hawaii where southerly and easterly winds were occurring. *Upper Troposphere*−The axis of the jet stream was near 30N over the western two−thirds of the flight track, but extended farther north over the eastern third of the track. The jet stream was not as intense as during earlier flights. Winds had a strong westerly component over the entire flight track.

Cloud Features and Other Goodies:

The flight track was relatively cloudy. Major comma shaped cloud patterns were associated with each of the major wave cyclones described above. The flight track of the DC−8 traversed the extensive area of multiple layered clouds associated with the westernmost system. Mid and high level clouds prevented a MOPITT evaluation between 150−160E. Flight track clouds associated with the eastern feature were not nearly so widespread. The region between the two systems−near the date line−was relatively cloud free. Stratospheric air was encountered at relatively low levels (~17,000 ft) during the climbout from Yokota, i.e., behind the cold front described above. This area was in the entrance region of the jet stream. Weaker stratospheric air was encountered just west of Kona. The first boundary layer run (near 0025Z) had multiple layered clouds providing overcast conditions. Winds at 500 ft were from 170 deg at 36 kt−stronger than encountered on most previous runs. The sea surface exhibited well developed white caps. This run occurred on the warm side of the westernmost cold front. The second boundary layer run (near 0217Z) had broken stratocumulus with bases ~3500 ft and tops ~4500 ft, as well as scattered cirrus. The third boundary layer run (near 0442Z) contained a variety of cumulus, altocumulus, and cirrus, yielding a broken ceiling. Some cumulus reached as high as 15,000 ft, providing rain showers in the area. The chemical effects of these showers were observed during the subsequent leg at 10,000 ft. The trade wind inversion near 6,500 ft was observed during the ascent/descent of the 3rd run.

Sunset occurred near 0432Z. Some clouds were present during the fourth boundary layer run (near 0554Z); however, the darkness prevented a good observation of them.

06 APR 2001

DC−8: flight 19, Kona local (20010406−20010406)

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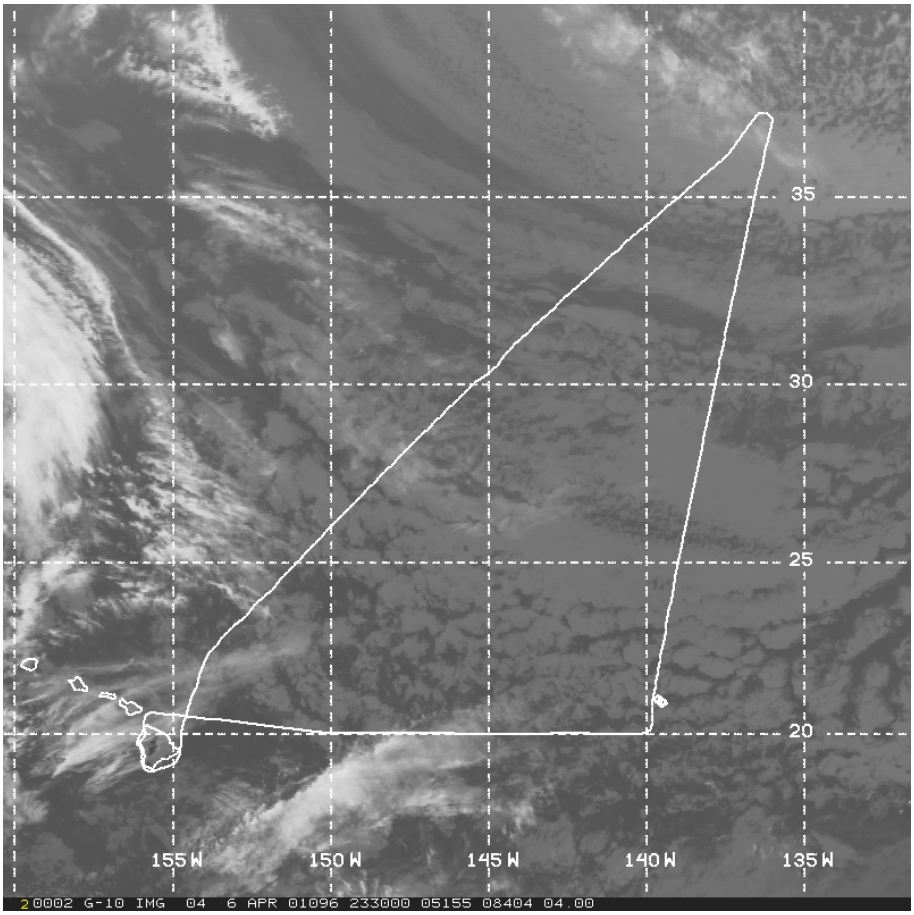

