Effects of Mountain Waves on the Initiation and Development of Convective Clouds

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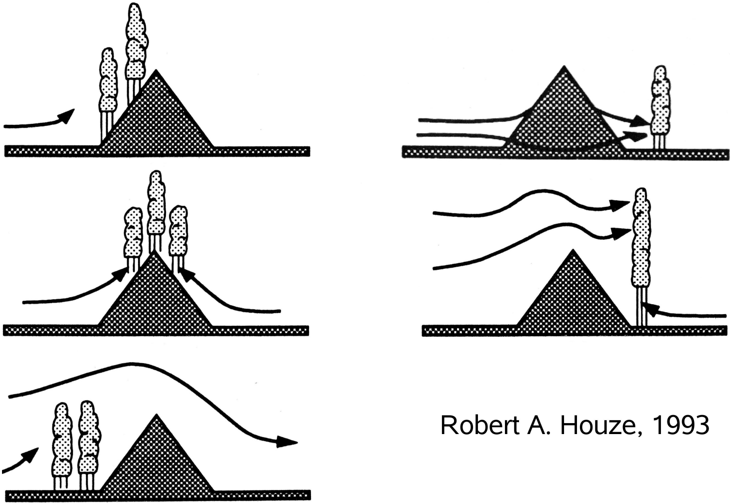
March 6th, 2007

Orographic Effects on Convective Clouds



Robert A. Houze, 1993

Linear Theory of Two-Dimensional Mountain Waves

The 2D Mountain Wave Equation

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial z^2}\right)\psi + \left(\frac{N^2}{U^2} - \frac{1}{U}\frac{d^2U}{dz^2}\right)\psi = 0$$

Topography

$$\tau(x) = \frac{h}{1 + (x/a)^2}$$

For $U(z) = U$ and $N(z) = N$

$$\psi(x,z) = U \int_{-\infty}^{\infty} \tilde{\tau}(k)\, e^{imz}\, e^{ikx}\, dk$$

Adiabatic Flow

$$\theta'/\theta_0 = -\frac{N^2}{Ug}\psi$$

Solution for $U/N \ll a \Longleftrightarrow$ Hydrostatic Approximation

$$\theta'/\theta_0 = -(N^2/g)ha\,\frac{a\cos(N/U\,z) - x\sin(N/U\,z)}{a^2 + x^2}$$

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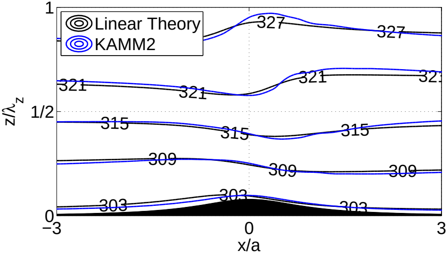
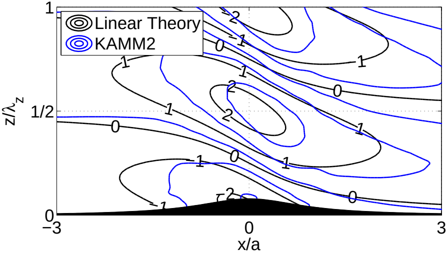
Validation of KAMM2-Simulations with Linear Theory

$N = 0.012\,\text{Hz}$, $U = 12\,\text{m/s}$, $h = \pm 500\,\text{m}$, $a = 20\,\text{km}$, $Nh/U = 0.5$, $\lambda_z = 2\pi U/N \approx 6\,\text{km}$

