Fog Forecasting

UPS Airlines Conceptual Models and Forecast Methods

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May 15, 2003

Purpose

- To share the conceptual models and forecast methods UPS Airlines meteorologists use to predict radiation fog.
- These ideas and techniques are not strictly limited to pure radiation fog; they apply to any fog situation involving radiative heat loss as an important component of boundary layer cooling.

Background

- Methodologies a result of trying to fill an operational need.
- 1 person per shift needed to assess fog risk for over 80 UPS airports each night. (Now 92 airports)

Conventional Model

- Basic requirements for radiation fog are well known:
  - Clear sky
  - High humidity
  - Light wind
- If T will cool to or a few degrees below T_d, fog is generally expected

UPS Airlines Conceptual Model

Involves a more vertical view of processes in potential fog layer.

- Vertical Distribution of water vapor (hydrolapse).
- Boundary layer turbulent mixing.
- Heat Fluxes from underlying ground surface.
- Also includes “stratus build-down.”

Importance of Hydrolapse

- The importance of hydrolapse (the vertical profile of humidity) is frequently neglected.

- In his 1940 classic Weather Analysis and Forecasting, Sverre Petterssen states, “As long as the specific humidity decreases along the vertical, fog usually does not form except in still air, and even then the cooling may result only in dew or rime on the ground.”

- Fog typically initiates 100-200 feet above the ground. (Pilie, et.al.,1975)

Importance of Hydrolapse

- In the absence of recent observations of humidity aloft for a particular airport, how do we make use of our knowledge of the importance of the hydrolapse?

- We can infer the humidity aloft by observing the behavior of the observed dew point temperatures during the warmest (most deeply well-mixed) part of the day.

The ‘Crossover’

- **Crossover Temperature (T_{XOVER}):** The lowest dew point temperature observed during the warmest part of the day. Conceptually, this represents the dew point temperature of the air at 200ft AGL. We forecast fog to form when the temperature cools to the crossover value or below.

