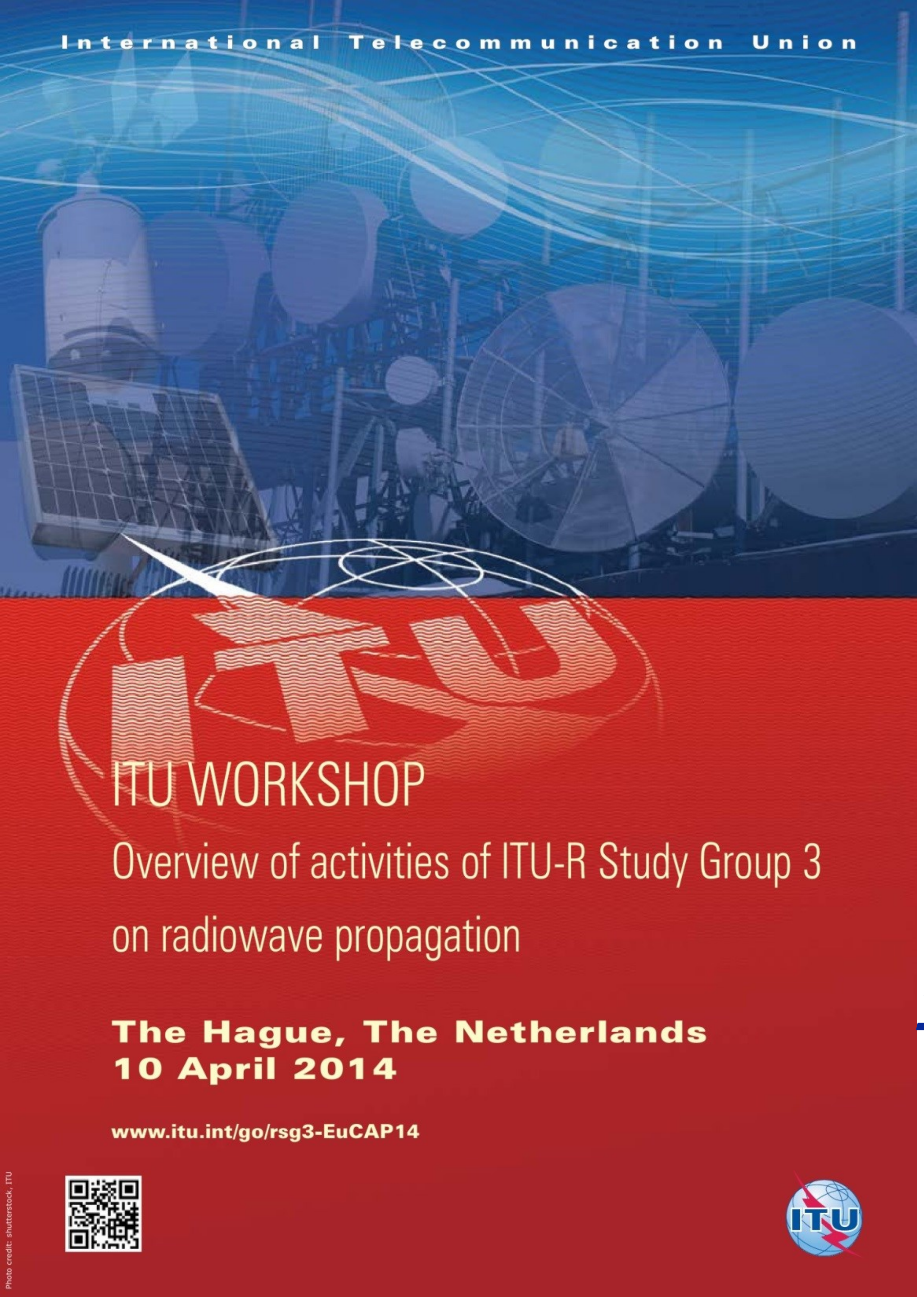
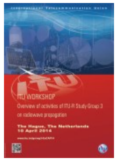


