Preliminary results of ABL observations in LAPS project in Huaihe river basin

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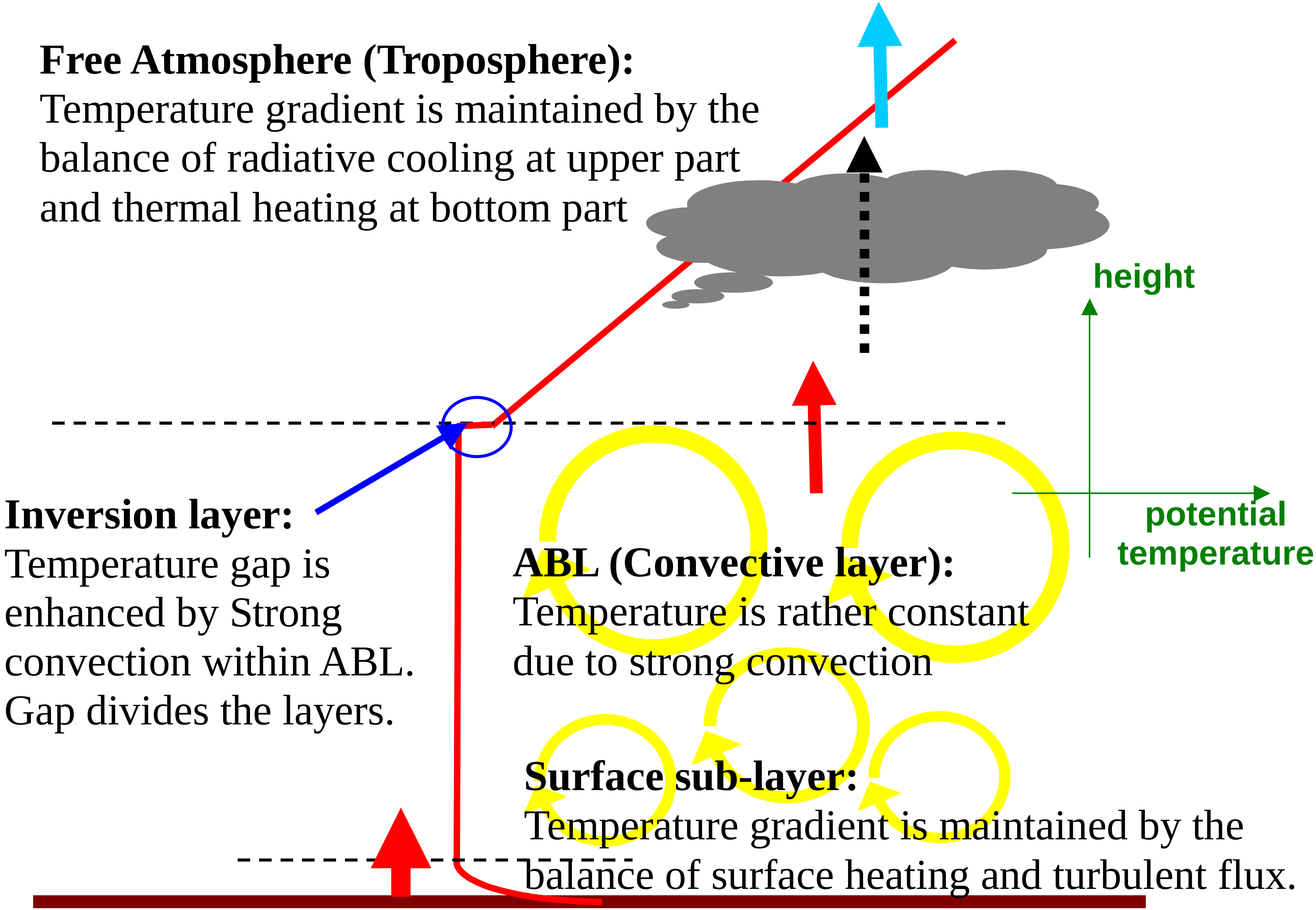
Objective

To know Air-Surface Interaction
To know Surface flux and ABL

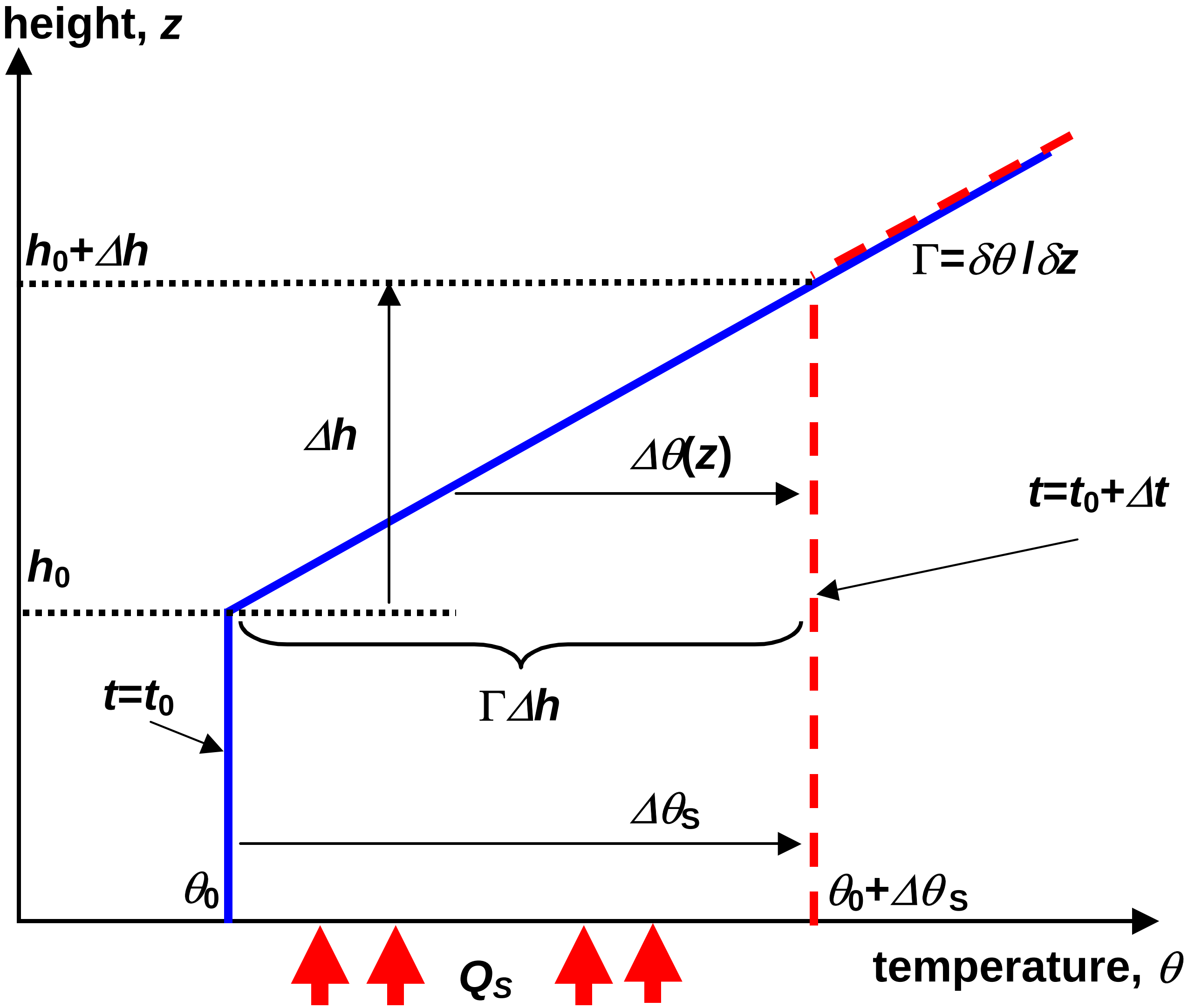
Backgrounds

- Requirements of Exact Knowledge about the Interaction:
    - Lower boundary for Meteorology
    - Upper boundary for Oceanography
- Developing of Instruments:
    - Wind profiler radar, Eddy flux system, etc.


