The Utility of Long-Range Lightning Networks

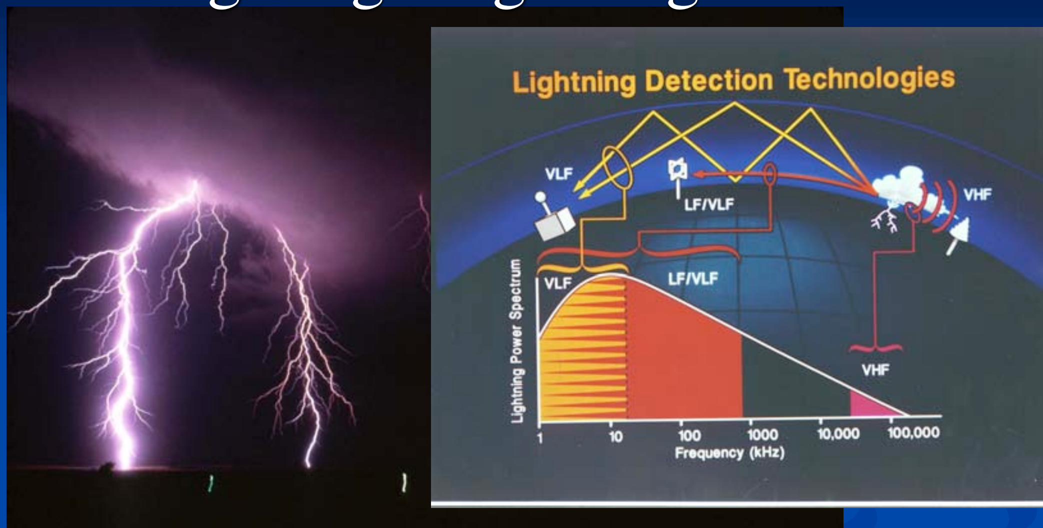
A UH view

Steven Businger

Outline

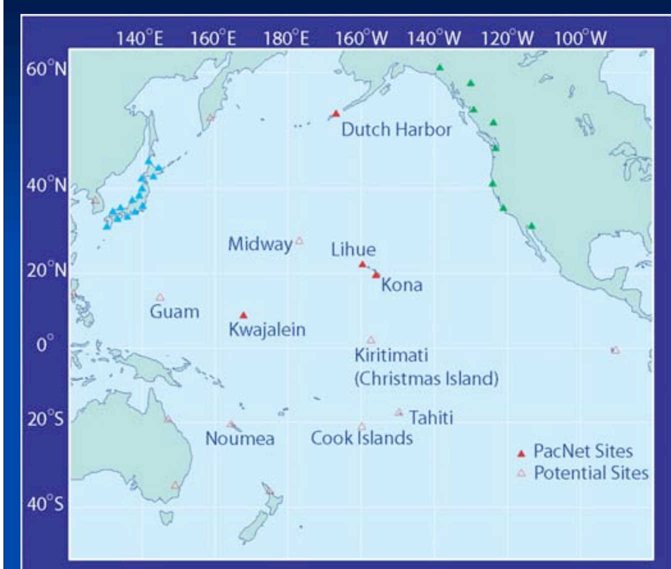
- Pacific Lightning Detection Network (PacNet)
- Lightning, cloud ice, aerosol, rainfall relationships
- Lightning in Hurricanes
- Lightning data assimilation

Long-range Lightning Detection



Ionosphere-earth wave guide allows VLF (5-25 kHz) emissions (sferics) from cloud to ground strikes to propagate thousands of km. Best propagation is over ocean and at night.

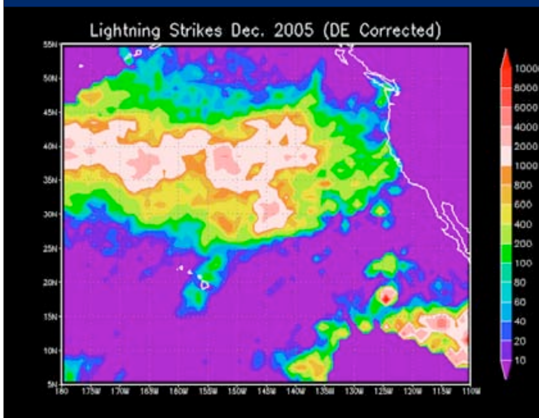
PacNet Sensor Sites

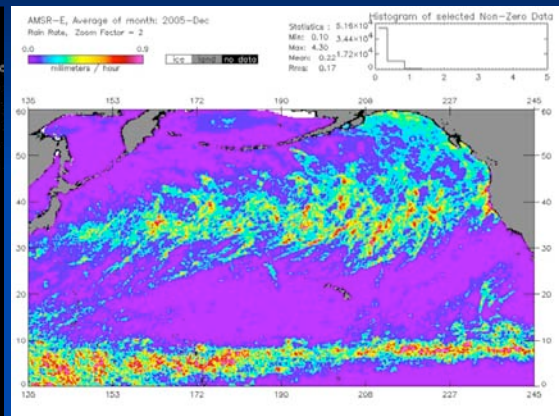


IMPACT ESP Sensor in Lihue, Kauai

Currently 4 sensors installed at Dutch Harbor, Lihue, Kona and Kwajalein. Sensors in North-America and Japan contribute.