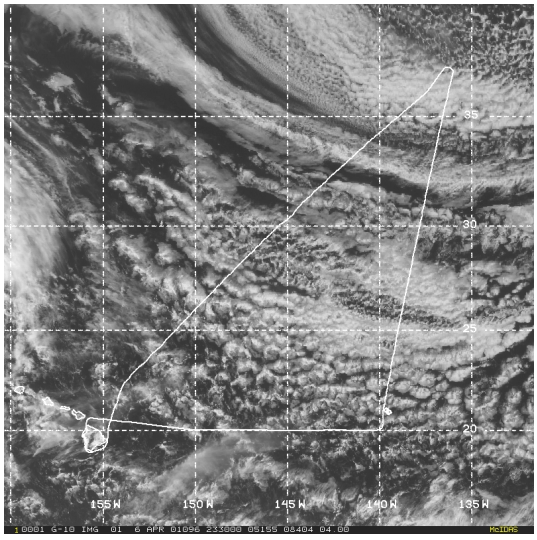

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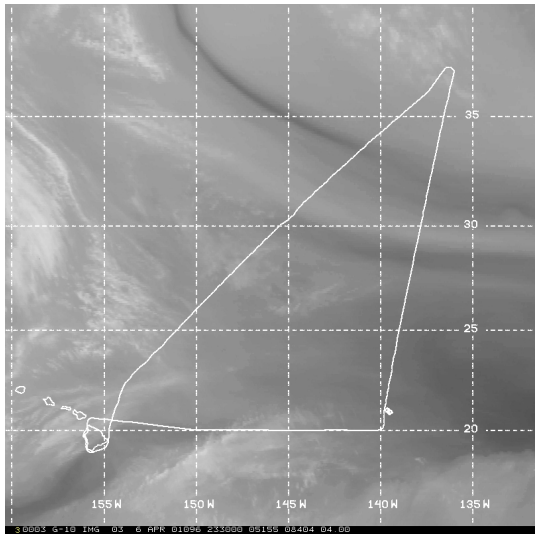

WV

DC−8 flight 19 Narrative

Take−off time 8:56 am local (1856Z); flight duration 10.3 hours
Title: Subsidence over East Pacific and MOPITT transect
Objectives:
(1) To characterize aged continental outflow subsiding around the East Pacific High;
(2) to conduct a MOPITT underpass spiral as well as an extensive transect along the Terra orbit track to validate horizontal gradients seen by MOPITT. (It was unfortunately not possible on this flight to sample Asian outflow traveling in the jet stream, because of a persistent blocking ridge over the central Pacific that deflected the jet stream north of 50N).
Execution: We flew from Kona (20N, 156W) straight E to (20N, 140W) for a MOPITT underpass spiral at (21N, 140W). From there we flew NNE to (37N, 136W), remaining in the MOPITT orbit track throughout and with extensive vertical profiling up to 28Kft. We then headed straight back to Kona along a SW track, again with extensive vertical profiling, and flew a series of low−altitude legs near Kona to characterize the chemistry of oxygenated organics in the MBL.
Results: The objectives were met. The MOPITT spiral (from 33Kft down) was conducted over a solid stratus deck with a few breaks and cloud tops at 6Kft. There were no higher−altitude clouds. Above cloud tops the CO concentrations were relatively uniform at 120 ppbv with a moderate pollution layer at 18−22Kft (CO up to 150 ppbv). In the MBL below cloud top was aged polluted air (150 ppbv CO, 1890 ppbv CH4, high C2Cl4, etc). Remarkably high concentrations of carbonyls and methylhydroperoxide were observed in the MBL. Heading NNE on the MOPITT transect we sampled a variety of air masses with a fair degree of layering and latitudinal structure (CO ranged from 80 to 210 ppbv). Solid stratus (tops 4−6Kft) with a few breaks and no higher−altitude clouds persisted for the duration of the transect. The CO/CH4/CO2 ratios varied quite a bit between pollution layers, and CH4/CO ratios were low in the higher−altitude layers, perhaps providing an indication of European vs. Asian origin. Heading back SW we encountered a few more aged pollution layers against a clean background, and persistently high concentrations of CO below 5Kft (typically 150 ppbv). Low−altitude legs at the end of the flight sampled air below, within, and above the stratus cloud deck.