Potential Temperature in K



Potential Temperature Perturbation in K



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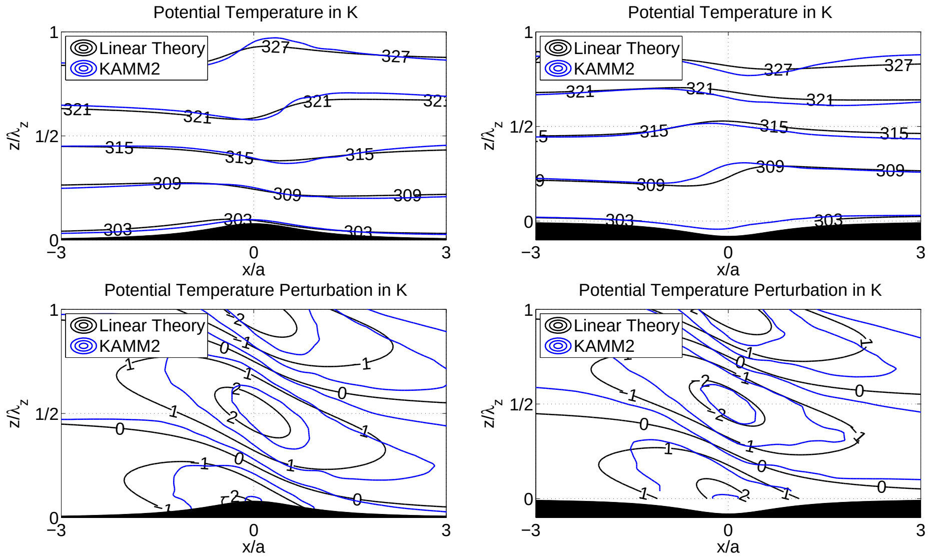
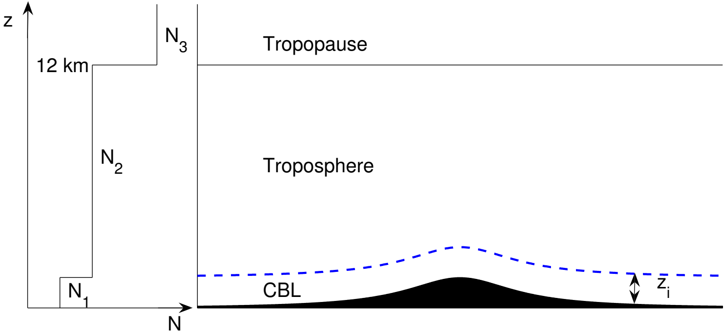
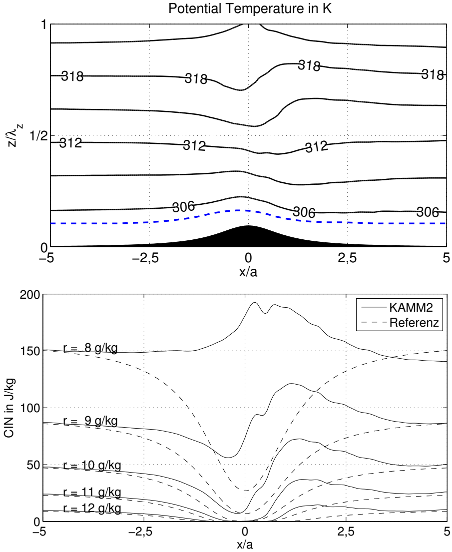


Two-Dimensional Mountain Waves in 3-Layered Flow



CIN from KAMM2-Simulations of Three-Layered Flow

$N = 0.01\,\text{Hz}$, $U = 10\,\text{m/s}$, $h = \pm 600\,\text{m}$, $a_u = 20\,\text{km}$, $Nh/U = 0.6$, $\lambda_z = 2\pi U/N \approx 6\,\text{km}$



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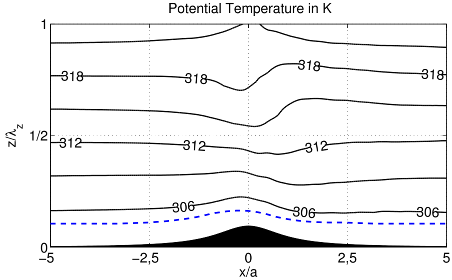

