Ionospheric Research Perspectives
1975-2015

John M. Goodman
JMG Associates
May 12, 2015
Contents

• Some Introductory Remarks
• Where were we then? (circa 1970-1980)
• Where are we now? (2015)
• Challenges
NRL Randle Cliff Radar at CBD, Maryland
(150-ft Diameter Dish Antenna)
Fig. 1-2. The HF Roller Coaster ride since the end of World War II.
IES History

- Motivations
- Early and Enduring Sponsors
- Notable Session Chairmen over the years
- Topics solicited
- Featured Speakers of IES
MOTIVATIONS for IES

- Jules Aarons and his “Radio Astronomical and Satellite Studies of the Atmosphere”
- NATO-AGARD topical conferences
- Sought to emphasize DoD and civilian applications of ionospheric science
- Sought to distinguish IES from IEEE, URSI, COSPAR, ITU
- Attempted to couple ionospheric specialists with users
# IES Number of Papers by Year

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>67</td>
</tr>
<tr>
<td>1978</td>
<td>88</td>
</tr>
<tr>
<td>1981</td>
<td>72</td>
</tr>
<tr>
<td>1984</td>
<td>61</td>
</tr>
<tr>
<td>1987</td>
<td>75</td>
</tr>
<tr>
<td>1990</td>
<td>61</td>
</tr>
<tr>
<td>1993</td>
<td>99</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>60</td>
</tr>
<tr>
<td>1999</td>
<td>90</td>
</tr>
<tr>
<td>2002</td>
<td>103</td>
</tr>
<tr>
<td>2005</td>
<td>117</td>
</tr>
<tr>
<td>2008</td>
<td>110</td>
</tr>
<tr>
<td>2011</td>
<td>137</td>
</tr>
<tr>
<td>2015</td>
<td>130+</td>
</tr>
</tbody>
</table>
IES & Sunspot Number

International sunspot number $R_i$: monthly mean and 13-month smoothed number

SILSO graphics (http://sidc.be) Royal Observatory of Belgium 01/11/2013
Keynote and Featured Speakers

- Dr. Herbert Friedman (NRL, 1975)
- Dr. Herbert Rabin (NRL, 1978)
- Dr. Robert Naka (Chief Scientist, USAF, 1978)
- Dr. Hans Mark (1981)
- Dr. J. N. Birch (1981)
- Prof. J.A. Van Allen (1981)
- Dr. Donald Latham (DoD, 1984)
- Dr. Owen K. Garriott (Scientist-Astronaut, 1984)
- Capt. David Hart (US Navy, 1987)
- Dr. Bruce Wald (NRL, 1987)
- Dr. Tom Quinn (DoD, 1990)
- Dr. Gerald Hawkins (1990)

- Prof. William Gordon (1993)
- Mr. John A. (Jack) Klobuchar (1996)
- Lt. General Emmit Paige Jr. (DoD, 1996)
- Dr. John V. Evans (COMSAT, 1999)
- Dr. Kenneth Davies (NOAA, 1999)
- Prof. Les Barclay (2002)
- Mr. Roger Easton (2002)
- Dr. Ernest Hildner (NOAA, 2005)
- Lt. Col Trey Cade (USAF/AFWA, 2005)
- Dr. Paul Cannon (2008)
- Prof. Lou Lanzerotti (NJIT, 2008)
- Dr. Paul Bernhardt (NRL, 2011)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Jules Aarons</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. David Anderson</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Paul Argo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. John Ballard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Ted Beach</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. O. de la Beaujardiere</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maj. Paul Bellaire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Paul Bernhardt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr Greg Bishop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Dave Boteler</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prof. Paul Cannon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Alan Bourdillon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lt. Col Trey Cade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Charles Carrano</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. A. Cerruti</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. Ray Conkright</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Robert Conley</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Anthea Coster</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major Mike Crawford</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Pat Crowley</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. Don Danskin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. G. DeFranceschi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Ken Davies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Ken Diamond</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ms. Patricia Doherty</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. John V. Evans</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Ed Fremouw</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Paul Fougere</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Tim Fuller-Rowell</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Ivan Galkin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Suman Ganguly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Dr. Larry Gardner</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Larisa Goncharenko</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. John Goodman</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Keith Groves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. George Hagn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. Jim Headrick</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. Bill Heidig</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. R.G. Joiner</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. John Kelso</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. John A. Klobuchar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. George Lane</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Robert McCoy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Leo McNamara</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Sid Ossakow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. Ernie Peterkin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Tom P. Quinn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. M.H. Reilly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prof. Bodo Reinisch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Juergen Richter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Chuck Rino</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Charles Rush</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Dave Sailors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Ludgar Scherliess</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. Kevin Scro</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. James Secan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Haim Soicher</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prof. Paul Song</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. Don Spector</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Iwona Stanislawski</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Al Rosen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. Joe Thomason</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. G. W. Ullrick</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. John Wang</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. W. Wasylkiwskyj</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Jules Aarons