Free Atmosphere (Troposphere):
Temperature gradient is maintained by the balance of radiative cooling at upper part and thermal heating at bottom part
height
potential temperature
Inversion layer:
Temperature gap is enhanced by Strong convection within ABL. Gap divides the layers.
ABL (Convective layer):
Temperature is rather constant due to strong convection
Surface sub-layer:
Temperature gradient is maintained by the balance of surface heating and turbulent flux.

ABL and Surface flux

(under learning)



Temperature profile

Convective ABL

$$\theta(z)=\theta_S$$

Free atmosphere

$$\theta(z)=\theta_S+(z-h)\Gamma$$

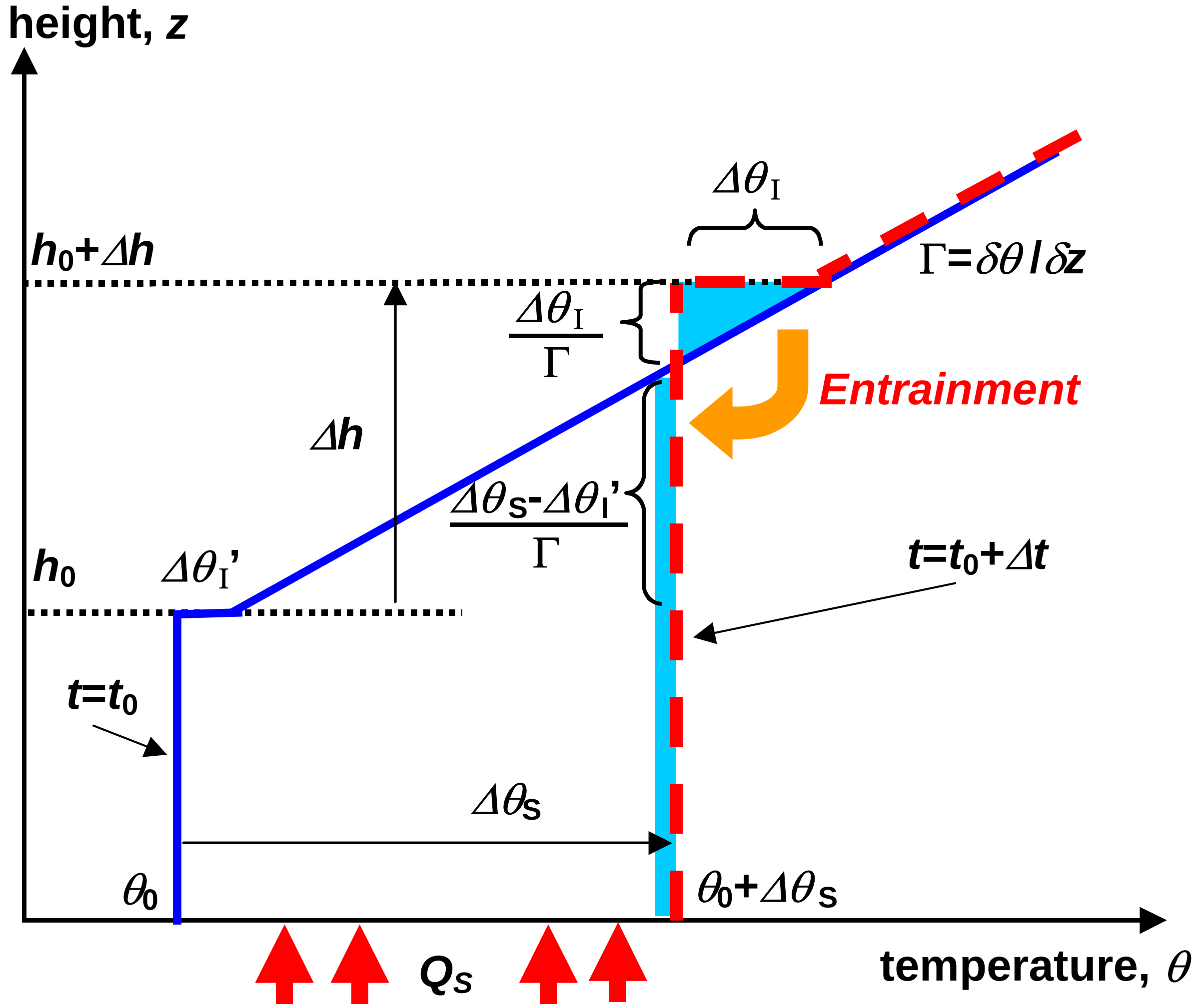
Surface flux

$$\int_{t_0}^{t_0+\Delta t}\overline{w_S'\theta_S'}dt\equiv Q_S$$

$$=\int_0^\infty \Delta\theta(z)dz=\Delta\theta_S\left(h_0+\frac{1}{2}\Delta h\right)=\Gamma\Delta h h_0+\frac{1}{2}\Gamma\Delta h^2$$

$$\frac{1}{2}\Gamma\Delta h^2+\Gamma h_0\Delta h-Q_S=0 \quad\Rightarrow \Delta h=-h_0+\sqrt{h_0{}^2+\frac{2}{\Gamma}Q_S} \quad\Rightarrow \left(h_0+\Delta h\right)^2=h_0{}^2+\frac{2}{\Gamma}Q_S$$

Entrainment effect



Inversion layer

$$Q_S = \Delta\theta_S h_0 + \frac{1}{2}\frac{(\Delta\theta_S - \Delta\theta_I')^2}{\Gamma} - \frac{1}{2}\frac{\Delta\theta_I{}^2}{\Gamma}$$

$$Q_E \equiv \frac{1}{2}\frac{\Delta\theta_I{}^2}{\Gamma} \qquad \left(Q_E' \equiv \frac{1}{2}\frac{\Delta\theta_I'^2}{\Gamma}\right)$$

$$\Gamma\Delta h = \Delta\theta_S - \Delta\theta_I' + \Delta\theta_I$$

$$Q_S = \left(\Gamma\Delta h - \sqrt{2\Gamma Q_E} + \sqrt{2\Gamma Q_E'}\right)h_0 + \frac{1}{2}\frac{\left(\Gamma\Delta h - \sqrt{2\Gamma Q_E}\right)^2}{\Gamma} - Q_E$$

$$\frac{1}{2}\Delta h^2 + \left(h_0 - \sqrt{\frac{2}{\Gamma}Q_E}\right)\Delta h - \left(\sqrt{\frac{2}{\Gamma}Q_E} - \sqrt{\frac{2}{\Gamma}Q_E'}\right)h_0 - \frac{1}{\Gamma}Q_S = 0$$

