Critical Need for Quantitative Images of Lower Tropospheric Methane Content Along Continental Slopes (Offshore) and In Tundra (Onshore) to Track Methane Clathrate Instability

As A Precursor of Accelerated Global Warming

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Summary of IPCC climate Change 2001 Report for 21st Century

- Assuming that increases in atmospheric green house gases are the major influence on global warming and land-ice additions to the sea for the next century, the estimates for sea level rise by year 2100 range from 0.09-0.87 meters (0.3-2.8 ft.), or 0.90-8.70 mm/year.
  - In a 2007 report, the Intergovernmental Panel on Climate Change, the international group of scientists charged with reviewing, validating and summarizing the latest research concluded that the warming of the climate system is unequivocal and that it is 90 percent certain that human-generated greenhouse gases account for most of the warming in the past 50 years.

What Current Satellites are Measuring

- The University of Colorado has used TOPEX/ POSEIDON satellite data to show (http://sealevel.colorado.edu/) that from 1998-2008, sea level rose by 34 mm (±3-4 mm), which is an annual rate of 3.4 mm/yr,
  - In one century, that would be 0.34 m, or 1.1 ft.

The IPCC Assumptions Leave Out Some Other Possibilities

- Tipping Point 1: The albedo effect is the uncovering of soil, vegetation, and water on land and sea that was previously covered by brighter ice and snow before they melted.
  - This warms the surface faster than additional green-house atmospheric gases warm it.
- Tipping Point 2: Methane clathrates (water ice with interstitial methane that has a freezing temp. a few degrees higher than water ice) act to store methane gas on the ocean bottom along continental slopes off-shore and in high-latitude tundra regions on-shore.
  - Methane from the clathrate itself is released to ocean water and air.
  - Methane gas is released from sedimentary units no longer impeded by methane clathrate.

How Do These Tipping Points Affect the Rate of Global Warming?

- The albedo effect is several times faster at warming high-latitude regions than is the increased rate of CO_2 from man-made emissions.
  - This is the most likely the cause of recently observed accelerated melting of high-latitude multi-year sea ice.
- Destabilization of methane clathrates is an even greater accelerant of global warming.
  - Around 15,000 years ago, ice cores show that the surface temperatures of both Antarctica and Greenland increased approximately 16 º C in two decades, or 0.8 º C/year (Bluneir et al, 1998, Nature; Blunier and Brook, 2001, Science).
  - We must map changes in methane content of the lower troposphere over time.

Some Have Modeled Methane Clathrate Destabilization

- D. D Harvey and Zhen Huang (JGR, 1995) modeled methane clathrate stabilization and in worst case, they say global warming increases would only be increased by 10-25%.
- Jean-Francois Lamarque of NCAR (Boulder, CO) in Gephycialal Res. Letters of 2008 also modeled low impact of such destabilizaiton.
- Methane clathrates are too little known and too complex to trust our lives to models alone.
- We MUST use remote sensing to monitor for clathrate destabilization along continental slopes and arctic tundra regions.

Methane Clathrate Mound on Sea Floor

How Can Methane Be Monitored from Satellite?

- Reflective IR band, 3.314 micrometer band, 7.7 micrometer band are available.
  - Reflective IR band not good for sea surface because of specular reflection of calm water.
  - The 7.7 micrometer band has not been able to observe methane in the lower Troposphere.
  - The 3.314 micrometer band could most likely be used to monitor methane is the lower Troposphere, but has not been tested from space.
    - My student, Willard Barnhouse, found it could image methane from the MAS (MODIS Airborne Simulator) airborne sensor.