- An inspirational Factor for IES
- Radio Astronomical & Satellite Studies of the Atmosphere
- NATO-AGARD Conferences
John A. “Jack” Klobuchar

- AF Co-Chairman for IES
- Noted TEC Investigator
- 1975 “1st Order Worldwide Time Delay Algorithm”
- ION Fellow
Professor James Van Allen

- Radiation Belts
Professor William Gordon

- Incoherent Scatter Radar
- Arecibo
Dr. Kenneth Davies

- Several Noteworthy Books
- Monograph 80
Dr. Owen K. Garriott

- Book
- Scientist Astronaut
Dr. John V. Evans

- Book
- Thomson Scatter Radar at Millstone Hill
- Jodrell Bank radar studies
- Cis-lunar ionosphere studies
- COMSAT
Prof. Paul Cannon

- Ionospheric studies
- Radio Systems
- Communications
- URSI
Professor Les Barclay

- HF Propagation Specialist
- CCIR/ITU contributions
- Numerous Publications
- Books
Roger Easton

- Father of GPS
- Space Surveillance System
- Timing & Navigation
Dr. Herbert Friedman

- Noted Astrophysicist
- Early rocket studies
- X-ray studies of lower ionosphere
Professor Louis Lanzerotti

- Plasma physics
- Telecommunications
- Space Weather Quarterly - Editor
Dr. Ernie Hildner

- Director, NOAA-SEC
- Forecasting
- Space Weather
Dr. Paul Bernhardt

• Ionospheric Modification
• Satellite & Terrestrial studies
Authorship Continuity 1975 and 2015

- Herbert Carlson
- Dennis Knepp
- Charles Rino
Technical Sessions: IES1975

- Scintillation & Irregularities (3 sessions)
- Heating Effects
- TEC Modeling
- NAVSTAR/GPS
- In-Situ Probes
Technical Sessions: IES1978

- Scintillation (2 Sessions)
- Radio Propagation (ELF-HF)
- Spacecraft Charging
- Ionospheric Forecasting
- Ionospheric Modification
- Ionospheric Effects: Ranging and Navigation
Technical Sessions: IES1981

- Ionospheric Modification (2 Sessions)
- Ionospheric and Scintillation Modeling
- Auroral & Equatorial Scintillation
- HF Propagation
- Remote Sensing
- Ionospheric Modification
- Ionospheric Effects: Ranging and Navigation
Technical Sessions: IES1984

- Adaptive HF Systems & Channel Assessment
- HF Probing & Performance Analysis
- Transionospheric Propagation
- Ionospheric Predictions & Modeling
- LF Propagation
- Artificial Modification
- Ionospheric Diagnostic Technology
Technical Sessions: IES1987