Meteorological Summary

Relevant Flow Features:

Surface−A weak subtropical low was located near 30N 165W. This system had been moving slowly northward during the previous several days, showing little change in intensity. A major area of high pressure was near 45N 150W. Its axis was oriented northwest to southeast. A weaker high was centered just south of Hawaii. The intertropical convergence zone was becoming better defined south of Hawaii along ~5N. *Middle troposphere*−The weak subtropical low was almost vertically stacked, extending through all flight levels. The major high northeast of Hawaii extended through 500 mb and then became a ridge line at higher levels. This feature brought northerly winds to the eastern leg of the flight track. The subtropical high south of Hawaii was evident at all altitudes. *Upper troposphere*−Westerly flow dominated the flight track in the upper levels. The closed subtropical low northwest of Hawaii and the ridge line east of the Islands caused some directional changes along the northern part of the track. The primary jet stream was far north of the flight track. However, a wind maximum just east of Hawaii brought flight level winds to ~95 kt in that area. Elsewhere, winds generally were less than 50 kt−sometimes much less.

Cloud Patterns and Other Goodies:

The subtropical low produced a broad area of low, middle, and high clouds. This area had a north−south axis, extending as far east as the central Hawaiin Islands. The wind maximum south and east of Hawaii produced a band of cirrus. Much of the flight track was covered by stratocumulus clouds that often reached broken to overcast conditions. The MOPITT spiral point (21N 140W) had good cloud conditions. Only overcast stratocumulus were present, with occasional small breaks. Bases were near 4800 ft and tops near 6300 ft. A few stratocumulus were at ~3,000 ft. The trade wind inversion was near 6300 ft, separating moist air below from very dry air aloft. The ensuing boundary layer run beginning near 2031Z had a few, very light rain showers. During the climbout, cloud tops were somewhat lower than below ~5100 ft. The second boundary layer run (near 2211Z) had broken cumulus clouds, with bases near 2900 ft and tops near 3500 ft. The trade wind inversion was well defined near 3500 ft. This height was considerably lower than during the first boundary run. The temperature at 500 ft (~12.8C) was cooler than at the first boundary run (17.3C). During he climbout beginning near 2241Z, the trade wind inversion was not well defined, with relatively humid ir extending into the middle troposphere. The initial part of the third boundary layer run (near 0028Z) had a broken layer of clouds with bases of 3100 ft and tops of 5100 ft. A scattered layer was at 2500 ft. The clouds became less common during the run. Winds initially were from the north, but changed to a more northeasterly direction as the leg continued. The fourth boundary layer run (beginning at 0213Z) included segments within the clouds and above the clouds. The clouds in the area had more vertical development than during previous runs. A scattered stratus deck was between ~6500 − 7500 ft. A broken layer of cumulus had bases of ~2000 ft and maximum tops of ~7500 ft. Some of the taller clouds produced light rainshowers The "above−cloud" segment did pass through some clouds.

09 APR 2001

DC−8: flight 20, Kona−Dryden, transit (20010409−20010409)