Three Components of Thermal IR Radiation from a Gas Plume

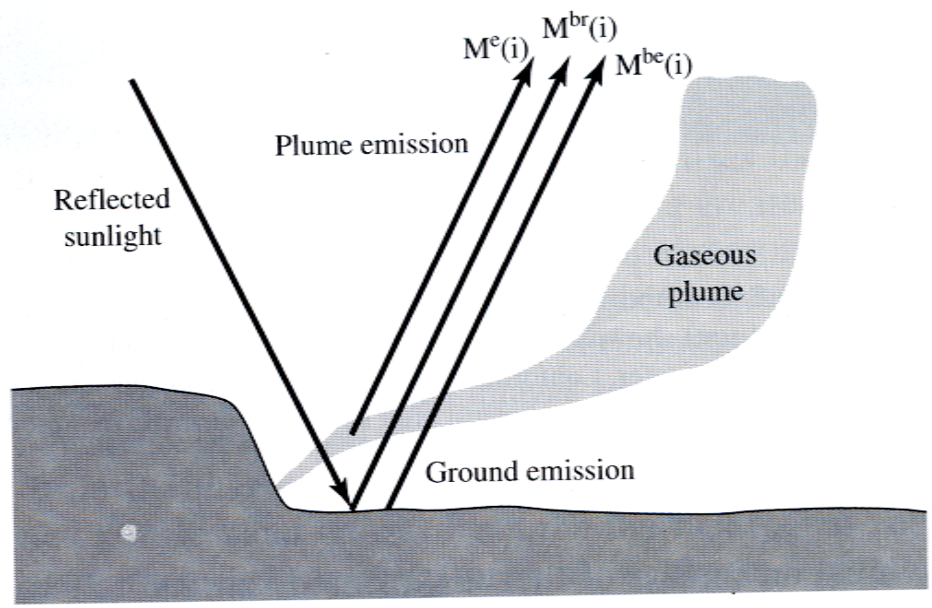
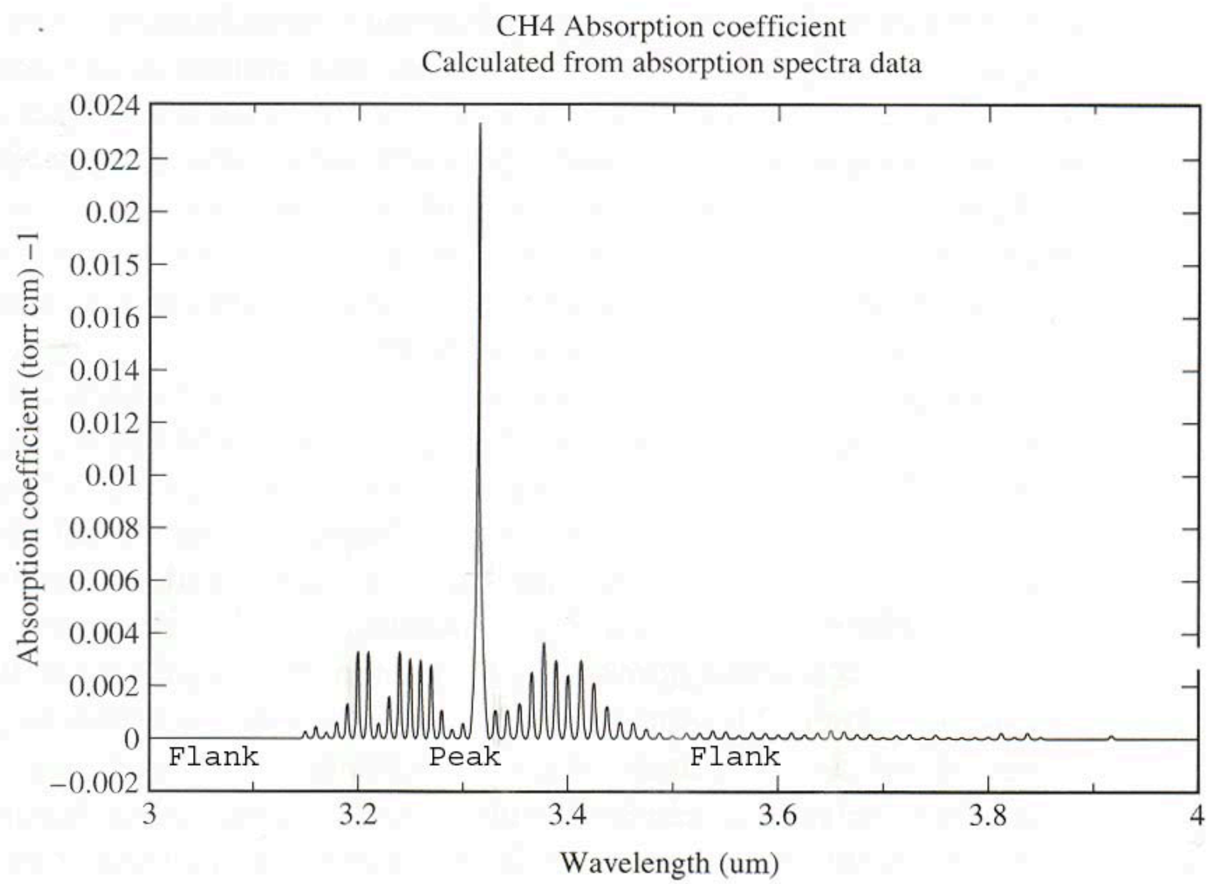