Visibility Forecast with Crossover Temperature

$T_{MIN} = T_{XOVER}$: 1-3 miles

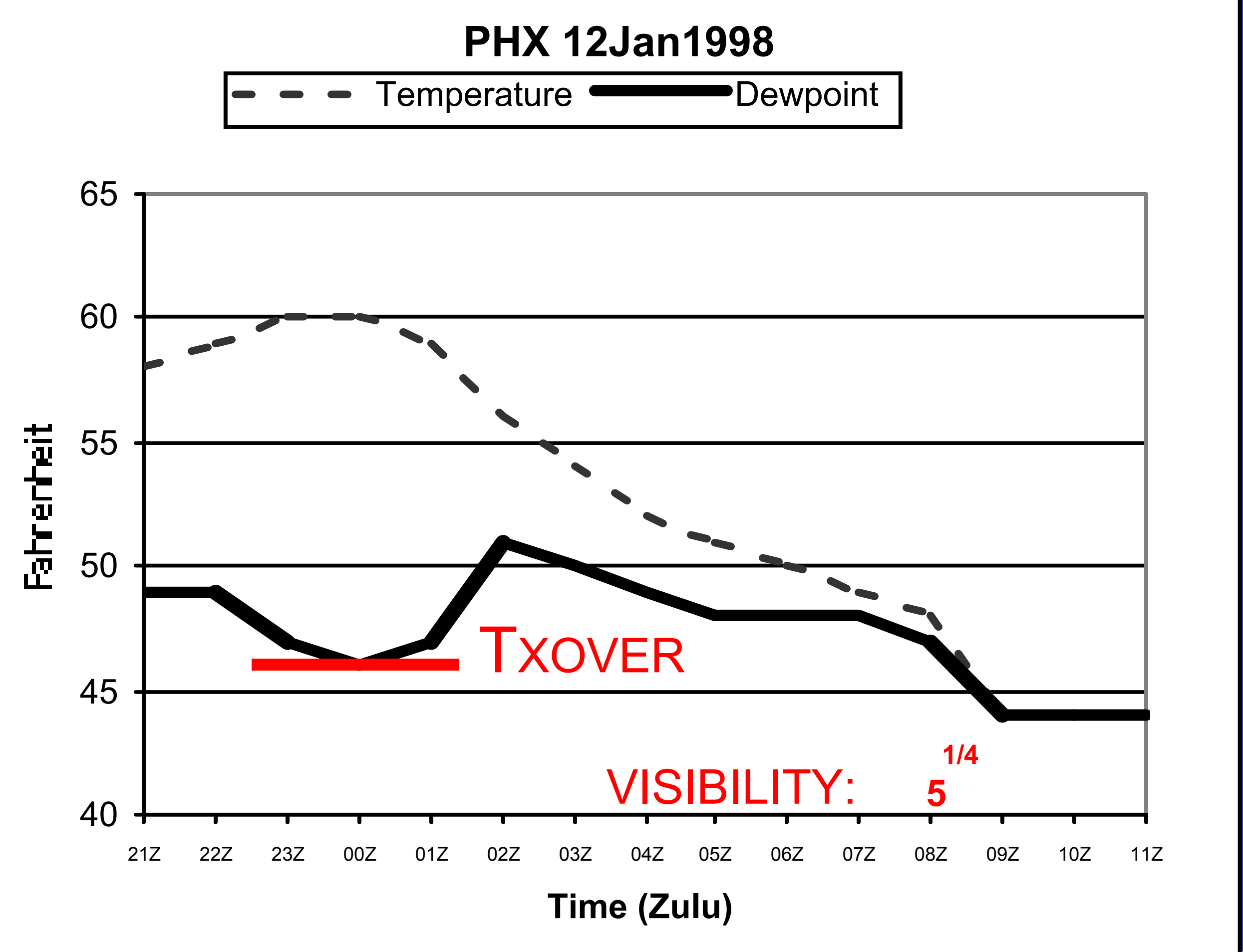
$T_{MIN} = T_{XOVER} - 3^{\circ}$ F : 1/2 mile or lower

Txover Adjustments

The strict application of this technique is limited to situations involving no significant moisture advection, and no significant addition of moisture from precipitation.