ITU WORKSHOP
Overview of activities of ITU-R
Study Group 3 on radiowave propagation:
(The Hague, 10 April 2014)

Point-to-point and Earth-space propagation

Carol Wilson
Chairman,
ITU-R Working Party 3M

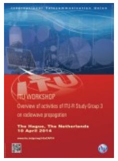
CSIRO, Australia



Working Party 3M

Propagation prediction methods for

- Fixed (terrestrial) services
- Satellite services (except trans-ionospheric effects)
- Interference and coordination between services



Radio services as defined by the ITU

- Aeronautical mobile
- Aero'l radionavigation
- Amateur
- Broadcasting
- Broadcasting-satellite
- Earth-exploration satellite
- Fixed (terrestrial)
- Fixed satellite
- Inter-satellite
- Land mobile
- Maritime mobile
- Maritime radionavigation
- Meteorological aids
- Meteorological satellite
- Mobile satellite
- Radioastronomy
- Radiolocation
- Radionavigation
- Space operations
- Space research
- Standard frequency and time

Propagation prediction methods

- Designers and manufacturers benefit from common standards for prediction of performance.
  ⇨ *Prediction of wanted signal levels.*

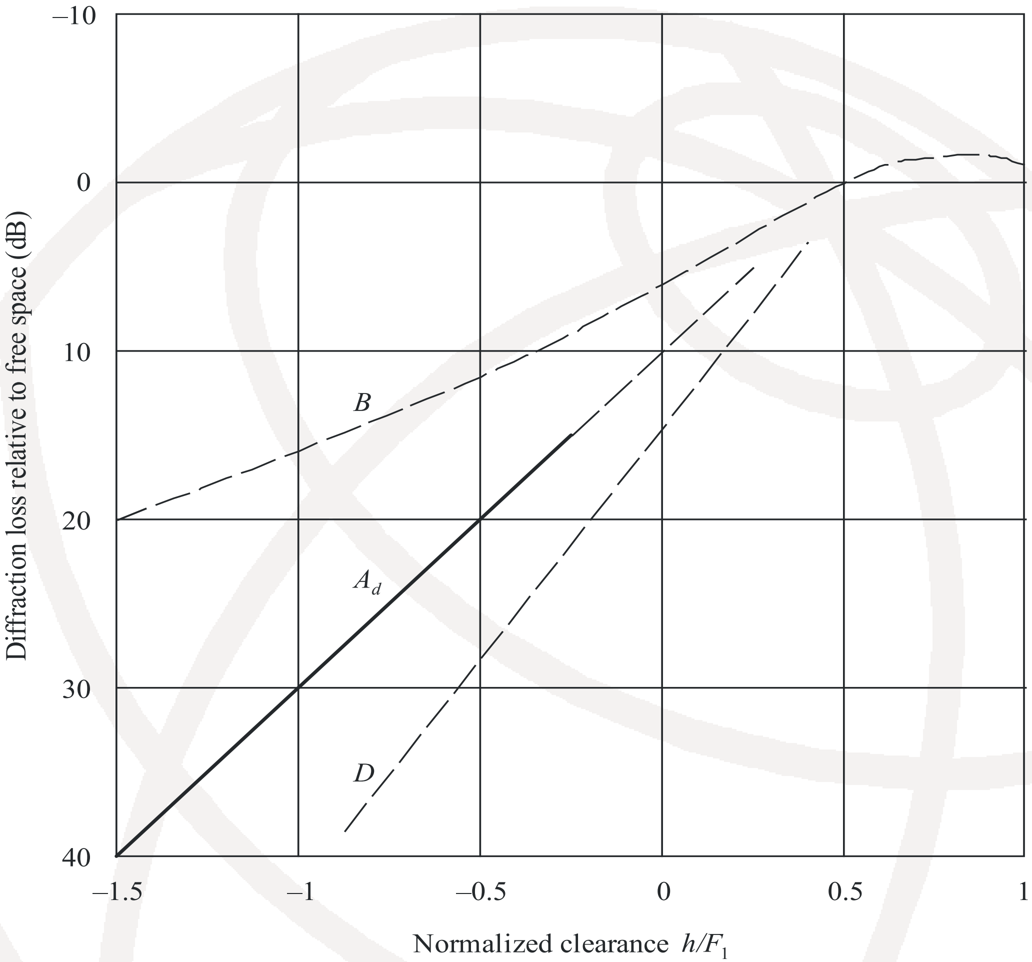
- Useful radio spectrum crowded; new technologies compete with existing users.
  ⇨ *Prediction of unwanted signal levels.*

