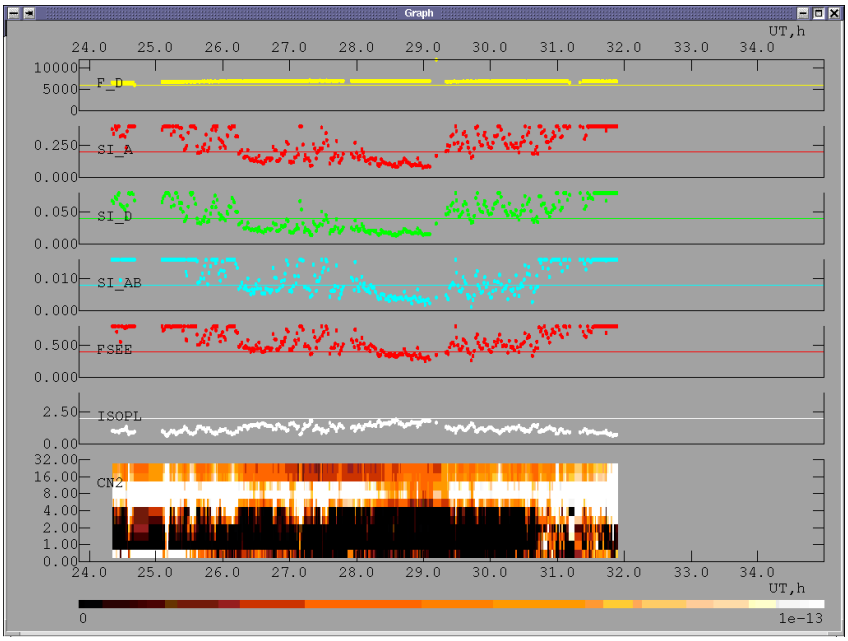
TURBULENT LAYERS AND THERMAL INVERSIONS

Abstract : In this document, we emphasize the link between turbulence profiles of the atmosphere and thermal inversions forecasted by Global Forecast System (GFS) model.

1. Turbulence profiles

These have been collected during two MASS runs, in March and September 2003. However, only data gathered during the second run in September are studied because the operator knew at that time what to look at. The first run brought primary hints about correlation between thermal inversions and turbulent layers shown in the turbulence profile of MASS.

A typical display plots the value of Cn2 (color-coded scale) in an altitude- vs. -time graph. An example is shown below.



From this, it's simple to get the strengthness, altitude and lifetime of turbulent layers (high Cn2).

In this example, black areas mean weak turbulence (very low Cn2), and brings good seeing, whereas white areas are the clues of high-Cn2 values, related to bad seeing. Here we see a persistent turbulent layer around 8km AGL which was active all night long.

In this document, we mainly focus on this kind of large, long life timed layers, which are often forecasted by the model. Thus, it may be a serious indicator of seeing trend for the upcoming night.

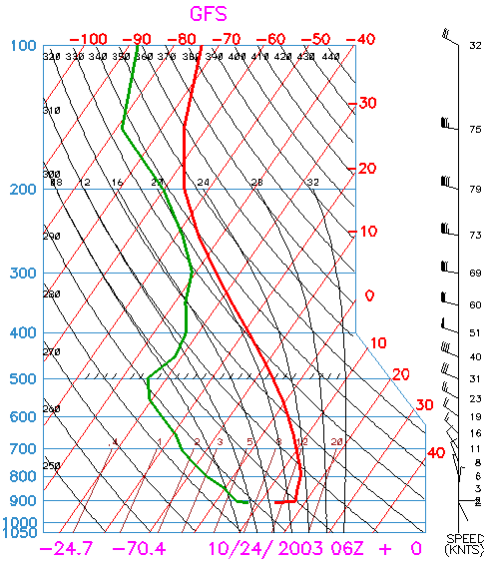
2. Thermal Inversions

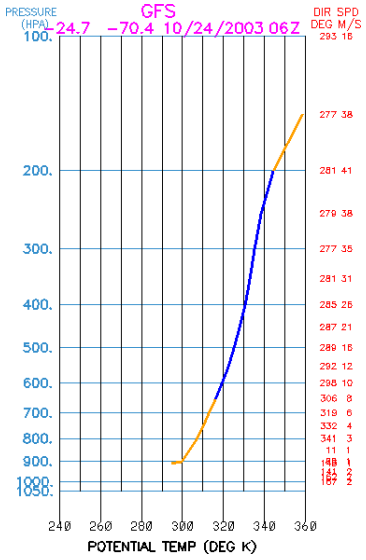
In the framework of thermal inversions related to turbulences profiles, the main issue was to characterize the relevant layers which were involved in the turbulence profile. This work was achieved by making comparisons between the turbulence profile (from MASS) and the GFS' model predictions for several nights in March and September 03.
Next step was to emphasize and quantify parameters which characterize a thermal inversion.

Basically, GFS model returns soundings predictions, as a cross section of the atmosphere in a Potential temperature (θ) vs. altitude graph. ASCII data have been collected during the run of September.
We determined thermal inversions in the profiles according to an unusual dθ/dz ratio compared to the neighbouring layers plus a notable Δθ between the bottom and the top suspected inversion layer.
Furthermore, GFS detects automatically large and commonly persistent thermal inversions. They are called “critical inversions” (Heffter 1983) if the two following conditions are fulfilled: dθ/dz > 0.005K and Δθ > 2K.
Those who are called “active layers” have been introduced by us according to the perturbations located in the sounding prediction.

Critical and active layers predictions were, most of the time, correctly correlated to the turbulence profiles returned by MASS several hours later, as shown in the data table in the annex.