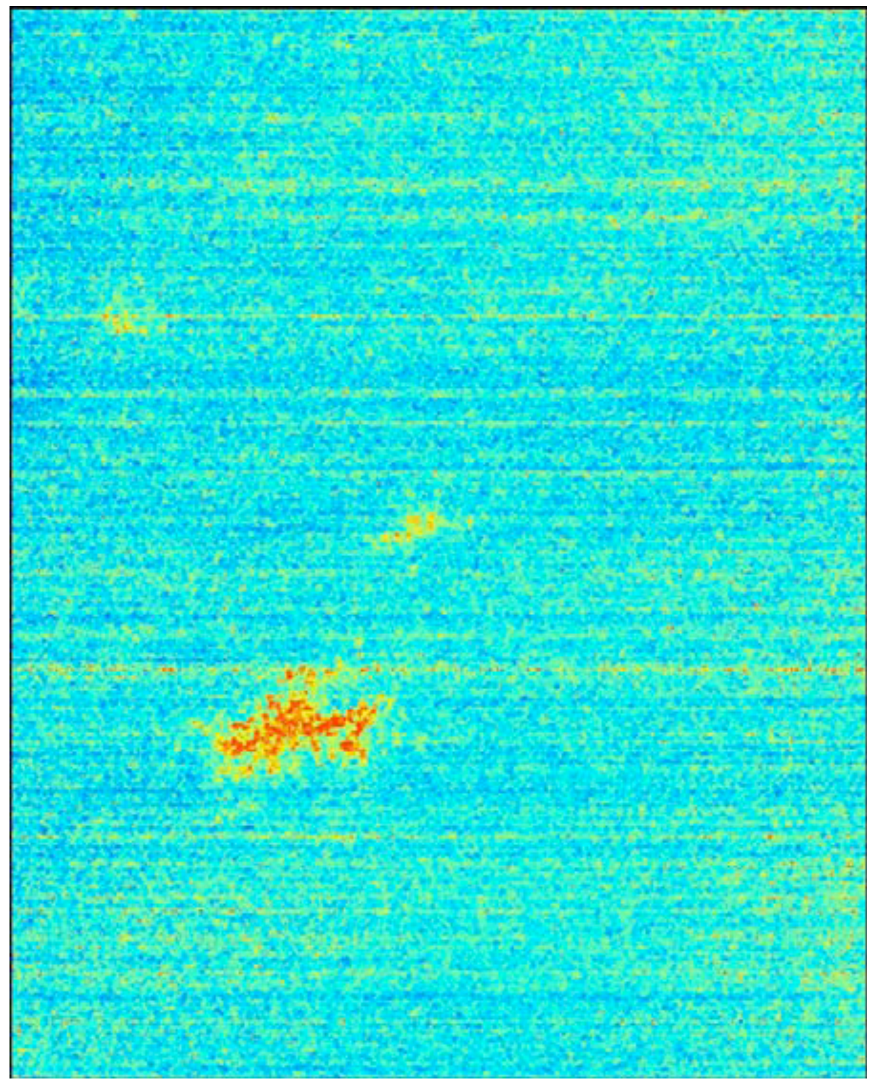
Figure 5.10 Schematic of three types of infrared radiation coming from a gaseous plume of methane exiting a solid waste landfill: ground emission, $M^{be}(i)$; reflected sunlight and atmospheric emission, $M^{br}(i)$; and plume emission, $M^{e}(i)$. *(Courtesy of R. K. Vincent.)*

Illustration of band selection for spectral analysis ratio algorithm. The Peak would be the band with greatest overall absorption potential while the Flanks would be bands with little or no absorption potential. (Modified from Vincent, 1997)



True color image of MAS 98031_02 (left image), offshore Santa Barbara, CA. The scene contains some low altitude visible clouds and some hazy, possibly higher altitude clouds. The right image is the same scene with color stretching to enhance oceanic features, showing oil slicks.