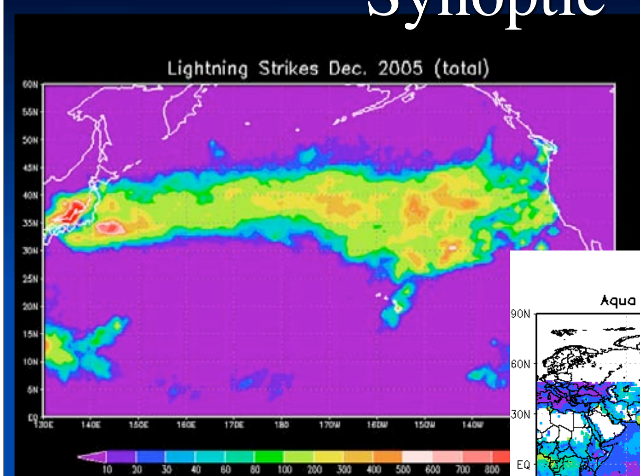
Synoptic View

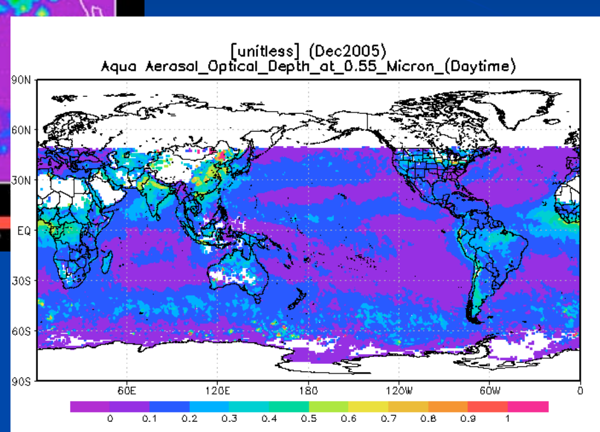




Like GOES, long-range lightning data provide a synoptic view over data-sparse oceans (left). Lightning strikes match broad pattern of rainfall from AMSR-E (right).

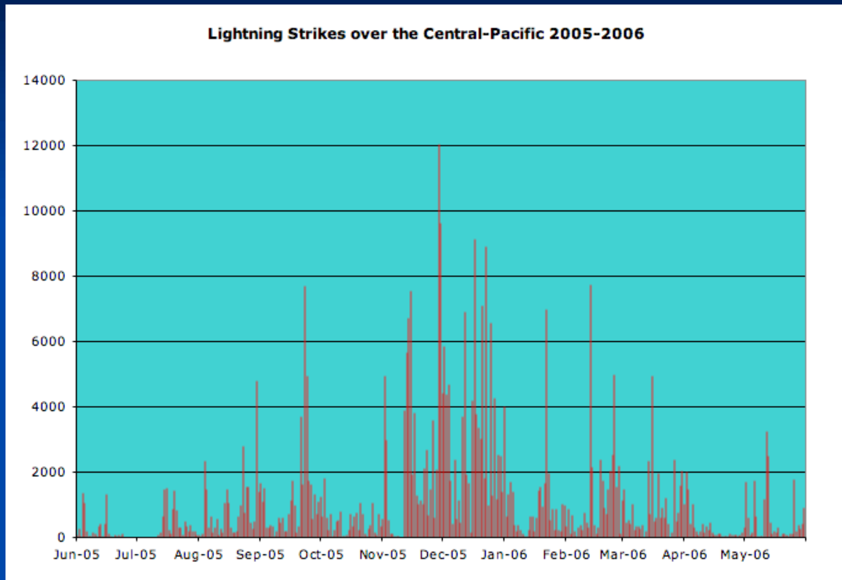
Synoptic View





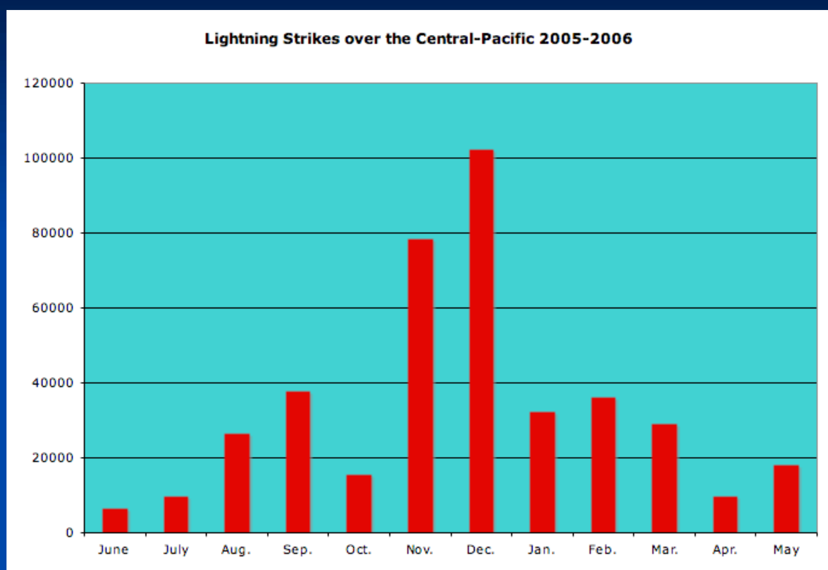
Like GOES, long-range lightning data provide a synoptic view over data-sparse oceans.