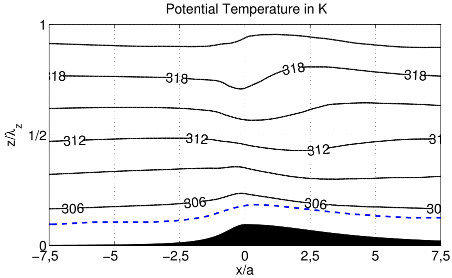

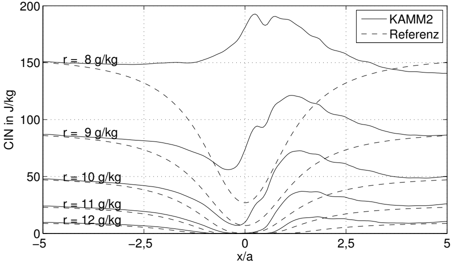

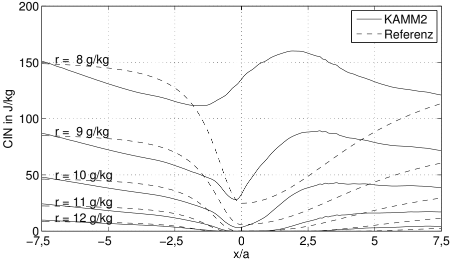

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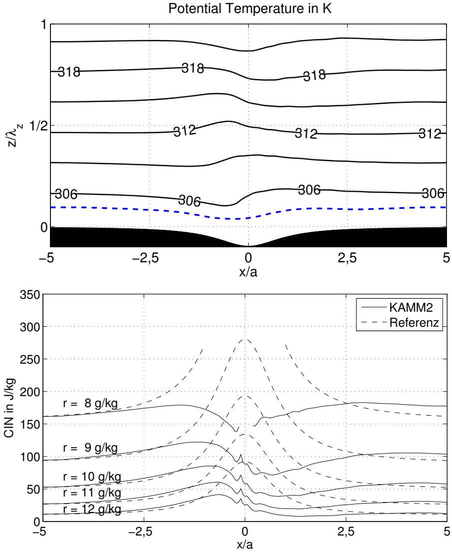

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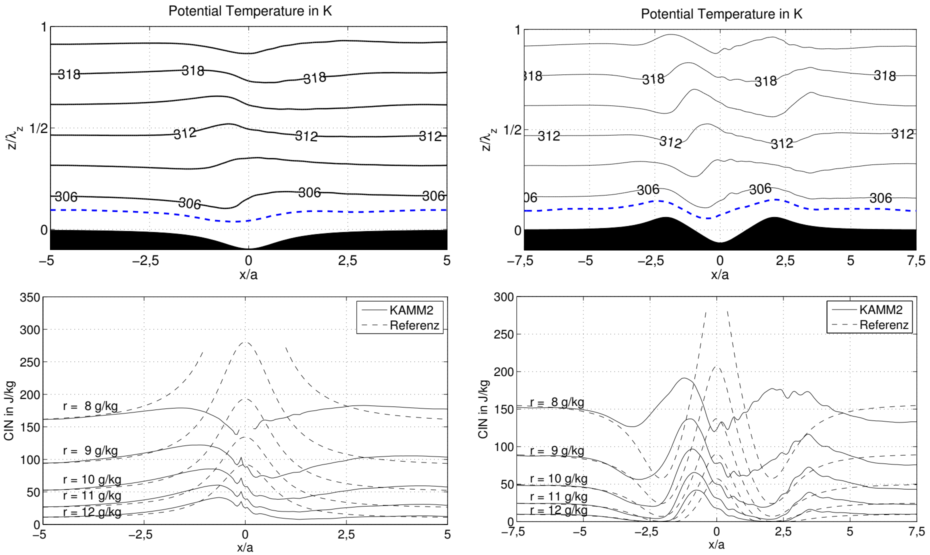
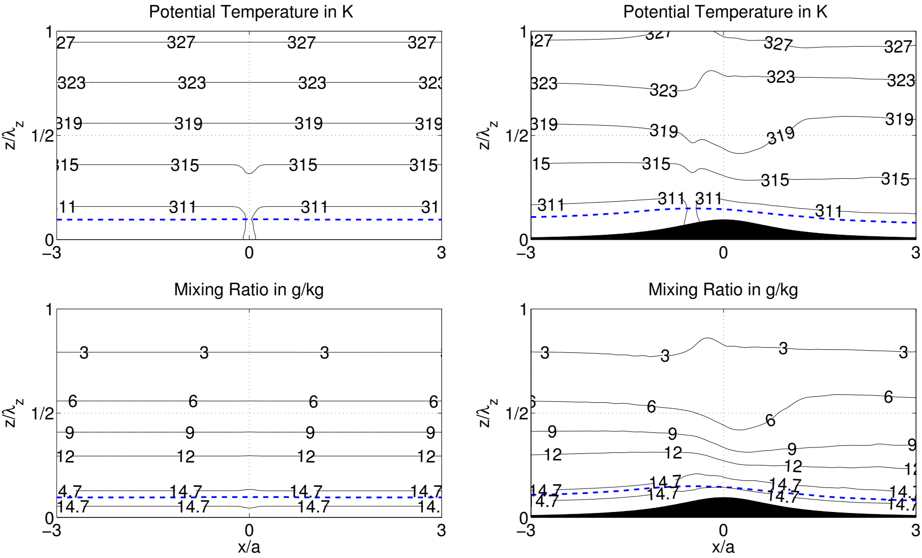