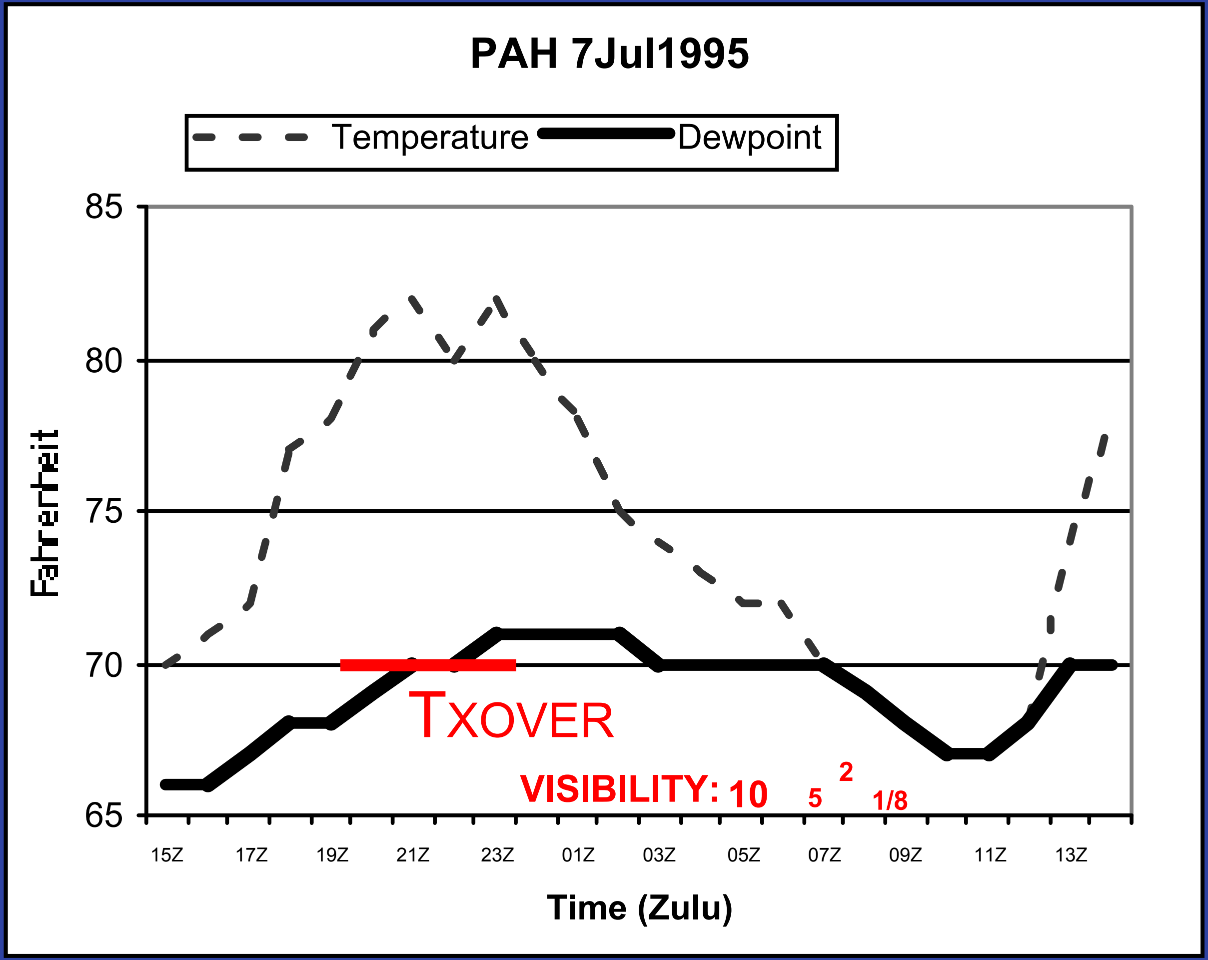
When moisture advection is present, forecasters must judiciously replace the crossover temperature with a suitable replacement (often an upwind dew point) that better reflects the expected humidity profile of the nocturnal stable layer.

TXOVER Example



An example of a more typical crossover pattern, where the dew point drops during the warmest part of the day. The crossover temperature would be 46°F. At 0756Z, the visibility was 5 miles with a temperature of 48°F, dew point 47°F. At 0824Z the temperature was 45°F, dew point 45°F, with visibility 1/4 mile.

TXOVER Example



TXOVER Example

```
SA 1850 M25 BKN 35 BKN 10 200/78/68/2608/013
SA 1950 25 SCT M35 BKN 10 197/81/69/2508/012
SA 2050 25 SCT M35 BKN 10 190/82/70/2307/010
SA 2150 25 SCT M35 BKN 10 190/80/70/2007/010
SA 2250 23 SCT 100 SCT 10 183/82/71/2307/008
SA 2350 23 SCT 10 183/80/71/2009/008
SA 0050 20 SCT 250 -SCT 10 183/78/71/1906/008
SA 0150 250 -SCT 10 184/75/71/2106/008
SA 0250 60 SCT 10 187/74/70/2105/009
SA 0350 60 SCT 10 187/73/70/2106/009
SA 0450 60 SCT 10 191/72/70/2206/010
SA 0550 55 SCT 7 195/72/70/2304/012
SA 0650 CLR 5F 195/70/70/2404/012
RS 0750 CLR 2F 195/69/69/2303/011
SP 0807 W1 X 1/2F 0000/012
SA 0850 W1 X 1/8F 195/68/68/0000/012
```

Boundary Layer Turbulent Mixing

Is it too windy for fog?