Synoptic View



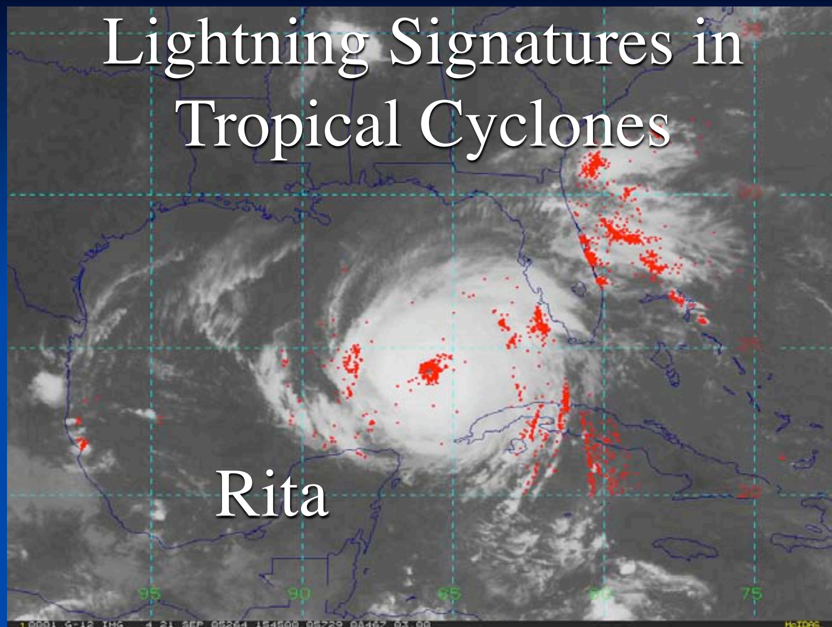
Time series of daily total lightning strikes

Synoptic View



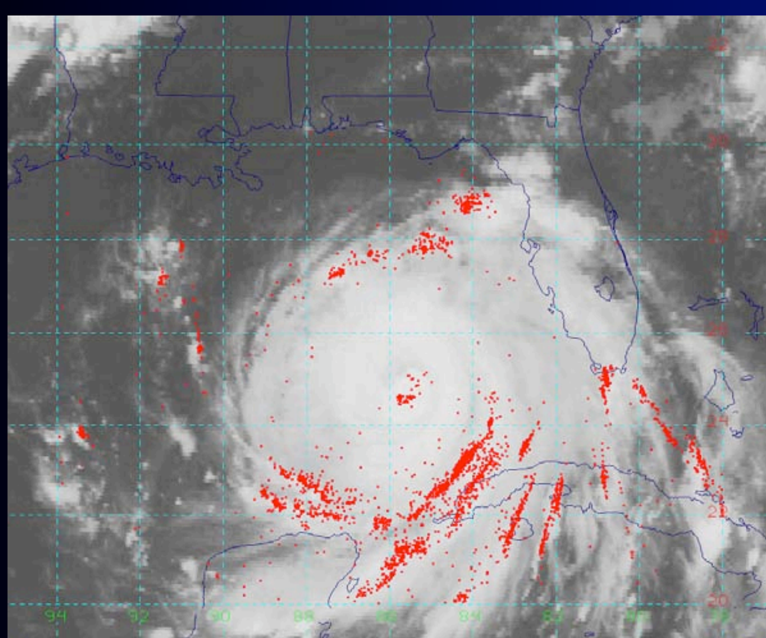
Histogram of monthly mean lightning strikes.

Lightning Signatures in Tropical Cyclones



GOES 12 IR Image 9-21-05 1545Z; Lightning Overlaid from 15Z - 16Z
Minimum Central Pressure 945 mb; 3 hours into Rapid Intensification
(30 Kts increase in M.S.W. in 24 hrs - John Kaplan HRD)