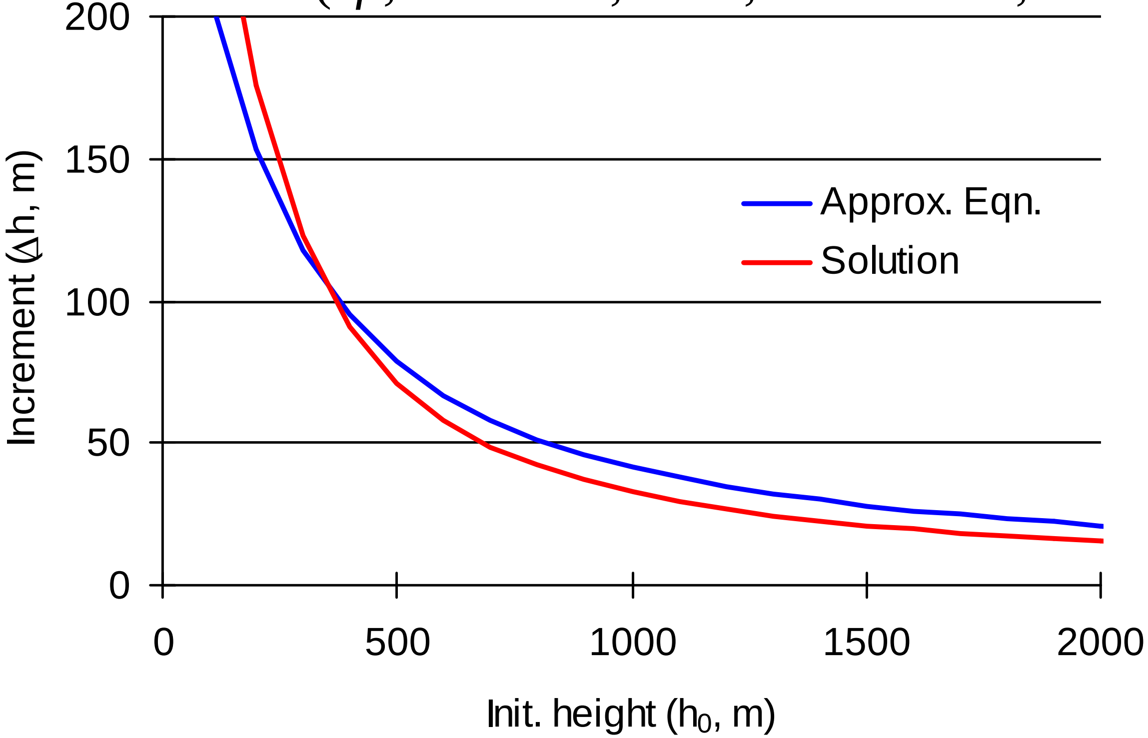
$$\Rightarrow \Delta h = -h_0 + \sqrt{\frac{2}{\Gamma}Q_E} + \sqrt{h_0^{\ 2} - 2h_0\sqrt{\frac{2}{\Gamma}Q_E'} + \frac{2}{\Gamma}Q_E + \frac{2}{\Gamma}Q_S}$$

$$\Rightarrow (h_0 + \Delta h)^2 = h_0^{\ 2} + \frac{2}{\Gamma}(Q_S + 2Q_E)$$

$$+2\left[\sqrt{\left(h_0 - \sqrt{\frac{2}{\Gamma}Q_E'}\right)^2 + \frac{2}{\Gamma}(Q_S + Q_E - Q_E')}\sqrt{\frac{2}{\Gamma}Q_E} - h_0\sqrt{\frac{2}{\Gamma}Q_E'}\right]$$

$$\sim \quad (h_0 + \Delta h)^2 \approx h_0^{\ 2} + \frac{2}{\Gamma}(Q_S + 2Q_E) = h_0^{\ 2} + \frac{2}{\Gamma}(1 + 2\varepsilon)Q_S$$

(*cf*., Tennekes, 1973; Banta *et al*., 2002), 1992) (ε=0.20~0.25; *cf*., Betts, 1973; Garratt)



Approximation agrees when

$$h_0^{\ 2} = \frac{(Q_S + Q_E)^2}{2\Gamma Q_E'}$$

$$= \frac{(1+\varepsilon)^2}{2\varepsilon\Gamma}Q_S$$

Problems

Approximation: $(h_0 + \Delta h)^2 \approx h_0{}^2 + \dfrac{2}{\Gamma}(Q_S + 2Q_E) = h_0{}^2 + \dfrac{2}{\Gamma}(1 + 2\varepsilon)Q_S$

Is this true or not?

The $\varepsilon = 0.2 \sim 0.25$ is correct?

Initial condition $\theta(z) = \theta_S + (z - h)\Gamma$ is OK?

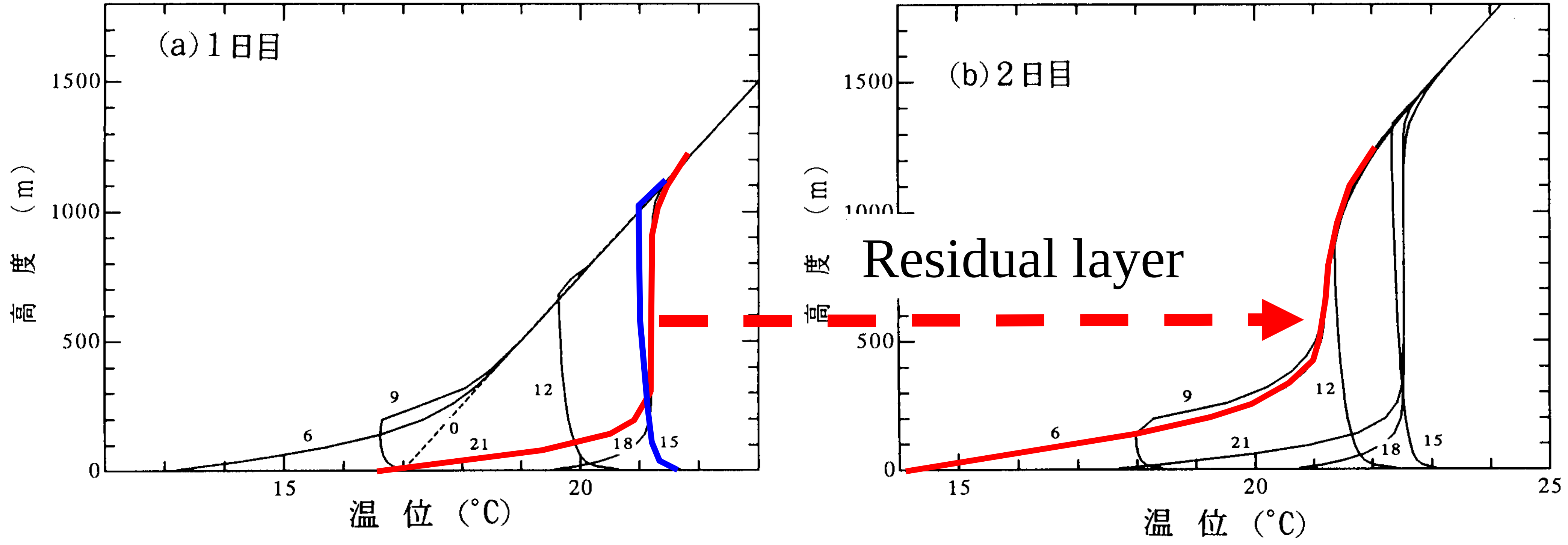


図 12.3 6時から21時までの3時間おきの温位の鉛直分布
数字は時刻（地方時）. a：1日目, b：2日目.