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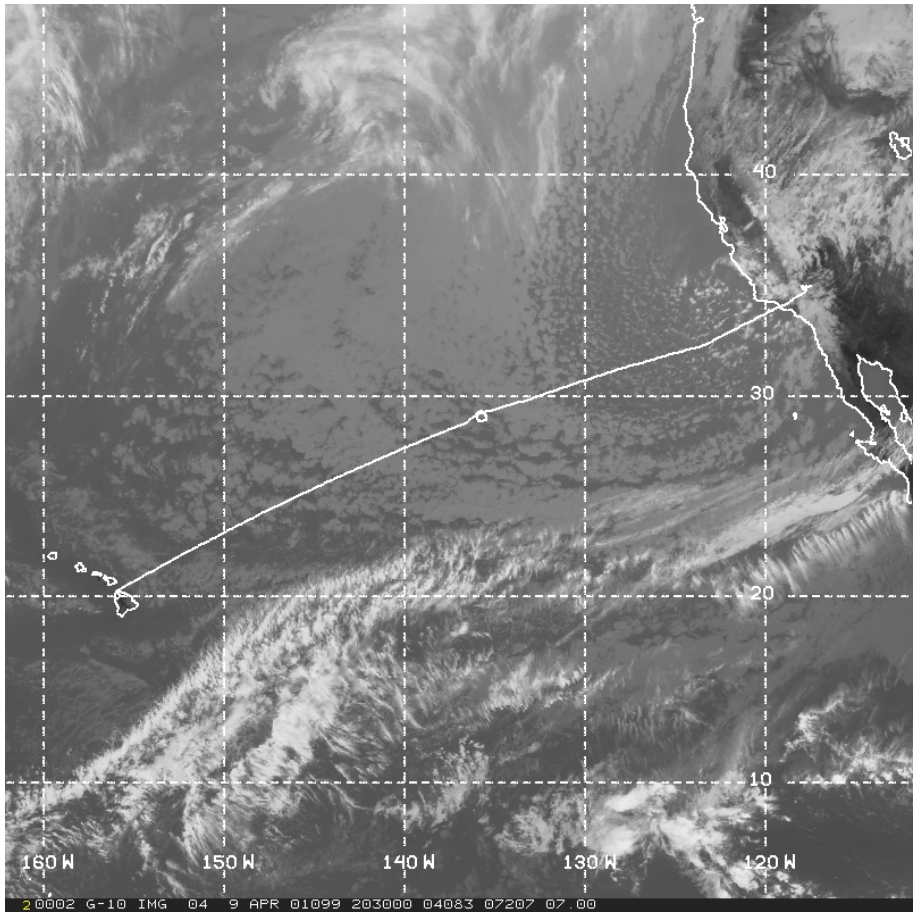

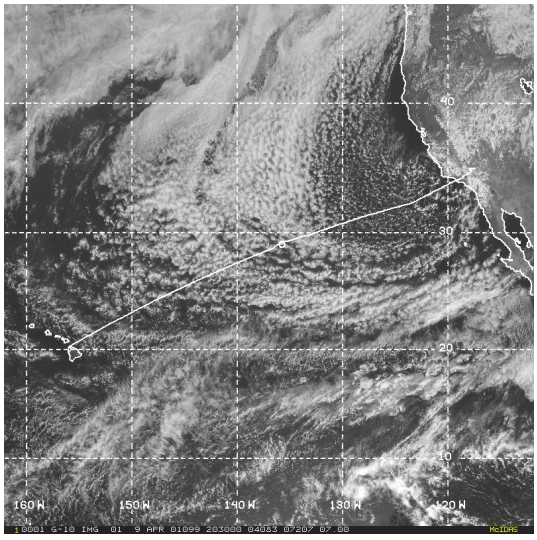

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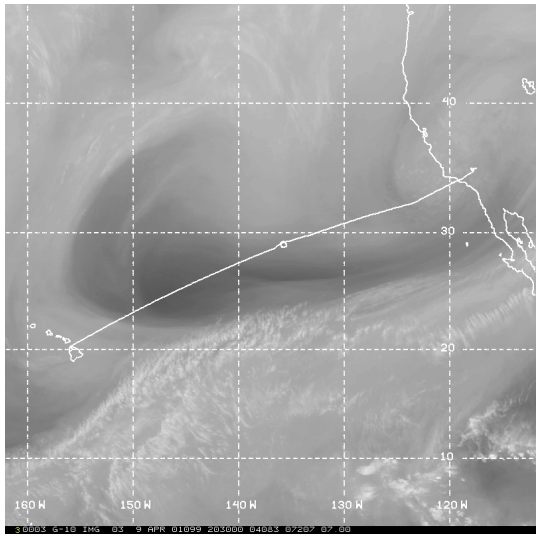