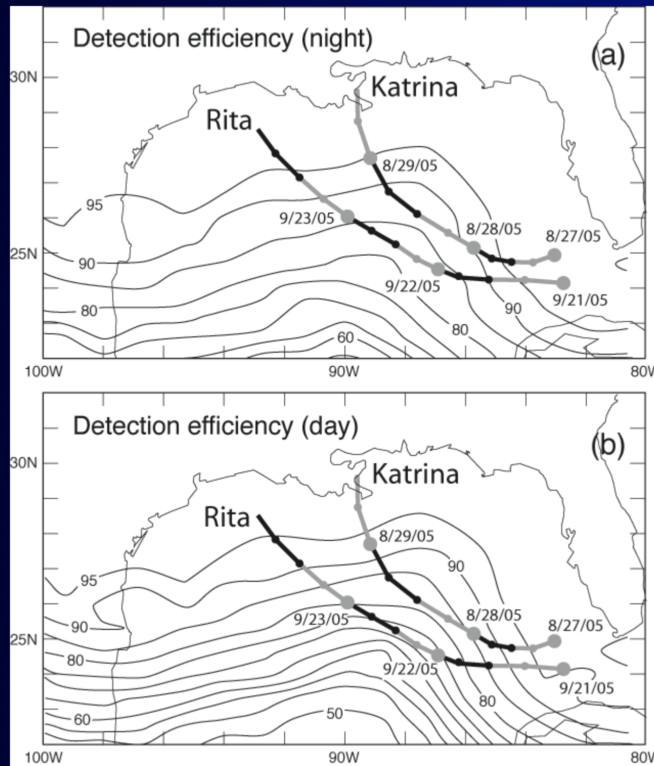
Katrina



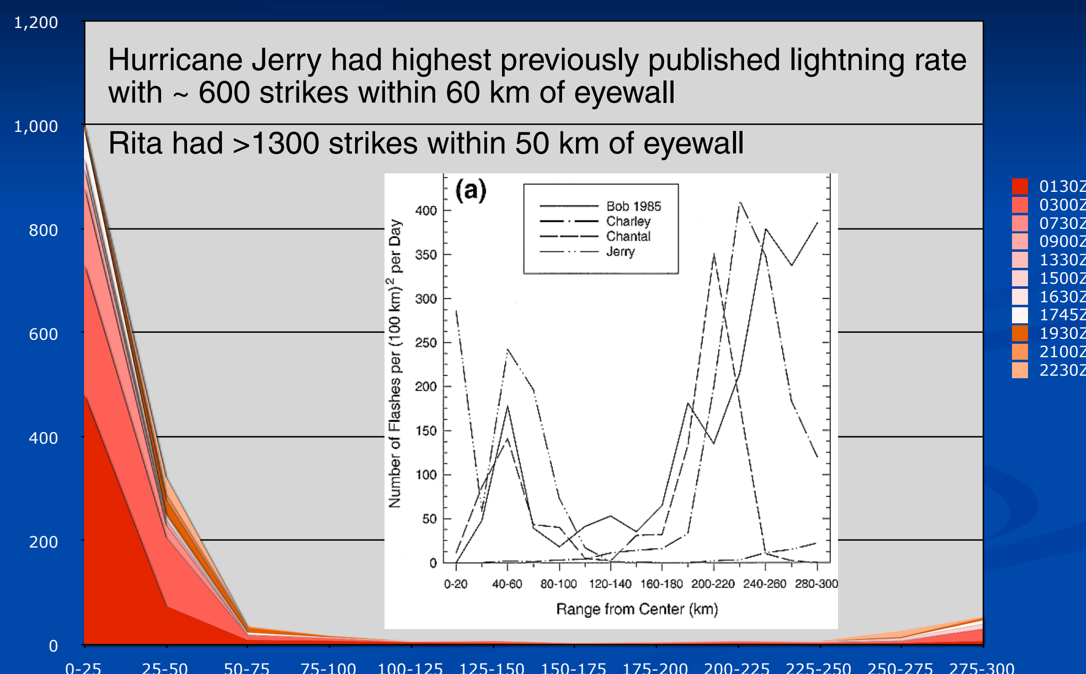
Animation of lightning distribution in Katrina

Detection Efficiency

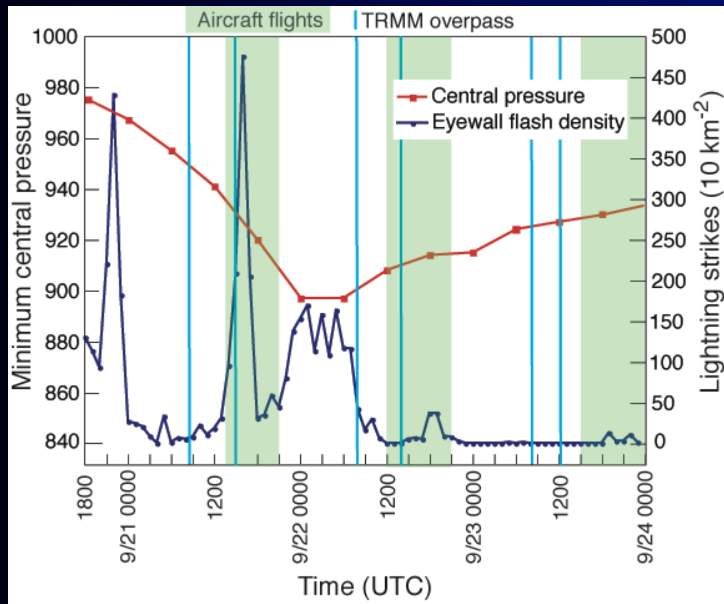
The detection efficiency (%) of the long-range lightning network must be taken into account in quantitative applications of the lightning strike data.