- Wideband HF Channels
- High Frequency Measurements
- HF Modeling
- Longwave Propagation Modeling
- Transionospheric Propagation & TEC
- Transionospheric Propagation & Scintillation
- Ionospheric Modification
- High Latitude Ionospheric Interactions
- Spacecraft Glow, Related Phenomena and Measurements
Technical Sessions: IES1990

- High Latitude Phenomena
- Scintillation Effects
- HF Radio Effects
- Radar System Effects
- Meteor Burst & Miscellaneous Systems
- TEC Modeling
- TEC and GPS
- Diagnostics: Sounders, Probes, and Radars
- Longwave Systems
- Modification
Technical Sessions: IES1993

- OTH Radar
- Ionospheric Tomography and Radar Applications
- Direction Finding Systems and Applications
- Meteor Burst Communications
- Transionospheric Propagation, Scintillation, TEC, etc.
- HF Propagation & Modeling
- Ionospheric Sounding & Probes
- High Latitude Phenomena
- Longwave Systems & Effects
- Radio Noise Modeling
- Ionospheric Heating and Modification
Technical Sessions: IES1996

- Ionospheric Tomography (3 sessions)
- OTH Radar
- HF Communication & Noise
- Ionospheric Utilities, Resources, & Forecasting
- Ionospheric Mapping & Sounding
- Ionospheric Modeling
- Ionospheric Scintillation & Spread-F
- Ionospheric Measurements (2 sessions)
- Propagation Experiments & Studies
- Total Electron Content & GPS Studies (3 sessions)
Technical Sessions: IES1999

- Space Weather
- Computerized Ionospheric Tomography
- Ionospheric Scintillation
- Sounder Methods & Measurements
- TEC Studies
- Mitigation of Ionospheric Effects on GPS: WAAS
- Ionospheric Modeling
- Ionospheric Measurements & Campaigns
- HF Propagation & Communication
- Longwave Measurements & Effects
- Radar and Radio Propagation Effects
- New Methods & Algorithms
Technical Sessions: IES2002

- Space Weather
- Ionospheric Models & Data Assimilation (2 Sessions)
- Satellite Navigation Systems & WAAS
- HF Propagation & Systems
- Advanced Ionospheric Sounding
- Total Electron Content (2 Sessions)
- Radiowave Scintillation (2 Sessions)
- Lower Ionosphere
- Tomography & Optical Measurements
- Panel on Ionospheric Modeling
Technical Sessions: IES2005

- Solar Flares & Storms (3 sessions)
- Ionospheric Radio Propagation
- HF Propagation & Systems (2 Sessions)
- HF Sounder Technology
- Ionospheric Effects on Space-Based Augmentation (2 Sessions)
- Limb Scanning Technology
- Miscellaneous GPS studies
- TEC
- Ionospheric Tomography
- Ionospheric Specification, Data Assimilation & Forecasting
- Scintillation (2 Sessions + C/NOFS session)
- General System Effects
Technical Sessions: IES2008

- Radio Burst & Solar Flare Effects
- Lower Ionospheric Effects
- Arctic Ionosphere
- Space Weather Effects on Communication & Navigation
- Ionospheric Effects on Aviation Systems
- Ionospheric Phenomena
- GPS Techniques and Applications
- Radio Propagation and HF Systems (2 Sessions)
- Modeling & Forecasting (2 Sessions)
- Sounder Methods & Measurements (2 Sessions)
- Irregularities & Scintillation
- Sensors & Measurement Techniques (3 Sessions)
IES2011 Topics

- Lower Atmosphere & Ionosphere
- Ionospheric Effects on Navigation
- GPS and TEC
- C/NOFS
- Sounder Methods & Measurements (3 Sessions)
- HF Radio & Communication Systems
- Radio Diagnostics
- Radar Applications
- Tomography

- Rocket Exhaust Effects & High Power Radio Modification
- Space Weather
- Equatorial Ionosphere (2 Sessions)
- Geomagnetic Storm Effects
- Modeling & Simulation (2 Sessions)
- Scintillation (2 Sessions)
- Radio Propagation
- SAR and Related Techniques
Technical sessions: IES2015