Kondo (1994)
(Chapter 12 written by Kimura)

ABL and Surface flux: Interactions, Relationships, and Complication

Observation: θ_S, Q_S, and h

If the initial θ(z) were known, the recurrent equation would be;

$$\theta(z)_n = \begin{cases} \theta_{S\,n} & (z \le h_n) \\ \theta(z)_{n-1} & (z > h_n) \end{cases}$$

Then, this (or $Q_{S,Obs}$) could be verified as follow;

$$Q_S = h_{n-1}\left(\theta_{S\,n} - \theta_{S\,n-1}\right) + \int_{h_{n-1}}^{h_n} \left(\theta(z)_n - \theta(z)_{n-1}\right) dz$$

Additionally,

$$Q_E = \int_{z(\theta_{S\,n} = \theta(z)_{n-1})}^{h_n} \left(\theta(z)_{n-1} - \theta(z)_n\right) dz$$

$$\varepsilon = Q_E / Q_S$$

Finally, $\left(h_0 + \Delta h\right)^2 \approx h_0{}^2 + \frac{2}{\Gamma}\left(Q_S + 2Q_E\right) = h_0{}^2 + \frac{2}{\Gamma}\left(1 + 2\varepsilon\right) Q_S$ might be verified.

Problem still remains on the initial θ(z).

Introduction of ABL observation by WPR

3-D wind vector:
Doppler velocity of
5beams

UHF wave is reflected by Turbulence.

$2d\sin\theta = n\lambda$ (Bragg scattering, *X-ray*)

$d = 0.5n\lambda$, when reflection ($\theta = 90^{o}$)

1.3GHz wave ~ $\lambda = {}^{(3E+8)}/_{(1.3E+9)} = 0.23$m

Detected turbulent scale, d ~> 0.1m

Received signal by WPR ~ $C_n^{\ 2}/l^2$

$C_n^{\ 2}$: representing turbulent structure

l: flight length (distance from WPR)

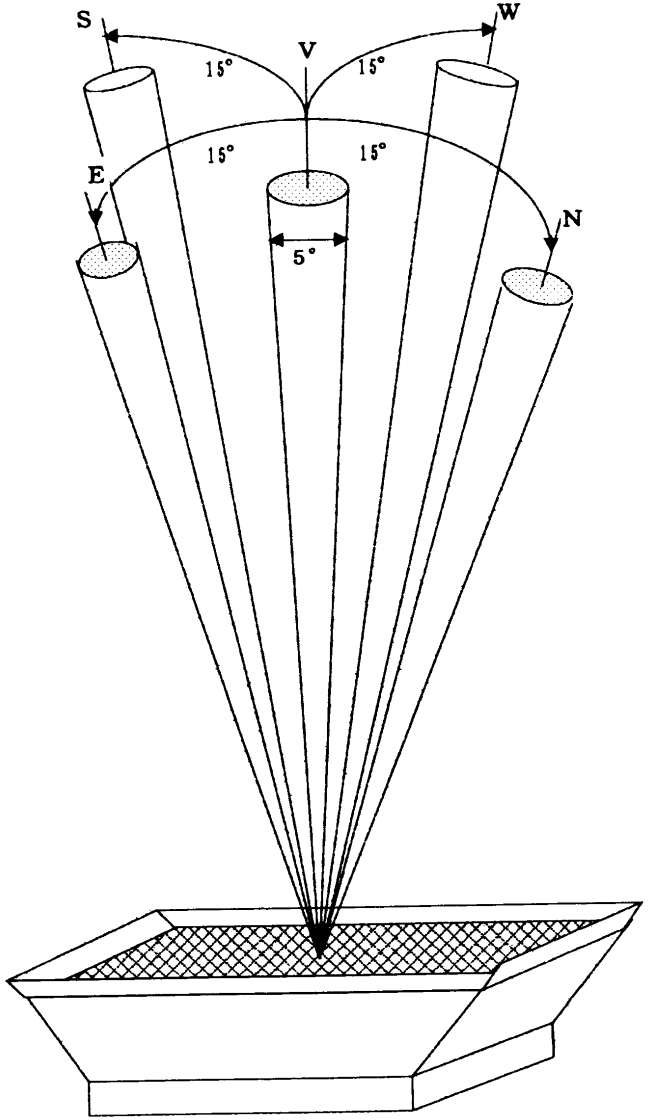


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図 1.2: ウィンドプロファイラーの模式図。

Data accessing

Spatial resolution depends on Pulse length.

$\Delta = Tp\ c/2 = 99.86\text{m}$ (Tp=666ns)

Height resolution:

$$\Delta h = \Delta \cos\alpha = \begin{cases} 99.86 & (\alpha = 0^{\circ}) \\ 96.43 & (\alpha = 15^{\circ}) \end{cases}$$

Time resolution: about 1 minute

Actually, it's 59sec or 58sec.

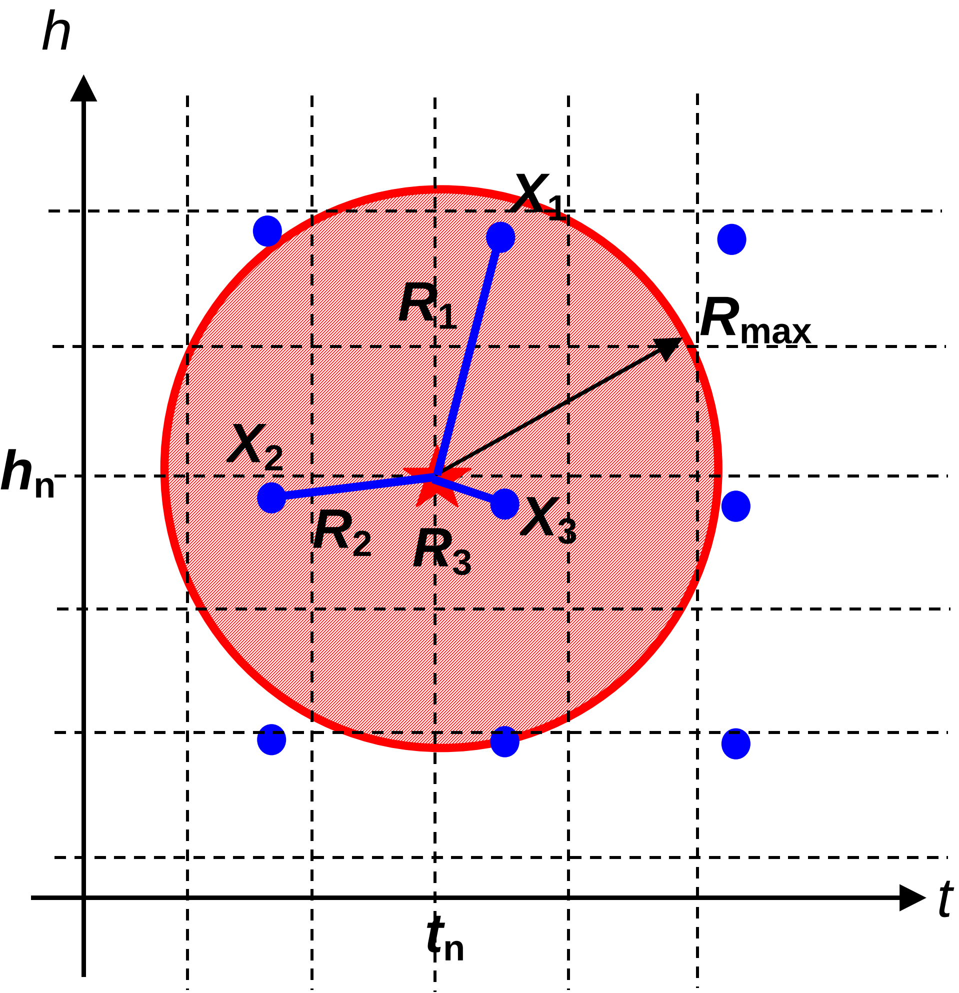
It is inconvenient to treat.