2005 Hurricanes Were Unusually Active in Lightning

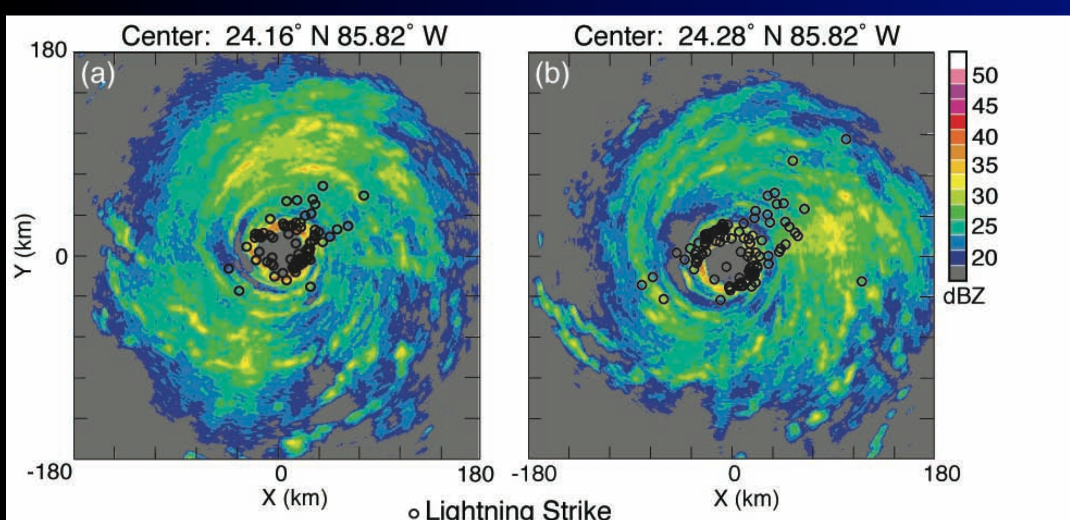


Rita



Central Sea-Level Pressure vs Lightning Rate

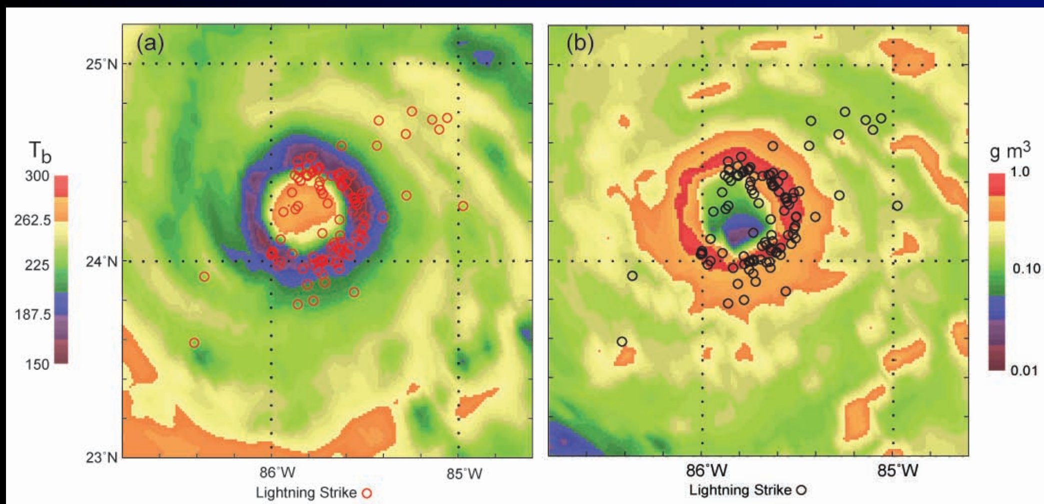
Rita



Aircraft radar reflectivity and lightning strikes

1513 UTC – 1533 UTC 21 September.

Rita



TRMM 87 GHz and Ice Product w/ lightning strikes

1506 UTC – 1617 UTC 21 September.

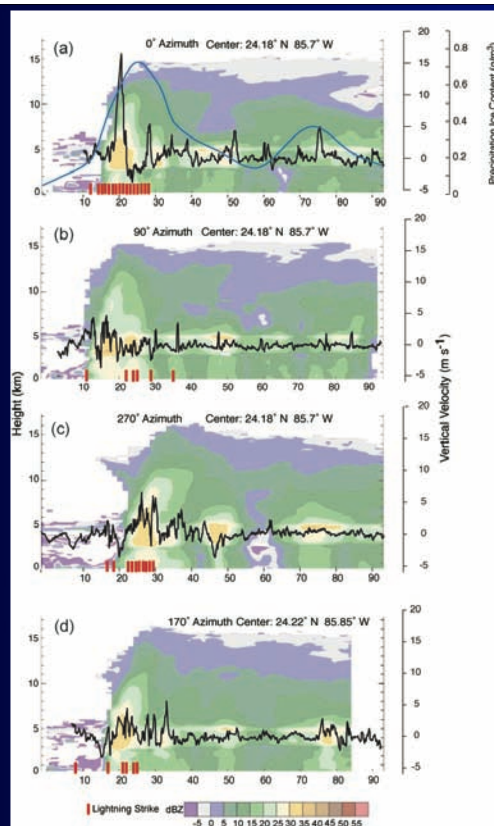
Rita

Aircraft radar reflectivity

TRMM ice product

and lightning strikes

1506 UTC – 1617 UTC 21 September.



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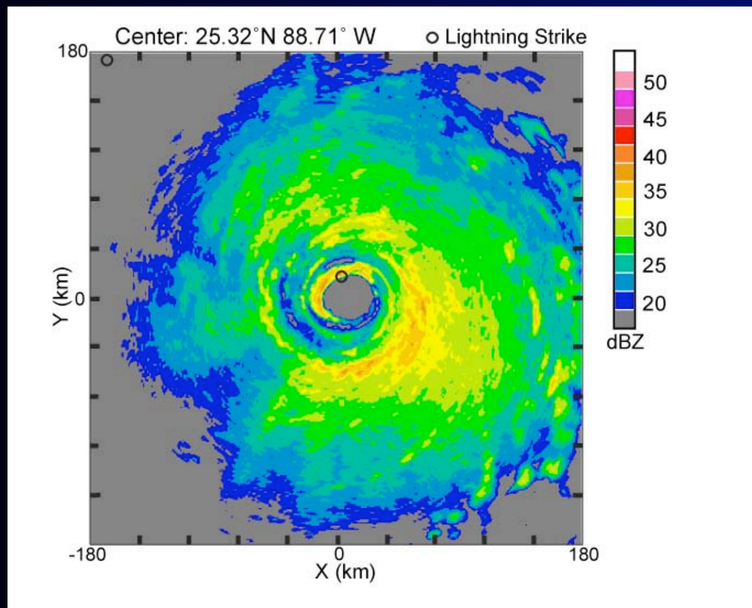


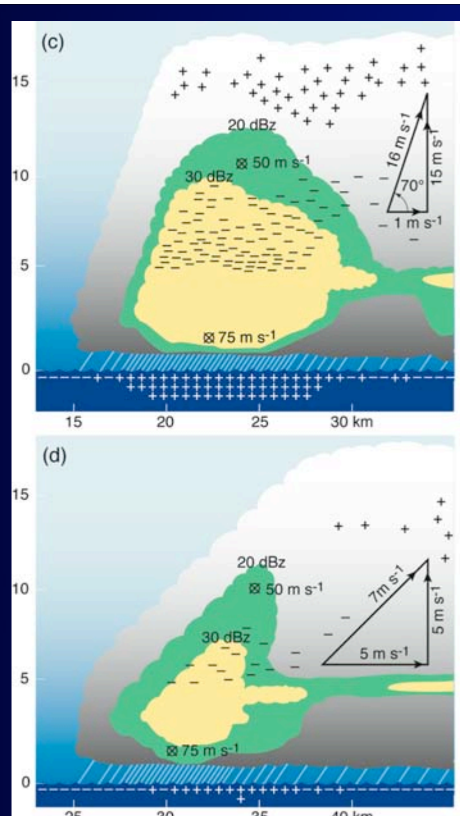
Aircraft radar reflectivity and lightning strikes

1452 UTC 22 September.

Conceptual Model

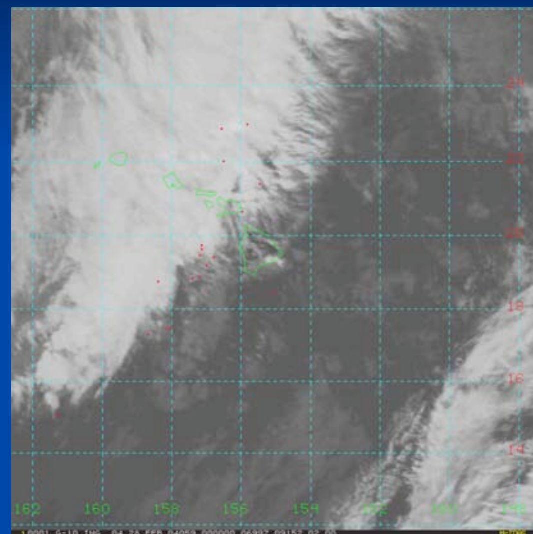
During high lightning rates: eye wall is steep and eye is small, vertical velocities and ice concentrations are large.