- HF-TIDs
- Scintillation & Irregularities
- Ionospheric Modification
- Storms & Anomalous Conditions
- Ionosphere & Space Weather Models
- GPS/GNSS
- Ionospheric Studies
- Mission & Data Services
- Natural Hazards
Consistent Themes

- Understanding the earth-space path
- Understanding of the HF skywave path
- Ionospheric modification
- Solar-Terrestrial and Space Weather relationships
- Ionospheric Modeling
- Ionospheric remote sensing
- Other less consistent themes
Some Ionospheric phenomena we don’t know very well

• Inhomogeneities
• TIDs
• Ionospheric Storm
Scenario-Dependent Situations
CONSEQUENCES

• Search for credible methods to specify "truth"
  • Update climatology?
  • Insertion of more physics?
  • Both?
• Situation has led variety of update schema and data assimilation techniques.
Where do we go from here?
Too much emphasis on development of models without experimental validation?

- Calculation, in general, is NOT an experiment.
Conclusions

• Consistent progress in understanding of the ionosphere has been made in the last half century
  • Better Diagnostics
  • Improved Computational Tools
  • Improved awareness of importance to Society
• IES conferences have mirrored changes
Where are we now?

- Ionospheric Propagation Studies & Modeling
  - Scintillation (C/NOFS)
  - TEC
Where were we then?

- Remote Sensing Technologies
  - VIS and OIS Sounding, Topside Sounding, OTHR
  - Rocket Probes
  - In-Situ plasma measurements
  - Incoherent Scatter Radar (Thomson Scatter)
  - DoD and NASA studies Space Program assets
Where are we now?

- Remote Sensing Technologies
  - VIS and OIS Sounding
    - Global quasi-real-time
  - ISR, EISCAT,
  - SuperDARN,
  - OTHR
  - TIDBIT
  - Occultation
  - Tomography
  - airglow
Where were we then?

- Ionospheric Modification
  - Heating (HF heaters and Luxembourg effect)
  - Chemical Releases (i.e., actual modification and diagnostic)
  - Man-Made
    - chemical reagents from exhaust such as Skylab
    - nuclear effects (principally HANE)
Where are we now?

- Ionospheric Modeling
  - Continuing editions of IRI
  - Assimilative models (GAIM, etc.)
Where were we then?

- Ionospheric Propagation Studies & Modeling
  - Scintillation (Radio Star, SATCOM)
  - TEC, Dispersive & Differential Doppler
Where were we then?

- Ionospheric Modeling
  - Penn State Mark 1, Appleton Lab, CCIR Models ➔ ITU-R Models
  - AF4D, AMBCOM
  - HFMUFES ➔ RADARC ➔ ICEPAC ➔ IONCAP ➔ VOACA
Where do we go from here?

Methodology

• Participate in Interdisciplinary Experiments. Generally a good thing but there are budgets to consider
• Incorporate known physics without sacrificing empirical results and insight
• Develop models of behavior (leading to forecasting, prediction, and simulation)
• Communicate with ultimate Users of Basic & Exploratory Research (collaboration should be considered)
• Conduct Challenge Workshops
• Publish results & submit to IES and other topical and/or general conferences (AGU, URSI, IEEE, etc)
Where are we now?

• Ionospheric Modification
  • Heating (HF heaters)
  • Chemical Releases and Man-Made (i.e., chemical reagents from exhaust, and nuclear effects)
Where were we then?

- Systems for Navigation and Timing
  - Loran
  - Transit
  - Navy Timation,
  - GPS Constellation

- Communication System Studies
  - Satellites (VHF, UHF, SHF)
  - HF radio (emergent adaptive HF systems)
Where are we now?

- System Studies
  - Communication
  - Surveillance
    - Radar (e.g., OTHR)
    - HFDF (i.e., HFGeo)
  - Navigation (GNSS)
    - GPS and augmentation system
    - GLONASS
    - European system