20040531000054.dat
20040531000153.dat
20040531000252.dat
20040531000351.dat
20040531000450.dat
20040531000548.dat
20040531000647.dat
20040531000746.dat

	a=0	a=15
100	100	96
200	200	193
300	300	289
400	399	386
500	499	482
600	599	579
700	699	675
800	799	771
900	899	868
1000	999	964
1100	1098	1061
1200	1198	1157
1300	1298	1254
1400	1398	1350
1500	1498	1446
1600	1598	1543
1700	1698	1639
1800	1797	1736
1900	1897	1832
2000	1997	1929

	a=0	a=15
2100	2097	2025
2200	2197	2121
2300	2297	2218
2400	2397	2314
2500	2497	2411
2600	2596	2507
2700	2696	2604
2800	2796	2700
2900	2896	2796
3000	2996	2893
3100	3096	2989
3200	3196	3086
3300	3295	3182
3400	3395	3279
3500	3495	3375
3600	3595	3471
3700	3695	3568
3800	3795	3664
3900	3895	3761
4000	3994	3857

The height difference is rather big problem to treat data, because the wind vector is computed by Combination from the 5 Doppler velocities. Not-constant time interval is also bit problem *e.g. to draw Graphs*.



$$X(t,h) = \left(\frac{X_1}{R_1^{\,2}} + \frac{X_2}{R_2^{\,2}} + \frac{X_3}{R_3^{\,2}} \right) \Big/ \left(\frac{1}{R_1^{\,2}} + \frac{1}{R_2^{\,2}} + \frac{1}{R_3^{\,2}} \right)$$

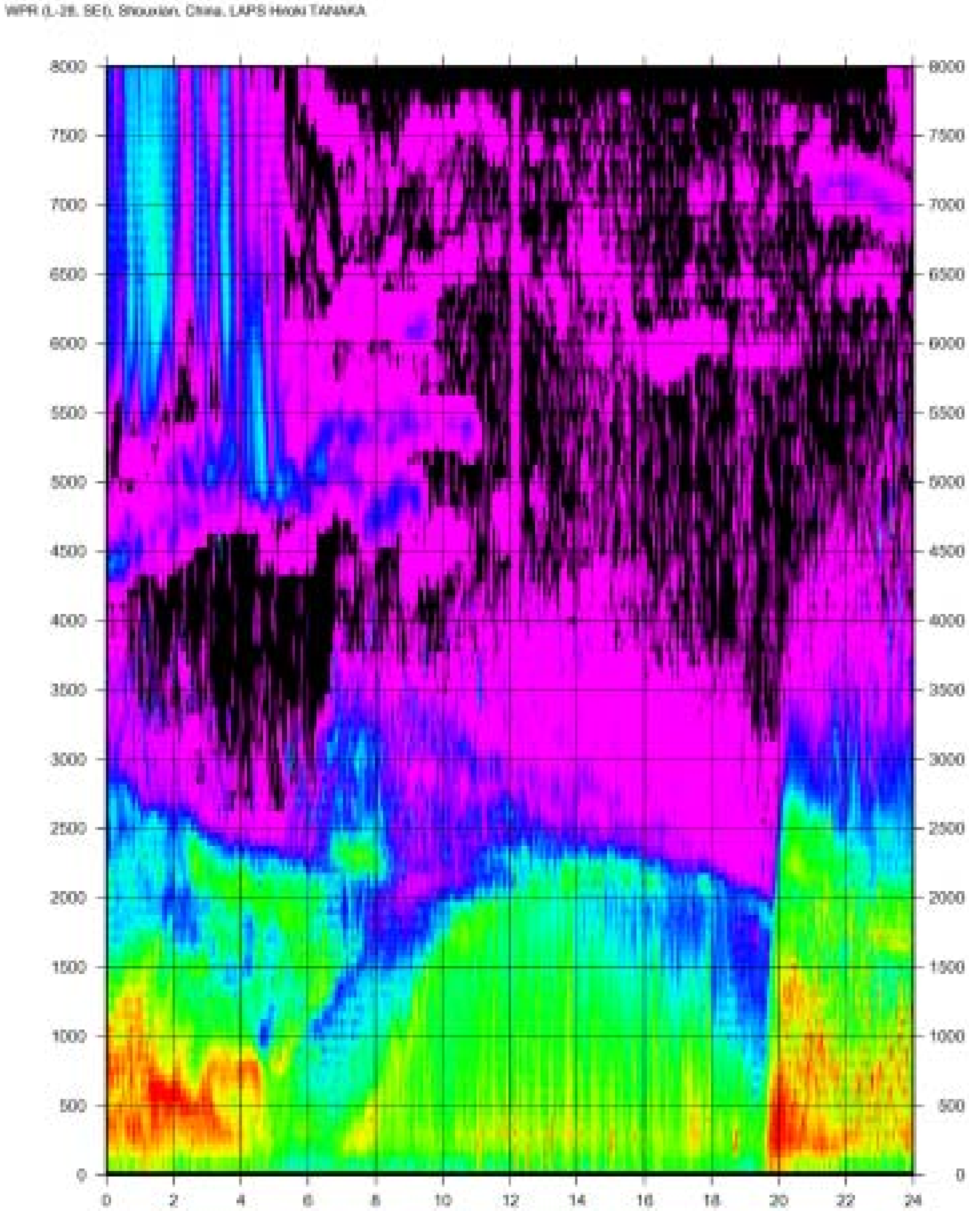
For one of trials,
Data is accessing under following;