During low lightning rates: eye is large, eye wall is sloped, vertical velocities are modest, and ice concentrations are low.



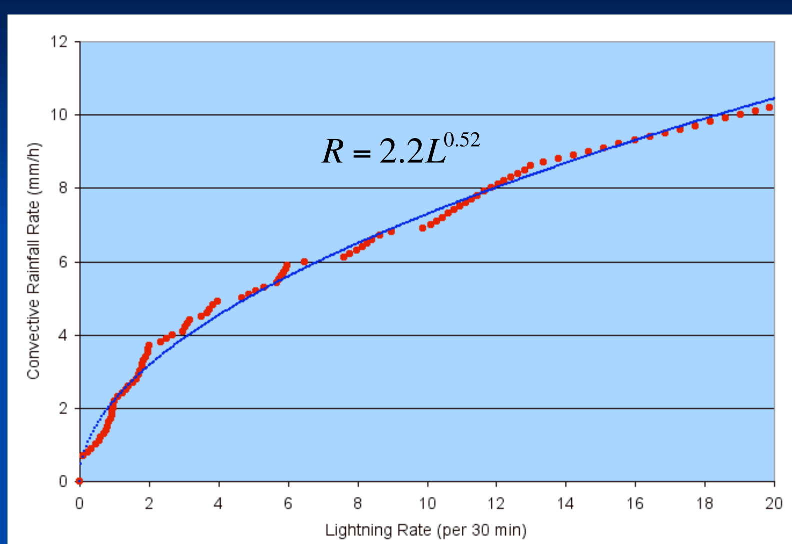
Methodology to Determine Relationship of Lightning to Rainfall

- Domain divided into 0.5˚ x 0.5˚ grid
- Lightning rates from Long-Range Network
- Rainfall rate from NASA AMSR-E and TMI sensors
- Lightning strokes occurring within ±15 min of satellite overpass time are counted
- Lightning count and average rainfall are computed over each square



28 February 2004

Lightning - Convective Rainfall Relationship



Composite analysis of 15 storms in the central Pacific. Blue line is fitted function where R is rainfall rate and L lightning rate. Data points were obtained using cumulative probability matching technique (Calheiros and Zawadski 1987)

Lightning Data Assimilation into a NWP Model

Two approaches:

- Four-Dimensional Data Assimilation (FDDA) of Moisture Profiles
- Latent heating assimilation

NWP Model Description

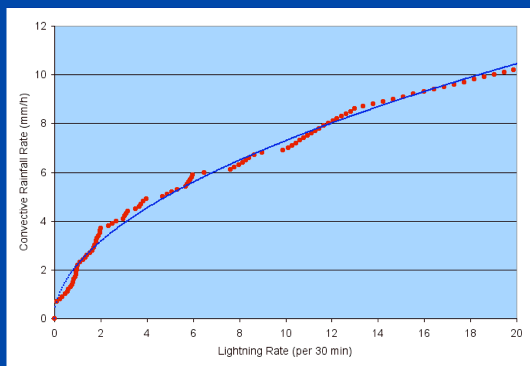
- PSU/NCAR Mesoscale Model (MM5)
- 40 vertical levels and 27-km grid spacing
- Kain-Fritch convective parameterization
- Reisner graupel explicit moisture scheme

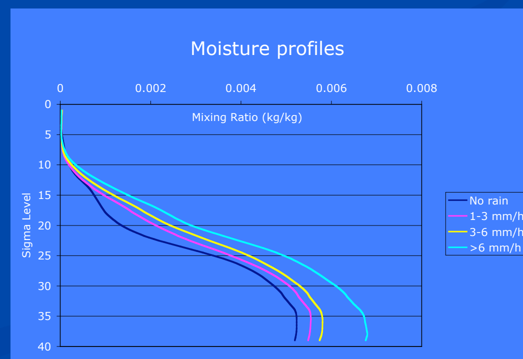
- Initial conditions from GFS-model
- Boundary conditions every 6 hours

Initialization
00Z or 12Z

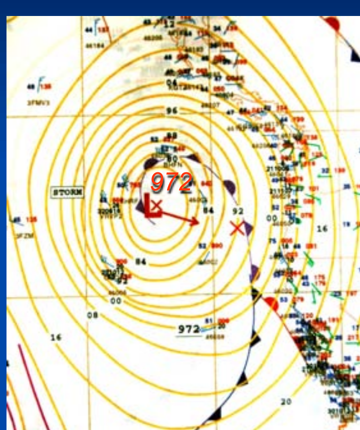
Assimilation of Lightning Data

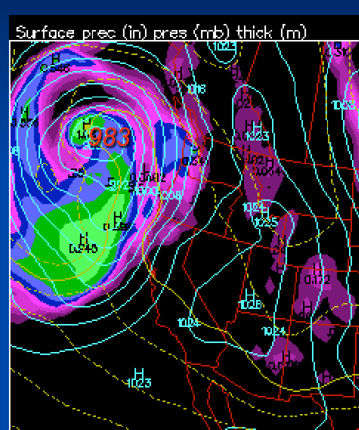
- Compute lightning rates over 0.25° x 0.25° squares and 30 min time window during the whole assimilation period
- Use lightning-rainfall relationship to match lightning rate with moisture profile.
- Radius of influence of observations in horizontal = 54 km
- Time window of influence = ±15 min
- Nudging every second time step if observed value is higher than model computed value.