Effects of Mountain Waves on Convective Clouds, P. 1

$N = 0.01$ Hz, $U = 10$ m/s, $h = 600$ m, $a = 20$ km   CAPE $= 2\,500$ J/kg



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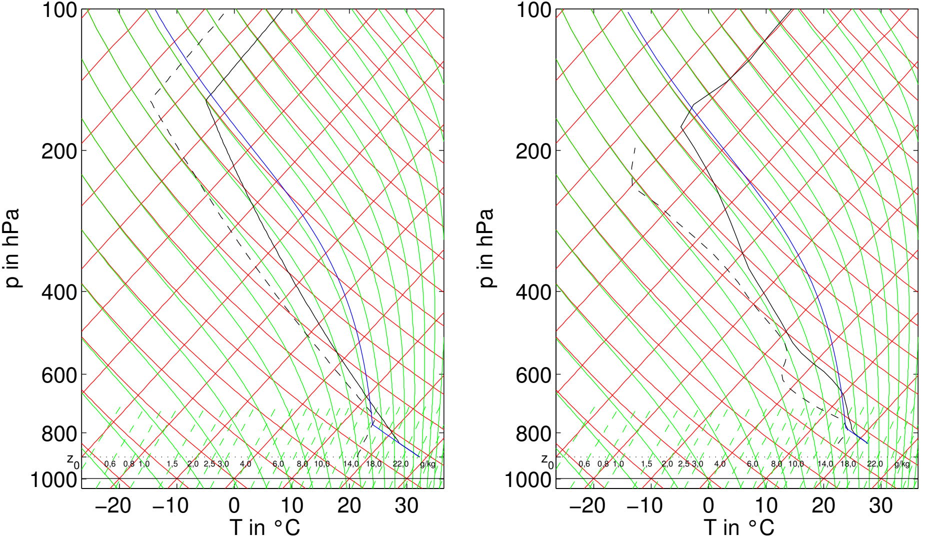
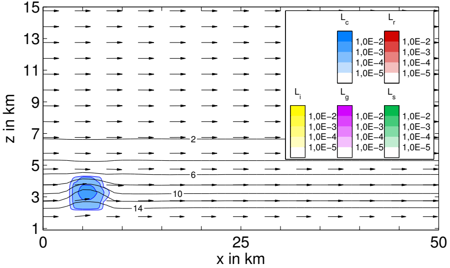
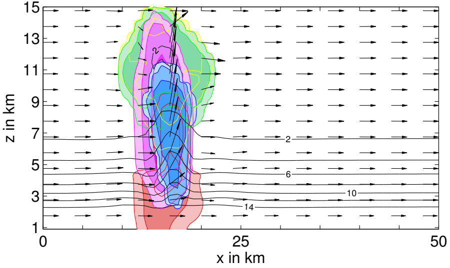


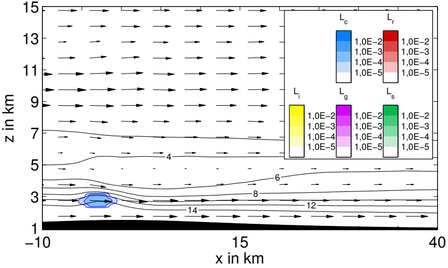
Effects of Mountain Waves on Convective Clouds, P. 1