Δh=50m, Δt=0.5minute

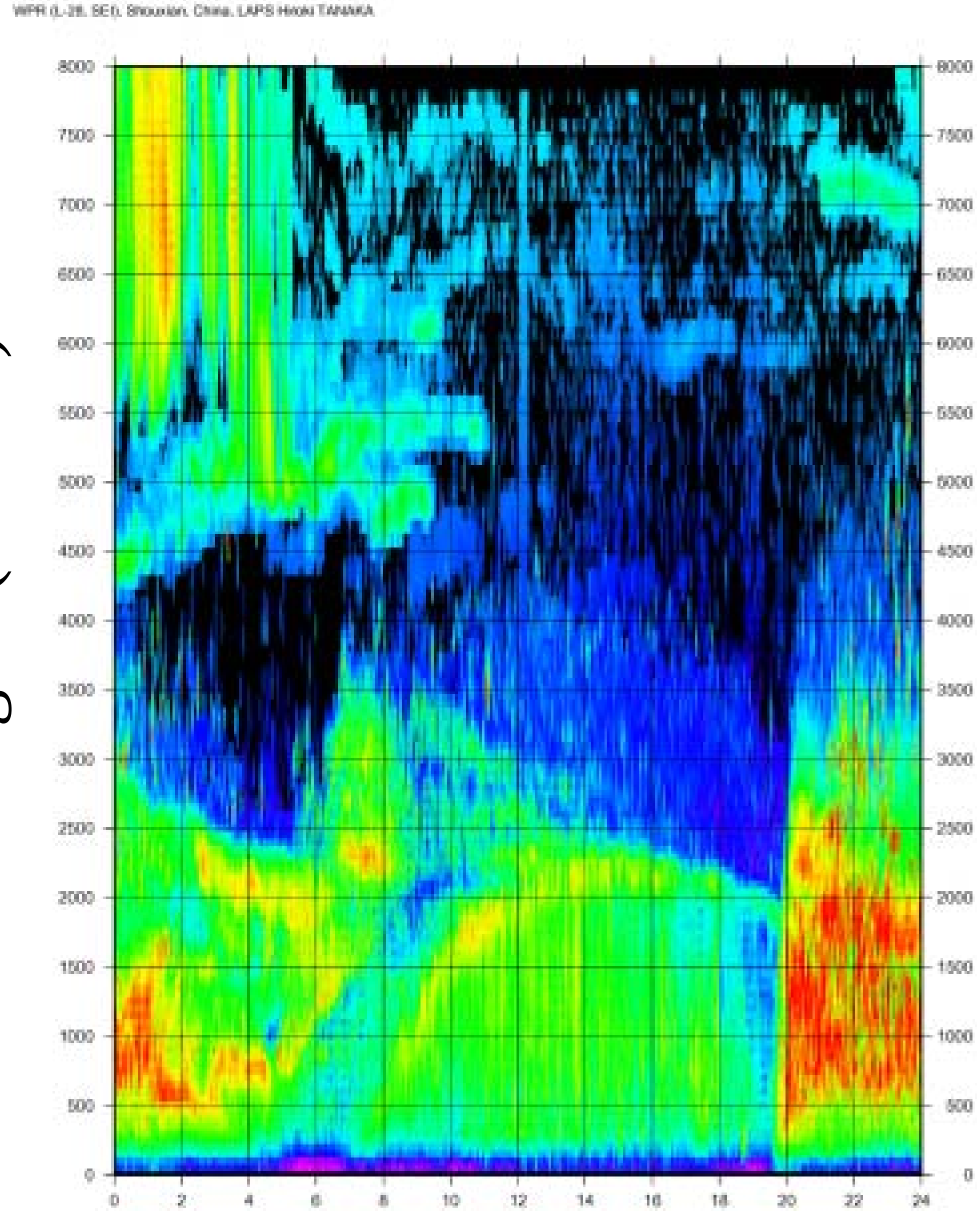
$R\mathrm{max}^2$=1.5 [(100m)^2+(minute)^2]

Raw echo → Normalized echo by

WPR signal ~ C_n^2/l^2 flight length (ref.=1km)



Height (0~8km)



Time (00:00~24:00)

WPR (L-28, SE1), Shouxian, China, LAPS Hiroki TANAKA

WPR (L-28, SE1), Shouxian, China, LAPS Hiroki TANAKA

2004/05/31

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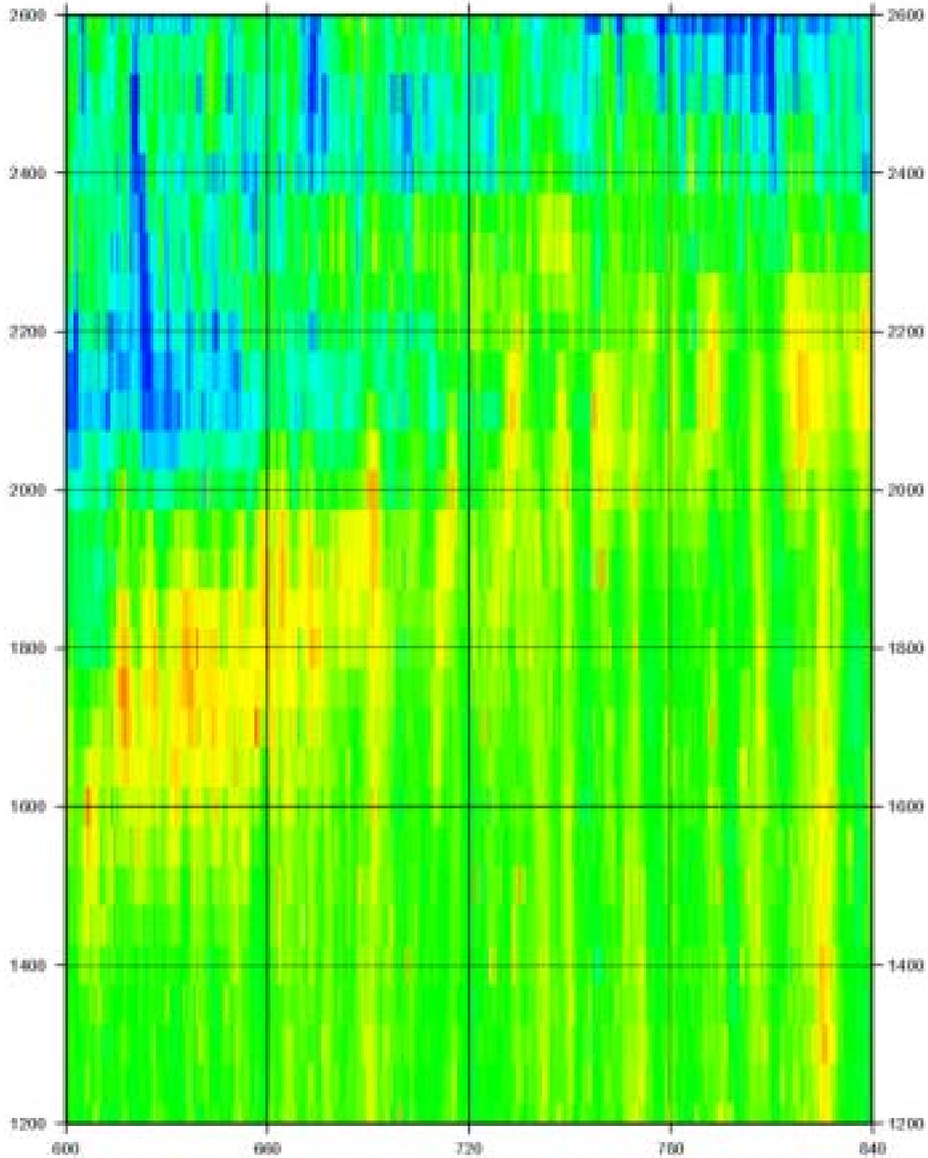