In the figures below, we show an example of a radio sounding prediction output :





The first is the well-known Skew-T diagram and the second is a plot of the potential temperature vs. pressure.
The former shows directly altitudes where critical inversions are located (in orange). Blue parts are assumed to be “stable” by the model.
For a precise interpretation, it was necessary to get the ASCII file of those plots (below). With the help of this one, it was very easy to confirm the altitudes of critical inversions and a means to locate other relevant active layers, according to the parameters discussed above.

Often, active layers are simply a stretch of existing critical layers. This is the case here :

HEIGHT	DT/DZ	TDIFF	CRITICAL INVERSION
969.	-.004	-1.8	
1013.	.120	5.3	****
1497.	.007	3.5	****
2010.	.008	3.9	****
2552.	.006	3.0	****
3127.	.005	2.9	****
3738.	.005	3.3	****
4390.	.005	3.1	####
5088.	.004	3.1	####
5840.	.004	2.8	
6654.	.003	2.7	
7544.	.003	2.6	
8523.	.002	2.3	
9617.	.002	2.7	
10859.	.003	3.2	
12313.	.004	5.8	####
14104.	.008	14.0	****
16526.	.011	26.5	****
20584.	.026	****	****
26311.	.031	****	****

Altitudes marked with “****” are the so-called critical layers, those marked with “####” are the active layers.

During the September run it was mandatory to check the viability of active layers' concept. It has been done by checking the correlation of MASS profiles with the model output, during each night. In the table below, we show the correspondences.

THERMAL LAYERS PREDICTION THROUGH GFS MODEL FORECAST

NIGHT	HOUR-UT	ACTIVE LAYERS KM(MASS)	FORECASTED BY GFS KM
16-17	00-03	0.5-3.5, 10-16	CL : 12-16+, AL : 3-4
	03-06	10-16	CL : 14-16+, AL : none
	06-09	10-16, 3-6	CL : 14-16+, AL : 4
17-18	00-03	Ground, 10-16	CL : 12-16+, AL : ground-4
	03-06	10-16	CL : 11-16+, AL : none
	06-09	10-16	CL : 11-16+, AL : none
18-19	00-03	Ground, 3-16	CL : ground-3, 11-16+, AL : none
	03-06	3-16	CL : ground-3, 11-16+, AL : none
	06-09	Ground-16	CL : ground-3, 11-16+, AL : none
19-20	00-03	1.5-16	CL : 12-16+, AL : none
	03-06	Ground, 8-10	CL : 14-16+, AL : none
	06-09	Ground	CL : 14-16+, AL : none
20-21	00-03	ALL (main:4)	CL : 14-16+, AL : 6-7
	03-06	ALL (main:4)	CL : 12-16+, AL : 6-7.5
	06-09	ALL (main:4)	CL : 12-16+, AL : 6-7.5
21-22	00-03	1-8 (main:4)	CL : 12-16+, AL : none
	03-06	1-8 (main:4)	CL : 14-16+, 3-4, AL : 7.5-9
	06-09	1-8 (main:4)	CL : 14-16+, 3-4, 7.5-9, AL : none
22-23	00-03	ground-4	CL : ground-3.5, 14-16+, AL : 5-6
	03-06	2-6	CL : ground-4, 14-16+, AL : 5-6.5
	06-09	3-5	CL : 4.5-6.5, 14-16+, AL: none
23-24	00-03	NO DATA----------	
	03-06	NO DATA----------	
	06-09	NO DATA----------	
24-25	00-03	ground-12 (main:7-8)	CL : 5, 10-16, AL : ground
	03-06	ground, 8	CL : 3.5-5, 10-16, AL : none
	06-09	main:7-8	CL : 4-5, 10-16, AL : 6
25-26	00-03	ground-8	CL : ground-3, 9-16, AL : none
	03-06	4-8	CL : ground-2, 12-16, AL : 3.5
	06-09	ground-8	CL : ground-4, 12-16, AL : none
26-27	00-03	6-9	CL : 1-3, 12-16, AL : none
	03-06	3-9	CL : 1-4, 12-16, AL : none
	06-09	4-9	CL : ground-2, 13-16, AL : none
27-28	00-03	ground	CL : ground, 12-16, AL : none
	03-06	ground, 8-14	CL : ground, 12-16, AL : none
	06-09	4-14	CL : ground, 12-16, AL : none
28-29	00-03	5-14	CL : ground, 12-16, AL : none
	03-06	8	CL : ground, 12-16, AL : 3-4.5
	06-09	5-14	CL : ground-4, 12-16, AL : none
29-30	00-03	4-8(weak), 8-16	CL : ground-4, 12-16, AL : 4-5
	03-06	4-8(weak), 8-16	CL : ground-4, 12-16, AL : 4-5
	06-09	4-8(weak), 8-16	CL : ground-4, 12-16, AL : 4-5.5

CL : So-called Critical Layers (definition by ARL-NOAA : dT/dz > 0.005, and DT > 2K).
AL : Not specifically defined. Here are depicted only the relevant cases where an instability is apparent in the turbulence profile

"10-16" means that the layer is between 10 and 16 kilometres high.
"5, 7" means that there are two layers, at 5 km and 7 km high.

GFS forecasts issued at 00Z (beginning of the astronomical twilight at Paranal)

Nights 21-22 and 22-23 are very interesting because they validate the "active layers".

3. First conclusions

We noted that this assumption is often right (at least 75%):

- "When GFS predicts (H-9) high intensity thermal layers, they are, most of the time, observable with MASS as turbulent layers".

However, the following assumption is not verified as often as the former (xx% ?):

- "When MASS observes a turbulent layer, it has been forecasted by GFS several hours before".