- Radio systems in one country can cause interference to those in another country.
  ⇨ *Calculation of coordination area.*

Recommendation P.530: point-to-point paths

- Propagation loss and enhancement:
  - attenuation by atmospheric gases and precipitation;
  - diffraction based on path clearance;
  - fading and enhancement due to multipath;
  - effects on multiple hops – clear-air and rain fading.
- Cross-polarisation effects
  - Long-term statistics of cross-polarisation due to rain or in clear-air conditions
  - Frequency scaling
- Prediction of outage in digital systems
- Angle, frequency and space diversity
- Angle of arrival variation
- Techniques for alleviating multipath

Simple diffraction model in Rec. P.530



B: theoretical knife-edge loss curve
D: theoretical smooth spherical Earth loss curve, at 6.5 GHz and $k_e = 4/3$
A_d: empirical diffraction loss based on equation (2) for intermediate terrain
h: amount by which the radio path clears the Earth's surface
F_1: radius of the first Fresnel zone

Diffraction loss (>15 dB) can be approximated by

$$A_d = -20\, h / F_1 + 10 \qquad \text{dB}$$

F_1 is the radius of the first Fresnel ellipsoid:

$$F_1 = 17.3 \sqrt{\frac{d_1 d_2}{f d}} \qquad \text{m}$$

Where

h is height difference (m) between most significant path blockage and the path trajectory

f is frequency (GHz)

d is path length (km)

d_1 and d_2 are distances (km) from the terminals to the path obstruction.

Future directions for Recommendation P.530

- Extend clear-air and rain prediction methods to 105 GHz
- Improve multipath fading prediction methods for short, highly-reflective terrestrial paths
- Rain attenuation model:
  - Use of full rainrate distribution; move towards physical basis.
- Urban clutter and total attenuation
- Fade dynamics

Input needed:

Attenuation and rain data from a wide range of climates, especially tropical

Testing at higher frequencies

Recommendation P.618 – satellites

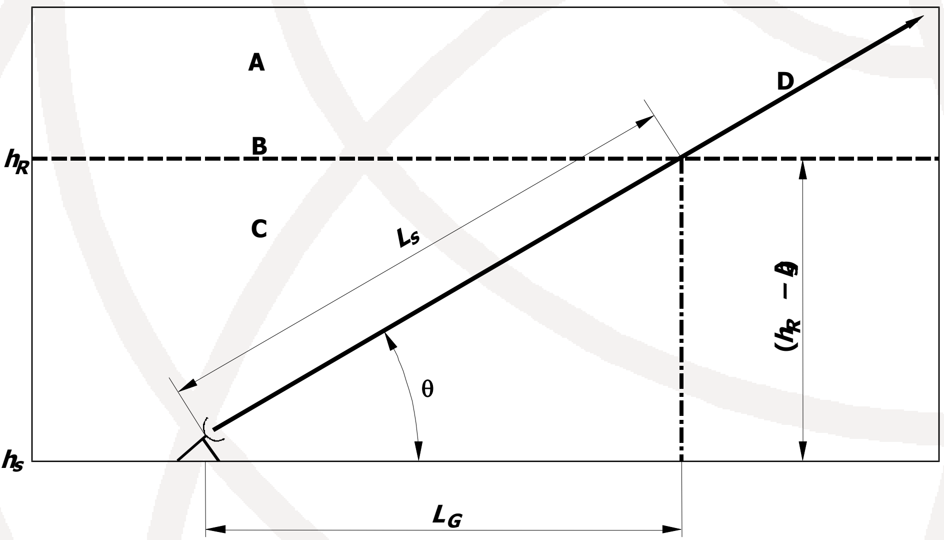
- Propagation loss:
  - attenuation by atmospheric gases, precipitation and clouds;
  - diversity improvement in rain;
  - decrease in antenna gain due to wave-front incoherence;
  - scintillation and multipath effects;
  - total attenuation due to multiple effects (rain, clouds, scintillation)
  - attenuation by sand and dust storms (mentioned).
- Cross-polarisation effects
  - Long-term statistics of cross-polarisation due to rain
  - Frequency, polarisation scaling
- Propagation delay
- Angle of arrival variation
- Statistics for non-GSO paths