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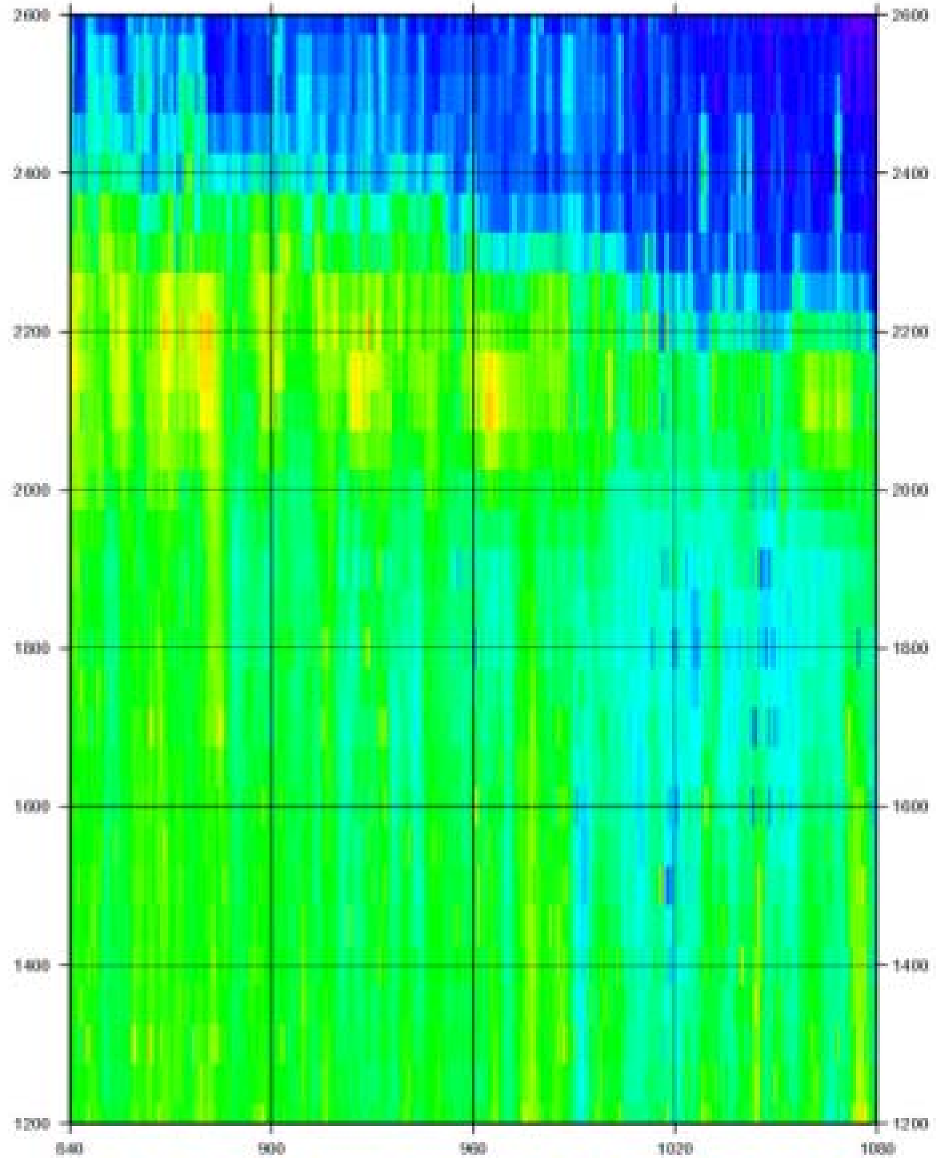

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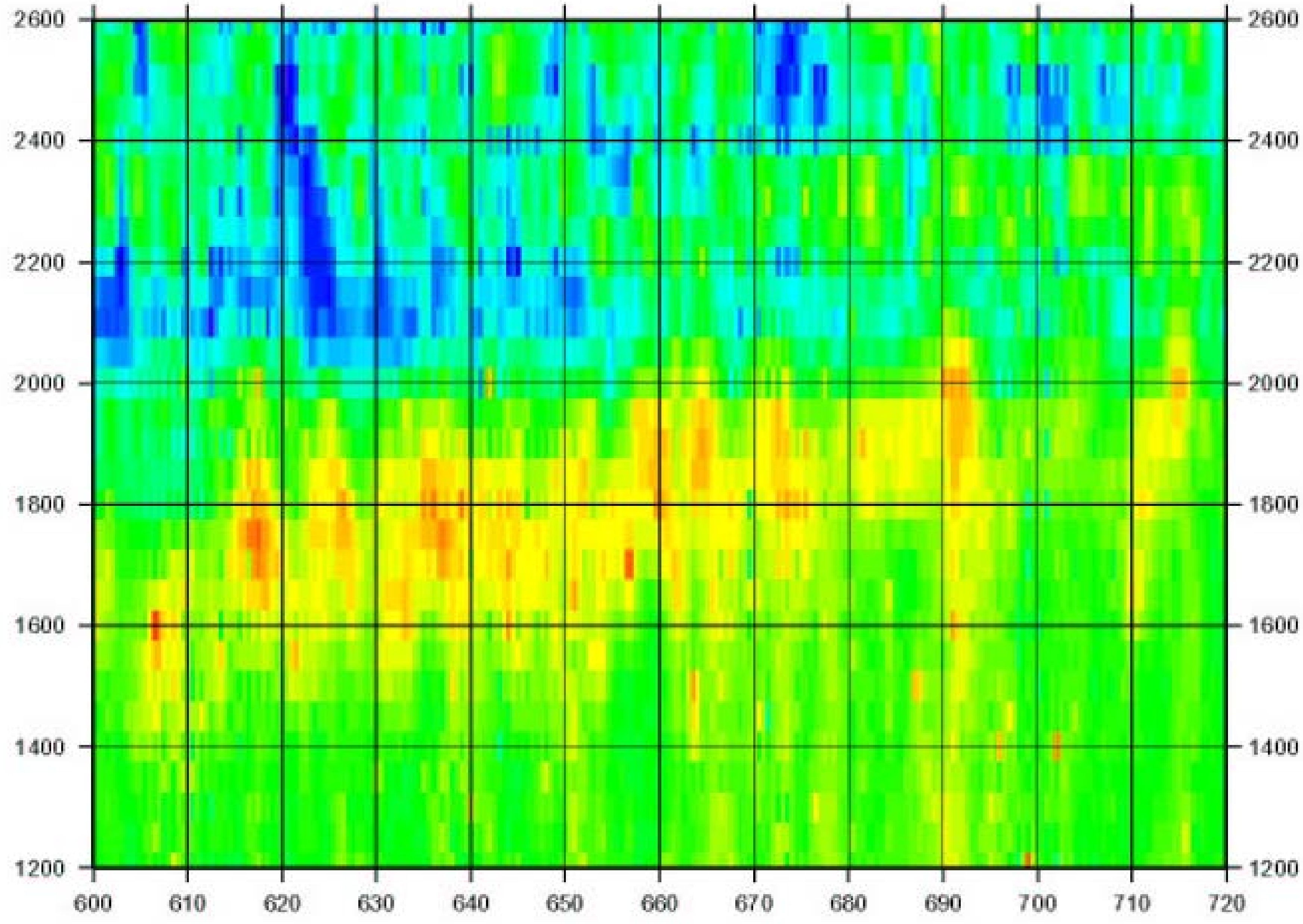