Flat Terrain





Mountain Ridge



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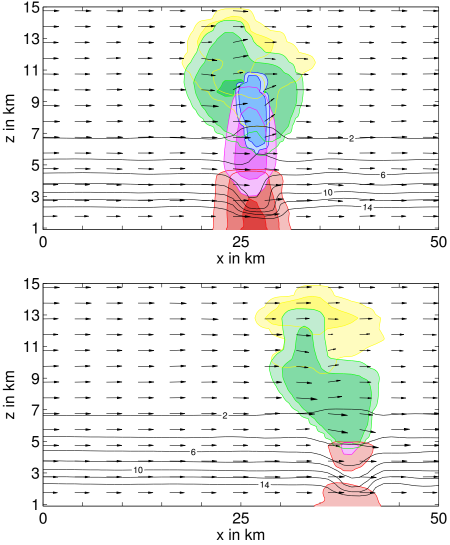
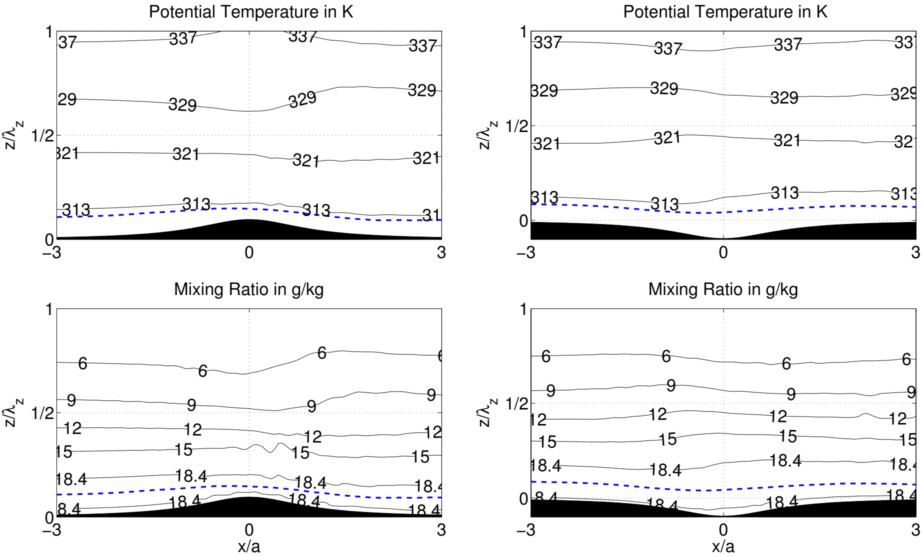


Effects of Mountain Waves on Convective Clouds, P. 2

$N = 0.012\,\mathrm{Hz}$, $U = 12\,\mathrm{m/s}$, $h = \pm 600\,\mathrm{m}$, $a = 20\,\mathrm{km}$ CAPE = 1 250 J/kg