Rain attenuation model in Rec. P.618

Step 4: **Obtain the rainfall rate, $R_{0.01}$, exceeded for 0.01% of an average year.**

Step 5: **Obtain the specific attenuation, g_R, using the frequency-dependent coefficients in Recommendation ITU-R P.838 and the rainfall rate by using:**

$$g_R = k\,(R_{0.01})^{a} \qquad \text{dB/km}$$



A: frozen precipitation
B: rain height
C: liquid precipitation
D: Earth-space path

Step 6: **Calculate the horizontal reduction factor, $r_{0.01}$, for 0.01% of the time:**

$$r_{0.01} = \frac{1}{1 + 0.78\sqrt{\dfrac{L_G\,\gamma_R}{f}} - 0.38\left(1 - e^{-2L_G}\right)}$$

Step 7: **Calculate the vertical adjustment factor, $v_{0.01}$, for 0.01% of the time:**

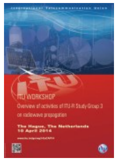
$$\nu_{0.01} = \frac{1}{1 + \sqrt{\sin\theta}\left(31\left(1 - e^{-(\theta/(1+\chi))}\right)\dfrac{\sqrt{L_R\,\gamma_R}}{f^2} - 0.45\right)}$$

Step 8: **The effective path length is:**

$$L_E = L_R\, n_{0.01} \qquad \text{km}$$

Step 9: **The predicted attenuation exceeded for 0.01% of an average year is obtained from:**

$$A_{0.01} = g_R\, L_E \qquad \text{dB}$$



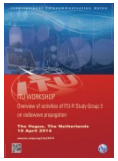
Future directions for Recommendation P.618

- Extend prediction methods to 105 GHz
- Extend to higher time percentages – particularly for VSATs
- Improve methods for low elevation angles
- Rain attenuation model:
  - Use of full rainrate distribution; move towards physical basis.
  - Ongoing testing of alternative models.

Input needed:

Attenuation and rain data from a wide range of climates, especially tropical

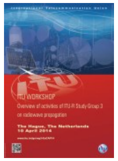
Testing at higher frequencies, lower angles, higher time percentages