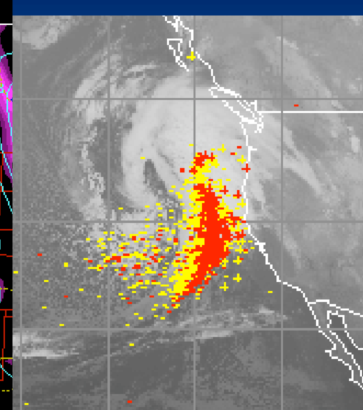




North-East Pacific Low 19 December 2002





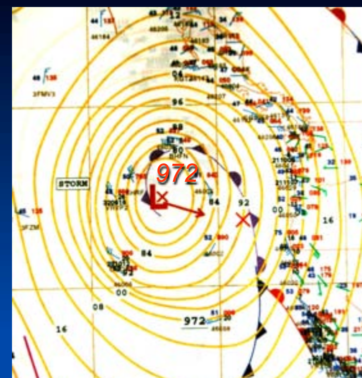


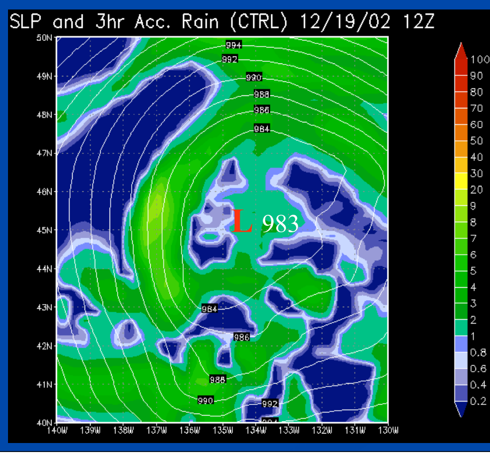
Observed Sea-level Pressure (left) and ETA 24-hr SLP and rainfall forecasts valid at 12 UTC 19 December 2002 (middle), show a 11mb forecast error in storm central pressure (12 hr forecast shows 9mb error).

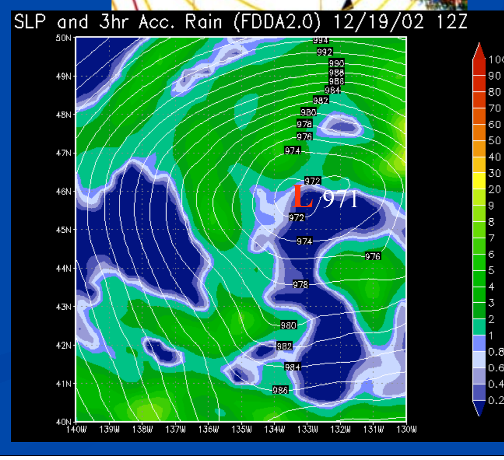
Lightning observations 09-12Z 12/19/2002

Reduced Forecast Error over the Eastern Pacific

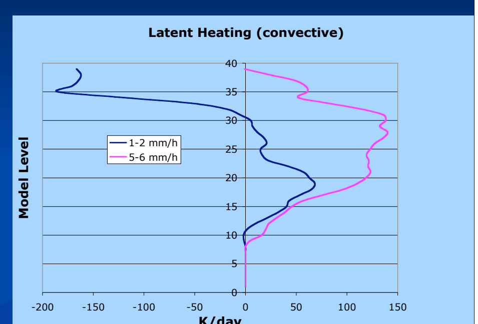
Assimilation of lightning data results in a significantly improved forecast of storm central pressure.







Latent Heating Approach



Sample convective latent heating profiles over the NE Pacific storm for 1-2 mm/h and 5-6 mm/h rain rates.

Rainfall rates derived from lightning observations are used to scale model's latent heating profiles