WV

DC−8 flight 20 Narrative

Take−off time 7:15 am local (1715Z); flight duration 6.8 hours
Title: Aircraft intercomparison, stratus chemistry, and jet stream transport
Objectives:
(1) To conduct an extensive intercomparison with the P−3;
(2) to examine chemical processing in stratus clouds;
(3) to sample Asian pollution transported in the jet stream around the east Pacific ridge and southward over California.
Execution: We flew from Kona (20N, 156W) to (22.5N, 151.5W) for the intercomparison, which consisted of a 20−min leg at 17Kft, a descent to 1Kft at 500fpm, and a 20−min leg at 0.5Kft. We then did a 20−min leg in stratus (6Kft) and headed to Dryden (35N, 118W) with a spiral followed by a climb to 39Kft along the way.
Results: The intercomparison was a success; all instruments were on−line and the aircraft flew within 200−400 ft from each other most of the time. Steady concentrations were observed on both the 17Kft and the 1Kft intercomparison legs. The stratus deck extended from 3 to 7 Kft. The 20−min leg at 6Kft following the intercomparison was conducted in almost−continuous stratus. No particularly strong pollution layers were observed in the flight; there were layers at 5−15Kft with CO up to 240 ppbv, and the boundary layer was enhanced in CO and CO2 also (typically 170 ppbv CO, 377.2 ppbv CO2, 56 ppbv O3). The atmosphere was featureless above 15Kft and did not reveal any structure that would be associated with jet stream transport of Asian pollution. Approaching California we flew a long leg in the stratosphere (39Kft) and sampled a major stratospheric intrusion extending down to 20Kft and capping thunderstorm activity over southern California.

Meteorological Summary

Relevant Flow Features:

Surface−A strong anticyclone was centered near 40N, 145W. A weak surface low was passing over southern California. Although not strong at the surface, this low was better defined aloft and associated with a strong short wave trough. Due to these pressure systems, surface winds were from the east on the western part of the flight track and mostly northerly on the eastern part of the track.

Middle troposphere−The high northeast of Hawaii, and the low over southern California persisted into the middle levels. Easterly winds continued along the westerly portion of the track and northerly winds along the western portions.

Upper troposphere−Due to the closed anticyclone, the polar jet stream was displaced far to the north of most of the flight track. However, the jet plunged southward along the California Coast. The subtropical jet stream extended from south of Hawaii to Baja California. The flight track was north of this jet. Winds along the western portion of the track were from the west, but from the northwest over eastern portions.

Backward trajectories at all levels showed considerable circular transport over much of the flight track. This was due to the persistent anticyclone noted above. Only near California did the trajectories show well defined transport from Asia. This air had traveled around the strong anticyclone located farther west.

Relevant Cloud Patterns and Other Goodies:

Most of the flight track was devoid of middle and high clouds. The only exception was near California−in association with the low pressure described above. However, much of the flight track was blanketed by broken layers of cumulus and stratocumulus.

The area of the DC−8/P−3 intercomparison had only broken cumulus and stratocumulus clouds At 17,500 ft, the winds were from 087deg at ~25 kt. During the descent to 500 ft, two major cloud layers were observed. Stratocumulus had bases of 5100 ft and tops of 7250 ft. The tops were uniform, and this level marked the trade wind inversion. A cumulus deck was below, with bases of ~3700 ft and varying tops that occasionally reached ~7000 ft. Some of these clouds produced light rainshowers. The intercomparison leg at 500 ft had winds from ~ 070 deg at ~27 kt−stronger than many runs at this altitude. The cloud level run at ~6000 ft remained in the clouds at most times, but some breaks did occur.

The second boundary layer run (near 2129Z) had an almost overcast cover of stratocumulus. Bases were near 3500 ft and tops near 5100 ft. A broken layer of cumulus was below, with bases near 2600 ft. The winds at this run were somewhat weaker than in the previous run, ~20 kt here. The direction was northeasterly at the beginning of the run, but shifted to northerly by the end.

The stratosphere was entered near 2225Z as the DC−8 was passing 35,700 ft for 39,000 ft. We remained in the stratosphere until the descent into Dryden. A line of weak thunderstorms was located off the California Coast and near Dryden .