Rec. P.452 - Interference between terrestrial stations

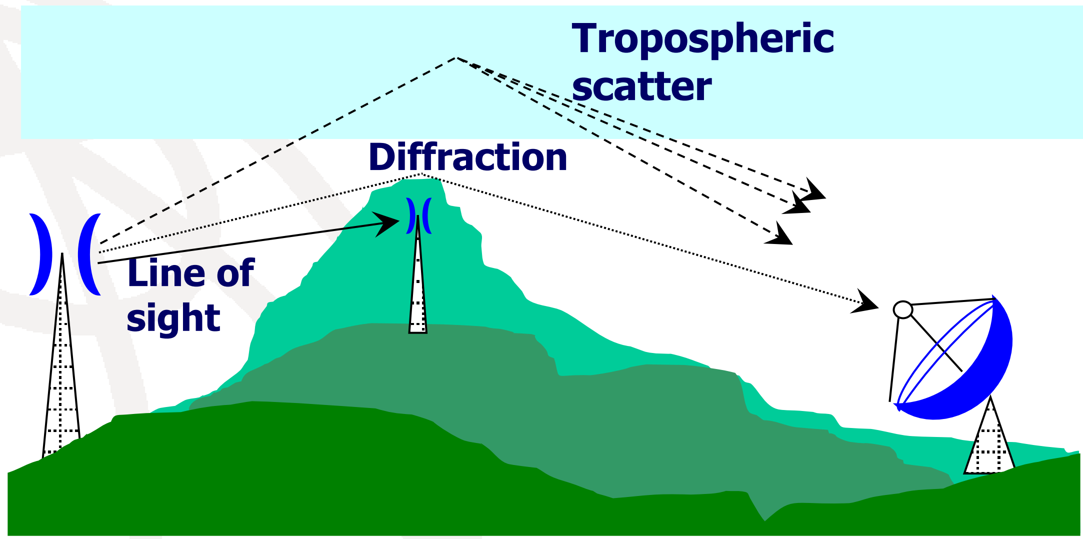
Calculations apply above 100 MHz

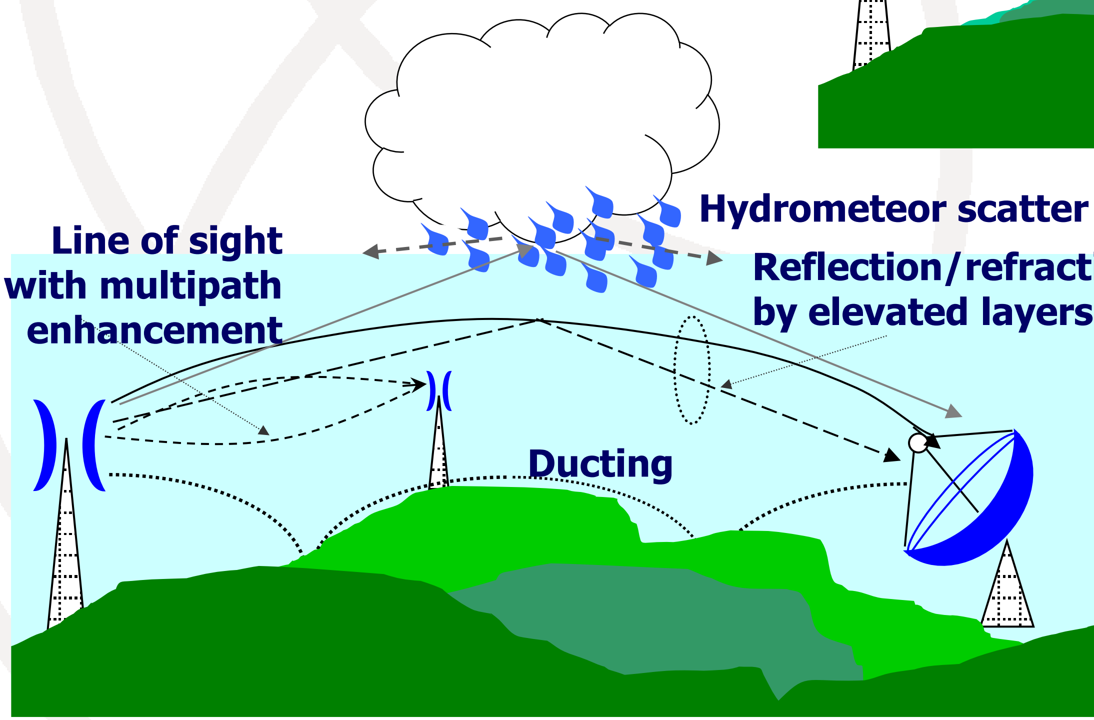
- Prediction of *wanted* signal estimates largest loss/weakest signal due to rare attenuating events.
- Prediction of *unwanted* signal estimates lowest loss/ strongest signal due to rare enhancing events.
  - Long-term mechanisms
  - Short-term mechanisms
  - Meteorological information (rain, atmospheric conditions)
  - Terrain and path type (land, water, mixed)
  - Calculates maximum loss for given small percentage of time due to combination of mechanisms