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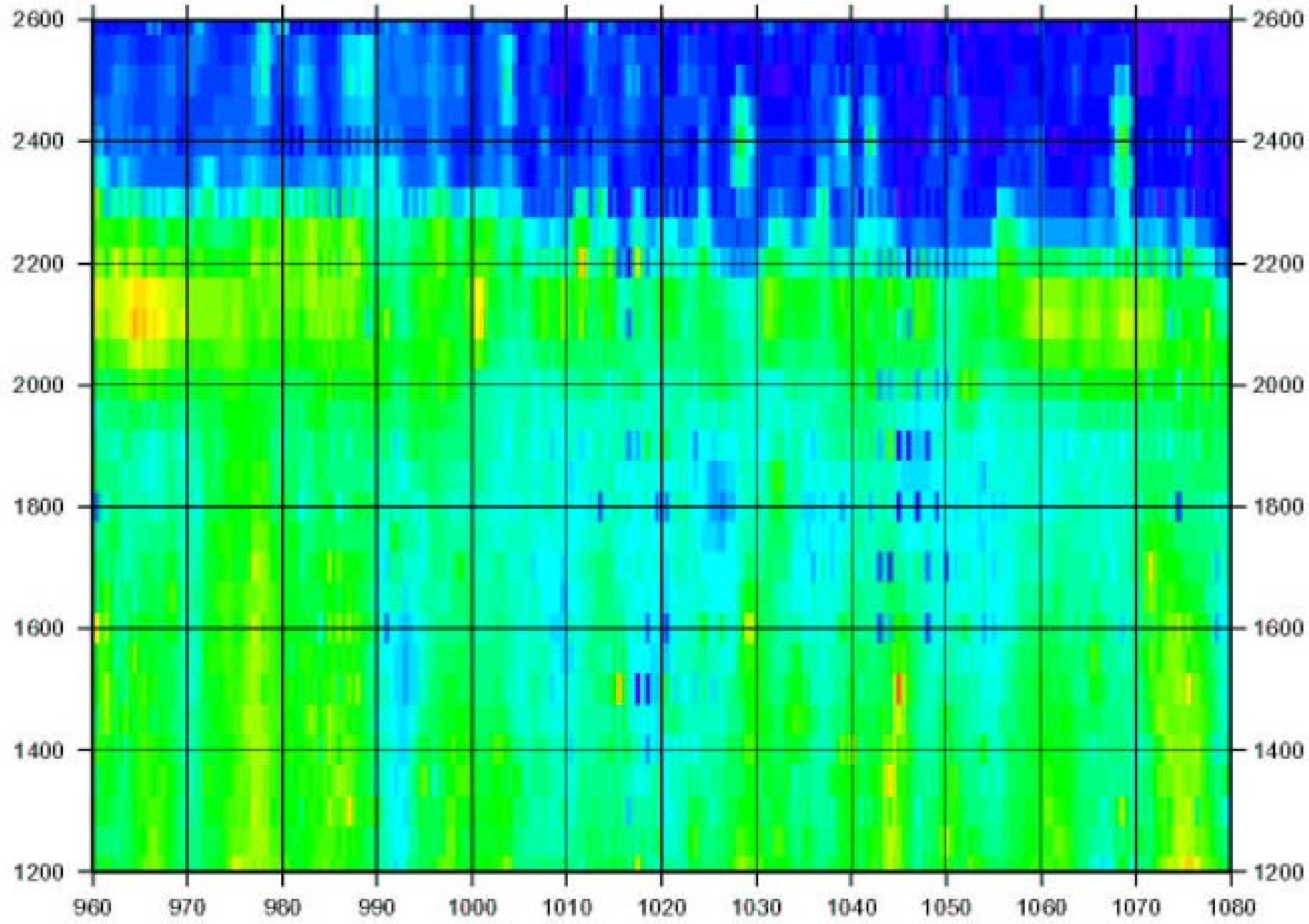
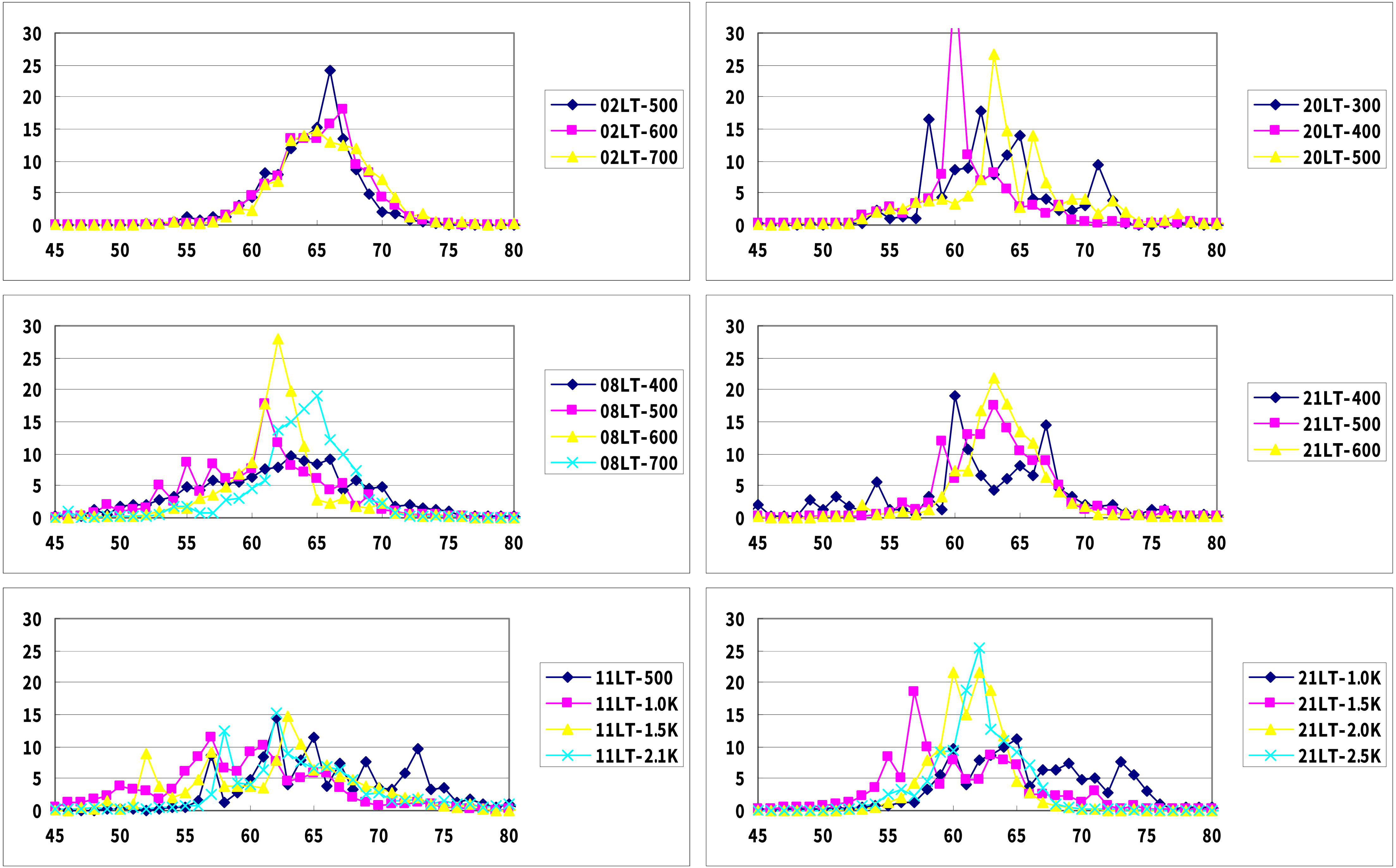


WPR (L-28, SEI), Shouxian, China, LAPS Hiroki TANAKA

Doppler Spectra



To be continued

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