The real requirement for radiation fog is not lack of *wind*, per se, but lack of *turbulence*, which can result from various combinations of stability and boundary layer wind speeds.

Modified Richardson Number

We use a modified version of the Richardson number (MRi) as follows:

$$\mathbf{MRi = (T_b - T_{sfc}) / (u)^2}$$

Where:

T_b = T1 or T3 (whichever is warmer) on FOUS60/ETA output.

T_{sfc} = forecast minimum temperature (°c)

u = boundary layer wind speed(FF from ETA/NGM (knots))

Modified Richardson Thresholds

Through operational forecast use we have found:

- MRi < 0.025 turbulent eddys; expect stratus rather than fog
- MRi 0.025 - 0.04; marginal; expect variable fog
- MRi > 0.04; stagnant air; expect fog development

MRi Adjustments

- Threshold for mixy adjusted downward to 0.015 for onshore flow (radiation/advection hybrid fog)

- Pure advection fogs (rare event) can produce fog in “mixy” boundary layers; for these extreme situations MRi is irrelevant.

MRi Example

```
OUTPUT FROM NGM 12Z JAN 11 98
TTPTTR1R2R3 VVVLI PSDDFF HHT1T3T5
PHX//755013 -0603 180206 50100497
06000563935 -1007 180105 53110499
12000433561 01206 172606 54130600
18000492447 -0506 173211 54120501
24000545545 -1006 173404 54110601
```

0000Z MRi = $(13-11)/6^2 = 0.055$ (decoupled).
0600Z MRi = $(12-08)/11^2 = 0.033$ (marginal).
1200Z MRi = $(11-07)/4^2 = 0.250$ (very decoupled).

Heat Fluxes from Underlying Surface
(Ground Temperature)

- UPS Airlines meteorologists use 4” soil temperatures where available.

Generalizations

- Radiation cooling is often partially offset by deep soil upward heat flux.
- When 4” soil temperature is colder than TXOVER, air in contact with the ground cools at a faster rate.
- Snowcover eliminates upward heat flux from soil.

Ground Temperature Applications

- T_{GROUND} 5^{o} F warmer than T_{XOVER} = reduced fog risk
- T_{GROUND} 5^{o} F colder than T_{XOVER} = increased fog risk

Stratus Build-down

The presence of stratus is often interpreted as sign fog will not form since clear sky requirement is not met.

In many cases, base of stratus builds downward into fog. (Pettersen)

Stratus Build-down

- Surface radiational cooling is reduced by stratus, but not eliminated.
- Stratus cloud top radiatively cools, causing thickening and lowering of cloud
- TGROUND is critical.
- Absence of higher clouds.

Stratus Build-down Applications

- $T_{GROUND} \geq 5^{\circ}$ F warmer than T_{XOVER}, stratus build-down (SBD) not expected.
- T_{GROUND} within 5° F of T_{XOVER}, SBD rates of 100-200 ft/hour
- $T_{GROUND} \geq 5^{\circ}$ F colder than T_{XOVER}, SBD fog risk elevated, rates of 300-400 ft/hour.

Summary

UPS conceptual models favor a more vertical and process-oriented approach to fog forecasting, rather than a surface or fog type classification method.

Highlights of UPS Conceptual Model

- Vertical Q / T_{XOVER}
- MRi - Turbulent mixing
- T_{GROUND}
- Stratus Build-Down

Our Goal

We share these with the aim of promoting their more general use.

Questions?

Results - Skill Scores

Fog Alerts - Last 6 years (1996-2001)

3840 fog events within 1 hour of aircraft arrival time.

We issued alerts for 2441 of them. Alerts only issued for 30% risk and above.

POD = 63.56%

Results - Skill Scores

Fog Assessment Map

Forecast made by 1 AM (ET), valid 3 - 9 AM (ET).

High Risk (50 - 100%) Pink Dot
Monitor Closely (10 - 40%) Orange Dot

Oct 2001 - Mar 2002 UPS POD = 81.7%