Interference mechanisms

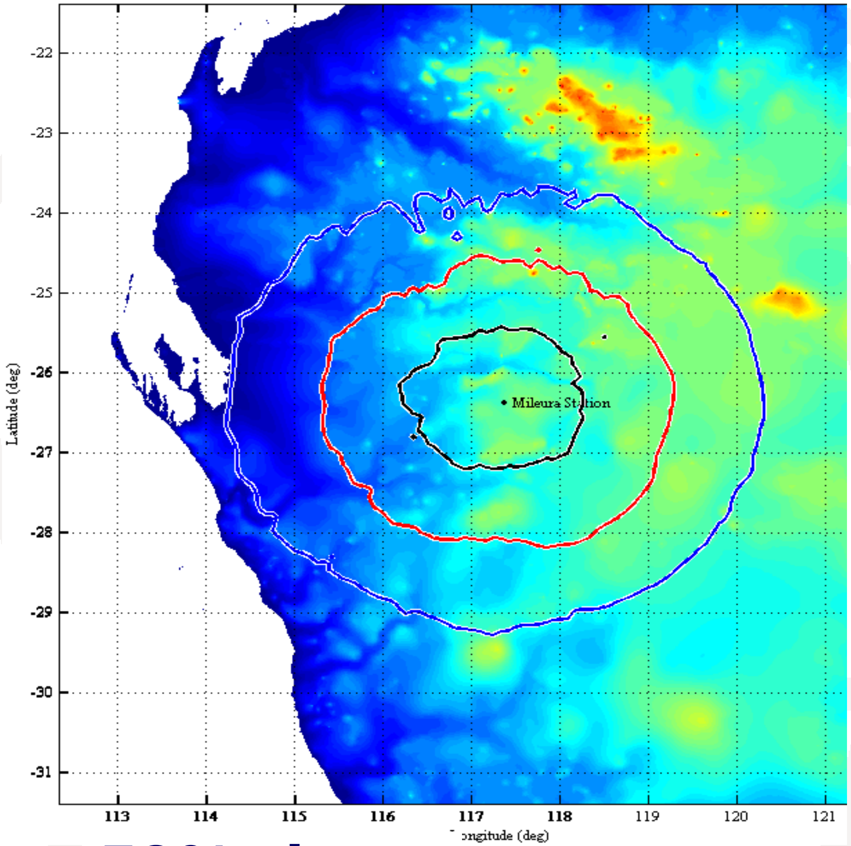
Long-term effects ⇨



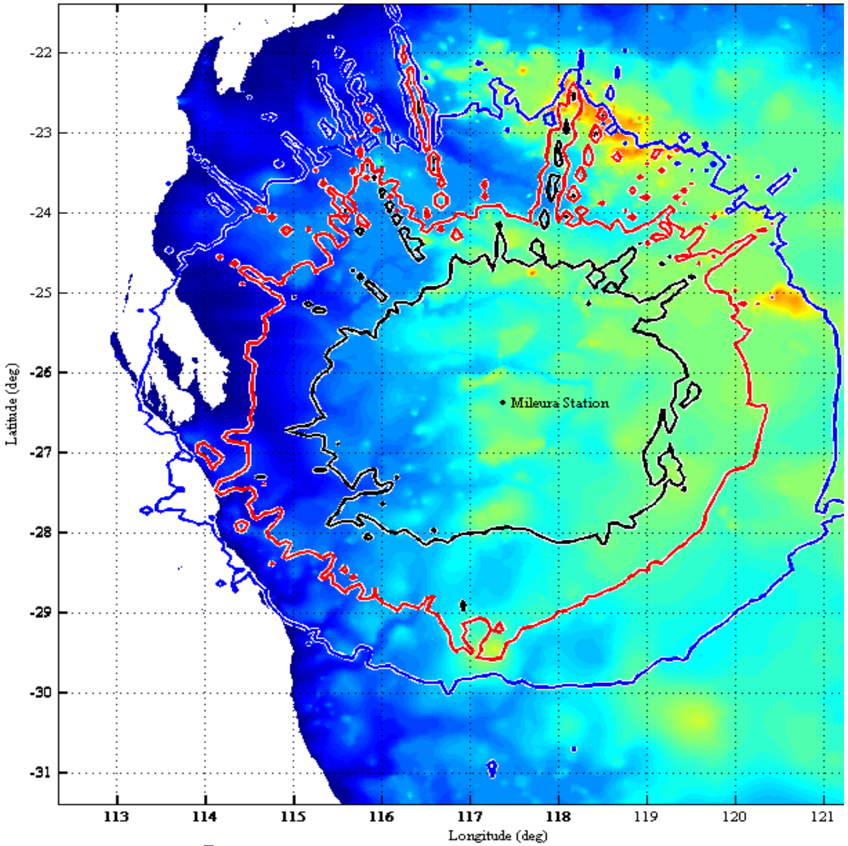


⇦ Short-term effects

Comparison of results



50% time



2% time

Transmitter: -16 dBm/Hz, 1 GHz, 90 m height

Receiver height 30 m

Black: VLBI threshold (-204 dBm/Hz)

Red: spectral line (-223 dBm/Hz)

Blue: continuum (-240dBm/Hz)

Future directions for Recommendation P.452

- Extend frequency range up to 105 GHz
- Extend time percentage down to 0.001%
- Make better use of digital climate data
- Reduce difficulty in hydrometeor scatter model
- Better prediction for urban interference paths and short paths in general
- Characterise clutter or low antenna heights

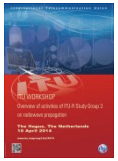
Input needed:

Testing of sub-models at higher frequencies, lower time percentage

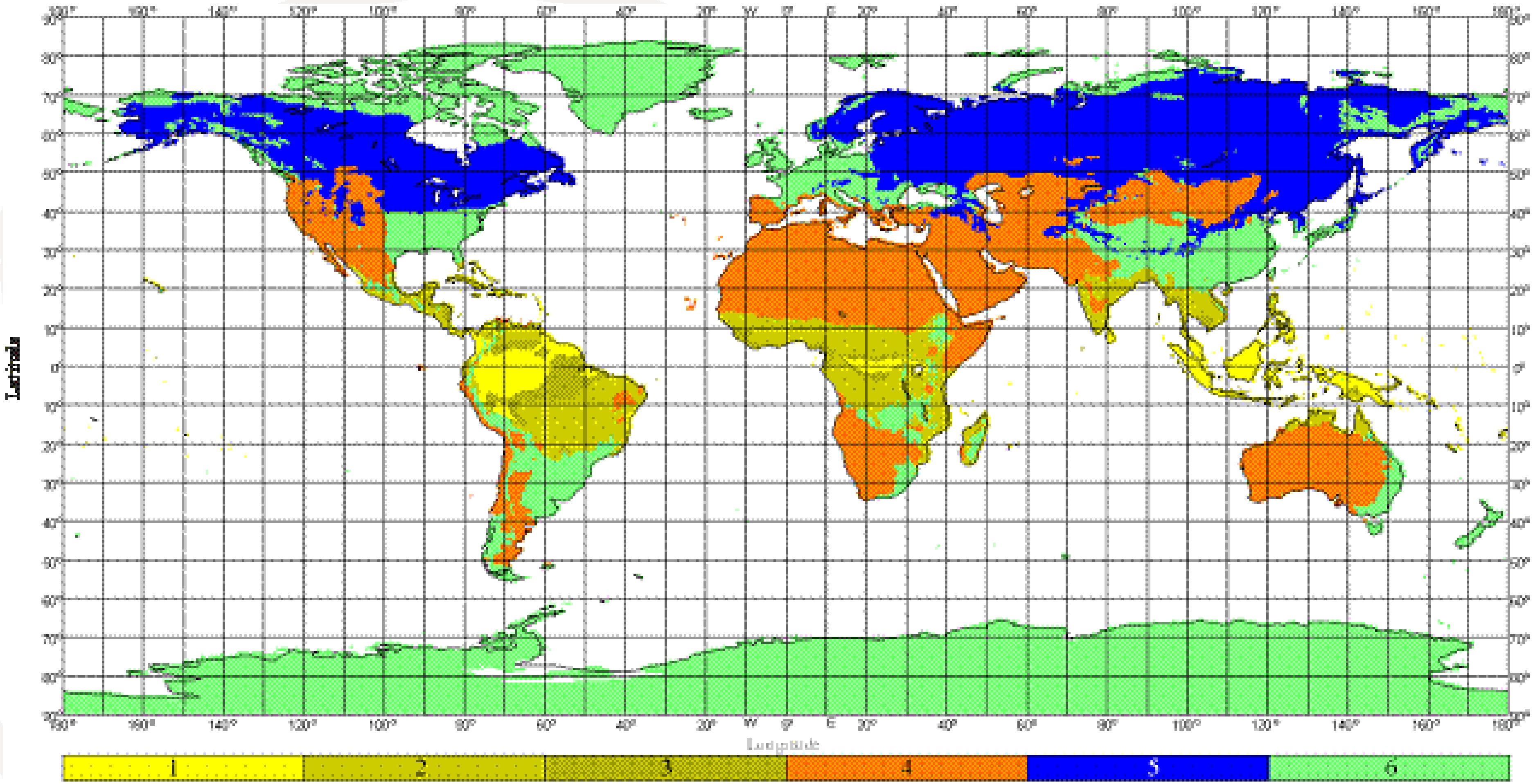
Better models for urban and short path prediction

Recommendation P.2001 terrestrial

- Frequency range 30 MHz to 50 GHz
- Time percentage effectively 0.001% to 99.999%
- Useful for system design and interference
- Distance range ~ 3 km to 1000 km
- Modules:
  - Sub-model 1. Propagation close to the surface of the Earth: diffraction, non-ducting clear-air effects and precipitation fading.
  - Sub-model 2. Anomalous propagation: ducting and layer reflection.
  - Sub-model 3. Propagation via atmospheric turbulence: troposcatter and precipitation fading for the troposcatter path.
  - Sub-model 4. Propagation via sporadic-E reflection.
- Final section on combination of output of four modules including for Monte Carlo simulations



Climate zones for troposcatter in Rec. P.2001



Future directions for Recommendation P.2001

- Similar for Earth-space paths?
- ????

Input needed:

Feedback on usability

Validation examples

Available on ITU-R website

Input values, intermediate and final results to test software implementations

Selected components of:

- P.530
- P.618

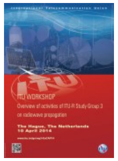
As well as WP 3J Recommendations:

- P.676
- P.838
- P.840

- More required – input welcome

Conclusions

- Recommendations are not static! Use latest version.
- Recommendations are not perfect! Challenge them.
- Input needed from research community!
- Your participation is welcome!



Thank you for your attention.

Acknowledgement:
Dr Hajime Suzuki, CSIRO, for interference maps