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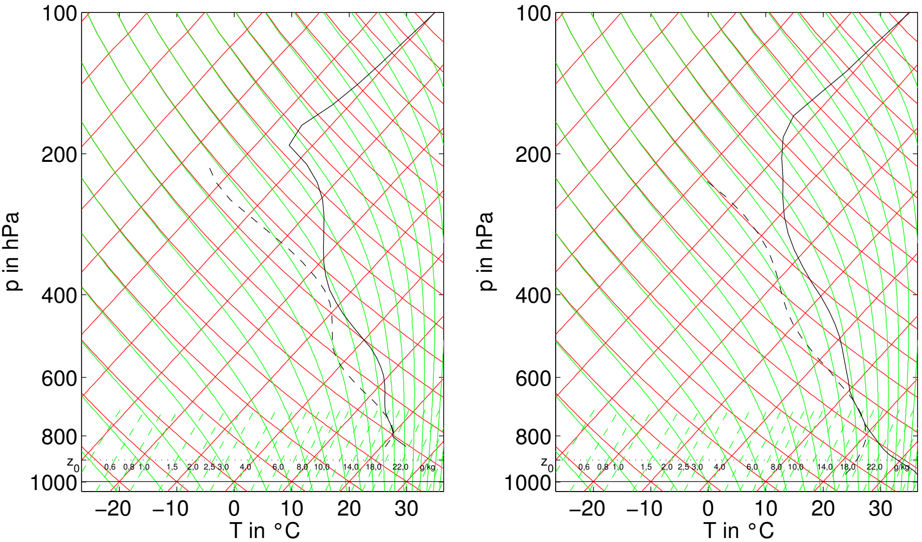
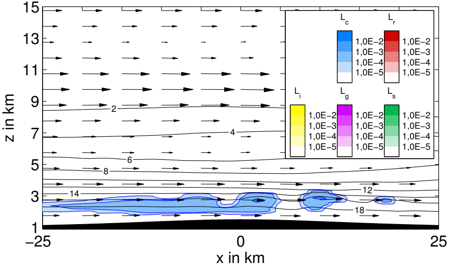
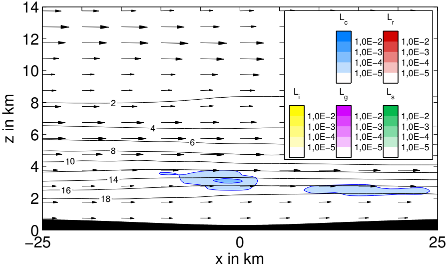


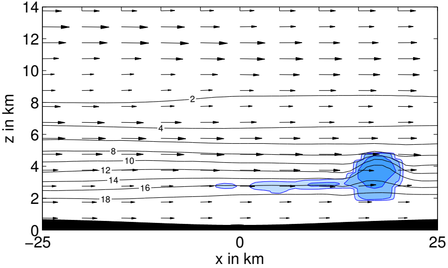
Effects of Mountain Waves on Convective Clouds, P. 2

Mountain Ridge



Valley





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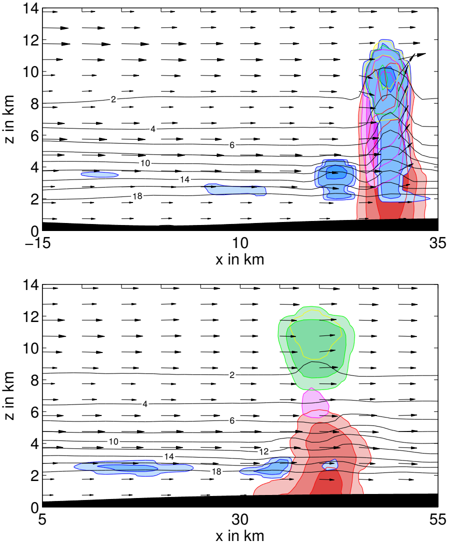
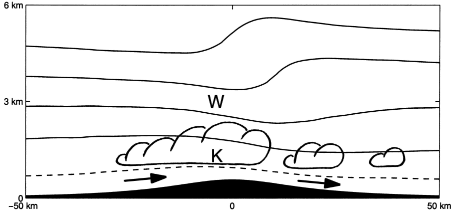
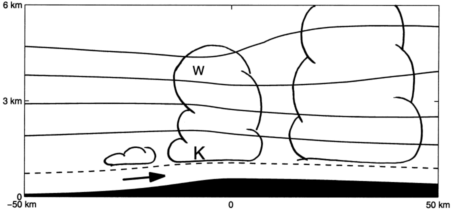


Summary

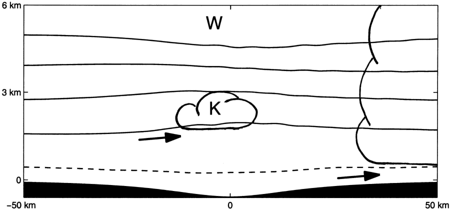
Symmetric Ridge



Asymmetric Ridge or Flat Terrain



Symmetric Valley



Summary

- While convective inhibition decreases over a mountain ridge in absence of mountain waves due to low wind speed, convective inhibition increases especially in the lee of mountain ridges in a mountain wave flow induced by a higher wind speed.
- In weak to moderate CAPE regimes, mountain wave flow tends to suppress deep convection over a mountain ridge and enhance deep convection downstream of a valley.

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