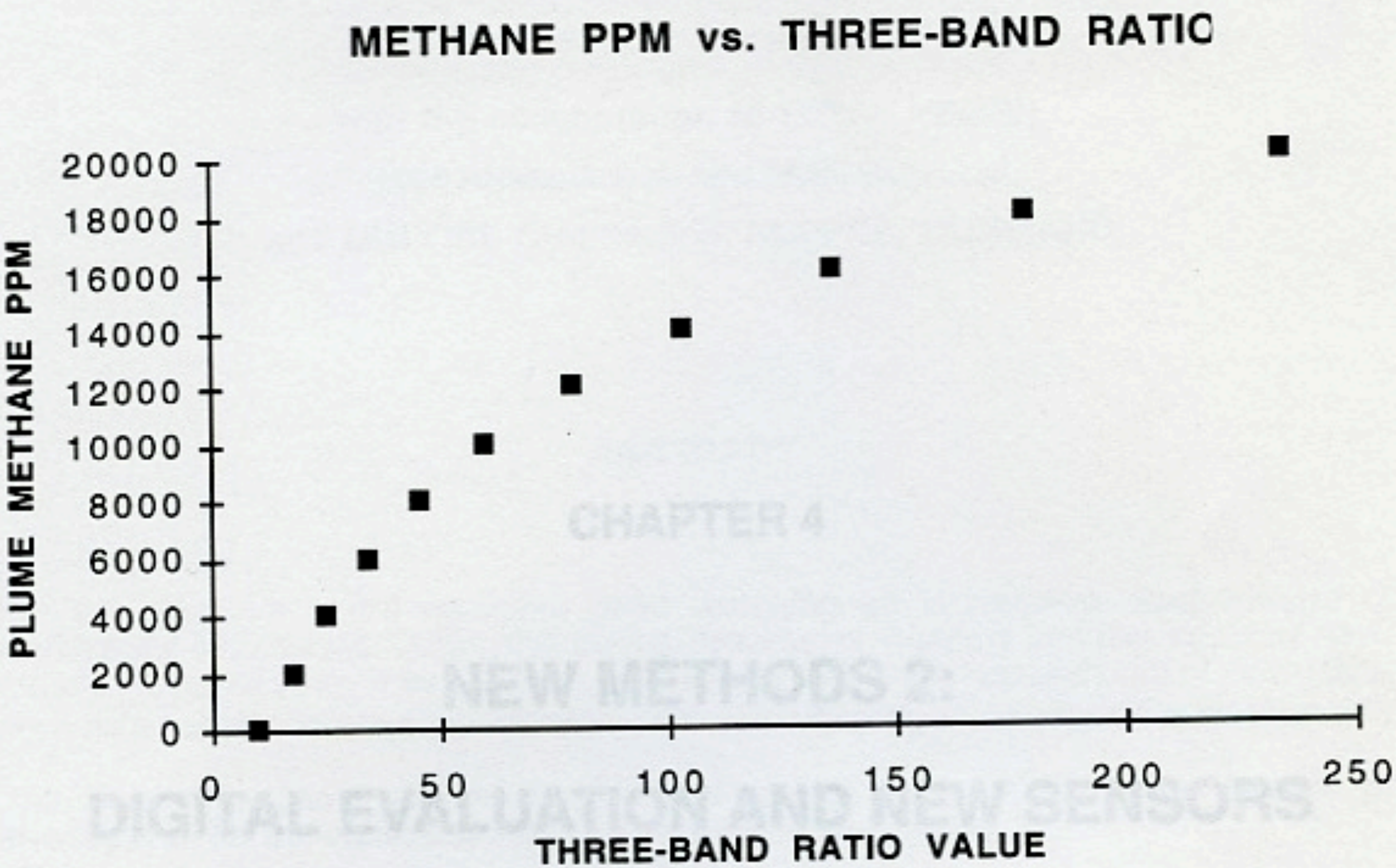
True color image of MAS 98031_02 (left image) and spectral ratio image (right image) of MAS bands 28/27 (W. Barnhouse, 2005, BGSU MS Thesis, Dept. of Geology). Methane content is high (red) in the latter image.



TIR Detection of Methane from Space

- No existing satellite sensor (MODIS, ASTER, AIRS) can map the 3.314 micrometer absorption band of methane, but it could be done with the following:
  - Bands 1,2, and 3 bandwidths of 3.100-3.132, 3.298-3.330, and 3.298-3.330 micrometers, with 300 m res.
  - Could map 10 km-tall plumes of methane with concentration of a few ppm by volume.
  - Next slide shows plot of ratio of the average of bands 1 and 3 to band 2 (above) versus methane content in ppm.

Fig. 1 Concentration of methane (in ppm by volume) in a methane/air plume of 10-meter thickness versus a three-band ratio ($R_{1+3,2}$) as observed over the ocean by a three-band (3.100-3.132 µm, 3.298-3.330 µm, and 3.500-3.532 µm) thermal infrared sensor from space, under conditions of the ocean surface temperature at 25°C and temperature of the plume (and sea-level atmosphere) at 5°C or less. (R.K. Vincent, Bowling Green State University)



What Should We Do?

- Search the existing AIRS data for the reflective IR band and the 7.7 micrometer band for evidence of methane at known geological sites of great methane escape.
  - If that is positive, look for methane in those images at the continental slopes and tundra regions.
- We need to try the 3.314 micrometer band and at least one nearby band for methane imaging from space.
- The future habitability of our planet may depend on how well and how soon we can map methane from space.