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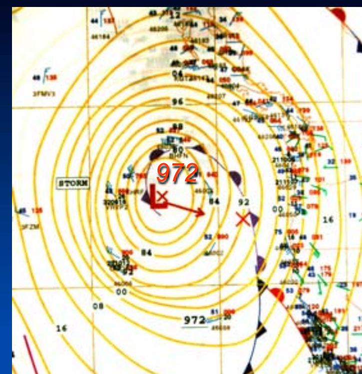
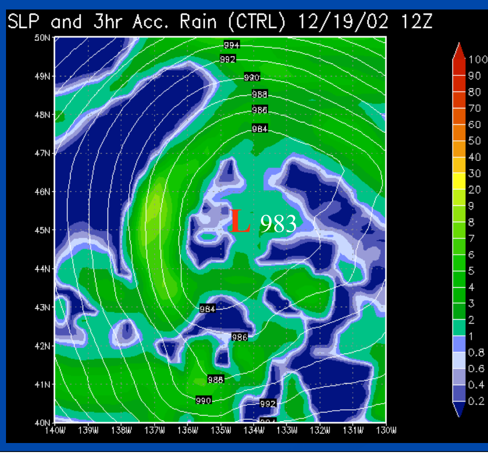
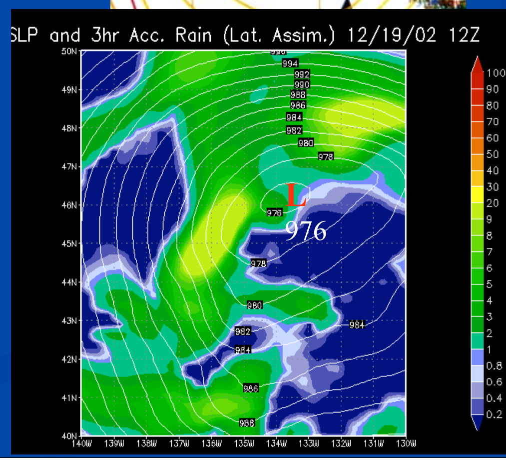
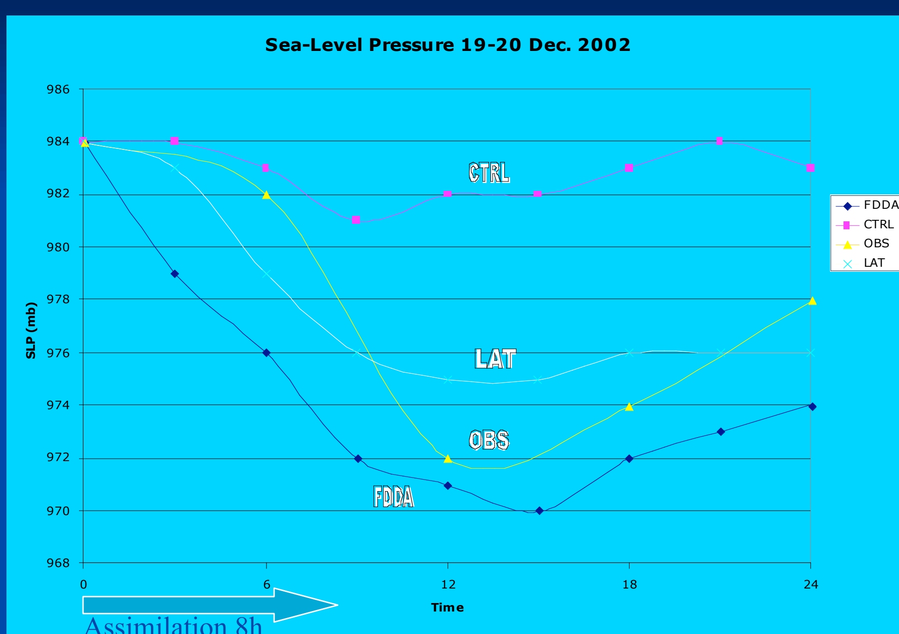
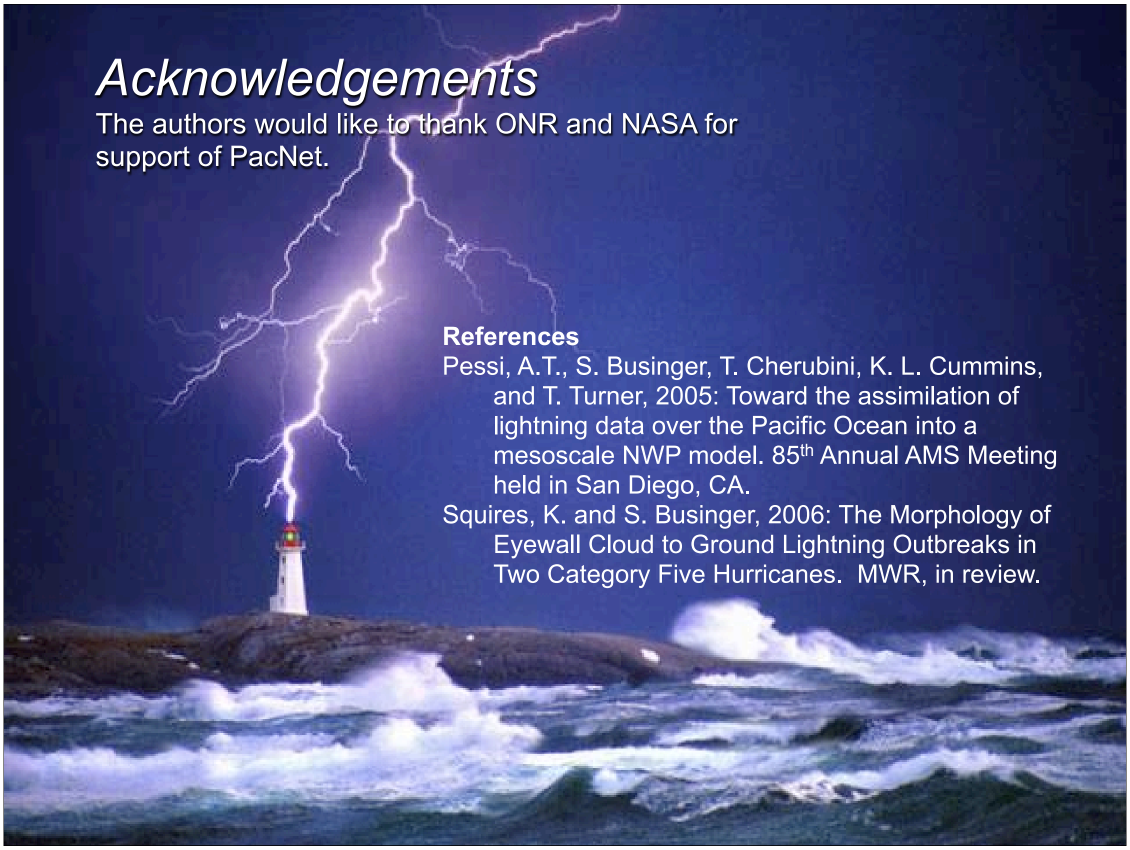






Time Series of Storm Central Sea-Level Pressure





Acknowledgements

The authors would like to thank ONR and NASA for support of PacNet.

References

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Squires, K. and S. Businger, 2006: The Morphology of Eyewall Cloud to Ground Lightning Outbreaks in Two Category Five Hurricanes. MWR, in review.